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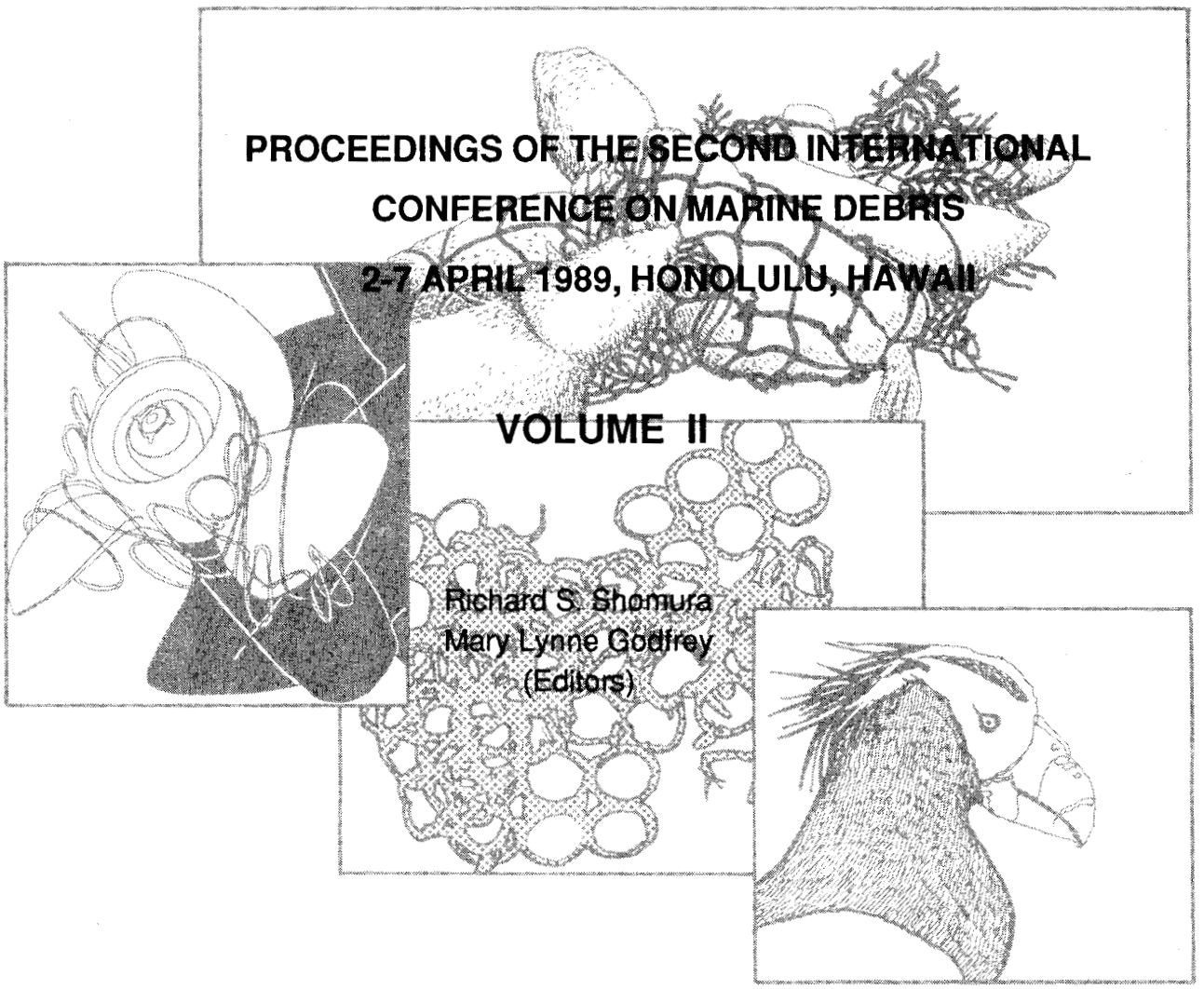
NOAA Technical Memorandum NMFS

**DECEMBER 1990**

# PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON MARINE DEBRIS

## 2-7 APRIL 1989, HONOLULU, HAWAII

## VOLUME II



Richard S. Shomura
Mary Lynne Godfrey
(Editors)

NOAA-TM-NMFS-SWFSC-154

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
University of Hawaii Sea Grant College Program

NOAA Technical Memorandum NMFS

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**DECEMBER 1990**

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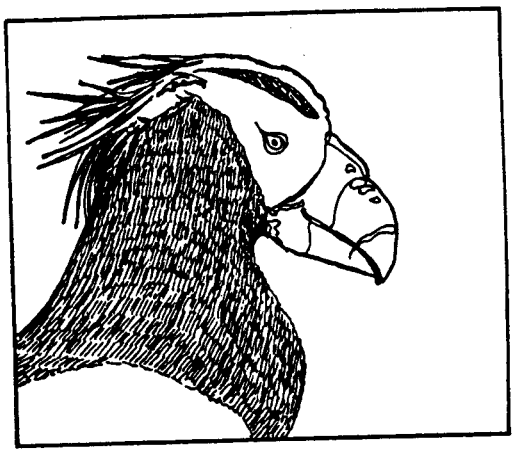
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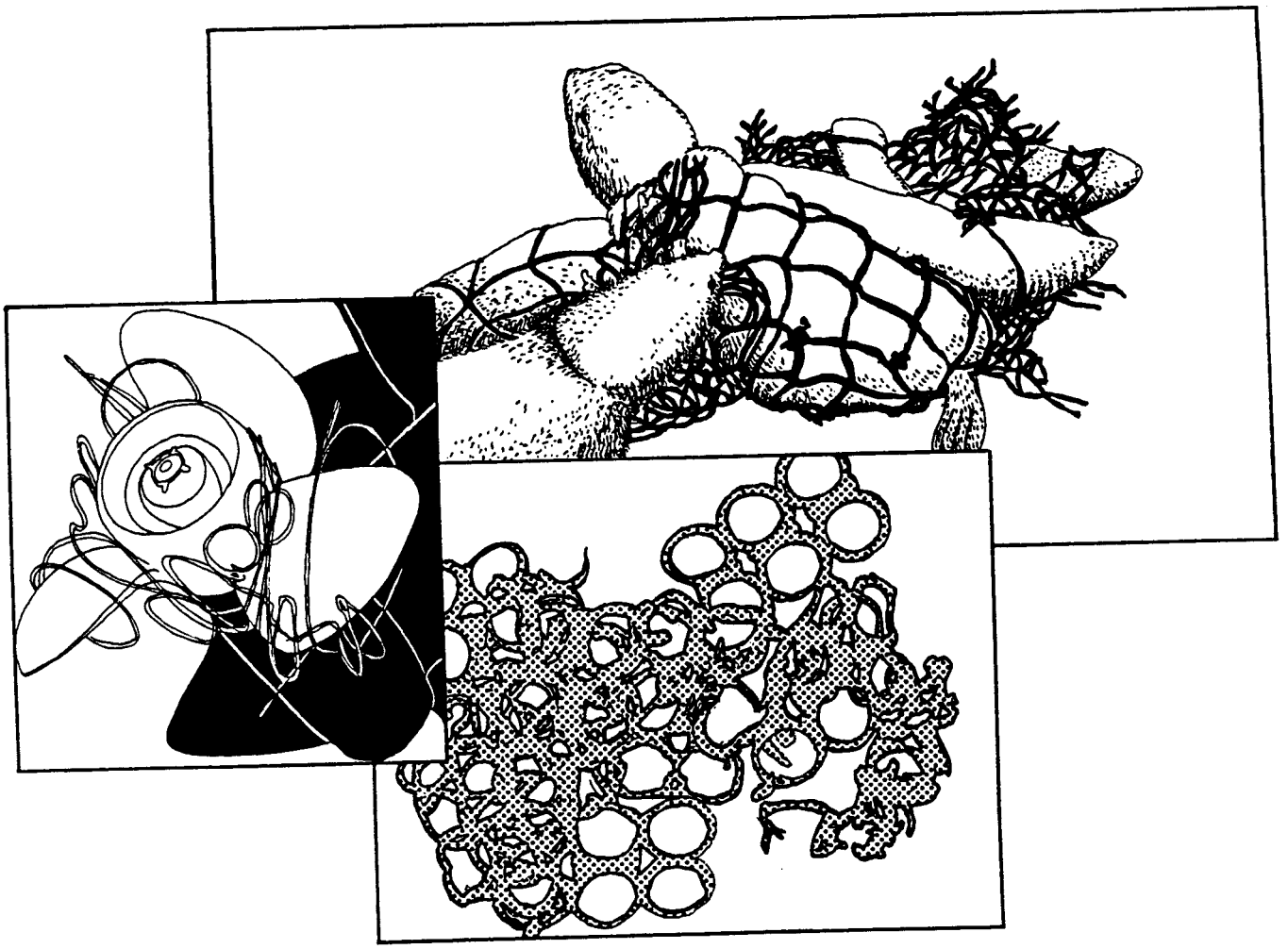
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# SESSION IV

## ECONOMIC IMPACTS ON VESSELS AND SHORELINES



# AN ECONOMIC PERSPECTIVE ON THE PROBLEM OF MARINE DEBRIS

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## ABSTRACT

This paper examines the role of economic analysis in the development and implementation of an effective public policy to address the problem of marine debris. The economic theory of common property resources and other relevant aspects of natural resource and environmental economics are explained and used as a basis to critically review the economics literature on marine debris. Gaps in knowledge are identified and an economic data collection and research agenda is proposed.

## INTRODUCTION

Many of the economic issues associated with the problem of marine debris are similar to those surrounding oil and hazardous substances pollution of the marine environment. The marine debris problem has not, however, received the same degree of attention by the research community as oil and hazardous substances pollution has. This is particularly true in the field of natural resource and environmental economics, as the review of the literature amply illustrates. Although a number of studies have shown that marine debris can have deleterious effects on marine life (Balazs 1985; Calkins 1985; Day et al. 1985; Bengston et al. 1988; Cooper et al. 1988), the current body of knowledge is insufficient to provide an assessment of the magnitude of the problem. And although research is continuing on the impacts of marine debris, neither does a coordinated effort exist to structure this research toward providing such an assessment, nor are efforts under way to ensure that research results are formulated in a way that will be useful for economic assessments.

This paper provides an overview of the economic aspects of the marine debris problem and suggests how economic analysis can play a role in finding effective and rational solutions. A research agenda is proposed to aid in quantifying the economic dimensions of the problem and assessing the effectiveness of economic incentives in achieving compliance with various laws and regulations.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## THE ECONOMIC PERSPECTIVE

Absent significant economic incentives, compliance with environmental laws and regulations is usually low. It is true that education, moral suasion, and fear of punishment will stimulate many to abide by laws and regulation, but past experience has shown that these efforts alone will not significantly reduce noncompliance with environmental regulations. Here we discuss how an economist would approach analytically the problem of marine debris, including the issue of compliance with prohibitions on debris disposal.

### Background

In order to show how economics can be used in analyzing the problem caused by marine debris, it is necessary to provide a brief description of the economic theory of natural resource and environmental economics. This will help clarify some of the concepts behind such familiar terms as market failure, economic efficiency, benefit-cost analysis, economic damage assessment, the value of environmental improvement, and cost effectiveness. These terms are related to methods for analyzing policy alternatives designed to correct problems in the way individuals use scarce natural resources (including environmental goods and services).

The literature on the problem of marine debris highlights a wide range of detrimental impacts on living and nonliving resources. These detrimental impacts are known, generally, in economic terms as external diseconomies (or simply "externalities" for ease of exposition). Externalities arise when the marketplace fails to balance competing uses of a resource so that a particular resource's value to society is maximized. Under ideal circumstances, competitive markets will consider all the costs and benefits of an activity, balance competing uses, and produce the maximum net benefit to society. Thorough study of the market failures which result in marine debris would undoubtedly lead to more effective solutions.

### Common Property Resources and Nonmarket Goods

Two sources of market failure predominate in the natural resource and environmental economics literature: common property resources and nonmarket goods. One type is discussed in a classic article by Hardin (1968) who wrote of the "tragedy of the commons." Common property is overexploited because everyone has the right to use it, but no one has personal responsibility for it. Rivers, estuaries, and oceans are examples of common property. It is not surprising then that these bodies of water are overutilized as waste repositories, since dumpers do not have to pay the full social cost for their use. Given the rising, high cost of land-based disposal, we can expect pressure on these resources to continue.

Even if private property rights for natural resources exist, the second type of market failure occurs because markets cannot be easily organized for many environmental goods and services. They form a general category called "nonmarket goods and services." An example of the existence of market failure where private property rights exist is in the

market for wetlands. Many wetlands are privately owned but may be used in a nonoptimal way by the private owner because he or she cannot capture the many social (public) benefits produced, such as water recharge, storm protection, water purification, wildlife habitat, and fishery production. The wetland owner is unable to identify the beneficiaries or measure the amount of individual benefit for each of these services, therefore these services go unpriced and undervalued in actual market transactions. From the owner's point of view, he or she may maximize the value of wetlands by developing them, but from society's point of view wetlands may be misallocated since the value of nonmarket services is ignored.

The marine debris problem combines both types of market failure. Most of the resources affected, living and nonliving, are common property and have nonmarket values. Effective solutions to the marine debris problem must focus on resolving these two market failures. Implementing systems of private property rights in the rivers, estuaries, and oceans does not seem feasible. The solution to the common property resource problem has largely been government ownership and management. The government, it is often assumed, could represent and balance competing uses of resources if all the costs and benefits of the various activities were known. The government, acting as the private sole owner, could presumably maximize the value of its resources. However, experience has shown that such an outcome is not likely for a variety of reasons: lack of information, overlapping jurisdictions, conflicts of interests across jurisdictions, and the co-opting of politicians and managers by a particular interest group, to name a few.

Markets are vitally important sources of information on the value of goods and services. It is this aspect more than any other that leads to efficient outcomes from smoothly functioning markets. The costs and benefits of various courses of action are discovered through billions of private transactions. The major problem for nonmarket goods and services is the absence of quantifiable information about the costs and benefits of actions which affect them. Two broadly defined categories of nonmarket goods and services are expected to account for a major portion of the social costs of marine debris: recreational use value and intrinsic value of natural resources and the environment.

## Recreational Use Value

Recreational use is generally recognized as second in importance only to human health as a beneficiary of water pollution control. Over the past 20 years, economists have been developing information collection and analytical techniques to estimate the recreational use value of natural resources. Survey sampling techniques and the use of questionnaires are the primary methods of information collection. Analytical techniques fall into two general categories; demand modeling and the use of direct valuation questions, e.g., contingent valuation approach. In demand modeling, individual expenditures on goods and services used in producing a recreational experience serve as proxies for actual market prices. In the contingent valuation approach, individuals are given a hypothetical situation defining the quantity and quality of the recreation experience. They are then asked how they would value in dollar terms a particular change in the quantity or

quality of a recreation resource. Some economists prefer the demand modeling approach because it is based on actual behavior; others prefer the contingent valuation method because of the flexibility it provides for addressing incremental environmental changes. Both have imperfections, and research on improved methods for estimating recreational use values continues.

### Intrinsic Value

One of the value categories that is often excluded from estimates of the total economic value of nonmarket goods is referred to as intrinsic value. This term is used to define values that people place on natural resources that are independent of their present use. These values can be reduced by human activities that lower the quantity and quality of the resources in question. Such values appear to derive from a variety of motives including the desire to bequeath a legacy of natural resources such as clean oceans to future generations, or the sense of well-being that results from simply knowing that certain natural resources exist.

In the few empirical studies that have been completed to date, aggregate intrinsic values for unique natural resources have been shown to be quite large. As to the likely ratio of intrinsic values to use values, it is still too early to draw any firm conclusions. Most who have studied this issue agree that intrinsic values exist, but continue to debate how they can be measured accurately. The methods of collecting and analyzing data on intrinsic values closely follow the contingent valuation method used for recreational use values. Research on this important area of valuation is likely to intensify in the near future.

## Efficient and Equitable Allocation of a Pollutant

Economic efficiency is one normative criterion for judging various policy outcomes. It is based on the maximization of the net social benefits to society from any activity (net benefits being equal to total social benefits minus total social costs). It is a normative criterion because there are an infinite number of economically efficient outcomes, each associated with a different distribution of wealth and income. A change in the distribution of wealth and income could change the benefits and costs of any activity and therefore the amount of the activity that is economically efficient. The distribution of wealth and income is another normative criterion used for judging policy outcomes and is commonly referred to as the equity or fairness criterion. Economists artificially separate the two criteria of economic efficiency and equity in order to make analysis tractable. Below, the concepts of economic costs and benefits and the economically efficient allocation of a pollutant are discussed. Following that, equity and another criterion related to efficiency, cost effectiveness, are presented.

### Economic Costs

The fundamental economic measure of the cost of any action is its opportunity cost. This basic concept has an analogy in physics: two objects

cannot occupy the same space at the same time. In other words, one cannot undertake one activity without giving up something else. Opportunity cost, therefore, measures the value of the next best thing forgone in order to have the preferred choice. Social cost is simply measured by how much of some other thing is given up in order to have the preferred choice. For example, to estimate the full social cost of cleaning a marsh after an oil spill, one should count the opportunity costs of all the equipment, supplies, and wages paid to employees (using market prices), plus the nonmarket opportunity costs of any physical damage done (including those caused by the cleanup itself). Of course measuring the value of the aesthetic and biomass damage inflicted, since there is no market price established for them, is difficult.

Opportunity costs are incurred regardless of whether monetary transactions, or exchanges, take place. Both explicit costs, which show up in an accounts ledger, and implicit costs should be included in any full social cost accounting of a change in the quality or quantity of a natural resource. For example, the social cost of a beach littered with debris includes the cost of cleanup plus the lost enjoyment of the beach caused by the nonmarket aesthetic insult of the debris' presence until the cleanup is accomplished. Thus the social costs of any activity (beach litter) include the lost benefits from other activities impaired by that activity (beach use).

**Economic Benefits**

A benefit is the economic value of any good or service that provides utility or satisfaction to one or more individuals. Benefits enhance a person or group's well-being. They can be derived from the consumption of commodities such as offshore oil and gas, or fish, or from nonconsumptive enjoyment of a sunset or body surfing. Commodities, especially those valued in the competitive marketplace, where externalities do not exist, are much easier to measure because their prices are determined in arm's length exchanges which reflect the consumer's willingness to pay and the cost of all inputs used in their production.

**Economic Efficiency**

Economically efficient outcomes in the choice between competing activities are ones where net benefits (total benefits minus total costs) to society are maximized. When dealing with pollution, this concept is more easily understood by an equivalent formulation involving the minimization of two rather different types of costs: damage costs and control (or avoidance) costs. In the case of marine debris, damage costs would include such social costs as lost recreational use, intrinsic damage such as harm to pristine environments or marine mammals, and damages to ships from entanglement of propellers and steering gear. Control or avoidance costs include the cost of avoiding the pollution as well as the cost of removing or recycling the marine debris causing the harm.

The economically efficient outcome will occur at the quantity of marine debris corresponding to the point where the marginal control cost is equal to the marginal damage cost. This is shown in Figure 1 as point $Q^*$.

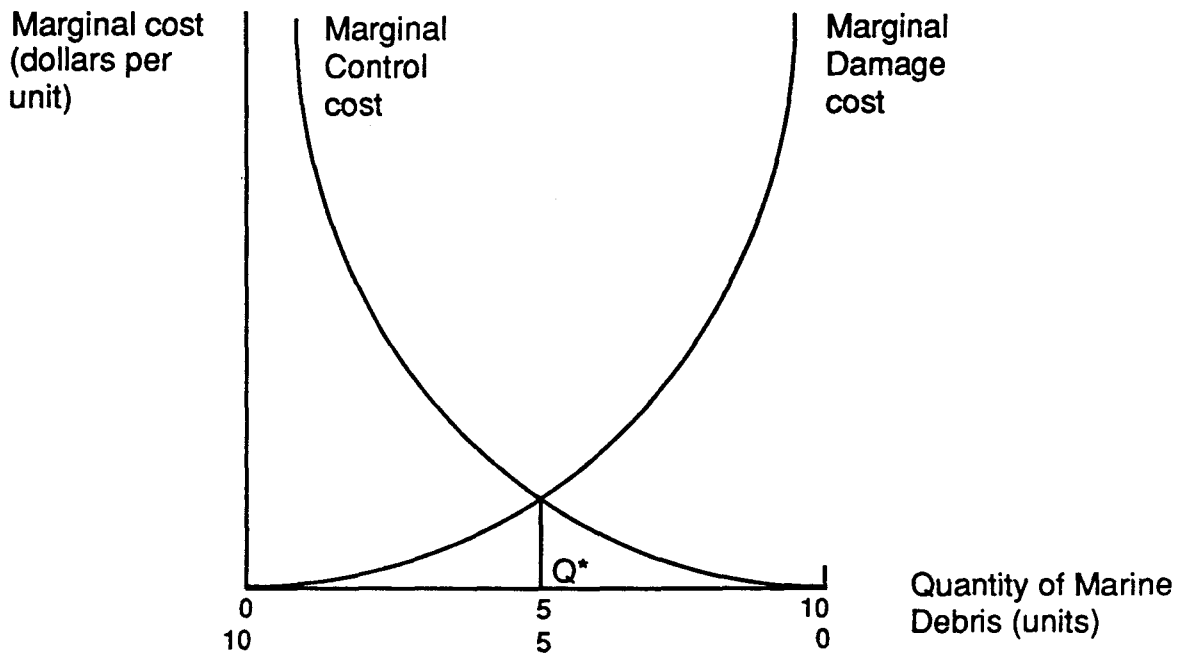



Figure 1.--Efficient allocation of a pollutant--static case.

A nonzero optimum quantity of marine debris at point Q* implies that there is some benefit from the use of products that end up as marine debris. Reducing the quantity of marine debris below Q* would be inefficient from society's point of view because the social cost of reducing it by an additional unit would exceed the value of an additional unit of other goods and services otherwise damaged. The zero level of marine debris is not a socially desirable outcome in this case.

The above static analysis assumes that marine debris items are not persistent pollutants, that is, the pollutant does not have detrimental impacts over many time periods. Some forms of marine debris, however, are persistent pollutants. Even if all marine debris were controlled today, the amount accumulated in the environment would still have detrimental impacts for years to come. Because of the persistent nature of this type of pollutant, the analysis of the efficient pollutant level must take into account the intergenerational transfer of costs and benefits. In economics, we call this the dynamic efficiency criterion. Dynamic efficiency would be achieved at the pollutant level that maximizes the present value of net benefits over time. The mathematical formulation would be:

$$PV[B_1 \ldots B_n] = \sum_{i=0}^{n} \frac{(B-C)_i}{(1+r)^i}$$

where B equals the total benefits of the goods that are produced jointly with the pollutant, i.e., marine debris; C the total cost of producing these goods plus the cost imposed on other goods and services impacted by the marine debris; i the time period; and r the social discount rate used

to make net benefits comparable across different time periods. The dynamically efficient allocation of a pollutant in this case has to satisfy the condition that the present value of the marginal net benefit from the last unit in period one equals the present value of the marginal benefit in each following period (Tietenberg 1988).

There is one interesting difference between the first efficiency outcome presented in Figure 1 (the static efficiency criteria) and the dynamically efficient outcome. In the dynamically efficient outcome, new marine debris after a certain amount of time must be eliminated. In the static outcome of Figure 1, Q*, marine debris enters the environment each new time period. However, the dynamically efficient outcome recognizes that marine debris such as plastics causes damage over many periods. Thus, as marine debris continues to accumulate in the environment, not only the new but also the old marine debris is causing damage resulting in social costs. At some future time the old marine debris will have accumulated to a point where the costs are so high that economic efficiency requires the elimination of all new marine debris. That is, the point is reached where it is less costly to recycle all new marine debris or switch to cheaper substitutes.

**Equity**

As mentioned above, there are an infinite number of economically efficient allocations of marine debris depending upon the distribution of wealth and income. Wealth, broadly speaking, would include the amounts of both human and nonhuman capital a person owns. Human capital is a person's skills and abilities. Income is a flow from the stock of human and nonhuman capital. An increase in marine debris may result in an increase in the cost of beach visitation, since a person may have to travel further to get to a clean beach. This increase in cost can be thought of as a decrease in income available to the person to purchase other goods and services--an opportunity cost. Equity addresses the question of fairness in the distribution of net benefits from any activity. No generally accepted standards of fairness exist. Resolution of disputes over fairness are generally resolved in political or judicial processes. Implementation of policies that have high net benefits can fail because the benefits of the activity are concentrated in one region of the country and the costs in another. Unless the region that is disadvantaged is compensated for the added costs imposed by the policy, the policy may be defeated. There are several criteria that are generally used in evaluating the issue of equity. They are horizontal equity, vertical equity, and sustainability.

Horizontal equity occurs when people with equal incomes are treated equally. This can be used in judging the geographic fairness of a given policy. If people with comparable income levels in different parts of the country receive different net benefits, the horizontal equity criterion is violated.

Vertical equity deals with the treatment of unequals or those with different incomes. In assessing vertical equity, net benefits are distributed among income groups either progressively, regressively, or

proportionally. Distribution is said to be proportional if the net benefit received is proportional to income. It is said to be regressive if the net benefit represents a larger proportion of the income of the rich than of the poor, and is progressive if, as a proportion of their income, the poor receive a larger share than the rich. Since many of our societal programs are designed to aid the poor, it is usually assumed that regressive policies are bad. Some economic efficiency may be sacrificed to achieve greater equity.

The last criterion is sustainability. This involves intergenerational transfers of net benefits. As we have seen in the discussion of efficiency above, the marine debris problem can be characterized by intergenerational transfers because of the persistent nature of the pollutant. The sustainability criterion suggests that, at a minimum, future generations should be left no worse off than present generations.

**Cost Effectiveness**

A concept more closely related to the efficiency criterion of policy is the cost effectiveness approach. Under this approach it is recognized that, due to the lack of full and accurate information, determination of the optimal efficiency point is impossible. The cost effectiveness approach evaluates policies and management strategies as to the least costly way in which a given level of environmental quality can be achieved. In the case of persistent marine debris, the economically efficient solution may be an eventual ban on its use and disposal in the oceans altogether. However, compliance with such a ban would likely result in economic hardship for certain sectors of the economy and would be costly to enforce.

Laws and regulations that contain market-based incentive systems are, in theory, less costly than traditional regulatory approaches. Incentive systems use market forces to reduce pollution by requiring polluters to pay all or part of the social cost of their activity. They are penalized economically for high levels of pollution and are rewarded with lower fees for reduced levels of pollution. The laws and regulations that currently exist on marine debris do not contain market-based incentive systems to achieve compliance. This is an area where future research could pay big dividends.

**Economic Impact**

Many government officials appear more persuaded by the effects of their decisions and policies on sales, employment, and income, i.e., economic impact, than by efficiency, equity, sustainability, or cost effectiveness. Much of the time, concern about sales, employment, and income is expressed in terms of equity or fairness and reflects genuine concern for the health and welfare of people in the communities affected by various decisions and policies. However, economists would generally agree that maximization of sales, employment, and income are not preferable to economic efficiency as objectives of social policy, since irrational conclusions are often derived from analyses based upon maximization of economic impact. An example should help clarify this point.

Consider Figure 2, showing the demand and supply of commercially caught fish. The demand for commercially caught fish is shown in $D_1$; $S_1$ and $S_2$ are the supply of fish before and after pollution, respectively. Before pollution, consumers purchase $Q_1$ pounds of fish per time period at price $P_1$ per pound. Total sales revenue is equal to the area $0P_1AQ_1$.

If pollution reduces the stock of fish, the supply curve shifts back to $S_2$ and consumers now purchase only $Q_2$ pounds per time period at the higher price, $P_2$. Total revenue is now equal to the area $0P_2BQ_2$. The problem with this analysis is that total revenue may have increased, decreased, or remained the same depending upon the price elasticity of demand. If demand is inelastic (a 10% increase in price will result in a <10% decrease in quantity demanded), then total revenue will increase. Thus, when demand is inelastic, if pollution reduces fish stocks it results in increases in total sales revenue.

Now consider the efficiency approach. Area $P_1P_1{*}A$ measures the net value (consumer's surplus) associated with commercial fishing before the pollution. This would be a measure of the net benefits of commercial fishing to society. Now when pollution reduces the stocks, supply shifts to $S_2$ and the new consumer's surplus is equal to the area $P_2P_1{*}B$, which is less than the area $P_1P_1{*}A$ by the amount equal to the area $P_1P_2BA$. Thus, using the efficiency criterion, there is a net loss to society from the pollution injury to this commercial fishery. This loss would then be compared to the gains in consumer's surplus from the products that result in the pollution to determine if society gains or loses from their production.

Such comparisons are commonly known as benefit-cost analyses. They provide more comprehensive information to decisionmakers about the overall result of a given project or policy change than the rather incomplete picture conveyed by economic impact analyses. A benefit-cost analysis can help determine whether, for example, the social benefits of a specific set of policies to reduce marine debris outweigh their costs.

## Categories of Social Cost

The following categories can be delineated as the major areas of known economic costs or externalities associated with marine debris:

- Commercial fisheries. Through what is called "ghost fishing," discarded or lost nets and other types of debris can entangle fish and reduce the quantity of various species and thereby impose costs on fishermen and consumers. Debris can also become entangled in fishermen's nets and either damage them or cause them to operate inefficiently.

- Ships. Debris can become entangled in the propellers and steering gear and can clog the water intake of vessels, thereby causing physical damage to ships of all types, including recreational fishing, cargo, military, and research vessels, and imposing repair and delay costs on their owners.

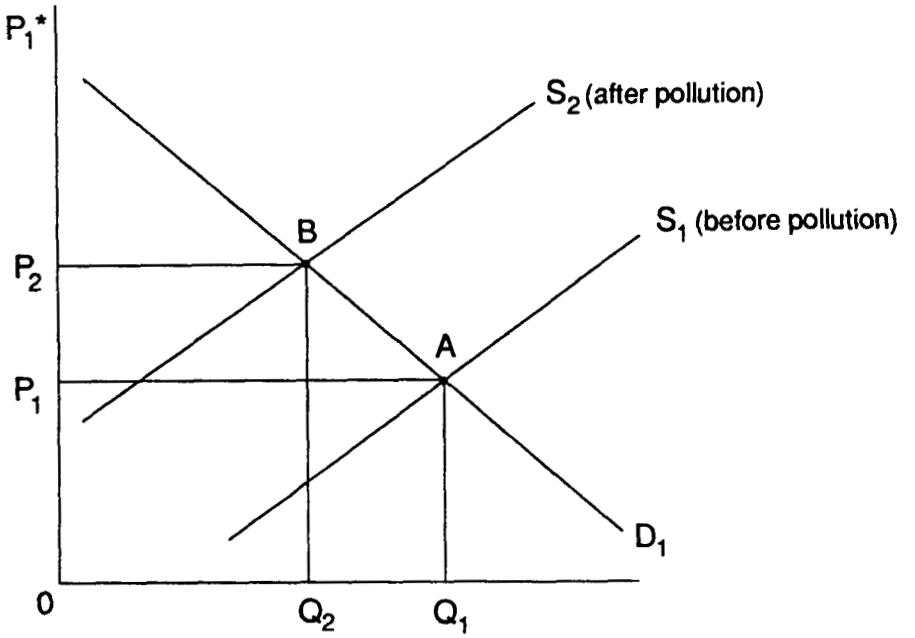



Figure 2.--Impact of pollution on the supply of commercially caught fish.

- Marine mammals, birds, and turtles. Through entanglement in and ingestion of plastics, we know that large numbers of birds and animals become injured and die, imposing costs on those members of society who obtain use value from these animals through viewing, hunting, and scientific research, or intrinsic values from the mere fact that these organisms exist.

- Recreation, such as beach use, hiking, camping, and picnicking. Debris causes aesthetic losses, as demonstrated by users who are willing to go to considerable expense to avoid it, such as through cleanup of beaches or extra travel to recreate in areas with less debris. Property owners in coastal areas may also suffer reductions in the value of their property if debris renders it less desirable from an aesthetic or recreational standpoint.

- Long-term impact. There could be other, as yet unknown, long-term impacts of marine debris on the health of humans and the biota which now, or may at some time in the future, impose unexpected costs on society.

## The State of Economic Knowledge on Marine Debris

To date there have been only a handful of economic studies directed at the problem of marine debris. The present state of knowledge is reminiscent of what was known about the economics of oil spills and their prevention

some 20 years ago. A small number of studies have been conducted by state or local governments on the out-of-pocket costs but not necessarily the full opportunity costs of cleaning up small sections of beaches. There has been one detailed study on the effects of debris on individuals' willingness to pay for tourist accommodations in a small area of coastal Massachusetts several years ago (Wilman 1984). It revealed that overnight tourists did place a premium on reduced quantities of beach debris. However, the study ironically did not set out to measure the benefits of debris reduction, but rather the economic costs of oil spills on Cape Cod beaches. Since there were no actual oil spills there to study, the author used debris as a surrogate for the effect of oil on the value of beach recreation. There has also been one study on the costs of recycling shipboard plastic waste in the Port of Newport, Oregon (Recht 1988). It provides some useful information and anecdotes of what such a program entails from both a management and a cost standpoint. And finally, there has been one paper written on the types of economic incentives that might be applied to the problem of debris and what general types would likely be effective (Sutinen 1988). At present there are economic studies under way on some aspects of the debris problem that plagued the New England and mid-Atlantic coasts of the United States during the summers of 1987 and 1988.

In addition to the modest amount of economic research directed at the debris problem, there is some important complementary research being conducted on the value of various types of beach use, intrinsic values of natural resources, the costs and benefits of waste recycling programs, and the costs and marketability of degradable plastics. Results of such governmental and academic research programs can be found in the natural resource and environmental economics literature.

## RESEARCH AGENDA

A review of the literature reveals that there is little known about the magnitude of the marine debris problem or of its social costs (or conversely, the benefits of a reduction in the quantity of debris). Justification of public programs to mitigate or eliminate these costs will require such estimates. But knowledge of these costs is only a first step. Laws and regulations require changing people's behavior to bring them into compliance. Market-based incentives will likely be the most cost-effective means of achieving compliance. Research is therefore needed on the relative effectiveness of various market based incentive programs in achieving compliance with various laws and regulations. Below is a list of suggested research projects that partially address both the issue of identifying the magnitude of the social costs of marine debris and various market-based incentive programs.

### Social Costs

#### Aesthetics

Debris makes beaches and other recreational areas less attractive. Shorefront properties are also made less attractive, but whereas the loss in value of shorefront properties may show up in market transactions, the recreational values are nonmarket. Two studies are recommended to help understand the magnitude of this type of economic loss.

1. A study of the economic costs of debris on a specific set of beaches. This study would pick a set of beaches and investigate the economic value of lost services that would result from different levels of debris on the beach. The beaches chosen would ideally have wide regional representation. The study should be designed so that the methodology and the loss estimates could be expanded to other regions of the country.

2. A study of property value losses due to marine debris. Property value studies have been used by economists in estimating the economic damages from various environmental pollution problems. These techniques could easily be extended to the marine debris problem. Several regional studies should be conducted to show the effects throughout the nation.

**Intrinsic Value**

Debris traps and entangles fish and wildlife. Fish and wildlife also ingest various types of debris resulting in morbidity and mortality. This type of physical injury to the environment results in economic damage to individuals that value the right of fish and wildlife to exist or remain unharmed in pristine environments.

A study could be made of the economic cost incurred when individuals of some subpopulation of a noncommercial species (e.g., birds, mammals) become entangled in or ingest marine debris. This study could involve the threat of extinction or only the loss in social value when a small number of a species are lost or harmed. The study should be based on a national survey since many individuals outside coastal areas will experience this type of loss.

**Fouling of Vessels and Fishing Gear**

When vessels and their gear are impaired by contact with marine debris, there are two kinds of costs: a) the repair and replacement cost for the damaged gear and b) the opportunity cost of the vessel and gear when it is not in productive service. Commercial fishing or shipping impacts entail market losses, but for recreational boating, market and nonmarket losses must be considered. Two projects could be undertaken to quantify the incidence of impairment and the magnitude of costs.

1. Investigate the incidence of impairment for each of the following industry groups: commercial fishing, shipping, and recreational boating. Research should attempt to quantify the extent of the problem nationally and identify regions of critical concern.

2. Estimate the magnitude of costs for each of the three industry groups above. These could be small surveys among owners or operators in each of the industry groups. Areas

identified as representing the most severe problems should be used for each industry group.

**Commercial and Recreational Fisheries**

The greatest impact of marine debris on fish stocks is, apparently, the ghost fishing phenomenon. A secondary, but potentially large, impact is the possibility that consumer perception of contamination of fish stocks by marine debris can influence the demand and price of related fish products. This impact could extend to recreational fisheries because one of the main components of value in the recreational fishery is the consumption of fish.

1. Ghost fishing. Ghost fishing has an economic cost in terms of the wasted resource. For commercial fisheries it is the market value of the lost product, whereas for recreational fisheries it is the lost value due to lower catch rates. This project should involve both biologists and economists. Current economic research on the impact of catch rates on recreational fishing demand and value could be utilized in assessing the cost of ghost fishing.

2. The impact of perceived contamination on the price of and demand for fish. A project which collects and describes incidents of market effects (i.e., commercial fisheries only) from perceived contamination would provide at least some evidence of the economic costs of marine debris. A survey of the economics literature and of knowledgeable people to gather these incidents in the form of a research report should be conducted. Additional studies could follow, if warranted.

**Compliance and Incentives**

The greatest challenge in resolving the marine debris problem will be in finding and implementing the right mix of market-based incentives and enforcement to bring about compliance with various laws and regulations on the disposal of debris. The following projects would investigate the use of fees and incentives as part of the marine debris solution.

1. Deposits on the return of nondegradable products. The efficiency of deposits on beverage containers as a means of controlling land debris is well documented. This research project would investigate the potential for deposits for the return of plastic marine debris. It should focus on coastal states which have experience with deposit systems.

2. Fees on the use of nondegradable materials. Business firms and households are good at allocating scarce resources which they must pay for. Fees on plastic would be an incentive to substitute other materials. However, business firms must be treated differently from the household sector because

foreign firms could simply displace domestic firms. Foreign made products using a host of nondegradable but cheaper materials could replace domestically produced goods made of more expensive degradable materials. This project would investigate the feasibility of fees on potential debris in the marine environment.

3. Investigation of the economic gains that can accrue to a particular region as a consequence of consolidating waste handling facilities. New U.S. laws require that vessels bring their nondegradable waste to port. Ports are required to handle the solid waste. Within particular regions, it may be very costly for ports to handle all of the vessel-borne waste. An economic study of the costs of onshore waste handling would prepare ports for the resource demands and for setting port fees. When the costs differ among ports, there may be incentives to use different ports. Further, there are incentives to dump trash if fees are based on the amount of trash that is brought ashore.

4. Investigation of alternatives to traditional methods of compliance. Policies combining punishment and reward which partly subsidize the adoption of compliance techniques and impose clear penalties for the absence of compliance are used elsewhere in government regulation. This research program, would study compliance programs which include education, incentives, and penalties for a specific portion of the industry.

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# ESTIMATION OF DAMAGES TO FISHING VESSELS CAUSED BY MARINE DEBRIS, BASED ON INSURANCE STATISTICS

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## ABSTRACT

An estimation has been made of the number of accidents, the amount of damage, and losses to and of fishing vessels caused by marine debris, based on data available from the insurance covering fishing vessels. Such accidents, damage, and losses caused by debris in the sea include those resulting from collision with drifting objects, entanglement of floating objects in the propeller blades, and clogging of the water intake for the engine cooling system. According to insurance statistics, losses attributed to the above-mentioned causes were ¥4.4 billion in 1985, whereas the losses and damage sustained by all the fishing vessels of <1,000 gross tons in Japan are estimated at ¥6.6 billion per year.

## INTRODUCTION

Since ancient times, many different kinds of objects drifting in the sea have endangered ships. In the past, drifting wood and blocks of ice usually made up such driftage. More recently new kinds of debris including discarded plastic materials have emerged. Accidents and trouble caused by lost or discarded fishing nets and ropes becoming entangled in propeller blades, and the overheating of engines resulting from plastic debris clogging the water intake of an engine cooling system have been reported.

However, there are very limited statistical data available showing the number of vessels damaged by marine debris and the magnitude of the damage and losses. The reason for this lies in the fact that there are few systems for collecting such statistical data. On the other hand, at least part of such damage is covered by insurance, and by analyzing insurance-related data, it is possible to obtain approximate figures on the number of cases and the amount of damage.

In Japan, there is an insurance system for fishing vessels of 1,000 gross tons (GT) based on the Compensation Law Concerning Damages, etc., to Fishing Vessels. Established for the purpose of stabilizing the fishing industry which, is said to be subject to a great many dangers, this system

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

operates with a subsidy from the central government. As many as 60% of all fishing vessels of <1,000 GT are covered by this insurance system.

This insurance covers a wide range of damage to fishing vessels including damage such as sinking and fire, damage to the cargo including fish caught and stored on board, and loss of life of the crew. Also covered by the insurance are accidents resulting from marine debris.

This report illustrates the accidents and trouble sustained by fishing vessels in Japan as documented by a nationwide organization handling damage insurance (the Fishing Vessel Insurance Center, which is principally in charge of management of the insurance system) and estimates the magnitude of the losses and damage as well.

## METHODS

The statistical data used in this report have come from two published reports relating to the damage to fishing vessels owing to accidents: Statistics of Fishing Vessel Insurance (hereinafter called the Insurance Statistics) and Report of Special Analyses on Accidents of Fishing Vessels Insured (hereinafter called the Special Report). The Insurance Statistics is issued annually, and the Special Report was compiled based on a detailed analysis of 1985 insurance data.

In the tables of the Insurance Statistics, damages sustained are classified according to those caused by bad weather such as heavy wind and rough seas, those caused by engine trouble such as a faulty lubrication system, those caused by human error in operating the ship and machines, those caused by drifting objects (this category is ambiguous but considered to be collision with drifting objects other than ice blocks), and those caused by foreign material tangled in the propellers. The cases to be discussed in this report will relate to damage caused by driftage, entanglement of foreign material in the propellers, and engine trouble resulting from trouble with the water cooling system.

Using the Special Report, more detailed analysis was possible. Accidents or trouble caused by drifting objects were classified into three categories: collision, cooling system trouble, and entanglement. As for the accidents or trouble with the cooling system, data indicating particular damaged points were also provided. As regards damage caused by drifting objects, the details given are those prepared especially for this report, obtained by reprocessing the original computer master tape used for the Special Report.

## RESULTS

### Fishing Vessel Insurance Statistics

Listed in Table 1 are the number of fishing vessels insured, the number of fishing vessels registered with the Fisheries Agency, the Government of Japan, and the percentage of insured fishing vessels (number of insured fishing vessels and number of registered fishing vessels). In

Table 1.--Number of fishing vessels registered, the number insured, and the ratio of vessels insured to total number of vessels (by gross tons (GT) and year) (Fishing Vessel Insurance Center 1985; Fisheries Agency of Japan 1975, 1982, 1983, 1984, 1985, 1986).

| Vessels (GT) | 1975 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|
| **Number of fishing vessels registered (1)** | | | | | | |
| <5 | 316,683 | 363,875 | 364,620 | 365,207 | 364,197 | 361,838 |
| 5-20 | 19,397 | 28,038 | 28,216 | 28,304 | 28,343 | 28,488 |
| 10-50 | 2,555 | 1,574 | 1,436 | 1,361 | 1,243 | 1,105 |
| 50-100 | 4,022 | 3,640 | 3,523 | 3,372 | 3,016 | 2,764 |
| 100-1,000 | 3,223 | 3,312 | 3,325 | 3,302 | 3,272 | 3,222 |
| Total | 345,880 | 400,439 | 401,120 | 401,546 | 400,071 | 397,417 |
| **Number of fishing vessels insured (2)** | | | | | | |
| <5 | 167,700 | 196,287 | 198,343 | 202,009 | 205,744 | 210,628 |
| 5-20 | 16,592 | 24,396 | 24,411 | 24,495 | 24,473 | 25,205 |
| 10-50 | 1,918 | 1,200 | 1,120 | 1,051 | 957 | 884 |
| 50-100 | 3,580 | 3,049 | 2,860 | 2,651 | 2,441 | 2,340 |
| 100-1,000 | 2,371 | 2,498 | 2,527 | 2,530 | 2,527 | 2,506 |
| Total | 192,161 | 227,430 | 229,261 | 232,736 | 236,142 | 241,563 |
| **Ratio of vessels insured to total vessels (2)/(1)** | | | | | | |
| <5 | 0.530 | 0.539 | 0.544 | 0.553 | 0.565 | 0.582 |
| 5-20 | 0.855 | 0.870 | 0.865 | 0.865 | 0.863 | 0.885 |
| 10-50 | 0.751 | 0.782 | 0.780 | 0.772 | 0.770 | 0.800 |
| 50-100 | 0.890 | 0.838 | 0.812 | 0.786 | 0.809 | 0.847 |
| 100-1,000 | 0.736 | 0.754 | 0.760 | 0.766 | 0.772 | 0.778 |
| Total | 0.556 | 0.568 | 0.572 | 0.580 | 0.590 | 0.608 |

1986, of the vessels smaller than 5 GT, >200,000 units were insured, or 58% of all the registered fishing vessels of that size group. (All fishing vessels in Japan must be registered when they are built.) The percentage of insured fishing vessels of 5 GT and greater is as high as about 80%, even though the total number of such ships is much smaller than the number of ships of <5 GT.

Figure 1-1 and Figure 2 show the frequency of accidents and the average amount of damage per accident, respectively, for the driftage, floating ice blocks, entanglement of the propeller blades, and trouble with the engine cooling system based on the Insurance Statistics.

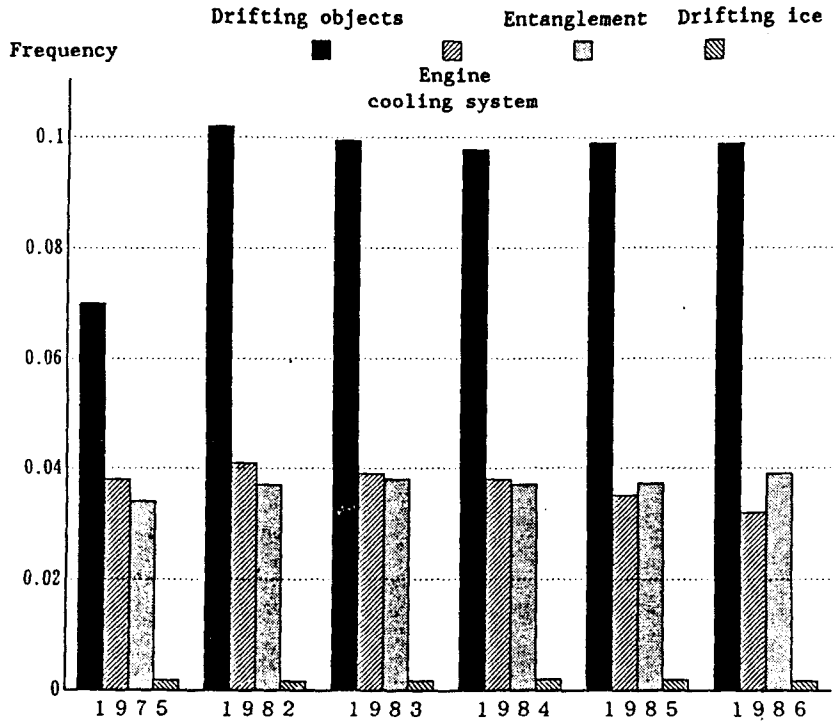



Figure 1-1.--Change in frequency of accidents (number of accidents/number of vessels insured) by type of accident. (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

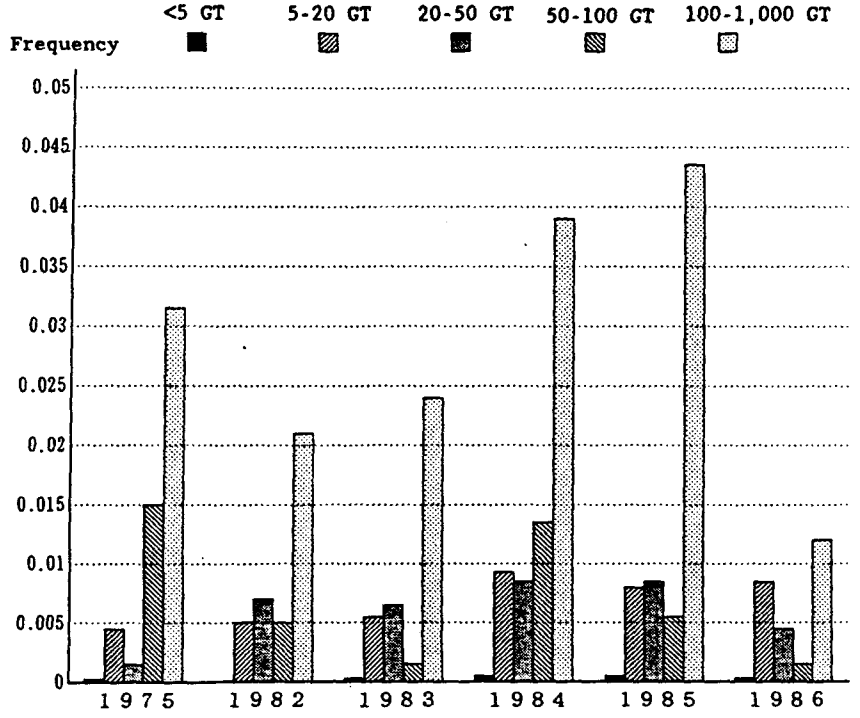



Figure 1-2.--Change in frequency of accidents caused by drifting ice blocks by size class of vessel. (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

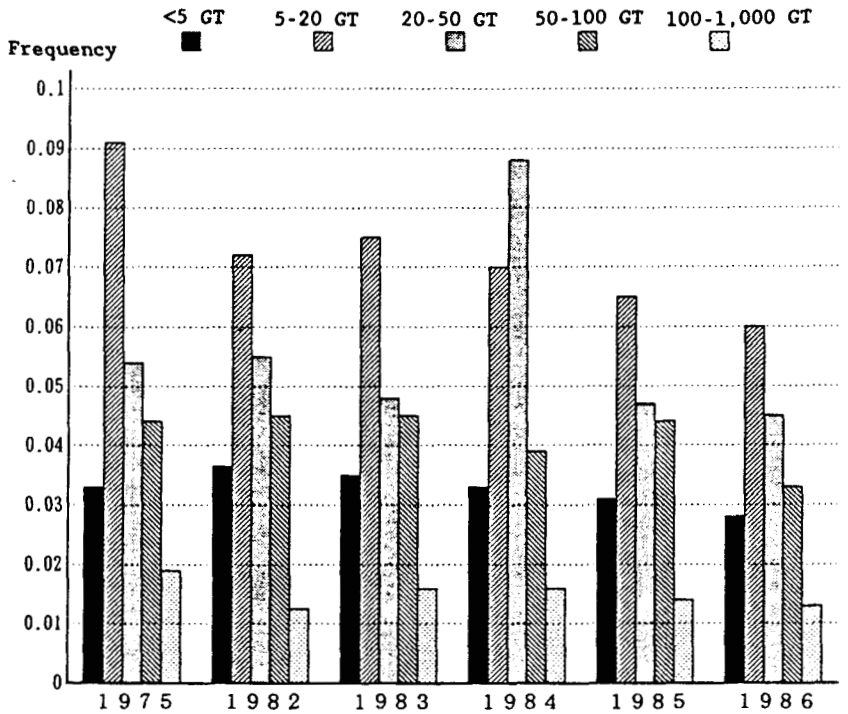



Figure 1-3.--Change in frequency of accidents or trouble with engine cooling system by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

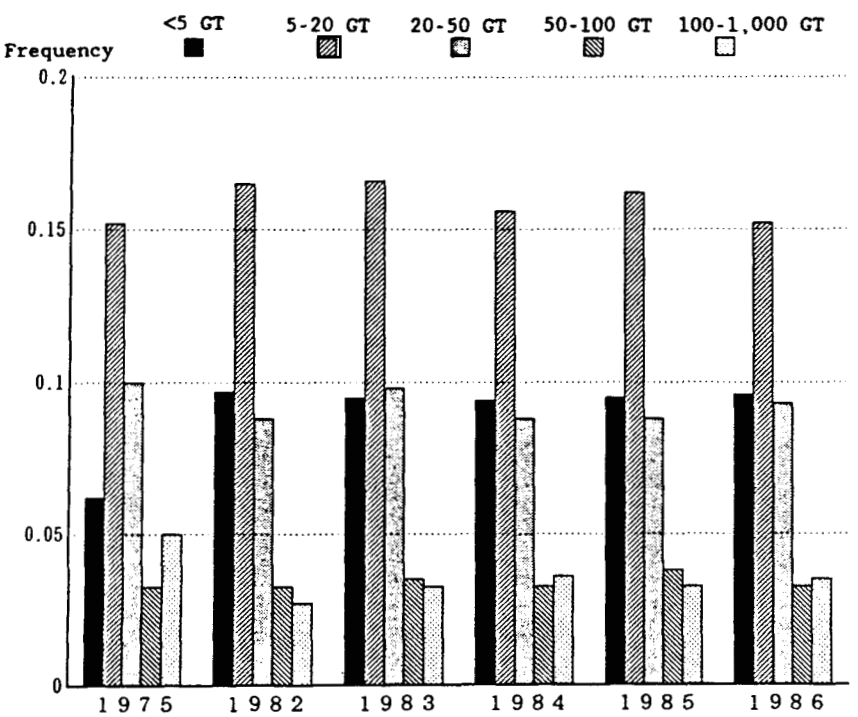



Figure 1-4.--Change in frequency of accidents caused by floating objects by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

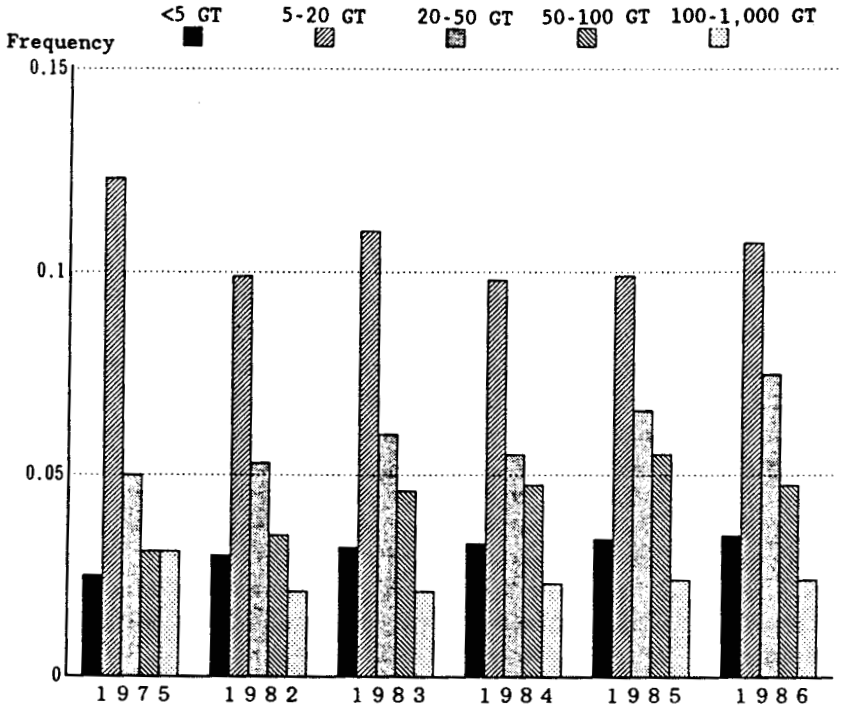



Figure 1-5.--Change in frequency of accidents caused by entanglement by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

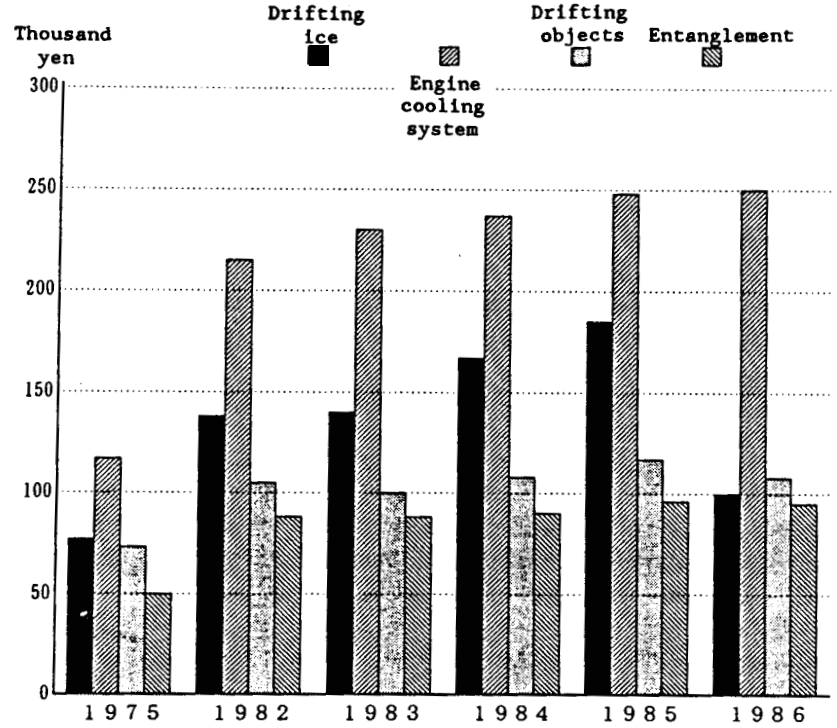



Figure 2.--Change in average cost of damage per accident by type of accident. Because the drifting ice category is so large, the cost shown in this figure has been divided by 10. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

The damage to the engine cooling system has a variety of causes including plastic bags. Damage by "drifting objects" has resulted from collision with objects floating in the sea, as described later. Damage by "entanglement" of fishing net and ropes in the propeller blades includes damage done not only by lost or discarded objects but also by fishing nets in actual use.

Except for damage done by "drifting objects," it was impossible to isolate the damage caused by only marine debris using the Insurance Statistics. These are, however, the only data available which enable us to review a historical change in accidents, and therefore, marine debris as a cause of the change is inferred by their use. In terms of frequency of accidents (number of accidents per number of fishing vessels insured), "drifting objects" is highest at about 10% (number of accident per number of insured vessels), which is more than twice the frequency attributable to other causes (Fig. 1-1). Conversely, the frequency of accidents is very low when it comes to the damage done by "floating ice," since such damage is limited to specific seasons and to specific areas of the sea. The frequency of accidents resulting from all categories shown has remained stable in the past 5 years. However, with regard to the accidents caused by drifting objects, this frequency is about 40% higher than it was in 1975, a percentage that has remained stable for the past 5 years.

Looking at the average cost per accident by type, "floating ice" stands out at ¥1 million or more suggesting that whereas its frequency of occurrence is low, the cost caused damage can be very great (Fig. 2). In contrast, accidents caused by drifting objects and entanglement in the propellers are low in cost, averaging around ¥100,000 per case.

With regard to differences in the frequency of accidents by size of fishing vessels, the frequency of "floating ice" is high in the case of ships of 100 GT or more, and is quite low with those of <5 GT. This is a natural consequence, because small ships rarely operate in a sea filled with drifting ice blocks during winter months (Fig. 1-2).

The frequency of accidents associated with the engine cooling system is highest for fishing vessels of 5-20 GT, next highest for those in the 20-100 GT class, and lowest for those of <5 GT. In any of these groups, the frequency of accidents tends to decline slightly over time (Fig. 1-3). The frequency of accidents caused by "floating objects," is highest with ships of 5 to 20 GT, followed by those of <5 GT and those 20 through 50 GT. It is the lowest with ships of 50 GT or larger. In most of those brackets, the frequency of accidents remains nearly the same. For vessels smaller than 5 GT, the frequency of accidents increased by 60% during the period from 1975 to 1982, and stabilized thereafter (Fig. 1-4).

In the entanglement of foreign materials in the propellers, too, the frequency is highest with vessels of 5 to 20 GT, followed by those <5 GT, 20 to 50 GT, and 50 to 100 GT. It is lowest with ships of 100 GT or larger. In terms of changes in frequency with time, ships in the of 20 to 50 GT and 50 to 100 GT classes are gradually increasing in number, whereas the frequency in the other brackets has remained stable (Fig. 1-5).

## Special Report on Accidents of Insured Fishing Vessels

The purpose of the Special Report was to produce a detailed analysis based on data provided by the fishing vessel insurance. In order to do so, statements requesting payment were reprocessed to be collectively indicated on the form appearing in Figure 3. On this form, the types of accidents are classified (e.g., collision, fire, grounding, entanglement, engine trouble) as are the causes of the accidents (e.g., floating ice, drifting objects, inadequate watch), and by combining these categories, it is possible to determine the number of accidents of different kinds that were caused by floating objects and the cost as well. On the form, trouble with the engine cooling system is broken down into trouble resulting from plastic debris and that caused by other factors.

### Accidents Caused by Floating Objects

Itemized in Table 2 by size of fishing vessel are the number of accidents classified by types of accidents caused by driftage and the amount of damage expressed in terms of money. Figures 4 and 5 show the frequency of accidents (the number of accidents divided by the number of insured fishing vessels) by type of accident and the average amount of damage per accident, respectively.

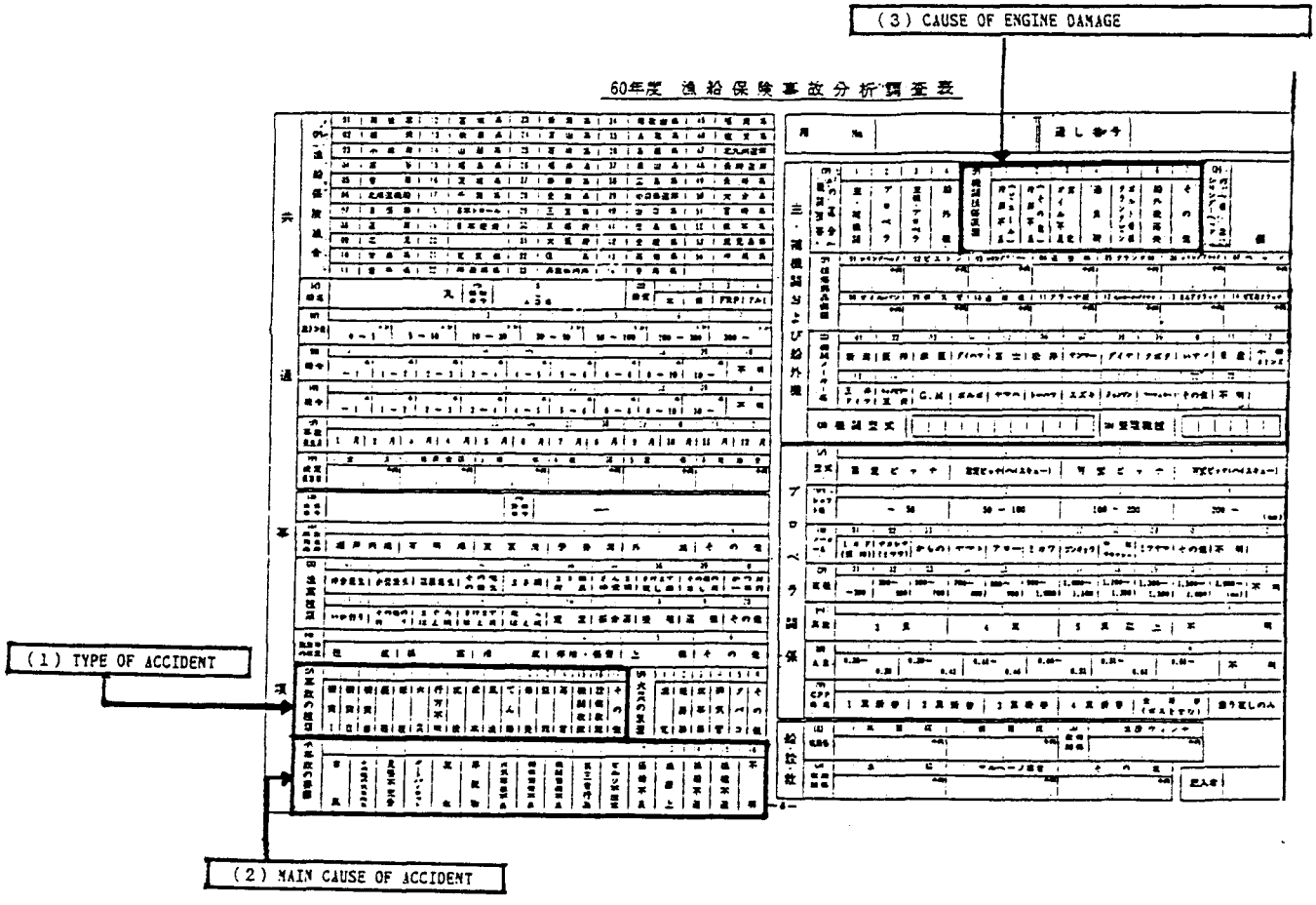
In 1985, there were a total of 32,8484 accidents resulting from drifting objects. There were 22,605 cases (69%) caused by collision, 5,809 cases (18%) with engine-related troubles, and 4,287 cases (13%) associated with entanglement. One hundred and forty-seven cases did not fall under any such classification (Table 2).

The cost of damage totaled ¥4.4 billion. It is said, in general, that the average such cost goes up as the size of the ship becomes larger. With ships <20 GT, the cost associated with engine trouble is the highest, and in the case of larger ships, the cost resulting from collision is the highest (Fig. 5).

In all size categories, accident frequencies are highest for those caused by collision, whereas the frequencies are lowest for engine trouble in all but the smallest ship size bracket. The frequency for the 5-20 GT category is highest in all types of accidents, whereas the frequency is low for size brackets of 50 GT or more, except for entanglement of foreign material in the propellers. The frequency of such entanglement is relatively high for 50 to 100 GT vessels, and low for those of <5 GT (Fig. 4).

### Comparison of Accidents Caused by Marine Debris With Those of Other Causes

Figure 6 shows accidents caused by floating objects as a percentage of all accidents, by type of accident. The causes other than the driftage include entanglement with the fishing gears in actual use in the category of entanglement, and collision with submerged rocks in the category of collision. Collision as referred to here does not include ship-to-ship collision or grounding.




| (1) Type of accident | (2) Main cause of accident | (3) Cause of engine damage |
|---|---|---|
| Collision with ships | Typhoon | Insufficient cooling resulting from clogging with plastic film. |
| Collision with ice blocks | Other weather phenomenon | Insufficient cooling from other causes. |
| Collision with others | Inadequate watch | Insufficient oil or deteriorated oil. |
| Grounding | Autopilot system | Overload. |
| Capsizing | Floating ice | Breakage of crank pin or bolt. |
| Fire | Floating objects other than ice | Dropping of outboard engine. |
| Missing | Careless handling of fire | Other. |
| Sinking | Improper ship maintenance | |
| Water intrusion | Improper machine maintenance | |
| Damage by rough sea | Intentional damage by others | |
| Entanglement | Improper ship mooring | |
| Explosion | Improper fishing operation | |
| Theft | Improper ship operation | |
| Damage by lightning | Improper machine operation | |
| Engine trouble | Other | |
| Machine trouble | | |
| Other | | |

Figure 3.--Compilation form for the Special Report.

Table 2.--Number of accidents and damage caused by marine debris by type of accident and by vessel size (gross ton (GT)). (Number is actual number, and amount of total damage and damage per accident are shown in ¥1,000.) (Fishing Vessel Insurance Center 1985; Fisheries Agency of Japan 1975, 1982, 1983, 1984, 1985, 1986.)

| Accident or damage | Vessels 0-5 GT | | | Vessels 5-20 GT | | | Vessels 20-50 GT | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number | Damage | D/N[a] | Number | Damage | D/N[a] | Number | Damage | D/N[a] |
| Collision | 18,644 | 1,639,473 | 87.9 | 3,715 | 626,365 | 168.6 | 78 | 102,718 | 1,316.9 |
| Entanglement | 2,852 | 192,917 | 67.6 | 1,279 | 159,982 | 125.1 | 44 | 18,244 | 414.6 |
| Engine trouble | 4,773 | 814,839 | 170.7 | 940 | 363,436 | 386.6 | 35 | 20,521 | 586.3 |
| Other | 94 | 16,962 | 180.4 | 42 | 22,881 | 544.8 | 5 | 4,799 | 959.8 |
| Total | 26,363 | 2,664,191 | 101.1 | 5,976 | 1,172,664 | 196.2 | 162 | 146,282 | 903.0 |

| Accident or damage | Vessels 50-100 GT | | | Vessels 100-1,000 GT | | | Total all vessels | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number | Damage | D/N[a] | Number | Damage | D/N[a] | Number | Damage | D/N[a] |
| Collision | 90 | 132,083 | 1,467.6 | 78 | 158,264 | 2,029.0 | 2,605 | 2,658,903 | 117.6 |
| Entanglement | 82 | 26,217 | 319.7 | 30 | 40,153 | 1,338.4 | 4,287 | 437,513 | 102.1 |
| Engine trouble | 48 | 46,613 | 917.1 | 13 | 17,045 | 1,311.2 | 5,809 | 1,262,454 | 217.3 |
| Other | 2 | 862 | 431.0 | 4 | 30,557 | 7,639.3 | 147 | 76,061 | 517.4 |
| Total | 222 | 205,775 | 926.9 | 125 | 246,019 | 1,968.2 | 32,848 | 4,434,931 | 135.0 |

[a]Damage divided by number.

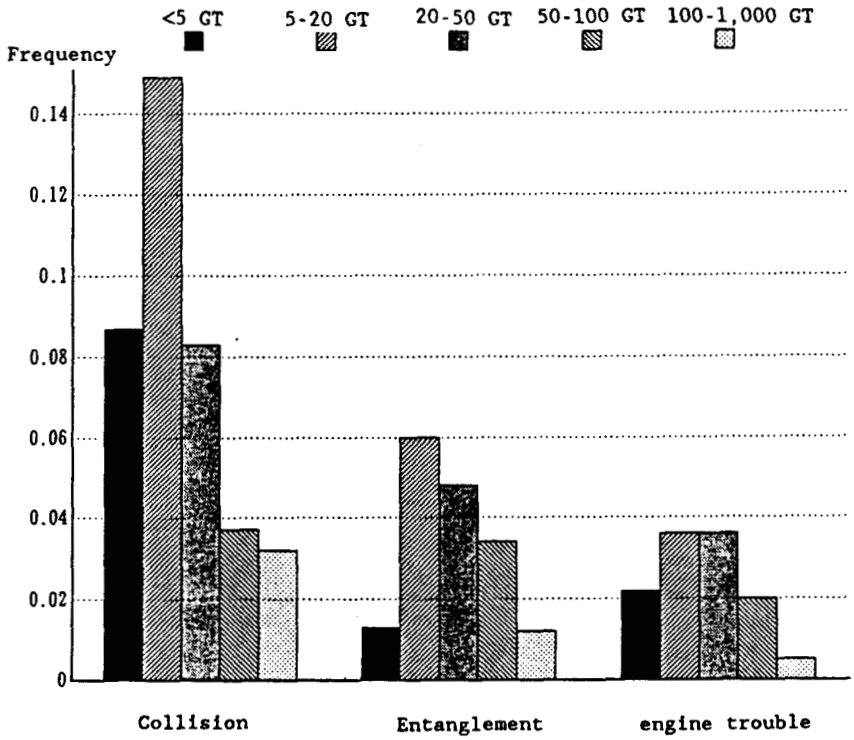



Figure 4.--Frequency of accidents caused by floating objects by type of accident and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

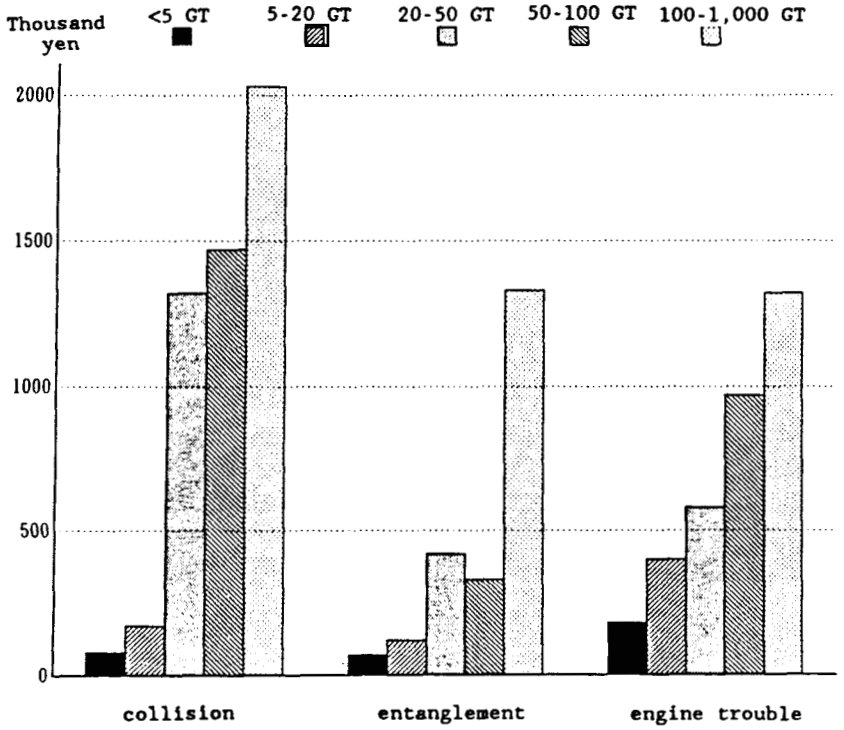



Figure 5.--Average cost of damage per accident caused by floating objects by type of accident and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

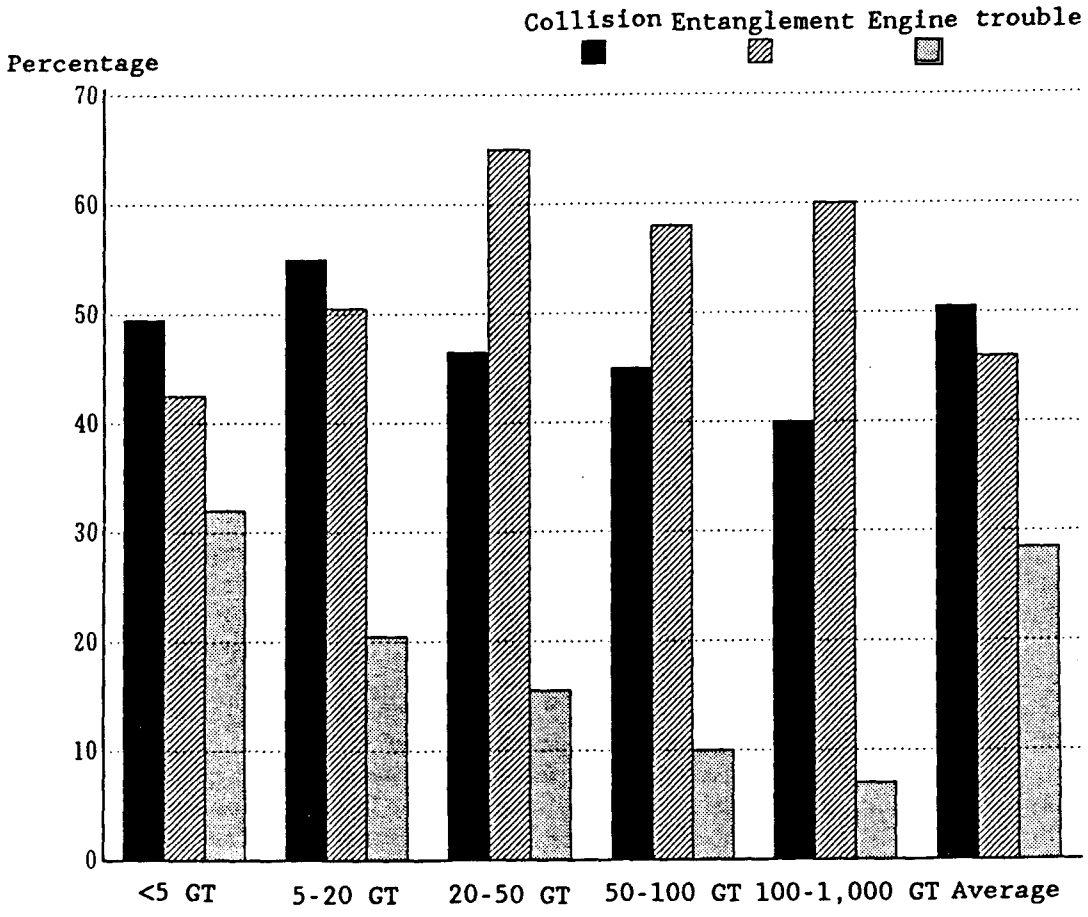



Figure 6.--Percentage of the number of accidents caused by floating objects in relation to total number, by type of accident, and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

Percentagewise, engine trouble caused by floating objects is low on the whole, and the percentage decreases in reverse proportion to the size of ships.

For vessels <50 GT, the percentage of entanglement trouble caused by driftage increases with vessel size, but with the vessels >50 GT, the percentage tends to decrease.

In cases of collision, the percentage is the highest for vessels in the 5 to 20 GT category, and decreases as vessel size becomes larger.

It may be generalized that the percentage of damages attributable to drifting objects is lower in reverse proportion to the size of ships (Fig. 6).

### Accidents or Trouble With the Engine Cooling System

The Special Report gives statistical data detailing the number of accidents or engine trouble and the amount (in yen) of damage resulting from improper engine cooling caused by plastic debris clogging the cooling water intake.

In 1985, there were 2,576 accidents with damage to engine cooling systems caused by plastic debris, which were covered by insurance. The cost of damages totaled ¥614 million. The frequency of accidents and the average cost per accident causing damages to the engines are shown in Figures 7 and 8, respectively. In those figures, causes of damage to the cooling system by other than plastic debris are added for reference. The frequency of accidents caused by plastic debris is lower for fishing vessels of larger size with the exception of those <5 GT. The average damage, on the other hand, increases with large ships.

There is slightly more engine trouble caused by factors other than plastic debris than trouble attributable to plastic debris, by size group of fishing vessels. The specific cause of these other accidents is not known. The cost per accident is nearly equal to or somewhat lower than that caused by plastic debris. According to Usui of the Fishing Vessel Insurance Center, who compiled the Special Report trouble with the cooling water systems occurs frequently as a result of clogging of the inlet ports for cooling water with drifting objects such as wood or grass. Since the average cost per accident is nearly the same, it is conceivable that accidents caused by other than plastic debris are similar to those caused by plastics. This seems to support Usui's statement.

Figure 9 shows the locations of main damage to the engines caused by a deficiency of the cooling system, which in turn was caused by plastic debris, as clarified in the Special Report. The damages to cylinder heads accounted for 57%; cylinder liners, 19%; and pistons, 14%.

## DISCUSSION

The data of the Special Report differ somewhat from the Insurance Statistics for 1988. According to the Insurance Statistics, the number of insured vessels is 236,142, whereas the number given in the Special Report is 245,826, greater than the former by 9,700 ships or 4%. This difference is mostly in small ships, and therefore does not seem to adversely affect a comparison between the two sets of data.

As shown in Figure 10, in comparing the frequencies of accidents caused by collision with floating objects (category "floating objects" from the Insurance Statistics and "collision with floating objects" from the Special Report), they were found nearly the same in all ship size brackets.

The frequency of "entanglement" accidents given in the Insurance Statistics coincides well with the frequency of "entanglement" accidents in the Special Report. The frequency of "floating debris-related entanglement" in the Special Report is much lower when compared to the

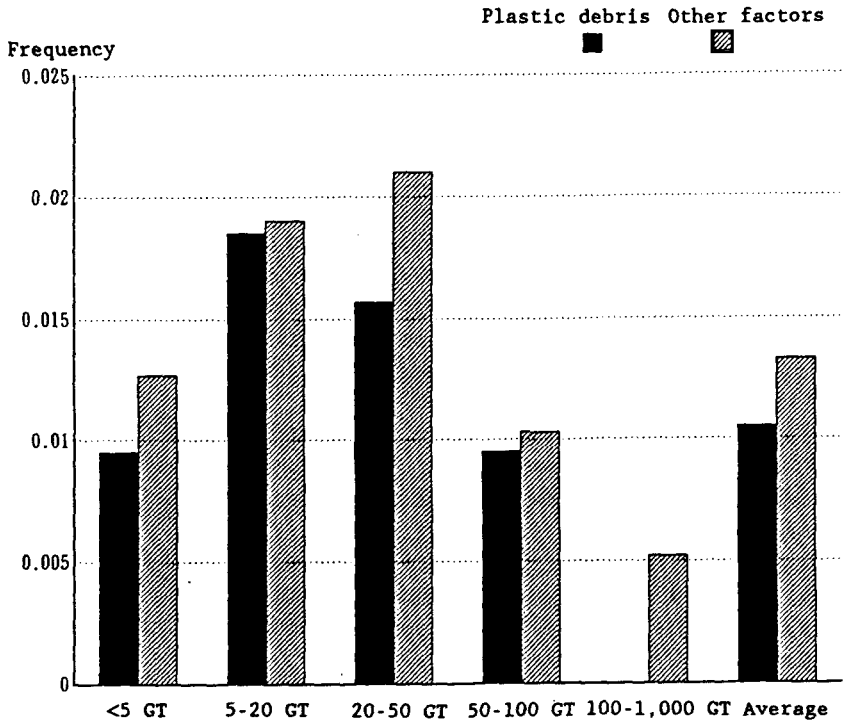



Figure 7.--Frequency of accidents of engine trouble caused by plastic debris and other factors by size class of vessel. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

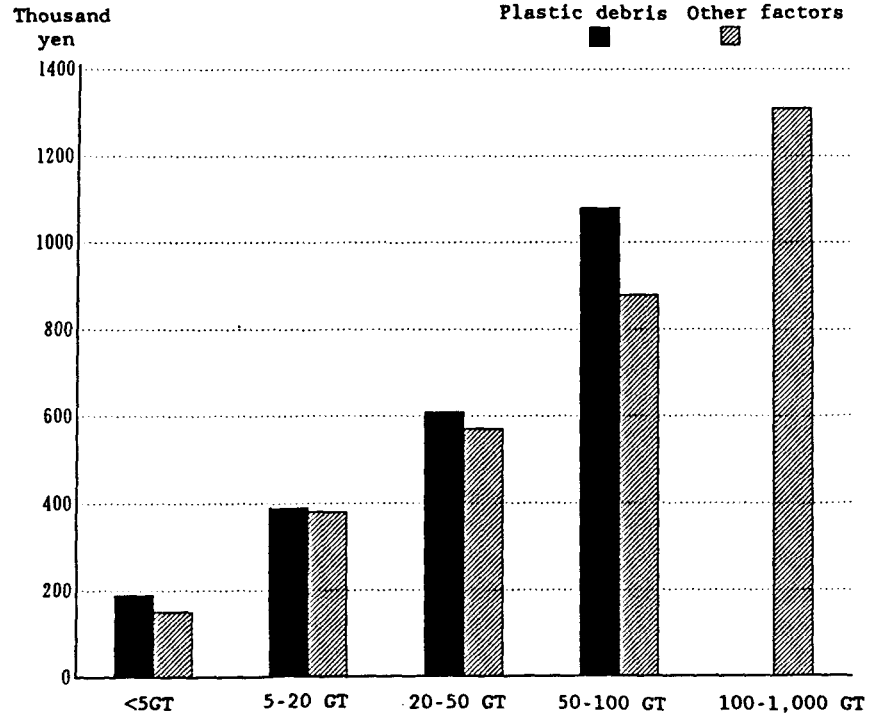



Figure 8.--Average cost per accident of engine trouble caused by plastic debris and other factors by size class of vessel. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

other two (Fig. 11). Because of this, "drifting objects" in Figure 1-1 represents changes in frequency of collisions with objects drifting in the sea, and "entanglement" in the same figure includes those accidents caused by other than floating debris, as previously stated. Further, Figure 11 shows that the percentage of entanglement accidents caused by other than floating debris becomes lower as the vessels become larger, when compared to entanglement accidents caused by floating debris. This is understandable, because human activities including fishing are much higher in the coastal areas than farther offshore and opportunities of encountering mooring ropes or fishing nets in actual use are greater in coastal waters. The density of marine debris distribution also lessens in the offshore waters.

The Special Report indicates that the frequencies of all three types of accidents (collision, entanglement, and engine trouble) show the same tendency, becoming lower as the vessel size become larger with the exception of vessels of <5 GT (Fig. 4). Such results are understandable, because the distribution density of drifting objects is high in the coastal waters in general, and small ships tend to operate in the vicinity of the coast. Several reasons can be conceived for the low frequency of accidents involving ships <5 GT. These are:

- Many boats with outboard engines are included in this category and their engine and water intake are easy to monitor, making it easier to detect the start of trouble such as trouble with the cooling system.
- Small vessels rarely operate at night.
- Small vessels are easier to monitor adequately than larger vessels.

According to the Special Report, the amounts of damages covered by insurance and resulting from collision, entanglement, engine trouble, and other accidents associated with objects floating in the sea were ¥2,659 million, ¥437 million, ¥1,262 million, and ¥76 million, respectively, for a total of ¥4,435 million. The total amount of such damage for all vessels in 1985 is estimated to be ¥6,608 million, a figure determined by extrapolation using ratios of the number of insured ships to the number of fishing vessels that were registered, by size (tonnage).

The estimated figure, however, is considered to be an overestimation. It is unrealistic to think that all the fishing vessels registered actually operated in that year. (Some are not in use any more and have not yet been removed from the register.) However, there are no statistics covering the number of fishing vessels that did operate during 1985. Furthermore, the statistical data used may have some problems in their characteristics since they were not prepared for this type of analysis, but they are considered to be pretty reliable. The actual size of the damage is thought to be somewhere between ¥4.4 billion and ¥6.6 billion. Such an amount is so huge that it calls for some review to determine its appropriateness. The total fishery production in 1985 by fishery management units with vessels of

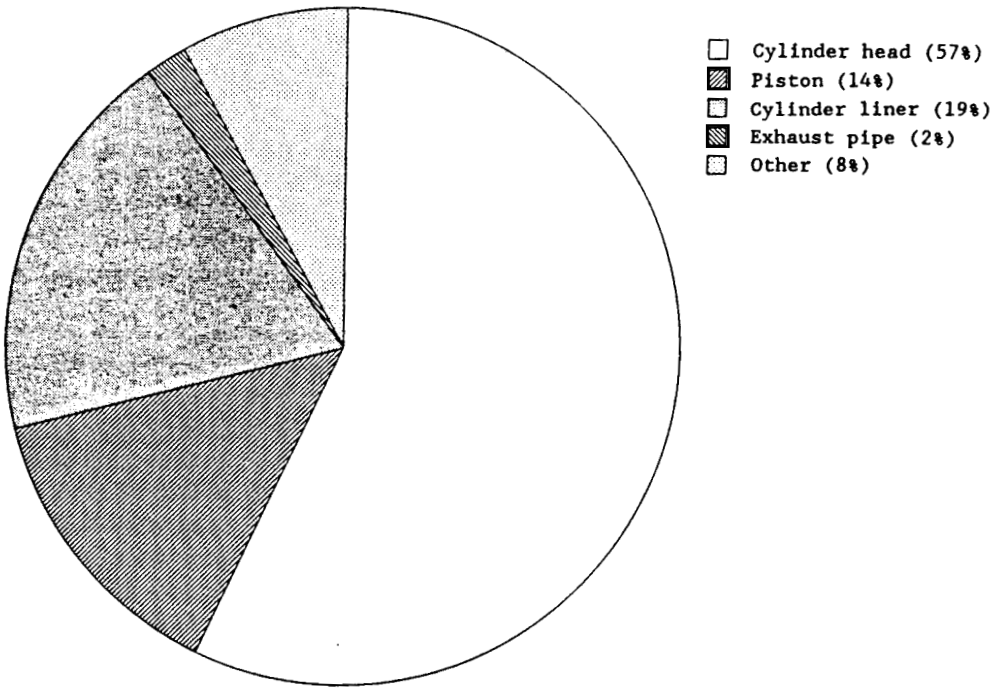



Figure 9.--Engine part which is reported as damaged most severely in an accident of engine trouble caused by plastic debris. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

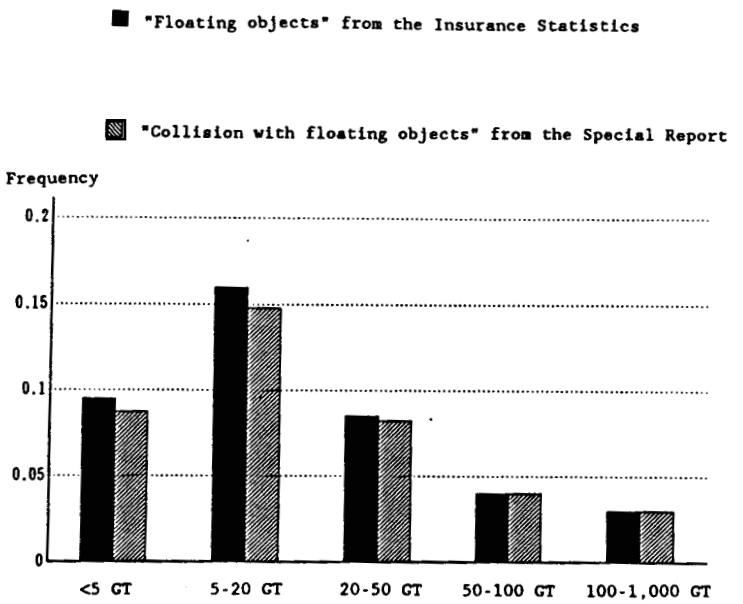



Figure 10.--Comparison of frequencies of accidents caused by "floating objects" from the Insurance Statistics, and "collision with floating objects" from the Special Report. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

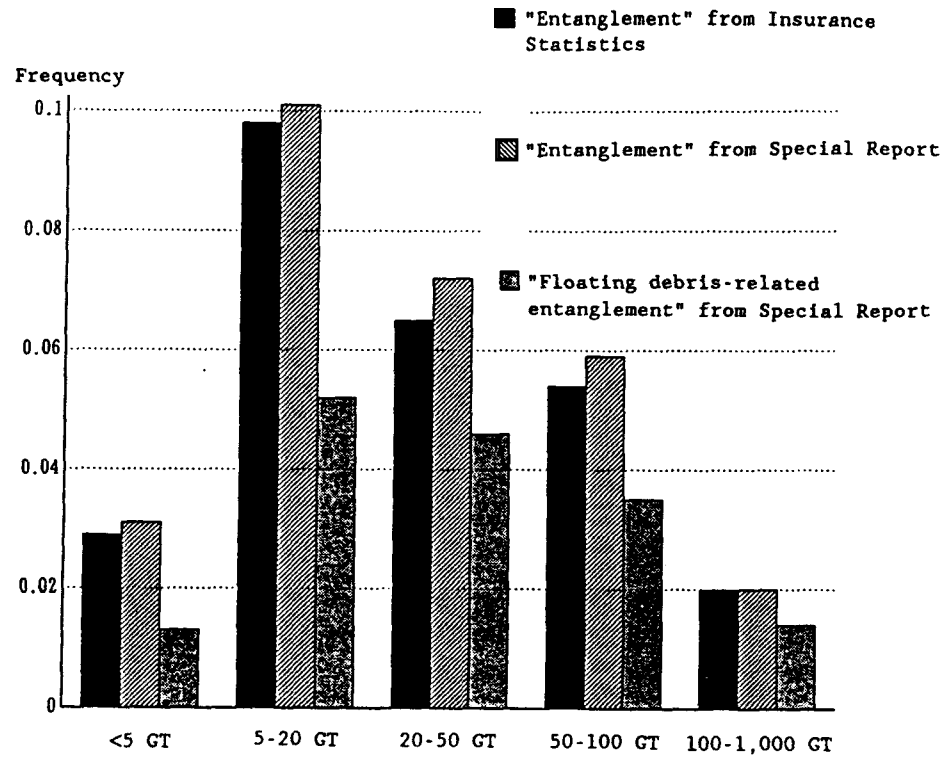



Figure 11.--Comparison of frequency of entanglement accidents. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center. Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

<1,000 GT was ¥2,165 billion. Realizing that the cost of running the fishing business in general is roughly 90% of the sales, and the total output is ¥1,949 billion, therefore damages costing ¥6.6 million, or 0.3% of the above-mentioned figure, do not seem to be unrealistic. It is, however, based solely on the available statistical data. No study has yet been made of the system used in the operation of the insurance, including confirming of the accidents. Also, no study has been made of the available ship accident reports. I invite comments and opinions from those involved in the Japanese fishing vessel insurance system.

## ACKNOWLEDGMENT

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# NEW YORK STATE MARINE DEBRIS PROGRAM

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## ABSTRACT

New York State has a multifaceted approach to prevention of marine debris. Regarding the sources of infectious waste-related debris, the state issued jointly with New Jersey a series of similar regulations which provided for a manifest tracking system. The state also recently passed additional legislation which increases the penalties for illegal disposal and removes the small quantities generator exemption; an additional US$2 million was earmarked for enforcement.

The program to prevent the major portion of debris continues. The Department of Environmental Conservation works with Federal and local agencies to minimize contribution from such sources as combined sewer overflows and solid waste handling. The department also works with local environmental groups, education institutions, and the marine trades association in a public awareness campaign. The conclusions drawn from documented cleanups at eight beaches during Beach Cleanup Day, 8 October 1988, are discussed.

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

# MEDICAL WASTES AND THE BEACH WASHUPS OF 1988: ISSUES AND IMPACTS

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## ABSTRACT

The beach washups of medical wastes in 1988 resulted in beach closings, even if the extent of public health hazard posed by these wastes is not known with certainty. The nature and extent of economic impacts of the closings to the Long Island and New Jersey areas are assessed, based on available information.

Investigations to determine the sources of medical waste and other floatable marine debris along the shores of New York City, Long Island, and other nearby coastlines find that the primary sources are the Fresh Kills landfill (including barges transporting waste to it), marine transfer stations, combined sewer overflows, raw sewage discharges, and storm water outlets. Other sources, such as illegal dumping, probably contribute a smaller portion of floatables. This has important implications for whether some types of laws and programs being proposed and adopted, such as a manifest tracking system, will adequately address the problem of beach washups.

## OVERVIEW

On 23 May 1988, a garbage slick nearly a mile in length along the shore of Ocean County, New Jersey, marked the season's first major washup of marine debris. Needles, syringes, and empty prescription bottles with New York addresses were among the floatable marine debris washed ashore. Beaches were closed as a result of this and similar incidents, including closing of more than 24 km (15 mi) of Long Island beaches from 6 to 8 July.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Throughout the summer of 1988, national attention focused on reports of beach washups of medical wastes at various locations in the United States, much of the attention being given to washups on the east coast.

The east coast washups actually were about 10% or less "medical-related" waste. The largest single medical-related floatable was the insulin-type disposable syringe (New York State Department of Environmental Conservation (NYSDEC) 1988). Misconceptions about the quantities and nature of medical wastes washed ashore apparently resulted in part from the misidentification of items and from inaccurate media reports.

The degree of risk posed by medical wastes is not known. Proper handling, treatment, and disposal of these wastes are believed to minimize human health and environmental risks. Yet incidents resulting from careless or illegal disposal do pose aesthetic problems, and certainly help create public apprehension over current medical waste management practices. Aesthetic degradation and possible adverse health effects from medical wastes on public beaches are impacts difficult to measure and assess directly. Economic impacts resulting from the washups may be a more direct measure of their importance.

First, it is useful to define medical wastes and look at the broader context within which they are generated, managed, and regulated. Medical wastes include all infectious waste, hazardous (including low-level radioactive) wastes, and any other wastes generated from all types of health care institutions, including hospitals, clinics, doctors' (including dental and veterinary) offices, and medical laboratories (Lee 1988). The main focus of concern has been on the portion of medical wastes that are defined as infectious or "red bag" wastes, and how they are classified (e.g., as a solid, hazardous, or "special" waste) and regulated. The Centers for Disease Control and the U.S. Environmental Protection Agency (EPA) both designate as infectious pathological waste blood and blood products, contaminated sharps, and microbiological wastes (U.S. Congress 1988). The main sources of these wastes receiving attention are hospitals and other large facilities, but other sources of infectious wastes, such as sewage overflows, can also be significant contributors of environmental contamination.

The EPA reports that approximately 3.2 million tons of medical wastes from hospitals are generated each year, or about 2% of the total municipal solid waste stream. Currently, most generators of medical waste designate between 10 and 15% of it as infectious. The NYSDEC estimates that approximately 315 tons of medical wastes a day are generated by New York City's (NYC) 75 hospitals; and of this about 63 tons is infectious waste (NYSDEC 1988). Most of the medical waste washed ashore in the Greater NYC, Long Island, New Jersey, and even Rhode Island coastal areas is presumed to have emanated from the Greater NYC area. The actual amount of waste which washes ashore is not known with certainty, but is regarded as a large volume (NYSDEC 1988). At times, in some locations two pieces of medical debris per mile are found, while during a "garbage slick," garbage bags full of medical waste can be collected (NYSDEC 1988; Associated Press 1989).

Most infectious waste from hospitals is incinerated, while most noninfectious medical waste is landfilled. However, just as beach wash-up incidents raise public concern over current medical waste management practices, considerations of liability and worker safety lead some operators of municipal solid waste landfills and incinerators to refuse to take any medical wastes. As medical waste management becomes increasingly problematic for these types of reasons, an additional concern becomes the increased potential for illegal disposal.

The situation is further complicated by an uncertain and incongruous regulatory climate. Inconsistencies exist in the Federal guidelines for states regarding definitions and management options suggested for medical and infectious waste. Currently, no Federal regulations exist that comprehensively address the handling, transportation, treatment, and disposal of medical waste. This could change if the issue of medical wastes remains part of the current reauthorization effort for the Resource Conservation and Recovery Act (RCRA) or if the demonstration program of the Medical Waste Tracking Act (MWTA 42 U.S.C. 6901 et seq.) is expanded and extended in the future. As will be discussed below, other, specific types of management and enforcement actions may best address the issue of medical waste in beach washups. The Office of Technology Assessment (OTA), as part of a larger assessment of municipal solid waste, issued a separate background paper on medical waste management in October 1988 (U.S. Congress 1988). Reference should be made to that paper for a more detailed overview of medical waste management issues.

## POSSIBLE ECONOMIC IMPACTS

The beach washups of 1988 in the Long Island and New Jersey areas had potential economic impacts of both revenue losses and costs. Revenue losses to the travel and tourism industry can result from declines in beach use, recreational fishing, and use of charter and party boats (R. L. Associates and U.S. Travel Data Center 1988; Thomas Conoscenti & Associates 1988; Ofiara and Brown 1989). Other possible economic impacts include increased beach maintenance and surveillance costs.

The focus here, based on very limited available information and in light of important caveats, is on the possible revenue losses to travel and tourism. Available information is suggestive of the types of short-term economic impacts which may be associated with the beach washups of 1988. It should be emphasized, however, that the information is not conclusive; some of it is anecdotal, most of the estimates of revenue losses are based on limited data (at most, for 2 or 3 years), and longer-term trends were not taken into account.

Causal links between the changes in beach use and tourism patterns and the beach washups and closings have not been carefully established, but are assumed in the estimates cited. Further, the methods used to estimate the changes and their impacts are not highly rigorous. Valid comparisons between losses to both New Jersey and Long Island coastal communities cannot be made given the different techniques used to estimate revenue losses.

The Long Island Tourism and Convention Commission reported a decline of 18% (i.e., an estimated 4.6 million fewer persons) in beach attendance in 1988 compared to 1987, and attributes this to the beach closings (Thomas Conoscenti & Associates 1988; Fey 1989). The commission also noted a decrease in attendance at all resorts and beaches (whether closed or not) as a result of the beach closings. Not surprisingly, decreased spending accompanied the lower beach attendance (Table 1). The difference between the 1987 tourism base and the estimated actual 1988 tourism base was $921.2 million. The commission, however, calculated an estimated net loss of $1.4 billion due to the beach closings in 1988, comparing the actual estimated tourism base of 1988 with that of an estimate of the industry base if it had grown in 1988 at the historical rate of 5.6% (Thomas Conoscenti & Associates 1988). The commission also reported that the actual net effect was likely to be considerably less than $1.4 billion since it could be assumed that some of the tourists who did not visit the beaches probably participated in other activities on Long Island.

One part of the tourism and travel industry which may not be reflected in the calculations of the commission's survey (but is included in the marine recreational fishing category of the New Jersey estimates discussed below) is the charter and party boat businesses. A survey of NYC and Long Island charter and party boats owners found a 30 and 26% decline, respectively, in the number of passengers carried and trips conducted in 1988 compared to previous years (reportedly from 1985 through 1987) (DiLernia and Malchoff 1989). Floatables, including medical wastes, were considered by 60% of the party boat captains to be the most important issue affecting their business in 1988. Yet the respondents also agreed that a number of other factors threaten the profitability of the boat businesses, such as general marine pollution, a drop in fish stock abundance, and the high cost of operating vessels (DiLernia and Malchoff 1989).

One preliminary analysis of the impacts of the beach washups on all the beach towns in Monmouth, Ocean, Atlantic, and Cape May Counties, New Jersey, found that the overall range in beach attendance decrease from 1987 to 1988 was 7.9 to 34% (Ofiara and Brown 1989). (It should be noted that these investigators are completing their investigation and a more detailed version of their results will be available in April 1989.) Each of the four coastal counties experienced beach closings in 1987, but the beach attendance decrease between 1986 and 1987 ranged from 8.9 to 18.7%. The survey also indicated a 58% decline in beach attendance from 1985 to 1988 reported by seven New Jersey communities (Ofiara and Brown 1989).

According to the New Jersey Division of Travel and Tourism, an estimated 1.9 million fewer persons visited the New Jersey shore in 1988 than in 1987, a 22% drop in attendance (R. L. Associates and U.S. Travel Data Center 1988). In a 1988 survey of visitors, 22% considered themselves less likely to visit the New Jersey shore in 1989, with approximately the same number of respondents in this category as in 1987. Forty-four percent of this group of respondents identified pollution as their number one reason for not returning in 1989 (R. L. Associates and U.S. Travel Data Center 1988). (Pollution was in fact the single biggest reason given by those who indicated they would not be returning the following year to the New Jersey shore. This is a 10 percentage point increase over those who

Table 1.--Tourist and convention expenditures. Total Long Island, 1987 and 1988. (Source: Thomas Conoscenti & Associates, Inc. 1988.)

| Visitors and their expenditures | 1987 | 1988 | Difference |
|---|---|---|---|
| Tourist and convention visitors (millions) | 25.5 | 20.9 | 4.6 |
| Expenditures (millions $) | | | |
| -Lodging[a] [b] | 368.9 | 332.2 | 36.7 |
| -Food[c] | 1,147.5 | 1,003.2 | 144.3 |
| -Transportation[d] | 255.0 | 219.5 | 35.5 |
| -Entertainment | 561.1 | 505.3 | 55.8 |
| -Other[e] | 1,009.2 | 908.8 | 100.4 |
| Total | 3,341.7 | 2,969.0 | 372.7 |
| Annual total impact (millions $) | 7,685.9 | 6,828.7 | 857.2 |
| Other direct summer activity (millions $)[f] | 589.0 | 525.0 | 64.0 |
| Total tourist/convention industry (millions $) | 8,274.9 | 7,353.7 | 921.2 |

[a]Based on 14,000 rooms.
[b]Average lodging rate (1987 = $95/night; 1988 = $100/night).
[c]Average $45/day in 1987 and $48/day in 1988.
[d]Includes day trips.
[e]Other = e.g., retail sales.
[f]Visitors to homeowners in summer.

had indicated in a survey the year before that they would be less likely to visit the shore in 1988 due to pollution. Yet about the same percentage (50% in 1987 and 47% in 1988) indicated that they were as likely to visit the shore the following year.)

The division also reports that a 9% decline in total expenditures occurred in 1988 at the New Jersey shore, a loss of approximately $745.6 million. A more extensive analysis of revenue losses sustained by recreational fishing, beach use, and travel and tourism combined finds total estimated losses to range from $545.9 million to $2,022.85 million and, with all indirect effects included, to range from $820.7 million to $3,060.8 million (Ofiara and Brown 1989; Table 2).

It should be stressed again that these calculations are not comparable given the different methods used to derive them, and that the bases for them may be imprecise and have not been evaluated by the OTA. Yet, even with these qualifications, it appears that revenue losses have occurred. And it seems reasonable to assume that part of these losses was due to changes in beach use, recreational fishing and boating, and travel and tourism patterns which seem to have resulted primarily from the beach closings of 1988.

Table 2.--Aggregate estimated economic impacts to beach use, travel and tourism, and marine recreational fishing, New Jersey, 1988. All dollars are in 1987 dollars. (Source: Ofiara and Brown 1989.)

| Category[a] | Trips (No.) | Economic benefits | Expenditures ($1,000,000) | Gross value |
|---|---|---|---|---|
| Beach use | | | | |
| Minimum | 5,763,200 | 117.61 | 223.07 | 340.68 |
| Maximum | 24,493,600 | 499.83 | 948.05 | 1,447.87 |
| Multiplier impacts | | | | |
| Minimum | | 117.61 | 423.61 | 541.22 |
| Maximum | | 499.83 | 1,800.35 | 2,300.18 |
| Travel and tourism | | | | |
| No. of businesses affected | | | | |
| Minimum | | | | 395 |
| Maximum | | | | 1,699 |
| No. of lost jobs | | | | |
| Minimum | | | | 9,553 |
| Maximum | | | | 14,114 |
| Lost wages ($) | | | | |
| Minimum | | | | 34.34 |
| Maximum | | | | 147.79 |
| Recreational fishing | | | | |
| Minimum | 1,332,600 | 88.28 | 82.60 | 170.88 |
| Maximum | 3,331,500 | 220.69 | 206.50 | 427.19 |
| Multiplier impacts | | | | |
| Minimum | | 88.28 | 156.86 | 245.14 |
| Maximum | | 220.69 | 392.15 | 612.84 |
| All activities | | | | |
| Minimum | | 205.89 | 305.67 | [b]545.90 |
| Maximum | | 720.52 | 1,154.55 | [b]2,022.85 |
| Multiplier impacts | | | | |
| Minimum | | 205.89 | 580.47 | [b]820.70 |
| Maximum | | 720.52 | 1,154.55 | [b]3,060.80 |

[a]Minimum refers to the minimum of the range. Maximum refers to the maximum of the range. Multiplier impacts are derived from the product of expenditures times 1.899; the New Jersey State multiplier associated with net output (includes value added), plus economic benefits.

[b]The sum of benefits, expenditures, and lost wages.

Even more limited information exists on the actual or estimated dollar impacts of various economic costs than on revenue losses for travel and tourism. For example, New Jersey spends approximately $3 million annually on beach cleanups (New Jersey State 1987). A National Park Service official in Long Island indicates that the amount of money allocated for cleaning beaches and water quality testing has tripled, however, given the need for increased monitoring and surveillance since the beach wash-up problem arose in 1988 (J. Tanacredi, National Park Service, pers. commun. 14 February 1989). Figures are not readily available on these exact costs or how prevalent such increases are.

The actual washups may not have contained much medical waste, but the perception created by media reports that these wastes were appearing with frequency on beaches might have been a deterrent to beachgoers (R. L. Associates and U.S. Travel Data Center 1988; DiLernia and Malchoff 1989). It is not clear, even with a summer of fewer washups and the attendant lack of publicity, how quickly these economies will recover. Ofiara and Brown's (1989) review of previous studies indicates that there can be economic impacts (in some cases depressing fish prices for several years) from health advisories and subsequent media reporting of them.

## BEACH WASHUPS: LOCATIONS AND SOURCES

In general, beaches closest to the sources of floatable marine debris (including medical waste floatable debris) are most likely to experience floatable strandings (New Jersey State 1987; NYSDEC 1988; Swanson 1988; Swanson and Zimmer 1989). Examination of potential sources and consideration of weather factors (i.e., winds and surface currents) seem to confirm this general relationship (NYSDEC 1988; Swanson 1988; Swanson and Zimmer 1989). There are a number of likely sources of the medical wastes and other materials in the beach washups along the NYC, Long Island, New Jersey, and other nearby shores. Table 3 lists the locations and dates of beach closings in the summer of 1988.

The weather appears to be an important factor in explaining the number of large beach washups in 1988. In 1988, as in 1976 (the last time long stretches of Long Island and other Greater NYC beaches closed due to pollution), a weather pattern of winds predominantly from one direction prevailed before the major washups (Swanson 1988; Spaulding et al. 1989; Swanson and Zimmer 1989). The most significant source of floatables is the Hudson/Raritan Estuary, and wind is the primary source of movement of floatables once they reach the bight. The prevailing south-southwesterly winds of early summer 1988 made Long Island beaches particularly susceptible to beach washups (Swanson 1988). A hindcast study for Long Island confirmed this relationship (NYSDEC 1988). The State of Rhode Island concluded that the New York Bight was also the probable source of the medical waste debris on its shores in 1988 (NYSDEC 1988; Spaulding et al. 1989).

Investigation showed that the primary sources of medical waste and other floatable marine debris along the shores of NYC, Long Island, and other nearby coastlines are the Fresh Kills landfill (including barges transporting waste to it), marine transfer stations, combined sewer

Table 3.--Summary of beach closings, 1988. (Source: New York State Department of Environmental Conservation 1988.)

| County | Beach | Dates |
|---|---|---|
| | **Long Island** | |
| Nassau | Nassau | 7/6-7 |
| | Long | 7/6 (7/29 high bacteria) |
| | Jones | 7/6, 7/8 |
| | Lido | 7/6 |
| | Oyster Bay Town | 7/7-8 |
| | Gilgo | 7/8 |
| Suffolk | Robert Moses State Park | 7/6-8 |
| | Fire Island | 7/7-8 |
| | Babylon Town | 7/8-10 |
| | Smith Point State Park | 7/10 |
| | Quogue | 7/23-27 (high bacteria) |
| | Shirley | 7/29 (high bacteria) |
| | **New York City** | |
| Queens | Rockaway | 7/8, 7/26-28 |
| | Jacob Riis Park | 7/17-20 |
| | Atlantic | 7/17 (7/29 high bacteria) |
| Kings | Coney Island | 7/12-13 (7/17 high bacteria) |
| | Brighton | 7/12-13 |
| | Manhattan | 7/12-13 |
| Richmond (Staten Island) | South | 7/11 to close of season (9/3) |
| | Midland | 7/10-8/18 |
| | Great Kills | 7/13-28 (8/9 high bacteria) |
| | Miller Field | 7/13-25 (8/9 high bacteria) |

overflows, raw sewage discharges, and storm-water outlets. Other sources such as illegal dumping probably contribute a smaller portion of floatables.

The NYSDEC's investigation into the sources of beach washups in 1988 concluded that medical-related wastes are sent to the Fresh Kills landfill, where some debris escapes into the water from a "hospital waste mooring" (NYSDEC 1988). Eight of nine municipal marine transfer stations (MTS's) and one private MTS currently operate in NYC. The NYC Department of Sanitation is responsible for off-loading wastes from trucks to barges for transfer to the landfills. Apparently, current loading practices cause spillage at the MTS's and there is not an effective system to remove such spillage (NYSDEC 1988).

The NYSDEC also reported that sewage treatment failures occurred prior to the beach washups in 1988, followed by rainstorms which flushed out floatable material collected in storm drains during a relatively dry period (NYSDEC 1988).

Although debris from the Fresh Kills landfill, sewage discharges (including combined sewage overflows), and MTS's are the most significant sources of floatables in the Greater NYC area, NYSDEC noted that "it is clear that medical-related waste has been disposed of illegally into the garbage and into the sewers [and that] these two sources contributed to the beach debris" (NYSDEC 1988). To date, illegal disposal of medical wastes appears to be a more significant problem on land than in the waterways, but it is possible that some illegal disposal directly into the water also occurs (NYSDEC 1988).

This information on the sources of medical waste in washups has important implications for whether some types of laws and programs being proposed and adopted to address the beach wash-up problem, such as a manifest tracking system, will be adequate. Another legitimate concern is that as regulation of medical wastes increases, disincentives for illegal disposal also need to be pursued, e.g., a manifest system or vigorous enforcement.

## GOVERNMENTAL RESPONSES AND RELEVANT POLICY ISSUES

Whatever their actual aesthetic, social, and economic impacts may be, a critical issue is what governmental efforts if any will be effective in addressing the problem of beach washups of medical wastes. As noted above, currently no comprehensive Federal requirements exist for the management of medical wastes (U.S. Congress 1988). The MWTA of 1988 passed by Congress was in part an attempt to address the problems of beach washups of medical wastes and illegal disposal of medical wastes.

It is not clear, however, in light of the sources which appeared primarily responsible for the beach washups of 1988, that the "cradle-to-grave" type of manifest tracking system established by MWTA will have a significant impact on the washups of medical wastes. Other actions, such as improved waste management handling at marine transfer stations and at landfills in marine areas may more directly address the problem. Increased enforcement efforts appear prudent in any case, given the need to ensure that incentives for illegal disposal do not increase if the handling, transportation, treatment, and disposal of medical waste are increasingly regulated.

The MWTA establishes a demonstration tracking system (MWTA, Sections 11001-11003) and directs the EPA and another Federal agency to undertake studies of certain medical waste management issues (Sections 11008 and 11009). The intent is to develop a basis for determining whether and in what ways the Federal Government should regulate medical wastes. The MWTA specifically applies to Connecticut, New Jersey, New York, and the Great Lakes States (Section 11001). Any of the Great Lakes States may opt out of the demonstration program and any state can opt in; Connecticut, New Jersey, and New York can petition out if they have a program at least as

stringent as that of the Federal Government. Civil penalties of up to $25,000 per day for each violation, criminal penalties of up to $50,000 per day per violation, and in addition, jail terms of up to 5 years may be imposed in states implementing the tracking system (Section 11005).

On 24 March 1989, EPA established the 2-year pilot Federal tracking program authorized by MWTA by publishing its "Standards for the Tracking and Management of Medical Waste; Interim Final Rule and Request for Comments" in the Federal Register (p. 12326-12395; 40 CFR Parts 22 and 259). Yet, as EPA points out in its press release of 13 March 1989:

> "Many of the suspected sources of last summer's beach wash-up problems will not be affected by the new tracking system. Preliminary analyses of last summer's beach washups and additional EPA studies underway indicate that likely sources of the washups included improper handling of ordinary trash and sewer overflows which contain wastes from home health care and illegal drug use. To the extent that all of these sources contribute to environmental degradation, the problems will persist despite the new regulations (EPA 1989a)."

The manifest will not track medical-related wastes emanating from a number of the primary sources identified by the NYSDEC investigation. Interestingly, the cost of compliance with the requirements of the MWTA, including the manifest system, is estimated by the EPA to increase the cost of medical wastes disposal by approximately $0.08/lb on average (EPA 1989b). According to EPA (1989b), average annual compliance costs per facility range from about $3,750 for hospitals to about $70 for dentists. These figures and the per pound figure are considered to be low estimates by some waste industry officials.

In any case, New York State and New Jersey cooperatively adopted a tracking system in August 1988. It is not clear, however, whether either state will petition to opt out of the Federal program. A number of other governmental actions, including an interagency Floatables Action Plan for the New York Bight and action programs by individual states (e.g., New York State), have been initiated to address the problem of floatable medical wastes and other floatable debris in the Greater New York Harbor area (Molinari 1989; Weisbrod 1989).

The New York Bight Floatables Action Plan, a multiagency effort led by EPA Region II, is part of the New York Bight Restoration Plan. It includes such actions as studies of floatables in 1987 and 1988 and continued surveillance, regular cleanups at "key locations," other cleanup as necessary, and a communication network (Molinari 1989). In addition to expanding its public information program, NYSDEC's response to control beach washups of floatables includes combined sewer overflow abatement, improved operation and maintenance at sewer treatment plants (STP's), stricter controls at MTS's for the handling of solid waste, more stringent regulation of medical waste, and enhanced enforcement of medical and all solid waste regulations (Weisbrod 1989).

The NYSDEC anticipates that when new state medical waste regulations become effective, a capacity shortfall for medical waste disposal may result (Markell 1989). Older facilities may close if they anticipate that it will be too expensive to meet new regulations and, given the difficulties of siting new waste facilities of any type, incentives for illegal dumping could indirectly be fostered. For this reason, the state increased the criminal and civil penalties for medical waste violations in 1988 and plans an aggressive enforcement program (Markell 1989). Brooklyn District Attorney Elizabeth Holtzman supports strong enforcement efforts in the NYC area and actively prosecutes violators of existing medical waste management laws (Holtzman 1987, 1988).

Congress amended the Ocean Dumping Act (formally known as the Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. Sections 1401 et seq.) in 1988 to increase the penalties for illegal disposal of medical wastes by public vessels. Some medical waste discovered along the coast of North Carolina and a few other locations was traced to discharges from U.S. Navy vessels (Associated Press 1988). According to the new amendments, civil penalties of not more than $125,000 for each violation can be assessed by EPA for "engaging in activity involving the dumping of medical waste" as regulated by the law. Criminal penalties of not more than $250,000, or imprisonment of not more than 5 years, or both, and possible forfeitures of property can also be imposed.

## CONCLUSION

The beach washups of the summer of 1988 had a range of impacts (aesthetic, social, and economic) which may not have been precisely calculated, but did generate governmental responses to the appearance of medical waste on our beaches. Medical waste along our coasts also drew attention to a broader range of issues associated with medical waste management. Some of the specific programs initiated by state and local governments to address the beach washups of floatables may be most effective in the near term. The importance of the Federal demonstration tracking program for medical wastes in abating medical waste floatables in beach washups is not clear. Its significance to the improved management of all medical waste will need to be evaluated in the light of future regulatory programs. Nonetheless, using experience gained in regulating the hazardous and solid waste streams, there is opportunity for government at all levels to proceed in devising programs to manage medical waste wisely and efficiently in order to alleviate public concern, protect human health, and provide environmental protection.

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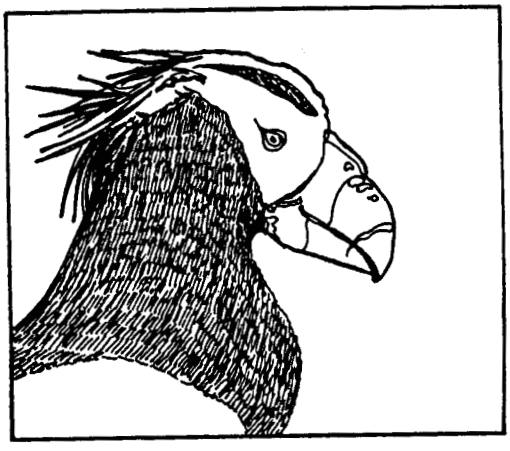
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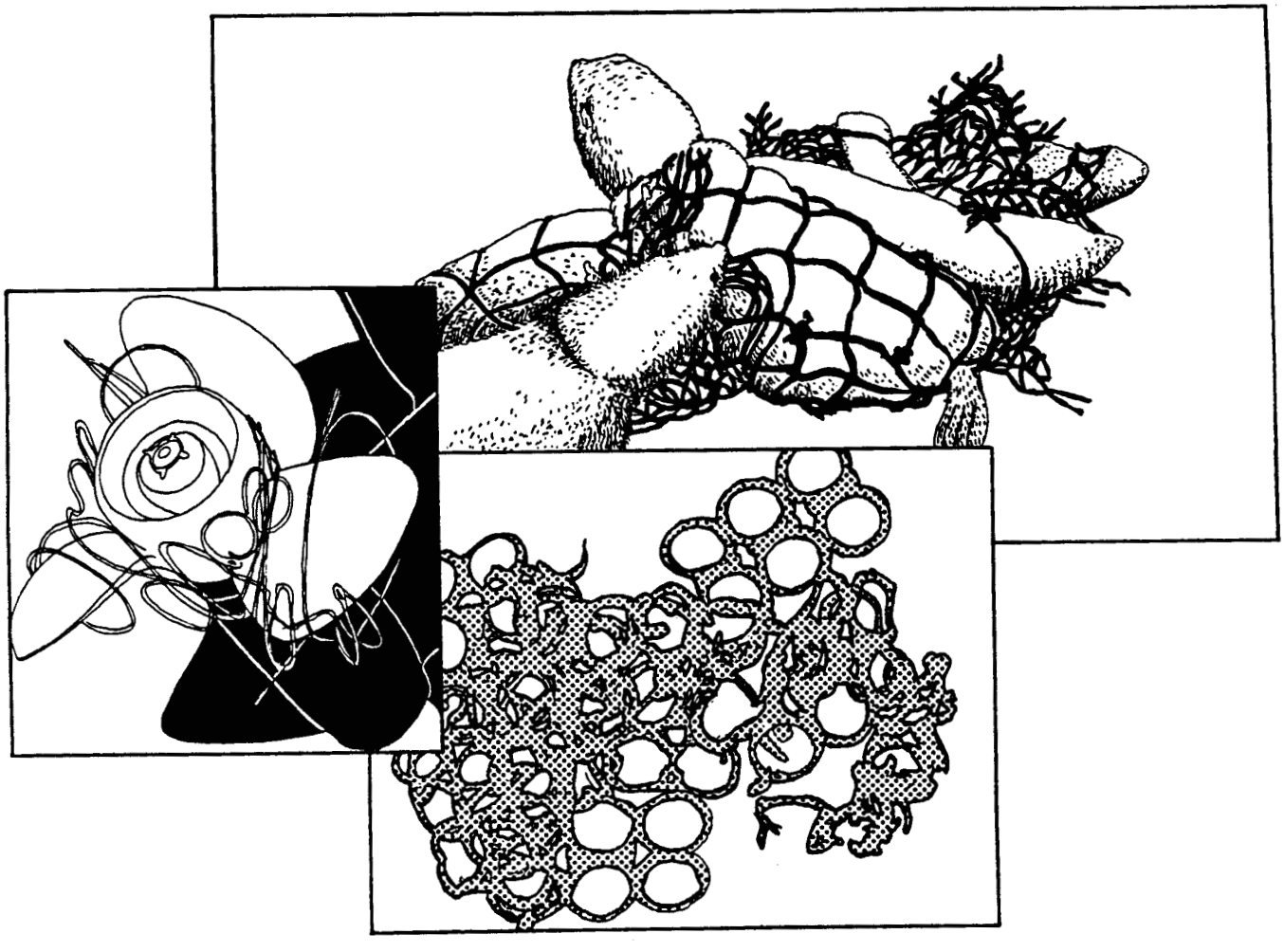
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# SESSION V



## SOLUTIONS THROUGH TECHNOLOGY



# THE PHILOSOPHY AND PRACTICE OF DEGRADABLE PLASTICS

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## ABSTRACT

A major advantage of plastics in packaging is their resistance to attack of microorganisms. After discard, however, this characteristic creates major problems in their disposal, since unlike nature's litter, they do not return to the biological cycle. Strategies for retaining the advantages of plastics during use but of triggering biodegradation after discard are discussed. Photobiodegradable plastics which have been used successfully as agricultural mulching film for many years are seen to be the potential solution to the marine debris problem.

## THE ENVIRONMENTAL IMPACT OF PLASTICS

The growth of consumer packaging has been one of the most visible phenomena of the twentieth century. On balance, it has been a beneficial development which has facilitated the distribution and storage of perishable goods to the advantage of the international community.

The modern packaging industry has its roots in the petrochemical industry, and the cheap commodity plastics, polyethylene, polypropylene, polystyrene, and polyvinyl chloride, are the major polymeric materials currently in use. They have a number of advantages in common, of which the following are the more important:

- They are cheap and easy to fabricate into common items of packaging.
- They are resistant to water and microorganisms and are, therefore, able to protect perishable goods from biological attack.

However, the very characteristics which make plastics so useful in packaging cause considerable problems in their ultimate disposal. Unlike cellulosic packaging materials (paper, cardboards, and the cellulose-based plastics), the oil-based plastics do not biodegrade back to the carbon

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

cycle when discarded in the environment. This is why they present one of the most visible litter problems of the twentieth century. The persistence of plastics litter in recreational areas, where it gave maximum offense, became evident in the late 1960's. The response of the plastics industry at that time was to say that it was unlikely that technical solutions to this problem could be found because the characteristics of biodegradable plastics were "the antithesis of the nature of packaging materials" (Staudinger 1970). The Society of Chemical Industry in 1970 expressed its alternative strategy as follows:

> ". . .the Society will seek to make common cause with all movements and organisations concerned with preventing environmental deriliction [sic] by littering" (Staudinger 1970).

This did not mean that they would encourage research into making plastics more biocompatible, but that they would encourage educational programs directed toward making the public more environmentally aware of the litter problem. This is still essentially the polymer industry's public stance today. The responsibility for plastics pollution is presented as that of the user, who must be educated into nonlittering habits (Claus 1987; O'Connell 1987; Society of the Plastics Industry 1988).

In the meantime, the problem continues to grow. There was a temporary respite in the mid-1970's, when it appeared that the oil crisis would lead to widespread recycling of plastics waste. This did not happen on any scale for technical and sociological reasons, and the problem became more severe even through the years of high polymer prices.

One of the earliest surveys of plastics pollution in the seas was carried out by the author in the early 1970's. Over a 3-year period, a fivefold increase in plastics litter was observed on a remote shoreline in northwest Scotland (Table 1) (Scott 1972a, 1975a). The conclusion drawn from this survey was that most of the plastic litter found on the seashore is seaborne and wind driven. The nature and location of the litter suggested that it came predominantly from shipping and not from local inhabitants or visitors. In this context, the good intentions of the educators were seen to be both misguided and misdirected. Commercial pressures to use the sea as a convenient "waste bin" have proved to be much more persuasive than homilies by The Tidy Britain Group, and even the threat of legislation has little effect due to the difficulty of policing this on the high seas.

This early evidence of sea littering has been confirmed by many subsequent studies (Dixon and Cooke 1977; Dixon 1978; Dixon and Dixon 1981; Fowler and Merrell 1986; Andrady 1987; Heneman 1988), and there is increasing evidence that plastics debris can kill birds and animals by ingestion and strangulation (Fowler and Merrell 1986; Andrady 1987; Heneman 1988).

Certain types of nonbiodegradable plastics waste have come in for most criticism over the years. The most visual and intrusive are the large polyethylene bags used for packaging agricultural and industrial products and domestic carrier bags, all of which float on the sea and accumulate on land. Even more aesthetically objectionable are the smaller items which

Table 1.--Accumulation of plastic litter at Strathaird Point, Isle of Skye, Scotland, in a 3-year period (number of packages per 50 yd).

| Type of packaging (polymer)[a] | August 1971 | August 1974 |
|---|---|---|
| Detergent (LDPE) | 7 | 5 |
| Detergent (HDPE) | -- | 31 |
| Bleach, sanitary fluid (HDPE) | 15 | 49 |
| Oil (HDPE) | 4 | 18 |
| Cosmetic (HDPE) | 3 | 3 |
| Carpet cleaner (HDPE) | -- | 5 |
| Food (HIPS or ABS) | 1 | 7 |
| Table salt (HDPE) | -- | 10 |
| Milk (HDPE) | -- | 16 |
| Heavy gauge bags (LDPE) | 2 | 6 |
| Small transparent bags (LDPE) | -- | 29 |
| Carrier bags (LDPE) | -- | 5 |
| Heavy gauge sheets (LDPE) | 6 | 15 |
| Miscellaneous unidentified | 3 | 14 |

[a]LDPE = low density polyethylene, HDPE = high density polyethylene, HIPS = high impact polystyrene, ABS = acrilonitrile-butadiene-styrene copolymer.

originate from sewage disposal and which, although probably harmless compared with other components of sewage, cause great offense on beaches and in other environmentally sensitive areas (Johnson 1987). Six-pack collars, used for carrying beer and soft drink cans, have been particularly indicted as a cause of entanglement for birds and small animals, and discarded ropes and fishing nets are equally a cause of suffering and sometimes death to wildlife. These are all examples of litter which does not biodegrade, and although the polymers do degrade slowly under the influence of sunlight and oxygen and the erosive influence of the weather, these natural processes are not fast enough to eliminate the dangerous effects of man-made polymers in the environment.

Fortunately, a good deal of work in academic laboratories, particularly in the United Kingdom and Canada, had led to an understanding of the chemistry involved in the oxidative degradation of polymers. Associated with this was a fundamental understanding of antioxidant and ultraviolet (UV) stabilizer mechanisms which suggested the possibility of designing polymers with controlled outdoor stability.

## THE ENVIRONMENTAL STABILITY OF POLYMERS

### Biodegradability of Polymers

As has been discussed above, the main reason that the man-made polymers have assumed a position of such importance in the packaging

industry is because of their excellent water barrier properties. Since they are not readily penetrated by water, they act as an effective barrier, even in very thin films, to the attack of microorganisms. However, just because they are not accessible to microorganisms, they normally remain resistant to microbiological attack after discard in the environment.

All man-made polymers are not so hydrophobic as the carbon-chain polymers, however, and in general, the closer in structure polymers are to the natural polymers, the more biodegradable they become. Thus, the polyamides, which resemble the polypeptides in chemical structure, do absorb water and slowly biodegrade. In the case of polyurethane foams, biodegradation may take place quite rapidly because of the high internal surface area of the foam structure. Recently, man has been able to utilize nature's ability to synthesize and store within the biological cell certain types of polyester (Table 2) to produce a truly biodegradable polymer with physical and mechanical resemblances to the polyolefins (Lloyd 1987).

It is an unfortunate irony, however, that the nearer synthetic polymers approach the structure and properties of the natural polymers, the less useful they become as packaging materials because of the impairment of their barrier properties. Cellulose-based packaging has been largely abandoned over the years in favor of the hydrophobic polymers, and it is highly unlikely that the packaging industry would now be willing to return to less effective materials even if they could be produced at the same price as commodity plastics. It appears then that some other stratagem has to be sought to ensure that packaging materials are returned to the biological cycle when discarded in the outdoor environment.

## Oxidative Degradation of Polymers

All organic polymers degrade due to the combined effects of oxygen, sunlight, and water by processes which do not, at least in the early stages, involve biological agencies (Scott 1965). They do so, however, at rates which differ by several orders of magnitude. Fluorinated polymers (e.g., Teflon) are in general the most resistant to environmental deterioration, and in the absence of light they can survive for many decades. Hydrocarbon polymers, and particularly the unsaturated rubbers, are much less resistant to oxidation, and even polyethylene, which on the basis of its structure should be chemically inert, does oxidize slowly unless protected against the effects of the environment. The small amounts of antioxidants which are added as processing stabilizers are normally sufficient to effectively stabilize polyethylene against the effects of oxidation in the absence of sunlight, but much more effective combinations of antioxidants and light stabilizers have to be used in order to give the polymer the durability required for use in outdoor applications (Scott 1979-88; Grassie and Scott 1985).

Oxidation of polymers leads to the formation of a variety of oxygen-containing functional groups as part of the polymer chain, of which the most important are hydroperoxides, carbonyl groups, alcohols, and carboxylic acids (Fig. 1) (Grassie and Scott 1985). These lead to the modification of the polymer surface, making it hydrophilic and allowing microorganisms to preferentially remove the oxygen functions. Figure 2

Table 2.--Commercially available degradable plastics.

| Common description | Composition | Trade name | Manufacturer |
|---|---|---|---|
| | **Biodegradable polymers** | | |
| Poly (3-hydroxy-butyrate-3-hydroxy valerate) | Biosynthetic copolymer of 3-hydroxybutyric and 3-hydroxy-valeric acids | Biopol | ICI (United Kingdom) |
| | **Polymers containing a biodegradable filler[a]** | | |
| Starch-filled polyethylene (Griffin process) | Physical blend of LDPE and starch | Bioplast<br>Ecostar | Coloroll (United Kingdom)<br>St. Lawrence Starch (Canada) |
| | **Photodegradable copolymers** | | |
| Ethylene-carbon monoxide copolymers | | E/CO | DuPont (United States)<br>Union Carbide (United States)<br>Dow (United States) |
| Vinyl ketone copolymers (Guillet process) | Copolymers of ethylene, propylene, and styrene with a vinyl ketone | Ecolyte | EcoPlastics (Canada) |
| | **Photosensitizing and photoactivating additives** | | |
| Iron salts | Probably ferric stearate | PolyGrade | Ampercet (United States) |
| Aromatic ketones | Probably benzophenone with metal stearates | Not commercial | Princeton Polymer Lab. (United States) |
| Antioxidant photoactivator (Scott-Gilead process) | Ferric thiolates (sometimes with other metal thiolates (in polyethylene) | Plastor | Plastopil (Israel)<br>Polydress (Germany) |
| | | Greenplast | Enichem Agricultura (Italy) |
| | | Plastigone | Plastigone Technologies Inc. (United States) |
| | | Ecoten[b] | Amerplast (Finland) |
| | | Litterless | Plastigone Technologies Inc. (United States) |
| | (in polypropylene baler twine) | Cleanfield | American Brazilian Company (United States) |

[a]LDPE = low density polyethylene. [b]Manufacture discontinued.

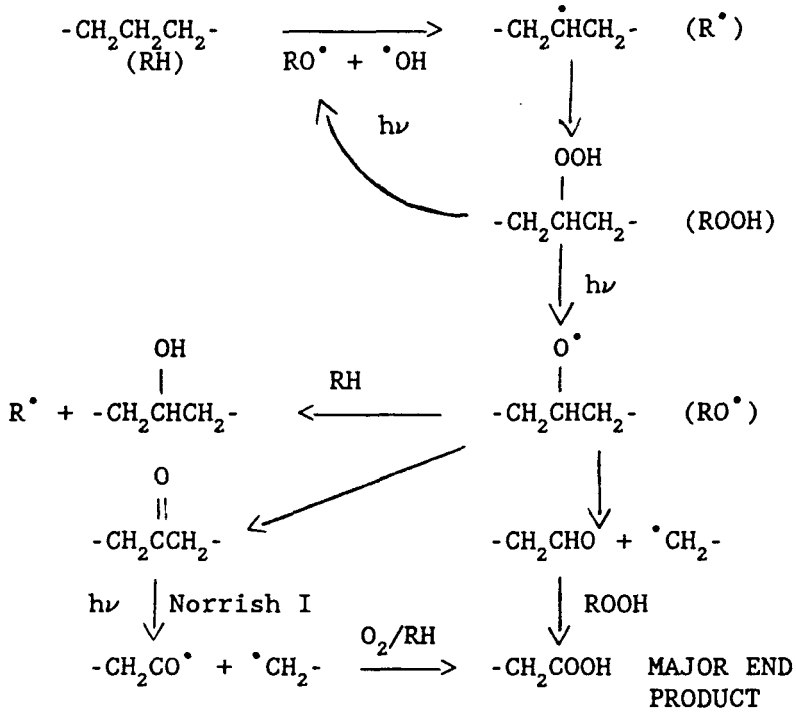



Figure 1.--Products formed in the photooxidation of polyethylene.

shows that polyethylene, stored under ambient conditions, develops a substantial concentration of carbonyl compounds (1,710-1,735 $cm^{-1}$), and that these can be selectively removed by microorganisms, leaving a chemically "purer" polymer behind (Grassie and Scott 1985).

Deliberate preoxidation of polyolefins leads to an enhanced rate of attack of thermophilic fungi at 40°-45°C due to the formation of readily assimilable dicarboxylic acids (Eggins et al. 1971). Some plasticizers also accelerate this process, probably in part by accelerating the autoxidation of the polymer (Eggins et al. 1971). Recently, the addition of oxidizable oils (e.g., soybean oil) to polyethylene has been used to accelerate the rate of thermal oxidation of starch-filled polyethylene in compost at elevated temperatures in order to make the starch available to microbiological attack (Griffin 1987; Maddovar and Chapman 1987). The rationale behind this approach to biodegradable polyethylene is not entirely clear, since the starch is encapsulated in biologically resistant polymer which does not oxidize at a significant rate at ambient temperatures. Moreover, the process cannot occur in landfill because no oxygen is present and the unoxidized polymer backbone cannot be assimilated by microorganisms (Potts 1982).

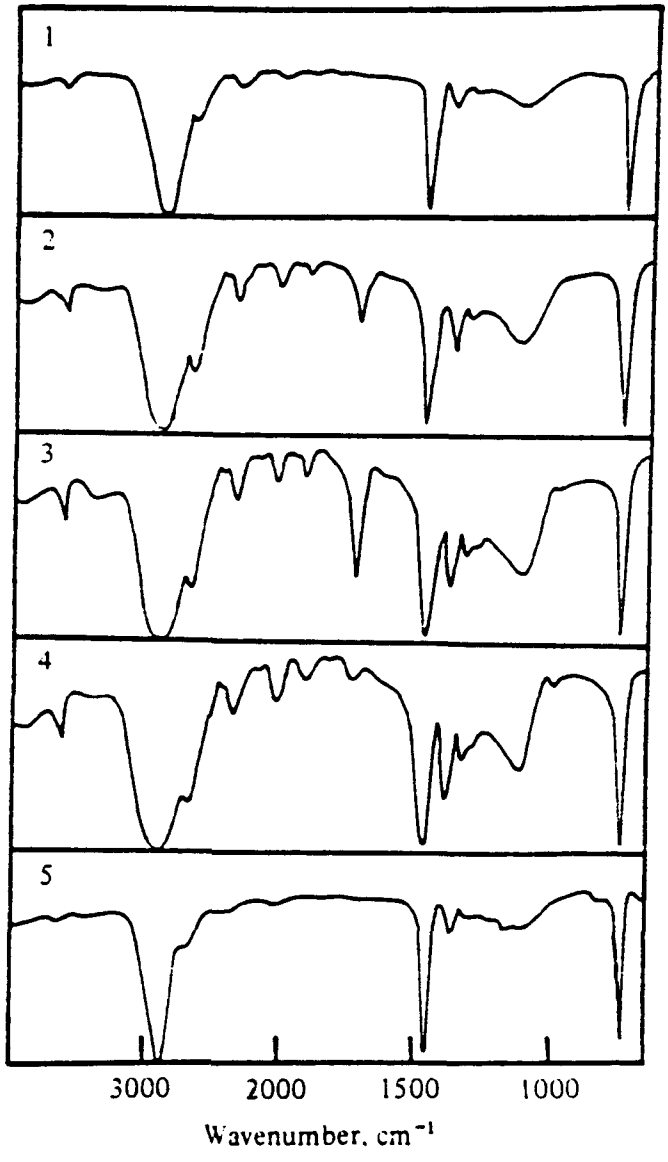



Figure 2.--Infrared spectra of high density polyethylene (HDPE) films with different histories: 1--with antioxidant after standing at ambient temperature for 1 year; 2--as 1 without antioxidant; 3--as 2 after standing for 3 years; 4--as 3 after treatment with an aerated medium inoculated with cultivated soil; 5--HDPE powder without antioxidant exposed to aerobic biodegradation for 2 years before molding to film with exclusion of air. (Grassie and Scott (1985) with permission, originally reproduced from a doctoral thesis by Dr. A. C. Albertsson with permission.)

## Photooxidation of Polymers

Thermal oxidation of polymers is not a very controllable process. Although it can be catalyzed by cooxidation agents or transition metal ions, these are present in varying amounts of foodstuffs. However, autoxidation is readily inhibited by antioxidants, which are deliberately added to stabilize the polymer during manufacture (Grassie and Scott 1985). Furthermore, the addition of even a few percent of polymer-soluble coagents substantially alters the physical characteristics of the polyolefins (Scott 1988a, 1988b).

Photooxidation, by contrast, is a much more controllable process, since it is not appreciably affected by thermal antioxidants or contaminants. As early as 1971, it was suggested (Eggins et al. 1971) that controlled photooxidation was a potentially useful way of dealing with the problem of nonbiodegradable packaging litter. It offers the very considerable advantage over true biodegradation of the main polymer chain that, until photooxidation has occurred in the environment where the package has been discarded, its properties do not differ in any respect from conventional packaging made from the same polymer. The mechanism of photooxidation is essentially similar to that of thermal oxidation. The essential difference is the way in which the autoxidation chain reaction is initiated, which, in turn, depends on the presence of photoinitiators in the polymer (Grassie and Scott 1985).

Typical photoinitiators that have been used to sensitize the photodegradation of plastics in the outdoor environment after discard are listed in Table 2. Although many more have been reported in the patent literature, these are the only ones which have reached the marketplace. Companies producing them are also listed in Table 2.

Photodegradable plastics can be broadly classified into types:

- Copolymers in which the sensitizer, a carbonyl group, is built into the polymer.
- Conventional plastics to which the sensitizer is added, generally as a masterbatch and in some cases as a replacement for the usual processing stabilizer.

### Copolymers

In the first approach, degradation occurs primarily by photolysis of the polymer backbone, leading to reduction in molecular weight and fragmentation of the polymer (Fig. 3). The Norrish Type II process is the predominant mechanism leading to chain scission, giving rise to ketone and vinyl groups at the end of the polymer chains (Grassie and Scott 1985). An early example of such a carbonyl-modified polymer was claimed in a patent by DuPont (Brubaker 1950), and this process has been commercialized relatively recently by DuPont and Union Carbide among others (Johnson 1987). The polymers embrittle rapidly and without any induction period (Harlen and Nicholas 1987; Statz and Dorris 1987), and if a period of

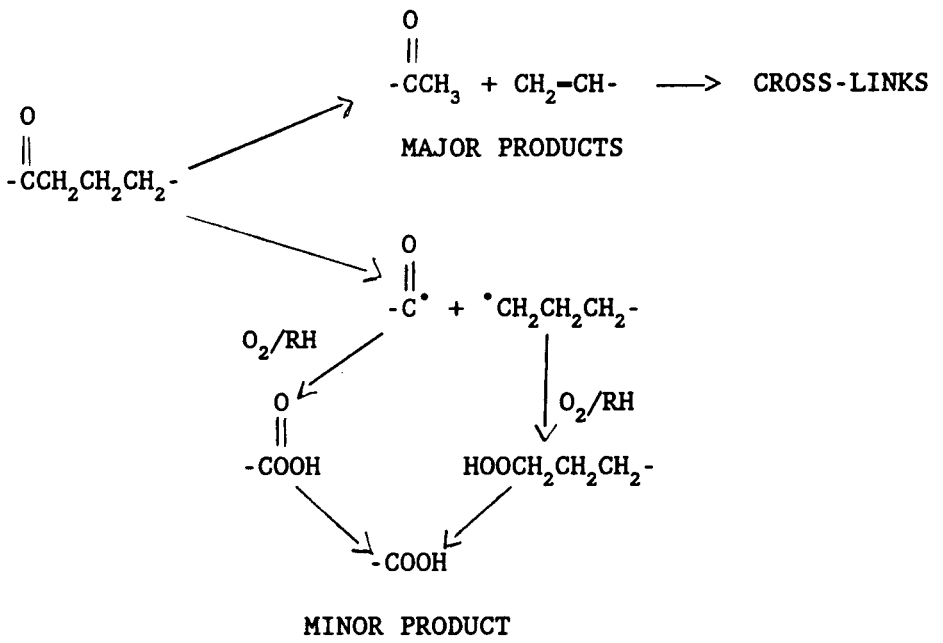



Figure 3.--Photolysis of in-chain carbonyl in polyethylene.

"safe" use is required, for example in storage or for a defined period out-of-doors, then the packaging has to be protected against UV irradiation. This kind of degradable plastic cannot, therefore, be used in agricultural protective film (mulch), where the polymer has to retain its strength for a well-defined period of time in sunlight but then has to photodegrade rapidly over a period of a few weeks. Rapid degradation appears to cease after all the in-chain carbonyl groups have photolyzed, and there is evidence (Harlen and Nicholas 1987) that the molecular weight decreases to a minimum and then increases again (Table 3). There is a similar minimum in the elongation to break, and these phenomena suggest that oxidation does not occur to any extent. This is consistent with the fact that if biodegradation does occur, it is extremely slow (Statz and Dorris 1987)--a considerable disadvantage of this type of product, since the fragmented products will still tend to accumulate in the environment.

In a more sophisticated approach to photodegradable copolymers, Guillet and his coworkers have copolymerized a variety of monomers, of which styrene, ethylene, and propylene are the most important, with vinyl ketones (Guillet 1973). These polymers have been commercialized under the name Ecolyte by Ecoplastics Ltd. (Redpath 1987). These polymers photolyze by essentially the same mechanism as the E/CO polymers, but both Guillet (Guillet et al. 1974; Jones et al. 1974) and Redpath (1987) have reported that the Ecolyte copolymers do biodegrade after fragmentation. This implies that the Norrish Type I process must play some part in initiating a conventional autoxidation chain reaction. However, the Ecolyte polymers suffer from the same disadvantage as the E/CO polymers in that they do not

Table 3.--Molecular weight changes in E/CO polymer (2.74% CO) on ultraviolet irradiation.

| Exposure time, h | $M_n$ | $M_w$ |
|---|---|---|
| 0 | 45,000 | 618,700 |
| 650 | 7,300 | 15,000 |
| 1,350 | 11,100 | 39,100 |

have a controllable induction period before rapid photodegradation commences.

**Sensitizer Additives**

In this approach, two main types of additive have been used. The first class falls broadly into the general class of triplet sensitizers, most importantly the benzophenones (Takahachi and Suzuki 1964) (see H. Omichi (1983) for a survey of the literature up to 1983). The mechanism of their action is summarized in Figure 4 and the related quinones act in the same way. Although the carbonyl sensitizers cause rapid photooxidation from the beginning of UV exposure, they autoretard rapidly in the case of

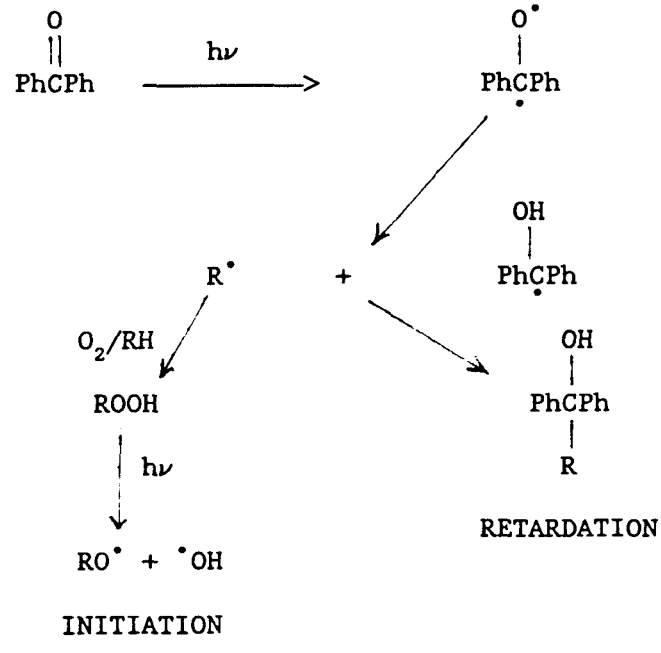



Figure 4.--Mechanism of photoinitiation and autoretardation by triplet sensitizers.

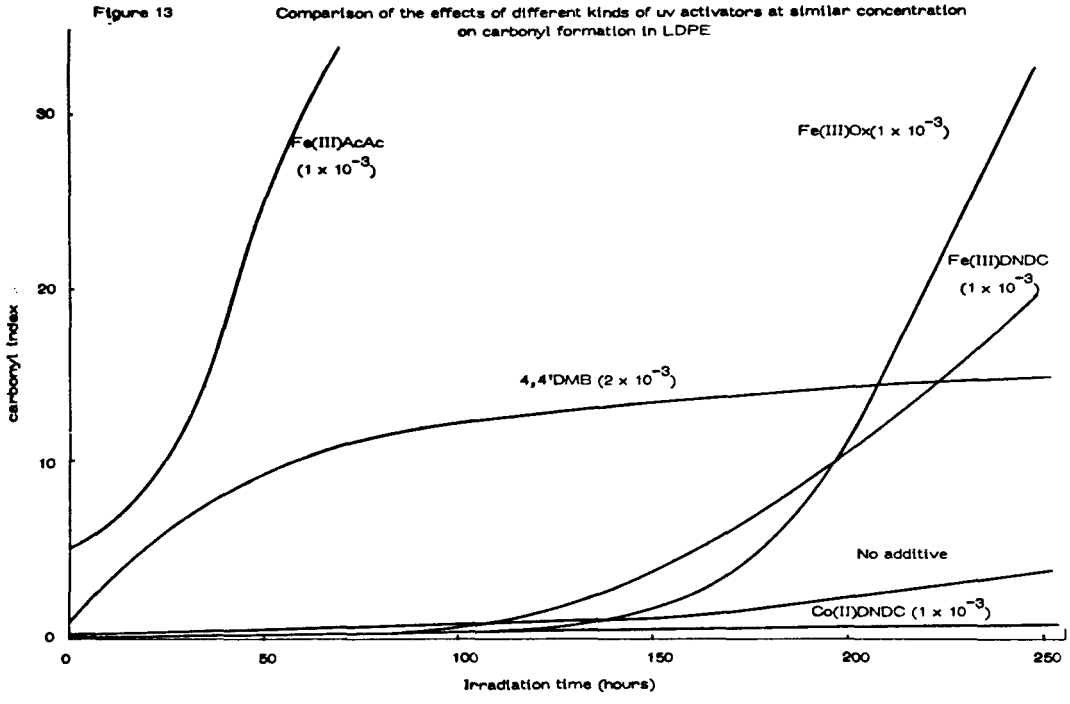



Figure 5.--Comparison of the photooxidation, as measured by carbonyl formation (at 1,710 $cm^{-1}$), of low density polyethylene (LDPE) films containing different kinds of photoactivator at similar concentrations. 4,4'DMB, 4,4'dimethoxybenzophenone; Fe(III)AcAc, iron acetyl acetonate; Fe(III)DNDC, iron dinonyl dithiocarbamate; Fe(III)L2, iron complex of 4-methyl-2-hydroxyacetophenone oxime; Co(II)DNDC, cobalt dinonyl dithiocarbamate (UV stabilizer). (From Amin and Scott (1974) with permission.)

polyethylene and the photooxidation virtually ceases after a period of time (Fig. 5) (Takahachi and Suzuki 1964). This is because the hydrogen abstraction step in Figure 4 leads to a "stable" radical which is able to trap out the chain-carrying species formed in the photooxidation process. This has unfortunate consequences for the long-term oxidation and biodegradation of the polymer, and this, coupled with the lack of an appropriate time control mechanism, has resulted in no commercial developments with this type of sensitizer system.

The second class of photosensitizer additives is based on transition metal ion compounds and is the most important class in use today. Transition metal ions have been extensively studied as photosensitizers for polyolefins (Takahachi and Suzuki 1964; Mellor et al. 1973; Amin and Scott 1974; Chew et al. 1977). Many polymer-soluble metal carboxylates, notably $Co^{3+}$ and $Fe^{3+}$, are powerful photoprooxidants which catalyze

photooxidation right from the beginning of UV irradiation (Fig. 5), and in the form of polymer-soluble carboxylates or acetylacetonates they cause melt degradation of the polymer during processing (Amin and Scott 1974). They cannot, therefore, be used alone in polymers in conventional processing operations because of their unfortunate effect on the melt stability of polymer and on the shelf-aging behavior of the fabricated product. Although conventional antioxidants improve processing and aging characteristics, they also interfere with the photosensitizing effect of the transition metal ions (Mellor et al. 1973).

The photoinitiating mechanism of the transition metal salts involves photolysis to give the reduced form of the metal ion and a free radical:

$$FeX_3 \xrightarrow{h\nu} [FeX_2\ X^\bullet] \longrightarrow FeX_2 + X^\bullet \qquad (1)$$

The anion radical readily abstracts a hydrogen atom from the polymer

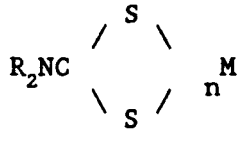
$$X^\bullet + PH \longrightarrow XH + p^\bullet \xrightarrow{O_2/RH} POOH \qquad (2)$$

Once formed, hydroperoxides control the subsequent oxidative degradation by the usual redox reactions with metal ions, e.g.,

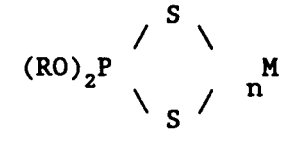
$$FeX_2 + ROOH \longrightarrow RO^\bullet + FeX_2OH. \qquad (3)$$

**Transition Metal Ion Antioxidant-Photosensitizers**

Many metal complexes containing sulphur as a ligand are antioxidants and photostabilizers. Although this behavior is not limited to sulphur compounds, members of the latter class have gained a position of some importance as heat and light stabilizers for polyolefins (Scott 1965; Al-Malaika et al. 1983; Al-Malaika and Scott 1983). The dithiocarbamates (I) and the dithiophosphates (II) are representative of this class of stabilizers and exert their effect by destroying hydroperoxides by an



I



II

ionic mechanism (Al-Malaika et al. 1983; Al-Malaika and Scott 1983). One of their most striking and useful attributes is that they produce a well-defined and reproducible induction period during which the ligand is destroyed and at the end of which the metal ions which form part of the antioxidant are released and subsequently behave very much like the free transition metal ions described in the previous section (Fig. 5) (Scott 1965).

In 1971, Scott filed a patent based on the above concept in which antioxidant and photosensitizer properties were both contained in the same molecule, although this could be made in situ in the polymer by reacting the metal ion with the antioxidant (Scott 1971). The Fe(III) complexes of I and II are representative of this class of "delayed action" photoactivators. Not only do they replace conventional processing stabilizers by virtue of their antioxidant properties, but they are also effective heat stabilizers and short-term light stabilizers. The fact that the induction period to photooxidation could be controlled by varying the concentration of the metal complexes led in the early 1970's to the use of this system in agricultural mulching film, which requires a finely controlled lifetime before rapid photooxidation and biodegradation commences (Scott 1972b, 1972c, 1973a, 1973b, 1973c, 1975b, 1975c, 1976; Scott and Gilead 1978). This material was marketed as Plastor by Plastopil Hazorea, and subsequent development in collaboration with Gilead led to further patents (Scott and Gilead 1978) concerned with the fine control of the "safe" period, which is so essential for agricultural purposes (Scott and Gilead 1982).

The later developments involve the use of two component systems in which the length of the induction period is controlled by one metal thiolate and the rate of photooxidation by a second. The Scott-Gilead process is currently used in the commercial growing of soft fruits, vegetables, and some cereals in Italy, Germany, France, and the United States. In addition to the name Plastor, these products are sold under the trade names Greenplast (Enichem Agricultura, Italy), Plastigone and Litterless (Plastigone Technologies Inc., United States). The process is also used in polypropylene binder twine by the American Brazilian Company in the United States under the trade name Cleanfield.

The use of the Scott-Gilead system in agriculture has established the reliability of this technology. Figure 6 shows it in use near the Dead Sea in Israel. At the end of the induction period, the polyethylene film photodegrades rapidly, and biodegradation is complete by the beginning of the following season. There has been no buildup of nonbiodegraded plastics on any of the sites where it has been used.

In parallel with the above developments, trials began on the use of the original iron thiolate system in packaging. This led to the manufacture of carrier bags in Finland in 1973 under the name Ecoten. Figures 7 and 8 illustrate the progression of the degradation of Ecoten carrier bags exposed at intervals out-of-doors in Birmingham (Scott 1976). The time delay of about 2 weeks of summer sunshine before rapid degradation commenced was introduced at the request of the user to safeguard against adventitious exposure to light of the packaging during use. A measure of the effectiveness of the iron thiolates as thermal antioxidants is the fact that 15 years after their manufacture, carrier bags made by this process and stored in the absence of light are still as strong as when they were first manufactured. This process is currently being evaluated in check-out bags (United States), carrier bags (United Kingdom), and six-pack collars (United States), all of which tend to end up as litter.

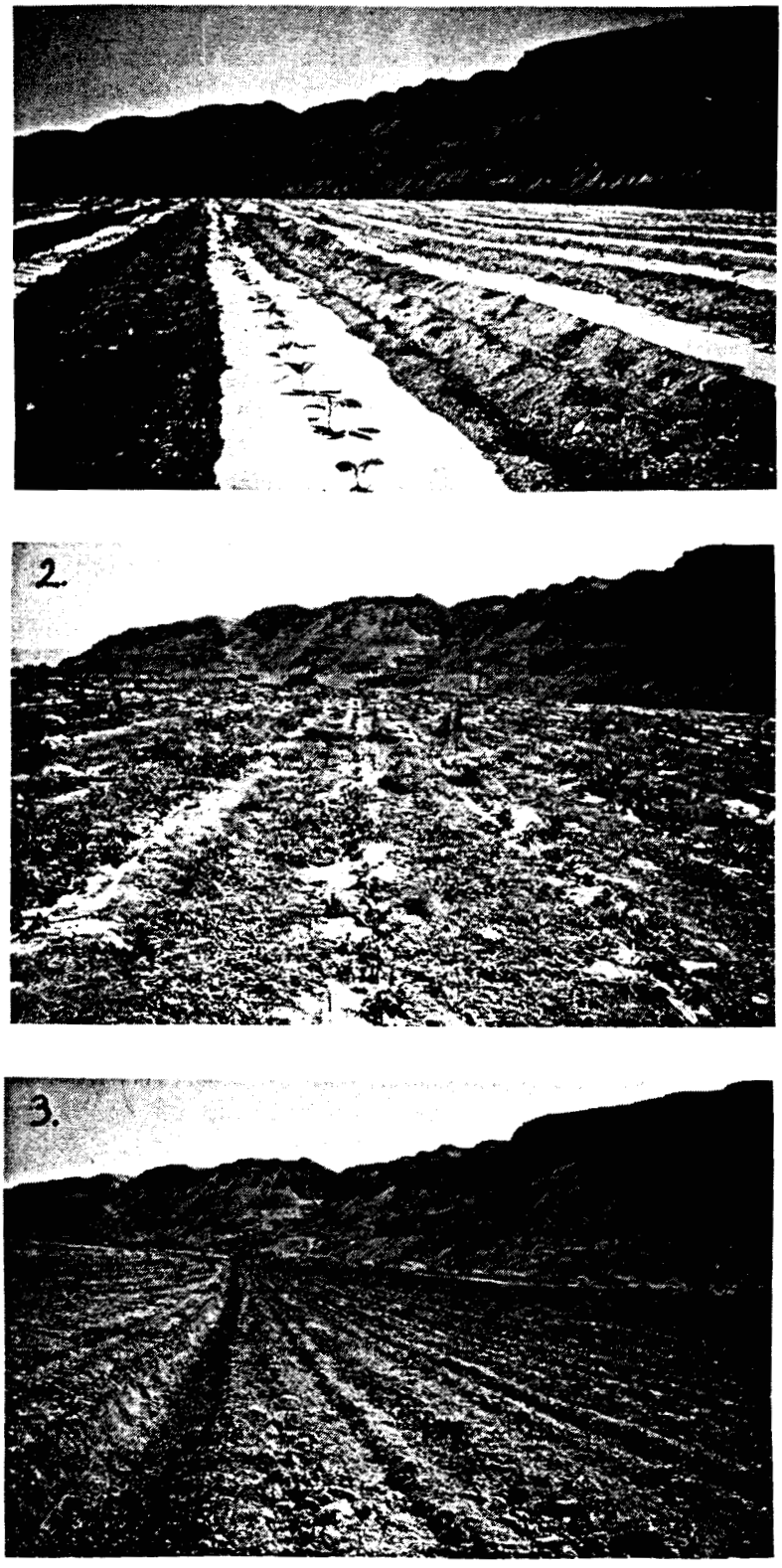



Figure 6.--Progress of photooxidation and biodegradation of Plastor (photobiodegradable) mulching film in Israel. 1--immediately after laying; 2--after cropping; 3--after ploughing. (Photographs by courtesy Plastopil Hazorea, Ltd.)



Figure 7.--Ecoten carrier bags exposed out-of-doors in Birmingham at 1-month intervals.

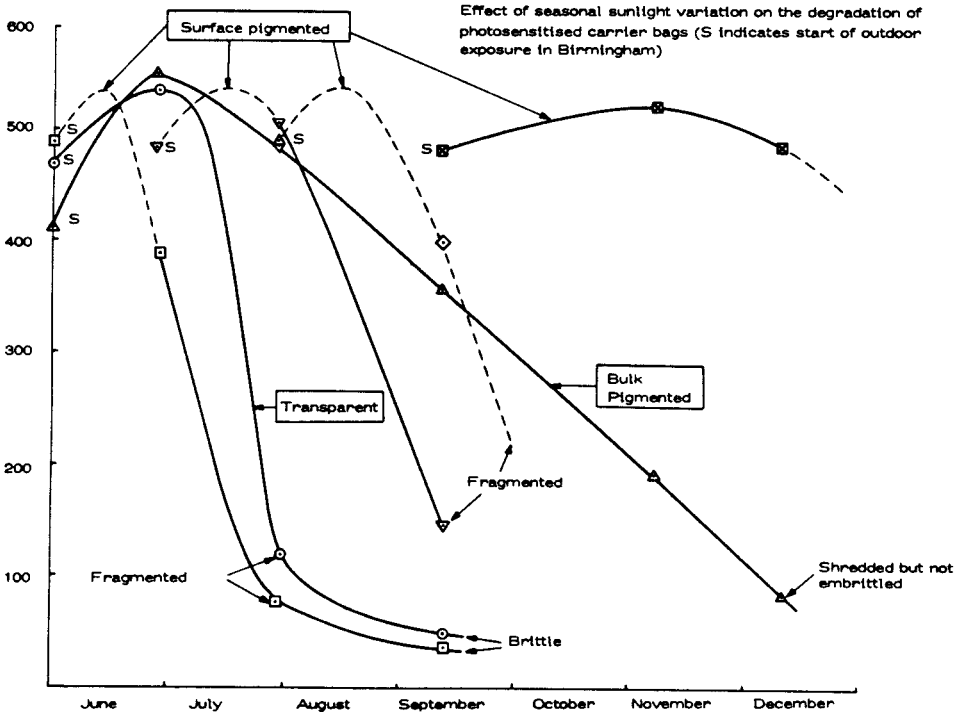



Figure 8.--Change in mechanical properties of Ecoten carrier bags exposed out-of-doors in Birmingham at 1-month intervals.

## TECHNICAL REQUIREMENTS OF PHOTOBIODEGRADABLE PLASTICS

In spite of the successful use of photobiodegradable plastics in agriculture and to a lesser extent in packaging over the past 15 years, the packaging industry has been reluctant to accept them as a contribution toward the control of plastics litter. The arguments used against them are frequently couched in technical language, but are very often based on misconception rather than on technical fact and experience. The critics of degradable plastics are generally governed less by the published scientific evidence than by a reluctance to accept liability for the pollution resulting from the activities of their own industry. The pseudosociological arguments frequently used are intended as much for politicians as for the users of packaging.

The use of degradable plastics in agriculture was dictated by economic necessity. The same pressures are not evident in the use of degradable plastic in packaging, since rapid disintegration after use does not enhance the primary function of the package. Legislative bodies have, therefore, been reluctant to prohibit the use of nondegradable materials for purely aesthetic reasons. However, it is now clear that the situation is much more critical in the oceans, where there is a real threat to marine birds and animals. Experience in agriculture has unambiguously demonstrated that there are no economic or technical reasons why photobiodegradable plastics should not now be introduced into all bulk packaging. There is increasing evidence that the manufacturers and users of packaging are beginning to listen to the "green" movements, which advocate working with rather than against nature. The idea of returning waste plastics to the biological cycle is rapidly gaining popularity with the retailers of "organic" products and even with the large supermarkets.

However, packaging manufacturers are faced with a dilemma. The claims of the various degradation systems available are very difficult to check out. Furthermore, where they have been evaluated, the performance of some of the processes does not match up to the claims made for them. The terminology used is often confusing, and most technologists cannot distinguish between the subtleties of anaerobic and aerobic biodegradation, photodegradation, and photobiodegradation. There are at present no objective performance tests currently available which allow the user to compare the performance of degradable plastics. Until such criteria are available, it seems likely that the polymer industries will continue to argue on specious grounds against the introduction of more biocompatible, but also potentially more expensive, materials. In these circumstances, it seems unlikely that the polymer industries themselves will wish to fund the necessary research to establish the appropriate standards. The pressure for change must come from the users of packaging in association with the environmental pressure groups.

## NET PACKAGING AND FISHING NETS

One of the most serious threats to marine life undoubtedly comes from ghost fishing, where both animals and fish become fatally entangled in

Table 4.--Combination effects of a photoactivator (FeDMC, 0.01 g/100 g) and a photostabilizer (NiDBC, variable) on the photooxidative stability of polypropylene.

| Concentration of NiDBC, g/100 g | 0 | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|---|
| Embrittlement time, in hours | 116 | 956 | 1,515 | 2,250 | 2,516 |

discarded nets. Much of this lethal debris arises accidentally by natural wear and tear on fishing gear, which has a finite life due to normal oxidative aging and biodegradation processes. Some of it, however, particularly in the packaging field, results from deliberate discard by the user. Most of the polymer used in these applications is polyolefin-based and so, as seen above, does not biodegrade rapidly unless sensitized to oxidation. An exceptionally wide range of lifetimes is thus required for netting, ranging from packaging, where ideally photobiodegradation should commence immediately on discard, to fishing net, where a service life of 5 years or more is required. This might at first sight appear to be an impossible achievement when coupled with the need for rapid photooxidation and biodegradation at the end of the useful life of the net. In practice, the Scott-Gilead system has been shown to be capable of providing this range of degradation times in polypropylene and high density polyethylene.

Table 4 shows that different combinations of photoactivator (FeDMC) and photoantioxidant (NiDBC) in polypropylene give a twenty-fivefold range of useful lifetimes (Scott and Gilead 1982), and more recent work has shown that this can be increased to a greater than fiftyfold range using a combination of different additives. In practice, this means that if a lifetime of 2 months is required for short-term packaging, then, using the same polymer but a different combination of the same additives, a lifetime of 8 years is technically feasible for fishing nets. This extraordinary lifetime control is accompanied in all cases by rapid photooxidation and biodegradation after embrittlement of the fiber. This process is already in commercial use in polypropylene binder twine (American Brazilian Company), where a lifetime of about 1 year is required followed by the rapid disappearance of the fiber from the field. It is fortunate that polypropylene, due to its low density, floats on the surface of water, where it is subjected to the combined effects of sunlight, oxygen, and microorganisms. This process is ideal for the protection of the environment from net packaging, ropes, and fishing nets which fail in service.

## THE FUTURE

Polymer technologists have in the past been concerned to make sure that their products lasted as long as possible in the environment. It is increasingly being recognized that a more sophisticated approach is required in the future. Many products are required to last only as long as

they fulfill their useful function, and the chemistry of stabilization has now advanced to the point where predictable lifetime control of polymeric materials is not only feasible but is now well proven through the pioneering activities of Gilead and his coworkers in plasticulture (Scott and Gilead 1982; Gilead 1985; Gilead and Ennis 1987).

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# ENVIRONMENTAL DEGRADATION OF PLASTICS UNDER LAND AND MARINE EXPOSURE CONDITIONS

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## ABSTRACT

Several types of thermoplastic and latex rubber materials commonly encountered in marine plastic debris were weathered outdoors in air and while floating in seawater, under North Carolina climatic conditions. The degradation of the different samples was monitored by tensile property determination.

In general, the various materials exposed outdoors in seawater tended to weather at a slower rate than the materials exposed outdoors in air. This retardation of weathering is probably a result of lack of heat buildup in samples exposed in seawater. Also, surface fouling on samples in seawater may have shielded them from light to some extent.

## INTRODUCTION

In spite of their short history, synthetic polymers, particularly plastics, have gained wide popularity as the material of choice in a wide range of packaging, building, and other applications. With the current consumption of plastics reaching around 27.5 million metric tons (MT) (50 billion lb) in the United States (Modern Plastics 1988), plastics will without doubt continue to replace conventional materials such as glass, metal, wood, and paper in a variety of additional uses. The projected production in the year 2000 is expected to be 41.3 to 55.1 million MT (75 to 100 billion lb).

The popularity of plastics in packaging and other applications is attributed to the unique, useful characteristics of the material. These include light weight, excellent mechanical strength (tensile properties, tear resistance, and impact resistance), readily controllable and superior optical properties (clarity, gloss, and color), biological inertness, easy processability, low cost, and outstanding durability. Because they are synthetic materials, plastic compositions might be "tailor made," within limits, to obtain specific useful characteristics. As a response to an historically consistent consumer demand for stronger and longer lasting plastics, the industry has continually improved the durability of plastics, especially for outdoor exposure conditions.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

The recent surge in the use of plastics as the material of choice in diverse applications is also reflected in uses of plastics at sea, particularly by the fishing industry. A very significant source of marine plastic debris is gear related. Introduction of plastics into the world's oceans started in the late 1940's with the changeover from natural fibers (jute, cotton, hemp) to synthetic polymer fibers in the construction of fishing gear (Uchida 1985). Today, nearly all the fishing gear used in developed countries is manufactured from durable synthetic materials (Klust 1973), and the commercial fishing industry is the prime source of plastics in the oceans.

In addition, passenger, freight, military, and research vessels, as well as beach users introduce plastic materials into the marine environment. Invariably, most of the non-gear-related plastic waste is discharged into the ocean as postconsumer waste from vessels or is washed into the ocean from the beach environment (Parker et al. 1987). The magnitude and the nature of this influx of plastics into the sea from such sources vary widely depending on the season of the year and the geographic region (Pruter 1987).

An inevitable consequence of increased usage of plastics, particularly in packaging applications, is the increased amounts of postconsumer plastic waste. The municipal waste stream (amounting to about >88,000 MT (160 million lb) annually in the United States) in urban areas now consists of about 7% postconsumer plastics, a figure that may increase to more than 9% by the year 2000 (Franklin Associates 1988). While accurate estimates of their lifetimes in the environment are not reliably known, plastics are perceived as being exceptionally persistent materials requiring hundreds of years of exposure to facilitate biodegradation.

Parallel estimates for the quantities of plastic waste in the world's oceans are not available. Estimates by several workers (Dahlberg et al. 1985; Pruter 1987), though probably very crude, allow an appreciation of the magnitude of waste at sea.

With a total annual world catch of about 45 million MT of fish (Parker et al. 1987), a substantial amount of plastic fishing gear is routinely introduced into the ocean. The estimates of worldwide losses of commercial gear vary from a low of about 750 MT tons annually (National Academy of Sciences (NAS) 1975) to as much as 75,000 MT/year (Merrell 1980). In addition to gear losses, fishing vessels also discharge "domestic" plastic waste. A 1986 estimate places the number of commercial vessels operating annually in the United States at 125,700 (Parker and Yang 1986). The world's fleet of fishing vessels is believed to discharge 23,000 tons of plastics annually into the sea (Horseman 1985).

A detailed discussion of the ecological concerns related to plastic debris at sea is beyond the scope of this paper. Several excellent reviews on the fate of plastic debris, the specific hazards posed by such debris in specific marine species, and the general impact of plastics on the populations of target species have been published (Day et al. 1985; Center for Environmental Education (CEE) 1987; Laist 1987).

Available evidence indicates entanglement by the debris and the ingestion of the debris to be the primary concerns with a variety of affected marine animals (including birds, turtles, marine mammals, and fish). These affected populations seem to seek out the debris (either mistaking it for prey or because of mere curiosity); such behavior leads to more fatalities than might be expected on the basis of random encounters with debris. The invariable association of either entangled fish or residual food in most of the plastic waste discharged into the sea also concentrates these species in the same geographic locations that have high incidences of plastic waste (Laist 1987). Recent declines in the natural populations of the Hawaiian monk seal, *Monachus schauinslandi*, by 4 to 8% per year have been attributed, at least in part, to entanglement in plastic waste (Fowler 1985, 1987).

## PLASTICS AT SEA

### Key Characteristics of Marine Plastic Waste

The potential negative impact of waste plastics on the marine resource depends upon the following key characteristics of the material.

- Geometry. Shape of the debris is important from the point of view of entanglement. Products such as six-pack rings and netting represent more of a potential hazard than an equivalent mass of the same polymer in the form of a laminate.

- Durability. The likelihood of encounter between a given item of marine debris and a marine animal depends upon the lifetime of the material. The duration available for the encounter is crucial in determining the potential hazard posed by the plastic material. Unfortunately, little information is available on the lifetime of plastics at sea. Lack of this information is a definite setback in the assessment of potential hazards posed by plastic waste.

- Strength. Strength of the debris material determines the likelihood that an entangled animal can escape. Alternatively, the possible obstruction of the gut in case of ingestion is less likely if the material is weak enough to mechanically fail during the ingestion process.

- Toxicity. Plastics, being undigestible macromolecules, cannot be absorbed through the gut lining. They are, therefore, not toxic materials. However, the plastics used in the fabrication of products may contain chemical additives which can be absorbed and assimilated.

Of these characteristics, lifetime is perhaps the most important. An attempt was therefore made in the present work to determine the relative lifetimes of some relevant debris items exposed on land and floating in seawater. The study will determine if the plastic materials floating on

seawater degrade at rates different from those exposed to the same natural weathering conditions, but in air.

### Weathering of Plastics Under Marine Exposure Conditions

Sunlight-induced degradation is the principal mechanism of weathering of plastics outdoors. As sunlight is freely available to plastics floating in the sea, weathering might be expected to occur at sea at rates comparable to those on land. However, there are several reasons to expect the rate of degradation at sea to be different from that on land.

- High humidity is known to accelerate the rates of degradation of several classes of plastics (Davis and Sims 1983). This may be brought about by the "plasticizing" action of small quantities of sorbed water leading to increased accessibility of the matrix to atmospheric oxygen or by the leaching out of stabilizing additives from the formulation.

- Plastics exposed to sunlight outdoors undergo "heat buildup," a process which results in the plastic material reaching significantly higher temperatures than the surrounding air (Summers et al. 1983). The higher temperatures generally result in an acceleration of light-induced degradation and may even be high enough to induce significant thermooxidative degradation. Plastics at sea will not suffer from such heat buildup and may consequently undergo slower oxidative degradation and photodegradation.

- All materials exposed to the sea invariably undergo fouling (Fischer et al. 1984). In the initial stages of fouling, a biofilm forms on the surface of plastic. Gradual enrichment of the biofilm leads to a rich algal growth within it. Consequently, the biofilm becomes opaque, and the light available to the plastic for photodegradation is restricted. Thus, the rate of photodegradation at sea might be determined in part by the rate of fouling.

- Advanced stages of fouling are characterized by the colonization of the plastic surface by macrofoulants such as bryozoans. The weight of the macrofoulant and that of debris they entrap might even partially submerge the material. As the ultraviolet portion of sunlight is attenuated on passage through seawater, submerged plastics would necessarily undergo a slower rate of photodegradation. Microbe-rich foulant film may, however, also tend to accelerate the biodegradation process by providing a rich biotic population in contact with the plastic surface.

## DEFINITIONS DEVELOPMENT

An important issue relating to the discussion of degradability and enhanced degradable plastics is that of definitions. The various terms are

used in a loose manner in the literature with no consistency. The need to develop adequate definitions has been pointed out recently by Andrady (1988) and others (General Accounting Office 1988). Definitions of the term "plastics" as it applies to the MARPOL Annex V Convention and the following terms relating to "degradability" are proposed as a starting point for further development.

For the purposes of MARPOL Annex V, the following definition of plastics has been proposed.

> Plastic: A solid material which contains as an essential ingredient one or more synthetic organic high polymer: and is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat and/or pressure.

The proposed definition includes both rubber and plastics (plastic products as well as virgin resin pellets). Inorganic polymers such as glasses are excluded along with low molecular weight polymers which are not "high" polymers or solids. The latter includes polymeric waxes, varnishes, and lubricants. The definition excludes any polymers produced by living organisms, including cellulose, natural rubber, and bacterial polyesters. In the case of a composite material where one component is a polymer, the material is excluded if the polymer itself is a minor component not essential to the formulation.

> Deterioration: Embrittlement and/or loss of physical integrity of a polymer regardless of the mechanism which brings about these changes.

The deterioration process might be the result of either a chemical or a physical process. Nonchemical deterioration of plastics plays an important role in environmental deterioration of plastics.

> Degradation: Deterioration which results from a chemical process.

Degradation might be further subdivided, based on the agency causing the chemical change. "Photodegradation" refers to degradation brought about by light. "Biodegradation" is that due to living organisms. Degradation due to slow oxidation of the plastic (especially at elevated temperatures) is "thermooxidative degradation," while that due to the chemical action of water is hydrolytic degradation or "hydrolysis." To be consistent with the definition for "degradation" proposed herein, it is necessary to show that a loss in property (in this case, tensile properties) occurred and that such loss is a result of a chemical reaction. The term "degradation" has been used throughout this paper without establishing that the loss was due primarily to a chemical change. However, the chemical nature of the processes which result in strength loss in plastics exposed to outdoor environments are well known.

The nonchemical deterioration processes might be similarly subdivided. "Dissolution" (or swelling in water), in which no chemical changes take

place, might be viewed as a deterioration of the plastic in water (or an aqueous solution). "Biodeterioration" can take place when the plastic is attacked by borers (at sea) and rodents: The net result is the breakdown of a larger piece of plastic into small fragments. In "physical deterioration" a plastic loses strength due to purely physical phenomena (for instance due to freeze-thaw cycles).

This proposed scheme allows a facile classification of the related processes and makes a clear distinction between degradation which tends to chemically break down plastics, and nonchemical deterioration processes, which merely reduce the particle size of the plastic. The distinction is of obvious importance from an environmental point of view.

## EXPERIMENTAL

### Materials

The following plastic products, selected on the basis of reported composition of beach debris (CEE 1987), were included in this study:

- Polyethylene film (low density). Representative of the plastic used in six-pack rings, plastic bags, etc.
- Polypropylene strapping tape. Commercially available.
- Trawl netting material (orange and blue-green color).
- Latex rubber balloons. Commercial sample.
- Foamed polystyrene sheet. Commercial sample.
- Rapidly degradable polyethylene. Commercial sample.

Polyethylene bags are a well-known component of marine debris. The threat to marine turtles via ingestion of plastic bags has been reported (Balazs 1985). While strapping bands (usually made of polypropylene or polyester) are not a major component of the debris, they present a particularly severe threat of entanglement to marine mammals (Laist 1987). Trawl webbing is a major component of floating plastic debris in some regions (Pruter 1987). A fraction of the latex rubber balloons released in promotional events may eventually reach the oceans, where their ingestion may present a threat to turtles and other species.

### Weathering and Sampling

Experiments were carried out at the exposure facility at Duke Marine Laboratory in Beaufort, North Carolina. Figure 1 shows the ambient temperature of the seawater during the period of exposure and the air temperatures for the area as recorded by the National Weather Service.

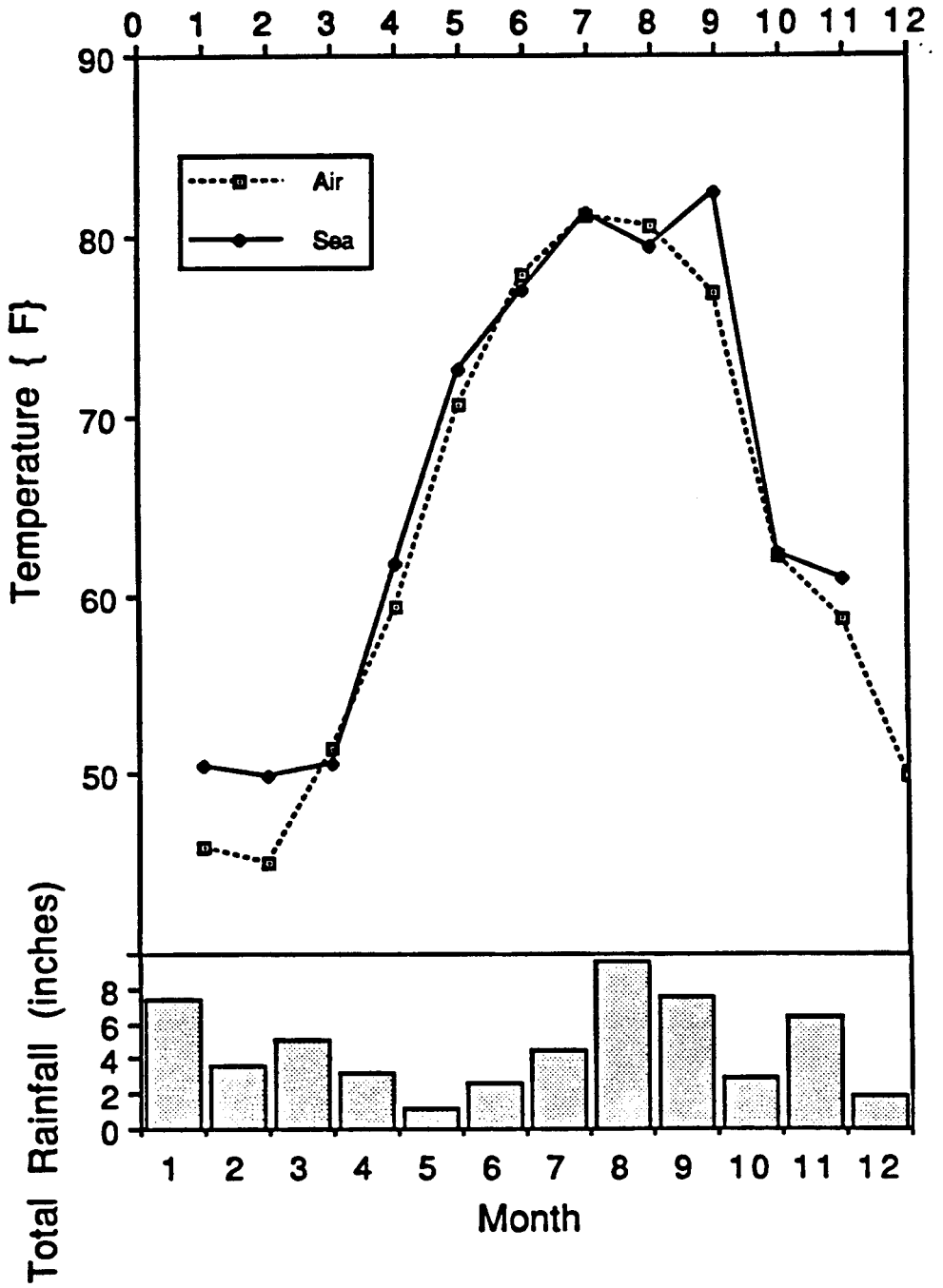



Figure 1.--Average monthly temperatures and rainfall for Morehead City, North Carolina for 1987.

The samples exposed on land were affixed with staples to a wooden platform and exposed horizontally on the flat roof of a laboratory building. These were backed by wood and were about 15.2 cm (6 in) from the roof surface. Another set of samples was exposed floating in a tank of seawater, with fresh seawater continuously flowing through the tank to maintain a depth of about 30.5-45.7 cm (12-18 in) of water at all times. Exposure in the tank as opposed to directly at sea has several associated advantages.

In the preliminary experiments carried out with samples directly floating in an enclosed section of sea, the samples tended to accumulate mud and debris on the surface due to tidal action. Exposure within the tank ensured minimal accumulation of soil and other floating debris on the sample while providing a fresh, clear, biologically active seawater medium. The experiment thus simulates the conditions best suited for rapid photodegradation. The exposure was carried out for a period of 1 year.

Sampling was carried out at the end of every second month for all samples. The exposed samples were placed in a black plastic bag and transported to the Research Triangle Institute for measurement of tensile properties. The samples exposed at sea were dried for about 3 h in an air oven at 50°C and were stored in the dark at ambient temperatures.

### Tensile Testing

Measurement of tensile properties was carried out with an Instron Mechanical Tester, Model 1122 generally in accordance with ASTM D 638 (American Society for Testing and Materials) Tensile Properties of Plastics. No further preconditioning of the samples was done prior to testing. Air-powered grips were used to hold the samples. Smooth grip faces were used with the polyethylene samples; for latex balloons and strapping tape, a serrated face had to be used to avoid slippage. Table 1 gives the test parameters for various types of samples tested. In the case of trawl webbing and strapping tape, where the fibrous nature and surface markings, respectively, made it difficult to determine the true area of cross section, the load to break is reported.

## RESULTS AND DISCUSSION

### Polyethylene Film

Table 2 summarizes the tensile property data for the polyethylene film samples exposed on land and at sea. Both the sea and air samples exhibit an increase in tensile strength after 2 months. This increase may be due in part to relaxation of stresses frozen into the sample during processing, a common occurrence during early exposure of processed thermoplastics.

Figure 2 shows the variation of ultimate extension with exposure time. Clearly, the samples exposed floating on seawater degraded at a much slower rate. The samples exposed at sea showed a 12% loss in ultimate extension after 12 months while the air-exposed samples lost 95% of the ultimate extension after only 6 months. Ultimate extension is considered a more

| Test parameter[a] | A | B | C | D | E |
|---|---|---|---|---|---|
| Beam capacity (kg) | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Full scale load (kg) | 10 | 20,100 | 5 | 200 | 2/5 |
| Crosshead speed (mm/min) | 100 | 100 | 20 | 100 | 50 |
| Gauge length (cm) | 5 | 1.5 | 4 | 4 | 3 |
| Clamp | Pneumatic | Pneumatic | Pneumatic | Pneumatic | Pneumatic |
| Jaw face size (in) | 1 × 1.5 | 1 × 1.5 | 1 × 1.5 | 1 × 1.5 | 1 × 1.5 |

[a]A = Polyethylene film and degradable polyethylene, B = strapping tape, C = Styrofoam sheets, D = trawl netting, E = balloons.

appropriate parameter than tensile strength for measuring physical degradation since it reflects the brittleness and consequent tendency of the plastic to fragment. Statistical tests at the 0.05 level of significance showed no significant difference in mean ultimate extension values of the 2- and 12-month samples exposed at sea but did show a significant difference in mean ultimate extension of the 2- and 6-month samples exposed in air.

### Polypropylene Tape

Table 3 gives the summary data relating to the weathering of polypropylene strapping tape. The formulation contained a filler and the material was highly anisotropic, easily tearing along its length. Material did not "neck" on extension but ruptured gradually. As the surface of the tape was not smooth enough (because of an embossed pattern on the surface) to obtain an accurate value for thickness, the maximum load rather than tensile strength is reported. Figure 3 illustrates the observed changes in ultimate extension. After 12 months, samples exposed on land had lost 90% of the initial ultimate extension, while samples exposed at sea had lost only 26% of the initial value. Thus, while some degradation does occur in samples exposed on seawater, it is much less pronounced than that for samples exposed in air for a comparable duration of exposure. This conclusion is further illustrated by testing for the statistical significance of differences in mean ultimate extensions at the 0.05 level. A significant difference exists in mean ultimate extension for the samples exposed in air for 0 and 12 months and for those exposed at sea for 0 and 12 months. As expected, a statistically significant difference was also found between the mean ultimate extensions of the 12-month samples exposed at sea and in air.

### Trawl Netting

Tensile property data for net samples are given in Table 4. The data are reported as maximum load (kg), which often coincided with the ultimate load of the material, and ultimate extension.

Table 2.--Summary of data relating to weathering of low-density polyethylene film samples.

| Duration (months) | Tensile strength ($kg/cm^2$) | | | Ultimate extension (%) | | | Number of samples |
|---|---|---|---|---|---|---|---|
| | Mean | S.D. | S.E. | Mean | S.D. | S.E. | |
| **Samples exposed in air** | | | | | | | |
| 0 | 124.1 | 19.6 | 6.1 | 548 | 71 | 29 | 6 |
| 2 | 143.1 | 9.9 | 4.4 | 541 | 38 | 17 | 5 |
| 4 | 99.9 | 5.1 | 2.9 | 188 | 166 | 96 | 3 |
| 6 | 115.8 | 6.5 | 3.3 | 27 | 18 | 9 | 4 |
| **Samples exposed in seawater** | | | | | | | |
| 2 | 139.5 | 17.1 | 7.7 | 613 | 133 | 59 | 5 |
| 4 | 131.0 | 12.8 | 5.7 | 547 | 95 | 42 | 5 |
| 6 | 132.3 | 23.6 | 13.7 | 601 | 197 | 114 | 3 |
| 8 | 117.3 | 13.4 | 6.0 | 511 | 147 | 65 | 5 |
| 10 | 117.8 | 7.3 | 2.9 | 550 | 106 | 46 | 6 |
| 12 | 118.7 | 7.6 | 3.4 | 541 | 87 | 39 | 5 |

Table 3.--Summary of data relating to weathering of plastic strapping tape.

| Duration (months) | Maximum load (kg) | | | Ultimate extension (%) | | | Number of samples |
|---|---|---|---|---|---|---|---|
| | Mean | S.D. | S.E. | Mean | S.D. | S.E. | |
| **Samples exposed in air** | | | | | | | |
| 0 | 75.5 | 2.0 | 1.0 | 82 | 2 | 1 | 4 |
| 2 | 68.2 | 1.7 | 0.8 | 70 | 7 | 3 | 4 |
| 4 | 40.2 | 5.2 | 2.6 | 43 | 4 | 2 | 4 |
| 6 | 20.1 | 3.2 | 1.6 | 19 | 5 | 2 | 4 |
| 8 | 14.9 | 3.5 | 1.8 | 12 | 4 | 2 | 4 |
| 10 | 13.2 | 2.7 | 1.4 | 10 | 5 | 1 | 4 |
| 12 | 11.3 | 0.7 | 0.4 | 8 | 1 | 1 | 3 |
| **Samples exposed in seawater** | | | | | | | |
| 0 | 76.5 | 5.4 | 2.7 | 89 | 5 | 2 | 4 |
| 4 | 77.0 | 4.0 | 2.0 | 91 | 3 | 2 | 4 |
| 6 | 74.3 | 2.5 | 1.3 | 82 | 2 | 1 | 4 |
| 8 | 73.2 | 5.6 | 2.8 | 79 | 5 | 3 | 4 |
| 10 | 64.0 | 5.2 | 2.6 | 63 | 8 | 4 | 4 |
| 12 | 67.2 | 3.3 | 1.6 | 61 | 9 | 4 | 4 |

Note: Sample width was half the size of regular width of the tape.

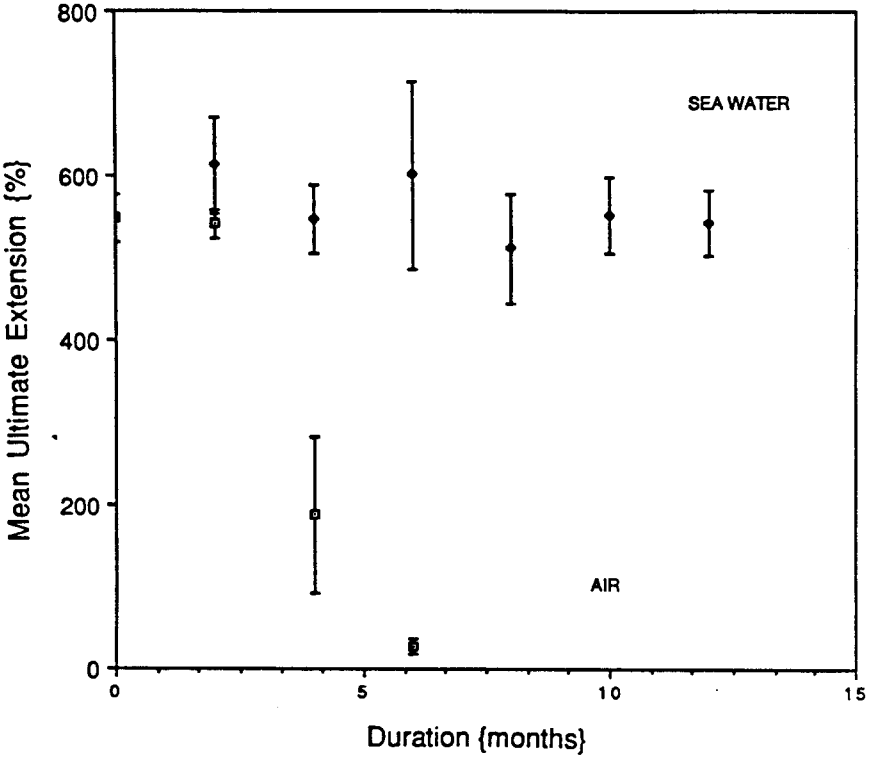



Figure 2.--The variation of the mean ultimate extension of polyethylene films with the duration of exposure.

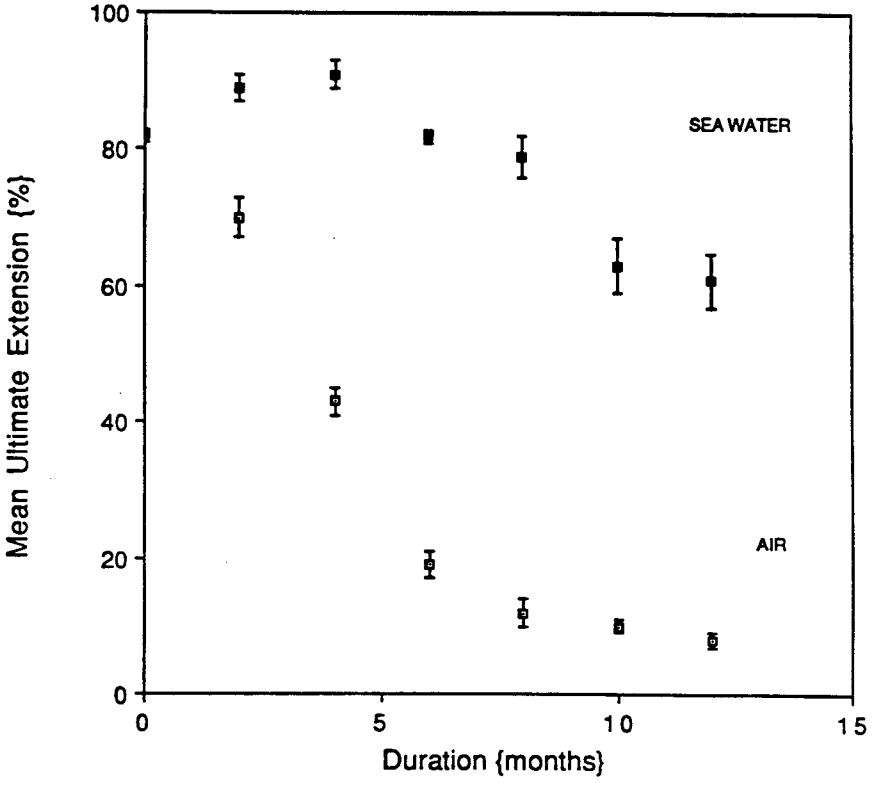



Figure 3.--The variation of the mean ultimate extension of polypropylene tapes with the duration of exposure.

Table 4.--Summary of data relating to weathering of trawl web material.

| Duration (months) | Maximum load (kg) | | | Ultimate extension (%) | | | Number of samples |
|---|---|---|---|---|---|---|---|
| | Mean | S.D. | S.E. | Mean | S.D. | S.E. | |
| **Orange-colored netting** | | | | | | | |
| Samples exposed in air | | | | | | | |
| 0 | 126 | 3.8 | 1.9 | 46.5 | 4.8 | 2.4 | 4 |
| 2 | 121 | 13.8 | 6.9 | 36.9 | 2.7 | 1.4 | 4 |
| 4 | 120 | 10.6 | 7.5 | 41.0 | 5.9 | 4.2 | 3 |
| 6 | 117 | 9.3 | 4.7 | 41.7 | 5.6 | 2.8 | 4 |
| 8 | 125 | 4.0 | 2.0 | 47.4 | 1.7 | 0.9 | 4 |
| 10 | 121 | 7.7 | 3.9 | 47.7 | 6.5 | 3.2 | 4 |
| 12 | 125 | 8.5 | 4.3 | 49.1 | 8.4 | 4.2 | 4 |
| Samples exposed in seawater | | | | | | | |
| 4 | 132 | 9.1 | 4.6 | 62.1 | 3.8 | 1.9 | 4 |
| 6 | 123 | 13.4 | 6.7 | 49.1 | 4.1 | 2.1 | 4 |
| 8 | 129 | 6.7 | 3.3 | 53.5 | 2.9 | 1.4 | 4 |
| 10 | 128 | 10.7 | 5.4 | 53.5 | 2.9 | 1.4 | 4 |
| 12 | 127 | 11.6 | 5.8 | 49.1 | 3.9 | 2.0 | 4 |
| **Blue-colored netting** | | | | | | | |
| Samples exposed in air | | | | | | | |
| 0 | 115 | 10.5 | 5.2 | 63.0 | 7.1 | 3.5 | 4 |
| 2 | 88 | 11.4 | 5.7 | 41.4 | 2.9 | 1.5 | 4 |
| 4 | 104 | 7.9 | 4.0 | 46.6 | 8.2 | 4.1 | 4 |
| 6 | 96 | 11.3 | 5.7 | 49.1 | 8.6 | 4.3 | 4 |
| 8 | 70 | 12.1 | 6.1 | 32.3 | 10.9 | 5.5 | 4 |
| 10 | 93 | 7.3 | 3.7 | 44.5 | 3.5 | 1.7 | 4 |
| 12 | 94 | 3.8 | 1.9 | 49.5 | 5.0 | 2.5 | 4 |
| Samples exposed in seawater | | | | | | | |
| 2 | 100 | 12.0 | 6.0 | 65.7 | 9.9 | 5.0 | 4 |
| 4 | 96 | 9.2 | 4.6 | 53.4 | 9.8 | 4.9 | 4 |
| 6 | 99 | 7.3 | 3.6 | 60.2 | 2.5 | 1.3 | 4 |
| 8 | 101 | 7.5 | 3.8 | 61.6 | 5.8 | 2.9 | 4 |
| 10 | 113 | 2.8 | 1.4 | 61.8 | 5.3 | 2.7 | 4 |
| 12 | 104 | 3.2 | 1.6 | 60.4 | 1.4 | 0.7 | 4 |

The changes in tensile properties obtained with trawl web samples on exposure in air and in seawater are less dramatic and are not shown in a figure. Netting intended for commercial fishing is compounded specifically for exceptional durability usually using hindered-amine and other light stabilizers. The data, however, did show that the blue netting is relatively more prone to outdoor degradation than is orange netting when exposed in air. While the difference is small, it is significant. On exposure in seawater, neither material underwent any significant change in maximum load up to 12 months of exposure (at which time the experiment was discontinued). The only conclusion that might be drawn from these samples is that they would persist longer in the environment, relative to the packaging materials and balloons tested.

## Rubber Balloons

The strength and extensibility of the rubber balloons determine to a great extent the likelihood of the ingested material obstructing the air or gut passages of turtles. Retention of elasticity is of particular concern, as elastic materials are likely to be difficult to dislodge from the air passages or alimentary canals. Table 5 summarizes the tensile property data on balloons exposed under present experimental conditions. Figure 4 shows the variation of ultimate extension with duration of exposure. In air, the rubber lost 59% of its ultimate extension after only 2 months. For the same time at sea, the rubber lost only 11% of its ultimate extension. The balloons continued to retain their elasticity during exposure in seawater, with only a 48% loss after 12 months. In air, however, the balloons lost 94% of their ultimate extension after 6 months, beyond which time the samples were too weak and brittle to be tested. As with the plastic samples, the rate of degradation in seawater was much slower than that in air. The degree of hazard associated with a partially deteriorated balloon depends on the particle size which might be safely ingested by the target species. Such information on turtles and other relevant species is not available at the present time. However, the above results indicate that if the balloons do pose a hazard to marine life, they would, under present experimental conditions, be a threat for a relatively longer period of time at sea than on land.

## Polystyrene Foam

In view of the abundance of polystyrene foam pieces in marine debris, the weathering behavior of polystyrene was particularly interesting. On exposure in air the foam underwent rapid yellowing, which apparently was a surface reaction. The sample exposed on seawater also underwent yellowing, although the algal fouling of the surfaces made it difficult to measure the extent of yellowing.

The yellowness index increased up to about the sixth month of exposure and decreased thereafter. However, the development of yellowness was also accompanied by embrittlement of the exposed surface. Over the exposure period of 1 year, a surface layer of up to half the original thickness became brittle enough to crumble on handling (and could be easily scraped out). Wind and rain are likely to remove at least some of the yellowed material during exposure. This may explain the reduction in the extent of yellowing at the longer exposure times.

Table 5.--Summary of data relating to weathering of latex rubber balloons.

| Duration (months) | Tensile strength ($kg/cm^2$) Mean | S.D. | S.E. | Ultimate extension (%) Mean | S.D. | S.E. | Number of samples |
|---|---|---|---|---|---|---|---|
| Samples exposed in air | | | | | | | |
| 0 | 96.7 | 7.2 | 3.6 | 986 | 100 | 50 | 5 |
| 2 | 3.6 | 1.9 | 0.9 | 405 | 184 | 92 | 4 |
| 4 | 1.9 | -- | -- | 140 | -- | -- | 2 |
| 6 | 1.4 | -- | -- | 63 | -- | -- | 2 |
| [a]8 | -- | -- | -- | -- | -- | -- | -- |
| [a]10 | -- | -- | -- | -- | -- | -- | -- |
| Samples exposed in seawater | | | | | | | |
| 2 | 22.7 | 3.4 | 1.5 | 874 | 107 | 48 | 5 |
| 4 | 21.5 | 5.4 | 2.4 | 727 | 75 | 34 | 5 |
| 6 | 16.0 | 3.1 | 1.5 | 611 | 69 | 34 | 4 |
| 8 | 14.0 | 3.6 | 1.8 | 600 | 87 | 44 | 4 |
| 10 | 18.3 | 3.5 | 1.7 | 719 | 74 | 37 | 4 |
| 12 | 9.1 | 1.0 | 0.6 | 513 | 26 | 15 | 3 |

[a]Too brittle or weak to be tested.

The yellowness index of the degraded polystyrene foam correlates well ($r = 0.90$) with the tensile strength of the degraded material up to 6 months of exposure in air. Lack of such a correlation at longer exposure times is also possibly due to loss of embrittled yellow surface material (from rain, wind).

In fact, the thickness of the degraded (removable) yellow surface layer increased with duration of exposure for both sets of samples. The reduced thickness of the samples after the embrittled layer was scraped off is given below.

| Duration Months) | Thickness of lower layer (cm) Air | Seawater |
|---|---|---|
| 0 | 0.418 | 0.418 |
| 2 | 0.349 | 0.221 |
| 4 | 0.308 | 0.164 |
| 6 | 0.234 | 0.168 |
| 8 | 0.217 | 0.229 |
| 10 | 0.214 | 0.155 |

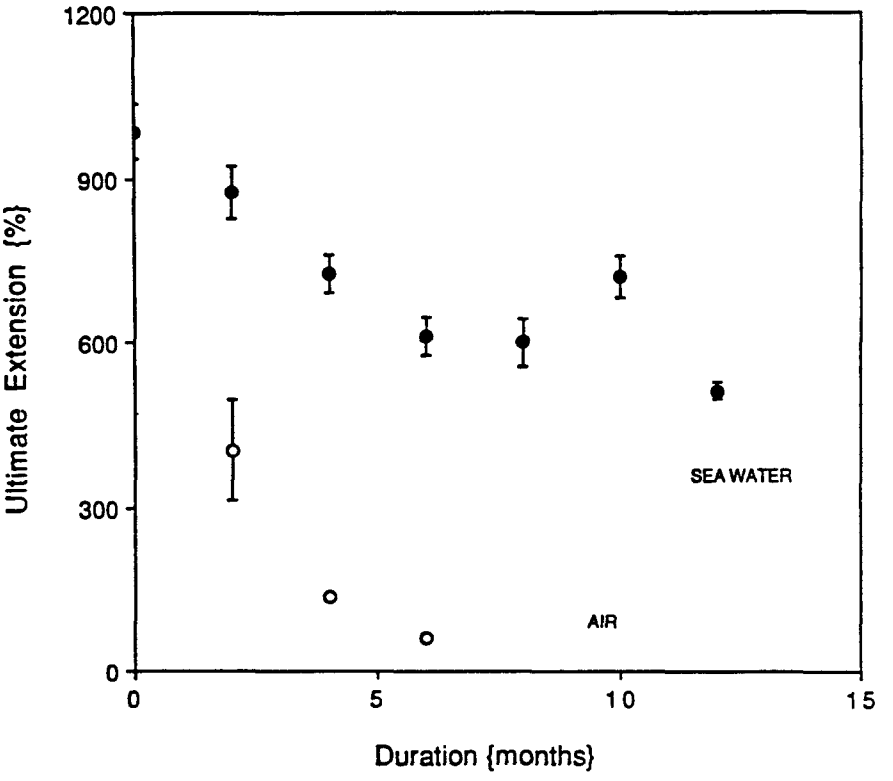



Figure 4.--The variation of mean ultimate extension of latex rubber balloons with the duration of exposure.

The tensile strength can thus be calculated in two ways: based on original thickness, and based on the thickness of the unembrittled layer. Table 6 summarizes the tensile property data. If the oxidative degradation process was restricted to the yellowed brittle surface layer, the tensile strength of the underlying polystyrene would yield about the same tensile strength regardless of the duration of exposure. However, as seen in the table and in Figure 5, the tensile strength based on reduced thickness of the material also decreases with the duration of exposure. The lower unembrittled region is apparently accessible to the free radicals generated during the photo reaction.

Expanded polystyrene was the only type of plastic material tested where the rate of deterioration (of tensile properties) was faster at sea than on land. In air, the material requires an exposure of at least a year to decrease its tensile strength by 40%. Exposure in seawater reduces the tensile strength by over 60% in 4 months!

Under the present exposure conditions, the polystyrene foam material deteriorates relatively rapidly when exposed outdoors on seawater. This would lead to the breaking up of the material into smaller pieces fairly easily. Unlike most other plastic debris items, pieces of foamed polystyrene are not capable of entanglement. They might, however, be ingested by a variety of species, especially when covered with foulants. Effects of ingestion of weathered polystyrene foam material are not known.

Table 6.--Summary of data relating to weathering of expanded-extruded polystyrene.

| Duration (months) | Tensile strength[a] ($kg/cm^2$) | | | Tensile strength[b] ($kg/cm^2$) | | | Ultimate extension (%) | | | Number of samples |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | S.E. | Mean | S.D. | S.E. | Mean | S.D. | S.E. | |
| Samples exposed in air | | | | | | | | | | |
| 0 | 3.89 | 0.50 | 0.21 | 3.89 | 0.50 | 0.20 | 3.9 | 1.70 | 0.07 | 6 |
| 2 | 4.31 | 0.34 | 0.17 | 5.16 | 0.40 | 0.20 | 3.5 | 0.29 | 0.14 | 4 |
| 4 | 3.46 | 0.59 | 0.29 | 4.70 | 0.80 | 0.40 | 3.9 | 0.32 | 0.16 | 4 |
| 6 | 2.45 | 0.27 | 0.19 | 4.37 | 0.48 | 0.24 | 2.9 | 0.13 | 0.06 | 4 |
| 8 | 2.39 | 0.27 | 0.19 | 4.60 | 0.52 | 0.26 | 3.2 | 0.24 | 0.12 | 4 |
| 10 | 2.61 | 0.14 | 0.07 | 5.09 | 0.27 | 0.14 | 3.2 | 0.24 | 0.12 | 4 |
| 12 | 2.37 | 0.27 | 0.19 | 4.53 | 0.51 | 0.25 | 3.3 | 0.32 | 0.16 | 4 |
| Samples exposed in seawater | | | | | | | | | | |
| 2 | 2.88 | 0.21 | 0.09 | 5.45 | 0.40 | 0.18 | 4.6 | 0.80 | 0.36 | 5 |
| 4 | 1.13 | 0.71 | 0.36 | 5.50 | 1.82 | 0.91 | 4.1 | 1.60 | 0.80 | 4 |
| 6 | 1.09 | 0.17 | 0.09 | 3.20 | 0.44 | 0.22 | 2.2 | 0.88 | 0.44 | 4 |
| 8 | 1.22 | 0.29 | 0.13 | 2.22 | 0.54 | 0.25 | 1.9 | 0.29 | 0.13 | 5 |
| 10 | 0.69 | 0.09 | 0.04 | 2.13 | 0.22 | 0.11 | 1.6 | 0.24 | 0.12 | 4 |

[a]Tensile strength calculated using the initial area of cross section.
[b]Tensile strength calculated using the area of cross section based on residual unembrittled layer.

## Enhanced Photodegradable Polyethylene (Ethylene Carbon Monoxide Copolymer)

The weathering behavior of the enhanced degradable polyethylene was quite different from that of the polyethylene homopolymer sample (Table 7). As might be expected, the samples exposed in air rapidly degraded, losing nearly 99% of the initial value of mean ultimate extension within 6 weeks of exposure (Fig. 6). The tensile strength decreased slowly reaching to about 50% of the initial value in the same period of exposure. At this stage samples were embrittled and too weak to be tested.

The samples exposed in seawater also degraded rapidly on exposure losing nearly 95% of the initial value of mean ultimate elongation in about 6 weeks. However, the material did not reach the same stage of final embrittlement obtained with samples in air until after 14 weeks of exposure. The mechanism leading to a plateau in the mean extension values from about the sixth to fourteenth week of exposure is not understood. But it is of little practical consequence. It is clear that under the experimental conditions of the study, the enhanced photodegradable polyethylene performs

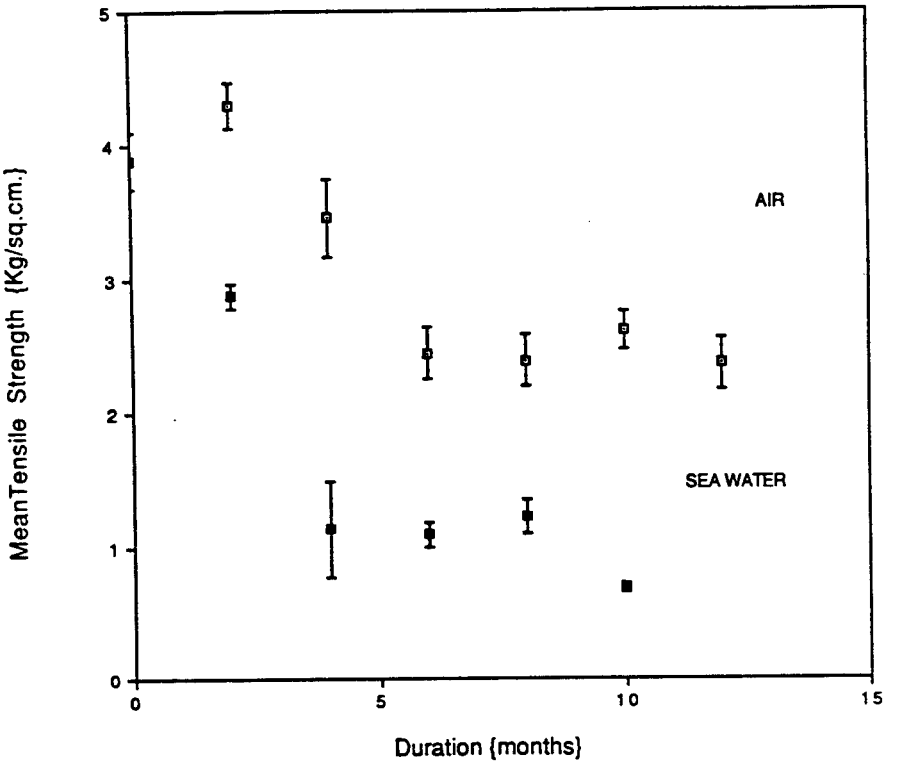



Figure 5.--The variation of mean tensile strength of expanded extruded polystyrene with the duration of exposure.

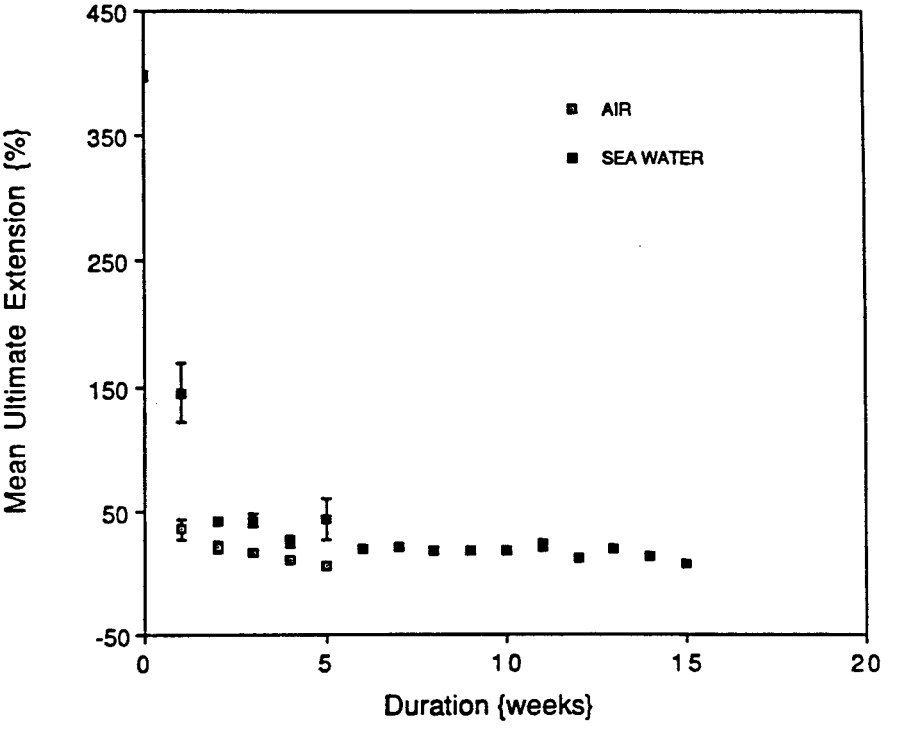



Figure 6.--The variation of mean ultimate extension of enhanced degradable polyethylene sheets with the duration of exposure.

Table 7.--Summary of data on outdoor weathering of enhanced photodegradable six-pack ring material (LDPE).

| Duration (weeks) | Tensile strength ($kg/cm^2$) | | Ultimate extension (%) | |
|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. |
| **Exposure in air** | | | | |
| 0 | 160.4 | 1.0 | 398 | 3.4 |
| 1 | 122.4 | 2.1 | 35.6 | 8.3 |
| 2 | 128.0 | 2.4 | 21.0 | 4.4 |
| 3 | 134.1 | 2.4 | 16.8 | 1.4 |
| 4 | 104.7 | 8.0 | 10.7 | 2.6 |
| 5 | 86.3 | 6.9 | 5.7 | 0.8 |
| **Exposure in seawater** | | | | |
| 0 | 160.4 | 1.0 | 398 | 3.4 |
| 1 | 112.0 | 3.7 | 145.6 | 23.3 |
| 2 | 112.3 | 1.0 | 42.4 | 3.3 |
| 3 | 115.1 | 0.8 | 42.3 | 5.4 |
| 4 | 120.4 | 0.9 | 25.8 | 4.1 |
| 5 | 116.5 | 2.6 | 44.1 | 16.7 |
| 6 | 120.2 | 12.6 | 19.1 | 1.0 |
| 7 | 122.9 | 0.8 | 21.0 | 3.1 |
| 8 | 121.1 | 0.4 | 17.71 | 0.5 |
| 9 | 119.7 | 2.8 | 18.4 | 1.4 |
| 10 | 122.6 | 0.5 | 18.1 | 0.6 |
| 11 | 122.8 | 0.5 | 22.6 | 5.1 |
| 12 | 116.3 | 5.7 | 11.3 | 1.3 |
| 13 | 119.1 | 14.0 | 19.4 | 0.8 |
| 14 | 73.77 | 21.8 | 13.9 | 2.2 |
| 15 | 58.9 | 6.6 | 6.9 | 1.7 |

satisfactorily at sea for all practical purposes. The initial rates of decrease in the mean tensile properties obtained with exposure in seawater, are somewhat slower than those obtained with exposure on land.

## SUMMARY FINDINGS

Table 8 illustrates the general findings of the exposure study by a comparison of tensile properties before and after exposure in air and in seawater for the different samples. Data relating to a single duration of exposure are shown to illustrate the general trend observed. Except for the netting, rates of degradation for the samples in seawater were much

Table 8.--Comparison of weathering data for exposure on land and at sea.

| Sample | Duration of exposure (months) | Percent decrease in the mean value of tensile property | | | |
|---|---|---|---|---|---|
| | | Air | | Seawater | |
| | | Strength[a] | Extension | Strength[a] | Extension |
| Polyethylene film | 6 | 6.6 | 95.1 | No change | No change |
| Polypropylene tape | 12 | 85.0 | 90.2 | 11.0 | 31.5 |
| Latex balloons | 6 | 98.6 | 93.6 | 83.5 | 38.0 |
| Expanded polystyrene | 10 | 32.9 | 18.0 | 82.3 | 65.2 |
| Netting | 12 | No change | No change | No change | No change |
| Rapidly degradable polyethylene | 1.25 | 46.2 | 98.6 | 27.1 | 88.9 |

[a]The percentages reported as based on the maximum load in the case of netting and polypropylene type materials.

slower than the degradation rates on land. Netting material did not show any significant variation in tensile properties due to the type or duration of exposure. Enhanced degradable polyethylene six-pack ring material degraded in about the same time scale under both air and seawater exposure.

The marked retardation of the weathering process observed in some types of plastic materials floating in seawater might be attributed to: (a) differences in heat buildup and (b) fouling of samples in seawater.

A significant fraction of the sunlight impinging on a plastic surface is absorbed by the material as heat. Depending on the nature of the plastic, the velocity of the air around it, and the temperature difference between the plastic and the surroundings, this absorbed energy maintains the plastic at a temperature higher than that of the surrounding air (Summers et al. 1983). Plastics exposed in air undergo heat buildup easily. The effect is even more pronounced in the present samples, which were exposed on a thermally insulating wood surface. Under such conditions, the heat buildup is likely to be higher than for the case of exposure on soil, thus simulating weathering under "worst case" conditions and accelerating the degradation process in the samples exposed in air. Samples exposed in seawater, however, are held at near ambient temperature leading to slower rates of degradation.

Samples floating on seawater underwent extensive fouling during the exposure. Foulants were mostly algae except for several *Balanus* sp. found on samples exposed for over 8 months. The experimental method used in the present study (containment of samples in a shallow tank) is likely to have reduced the extent of fouling and prevented the settlement of debris (or

"silting") on the sample surface. Fouling retards the photodegradation by restricting the light available to the plastic.

## CONCLUSIONS

Under present experimental conditions, low density polyethylene film, polypropylene tape, and latex rubber balloon samples were found to significantly degrade when exposed in air outdoors. Marked decreases in ultimate extension were obtained in 1 year of exposure. Similar samples exposed at the same site, but floating on seawater, degraded at a significantly slower rate during the same period of time.

The lower rates of degradation might primarily be attributed to lack of heat buildup in samples exposed on seawater. Biofouling of sample surface leading to reduced light availability may also have decreased the rate of weathering.

Foamed polystyrene degraded at a faster rate in seawater than in air when exposed outdoors.

Enhanced degradable six-pack ring polyethylene degraded at nearly the same rate when exposed in air and in seawater.

## ACKNOWLEDGMENTS

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# RECYCLING OF MARINE PLASTICS DEBRIS THROUGH MELT REPROCESSING: A CASE FOR LOST OR ABANDONED FISHING GEAR

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## ABSTRACT

In attempts to offer a technological solution to the marine plastic debris problem, the Polymer Processing Institute in collaboration with the New Jersey Marine Sciences Consortium began in January 1989 a 2-year research program that focuses on the collection, characterization, and subsequent recycling of unusable plastic fishing gear. The present paper contains initial data developed during the first quarter of 1989 (Phase I) on netting containing nylon-6, nylon-6,6, and polypropylene plastics. Molecular weight determination and thermal analysis suggest that none of the nylons are badly degraded; thus, the nets could be reprocessed without difficulties in the recycling extruder. However, the presence of fiber coatings (e.g., "green enamel," "tar") was found to complicate the polymer characterization and to interfere with the recycling process. The fact that these coatings cannot be easily removed suggests that further work is required to determine their possible adverse effects on the processing and product characteristics. The present paper also provides a complete description of the work planned for the two successive phases of the project.

## INTRODUCTION

Among the various marine plastic debris items, abandoned or lost fishing gear is a major pollutant adversely affecting marine life and disturbing the ecological equilibrium. Recent estimates of the National Academy of Sciences bring the amount of fishing gear lost in the sea to about 135,000 metric tons/annum (Lautenberg 1987). Many marine species die from entanglement in such plastic debris. It is believed that 30,000

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northern fur seals, *Callorhinus ursinus*, and at least 250,000 birds die each year in nets laid by salmon fishermen, as well as in other debris. The problem appears to become increasingly important as a result of the recent deployment in the North Pacific of huge drifting nets stretching up to 30-50 km (Shabecoff 1989). If these lightweight monofilament nets are discarded or lost, they do not degrade but continue to drift unless retrieved.

The Polymer Processing Institute, in a joint effort with the New Jersey Marine Sciences Consortium (NJMSC), began in January 1989 a 2-year program having as an ultimate goal the development of cost-effective methods for complying with the prohibition of marine pollution. The project is funded by the Saltonstall-Kennedy Act and will attempt to offer a technological solution to the marine plastic debris problem. Its specific objective is to establish incentives for recycling lost or abandoned fishing gear such as nets, lines, and ropes by demonstrating that these materials can be converted into useful products when melt reprocessed.

## DESCRIPTION OF THE RESEARCH PROJECT

This project consists of two phases: Phase I, completed in January 1990, concentrates on the collection, on a national level, of discarded fibrous fishing gear, followed by separation, identification, and subsequent chemical and physical characterization of the plastics involved. Preliminary data indicate that the major types of plastics to be recovered are nylon-6, nylon-6,6, and polypropylene (PP), all possibly contaminated or degraded as a result of prolonged exposure in the marine environment. The extent of environmental degradation and its effect on rheological and mechanical properties will dictate the design of the melt reprocessing experiments of the next phase.

In Phase II of the project (to be completed in its second year), various processing methods will be evaluated with the final objective of producing molding materials with properties equivalent or superior to those of virgin resins. Reprocessing will be conducted in a twin-screw extruder and will involve blending of the recovered netting with virgin resin, blending with other recycled resins of different chemical structure, or chemical modification. It is expected that these methods will upgrade the properties of the recovered plastics and produce value-added compounds. At this stage of the project, potential markets for the recycled product will be identified as well as companies interested in establishing facilities for recycling and reprocessing. Based on the analysis of the collection and separation data, the possible financial incentives that will encourage recycling will be estimated.

## EXPERIMENTAL RESULTS

### Characteristics of Collected Fishing Gear

Samples of used and new fishing nets were supplied by NJMSC. The used samples that were collected during the first quarter of Phase I varied

widely in characteristics such as net mesh size, filament diameter, type of coating, degree of exposure, polymer type, and site of collection. All samples were classified and characterized as shown in Table 1. The majority of the collected nets were relatively clean, with minimum visible gross contamination from either organic or inorganic matter.

## Identification of Plastics and Contaminants

The identification of plastics and their contaminants was undertaken in order to establish the proper reprocessing conditions and to minimize any possible adverse effects of the contaminants on processing and long-term polymer stability.

Identification methods used for plastics were infrared (IR) spectroscopy, melting temperature determination, and solubility measurements (the latter only for nylons). The preferred analytical method was IR spectroscopy, since the presence of coatings (e.g., "green dip," "tar") often interfered with the melting temperature and solubility determinations. The IR spectra were obtained on films cast on a AgCl plate from solutions of 90% formic acid (nylons) or hot xylene (polypropylene). Table 2 summarizes the identification results for all plastics. It is shown that nylon-6 and nylon-6,6 are the materials of choice for nets, whereas polypropylene is used for ropes and lines. It is interesting to note that the green-dipped twine in 88-2 contained both nylon-6 and nylon-6,6 fibers; by contrast, the attached repair portion was only nondipped nylon-6,6 fibers.

A thorough analysis and identification of contaminants was not completed at this stage of the project. Some surface elements that were identified by combined scanning electron microscopy and energy dispersive x-ray analysis included silicon and iron on the 88-2 fibers. These could correspond to sand and rust, respectively. Also, the "green dip" on 88-2 and 89-2 and the tar coating of 89-1 contain infusible cross-linked organic materials that turn black (degrade?) when heated near the melting temperature of nylons. The coatings level was not precisely determined. Preliminary thermogravimetric data suggest that the green dip content is at least 3-5%, whereas the tar content is at least 1% of the weight of the fiber.

## Separation of Individual Plastics and Removal of Contaminants

Separation of the individual identified plastics present in the nets or the net and line combinations was not considered necessary at this stage of the project, since the proximity in chemical structures and melting points could allow these polymers to be eventually processed as blends (e.g., nylon-6 with nylon-6,6 in sample 88-2, nylon-6 with PP in sample 88-3). Floats, buoys, and lead-containing lines were the only articles that were removed. With respect to contaminant removal, the insolubility of the "green dip" and "tar" coatings in either water or organic solvents appears to preclude their economical separation from the fibers. Also, any water treatment of the fibers by slurrying under agitation does not seem to be beneficial in improving their thermooxidative stability, as certain

Table 1.--Classification and description of used and new fishing gear received in 1988 and first quarter 1989.

| Designation | Type or description | Color | Mesh (cm)/ diameter (mm) | Other information |
|---|---|---|---|---|
| Used | | | | |
| 88-1 | Fyke(?) net with braided line attached; ca. 14 kg | Dark brown | Net: 7.5/1.2<br>Line: --/6.3 | Brittle, dusty, badly degraded. |
| 88-2 | Trawl net, apparently dipped in green "enamel" and repaired with non-dipped net; ca. 50 kg | Dipped part: green or faded green<br>Repaired part: off-white | 8.3-10.5/3 | Collected in New Jersey; variable in color, mesh and diameter; tar patches. |
| 88-3 | Monofilament gillnet with braided line attached; ca. 10 kg | Net: natural<br>Line: green | Net: 8.3/0.37<br>Line: --/6.3 | Collected in New Jersey. |
| 89-1 | Trawl net [30-ft flat otter] dipped in tar; ca. 25 kg | Black | 4.5/1.2 | Bought in Connecticut; used once per month for 1 year, stored in shed, repaired. |
| 89-2 | Trawl net [30-ft flat otter] dipped in green enamel; ca. 25 kg | Light green | 3.8/1.2 | Bought in Mississippi; used twice per month for 1 year, stored in shed. |
| New | | | | |
| 89-3-V | Twine net sample | Off-white | 3.8/1.6 | None. |
| 89-4-V | Multifilament net sample | Light green | 12.7/0.8 | None. |
| 89-5-V | Braided net sample | Light green | 20/2.5 | None. |
| 89-6-V | Twine net sample | Blue | 3.4/1.6 | None. |

Table 2.--Identification of polymers (by infrared spectroscopy, and solubility and melting temperature measurements) in used and new fishing gear.

| Gear designation | Type of polymers |
|---|---|
| **Used** | |
| 88-1 | |
| Net | Not identified |
| Line | Not identified |
| 88-2 | |
| Green net | Nylon-6 and nylon-6,6 |
| Faded green net | Nylon-6 and nylon-6,6 |
| Repair net | Nylon-6,6 |
| 88-3 | |
| Net | Nylon-6 |
| Line | Polypropylene |
| 89-1 | |
| Net | Nylon-6 |
| 89-2 | |
| Net | Nylon-6 |
| **New** | |
| 89-3-V | Nylon-6,6 |
| 89-4-V | Nylon-6 |
| 89-5-V | Polypropylene |
| 89-6-V | Polypropylene |

experiments showed. Thus, the only treatment prior to characterization was the removal of loose surface debris by air jetting.

### Characterization of the Recovered Nylon Plastics

The characterization of the recovered plastics could provide valuable information on the extent of their degradation and their thermooxidative stability during reprocessing.

Table 3 summarizes the intrinsic viscosity and molecular weight data of all nylon polymers including three virgin materials in pellet form. Since the exact molecular weight of a fiber prior to exposure is not known, the extent of degradation can be only approximated. Thus, by comparing the intrinsic viscosities of the recovered polymers with those in the new nets and certain virgin pellets, one can conclude that with the possible exception of the "88-2 faded green" none of the other used nets showed extensive degradation of molecular weight. Thermal analysis (Table 4) by differential scanning calorimetry (DSC) and thermal stability investigations (Table 5) by thermogravimetry (TGA) tend to support the above conclusion. Differences in fusion and crystallization behavior between the fibers in the used or new net and the commercial pellets reflect largely the presence of

Table 3.--Intrinsic viscosity and molecular weight of nylon polymers: comparison of used and new fishing nets with commercial polymer pellets.

| Sample designation | Intrinsic viscosity $\eta^a$(dl/g) | Molecular weight ($M_v$) | |
|---|---|---|---|
| | | Nylon-6 | Nylon-6,6 |
| **Used nets** | | | |
| 88-2 | | | |
| Green | 1.45 | [b]43,840 | or 21,480 |
| Faded green | 1.07 | [b]30,380 | or 14,140 |
| Repair | 1.31 | | 18,710 |
| 88-3 | 1.52 | 46,520 | |
| 89-1 | 1.42 | 42,660 | |
| 89-2 | 1.31 | 38,840 | |
| **New nets** | | | |
| 89-3-V | 1.44 | | 21,460 |
| 89-4-V | 1.61 | 50,090 | |
| **Pellets** | | | |
| Zytel 101-F | 1.16 | | 15,760 |
| Capron 8207-F | 1.47 | 44,730 | |
| Capron BHS-D | 1.70 | 53,440 | |

[a]$\eta$ = Measured in 90% formic acid solution at 25°C.
[b]Figures given refer to the individual polymers since both nylons are present in these nets in unknown ratios.

Table 4.--Thermal analysis (differential scanning calorimetry (DSC)) of nylon polymers: comparison of used and new fishing nets with commercial polymer pellets. Note: Heating, cooling, and reheating at 20°C/min; fusion data on second heating.

| Polymer | Fusion temperature onset/maximum (°C) | Heat of fusion (cal/g) | Crystallization temperature onset/maximum (°C) | Heat of crystallization (cal/g) |
|---|---|---|---|---|
| | | **Nylon-6** | | |
| Used nets | | | | |
| 88-2 | | | | |
| Green | 211/222 | 10.7 | 187/181 | -12.1 |
| Faded green | 212/223 | 10.9 | 187/182 | -12.4 |
| 88-3 | 202/215 | 10.4 | 173/164 | -11.4 |
| 89-1 | 208/221 | 8.3 | 181/174 | -10.4 |
| 89-2 | 195/200 | 10.2 | 184/176 | -12.0 |
| New nets | | | | |
| 89-4-V | 205/220 | 9.9 | 186/171 | -12.1 |
| Pellets | | | | |
| Capron 8207-F | 209/222 | 12.8 | 180/168 | -13.4 |
| Capron BHS-D | 212/226 | 11.4 | 172/163 | -10.7 |
| | | **Nylon-6,6** | | |
| Used nets | | | | |
| 88-2 | | | | |
| Repair | 253/263 | 16.2 | 231/227 | -12.7 |
| New nets | | | | |
| 89-3-V | 250/259 | 11.8 | 229/222 | -12.9 |
| Pellets | | | | |
| Zytel 101-F | 256/265 | 11.3 | 226/214 | -14.0 |

coatings, rather than extensive polymer degradation. For example, coatings and contaminants or their residues appear to act as nucleating agents, as evidenced by the higher crystallization temperatures of the polymers in all the coated used and new nets. Also, extensive weight losses in TGA are probably associated with the early decomposition of the coatings and contaminants and not with that of the degraded polymer itself (with the possible exception of the "88-2 faded green" sample). Table 5 also shows that the thermal stability of the samples is practically independent of the type of test atmosphere (nitrogen versus oxygen).

Table 5.--Thermal stability (thermogravimetry (TGA)) of nylon polymers: comparison of used and new fishing nets with commercial polymer pellets.

| Polymer | Standard TGA[a] | | | | Isothermal TGA[a] | | |
|---|---|---|---|---|---|---|---|
| | Onset decomposition temperature (°C) | | Temperature at 10% weight retention (°C) | | Isothermal temperature (°C) | Weight % decrease after 15 min | |
| | Nitrogen | Oxygen[b] | Nitrogen | Oxygen[b] | | Nitrogen | Oxygen |
| **Nylon-6** | | | | | | | |
| Used nets | | | | | | | |
| 88-2 | | | | | | | |
| Green | 429 | NM | 560 | NM | 225 | 4.03 | 4.84 |
| Faded green | 396 | NM | 673 | NM | 230 | 1.35 | 1.48 |
| 88-3 | 445 | NM | 513 | NM | 225 | 0.33 | 0.42 |
| 89-1 | 459 | NM | 519 | NM | 230 | 0.91 | 1.06 |
| 89-2 | 426 | NM | 525 | NM | 230 | 2.71 | 3.49 |
| New nets | | | | | | | |
| 89-4-V | 459 | NM | 513 | NM | 230 | 0.26 | 0.38 |
| Pellets | | | | | | | |
| Capron 8207-F | 466 | 453 | 513 | 497 | 225 | 0.25 | 0.25 |
| Capron BHS-D | 471 | NM | 506 | NM | 230 | 0.62 | 0.67 |
| **Nylon-6,6** | | | | | | | |
| Used nets | | | | | | | |
| 88-2 | | | | | | | |
| Repair | 449 | NM | 530 | NM | 270 | 1.18 | 4.31 |
| New nets | | | | | | | |
| 89-3-V | 451 | NM | 514 | NM | 270 | 1.23 | 1.75 |
| Pellets | | | | | | | |
| Zytel 101-F | 439 | 436 | 503 | 512 | 270 | 0.33 | 0.58 |

[a]Standard TGA at 40°C/min; in isothermal TGA temperature reached withn 2 min.

[b]NM indicates not measured.

### Experiments on Net Size Reduction and Extrusion Reprocessing

Attempts to chop net 88-2 into smaller pieces in a laboratory granulator were not successful even in the presence of dry ice. However, it was possible to feed continuously the same net into the hopper of a single-screw extruder and produce an extrudate that could be pelletized. The extrudate was black in color, presumably as a result of the decomposition of the fiber coating. Further experiments are under way in order to produce solid particles with dimensions suitable for feeding in polymer processing machinery such as extruders or injection molding machines.

## CONCLUSIONS

The identification results on samples of unusable fishing gear collected during the first quarter of 1989 indicate that the major plastic involved are nylon-6, nylon-6,6, and to a lesser extent polypropylene. Th initial characterization results of the exposed nylons are encouraging: it appears that none of the nylons are badly degraded in terms of reduced molecular weight or loss of thermooxidative stability. This could mean satisfactory processing characteristics during remelting of the net in the recycling extruder. The presence of fiber coatings that cannot be easily removed tends to complicate not only identification and characterization, but also the reprocessing behavior of the nylon nets. Our future efforts will include the complete analysis and characterization of typical commercial fiber coatings for a better understanding of their effects on processing. Other research areas addressed during this phase of the project include the full characterization of the collected exposed polypropylene gear and the investigation of net size reduction methods.

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# CONTROL OF PLASTIC WASTES ABOARD NAVAL SHIPS AT SEA

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## ABSTRACT

The U.S. Navy is taking a proactive approach to comply with the prohibition on the at-sea discharge of plastics mandated by the Marine Plastic Pollution Research and Control Act of 1987. For U.S. naval ships, space and weight constraints, high crew densities, and mission requirements create unique solid waste management problems.

In pursuit of a zero discharge goal without significant adverse impact, processes, activities, operations, and systems to reduce plastics discharges are being identified, evaluated, and documented. Operational, supply, and technology-oriented solutions are now being demonstrated. Seven ships have been nominated by Commander in Chief U.S. Atlantic and Commander in Chief U.S. Pacific Fleets to participate in a plastics waste reduction demonstration project. Each ship was asked to develop its own instructions and procedures to eliminate the discharge of plastic wastes and to implement those instructions in a manner consistent with the operational requirements and mission of the ship.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Thus far, a submarine tender, a frigate, a destroyer, and two submarines have participated. Scientists and engineers from the David Taylor Research Center have collected waste generation rate and characterization data and have monitored and documented lessons learned. Naval Supply Systems Command has provided support for the demonstrations by recommending substitutes for plastic products, and new waste processing systems being developed by the Naval Sea Systems Command have been evaluated. Procedures for both the source separation of plastic and non-plastic wastes and the separation of food-contaminated plastic waste from non-food-contaminated plastic waste have been very successful aboard each of the demonstration ships. Plastic wastes have been stored and returned to port. A new Navy-developed vertical trash compactor has been successfully used to process plastic and nonplastic waste separately, and a pulper has been successfully used to process large volumes of degradable, nonplastic waste for ocean discharge.

## SOLID WASTE: THE NAVY SHIPBOARD PROBLEM

For as long as ships have sailed the oceans, waste has been thrown overboard at sea. This practice continued unchallenged for centuries. The ocean's vast size and powerful assimilative capacity easily absorbed ship-generated waste with no apparent adverse impact. For many years, the waste consisted of simple degradable materials; later, the waste included metal, which sank. However, the relatively recent development of synthetic materials such as plastic, which float and persist in the marine environment when thrown into the sea, has changed the perception that there is no harm in discharging ship-generated trash at sea.

The visible evidence of ships' discharges now points an accusing finger at the maritime industry and the military for polluting the oceans, even though a great proportion of trash on the beach originates from sources ashore. Initially, the concern over marine debris, whether floating at sea or washed onto the beach, was because it offended our sense of aesthetics. However, as plastic became more pervasive in its application, other problems developed. Plastic line began to foul ships' propellers, and drifting plastic sheeting clogged ships' seawater intakes.

Floating marine debris also presented a unique problem for warships--it compromised security. Buoyant bags of trash establish a trail of floating waste which can betray a ship's location. Floating waste can be recovered more easily, enabling adversaries to gain information from the items contained therein.

Regulations of the U.S. Navy prohibit the discharge of any trash within 25 nmi of any shore, and require that all trash be weighted before disposal at sea to ensure that it sinks. However, it is difficult for shipboard personnel to consistently package or process waste for negative buoyancy without the use of special equipment.

In 1970, when the nation finally confronted the environmental crisis and sweeping clean air and water legislation was established, the Commanders in Chief of the Atlantic and Pacific Fleets recognized the need to develop strategies and technologies to deal with the solid waste problem. A comprehensive Naval Shipboard Refuse Study (NSRS) revealed that each person afloat generated about 1.4 kg (3.05 lb) of solid waste per day (Table 1). (Note that less than five thousandths of a kilogram per person per day was plastic waste.)

However, warships at sea had no holding capacity to store waste on board. Waste storage also created health and sanitation hazards and fire control problems. Overboard disposal by Navy ships continued to be the practice.

Recognizing that an alternative to overboard disposal was necessary, the Naval Sea Systems Command set out to find suitable solid waste processing systems. Initially, their goal was to process the degradable waste so it would not float when discharged and to compact the intrinsically heavy, inert material so it would sink to the bottom. This would eliminate the problems caused by floating debris. At the time, plastic waste was not viewed as a serious problem because of the small amounts generated aboard ship.

What seemed a simple concept in the early 1970's proved to be extremely difficult to execute. Commercially available equipment could not meet the rigorous requirements imposed by the Navy (Table 2). Dozens of candidates were evaluated at the Navy's David Taylor Research Center, but none could satisfy the demands of a warship. The first real equipment successes began when industry teamed with the increasing experience of the Navy, and a family of Navy-model food waste disposers was developed.

During the late 1970's, the Navy's engineering communities at the Naval Sea Systems Command and David Taylor Research Center initiated a long-term shipboard solid waste control research and development program.

## RISING TIDE OF MARINE PLASTICS AND U.S. REACTION

Public concern over marine debris magnified enormously in the 1980's because of the terrible impact that synthetic material, particularly plastic, was having on marine life. The amount of floating marine debris continued to increase, creating more beach litter and overwhelming waterfront communities struggling to maintain a high-quality beach environment.

The increase in floating marine debris corresponded to the increased use of plastic products in the home, industry, and marketplace. Plastic and synthetic products found their way aboard maritime ships--and then overboard. Comparing studies conducted in 1971 and 1987, Table 1 shows an approximate twentyfold increase in Navy shipboard plastic waste. No prohibitions existed in the early 1980's against the discharge of shipboard-generated waste once a ship was beyond 3 nmi of the shoreline.

Table 1.--Generation of naval shipboard solid waste (kg (lb) per person per day).

| Item | Naval shipboard refuse study - 1971 | Naval shipboard refuse study - 1987 |
|---|---|---|
| Plastic | 0.004 (0.01) | 0.095 (0.21) |
| Food waste | 0.603 (1.33) | 0.580 (1.28) |
| Glass | 0.008 (0.02) | 0.059 (0.13) |
| Metal | 0.299 (0.66) | 0.186 (0.41) |
| Rubber | 0.004 (0.01) | 0.004 (0.01) |
| Paper, other | 0.463 (1.02) | 0.503 (1.11) |
| Total | 1.38 (3.05) | 1.43 (3.15) |

Table 2.--Criteria for naval shipboard waste processing equipment.

| Parameter | Requirement |
|---|---|
| Reliability | High |
| Manpower | Low |
| Safety | Extremely safe |
| Space needed and weight | Low |
| Simplicity | Extremely simple |
| Ability to withstand shock and vibration | Rugged beyond belief |

During the past few years, the deadly impact that synthetic plastic materials have on marine sea life has been graphically documented and widely publicized by environmental organizations. Countless photographs document the deadly consequences of ingestion of plastic by birds, turtles, and marine mammals, and their entanglement in synthetic fishing line and nets and in plastic sheeting.

Clearly, the Navy is not a contributor to the deadliest form of marine plastic--the synthetic rope of fishing nets. The low number of Navy ships at sea compared to the commercial fishing and merchant fleets makes the Navy a minor contributor (ca. 2.5%) to the total plastics waste problem. However, the high population density aboard naval vessels and the plastic waste discharged daily from each ship at sea adds up over time. As a role model, the Navy must demonstrate leadership with an intensive effort to eliminate the discharge of floating marine debris.

The International Convention for the Prevention of Pollution from Ships (commonly known as MARPOL) was the first comprehensive agreement to

control marine pollution worldwide. The MARPOL was drafted in 1973 (MARPOL 73) and updated in 1978 (MARPOL 73/78). The MARPOL 73/78 included Annex V as an option which would prohibit ships from discharging plastic wastes at sea. The convention was ratified in 1980 with its protocol of Annexes 1 and 2 to eliminate the discharge of oil at sea; yet, it was 1987 before the international outcry against plastic waste forced leaders around the world to take action on Annex V.

In the fall of 1987, the U.S. Senate gave its unanimous consent to the ratification of Annex V to MARPOL 73/78. The 29 signatory nations represented over 50% of the world's merchant fleet tonnage. Annex V dictates that no vessel from a signatory nation may dispose of any plastics into the sea or dump floating solid waste within 25 nmi of any shoreline. Annex V also prohibits the discharge of any solid waste (except ground food waste) into special areas such as the Baltic or Mediterranean Seas.

Congress passed enabling legislation immediately after ratification of Annex V--the Marine Plastic Pollution Research and Control Act of 1987 (Public Law 100-220), which took effect 1 January 1989 for all maritime vessels, and takes effect 1 January 1994 for Navy ships. Congress recognized that full compliance in 5 years would be extremely difficult for the Navy because of the time required to complete development of and to procure and install the appropriate equipment on about 500 ships. Therefore, Congress required that the Navy report in 3 years on progress made toward full compliance, with the expectation that the compliance deadline could be extended if warranted.

In October 1987, the Assistant Secretary of the Navy for Shipbuilding and Logistics created an ad hoc advisory committee on plastics. For 7 months, the committee met and traveled to Navy research centers and supply depots, and visited several naval ships of various types. In June 1988 it delivered its final report to the Assistant Secretary. The report contained 42 specific recommendations for the Navy to meet its solid waste management goals by 1994. The recommendations were divided into four categories: technology, operations, supply, and education.

## CRITICAL NAVY ISSUES

In formulating a plan to achieve full compliance with P.L. 100-220, a number of critical issues had to be addressed.

- How do we separate the plastic waste, which comprises 7% by weight of all the solid waste generated, without creating labor-intensive efforts, which could negatively affect crew morale?

- Where do we install solid waste processing equipment aboard a military vessel so that it is centrally located, efficiently arranged, and minimizes the crew's labor burden? (While the food waste (0.58 kg (1.28 lb) per person per day) can be discharged directly overboard at sea when processed through galley or scullery garbage grinders, the remaining solid

waste (0.85 kg (1.87 lb) per person per day) must be transported and processed for disposal or storage. For example, 900 kg (close to 1 ton) of waste per day is generated at dozens of different rates and locations aboard a 1,000-man ship. It must be carried by hand to processing centers and then carried elsewhere for disposal or long-term storage.)

- Where do we find space to store solid waste? (There is very little designated trash storage space aboard a warship, and there are no unused spaces that can readily be made available. However, since plastic waste cannot be discharged overboard, space must be found without creating fire, health, or sanitation hazards, and without reducing the quality of life aboard ship. Full regulatory compliance demands that equipment be developed specifically to process plastic waste for volume reduction and sanitation.)

- How do we reduce the quantity of plastic waste generated aboard ship? (Alternatives are available for products such as polyethylene trash bags and polystyrene coffee cups. However, plastic is widely used for packaging, and often is the most cost-effective material for that application, especially food products. It has taken years to develop and implement plastics that are efficient and economical (e.g., shrink wrap). Material and product substitutions that perform as well and are as economical may require a long-term search.) Realistically, plastic waste may best be managed by accepting its continued use and developing a plastic waste processor which, together with recycling, will allow us to control the plastic waste storage problem aboard ship.

## NAVY PLAN FOR FULL COMPLIANCE

The Navy's approach to full compliance with MARPOL Annex V and P.L. 100-220 contains four parts. They are technology initiatives, operational changes, substitutes for plastic products, and education. We may think of "people" as the fifth part of our approach. Unfortunately, the human side is sometimes the most difficult to specify, predict, and control.

### Technology Initiatives

In the context of naval ships, technology refers to the equipment that will be installed to provide each ship with part of the capability required for onboard management of solid and plastic wastes. It is important to understand the rationale behind solid waste technology initiatives before the details can be presented.

First, our shipboard technology initiatives reflect the need to comply with all of the requirements of Annex V, which includes managing the total solid waste stream and prohibiting the discharge of plastics. The complexities associated with shipboard equipment installation force us to consider

the total solution to the problem rather than small areas at a time. This approach seems necessary also if we are to achieve our goal and implement timely solutions at a reasonable cost. Therefore, the Navy's technology program places the same emphasis on solid waste management as on plastics discharge prohibition.

Second, a "generic" solution for a "typical" ship would be reassuring; however, many unique solutions are needed to satisfy the multiplicity of ship designs and operating scenarios. The Navy may install solid waste management equipment on approximately 500 ships that fall into about 60 different ship classes! Additionally, surface ships may carry as few as 200 people or as many as 6,000, and submarines have requirements that are entirely unique.

Third, naval ships differ significantly from commercial vessels and will find it more difficult to comply with Annex V because their population density usually is much higher. A 305-m (1,000-ft) naval ship may have a crew of 6,000, while the same size oil tanker may have a crew of 40. Obviously, the contributing population determines the quantity of plastic and other solid waste produced. While the maritime fleet has similar problems with large population densities on cruise ships, they differ significantly from Navy ships in their mission, purpose, and time at sea. Furthermore, Navy ships have no occupational specialty to manage solid waste.

The Navy is developing three shipboard systems that will be major factors in our compliance with Annex V: a vertical trash compactor, a solid waste pulper, and a plastic waste processor. Each system will be of a single size with a fixed capacity, making it easier to train operators and obtain parts necessary for repair and maintenance. Larger ships may require multiple units.

Presently, onboard incineration of solid and plastic wastes does not play a major role in the Navy's plan to comply with Annex V, because this type of burning emits potentially toxic and corrosive waste products in its exhaust gases and ash. Additionally, our experience with conventional marine solid waste incinerators has shown that suitable, high-capacity incinerators that meet the requirements of Table 2 are unavailable. However, we are investigating advanced thermal destruction technologies for limited use on ships operating under unique conditions; in some cases, this may be the best alternative to achieve ultimate, at-sea volume reduction of solid waste.

**Shipboard Vertical Trash Compactor**

The Navy's research and development program of trash compactors began in 1979. Our objective was to develop a machine that was reliable, easy to operate, sanitary, safe, and would allow ships to meet environmental regulations for the discharge of solid waste. We found it difficult to achieve negative buoyancy in trash that was compacted into a degradable container. Finally, we were able to ensure that the container would sink by spraying seawater into the compaction chamber, then using high compaction pressure

to force the water into the pores of the trash to displace the air. A preproduction prototype, such as the one shown in Figure 1, is undergoing technical evaluation aboard a Navy destroyer and has met with outstanding success in the past year.

The Navy shipboard vertical trash compactor was designed to meet Navy standards for maintainability, reliability, safety, shock, vibration, structure-borne and airborne noise, electromagnetic compatibility, and habitability. It can process solid waste composed of glass bottles, metal cans, paper products, and other nonindustrial and nonhazardous waste into 20.4-kg (45-lb) trash slugs. The slugs are contained in cloth bags that can be hand carried. The compactor provides extended-time trash storage, trash slugs that sink without added metal weights, continuous safety checks, and fully automated operation controlled by a programmable logic controller. The most critical parts of the compactor are made from materials that are corrosion resistant; the compactor can be disassembled for movement and installation aboard ship. Its vertical configuration results in a footprint only 0.6 × 1.8 m (2 × 6 ft). Volume reductions greater than 5:1 were achieved when processing plastic waste for storage aboard ship. The first of these units should be delivered to the fleet within 2 years.

**Shipboard Solid Waste Pulper**

Pulping solid waste is not new to the Navy. One class of ship has been successful in using commercial pulpers to process mixed solid waste. Galley and scullery food waste disposers are actually small pulpers. Used as a shipboard solid waste processing method, pulping mixes waste with water, reduces the size of the solids, and creates a wet pulp or slurry, which can be pumped directly overboard. Pulped waste is more readily biodegradable than unpulped waste, tends to be negatively or neutrally buoyant, and disperses rapidly when discharged.

Typically, pulpers operate as follows. Waste enters a large tank through a feed chute and is mixed with water. The water softens and saturates the waste material so that it can be reduced in size more easily. The mixture forms a vortex caused by the rotation of a cutting mechanism located in the bottom of the tank. The pumping action of the cutting mechanism draws trash down the vortex to the bottom of the tank where it is cut and pressed through a perforated sizing ring before being discharged as a slurry. The Navy shipboard pulper is being designed to process paper, food waste, and fiberboard. A conceptual design of the pulper appears as Figure 2. Metal, glass, plastic, and cloth are considered nonpulpable, although the design of the pulper makes it highly resistant to damage from accidental insertion of these items. It will process about 75% of the total solid waste generated aboard a ship at a rate of 262 kg (600 lb) of mixed solid waste per hour. Our experience demonstrates that these pulpers are extremely reliable and simple to operate. The first units could be delivered to the fleet within 4 years.

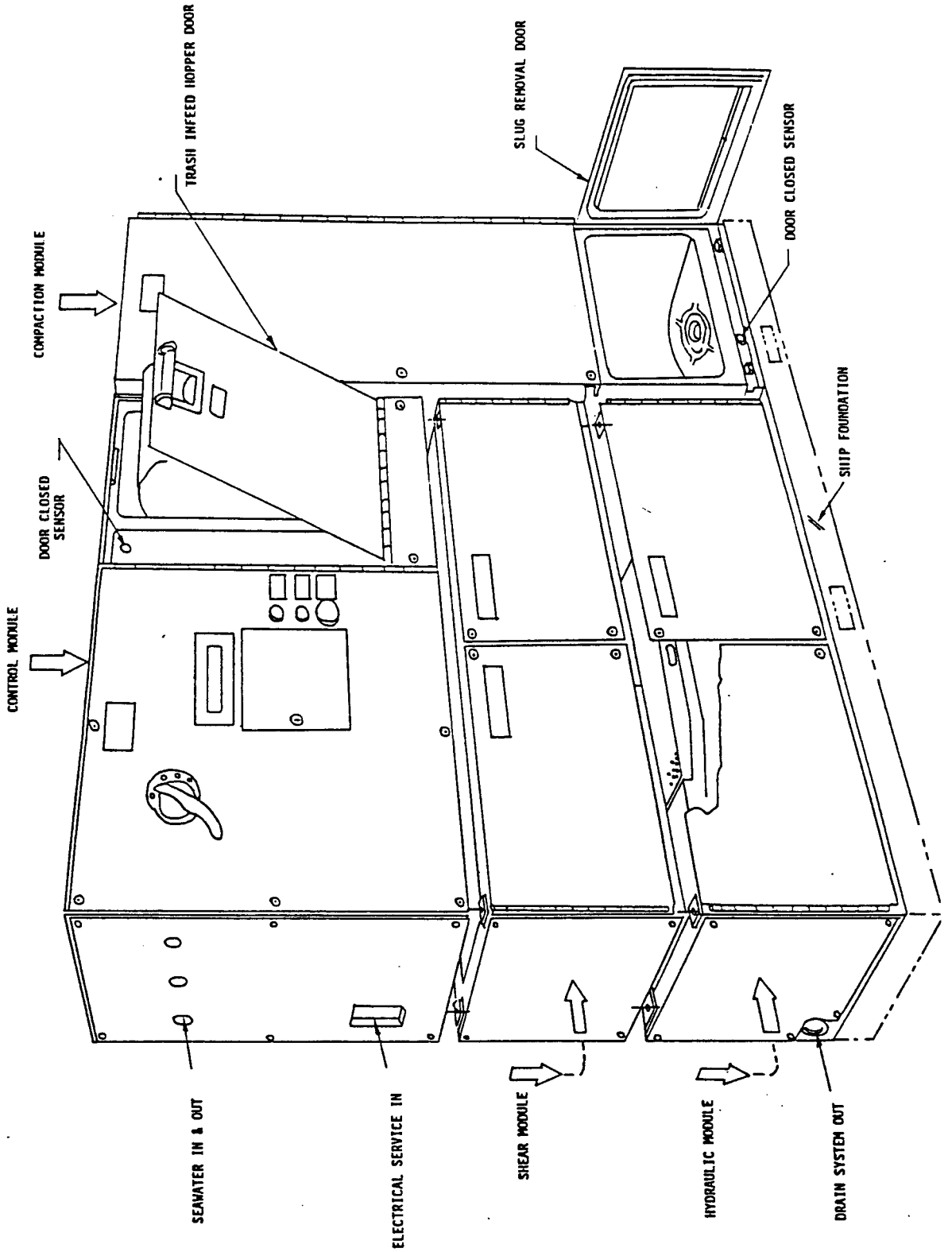



Figure 1.--Shipboard vertical trash compactor.

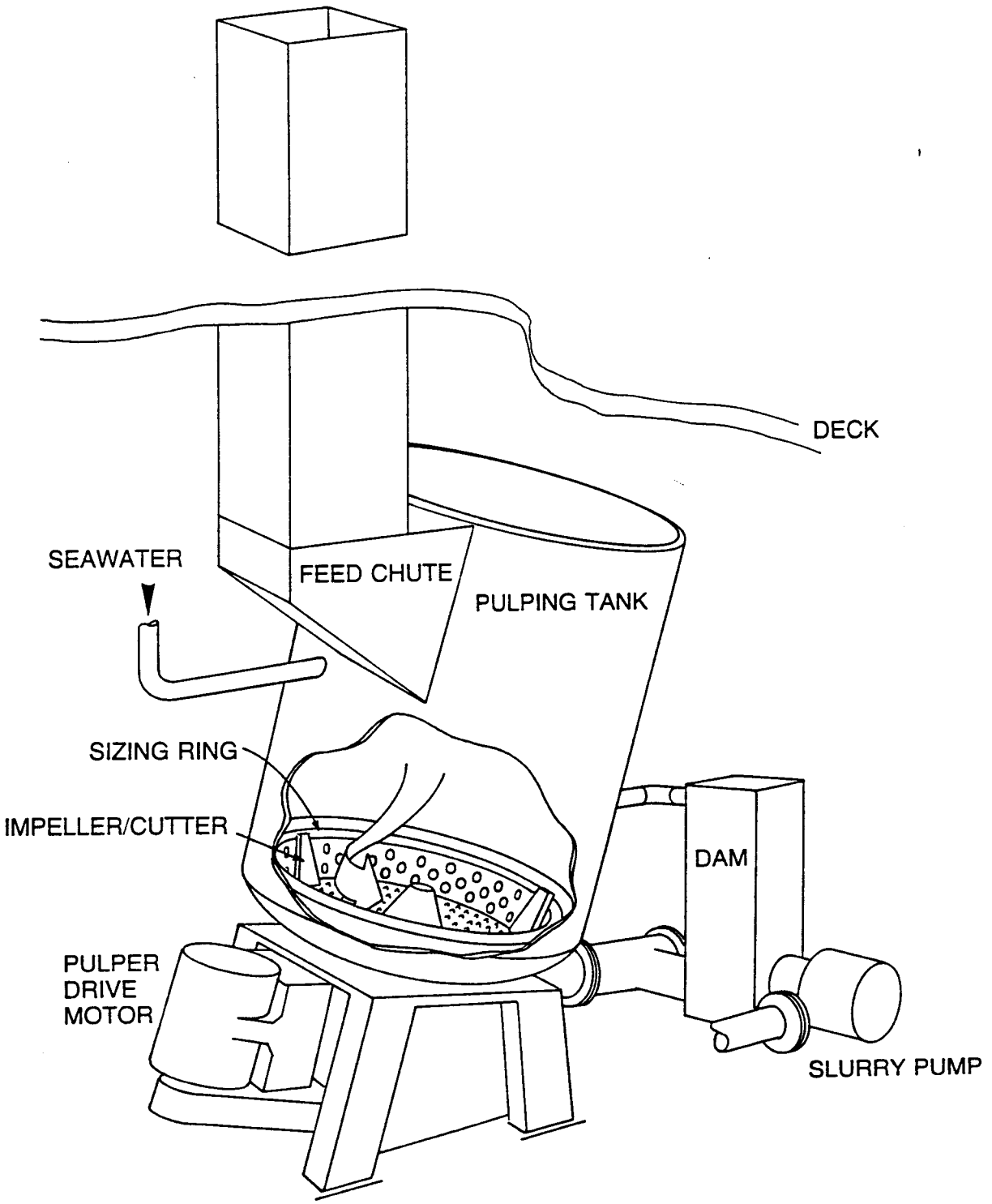



Figure 2.--Shipboard solid waste pulper.

**Plastic Waste Processor**

Plastic waste comprises about 7% by weight of the total solid waste generated on board a Navy ship. Of that quantity, 50% is contaminated with food waste. Storage of food-contaminated waste aboard ship requires significant volume reductions along with sterilization or similar treatment to control noxious odors.

The Navy's shipboard plastic waste processor is in the early stage of development. While the exact design and configuration are uncertain, Figure 3 depicts our developmental objective. The densified, sanitized block of waste plastic will be suitable for long-term shipboard storage until it can be off-loaded ashore. We anticipate a 30:1 volume reduction and an end product that is recyclable. Our goal is to have the first units delivered to the fleet within 6 years.

**Shipboard Equipment Configurations**

To plan the installation of our solid waste management equipment, naval ships are grouped into four categories--small, medium, and large surface ships, and submarines. The conceptual plan calls for compactors only to be installed on small surface ships; compactors and plastic waste processors on the mid-sized ships; and compactors, plastic waste processors, and pulpers on larger ships. Some larger ships may require more than one of each system to ensure maximum efficiency. This plan assumes that personnel on board each ship will separate plastic manually at its source and will use their food waste disposers.

On smaller surface ships, all solid waste (except food) will be processed through the compactor. Negatively buoyant, nonplastic slugs will be stored on board for shore disposal or for overboard discharge where permissible. The compactor can process an all-plastic slug which provides at least a 5:1 volume reduction.

Medium-sized surface ships can accommodate a compactor and a plastic waste processor. The compactor will process all of the solid waste except separated plastics and food waste. Nonplastic slugs will be stored on board for disposal ashore or for overboard discharge. The plastic waste processor will process all plastics including food-contaminated waste, and the densified (30:1) and sanitized plastic will be stored on board for disposal ashore.

All three systems will be installed on larger surface ships in single or multiple units, depending on the need and the space available. Each system will be targeted to a specific segment of the solid waste stream to ensure maximum utilization and efficiency. Separated plastic waste will be processed for storage and shore disposal. The remainder of the solid waste stream will be separated at its source into pulpables (e.g., paper, fiberboard, and light wood) and nonpulpables (e.g., glass and metal cans). The compactor will process nonpulpables into negatively buoyant slugs for overboard discharge when the ship is 25 nmi from the shoreline. Pulpables will be processed by the pulper when the ship is at least 12 nmi from shore

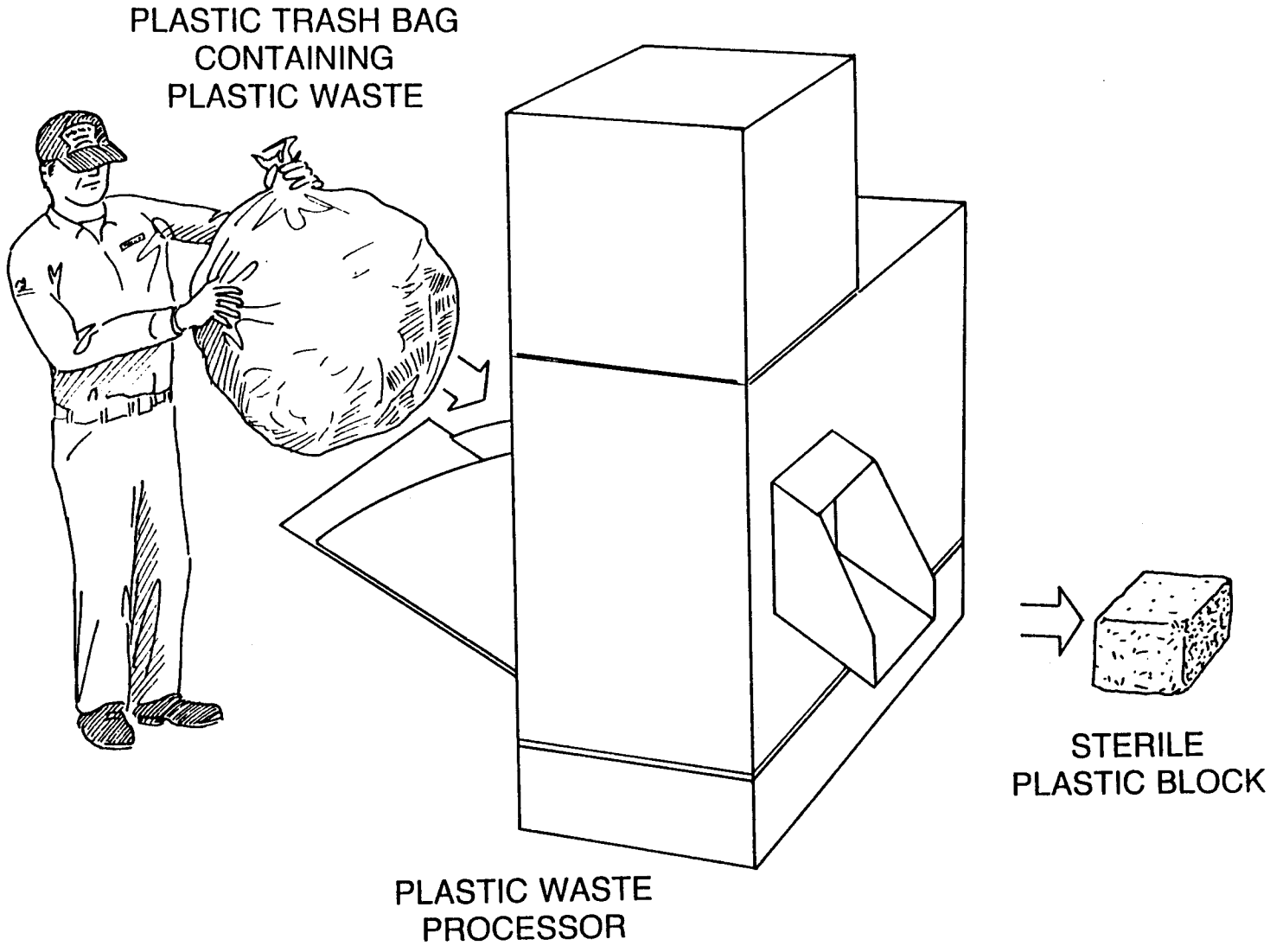



Figure 3.--Shipboard plastic waste processor.

and pumped overboard. Larger ships are most able to maximize the use of waste management technology and minimize the amount of waste retained on board for shore disposal.

Because of limited space and other constraints, the current Navy plan does not include the development and installation of new solid and plastic waste equipment for submarines. However, submarines will comply with Annex V to the maximum extent possible by using material substitutions to minimize the generation of plastic waste; by source separation and onboard storage of plastic waste that is not food-contaminated; and by continuing the current practice of compaction, weighting for negative buoyancy, and overboard discharge of the remaining solid waste.

## Operational Constraints

The Navy's response to the need for operational changes met with four major constraints.

1. *Manpower.*--An 81-h work week is standard for sailors operating at sea, and expectations of what a crew member is to accomplish during a shift leaves no time for special handling of plastic waste. The establishment of additional jobs to fulfill this need is not probable because no funding is available for such a position, and there is no berthing space on the ships for additional crew members.

2. *Space.*--Space is at a premium aboard even the largest naval ships. The typical seagoing merchant ship is considerably larger than the average naval surface combatant, yet its crew numbers 30 compared to 300 sailors aboard a Navy ship. While aircraft carriers are the largest ships in the fleet, their crew exceeds 6,000, thus making their population density similar to that of our smaller surface ships. The cramped quarters aboard our ships leave little space for the installation of new equipment.

3. *Quality of life.*--It is critical that the Navy maintain the quality of life at sea as a top priority to enable us to continue to attract high quality personnel. Routine operations involve 7 to 25 continuous days at sea, with 45 days not unusual. Long deployments may require 80 to 150 continuous days at sea. Thus, it is imperative that each sailor have a clean, healthy, and safe place in which to live. Controlling plastic waste cannot be allowed to negatively affect quality of life aboard ship.

4. *Financial constraints.*--Congress has not allocated additional funds for the increased operating costs that will be incurred during implementation of the procedures to prevent plastic pollution. In fact, budgets are being cut and daily operating funds are scarce. In forecasting the operational changes ahead, funding concerns force us to note that the

cost of paper coffee cups is double that of polystyrene cups, and paper trash can liners are quadruple the price of those made of plastic.

Hence, the Navy must reduce plastic pollution in the marine environment while operating within these realities. We must change the way we process solid waste, yet minimize the increase in manpower and financial resources required and maintain the high quality of life aboard ship.

### Substitutes for Plastic Products

Many items contribute to the problems of plastic waste aboard ship, most of which cannot be controlled. A destroyer with a crew of approximately 300 was used as one of our plastic waste reduction demonstration study ships. During one 16-day period, the David Taylor Research Center study team inventoried 6,179 individual pieces of plastic waste. "Miscellaneous" sources, those not attributable to berthing, work center, or food service areas, accounted for 25% of the waste. The two most numerous items were six-pack rings and trash bags; however, frozen meat packaging, food wrap, and food containers accounted for 14 of the remaining top 23 categories of plastic waste collected. Acceptable, nonplastic substitutes for these items will not be available for many years, if ever.

However, nonplastic substitutes are available for some of the plastic items. Ships have found nonplastic substitutes for coffee cups and stirrers, tableware, and trash can liners. While plastic bags are still used to collect and hold plastic waste for disposal ashore, paper bags are now specified for collection and at-sea disposal of nonplastic solid waste.

New procedures will eliminate some disposable plastic products. For example, food waste can be disposed in food pulpers or garbage grinders, which eliminates serious storage problems caused by the collection of food waste in plastic bags. This practice also requires less manpower; the daily garbage does not have to be carried from the galley to the fantail and dumped overboard for disposal.

### Education

All shipboard personnel must be educated on the hazard that waste plastic poses to marine life and on the procedures necessary for effective shipboard solid waste management. Navy personnel have become increasingly aware of the potential adverse impact that shipboard operations have on the environment. Shipboard solid waste separation management must become a task that each crew member accepts as part of the ship's routine operation.

## IMMEDIATE REDUCTIONS IN PLASTICS DISPOSAL AT SEA: SHIPBOARD PLASTIC WASTE REDUCTION DEMONSTRATIONS

The 5-year implementation period does not afford us the time to conduct paper studies. While the research and development required for technical solutions have been accelerated and are moving forward as quickly

as possible, we must implement changes in waste management and disposal practices now, not because Congress expects it of us, but because it is environmentally expedient.

Changing shipboard operational procedures was the single viable alternative to effect the expeditious reduction of plastic wastes discharged at sea. Our focus was on the segregation of plastic wastes from other solid wastes, and its short-term storage aboard ship. Many of the recommendations in the report of the ad hoc advisory committee on plastics were directed toward achieving this objective. Shipboard plastic waste reduction demonstration studies were conducted aboard five surface ships and two submarines to test and evaluate each recommendation. Studies on two additional surface ships are planned. Thus far, the demonstration studies have illustrated several major points:

- Navy shipboard plastic waste represents about 7% by weight of the total solid waste stream; 50% of that waste originates in food service areas.

- Plastic waste generation is nearly constant across ship classes, ranging between 45 and 90 g (0.1 and 0.2 lb) per person per day.

- Separation of the plastic from other waste at its source was most effective and required the least effort. Trash cans or bags labeled "Plastic Waste Only" were essential. In most living and work spaces they would hold a 1- to 2-week accumulation of plastic waste.

- Onboard storage of plastic contaminated with food waste was limited to approximately 3 days before the noxious odor began to affect the quality of life and it posed a threat to health and sanitation conditions.

- Uncontaminated plastic waste can be stored on board up to 3 weeks; the originating work center seems to be the most appropriate choice for storage on most ships. The plastic waste was collected and placed in pier-side dumpsters when a ship returned to port.

## POLICY GUIDANCE

The commanders of the Atlantic and Pacific fleets have issued policy guidance to the commanding officers of the ships. Each ship must separate and store plastic that is not contaminated with food waste for at least the first 20 days of any underway period, and longer if space allows. Plastic that is contaminated wth food waste must be held on board for the last 3 days of any underway period. Plastic waste stored on board will be offloaded in port. If retention compromises the health, safety, or combat readiness of the ship and those aboard, properly packaged and negatively buoyant plastic waste may be discharged overboard when the ship is beyond 50 nmi from any shoreline. Such disposal must be approved by the

commanding officer and a log entry made indicating the time and position of overboard discharge. Noncompliance with the dumping policy must be reported in writing. This policy became effective 15 January 1989 for ships in the Atlantic fleet, and 1 March 1989 for Pacific fleet ships. The effective dates were chosen to coincide with the issuance of education packages for each ship. Each package includes the "Ship's Guide for the Management of Plastic Waste at Sea."

Fleet implementation of the new procedures will produce an immediate reduction in the total plastic waste discharged overboard by an astounding 70%! The aggressive action exhibited by our operational forces affords our engineering community time to develop and install solid waste management equipment aboard ships that will promote still further reductions. Also, the Navy's supply community will use this opportunity to research alternative products to reduce the amount of plastic used on board ship. The U.S. Navy stands firmly committed to achieving full compliance with all environmental regulations.

# SHIPBOARD WASTE DISPOSAL: TAKING OUT THE TRASH UNDER THE NEW RULES

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## ABSTRACT

In 1988, the Society of Naval Architects and Marine Engineers Panel M-17, Disposal of Shipboard Wastes, convened two workshops to encourage open discussion of the diverse options available to comply with MARPOL 73/78 Annex V (Garbage). This paper reviews the available engineering, operational, and managerial changes useful in implementing Annex V and outlines the "good marine practice" suggested by the discussions in Panel M-17. Examples of approaches actually adopted by different commercial operators will be offered.

## INTRODUCTION

A new marine pollution prevention regime, MARPOL 73/78 Annex V (Garbage), came into force internationally on 31 December 1988 (International Maritime Organization (IMO) 1978; U.S. Congress 1987). Annex V requires ship operators to change the way shipboard garbage is handled and immediately bans discarding plastic materials anywhere in the sea (Whitehead 1988). Disposing of shipboard garbage properly matters more to the company, the sailor, and the national authorities, because Annex V changes the long-accepted maritime practice of tossing garbage into the sea. However, taking out the trash under the new rules means more than stopping sailors from chucking everything over the side. Annex V is no antilitter campaign, but is part of a fundamental shift in the way ship crews and managers operate (Horsman 1982; Vauk and Schrey 1987). Making the transition to a commercial fleet that is able to obey the MARPOL Annex V will take a combination of changing how people have usually done things and providing them with the tools they need to do things differently.

Implementing Annex V has become the job of ship designers, ship operators, and maritime environmental specialists who have the expertise in shipboard systems design and operation. A ship is a small place, of a fixed size, occupied by people, cargo, and a lot of machinery. Rarely is a ship built with spare space or operated with extra people. Under these common constraints, a change in one shipboard activity often has a consequence in another activity. In this paper, the author examines the implementation of the MARPOL Annex V in the merchant fleet from the

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perspective of the marine technical professionals, to convey a sense of the "good marine practice" they need to select, install, and operate solutions to comply with Annex V.

## Background: The Role of the Society of Naval Architects and Marine Engineers

The Society of Naval Architects and Marine Engineers (SNAME) is a U.S. organization of ship designers, ship builders, and ship operators. One standing technical panel of the society is Panel M-17 (Disposal of Shipboard Wastes), which is made up of professionals who work in engineering and management to enable ships to meet the legal requirements for environmental protection (SNAME 1982). In 1988, the SNAME Panel on Disposal of Shipboard Wastes convened two shirt-sleeves workshops on "The Shipboard Engineering and Environmental Aspects of Implementing MARPOL 73/78 Annex V (Garbage)" to encourage open discussion of the diverse options available to comply with Annex V. The first panel workshop on 18 July 1988 was hosted by the Office of the Chief Scientist, National Oceanic and Atmospheric Administration (NOAA). By popular demand, a second meeting was held on 12 October 1988, hosted by the Waste Combustion Equipment Council of the National Solid Waste Management Association (NSWMA).

The Panel M-17 workshops have been lively and useful exchanges of information and opinion. More than 80 people attended, including waste disposal firms representatives, port authority representatives, fleet operators, marine engineers and designers, environmental lawyers and regulators, and supply officers, all of whom have work to do to implement Annex V. The meeting participants provided useful information about shipboard and shoreside waste disposal equipment, local port implementation needs, disposal costs, U.S. Coast Guard regulatory proposals, and ways to design a compliance alternative that make sense for individual ships (Martinez 1989).

Enlightened self-interest helped motivate such a free exchange of information. Each fleet had to comply with the new international convention by 31 December 1988, with little lead time to order equipment or change vessel operations. Domestically, the Coast Guard had only a year after Congress passed the new law to draft and issue new rules that apply to all boats, ships, and oil rigs operating in the waters of the United States. No regulations were in place and many in the merchant marine were uncertain what would satisfy the authorities or how to do it. It seemed a good idea to sit down and talk about what we faced.

## Background: MARPOL Implementation Philosophies

The MARPOL 73/78 Annex V (Garbage) is the third pollution prevention regime to be imposed on the world merchant fleet. Official shorthand for the International Convention for the Prevention of Pollution from Ships 1973, as amended by the Protocol of 1978, the MARPOL 73/78 contains five annexes that address particular types of ship-source marine pollution. The first annex implemented addressed oil pollution and the second addressed chemical cargo wastes. However, Annex V is philosophically different in

its approach, and maritime professionals need to understand that philosophical difference.

The MARPOL 73/78 Annex I (Oil) and Annex II (Bulk Chemicals) prescribed the way to comply, including which equipment to use and what procedures to adopt. In addition, it was clear where the responsibility for day-to-day compliance rested. The wastes involved come from cargo tanks, which are the responsibility of the deck officers, or from machinery spaces, which are the responsibility of the engineers. Enforcement and compliance were rigidly defined, and neither the Coast Guard nor ship operators had much leeway from the very start. Finally, not all vessels had to comply by the same date, because internationally agreed upon schedules gave older vessels more time to come into compliance.

The MARPOL 73/78 Annex V (Garbage) is so different that it has taken a while to get used to it. Annex V mandates that overboard disposal must change and that plastic disposal must cease, but implementing Annex V relies on none of the methods which were so central to the previous pollution conventions. Annex V instead:

- applies to ship-generated garbage, regardless of the source, and clearly includes hotel and galley services, which are the responsibility of the stewards;
- does not require specific new equipment in either ships or ports;
- does not tell ship operators or port authorities how to comply; and
- applies to all vessels in all waters immediately, with no delayed implementation schedules for existing vessels.

These are both the strengths and the weaknesses of the entry into force of Annex V. On the positive side, operators are not shackled to a technologically rigid solution and are free to develop their own best way to comply with the new requirements. Also on the positive side, implementing Annex V is not just the engineer's or deck officer's responsibility, but is a shared responsibility across the ship's crew and the shoreside supporting organization. This allows an operator to experiment and make incremental changes that can yield a compliance solution tailored to the way the ship operates (U.S. Department of Commerce 1988). On the negative side, the entire fleet had to comply by 31 December 1988, which meant that few people had the experience in solving the problem aboard ships and few were familiar enough with the annex to protect themselves from the uninformed speculation that was circulating, and everyone wanted equipment or advice at the same time.

## TACKLING THE PROBLEM

Table 1, the "MARPOL 73/78 Annex V Summary of Garbage Discharge Restrictions," (U.S. Department of Transportation 1988b, 1988c) sets out

Table 1.--The MARPOL 73/78 Annex V summary of garbage disposal restrictions.

| Garbage type | All vessels except offshore platforms and associated vessels | | Offshore platforms and associated vessels[b] |
|---|---|---|---|
| | Outside special areas | In special areas[a] | |
| Plastics--includes synthetic ropes and fishing nets and plastic bags | Disposal prohibited | Disposal prohibited | Disposal prohibited. |
| Floating dunnage, lining and packing materials | Disposal prohibited 25 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| Paper, rags, glass, metal, bottles, crockery, and similar refuse[c] | Disposal prohibited <25 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| Food waste not comminuted or ground | Disposal prohibited <12 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| Food waste comminuted or ground[c] | Disposal prohibited <3 nmi from nearest land | Disposal prohibited <12 nmi from nearest land | Disposal prohibited <12 nmi from nearest land. |
| Mixed refuse types | (d) | (d) | (d) |

[a]Special areas are the Mediterranean, Baltic, Red and Black Seas, and Persian Gulf areas.

[b]Offshore platforms and associated vessels includes all fixed or floating platforms engaged in exploration or exploitation and associated offshore processing of seabed mineral resources, and all vessels alongside or within 500 m of such platforms.

[c]Comminuted or ground garbage must be able to pass through a screen with a mesh size no larger than 25 mm.

[d]When garbage is mixed with other harmful substances having different disposal or discharge requirements, the more stringent disposal requirements shall apply.

the different classes of wastes that are now regulated and where their disposal is now restricted. As stated previously, the saving grace of Annex V is that no technology is mandated. This injects a little breathing room into the transition and removes any cause for alarm if you cannot retrofit equipment by the entry-into-force date. The open "philosophy" for compliance gives a company more freedom to design its own "right" way, but also compels a designer to consider more alternatives. It means that the role of the marine engineer in implementing Annex V is different. A company cannot delegate the task to an engineer, as was done with Annexes I and II, and expect everything to fall into place neatly. It's not that the engineer cannot deliver a technical solution, it is rather that the solution is not in the hardware.

Diverse ways are available to comply with Annex V, exercising both managerial and technical prerogative. "Management" changes can greatly reduce the amount of waste generated and reduce the size of the "engineering" solution needed. Some options affect vessel operations that are not the usual jurisdiction of the marine engineers, such as provisioning the accommodations and securing the cargo. A good starting point for evaluating the situation is to read the Marine Environment Protection Committee (MEPC) Guidelines for the Implementation of Annex V (Garbage) (IMO 1988b). This document has been written to introduce the merchant mariner and the maritime designers to the problem-solving method that is best used in handling shipboard wastes. It works well, and the credit goes to the drafters of the document for producing a practical and usable text. The guidelines are well regarded by the designers and operators who have had the opportunity to use them. Better yet, the guidelines are amenable to modifications as operators and authorities gain experience in implementing Annex V.

In the United States, marine engineers and designers have had only partial information available for fulfilling the marine engineering tasks related to Annex V. Each compliance decision has consequences for the way the ship operates, and some apparently simple solutions affect shipboard operations and costs more severely than do some apparently more complex solutions.

Shipboard sanitation and safety must be safeguarded when selecting an installation or retrofit (Signorino 1988). Panel M-17 convened to become familiar with the solid waste management practices in port facilities and with the state of the art of types of equipment used to process or destroy the wastes now addressed in the Annex V (Garbage) requirements. Very few of us, even in the Panel M-17 community of specialists, had previously studied the ship's garbage, Annex V, garbage equipment available for shipboard or shoreside use, or how to safely retrofit garbage equipment on existing ships. Some options use expensive and unfamiliar equipment, such as package incinerators, large capacity compactors, or pulpers. A quick review of the decision and technical options follows.

## Estimating the Waste Stream

Before the problem can be solved, some estimate has to be devised of how much garbage will be handled. If possible, detailed inventories can be

done, but many operators are unable to spend the time and money on gathering such information before compliance is required. The discussion in the M-17 meeting reviewed the various ways that people have selected to estimate the ship-generated garbage needing treatment. The following ways have been used with some success:

- The Coast Guard regulatory docket for the implementation of the MARPOL Annex V includes a study that creates a unit called the GBE or "40-gallon garbage bag equivalent" (U.S. Department of Transportation 1988a).

- The U.S. Navy 1988 inventory of shipboard waste yielded numbers of 1.4 kg(3 lb)/person/day of garbage which includes 0.5 kg (1 lb) of food waste and 0.9 kg (0.2 lb) of plastic. This is a twentyfold increase in the average amount of plastic since the 1971 inventory.

- The waste disposal industry categorizes "incinerable waste" according to its heat release by the following classification (Norske Hydro 1988). Note that these categories presume no presorting of waste (Table 2).

## Characterizing the Waste Stream

Along the way, the types of shipboard activities that generate the plastic waste will be identified. Each solution to Annex V is simplified if the shipboard waste streams are kept separate, rather than being mixed. Clean plastic can be kept separate from the food-contaminated plastics and both can be collected separately from the other waste that can still be discharged at sea. But making waste separation work requires some cooperation from the crew members or passengers on the ship. It was suggested that SNAME help develop some simple crew and officer training sessions on waste source separation, to motivate and inform people about how it simplified the overall Annex V solution.

## The Zero Equipment Option

Having evaluated the amounts, sources, and types of plastic being used and discarded as a result of shipboard operations, the ship operator can implement a few shipboard and shoreside managerial options to comply with Annex V. Those actions require no equipment installations, but affect shoreside company practices and shipboard crew practices.

## Change the Purchasing of Ship Supplies

A quick scan of most ships identifies where plastics and other problem materials are used (Cavaliere 1988). In a number of uses, plastic has become the material of choice because it is safer to work with and is unbreakable. Other uses aboard ship, however, are convenience uses, just as are the uses of plastic ashore. It is similar to converting a shoreside business or home away from using the plastics that are so easily available.

Table 2.--Incinerable waste categorized according to its heat release.

| Type | Classification of solid combustible waste materials | KJ/kg | Incombustible solids % | Moisture content % | Kg/dm$^3$ |
|---|---|---|---|---|---|
| 0 | TRASH, a mixture of highly combustible waste--paper, cardboard cartons, wood boxes, and combustible floor sweepings from commercial and industrial activities. Contains up to 10% by weight of plastic bags, coated paper, treated corrugated cardboard, oily rags, and plastic or rubber scraps. | 20,000 | 5 | 10 | 0.15-0.2 |
| 1 | RUBBISH, a mixture of combustible waste--paper, cardboard cartons, wood scrap, foliage, and combustible floor sweepings from commercial and industrial activities. Contains up to 20% by weight of restaurant or cafeteria waste, but little or no treated papers, plastic, or rubber wastes. | 15,000 | 10 | 25 | 0.15-0.2 |
| 2 | REFUSE, an approximately even mixture of rubbish and garbage by weight, common to apartment and residential occupancy. | 10,000 | 7 | 50 | 0.2-0.3 |

When a plastic item loses its disposable advantage, it loses most of its purchase appeal. Sometimes, an item that is currently purchased can be done without. A plastic item can be purchased in another material, a disposable item can be eliminated in favor of buying a reusable version that needs to be washed. A formal inventory may not be needed as much as a scavenger hunt for the unnoticed plastics that then become candidates for elimination.

### Establish Who Is Responsible Aboard the Ship

Every cause needs a champion. In the U.S. merchant marine, jobs are commonly defined rigidly as deck, engine, or steward. Tackling Annex V implementation falls in no single department and requires the participation of all personnel or passengers aboard. Each ship should designate a specific person to be responsible for shepherding the entire ship into compliance with Annex V.

## Port Reception Facilities

### Send It Ashore, But Where?

Each port must provide reception facilities for shipboard garbage. If Annex V creates uncertainties for ship operators, the port operators are just as uncertain about what to do. In the past, it has been difficult and expensive for some ports to provide the reception facilities required by the previous MARPOL annexes, so ports are not thrilled by the obligation to provide "adequate" garbage reception facilities. The task is difficult for the port, which can only guess at (1) the number of ships bringing in foreign "food wastes" that will need Animal and Plant Health Inspection Service (APHIS) certified disposal, and (2) the amount of plastic-contaminated waste that will now be brought ashore to add to the port community's shoreside waste stream.

Many port cities are already straining to deal with their own municipal garbage problems, and adding more ship-generated garbage to the local landfill is not an easy thing to sell. The sentiment of those attending the M-17 meetings seemed to be that most U.S. ports are unprepared to meet the reception facility requirement and the ship operator will still be left "holding the bag."

Some German ports have already imposed a vessel fee, whether the vessel uses the port garbage service or not. At least one U.S. port is considering the same action (Nightingale 1988). Such a fee would be about $150 or more per ship per port call. Such mandatory fees affect the ship operators on those routes, because they may lessen the incentive to install extensive garbage handling equipment on board the ship.

When contracting for disposal services, the usual measurements are tons or cubic yards, because that is how the hauler is charged at the landfill (NSWMA 1988).

**Animal and Plant Health Inspection Service Requirements**

The port reception facilities must include APHIS waste-handling facilities. The APHIS restrictions are intended to prevent the introduction of foreign plagues, such as foot-and-mouth disease, into the United States (U.S. Department of Agriculture undated). Any organic wastes that have possibly been contaminated by contact with foreign foodstuffs or foreign livestock are subject to quarantine and can be handled only by authorized APHIS contractors or APHIS personnel themselves. The wastes taken off the ship must be totally sterilized, either through autoclaving or by incineration, and the remaining matter must be securely landfilled. The APHIS requirements are not new and are not changed by the Annex V regulations. Much of the plastic wastes coming from ships as a result of the Annex V regime, however, will be food packaging or food serving articles and is subject to the APHIS restrictions. That volume of waste may increase greatly, especially in the interim compliance periods, when vessel operators may prefer to store rather than treat the plastic wastes.

All APHIS wastes must be stored separated from other garbage to avoid contamination, and when off-loaded, it must be delivered to a certified facility for proper sterilization or incineration. All transport must meet strict quarantine requirements. As a result, APHIS waste is expensive to handle. A ship may be billed by the pound of APHIS waste handled per pick up and frequency of pick up, since transport to an APHIS-certified facility is regulated. Ship officers and crew should make all efforts to keep the APHIS waste separated from regular garbage that does not require quarantine. Otherwise, the APHIS inspector, who makes the final decision as to which wastes must be quarantined, may require much larger amounts of ship's garbage to be quarantined, at the expense of the ship operator. The APHIS wastes should be stored on board the ship in leakproof containers until removal. There is no approved container, and it was the opinion of the waste handlers at the meeting that a Rubbermaid Roughneck, such as is used for curbside garbage pickup, was probably sufficient.

There are currently no more than 43 APHIS facilities in the area of U.S. ports. Wastes may not be transported through rural areas, which makes reaching some remote marine terminals almost impossible. Ship operators should contact their local APHIS officers immediately to get the details about any existing or planned APHIS-certified facilities in the vicinity of the ports where they anticipate needing APHIS wastes handled. It was also suggested that operators inquire of their shipping agents or ship management agents what kind of services the agents can provide.

Recently, APHIS administrators have brought up a new concern about handling compacted wastes. The APHIS regulations for steam sterilizing foreign garbage are based on experience with handling fresh, uncompacted wastes such as are off-loaded from an international airline flight. The autoclaving procedures depend on killing temperatures penetrating the core of the mass of garbage, and a half hour has generally proved effective with a margin of safety. However, well-compacted wastes are, by definition, more dense, and the APHIS has no confidence that a half hour of steam exposure will penetrate the core of the garbage mass. Practically, this means

that a ship operator should now be cautious about compacting APHIS wastes as well, because the savings in storage may be offset by a higher cost for APHIS disposal. The APHIS is likely to have to recalibrate the autoclaving time to compensate for the degree of compaction of the wastes (i.e., 10 to 1, 20 to 1, 40 to 1) in order to ensure that the steam penetrates to the core and kills. Any longer interval of autoclaving is certainly going to increase the operating costs of the autoclave and the price of APHIS disposal for the compacted wastes.

The APHIS-quarantined wastes are not the same as "infectious" wastes. It is important not to confuse the two, because it is much more expensive to dispose of infectious wastes (i.e., hospital wastes). Plus, there is so much public outcry over the recent well-publicized incidents of hospital waste washing ashore on eastern U.S. beaches that no ship operator should invite trouble by using the term "infectious waste" when he means APHIS-quarantined waste.

## The Shipboard Equipment Option

Though Annex V requires no equipment to be installed on a ship, many operators will choose to add garbage handling equipment such as compactors, comminuters, or incinerators. Each piece of equipment installed, whether new or retrofit, needs to operate safely and effectively and not create any disease hazards for the shipboard personnel. In all cases, the tradeoffs need to be identified before expensive decisions are made. In the MEPC Guidelines, Section 5, "Shipboard Equipment for Processing Garbage" requests ". . .information on the development and use of shipboard. . ." comminuters, compactors, and marine garbage incinerators. This is a genuine request for a technical exchange and is another of the provisions unique to Annex V implementation.

### Comminuters: Specifications and Installation Needs

Comminuters are a type of heavy-duty garbage grinder. Though not required by Annex V, comminuters are mentioned in both Annex V and in the proposed U.S. regulations. They are useful primarily for handling galley and scullery wastes that can be discharged in the zone between 3 and 12 nmi offshore (or anywhere within a special area). Comminuters must reduce the wastes to pass through a screen 25-mm (1-in) square. Such equipment is available for galley installation and works well.

Storage tanks for comminuted food wastes were discussed briefly. Such a tank allows a ship's steward to continue comminuting food wastes while within 3 nmi, but avoid discharging it into restricted waters. If used, the tanks must be installed so as to be easily flushed clean. Tank materials must be able to withstand potential corrosion from rotting food slurries and must be adequately vented to prevent anaerobic conditions in the tank.

Comminuted food wastes should never be flushed to black water (sewage) holding tanks or to marine sanitation devices (shipboard sewage treatment plants). Food wastes cannot be adequately degraded by the microorganisms

in the systems and can overload the aerobic capacity of the tanks and make the whole system go septic. Such a ghastly mess must be avoided at all costs.

**Pulpers**

The SOMAT Corporation makes a pulper for use on U.S. Navy ships that works like a comminuter, but further processes the slurried waste to press out the water and dry the waste material enough to make it easier to burn or store. One unit can separate out plastics because the plastics float in the pulping chamber while the other wastes pass through. These devices are about the size of a washing machine.

**Compactors: Specifications and Installation Needs**

Garbage compactors, used on some ships, have had mixed success. Many of the original units were never intended to be installed on a rolling, heaving ship or be used in the salt-laden sea atmosphere. Purpose-built units for marine installation are now readily available, however, and they fare better. The principal reason for using a compactor is clear: garbage storage takes less room. However, the stored compacted garbage, especially food-contaminated plastics, can "ripen" to a stinky mess if not properly isolated and disinfected. The M-17 discussion raised the following points:

- Hygiene for stored wastes needs to be guaranteed, since the accumulated wastes will otherwise rot and attract vermin. The U.S. Public Health Service (PHS) has standards for shipboard sanitation that must not be compromised. To prevent rotting, food wastes may need to be frozen or at least refrigerated in the 40°F cold room until disposal ashore. This may cut into the steward's storage space.

- Though compactors are usually not large, using them requires organizing the garbage collection and installing them requires identifying enough space for storing the compacted garbage as well. Both the compactor space and the storage space should have adequate space drains and hose washdown fixtures. The discharge of the "compactor juice" created is not regulated, as far as anyone present knew.

- Compactors may be used with unsorted garbage or with separated waste streams. It may be worthwhile for a ship to install more than one compactor, if one is used principally for the APHIS wastes generated from the galley and the other is used for all other plastic-containing wastes generated on board the ship that do not need quarantine. One fleet operator suggested that compactors were also useful for baling dry wastes to be recycled.

**Incinerators: Specification, Selection, and Use**

Using an incinerator for plastic wastes enables the ship crew to destroy the troublesome wastes rather than hold them and rely exclusively

on port reception facilities or shoreside waste haulers. Ship operators consider incinerators in a tradeoff study against other compliance options in the implementation of the MARPOL Annex V. The Annex V rules require only compliance, and the ship operator will want to know as much as possible about the consequences of installing an incinerator before making the decision.

Incinerators available for shipboard use differ significantly from each other and cannot be considered all the same. They differ in number of combustion chambers, rate of waste feed, form of waste feed, auxiliary fuel required, pretreatment or waste separation needed, amount of operator training needed, auxiliary equipment or ventilation needed, retrofit installation difficulties, and other ship-specific parameters.

Before installing an incinerator, a ship operator must know what needs to be incinerated and in what amounts. Some wastes require shredding or similar pretreatment before incineration. Other wastes require more fuel to destroy than makes sense, so those wastes (e.g., metal scraps) should be separated ahead of time. Some wastes (e.g., glass) cannot be incinerated in some incinerators, but are handled by others. No single size vessel "needs" an incinerator. Ship owners are going to make this type of decision based more on how many people are on the ship and how the ship operates.

There are no technical standards for shipboard incinerators under Annex V. Neither the IMO nor the U.S. Environmental Protection Agency have set effluent or emission standards for the ashes, residues, or stack gases. The American Society for Testing and Materials (ASTM) Committee D-34 Waste Disposal is the proper group to develop performance and effluent standards, but there is no activity in D-34 to develop standards for incinerators of any size. The last attempt to develop such a standard failed due to a lack of agreement on what was acceptable.

In the United States, the operation of incinerators of a size suitable for shipboard use is not regulated by the Federal Government. At the state and port level, the regulation of small incinerators in communities ashore varies greatly. A shipboard incinerator might be subject to local incinerator restrictions if the incinerator is used while the ship is in port, just as ships operating in some California ports have to burn different fuels in order to meet the local air quality restrictions.

There are no IMO, United States, or Coast Guard residence time or minimum temperature standards for the combustion chamber used in shipboard incinerators. The Waste Combustion Equipment Council is working on an "industry standard" for incinerator performance. The classification society Germanischer Lloyd has developed regulations (Germanischer Lloyd 1987) and the Norwegian ship classification society Det Norske Veritas also has regulations for the equipment Det Norske Veritas (1980). In the United States, a shipboard incinerator construction standard and a selection guide are being developed under ASTM Committee F-25 Shipbuilding. When that is completed and accepted by ASTM, the Coast Guard may accept it as a technical standard. Until then, the Coast Guard is constrained to regulate

incinerators according to its existing marine engineering regulations on auxiliary boilers: control systems, flameout protections, space ventilation, enough room around the installation, and fire protection.

I am skeptical about using garbage incinerators for destroying shipboard plastics. The Canadian experience with municipal incinerators seems to have fallen short of what incineration might promise, because operating the plants perfectly is so crucial to the environmental effectiveness of the technology (Mohr 1988). Shipboard incinerators, unless carefully tested and tended, may only make the plastics prohibition another shell game by dumping dangerous substances into the sea via the air and the ash.

### Integrated Waste Collection, Treatment, and Disposal

Some firms have developed totally integrated ship waste handling systems, and these have been installed on a number of passenger vessels. Successfully operating these systems requires that the crew learn how the system operates and uses the parts of the system to their best advantage. Unfortunately, some have proved too easy to ruin when silverware is thrown into the incinerator or the shredder is fed a full dose of bed linens.

## EXAMPLES FROM THE FLEET

How have ship operators actually responded? Many organizations are still trying to make cost-effective decisions about how to comply with the new Annex V requirements. Some examples can be given, but the identities of the fleets have been removed because this information is largely anecdotal and companies may still decide to change their approach as they develop permanent compliance. The compliance approaches presented are eliminating shipboard plastics, installing compactors, installing fuel-fired incinerators for select waste streams, and installing an incinerator for all shipboard wastes.

### Eliminating Plastics

Company A operates chemical carriers in the domestic trade of the United States. Most of the voyages are between refineries in the Gulf of Mexico and tank farms along the eastern seaboard. A separate portion of the fleet services the west coast of the United States. The crews make short voyages with frequent port stops, but no foreign trips. For this firm, APHIS restrictions pose no problem. However, because the Gulf of Mexico is part of a trade route, the company has to think now about what might be needed to comply with a special area designation in the Gulf of Mexico. Company A began changing its supply procurement practices in 1987 to eliminate plastics and disposable goods wherever possible. Polystyrene coffee cups were banned and heavyweight paper cups were purchased instead. Crew support for eliminating plastics has been strong, because the trash problem in the Gulf of Mexico is apparent as they sail her waters. Further material substitutions will be made, such as asking suppliers to deliver maintenance supplies in metal cans rather than plastic containers. The company has no clear idea how much plastic waste they can eliminate from the ships' garbage, but they want to do as much as they can with replacing

materials before locking themselves into an engineering solution. Equipment may be limited to galley comminuters and compactors, which fit more easily into the vessels' operations than do incinerators.

### Compactors

Company B operates tankers with few people aboard along trade routes that bring the vessels into U.S. ports frequently. Company B chose to install compactors, after having previously considered installing incinerators on each vessel. The compactors are intended to be an interim compliance solution and Company B has not ruled out installing incinerators. First, however, the company wants to see what the wastes are on the ships, how they can be changed to nonplastic materials, and what standards for incinerator performance are developed by ASTM or IMO.

### Incinerators for Selected Wastes

Company C ships carry general cargo and have a relatively small number of people working on board any vessel. They operate an irregular trade route around the Pacific with no guarantee of port facilities in some of the less frequently visited ports. Company C chose to install purpose-built diesel-fired incinerators to handle their waste while at sea and free them from relying on the uncertainties of the foreign port facilities. The managers and operators of the vessels appear satisfied with the units, which are regularly used.

### Incinerator Installed for All Shipboard Wastes

Company D has tankers, so the ships have relatively few crew members, no passengers, and a steady load of maintenance activities with the probability of small oil leaks around machinery and deck piping fixtures. They service relatively remote terminals where it would be difficult to arrange for APHIS waste disposal. This firm elected to retrofit a large incinerator, so that the crew could destroy all the shipboard wastes without relying on port facilities for any garbage disposal. The experience of the fleet operators has been that the system works well so long as a high temperature is attained in the combustion chamber. One unanticipated limiting factor has been the disposal of dirty oil sorbent pads. The material of the pad itself burns nicely, but it also melts if the combustion chamber is not hot enough, and the melting pad material can pool and leak out the air inlets of the incinerator. The temperature of the chamber must be high enough when the pads enter the chamber to take the waste directly to combustion.

## FUTURE MARPOL ANNEX V DEVELOPMENTS: SPECIAL AREAS

The term "special area" means an area where no dumping of garbage is allowed (U.S. Department of Transportation 1988a). An important point is that the requirements of each special area do not go into effect until all the national authorities bordering on the proposed special area officially notify the IMO that adequate reception facilities are available. Only then

does IMO send out a global notice of the special area designation, and 1 year later the designation goes into effect. At this point, only the Baltic Sea has met that requirement. The Baltic Sea will be a special area as of October 1989. The North Sea has also been proposed and the border countries are filing notices with IMO. The formal designation of the North Sea as a special areas under Annex V will occur in the fall of 1989. The Gulf of Mexico, bordered by Mexico, the United States, and Cuba, has been suggested as a special area under the MARPOL Annex V (IMO 1988a). However, neither Cuba nor Mexico are signatories to the MARPOL convention and it is not possible for IMO to designate a special area without the advance consent of all nations surrounding the proposed area. The problems that face those who favor designating the Gulf of Mexico as a special area point up the limitations of MARPOL Annex V, even after its entry into force.

## SUGGESTIONS FOR FUTURE DEVELOPMENT

### Educating Passengers and Tourists

Passenger ships have been the source of a lot of garbage tossed into the sea (Smock 1988). Citizen outreach should include a campaign to tell potential passenger ship customers about MARPOL Annex V and their role in ensuring its success. Environmental professionals interested in eliminating marine debris should target the travel industry and the vacationing public with information emphasizing the benefits of the changes in shipboard handling of plastic materials. Passenger ship operators will be affected by this pollution prevention annex far more than they have been affected by any previous MARPOL annex. As "hotels" in a highly competitive travel and leisure market, passenger ship operators must have some assurance that complying with Annex V can be accomplished with a minimum of disruption to the carefree atmosphere that they try to provide to the vacationing passengers. Recent practice on many short cruises and "party boats" operating out of U.S. ports has been to use disposable materials, principally plastics, for many food and drink services. On longer voyages, passengers bring a variety of personal products for their own use. In North America at least, travellers can buy shampoos, razors, and deodorants in convenient unbreakable small plastic packages that are expected to be discarded when empty. Till now, there was no reason for a ship passenger to think twice about bringing aboard plastic containers. This may be the first time a person realizes the toothpaste tube is plastic. The MARPOL Annex V changes all that, and the travelling public should be encouraged via the travel magazines and other literature to learn to leave the plastic disposables ashore or to expect to keep them until returning to shore. The travelling public is increasingly sophisticated and will probably be glad to make such small changes, if it protects the pristine open sea that they desire.

Switching to nonplastic items will be a bigger adjustment on these vessels, because it will affect how service is delivered to the fare-paying passengers. First, fare-paying passengers cannot be compelled to sort their garbage, as crew members can, so the ship operator must devise a shipboard system that either handles all the collected waste without sorting, or depends on the crew members to separate the trash after it is

picked up from throughout the ship. Second, replacing plastics in some instances will increase costs directly. For example, paper cups cost two or three times as much as expanded polystyrene cups cost. A passenger ship operator should be rewarded, not penalized, for moving away from the disposable plastics that are cheaper to use. Passengers and environmental organizations should praise the successful ship operators and challenge the others to do as well.

### Develop Plastic Melters for Port Facilities or for Ships

This promising technology is already available for shoreside use, though it has not been widely used in the United States. The process reduces the volume of the typical plastic trash by a factor of 40, creating extruded blocks of plastic that are also likely to meet the hygiene and vermin-killing standards of the APHIS and PHS for shipboard sanitation. Plastic treated by a "melter" does not have to be sorted by material types. On the other hand, the plastic handled this way is not being recycled as such; it is simply being reduced in volume and must still be returned to shore for disposal.

Burning plastics may not be necessary, if a manageable melter for plastic wastes can be devised. A small unit might be useful for a passenger vessel or a small terminal, and a larger unit might be very useful for a remotely located terminal that has no easy way to handle the plastic wastes that are delivered by ships. The U.S. Navy is researching the development of a shipboard piece of equipment for use aboard its larger vessels, but that work is not expected to produce a prototype for several years.

### Repackage With Selective Plastics

All plastics are not equal (Society of the Plastics Industry 1988). Incineration creates different combustion products, for example. Polyvinyl chloride polymer contains chlorine atoms, so that incinerating these materials is guaranteed to release hydrochloric acid. Other plastics, such as polyethylene or polypropylene, burn with less hazardous combustion products. In addition, plastics melt at different temperatures and react differently in waste treatment processes. So, the operators may gain some advantage in waste handling by changing from one kind of plastic to another. By investigating the types of plastic used in the products brought aboard ship, the ship operator can retain the advantages of using plastic in some products, but the disposal problems can be simplified, both at the ship and in the ports (Council on Plastics and Packaging in the Environment 1988).

In some senses, repackaging means rethinking away from disposable items to items that have a longer life span. Some shoreside restaurants have replaced plastic plates with plastic or wicker baskets that are lined with paper napkins for each serving. Yes, more paper napkins get used, but the waste bin has much less plastic debris in it.

### Switch to Degradable Plastic

Some new plastic resins are being marketed as degradable, either because they photodegrade in ambient light or because they biodegrade when microbes decompose certain starches or celluloses used in their manufacture. These resins and any products made from them are considered plastic under Annex V and the Coast Guard regulations.

### Refining Waste Handling to Large-Scale System

Now the APHIS system is set up to handle daily operations at airports, but it is much less prepared to handle daily operations at seaports. The APHIS organization must make the transition to be able to handle a larger volume of wastes, without the extraordinary arrangements that ship operators are having to deal with today. That may require more APHIS inspectors and will certainly require more APHIS-certified facilities accessible to arriving ships throughout the country.

### Long-Range Prospects--Ten Years Down the Road

Ten years from 31 December 1988 should find the MARPOL 73/78 Annex V (Garbage) transition complete. At some time between now and then, ports and ships will learn how to manage shipboard garbage in a way that satisfies the annex, safeguards the sanitation and hygiene of the ship, safeguards the port country from animal or plant pestilence, and compensates the disposal firms without bankrupting the ship operators. After all, the shift in shipboard garbage disposal is not happening in isolation. Concurrently, shoreside communities and industries are recognizing that the present disposal practices for municipal garbage must change and that the popular use of "disposable" products leaves a permanent legacy ashore, just as it does at sea. The changes that the annex demands of the ship operators may soon be mirrored ashore. As more people confront the same garbage handling problems in their businesses and homes, engineers and designers will have more incentive to develop efficient products and processes, which may then offer a better alternative to the ship operators than those that exist now. Ten years from now, taking out the garbage will be very different, whether you are at sea or on land.

## ACKNOWLEDGMENTS

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# LOW TECHNOLOGY (BURN BARREL) DISPOSAL OF SHIPBOARD-GENERATED (MARPOL V) WASTES

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## ABSTRACT

To help ensure more widespread compliance with marine disposal laws, alternatives are needed that are applicable to a variety of wastes, but are less costly than using marine incinerators. Burn barrels are low technology burners for disposing of MARPOL wastes at sea. They are not considered state-of-the-art combustion devices, but they are a practical, technically feasible alternative. They comply with existing environmental and marine regulations and are currently in use. Design and operational guidelines for optimizing safety and combustion in burn barrels were developed.

## INTRODUCTION AND REGULATORY FRAMEWORK

Traditionally, shipboard waste has been dumped at sea without regard for the impact of the waste on marine life or navigation. Marine debris is recognized as a growing problem, threatening marine life, beaches, and vessel safety worldwide. Public Law 100-220, The Marine Plastic Research and Control Act (effective 30 December 1988) domestically implements MARPOL Annex V. It restricts at-sea discharge of garbage to certain zones and bans all at-sea disposal of plastics. In addition, it requires ports to have available suitable waste reception facilities.

Shoreside disposal of certain wastes is resticted by U.S. Department of Agriculture (USDA) regulations for controlling plant and animal diseases and pests. Wastes contaminated by food from foreign ports (except Canada) must be enclosed in leakproof containers and brought ashore under USDA supervision. These wastes must then be disposed of via incineration, steam sterilization, or grinding into a sewer. Thus, existing regulations make disposal of shipboard wastes more difficult both at sea and ashore.

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## ALTERNATIVES FOR DISPOSAL OF SHIPBOARD WASTES

Under MARPOL and USDA regulations, vessel operators are faced with the following disposal alternatives, each of which has drawbacks:

- Incineration. True marine incinerators, those with combustion air fans, are expensive, moderately complicated, and occupy valuable deck space.
- Grinding. This process is generally suitable only for food wastes and cannot be used to dispose of plastics at sea.
- Compaction. Requires wastes to be stored, using valuable space. It creates possible odor problems and a potential for morale and aesthetics problems as the crew must work in close proximity to stored garbage.
- Onshore disposal (per local solid waste or USDA regulations). Drawbacks are similar to compaction, but uncompacted garbage requires even more space aboard ship.
- Biodegradable plastics. This may apply to some packaging materials; biodegradable rope and nets are not yet available; degradation products may be toxic or otherwise harmful to marine life.
- Burn barrels (low-technology burners). These may produce excessive harmful emissions or pose safety and fire hazards.

## BURN BARRELS--ONE POSSIBLE SOLUTION

No single technology or disposal method can solve the marine debris problem by itself. A variety of technologies are necessary to accommodate the range of wastes produced, vessel and crew sizes, trip durations, and missions. To help ensure more widespread compliance with marine disposal laws, alternatives are needed that are applicable to a variety of wastes, but are less costly than using marine incinerators.

It has been reported that a variety of vessels are currently utilizing low-technology burn barrels to dispose of their wastes at sea. Burn barrels are simple (typically, a 208.2-L (55-gal) drum with some holes cut in the sides), "low tech," and similar to those barrels commonly used to burn household trash during the 1950's. The Marine Entanglement Program, National Marine Fisheries Service, NOAA, retained SCS Engineers to evaluate the technical feasibility, safety, and potential environmental impacts of using burn barrels to dispose of shipboard wastes.

It should be stressed that the burn barrel technique is not being advocated. However, under present regulatory authority, such technology is permissible and actively being utilized. Thus, the goal of the investigation was to provide guidelines for burn barrels that would enable legal

disposal of shipboard wastes while protecting the environment, shipboard personnel, and the vessel itself.

## Design Guidelines

Because actual construction and testing of a burn barrel were beyond the scope of this project, guidelines for the design, construction, and operation of burn barrels were developed (Fig. 1). A primary consideration was to optimize combustion, that is, to make the barrel act like an incinerator as far as practical in a unit with no moving parts. Types of wastes to be burned, environmental regulations, operator safety, and fire prevention were also evaluated. The burn barrel should be large enough to burn the expected volume of waste in a reasonable time, but without occupying too much deck space.

As shown in the schematic, a complete burn barrel installation should have the following features:

- Combustion chamber (208.2-L (55-gal), 16-gauge steel, Department of Transportation standard 17C drum) located inside an 321.7 L (85-gal) steel overpack drum.
- Combustion air inlets for underfire and overfire air.
- Air gap to cool combustion chamber and preheat combustion air.
- Spark arrester, grate, ash scoop or pan, rain cap.
- Suitable anchoring and insulation.
- Adequate clearances from all combustible surfaces.
- Location: aft and downwind.
- Nearby fire hose or extinguisher and first-aid kit.

## Operational Guidelines

Operational guidelines for burn barrels are largely a matter of common sense. Primary concerns are good combustion and fire safety.

- Burn during calm sea conditions, avoiding rainy weather.
- Build the fire with loosely stacked paper and wood kindling, not with flammable liquids. Add plastics in small amounts to ensure burning rather than melting.
- Avoid potential explosives such as liquid-filled bottles and aerosal cans.

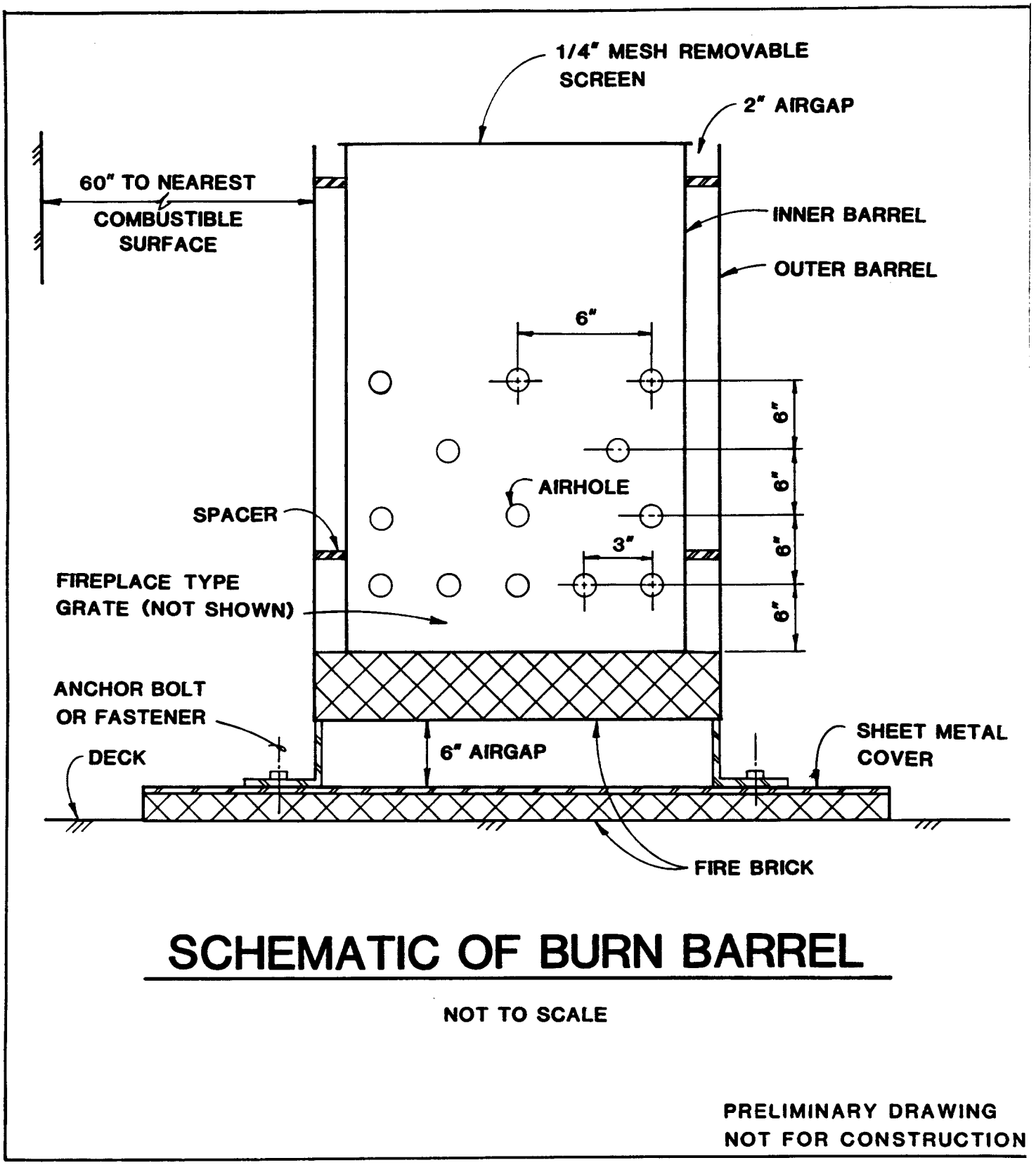



Figure 1.--Schematic of a burn barrel.

- Agitate the wastes with a metal poker for more complete combustion.
- Don't cook food over the fire.
- Wear safety goggles or glasses while operating the burn barrel.
- Avoid inhaling burn barrel smoke and fumes, which might contain hydrochloric acid from burning plastics.

## ENVIRONMENTAL CONSIDERATIONS

### Ash Disposal

The ash resulting from proper burn barrel operations should consist of only sand, dirt, metal, and glass (all of which do not burn); small amounts of unburned carbon (similar to charcoal); and small globules of melted plastic. The latter are still considered to be plastic and cannot be legally disposed of at sea. Since separating the plastic is inconvenient, the entire supply of ash should be stored in a metal container and disposed of properly ashore.

### Air Emissions

The U.S. Environmental Protection Agency currently has no air pollution regulations that apply to burn barrels, and has no plans to promulgate any. State and local air pollution district regulations vary widely, and some of these may affect the use of burn barrels in certain coastal jurisdictions.

Actual air emissions from a burn barrel were not tested, but major components are expected to be water vapor, carbon dioxide, particulates (smoke), carbon monoxide, small amounts of hydrogen chloride (from chlorinated plastics and salt air), and various products of incomplete combusions.

The combustion conditions in burn barrels are more similar to open burning than to an incinerator. Furthermore, they lack air pollution control equipment to clean emissions. On the other hand, due to the small quantities of wastes per burn barrel, airborne emissions are expected to be modest. Air quality impacts from burn barrels operated on the open ocean are not anticipated to be significant. However, emissions testing of burn barrels is warranted.

## COST CONSIDERATIONS

A burn barrel is expected to cost approximately $500, while steam sterilization of wastes to meet USDA regulations is estimated to cost about 30¢/lb. Assuming a 5-day trip with a 30-person crew generating 1.64 kg (4.4 lb) per person per day, it would cost about $200 to dispose of their wastes via steam sterilization. If a burn barrel were used instead, it would pay

for itself in only 2.5 trips. Alternatively, a marine incinerator would cost upwards of $20,000.

## CONCLUSION

While they are not considered to be state-of-the-art combustion devices, burn barrels are a practical and technically feasible alternative. When properly used, they appear to comply with existing environmental and marine regulations. It is believed that they can provide a safe, convenient, and low-cost alternative to either onshore disposal or incineration of shipboard-generated wastes.

# PROVIDING REFUSE RECEPTION FACILITIES AND MORE: THE PORT'S ROLE IN THE MARINE DEBRIS SOLUTION

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## ABSTRACT

A marine debris pilot project was conducted by the Port of Newport, Oregon, in response to the requirements of MARPOL Annex V. Project findings are summarized. The authors also document what has been learned from the preliminary application of these findings to several other west coast U.S. ports. They discuss the different aspects of refuse collection and recycling that should be examined by a port when gearing up for adequate dockside refuse disposal.

The technical part of dealing with marine refuse in a west coast U.S. port is seldom difficult. Initiating action can be--many ports and mariner groups do not consider marine debris a high priority item. However, those with port responsibility have responded positively to outside encouragement and minimal assistance.

## INTRODUCTION

If mariners are expected to return plastics and other refuse to port they must have convenient dockside refuse disposal available to them. The U.S. Coast Guard has acknowledged this when writing the regulations to implement the provisions of MARPOL Annex V. Regulations require that all commercial ports and docks, no matter their size, provide refuse reception facilities.

While it may seem logical to expect all docks to have garbage containers, similar laws designed to control ocean pollution (e.g., those regulating oil or sewage disposal) have not succeeded because they failed to assure that facilities were universally available. Pollution containment facilities were required only of ports meeting some minimum size requirements. Mariners have often been uncertain where oil or sewage could be off-loaded.

Fortunately, this will not be the case with garbage. A fisherman off-loading fish at the processing house will be also able to off-load a

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

sack of plastics or a used net. A fisherman from California, calling for the first time at a port in Alaska, will know that he can find a place to deposit trash and that the port must accept his old cable.

With these regulations then, ports and docks have been handed a much-expanded if not new role as garbage collectors--a role that many ports are unprepared to handle. Realizing this lack of preparedness and the crucial role that ports would play in solving the marine debris problem, the Marine Entanglement Research Program, of the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA) provided funding for a pilot port project. Between January 1987 and May 1988, the Port of Newport, Newport, Oregon, conducted a demonstration program which addressed questions about port refuse disposal facility needs especially for fishermen and boaters, costs and cost recovery, and mariner education. A report, a detailed reference guide, and a videotape summary resulted from that pilot program and are available through the Marine Debris Information Offices, NOAA.

Work was begun in November 1988 to apply the findings of the demonstration project to ports and fishing groups on the west coast of the United States. It continued through June 1990. This work was coordinated by the Pacific States Marine Fisheries Commission with funding from a Saltonstall-Kennedy fisheries development grant. Various methods were used: Ports and fishing groups were sent written information and educational resources, marine debris exhibits were featured at trade expositions, and workshops and seminars were conducted with port groups, extension agents, and educators. Additionally, eight target ports (two in each of the west coast states) were visited periodically to provide them with direct assistance in assessing their refuse disposal needs and options, enlisting local mariner support, and encouraging community awareness. Targeted areas were chosen with the help of the commercial fishing industry and the Sea Grant marine agents. They were areas with active commercial and recreational fishing activity where need was shown and mariner and port support was considered likely. These port areas will in turn serve as examples for and be able to assist surrounding areas on the basis of their experiences. The target port areas were Petersburg and Homer, Alaska; Anacortes and Westport, Washington; Astoria and Coos Bay, Oregon; and Eureka and Morro Bay, California.

This paper will summarize the findings of the pilot port program. It will then mention what has been learned in applying the pilot project experiences to other port areas on the west coast of the United States.

## PILOT PORT PROJECT SERVES AS MODEL

While no port is likely to be thrilled with the news that it is legally obligated to accept refuse from vessels, pilot project experiences indicated that ports can benefit by examining and improving their refuse handling system and by becoming involved in educating their customers about the marine debris problem. Some of the positive results of the Port of Newport pilot project were:

- a high and voluntary (Annex V had not yet been implemented) return of refuse back to shore;
- reduced port refuse disposal costs, despite the much-increased volume of refuse being returned;
- an improved rapport of the port with the fishing community;
- the pride of ownership mariners, port workers, and community members felt in the project; and
- frequent, positive media attention focused on the port and fishermen's efforts.

The acceptance and continuity of the marine refuse disposal project at the port resulted from:

- the convenience and comprehensiveness of the refuse reception facilities;
- the use of a simple, low-cost recycling system which reduced refuse disposal costs and port labor involvement;
- port management and worker support for recycling efforts; and
- fishermen's cooperation with port refuse and recycling efforts.

The support of commercial fishermen and other mariners for ocean cleanup efforts and for increasing community awareness of the marine debris problem resulted from:

- involvement of respected mariners and community members in the project advisory group and their willingness to take an active role in promoting awareness among their peers;
- direct contact with mariners, port workers, and community members (such as is achieved by conducting an oral survey, asking for ideas about improving the refuse system, or by organizing a beach cleanup) as a means of provoking thought and creating a sense of involvement;
- the widespread dispersal of a variety of educational and promotional materials such as brochures, decals, posters, displays, and slide and videotaped shows; and
- frequent local media reports of port, mariner, and community efforts to deal with the marine debris problem.

In work with other ports these approaches are emphasized and have been found to be generally adaptable.

## APPLICATION OF PILOT PROJECT FINDINGS TO OTHER PORTS

The pilot port project differed from the situation to be encountered in most ports. The pilot project provided both focus and funds for marine debris work at the Port of Newport, minimizing port risk and financial restrictions and allowing the hiring of a full time manager, who was able to concentrate solely on marine debris work and plan and implement activities related both to facility development and education.

Though Annex V implementation might focus port attention on refuse facility work, ports we have seen seem generally unconcerned about this regulation's enforcement and have not made compliance a high priority. Most have not planned or budgeted for refuse system changes, nor assigned anyone to be in charge of carrying out necessary work. An active role in mariner and public education has not been considered by most ports.

What then of the Newport experience can be applied to other ports? Can the factors that made Newport's project successful--the convenient and cost-effective refuse disposal system which emphasized recycling, the mariner cooperation and support, and the community involvement--be counted on in other areas? What changes have been observed in work with ports that differ in physical size and layout, types of vessels and clientele served, type of equipment and services offered, and political organization?

### Beginning Work With a Port

Given the general willingness of a port to look at its refuse handling situation in light of Annex V, the approach of holding a meeting to bring together the port, mariners, and refuse handlers has been found to be applicable and effective. Though it is unlikely that such a meeting will be initiated by either the port or the mariner group, we have found it easy to arrange by initiating the idea with these parties and asking the Sea Grant marine agents (or other community organizers) for help in identifying and inviting participants, arranging meeting facilities, and helping to moderate the discussion. The preliminary meeting is used to inform participants of the marine debris problem and the applicable laws, encourage the discussion of refuse service needs and options, and plan the necessary improvements.

In order to encourage the port to commit to making changes, it is important that mariner concern about the issue be evidenced by attendance at the meeting and participation in discussions. Mariner input to the port can be obtained at the meeting if the moderator will ask specific questions to draw out mariner discussion. It may be important for the moderator to discuss needs, ideas, and problems with mariners beforehand in order to foster honest discussion. The advisory group, if one can be formed, or an interested mariner group will need to follow through and continue to encourage the port to accomplish the suggested changes. While we have found that fostering the formation of an active advisory board is difficult unless a specific marine debris or solid waste project is defined, it is not an impossibility if a local person takes the initiative to keep things going, define a role for the advisory group, and call the meetings.

It is also effective for the moderator or a port official to ask about resources or specific commitments from the refuse haulers or recyclers at this preliminary meeting. (For example, What size bins can you provide? How frequently will the containers be emptied?) However, even with these details worked out, it is imperative that someone at the port be assigned to follow through to make the necessary arrangements.

In ports where either the port or the refuse service is operated under the jurisdiction of the municipality or city, special attention needs to be paid to informing these entities of mariner needs. City managers, engineers, and public works employees should be involved in the preliminary meetings with mariners and port officials in order to avoid subsequent problems and misunderstandings.

## Gaining Port Interest

The attitude and interest of the port or dock manager or harbormaster regarding the marine debris problem and the new law will be the key determinants of progress regarding port refuse facility needs.

Many ports consider themselves to be already providing adequate refuse reception facilities, even though dumpsters may regularly overflow or be inaccessible, and mariners have no place to dispose of large refuse items. These ports need to be "pushed." That push can come from a manager who becomes especially interested in this marine debris issue. It is not uncommon to find such people, especially when the potential for more efficient refuse service and improved port-customer relations become apparent. Interested managers have quickly influenced change by establishing informal refuse reception areas (i.e., by beginning piles for wood, metal, and net), by speaking to mariners about new laws and port plans, by increasing the size of refuse containers, by pursuing recycling options, by including plans for marine debris facility improvements in their grant applications, and by encouraging education about marine debris in public schools.

We have found port and harbormaster groups quite interested in having their members informed of the new laws, refuse handling options, and available resources, and have found them quite willing to distribute written information and promotional materials to their members and arrange for presentations before their groups. We have also found harbormasters involved in marine debris work willing to share their experiences with their peers at port association meetings. These short presentations are extremely influential and generate many "hands on"-type questions, result in new cost-saving ideas, and foster a positive attitude toward attempting refuse system changes.

The biggest stumbling blocks we have encountered are not technical or financial, but attitudinal and political: managers who care only to meet the letter of the law, or who are unconcerned with user relations; city and port tensions that restrict port autonomy and the ability and willingness of the port to make financial commitments or changes or to solve problems (e.g., lack of cooperation between city and port in prosecuting the non-mariner citizens who use port dumpsters).

## Assessing a Refuse System for Adequacy and Convenience

Analysis of the existing refuse handling system and port layout is useful in identifying problem areas and needs specific to that port's situation. It is important to critically examine refuse can or dumpster placement (for convenience and visibility), refuse container capacity, and emptying schedules to identify their adequacy in serving mariners and in handling refuse loads especially during the high-use times. The availability of carts, hoists, and forklifts for moving refuse may also be a determinant of convenience.

A one-time walk-around assessment is not adequate, however. Observations must be made during the various busy seasons of the port and these observations should be "reality checked." Resident mariners and port workers can be valuable resources for determining problem areas and times, but only if specific questions are asked. "When do refuse containers overflow and where?" gives much better information than asking, "Is the refuse system adequate?" It is also important to observe what mariners or the port actually do, despite what one might be told. For example, if a refuse container is located far from the access ramps to the vessels, notice whether the mariners actually use it, even if the port or mariners themselves report that they do.

## Negotiating Refuse System Options

Often better service, additional service, and lower costs can be negotiated in port meetings with refuse haulers. In Astoria, Oregon, the port meeting with refuse company officials resulted in the willingness of the refuse hauler to back farther out on the dock to service a container. The Petersburg, Alaska, harbor district, under city jurisdiction, is meeting with city officials, who also operate the refuse service, to negotiate charges to account for the dumping of household refuse in port containers and for emptying half-filed dumpsters.

## Determining Whether Recycling Will Work

A recycling system is a viable and cost-saving option for ports in which the following conditions exist:

- Ports are convinced that there are substantial benefits to recycling: recycling saves them significant refuse disposal costs, expands their refuse reception capacity, or provides a welcome service to mariners.

- There are operating recycling systems in the area and nearby markets for recycled goods. (If markets are far away, recycling is still a possibility if nonprofit groups can arrange with shipping companies to waive their backhauling charges.)

- Recyclers or community organizations will come to the port to haul away the collected materials without port involvement.

(Ports generally have shown little interest in collecting recyclables if they must also haul them away.)

- Port concerns about recycling can be addressed. Lack of familiarity with recycling, concern about system efficiency, and uncertainty about recycling markets are deterrents to port recycling interest. Ports need to be assured that the materials they accumulate will not be difficult to get rid of. Ports need to be willing to experiment with recycling.

- Recycling provides mariners increased convenience and benefit. Mariners will use recycling areas if they are provided at the point of disposal and if they are clearly signed. It helps if mariners are familiar with a recycling system or concept (e.g., fishermen in Coos Bay, Oregon, were aware of the Newport system; cardboard was already being recycled in the town of Bellingham, Washington).

**Anticipating Recycling Potential and Possibilities**

Refuse container contents can be examined and mariners queried to determine the types of waste materials generated and the potential for cost savings through recycling. Speaking to mariners will also indicate their level of awareness about recycling and their interest.

Visual examination of refuse container contents from port to port indicates that the amounts of metal, wood, paper, glass, and gear items found are quite variable. However, we have found that most all commercial fishing ports examined to date could realize cost savings by collecting and separating cardboard items for recycling. The recycling of this item is an easy and impressive first step and may stimulate further interest in recycling. (This was Newport's experience as well as that in Coos Bay, Oregon, where the harbormaster noted with much enthusiasm, "It works!")

In most ports serving the larger commercial fishing vessels, the establishment of a central area to both collect and store wood, cable, metal, and net items (for recycling or giving away) can provide a convenience to mariners and also encourage the proper disposal of particularly large items. Ports have often started these areas informally by stacking materials on pallets or in old containers, or by simply making distinct piles of different types of materials and posting signs. All those that have done so are impressed by how quickly additional materials get placed on the piles by mariners. Even hand-painted signs are effective in encouraging the proper sorting of refuse items. Ports that serve a primarily recreational vessel fleet will probably not find a need for such a central area, unless infrequent pickup of recyclable materials necessitates storage.

We have found that wherever there has been an established recycling program in a local area, it is relatively easy for the port to tie into it. Port contact with the recyclers has always resulted in their willingness to cooperate with the ports in establishing a workable recycling system and hauling schedule. Recycling containers need not be elaborate or expensive

and can usually be built by the port or acquired. Refuse or recycling companies often provide free recycling bins, while donations of the bins can often be obtained from local businesses, from a city (e.g., they may have surplus bins), or from restaurants (208.2-L (55-gal) drums). School shop classes may also be willing to fabricate them. Ports may find it awkward to ask for such donations, and such requests may be easier and more effective if they come from a local mariner or a citizen.

Recycling containers must be able to be emptied easily by the recycler and must be clearly designated so as not to accumulate trash. Bright colors and clear signage are essential. The color blue is being used by most west coast ports for their recycling containers, with the idea that coast-wide consistency will make mariner recognition easier.

Seine and trawl nets are in demand by fishermen and the general public and will be removed from an accessible collection area if it is signed.

Though nets are made of materials with recycling potential (nylon, polyethylene, and polypropylene), used-net recycling efforts are still experimental in nature in the United States, and the details of collection, transportation, and market value of the nets are still undetermined.

At least 20 ports on the west coast have begun recycling programs. Table 1 summarizes these efforts.

**Beginning a Port Recycling Program**

Though ports may not set up a recycling system on their own, most welcome assistance in getting one started. The following steps are usually followed to establish a recycling program:

1. Assess refuse materials generated at the port.
2. Determine which materials are accepted or collected by area recyclers.
3. Explore demand and markets for uncollected but recyclable goods, e.g., fish nets.
4. Work with mariner groups and port to design a system that will be utilized.
5. Order or make recycling signs.
6. Order or make recycling bins or designate reception areas.
7. Implement the recycling plan, placing signs and bins.
8. Inform mariner groups of the bins and encourage their proper use. Inform the media.

Table 1.--West coast port recycling systems.[a] (Note: Used oil is also recycled at all these marinas.)

| Port and contact | Type of materials collected | Collection methods | Other notes |
|---|---|---|---|
| Newport, OR<br>Bud Shoemake<br>(503) 265-7758 | Cardboard, metal, wood<br>Troll wire<br>Metal, cable, wood, nets | Wood fish bins 208.2 L (55 gal) barrel<br>Reception area, barge | System's 3d year<br>Compounds/screens<br>Refuse volume reduced one-third. |
| Charleston, OR<br>Don Yost<br>(503) 888-2548 | Cardboard, metal, wood<br>Cable, nets | Wood fish bins<br>Reception area | 8 h/month labor saves $200/month due to cardboard reduction alone. |
| Astoria, OR<br>Bill Cook<br>(503) 325-8279 | Cardboard, metal, wood<br>Cable, nets, some plastic | Reception area<br>Reception area | New refuse area<br>Completed December 1989. |
| Westport, WA<br>Karl Wallin<br>(206) 533-9528 | Cardboard, plastic, lines<br>Glass, cable, nets | Wood fish bins<br>Wood fish bins | System in place October 1989<br>Located dockside and near office, launch ramp, net repair. |
| Anacortes, WA<br>Dale Fowler<br>(206) 293-0694 | Metal, cable, nets, wood | Reception area | Got free advertising of net availability. |
| Bellingham, WA<br>Art Choat<br>(206) 676-2500 | Aluminum, cardboard<br>Wood, metal, nets | Wood fish bins<br>Reception area | Recycling project assisted by Washington Sea Grant. |
| Friday Harbor, WA<br>Bart Mathews<br>(206) 378-3688 | Glass (white, brown, green)<br>Aluminum | Commercial 15.3 $m^3$ (20 $yd^3$) recycling bin, provided and hauled by garbage company | Recycling system so well-used had to enlarge and automate system. |

Table 1.--Continued.

| Port and contact | Type of materials collected | Collection methods | Other notes |
|---|---|---|---|
| Everett, WA<br>Karen Bukis<br>(206) 259-6001 | Cardboard, aluminum, mixed paper, glass plastics (in 1991) | 208.2-L (55-gal) barrels obtained from yogurt company for $8 each | Three barrels in each of 13 locations. Started April 1989, in first 10 months recycled 2,270 kg (5,000 lb) paper, 1,816 kg (4,000 lb) glass, 454 kg (1,000 lb) aluminum. Garbage bill reduced $7,500 from previous year. |
| Ilwaco, WA<br>Bob Petersen<br>(206) 642-3144 | Aluminum cans<br>Nets, cable, wood, metal | Wire mesh cans<br>Reception area | Cans benefit baseball team. |
| Port Townsend, WA<br>Andrea Fontenot<br>(206) 385-2355 | Cans, papers, glass | 113.5-L (30-gal) garbage cans | Five roofed "environmental centers" built summer 1989. Part of waterfront revitalization plan. |
| Seattle, WA<br>Marla Kleiven<br>(206) 728-3394 | Glass, aluminum, newspaper | 208.2-L (55-gal) drums | In 11 cedar-fenced refuse areas at recreational marina. |
| Greg Money<br>(206) 728-3395 | All types recyclables, including plastics, paper | 3.1 $m^3$ (4 $yd^3$) dumpster | Three locations at commercial fishing marina for comingled materials. Port pays to have hualed but less than for trash. |
| Sequim, WA<br>Jan Hardin<br>(206) 683-9898 | Cardboard<br>Glass, aluminum | Wood fish bins<br>Wood fish bins | In place<br>Planned for 1990. |
| Half Moon Bay, CA<br>Bob McMahon<br>(415) 726-5727 | Cardboard, paper, glass<br>Plastic jugs, aluminum | Rubbermaid 2-wheeled 208.2-L (55-gal) carts, transferred weekly to storage bins | Pilot study by Coastal Resources Center. Handbook available December 1990 from (916) 323-3508. |

Table 1.--Continued.

| Port and contact | Type of materials collected | Collection methods | Other notes |
|---|---|---|---|
| Oakland, CA area[b]<br>Calvin Young<br>(415) 891-3912 | Aluminum, glass, plastic beverage bottles | Mini-house structures contain two 208.2-L (55-gal) barrels. PVC tube prevents removal of deposited materials | Materials for each of 27 units cost $200. Emptied twice/week even in winter. In operation since April 1989. |
| Kodiak, AK<br>George McCorkle<br>(907) 486-5438 | Aluminum, plastics/rubber<br>Wood, metal, nets/rope<br>Paper/cardboard<br>Batteries | 3.1 $m^3$ (4-$yd^3$) dumpsters<br><br>Separate collection area | Seven dumpsters in each of two MARPOL stations. Operating since February 1990. |

[a]Other systems planned: Santa Cruz, CA, Steve Scheiblauer (408) 475-6161; Chula Vista, CA, Becky Clark, 550 Marina Parkway, Chula Vista, CA 92010; San Diego, CA area (a number of marinas); Libby Lucus (619) 235-0281; Edmonds, WA, Bill Stevens (206) 457-4505; Port Angeles, WA, Chuck Faires (206) 457-4505; Crescent City, CA, Rich Taylor (707) 464-6174.

[b]Six marinas.

9. Monitor the recycling system to make sure materials are hauled on time and problems are resolved.

### The Port Role in Mariner and Community Education

Most ports will play a limited but important role in stimulating mariner awareness and involvement in the marine debris solution. Ports welcome and even solicit help from mariner groups, community groups, and recyclers to inform mariners of the refuse disposal law and to stimulate interest. The ports are willing to make notices about the law available to mariners and, when they are provided, will display posters and distribute stickers and brochures. A limited number of ports, fish processors, and dock facilities actively seek out information to pass on to mariners.

Ports may be willing to meet with their user groups to discuss Annex V regulations, but they are not likely to coordinate or organize such meetings on their own. Likewise, though most ports welcome press coverage about their marine debris efforts and do not object to public service announcements that say "brought to you by your local port," they are not likely to seek out media contacts.

A few interested harbormasters have actively sought support for marine debris cleanup efforts. The harbormaster in Petersburg, Alaska, spent a whole day going from boat to boat to explain the law to mariners and his need to raise moorage rates in anticipation of the extra refuse load. The harbormaster in Astoria, Oregon, showed marine debris promotional materials to a solid waste committee. He has asked for their assistance in contacting mariners on the docks and has inspired them to go into the schools to inform children. In Avila Beach, California, the port manager, a former teacher, is developing a marine debris educational package for school children.

### Fishing Industry Support

Our experience shows that support from commercial fishing groups can be expected. Fishing industry groups are interested in solving the marine debris problem and are willing to become involved in marine debris work.

When supplied with information about Annex V, industry groups and Sea Grant marine agents will promote awareness of the issue through newsletters. They will discuss the regulations at fishing group meetings and encourage affirmative action among members. Industry groups have also been willing to promote marine debris awareness at expositions by handing out materials, displaying posters, talking with mariners, and by making display space available for marine debris pictures.

When prompted or during a meeting, fishermen as well as Sea Grant agents are willing to talk to their port harbormasters about refuse disposal needs and ideas. Many individual fishermen have personal interest in this issue, and their support is an essential factor influencing the attitudes of others, promoting peer action, and pushing for port changes. Some fishermen, when provided information and promotional items may also

act on their own to bring this material to the attention of their peers, other mariner groups, and the schools.

### Taking Action

Action related to the marine debris problem is unlikely unless someone takes charge. Someone must define and plan activities that address the marine debris problem, must organize and facilitate meetings, and must delegate the work. Do not assume that a port employee will take on or be assigned the lead role. If that level of involvement is not likely from the port, look for other individuals and groups for the port to work with.

Groups that have already been organized around beach cleanups or recycling are logical groups with which to work. They may be able to research or put together a port recycling program, coordinate a special promotional event, conduct mariner surveys, or organize a harbor cleanup or educational campaign. They are often willing to distribute information and show readymade video tape or slide presentations. The reference guide resulting from the Newport pilot project outlines such an outreach program, and emphasizes approaches such as involvement of port employees and mariners in program design and trouble shooting. This involvement has been effective in assuring the support of a marine debris program.

Groups already taking part in boater education efforts (e.g., the U.S. Power Squadrons and Coast Guard Auxiliary) can also provide support. They may be willing to incorporate marine debris information into their classes and during their contacts with mariners.

Other groups which may be interested in marine debris cleanup and recycling activities are environmental groups, community, senior, and scouting groups, and school science classes. They are most likely to act when they have readymade materials to give out or use. Interest and action are encouraged simply by making brochures, stickers, posters, curriculum materials, photo displays, and slide or video programs available to groups and teachers.

## CONCLUSION

The technical part of dealing with marine refuse in a port is usually simple. Refuse containers are readily available in various sizes, hauling schedules or container sizes can be adjusted to meet increased demand, and recycling can often be used to decrease refuse disposal costs.

What is difficult is the initiation of action. What has been most apparent in work with the eight target ports, and with other ports on the west coast, is that while there is general support and interest by the port and mariner groups in the marine debris problem, it is not a high priority action item.

Most ports and mariner groups are not likely to take action on their own. However, if ports are approached, offered assistance, and encouraged (even by providing a simple catalyst such as information, notices, posters,

or brochures) much can be accomplished. All ports have been willing to attend and even help organize meetings which bring them together with mariners, refuse haulers, and others. Once port officials are stimulated to begin (by the development of personal interest, by gaining the tangible assistance of supportive mariners or community groups, by guilt, or by seeing the examples set by other ports) we found that many then initiate activities on their own.

This essential outside push can be provided by a mariner, citizen, recycler, or community group willing to do some research regarding refuse and recycling options, organize meetings or activities, and encourage the awareness of mariners. States, counties, and cities may be able to designate part of an employee's time for such port assistance through their solid waste, environmental quality, boating, or fishing departments. If such a person can organize the readily available assistance of the fisheries groups and the ports, tangible progress on the marine debris problem will soon be noted.

Further information on the NMFS-sponsored pilot port marine debris project is available in two reports: "Report on a port-based project to reduce marine debris" and "Dealing with Annex V--reference guide for ports." The former report describes the project in detail. The latter presents guidelines and resources that resulted from the pilot project. A video tape about the Newport project called "A marine refuse disposal project" has also been completed. All three resources are available from NOAA's Marine Debris Information Office, 1725 DeSales Street, N.W., Suite 500, Washington, D.C., 20036, U.S.A., phone (202) 429-5609.

# DISPOSITION AND RECYCLING OF PLASTIC PRODUCTS INCLUDING USED NETS

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## ABSTRACT

Disposition and recycling technologies of various plastic wastes are reviewed. The technologies employed vary by material and type of waste.

Case studies were carried out at Akkeshi and Wakkanai ports in Hokkaido, which are major base ports of Japanese salmon fishing vessels. Some used nets are recycled into nylon pellets; others are incinerated or landfilled.

## BACKGROUND

Recycling technologies in Japan have been developed because Japan is poor in some natural resources. Japan must import most raw materials needed to produce industrial goods, and there exists national recognition of the necessity to make the utmost of raw materials through recycling and other means.

Japan is also a small and densely populated country. It is not easy to find places for waste disposal, and the environment tends to be susceptible to damage from waste disposal practices. Thus, Japan finds it necessary to develop effective recycling technologies. To date, effective recycling technologies have been developed mostly by small- and medium-scale enterprises, rather than by public research institutes. Thus, these enterprises tend to be small in scale and of great variety.

There are two principal methods of recycling used fishing nets--pelletization and reutilization. Both methods have problems. Pelletization as a recycling business requires profit stabilization, while reutilization of nets requires further development of recycling methods in order to increase demand.

## PLASTIC CONSUMPTION IN JAPAN

The output of primary products of plastics in Japan reached 4.77 million tons (MT) in 1987, an increase of about 12% over the 4-year period

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

from 1984. Responsible for this increased production is the continuous development of new plastic products, progressive development of synthetic technologies of resins, and the easy-to-process nature and low prices of plastics.

The lifespan of plastic products from marketing to disposal varies according to the resins and their products. The life of packaging materials and disposable containers, which together account for some 40% of plastic products, averages 1 to 2 years; on the other hand, sundry goods for household use and toys last for 3 to 5 years. As a result, 55% of plastic products are discarded within 5 years after their production. Pipes and other plastic products used in construction last for more than 10 years, but they account for only 20% of the total.

The most notable characteristics of plastic products are durability and low prices. The low prices, however, have brought about the "throw-away" practice; thus, the useful life of the products themselves is much shorter than that of plastic as a substance. The present problem is that the disposal of plastic is difficult, the difficulty stemming from its high durability.

## CASE STUDIES OF RECYCLING WASTE PLASTICS

Introduced here are some Japanese technologies for recycling waste plastics. In recycling waste plastics, effective classification and separation of various plastics are essential to maintain good quality of recycled products and to lower production costs.

Plastic products are being used in almost every field, often in combination with wood, steel, or other materials. As a result, discarded plastics are mixed in with other waste material. Moreover, even if plastics are grouped by kinds at the time of refuse collection, they are usually covered with dust, earth, or sand, in which case additional processing is required.

Various techniques for classifying municipal refuse have been developed. They include techniques developed under the "Stardust '80 Project" conducted by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry in 1972-82 with the aim of turning such refuse into new resources.

There are two ways to recycle waste plastics--one is using it in new plastic products and the other is reducing the plastic as a material. Although in both cases quality control is a difficult task, this has developed into a new business in which 88 companies are already engaged throughout Japan. Recycled plastic products include manhole covers, piles, and flowerpots. The Ministry of International Trade and Industry has established the Japan Industrial Standard as guidelines for uses and quality control of such recycled products.

The pyrolytical method converts organic substances of high molecular weight into those of low molecular weight by use of heat energy. Suitable

substances for this process are waste plastics, used tires, and waste oils. As opposed to incineration, pyrolysis needs not only strictly controlled operations, but must also meet two conditions:

- Waste plastics as materials must be even in quality and available steadily and in large quantity.
- A reliable supply system of recycled products like oil and gas must be established.

## TECHNOLOGY FOR SORTING MUNICIPAL WASTES (STARDUST '80 PROJECT)

This system is designed to sort municipal refuse into two or three groups by applying both the pulverizing and sorting processes simultaneously. These processes utilize the principle that different materials can be crushed into different sizes in accordance with their resistance to shock, compression, and shearing stress.

One such group is composed of kitchen garbage, fragile paper, and other goods which can be easily reduced to small pieces and passed though small screen holes. Another group is made up of plastics, metals, fibers, stronger paper products (cardboard paper and laminated paper), and other things which cannot be broken easily and are extracted from the machine almost in their original sizes. When compared with conventional pulverizing machines, this system has the following advantages:

- Pulverization and sorting are possible in one process with a small amount of power.
- As metals, plastics, and other items can be selectively broken almost in their original forms, the system faces less wear and therefore entails lower maintenance costs.
- Owing to its slow speed, the device produces less noise, vibration, and dust.
- A special anticoiling device prevents long objects from wrapping around the rotating shaft.
- It is possible to easily discharge overloading objects such as metal blocks, bulk waste, etc., out of the system through adjustment of its rotating speed.

## TECHNOLOGY FOR SORTING AGRICULTURAL FILM

This system is capable of sorting and utilizing soil-smeared agricultural films without resorting to a washing process.

Films are first roughly crushed (about 40 mm) and then sent to a heavy, oil-fired stirring dryer where the material is dried with 110°C hot air. Soil and sand are loosened from the films and discharged from the

screen at the bottom of the drying chamber. Iron elements are eliminated by the use of magnets. The films are further crushed and once again dried (air drying) so that their quality is improved. After this, iron pieces are again removed by magnet and the films recovered in the form of fluff.

Recovery costs, excluding those of pelletization, amount to about ¥37.5/kg.

## TECHNOLOGY FOR RECYCLING FOAMED STYROL FISH BOXES

Foamed styrol is used to make fish boxes and package cushioning, the latter used extensively in business offices and households.

Fish boxes are first used in fishing ports and later accumulated in markets and retail stores. Of the fish boxes handled in central wholesale markets throughout Japan in 1979, 42% were incinerated and about 22% were recycled.

Fish boxes to be recycled must be relatively clean. After being cut, they are heated and melted at 270°-280°C and molded into blocks weighing 8 kg each. These plastic blocks are exported through chemical companies to Southeast Asia, where they are used as raw materials for toys and re-exported to Japan, the United States, and elsewhere.

Such boxes were initially sold at ¥25/kg but their current price is ¥5/kg; the decline resulting from the price competition with virgin materials produced at low cost reflecting the current stagnant oil prices.

## RECYCLING WASTE PLASTICS INTO ARTIFICIAL FISH REEFS

In Japan, the establishment of artificial habitats for fish has been promoted under a long-term national project designed to increase fish resources along the coasts.

Man-made waste plastics fish reefs are made of recycled polyethylene, polypropylene, and other polyolefin plastics derived from the plastic films used for packaging foods and other purposes.

In order to strengthen artificial fish reefs, various measures are taken, such as mixing ferro-oxide into the melted plastic to substantially increase density and building structural-use steel pipes into props. Between 1972 and 1988, a total of 250,000 $m^3$ of fish reefs weighing about 18,000 MT, were installed on the seabeds around the Japanese coasts. These artificial reefs have the following characteristics:

- There is no limit to their durability.
- As they are made of assembling units, it is easy to adjust their shapes and sizes.
- Easy to assemble, the time needed for installation is short.

- As they do not exude alkali elements, a variety of seaweed and shellfish can safely attach to the artificial reef.

## TECHNOLOGY FOR RECYCLING FISHING BOATS OF FIBER-REINFORCED PLASTICS

About 1965, fiber-reinforced plastics (FRP) began to be used for building fishing boats. Easy to mold, lightweight, durable, and economical, FRP fishing boats have been used widely in the coastal fisheries. In Japan the number of powered FRP boats reached 290,000 in 1984. The earliest of these vessels have reached "retirement age," and safe disposal is now a major problem.

In 1985 and 1986, the Fisheries Agency developed an FRP boat disposal system. The disposal procedure is discussed below.

Chosen for the experiment was an FRP vessel from the set net fishery; the vessel weighed 3.42 MT and measured 9.86 × 2.6 × 0.59 m. The vessel was first crushed by a hammer crusher into 10 to 20 $cm^3$ pieces. These pieces were carbonized in a batch-type pyrolysis incinerator which measured 3.4 $cm^3$. Waste tires were used as fuel for the carbonization process.

The plastics decomposed in the pyrolysis were gasified and recovered in the form of oils, which were further separated into water, tar, pitch, and waxes and stored as reprocessed oils. Glass fiber residue was burned in the pyrolysis furnace.

Recovered were the following substances:

- Oils--For reasons of smell, low calories, and irregular viscosity, the recovered oils were traded as products below C-class fuel oil (heavy oil).

- Glass fibers--Recovered glass fibers were utilized as composite plastics for compound plastics called AMC or FMC. Pending further research, they may be usable as molded products for automobiles. Their utilization as powdered glass may also be possible.

- Carbons--They are a mixture of products from FRP and waste tires. It is possible to market those sifted through an 80-mesh screen.

## TECHNOLOGIES FOR RECYCLING AND INCINERATING USED FISHING NETS

Used fishing nets can be utilized in their original form for applications other than fishing or they can be reprocessed into basic material and used to produce other things.

## Recycling of Used Fishing Nets in Their Original Forms

There is a wide range of purposes for used fishing nets other than fishing. These include:

### Collection of Planktonic Larvae of Scallops

When used for catching planktonic larvae of scallops, one-sixth of a unit (about 100 m/unit) of nylon monofilament driftnet used in the salmon fishery is packed in one onion bag. Salmon driftnets are used and not squid driftnets; the latter are unsuitable because they are smeared with squid ink. Scallop fishermen buy used nets from net-weaving companies at a price of about ¥1,600 per unit (including shipping costs) in Hakodate, Hokkaido.

### Protection of Trees From Deer

In 1986, in order to protect trees in the training plantation of Kyoto University in Shibecha, Hokkaido, a reforested area within the plantation was surrounded with nets 1.4 m high that had been used previously for salmon fishing. Before such protection, 79% of the 86 trees in the area had been damaged by deer, *Cervus nippon esoensis*. No further damage has been reported since the installation of the nets.

Although such protective nets can be considered effective for preventing deer from harming trees in Hokkaido, this method is costly and labor intensive. In Chiba Prefecture located east of Tokyo, a deer was reported to have died when its antlers became entangled in a net.

### Drying Tangle

In Japan, tangle is usually dried on pebbles after it is gathered from the sea. In some regions, trawl nets are used instead as drying racks.

### Antibird Nets at Garbage Collection Sites

In Wakkanai, Hokkaido, used trawl nets cut into 2-m squares are spread over garbage cans at community garbage collection sites so that crows cannot scatter the garbage.

## Reprocessing of Used Fishing Nets

Since 1988, three factories (two in Akkeshi and one in Hakodate) have been in operation pelletizing used nylon monofilament salmon and squid driftnets. The companies collect nets from various ports in Hokkaido. The pelletizing process is similar at all the companies and total production is an estimated 700 MT a year. The pellets are sold to chemical companies at a price of about ¥210/kg (1988) for the manufacture of electrical equipment for automobiles, bicycle saddles, electric fans, and other kinds of goods. When compared to virgin pellets, however, the tensile strength of recycled pellets is reported to be weaker by 10%.

One of the problems concerning pelletization lies in the great effort required in washing nets or otherwise removing impurities from them. Trawl nets are more likely to retain soil and trash at their webbings due to the method of fishing. As far as we are informed, there is practically no reprocessing of trawl nets at this time, presumably due to the cost of preparation.

Economically, the competitive advantage of reprocessed pellets over virgin pellets is very unstable; the price of the latter being subject to the price of petroleum.

### Incineration of Used Fishing Nets

In Japan, as a means of reducing the volume of bulky fishing nets, high heat incineration, which is effective in minimizing harmful substances and ash, has been under study. Under consideration are batch-type pyrolysis furnaces (0.7 to 50 $m^3$ in size) placed underground and designed to attain complete combustion through use of water-gas reactions.

This furnace is constructed so that combustion may take place using an air intake from above. This also makes it possible to adjust the supply of air so as to prevent unburned soot and dust from being discharged. The chimney flue helps combustion by serving as a secondary furnace.

When burned, plastics generally give off black smoke and, in some cases, harmful gases. No noxious smell or black smoke is produced, however, in this particular type of incinerator, even if used fishing nets, tires, foamed styrol, or lumps of plastics are burned.

## RECYCLING OF USED FISHING NETS IN HOKKAIDO

Information regarding recycling of used fishing nets in Hokkaido was obtained from oral surveys conducted among staffs at government offices, fishing operators, net-weaving companies, and other related industries in Akkeshi and Wakkanai in 1988. Akkeshi is one of the five main ports in Hokkaido engaged in medium-sized salmon driftnet fishing operations. It is also known as a port for the squid driftnet fishery. Wakkanai, on the other hand, is a port mainly supporting a trawl fishery.

### Akkeshi

#### Use of Fishing Nets

As of 1987, fishing operators in Akkeshi owned 13 fishing boats authorized for use in salmon and trout fishing with medium-sized driftnets. Six of them were also engaged in driftnet fishing for squid. In addition, 10 other boats from other ports landed their catch at Akkeshi; these vessels were not involved with the disposition of fishing nets.

Medium-sized salmon driftnets in use at Akkeshi mostly measure about 100 m in length. When the salmon and trout fishing season using medium-sized nets comes to an end around July, some nets are used again for squid

catching and then scrapped. Nets aboard boats used exclusively for salmon and trout fishing are transported to net-weaving companies. About 50% of the nets need no repairs and are used again the following season; 30 to 40% of the remaining nets are repaired and used again. About 20% of the salmon and trout fishing nets are scrapped each year, and almost all nets used to catch both salmon and squid are scrapped after the cuttlefish season ends. The lifespan of nets averages from 2.5 to 3 years.

### Disposal and Recycling of Fishing Nets

For lack of landfill space and to avoid pollution, Akkeshi Town does not incinerate used fishing nets or discard them in landfills, although it discards foamed plastics like fish boxes as "incombustible refuse." Fishing operators burn their ropes and buoys separately.

In Akkeshi, there are two companies that reprocess nylon monofilament salmon and squid driftnets into pellets. Used nets are either brought to the processors by fishing operators and net-weaving companies or gathered without charge at port collection sites. Nets purchased from net makers and repairmen cost the processors ¥20/kg. It is estimated that about 600 to 900 MT of used nets are collected within and from outside Akkeshi annually. Among them, those unfit for recycling are incinerated by the reprocessors. The rest are melted and pelletized into an estimated 450 MT at the two reprocessing companies. Before 1987, some used fishing nets were exported through trading firms to China and Taiwan to be made into valves and other products. Such exports are not carried out today because of the unfavorable prices of petroleum.

One of the two pellet processors in Akkeshi is capable of producing 1.5 MT a day in a 9-h operation, but such facilities are in operation for only about one-third of the year. The company spent ¥14 million on a washing machine and another ¥13.5 million on a machine for melting and pelletizing plastics, with the total investments estimated to be some ¥60 million, including the land and building. The monthly production of 15 MT of pellets requires ¥740,000, including ¥200,000 for fuel and electricity and ¥520,000 for 100 man-days of labor.

## Wakkanai

### Use of Fishing Nets

As of 1987, Wakkanai had 19 boats which were allowed to fish in the offshore trawl fishery. On an average there are about 10 fishing nets for each boat; usually 2 or 3 nets are loaded on the boats, and also on board are 1 or 2 nets to be repaired. The remainder of the net supply is stored in warehouses or other locations of the fishing operators or net-weaving companies.

Damaged nets are repaired aboard the fishing boats when the damage is slight. Major repairs are made either in the fishing operators' own net-weaving shops or shops of independent net-weaving companies. Repairs usually become necessary after six or seven fishing operations; repairs

mostly concern the dislocation of rope from net mesh. Net webbing usually lasts for 2 years. Torn webbing is usually not mended, but replaced with a new section of webbing. Fishing operators spend about ¥10 million each year for net-repairing purposes.

**Scrapping of Fishing Nets**

Scraps of trawl webbing are accumulated during the process of repairing by net-weaving companies and fishing operators. About 15 to 18 MT of scrapped webbing is accumulated by net-weaving companies; the total excludes webbing used for heating purposes during winter. The amount of scrapped webbing accumulated by fishing operators is estimated at 17 MT per year.

**Disposal and Recycling of Fishing Nets**

Scrapped nets not used for heating or recycling are brought to garbage disposal plants in Wakkanai. An estimated 700 MT of fishing materials are brought to landfills annually, accounting for 1.6% of the municipal total in 1987. Of the 700 MT, nets made up 80% and ropes, 20%.

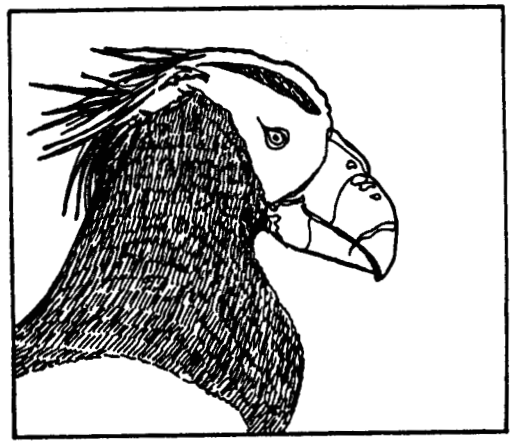
Some of the scrapped nets are incinerated at establishments of net makers and fishing operators. Here, stoves used as heaters during winter burn nets exclusively (or together with waste oil). This is probably the most popular method of used trawl net recycling practiced in Wakkanai.

Between 1982 and 1987, a producer of animal feed in Wakkanai used scrapped trawl nets as an auxiliary fuel in its coal boiler. To operate the boiler the company burned 30 used 12-MT truck tires every day and burned 2 to 3 MT of scrapped fishing nets every year. The feed producer obtained these nets free of change at net-repairing shops.

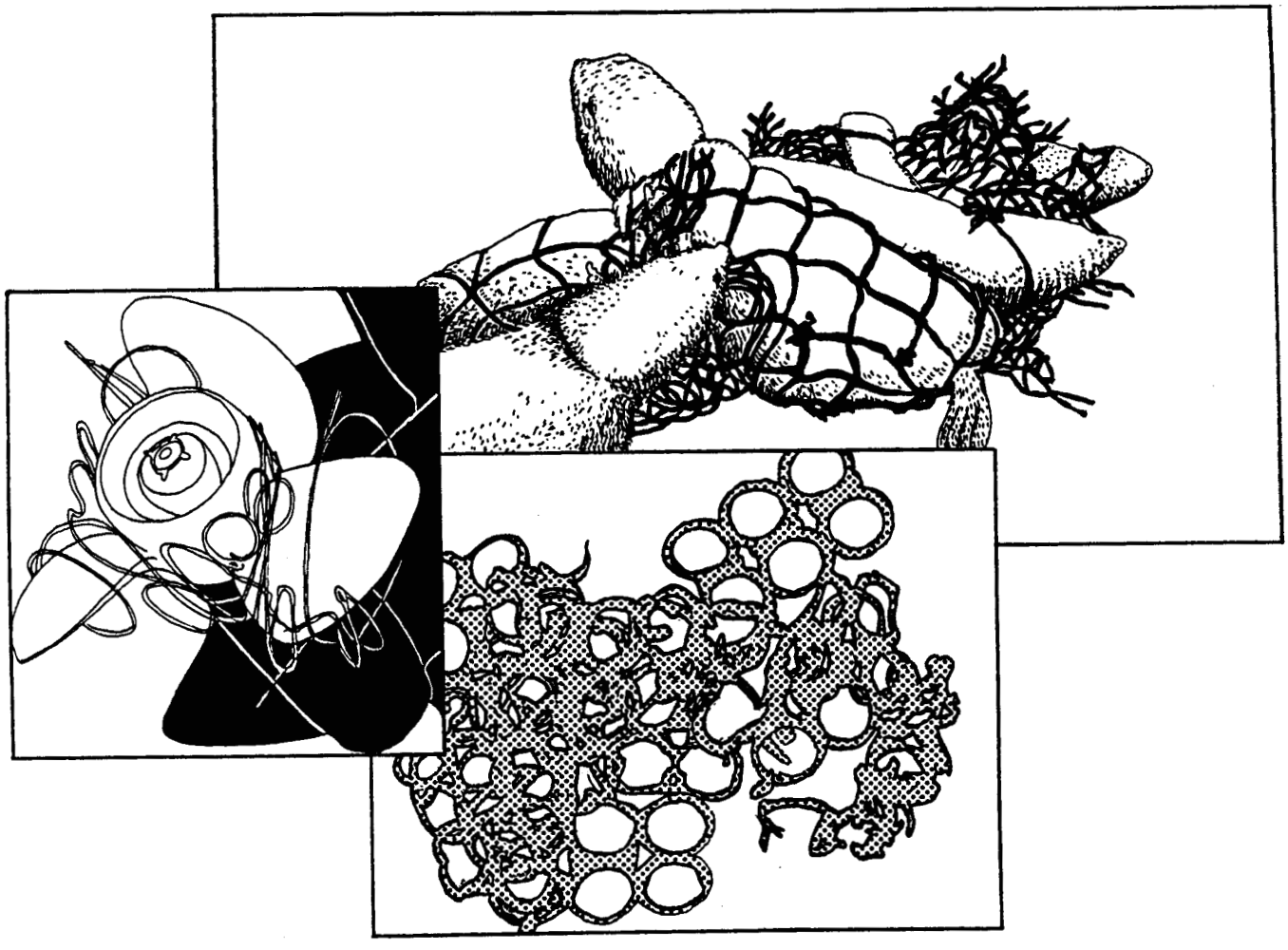
**ACKNOWLEDGMENTS**

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# SESSION VI



## SOLUTIONS THROUGH LAW AND POLICY



# STATUS OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY MARINE DEBRIS ACTIVITIES AND PROGRAMS

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## ABSTRACT

The U.S. Environmental Protection Agency (EPA) issued on 18 January 1989 an Interim National Coastal and Marine Policy (NCMP), which addresses marine debris as one aspect of a number of marine degradation problems. This policy states that one of EPA's goals is the recovery of full use of shores, beaches, and water by reducing sources of plastics, floatables, and debris.

The EPA's objectives include:

1. To control disposal of medical wastes and aggressively enforce laws to protect the public from exposure to them.

2. To accelerate efforts to identify the sources of floatables, debris, and plastics.

3. To control these materials through new technologies and substitutes, permitting, and enforcement, as well as aggressive source reduction and waste minimization programs.

This paper summarizes the status and progress of many EPA activities and programs aimed at addressing and implementing the marine debris aspects of the NCMP.

## DISCUSSION

Plastic debris in the marine environment has been shown to kill or harm marine life, damage vessels, and cause aesthetic and economic damage to beach communities.

The Final Report of the Interagency Task Force on Persistent Marine Debris (1988) described the potential sources of marine debris and separated these sources into two categories: ocean sources and land-based sources. Ocean sources include commercial fishing vessels, recreational

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

boating, merchant vessels, cruise ships, military and research vessels, and offshore oil rigs and supply vessels. Land-based sources include plastic manufacturing and processing activities, combined sewer overflows (CSO's) and sewage treatment plants, solid waste management practices, and litter. Debris from these sources washes up on U.S. beaches and clogs our waterways. Last summer's problems on the northeastern U.S. beaches show the large-scale impact that marine debris can have.

On 18 January 1989, the U.S. Environmental Protection Agency (EPA) issued an interim National Coastal and Marine Policy (EPA 1989b), which included the agency's position on marine debris.

The EPA is taking action against many of the sources of marine debris described above and the problems they pose. These actions include

- assessment of the items that make up marine debris and their sources,
- assessment of the specific items released to the environment from CSO's and storm sewers,
- medical waste tracking,
- enforcement,
- public education,
- cleanup plans.

Some of EPA's activities are described below in relation to the authority under which they are being implemented.

## MARINE PLASTIC POLLUTION RESEARCH AND CONTROL ACT OF 1987

The Marine Plastic Pollution Research and Control Act (P.L. 100-220) (MPPRCA) contains several sections pertaining to plastics and marine debris. Among these are:

1. The development of regulations by the U.S. Coast Guard implementing the requirements of MARPOL Annex V. These regulations set forth the restrictions for disposal of garbage from ships and include prohibition of the disposal of plastics.
2. An assessment of the effects of plastic materials on the marine environment by the Secretary of Commerce.
3. The development of a joint public education program by EPA, the U.S. National Oceanic and Atmospheric Administration (NOAA), and the Secretary of Transportation.

4. An assessment of the problems associated with plastic debris in the New York Bight by the EPA.

5. An assessment by the EPA of methods to reduce plastic pollution.

Activities being carried on by EPA under the requirements of MPPRCA are described below.

### New York Bight Report to Congress

The EPA has prepared a report to Congress on plastics in the New York Bight (EPA 1989d), describing the types and sources of floatable debris, the fate of floatable material, the recreational activities, control programs, and recommendations for research, monitoring, and control. The recommendations presented in the report include:

1. Monitoring and surveillance
   - Monitor sources.
   - Monitor beaches and waterways.
2. Local control measures
   - Improve combined sewer overflows.
   - Increase street cleaning.
   - Remove debris from beaches and waterways.
   - Encourage volunteer cleanup activities.
   - Develop public awareness and education campaigns.
3. Research
   - Study the rates of plastic degradation.
   - Study degradable plastics and potential applications.
   - Develop cost-effective recycling approaches.

### Public Awareness and Citizen Monitoring

The EPA is working with the NOAA, the Coast Guard, and other agencies in developing citizen monitoring and cleanup patrols and a public awareness program on marine debris. To date, this has included the financial support for this conference, the Second International Conference on Marine Debris held in Hawaii, financial support for the 1988 beach cleanups conducted during Coastweeks by the Center for Environmental Education (now the Center for Marine Conservation (CMC)), and sponsorship of an upcoming informal

roundtable meeting on marine debris. The EPA will be using the results of the Hawaii conference and the roundtable meeting to plan future national-level public education activities.

These future activities will also be developed using the results of the Washington State Marine Debris Task Force studies, where EPA is working with the State of Washington and many Federal, state, and local groups to combat local marine debris problems. This task force, which was set up by Washington State on its own initiative, has pulled together Federal, state, and local interests and published a report (Marine Plastic Debris Task Force 1988). The report makes a variety of recommendations for controlling, monitoring, and removing marine debris. The recommendations already implemented, such as a state information coordinator, derelict fish net removal, and a citizen monitoring program, will be evaluated by EPA as potential activities to be included in the national program to be coordinated with other Federal agencies.

### New York Bight Restoration Plan

A New York Harbor Floatables Action Plan (EPA 1989a) was developed as part of the New York Bight Restoration Plan. This floatables action plan describes the routine and responsive monitoring and cleanup activities that will occur in New York Harbor to remove floating debris that may cause environmental, aesthetic, and economic damage. The plan includes:

1. routine monitoring and cleanup of debris (particularly during times of extreme high tides or major storm events) using vessels, helicopters, and planes to monitor and specially designed vessels to cleanup debris;

2. development of a reporting and action network to report sightings of debris;

3. a contingency plan using the reporting network to activate the cleanup vessels to respond to reports of debris sightings.

### Methods to Reduce Plastic Pollution

The EPA is preparing a report, due to Congress in the summer of 1989, which describes:

- the production of and major markets for plastics in the United States;

- the generation of plastic waste in the United States;

- the impacts of plastics on the management of solid wastes in the United States including transportation, disposal in landfills, and incineration;

- the sources, fates, and effects of plastics in the marine environment;
- an evaluation of potential solutions such as source reduction, use of degradable plastics, recycling, and substitution; and
- recommendations for action.

In assessing the potential sources and fates of plastics for this report to Congress, EPA has funded several field investigations. One such study was the 1988 CMC beach cleanups previously mentioned. These data will help determine the distribution of plastic articles on our nation's beaches and will be useful in determining which items are most prevalent and where EPA must focus more effort. The 1988 data and data from previous beach cleanups will be a useful baseline in estimating the effect of the U.S. regulations to implement MARPOL Annex V and other mitigation efforts. Future beach surveys will be used in an attempt to indicate trends and possibly show the effectiveness of the new controls on shipboard sources of plastic debris. It may still be difficult, however, to determine which plastic articles found on beaches come from shore-based sources and which come from vessels.

To determine the variability of plastic items in inshore waters and to assess the harbors as potential sources of debris in other coastal areas, the EPA has also conducted field investigations of the floating debris in several U.S. harbors through a contract to Battelle Ocean Sciences of Duxbury, Massachusetts (December 1988-February 1989). Harbors surveyed include Boston, New York, Philadelphia, Baltimore, Miami, Seattle, Tacoma, San Francisco, and Oakland. These surveys were conducted by towing surface nets through slicks of floating debris and then sorting, identifying, and counting the contents. Plastic items 0.3 mm and larger were studied, yielding information on not only the larger plastic items readily observed on beaches but also on the smaller plastic pellets and pieces which are not so obvious to a casual observer. The final EPA report of these surveys is currently being prepared. A summary of preliminary results is presented by Trulli et al. (1990). The preliminary findings of these surveys indicates that the presence of certain plastic items can be directly linked to the presence of CSO's where storm water and street runoff combine with sewage at times of heavy rain and are discharged directly into receiving water.

The apparent correlation between certain debris items and the presence of CSO's is the basis for a new study, being designed by Battelle Ocean Sciences, where the materials released from several of the CSO's in two cities, Philadelphia and Boston, will be identified and quantified. To do this, EPA will be placing nets around the outfalls from selected CSO's in these cities (May-June 1989) to collect the materials exiting the system during dry weather and during rainy conditions. The results of this study will directly address CSO's as a source of debris, and will be used by the agency in determining the appropriate actions to be taken under the Clean Water Act. Storm drains will also be sampled during this study to determine their contribution to marine debris.

## LITTER FROM VESSEL TRANSPORT OF SOLID WASTE

The Shore Protection Act (P.L. 100-688, Sections 4001-4204) provides for controls on operations relating to the vessel transport of certain solid wastes (i.e., municipal or commercial waste) so that these wastes are not deposited in coastal waters.

The EPA is developing guidance with the Coast Guard to minimize deposition of solid wastes into coastal waters during loading, transporting, or unloading. A permit and enforcement program is being developed by the U.S. Department of Transportation such that all vessels transporting solid wastes would require a permit from the Coast Guard. It is estimated that about 400 vessels will need permits--about 100 in the New York Harbor area and 300 in the Gulf of Mexico, plus a few in other locations.

Under this act, EPA is also preparing a report to Congress describing the need and effectiveness of a tracking system for vessels transporting wastes in U.S. waters. Such a tracking system could be used to monitor the movement of wastes in U.S. waters and provide the agency with a mechanism for assuring that wastes are not illegally discharged.

In New York Harbor, an area where large volumes of trash are transported by barges, the State and City of New York have strengthened the requirements for trash barges. The implementation of these requirements is expected to minimize the loss of trash during the marine transport process. The new requirements include:

- limitations on load heights in barges;
- the placement of booms around marine transfer facilities;
- the use of scavenger vessels at marine transfer facilities to collect trash which falls into the water;
- the use of covers over barges to keep the wind from blowing trash off barges.

## MEDICAL WASTE--TRACKING AND DISPOSAL

The Medical Waste Tracking Act of 1988 (P.L. 100-582) requires EPA to develop a 2-year demonstration program for the tracking of medical wastes. This program would track the generation and movement of medical wastes from "cradle to grave."

The EPA has prepared an Interim Final Regulation (EPA 1989e) which describes a tracking system to be used by the states participating in the demonstration program. Medical wastes from generators of 22.7 kg (50 lb) or greater per month would have to track the movement of their wastes to the point of final disposition. Generators of less than 22.7 kg (<50 lb) per month have the same requirements but need to keep logs for their medical wastes rather than initiate tracking forms. It is anticipated that

this tracking system will allow EPA to monitor the movement of medical wastes from the point of generation to final disposal and will assure that the wastes are not disposed of illegally where they may endanger public health or degrade the marine environment.

The U.S. Public Vessel Medical Waste Anti-Dumping Act of 1988 (P.L. 100-688 Sections 3101-3105) requires that all public vessels have a management plan for medical wastes on board ship and prohibits the disposal of these wastes at sea except in times of national emergency. The EPA is distributing guidance to all EPA programs that operate boats and ships. The guidance states EPA's policy that all medical wastes generated on board an EPA vessel will be stored in a secure area on board for disposal at an appropriate shore-based facility upon return from sea. No medical wastes can be thrown overboard. Other Federal agencies are also required by the act to issue similar guidance.

## COMBINED SEWER OVERFLOWS AND STORM SEWERS

The Clean Water Act (33 U.S.C. 1251 et seq.) requires EPA to regulate discharges from municipal and industrial outfalls into U.S. waters. Under this authority, the agency recently developed a strategy for enforcing the provisions of the act regarding CSO's (EPA 1989c), which are significant sources of plastic street debris entering the marine environment.

The strategy requires that all CSO's be identified and categorized according to their status of compliance with technology and water quality-based regulations. There are about 1,200 combined sewer systems in the United States serving an estimated population of 43 million. States will be required to develop a state-wide strategy for the development and implementation of measures to reduce pollutant discharges from CSO's.

The EPA strategy sets forth three objectives:

1. to ensure that all CSO discharges occur only as a result of wet weather;

2. to bring all wet weather CSO discharge points into compliance with the technology-based requirements of the Clean Water Act and applicable state water quality standards; and

3. to minimize water quality, aquatic biota, and human health impacts from wet weather overflows that do occur.

The strategy confirms that CSO's are point sources independent of the treatment works and reaffirms that both technology-based and water quality-based requirements apply to CSO's. The strategy emphasizes that CSO point sources which are discharging without a permit are unlawful and must be issued permits or eliminated.

The agency has also proposed regulations which will describe the effluent requirements for storm sewers (EPA 1988). By controlling

the effluent from CSO's and storm drains, the agency hopes to significantly curtail the discharge of sewage and sewage-related plastics and street litter into the marine environment at times of heavy rain. To implement the types of controls available for long-term solutions will require major resource expenditures.

## ENFORCEMENT ACTIONS

The Ocean Dumping Regulations (40 CFR parts 220-229), which implement a section of the Marine Protection, Research, and Sanctuaries Act (MPRSA) (33 U.S.C. 1401 et seq.), were promulgated in 1977. These regulations prohibit the transport for the purpose of dumping into the ocean of any "persistent inert synthetic or natural materials which may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing, navigation, or other legitimate uses of the ocean." Activities involving transport for the purpose of disposal at sea are regulated under this act, and permits granted by the agency prohibit the dumping of floatable plastics. Any activity involving the transport of floatable plastics or debris out to sea for the purpose of dumping is illegal, and subject to the fines and penalties described under the act.

Under this authority, EPA has initiated enforcement actions against Nassau County and the City of Long Beach, in New York, and National Seatrade, Inc., for the disposal of sludge containing plastics at the 170.5-km (106-mi) sewage sludge disposal site.

The agency is seeking a total of $100,000 in fines for these violations of the MPRSA. The county, city, and National Seatrade, which barges treated sewage sludge, are charged with one violation which occurred in September 1988 when EPA staff observed floatables being dumped along with sewage sludge from the county and city at the 170.5-km (106-mi) site. The proposed civil penalty for this violation is $50,000. The city is also charged in a second count with sending floatables along with its sludge to be ocean dumped in December 1988. The proposed penalty for this violation is $50,000.

## CONCLUSION

The EPA is taking steps to identify and control sources of marine debris, to cleanup existing marine debris, and to involve and educate the public through cooperation with other Federal, state, and local groups. Through a combined effort, EPA hopes to greatly reduce the volume of marine debris generated and its impacts. The EPA believes that one of the primary steps in reaching this goal is to control nondegradable debris before it becomes marine debris--that is, to control it at its source. This should include source reduction and recycling as well as general pollution prevention. Wastes must be managed correctly not only by transport and disposal companies but also by the consumer. Litter thrown into the streets or directly into waterways does have an impact on the marine environment. Plastic items flushed down toilets can, in some cities, end up in the ocean through combined sewer overflows or treatment plant shutdowns. The actions being taken today by EPA as well as other Federal, state, and local

agencies will have a beneficial impact on the environment. These actions must be supplemented, however, by consumers. Proper handling of discarded items by consumers is essential for the trash and sewage collection systems to work. It is the responsibility of all Federal, state, and local agencies to get this message out and build a national/world environmental ethic, or we will be forever cleaning up our environment rather than enjoying and benefiting from it.

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# INTERNATIONAL REGULATIONS FOR THE PREVENTION AND CONTROL OF POLLUTION BY DEBRIS FROM SHIPS

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(The views expressed herein are those of the authors and are not necessarily those of the International Maritime Organization.)

## ABSTRACT

The amount of solid wastes entering the world's oceans each year is estimated to be in millions of metric tons. The sea floor, water surface, and beaches of the Earth's marine environment are littered with man-made materials. Studies show that most of the refuse washed up on beaches comes from ships. The International Maritime Organization, being responsible for the prevention and control of marine pollution from ships, adopted in 1973 the International Convention for the Prevention of Pollution from Ships. This convention, as modified by the 1978 Protocol hereafter referred to as MARPOL 73/78, applies to any ship of any type whatsoever. It covers all aspects of intentional pollution from ships by oil (Annex I), noxious substances carried in bulk (Annex II), or in packaged forms (Annex III), sewage (Annex IV), and garbage (Annex V).

The Annex V of MARPOL 73/78, entitled "Regulations for the Prevention of Pollution by Garbage from Ships," entered into force on 31 December 1988. In order to assist governments in developing and enacting domestic laws which would implement Annex V, the Marine Environment Protection Committee of the International Maritime Organization developed the Guidelines for the Implementation of Annex V of MARPOL 73/78. The guidelines are discussed in this paper.

## INTRODUCTION

A considerable amount of debris originating from ships is disposed of at sea. Garbage from ships has traditionally been dumped into the sea as a matter of course and in proportion to the amount of similar wastes poured into the sea each year from the land. The quantities of waste disposed of in this way in the past are not considered excessive.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Today, however, the situation is very different. One reason is the growing everyday use of substances such as plastics which are nonbiodegradable: Once thrown into the sea, they are extremely persistent and potentially harmful if ingested by seabirds and marine mammals. Also, the aesthetic quality of coastlines and beaches has been devalued by the accumulation of such wastes.

Studies carried out in the United Kingdom by The Tidy Britain Group in 1978-79 showed that most of the refuse washed up on British beaches came from ships. Of some 20,000 items recovered, 42% were plastic (mostly containers of household products such as disinfectants, bleach, and washing-up liquid) and 22% metal. Of the latter, more than two-thirds turned out to be drink cans (International Maritime Organization (IMO) 1988b).

The amount of wastes generated by ships can be prodigious. A study carried out by a marine biologist at Newcastle University in 1982 showed that during a 44-day voyage, the 46 members of a merchant ship's crew dumped overboard 320 cardboard or paper boxes, 370 plastic beer-can holders, 162 crisp packets, 19 plastic bags, 2 plastic drums, 240 bottles, 5 glasses, 5,176 cans, and 2 metal drums. Not surprisingly perhaps, the same survey showed that of 600 ships entering ports in South Wales in 1977-78, only 13.5% used the waste disposal facilities provided on shore (Jones et al. 1981).

More recently, a survey carried out in the German Bight showed that the minimum amount of refuse drifting between Helgoland and the Elbe estuary is approximately 8.5 million pieces annually with a weight of 1,300 metric tons (MT), and 95% of the refuse found could be attributed to shipping (Vauk et al. 1987). In the Mediterranean, litter generated by shipping and oil drilling has been estimated at $325 \times 10^6$ kg/year. The total amount of litter generated in the world's oceans each year, assuming all ships' solid wastes are disposed of overboard, has been estimated at $6.5 \times 10^6$ MT/annum (Dixon and Dixon 1983).

According to the Center for Environmental Education (1986), the worldwide rate of disposal of domestic litter from merchant ships has been estimated at 110,000 MT, 0.7% of which is plastic. The amount of cargo-associated wastes including dunnage, shoring, pallets, wires, and covers is estimated at 5.6 million MT per year. Our considerations are limited to prevention of marine pollution from ships.

## REGULATIONS DEVELOPED BY THE INTERNATIONAL MARITIME ORGANIZATION

To mitigate and control or even eliminate operational discharge from ships into the sea of all kinds of wastes including disposal of garbage, the IMO adopted in 1973 the International Convention for the Prevention of Pollution from Ships. This convention as modified by the 1978 Protocol (MARPOL 73/78) applies to any ship of any type whatsoever including hydrofoil boats, air-cushion vehicles, submersibles, floating rafts, and fixed or floating platforms operating in the marine environment. It covers all

aspects of intentional pollution from ships by oil (Annex I), noxious substances carried in bulk (Annex II) or in packaged forms (Annex III), sewage (Annex IV), and garbage (Annex V). (Annex V is attached as Appendix A.)

As of 8 February 1989, 55 states--the combined merchant fleets of which constitute 80.92% of gross tonnage of the world's merchant shipping--ratified the convention.

The Annexes III, IV, and V of MARPOL 73/78 are so-called "optional annexes." Each of them enters into force 12 months after the date on which at least 15 states with a combined merchant fleet of at least 50% of the gross tonnage of the world's merchant shipping have accepted it. With respect to Annex V, these conditions were fulfilled in December 1987, and subsequently, in accordance with the provisions of article 15(2) of the MARPOL Convention, this annex entered into force on 31 December 1988.

Thirty-nine states--the combined merchant fleets of which constitute 56.6% of gross tonnage of the world's merchant shipping--ratified Annex V. As of 8 February 1989, the states that have accepted Annex V are: Algeria, Antigua and Barbuda, Austria, Belgium, China, Colombia, Cote d'Ivoire, Czechoslovakia, Democratic People's Republic of Korea, Denmark, Egypt, Finland, France, Gabon, German Democratic Republic, Federal Republic of Germany, Greece, Hungary, Italy, Japan, Lebanon, Marshall Islands, Netherlands, Norway, Oman, Panama, Peru, Poland, Portugal, St. Vincent and Grenadines, Suriname, Sweden, Tunisia, Tuvalu, United Kingdom, U.S.S.R., United States, Uruguay, and Yugoslavia.

**ANNEX V**

The purpose of Annex V, in particular, is to prevent pollution caused by dumping into the sea all kinds of solid waste garbage, which includes inter alia all plastics, synthetic ropes, synthetic fishing nets, and plastic garbage bags. Disposal into the sea of all plastics is completely prohibited in all areas. However, some other forms of garbage may be disposed of at sea under strictly controlled conditions.

Dunnage, lining, and packing materials can only be disposed of at sea more than 25 nmi from land. Food wastes and all other garbage (including paper products, rags, glass, metal, bottles, and crockery) cannot be disposed of at sea within 12 nmi of land. Even stricter controls apply in sea areas called "special areas." For the purpose of Annex V, the special areas are: The Mediterranean Sea Area, the Baltic Sea Area, the Black Sea Area, the Red Sea Area, and the Gulfs Area. The Gulfs Area means the sea area located northwest of the rhumb line between Ras al Hadd (lat. 22°30'N, long. 59°48'E) and Ras al Fasteh (lat. 25°04'N, long. 61°25'E).

In order for ships to fully comply with the requirements on disposal of garbage within the special areas, they should be provided at ports and terminals in that area with facilities for the reception of garbage, without causing undue delay to ships.

Therefore, the government of each party to the convention whose coastline borders a special area is obliged to ensure that as soon as possible in all ports within the area, adequate reception facilities will be provided in accordance with Annex V regulations, taking into account the special needs of ships operating therein.

The IMO, after receiving notification from all governments of the states bordering a special area where adequate reception facilities have been provided, establishes the date when the requirements of the regulations on special areas shall take effect.

So far, only the states of the Baltic Sea Area (Denmark, Finland, German Democratic Republic, Federal Republic of Germany, Poland, Sweden, and U.S.S.R.) have notified IMO that requirements concerning provision of adequate reception facilities in that area have been fulfilled. The IMO notified all parties to the convention that 1 October 1989 was the established date, and starting on that date, the requirements on disposal of garbage within the Baltic Sea Area took effect (Resolution Marine Environment Protection Committee (MEPC) 31(26) adopted on 9 September 1988).

The establishment of special requirements for disposal of garbage from fixed and floating platforms is incorporated in Annex V. The disposal of any materials regulated by Annex V is completely prohibited from fixed and floating platforms which are engaged in exploration, exploitation, and associated offshore processing of seabed mineral resources, and from all other ships when alongside or within 500 m of such platforms.

The exception is the disposal into the sea of food wastes, which are permitted when they have been passed through a comminuter or grinder, but only when such fixed or floating platforms are located more than 12 nmi from land and all other ships are alongside or within 500 m of such platforms.

Limitations on the discharge of garbage from ships, as specified in Annex V, are summarized in Table 1.

## GUIDELINES FOR THE IMPLEMENTATION OF ANNEX V OF MARPOL 73/78

The MEPC of the IMO at consecutive sessions in 1987 and 1988 considered the problem of implementation of Annex V. The working groups on optional annexes, under the chairmanship of T. A. Wastler for the 24th and 25th sessions and D. B. Pascoe for the 26th session, both chairmen from the United States, worked on the development of the Guidelines for the Implementation of Annex V of MARPOL 73/78, which were approved at the 26th session of MEPC, 5-9 September 1988 (IMO 1988a).

The main objectives of these guidelines are to (1) assist governments which have ratified Annex V in developing and enacting domestic laws which give force to and implement Annex V; (2) assist vessel operators in complying with the requirements set forth in Annex V and domestic laws;

Table 1.--Summary of at-sea garbage disposal regulations, MARPOL, Annex V.

| Garbage type | All ships except platforms[a] | | Offshore platforms[a] |
|---|---|---|---|
| | Outside special areas | In special areas[b] | |
| Plastics--includes synthetic ropes and fishing nets and plastic garbage bags | Disposal prohibited | Disposal prohibited | Disposal prohibited. |
| Floating dunnage, lining, and packing materials | >25 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| Paper, rags, glass, metal, bottles, crockery, and similar refuse | >12 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| All other garbage including paper rags, glass, etc., comminuted or ground | >3 nmi from nearest land | Disposal prohibited | Disposal prohibited. |
| Food waste not comminuted or ground | >12 nmi from nearest land | >12 nmi from nearest land | Disposal prohibited. |
| Food waste comminuted or ground[c] | >3 nmi from nearest land | >12 nmi from nearest land | >12 nmi from nearest land. |
| Mixed refuse types | (d) | (d) | (d) |

[a]Offshore platforms and associated ships include all fixed or floating platforms engaged in exploration or exploitation of seabed mineral resources, and all ships alongside or within 500 m of such platforms.

[b]Garbage disposal regulations for special areas shall take effect in accordance with regulation 5(4)(b) of Annex V.

[c]Comminuted or ground garbage must be able to pass through a screen with mesh size no larger than 25 mm.

[d]When garbage is mixed with other harmful substances having different disposal or discharge requirements, the most stringent disposal requirements shall apply.

Note: The Baltic Sea Special Area Disposal Regulations take effect on 1 October 1989.

and (3) assist port and terminal operators in assessing the need for and providing adequate reception facilities for garbage generated on different types of ships.

The guidelines are divided into seven categories that provide a general framework upon which governments will be able to formulate programs for education and training of seafarers and others who must comply with the regulations; methods of reducing shipboard generation of garbage; shipboard garbage handling and storage procedures; shipboard equipment for processing garbage; estimation of the amounts of ship-generated garbage delivered to port; and actions to ensure compliance with the regulations.

Recognizing that Annex V regulations promote waste management systems for ships, and that ships vary tremendously in size, mission, complement, and capability, these guidelines include a range of waste management options that may be combined in many ways to facilitate compliance with Annex V. Further, recognizing that waste management technology for ships is in an early stage of development, it is recommended that governments and the IMO continue to gather information and review these guidelines periodically.

The convention provides definitions for terms used throughout these guidelines which establish the scope of Annex V requirements. These definitions are incorporated in Section 1 as follows:

- "Food waste" is any spoiled or unspoiled victual substance such as fruits, vegetables, dairy products, poultry, meat products, food scraps, food particles, and all other material contaminated by such waste generated aboard ship, principally in the galley and dining areas.

- "Plastic" is any solid material which contains as an essential ingredient one or more synthetic organic high polymers and which is formed (shaped) by heat and/or pressure during either manufacture of the polymer or its fabrication into a finished product. Plastics have material properties ranging from hard and brittle to soft and elastic. Plastics are used for a variety of marine purposes including, but not limited to, packaging (vapor-proof barriers, bottles, containers, liners), ship construction (fiberglass and laminated structures, siding, piping, insulation, flooring, carpets, fabrics, paints and finishes, adhesives, electrical and electronic components), disposable eating utensils and cups, bags, sheeting, floats, fishing nets, strapping bands, and rope and line.

- "Domestic waste" includes all types of food wastes and wastes generated in the living spaces on board ship.

- "Cargo-associated waste" is all materials which have become wastes as a result of use for cargo stowage and handling on board ship. Cargo-associated waste includes but is not

limited to dunnage, shoring, pallets, lining and packing materials, plywood, paper, cardboard, wire, and steel strapping.

- "Maintenance waste" is materials collected by the engine and deck departments while maintaining and operating the vessel, such as soot, machinery deposits, scraped paint, deck sweeping, wiping wastes, and rags.

- "Operational waste" is all cargo-associated waste and maintenance waste, and cargo residues defined as garbage in "Cargo residues" (see below).

- "Dishwater" is the residue from the manual or automatic washing of dishes and cooking utensils which have been precleaned to the extent that any food particles adhering to them would not normally interfere with the operation of automatic dishwashers. "Gray water" is drainage from dishwater, shower, laundry, bath, and washbasin drains and does not include drainage from toilets, urinals, hospitals, and animal spaces or drainage from cargo spaces.

- "Oily rags" are rags which have been saturated with oil as controlled in Annex I to the convention. "Contaminated rags" are rags which have been saturated with a substance defined as a harmful substance in the other annexes to the convention.

- "Cargo residues," for the purposes of these guidelines, are defined as remnants of any cargo material on board that cannot be placed in proper cargo holds (loading excess and spillage) or which remain in cargo holds and elsewhere after unloading procedures are completed (unloading residual and spillage). Cargo residues are expected to be in small quantities.

- "Fishing gear" is defined as any physical device or part thereof or combination of items that may be placed on or in the water with the intended purpose of capturing, or controlling for subsequent capture, living marine or freshwater organisms.

- "Seafarer," for the purposes of these guidelines, means anyone who goes to sea in a ship for any purpose including, but not limited to, transport of goods and services, exploration, exploitation and associated offshore processing of seabed mineral resources, fishing, and recreation.

In order to clarify the application of Annex V, the following comments and explanations were added.

- Dishwater and gray water are not included as garbage in the context of Annex V.

- Ash and clinkers from shipboard incinerators and coal burning boilers are operational wastes in the meaning of Annex V regulation 1(1) and therefore are included in the term "all other garbage" in the meaning of Annex V Regulations 3(1)(b)(ii) and 5(2)(a)(ii).

- Cargo residues are to be treated as "garbage" under Annex V except when those residues are substances defined or listed under the other annexes to the convention.

- Cargo residues of all other substances are not explicitly excluded from disposal as "garbage" under the overall definition of garbage in Annex V. However, certain of these substances may pose harm to the marine environment and because of their possible safety hazards may not be suitable for disposal at reception facilities equipped to handle general garbage. The disposal of such cargo residues should be based on the physical, chemical, and biological properties of the substance and may require special handling not normally provided by garbage reception facilities.

The remaining sections of the guidelines follow.

**Training, Education, and Information**

The definition of "ships" used in the convention requires these guidelines address not only the professional and commercial maritime community but also the noncommercial seafaring population as sources of pollution of the sea by garbage. Uniform programs in the field of training and education will make a valuable contribution to raising the level of the seafarers' compliance with Annex V, thereby ensuring compliance with the convention. Accordingly, governments should develop and undertake training, education, and public information programs suited for all seafaring communities under their jurisdictions.

Governments may exchange and maintain information relevant to compliance with Annex V regulations through the IMO. Accordingly, governments are encouraged to provide the organization with the following:

- Technical information on shipboard waste management methods such as recycling, incineration, compaction, sorting and sanitation systems, packaging, and provisioning methods.

- Copies of current domestic laws and regulations relating to the prevention of pollution of the sea by garbage.

- Educational materials developed to raise the level of compliance with Annex V. Contributions of this type include printed materials, posters, brochures, photographs, audio-

and videotapes, and films as well as synopses of training programs, seminars, and formal curriculums.

- Information and reports on the nature and extent of marine debris found along beaches and in coastal waters under their respective jurisdictions. In order to assess the effectiveness of Annex V, these studies should provide details on amounts, distribution, sources, and impacts of marine debris.

Governments are encouraged to amend their maritime certification examinations and requirements, as appropriate, to include a knowledge of duties imposed by national and international law regarding the control of pollution of the sea by garbage.

Governments are recommended to require all ships of their registry to permanently post a summary declaration stating the prohibition and restrictions for discharging garbage from ships under Annex V and the penalties for failure to comply. It is suggested this declaration be placed on a placard at least 12.5 x 20 cm made of durable material and fixed in a conspicuous place in galley spaces, mess deck, wardroom, bridge, main deck, and other areas of the ship, as appropriate. The placard should be printed in the language or languages understood by the crew and passengers.

Governments are encouraged to have maritime colleges and technical institutes under their jurisdiction develop or augment curriculums to include both the legal duties and the technical options for handling ship-generated garbage available to professional seafarers. These curriculums should also include information on environmental impacts of garbage. Suggested topics are listed below:

- Garbage in the marine environment, sources, types, and impacts.

- National and international laws related to or impinging upon shipboard waste management.

- Health and sanitation considerations related to the storage, handling, and transfer of ship-generated garbage.

- Current technology for onboard and shoreside processing of ship-generated garbage.

- Provisioning options, materials, and procedures to minimize the generation of garbage aboard ship.

Professional associations and societies of ship officers, engineers, naval architects, shipowners and managers, and seamen are encouraged to ensure their members' competency regarding the handling of ship-generated garbage.

Vessel and reception facility operators should establish training programs for personnel operating and maintaining garbage reception or processing equipment. It is suggested that the programs include instruction on what constitutes garbage and the applicable regulations for handling and disposing of it. Such training should be reviewed annually.

Generalized public information programs are needed to provide information to nonprofessional seafarers and others concerned with the health and stability of the marine environment regarding the impacts of garbage at sea. Governments and involved commercial organizations are encouraged to utilize the organization's library and to exchange resources and materials as appropriate to initiate internal and external public awareness programs.

Methods for delivering this information include radio and television, articles in periodicals and trade journals, voluntary public projects such as beach cleanup days and adopt-a-beach programs, public statements by high government officials, posters, brochures, conferences and symposia, cooperative research and development, voluntary product labeling, and teaching materials for public schools.

Audiences include recreational boaters and fishermen, port and terminal operators, coastal communities, ship supply industries, shipbuilders, waste management industries, plastic manufacturers and fabricators, trade associations, educators, and government.

The subjects addressed in these programs are recommended to include the responsibilities of citizens under national and international law; options for handling garbage at sea and upon return to shore; known sources and types of garbage; impacts of plastic debris on seabirds, fish, marine mammals, sea turtles, and ship operations; impacts on coastal tourist trade; current actions by governments and private organizations; and sources of additional information.

**Minimizing the Amount of Potential Garbage**

All ship operators should minimize the taking aboard of potential garbage and onboard generation of garbage.

Domestic wastes may be minimized through proper provisioning practices. Ship operators and governments should encourage ship's suppliers and provisioners to consider their products in terms of the garbage they generate. Options available to decrease the amount of domestic waste generated aboard ship include the following:

- Bulk packaging of consumable items. This may result in the creation of less waste, but factors such as inadequate shelf life once a container is opened must be considered to avoid increasing wastes.

- Reusable packaging and containers. This can decrease the amount of garbage being generated. Use of disposable cups,

utensils, dishes, towels and rags, and other convenience items should be limited.

- Provisions packaged in or made of materials other than disposable plastic. These should be selected to replenish ship supplies unless a reusable plastic alternate is available.

Operational waste generation is specific to individual ship activities and cargoes. It is recommended that manufacturers, shippers, ship operators, and governments consider the garbage associated with various categories of cargoes and take actions as needed to minimize their generation. Suggested actions are listed below.

- Replace disposable plastic sheeting used for cargo protection with permanent, reusable covering materials.

- Adopt stowage systems and methods that reuse coverings, dunnage, shoring, lining, and packing materials.

- Dispose of dunnage, lining, and packaging materials generated in port during cargo discharge at the port reception facilities and do not retain it on board for discharge at sea.

It may, in certain cases, be difficult for port reception facilities to handle cargo residues. They are usually created through inefficiencies in loading, unloading, and onboard handling, and it is, therefore, recommended that cargo be unloaded as efficiently as possible in order to avoid or minimize cargo residues.

Spillage of the cargo during transfer operations should be carefully controlled, both on board and from dockside. Spillage typically occurs in port. It should be completely cleaned up prior to sailing and either delivered into the intended cargo space or into the port reception facility. Shipboard areas where spillage is most common should be protected so that the residues are easily recovered.

Fishing gear once discharged becomes a harmful substance. Fishing vessel operators, their organizations, and their respective governments are encouraged to undertake such research, technology development, and regulations as may be necessary to minimize the probability of loss and maximize the probability of recovery of fishing gear from the ocean. It is recommended that fishing vessel operators record and report the loss and recovery of fishing gear. Techniques both to minimize the amount of fishing gear lost in the ocean and to maximize its recovery are listed below.

- Operators and associations of fishing vessels using untended, fixed, or drifting gear are encouraged to develop information exchanges with such other ship traffic as may be necessary to minimize accidental encounters between ships and gear.

Governments are encouraged to assist in the development of information systems where necessary.

- Fishery managers are encouraged to consider the probability of encounters between ship traffic and fishing gear when establishing seasons, areas, and gear-type regulations.

- Fishery managers and fishing vessel operators and associations are encouraged to utilize gear identification systems which provide information such as vessel name, registration number, and nationality. Such systems may be useful to promote reporting, recovery, and return of lost gear.

- Fishing vessel operators are encouraged to document positions and reasons for loss of their gear. To reduce the potential of entanglement and ghost fishing (capture of marine life by discharged fishing gear), benthic traps, trawls, and gillnets could be designed to have degradable panels or sections made of natural fiber twine, wood, or wire.

- Governments are encouraged to consider the development of technology for more effective fishing gear identification systems.

Governments are encouraged to undertake research and technology development to minimize potential garbage and its impacts on the marine environment. Following are suggested areas for such study:

- Development of recycling technology and systems for synthetic materials returned to shore as garbage.

- Development of technology for degradable synthetic materials to replace current plastic products, as appropriate. In this connection, governments should also study the impacts on the environment of the products of degradation of such new materials.

### Shipboard Garbage Handling and Storage Procedures

Compliance with limitations on the discharge of garbage from ships as specified in Annex V requires personnel, equipment, and procedures for collecting, sorting, processing, storing, and disposing of garbage. Economic and procedural considerations associated with these activities include storage space requirements, sanitation, equipment and personnel costs, and in-port garbage service charges.

In complying with the provisions of Annex V, the most appropriate procedures for handling and storing garbage on ships will vary depending on factors such as the type and size of the ship, the area of operation (e.g., distance from nearest land), shipboard garbage processing equipment and storage space, crew size, duration of voyage, and regulations and reception

facilities at ports of call. Proper handling and storage minimize shipboard storage space requirements and enable efficient transfer of retained garbage to port reception facilities.

To ensure that the most effective and efficient handling and storage procedures are followed, it is recommended that vessel operators develop waste management plans that can be incorporated into crew and vessel operating manuals. Such plans should include the appointment of an environmental control officer. The manuals should identify crew responsibilities and procedures for all aspects of handling and storing garbage aboard the ship. Procedures for handling ship-generated garbage can be divided into four phases: Collection, processing, storage, and disposal. A generalized waste management plan for handling and disposal of ship-generated garbage is presented in Table 2. Specific procedures for each phase are discussed below.

## Collection

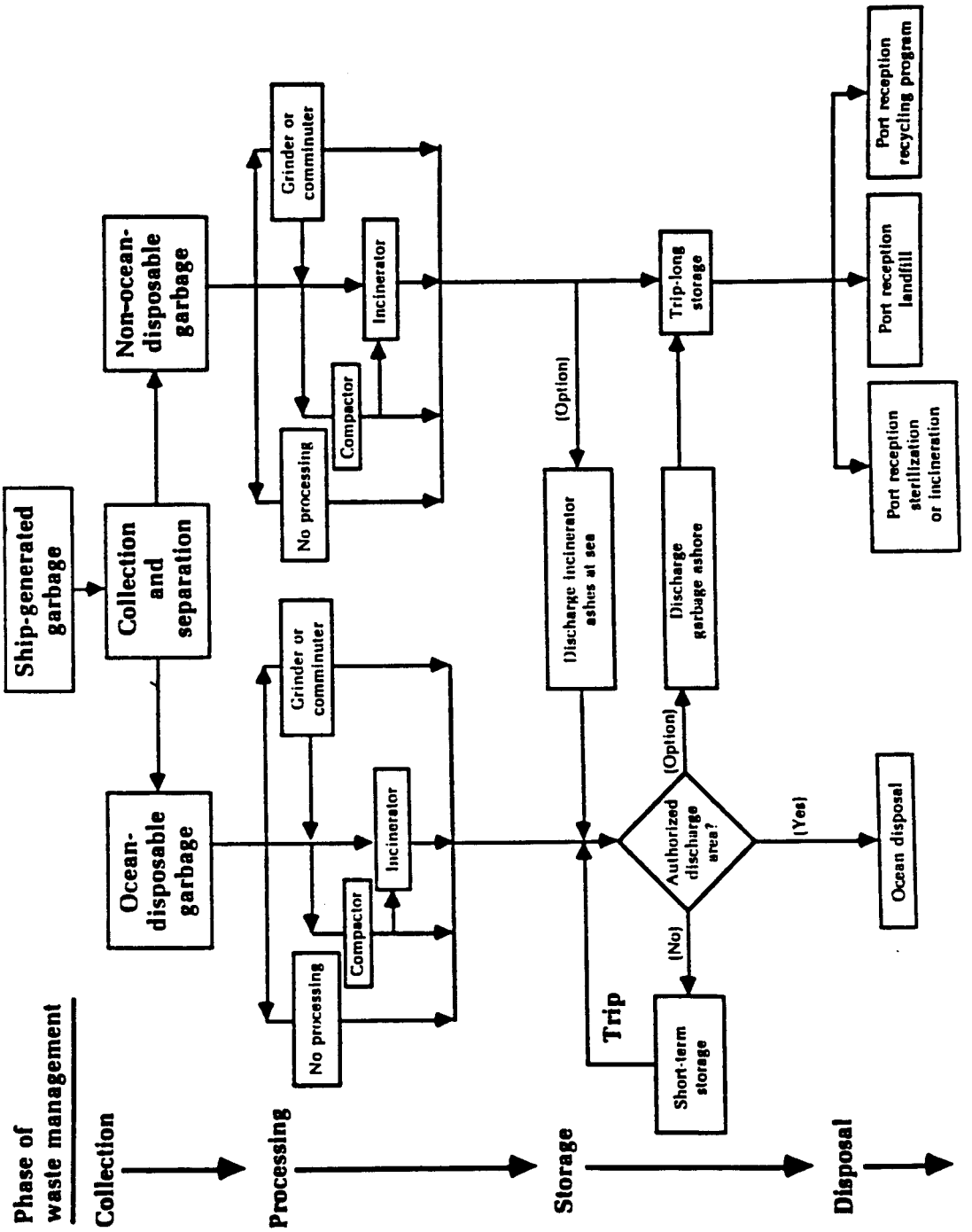
Procedures for collecting garbage generated aboard ship should be based on consideration of what can be discarded overboard while en route. To reduce or avoid the need for sorting after collection, it is recommended that three categories of distinctively marked garbage receptacles be provided to receive garbage as it is generated. These separate receptables (e.g., cans, bags, or bins) would receive (1) plastics and plastics mixed with nonplastic garbage, (2) food wastes (which includes materials contaminated by such wastes), and (3) other garbage which can be disposed of at sea. Receptacles for each of the three categories of garbage should be clearly marked and distinguishable by color, graphics, shape, size, or location. These receptacles should be provided in appropriate spaces throughout the ship (e.g., the engine room, mess deck, wardroom, galley, and other living or working spaces), and all crew members and passengers should be advised of what garbage should and should not be discarded in them. Crew responsibilities should be assigned for collecting or emptying these receptacles and taking the garbage to the appropriate processing or storage location. Use of such a system will facilitate subsequent shipboard processing and minimize the amount of garbage which must be stored aboard ship for return to port.

Separate cans or bags could be provided for receiving and storing glass, metal, plastics, paper, or other items which can be recycled. To encourage crew members to deposit such items in provided receptacles, proceeds generated from their return might be added to a ship's recreational fund.

Plastics and plastics mixed with nonplastic garbage.--Plastic garbage must be retained aboard ship for discharge at port reception facilities unless reduced to ash by incineration. When plastic garbage is not separated from other garbage, the mixture must be treated as if it were all plastic.

Synthetic fishing net and line scraps generated by the repair or operation of fishing gear may not be discarded at sea and should be

Table 2.--Options for shipboard handling and disposal of garbage.



collected in a manner that avoids its loss overboard. Such material may be incinerated, compacted, or stored along with other plastic waste, or it may be preferable to keep it separate from other types of garbage if it has strong odor or great volume.

Food wastes.--Some governments have regulations for controlling human, plant, and animal diseases that may be carried by foreign food wastes and materials that have been associated with them (e.g., food packaging and disposable eating utensils). These regulations may require incinerating, sterilizing, or other special treatment of garbage to destroy possible pest and disease organisms. Such garbage should be kept separate from other garbage and preferably retained for disposal in port in accordance with laws of the receiving country. With regard to such garbage, governments are reminded of their obligation to assure the provision of adequate reception facilities. Precautions must be taken to ensure that plastics contaminated by food wastes (e.g., plastic food wrappers) are not discharged at sea with other food wastes.

Other garbage.--Garbage in this category includes, but is not limited to, paper products, rags, glass, metal bottles, crockery, dunnage, lining, and packing materials. Vessels may find it desirable to separate dunnage, lining, and packing material, which will float, since this material is subject to a different discharge limit than other garbage in this category (Table 1). Such garbage should be kept separate from other garbage and preferably retained for disposal in port.

Oily rags and contaminated rags must be kept on board and discharged to a port reception facility or incinerated.

Recovery of garbage at sea.--Fishermen and other seafarers who recover derelict fishing gear and other persistent garbage during routine operations are encouraged to retain this material for disposal on shore. If lost pots or traps are recovered and space is not available for storage, fishermen and other seafarers are encouraged to remove and transport any line and webbing to port for disposal and return the bare frames to the water or, minimally, to cut open the traps to keep them from continuing to trap marine life.

Seafarers are further encouraged to recover other persistent garbage from the sea as opportunities arise and prudent practice permits.

Processing

Depending on factors such as the type of ship, area of operation, and size of crew, ships may be equipped with incinerators, compactors, comminuters, or other devices for shipboard garbage processing (see "Shipboard Equipment for Processing Garbage" below). Members of the crew should be assigned responsibility for operating this equipment on a schedule commensurate with ship needs. In selecting appropriate processing procedures, consider that compactors, incinerators, comminuters, and other such devices have a number of advantages, such as making it possible to discharge certain garbage at sea, reducing shipboard space requirements for storing

garbage, making it easier to off-load garbage in port, and enhancing assimilation of garbage discharged into the marine environment.

It should be noted that special rules on incineration may be established by authorities in some ports and may exist in some special areas. Incineration of the following items requires special precaution due to the potentially harmful environmental and health effects from combustion of by-products: Hazardous materials (e.g., scraped paint, impregnated wood) and certain types of plastics (e.g., polyvinyl chloride-based plastics). The problems of combustion of by-products are discussed in the section entitled "Shipboard Equipment for Processing Garbage."

Ships operating primarily in special areas or within 3 nmi of the nearest land should choose between storage of either compacted or uncompacted materials for off-loading at port reception facilities or incineration with retention of ash and clinkers. This is the most restrictive situation in that no discharge is permitted.

Compactors make garbage easier to store, to transfer to port reception facilities, and to dispose of at sea when discharge limitations permit. In the latter case, compacted garbage also may sink more readily, which would reduce aesthetic impacts in coastal waters and along beaches and perhaps reduce the likelihood of marine life ingesting or otherwise interacting with discharged materials.

Ships operating primarily beyond 3 nmi from the nearest land are encouraged to install and use comminuters to grind food wastes to a particle size capable of passing through a screen with openings no larger than 25 mm. Although larger food scraps may be discharged beyond 12 nmi, it is recommended that comminuters be used even outside this limit because they hasten assimilation into the marine environment. Because food wastes comminuted with plastics cannot be discharged at sea, all plastic materials must be removed before food wastes are ground.

**Storage**

Garbage collected from living and working areas throughout the ship should be delivered to designated processing or storage locations. Garbage that must be returned to port for disposal may require long-term storage depending on the length of the voyage or arrangements for off-loading (e.g., transferring garbage to an offshore vessel for incineration or subsequent transfer ashore). Garbage which may be discarded overboard may require short-term storage or no storage. In all cases, garbage should be stored in a manner which avoids health and safety hazards. The following points should be considered when selecting procedures for storing garbage:

- Ships should use separate cans, drums, boxes, bags, or other containers for short-term (disposal garbage) and trip-long (nondisposable garbage) storage. Short-term storage would be appropriate for holding otherwise disposable garbage while a ship is passing through a restricted discharge area.

- Sufficient storage space and equipment (e.g., cans, drums, bags, or other containers) should be provided. Where space is limited, vessel operators are encouraged to install compactors or incinerators. To the extent possible, all processed and unprocessed garbage which must be stored for any length of time should be in tight, securely covered containers.

- Food wastes and associated garbage which are returned to port and which may carry diseases or pests should be stored in tightly covered containers and be kept separate from garbage which does not contain such food wastes. Both types of garbage should be stored in separate, clearly marked containers to avoid incorrect disposal and treatment on land.

- Waste fishing gear can be stored on deck if materials have strong odors or if their size is too great to permit storage elsewhere on the ship. In cases where gear is fouled with marine growth or dead organisms, it may be reasonable to tow gear behind the vessel for a time to wash it out before storing. If it cannot be recovered by the vessel, the appropriate coastal state should be notified of its location.

- Disinfection and both preventive and remedial pest control methods should be applied regularly in garbage storage areas.

**Disposal**

Although disposal is possible under Annex V, discharge of garbage to port reception facilities should be given first priority. Disposal of ship-generated garbage must be done in a manner consistent with the regulations summarized in Table 1. When disposing of garbage, the following points should be considered:

- Garbage which may be disposed of at sea can simply be discharged overboard. Disposal of uncompacted garbage is convenient, but results in a maximum number of floating objects which may reach shore even when discharged beyond 25 nmi from the nearest land. Compacted garbage is more likely to sink and thus less likely to pose aesthetic problems. If necessary and possible, weights should be added to promote sinking. Compacted bales of garbage should be discharged over deep water (50 m or more) to prevent rapid loss of their structural integrity due to wave action and currents.

- Floating cargo-associated waste that is not plastic or otherwise regulated under other MARPOL annexes may be discharged beyond 25 nmi from the nearest land. Cargo-associated waste that will sink and is not plastic or otherwise regulated may be discharged beyond 12 nmi from the nearest land. Most cargo-associated waste is generated during the loading and unloading process, usually at

dockside. It is recommended that every effort be made to deliver these wastes to the nearest port reception facility prior to the ship's departure.

- Maintenance wastes are generated more or less steadily during the course of routine ship operations. In some cases, maintenance wastes may be contaminated with substances, such as oil or toxic chemicals, controlled under other annexes or other pollution control laws. In such cases, the more stringent disposal requirements take precedence.

- To ensure timely transfer of large quantities of ship-generated garbage to port reception facilities, it is essential for ships or their agents to make arrangements well in advance for garbage reception. At the same time, disposal needs should be identified in order to make arrangements for garbage requiring special handling or other necessary arrangements. Special disposal needs might include off-loading food wastes and associated garbage which may carry certain disease or pest organisms, or unusually large, heavy, or odorous derelict fishing gear.

## Shipboard Equipment for Processing Garbage

The range of options for garbage handling aboard ships depends largely upon costs, personnel limitations, generation rate, capacity, vessel configuration, and traffic patterns. The type of equipment available to address various facets of shipboard garbage handling include incinerators, compactors, comminuters, and their associated hardware.

### Grinding or Comminution

When not in a special area, the discharge of comminuted food wastes and all other comminuted garbage (except plastics and floatable dunnage, lining, and packing materials) may be permitted under Regulation 3(1)(c) of Annex V beyond 3 nmi from the nearest land. It is recommended that such comminuted or ground garbage not be discharged into a ship's sewage treatment system unless the system is approved for treating such garbage. Furthermore, it should not be stored in bottoms or tanks containing oily wastes. Such actions can result in faulty operation of sewage treatment or oily water separator equipment and can cause sanitary problems for crew members and passengers. Options for grinding or comminution include the following:

- A wide variety of food waste grinders are available in the market and are commonly fitted in most modern ships' galleys. These food waste grinders produce a slurry of food particles and water that washes easily through the required 25 mm screen. Output ranges from 10 to 250 L/min. It is recommended that the discharge from shipboard comminuters be directed into a holding tank when the vessel is operating within an area where discharge is prohibited.

- Size reduction of certain other garbage items can be achieved by shredding or crushing, and machines for carrying out this process are available for use on board ships.

Information on the development and use of comminuters for garbage aboard ships should be forwarded to the organization.

**Compaction**

Table 3 gives compaction information for various types of garbage.

Most garbage can be compacted; the exceptions include unground plastics, fiber- and paperboard, bulky cargo containers, and thick metal items. Pressurized containers should not be compacted since they present an explosion hazard.

Compaction can reduce the volume of garbage into bags, boxes, or briquettes. When these compacted slugs are equally formed and structurally strong, they can be piled up in building block form; this permits the most efficient use of space in the storage compartments. The compaction ratio for normal mixed shipboard garbage may range as high as 12:1.

Some of the available compactors have options such as sanitizing, deodorizing, adjustable compaction ratios, bagging in plastic or paper, boxing in cardboard (with or without plastic or waxed paper lining), and baling. Paper or cardboard tends to become soaked and weakened by moisture in the garbage during long periods of onboard storage. There have also been problems due to the generation of gas and pressure which can explode tight plastic bags.

If grinding machines are used prior to compaction, the compaction ratio can be increased and the storage space decreased.

A compactor should be installed in a compartment with adequate room for operating and maintaining the unit and storing trash to be processed. The compartment should be located adjacent to the areas of food processing and commissary storerooms. If not already required by regulations, it is recommended that the space have freshwater washdown service, coamings, deck drains, adequate ventilation, and hand or automatic fixed fire fighting equipment.

Information on the development and use of shipboard compactors should be forwarded to the organization.

**Incineration**

Compared to the technology of land-based incineration, the state of the art in marine incinerators is not highly advanced, primarily because the technology has not yet been subject to constraints on air emissions or on the types of materials that could be incinerated. Marine incinerators in current use are predominately designed for intermittent operation and hand stoking, and typically do not include any provisions for air pollution

Table 3.--Compaction guide for shipboard-generated garbage.

| Typical examples | Special handling by vessel personnel before compaction | Compaction characteristics | | | Onboard storage space |
|---|---|---|---|---|---|
| | | Rate of alteration | Retainment of compacted form | Density of compaction form | |
| Metal food and beverage containers, glass, small wood pieces | None | Very rapid | Almost 100% | High | Minimum |
| Comminuted plastics, fiber and paper-board | Minor--reduce material to size for feed, minimal manual labor | Rapid | Approximately 80% | Medium | Minimum |
| Small metal drums, uncomminuted cargo packing, large pieces of wood | Moderate--longer manual labor time required to size material for feed | Slow | Approximately 50% | Relatively low | Moderate |
| Uncomminuted plastics | Major--very long manual labor time to size material for feed; usually impractical | Very slow | Less than 10% | Very low | Maximum |
| Bulky metal cargo containers, thick metal items | Impractical for shipboard compaction not feasible | Not applicable | Not applicable | Not applicable | Maximum |

control. Control of air pollution is normally required in many ports in the world. Prior to using an incinerator while in port, permission may be required from the port authority concerned. In general, the use of shipboard garbage incinerators in ports in or near urban areas should be discouraged, as their use will add to possible air pollution in these areas.

Table 4 is a guide for incineration of garbage, including combustibility, reduction of volume, residual materials, exhaust, onboard storage space, and any required special handling by vessel personnel. With the exception of metal and glass, most garbage is amenable to incineration.

In contrast to land-based incinerators, shipboard incinerators must be as compact as practicable, and with operating personnel at a premium, automatic operation is desirable. Most shipboard incinerators are designed for intermittent operation: The waste is charged to the incinerator, firing is started, and combustion typically lasts for 3 to 6 h.

Commercial marine incinerators currently available vary greatly in size, have natural or induced draft, and are hand-fired. It should be noted that incinerator ratings are usually quoted on the basis of heat input rate rather than on a weight charged basis because of the variability of the heat content in the wastes. Some modern incinerators are designed for continuous firing and can handle simultaneous disposal of nearly all shipboard waste.

Some of the advantages of the most advanced incinerators are: They operate under negative pressure, they are highly reliable since they have few moving parts, they require minimal operator skill, they are light in weight, and they have low exhaust and external skin temperatures.

Some of the disadvantages of incinerators are: The possible hazardous nature of the ash or vapor; dirty operation; excessive labor required for charging, stoking, and ash removal; and the probability of not meeting air pollution regulations imposed in certain harbors. Some of these disadvantages can be remedied by automatic equipment for charging, stoking, and discharging ash into the sea outside areas where such discharge is prohibited. The additional equipment to perform these automatic functions requires more installation space.

The incineration of predominantly plastic wastes, considered under some circumstances in complying with Annex V, requires more air and much higher temperatures for complete destruction. If plastics are to be burned in a safe manner, the incinerator should be suitable for the purpose; otherwise, the following problems can result:

- Depending on the type of plastic and conditions of combustion, some toxic gases can be generated in the exhaust stream, including vaporized hydrochloric (HCl) and hydrocyanic (HCN) acids. These and other intermediary products of plastic combustion can be extremely dangerous.

Table 4.--Incineration[a] guide for shipboard-generated garbage.

| Typical examples | Special handling by vessel personnel before incineration | Incineration characteristics | | | | Onboard storage space |
|---|---|---|---|---|---|---|
| | | Combustibility | Reduction of volume | Residual | Exhaust | |
| Paper packaging, food and beverage containers | Minor--easy to feed into hopper | High | Over 95% | Powder ash | Possibly smoky and not hazardous | Minimum. |
| Fiber and paperboard | Minor--reduce material to size for feed; minimum manual labor | High | Over 95% | Powder ash | Possibly smoky and not hazardous | Minimum. |
| Plastic packaging, food and beverage containers | Minor--easy to feed into hopper | High | Over 95% | Powder ash | Possibly smoky and hazardous based on incinerator design | Minimum. |
| Plastic sheeting, netting, rope, and bulk material | Moderate manual labor time for size reduction | High | Over 95% | Powder ash | Possibly smoky and hazardous based on incinerator design | Minimum. |
| Rubber hoses and bulk pieces | Major manual labor time for size reduction | High | Over 95% | Powder ash | Possibly smoky and hazardous based on incinerator design | Minimum. |
| Metal food and beverage containers | Minor--easy to feed into hopper | Low | Less 10% | Slag | Possibly smoky and not hazardous | Moderate. |
| Metal cargo, bulky containers, thick metal items | Major manual labor time for size reduction (not easily incinerated) | Very low | Less 5% | Large metal fragments and slag | Possibly smoky and not hazardous | Maximum. |
| Glass food and beverage containers | Minor--easy to feed low into hopper | Low | Less 10% | Slag | Possibly smoky and not hazardous | Moderate. |
| Wood, cargo containers and large wood scraps | Moderate manual labor time for size reduction | High | Over 95% | Powder ash | Possibly smoky and not hazardous | Minimum. |

[a]Check local rules for possible restrictions.

- The ash from the combustion of some plastic products may contain heavy metal or other residues which can be toxic and should, therefore, not be discharged into the sea. Such ash should be retained on board where possible, and discharged at port reception facilities.

- The high temperatures generated during incineration of primarily plastic wastes may damage some garbage incinerators.

Plastic incineration requires 3 to 10 times more combustion air than average municipal refuse. If the proper level of oxygen is not supplied, high levels of soot will form in the exhaust stream.

Certain ship classification societies have established requirements for the operation or construction of incinerators. The International Association of Classification Societies can provide information as to such requirements.

Information on the development and utilization of marine garbage incinerator systems for shipboard use should be forwarded to the organization.

**Port Reception Facilities for Garbage**

Governments are urged to initiate at the earliest opportunity studies into the provision of reception facilities at ports in their respective countries. They should carry out the studies in close cooperation with port authorities and other local authorities responsible for garbage handling. Such studies should include information such as port-by-port listing of available garbage reception facilities, the types of garbage they are equipped to handle (e.g., food wastes contaminated with foreign disease or pest organisms, large pieces of derelict fishing gear, or refuse and operational wastes only), their capacities, and any special procedures required to use them. Governments should provide the results of their studies to the organization for inclusion in the Annex V library.

While selecting the most appropriate type of reception facility for a particular part, consideration should be given to several alternative methods available. In this regard, floating plants such as barges or self-propelled ships might be considered more effective for collection of garbage in a particular location than land-based facilities.

The equipment for treatment and disposal of garbage is a significant factor in determining the adequacy of a reception facility. It not only provides a measure of the time required to complete the process, but it also is the primary means for ensuring that ultimate disposal of the garbage is environmentally safe.

Governments, in assessing the adequacy of reception facilities, should also consider the technological problems associated with the treatment and disposal of garbage received from ships. Although the establishment of

waste management standards is not within the scope of the convention, governments should take responsible actions within their national programs to consider such standards.

The methodology for determining the adequacy of a reception facility should be based on the needs of each type of ship as well as the number and types of ships using the port. The size and location of a port should be considered in determining adequacy. Emphasis should also be given to calculating the quantities of ship-generated garbage not discharged into the sea in accordance with the provisions of Regulations 3, 4, and 5 of Annex V.

Vessel, port, and terminal operators should consider the following when determining quantities of garbage on a per ship basis:

- type of garbage,
- ship type and design,
- ship operating route,
- number of persons on board,
- duration of voyage,
- time spent in areas where discharge into the sea is prohibited or restricted, and
- time spent in port.

It should be noted that reception procedures may differ, and port reception may require onboard separation of food wastes (e.g., raw meat because of risk of animal diseases), cargo-associated waste, and domestic and maintenance waste.

The purpose of these guidelines will be attained if they provide the necessary stimulus to governments to initiate and continue studies of reception facilities and of treatment and disposal technology. Information on developments in this respect should be forwarded to the organization.

## Ensuring Compliance With Annex V

Recognizing that direct enforcement of Annex V regulations, particularly at sea, is difficult to accomplish, governments are encouraged to consider not only restrictive and punitive measures but also the removal of any disincentives, creation of positive incentives, and the development of voluntary measures within the regulated community when developing programs and domestic legislation to ensure compliance with Annex V.

**Enforcement**

Governments should encourage their flag vessels to advise them of ports in foreign countries party to Annex V which do not have port reception facilities for garbage. This will provide a basis for advising responsible governments of possible problems and calling IMO's attention to possible infractions. An acceptable reporting format is in Appendix B.

Governments should establish a documentation system (e.g., letters or certificates) for ports and terminals under their jurisdiction having adequate facilities for receiving ship-generated garbage. Periodic inspection of the reception facilities is recommended.

Governments should identify appropriate enforcement agencies providing legal authority, adequate training, funding, and equipment to incorporate the enforcement of Annex V regulations into their responsibilities. In those cases where customs of agricultural officials are responsible for receiving and inspecting garbage, governments should ensure that the necessary inspections are facilitated as much as possible.

Governments should consider, where applicable, the use of garbage discharge reporting systems for ships (e.g., existing ship's deck logbook or record books). Such logs should, at a minimum, document the date, time, location by latitude and longitude or name of port, type of garbage (e.g., food, refuse, cargo-associated waste, or maintenance waste), and estimated amount of garbage discharged. Particular attention should be given to the reporting of:

- the loss of fishing gear,
- the discharge of cargo residues,
- any discharge in special areas,
- discharge at port reception facilities, and
- discharge of garbage at sea.

The issue of documents or receipts by port reception facilities might also assist the reporting system.

**Encouraging and Facilitating Compliance**

The augmentation of port reception facilities to serve ship traffic without undue delay or inconvenience may require capital investment from port and terminal operators as well as the waste management companies serving those ports. Governments are encouraged to evaluate means within their authority to lessen this impact, thereby helping to ensure that garbage delivered to port is actually received and disposed of properly at reasonable costs or without charging special fees to individual ships. Such means include, but are not limited to:

- tax incentives;
- loan guarantees;
- public vessel business preference;
- special funds to assist in problem situations such as remote ports with no land-based waste management systems to receive ships' garbage;
- government subsidies and special funds to help defray the cost of a bounty program for lost, abandoned, or discarded fishing gear or other persistent garbage. The program would make appropriate payments to persons who retrieve such fishing gear or any persistent garbage other than their own from marine waters under the jurisdiction of a government.

The installation of shipboard garbage processing equipment would facilitate compliance with Annex V and lessen the burden on port reception facilities to process garbage for disposal. Therefore, governments should consider actions to encourage the installation of certain types of garbage processing equipment on ships operating under their flag. For example, programs to lessen costs of purchasing and installing compactors, incinerators, and comminuters during construction of new ships would be very helpful.

Governments are encouraged to consider the economic impacts of domestic regulations intended to force compliance with Annex V. Unrealistic regulations may lead to higher levels of noncompliance than would an education program without specific regulatory requirements beyond Annex V itself. Due to the highly variable nature of ship operations and configurations, it seems appropriate to maintain the highest possible level of flexibility in domestic regulations to permit ships the greatest range of options in complying with Annex V.

Governments are encouraged to support research and development of technology that will simplify compliance with Annex V regulations for ships and ports. This research should concentrate on:

- shipboard waste-handling systems;
- ship provision innovations to minimize garbage generation;
- loading and unloading technology to minimize dunnage, spillage, and cargo residues; and
- new ship construction design to facilitate garbage management and transfer.

Governments are encouraged to work within the organization to develop port reception systems that simplify the transfer of garbage for international vessels.

**Voluntary Measures**

Governments are encouraged to assist ship operators' and seafarers' organizations in developing resolutions, bylaws, and other internal mechanisms that will encourage compliance with Annex V regulations. These groups include seamen's and officers' unions, associations of ship owners and insurers and classification societies, and pilot associations and fishermen's organizations.

Governments are encouraged to assist and support where possible the development of internal systems to promote compliance with Annex V in port authorities and associations, terminal operators' organizations, stevedores' and longshoremen's unions, and land-based waste management authorities.

## CONCLUSIONS

The legal framework for international cooperation in the protection of the marine environment from pollution caused by disposal into the sea of garbage from ships was given effect with the entry into force of Annex V of MARPOL 73/78 on 31 December 1988 (Marine Environment Protection Committee of the International Maritime Organization 1988).

First priority was given to the uniform implementation of Annex V through the development and enactment of enabling domestic laws. It is envisaged that the guidelines described in this paper will facilitate this process and improve the effectiveness of these measures to prevent pollution of the seas by garbage from ships.

The next step will necessarily be the encouragement of the widest possible acceptance and implementation of Annex V by states. The IMO Secretariat has integrated implementation of Annex V into its technical assistance Program for the Protection of Marine Environment. It can, therefore, be expected that global and regional workshops and seminars will be organized by IMO in cooperation with interested international and regional organizations with the aim of familiarizing experts, in particular those from developing countries, with the regulations and guidelines and providing advice on their implementation.

In 1981, the IMO assembly of its member states adopted Resolution A.500(XIII). The crux of this resolution is the agreement that it is undesirable to amend existing conventions unless they have been in force for a reasonable period of time and experience has been gained regarding the costs to the maritime industry of their operation and the burden on the legislative and administrative resources of IMO member states. The principle endorsed is that new conventions or amendments to existing conventions should be considered on the basis of a "clear and well-documented demonstration of compelling need."

After further practical experience has been gained with the implementation and enforcement of Annex V, there will doubtless be suggestions coming forth on strengthening the provisions of the annex and on further elaborating the guidelines. These suggested changes are likely to include:

- a requirement that individual waste management plans be developed for particular categories of vessels;
- a requirement that log entries be made for all waste garbage disposal practices to facilitate port control;
- requirements concerning standards of the garbage handling equipment to be installed on ships;
- a requirement concerning garbage separation on board ships; and
- guidelines on incineration of garbage on board ships.

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## APPENDIX A

## ANNEX V

## REGULATIONS FOR THE PREVENTION OF POLLUTION BY GARBAGE FROM SHIPS

### Regulation 1

### Definitions

For the purposes of this Annex:

(1) "Garbage" means all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes to the present Convention.

(2) "Nearest land". The term "from the nearest land" means from the baseline from which the territorial sea of the territory in question is established in accordance with international law except that, for the purposes of the present Convention "from the nearest land" off the north eastern coast of Australia shall mean from a line drawn from a point on the coast of Australia in

latitude 11°00′ South, longitude 142°08′ East to a point in latitude 10°35′ South,
longitude 141°55′ East, thence to a point latitude 10°00′ South,
longitude 142°00′ East, thence to a point latitude 9°10′ South,
longitude 143°52′ East, thence to a point latitude 9°00′ South,
longitude 144°30′ East, thence to a point latitude 13°00′ South,
longitude 144°00′ East, thence to a point latitude 15°00′ South,
longitude 146°00′ East, thence to a point latitude 18°00′ South,
longitude 147°00′ East, thence to a point latitude 21°00′ South,
longitude 153°00′ East, thence to a point on the coast of Australia in latitude 24°42′ South, longitude 153°15′ East.

(3) "Special area" means a sea area where for recognized technical reasons in relation to its oceanographical and ecological condition and to the particular character of its traffic the adoption of special mandatory methods for the prevention of sea pollution by garbage is required. Special areas shall include those listed in Regulation 5 of this Annex.

### Regulation 2

### Application

The provisions of this Annex shall apply to all ships.

## Regulation 3

### Disposal of Garbage Outside Special Areas

(1) Subject to the provisions of Regulations 4, 5, and 6 of this Annex:

(a) the disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags is prohibited;

(b) the disposal into the sea of the following garbage shall be made as far as practicable from the nearest land but in any case is prohibited if the distance from the nearest land is less than:

(i) 25 nautical miles for dunnage, lining and packing materials which will float;

(ii) 12 nautical miles for food wastes and all other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse;

(c) disposal into the sea of garbage specified in sub-paragraph (b)(ii) of this Regulation may be permitted when it has passed through a comminuter or grinder and made as far as practicable from the nearest land but in any case if prohibited if the distance from the nearest land is less than 3 nautical miles. Such comminuted or ground garbage shall be capable of passing through a screen with openings no greater than 25 millimetres.

(2) When the garbage is mixed with other discharges having different disposal or discharge requirements the more stringest requirements shall apply.

## Regulation 4

### Special Requirements for Disposal of Garbage

(1) Subject to the provisions of paragraph (2) of this Regulation, the disposal of any materials regulated by this Annex is prohibited from fixed or floating platforms engaged in the exploration, exploitation and associated offshore processing of seabed mineral resources, and from all other ships when alongside or within 500 metres of such platforms.

(2) The disposal into the sea of food wastes may be permitted when they have been passed through a comminuter or grinder from such fixed or floating platforms located more than 12 nautical miles from land and all other ships when alongside or within 500 metres of such platforms. Such comminuted or ground food wastes shall be capable of passing through a screen with openings no greater than 25 millimetres.

## Regulation 5

### Disposal of Garbage Within Special Areas

(1) For the purposes of this Annex the special areas are the Mediterranean Sea area, the Baltic Sea area, the Black Sea area, the Red Sea area and the "Gulfs area" which are defined as follows:

(a) The Mediterranean Sea area means the Mediterranean Sea proper including the gulfs and seas therein with the boundary between the Mediterranean and the Black Sea constituted by the 41°N parallel and bounded to the west by the Straits of Gibraltar at the meridian of 5°36'W.

(b) The Baltic Sea area means the Baltic Sea proper with the Gulf of Bothnia and the Gulf of Finland and the entrance to the Baltic Sea bounded by the parallel of the Skaw in the Skagerrak at 57°44.8'N.

(c) The Black Sea area means the Black Sea proper with the boundary between the Mediterranean and the Black Sea constituted by the parallel 41°N.

(d) The Red Sea area means the Red Sea proper including the Gulfs of Suez and Aqaba bounded at the south by the rhumb line between Ras si Ane (12°8.5'N, 43°19.6'E) and Husn Murad (12°40.4'N, 43°30.2'E).

(e) The "Gulfs area" means the sea area located north west of the rhumb line between Ras al Hadd (22°30'N, 59°48'E) and Ras al Fasteh (25°04'N, 61°25'E).

(2) Subject to the provisions of Regulation 6 of this Annex:

(a) disposal into the sea of the following is prohibited:

(i) all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags; and

(ii) all other garbage, including paper products, rags, glass, metal, bottles, crockery, dunnage, lining and packing materials;

(b) disposal into the sea of food wastes shall be made as far as practicable from land, but in any case not less than 12 nautical miles from the nearest land.

(3) When the garbage is mixed with other discharges having different disposal or discharge requirements the more stringest requirements shall apply.

(4) Reception facilities within special areas:

(a) The Government of each Party to the Convention, the coastline of which borders a special area undertakes to ensure that as soon as possible in all ports within a special area, adequate reception facilities are provided in accordance with Regulation 7 of this Annex, taking into account the special needs of ships operating in these areas.

(b) The Government of each Party concerned shall notify the Organization of the measures taken pursuant to sub-paragraph (a) of this Regulation. Upon receipt of sufficient notifications the Organization shall establish a date from which the requirements of this Regulation in respect of the area in question shall take effect. The Organization shall notify all Parties of the date so established no less than twelve months in advance of that date.

(c) After the date so established, ships calling also at ports in these special areas where such facilities are not yet available, shall fully comply with the requirements of this Regulation.

**Regulation 6**

Exceptions

Regulations 3, 4 and 5 of this Annex shall not apply to:

(a) the disposal of garbage from a ship necessary for the purpose of securing the safety of a ship and those on board or saving life at sea; or

(b) the escape of garbage resulting from damage to a ship or its equipment provided all reasonable precautions have been taken before and after the occurrence of the damage, for the purpose of preventing or minimizing the escape; or

(c) the accidental loss of synthetic fishing nets or synthetic material incidental to the repair of such nets, provided that all reasonable precautions have been taken to prevent such loss.

**Regulation 7**

Reception Facilities

(1) The Government of each Party to the Convention undertakes to ensure the provision of facilities at ports and terminals for the reception of garbage, without causing undue delay to ships, and according to the needs of the ships using them.

(2) The Government of each Party shall notify the Organization for transmission to the Parties concerned of all cases where the facilities provided under this Regulation are alleged to be inadequate.

## APPENDIX B

### FORM FOR REPORTING ALLEGED INADEQUACY OF PORT RECEPTION FACILITIES FOR GARBAGE

1. Country
   Name of port or area
   Location in the port (e.g., berth/terminal/jetty)
   Date of incident

2. Type and amount of garbage for discharge to facility:

   a. Total amount ($m^3$):

      Food waste
      Cargo-associated waste
      Maintenance waste
      Other

   b. Amount not accepted by the facility ($m^3$):

      Food waste
      Cargo-associated waste
      Maintenance waste
      Other

3. Special problems encountered:

      Undue delay
      Inconvenient locality of facilities
      Unreasonable charges for use of facilities
      Use of facility not technically possible
      Special national regulations
      Other

4. Remarks: For example, information received from port authorities or operators of reception facilities, reasons for nonacceptance (2.b above).

5. Ship's particulars:

      Name of ship
      Owner or operator
      Distinctive number or letters
      Port of registry
      Number of persons on board

_____ _____

Date of completion of form Signature of master

# REDRESSING THE PROBLEM OF PERSISTENT MARINE DEBRIS THROUGH LAW AND PUBLIC POLICY: OPPORTUNITIES AND PITFALLS

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## ABSTRACT

This paper explores a variety of legal and institutional authorities for redressing the problems of persistent plastic debris in ocean environments. A major focus is on the recently ratified Annex V of the International Convention for the Prevention of Pollution by Ships (MARPOL) and its implementing legislation in the United States, the Marine Plastic Pollution Research and Control Act of 1987. The U.S. Coast Guard's new implementing regulations are described and critiqued, and important problems in the initial implementation of these new requirements analyzed.

The discussion of MARPOL and its initial implementation will introduce two related concerns. The first is the potential for solutions to the persistent debris problem to create an entirely different set of environmental problems. For example, the apparent intention of many shipping interests to turn to on-board incineration as the preferred means of complying with MARPOL's prohibition against the disposal at sea of plastics creates potential new problems in the form of hazardous air emissions and disposal of ash at sea. The limited legal authorities for responding to those potential problems under the Resource Conservation and Recovery Act, section 311 of the Clean Water Act, and other laws are described.

A further example is the fact that the enormous public attention to the problems associated with persistent plastic debris in the oceans and elsewhere has stimulated much interest in requiring "degradable" plastics before very much is known about the environmental hazards of the products of degradation and the impact of degradability upon efforts to recycle plastics. Some of the recently enacted laws and pending legislation relating to degradable plastics are reviewed.

The second consideration raised by the discussion of MARPOL is the difficulty of addressing the problem of marine plastic pollution as a problem separate from the larger problem of the

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

proliferating use of plastics generally. The paper concludes with an appraisal of opportunities to redress marine plastic pollution by public policy measures that touch upon that problem only indirectly in the context of designing sensible overall solid waste disposal programs. Some of the key public policy issues before Congress and local legislative bodies with important implications for plastics will be addressed.

## INTRODUCTION

The first international conference on marine debris (Shomura and Yoshida 1985) was a major catalyst for a startling array of legislative and public policy initiatives to address a suddenly critical environmental problem that few had previously considered to be a problem at all. This paper examines some of the more important of these initiatives, pointing out their potential for reducing the marine debris problem, their limitations, and their possible pitfalls in terms of exacerbating other environmental problems. Finally, while the focus of the original symposium was on plastics in the marine environment, it has become increasingly clear that plastics present a variety of environmental problems, not simply in the marine environment, but elsewhere as well. As a result of this fact, this paper argues that the most significant benefits to the marine environment may come about as a result of measures that are aimed at addressing the broader set of problems for which plastics generally are responsible.

## MARPOL ANNEX V

Undoubtedly, the most significant public policy advance since the 1984 conference pertains to Annex V of the International Convention for the Prevention of Pollution from Ships, better known simply as MARPOL. As a result of the subsequent ratification of MARPOL Annex V by the United States, the Soviet Union, and a number of other countries, that international agreement banning the disposal at sea of vessel-generated plastic waste came into force on 31 December 1988. In the United States, legislation to implement Annex V and, in certain respects, to impose duties beyond those of Annex V itself, was enacted in late 1987. Most of the duties imposed by that legislation, the Marine Plastic Pollution Research and Control Act of 1987 (MPPRCA), were to take effect concurrently with the coming into force internationally of MARPOL Annex V. However, the U.S. Coast Guard has thus far published only proposed regulations to implement the new legislation. Until final regulations are promulgated, the duties imposed by MARPOL Annex V and its U.S. implementing legislation are in a sort of regulatory limbo.

Before turning to the issues that have slowed the promulgation of implementing regulations, let us review first what MARPOL Annex V is intended to do. Put simply, MARPOL Annex V, in tandem with the London Dumping Convention, makes unlawful the deliberate disposal at sea of persistent plastics. The MARPOL Annex V picks up where the London Dumping Convention leaves off; the latter prohibits the dumping of plastics from

sources other than the routine operation of the vessel itself; MARPOL Annex V, on the other hand, restricts the disposal of vessel-generated wastes at sea, requiring that certain types of waste be disposed of beyond specified distances from land and prohibiting altogether the disposal at sea of other types of waste, including all plastics. Since, from time immemorial, it has been the nearly universal practice of ships at sea to dispose of their own wastes overboard, and since plastics represent a rapidly growing fraction of the shipboard waste stream, MARPOL Annex V has the potential to reduce a significant source of marine plastic debris. How significant this source is for the most serious environmental problems associated with marine plastic debris and how much of MARPOL'S potential to cut into this source will actually be realized are still very much matters of conjecture.

In retrospect, considering the dramatic changes that MARPOL Annex V was intended to effect in the long established practices of ships at sea, it is remarkable how little controversy attended the U.S. ratification of Annex V and enactment of domestic implementing legislation for it. No significant opposition to either measure was voiced at congressional hearings, there were no contested floor amendments offered in either house of Congress, and both houses approved the legislation by unrecorded voice vote, indicating the absence of any serious opposition or controversy. Either the interests that were to be affected by the legislation had carefully considered its potential impact and concluded that those impacts were acceptable, or those interests simply failed to take notice that legislation with potentially far-reaching consequences was zipping through Congress with uncharacteristic speed. The subsequent anxieties expressed by parts of the shipping industry during the course of Coast Guard rule making incline me toward the latter explanation.

The first noteworthy aspect of MARPOL Annex V is its extraordinary scope. Prior to the coming into force of Annex V, MARPOL affected only a few large ships, the oil and chemical tankers whose operations are subject to regulation under Annexes I or II, the mandatory MARPOL annexes. Annex V, on the other hand, applies literally to "all ships," save for warships and other government-owned or operated ships being used for government noncommercial service. Thus, not just major merchant vessels, but also commercial fishing vessels, cruise liners, recreational craft, and even rowboats and canoes are subject to Annex V's proscriptions. Moreover, the U.S. domestic implementing legislation goes beyond Annex V's already broad scope by requiring military and other government vessels to comply fully within 5 years after MARPOL enters into force (i.e., by 31 December 1993).

The domestic implementing legislation expands Annex V's geographic scope as well. Whereas Annex V applies only to ships at sea, the MPPRCA applies to vessels in U.S. internal waters as well. Both foreign and U.S. vessels are subject to the U.S. law while in navigable waters or the exclusive economic zone (EEZ) of the United States. United States vessels remain subject to the proscriptions of the U.S. law wherever they may be, even beyond the U.S. EEZ. With respect to penalties for violations, MARPOL itself requires only that these "be adequate in severity to discourage violations." The U.S. implementing legislation fixes very high maximum criminal and civil penalties for violations of Annex V; indeed, they are

the same as those for violations of Annex I or II involving oil or noxious liquid substances. A knowing violation of any of the MARPOL annexes, the requirements of the implementing legislation, or regulations adopted thereunder may be punished by a fine of up to $50,000 per offense and up to 5 years in prison. A civil penalty of up to $25,000 may also be assessed for any violation of the above.

Clearly, MARPOL Annex V and its implementing legislation in the United States represent, on paper at least, a major commitment to eliminating at least one source of marine plastic debris. How will it work in practice? MARPOL Annex V does not tell a vessel operator what he should do with ship-generated plastic waste--it only tells him that he cannot dispose of it in the ocean. The Coast Guard, charged with developing regulations to implement Annex V and the MPPRCA, has not sought through those regulations to steer vessel operators in any particular direction. Rather, it too leaves up to each individual operator the decision of what to do with plastic waste.

Implicitly, there is in Annex V a sort of presumption that the best solution is to off-load any plastic waste in port. This is because Annex V not only restricts the trash disposal practices of ships, but also requires that there be adequate reception facilities for garbage at ports and terminals. There is a rather obvious ambiguity here, in that most nonplastic garbage can still be disposed of at sea. Thus, it is unclear whether to be "adequate" a reception facility must be capable of handling only ship-generated plastic waste (the only waste that cannot be disposed of at sea), or whether it must be capable of handling the much larger volume of other garbage that might--or might not--be brought back to port.

On this issue, the Coast Guard's proposed regulations basically punt. The proposed regulations include a recommended "worksheet" for estimating the likely quantity of garbage that a port or terminal may be expected to handle, but then go on to disavow the likely accuracy of the formulas in the worksheet and any intention to rely upon those formulas in determining whether a port or terminal has met its obligation to provide adequate reception facilities. Indeed, the proposed regulations rely upon a system of self-certification, and require such self-certification for only a limited number of ports, principally those that already receive ships subject to Annexes I or II. Moreover, the proposed regulations do not even require that in certifying its reception facilities as adequate, a port or terminal identify what those facilities are.

## VESSEL RESPONSE: INCINERATION AT SEA

Now, if you are a ship owner, you might at this point begin to get a bit nervous. The Coast Guard's proposed regulations were published on 27 October; Annex V was scheduled to come into force just 9 weeks later. As of that time it would no longer be lawful to dispose of plastic trash at sea, yet the availability of adequate reception facilities in port to handle any trash brought back to port had to be taken on faith. It was very clear that many of the larger shipping interests did not have that faith. In a number of public and private forums connected with the Coast

Guard rule making, two sentiments were very clearly expressed by these interests. The first was that 31 December 1988, was simply too soon to expect effective compliance with Annex V's new requirements for both ships and ports. The second was that in order to guard against the contingency that ports and terminals might in fact not have the ability to handle ship-generated garbage expeditiously or at all, larger ships would have to take care of their waste disposal problems by themselves by installing shipboard incinerators. It was rather remarkable, given the expense, potential danger, and generally primitive technology of shipboard incinerators, that installation of incinerators was the first alternative many shipping interests chose to explore, while reduction or elimination of optional plastics aboard ship seemed scarcely to have been considered.

It is unclear at this juncture just how much use of shipboard incineration will be stimulated by MARPOL Annex V, but it is very clear that it has stimulated a great deal of consideration of that option as a way of complying with the annex. Whether at-sea incineration of plastics represents a net environmental gain or merely solves one environmental problem by creating another is an open question. The Coast Guard, in its notice of proposed rule making, acknowledged that "proper disposal of incinerator ash has not been fully studied," but advised that for purposes of Annex V, ash is to be treated as operational waste that can be disposed of in the ocean beyond 3 nmi from shore. Rather more cautious advice can be found in the Guidelines for the Implementation of Annex V adopted by the Marine Environment Protection Committee of the International Maritime Organization in September 1988. Those guidelines, which are advisory only, state that the "ash from the combustion of some plastic products may contain heavy metal or other residues which can be toxic and should therefore not be discharged into the sea. Such ashes should be retained on board, where possible, and discharged at port reception facilities."

Even the more cautionary advice found in the guidelines probably understates the likelihood that incinerator ash will contain toxic heavy metals. About half of the tests that have been done of mixed bottom and fly ash, and virtually all of the tests of fly ash alone from municipal incinerators have found levels of lead or cadmium or both that exceed U.S. Environmental Protection Agency (EPA) criteria for designating such material as "hazardous waste" under the Federal Resource Conservation and Recovery Act (RCRA) (Denison and Silbergeld 1988). Plastics, some of which use lead or cadmium as stabilizers and colorants, are believed to be a major source of both of those heavy metals in municipal incinerator ash. Indeed, a recent study indicates that plastics account for 71% of the lead and 88% of the cadmium in the combustible portion of the municipal solid waste stream (Franklin Associates 1989).

The above percentages are all the more remarkable, given that plastics represent only about 7% (by weight) of the municipal solid waste stream. There is every reason to expect plastics to comprise an even greater percentage of the waste stream fed into an onboard incinerator, since it is only plastics that cannot otherwise be disposed of at sea. Thus, while lead and cadmium levels are generally high enough in municipal incinerator ash to be considered hazardous, even higher levels appear quite likely in

ash from shipboard incinerators. If that ash were brought to shore, it might have to be disposed of as hazardous waste under the RCRA. Since RCRA's reach does not extend beyond 3 nmi from shore, however, neither it nor MARPOL prohibits the disposal of the same ash directly into the sea. Section 311 of the Clean Water Act authorizes the EPA to prohibit the discharge of hazardous substances into the contiguous zone of the United States, but incinerator ash is not yet among the substances designated as hazardous under this authority.

Incineration of plastics at sea presents not only the problem of disposing of ash, but also that of controlling atmospheric emissions. Land-based incinerators are typically equipped with sophisticated technology to capture harmful flue gases and reduce particulate emissions. Emissions from land-based incinerators are closely regulated under authority of the Clean Air Act. Onboard incinerators, because of their smaller size, shorter stacks, and other limitations, are unlikely to be equipped with any sort of emission control equipment; in any event, inasmuch as vessels at sea are outside the scope of the Clean Air Act, they will not be required to control their emissions. Yet, the incineration of some plastics, in particular polyvinyl chloride, produces highly toxic, corrosive gases.

Whether widespread conversion to at-sea incineration of plastics will create a new set of environmental problems is open to debate. What is clear is at least the potential for solutions to one problem to become themselves the source of another problem. Just as the long distance transport of acid rain-causing sulphur oxides was the unforeseen result of building higher and higher emission stacks to reduce local air pollution problems, so too might some of the solutions to the environmental problems of plastic debris cause other, largely unforeseen problems.

## DEGRADABLE PLASTICS

Let me illustrate this with a discussion of a very hot topic--"degradable" plastics. The concern with the problem of marine plastic pollution has helped trigger what can only be described as an avalanche of interest among public policy makers in the subject of degradable plastics. The MPPRCA of 1987 does not merely implement MARPOL Annex V. It also directs EPA to carry out a study of the adverse environmental effects of plastics generally, and to evaluate the feasibility of making products that present a particular hazard to the environment from "degradable plastics materials." Less than a year later, in October 1988, Congress passed another law, Public Law No. 100-556, requiring EPA, within 2 years thereafter, to issue regulations requiring that "plastic ring carriers" be made of "naturally degradable material" unless doing so is infeasible or will result in byproducts of degradation that present a greater threat to the environment. Only a month earlier, Congress included in the Defense Department Authorization Act, Public Law No. 100-456, a provision (section 352) directing the Secretary of Defense to report to Congress by 1 March 1990 his recommendations concerning the substitution of "degradable plastic items for nondegradable plastic items" used by the military. The Senate also passed Senate Resolution 412, a nonbinding resolution

expressing the sense of the Senate that EPA should encourage the use of biodegradable plastic bags and other items through its regulatory and informational programs.

In addition to these enacted measures, there were also a number of other bills introduced in the last Congress that would have mandated either the study of, or use of, degradable plastics for a variety of purposes. In the new Congress, interest will almost certainly be even higher. At the state level, degradable plastics are required for beverage ring carriers in at least 17 states and for still other products in a number of states. Corn-growing states in particular have an interest in pushing degradable plastic requirements, since at least some of the technologies for producing degradable plastic utilize corn starch as the ingredient that imparts degradability. Thus, it came as no great surprise to me to learn recently that the incoming chairman of the National Governor's Association, the Governor of Iowa, has degradable plastics near the top of the environmental agenda that he wants the association to pursue.

The rush to impose degradable plastic requirements has far outpaced any reasonable understanding of the extent to which degradable plastics are actually likely to contribute to the solution of current environmental problems and the likelihood that they might exacerbate others or create altogether new ones. Some of the promoters of degradable plastics have argued that products that might otherwise entangle marine animals will be so weakened that they will be readily broken. One seldom hears acknowledged, however, that those same products, and others that never presented any entanglement threat, may, by virtue of their gradual breakdown into multiple fragments, be far more likely to contribute to the problem of ingestion than they would have done had they remained intact. As for the chemical products of degradation, the discussions to date have rarely included mention of the fact that heavy metals and other toxic chemicals are commonly used as plasticizers, stabilizers, catalysts, and colorants in a wide variety of plastics. While a plastic product remains intact, these are relatively inaccessible to the environment. As that product degrades into ever smaller pieces and shorter polymer chains, however, these same chemicals are likely to become much more accessible to the environment. My point is not to say that, on balance, degradable plastics represent a greater environmental threat than nondegradable plastics; rather, it is only to say that no one yet knows what trade-offs are involved, yet the rush by many legislators to embrace degradable plastics has nearly become a stampede.

If degradable plastics are an unlikely panacea for the problem of marine plastic pollution, what other measures beyond MARPOL itself offer some hope of redressing the problem? The limitations of MARPOL Annex V are apparent. Even assuming widespread voluntary compliance with, and effective enforcement of, its prohibitions--and such assumptions are not easily indulged--MARPOL Annex V at best only addresses a fraction of the problem. It does not touch at all the problem of lost or damaged fishing gear, or marine plastic waste that can be traced back to beach litter, storm water runoff, sewage disposal, spills associated with marine transfer of municipal waste, factory discharges into inland waters and estuaries,

and other essentially land-based sources. All water runs downhill, and at the bottom of all those hills lies the ocean. Add to this diversity of sources of marine plastic pollution the fact that the incredible penetration of the market by more and more plastic products continues unabated, and it is not difficult to look upon the task of protecting the oceans from plastic debris as a job suited for Sisyphus.

## PLASTICS IN THE SOLID WASTE STREAM

What public policy alternatives exist for making additional inroads into the marine plastic pollution problem? At least part of the answer, it seems likely, will derive from the eventual recognition that the problem of marine plastic debris is but one facet of a much larger set of problems stemming from the growing abundance of plastics in the solid waste stream.

Plastics present a number of unique problems, not just for living marine organisms, but for human communities struggling with the growing solid waste crisis. As already noted, plastics are primary contributors of some of the heavy metals in municipal incinerator ash that may cause that ash to be treated--and very expensively--as hazardous waste. In addition, the very low level of plastics recycling frustrates effective solid waste management programs.

Increasingly, many communities are recognizing that the most economical and environmentally sound response to the growing solid waste problem is to include an aggressive recycling component in their solid waste management programs. Yet, plastics in the waste stream are, by and large, replacing the very glass and metal containers that enjoy some of the highest recycling rates. Pressed on one side by the prospect of diminishing landfill capacity and on the other by the high cost of building and operating incinerators, many states and local governments are enacting laws that prescribe some minimum level of recycling of the overall municipal solid waste stream--typically at least 25% and sometimes twice that. Achieving those prescribed rates will be difficult unless either the amount of plastic in that stream is limited or the extent of plastics recycling dramatically increases. A number of communities are already trying to accomplish the former by prohibiting certain types of plastic packaging or by imposing differential taxes on certain products, with a higher tax on those made from materials not readily recycled. Suffolk County, New York, is an example. Its law prohibiting plastic bags and certain fast food packaging is serving as something of a test for how far local communities can go in banning plastic products. The plastics industry does not take this lightly. It has challenged the Suffolk County law in a New York trial court in a case entitled Society of the Plastics Industry v. County of Suffolk; the Environmental Defense Fund and the Natural Resources Defense Council have intervened in support of the county law.

Laws like that of Suffolk County are likely to become increasingly common unless dramatic strides in the recycling of plastics are made very soon. Of the more than 9 million MT (20 billion lb) of plastic in the municipal solid waste stream in 1986, only 68,000 MT (150 million lb), or

<1%, was recycled (EPA 1989). By contrast, more than 26% of paper and paperboard, and more than 50% of aluminum cans are recycled (EPA 1989). Virtually the only plastic product with a more than negligible recycling rate is the PET (polyethylene terephthalate) soft-drink bottle. However, returnable deposit legislation, which currently exists in only 10 states, represents the only significant means through which plastic bottles are currently being collected for recycling (EPA 1989). In Michigan, which has a required 10 cent deposit, the recovery rate is nearly 90%. In states without mandatory deposit legislation, there is virtually no recycling of plastic bottles. Thus, if the plastics industry wanted to give a real boost to recycling, it would break ranks with the bottling industry and support state mandatory deposit legislation.

In the long run, the amount of plastic debris in the marine environment is likely to be a function not merely of the waste disposal practices of vessels at sea, but of the laws and public policy measures that influence how much further growth of the plastics market will occur and how plastics in the solid waste stream generally are treated. Measures to mandate or encourage reusable or recyclable products, to limit product packaging, or to encourage nonplastic alternatives may ultimately contribute as much or more to the solution of the marine plastic debris problem as measures aimed directly at marine industries.

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# IMPLEMENTATION AND ENFORCEMENT OF ANNEX V OF MARPOL 73/78 IN THE UNITED STATES

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## ABSTRACT

A new, bold international law entered into placed on 31 December 1988 in response to the threat to the marine environment posed by marine debris. Annex V of MARPOL 73/78, as it is known, is the first international agreement to attempt to reduce the amounts of plastics and other garbage waste discharged into the oceans from vessels. The U.S. Coast Guard's role was to interpret broad international guidelines and directives by Congress as stated in the Marine Plastic Pollution Research and Control Act of 1987, and develop practical enforceable regulations. These regulations which were developed reflect both the Coast Guard's expertise in enforcing Annexes I and II of MARPOL 73/78, and the numerous comments received from industry and the environmental and public sectors. The resulting performance-based regulations left the details of compliance up to vessels, which were required to restrict their discharge of garbage, and to the terminals and ports, which were required to provide reception facilities for the garbage wastes. Vessels have employed numerous different strategies to comply with the regulations. These strategies range from different operational methods to the installation of large garbage-treating equipment, based on the route, passenger load, type of trade, and size of vessel. Port facilities have applied an equally diverse response to compliance.

The Coast Guard's enforcement of these regulations involves a multiagency effort. The Department of Agriculture and the National Marine Fisheries Service, NOAA, conduct enforcement in areas of their own influence and expertise. The Coast Guard expects that these enforcement strategies together with educational efforts by local captains of the port should result in a high compliance rate on the part of the shipping community.

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# THE COAST GUARD'S ANNEX V COMPLIANCE REPORT: A CASE STUDY

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## ABSTRACT

This case study documents the U.S. Coast Guard process for accomplishing the congressional mandate for a compliance report concerning the implementation of Annex V (Regulations for the Prevention of Pollution by Garbage from Ships) of MARPOL 73/78. Annex V was implemented by Title II of Public Law 100-220, the Marine Plastic Pollution Research and Control Act of 1987.

The study follows the development of an empirical methodology for assessing compliance with new regulations that implement Annex V. The goal is a report that measures the amount of Annex V garbage being brought ashore both before and after Annex V became effective. As a secondary objective, the Coast Guard would like to assess the effects of Annex V regulations on the coastal and marine environments. The project involves an evaluation of current information and its statistical validity as a preimplementation baseline. The evaluation is then used to develop a baseline estimate for the amount of Annex V garbage being generated. Once that information has been collected, a methodology for measuring Annex V compliance and for assessing the effects of Annex V regulations on the coastal and marine environments will be developed.

The Coast Guard must follow specific congressional intent for the compilation of this report. Congress required in section 2201, Title II of PL 100-220, that within 1 year from the date of enactment of the act, and every 2 years thereafter for a period of 6 years, the Coast Guard, in consultation with the Secretary of Agriculture and the Secretary of Commerce, report to them on compliance with Annex V in U.S. waters, including the waters of the U.S. exclusive economic zone. The report is to include a description of the enforcement mechanisms in place and an assessment of the need for additional enforcement authority. It must also address the extent to which garbage reception facilities have been made available at the ports, and the mechanisms used by the Coast Guard to ensure that these facilities are made available as required by Annex V.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

In preparing this report, the Coast Guard must assess the extent to which vessels dispose of floatable dunnage materials beyond 25 nmi from shore and the extent to which they wash ashore, and recommend whether Annex V should be amended to prohibit the disposal of these materials at sea. The report must also include a detailed assessment of the fines levied by foreign nations for violations of Annexes I, II, and V committed by foreign flag vessels in the U.S. exclusive economic zone. Finally, the report must summarize the education efforts undertaken to inform the public of the problem of pollution of the marine environment by improperly disposed garbage.

## HISTORY OF ENACTMENT

### MARPOL 73/78

The International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978 (MARPOL 73/78), established baseline levels of practice in attempting to mitigate or eliminate damage to the environment by pollution from vessels. The MARPOL 73/78 is built of five annexes. Each annex is concerned with preventing pollution of the world's oceans by a different product or group of products. Annex I is concerned with preventing oil pollution, Annex II with the noxious liquid substances or chemicals, Annex III with the release of packaged hazardous materials, Annex IV deals with the prevention of pollution by sewage, and Annex V with the prevention of pollution by garbage. Annexes I and II are mandatory for signatories, while Annex III, IV, and V are optional, only becoming effective 1 year from the date when at least 15 nations have ratified them. The 15 nations must represent a cumulative total of 50% of world shipping tonnage.

### The Act to Prevent Pollution From Ships

Domestic legislation was needed to implement the convention and its annexes in the United States. The MARPOL 73/78 was incorporated into U.S. law when the Act to Prevent Pollution from Ships was passed by the Congress of the United States in 1980. (For a more complete description of this process, see Whitehead 1988.) The Act to Prevent Pollution from Ships was codified in Title 33, United States Code, Sections 1901-1910.

### The Marine Plastic Pollution Research and Control Act of 1987

Scientific and environmental forums during the 1970's and 1980's highlighted the amount and impact of garbage from ships on the world's oceans. Although ocean disposal of any type of garbage presents the potential for environmental damage, plastics seemed to be the most immediate problem. The characteristics of plastics which make them useful: lightweight, strong, and persistent, make them deadly to the ocean's biota. Title II of Public Law 100-220, the Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987, implemented Annex V of MARPOL 73/78. Annex V prohibits the discharge of any plastic materials from ships at sea, limits the locations

where other garbage may be discharged, and requires signatories to provide reception facilities for the discharge of ships' garbage. Title II includes additional requirements for Annex V's implementation in the United States. One of those requirements is a report on compliance with the new law's requirements.

## COMPLIANCE REPORT REQUIREMENTS

### Provisions in the Law

Congress mandated in the law that "within 1 year after the effective date of this section, and biennially thereafter for a period of 6 years, the Secretary of the Department in which the U.S. Coast Guard is operating, in consultation with the Secretary of Agriculture and the Secretary of Commerce, shall report to the Congress regarding compliance with Annex V to the International Convention for the Prevention of Pollution from Ships, 1973, in United States waters" (P.L. 100-220).

The Congressional Record elaborated on this reporting requirement (U.S. Congress 1987). The report is required to include a description of the enforcement mechanisms in place and an assessment of the need for additional enforcement authority. It is to address the extent to which garbage reception facilities have been made available at the ports, and the mechanism used by the U.S. Coast Guard to ensure that these facilities are made available as required by Annex V. In preparing this report, the Coast Guard is to assess the extent to which vessels dispose of floatable dunnage materials beyond 25 nmi from shore and the extent to which they wash ashore, and to recomend whether Annex V should be amended to prohibit the disposal of these materials at sea. The report is to provide a detailed assessment of the fines levied by signatory nations for violations of Annexes I, II, and V by their vessels in the U.S. exclusive economic zone. Finally, the report is required to summarize the education efforts undertaken to inform the public of the problem of pollution of the marine environment by garbage that is improperly disposed of.

The Coast Guard is to solicit the advice of interested parties, including the shipping industry, ports, the commercial fishing industry, environmental groups, waste handling firms, and recreational boaters, in preparing this report. The input of industry and environmental groups is to be solicited through existing forums such as the Workshop on National Marine Pollution Problems and Needs conducted by the National Marine Pollution Planning Office of the U.S. National Oceanic and Atmospheric Administration (NOAA); the Marine Debris Roundtable, a national discussion group informally established by NOAA; the National Committee for the Prevention of Pollution, a subcommittee of the Shipping Coordinating Committee, which meets in advance of meetings of the Marine Environmental Protection Committee of the International Maritime Organization; and the National Boating Safety Advisory Council, an advisory committee to the Coast Guard that considers matters affecting recreational boating.

### Completing the Feedback Loop

The Coast Guard wants to present a complete picture to Congress in the report. The current report requirements include information on violations, facilities available, and other enforcement information. However, it does not require relative measures against which enforcement data can be viewed. The Coast Guard compiled information on various vessel classes and their contribution to the garbage load in the oceans as a required portion of the regulatory process. It is logical that the report should examine compliance by the different vessel classes already identified. Compliance and regulatory effectiveness are related, and the information would be valuable to this and other Coast Guard regulatory efforts.

The regulation's effect on the environment is another item selected for examination by the report. The law's intended result is the elimination of ship-generated plastics from the waters of the United States, and a reduction in ship-generated garbage. Measurements of amounts of plastic and other garbage in the marine environment seem a necessary part of a compliance report. The effects of the law will be seen by evaluating compliance and environmental effects.

## INITIAL PARAMETERS

### Constraints

The plan for the required and desired portions of the report filters through a screen of constraints. The first of these is that no additional funds or other resources were allocated by Congress for implementation, enforcement, or for reporting compliance. The compliance report is to be developed using such resources as can be reprogrammed within the Coast Guard. What makes this constraint more difficult to work with is the routine shortage of Coast Guard operating funds. The lack of resources is amplified by any regulatory project's ability to compete within the Coast Guard's needs for operational missions. This is particularly true when those missions include drug interdiction efforts and Maritime Defense Zone planning. Another constraint is the internal human resources available to complete the task. Those responsible for developing the regulation and enforcement plans cannot devote the necessary time to the project without seriously impairing their abiity to perform other necessary functions. A final constraint is the lack of information on the amounts, constituents, and sources of garbage in the waters of the world. Estimates and inferences are all that are currently available.

### Needs

The report will need baseline information from which to estimate compliance. Knowledge of the amount of garbage, especially plastic garbage, presently in the ocean is necessary to gauge the effectiveness of the regulatory program. The effects of plastic and other garbage on the environment prior to the regulation will also have to be assessed. Measurements of current compliance and garbage generation by vessel types need to be made or estimated if trends are to be analyzed.

The Coast Guard is interested in assistance in developing the feedback-loop items necessary for placing in perspective the measures of compliance that Congress had identified. Questions concerning data collection needs and possible measures of effectiveness need to be answered. The report's time constraints make additional resource input necessary. In this instance the resource is expertise in evaluative design.

## WORK PLAN

### Need for Action

The Coast Guard is utilizing an incremental approach for the reporting process because of the short time allotted for the entire regulatory package, including the compliance report. The incremental approach allows general planning for completion of the regulatory project, while permitting changes in detail if new techniques or resources are identified. The method for compilation of the report has not been determined, but the end points for completion, as well as resource parameters for efforts to complete the report, are known. The Coast Guard began by identifying areas in which additional information and expertise were needed. It was decided that these areas should be addressed first. Members of the Transportation System Center (TSC), U.S. Department of Transportation, were retained for this effort.

### Initial Studies

The first phase involved the search for existing information and studies. The Coast Guard was especially interested in data on the quality of the environment prior to enactment of the MPPRCA of 1987. However, it was also important to identify sources of empirical data for follow-on studies. Continuing information-gathering efforts or studies would be highly beneficial, as the data gathered would continue through the period in which the Coast Guard was interested.

The information search identified entities actively involved in surveying ocean surface debris and beach litter. Fifty organizations were identified and each was contacted by TSC representatives. Ongoing research efforts were separated and further disaggregated into one-time or continuing efforts. Twelve of the fifty organizations contacted actually had conducted ocean or beach surveys. Five of the twelve that had conducted surveys were doing so on a continuing basis. These five activities appeared to be good sources for data concerning the effects of the new regulations on the environment (U.S. Department of Transportation 1988b).

Information was also needed on the amounts of garbage being generated and preregulation vessel garbage disposal practices. Eastern Research Group had developed much of this information for the Coast Guard during the regulatory development process as part of the regulatory evaluation (U.S. Department of Transportation 1988c). The estimated garbage generation rates for various vessel types are included in Table 1.

Table 1.--Estimated annual quantitites of domestic garbage generated by vessels operating in U.S. waters.

| Source | Tons | Percentage of total |
|---|---|---|
| Merchant marine | 33,574 | 1.74 |
| Commercial passenger vessels | 283,881 | 14.71 |
| Commercial fishing | 256,494 | 13.29 |
| Recreational boating | 1,264,114 | 65.52 |
| Offshore oil and gas industry | 18,381 | 0.95 |
| Miscellaneous vessels | 1,801 | 0.09 |
| U.S. Navy | 63,356 | 3.28 |
| U.S. Coast Guard | 6,782 | 0.35 |
| U.S. Army | 539 | 0.03 |
| National Oceanic and Atmospheric Administration | 349 | 0.02 |
| Total | 1,929,271 | 100.00 |

It was apparent, even allowing for errors based on incomplete data, that recreational boating and commercial passenger and fishing vessels create most of the domestic waste (U.S. Department of Transportation 1988a). The garbage disposal practices for different classes of vessels were also estimated and are displayed in Table 2.

It was concluded that recreational boating, commercial fishing, and the U.S. Navy were the leaders in the amount of waste dumped overboard.

## METHODOLOGY DEVELOPMENT

### Requirements

The most difficult task in planning the report's completion is development of a methodology for measuring compliance with the law and the effects of the new regulations on the coastal and marine environment. Most other portions of the report are straightforward, requiring only data acquisition and formatting. Measuring compliance is another matter. The TSC began with given parameters for developing the methodology. The methodology is to rely on information already being collected by the Coast Guard or other governmental and nongovernmental agencies. The information for measuring compliance should be updated regularly, preferably on an annual basis. In the event that existing data sources and surveys are not adequate to this task, TSC is to recommend ways to acquire the appropriate data. Measurements of the effect of the law on the environment are to use only current data collection and survey efforts.

Table 2.--Estimated amount of vessel-generated domestic garbage disposed of at sea by vessels operating in U.S. waters.

| Source | Tons | Percentage of total |
|---|---|---|
| Merchant marine | 30,493 | 3.76 |
| Commercial passenger vessels | 27,846 | 3.43 |
| Commercial fishing | 256,494 | 31.63 |
| Recreational boating | 421,371 | 51.96 |
| Offshore oil and gas industry | 6,574 | 0.81 |
| Miscellaneous vessels | 1,796 | 0.22 |
| U.S. Navy | 63,356 | 7.81 |
| U.S. Coast Guard | 2,059 | 0.25 |
| U.S. Army | 539 | 0.07 |
| National Oceanic and Atmospheric Administration | 349 | 0.04 |
| Total | 810,877 | 100.00 |

**Measuring Compliance**

Measuring compliance appears to be a fairly simple task. First, find out how many entities are in the regulated population. Then ascertain what portion of the regulated population is obeying the statute. The task is complicated in this instance by the lack of available or collectable data.

The Coast Guard is the primary Federal agency source for information on vessels in the waters of the United States. However, data collection efforts are related directly to legal requirements for maintaining that information. The Coast Guard has a spectrum of information on many types of vessels. Most of the information collected by the Coast Guard is on vessels that are inspected regularly for structural, electrical, safety, and operational requirements. However, Eastern Research Group's estimate is that this population generates less than 20% of the total garbage load entering the waters of the United States. The Coast Guard collects some information on recreational boating, estimated to be the largest garbage contributor. This information is collected through random boardings by Coast Guard regular and reserve personnel and by the Coast Guard Auxiliary. However, less information is collected on recreational vessels than on commercial vessels, and collections are not made on a regular basis. The Coast Guard has virtually no contact with commercial fishing vessels, which are estimated to generate approximately 14% of the total garbage load. Finally, the estimate for the U.S. Navy's contribution to the problem made it the fourth largest contributor. The Coast Guard had no data on or regular contact with the U.S. Navy vessels.

Measurement of the amounts of garbage deposited at ports in the United States before and after implementation of the regulations is likewise hindered by the lack of data. It is apparent that current data collection efforts have to be expanded and other sources of data identified if compliance is to be adequately measured.

## Recommended Approach

The study by TSC identified methods by which current data collection shortfalls for measuring compliance with the regulations could be corrected (Department of Transportation 1989). The easiest to address are the data collection efforts associated with commercial vessels currently required to be inspected on a regular basis. Additional data collection would involve requirements associated with the implementation of Annex V. The Coast Guard could also include items associated with Annex V in its examinations of port and terminal facilities.

More information on recreational boating compliance could be obtained by modifying the data collection requirements of the random boarding program to include Annex V requirements. The Coast Guard Auxiliary could also gather information on the level of compliance observed during the courtesy marine examinations that they conduct.

The compliance levels of commercial fishing vessels could be determined by establishing a cooperative effort with the National Marine Fisheries Service (NMFS) for inspecting garbage and fishing net pieces brought in to shore when fishing vessels are off-loading their catches. This would not require an expansion of manpower efforts on NMFS' part.

The compliance level could also be better estimated by conducting in-depth studies of selected ports and vessels on a voluntary basis to observe choices of compliance methods, problems encountered, improvements, and port/vessel interactions.

## CURRENT STATUS

The Coast Guard is now processing the recommendations for action. The report is to be developed by a contractor selected through the competitive bidding process. Those entities that are currently conducting studies and surveys are being contacted to ascertain how their information may best be utilized. The Coast Guard is acting internally to effect the changes necessary to collect the additional information needed to measure compliance within the various vessel categories. The NMFS is being approached to ascertain their ability to collect data on fishing vessels returning to off-load their catch. The effort to compile the report has been an interesting exercise in measuring compliance with an environmental regulation that affects a wide range of people. Its success in aiding regulatory efforts will be important, as will the lessons learned in attempting to measure those efforts.

The opinions or assertions contained herein are those of the author and are not to be construed as official or reflecting the opinions of the

Commandant of the Coast Guard, the Chief Counsel of the Coast Guard, or the Coast Guard at large.

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# CONTROL REGULATIONS FOR DISCHARGE OF ONBOARD WASTES FROM SHIPS

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## ABSTRACT

In Japan, the disposal into the sea of waste from ships is prohibited in principle, except for its disposal in accordance with discharge standards or under emergency conditions as set forth in the Law Relating to Prevention of Marine Pollution and Maritime Disaster. Especially, the disposal of any form of plastics, including but not limited to synthetic ropes, synthetic fishing nets, cups, and bags, is not permitted. These provisions of the law apply to all ships.

## INTRODUCTION

Japan introduced regulations on waste discharge from ships by the Law Relating to the Prevention of Marine Pollution and Maritime Disaster (1970). The law went into effect in 1972, when sea areas of discharge and methods of discharge were specified. It was revised in 1988. Annex V of MARPOL 73/78 went into effect on 31 December 1988.

Wastes generated on board ship are classified in two categories: Wastes from the daily life of crews, and wastes arising from the ordinary operation of ships (e.g., fishing and dredging). Regarding wastes from the crews' daily life, the regulations are equivalent to those of Annex V, and the regulations for wastes generated during ordinary operation are in general more stringent than the annex.

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## OUTLINE OF ANNEX V TO MARPOL 73/78

The garbage subject to regulations under Annex V to MARPOL 73/78 is all kinds of victual, domestic, and operational waste, excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically. Excluded are those substances which are defined or listed in other annexes to the present convention. As to garbage disposal outside special areas, sea areas of discharge and methods of discharge are outlined for each category of garbage in Annex V. Regulations of discharge are the toughest on plastics, including fishing nets, rope, and nylon bags. Their discharge is prohibited in all areas. Dunnage, lining, and packing materials which will float must not be disposed of into the sea <25 nmi from the nearest land. Food wastes and all other garbage must not be discharged <12 nmi from land. However, they can be discharged within 3 to 12 nmi of land if they are <25 mm in size. Any garbage generated on board must not be discharged <3 nmi from land. All ships are subject to the regulations irrespective of their type, size, or usage, even a one-man pleasure boat.

## HISTORY OF DOMESTIC REGULATIONS

Japan has the Law Relating to the Prevention of Marine Pollution and Maritime Disaster (hereinafter referred to as "the marine pollution prevention law") (see Appendix A) to preserve the marine environment and protect the life, health, and assets of the people. The marine pollution prevention law in principle prohibits discharge of garbage into the sea unless it is required for emergency evacuation or force majeure and unless certain discharging standards are met. Substances subject to discharge regulations are oil, noxious liquid substances, and other garbage generated on ships, maritime facilities, and aircraft. Japan established the Law Relating to the Prevention of Maritime Pollution by Oil from Ships in 1967 to make 54 OILPOL, including a 1962 amendment, into domestic law. This law was replaced by the marine pollution prevention law in 1970 to include a 1969 amendment to 54 OILPOL, regulate discharging of garbage from ships and of oil and garbage from marine facilities, and implement measures for preventing maritime pollution by oil and other substances. In 1976, obligations to deploy oil-skimming ships, measures for prevention of maritime disaster, and the establishment of a maritime disaster prevention center were added to the law. At the same time, it was renamed the Law Relating to the Prevention of Marine Pollution and Maritime Disaster in order to specify prevention of maritime disaster as well as pollution.

In response to the London Dumping Convention, Japan revised the marine pollution prevention law in 1980 to toughen regulations by establishing controls on waste discharge from aircraft and incineration at sea, and a waste discharge confirmation system. Japan also modified the maritime pollution prevention law in 1983 to subject not only heavy oil but also light oil, noxious liquid substances in bulk, sewage, and other garbage to controls, introduce controls on structures and equipment of ships, and conduct inspection regarding the new controls in order to abide by MARPOL 73/78.

Japan has in this way gradually enhanced regulations for prevention of maritime pollution in response to an international trend and domestic public opinion, and is ready to further toughen and expand such regulations in the future.

## CONTROL OF DISCHARGE OF WASTES

Japan's marine pollution prevention law covers both Annex V to MARPOL 73/78 and the London Dumping Convention to regulate discharge of wastes. Annex V regulates garbage generated offshore, while the London Dumping Convention subjects wastes generated on shore to controls. The scope of garbage for Annex V is different from that for the London Dumping Convention, but the marine pollution prevention law unifies regulations under both. It prohibits discharge of wastes from ships in principle, and allows such discharge for emergency evacuation or force majeure and under certain conditions. The marine pollution prevention law defines "wastes" as leavings or rubbish people do not require, excluding oil, noxious liquid substances, and the like. "Discharge" is defined as any action to set afloat or drop matter into the sea. Japan has the same regulations as those under Annex I to MARPOL 73/78 on oil and under Annex II on noxious liquid substances. The marine pollution prevention law thus regulates all wastes other than oil, noxious liquid substances, and the like. It will eventually cover garbage under Annex V to MARPOL 73/78, sewage under Annex IV, and wastes generated on shore under the London Dumping Convention. The law includes waste-discharging standards in accordance with the London Dumping Convention. Hereinafter, we discuss regulations responding to Annex V under the revised marine pollution prevention law put into effect 31 December 1988 and Japan's original controls on discharge of sewage since 1972. Annex IV to MARPOL 73/78, which deals with sewage, has not taken effect, and regulations under this annex have yet to be implemented internationally.

Garbage generated on ships is divided into two categories. One is related to people's daily life and includes trash and sewage. Another covers garbage linked to routine operations of ships. Human life-related trash and sewage are limited in volume and mostly disposable in the sea. Therefore, only on large ships had such garbage been subjected to regulations on discharge. Until Annex IV and V to MARPOL 73/78 take effect, Japan will continue to separate trash from soil in discharging regulations to satisfy the respective annexes. Regulations on human life-related soil have remained unchanged even after Annex V to MARPOL 73/78 went into effect. Japan's regulations on trash were less stringent than those stipulated in the annex, and Japan revised the marine pollution prevention law to introduce regulations conforming to the annex for all ships irrespective of size or type. Under the new regulations, (1) discharge of wastes is prohibited within a distance of <3 nmi from the baseline for territorial waters, (2) discharge of plastics is totally prohibited, but those burned to powder ashes can be dischaged at and beyond a 3-nmi distance from the territorial water baseline, and (3) garbage, whose size must be reduced to <25 mm before discharging under MARPOL 73/78, must be burned to ashes or pulverized by machines meeting certain technical standards before discharge. A type certificate system is established for

the pulverizing machines. These machines are required (1) to reduce the size of any garbage put into them to <25 mm, (2) to perform normal functions despite shaking or vibrations, and (3) to be easy to maintain and clean.

"Ship" is defined under MARPOL 73/78 as a vessel of any type whatsoever operating in the marine environment, and includes hydrofoils, air-cushion vehicles, submersibles, floating craft, and fixed or floating platforms. The ship as defined in the convention thus covers both what is defined as ship and what is defined as maritime facility under the Japanese marine pollution prevention law, so that Japan has subjected both ships and maritime facilities to the same discharging regulations. A ship under the Japanese law is defined as any floating craft used for navigation in the sea. A maritime facility is defined as any structure installed in the sea to house people, treat things, transport things, or stockpile things. It excludes structures which are linked to the shore through fixed facilities for free traffic of people and those connected to the shore for discharging oil or other wastes from the shore. As to garbage generated in relation to routine ship operations, including transportation and fishing, discharging regulations under the Japanese marine pollution prevention law were already tough and almost satisfied requirements under Annex V to MARPOL 73/78. The tough regulations already limited garbage for conditional discharge to what must be disposed of in the sea and prohibited discharging of garbage other than animal waste within 50 nmi of the territorial water baseline. Therefore, Japan made only minor changes in respect to garbage generated as a result of routine ship operations. Regulations on plastics were made as tough as those on human life-related plastic trash, and a distance for prohibiting the discharge of garbage other than animal waste was cut to <12 nmi from the territorial water baseline to conform to Annex V to MARPOL 73/78.

As to garbage generated on maritime facilities in relation to their usual operations, a prohibition against discharging had already been established under the law before the latest revision and has been retained. The garbage discharging standards under the Japanese law were different from those under MARPOL 73/78, and the difference has remained even since Annex V to the convention took effect. But the overall Japanese standards sufficiently fulfill all the requirements under the convention. Furthermore, the Japanese marine pollution prevention law includes independent regulations on discharging of garbage generated on aircraft during flights.

Regulations for discharging garbage generated on ships, maritime facilities, and aircraft under the marine pollution prevention law follow.

## CONTROL OF DISCHARGE OF WASTE FROM SHIPS

### Daily Life-Related Garbage

Daily life-related garbage is garbage generated in relation to daily life of seamen and other persons on board ships.

**Waste Plastics**

Sea areas of discharge.--Waters at and beyond 3 nmi from the territorial water baseline.

Method of discharge.--The garbage must be transformed into ashes before discharging. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

**Food Wastes**

Sea area of discharge.--Waters between 3 and 12 nmi of the territorial water baseline and waters within 500 m of ships or maritime facilities engaged in mining mineral resources at or under the sea bottom beyond 12 nmi from the baseline.

Method of discharge.--The garbage must be transformed into ashes or processed by pulverizing machines meeting certain technical standards before discharging. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

Sea area of discharge.--Waters >12 nmi from the territorial water baseline.

Method of discharge.--Method of discharge is not limited. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

**Paper, Wood, and Textile Trash and Other Inflammable Garbage**

Sea area of discharge.--Waters between 3 amd 12 nmi from the territorial water baseline.

Method of discharge.--The garbage must be transformed into ashes or processed by pulverizing machines meeting certain technical standards before discharge. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

Sea area of discharge.--Waters >12 nmi from the territorial water baseline.

Method of discharge.--Method of discharge is not limited. Discharge must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in water.

**Metal, Glass, and Ceramic Trash and Other Garbage**

Sea area of discharge.--Waters between 3 and 12 nmi of the territorial water baseline.

Method of discharge.--Before discharging, the garbage must be processed by pulverizing machines meeting certain technical standards. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

Sea area of discharge.--Waters >12 nmi from the territorial water baseline.

Method of discharge.--Method of discharge is not limited. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

**Sewage**

Sea area of discharge.--All waters.

Method of discharge.--Discharging is free.

**Soil**

Sea area of discharge.--Port waters, waters within 10,000 m of a low-water line on the coast, Ise Bay, and the Seto Inland Sea.

Method of discharge.--The garbage must be pulverized before discharge. Discharging must be done under the sea surface, during navigation, in small amounts, and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

Sea area of discharge.--Waters other than the above.

Method of discharge.--Method of discharge is not limited. Discharging must be done in small amounts and as far as possible from the coast, and efforts must be made to promptly diffuse the garbage in the water.

Note: Discharging of soil is allowed in all waters for ships whose maximum accommodation capacity slips under 100 persons. It is also allowed in all waters for ships whose accommodation capacity is 100 persons or more if soil is processed by soil treatment machines meeting certain technical standards.

Sea areas of discharge (except for sewage and soil) do not include waters within 500 m of ships or maritime facilities which are engaged in mining mineral resources at or under the sea bottom. Discharging of

garbage is prohibited in such waters with the exception of food trash discharged in waters beyond 12 nmi from the territorial water baseline.

## Operation-Related Garbage

Operation-related garbage is garbage generated in relation to transportation, fishing, and other usual operations of ships.

### Garbage

Garbage with an ignition loss of 15% or less (an ash state of waste plastics) and inorganic garbage (e.g., ore powder generated on ore carriers).

Sea area of discharge.--Waters >50 nmi from the territorial water baseline.

Method of discharge.--Specific gravity must be raised to 1.2. Garbage must not be discharged in powder form. Efforts must be made to sink the garbage to the sea bottom as promptly as possible. Discharge should be avoided in waters where it is expected to affect growth of marine animals and plants.

> Note: "Ignition loss" indicates how much the mass of a garbage sample (burned garbage) dried at 105°C for 4 h is reduced after the dried sample is heated at 600°C for 2 h. Garbage with an ignition loss of 15% or less has a weight loss of 15% or less. This percentage indicates garbage which has been burned almost completely.

### Plant Garbage

Plant garbage consists of wood chips whose sizes have been reduced to 15 cm or less by pulverizing or cutting (e.g., bark generated on timber carriers).

Sea area of discharge.--Waters >50 nmi from the territorial water baseline.

Method of discharge.--Discharging must be done during navigation and in small amounts. Efforts should be made to diffuse the garbage in waters as promptly as possible. Discharging should be avoided in waters where garbage discharge is expected to affect growth of marine animals and plants.

### Animal Garbage

Animal garbage (e.g., livestock which died during transport) (excluding fresh fish and parts thereof).

Sea area of discharge.--Waters >12 nmi from the territorial water baseline.

Method of discharge.--Method of discharge is not limited, but discharge should be avoided in waters where it is expected to affect growth of marine animals and plants.

**Fish and Other Marine Animals and Their Parts**

Sea area of discharge.--Port waters within 10,000 m of a low-water line on the coast, Ise Bay, and the Seto Inland Sea.

Method of discharge.--Method of discharge is not limited, but discharge should be avoided in waters where it is expected to affect growth of marine animals and plants.

**Sewage**

Sewage--excluding waste water which does not meet the standards in Appendix B (e.g., waste water used for washing cargo holds or the deck). Waste water used for removing garbage on the deck or other places is classified as sewage. Waste water used for removing garbage accumulated on ships is deemed not sewage but the garbage itself.

Sea area of discharge.--All waters.

Method of discharge.--Method of discharge is not limited. Discharge should be avoided in waters where it may affect growth of marine animals and plants.

Notes: Sea areas of discharge for the first three categories of operation-related garbage do not include waters within 500 m of ships or maritime facilities which engage in mining mineral resources at or under the sea bottom. Discharging is prohibited in such waters.

Subject to restrictions set forth in the first three categories of operation-related garbage is garbage generated in relation to ships' usual activities including transportation, fishing, surveying, observation, and rescue operations. If there are two or more categories of garbage meeting different sets of restrictions, the appropriate regulations will be applied.

## REGULATIONS ON DISCHARGE FROM MARITIME FACILITIES

### Daily Life-Related Garbage

Daily life-related garbage is garbage generated in relation to the daily life of people on marine facilities.

The same regulations as those for control of discharge of waste from ships are applied to maritime facilities, although discharge of sewage and soil is allowed in all waters. Such discharge should be done as gradually as possible. If garbage is discharged in waters within 500 m of facilities

for mining mineral resources beyond a distance of 12 mi from the territorial water baseline, the garbage must be burned to ashes or processed by pulverizing machines meeting certain technical standards. Discharge of food waste is allowed without such processing if discharge is done as gradually as possible.

### Operation-Related Garbage

Discharge is prohibited.

## CONTROL OF DISCHARGE FROM AIRCRAFT

### Daily Life-Related Garbage

Daily life-related garbage is garbage generated in relation to daily life of people on aircraft.

**Sewage and Soil**

Sea area of discharge.--All waters.

Method of discharge.--Free discharge is allowed.

**Garbage Other Than Above**

Discharging is prohibited.

### Operation-Related Garbage

Discharging is prohibited.

## APPENDIX A

**REGULATIONS UNDER THE LAW RELATING TO THE PREVENTION OF MARINE POLLUTION AND MARITIME DISASTER: MEASURES FOR PREVENTION OF MARINE POLLUTION AND MARITIME DISASTER**

I. Preventive measures.

A. Regulations on pollution.

1. Regulations on discharge at sea.

a. From ships.

b. From maritime facilities and aircraft.

2. Regulations on incineration at sea.

3. Regulations on abandonment of ships.

B. Improvement of garbage treatment on ships.

1. Preparation of manual for the prevention of oil pollution and appointment of oil pollution supervisor.

2. Preparation of manual for the prevention of pollution by noxious liquid substances and appointment of supervisor for prevention of pollution by noxious liquid substances.

3. Preparation and maintenance of oil record book.

4. Preparation and maintenance of noxious liquid substance record book.

C. Regulations on structures and equipment of ships.

1. Structure and equipment standards.

2. Regular checks and receipt of check certificates.

D. Improvement of pollutive substance treatment: The establishment of waste oil disposal facilities and their technical standards.

E. Surveillance, patrol, and instruction.

1. Surveillance and patrol using aircraft and patrol boats.

2. Lectures, instructions.

3. Measures after pollution and disaster.

A. Elimination of pollution.

1. Obligations to report on discharge of oil or noxious liquid substances and vessel-contained noxious liquid substances.

2. Emergency measures.

3. Instructions to eliminate oil, noxious liquid substances, and garbage.

B. Establishment of pollution elimination setup.

1. Preparation of discharged oil elimination plans.

2. Obligations to set up equipment for eliminating discharged oil.

3. Maritime disaster prevention center.

C. Measures for prevention of marine fire.

1. Obligations to report on discharge of dangerous substances and fire.

2. Emergency measures.

3. Allocation of costs.

4. Disposal of assets.

5. Controls on traffic of ships.

D. Technical research and survey.

1. Survey on pollution.

2. Research and development of pollution prevention technology.

E. Penalty and administrative measures.

## APPENDIX B

### CRITERIA FOR WATER THAT CAN BE DISPOSED OF AT SEA AS OPERATION-RELATED SEWAGE

| | |
|---|---|
| Cadmium contents | 0.1 mg or less/L |
| Cyanogen contents | 1.0 mg or less/L |
| Organic phosphorus contents | 1.0 mg or less/L |
| Plumbum contents | 1.0 mg or less/L |
| Hexad chromium contents | 0.5 mg or less/L |
| Arsenic contents | 0.5 mg or less/L |
| Total mercury contents | 0.005 mg or less/L |
| Alkyl mercury contents | Not detected |
| PCB contents | 0.003 mg or less/L |
| Trichloroethylene contents | 0.3 mg or less/L |
| Perchloroethylene contents | 0.1 mg or less/L |

# MARINE PLASTIC DEBRIS: WHAT WASHINGTON STATE HAS DONE

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## ABSTRACT

This paper describes the formation of an interagency task force in Washington State to address the problem of marine plastic debris along its coast and in its waterways, and the resulting action plan.

## INTRODUCTION

Early in 1987, Commissioner of Public Lands for the State of Washington, Brian Boyle, focused his interest on how marine plastic debris was affecting Washington State's coastal and inland waters. In his role as president of the Western States Land Commissioners' Association, he was familiar with efforts in Texas to increase public awareness about marine plastic debris in that state. As the elected official charged with administering the proprietary interests in more than 2 million acres (810,000 ha) of Washington's submerged lands, the commissioner saw this issue as one of major environmental importance as well as a way to focus attention on the stewardship of the state's aquatic lands.

Recent passage of Federal legislation to prevent dumping plastic into the nation's coastal waters, and a recognition that these persistent materials ultimately pollute aquatic lands, meant that this was an issue with immediate and long-term implications for the health of the state's aquatic lands. Persistent marine debris is a highly visible warning for a wide range of environmental contaminants.

## BACKGROUND

Late in 1987, the Analysis and Planning Section of the Washington State Department of Natural Resources (DNR) researched the issue. At that time, levels of awareness varied in Washington State government about marine plastic debris and the Marine Entanglement Research Program. No comprehensive analysis of the issue had been done in Washington State, particularly in light of the recent signing by the United States of MARPOL Annex V and the passage of the Marine Plastic Pollution Research and Control Act of 1987. The interjurisdictional nature of the problem required an interagency cooperation with significant information provided by affected private and public and volunteer groups. Other state agencies and

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

organizations expressed interest and a willingness to participate with the DNR in reaching a mutually agreed course of action to develop a framework for state policy.

In January 1988, the commissioner held a briefing for key principals from affected Federal, state and local agencies, the legislature, private industry and organizations, and other interested parties. At that briefing, participants agreed to select representatives to serve on a task force that would develop a state action plan to address marine plastic debris in Washington's waters and on its shores.

## THE WASHINGTON STATE MARINE PLASTICS DEBRIS TASK FORCE

The commissioner appointed a chairman (Robert Rose) and directed DNR staff to support the effort. Each of the 30 active task force members represented an agency or organization (Fig. 1). A steering committee of six worked closely with the chairman and support staff.

The marine plastics debris task force met monthly from February through July 1988. A detailed agenda was prepared for each meeting, which lasted approximately 7 h. Meetings were advertised and open to the public, with a chance for comments scheduled at the close of each meeting. In the course of the first two meetings, the task force adopted a 6-month work program, and agreed upon its mission, goals and objectives, and policies. The task force divided itself into three working groups: environment, education, and government and economic impact. Each group was to identify issue areas and possible actions.

In following meetings, the groups examined the diverse programs and regulations administered by agencies dealing with marine debris. Each agency or organization representative developed a "Status of Marine Debris Program" sheet and presented this material to the group (Fig. 2). Each status sheet gave the name of the agency or organization, the contact person, importance of the issue, legal authority to deal with the issue, additional authorities needed, resources currently available, and a description of the 1988 action plan (Appendix A). From this information, the staff developed a matrix of the existing authorities of agencies to deal with marine plastic debris (Fig. 3).

The steering committee assembled specific issue areas identified by the task force and developed a number of draft action recommendations which conformed to the objectives and policies. With subsequent approval by the group as a whole, the chairman and steering committee then developed a brief narrative statement explaining the issue area and identifying the agencies responsible for each issue. The recommendations and preferred-lead agencies to carry out the actions were collated and organized by staff and presented to the committee. Over the course of the next two meetings, bolstered by telephone conferences and mailed-in comments, the chair and staff clarified the committee's intent. At the sixth meeting, the task force gave its final approval to the text of the report. With agreement on issue areas, lead agencies, and participating agencies, a detailed matrix was prepared so that agency or organization directors and staff could

# ACKNOWLEDGEMENTS

## Marine Plastic Debris Task Force

### Members

| AGENCY / ORGANIZATION | REPRESENTATIVE |
|---|---|
| **FEDERAL** | |
| Department of Commerce<br>National Oceanic and Atmospheric Administration | Alan Buma, LCDR |
| Department of Interior<br>Fish and Wildlife<br>National Park Service | Don Kane<br>Chuck Janda |
| Department of Transportation<br>13th Coast Guard District | Stephen D.Heath, LCDR |
| Environmental Protection Agency,<br>Region X | Michael Ryiko |
| **STATE** | |
| Department of Community Development | Sandi Benbrook<br>George Turnbull, Jr. |
| Department of Ecology | Mikel DeBuse<br>Brad Everson<br>Rhonda Hunter<br>Dennis Johnson<br>Pam Miller<br>Leighton Pratt |
| Department of Fisheries | Sally Hicks<br>Phil Kauzloric<br>Sandra O'Neill |
| Department of Natural Resources | David G. Bortz<br>Margie Reed<br>Bob Rose, Chairman<br>Glenn Yeary |
| Department of Wildlife | Steve Jeffries |
| Office of the Governor | Gerard (Sid) Sidorowicz |
| Puget Sound Water Quality Authority | Sarah Barton<br>Richard Tucker |
| State Parks and Recreation Commission | Nina Carter |
| **LEGISLATIVE** | |
| Rep. Nancy Rust, House Environmental Affairs Committee | Ya-Yee J. Van |
| Joint Select Committee Marine and Ocean Resources | Bob Butts |
| Senate Environment and Natural Resources Committee | Laurie Schock |
| **LOCAL** | |
| Association of Washington Cities | Andrea Dahl |
| Northwest Indian Fisheries | B. J. Whitener |
| Port of Seattle | Linda Cox |
| Washington Public Ports Association | Eric Johnson<br>Darrell Russell |
| **PRIVATE** | |
| Battelle Marine Research Laboratory | Betsy Brown |
| Dolco Packaging | Raye Little |
| Inner Club Boating Association of Washington | Ray Nelson |
| Marine Digest | Donna Mooney |
| Natural Resources Consultants | Jeff June |
| R. W. Beck and Associates | David E.B. Nightingale |
| Society of Plastics Engineer | Chai B. Rogers |
| **CITIZEN ORGANIZATIONS** | |
| Adopt-A-Beach,<br>c/o Volunteers for Outdoor Washington | Ken Pritchard |
| The Mountaineers | Margaret Hansen |
| Washington Citizens for Recycling | Nancy Pearson |
| Washington Environmental Council | Lisa Macchio |
| **EDUCATIONAL ORGANIZATIONS** | |
| Friday Harbor Laboratories of University of Washington | Dr. Frederick E. Ellis |
| Poulsbo Marine Science Center | Laurie Dundle |
| Seattle Aquarium | John McMahon<br>Cherie Williams |
| University of Washington/Sea Grant | Xan Augerot<br>Jim Humphreys<br>Patti Mullin |

### Other Participants

American President Lines, Ltd.

Board of Clallam County Commissioners

Board of Grays Harbor County Commissioners

Board of Jefferson County Commissioners

Board of Pacific County Commissioners

Board of San Juan County Commissioners

Board of Wahkiakum County Commissioners

Marine Resources Company

Northwest Marine Trade Association

Superintendent of Public Instruction

Washington Association of Counties

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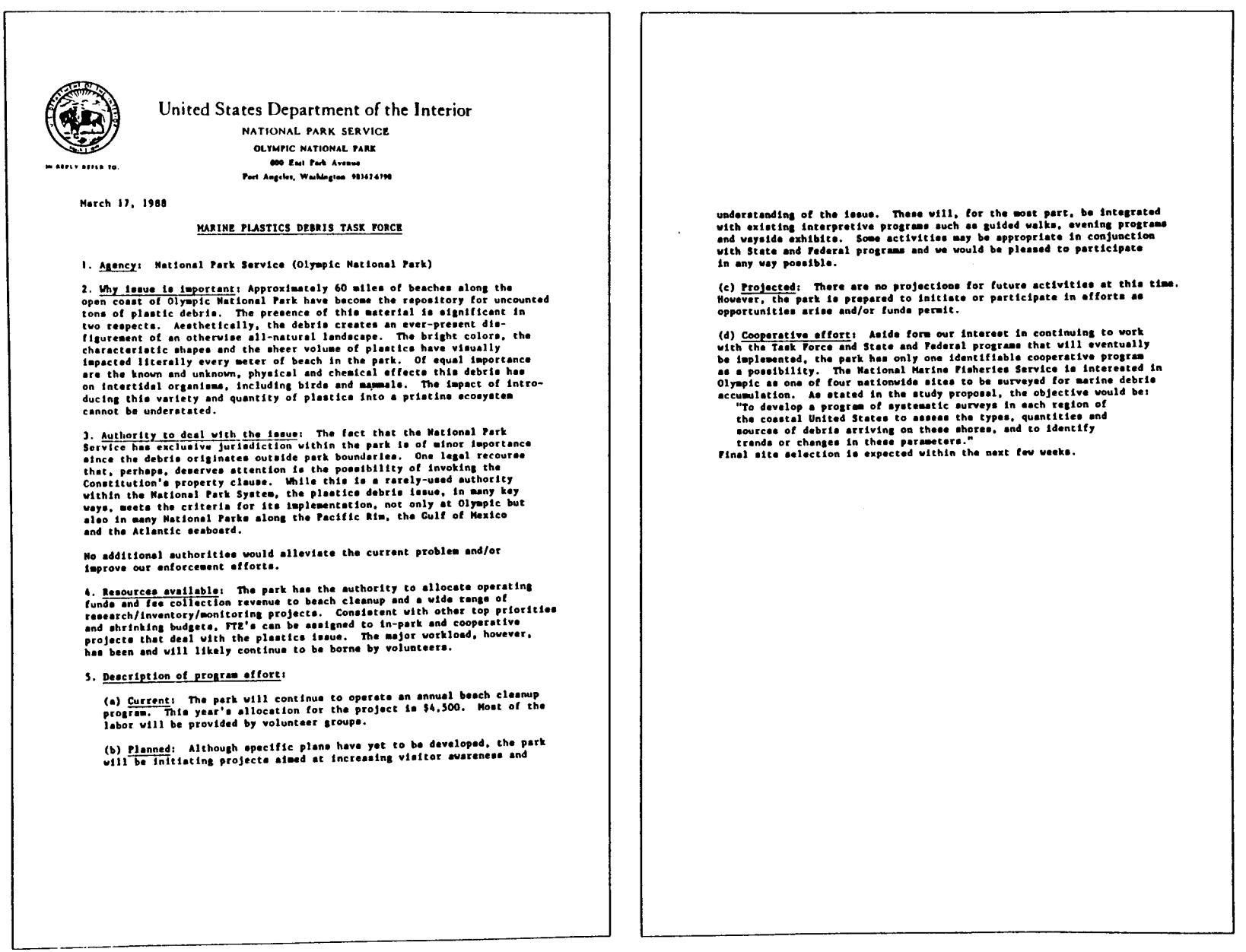
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Figure 1.--Marine Plastic Debris Task Force members.



United States Department of the Interior
NATIONAL PARK SERVICE
OLYMPIC NATIONAL PARK
600 East Park Avenue
Port Angeles, Washington 98362-6798

IN REPLY REFER TO:

March 17, 1988

MARINE PLASTICS DEBRIS TASK FORCE

1. Agency: National Park Service (Olympic National Park)

2. Why issue is important: Approximately 60 miles of beaches along the open coast of Olympic National Park have become the repository for uncounted tons of plastic debris. The presence of this material is significant in two respects. Aesthetically, the debris creates an ever-present disfigurement of an otherwise all-natural landscape. The bright colors, the characteristic shapes and the sheer volume of plastics have visually impacted literally every meter of beach in the park. Of equal importance are the known and unknown, physical and chemical effects this debris has on intertidal organisms, including birds and mammals. The impact of introducing this variety and quantity of plastics into a pristine ecosystem cannot be understated.

3. Authority to deal with the issue: The fact that the National Park Service has exclusive jurisdiction within the park is of minor importance since the debris originates outside park boundaries. One legal recourse that, perhaps, deserves attention is the possibility of invoking the Constitution's property clause. While this is a rarely-used authority within the National Park System, the plastics debris issue, in many key ways, meets the criteria for its implementation, not only at Olympic but also in many National Parks along the Pacific Rim, the Gulf of Mexico and the Atlantic seaboard.

No additional authorities would alleviate the current problem and/or improve our enforcement efforts.

4. Resources available: The park has the authority to allocate operating funds and fee collection revenue to beach cleanup and a wide range of research/inventory/monitoring projects. Consistent with other top priorities and shrinking budgets, FTE's can be assigned to in-park and cooperative projects that deal with the plastics issue. The major workload, however, has been and will likely continue to be borne by volunteers.

5. Description of program effort:

(a) Current: The park will continue to operate an annual beach cleanup program. This year's allocation for the project is $4,500. Most of the labor will be provided by volunteer groups.

(b) Planned: Although specific plans have yet to be developed, the park will be initiating projects aimed at increasing visitor awareness and understanding of the issue. These will, for the most part, be integrated with existing interpretive programs such as guided walks, evening programs and wayside exhibits. Some activities may be appropriate in conjunction with State and Federal programs and we would be pleased to participate in any way possible.

(c) Projected: There are no projections for future activities at this time. However, the park is prepared to initiate or participate in efforts as opportunities arise and/or funds permit.

(d) Cooperative effort: Aside form our interest in continuing to work with the Task Force and State and Federal programs that will eventually be implemented, the park has only one identifiable cooperative program as a possibility. The National Marine Fisheries Service is interested in Olympic as one of four nationwide sites to be surveyed for marine debris accumulation. As stated in the study proposal, the objective would be:

> "To develop a program of systematic surveys in each region of the coastal United States to assess the types, quantities and sources of debris arriving on these shores, and to identify trends or changes in these parameters."

Final site selection is expected within the next few weeks.

Figure 2.--Sample agency status sheet.

## EXISTING AUTHORITIES AND AGENCIES DEALING WITH MPD

| | PROGRAM | | ENFORCEMENT | | | |
|---|---|---|---|---|---|---|
| AGENCY | DEVELOPED | POTENTIAL | DEVELOPED | POTENTIAL | STATUTES | FUNDING |
| EPA, REGION X | ▮ National ongoing plastics pollution study<br>▮ 1986-87 Adopt-A-Beach program with Seattle Aquarium; volunteer project hndbk. completed<br>▮ State of the Sound exhibit with Seattle Aquarium | ▮ Public Education in cooperation with NOAA and Dept. of Transportation<br>▮ Support establishment of baseline data and monitoring program<br>▮ Additional technical support | | | ▮ Marine Plastics Pollution, Research and Control Act (MPPRCA) (PL 100-220)<br>▮ Clean Water Act, Section 108 | |
| USFWS | ▮ Beach cleanup | ▮ Cooperative actions<br>▮ Field monitoring<br>▮ Public education materials | | | ▮ Fish and Wildlife Coordination Act<br>▮ Endangered Species Act<br>▮ Migratory Bird Treaty Act<br>▮ Anadromous Fish Conservation Act<br>▮ Rivers and Harbors Act of 1899<br>▮ Clean Water Act | |
| NPS | ▮ Beach cleanup | ▮ Research and monitoring; Olympic Nat'l Park as an accum. monitoring site<br>▮ Cooperative action<br>▮ Visitor information/education | ▮ Exclusive jurisdiction in national parks<br>▮ Authority to prosecute | ▮ Increased enforcement | ▮ Title 16, 18 U.S. Code | |
| NMFS | ▮ Marine entanglement research program | | ▮ Enforcement personnel available | | ▮ National Marine Mammal Protection and Control Act | |
| COAST GUARD | | ▮ Participation with EPA and NOAA on public education | ▮ Fines for vessels<br>▮ Certification of port facilities<br>▮ Developing regulations | ▮ Increased enforcement (with increased funds) | ▮ MPPRCA | |

Figure 3.--Sample taken from table of existing authorities and agencies.

quickly reference their responsibilities and relationships with other agencies (Fig. 4).

The task force recognized that marine plastic affects fisheries and wildlife resources, endangers boaters and divers, and diminishes aesthetic enjoyment of the state's shorelines. Increasing public awareness and interest about the specific issue of marine plastic debris is a key element of the plan, with a strong emphasis on education. The task force recommendations emphasize recycling and proper disposal of potential marine plastic debris materials. In addition, the coordination of present and future cleanup efforts is critical to use Federal, state, local, and citizen resources efficiently.

The task force wanted its recommendations to be thoroughly examined by the affected agencies and incorporated into future work plans and budgets. Because the issue involves so many agencies and organizations and will involve a commitment of resources over time, the task force recommended designation of an overall coordinating agency.

## MARINE PLASTIC DEBRIS: ACTION PLAN

The action plan was completed in October 1988 and presented to the commissioner, the public, and media at a press conference on the Seattle waterfront. The publication of the document was timed to coincide with the last day of Washington State's Coastweeks '88. The Adopt-A-Beach Program, sponsors of Coastweeks (under the auspices of the Washington Department of Ecology), organized the event and collected a representative sampling of debris from the riprapped shore of Elliott Bay.

The 1988 plan is organized into four sections.

Part 1 of the action plan explains how the Marine Plastic Debris Task Force developed a plan to address a major environmental problem: debris in Washington waterways. The floating garbage was not only unsightly but dangerous. How the task force focused on issues and their recommended actions are discussed.

Part 2 of the action plan presents the mission statement for the Marine Plastic Debris Task Force and the goal and objectives for the plan. Policies to guide and coordinate future activities are followed by 20 action recommendations designed to implement the policy statements. These recommendations are divided into three sections: environment, education, and government/economic impact. Part 2 also lists seven required legislative or administrative initiatives. (The mission statement, goal and objectives, and policies of the Marine Plastic Debris Task Force (1988), as documented in the Marine Plastic Debris Action Plan, are found in Appendix A of this paper. A summary of the marine debris action recommendations and the required legislative or administrative initiatives are found in Appendix B of this paper.)

Part 3 of the action plan contains the full text for each of the action recommendations including a short narrative explaining the

## ACTION RECOMMENDATIONS AND THE LEAD AGENCIES INVOLVED

ENVIRONMENT

| ACTION RECOMMEN-DATIONS / ORGANIZATIONS | 1 Designate coordinating and clearing-house agency | 2 Develop environmental baseline and monitoring system | 3 Coordinate beach cleanups | 4 Conduct research on wildlife and fisheries effects | 5 Coordinate ghost net removals | 6 When feasible, require and promote recycling and alternative products | 7 Recycling and disposal | 8 Convene biennial statewide conference | 9 Develop and implement a public outreach program |
|---|---|---|---|---|---|---|---|---|---|
| Coordinating agency | | L | | | | | | L | L |
| NOAA/NMFS | P | P | | P | P | P | P | | P |
| USFWS | P | P | P | P | | | | | P |
| NPS | P | P | P | | | | | | P |
| CG | P | P | | | | | P | | P |
| EPA | P | P | | P | | P | P | | P |
| DOL | P | | | | | | | | P |
| DCD | P | | | | | | | | P |
| DOE | L | P | L | | | L | L | | P |
| WDF | P | P | P | L | L | P | | | P |
| DNR | L | P | P | | L | P | | | P |
| WDW | P | P | P | L | P | | | | P |
| OFM | | | | | | | | | P |
| Office of Governor | P | | | | | | | | P |
| DOR | | | | | | | | | P |
| PSWQA | P | | | | | | | | P |
| State Bd. of Pilotage | P | | | | | | | | P |
| Parks | L | P | | | | P | L | | P |
| SPI | P | | | | | | | | P |
| IAC | P | | | | | | L | | P |
| Hse Env. Affrs. Com. | P | | | | | | | | P |
| House Energy & Nat. Res. Coms. | | | | | | | | | P |
| Joint Select Com. Mar. & Ocean Res. | P | | | | | | | | P |
| Senate Environ. & Nat'l Res. Com. | P | | | | | | | | P |
| State Legislature | P | | | | | | L | | P |
| Association of Washington Cities | | P | P | | P | P | P | | P |
| Wa. Assoc. of Counties | | P | P | | P | P | P | | P |
| Port of Seattle | | P | P | | | | P | | P |
| Wa. Pub. Ports Assoc. | | P | P | | P | | P | | P |
| County Auditors | | | | | | | | | P |
| Colleges & Universities | P | P | P | | | | | | P |
| Private Companies | P | P | P | P | | P | P | | P |
| Aquariums | | P | | P | | | | | P |
| Marine Labs | | P | | P | | | | | P |
| Adopt-A-Beach | | P | P | | | | | | P |
| Indian Tribes | | P | | | | | | | P |
| Dive Groups/Shops | | | | | P | | | | P |
| Environ. Groups | | | | | | | | | P |
| Citizen Recycling Org. | | | | | | | P | | P |

L - Lead agency P - Participating agency

Figure 4.--Sample taken from Table 4 of action recommendations.

background of the issue. For each action recommendation, a lead agency is designated as well as a listing of agencies likely to participate in carrying out the action. A suggested time frame for implementation and an estimate of the duration of the action are proposed for each of the 20 action recommendations.

Part 4 of the action plan consists of three appendixes. Appendix A of the plan is a compilation of reports outlining the status (as of September 1988) of agency and organization activities, authorities, and current and proposed programs. Appendix B of the plan contains an overview and explanation of the Marine Plastic Pollution Research and Control Act of 1987. Appendix C of the plan encapsulates various Washington State programs addressing the problem of marine debris.

Copies of the action plan are available from Photo and Map Sales, Department of Natural Resources, 1055 Capitol Way S, AW-11, Olympia, WA 98504, (206) 753-5338.

## IMPLEMENTATION

Since presenting the task force report to Commissioner Boyle, a number of steps have been taken to make the action plan a reality.

Designees of the directors of Parks, Ecology, and Natural Resources met in early 1989 to decide which agency should take the lead for coordinating future state marine plastic debris activity. As a result of that meeting, the Department of Natural Resources, having initiated and staffed the planning effort, was designated lead agency. The relationship among the agencies was formalized in a memorandum of understanding. Based on this agreement, the department prepared legislation for the 1989 Legislature. House Bill 1249 was to authorize the DNR to coordinate implementation of the action plan and to develop rules for cleanup and prevention of pollution in state waters. The department is also authorized to enter into intergovernmental agreements with Federal, state, or private parties, and to hire employees necessary to coordinate the plan.

An important conclusion of the task force deliberations was the recognition that a coordinator was necessary to assure that agencies followed through on the tasks contained in the action plan. This legislation provides the authority and funding source to make the plan a success.

At the same time, the Department of Ecology has funded through the coastal zone management program a baseline inventory survey of selective beaches. This will be carried out by the Adopt-A-Beach program using a newly revised inventory form. Beginning on 25 March, a scientific inventory of selected beaches will occur biweekly for a year, thus providing the first baseline information on marine plastic debris occurrence on Washington's shores.

As a result of widespread publicity about the report, the 1989 and 1990 Department of Transportation's Tide Tables, a popular and necessary document requested by boaters and fishermen along the Washington coast,

contains a special eight-page insert about proper disposal of all marine debris and sewage, with a special emphasis on plastic and other nonbiodegradable materials.

A ghost net task force with representatives from State Departments of Fisheries, Wildlife, and Natural Resources, interested citizens and divers, and the National Marine Fisheries Service, NOAA, is developing an interagency memorandum of understanding and protocols for ghost net and crab pot removal.

The Department of Natural Resources will start publishing a marine plastic debris newsletter to bring current activities and opportunities to the attention of boaters, lessees, citizen groups, and others interested in maintaining and improving Washington's aquatic environment.

## CONCLUSION

The development and publication of the "Marine Plastic Debris Action Plan for Washington State" was the first and necessary step for addressing the presence and consequences of persistent debris in the state's waters and on its shores. As a result of the plan, institutional arrangements have developed which would not have been possible without the framework proposed by the task force. Positive response by the Washington Legislature portends support for the Department of Natural Resources to develop the necessary educational materials, to create public and private partnerships, and to raise the importance of this issue in the public mind.

## REFERENCES

Marine Plastic Debris Task Force.
1988. Marine plastic debris action plan for Washington State. Marine Plastic Debris Task Force, Washington State Department of Natural Resources, 2d ed., December 1988, var. pag.

## Appendix A.--The mission statement, goal and objectives, and policies of the Marine Plastic Debris Task Force (1988).

### MISSION STATEMENT

The purpose of the task force is to increase public awareness and interest about marine plastic debris and to develop a framework for coordinating public and private efforts to ensure an effective response. Plastic debris in the aquatic environment has an adverse impact on wildlife, aesthetics, navigation and overall environmental quality. The task force recognizes that this material is part of a larger problem of waste generation and management. The Washington State plan will link private, local, state and federal efforts in managing the plastic waste stream as it affects the shorelines and aquatic environment.

### GOAL AND OBJECTIVES

#### Goal

To develop a state action plan to address the marine plastic debris issue that affects Washington's shorelines and aquatic environment.

#### Objectives

1. Identify plastic debris in the aquatic environment as a distinct issue.

2. Develop and support mechanisms to reduce or eliminate marine plastic debris.

3. Focus primarily on marine resources affected by plastic debris, with attention to impacts on other aquatic environments in the state.

4. Provide input to and develop steps for emerging private, local, state and federal policies and actions.

5. Develop and implement mechanisms that will coordinate actions performed by agencies and organizations.

6. Encourage and support private and public policy to increase awareness through education efforts in Washington State.

### POLICIES

The Marine Plastic Debris Task Force recommends that the state of Washington, acting through its elected officials, and in cooperation with other appropriate agencies, offices, organizations and the private sector, should seek to:

1. Increase public awareness about effects of marine plastic debris.

2. Designate a lead agency to act as a clearinghouse and coordinator for marine plastic debris activities in Washington.

3. Designate appropriate agencies to draft, review and support legislation and/or regulations recommended by the task force.

4. Empower responsible agencies to implement and participate to the fullest extent in actions recommended by the task force and other actions judged necessary.

5. Encourage funding measures on all levels to facilitate compliance with MARPOL requirements and to implement task force recommendations.

6. Coordinate, support and encourage continued volunteer efforts and special events related to the marine plastic debris issue.

7. Encourage and support efforts by all the state's users of the marine environment to reduce and eliminate marine plastic debris.

8. Support and encourage the plastics industry and other industries to continue research and development of products which are adaptable to recycling and proper disposal.

9. Maintain and expand baseline data collection and research on sources, quantities, effects and fates of marine plastic debris.

10. Encourage ports and local governments to collect and dispose of marine plastic debris in an environmentally sound manner.

11. Support regional, national and international efforts to reduce and eliminate marine plastic debris.

**Appendix B.--Summary of the marine debris action recommendations and the required legislative or administrative initiatives (Marine Plastic Debris Task Force (1988)).**

SUMMARY OF ACTION RECOMMENDATIONS

(1) ACTION RECOMMENDATION: Designate an agency or entity to coordinate activities and serve as a clearinghouse for marine plastic debris data reception and information dissemination.

ENVIRONMENT

(2) ACTION RECOMMENDATION: Develop an environmental baseline and monitoring system for marine plastic debris in Washington.

(3) ACTION RECOMMENDATION: Coordinate beach cleanup efforts among various agencies.

(4) ACTION RECOMMENDATION: Conduct additional research about the effects of plastic debris on wildlife and fisheries resources and habitat.

(5) ACTION RECOMMENDATION: Coordinate information about and and removal of ghost nets and other derelict equipment from state waters among DNR, Department of Fisheries, NOAA, and local agencies.

(6) ACTION RECOMMENDATION: Require and promote recyclable or alternative products when feasible for use in or near the marine environment.

(7) ACTION RECOMMENDATION: Require recycling and proper disposal of potential marine plastic debris materials for federal, state and local agencies and Indian tribes.

EDUCATION

(8) ACTION RECOMMENDATION: Convene a biennial statewide conference by the designated marine plastic debris coordinating agency.

(9) ACTION RECOMMENDATION: Develop and implement a public outreach program using the recommended logo [Illustration 6], public service announcements, publications and special events.

(10) ACTION RECOMMENDATION: Develop and distribute media materials directed at domestic and foreign maritime communities.

(11) ACTION RECOMMENDATION: Develop a marine debris curriculum for use at state and private maritime schools training the professional maritime community.

(12) ACTION RECOMMENDATION: Post permanent information signs about why MPD and other litter is harmful to water quality, wildlife and fish as well as a threat to boating safety at all boat launch ramps, public access sites and public and private marinas.

(13) ACTION RECOMMENDATION: Require that all state-licensed and registered users of Washington waters receive MPD information materials and display a plaque or decal about proper disposal of MPD and other litter.

(14) ACTION RECOMMENDATION: Encourage retail and manufacturer cooperation to aid in marine plastic debris public education.

(15) ACTION RECOMMENDATION: Incorporate the MPD problem into the environmental section of the state's required curriculums for grades K-12 and in other educational material.

GOVERNMENT/ECONOMIC IMPACT

(16) ACTION RECOMMENDATION: Incorporate an analysis of the true costs of marine debris, including fiscal impacts and nonquantifiable environmental costs into policy decisions.

(17) ACTION RECOMMENDATION: Conduct an independent cost/benefit analysis of MPD compliance and cleanup.

(18) ACTION RECOMMENDATION: Integrate MPD disposal with comprehensive solid waste planning.

(19) ACTION RECOMMENDATION: Increase public awareness about the legal consequences for improper MPD disposal.

(20) ACTION RECOMMENDATION: Develop a framework of financial incentives to encourage proper disposal of MPD.

REQUIRED LEGISLATIVE OR ADMINISTRATIVE INITIATIVES

1. Marine Debris decal--Departments of Fisheries and Licensing should require that all Washington-licensed boats have a prominently displayed decal regarding proper disposal of marine plastic debris and other wastes.

2. Information for boaters--Require the Department of Licensing include an information packet containing legal requirements for marine plastic debris disposal when issuing boat registrations or renewals.

3. Legislation--Support passage of the State Parks legislation for Boater Recreation Fee Account funds to be used for boater environmental education and to provide capital for sewage pump-out facilities and educational signs.

4. Agreement--Formal agreement among DNR, Department of Fisheries, NOAA (and other appropriate agencies) is necessary to assume prompt location and removal of ghost nets.

5. Funding--Investigate Ecology's Litter Tax program (Chapter 70.93 RCW) for the possibility of directing funding from that program to the marine debris cleanup issue.

6. Clearinghouse--Develop an appropriate memorandum of understanding for the coordinating agency.

7. Staffing--Consider increased state enforcement through WDOE, WDF personnel to carry out these recommendations.

# THE PROTECTION OF SPECIFIC SEA AREAS AGAINST MARINE DEBRIS

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(This paper was presented in April 1989. It has since been updated (e.g., a new title, amended criteria) to include developments occurring at the Marine Environment Protection Committee meeting of March 1990.)

## ABSTRACT

The problems associated with debris in the marine environment are being given increased attention. At the international level this attention is reflected in a number of international agreements. Most of the relevant international regulations aim at reduction of debris-associated pollution at the source. In addition to policies aimed at source control, efforts are also made to develop protective measures for specific sea areas. This paper discusses efforts currently under way within the framework of the International Maritime Organization.

In the mid-1980's, the International Maritime Organization decided to develop guidelines for the designation of "special areas" and the identification of "particularly sensitive areas." These guidelines should assist national authorities in developing measures to provide specific areas with additional protection from environmental damage caused by shipping activities. The Baltic Sea became a special area as of 1 October 1989. The United States has announced a proposal to designate the Gulf of Mexico as an Annex V special area as well. The Governments of the North Sea States have formally proposed to do the same for the North Sea. Another major option to protect specific sea areas is the designation "area to be avoided by ships." The Northwestern Hawaiian Islands are an example of such an area.

## INTRODUCTION

Several years ago, a photograph of a dead albatross spread out on a beach together with a systematic display of the plastics found in the bird's stomach brought home to me the point that there was more to pollution of the seas than oil or chemicals. Photographs like this one of

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

birds and sea mammals entangled in or killed by plastics and other persistent materials have helped to increase attention for the problems associated with debris in the marine environment worldwide.

My first real encounter with debris-associated pollution was on board a Greek passenger ferry in the Mediterranean. Passengers freely threw plastic bags and other garbage overboard. It emphasized the importance of shipping as a source of this type of pollution.

My second important encounter with debris-associated pollution involved an invitation by an artisanal fisherman in one of the Southeast Asian countries to come and see how plastics rather than fish filled his nets. He took me to the source of these plastics. The waste dump of the town he lived in was located on a waterfront. One of the ironies of this was that waste from this dump would not only fill the fisherman's nets, but would also wash up at the town's beaches. These beaches were cleaned regularly, and the collected waste brought to this waste dump. It reminded me that there were more sources of debris-associated pollution than ships.

Increased attention to the problem has now led to increased attention to measures to control pollution from land-based sources as well as from ships on both national and international levels. This paper concentrates on international measures.

## SOURCES OF DEBRIS-ASSOCIATED POLLUTION AND INTERNATIONAL AGREEMENTS FOR POLLUTION CONTROL

### Land-Based Pollution

Although the international dimension of debris-associated land-based pollution appears to be limited, there are some important international agreements in this respect. The Convention for the Protection of the Mediterranean Sea Against Pollution and its related protocols (1976) is one of these. "Persistent synthetic materials which may float, sink or remain in suspension and which may interfere with any legitimate use of the sea" are on the Annex I list of the Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources (1980); "substances which, though of a non-toxic nature, may become harmful to the marine environment or may interfere with any legitimate use of the sea owing to the quantities in which they are discharged" are on the Annex II list of this protocol. Pollution by Annex I substances should be eliminated (Art. 5 of the protocol); pollution by Annex II substances should be strictly limited (Art. 6 of the protocol). Similar regulations have been included in other international agreements regarding land-based pollution such as the Convention for the Protection of the Marine Environment and Coastal Area of the Southeast Pacific and its Supplementary Agreements (1981, 1983), and the Paris Convention for the Prevention of Marine Pollution from Land-Based Sources (Northwestern Europe 1974).

If effectively implemented, these regulations should provide a basis for sufficient control of debris-associated land-based pollution in the areas where these regulations apply.

## Dumping of Wastes at Sea

Another source of debris-associated pollution is the dumping of wastes at sea. On a global as well as on a regional level, international agreements have been developed to regulate the dumping of wastes at sea. The global Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the so-called London Dumping Convention of 1972) has addressed the dumping of plastics and other types of debris by putting "persistent plastics and other persistent synthetic materials, for example, netting and ropes, which may float or remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea" on its Annex I. The dumping of Annex I substances at sea is prohibited (Art. IV.1.a). "Containers, scrap metals or other bulky wastes liable to sink to the sea bottom which may represent a serious obstacle to fishing or navigation" and "substances which, though of a nontoxic nature, may become harmful due to the quantities in which they are dumped, or which are liable to seriously reduce amenities" were put on Annex II, thus requiring a prior special permit if dumping is to take place (Art. IV.1.b).

Guidelines have been developed for the identification of discharge or dump sites. These guidelines include consideration of such factors as the capacity of the receiving marine environment to receive wastes without undesirable effects and the ecological condition of the area.

Effective implementation of the London Dumping Convention (which, in early 1989, had been ratified by 63 states) could be the basis for controlling this source of pollution.

## Operational Pollution From Ships

Research into the origin of plastics and other marine debris suggests that a substantial part of these substances originates from ships at sea (e.g., Dixon and Dixon 1981). A recent report about the German Bight (Schrey 1987) estimates that 95% of the refuse found on beaches of the German Bight can be attributed to shipping.

Any effort to control this source of debris-associated pollution from ships must have an international dimension since most of the world's seas and oceans are international waters. Ships traveling these waters are flying the flags of many nations. International regulations affecting these ships are developed by the International Maritime Organization (IMO), a United Nations agency which as of April 1989 had 133 member states and which consequently is well placed to effectively develop such international regulations.

Operational pollution from ships has been regulated by the IMO in the International Convention for the Prevention of Pollution from Ships (the so-called MARPOL Convention of 1973/78). This convention is now under constant review by IMO's Marine Environment Protection Committee (MEPC). The MARPOL Convention includes regulations to control operational pollution from ships with oil (Annex I), noxious liquid substances in bulk (Annex

II), harmful substances in packaged forms (Annex III), sewage (Annex IV), and garbage (Annex V). Marine debris falls within the scope of Annex V of the MARPOL Convention.

It is important to properly appreciate the MARPOL Convention. This convention was concluded in 1973 and, at that time, already included very strict rules with regard to the disposal of plastics at sea. Yet, its Annex V, the plastic and garbage regulations, did not enter into force until more than 15 years later, on 31 December 1988.

## THE EFFECTIVENESS OF EXISTING INTERNATIONAL MEASURES WITH RESPECT TO MARINE DEBRIS

International regulations for control at the source of the introduction of marine debris into the marine environment do exist. The important question, however, is whether they are effective.

As regards land-based pollution, there is only one global international instrument, the so-called Montreal Guidelines. Their effectiveness is limited because they are not binding. Most of the regional international regulations are no more than one or two general articles in a general convention on environmental protection. There are only a few exceptions where special protocols or specific conventions with regard to land-based pollution were developed. The effectiveness of the existing regulations is limited because there is no worldwide coverage of international regulations; many regions do not have such regulations.

There is some doubt about the effectiveness of regional international regulations where these have been developed up to a level of specialized protocols or even specific conventions. One example may illustrate this. With respect to synthetic materials (a blacklisted substance in the Paris Convention), no action at all appears to have been taken by the Commission of the Paris Convention in the first 10 years of its existence (Oslo and Paris Commission 1984; Paris Commission 1987).

As for the dumping of wastes, the London Dumping Convention seems to be an effective instrument. Nevertheless, in at least one instance the convention failed for lack of enforcement.

In April 1988, the car-carrier *Reijin*, with more than 5,000 new cars on board, capsized close to the Portuguese coast. After considering the various salvage options, it was decided to dump two-thirds of the cars from the ship into water 2,000 m deep. The wreckage of the ship together with the remaining cars were then to be sunk in deep water as well (MEPC 1989a). In effect this would mean the dumping at sea of a number of substances from Annex I of the London Dumping Convention for which dumping at sea is prohibited. Plastics and other persistent materials used in the cars were among these Annex I substances. During the 1988 Consultative Meeting of Contracting Parties to the London Dumping Convention, the delegation of Denmark as well as observers from the environmental organizations Greenpeace and Friends of the Earth International raised the issue as being at odds with the regulations and spirit of the London Dumping Convention. The

consultative meeting took no action (pers. observ.). Dumping of cars at sea did start but was stopped after a time.

Finally, with respect to operational discharges by ships, not enough time has elapsed since the entry into force of Annex V of the MARPOL Convention to judge its effectiveness. Doubts have been raised, however, in this regard. Many consider control and enforcement of the provisions of the annex to be extremely difficult. Guidelines for its implementation were completed by MEPC in September 1988 (MEPC 1988f), less than 4 months before its entry into force. It is doubtful whether the necessary reception facilities are available in all ports.

## THE PROTECTION OF SENSITIVE SEA AREAS AGAINST DAMAGE BY SHIPPING ACTIVITIES: BACKGROUND

Considering the problems encountered in controlling the discharge of marine debris at the source, one wonders whether a complementary approach of giving special protection to specific sensitive areas might be useful. Within the IMO, efforts are now under way to assess the opportunities such an approach might offer with respect to marine pollution caused by ships.

The IMO has several options for providing additional environmental protection to specific sensitive sea areas. These include the designation of areas as "special areas" under the MARPOL Convention, the designation of areas as "areas to be avoided," or the use of other ship's routing measures such as traffic separation schemes and deep-water routes. With respect to debris-associated pollution, the first two options are especially relevant.

Special areas will normally be larger sea areas. To provide some protection for sea areas which would not qualify as special areas, the International Conference on Tanker Safety and Pollution Prevention in 1978 adopted a resolution which invited the IMO:

> "to initiate. . .studies, in collaboration with other relevant international organizations and expert bodies, with a view to making an inventory of sea areas. . .which are in special need of protection against marine pollution from ships and dumping. . .; assessing. . . the extent of the need of protection, as well as the measures which might be appropriate. . .; to consider. . .what action will be needed. . .; to take action. . .within the framework of the relevant conventions. . . ."

In 1985, the IMO started to work on this issue of particularly sensitive sea areas and put it on the agenda of the twenty-third session of the MEPC, which was to take place in 1986. Discussion of the issue at this meeting (MEPC 1986) resulted in the decision to send out a circular letter to IMO member states inviting these states to provide information on the following:

- Criteria which have been used in designating existing marine areas under national jurisdiction which are particularly sensitive with respect to their renewable natural resources

or their importance for scientific purposes, and for which special protection measures are in force.

- National protection measures and restrictions affecting the use of such areas by ships and related maritime activities, and the specific purpose of the restrictions imposed.

- The geographical location of those marine areas which are already protected and of those areas considered for future protection, the seaward limits of which extend beyond the territorial seas established in accordance with international law.

On the basis of the responses to this circular letter, the MEPC developed criteria for the designation of particularly sensitive sea areas and also started work on developing criteria for the designation of special areas. At the twenth-sixth session of MEPC, a proposal was put before the MEPC on how to proceed and how to make the concept of particularly sensitive sea areas operational (MEPC 1988d).

The proposal did not aim at developing new legal instruments, but at making better use of existing international regulations (such as the designation of special areas) for the protection of specific sea areas against damage caused by shipping activities. The MEPC adopted this proposal (MEPC 1988f) and decided to develop a manual for the designation of particularly sensitive sea areas and special areas. Since the adoption of this proposal some changes have been made to the concept of the manual, including its title, which now is "Guidelines for the designation of special areas and the identification of particularly sensitive areas" (MEPC 1990). The basic concept of providing guidance for better use of existing international regulations is still the same.

## GUIDELINES FOR THE DESIGNATION OF SPECIAL AREAS AND THE IDENTIFICATION OF PARTICULARLY SENSITIVE AREAS

The main objective of the guidelines is to provide governments or government departments having limited experience in developing proposals to the IMO with detailed guidance on how to prepare such proposals for environmental protection of specific sea areas. It will also set standards which proposals for the designation of special areas will have to meet if they are to be accepted.

The guidelines will present a range of existing international regulations which could be used better or more frequently for environmental protection purposes. They will be restricted to damage from ships in or in the direct vicinity of an area, and will not address land-based pollution or the dumping of wastes at sea.

They will consist of three parts: (1) a general introduction, (2) criteria and procedures for the designation of special areas as well as some examples of special areas already designated, and (3) criteria for the identification of particularly sensitive areas, criteria and procedures to

provide such areas with additional protection in accordance with IMO regulations, and some examples of areas which have already been given such additional protection.

**Guidelines: General Introduction**

This first chapter of the guidelines will review their history and background as well as the role the IMO can play in the protection of sensitive sea areas. Attention will also be given to the types of damage ships can cause to sensitive sea areas. One of these will be the discharge of marine debris, including plastics.

The list will, however, not be limited to discharges of the "traditional" substances such as oil or chemicals; it will also include the discharge of ballast water contaminated with "alien" organisms (which has already caused problems near Tasmania, Australia, and in the Great Lakes, Canada, and the United States), the "discharge" of TBT paints from the hull of ships into the marine environment, and even the "discharge" of noise.

Neither will it be limited to damage caused by discharges; physical damage to marine ecosystems (such as the damage to coral reefs caused by the grounding of the *Wellwood* off Key Largo, Florida, United States, in 1984) will also be discussed.

**Guidelines: Special Areas**

The second chapter of the guidelines will address the designation of special areas. Annex V of the MARPOL Convention defines a special area as "a sea area where for recognized technical reasons in relation to its oceanographic and ecological condition and to the particular character of its traffic the adoption of special mandatory methods for the prevention of sea pollution by garbage is required" (Annex V, Reg. 1.3). The disposal of all plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags, and of all other garbage, including paper products, rags, glass, metal, bottles, crockery, dunnage, lining, and packing materials is prohibited in special areas. Food wastes can only be disposed of as far as practicable from land but in any case not less than 12 nmi from the nearest land (Annex V, Reg. 5.2).

A word of caution is appropriate with respect to the potential merits of the stricter discharge regime of an Annex V special area: The disposal into the sea of all plastics is prohibited everywhere in the world's seas and oceans. The designation of an area as an Annex V special area will not give any additional protection against plastics pollution beyond that. The merit in this respect would be the increased pressure in such areas to provide the necessary port reception facilities for plastics and other garbage. The disposal into the sea of other types of garbage (e.g., dunnage, lining) would be further limited by a designation as an Annex V special area provided the area is large enough to include areas which are more than, respectively, 25 or 12 nmi from the nearest land. If not, discharge regulations similar to those for a special area will apply anyway within 25 nmi from the nearest land for dunnage, lining, and packing

materials which will float, and within 12 nmi from the nearest land for food wastes and all other garbage.

Five sea areas (the Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea, and the "Gulfs Area" (Annex V, Reg. 5.1)) have each been designated as Annex V special areas, but this designation is effective only for the Baltic Sea. For the other sea areas, the special area status will enter into force as soon as there are sufficient reception facilities for garbage in the area (Annex V, Reg. 5.4). In October 1989, the decision was made to designate the North Sea as an Annex V special area. A proposal to designate the Gulf of Mexico as an Annex V special area has been discussed by MEPC but no decision to do so has been made.

Criteria for the designation of special areas were developed during MEPC's twenty-sixth session (MEPC 1988a) and were amended in March 1990 during MEPC's twenty-ninth session (MEPC 1990). They include oceanographic conditions (e.g., particular circulation patterns, long residence times, extreme ice states or adverse ice conditions), ecological conditions (e.g., depleted, endangered, or threatened species; areas of high natural productivity; spawning, breeding, and nursery areas; rare or fragile ecosystems or critical habitats), and vessel traffic characteristics. A special area should also be an area of such a size that, were it not a special area, discharges of garbage could be made in the area in accordance with the discharge criteria of Annex V established for open sea areas.

It was also noted that consideration should be given to the extent to which the condition of a sea area is influenced by nonmaritime sources of pollution. Proposals for the designation of a special area will be strengthened by information on measures that are being or will be taken to prevent, reduce, and control pollution of the marine environment by these other sources of pollution.

**The Baltic Sea: The First Annex V Special Area**

To date, the Baltic Sea is the only Annex V special area to enter into force. At the twenty-sixth session of the MEPC, the Governments of the Baltic Sea States submitted notification to the IMO that adequate reception facilities had been provided in all ports within the Baltic Sea Area (MEPC 1988e). The MEPC then unanimously decided that the Annex V special area status for the Baltic Sea would take effect on 1 October 1989 (MEPC 1988f).

**The North Sea: A New Annex V Special Area**

At the same twenty-sixth session of the MEPC, the Governments of the North Sea States submitted a proposal to the MEPC to designate the North Sea as an Annex V special area (MEPC 1988b, 1988c). The proposal was finally adopted in October 1989 at the twenty-eighth session of the MEPC.

The proposal was a result of the second International Conference on the Protection of the North Sea, which was held in London in November 1987. The North Sea States were under considerable pressure from some of their members and environmental organizations to designate the North Sea as a special area for the purposes of Annex I (oil) and Annex II (chemicals in

bulk) of the MARPOL Convention. While no agreement on this could be reached during this conference, they did in the end agree to designate the North Sea as an Annex V special area.

Is this proposal superfluous? No, there is good reason for the designation. Reports on plastics and debris in the North Sea area published about the time of the North Sea Conference (e.g., Schrey 1987) have indicated the seriousness of the situation, a situation underscored during the coffee break that followed the decision on Annex V special area status for the North Sea. As delegates to the twenty-sixth session of the MEPC watched, a rising tide brought an influx of garbage up the Thames. The Annex V special area status will contribute considerably to limiting the input of nonplastic or nonsynthetic garbage into the North Sea.

## Guidelines: Particularly Sensitive Areas

### Criteria and Options

Criteria for the identification of particularly sensitive areas include ecological criteria (uniqueness, dependency, representativeness, diversity, productivity, naturalness, integrity, vulnerability); social, cultural, and economic criteria (economic benefit, recreation, human dependency); and scientific and educational criteria (research interest, suitable conditions for baseline and monitoring studies, opportunities for educational activities, historic value).

Actions already under way may indicate the need for further protective measures. Consideration should be given to the beneficial effects of such measures, in view of the environmental stress from other sources.

Once an area has been identified by the IMO as a particularly sensitive area, the IMO has several options for providing it with additional protection. These include the introduction of special ships' routing measures to increase safety of navigation in or near the area such as vessel traffic separation schemes, deepwater routes, or even vessel traffic management systems. The most important instrument the IMO can use is the designation "area to be avoided."

### Areas to Be Avoided

The guidelines will give substantial information about the designation of a particularly sensitive area as an area to be avoided. It is a ship's routing measure "comprising an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all ships, or certain classes of ships" (IMO 1984). From a number of existing areas to be avoided, it appears to be accepted practice now that "casualties" are interpreted as environmental damage. Areas which for environmental purposes have been designated as areas to be avoided include waters near Cape Terpeniya (Sakhalin, U.S.S.R.), the waters of Nantucket Shoals (United States), a part of the Great Barrier Reef (Australia), an area near the Bermuda Islands (Great Britain), and the Northwestern Hawaiian Islands (United States) (IMO 1984).

The designation of an area as an area to be avoided is not a measure to limit discharges, yet it is consequential to such a decision that in an area where fewer ships are allowed, ships cannot discharge.

The Northwestern Hawaiian Islands (a U.S. wildlife refuge) was established as an area to be avoided after a shipping accident there pointed up the associated risk of pollution. All vessels of more than 1,000 gross tons (GT) carrying cargoes of oil or hazardous materials should avoid the area, which includes the waters within a circle radius of 50 nmi around Pearl and Hermes Reef, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Necker Island, and Nihoa (IMO 1984). There is a substantial area of ocean space beyond 12 and 25 nmi where certain types of garbage can legally be discharged by ships larger than 1,000 GT if these ships can enter the area.

The prevention of discharge of garbage or other marine debris by ships has, of course, not been an objective of this designation. It would nevertheless be interesting to know whether the status of these waters as an area to be avoided has contributed in any way to limit debris-associated pollution.

## CONCLUSION

Reduction of discharges at the source on the basis of globally enforced discharge standards should continue to be the first choice when dealing with pollution by marine debris. However, the "guidelines for the designation of special areas and the identification of particularly sensitive areas" can nevertheless provide a useful tool in the protection of specific sea areas against this type of pollution. The designation of special areas in accordance with MARPOL Annex V should, if effectively implemented, prove to be a valuable instrument against marine debris discharged by ships. Measures such as the designation of areas to be avoided could further add to the opportunities to protect specific sea areas against marine debris.

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# USING THE PROTECTIVE PRINCIPLE TO UNILATERALLY ENFORCE TRANSNATIONAL MARINE POLLUTION STANDARDS

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## ABSTRACT

Annex V to the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL) contains a broad prohibition against the marine disposal of all plastics; however, not all polluting states have ratified this treaty. While it is a principle of international law that treaty obligations are binding only upon the ratifying states, it may be possible to hold nonsignatory states equally liable for marine pollution damage prohibited by this convention under principles of customary international law. A case can be made that the general principles of liability for marine pollution damage as codified in this treaty and elsewhere represent, in fact, customary international law. Since customary international law relies on nation states to enforce its principles, liability for marine pollution damage may be enforced by national courts against all states, including those who have not yet signed or refuse to sign the international antipollution conventions.

Furthermore, a case can also be made that neither these conventions nor customary international law limits unilateral enforcement of stricter pollution standards, including enforcement on the high seas. The protective principle of international law permits a state to assert temporary jurisdiction over a person or a commercial entity whose conduct outside a state's territory threatens its national interest. By utilizing this transnational jurisdiction principle in the field of international environmental law enforcement, substance can be added to general admonitions not to pollute the high seas. As a protective principle case study, this paper analyzes the problem of renegade gillnets lost or cast aside on the high seas of the North Pacific.

## INTRODUCTION

One of the tragic legacies of the 20th century is that the ocean has become a final resting place of man's waste products: oil, toxic wastes,

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dredge tailings, sewage, and garbage drift with the currents, wash up upon the beaches, or settle upon once productive fishing grounds. Each night in the North Pacific, fishing fleets from Japan, Korea, and Taiwan set some 48,270 to 64,360 km (30,000 to 40,000 mi) of driftnet for a total of more than 8 million km (5 million mi) a year (Wolfe 1989; Marine Mammal Commission 1990). Additional driftnet fleets set thousands of miles of large mesh driftnets in the South Pacific and driftnet fleets from Taiwan have also been reported in the western Atlantic. In addition to their targeted catch, driftnets annually entrap close to a million seabirds and tens of thousands of marine mammals. It is estimated that 30 to 50% of the fish caught and killed drop out of the nets before being brought on board. In addition, over 965 km (600 mi) of the driftnets are thought to be lost or discarded from these fisheries annually. These monofilament net fragments may continue to entrap animals for years, including populations well within the 200-mi exclusive economic zone (EEZ) and territorial waters of the United States. In an effort to document and control the destructiveness of this fishery, the United States Government has attempted repeatedly, yet for the most part unsuccessfully, to reach agreements on cooperative arrangements for research, monitoring, and enforcement of flag-state restrictions on driftnet vessels fishing the high seas (U.S. Congress 1987a; Wolfe 1989).

With an ever-growing world population, marine pollution is a problem that won't diminish and seemingly defies solution. Numerous treaties have been drafted, signed, and ratified, all of which universally condemn pollution of the marine environment and obligate nation states to honor international pollution standards (London Dumping Convention 1972; Stockholm Declaration 1972; MARPOL 1973). The problem is how to enforce the admonition. Many states have refused to sign these treaties; those that have frequently fail to enforce the treaties' provisions.

This paper begins with a general discussion of existing conventional and customary international laws of liability for transnational pollution damage. Since international law in its current state of development relies on nation states to enforce its principles, this paper focuses on the strategies available to states and their citizens to enforce both international and national marine pollution standards. One such strategy is the use of the protective principle of international law that permits a state to assert temporary jurisdiction over a person or a commercial entity whose conduct outside a state's territory threatens its national interest (Levi 1979). By utilizing this transnational principle in the field of international environmental law enforcement, substance can be added to general admonitions not to pollute the high seas.

This paper also explores one particular pollution problem as a protective principle case study: that of renegade gillnets which have either been lost or cast aside on the high seas of the North Pacific. It examines existing treaties and domestic United States legislation applicable to the gillnet problem and outlines some remedial paths that may be taken.

The paper concludes with a proposal for a liability enforcement program that will encourage both domestic fishing vessels and foreign

vessels fishing in the United States EEZ under a Governing International Fishing Agreement (GIFA) to comply with United States law prohibiting the dumping of fishing gear overboard. The implementation of a liability fund program and its financing by the owners of fishing vessels will help prevent the "loss" of drift gillnets and provide compensation for any resource and property damage resulting from discards, as well as a source of funds for resource conservation activities, including biodegradable gear research.

## TREATY AND CUSTOMARY INTERNATIONAL LAW

International law comes from several sources: (1) multilateral and bilateral treaties and conventions; (2) international custom as evidenced by the practice of states; (3) general principles recognized by states and articulated by learned scholars in treatises; and (4) judicial decisions by the International Court of Justice (ICJ), other international tribunals and, to a lesser extent, the national courts of sovereign states (ICJ Statute 1945). Of all these sources, only the first, treaty law, is considered "hard law." The rest form a body collectively regarded as customary international law. Customary law, however, may be equally as binding as treaty law depending on its general acceptance by nation states and evidenced by the extent to which those states honor and enforce it. All international law, treaty, and otherwise, depends on individual sovereign states for enforcement.

Customary international law, like treaty law, is being continuously created and modified. While it used to take many decades, if not centuries, of common practice by states to establish that a certain general principle of international law imparted an obligation on all states regardless of any treaty, that process may now be accomplished in a few years. A good example is the existence of a customary law against airline hijacking. Another is the recognition that coastal states now have a right to exercise jurisdiction over the resources of a 200-mi-wide EEZ once considered part of the high seas. The rapidly increasing exploitation of the world's resources, accompanied by a corresponding degradation of the world's environment, also supports an argument that there is a rapidly growing body of customary international law that governs resource conservation and pollution abatement.

One of the general principles of international law recognized by states is that conventional law may give rights to nonparty states, but may obligate only parties to a convention. To the extent that a treaty codifies customary law, however, it is binding on all states, whether or not they are parties. In the last two decades, treaties dealing with the environment have multiplied. Most of these conventions have incorporated into them certain common principles, including the obligation of "reasonable use" of shared resources (ICJ 1974) and the obligation of a state to ensure that activities within its jurisdiction do not damage its neighbors (Stockholm Declaration 1972).

Although international environmental law may impose general obligations to protect and conserve the world's resources, it is dependent on

sovereign states to enforce the obligations. Furthermore, it is understood that while international and regional cooperative efforts to protect the environment are important and should continue, they tend to be slow and ineffective. Most states recognize that neither they nor the planet can afford to wait for committee consensus. As a result, almost every pollution convention includes provisions whereby the contracting parties not only obligate themselves to carry out the terms of the convention, but also reserve the right to take unilateral measures to protect themselves against the acts of other states that threaten their environment (International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL) 1954; Brussels Liability Convention 1969; Intervention 1969; London Dumping Convention 1972; MARPOL 1973; MARPOL Protocol 1978). This treaty reservation is pervasive, and to the extent that it is backed up by states' practice, it can be considered a rule of customary international environmental law.

The unilateral measures reserved by states may include prescribing stricter environmental standards than those provided by conventional international law. The jurisdiction to enforce these stricter standards, however, can only be exercised where a state has personal or territorial jurisdiction. A state has primary jurisdiction over acts committed within its territory; it may also have jurisdiction over transnational acts that substantially affect its territory. This extraterritorial jurisdiction is based on the protective principle.

## THE PROTECTIVE PRINCIPLE IN INTERNATIONAL LAW

Based on the ancient doctrine of self-defense, the protective principle permits a state to assert jurisdiction over a legal person (including corporate individuals) whose conduct outside a state's territory threatens its national interests (Levi 1979). The "Restatement (Third) of Foreign Relations Law of the United States" outlines the scope of this principle in §402:

> "A state has jurisdiction to prescribe law with respect to. . .(3) certain conduct outside its territory by persons not its nationals that is directed against the security of the state or against a limited class of other state interests." (American Law Institute 1987)

According to the "Restatement (Third)," §402 comment f, the protective principle is considered to be an application of the territorial effects principle. In the U.S. view, if an extraterritorial act produces an effect within a state's territory, that state can assert jurisdiction on the basis of territoriality. The United Kingdom takes a slightly different and more conservative view. If the commission of at least part of an extraterritorial act occurs inside a state's territory, jurisdiction can be asserted on the basis of an "objective territorial principle." When all acts are concluded outside the territory with only the effects felt within the territory, then it falls within a more limited doctrine of "extraterritorial" jurisdiction (Higgins 1984). Whether there is a real distinction between these two viewpoints depends on how jurisdiction is applied to a

particular set of facts. There apparently is no single rule of international law on the applicability of extraterritorial jurisdiction. Different rules are applied to different situations or legal relationships (Weil 1984).

The "Restatement (Third)," §403(1), however, notes that the exercise of any such jurisdiction must not be unreasonable, and §403(2)(a) further notes that states have an obligation to consider "all relevant factors," including whether the extraterritorial activity has a "substantial, direct, and foreseeable effect upon or in the territory." Additional factors to consider that are particularly relevant to transnational pollution activities are included in §402(2)(c) and (f): the importance of the regulation to the regulating state, the extent to which other states regulate such activities, and the degree to which the desirability of such regulation is generally accepted and consistent with the traditions of the international system.

## THE PROTECTIVE PRINCIPLE APPLIED TO CIVIL ACTIONS

The jurisdictional regime described by the "Restatement (Third)," §402 and §403, applies to both civil and criminal actions. The civil application of the territorial effects principle to economic activity has been accepted by most Western European states, as well as Canada and Japan. European Economic Community (EEC) law has been applied to extraterritorial enterprises whose anticompetition activities have affected trade within the EEC. The EEC rules on competition, in particular those contained in articles 85 and 86 of the Treaty of Rome, apply to all agreements and practices of "undertakings" that prevent, restrict, or distort competition within the Common Market, even if those undertakings are situated in third countries (Lasok and Bridge 1987).

The United States applies the territorial effects principle in regulating the resale of technically sensitive U.S. products abroad and in antitrust restraint-of-trade actions. In *United States* v. *Aluminum Co. of America* (1945) Judge Learned Hand imposed a twofold test for the extraterritorial application of U.S. antitrust law: intent to affect the commerce of the United States and actual effect on that commerce. In *Timberlane Lumber Co.* v. *Bank of America* (1976), a Sherman Antitrust case, the court held that if commerce had in fact been affected, intent to affect was not required.

The use of the territorial effects principle to obtain relief from damaging acts committed by foreign states, as opposed to private foreign nationals, may be barred by the "act of state" doctrine. Under this doctrine, acts by sovereign states on their own territory are immune from the jurisdiction of foreign courts unless the state has expressly or by implication waived its immunity or the activity falls within the commercial exception (Akehurst 1984). The Foreign Sovereign Immunity Act (FSIA), 28 U.S.C. §1602, states that "[u]nder international law, states are not immune from the jurisdiction of foreign courts insofar as their commercial activities are concerned." Section 1603(d) of the FSIA defines "commercial activity" as "either a regular course of commercial conduct or a particular commercial transaction or act." In *Mannington Mills, Inc.* v. *Congoleum*

*Corp.* (1979, p. 1292), another case involving the Sherman Antitrust Act, the court held that the act of state doctrine, which would normally preclude private claims based on the contention that the damaging act of another nation violated either American or international law, does not provide a defense "where the governmental action rises no higher than mere approval." Private foreign nationals, unless they are acting as agent of the state, are not protected by the act of state doctrine and can be sued under principles of private international law.

## THE PROTECTIVE PRINCIPLE APPLIED TO CRIMINAL ACTS

The United States Supreme Court first recognized the protective principle in *Strassheim* v. *Daily* (1911, p. 285). Justice Holmes defined the principle as "acts done outside a jurisdiction, but intended to produce and producing detrimental effects within it." Eleven years later, in *United States* v. *Bowman* (1922, p. 98), the Supreme Court applied the principle to a case involving a conspiracy to defraud the U.S. Government by American citizens on American ships on the high seas. The lower court had dismissed the case since the controlling criminal statute did not expressly confer jurisdiction on U.S. courts for fraudulent acts committed on the high seas. The Supreme Court reversed, holding that jurisdiction could be inferred since certain criminal statutes are "not logically dependent on their locality for the government's jurisdiction, but are enacted because of the right of the government to defend itself. . . ." In 1968, the Second Circuit Court of Appeals applied the principle in *United States* v. *Pizzarusso* (1968, p. 10), a case involving false statements made abroad by a foreign national to a U.S. consular officer for purposes of obtaining an immigrant visa. The court held that because the false statements had a "potentially adverse effect" upon U.S. governmental functions, they were sufficient to infer jurisdiction.

The bulk of U.S. case law implementing the criminal application of this principle, however, focuses on violations of customs statutes by drug smugglers and the high seas enforcement of these statutes by the U.S. Coast Guard under "Regular Coast Guard: Functions and Powers," 14 U.S.C. §89(a). Although the State Department routinely requests the consent of the foreign flag state before authorizing the Coast Guard to board a foreign commercial ship on the high seas, Federal courts have ruled that this consent is not essential if the boarding is reasonable under the fourth amendment to the Constitution (*United States* v. *Conroy* 1979; *United States* v. *Streifel* 1981; *United States* v. *Alomia-Riascos* 1987). In *United States* v. *Verdugo-Urquidez* (1990, p. 1059) the Supreme Court held that the fourth amendment does not apply to search and seizure by U.S. agents of property owned by nonresident aliens and located in a foreign country. Presumably this holding might be applied to searches and seizures of foreign vessels on the high seas under the traditional view that flag vessels are extensions of state territory. The court did not consider whether such warrantless searches and seizures had to be reasonable.

## THE PROTECTIVE PRINCIPLE APPLIED TO ACTS ON THE HIGH SEAS

The high seas are a jurisdictional void. International law attempted to fill this void by creating a flag-state regime. Flag states once enjoyed

exclusive jurisdiction over ships flying their flags on the high seas under the old notion that a ship was a floating extension of a state's landed territory (Sohn and Gustafson 1984). This fiction is slowly dissolving under a growing number of exceptions, exceptions based on the protective principle and prompted by abuse of the flag-state prerogative. Many commercial ships fly "flags of convenience." By registering "ownership" in a state such as Panama or Liberia that is not a party to conventions that set international navigation, wage, safety, pollution, and resource conservation standards, shipowners can avoid compliance. This common practice belies the territorial justification for flag-state jurisdiction. In *Cunnard Steamship Co.* v. *Mellon* (1922), the U.S. Supreme Court maintained that flag-state jurisdiction "arises out of the nationality of the ship, as established by her domicile, registry, and use of the flag and partakes more of the characteristics of personal than of territorial sovereignty."

For strictly shipboard matters, the flag-state regime is still an acceptable basis for claiming jurisdiction, but when the effects of a ship's activities spread beyond the confines of the ship, flag-state jurisdiction must be qualified. Ship-generated pollution is only the latest in a long list of activities that have caused nonflag states to assert claims of jurisdiction.

Legal inroads into the tradition of exclusive flag-state jurisdiction can be found in the 1958 United Nations Convention on the High Seas (Law of the Sea (LOS) Convention 1958), a codification of customary international sea law up until that date. Article 22 of the LOS Convention (1958) acknowledges that the exclusive jurisdiction of the flag state over its vessels on the high seas is subject to some exceptions: the boarding of foreign merchant ships by warships is permitted if they are suspected of piracy, slave trading, or if they are in fact the same nationality as the warship. Article 28 of the LOS Convention (1958) also codified the protective principle embodied in the doctrine of "hot pursuit." Hot pursuit of a foreign ship is permitted when authorities of a coastal state have good reason to believe that the ship has violated the laws and regulations of that state. Coastal states are allowed to pursue offenders committing illegal acts in the territorial sea and contiguous zone out into the high seas, subject to the limitation that the pursuit be uninterrupted. Pursuit must be terminated when the ship being pursued enters the territorial sea of another coastal state.

The 1982 United Nations Convention on the LOS codified an expanding application of the protective principle in article 110, adding "unauthorized broadcasting" to the 1958 Convention's list of exceptions (LOS Convention 1982). Hot pursuit was expanded in article 111 to include the right to pursue ships committing illegal acts in the EEZ and over the Continental Shelf. In article 108, the LOS Convention (1958) acknowledges by implication that states are applying the protective principle to high seas drug trafficking and attempts to modify unilateral actions by authorizing flag states to request the cooperation of other states in the suppression of such traffic on the high seas.

## THE PROTECTIVE PRINCIPLE AND JURISDICTION OVER HIGH SEAS RESOURCES

The expansion of coastal state jurisdiction over the resources of the high seas is a recent phenomenon prompted in large measure by actions of the United States. In 1945, President Truman issued two proclamations, one claiming jurisdiction over the natural resources of the United States' Continental Shelf, the other over high seas fishery resources adjacent to its territorial sea. Prompted by World War II and a growing dependence on foreign sources of fossil fuels, the President proclaimed:

> "[T]he Government of the United States regards the natural resources of the subsoil and sea bed of the continental shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United States [and] subject to its jurisdiction and control." (Presidential Proclamation No. 2667, 1945.)

In 1953, this proclamation was enacted into law by Congress in the Outer Continental Shelf Lands Act, 43 U.S.C. §1,331-§1,343.

The second Presidential proclamation announced the policy that conservation zones would be established by treaty in areas of the high seas contiguous to the territorial waters of the United States (Presidential Proclamation No. 2668, 1945). In these zones, all fishing would be subject to U.S. regulation and control. Although nation states had been regulating the exploitation of coastal fishing stocks by treaty for more than a hundred years, overfishing still occurred, prompting the United States to invoke a unilateral policy (Sohn and Gustafson 1984). The fishing proclamation was never enacted into statutes, but the United States did thereafter conclude treaties which extended a regional jurisdictional regime over some high seas fishery resources (North Pacific Convention 1952; Halibut Convention 1953).

The Truman proclamations prompted Chile, Ecuador, and Peru to sign the Declaration of Santiago on the Maritime Zone in 1952, whereby each nation claimed complete sovereignty over a 200-mi-wide zone adjacent to its coast (Sohn and Gustafson 1984). In 1958, the High Seas Fishing Convention attempted to limit unilateral extensions of territorial jurisdiction into the high seas that were based on the protective resource conservation rationale. The convention acknowledges that coastal states have a "special interest" in the high seas resources adjacent to their territorial seas, but grants them limited preferential rights in article 6. Article 7 of the convention permits unilateral conservation measures by coastal states only if resource management negotiations between all interested parties have failed.

The concept of a 200-mi EEZ was developed by the Third United Nations Conference on the Law of the Sea in the 1970's. Simultaneously, other states unilaterally claimed their own exclusive zones. In 1972, Iceland established a 50-mi exclusive fishery zone, which was contested by the United Kingdom and the Federal Republic of Germany before the ICJ (1974). In 1976, the United States unilaterally established a 200-mi fishery conservation zone in which it assumed "exclusive fishery management authority over

all fish, except highly migratory species, and. . .authority beyond such zone over such anadromous species and Continental Shelf fishery resources" (Magnuson Fishery Conservation and Management Act (MFCMA) 1986, 16 U.S.C. §1801-§1882). Article 56 of the LOS Convention (1982) gives coastal states "sovereign rights" to explore, exploit, conserve, and manage the natural resources of a 200-mi-wide EEZ, and article 64 permits coastal state jurisdiction over highly migratory species found within that zone. Furthermore, the right to fish on what is left of the high seas is no longer absolute. The right to fish for anadromous stocks on the high seas is contingent upon negotiated agreement (article 66), and the remaining high seas fishing rights are subject to the interests of coastal states (article 116). The convention imposes on all states the duty to cooperate with other states and to take "such measures for their respective nationals as may be necessary for the conservation of the living resources of the high seas" (article 118).

The protective principle is also applied in the LOS Convention (1982) to the conservation of marine mammals. The convention specifies that "[n]othing in this part restricts the right of a coastal State. . .to prohibit, limit or regulate the exploitation of marine mammals more strictly than provided for in this part" (article 65). It also specifies that these provisions apply to the conservation and management of marine mammals on the high seas (article 120). The LOS Convention (1982) seems to sanction the high seas enforcement of coastal state conservation measures, if the high seas activities of foreign nationals "exploit" protected marine mammals.

## POLLUTION ENFORCEMENT AND THE PROTECTIVE PRINCIPLE

The protective principle can also be found in the pollution provisions of the LOS Convention (1982). Exclusive flag-state jurisdiction over vessels beyond the territorial sea had not succeeded in eliminating vessel-source pollution or in protecting the environment of coastal states from it (Boyle 1985). The LOS Convention (1982) authorizes port states to investigate and prosecute foreign vessels voluntarily coming into their jurisdiction who have violated international pollution rules and standards on the high seas (article 218(1)). Presumably these standards are those embodied in the International Convention for the Prevention of Pollution from Ships (MARPOL 1973) and the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention 1972). This provision represents an expansion of port state jurisdiction beyond that authorized by MARPOL, which limits port states to inspection and the reporting of any violation of the 1973 convention to the flag state.

Coastal states under the LOS Convention (1982) may enforce their own pollution rules and standards against foreign vessels voluntarily coming into their ports, but only with respect to acts committed in their territorial waters and EEZ's (article 220(1)). As for stopping ships in transit passage, a coastal state may enforce its own laws for acts committed in its territorial waters (article 220(2)), but may enforce only international pollution standards for acts committed in its EEZ, provided they result "in a discharge causing major damage or the threat of major damage to the coastline or related interests of the coastal State, or to any resources of its territorial sea or exclusive economic zone" (article 220(6)).

Both port state and coastal state jurisdiction can be preempted by the flag state (article 228(1)), subject to the provision that the flag state continue the proceedings within 6 months and unless there is major damage to the coastal state or the flag state "has repeatedly disregarded its obligations to enforce effectively the applicable international rules and standards in respect of violations committed by its vessels" (article 228(2)).

The 1982 LOS Convention is not yet in force. However, aside from the provisions regarding the deep seabed in part IX, it may be considered to represent a codification of both existing and developing customary international law. Those provisions which are not found in other multilateral treaties or do not represent the practice of a majority of states are, of course, not yet part of international law. Yet most of the provisions cited above represent only an expansion of existing principles already established. For example, LOS Convention (1982) provisions dealing with marine pollution represent an extension of the standards set forth in a plethora of conventions which came into being as a result of maritime oil disasters. The obligations in each of the pollution conventions cited below are applicable only to the states' parties, but taken in aggregate, the conventions establish the right to a pollution-free environment that is shared by all states. Many of the provisions noted in the following conventions represent an emerging regime of customary international pollution law, law that is based on the protective principle.

## THE PROTECTIVE PRINCIPLE IN THE MARINE POLLUTION CONVENTIONS

The protective principle is incorporated into the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL 1954: article 11), the Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (Intervention 1969, article 1), the International Convention on Civil Liability for Oil Pollution Damage (Brussels Liability Convention 1969), the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention 1972, article 7, 13), the Protocol Relating to Intervention on the High Seas in Cases of Marine Pollution by Substances Other Than Oil (High Seas Protocol 1973, article 1), and the International Convention for the Prevention of Pollution from Ships (MARPOL 1973, article 9). For example, Intervention (1969) specifies:

> "Parties to the present convention may take such measures on the high seas as may be necessary to prevent, mitigate or eliminate grave and imminent danger to their coastline or related interests from pollution or threat of pollution of the sea by oil, following upon a maritime casualty or acts related to such a casualty, which may reasonably be expected to result in major harmful consequences" (article 1(1)).

This same provision can also be found in the High Seas Protocol (1973). "Substances other than oil" in this treaty include, inter alia, other substances "which are liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea" (article 1(2)).

Relevant provisions in the 1973 MARPOL Convention, conceived in the early seventies, are considerably more conservative in terms of the protective principle than current states' practice and evolving customary international law as is evidenced by the LOS Convention (1982). The MARPOL Convention, while imposing universal obligations not to pollute, essentially leaves its high seas pollution enforcement up to the flag state, limiting the port state to inspection and reporting activities. Coastal states are given the option of either reporting a violation occurring within their jurisdiction to the flag state or initiating proceedings on their own (MARPOL 1973, article 4(2)). The extent of coastal state jurisdiction, however, was the source of considerable controversy during the drafting of the treaty. The issue was never resolved, and as a result the phrase "within the jurisdiction of any Party" (article 4) must be interpreted according to current interpretations of the term in international law (Timagenis 1980).

The MARPOL negotiators also disagreed over the power of states to take stricter regulatory measures than those expressly provided for in the convention. The compromise text, adopted by a majority of the delegates, but not by the required two-thirds, provided that

> "(1) Nothing in the present Convention shall be construed as derogating from the powers of any Contracting state to take more stringent measures where circumstances so warrant, within its jurisdiction, in respect of discharge standards" (article 8, now article 9).

In its final form, MARPOL defers to future decisions by the United Nations Conference on the LOS, stipulating only that nothing in MARPOL "shall prejudice. . .the present or future claims and legal views of any State concerning the law of the sea and the nature and extent of coastal and flag State jurisdiction" (article 9(2)). It leaves interpretation of the term "jurisdiction" up to customary international law (article 9(3)).

With the failure of the compromise text, Australia reserved the right to impose unilateral conditions within its jurisdiction to protect its "adjacent" marine environment from pollution (Timagenis 1980, p. 503). The Canadian delegation stated that since there was no provision restricting the powers of the contracting states to take measures within their jurisdiction, the Canadian Government reserved the right "to take any and all measures within its jurisdiction for the protection of its coasts and the adjacent marine environment from pollution from ships" (Timagenis 1980, p. 505). Ireland and the Philippines made similar statements (Timagenis 1980, p. 506).

## THE PROTECTIVE PRINCIPLE AND STATES' PRACTICE--A CANADIAN EXAMPLE

In 1970, Canada unilaterally implemented the protective principle in response to a pollution threat to its Arctic coastline. Fearful of a devastating accident associated with the United States' development of the Alaskan North Slope and the use of the Northwest Passage for transport of crude oil to refineries on the east coast, the Canadian Parliament passed

the Arctic Waters Pollution Prevention Bill, extending Canadian jurisdiction 100 nmi into the Beaufort Sea for purposes of regulating marine pollution. The act held both prospector and ship owner liable for all costs associated with any discharge of wastes into this region (Canadian Arctic Waters Pollution Prevention Bill 1970). In reply to a protest letter from the United States, the Canadian Government responded "that a danger to the environment of a state constitutes a threat to its security. . . . The proposed anti-pollution legislation is based on the overriding right of self-defense of coastal states to protect themselves against grave threats to their environment" (Canadian Reply 1970). This unilateral declaration caused considerable controversy in the world community. The 1982 LOS Convention resolved the controversy with a special provision granting coastal states the right to adopt and enforce laws and regulations to prevent and control pollution in ice-covered areas within the EEZ (article 234).

## THE PROTECTIVE PRINCIPLE IN UNITED STATES ENVIRONMENTAL LEGISLATION

In 1961, Congress passed the Oil Pollution Act, 33 U.S.C. §1001-§1015, implementing OILPOL. Over the next decade the convention was amended and more legislation was enacted as marine pollution and public awareness grew. In 1974, the Intervention on the High Seas Act, 33 U.S.C. §1471-§1487, implemented Intervention 1969 and its companion treaty dealing with substances other than oil. This legislation, extending the protective principle to pollution activities on the high seas, empowers the United States to take measures to "prevent, mitigate or eliminate" danger to its coastline caused by oil pollution casualties on the high seas when they "may reasonably be expected to result in major harmful consequences" (§1472).

The 1973 version of MARPOL did not enter into force before it was superseded by the Protocol of 1978, which extensively modified Annex I (Regulation for the Prevention of Pollution by Oil) and Annex II (Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk). The modifications in the pollution prevention standards were the result of an international conference convened at the request of the United States following 16 major tanker accidents in waters around the United States in 1976-77 (U.S. Congress 1980). Although the MARPOL Protocol did not come into force until 1983, many of its provisions were immediately implemented by Congress in the Port and Tanker Safety Act of 1978, 33 U.S.C. §125, §128-§1232 and 46 U.S.C. §391(a), §1221, §1224. The Senate ratified the 1978 MARPOL Protocol in 1980 and implemented the balance of its provisions that year in the Act to Prevent Pollution from Ships, 33 U.S.C. §1901-§1911. The other three original MARPOL annexes are optional. Annex III and Annex IV have not been ratified by the United States and are not in force.

Annex V of the original 1973 MARPOL Convention came into force in December 1988, with U.S. ratification. Not revised by the Protocol of 1978, Annex V prohibits the disposal at sea of garbage and plastic waste; however it excepts the accidental loss of synthetic fishing nets incidental to the making of repairs from its general prohibition. Congress implemented Annex V on 29 December 1987 with an amendment to the Act to Prevent Pollution from Ships, adding simply the word "garbage" to its list of prohibited discharges, 33 U.S.C. §1907(d)(1) and (e)(1). Although the

Annex V amendments continue to defer to the flag-state enforcement scheme of the MARPOL Protocol as enacted into U.S. law in 1980 (§1907(c)), they also include a preemption requirement mandating that "[e]xcept as specifically provided. . ., nothing in this title shall be interpreted or construed to supersede or preempt any other provision of Federal or state law. . .[or] any State from imposing any additional requirements" (33 U.S.C. §1901(a)).

The MFCMA regulations regarding fishing gear disposal were also amended in 1987. Previously these regulations had exempted all accidental gear loss from its general prohibitions. Now any gear discards, including accidental discards, are strictly prohibited except in case of emergency or with specific Coast Guard authorization (50 C.F.R. §611.12). This is a stricter discard standard than that of MARPOL Annex V.

In conjunction with implementation of Annex V, Congress also enacted the Driftnet Impact Monitoring, Assessment, and Control Act of 1987, 16 U.S.C. §1822. This act requires the Secretary of Commerce to assess the impact of driftnets on U.S. marine resources and the Secretary of State to initiate

> "negotiations with each foreign government that conducts, or authorizes its nationals to conduct driftnet fishing that results in the taking of marine resources of the United States in waters of the North Pacific Ocean outside of the exclusive economic zone and territorial sea of any nation, for the purpose of entering into agreements for effective enforcement of laws, regulations, and agreements applicable to the location, season, and other aspects of the operations of the foreign government's driftnet fishing vessels." (16 U.S.C. §1822)

The act further specifies that if the foreign government fails to enter into and implement such an agreement within 18 months, certification under the Pelly Amendment will result (16 U.S.C. §1822, 22 U.S.C. §1978(a)). The Pelly Amendment provides that when the nationals of a foreign country, directly or indirectly, are (1) conducting fishing operations in a manner or under circumstances which diminish the effectiveness of an international fishery conservation program, or (2) engaging in trade or taking which diminishes the effectiveness of any international program for endangered or threatened species, the Secretary in charge of the finding shall certify the fact to the President. The President in turn may then direct the Secretary of the Treasury to prohibit the bringing or importation in the United States of fish products of the country whose nationals are engaging in such conduct (22 U.S.C. §1978(a)).

Congressional intent on the extent of jurisdiction can be found in the final committee report to the House. The Merchant Marine and Fisheries Committee expressly stated that no extension of U.S. jurisdiction was to be construed by passage of the legislation. It affirmed, however, "the sovereign rights of the United States to conserve and manage marine resources within its exclusive economic zone and anadromous species on the high seas to the extent provided for in United States law" (U.S. Congress 1987a).

## UNITED STATES MARINE RESOURCE CONSERVATION ENFORCEMENT AND THE PROTECTIVE PRINCIPLE

In only a few instances has the United States asserted through active enforcement the protective principle codified in its various conservation and pollution laws. Current case law reveals an enforcement focus on violations of the MFCMA in the EEZ by foreign fishing nations signing GIFA's with the United States. A GIFA is an executive agreement between the United States and a foreign state which gives the foreign state the right to fish for specified quantities of designated species in the United States EEZ for a specified period of time. In return, the foreign fishing nation agrees to abide by the terms of the MFCMA (Japanese GIFA 1982; Korean GIFA 1982; Taiwanese GIFA 1982). Consent to be boarded and inspected for suspected violations, included in the agreement, considerably simplifies jurisdictional questions. Federal courts have assumed GIFA jurisdiction for violations of the MFCMA in the EEZ in *United States* v. *Tsuda Maru*, 470 F.Supp. 1223 (D. Alaska 1979); *United States* v. *Marunaka Maru No. 88*, 559 F.Supp. 1365 (D. Alaska 1983).

The signatory state also must agree to comply with any administrative measures taken in accordance with the agreement and to pledge not to kill or harass any marine mammal within the EEZ without express authorization. If the state fails to agree to acceptable monitoring and enforcement arrangements, the Secretary of Commerce has the authority to deny fishing permits to any of its vessels. In addition, Federal regulations implementing the MFCMA prohibit a foreign fishing vessel from throwing overboard any article that may damage any marine resource, including marine mammals and birds (50 C.F.R. §611.12(c)). This regulation is now reinforced by legislation implementing Annex V of the MARPOL treaty.

A GIFA is enforced by both overflight and boarding inspections by the Coast Guard and by placing National Marine Fisheries Service (NMFS) observers on board some foreign vessels fishing in the EEZ. A few observers have also been placed on the Japanese salmon mothership fleet operating in the high seas of the North Pacific (Marine Mammal Commission 1990). In addition, three United States observers were permitted to observe commercial squid driftnet operations on board Japanese vessels in 1982 (Cary and Burgner 1983) and 1986 (Tsunoda 1989) and on a Korean vessel in 1988 (Gooder 1989). A few additional observations have been made by observers from the vantage point of Coast Guard cutters (Ignell et al. 1986) and private vessels. In 1989, following a mandate from Congress (Driftnet Impact Monitoring, Assessment, and Control Act 1987) agreements were concluded with Japan, Korea, and Taiwan to place a few observers on board commercial driftnet vessels. Japan agreed to allow 9 United States and 5 Canadian observers on board 14 of its commercial squid driftnet vessels during the 1989 season (Japan-United States Agreement 2 May 1989). Agreements with Korea and Taiwan were concluded too late to implement a foreign observer program for 1989. Korea agreed to deploy "at least 13" United States observers on board its "commercial driftnet vessels for at least 45 days each to observe 45 or more driftnet retrievals on each vessel" (Republic of Korea-United States Agreement Annex II, 13 September 1989). Taiwan agreed only to deploy "observers of the parties. . .aboard

commercial driftnet vessels. . .for at least 30 days to observe 30 or more driftnet retrievals on each vessel" (American Institute of Taiwan-Coordination Council for North American Affairs Agreement article VII, 13 July 1989).

Data from the joint Canadian-Japan-United States observer program were collected between early June and early October 1989, by observers on board commercial Japanese driftnet vessels chosen by lot fishing between long. 170°E and 145°W, and between lat. 36° and 45°N. The results were released on 30 June 1990 (Joint Report Fisheries Agency of Japan, Canada Department of Fisheries and Oceans, NMFS, and Fish and Wildlife Service (FWS) 1990). In summary 1,402 operations were observed involving 1,427,225 tans of net (50-m each). The catch included 3,119,061 neon flying squid, 914 dolphins, 22 marine turtles, 9,173 seabirds, and 1,580,068 nontargeted fish, including 79 salmonids, 1,433,496 pomfrets, 59,060 albacore, 10,495 yellowtail, 7,155 skipjack tuna, and 58,100 blue shark. The data did not indicate what percentage of the huge incidental catch of assorted fishes were actually brought on board and kept.

Estimates of incidental catch rates of nontargeted species vary greatly depending on the year, the vessel, its location, the time of year, who is doing the reporting, and the proximity of the observer. The total number of sets observed and recorded is extremely small compared to the total amount of driftnet fishing actually done. Obtaining statistically significant data may be an impossible goal. Between 1978 and 1983 the amount of fishing effort by the driftnet fleet rose dramatically and exponentially; since then it has increased much more gradually. Thus the maximum incidental catch of long-lived species such as marine mammals and turtles would have occurred in the early eighties at a time when practically no data were being kept. Incidental catches today probably reflect the impact of driftnet fishing on much reduced populations. Fishermen have also been observed shaking undesired species free of the nets before hauling them on board (Gooder 1989; Tsunoda 1989), a factor which would distort vessel owners' reports of total incidental takings. Although there have been few observations of torn netting being discarded at sea, this may have been influenced by the fact that observers were watching.

In 1984, a NMFS observer on board a Japanese vessel fishing in the EEZ near Dutch Harbor, Alaska, saw its crew members on five separate occasions toss several 0.45 × 0.76-m (1.5 × 2.5-ft) fragments of synthetic trawl netting overboard. At a hearing before a National Oceanic and Atmospheric Administration (NOAA) administrative law judge, expert testimony revealed that some 30% of documented fur seal entanglements involve net fragments in the same size range as those discarded and some 40% of the seals caught in such net fragments die (*In the Matter of Kenji Nakata, Ohoura Gyogyo Co. Ltd.*, 4 O.R.W. 814 (NOAA 1987)). In his decision, the judge indicated that every vessel discarding such net fragments must be held responsible for the cumulative effect on the fur seal population and that the civil penalties assessed for such violations must be large enough to serve as a deterrent and not be considered as a mere cost of doing business. The owners of the offending vessel were fined $15,000 total for two violations. The MFCMA authorizes up to $25,000 assessment for each violation (16 U.S.C. §1858(a)).

Although it has been asserted that lost sections of driftnet ball up within a week and thus no longer ghost fish, evidence indicates that tangled driftnets continue to ghost fish, both on the surface (DeGange and Newby 1980; Henderson 1984; von Brandt 1984; Gooder 1989) and on the bottom (Way 1977; Carr and Cooper 1987). In 1978, a 3,500-m section of lost driftnet was found floating in the North Pacific (lat. 49°15'N, long. 168°14'E). Entangled within the 1,500 m brought on board were 75 newly snared salmon and at least twice that many rotten ones, plus assorted other fish and some 99 seabirds (DeGange and Newby 1980). Endangered Hawaiian monk seals have also been found entangled in masses of monofilament driftnet (Henderson 1984).

## THE NORTH PACIFIC DRIFTNET FISHERY--A CASE FOR APPLICATION OF THE PROTECTIVE PRINCIPLE

The 20th century development of nylon and plastics has greatly benefited human "progress" and greatly burdened the global environment. Except for the hulls of vessels, plastics dominate the fishing industry: polystyrene and polyurethane foams are used for flotation in lifejackets and fishnet floats; polyethylene is used to make cable coverings, buckets, packaging film, and shipping containers; polyamide (nylon), polyester, polyethylene, and polypropylene are used for ropes and nets (Pruter 1987). Gillnets, one of the most efficient fishing methods ever developed, are made of monofilament nylon. Strong, transparent, and durable, nylon is the perfect material for constructing the miles of pelagic drift gillnets used by high seas salmon and squid fishermen. Gillnets are also cheap, difficult to mend, and easily replaced, usually after only one season of use (Eisenbud 1985). Pelagic gillnets are made in panels 6-8 m deep and may be over a 100 m long. These individual panels are strung together by the fishermen on lines with floats on surface and weights on the bottom to create an invisible wall which may stretch for miles. Set at night, the gillnets are either left to drift free until the following morning, or remain attached to the catcher boat at one end.

There are two Japanese salmon driftnet fisheries: a mothership fishery in the Bering Sea and a land-based fishery that operates south of the Aleutian Islands. They are regulated by the International North Pacific Fisheries Commission, established to implement the provisions of the 1952 North Pacific Convention. The North Pacific Convention is a tripartite agreement between the United States, Canada, and Japan to: "1) ensure cooperation in scientific research and data collection on salmon and other fish species in the North Pacific Ocean and Bering Sea; 2) minimize interceptions of North American origin salmon by Japan; and 3) facilitate cooperation in marine mammal research" (Beasley 1984). Each party agreed to enact and enforce the necessary domestic laws and regulations to implement the convention provisions (North Pacific Convention, article 9(2); 16 U.S.C. §1021-§1035).

In 1976, the MFCMA claimed exclusive management authority over anadromous species of U.S. origin throughout their range, unless they are within the jurisdiction of another nation (16 U.S.C. §1812). The MFCMA required that the North Pacific Convention be renegotiated to the extent that it was in conflict with the act (16 U.S.C. §1822(b)). In 1978 a

protocol was signed amending the North Pacific Convention and shifting the eastern boundary of the salmon mothership fishing area from long. 175°W to 175°E, except for a small enclosed area of high seas in the middle of the Bering Sea known as the donut hole (North Pacific Convention Protocol 1978). The Japanese land-based fleet is limited to an area south of lat. 46°N east of long. 170°E, and south of lat. 48°N west of long. 170°E. The Japanese also have a treaty with the Soviet Union which excludes all salmon fishing within the Soviet EEZ and regulates high seas salmon fishing outside of this zone (Japan-U.S.S.R. 1956). In May 1990, the Soviet Union seized a fleet of more than 10 "North Korean" driftnet vessels for harvesting thousands of tons of Soviet salmon. The fleet had previously been spotted by the U.S. Coast Guard fishing south of the Aleutian Islands. North Korea is not a party to any of the North Pacific fishing agreements. Following arrest it was discovered that the fleet and more than 140 fishermen were actually Japanese and were fishing under the North Korean flag to circumvent treaty restrictions.

The high seas driftnet fisheries are condemned by many as an economically inefficient method of fishing. They catch salmon before they reach full size and can bring the maximum market price, as well as nontargeted species, which are discarded; 50% of the fish caught are estimated to drop out of the nets before they can be brought on board; the various salmon stocks mingle on the high seas making it almost impossible to manage individual stocks; and driftnets are lost or discarded at sea where they continue to entrap fish (Sathre 1986). Furthermore, the high seas squid driftnet fisheries of Japan, the Republic of Korea, and Taiwan have high "incidental" catches of salmon which may not be so incidental (the Japanese squid fishery uses driftnets similar to those used by the salmon fishery) (Anderson 1989; Matsen 1989). Begun in 1978, the Japanese squid fishery now extends across much of the North Pacific and by agreement is supposed to stay in waters too warm for salmon (15°-22°C). However, the Coast Guard has sighted numerous Japanese vessels fishing north of the boundaries established by Japanese regulations (Gordon 1985). Furthermore, neither the Republic of Korea nor Taiwan is bound by the 1978 Protocol's salmon fishing boundary restrictions, although Taiwan has agreed to respect a squid fishing boundary similar to Japan (Gordon 1985). In 1988, the Soviets seized three Taiwan driftnet vessels reportedly carrying 3,357,000 kg (9 million lb) of immature salmon (Anderson 1989). As for MARPOL prohibitions against abandoning old driftnets, only Japan is currently a party to Annex V.

Driftnets fish indiscriminately. While mesh size is targeted for a particular species, the nets are capable of catching almost anything that swims or dives: small whales, porpoises and dolphins, seals and sea lions, turtles, and almost every kind of diving seabird have been found trapped in them (DeGange and Newby 1980). Lost and discarded net sections from high seas gillnet fisheries frequently drift into the U.S. EEZ and continue to entrap large numbers of migratory seabirds and marine mammals. This gear may ghost fish for years before settling on the bottom or washing up on a beach. Although the "act" of losing this deadly gear may have occurred on the high seas, the effect constitutes a taking of migratory seabirds and marine mammals within U.S. EEZ and territorial waters that is in direct

contravention of both treaty and U.S. domestic law. This entrapment of birds and mammals by ghost nets drifting into the EEZ is arguably illegal under the "taking" provisions of the Marine Mammal Protection Act (MMPA), 16 U.S.C. §1361-§1407, the Endangered Species Act (ESA), 16 U.S.C. §1531-§1542, the North Pacific Fur Seals Act, 16 U.S.C. §1151-§1175, and the Migratory Bird Treaty Act (MBTA), 16 U.S.C. §703-§712.

The MMPA defines the term "take" as meaning to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal (16 U.S.C. §1362(12)). Pursuant to this act, a permit is required for any incidental take of marine mammals in the course of commercial fishing operations (§1362(14)). The goal, however, is that incidental takes "be reduced to insignificant levels approaching zero" (§1371(a)(2)). The MMPA also authorizes the Secretary of the Treasury to ban the importation of fish products from fish which have been caught using technology that results in killing or seriously injuring marine mammals "in excess of United States standards" (§1371(a)(2)). Amendments to the MMPA passed in 1988, however, permit exemptions from the incidental taking provisions until 1 October 1993, provided that fishing vessels keep detailed annual records of all such takings (Public Law 100-711, 23 November 1988, adding §114; 50 C.F.R. part 229).

The ESA was created to "provide for the conservation, protection and propagation of endangered species of fish and wildlife by Federal action. . ." (U.S. Congress 1973). The ESA makes it "unlawful for any person subject to the jurisdiction of the United States to take any protected species on the high seas" (16 U.S.C. §1538(a)(1)(C)). Any exceptions require permits (16 U.S.C. §1539 and 50 C.F.R. §10.1 et seq.). The ESA further authorizes the Secretaries of Commerce and State to enter into bilateral or multilateral agreements for the protection and conservation of endangered and threatened species and to encourage citizens of foreign states "who directly or indirectly take fish or wildlife or plants in foreign countries or on the high seas for importation into the United States for commercial purposes. . .to carry out. . .conservation practices designed to enhance such fish or wildlife or plants and their habitat" (16 U.S.C. §1537(b)). The enforcement provisions of the ESA permit any U.S. citizen to bring a civil suit to enjoin any person, including the United States Government, who may be in violation of the ESA (§1540(g)). Worldwide service of process may be implied in the language of the ESA, 16 U.S.C. §1540(c), which specifies that "the several district courts of the United States. . .shall have jurisdiction over any action arising under this chapter." According to reporters' notes 7 and 9 of §421 of the Restatement (Third), where nationwide jurisdiction is conferred by statute, jurisdiction of a Federal court no longer depends on the laws of the state where the court sits. Evidence of an intent to apply the ESA extraterritorily has been found by courts (*Defenders of Wildlife* v. *Hodel* 1989) in the broad definition of "endangered species," §1532(6), which includes many species not native to or present in the United States, along with §1538(a)(1)(C), which prohibits takings on the high seas, coupled with §1532(13), which defines "persons" to include foreign governments.

Japan and the United States are parties to the bilateral 1972 Migratory Bird Convention, which prohibits the taking of migratory birds in

the territories of both countries (Migratory Bird Convention 1972). The annex to the convention lists 189 protected species; virtually all are species listed in regulations implementing the ESA and the MBTA (50 C.F.R. §10.13). In addition to prohibitions, the convention also includes some affirmative duties. The Migratory Bird Convention mandates that each contracting party "shall (a) [s]eek means to prevent damage to such birds and their environment, including, especially, damage resulting from pollution of the seas. . ." (article 6(a)). Article 6(a) also specifies that "[e]ach Contracting Party agrees to take measures necessary to carry out the purposes of this Convention." Of the 800,000 seabirds estimated to die each year in the gillnets of the Japanese mothership and land-based salmon fisheries of the North Pacific, many belong to species that are listed in the Migratory Bird Convention Annex (U.S. Congress 1987b). Data from the 1989 Canadian-Japan-United States squid driftnet observer program included birds from at least five species listed in the annex (331 Laysan albatrosses, 38 northern fulmars, 20 horned puffins, 5 tufted puffins, and 17 Leach's storm petrels). Ghost driftnet data have also reported catches of listed birds. In one mass of tangled driftnet, DeGange and Newby (1980) identified birds from 6 listed species (4 Laysan albatrosses, 15 northern fulmars, 15 tufted puffins, 14 sooty shearwaters, 40 slender-billed (short tailed) shearwaters, and several fork-tailed storm petrels).

The Migratory Bird Convention is implemented in part in the MBTA (16 U.S.C. §703-§712. The MBTA prohibits the taking of listed migratory birds without a permit from the Department of the Interior (16 U.S.C. §703 and 50 C.F.R. §10.13 and §21.11). In recent testimony given by the Department of the Interior on driftnet takings of migratory seabirds by the Japanese salmon fisheries, there was no mention of any permits having been issued (Lambertson 1985), possibly because the FWS does not believe it has jurisdiction. However, under customary international law, as codified in the 1982 LOS Treaty and recognized as such by Presidential Proclamation No. 5030 on 10 March 1983, the United States has jurisdiction over all "living resources" of its EEZ. The term "marine resources" has been defined by Congress in the 1986 amendments to the MFCMA as including "fish, shellfish, marine mammals, seabirds, and other forms of marine life or waterfowl."

Japan is also a party, along with the Soviet Union, Canada, and the United States, to the 1957 Interim Convention on the Conservation of North Pacific Fur Seals prohibiting the taking of fur seals in the North Pacific Ocean (Fur Seal Convention 1957). The Fur Seal Convention empowers any party to board and inspect another party's fishing vessel anywhere except in territorial waters if there is reasonable cause to suspect that the vessel is violating the prohibition against sealing (article 6). Pelagic "sealing" is defined as the killing, taking, or hunting in any manner whatsoever of fur seals at sea" (article 1). If the suspicion is well founded, the vessel may be seized and the persons on board arrested. Judicial proceedings, however, are left to the flag state. This treaty has been enacted into U.S. law in the North Pacific Fur Seals Act, 16 U.S.C. §1151-§1175. The act, however, permits U.S. flag fishing vessels to refuse boarding if they are within the U.S. EEZ (§1152). Fur seals are, of course, also covered under the MMPA. Although the NMFS has issued permits to GIFA holders for the incidental taking of fur seals and sea lions, NMFS was enjoined by an order of the U.S. District Court in Washington, D.C., from

issuing a permit for the 1988 season (*Kokechik Fishermen's Association* v. *Secretary of Commerce*, 839 F.2d 795 (D.C. Circuit 1988)). The court ruled that the northern fur seal, *Callorhinus ursinus*, incidentally taken by the Japanese mothership salmon driftnet fleet are depleted below optimum levels and that the MMPA prohibits the issuance of a permit to take any such depleted marine mammals.

## ACTION TO BAN DRIFTNETS BY THE INTERNATIONAL COMMUNITY

Several foreign states have already taken action to ban driftnet fishing in waters under their jurisdiction, including Japan, Australia, Canada, the Cook Islands, the Federated States of Micronesia, New Zealand, Peru, French Polynesia, American Samoa, and Vanuatu. In July 1989, the South Pacific Forum states signed the Tarawa Declaration, which expressed regret that Japan and Taiwan "failed to respond to the concerns of regional countries" about pelagic driftnet fishing and called for a ban on driftnet fishing in the South Pacific. Korea had already announced its intention to withdraw its driftnet vessels from the South Pacific area. In November 1989, several South Pacific states signed the Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific. The convention bans driftnet fishing within the 200-mi EEZ's of the signatory states and within certain adjacent high seas areas. In December 1989, the United Nations General Assembly unanimously adopted a resolution that condemns the commercial use of driftnets and calls for a ban on driftnet fishing in the South Pacific, beginning 1 July 1991, and a worldwide ban beginning 30 June 1992. [On 26 June 1990, Taiwan announced that it would prohibit its driftnet fleet from fishing in the South Pacific by July 1991.]

## REMEDIES FOR VIOLATIONS OF INTERNATIONAL ENVIRONMENTAL STANDARDS

If activities within a state's jurisdiction cause significant damage to its neighbors or the common environment, that state is responsible to all injured states for violation of its obligations. A state may be obligated by either treaty or customary international law. If the obligation is owed to the international community as a whole, any state may bring a claim before the ICJ without showing that it has suffered a particular injury (American Law Institute 1987, §902(1), §602 comment a). Consent to jurisdiction of the ICJ by the defendant state is not necessary under the Statute of the ICJ. In general, the state seeking redress has the burden of proving the existence of an international obligation and its breach; the responding state has the burden of establishing any justification or excuse. The burden of proof may shift to the party that has control of the evidence (American Law Institute 1987, §901 comment a). Thus any state may call on the violating state to terminate activities which are causing significant injury to the general environment.

If the obligation is owed to a particular state or states, the injured states may also file international claims. Treaties generally include a dispute resolution clause in their text. If the method chosen does not produce results, or if there is no such clause, the injured state(s) may take its grievance before an international tribunal with the consent of the responding state or the ICJ without the responding state's consent. The enforcement power of the ICJ, however, is that of world opinion and

voluntary compliance by sovereign states. If a citizen of a state has a cause of action, it must be taken up by his parent government before the ICJ. Article 34 of the Statute of the ICJ gives it jurisdiction only over states. The injured person must also have exhausted local remedies (American Law Institute 1987, §703 comment b).

A state may also sue a fellow sovereign state in any domestic court that will accept jurisdiction, but because of the principle of sovereign immunity, domestic courts will generally accept jurisdiction only if a state waives its sovereign immunity or if the offending acts attributable to the state involve commercial activities (Foreign Sovereign Immunities Act, 28 U.S.C. §1605(a)(2)). Because of the vagueness of customary international law and the domestic court's general unfamiliarity with it, plus the fact that, at least in the United States, foreign policy issues are reserved to the executive branch, adjudication in a domestic forum stands a better chance of success if arguments are based on domestic law.

Private persons, including organizations, may also bring suit when international environmental standards are violated. Injured persons may bring a claim directly against a foreign state in an international forum when that state has consented to the forum's jurisdiction, or in any domestic court that will accept jurisdiction (American Law Institute 1987, §906, §907). In the United States, Federal courts have jurisdiction over cases arising under international law and international agreements of the United States. However, "international agreements, even those directly benefiting private persons, generally do not create private rights or provide for a private cause of action in domestic courts" unless the provisions are "self-executing" (American Law Institute 1987, §907 comment a).

Whether a treaty of its own force makes law depends on two requirements: (1) the treaty-drafters must have intended that the treaty provision be self-executing as ascertained by the applicable international rules of treaty interpretation (Vienna Convention on the Law of Treaties 1969) and (2) the treaty provision in question must have the force of legislation without any further action by a legislative body (Henry 1928). Treaty obligations not to act, or to act only subject to limitations, are generally self-executing. Self-executing obligations may also arise under customary international law. In conjunction with driftnet fishing there are two customary obligations that may be considered self-executing: (1) "fisheries for anadromous stocks shall be conducted only in waters landward of the outer limits of exclusive economic zones" (LOS Convention 1982, article 66(3)(a)) and (2) "the taking of endangered species is prohibited" (implied in a whole host of multilateral and bilateral treaties). Rules of customary international law are part of U.S. law and as such may permit domestic remedies. Again, suits against foreign states may be barred by sovereign immunity unless there is a waiver or the activity falls within the commercial exception.

Private persons can also bring claims directly against private foreign polluters. The chief hurdle is obtaining personal jurisdiction over the polluter. While filing suit in the foreign polluter's home state may cure this problem, it may cause others. The laws and courts of that state may be less than friendly and the costs and inconvenience of doing so are

usually a severe limitation. Procedural and discovery problems are also magnified in transnational cases.

In the United States, citizens and private organizations may also sue their government, its agencies, and its officials for nonenforcement of environmental laws which implement treaty provisions. The Act to Prevent Pollution From Ships, 33 U.S.C. §1910(a), permits any person having an interest adversely affected to bring an action not only against a private violator, but against the Coast Guard for failure to perform a nondiscretionary act and the Secretary of the Treasury for failure to enforce the ship clearance provision (§1908(e)). The ESA allows a citizen to sue (A) to enjoin any person, including the United States or its agencies, if it is in violation of the ESA; (B) to compel the Secretary of the Interior to apply ESA prohibitions with respect to the taking of any threatened species; and (C) the Secretary if he fails to perform a nondiscretionary duty (16 U.S.C. §1540(g)(1)). Other legislation may also permit citizens to sue public officials for acts which are arbitrary, capricious, involve an abuse of discretion or are contrary to law (Administrative Procedure Act, 5 U.S.C. §553, §701 et seq.). Citizens may or may not be able to recover attorney's fees (33 U.S.C. §1910(d), 16 U.S.C. §1540(g)(4)).

Adjudication has many advantages, including the availability of immediate injunctive relief when it is needed and serving as a catalyst for change by goading inactive commissions, legislatures, and the public into action. Adjudication can also prevent further damage. However, there are other, less confrontational methods of mitigating or preventing environmental harm. One of these methods is the liability fund.

## A LIABILITY ENFORCEMENT PROGRAM TO DISCOURAGE GEAR LOSS

Liability funds to compensate for damage caused by environmental pollution are not new to the oil and ultrahazardous waste industries, but are a new idea for curing generally pervasive types of environmental pollution such as acid rain and the disposal of garbage at sea. They have the virtue of serving both as a deterrent to future pollution, if set at punitive levels, and as a source of funds for those damaged by the polluting party's activities. They are also in line with the liability provisions contained in the LOS Convention (1982, article 235). The convention includes compulsory insurance and compensation funds as methods that states should employ in order to provide adequate compensation for pollution damage caused by persons under their jurisdiction (article 235(3)). A liability enforcement program such as the one that follows should encourage both domestic fishing vessels and foreign vessels fishing in the U.S. EEZ under a GIFA to comply with U.S. law prohibiting the dumping of fishing gear overboard. The conclusion of bilateral and multilateral liability fund agreements with high seas fishing nations who have not signed GIFA's should also be considered.

Specifically, the owner of a fishing vessel fishing in the EEZ would be entitled to limit his liability for lost driftnets and any damage caused by them if he constitutes a fund for the total sum representing the limit of his liability. The fund can be constituted either by depositing the sum with the administering agency or by producing an acceptable bank guarantee

or proof of insurance. The liability ceiling would be established according to the risk each fishing enterprise poses to the resource. The risk can be calculated using conventional measures of fishing effort: size and number of vessels, amount and type of gear, and number of days fished.

Control methods would utilize an inventory reporting system to account for all gear purchases, gear retirement, and "lost" gear. Penalties for lost gear would be paid out of the fund. Credit and a lowering of total liability would be awarded for expenditures made for conservation measures such as investing in gear with biodegradable panels and knots. Failure to report could result in a tripling of the normal penalties assessed and a doubling of the liability ceiling. Exceptions may be made for natural disasters and intentional acts by third parties.

A liability fund has several advantages. For the fisherman, contributions can be internalized as a cost of doing business; fishing vessels will no longer be subject to seizure for violations and judgment payments; other assets will be immune from attachment; and fishery allocations will not be jeopardized for inadvertent gear loss. For those specifically injured by renegade gear, the fund will provide a source of compensation for resource and property damage. For the government, proceeds from penalties assessed may be used to finance resource conservation activities and the development of traceable and biodegradable fishing gear. The fund also would be easier to enforce than current methods of trying to catch vessels in the act of discarding gear on the high seas.

## CONCLUSION

While additional information on the effects of driftnet fishing is useful, it is not necessary in order to legally proceed against persons whose high seas fishing activities damage the coastal resources of the United States. The effective management of marine resources within the EEZ necessitates that the United States regulate foreign fishing activities on the high seas and in fact legislation already exists that implements this application of the protective principle. Although there are as yet few cases where the United States has extended the protective principle codified in its various conservation and pollution laws to the high seas, such an extension is already legal under both domestic and international law. If the protective principle can be used to enforce narcotics laws on the high seas, it can be used to enforce environmental laws.

The Stockholm Declaration on the Human Environment (1972) directs states to "take all possible steps to prevent pollution of the seas by substances that are liable to. . .harm living resources and marine life. . ." (article 7). The doctrine of "reasonable use" of the high seas, addressed in a 1974 decision by the ICJ, establishes that "[t]he former laissez faire treatment of the living resources of the sea in the high seas has been replaced by recognition of a duty to have due regard to the rights of other states and the need of conservation for the benefit of all" (ICJ 1974, p. 175). It is the role of international treaties and tribunals to establish global environmental standards; it is the role of individual sovereign states to enforce those standards. International and regional cooperative efforts are important and should be promoted, but the global community cannot

afford to wait. Under conventional and customary international law, states not only have the right, they have the obligation to protect the global environment using all the tools available to them.

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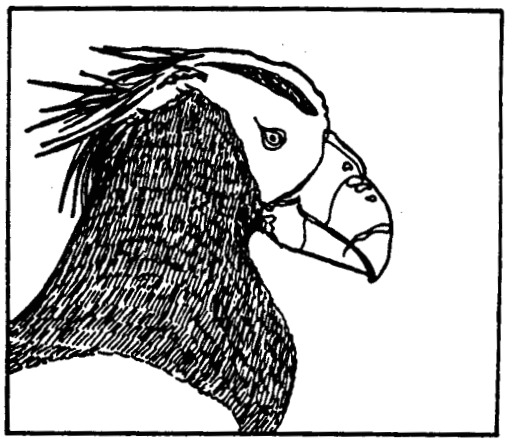
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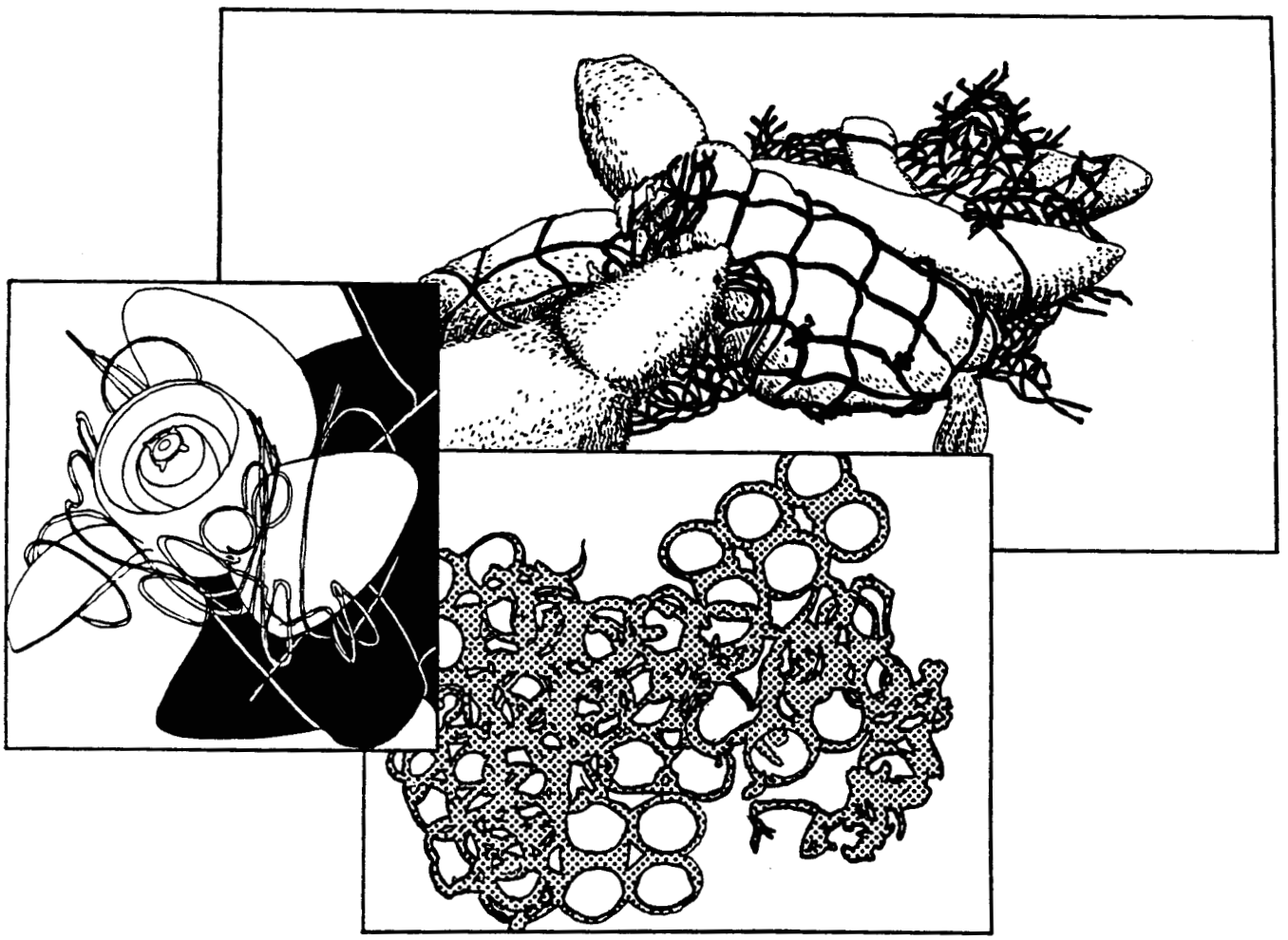
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# SESSION VII



## SOLUTIONS THROUGH EDUCATION



# THE PLASTICS INDUSTRY AND MARINE DEBRIS: SOLUTIONS THROUGH EDUCATION

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## ABSTRACT

Over the past several years, intense media attention and congressional debate have focused on the problems caused by plastics discarded or lost in the marine environment. Less well known are the efforts of the plastics industry, through its major trade association, The Society of the Plastics Industry, Inc. (SPI), to help find solutions to these problems. Since 1986, SPI has been working with the Center for Marine Conservation--formerly the Center for Environmental Education--and the U.S. National Oceanic and Atmospheric Administration to implement public service educational campaigns with specific messages targeted to selected audiences.

When the marine debris problem is examined in detail, it is clear that among the various types of plastic debris, all but one end up in the oceans as the result of activity by individuals beyond the "control" of the plastics industry. The one exception involves resin pellets, the raw material for making plastics products. This presentation will examine how the plastics industry has responded to the marine debris problem in general, and specifically to the presence of resin pellets in the aquatic environment.

## INTRODUCTION

Over the past several years, intense media attention and congressional debate have focused on problems caused by plastics that have been intentionally discarded or accidentally lost in the marine environment. Less well known are the efforts of the plastics industry, primarily through its major trade association, The Society of the Plastics Industry, Inc. (SPI), to help find solutions to these problems.

Since 1986, SPI has been working with the Center for Marine Conservation (CMC)--formerly the Center for Environmental Education--and the U.S. National Oceanic and Atmospheric Administration (NOAA) to develop and implement a public service educational campaign with very specific messages

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

targeted to selected audiences. This paper will examine that segment of the public service campaign targeted to the plastics industry, as well as other activities aimed at educating plastics companies about the role of discarded plastics in the marine environment and what should be done about them.

## THE SOCIETY OF THE PLASTICS INDUSTRY POLICY STATEMENT

The SPI's educational efforts have been strongly backed at the highest levels of the organization. Their board of directors developed and passed on 18 September 1987 an official policy statement on marine debris that pledged the industry to help solve the problem.

That policy stated, in part:

"The SPI supports the responsible use of its industry's materials and proper disposal of those products when they become waste. Plastics should not be discarded into the ocean or any other body of water.

- "Plastics Resin Pellets--The SPI is dedicated to working with its member companies to eliminate circumstances that result in resin pellets being lost in manufacturing or transportation and possibly rendering harm to animal or marine life that mistake the pellets for food.

- "MARPOL Ratification--The SPI supports U.S. ratification and implementation of the Annex V of the MARPOL Convention, which would prohibit the dumping of plastics waste into the ocean.

- "Degradability--The SPI endorses continued research and development on degradable plastics. However, it believes there are limitations on what products are suitable to be made degradable. Performance and safety requirements should not be compromised in order to make a product degradable. . . .

- "Public Education--The SPI supports public education encouraging the proper disposal of plastics and other materials as the most effective way to reduce harm to the marine environment. The association is willing to work with other organizations sharing this position on projects to further education on the proper disposal of plastics in the marine environment."

In addition, SPI invited CMC President Roger McManus to make a special presentation on the subject to its board of directors' Issues Management Committee on 12 May 1988, and CMC staffer Kathy O'Hara has addressed the SPI Issues Communication Committee and other industry audiences on several occasions. These presentations were particularly helpful in raising the level of sensitivity and responsiveness within the industry.

## THE SOCIETY OF THE PLASTICS INDUSTRY SUPPORTS MARPOL ANNEX V

In 1987, when the U.S. Congress was considering ratification of Annex V, many organizations--including the plastics industry--spoke out in support of it. The SPI was emphatic in its view that the time has come to stop discarding trash of all kinds into the marine environment. Testifying before a subcommittee of the U.S. Senate Committee on Environment and Public Works, SPI's Lew Freeman, vice president of government affairs, said:

> ". . .To the extent that plastics are part of the marine debris problem the SPI and the plastics industry will continue to work with government, environmental groups, and other industries to develop responsible and effective solutions. But marine debris is more than just a problem of 'plastics pollution,' the term so frequently used to describe it. It is a broader problem of debris from all types of materials being discarded in the oceans.
>
> "There will be a marine debris problem with or without plastics as long as a growing and affluent world population continues the overt--and sometimes covert--practice of using the oceans of the world as a convenient place to put waste. . . . Clearly, plastics waste does not belong in the oceans. However, neither do glass, metal or even paper wastes" (Freeman 1987).

## RESIN PELLETS

When the scope of marine debris is examined in detail, it is clear that the problem stems from many sources. In the CMC's 1987 report for the U.S. Environmental Protection Agency, at least nine distinct sources were identified: commercial fishing operations, merchant shipping, naval and research vessels, plastics manufacturing, offshore drilling operations, recreational boaters, docks and marinas, municipal stormwater and sewage systems, and general littering by beachgoers. All but one of these "sources" are the result of activities that are beyond the sphere of direct influence of the plastics industry. That one exception involves resin pellets, the raw material for making plastics products.

Resin pellets, while not particularly an aesthetic problem in the marine environment, have been identified as a hazard to seabirds who ingest them. Although resin pellets are not as abundant as other debris items in the ocean, they seem to be preferred by seabirds. In studies of plastic pieces in the North Pacific (Wilbur 1987), only 0.5% of the pieces of plastic collected from surface waters were pellets. Yet these pellets form about 70% of the plastic found in the stomachs of seabirds.

## BRIEFING FOR RESIN PELLET PRODUCERS

One of SPI's first steps in dealing with the question of resin pellets in the marine environment was to alert companies that produce these materials. In September 1986, SPI hosted a briefing in Washington, D.C. which

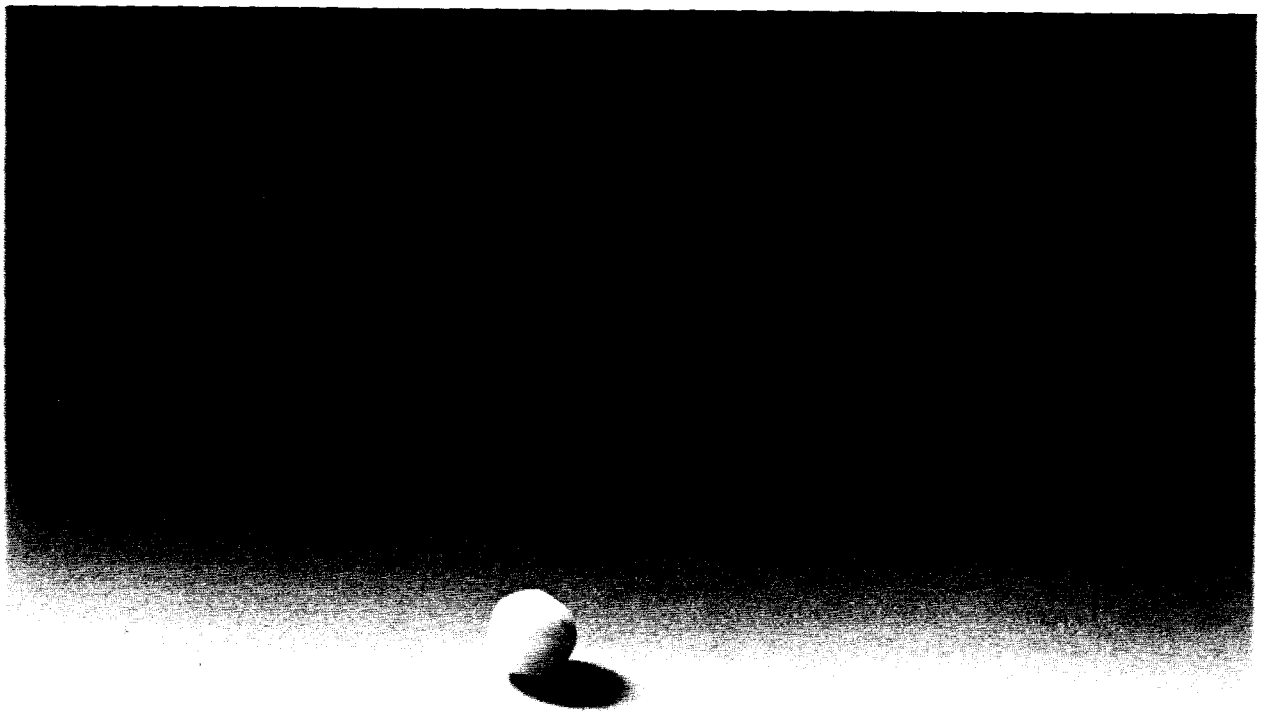
featured a presentation by Kathy O'Hara from CMC on the marine debris problem and a videotape on resin pellet reclamation produced by Dow Chemical Co., an SPI member company. Virtually all the major resin-producing companies sent representatives. Discussions at that meeting yielded insights that later would be incorporated into a variety of public service materials. The foundation also was laid for an informal survey of the pellet-handling practices of resin producers. While not a definitive study, the results showed that containment procedures for handling resin pellets generally were implemented in the early-to-mid-1970's and that current practices at resin plants seem to preclude significant losses into the environment. Less was known about the thousands of companies that process the resin pellets into final products; thus materials were developed to inform them of the problem as well as of corrective actions to be taken.

## PUBLIC SERVICE ADS AND BROCHURES

As noted in the Introduction, the plastics industry was one of three audiences initially targeted by the SPI/CMC/NOAA public service campaign. Materials developed under the joint logo included a full-page, black-and-white magazine ad (Fig. 1) for use in plastics industry publications and an eight-panel collateral brochure. The ad, which shows an enlargement of a resin pellet, carries the headline "A seabird could mistake this resin pellet for a fish egg. And die." The copy reads:

> "One little pellet may be insignificant to your plastics processing operation. But to thousands of seabirds, it could lead to a fatal error.
>
> "These pellets, in many shapes and sizes, can be washed down drains as waste or reject material, or spilled in the course of normal handling. But ultimately, they may find their way to bodies of water, where the real trouble begins.
>
> "When eaten in sufficient quantity by a seabird, they can block digestion or sometimes fool the bird into thinking it is not hungry, causing eventual starvation. Fish and sea turtles can suffer the same fate.
>
> "The growing problem of plastic trash in our oceans threatens more than wildlife. This critical issue is destined to invite increasing public and government scrutiny unless we take action to solve it.
>
> "So please: see that resin pellets are reclaimed or disposed of properly. If we ignore the problem we--like the unfortunate seabird--will be making a serious mistake."

Camera-ready reproduction materials (negatives and veloxes) were made available free-of-charge to plastics trade publications, and readers of the ad were invited to write to SPI for additional information. Initially, that consisted of an eight-panel brochure, which offered these recommendations:



# A seabird could mistake this resin pellet for a fish egg. And die.

One little pellet may be insignificant to your plastics processing operation. But to thousands of seabirds, it could lead to a fatal error.

These pellets, in many shapes and sizes, can be washed down drains as waste or reject material, or spilled in the course of normal handling. But ultimately, they may find their way to bodies of water, where the real trouble begins.

When eaten in sufficient quantity by a seabird, they can block digestion or sometimes fool the bird into thinking it is not hungry, causing eventual starvation. Fish and sea turtles can suffer the same fate.

The growing problem of plastic trash in our oceans threatens more than wildlife. This critical issue is destined to invite increasing public and government scrutiny unless we take action to solve it.

So please: see that resin pellets are reclaimed or disposed of properly. If we ignore the problem, we—like the unfortunate seabird—will be making a serious mistake.

*To learn how you can help, write: The Society of the Plastics Industry, 1275 K Street, N.W., Suite 400, Washington, D.C. 20005.*

A public service message from
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

**Figure 1.--Full-page public service ad developed for plastics industry publications has been published more than 25 times. Value of the donated space exceeds $100,000.**

- Conduct an "audit" of manufacturing facilities to seek out and eliminate practices which could allow pellets to escape into the environment.

- Initiate an awareness and information program within the company.

- Install closed-loop pellet containment and collection systems in resin production facilities.

- If resin pellets are spilled during processing, clean them up promptly and either recycle them or dispose of them in ways that prevent their release into the environment.

- When cleaning hopper cars, do not flush residual pellets into the environment.

- Instruct employees to close valves on the unloading shoes of rail cars and hopper trucks after they have been unloaded. (If left open, small quantities of pellets stuck in the corners may vibrate loose and be scattered along railroad tracks and highways, ready to be washed by rain into the nearest stream.)

- Do not store or dispose of pellets in areas subject to flooding.

- Make sure resin pellets are used only as intended--for manufacture of plastics products.

Subsequently, a 20-piece marine debris information kit (described in detail on the following pages) was provided to all who wrote or called for more information. Individual companies also prepared materials. Dow Chemical Company produced and made available a videotape as well as a special flyer on resin pellet containment procedures.

## PLASTICS MEDIA BRIEFINGS

Upon completion of the public service ad, brochure, and a special flip-chart presentation, a two-person SPI/CMC team set out to inform editors and publishers of major plastics industry publications on the importance of the marine debris issue. During the fall of 1987, the briefing team personally met with Bob Martino, editor, and Bob Leaversuch, senior editor, at Modern Plastics; Doug Smock, editor, at Plastics World; Matt Naitove, editor, and Bob Burns, associate editor, Plastics Technology; Bob Forger, publisher, and Abe Schoengood, editor, Plastics Engineering; and Peter Sullivan, group vice president, Suzanne Witzler, executive editor, and Mel Friedman, editor, of Edgell Publications (formerly HBJ Publications, which includes Plastics Machinery and Equipment, Advanced Composites, Plastics Compounding, Plastics Design Forum, and Plastics Packaging). The readers of these publications represent a "Who's Who" in plastics, reaching virtually every segment of the industry.

In each case, the overall marine debris problem was discussed with emphasis on the resin pellet aspect, and the publication was asked not only to write about it but also publish the ad on a public service basis.

## PLASTICS MEDIA RESPONSE

The response to the visits by the briefing team was overwhelming, and some publications continue to run the ad nearly 18 months later. (In the summer of 1988, two smaller versions of the ad were developed and reproduction materials provided to each of the publications.) Through February 1989, plastics industry publications have devoted more than 1,000 column inches of space either to the ad or to news coverage of the marine debris issue. The ad alone has been published on at least 25 occasions by 10 different publications. Their combined circulations in conjunction with the number of publication times means that more than 1.1 million magazine pages featuring the resin pellet ad are now circulating within the plastics industry. It is estimated that the donated advertising space alone would have cost in excess of $100,000 had it been purchased at the regular rates.

Not only was the ad published with great frequency, but it also was read! Plastics Design Forum (circulation: 47,500 design engineers) reported that a Readex study of its January 1988 issue showed the resin pellet ad was "the second best read ad in the whole issue" (second only to a multipage, full-color special section). "I think that says a lot of things--both in terms of the quality of the ad, but maybe even more significantly, in terms of the importance of the message," commented Peter Sullivan in reporting the results of the study to SPI.

As gratifying as the advertising support has been by plastics industry publications, even more crucial has been their editorial endorsement of the need for the plastics industry to respond to the problem of plastics in the marine environment. Within months of the visits by the briefing team, four of the largest publications devoted their editorial pages (Fig. 2) to the subject. An example is this excerpt from Modern Plastics (Martino 1987, p. 41):

> "Goodbye, George F. Babbitt.--The era of Babbittry has ended--at least in plastics. Sinclair Lewis' fictional businessman might still find a home in the backwaters of industry, but here in the mainstream Babbitt's boosterism and distrust of skeptics no longer has an audience. We see this clearly in environmental issues. There is a new generation of plastics leadership--mindful that plastics surround citizens in daily life, pragmatic enough to listen to these citizens, and responsible enough to want to listen.
>
> "One hopes that the passing of Babbitt will be mirrored by the passing of those who have made it their personal mission to save the world from plastics. The need for cooperation between industry and citizens on environmental issues is so apparent that responsible people should no longer have patience with this sort of axe grinding. . . .

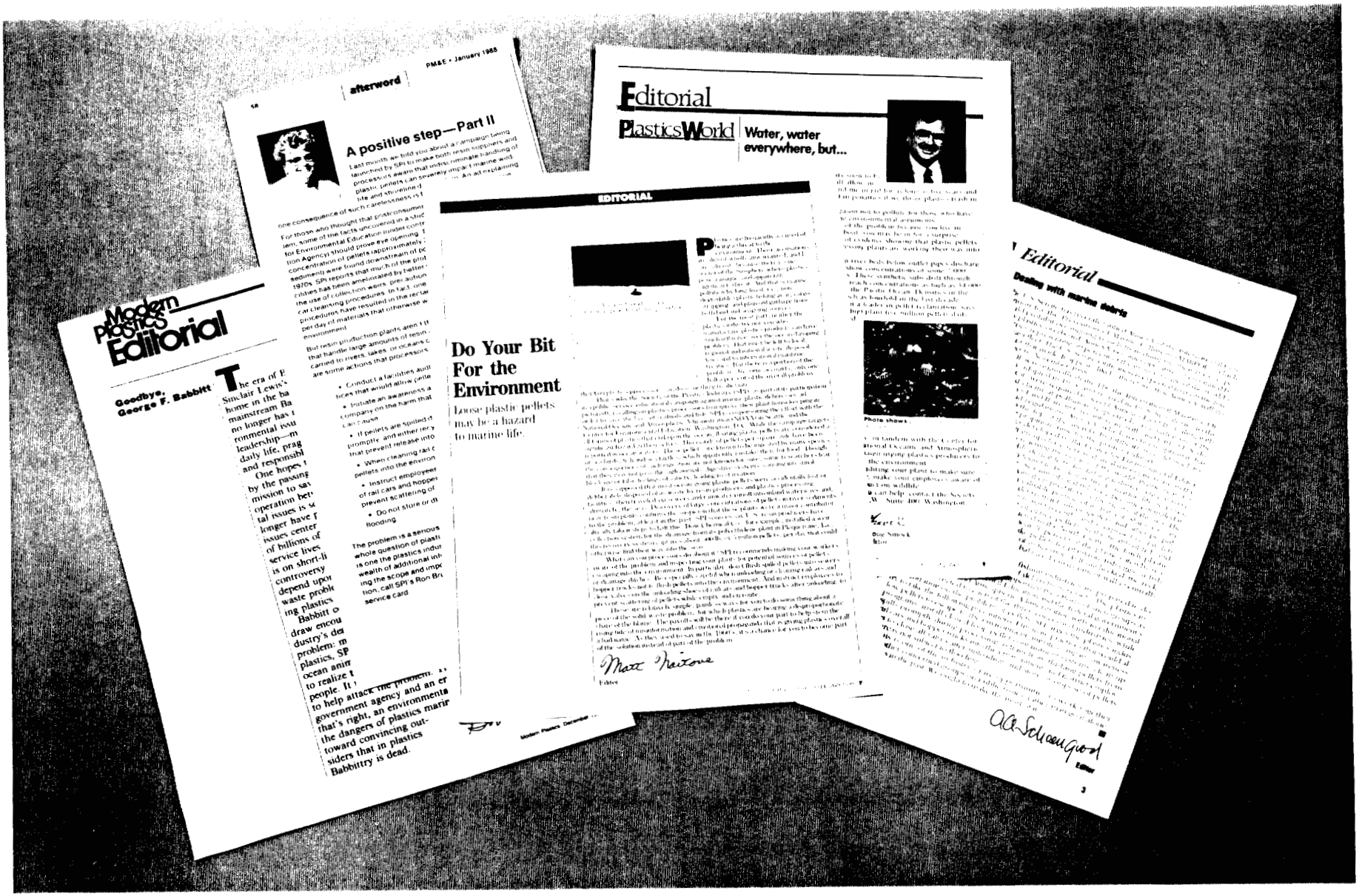



Figure 2.--All the major plastics industry publications wrote editorials calling attention to the marine debris situation and encouraging the industry to support corrective actions.

> "Babbitt could never have coped. We, however, can draw encouragement from the Society of the Plastics Industry's dealings with one special form of solid waste problem: marine litter. Instead of knee-jerk defense of plastics, SPI's response to reports that plastics litter kills ocean animals was to take the reports seriously enough to realize that they were accurate accounts from sensible people. It then undertook practical, reasonable measures to help attack the problem. The latest, joining with a government agency and an environmentalist group--that's right an environmental group--to warn about the dangers of plastics marine litter will go far toward convincing outsiders that in plastics Babbittry is dead" (Martino 1987).

Closer to home, SPI has published the full-page public service ad several times in its President's Report to the Members, distributed quarterly to 4,000 leading executives in the plastics industry. In addition, stories have been carried in that same publication as well as in Plastics News Briefs, also published by SPI and distributed to nearly 11,000 people in the industry.

## PLASTICS MARINE DEBRIS EDUCATION KIT

While publication of the public service ads, editorials, and news stories in the plastics trade press was raising the awareness level of the issue within the industry, SPI was busy developing additional materials for use with its members. Those materials took the form of the Plastics Marine Debris Education Kit (Fig. 3), which was distributed in May 1988 to some 1,500 resin-producing and processor companies on SPI's membership list. The cover letter, distributed with the kit and signed by SPI President Larry Thomas, said in part:

> "As you know, the problem of plastics in the marine environment has gained widespread attention over the past year from both the media and government officials. For the most part, the situation is out of our hands--obviously it is difficult for us to keep track of how the end-user disposes of our products, and the vast majority of the plastics in the marine environment were dumped there by others.
>
> "But the problem of resin pellets in the ocean is ours alone.
>
> "It is time to escalate our education efforts to be sure that pellets are not escaping during routine handling, transportation and shipping procedures. . . . I urge you to make this education effort a priority. Employees who manufacture, ship and handle resin pellets need to become more aware of the importance of careful handling procedures. . . ."

The information kit, which carried the resin pellet theme from the public service ad and brochure, was designed to enable any company to carry out its own internal information campaign. Included in the kit were:

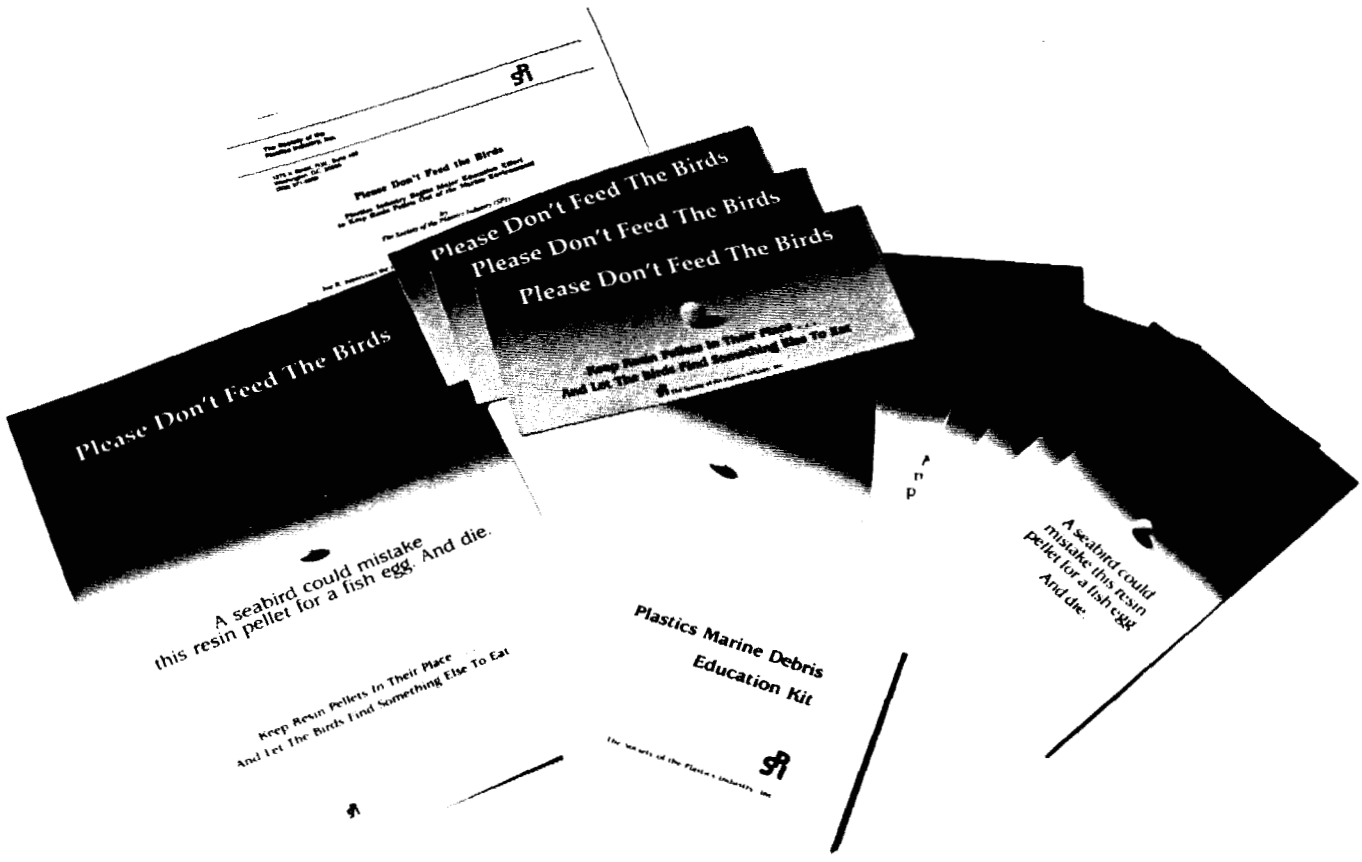



Figure 3.--Plastics Marine Debris Education Kit developed by The Society of the Plastics Industry, Inc., was mailed to some 1,500 of its member companies.

- Posters (in two sizes) for placement on bulletin boards or in well-traveled areas of the plant.
- Stickers for placement on trash cans and other appropriate waste disposal containers.
- A feature article about marine debris and resin pellets for use in company magazines or newsletters.
- Brochures with additional information for distribution to employees.
- Order form to secure additional quantities of any of the printed materials.

The SPI has filled many orders for kits and individual parts of the kit, both from SPI members and nonmembers, many of whom were alerted to the availability through the public service ad. In addition, kits were distributed via other means, such as SPI resin producer member companies to their customers in the processing business.

The information kit also has been distributed to the plastics industry on the international scene. In the summer of 1988, SPI's Thomas presented copies of the kit to attendees at a meeting of the International Plastics Associations Directors (IPAD) held in Berlin, West Germany. The IPAD periodically brings together the chief executive officers of the 50 worldwide plastics associations to exchange information.

## THE SOCIETY OF THE PLASTICS INDUSTRY--PLASTICS WORLD ROUNDTABLE

Representing the plastics industry on the marine debris roundtable spearheaded by NOAA's James Coe, SPI gained a greater understanding of many aspects of marine debris--and saw that the solution must be multifaceted. The many hours of discussion convinced SPI's director of technical and regulatory affairs, H. Patrick Toner, that there must be a role for the SPI beyond what it already was doing.

The plastics industry is noted for its entrepreneurial, turn-a-problem-into-an-opportunity approach to business. The question was how to spark that creative problem-solving for the benefit of the marine environment. As a trade association, SPI does not actually develop specific products. That didn't mean, however, that it couldn't facilitate the process with information.

Working with Plastics World magazine, SPI sponsored in July 1988 a roundtable discussion on the marine debris problem, bringing together representatives from major industries and organizations with a stake in the situation. Participants included:

James Coe, U.S. National Marine Fisheries Service
Joe Cox, American Institute of Merchant Shipping
William Gordon, New Jersey Marine Sciences Consortium
Carl Kirkland, Plastics World
Ralph Rayburn, Texas Shrimpers Association
Thomas S. Scarano, U.S. Navy
Gary Schmidt, American President Lines
Mark D. Sickles, American Association of Port Authorities
Doug Smock, Plastics World
H. Patrick Toner, The Society of the Plastics Industry, Inc.

The result was a five-page story by Smock in the September 1988 issue of Plastics World entitled "Are shipboard plastics all washed up?" Smock (1988) examined the scope of the problem and what options were under consideration, and noted: "Many of the changes being considered will create commercial opportunities for alert entrepreneurs. There are visions of recycling industries sprouting at harbors. And who will manufacture the on-board compactors, incinerators and waste processing equipment being contemplated for marine plastics?"

Clearly, the message had been delivered to the industry. Now, only time will reveal the degree of success.

## THE SOCIETY OF THE PLASTICS INDUSTRY SYMPOSIUM ON DEGRADABLE PLASTICS

Since marine debris first began showing up in headlines and on the evening news, the notion of degradable plastics often has been posed as a solution. In late 1986 and early 1987, increased references to this prompted SPI to plan a symposium on the subject. As the "voice of the plastics industry," SPI was being called upon to respond to the viability of the idea, but there was not a ready compendium of current information.

The Symposium on Degradable Plastics, held 10 June 1987 in Washington, D.C., helped solve that problem. Ten presentations on the technology of biodegradable and photodegradable plastics, plus additional papers, resulted in a proceedings book that contained the best available public information on the subject at that time.

In his opening remarks to the overflow crowd of nearly 400, C.E. O'Connell, then president of SPI, said:

> "I hope that by the end of the day we will have enough information to go away thinking about plastics, and particularly plastics packaging, in a new way. We are being asked to think about product design from the cradle to the grave, and as a responsible industry, we must give serious thought to the ultimate disposal of our products after their useful life is finished.
>
> "I doubt that we will come away with many answers today, but as far as I am concerned, that is not really our goal. If we can come away with an appreciation for the difficult questions, and an awareness of the perceived needs, we will be that much closer to determining just where degradability is truly feasible, both today and in the future."

Perhaps Michael Bean of the Environmental Defense Fund, one of the symposium speakers, summed it up best when he told the audience that day:

> "The important environmental questions that must be asked are whether the products of degradation are themselves environmentally safe and whether degradation can occur rapidly enough to reduce significantly the hazards of plastics in the environment. The obvious marketing question is whether plastic products made to degrade can continue to serve their intended function in the marketplace."

Some of the questions posed then still deserve consideration today, but much has happened since that symposium in 1987. Many legislative proposals have been made. Some laws have been passed. A number of companies now offer degradable plastics products.

## CONCLUSION

Just as the cause(s) of the marine debris problem is largely an accumulation of careless actions over many years, so too will the solution come in the form of years of dedicated efforts on a variety of fronts. The industry is committed to being a meaningful part of that solution--through both cooperative educational efforts and the development of environmentally safe products.

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# MARPOL 73/78 INFORMATION, EDUCATION, AND TRAINING: MEETING THE CHALLENGE

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## ABSTRACT

In response to growing public concern about the widespread distributions of marine litter, The Tidy Britain Group, the United Kingdom's agency responsible for the prevention and control of mishandled waste, established a Marine Litter Research Program in 1973. The program's overall strategy has been to quantify the nature and scope of the problem in the coastal and oceanic waters of Western Europe, and to persuade governments, intergovernmental organizations, and the shipping industry of the need for remedial actions.

To date a series of information surveys, public awareness campaigns, and educational initiatives has been completed, including a contribution toward an International Maritime Organization (IMO) training package for ships' crews.

This paper provides an insight into these activities, focusing primarily upon the data collection methods developed for the surveillance of marine litter by beach surveys, the approaches adopted in the public awareness campaigns and educational initiatives, and the observed impacts upon coastal environments. These activities have provided background expertise and knowledge to support the information, education, and training recommendations contained in the IMO Guidelines for the Implementation of Annex V of MARPOL 73/78.

An immediate objective of the information surveys was the development of standardized field survey techniques and analytical methods for the surveillance of marine litter. This has been accomplished by the use of appropriate sampling techniques and the establishment of technical support networks. Consequently, major trends in the composition, origins, distributions, and lifetimes of litter in the marine environment have been identified in a series of baseline surveys. Other studies have identified the safety hazards arising from packaged dangerous goods, clinical wastes, munitions, and pyrotechnics washed ashore.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Two national shoreline surveys have been completed since 1979, with observations at 4,000 sites around the coastline. Studies of marine litter have been undertaken at all levels within the formal education system, and beach cleanups are frequently undertaken by environmental land amenity groups.

A more recent development is the Blue Flag Campaign in European Economic Community member states. Beaches which receive these awards are expected to be litter free, and ports or marinas are required to provide facilities for the disposal ashore of garbage from ships and pleasure craft.

## INTRODUCTION

The Tidy Britain Group is the United Kingdom's national litter abatement organization, with a broad membership including national and local government, industry, commerce, and voluntary organizations. It functions primarily as an advisory body, making available a range of practical programs which it has developed through research, evaluation, and experience over the years.

The group's broad strategy is to deal with the litter problem by tackling the two main root causes: first, the attitudes and behavior of all people towards littering and the environment generally; and secondly, the incorrect handling of rubbish and waste. This has been achieved by a series of ongoing educational and action programs which involve, and target, the entire community.

The Marine Litter Research Program is an integral part of this structure and approach towards litter abatement. It was established in 1973 with an honorary director supported by specialist advisers in educational institutions, industry, commerce, conservation, and amenity groups.

This paper examines the various activities undertaken by the program during the last 16 years, activities that have made a contribution of background knowledge and expertise to the International Maritime Organization's (IMO's) information, education, and training programs for the successful implementation of Annex V of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 Protocol (MARPOL 73/78) (IMO 1988).

## INFORMATION

### Program Strategy

Against a 1973 baseline, the strategy of the Marine Litter Research Program was to provide systematic data showing qualitatively and quantitatively the nature and scope of the problem, thereby providing a framework for subsequent remedial actions. To achieve this strategy, and in the absence of any comparative studies, priority was given to meeting basic information requirements. In particular, the program needed to produce data

of sufficient accuracy, drawn from a large enough geographical area, to alert national authorities and intergovernmental organizations to the consequences of uncontrolled discharges of ships' garbage at sea.

The immediate objectives were to:

- Develop standardized field survey techniques and analytical methods for the surveillance of marine litter, and
- Identify the major trends in the composition, distribution, and origin of litter occurring in the coastal and oceanic waters of Western Europe.

## Use of Beach Surveys

The relative merits of the different approaches used in assessments of marine litter have been discussed (Dixon and Dixon 1981). Beach surveys supported by adequate site selection sampling methods were selected in preference to observations of litter distributions at sea or estimates of discharges from ships for two reasons:

1. Temporal and spatial sampling constraints are more easily overcome, hence representative areas of shoreline can be surveyed more effectively and accurately than sections of water masses, under most weather conditions.
2. Litter tends to accumulate in the short term on beaches and therefore statistically representative samples can be collected at any given time, avoiding uncertain extrapolations from small sample sizes.

A common component of West European beach litter is containers of all types including bottles, cartons, drums, and cans fabricated from glass, metal, paperboard, plastics, and wood. To discover their characteristics, including geographical origins, contents, and dates of production, samples of the most frequently occurring types and brands were collected and their details recorded. Technical support networks were established with packaging and product manufacturers, especially plastics bottle makers, worldwide. The required information was made available from manufacturers' records of container dimensions and designs and the interpretation of article number codes, manufacturers' imprints, individual date codes, and other overprinted or embossed markings.

Consequently, a data base has been compiled for several hundred different containers on the basis of the following selection criteria:

- They had been marketed continuously for more than 10 years in disposable or one-journey packaging, with documented histories of changes in designs or markings.
- The selected brands were market leaders, and therefore produced in large quantities each year, often in several different countries, with distinctive packages.

- The specimen types constituted a representative sample of all containers observed on beaches, by fabrication materials and contents.

Information gathered from shoreline transects has included total weights of all litter collections and each of the main fabrication materials, and the presence or absence of noncontainer items including plastics fragments, fishing gear, plastics sheeting, clothing, rope, and strapping.

### Assessment of Major Trends in Surface Marine Litter

Analysis of the combined data has enabled an assessment of major trends in the composition, distributions, geographical origins, and persistence of litter in the surface waters of Western Europe. Findings show:

- Widespread distributions in both coastal and oceanic waters.
- The prominence of plastics materials, especially polyethylene bottles, polythene sheeting, and fragments of expanded polystyrene.
- The identification of the most frequently occurring containers, by fabrication materials and original contents, including polyethylene lavatory cleanser and household cleaner bottles, glass wine and spirits bottles, metal cans and drums originally filled with beverages and petroleum derived products, and wooden fish boxes.
- A global distribution of countries in which containers are manufactured or marketed, with up to 30% from non-European Economic Community (EEC) member states, including Australia, Brazil, Canada, China, Japan, New Zealand, South Africa, the United States, U.S.S.R., and Venezuela.
- The presence of dangerous items of litter, including fragments of broken glass, sharp pieces of metal, nails protruding from timber, pharmaceutical drugs, syringes and other clinical wastes, civilian and military pyrotechnics, munitions, and packaged dangerous goods.
- The absence of any field evidence to show an accumulation of plastics containers in the marine environment. Relative dating methods have indicated that less than 15% of samples have been obsolete types, and absolute dating from individual date codes has shown that between 86 and 94% of container samples have been <4 years old (Dixon and Dixon 1983).

On the basis of these findings and those from more recent studies, discharges of garbage from ships and other craft have been shown to be the major source of litter found on West European beaches (Chaussepeied 1985;

Vauk and Schrey 1987). The contribution from land-based sources is believed to be relatively small, in the region of 30% of the total, and the result of discards from beach users during the summer holiday season.

Baseline surveys at 185 sample sites around the coastline of the United Kingdom were completed between 1979 and 1987. These will be repeated at the same sites during the next 5 years, and the data will be analyzed on a "before" and "after" basis to evaluate the effectiveness of the Annex V regulations. Supplementary studies will also be undertaken during the same time period to examine the efficiency of port reception facilities for ships' garbage.

## Other Findings

Questionnaire surveys and desk studies in cooperation with local authorities and government departments, including the Ministry of Defense, have generated more detailed information on the environmental impacts of marine litter.

For example, local authority beach cleaning operations have usually been confined to the summer holiday period, but recently they have been undertaken throughout the year in many locations to remove increasing quantities of litter washed ashore. The costs incurred are met by the local community and have not been recovered in accordance with the "polluter pays" principle.

Local authorities are also responsible for removing and safely disposing of dangerous substances or items recovered on beaches, especially packages of dangerous goods lost from ships' deck cargoes at sea. At least 100 adults and children have undergone precautionary medical examinations or hospital treatment following exposure to the contents of chemical packages washed ashore in southern England between 1976 and 1986 (Dixon and Dixon 1986).

The shipping industry has reported the loss of productive time as well as repair and replacement costs following damage to ships and pleasure craft from surface floating or semisubmerged items of litter.

Munitions are also widely distributed throughout the coastal waters of the United Kingdom following accidental losses or deliberate dumping in the past. Substantial quantities have been discovered by the general public on beaches, and occasional injuries or fatalities have resulted from the improper handling of a small proportion in dangerous condition (Dixon and Dixon 1979).

## Marine Litter Research Program Contributions

The Marine Litter Research Program results and subsequent recommendations have made a contribution to debates and discussions on the subject by national authorities and intergovernmental organizations, thereby achieving the program strategy identified above.

For example, the United Kingdom's Royal Commission on Environmental Pollution supported The Tidy Britain Group's recommendations concerning the need for the government to ratify Annexes III and V of MARPOL 73/78 and provide adequate means for the disposal of shipboard-generated garbage ashore (Royal Commission on Environmental Pollution 1984, 1985).

Similarly, The Tidy Britain Group's recommendation concerning the need to designate the North Sea as a special area for the purpose of Annex V was one of the proposals considered at the Second International Conference on the Protection of the North Sea in November 1987. On behalf of all North Sea states, the United Kingdom has since submitted a proposal with the necessary background information and justification for declaring the North Sea a special area at the Twenty-Sixth Session of the IMO's Marine Environment Protection Convention (MEPC) in 1988. The MEPC subsequently approved amendments to Annex V of MARPOL 73/78 in this regard, and it is envisaged they will be formally adopted by the MEPC at its twenty-eighth session.

Recommendations concerning improvements in the extent and durability of markings and labels on packages containing dangerous and polluting substances, and the efficiency of reporting losses of packaged goods overboard were submitted by the Advisory MEPC on Pollution of the Sea to the MEPC in 1985 and 1986 (IMO 1985, 1986).

## EDUCATION

The importance of public awareness campaigns and general educational programs in the protection of the marine environment have long been recognized. In the United Kingdom, attitude surveys have consistently suggested that beach pollution and litter are major areas of public concern (National Opinion Poll 1987). Consequently, considerable effort has been invested by The Tidy Britain Group in the development of suitable resources and materials to focus public attention on the marine litter problem.

At the planning stage a series of informal meetings were held with interested parties including educationists, environmentalists, and potential sponsors in order to identify their requirements and enlist support for the public awareness and general education programs. Considerable experience was made available by The Tidy Britain Group's Schools Research Project Team, which specializes in finding ways of increasing environmental awareness and responsibility in children, with particular reference to the awareness of litter.

At these meetings, formal educationists stressed the need for environmental education programs to meet requirements of existing curriculums, especially the promotion of field studies incorporating a variety of different study skills and learning activities across the educational spectrum. Nonformal educationists pressed for detailed information and practical action, as did environmental groups who, in addition, preferred activities which could attract the media. Potential sponsors set forth numerous requirements, often conflicting with each other. Basically, however, they were all prepared to support environmentally worthwhile projects which were structured with clearly defined objectives.

## COMMUNITY PARTICIPATION

### Public Awareness Activities

A variety of public awareness campaigns and activities have been completed. Some have been directed specifically at professional and nonprofessional seafarers, and port and terminal operators. For example, the owners of pleasure craft were asked to "Stash their trash ashore" in a poster featuring Dame Naomi James, the first lone round-the-world yachtswoman. In another approach, a soft drinks manufacturer sponsored a comic beachcomber competition in which children were asked to record different plastic bottle makers' imprints, and were awarded prizes for their efforts. Beach cleaning competitions organized by local authorities have also been successful, together with more conventional beach cleanups by members of conservation and amenity groups. Among the numerous events and supporting materials is a poster based on a photograph by Linda McCartney, entitled "Please leave nothing but footprints in the sand."

### National Shoreline Litter Surveys

The Sunday Times sponsored the First National Shoreline Litter and Refuse Survey, which ran from June 1978 to October 1979. It was questionnaire-based, and participants were asked to record details of litter, especially container markings and codes, from transects between the water's edge and the backshore zone of beaches. Details from 20,000 containers and the presence or absence of other types of litter were recorded at 797 sites around the coastline. The survey report with a foreword written by Marcus Fox, a parliamentary under secretary of state for the environment, generated considerable media interest nationally and therefore attracted the attention of other government departments and shipping interests (Dixon and Hawksley 1980). It was later submitted to the IMO's MEPC by the Department of Transport as an information paper. Some sewage disposal-related issues were included in the report after one participant explained how she had inadvertently flushed a toilet roll holder down the lavatory and recovered it again 2 days later during a local beach survey.

A Second National Shoreline Survey was launched in 1980, sponsored by the Sunday Times and Sealink UK, a major ferry operator, with the added support of network television time. It was again questionnaire-based but the procedures were improved, giving more detailed information on how to identify litter. Observations were undertaken at more than 3,000 sites around the coastline. Among the unexpected discoveries was a sequence of reports from different localities of foreign items of litter, which appeared to have monitored the passage of an East European fishing fleet. Snowmobile bottles were found elsewhere, and these were traced to the discards of Canadian Eskimos near the polar ice cap.

Both shoreline surveys achieved their objectives, including the provision of detailed information on container markings, which in turn has supported the more specialized research. Compared with similar promotions undertaken by The Tidy Britain Group, the shoreline surveys generated considerably more media interest locally and nationally, and were also highly cost-effective. In many instances, educational institutions from

primary schools to universities have adopted the surveys, with suggested learning activities, on a long-term basis.

### The Blue Flag Campaign

A major public relations operation in favor of the marine environment is the Blue Flag Campaign, launched during the European Year of the Environment by the Foundation for Environment Education in Europe. The campaign has the financial support and patronage of the Commission of the European Communities. The main objective is to raise awareness about the quality of the marine environment and the need to protect it. During 1988, a total of 373 beaches and 102 ports and marinas in 10 EEC member states were awarded blue flags for the high standards of environmental quality, the provision of services, and the promotion of environmental education (Foundation for Environment Education in Europe 1988). Blue Flag beaches are required to be free from litter, and ports or marinas which qualify are expected to provide facilities for the disposal of garbage ashore from ships and pleasure craft. There is also a Blue Flag charter for boat owners, which is based upon a voluntary code of conduct.

In the United Kingdom, beaches that are unable to qualify for blue flags on the basis of inadequate bathing water quality, are encouraged to enter for Clean Beach awards, a scheme funded by the Department of the Environment.

## TRAINING

Throughout its history, the IMO has attached the utmost importance to the training of ships' personnel to help achieve its most important objectives, namely, improvements in maritime safety, and the prevention and control of marine pollution from ships.

Given the rapid changes and developments in world maritime trade and shipping operations, there is an even greater emphasis on the part of the IMO to ensure that the various conventions, codes, and other instruments already adopted are effectively enforced and implemented.

Therefore, in the context of the implementation of Annex V of MARPOL 73/78, considerable effort has been directed towards the preparation of comprehensive and practical guidelines with the following objectives:

- To assist governments in developing and enacting domestic laws which give force to and implement Annex V.
- To assist vessel operators in complying with the requirements set forth in Annex V and domestic laws.
- To assist port and terminal operators in assessing the need for, and providing, adequate reception facilities for garbage generated on different types of ships.

Section 2 of the guidelines recognizes the importance of information, education, and training programs in the implementation process. Given the

need for commercial vessels and other craft to change garbage disposal practices which have persisted for many generations, it is generally believed that comprehensive training packages have an important role in assuring the success of Annex V.

Consequently, with funding provided by the United Kingdom Government and the IMO/Swedish International Development Authority Program for the Protection of the Marine Environment, a training package on marine litter has been prepared for worldwide distribution. Data and other expertise held by The Tidy Britain Group were extensively drawn upon in the production of this material.

The principal aims of the training package are first, to change attitudes and create an awareness of the need to prevent damage to the marine environment from the improper disposal of ships' garbage at sea, and secondly, to provide the necessary background knowledge and identify the practical means of doing so.

The target audience includes not only seafarers and port or terminal operators, but trade associations, shipbuilders, packaging manufacturers, waste management industries, coastal communities, educators, and governments.

With background resource materials contributed by interested parties worldwide, including conservation groups, governments, and the private sector, the training package provides a general overview of the marine litter problem focusing upon:

- the sources and types of garbage generated by ships;
- the environmental impacts of marine litter on wildlife and coastal amenities;
- shipboard garbage handling and storage procedures;
- equipment available for port reception facilities; and
- the Annex V regulations and their implications.

Despite the enormity of the task to be achieved in the successful implementation of Annex V, evidence of new initiatives and innovations has already come to light. Manually operated garbage compactors are now included in the design and construction of some yachts and other pleasure craft in Scandinavian countries, and in some coastal communities of the United States unwanted fishing gear is recycled for decorative purposes instead of being discarded at sea.

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# EDUCATION AND AWARENESS: KEYS TO SOLVING THE MARINE DEBRIS PROBLEM

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1725 DeSales Street, N.W.
Washington, D.C. 20036, U.S.A.

## ABSTRACT

The Center for Marine Conservation (CMC)--formerly known as the Center for Environmental Education--is a nonprofit conservation organization. The CMC currently conducts a national education campaign on the problems caused by plastic debris in the marine environment. The campaign includes the development and distribution of educational materials to the commercial fishing, merchant shipping, and plastics industries as well as to recreational fishermen, pleasure boaters, and the general public. This program is sponsored in part by the U.S. National Oceanic and Atmospheric Administration's (NOAA), Marine Entanglement Research Program and The Society of the Plastics Industry. Also, under contract to NOAA, CMC distributes information through its National Marine Debris Information Office. The CMC also administers the National Marine Debris Data Base. With support from NOAA, the U.S. Coast Guard, and the U.S. Environmental Protection Agency, the CMC distributed 43,000 data cards to volunteers in all 25 coastal states. Information obtained from volunteer data collection efforts will become part of CMC's national analysis of marine debris data.

## INTRODUCTION

There is virtually unanimous agreement that education is necessary to motivate groups and individuals to dispose properly of wastes, especially plastic waste. Several international conferences have stressed the need for marine debris education programs, including the 1984 International Workshop on the Fate and Impact of Marine Debris, the North Pacific Rim Fishermen's Conference on Marine Debris, and the Oceans of Plastic Fishermen's Workshop. Federal legislation entitled the Marine Plastic Pollution Research and Control Act of 1987 mandates that the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA) conduct a 3-year public education program. The 1989 Interagency Task Force on Marine Debris encourages marine debris education: "Concerned federal agencies should work with each other, state

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

and local governments, private industry, and environmental groups to develop comprehensive educational materials on problems caused by marine debris and on ways to solve those problems" (Interagency Task Force on Persistent Marine Debris 1988).

The Center for Marine Conservation (CMC)--formerly the Center for Environmental Education (CEE)--knows that education will be the most effective method to alter 4,000 years of ocean disposal behavior. When mariners realize and understand the effects that their age-old habits have on wildlife and human and vessel safety, they are willing to make a change. Since 1985, the CMC has developed an education campaign that encourages all members of industry, the general public, and the maritime community to get involved. It publishes documents, organizes beach cleanups, and responds to requests for information that encourages groups and individuals to take part in the solution to ocean pollution.

## GETTING THE MESSAGE OUT

### Early Efforts at Education

Prior to 1984 there were only a handful of programs working to teach people about the problem of marine debris. Judie Neilson's "Get the Drift and Bag It" campaign was not only the first marine debris education program, but also a highly successful coastal cleanup in Oregon (Neilson 1985). Also in 1984, the Workshop on the Fate and Impact of Marine Debris produced several recommendations discussing the need for marine debris education programs (Shomura and Yoshida 1985). The concept of marine debris education was so new that in the workshop proceedings these education recommendations were hidden under the general category of "Report of the Working Group on Management Needs." The subcategory entitled "Public information and education" recommended:

> "Recognizing that greater benefits are likely to be realized as a result of positive rather than negative incentives, (Working) Group participants urged that significant emphasis be placed upon public information and education and that steps specifically be taken to:
>
> "a. Work with fisheries organizations and the fishery management councils to develop and carry out comprehensive information and education programs for foreign fishermen, working within the exclusive economic zone, and U.S. fishermen;
>
> "b. Work with appropriate national and international organizations to undertake cooperative comprehensive information and education programs; and
>
> "c. Work with relevant industries, such as has been done with elements of the plastics industry, on public education programs."

The subcategory entitled "Debris cleanup" recommended:

> ". . .immediate steps to remove existing debris from the environment are clearly needed and concentrated efforts should be directed to reducing the rate at which new debris is deposited. The management steps recommended are:
>
> "a. To undertake cleanup programs to remove existing debris from shore areas and the water column;
>
> "b. To assign priority to areas where the density of debris is such that it affects endangered, threatened, or commercially valuable species;
>
> "c. To require that all potentially harmful debris be retained onboard vessels until proper disposal is possible;
>
> "d. To encourage the removal of debris from the environment and prevent the discarding of additional debris, positive incentives such as financial rewards for the return of discarded netting material should be considered as should possible negative incentives; and
>
> "e. To take such actions as may be necessary to assure the proper disposal of unwanted materials in a nonharmful manner."

These recommendations identified a need for marine debris education and provided the baseline for all future education programs.

## Plastics Debris Problem

In 1986, the EPA commissioned CMC to prepare a report on the plastics debris problem in the marine and Great Lakes waters of the United States. As the first comprehensive review of available information on marine debris, this document showed that plastics debris is a nationwide problem for marine wildlife. The report identified the major ocean- and land-based sources of plastics debris, and indicated that the total amount of debris generated by these sources is unknown. The report noted the absence of appropriate laws to address the plastic debris problem (CEE 1987a). Finally, the study helped to redirect attention from general marine debris to those problems caused specifically by plastic items.

Upon completion of the document, CMC presented the report to members of The Society of the Plastics Industry (SPI), explaining that plastics debris was threatening wildlife and vessel safety in addition to being unsightly. The plastics industry accepted CMC's invitation to become part of the solution. The result has been the development of numerous brochures, books, and posters geared to promoting proper disposal of plastics at sea.

## PUBLIC AWARENESS AND RESPONSE

### Beach Cleanups

The CMC's most successful efforts have been its citizen beach cleanups in Texas and Florida. From 1986 to 1988, it organized the largest beach cleanups in American history, accounting for one-third of the nation's total participation. Diverse groups worked toward a common goal: industry provided financial and in-kind support; government and environmental organizations acted as regional coordinators; and the general public together with all these groups removed trash from the beaches.

Since 1984 there has been a steady growth in beach cleanup participation (Fig. 1). In 1984, Judie Neilson encouraged 2,100 Oregonians to clean the beaches. Nationwide during Coastweeks '88, more than 47,000 people participated in coastal cleanups. In 1989, we expect the participation to increase to 60,000, and our goal is to work with the states to encourage 100,000 citizens to clean the beaches by Coastweeks '92.

A beach cleanup is not just a 1-day event, but rather an ongoing education campaign. The CMC's volunteer data collection system is one mechanism that ensures continuing education. Beach cleanup data help identify possible sources and quantify the amounts of debris found by volunteers. Each cleanup volunteer receives a data card and a "Guide to Good Data Collection." The data card lists items volunteers will likely collect during a beach cleanup. The guide explains the importance of data collection and describes items that are found on most beaches yet are difficult to identify.

In Texas and Florida, volunteers work in pairs to share the tasks of debris collection and data recording. From volunteer data, the CMC published two reports on the Texas debris problem (CEE 1987b, 1988b). These reports document the sources of debris and include recommendations to reduce the marine debris problem. In some cases it is possible to attribute certain types of beach debris to a specific source. For example, volunteers found 4,170 plastic light sticks on Texas beaches in 1987. Fishermen commonly use light sticks to attract fish to their hooks. Although it is counterproductive to point accusatory fingers, CMC uses indicative data to encourage possible debris contributors to become active contributors to the solution.

Press generated from a cleanup also helps maintain the long-term education effects. Media coverage reaches people who may not donate their Saturday mornings to clean the beach, but may unconsciously discard their boat or beach trash. The CMC uses the media to remind the public that their plastic trash can have disastrous effects on marine wildlife. The 1986 Texas Coastal Cleanup campaign not only increased awareness among the general public, but also helped the Texas General Land Office initiate a statewide "Adopt-A-Beach" program.

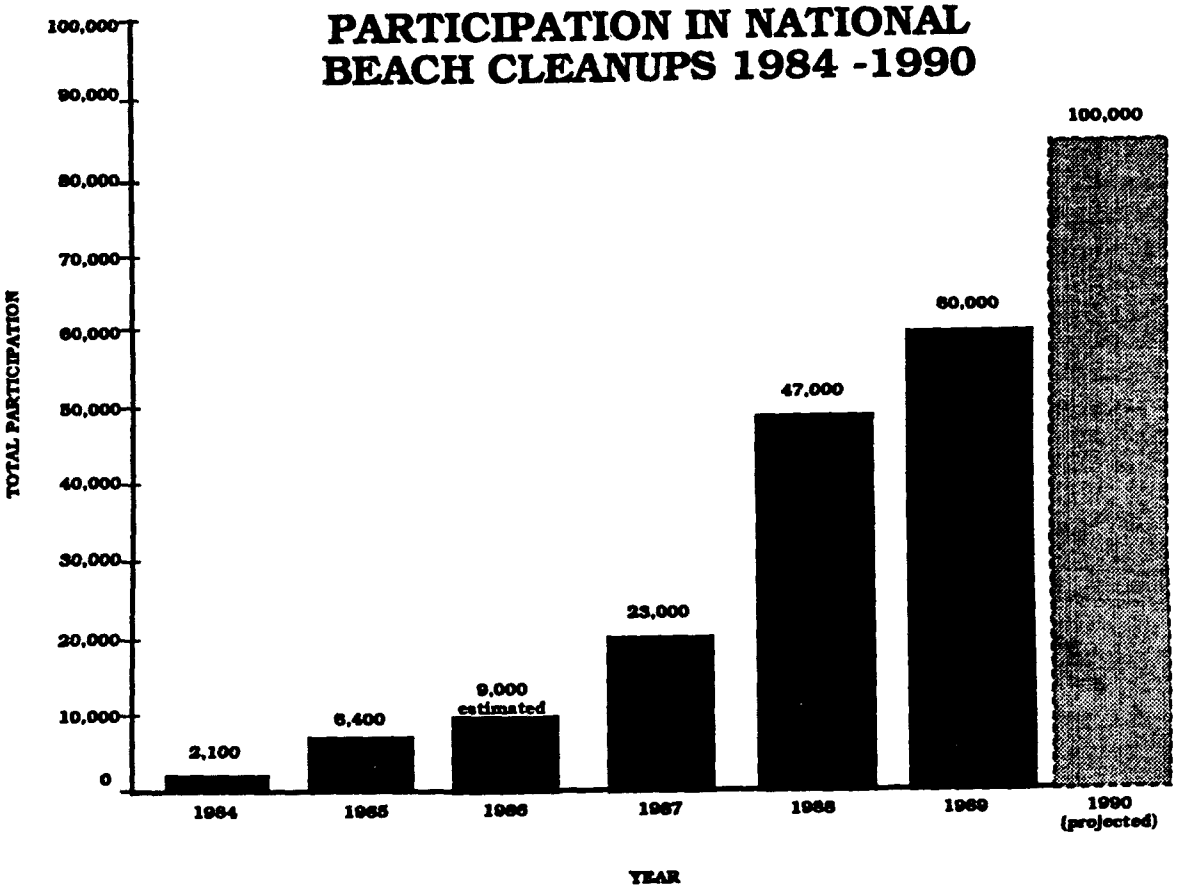



Figure 1.--Volunteer participation during beach cleanups from 1984 to 1990.

## National Marine Debris Data Base

In 1988, the CMC expanded its Texas data collection efforts to establish a National Marine Debris Data Base. With support from the EPA, NOAA, and the U.S. Coast Guard, CMC distributed 43,000 data cards to cleanup volunteers in all 25 coastal states. In addition, Spanish data cards were sent to cleanups in Puerto Rico, Costa Rica, and the Dominican Republic. The resulting data base is providing essential information for understanding specific debris problems in each part of the country. O'Hara's paper entitled "National Marine Debris Data Base" gives a detailed analysis of the preliminary results from the first nationwide assessment of coastal debris (O'Hara 1990). The CMC's final report will be out in June 1989.

The CMC's data base relies on volunteer cooperation, and CMC realizes that it is not the same as a rigorous scientific survey. Nonetheless, their data give consistent perspectives of the problem and indicate some

common trends. For example, in all states plastics account for between 55 and 65% of all debris types collected. In 1988, the fact that Florida volunteers collected 489.1 km (304 mi) of monofilament fishing line indicates a large (although not exclusive) contribution from the recreational fishing community. The data from Florida were used by Governor Bob Martinez and his staff to prepare an executive order to provide state enforcement of MARPOL Annex V and to research the use of degradable fishing line. Finally, data collected in 1988, prior to implementation of Annex V, will provide a baseline of information to measure loosely the effectiveness of international and national legislation to reduce ocean pollution.

**Marine Debris Information Offices**

Under contract to NOAA, CMC coordinates two marine debris information offices (MDIO). The first is in Washington, D.C., to serve the Atlantic coast and Gulf of Mexico. The second, in San Francisco, responds to Pacific coast inquiries. The CMC and NOAA created these offices in response to a growing number of requests for information on the marine debris problem. The MDIO functions to disseminate educational materials and other information on marine debris to government agencies, industry groups, educators, the press, and the general public. In most cases, requests for information fall into specific categories. To respond efficiently to these requests, 16 standardized educational packets were developed :

- General public.
- Teachers and educators.
- Elementary (kindergarten to fifth grade),
- Middle school, high school (6th to 12th grade) and college students.
- Beach cleanup information.
- Recreational fishermen and boaters.
- Press and media personnel.
- Plastics recycling and degradable plastics information.
- Cruise ship passengers.
- Fishermen and fish processors.
- Cargo vessel operators and crews.
- Offshore oil and gas (companies).
- Offshore oil and gas (workers).
- Plastics manufacturers and resin pellet producers.
- Port and terminal operators.
- Charter vessel operators.

All packets contain general information about the marine debris problem, with additional information specific to the requester's interest. From the establishment of the MDIO in October 1988 until 1 April 1989, CMC responded to 842 requests for information. Also available from the MDIO are numerous education materials developed by NOAA, SPI, and CMC as part of a national campaign to promote the proper disposal of plastics.

Chronologically, the first element of the joint educational campaign consisted of print public service advertisements developed for each of the



# This discarded net is done fishing. But it's not done killing.

When worn fishing nets or other plastic gear is dumped or lost in the water, something else happens: animals die.

Seabirds get caught in nets when diving for food, and drown. Other marine animals become entangled in them and slowly strangle.

Discarded nets and traps even compete with you, by needlessly catching and killing millions of pounds of potentially valuable fish and shellfish.

In addition, plastic wastes can foul propellers and block cooling intakes, causing costly vessel disablement.

Over 100,000 tons of plastic fishing gear are dumped into our oceans every year. This critical issue is destined to attract increasing public and government scrutiny if we fail to take action to solve it.

So please, alert your dock operators that you'll need trash facilities, because you're saving your plastic trash and worn out gear for proper disposal on land. That's not all you'll be saving.

*To learn how you can help, write: Center for Environmental Education, 1725 DeSales Street, N.W., Suite 500, Washington, D.C. 20036.*

A public service message from:
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

Figure 2.--Commercial fishing public service advertisement.

following groups: commercial fisheries (Fig. 2), merchant shippers (Fig. 3), the plastics industry (Fig. 4), recreational boaters (Fig. 5), and recreational fishermen (Fig. 6). To date these ads have appeared in 30 magazines and major trade journals in addition to several regional and local publications including National Fisherman, Marine Log, Modern Plastics, Outdoor Life, and Saltwater Sportsman. Each advertisement directs interested persons to the MDIO for more information about marine debris. The MDIO in turn responds to each request by sending the appropriate information packet and relevant materials.

Each public service advertisement has a corresponding eight-panel brochure with more information on how marine debris affects that particular group. For example, commercial fishermen may be more interested in the fact that discarded gillnets will foul their propellers rather than in the effects the nets may have on seals, which in some cases are viewed as competitors. Groups often request large quantities of brochures for their own distribution. To date, the MDIO has distributed over 60,000 brochures to educators, individuals, and the government, including 15,000 National Safe Boating Week press packets, 8,000 for National Fishing Week, and 3,000 to Coast Guard port captains.

A Citizen's Guide to Plastics in the Ocean: More Than a Litter Problem is another product of the cooperative NOAA, SPI, and CMC campaign that is now available through the MDIO (CEE 1988a). The book informs citizens of the growing problem of plastics in the ocean and gives suggestions on how individuals can become involved in solving this problem. The MDIO has distributed 19,000 copies of this guide since September 1988, including 5,000 copies to the U.S. Navy as part of their educational package on marine debris. Due to the popularity of the book, it is now ready for a second printing that will contain more current information on Annex V and new initiatives to stop plastic pollution at sea.

The MDIO also distributes materials produced by other groups. Recht's (1988) Reference Guide for Ports is a valuable source of information on how ports can comply with the requirements of MARPOL Annex V and the U.S. Marine Plastic Pollution Research and Control Act of 1987. Figure 7 shows the most current version of the MDIO order form with the most frequently requested educational materials.

The CMC staff believe that each person requesting information is a potential grassroots organizer able to educate others about the problems of plastic debris. The staff cultivates each request and acts to network people and information. The elementary school information packet uses a "Playa Pen Pal" program to network even the youngest requests ("playa" means beach in Spanish). All children who ask for information receive the names and addresses of the last three children who wrote in, and are encouraged to exchange information about marine debris in their part of the country with their playa pen pal.



# When it's done holding your ship's garbage, it could hold death for some marine animals.

This plastic trash bag may not look like a jellyfish to you. But to a hungry sea turtle, it might. And when the turtle swallows an empty bag, the mistake becomes fatal.

The problem is more than bags. Plastic six-pack holders sometimes become lodged around the necks and bills of pelicans and other seabirds, ultimately strangling or starving them. Other plastic refuse, either through ingestion or entanglement, causes the deaths of thousands of seals, whales, dolphins and other marine mammals every year.

Plastic debris also causes costly and potentially hazardous delays to shipping when it fouls propellers or clogs intake ports.

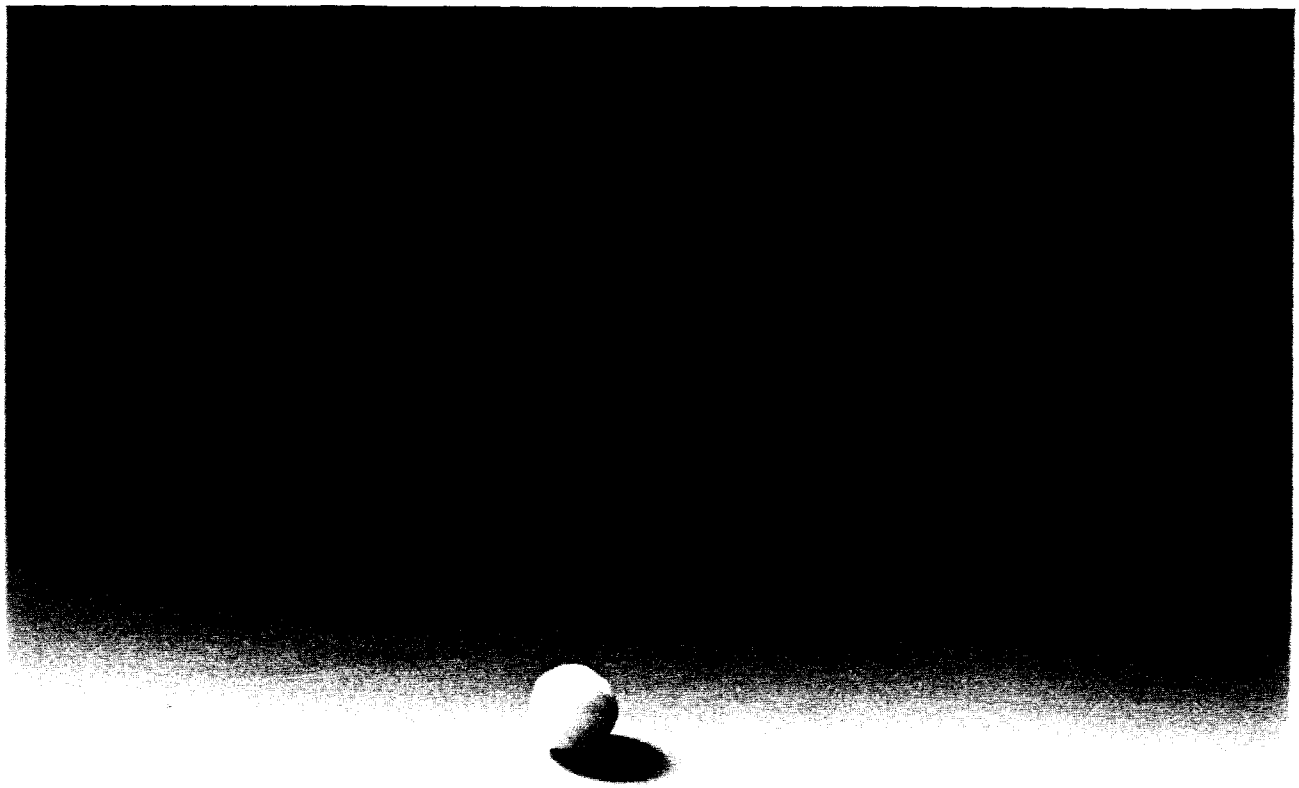
It's a critical issue, destined to attract public and government scrutiny if we fail to take action to solve it.

So please, stow your trash, and alert your shipping terminals that you will need proper disposal on land. A sea turtle may not know any better. But now, you do!

*To learn how you can help, write: Center for Environmental Education, 1725 DeSales Street, N.W., Suite 500, Washington, D.C. 20036.*

A public service message from
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

Figure 3.--Commercial shipping public service advertisement.



# A seabird could mistake this resin pellet for a fish egg. And die.

One little pellet may be insignificant to your plastics processing operation. But to thousands of seabirds, it could lead to a fatal error.

These pellets, in many shapes and sizes, can be washed down drains as waste or reject material, or spilled in the course of normal handling. But ultimately, they may find their way to bodies of water, where the real trouble begins.

When eaten in sufficient quantity by a seabird, they can block digestion or sometimes fool the bird into thinking it is not hungry, causing eventual starvation. Fish and sea turtles can suffer the same fate.

The growing problem of plastic trash in our oceans threatens more than wildlife. This critical issue is destined to invite increasing public and government scrutiny unless we take action to solve it.

So please: see that resin pellets are reclaimed or disposed of properly. If we ignore the problem, we—like the unfortunate seabird—will be making a serious mistake.

*To learn how you can help, write: The Society of the Plastics Industry, 1275 K Street, N.W., Suite 400, Washington, D.C. 20005.*

A public service message from:
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

**Figure 4.--Plastics industry public service advertisement.**



# This discarded line is done fishing. But it's not done killing.

Carelessly discarded plastic fishing line can keep working long after you're done with it—entangling birds, seals, sea turtles, and other animals.

And because plastic line is strong and durable, it's nearly impossible for these animals to break free. They strangle, drown, or starve. That's not sporting.

Some birds even use old fishing line in their nests, creating death traps for their young.

Other plastic debris can be dangerous, too. Fish, birds, and seals become entangled in six-pack rings. Sea turtles eat plastic bags—which they mistake for jellyfish—and suffer internal injury, intestinal blockage, or death by starvation. Birds are known to ingest everything from small plastic pieces to plastic cigarette lighters and bottle caps.

Plastic debris also can foul boat propellers and block cooling intakes, causing annoying—sometimes dangerous—delays and causing costly repairs.

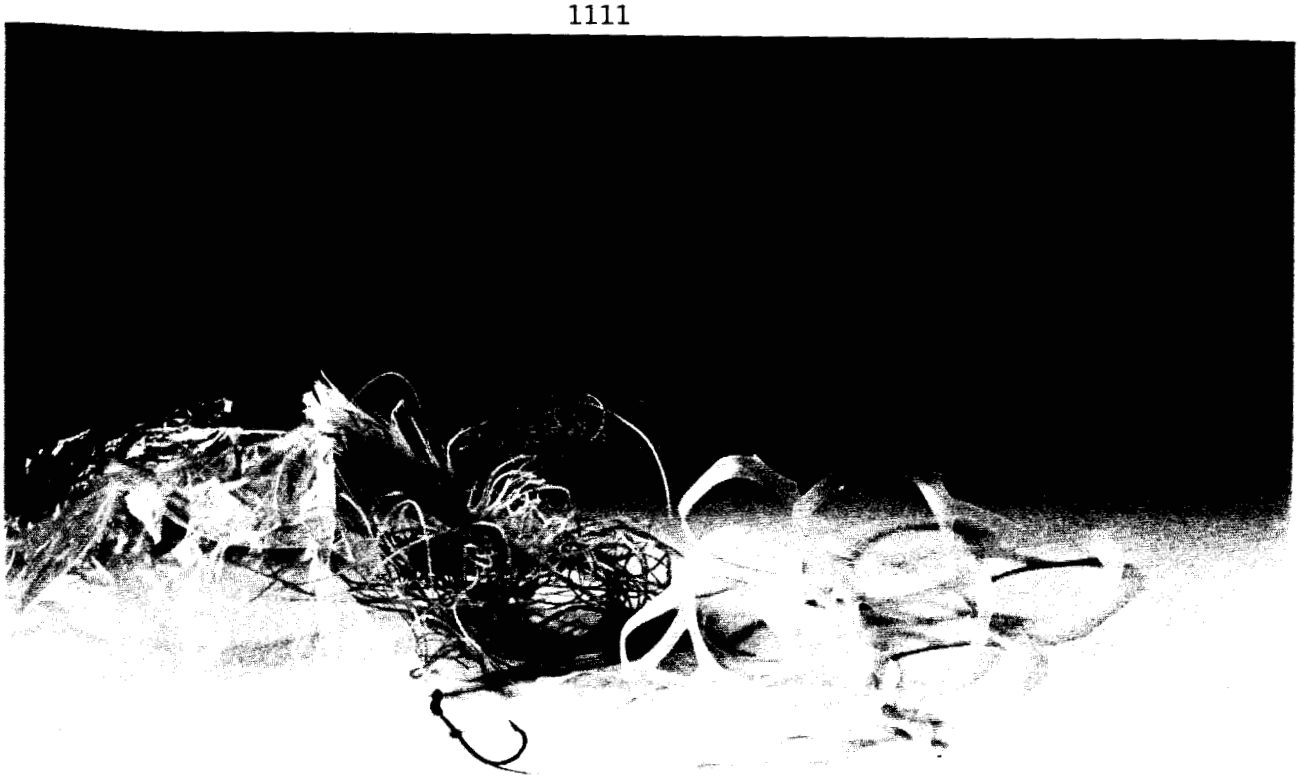
So please, save your old fishing line and other plastic trash for proper disposal.

That's not all you'll be saving.

*To learn more about how you can help, write: Center for Environmental Education, 1725 DeSales Street, N.W., Suite 500, Washington, D.C. 20036.*

A public service message from
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

**Figure 5.--Recreational fishing public service advertisement.**



# Tossing this trash overboard could leave death in your wake.

Throwing a few plastic items off a boat may seem harmless enough. What's one more six-pack ring, plastic bag, or tangled fishing line?

Actually, it's one more way a fish, bird, seal, or other animal could die.

Fish, birds, and seals are known to strangle in carelessly discarded six-pack rings. Sea turtles eat plastic bags – which they mistake for jellyfish – and suffer internal injury, intestinal blockage, or death by starvation.

Other plastic trash can be dangerous, too. Birds are known to ingest everything from small plastic pieces to plastic cigarette lighters and bottle caps.

Birds, seals, sea turtles, and whales die when they become trapped in old fishing line, rope, and nets.

Plastic debris also can foul boat propellers and block cooling intakes, causing annoying – sometimes dangerous – delays and causing costly repairs.

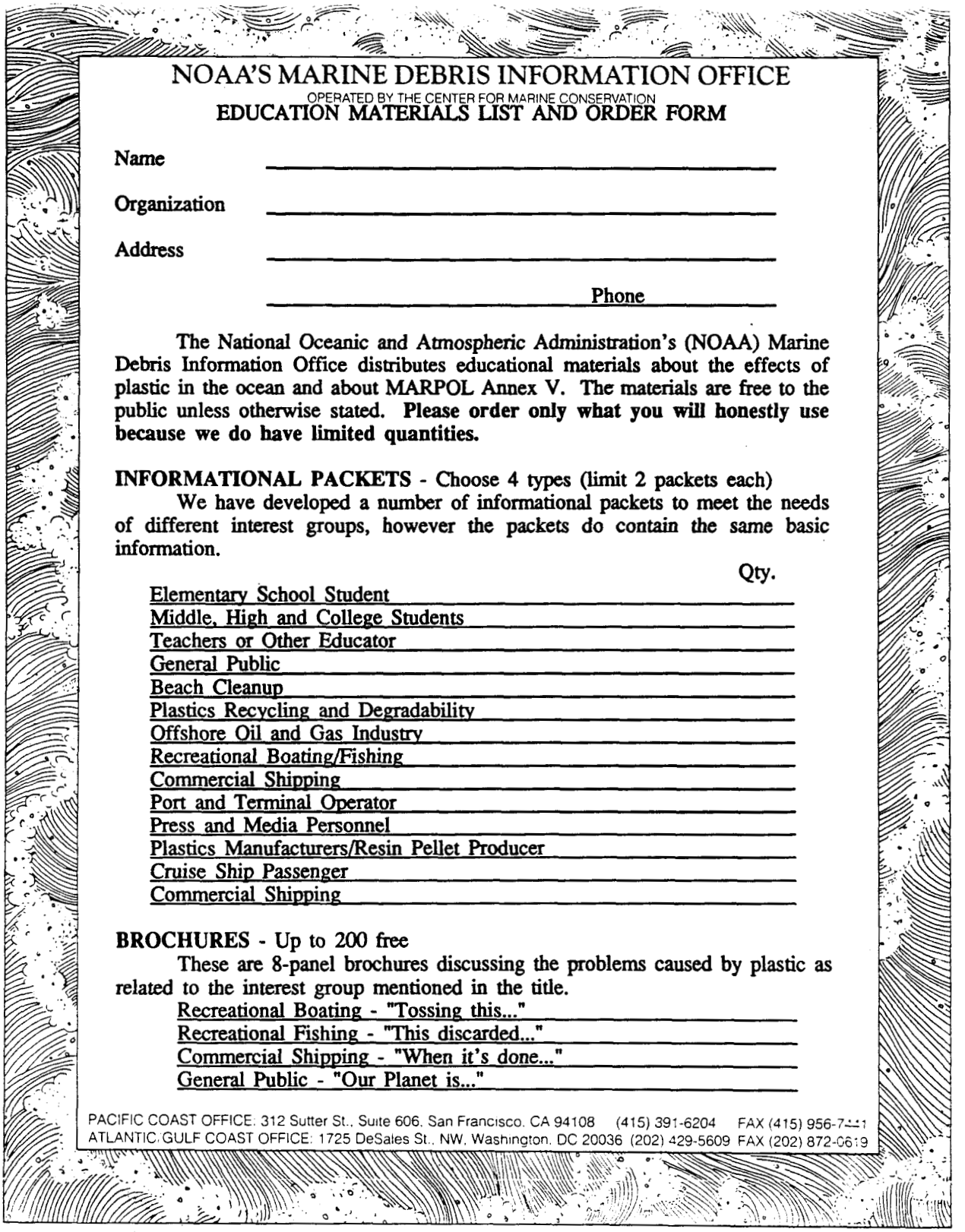
So please, save your trash for proper disposal on land.

That's not all you'll be saving.

*To learn more about how you can help, write: Center for Environmental Education, 1725 DeSales Street, N.W., Suite 500, Washington, D.C. 20036.*

A public service message from
The Center for Environmental Education
The National Oceanic and Atmospheric Administration
The Society of the Plastics Industry

**Figure 6.--Recreational boating public service advertisement.**



# NOAA'S MARINE DEBRIS INFORMATION OFFICE

OPERATED BY THE CENTER FOR MARINE CONSERVATION

## EDUCATION MATERIALS LIST AND ORDER FORM

Name _____

Organization _____

Address _____

_____ Phone _____

The National Oceanic and Atmospheric Administration's (NOAA) Marine Debris Information Office distributes educational materials about the effects of plastic in the ocean and about MARPOL Annex V. The materials are free to the public unless otherwise stated. **Please order only what you will honestly use because we do have limited quantities.**

**INFORMATIONAL PACKETS** - Choose 4 types (limit 2 packets each)

We have developed a number of informational packets to meet the needs of different interest groups, however the packets do contain the same basic information.

Qty.

Elementary School Student _____
Middle, High and College Students _____
Teachers or Other Educator _____
General Public _____
Beach Cleanup _____
Plastics Recycling and Degradability _____
Offshore Oil and Gas Industry _____
Recreational Boating/Fishing _____
Commercial Shipping _____
Port and Terminal Operator _____
Press and Media Personnel _____
Plastics Manufacturers/Resin Pellet Producer _____
Cruise Ship Passenger _____
Commercial Shipping _____

**BROCHURES** - Up to 200 free

These are 8-panel brochures discussing the problems caused by plastic as related to the interest group mentioned in the title.

Recreational Boating - "Tossing this..." _____
Recreational Fishing - "This discarded..." _____
Commercial Shipping - "When it's done..." _____
General Public - "Our Planet is..." _____

PACIFIC COAST OFFICE: 312 Sutter St., Suite 606, San Francisco, CA 94108 (415) 391-6204 FAX (415) 956-7441
ATLANTIC/GULF COAST OFFICE: 1725 DeSales St., NW, Washington, DC 20036 (202) 429-5609 FAX (202) 872-0619

Figure 7.--Current version of NOAA's Marine Debris Information Office order form.

## ASSESSING THE IMPACT OF THE CENTER FOR MARINE CONSERVATION'S EDUCATIONAL PROGRAMS

Although empirical evidence shows us that hands-on programs are the best form of education, the CMC's 1989 Saltonstall-Kennedy (SK) grant will demonstrate the actual effects of its education programs. Prior to conducting any education events, CMC distributed surveys to a random sample of commercial and recreational fishermen in four designated test areas: Hampton, Virginia; Martin County, Florida; Bayou La Batre, Alabama; and Taylor County, Florida (as a control group). Wallace (1990) of Kearney-Centaur Associates discusses the results of this first SK survey in the paper entitled: "How Much Do Commercial and Recreational Fishermen Know About Marine Debris and Entanglement? Phase 1."

From March to July 1989, the CMC will conduct concentrated educational activities within three of the test areas, excluding the control area of Taylor County, Florida. It will adapt educational activities to accommodate regional differences, style, and events. For example, a large percentage of Martin County, Florida's, recreational fishing community will participate in or attend Arthur Smith Kingfish, Dolphin, Wahoo Fishing Tournament. In addition to providing educational materials to tournament participants, CMC will involve spectators by conducting "Stow It, Don't Throw It" raffle contests for such prizes as boat coolers and fishing reels.

The CMC will distribute a revised version of the survey upon the conclusion of these educational programs. The second survey developed by Kearney-Centaur Associates will assess the impacts of CMC's educational activities. It believes the survey results will statistically demonstrate increased public awareness.

The CMC makes one primary assumption in its approach to solving the marine debris problem. It believes that education will motivate people to alter any harmful disposal behavior. Enforcement of international and national legislation will be very difficult. Marine debris research is both expensive and difficult to conduct in the ocean environment. The CMC feels that education in the form of publicity, books, and if possible hands-on educational events such as beach cleanups will encourage people to keep harmful trash out of the water.

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# SHIPPING INDUSTRY MARINE DEBRIS EDUCATION PLAN

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## ABSTRACT

The Shipping Industry Marine Debris Education Plan is an education and awareness program on MARPOL Annex V and its consequences for foreign and domestic commercial shippers and cruise lines operating in U.S. waters and for port and terminal operators. The plan is based on the premise that education may be a key factor in gaining voluntary compliance with MARPOL Annex V provisions and, therefore, in reducing the problems caused by marine debris and entanglement. The plan identifies five core and three ancillary activities to increase the shipping industry's awareness of MARPOL Annex V and the consequences of marine debris and entanglement. It was developed in late 1988 and early 1989 under contract to the Marine Entanglement Research Program, U.S. National Marine Fisheries Service. The recommended activities will be implemented over a 9-month period beginning in the spring of 1989. The core activities are: 1) development of case studies of MARPOL Annex V compliance activities, 2) development of a model plastics refuse control and minimization plan, 3) preparation of a MARPOL Annex V kit--a one-source document on MARPOL Annex V implementation in the United States including crew awareness training on the consequences of marine debris, 4) liaison activities with international shipping industry trade associations, and 5) seminars for cruise line owners/operators. The ancillary activities are: 1) placement of public service advertisements on marine debris in trade journals, 2) placement of posters on MARPOL Annex V and marine debris in port areas and on board vessels, and 3) presentations on the plan and its activities at seminars and workshops.

## INTRODUCTION

On 31 December 1988, in response to at-sea garbage disposal limitations that went into effect worldwide, the way mariners handle disposal of ship-generated garbage changed. On that date, Annex V of the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 73/78) went into effect. Formally, MARPOL Annex V is entitled,

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

"Regulations for the Prevention of Pollution by Garbage from Ships." Simply, Annex V prohibits at-sea disposal of plastic materials and specifies the distance from shore that all other materials may be dumped.

The MARPOL Annex V will be difficult to enforce. Among other things, it changes the traditional way of handling ship-generated garbage. Education may be a key factor in gaining compliance with MARPOL Annex V. In the last several years, marine debris education programs have been developed and implemented for several major marine industry groups (for example, offshore oil and gas workers and commercial fishermen). The current project focuses on marine debris education for the shipping industry.

The amount of garbage generated by the shipping industry varies. It is estimated that large commercial vessels generate between 18 and 40 garbage bags of plastic during a typical voyage. This includes both domestic wastes and plastics included in dunnage. Tow and tugboats are estimated to generate one to three bags of plastic per voyage. Cruise ships are estimated to generate over 70 bags of plastic per day (Eastern Research Group 1988). Until MARPOL Annex V, much of this garbage was disposed of at sea.

The Shipping Industry Marine Debris Education Plan was developed under contract to the Marine Entanglement Research Program, U.S. National Marine Fisheries Service (NMFS) to: 1) ensure that foreign and domestic commercial shippers and cruise lines operating in U.S. waters, and port and terminal operators are aware of the provisions of MARPOL Annex V as it is being implemented in the United States; and 2) encourage voluntary compliance with those provisions. It was developed to help avoid disruption of shipping schedules, which could occur if U.S. prosecution of at-sea garbage disposal violators is necessary. The plan was also designed to be part of the solution to the problems of marine debris by furthering awareness of its consequences.

## METHODOLOGY

The Shipping Industry Marine Debris Education Plan was developed using four concurrent tasks (Fig. 1) involving data collection and review of existing information, a synthesis task, and an industry advisory panel. The concurrent tasks were completed using secondary sources and key informant contacts. The major points which emerged from the tasks helped to structure the recommended plan activities.

An industry advisory panel for the project was created to involve the industries affected by the plan in its development. By doing so, the intent was to avoid identifying marine debris education activities which would not work. It was also a mechanism to encourage industry's further involvement with the plan, its implementation, and the issue of marine debris and entanglement. Four trade associations, the U.S. Department of Agriculture, the U.S. Coast Guard, and a maritime professional association participated on the panel.

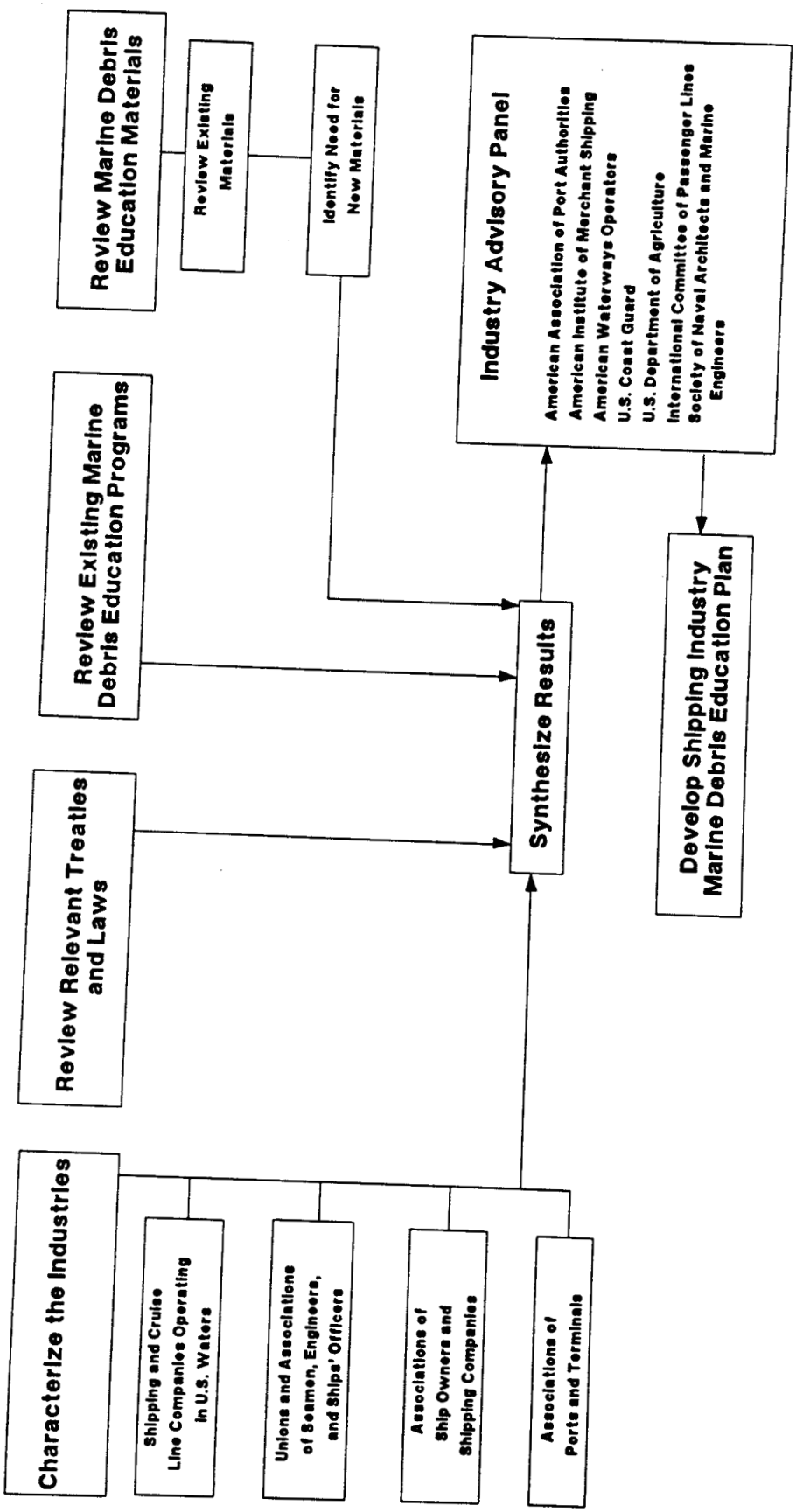



Figure 1.--Plan development methodology.

A preliminary list of marine debris education activities was developed based on the results of the data collection and synthesis tasks. A packet of materials, including a one-page summary of eight marine debris education activities, was sent to each panel member for review. The industry advisory panel attended a 1-day meeting in Alexandria, Virginia, to discuss MARPOL Annex V implementation and the Shipping Industry Marine Debris Education Plan. The marine debris education activities recommended in the plan reflect the input of the industry advisory panel.

## RECOMMENDED MARINE DEBRIS EDUCATION ACTIVITIES FOR THE SHIPPING INDUSTRY

Eight marine debris education activities are recommended for the shipping industry. An overview of these activities is presented in Figure 2. Activities 1 through 5 are the core activities in terms of time and budget. Activities 6 through 8 will have a secondary emphasis, but some time and funds will be allocated to them.

### Core Activities

Activity 1: Case Studies of MARPOL Annex V Compliance Activities

No one method of compliance with MARPOL Annex V will work for all vessels because of differences in such things as size, routes, cargo, and owners. The case studies will document policies and activities (including crew awareness training) that operators of different types of vessels as well as port and terminal operators are using to comply with MARPOL Annex V. The approaches different companies are using for MARPOL Annex V compliance are expected to reflect these differences. For example, seagoing vessels, which include commercial shippers and cruise lines, must comply with regulations on food waste coming from foreign waters, as set forth by the Department of Agriculture Animal and Plant Health Inspection Service (APHIS), as well as the provisions of MARPOL Annex V. Some of these vessels may also travel to special areas as defined by MARPOL Annex V, where dumping limitations are further restricted. Some coastal waterway vessels travel far enough from shore to be able to dump some types of garbage at sea legally. These vessels do not leave U.S. waters and, therefore, do not need to comply with APHIS regulations or the dumping restrictions in MARPOL Annex V special areas. Vessels in inland waterways and harbor areas have been prohibited from dumping garbage overboard for almost 100 years. Flexibility in the method used is seen by many in the industry as a key to voluntary compliance. The case studies will document how and to what extent flexibility is used for MARPOL Annex V compliance.

Until recently, much effort in marine debris education was spent identifying the sources of debris and convincing those industries or marine user groups that their practices were causing problems. This had a negative tone. The case studies will be examples of positive actions companies have taken to change the way they handle plastics and garbage disposal. They will demonstrate the range of techniques that companies have used to comply with MARPOL Annex V. They will also identify some of the problems encountered and how these were overcome. The case studies will be developed through key contact interviews and documents provided by these contacts.

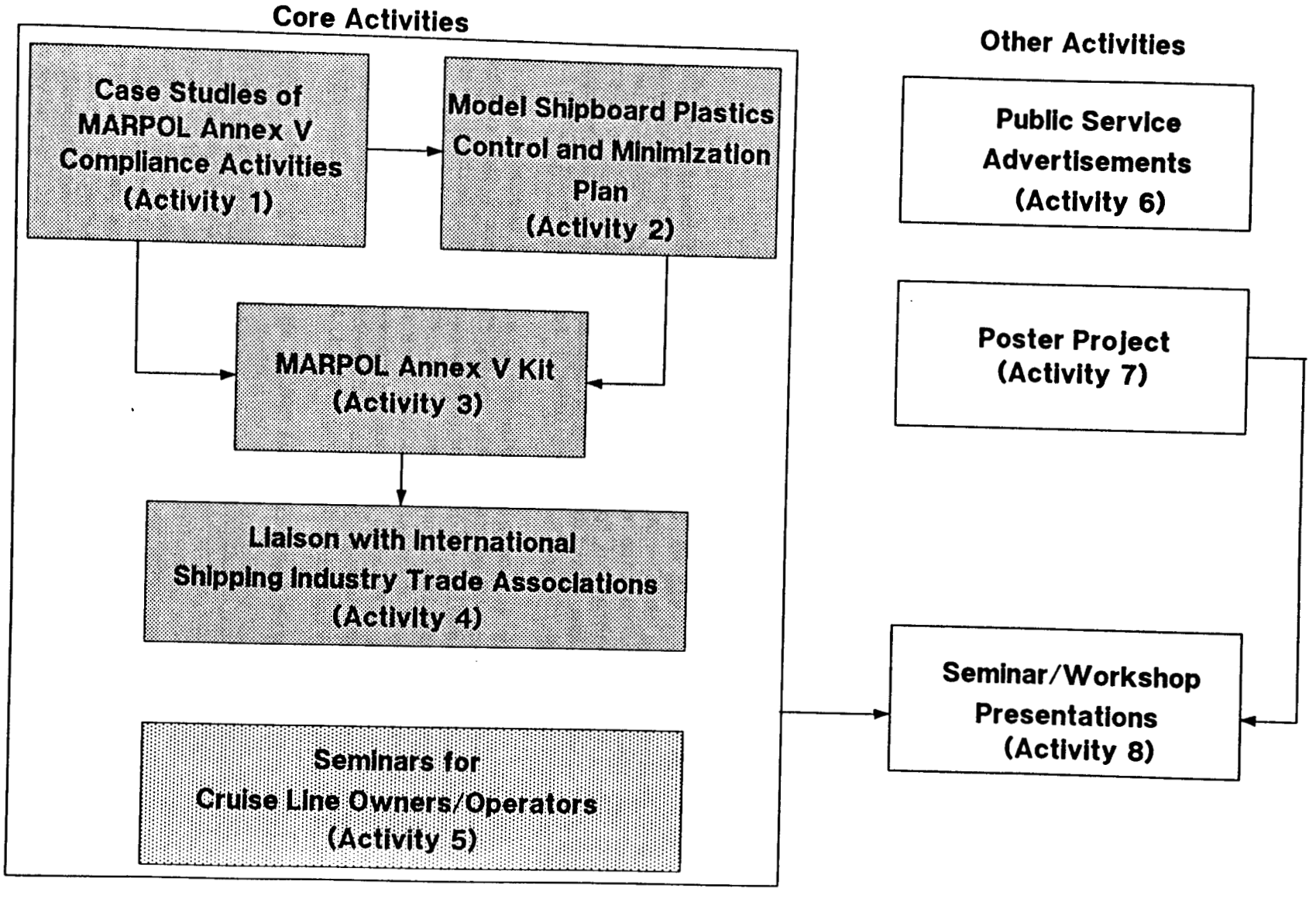



Figure 2.--Shipping industry marine debris education plan overview.

Activity 2: Model Shipboard Plastics Refuse Control and Minimization Plan

Each company will need to determine how to handle garbage under MARPOL Annex V. To facilitate that process, some documentation is needed on what to consider in developing strategies for plastic garbage disposal. A formal plastics refuse control and minimization plan can be an important component of a company's policy on garbage handling.

The model plan will outline the development of waste management procedures and the content and possible formats of a plastics refuse control and minimization plan. It will include techniques for increasing crew awareness of the consequences of marine debris and entanglement, and will use existing marine debris education materials. The model plan will be based on experiences profiled in the case studies and in existing waste management plans. Key contact interviews also will be used.

It should be noted that the Coast Guard will require certain vessels to have a waste management plan. Coast Guard guidance will be sought during the preparation of the model plan. However, the model plan may not be fully in keeping with Coast Guard requirements because it is likely to be completed before the Coast Guard issues instructions on the requirements for waste management plans.

Activity 3: MARPOL Annex V Kit

The MARPOL Annex V kit will assemble existing information on MARPOL Annex V implementation in the United States. The kit will provide a focal point for discussion with international groups on what is available on MARPOL Annex V implementation in the United States, and will be a product which can be printed and distributed by different groups (for example, trade associations and the NMFS Marine Debris Information Offices).

The kit, probably in looseleaf binder form, will include such things as the Coast Guard compendium of materials on MARPOL Annex V implementation in the United States, examples of how the requirements are being implemented by different types of vessels (from Activity 1), and guidance on how to set up shipboard waste management procedures and crew awareness training (from Activity 2). The kit will also include examples of existing marine debris education products (brochures, posters, stickers) that can be used on vessels for training or reminders about MARPOL Annex V requirements.

Activity 4: Liaison with International Shipping Industry Trade Associations

There are too many foreign flag vessels operating in U.S. waters to approach each owner and operator directly. However, the international shipping industry trade associations can be used as an indirect means of contact with foreign commercial shipping owners and operators. Personal contact, such as has been used with shipping industry trade associations in the United States, is more effective than telephone and mail contact in soliciting cooperation and exchange of information on MARPOL Annex V implementation. Meetings will be requested with the international shipping trade associations located in London. These meetings will be used to: 1)

make the associations aware of the marine debris education and MARPOL Annex V implementation materials available, 2) encourage them to publish announcements of marine debris education products in their trade publications, 3) encourage them to reproduce some of the materials, 4) increase awareness of the marine debris education activities taking place in the United States, and 5) identify specific needs where existing materials and programs may be of help.

Activity 5: Seminars for Cruise Line Owners and Operators

Experience in marine debris education activities has shown that involvement of the targeted group in development of an education program can be effective in making the program a success. This is the first time in a NMFS-sponsored marine debris education program that the cruise industry is the focus of marine debris education activities. Since the number of cruise lines operating in U.S. waters is small, it is possible to approach these companies directly.

Seminars with cruise line owners and operators will be conducted in Miami, San Francisco, and Washington, D.C. Offices of the majority of the cruise lines are located in or near these cities. These meetings will be used to: 1) solicit individual company support for marine debris education activities; 2) identify specific educational activities (e.g., working with the Centers for Disease Control to include marine debris information in procedures for shipboard inspections); 3) identify mechanisms to distribute information (e.g., include information with paychecks or stubs); and 4) develop educational materials or assemble existing materials in cooperation with company and industry representatives.

## Other Activities

Activity 6: Public Service Advertisements

Art work and brochures that made up a previously used public service advertising campaign are available. Since there is new interest in marine debris as a result of MARPOL Annex V implementation, there may be new opportunities to place the ads in appropriate trade publications. The art work for the public service advertisements will be offered to editors of shipping, port, and cruise line trade journals.

Activity 7: Poster Project

There are several posters available which could be used on ships or in port areas as reminders of the consequences of plastics in the ocean. Some vessel owners and operators have expressed interest in having posters, and their use would probably increase if more people knew about them. Written announcement about the posters on marine debris will be sent to: 1) Federal agencies with offices in port districts (e.g., Coast Guard, U.S. Customs, U.S. Immigration and Naturalization Service, and Department of Agriculture); 2) port authorities; 3) terminal operators; and 4) shipping companies.

Activity 8: Seminar and Workshop Presentations

Seminar and workshop presentations are a means of reaching different types of audiences and increasing awareness of the problem of marine debris as well as the ongoing activities on MARPOL Annex V implementation in the United States. The Shipping Industry Marine Debris Education Plan and its implementation will be presented at appropriate forums, should the opportunity arise.

## SHIPPING INDUSTRY MARINE DEBRIS EDUCATION PLAN IMPLEMENTATION

The Shipping Industry Marine Debris Education Plan will be implemented during a 9-month period beginning in the spring of 1989. The first half of the implementation phase for the core activities (Activities 1-5) will be used to prepare the new marine debris education products and establish a working relationship with the cruise line owners and operators. The second half of the implementation phase will be used to gain acceptance and distribution of the education products. The optional activities (Activities 6-8) will be undertaken throughout the implementation phase as the opportunity arises and time and budget permit.

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# CLEANUP PROGRAM IN JAPAN

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## ABSTRACT

The amount of marine debris accumulated in Japanese coastal areas has showed an increasing trend from the early 1970's, and this debris has become an obstruction to fisheries operating there, causing destruction of habitats of target species and interfering with fishing operations. In fiscal year 1973, the Fisheries Agency started a program to cope with these issues in coastal areas.

This program consists of two activities. One is the education of local residents including fishermen, and the other is the actual cleanup of the seashore and sea bottom. There are three parts to the cleanup activities: cleaning up the seashore using manpower, cleaning up the fishing grounds using trawl nets, and cleaning up the rocky bottoms using divers.

Cleanup activities were carried out in 137 areas in fiscal year 1987, at a cost to the Japanese Government of ¥342,249,000 (US$2,738K).

## INTRODUCTION

From early times, the Japanese have shown keen interest in various types of drifting objects stranded on beaches. In some places, people even developed habits of worshipping strange-shaped pieces of driftwood as deities. In coastal areas where the Kuroshio passed, people picked up coconuts which drifted ashore on rare occasions and dreamed of islands far to the south.

In recent years, however, great changes have been observed in the types and quantity of debris. Debris items were no longer objects of veneration as in past times but were a nuisance, causing damage to people's livelihood.

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## PROGRAM BACKGROUND

In the early 1970's, complaints were voiced by fishermen in various parts of Japan that wastes stranded ashore or accumulated on the sea bottom were causing serious damage to fishing activities. Such wastes ranged from man-made objects, including bottles, bottle covers, cans, worn-out tires, plastic bags, and other disposed plastics, to natural objects such as grass, wood, and vegetable garbage carried by rivers after torrential rains. Damage assumed to be caused by debris was varied, according to the fishermen. Some extremists contended that debris not only obstructed fishing operations but even caused a decline in the number of fish as a whole. Fishermen presented these problems in all earnestness because they were experiencing direct economic losses.

The damage seeming to have most apparent causal relations with wastes is summarized as follows:

1. Damage to organisms. Plastic bags attached to rocks on the sea floor (the natural habitat for seashells) make it impossible for the seashells to live there. Nondegradable wastes accumulated in shallow water deprive fish of spawning and nursery grounds. Fishing lines, cut or abandoned at sea or on the beach, break seaweed and entangle seabirds.

2. Damage to ships. Plastic bags obstruct engine cooling water intakes. Lost or discarded nets entangle propellers.

3. Damage to fishing activities. Plastic bags caught in trawl net meshes increase water resistance and thereby damage fishing gear. Increased resistance of gear in the water lessens energy efficiency of fishing vessels and increases fuel cost.

   Much time is required to sort out fish from debris caught in trawl nets, cutting down on fishing efficiency. Also, fish taken together with debris frequently bring a lower price.

4. Others. The scenery of beaches is affected, giving an unfavorable impression to visitors who come for sea bathing.

   Besides reports on damage, proposed solutions came from various parts of the country. These included requesting the public not to dispose of garbage in the sea and actively collecting debris being accumulated on beaches and the sea floor.

   However, several problems complicated the solution. First, there was the difficulty of identifying who actually discarded the wastes. The wide range of potential contaminators included ordinary residents, factories, tourists, ships, and fishermen themselves. Therefore, it was impossible to identify the actual polluters and have

them bear the cost of the damages. Second, the effort of people in any particular area is not sufficient to solve the problem. As marine debris comes from various areas including inland areas and areas hundreds of miles away, a number of municipality offices need to cooperate in efforts against this problem.

## ESTABLISHMENT OF THE PROGRAM

In fiscal year 1973, the Fisheries Agency launched a program (hereafter referred to as the "Cleanup Program") aimed at preserving the marine environment and recovering deteriorated fishing grounds. The Fisheries Agency formulated and coordinated the entire program, while regional authorities for each area concerned were responsible for the actual implementation.

### Contents of the Program

As for specific program items, local authorities were entitled to select from among the following options, giving due consideration to issues peculiar to their own areas:

1. Alert regional residents including fishermen to the need to preserve the marine environment, conducting appropriate educational activities through television and radio broadcasting and newspapers as well as through calls from aircraft, lectures, public ads, posters, leaflets, calendars, and bathing caps and towels.

2. Cleanup debris accumulated on the sea bottom using trawl vessels.

3. Cleanup debris on the rocky bottom using divers.

4. Eliminate wastes drifting on the sea surface using dipnets.

5. Cleanup the beaches using manpower.

6. Use manpower and machines to cleanup rivers and lakes.

7. Establish councils composed of local authorities, fishermen, and academics to formulate specific cleanup programs.

### National Budget for the Program

The cost of implementing the Cleanup Program is covered in part (usually half of project costs) by the National Government, with the remaining amount shouldered by local authorities actually enforcing the program. The government budget for this purpose increased annually, the subsidy for fiscal 1973 (April 1973-March 1974) being ¥96,000,000 (US$768K), rising to ¥401,126,000 (US$3,209K) in fiscal 1979. After that the budget remained more or less unchanged (Fig. 1).

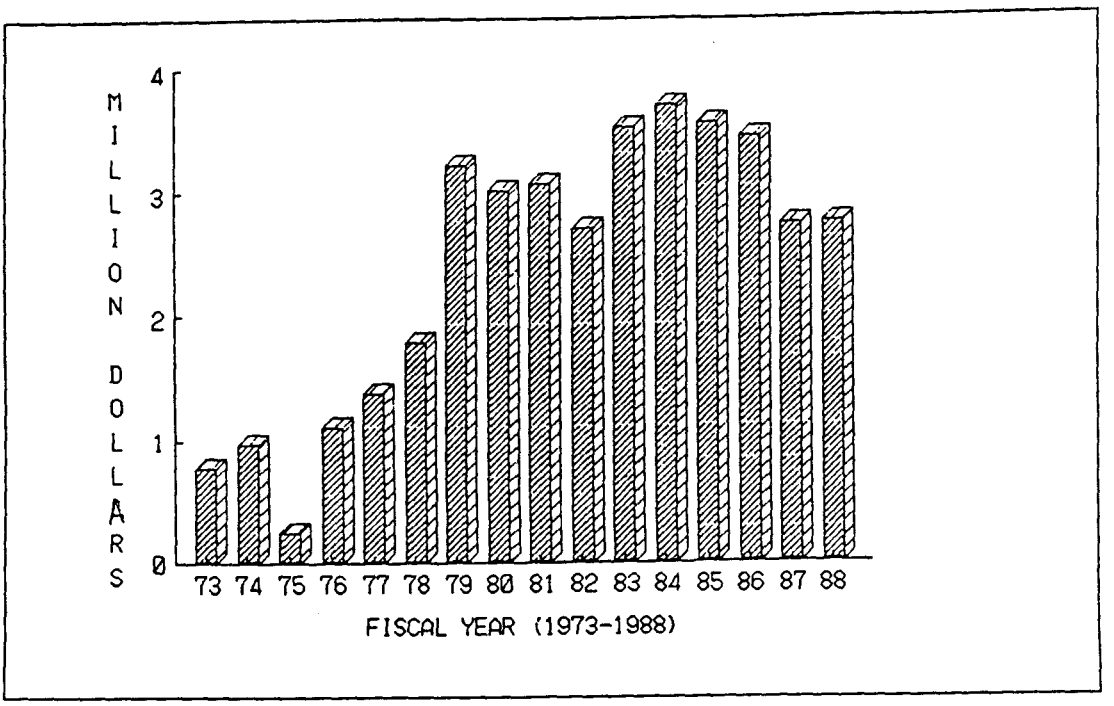



Figure 1.--Annual changes of subsidy under the government budget for the Cleanup Program.

## CLEANUP TODAY

At a cost to the national treasury of ¥342,249,000 (US$2,738K) in fiscal year 1987, the program was conducted in a total of 132 areas throughout Japan. The number of areas differed in different prefectures. Some prefectures conducted the program in as many as 23 areas, while some did not carry out any program (Fig. 2).

Following are actual situations in four areas during fiscal year 1987 and the cleanup programs in each area (Fig. 3).

### Mutsu Bay, Aomori Prefecture

Mutsu Bay measures about 1,660 $km^2$, with a total coastline extension of 251 km. Fishing is a major industry there, notably the scallop fishery, with production worth about ¥13 billion (US$104 million) in fiscal year 1987. In 1975, a large number of scallops died of an unidentifiable cause in the bay, which up to then was known for its relative cleanliness. This incident prompted local fishermen to request measures to preserve the fishing ground environment, and a cleanup program was implemented in the same year.

In 1987, cleanup activities were conducted in 10 towns and villages covering more or less the entire coast of the bay at an overall cost of ¥11,640,000 (US$93,120). The scale of the program has been about the

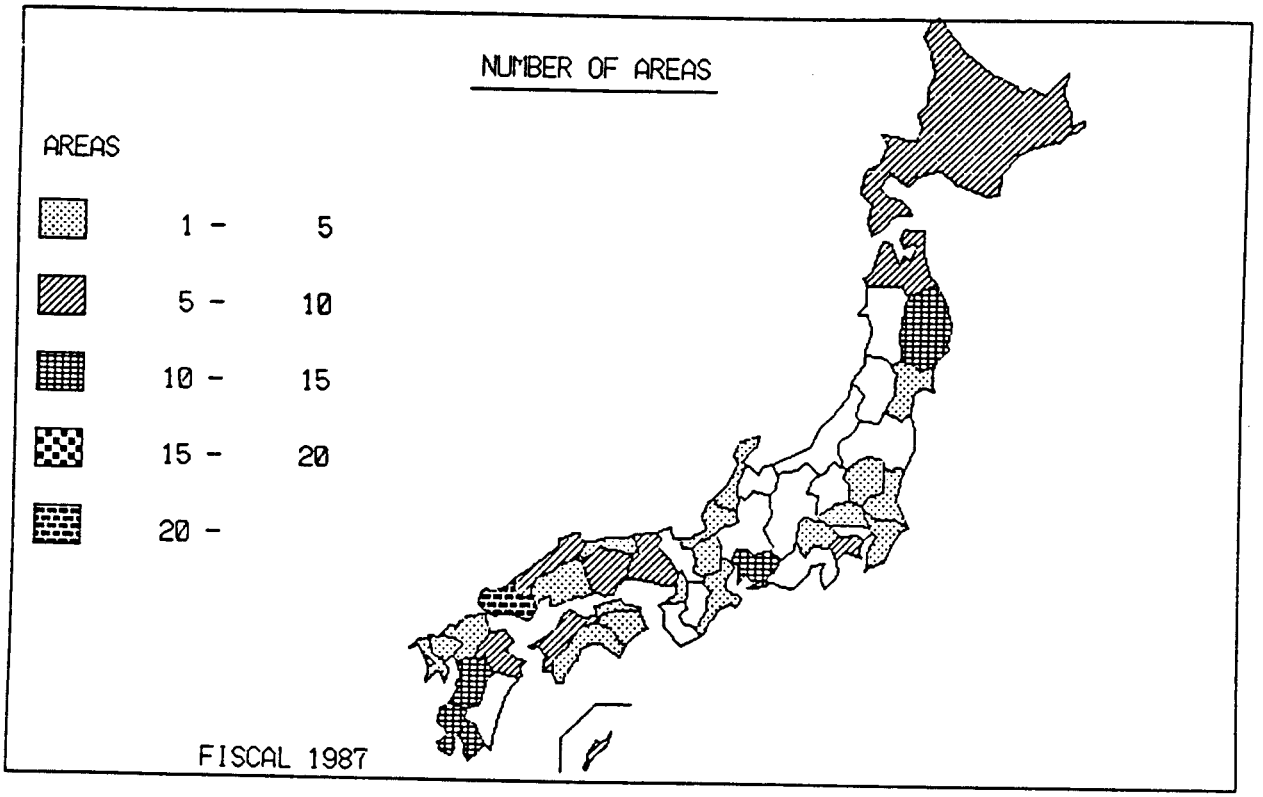



Figure 2.--Distribution of prefectures taking part in the program, shown by number of areas in which the program was conducted in 1987.

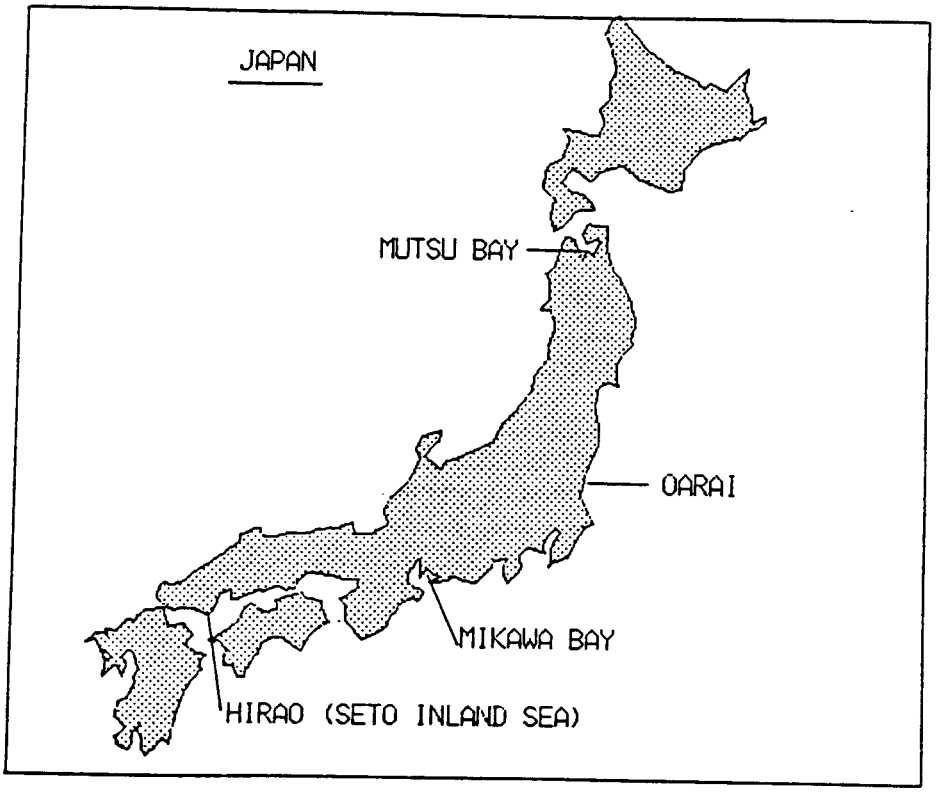



Figure 3.--Location of the four areas: Mutsu Bay, Oarai, Mikawa Bay, and Hirao.

same ever since. The program consisted of three major parts: cleaning up the beach, cleaning up the sea bottom, and conducting educational activities.

Beach cleaning was carried out for several days in July and August, with a total of 5,872 residents taking part, including fishermen, housewives, and students. Each participant was supplied with a pair of cotton gloves and a garbage bag, and wastes gathered totaled 356.2 metric tons (MT). Major components were wood fragments and seaweed. Combustible wastes were incinerated at the beaches, and incombustible items were transported by truck to garbage storage areas of local authorities to be used as landfill.

Sea bottom cleaning was conducted for several days mainly in July, with a total of 2,089 small-sized beam trawlers participating. Fishermen used their own nets for collection of wastes. Debris collected amounted to 163.8 MT, and consisted mainly of used cans and seaweed. There was a larger percentage of seashells and used cans than other wastes on the beaches. All the debris was transported to local authorities' garbage storage areas and landfills.

Educational activities were mainly targeted at elementary school pupils and junior high school students with a view to achieving long-term effects. Guidance on the importance of preserving the marine environment was extended in the course of ordinary school curriculums, and pupils and students were encouraged to make posters and catchphrases contributing to environmental preservation. A total of 1,146 posters and 1,904 catchphrases on marine environmental preservation were collected from the children at 37 schools from July to September 1987. Excellent works were publicly commended with commemorative awards worth ¥3,000-5,000 (US$24-25) (including a book of gift coupons and a painting set). These were distributed for public presentation in the towns and villages concerned. This program has been established as an annual event in the area.

**Oarai, Ibaraki Prefecture**

Oarai is a Pacific coast town with a population of 21,000, and its major industries are tourism and a coastal fishery. Located relatively close to the Tokyo metropolitan area, Oarai has seen rapid urbanization during the past few years. The amount of wastes has been rising, making their disposal increasingly difficult despite the municipal authorities' effort. The town is situated at the mouth of a big river (Nakagawa River), and it has been pointed out that a great amount of debris flows into the sea from the river. Fishermen are worried that sardine fry, caught with trawl nets, can be easily damaged by garbage netted simultaneously. In the summer, about 8 million people visit this town for sea bathing. The municipal authorities have a hard time disposing of used cans and bottles generated by these seagoers.

Sea bottom 15-30 m deep and totaling 7.84 $km^2$ was cleaned on 18 January and again on 20 February 1988 using 57 small (5-ton) trawlers. Fuel expenses of ¥5,400 (US$43) and ship depreciation expenses of ¥22,000

(US$176) per day were provided to each vessel. Fishermen used their own trawl nets for cleaning activities. The program was conducted during off seasons of the coastal trawl fishery to avoid an unnecessary by-catch of fish. As a result of the cleanup, 15.5 MT of debris, mostly used cans and plastic bags, were collected and removed to a landfill.

Since the Cleanup Program was launched in 1974, fishermen have seen a decrease in the amount of debris caught in their nets, and they have become increasingly active in many areas in this region.

**Mikawa Bay, Aichi Prefecture**

Mikawa Bay, with an area of 604 $km^2$ and an average depth of 9 m, is a closed area with poor tidal interchange. At the back are located industrial and urban areas, and many rivers which run through these areas flow into the bay. Major industries of the bay area are fishing and tourism, with a resort business targeted at sea bathers.

In cleanup activities implemented in fiscal 1987, a total of 464 residents in 8 areas cleaned up the 30.9 km coastline along the bay, collecting 5,810 kg of wastes from 120,000 $m^2$ covered. Principal debris was wood fragments, cans, and bottles (Fig. 4). All the debris collected was either taken to a landfill or incinerated. A total subsidy of ¥1,000,000 (US$8K) was granted, and was used for purchasing commemorative items, gloves, polyethylene bags, and fuel for incinerating waste.

**Hirao, Yamaguchi Prefecture**

Hirao is an agricultural and fishing town with a population of 15,000, facing the Seto Inland Sea. The Seto Inland Sea is the largest of its kind in the country, with a latitudinal extension of 445 km, a longitudinal extension of 15-18 km, and a total area of 2,200 $km^2$. The average depth is relatively shallow at 37.3 m. This is an area of serious concern when it comes to marine environmental pollution, as it is a closed area and has a population of 29,359,000 along the coast.

Impressive educational activities are being carried out in Hirao. With the collaboration of residents, an experiment was conducted to find out how the garbage arrived at the town by way of sea currents and winds, and where the garbage originating in the town goes. This experiment is known among the residents as "Coconut Strategy," with the capsules used in the experiments being thought of as coconuts. In July 1987, 25 plastic capsules 10 cm in diameter and 40 cm long were set adrift from 25 points along the coast within a radius of 50 km from the center of the town. Posters were placed in the town and surrounding areas in order to draw the attention of residents and ensure that reports would be made when the capsules were found on beaches. So far, a total of 15 capsules have been recovered. Around the areas where capsules were released, the results were publicized using posters saying, "The capsule released from your town arrived at such-and-such an area. This means if you discard garbage into the sea, it will possibly drift to that area and cause trouble. The sea does not belong only to you. Please take heed not to contaminate the sea."

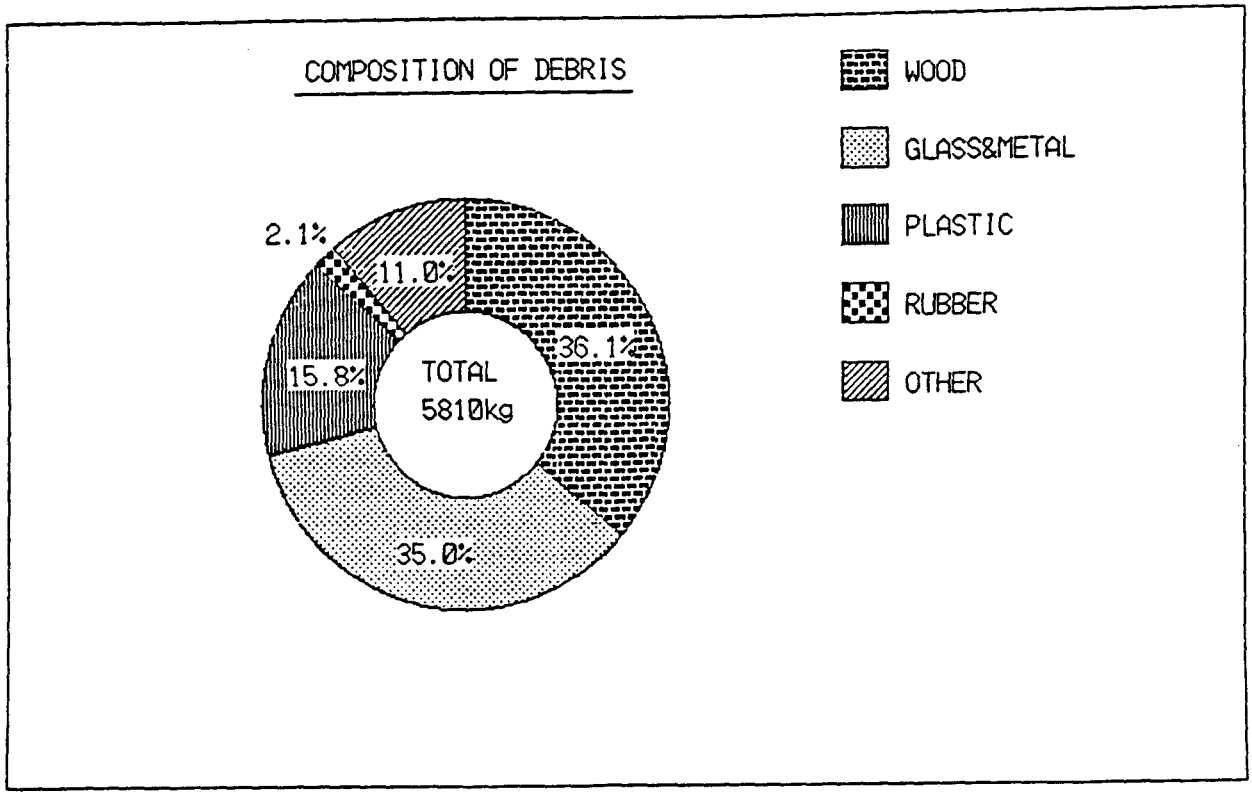



Figure 4.--Composition of debris collected from beaches during the cleanup of Mikawa Bay in July 1987.

A total of ¥322,000 (US$2,576) was used for producing capsules and posters and for other purposes.

The campaign has grown as town residents have begun to realize the need to raise public ethical standards, and an increasing number of people are participating.

## DISCUSSION

### Effects of the Program

The Cleanup Program was initiated under the leadership of the administrative authorities, but in many cases, programs were taken over willingly by local residents as years passed.

People's interest has grown as the educational programs have continued, and many people hope that the programs will carry on. Some communities have even formulated their own new and voluntary initiatives, in addition to the basic guidelines. One such example is the establishment of "Fishing Ground Preservation Month," during which stepped-up publicity is conducted.

There have been two different views concerning the effects of the Cleanup Program. One recognizes the effectiveness of the program based on

the fact that the amount of garbage has been steadily declining since the program was launched. The other questions the effectiveness of the Cleanup Program, pointing out that the garbage amount has not decreased substantially even after several years. These differences are due to the fact that the pace of waste accumulation differs from area to area, that amounts collected are subject to weather and sea conditions, and that it is difficult to assess the effects of the program quantitatively. However, even people taking the latter position believe that implementation of the Cleanup Program contributes to an increase in public awareness of environmental preservation. It is therefore concluded that the program as a whole has been significant.

## Future Themes

Some future tasks have been pointed out that will improve the effectiveness of the program. First is the need to conduct the program in a comprehensive manner covering a larger area than at present. In many cases, cooperation in the present program has been limited to the level of muncipalities along a bay area. In order to cope with environmental problems covering the vast ocean, it will be necessary to step up and expand collaboration. Further, it will be no less important to expand the scope of the program to inland areas. A considerable amount of wastes generated by the people in those areas is transported through rivers to the sea. Garbage originating inland can accumulate on the beaches.

Second, it is necessary to hunt for new ways to promote a voluntary environmental preservation campaign. One potential method is to install garbage processing facilities in areas where individuals voluntarily collect wastes. Such support is expected to further increase the local communities' awareness of the need for environmental preservation. Lastly, some technological problems need to be solved. Although the program does not require any special technology, some problems have arisen as a result of its actual implementation. These include the disposal of incombustible objects containing large amounts of sand and seawater (salt water) and the elimination of wastes accumulated around complex bottoms or man-made structures such as artificial and natural reefs.

## ACKNOWLEDGMENTS

We express our gratitude to all those who are striving to promote the Cleanup Program. Special appreciation is due to Messrs. Nagatsu of Aomori Prefecture, Chinone of Ibaraki Prefecture, Matsui of Aichi Prefecture, and Asaka of Yamaguchi Prefecture, who collaborated in collecting materials.

# U.S. NAVY'S PLASTICS WASTE EDUCATIONAL EFFORTS

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## ABSTRACT

The U.S. Navy is responding to the at-sea plastics discharge prohibition in the Marine Plastic Pollution Research and Control Act with a program that includes new shipboard solid waste management equipment, changes in the supplies taken on board, and educational efforts.

Basic strategy of the Navy's plastics waste education program focused on motivating the entire chain of command, ships' officers, and ships' crews by providing justification for and information about the new requirements.

Before designing an effective shipboard plastics waste management program, it was necessary to learn (1) the nature and quantities of plastics waste on Navy ships, (2) feasible shipboard plastics waste management practices, and (3) sailors' attitudes about plastics pollution control. The Shipboard Plastics Waste Reduction Demonstration Project gathered this information on seven ships. Then, using recommendations from an ad hoc advisory committee on plastics and actual experiences on the demonstration ships, the Navy designed an educational package to send to all Navy ships.

The Navy's plastics education package includes guidance material, videotapes, posters, and general literature. To educate the ships' officers, a ship's guide contains chapters on (1) problems caused by plastics in the oceans, (2) Navy

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

requirements, (3) essential elements of a successful shipboard program, (4) example approaches used on the demonstration ships, and (5) general information about related issues. Appendixes to the guide include lists of common plastic and substitute nonplastic items, sample ship instructions to implement the program, descriptions of other materials in the package, and Navy points of contact for further information. To education the crew members, a 10-min videotape explains the problem, the Navy's program, and appropriate shipboard actions. A series of 30-sec videotapes and written announcements highlight specific aspects of the problem and the program.

Preliminary responses to the education package from Navy ships are very positive.

## INTRODUCTION

### Impetus for Navy's Plastics Program

Recent and unexpected national regulatory initiatives caused the U.S. Navy to quickly develop and implement shipboard plastics waste management programs. The Navy anticipated more stringent international regulations affecting solid waste disposal at sea, but not a prohibition on plastics discharge.

Annex V of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships (MARPOL), prohibits disposal of all plastics, and restricts discharges of all types of solid wastes, into the sea from ships. Public vessels are exempt from Annex V restrictions but are expected to comply to the extent possible. However, the U.S. Congress, in passing the U.S. Marine Plastic Pollution Research and Control Act of 1987 (P.L. 100-220), made the plastics discharge prohibition apply to the U.S. Navy. The Congress is requiring the Navy to comply within 5 years or demonstrate why it cannot.

For decades the Navy has worked to eliminate the discharge of floating marine debris from its ships, and for the last 5 years, has been developing suitable shipboard equipment for pulping, compacting, and processing all solid waste (Alig et al. 1990). The equipment will convert all shipboard solid wastes to acceptable forms for overboard disposal at prescribed distances from shore. However, plastics waste would have been processed along with other solid wastes, so the new requirement to eliminate plastics waste disposal at sea created an unexpected and difficult challenge.

### Ad Hoc Plastics Advisory Committee

The Navy formed an ad hoc committee on plastics to develop recommendations for reducing plastics waste discharge from Navy ships, and in October 1988, the committee presented its report to the Assistant Secretary at a Washington, D.C., news conference. The report contains 42 recommendations covering 4 areas: supply system, technology, ship operations, and education.

The Navy's shipboard pollution abatement program was already addressing most of the committee's technology recommendations as part of the shipboard solid waste management program. The recommendations in the areas of the supply system, ship operations, and education, however, embodied major changes in Navy practices. Nevertheless, the Navy began implementing many of the recommended actions to help reduce plastics discharge at sea.

Following are the six recommendations made in the area of education:

1. Disseminate information on the plastics problem and the Navy's plans to all levels in the Navy.

2. Develop education materials for ships, supply centers, and procurement offices.

3. Use an education package composed of several key elements on every Navy ship.

4. Assess effectiveness of education efforts through a survey.

5. Use the Navy's environmental award to recognize outstanding ships for their efforts to reduce plastics waste.

6. Sponsor shipboard contests on plastics reduction methods.

### Navy Actions

The Navy has already taken significant actions to control plastics pollution at sea. As examples, fleet commanders ordered all ships to separate plastics from nonplastics waste on board and return the plastics waste to port for disposal or recycling. Supply centers have replaced plastic items with nonplastic ones on ships wherever possible. The Chief of Naval Operations office sent a plastics education package to all ships. This paper describes the Navy's initial efforts to educate ships' officers and crews about the new requirement to eliminate plastics waste at sea.

## GUIDING PRINCIPLES

The key to success for a new Navy program is to motivate the chain of command and the sailors to participate fully. But in the case of the plastics waste program, the entire chain of command also had to support the program, both financially and authoritatively.

Before the top echelons of the Navy's chain of command would impose such drastic measures as storing wastes on Navy warships, they needed evidence showing shipboard plastics waste programs to be feasible, effective, and safe. Therefore, we had to assess the feasibility, effectiveness, and safety of potential shipboard plastics waste management practices before we could propose a program concept that the chain of command would support.

The program needed careful planning and coordination among many diverse Navy organizations (e.g., Office of the Chief of Naval Operations,

Fleet Commands, Naval Sea Systems Command, Naval Supply System Command, and Navy laboratories). Even then, edicts and emotional appeals do not ensure a successful program. For drastic changes in shipboard waste management practices, a variety of motivation techniques would be needed to get full cooperation on ships. Some officers and crew would be sufficiently motivated by direct orders. Others might respond to the military benefits of new procedures. Sound explanations of the reasons for new requirements would suffice for some. Still others would get personally motivated by appealing to their sense of pride or the need to protect wildlife.

Our guiding principles, then, in developing the educational program were to invoke as many response stimuli as we could.

## EDUCATION OF NAVY PROGRAM MANAGERS

Successful reduction of plastics discharge from Navy ships requires two educational efforts. One is educating the Navy chain of command about what shipboard practices are feasible and effective. The other is educating ships' officers and crews about the new practices. To achieve the first step, the Navy needed to learn (1) the nature and quantities of plastics waste on Navy ships, (2) feasible shipboard plastics waste management practices, and (3) sailors' attitudes about plastics pollution control. In 1988, the Navy's Shipboard Plastics Waste Reduction Demonstration Project began collecting this information.

During the demonstration project, Navy researchers traveled on seven ships to quantify shipboard plastics waste, and evaluated prototype equipment and plastics waste management procedures. They sorted and inventoried all plastics waste generated on board. On two ships they evaluated Navy-developed prototypes of a trash compactor and a waste pulper. Other researchers surveyed the crews' knowledge about the plastics problem.

The preliminary conclusions from the demonstration project regarding an education effort are the following:

- Sailors are generally receptive to the major new requirement to separate and store plastics waste on board, once the problem with plastics in the oceans is explained to them.
- The mission, size, crew density, and operating characteristics of different ships differ so much that a single set of prescribed plastics waste management procedures is not appropriate for all ships.
- Ships prefer to find their own approaches to meeting the requirements, i.e., be told what to do, not how to do it.

## EDUCATION OF SHIPBOARD PERSONNEL

### Development of Education Package

Initially, we planned to prepare a prototype educational package and test its effectiveness on several demonstration ships before sending it to

all Navy ships. However, the Commander of the Atlantic Fleet took a personal interest in the plastics problem and pushed for faster implementation of shipboard programs. His staff prepared instructions for ships to retain plastics waste on board to the extent practicable. He wanted an educational package sent to ships before he would issue the new instructions. Consequently, we had to assemble educational materials quickly without knowing exactly what shipboard procedures were feasible and what educational materials would be effective on ships.

Our basic strategy for the educational package targeted two audiences on ships: executive officers and crew members. We prepared a ship's guide and a new videotape, and supplemented these two key items with available literature, posters, brochures, and videotapes.

The ship's guide serves as a compilation of useful information about the new requirements and suggestions for implementing a shipboard program. To allow ships' officers and crews to find their own ways of meeting the new requirements, the material was presented as a guide, not an instruction.

Because closed circuit television is the prime source of news and entertainment on ships, we believed that videotapes would be the best way to influence and communicate with sailors. Therefore, the Navy produced new videotapes that focused specifically on the Navy's role in the plastics problem. As a general overview, we prepared a 12-min tape that covers all aspects of the problem and the Navy's program. To add authority and credibility to the new requirements, the Vice Chief of Naval Operations made a 3-min statement on videotape. To keep the issue visible to the sailors and reiterate the theme of the plastics program, we produced a series of 30-sec tapes that could be shown on board between movies. For variety, we included in the package existing videotapes produced by other organizations.

## Contents of Education Package

The Navy's plastics waste educational package that was sent to all ships included the following items.

- "Ship's Guide to Recent Navy Initiatives for Shipboard Solid and Plastics Waste Management" (U.S. Navy).
- Videotapes in Beta and VHS formats with six selections:
  - "Plastics At Sea, More Than a Litter Problem" (12 min, U.S. Navy).
  - Statement by Admiral Edney, Vice Chief of Naval Operations (3 min).
  - Eight 30-sec public service-type announcements (U.S. Navy).

  - Navy Broadcast News segment on the plastics problem (7 min).
  - ABC News excerpt on ocean pollution (3 min).
  - "Trashing the Oceans" (7 min, U.S. National Marine Fisheries Service).

- "A Citizen's Guide to Plastics in the Ocean: More Than a Litter Problem" (Center for Environmental Education, Washington, D.C.).
- Three posters:
  - "Don't Splash Navy Trash--Others Can Pick It Up" (U.S. Navy).
  - "Our Ocean Is Drowning" (U.S. National Marine Fisheries Service).
  - Photograph of large plastic bag of trash with narrative (Center for Environmental Education, Washington, D.C.).
- "Our Water Planet is Becoming Polluted with Plastic Debris" (brochure prepared by U.S. National Marine Fisheries Service).

The Navy's videotape "Plastics At Sea, More Than a Litter Problem" explains the problems caused by plastics in the oceans, the Navy's overall program for shipboard solid and plastics waste management, and what actions are needed by each ship and crew member. The tape is narrated by an actor in an enlisted man's uniform and contains footage of healthy marine life, entangled animals, Navy ships, shipboard scenes, and computer graphics. To appeal to sailors, segments of the Huey Lewis videotape "Perfect World," showing his band singing in a huge garbage dump, appear throughout the tape.

The ship's guide is similar to a citizen's handbook, except that it contains information applicable to Navy ships and the Navy's plastics waste program. The guide is approximately 50 pages long, with 6 chapters and 9 appendixes. Chapter 1 (Introduction) briefly describes the problems caused by plastics at sea and the international and national regulations restricting disposal at sea. Chapter 2 (Navy Requirements) explains the major changes needed in shipboard solid waste management. Chapter 3 (Essential Elements of Successful Shipboard Program) emphasizes that a shipboard program needs comprehensive operational changes, leadership, crew education, constant reinforcement, and clear definitions of responsibilities. Chapter 4 (Example Approaches Used on Demonstration Ships) provides suggested procedures for ships to use in their own shipboard plastics waste program, based on successful and unsuccessful approaches used on the demonstration ships. Chapter 5 (Medical Wastes) describes the new requirements for managing medical wastes on board. Chapter 6 (Status of Related Issues)

addresses three topics related to the plastics program: degradable plastics, shipboard incinerators, and commercial products.

The nine appendixes are a collection of miscellaneous items to help executive officers develop their ship's program. We provided lists of common plastic items on ships and the available nonplastic substitutes. Brief synopses of information about the plastics problem, sources of marine debris, legislation, and the Navy's program are included as sample "Plan of the Day" announcements for executive officers' use in keeping the program visible to crews. Included also are example ship instructions for implementing a shipboard program and an example message report for reporting any necessary plastics discharge at sea. Other appendixes describe the contents of the educational package and give Navy points of contact for additional information.

## PRELIMINARY OBSERVATIONS ON EFFECTIVENESS OF PACKAGE

The Navy sent complete educational packages directly to all ships in the U.S. Fleet in early 1989. Preliminary responses to the education package are very positive. The combination of useful information and multimedia motivational techniques in the package seems appropriate for Navy ships. Each item in the package seems useful for one or more purposes. However, the two items specifically prepared by the Navy for the education package (i.e., ship's guide and videotape) are the most valuable.

The Navy will continue its shipboard plastics educational program and extend it to shore facilities. Plans to modify the videotape and distribute it to shore facilities are ongoing. The future direction of the program will depend on the success of the initial effort and the need to modify the program.

## CONCLUSIONS

The requirement for U.S. Navy ships to separate and retain plastics waste on board is so new and the educational packages were distributed so recently that any conclusions about the effectiveness of the program would be premature. However, from our experiences so far, we make the following observations:

1. Sailors generally respond positively to the plastics waste program and the educational materials. We believe the general environmental awareness and young age (average age is about 20 years) of Navy sailors are major factors affecting the positive response.

2. High quality videotapes are an effective means for communicating with shipboard audiences. However, useful guidance material about specific procedural details must accompany the videotapes.

3. Attention by the entire chain of command is needed for successful program implementation.

4. Edicts, emotional appeals, and good educational materials do not ensure successful shipboard plastics waste programs. The program must be carefully planned, coordinated, and implemented. Proposed new plastics waste requirements must be first proved feasible, effective, and safe on ships for the program to succeed.

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# HOW MUCH DO COMMERCIAL AND RECREATIONAL FISHERMEN KNOW ABOUT MARINE DEBRIS AND ENTANGLEMENT? PHASE 1

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## ABSTRACT

Education is assumed to be a cost-effective method to encourage shoreside disposal of plastics and other garbage. To test this assumption, a demonstration project is under way at four sites to develop, test, and evaluate marine debris education as a technique for changing the waste management practices of commercial fishermen and recreational boaters. The project is structured in three phases: 1) a baseline survey of commercial fishermen and recreational boaters on their garbage disposal practices and perceptions of the problems of marine debris and entanglement; 2) a targeted marine debris education program for the survey groups at three of the four sites; and 3) a survey of the same groups used in phase 1 on their garbage disposal practices and perceptions of the problems of marine debris after the education program. The project sites are: Bayou La Batre, Alabama; Martin County, Florida; Hampton, Virginia; and Taylor County, Florida. Phase 1 of the project was completed in the spring of 1989. Commercial fishermen and recreational boaters at the four sites were asked questions in six areas: 1) current garbage disposal practices, 2) experiences with plastic marine debris, 3) opinion on the problems caused by plastic marine debris, 4) knowledge of laws on at-sea garbage disposal, 5) opinion on ways to encourage shoreside disposal of plastic garbage, and 6) background information. Results of the phase 1 survey revealed the garbage disposal practices of those surveyed as well as their opinions on and experiences with plastic marine debris.

## INTRODUCTION

Annex V of the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 73/78) went into effect 31 December 1988. The MARPOL Annex V, formally entitled "Regulations for the Prevention of Pollution by Garbage from Ships," prohibits at-sea dumping of plastics and specifies the distance from shore that all other materials may be dumped. This means overboard disposal of most garbage is no longer an option.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Enforcement of MARPOL Annex V will be difficult because of competing priorities and limited resources of the Federal enforcement agencies. The success of MARPOL Annex V will depend in part on voluntary compliance.

Education is expected to be a key factor in gaining voluntary compliance with MARPOL Annex V. Education is also assumed to be a cost-effective way of encouraging shoreside disposal of plastics and other debris. To test this assumption, a demonstration project is under way to develop, test, and evaluate a marine debris education project for commercial fishermen and recreational boaters. The project is sponsored by a Saltonsall-Kennedy grant from the U.S. National Marine Fisheries Service. This paper outlines the overall structure of the project. Results of a survey of commercial fishermen and recreational boaters at four sites taken before a targeted marine debris education program are also presented.

## METHODOLOGY

The project is structured in three phases: 1) a baseline survey of commercial fishermen and recreational boaters on their garbage disposal practices and perceptions of the problems of marine debris and entanglement; 2) a targeted marine debris education program for the survey groups at three of the four sites; and 3) a survey of the same groups used in phase 1 on their garbage disposal practices and perceptions of the problems of marine debris after the education program (Fig. 1). Phase 1, the initial survey, was conducted in the spring of 1989. Phase 2, the marine debris education program, will be conducted from the spring through the summer of 1989. The second and final survey, Phase 3 of the project, will be conducted in the fall of 1989.

The project is being conducted using four sites: Bayou La Batre, Alabama; Martin County, Florida; Hampton, Virginia; and Taylor County, Florida. Taylor County will serve as the control site. Commercial fishermen and recreational boaters in Taylor County will receive no marine debris education as part of this project, but will be surveyed twice. This approach was taken because some of the education activities cannot be restricted to the survey sample.

These sites were selected after consultation with state natural resource agencies. Other factors considered in the selection process included distance from other known marine debris education projects, prior involvement of the state with the marine debris issue, the ability of the state to provide comprehensive lists of commercial fishermen and recreational boaters, the number of commercial fishermen and recreational boaters, and the opportunity to coordinate marine debris education activities with local events or projects. In Martin County, for example, marine debris education activities will be tied to a fishing tournament.

The survey groups were selected from mailing lists of recreational boat registrations and commercial fishing licenses maintained by state agencies. The goal was to obtain 100 completed surveys at each site for both commercial fishermen and recreational boaters. For each site, an initial sample of 300 individuals with registered motorboats used for pleasure was selected

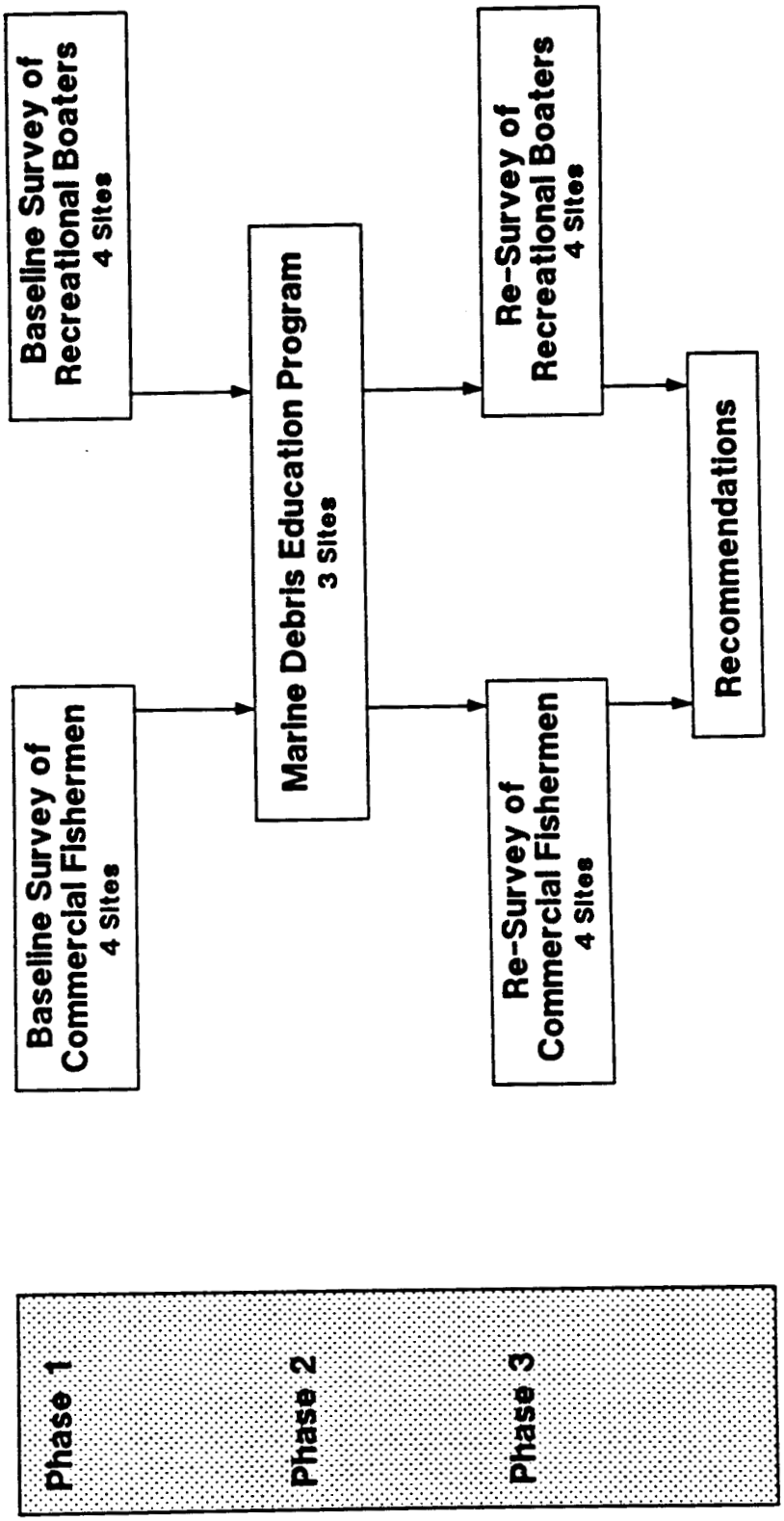



Figure 1.--Overview of project methodology.

using a systematic sampling technique. Surveys returned because of incorrect addresses were replaced with new names drawn using the same sampling technique. An additional sample of up to 150 names was drawn after initial survey returns indicated that fewer than 100 completed surveys would be received. All individuals on the commercial fishing license lists at each site were included in the survey. The number of commercial fishing licenses at the four sites ranged from about 200 to 330. Over 400 surveys were completed and returned--161 (16% of the potential respondents) from commercial fishermen and 257 (20% of the potential respondents) from recreational boaters. The number of completed commercial fishermen surveys ranged from 8% from Bayou La Batre to 21% from Martin County. For recreational boaters, the range was from 7% from Bayou La Batre to 27% from Hampton. None of the sites reached the goal of 100 completed survey forms, although 97 recreational boater surveys from Hampton were completed and returned. The description of the survey responses which follows represents the answers of those responding to the survey only and should not be generalized to a larger population. Unless otherwise noted, the following description of the responses combines the responses from all four sites.

## DESCRIPTION OF RESPONDENTS

### Commercial Fishermen

About one-quarter of the commercial fishermen responding to the survey were between 30 and 39 years of age. Another quarter of the respondents were 60 years or older. The percentage of income from commercial fishing in 1988 ranged from 0 to 100%, with the average being about 41%. The types of gears used in 1988 in order of percentage of use were as follows: rod and reel (42%), gillnet (38%), traps and pots (26%), tongs (24%), trawl (12%), dredge (4%), and longline (4%). Rod and reel were used at all sites, but most often in Martin County and Taylor County. Gillnets were also used at all sites, but most often in Hampton and Taylor Counties. Surf fishermen and spear fishermen were represented among the respondents from Martin County. Most of the commercial fishermen responding to the survey typically make day trips. However, one or more of the respondents at each of the four sites make longer trips. Some of the trips last up to 14 days at a time. About 28% of the respondents are members of a commercial fishermen's association. Only about 13% of them had participated in an organized beach cleanup in the past 3 years.

### Recreational Boaters

The age distribution among the recreational boaters responding to the survey was evenly divided among three groups: 40 to 49 years, 50 to 59 years, and 60 and older. About one-quarter of the respondents fell into each group. About 40% of the respondents fish on every boat trip they make. Only 5% of the respondents never fish from their boats. About 8% of the respondents are members of fishing clubs, and about 11% had participated in an organized beach cleanup within the past 3 years.

## CURRENT GARBAGE DISPOSAL PRACTICES

### Commercial Fishermen

About 95% of the respondents have one or more trash receptacles on their vessels. The most prevalent types are buckets (52%) and plastic garbage bags (36%). Other receptacles used include trash cans, paper bags, and fish boxes. Only two respondents (1.3%) have compactors and one (0.6%) has an incinerator on board. Over half of the respondents said they consider what plastic items are taken on board which will need to be thrown away. Over 80% of the respondents said they have picked up plastic trash from the ocean, bay, or sound and returned it to shore for disposal. Plastic trash is generally disposed of at home (50%), at the dock or marina (27%), or at the fishhouse (20%). Fewer than 3% of the respondents admitted to disposing of plastic trash in the ocean, bay, or sound. Unwanted gear is generally disposed of at home (54%), at the dock or marina (23%), and at the fishhouse (10%). Fewer than 2% of the respondents admitted to disposing of their fishing gear in the ocean, bay, or sound. Unwanted gear is also left at city and county garbage dumps and landfills, or in dumpsters away from a dock or marina.

### Recreational Boaters

Like the commercial fishermen, most recreational boaters responding to the survey have one or more trash receptacles on board their boats. The most common trash receptacles among the respondents are plastic garbage bags (51%) and buckets (43%). Among the other types of receptacles used for trash are coolers and dry and live wells. Over 56% of the respondents said they consider what plastic items will need to be thrown away when deciding what to take on board. About 75% of the respondents have picked up plastic trash from the ocean, bay, or sound and returned it to shore for disposal. Plastic trash from day trips is generally disposed of at home (73%) or at the dock or marina (23%). Fewer than 1% of the respondents said they throw plastics into the ocean, bay, or sound. On overnight trips or longer trips, the respondents generally dispose of their plastic trash at the dock or marina (56%) or at home (38%).

## EXPERIENCE WITH PLASTIC MARINE DEBRIS

### Commercial Fishermen

The respondents were asked first to identify which of six problems caused by plastic marine debris they had seen or experienced. They were then asked to identify the one they considered to be the most important among the six. Figure 2 summarizes the experience of the respondents with plastic marine debris. More than 95% of the commercial fishermen said they have seen plastic trash floating in the ocean, bay, or sound. This was also identified by the commercial fishermen as the most important problem among the six. About 75% of the respondents said they have seen plastic trash floating near the dock. Many of the respondents have had personal experience with plastic marine debris. Over 45% have had their vessel's propeller caught in plastic. Over 30% have had their gear caught or fouled by

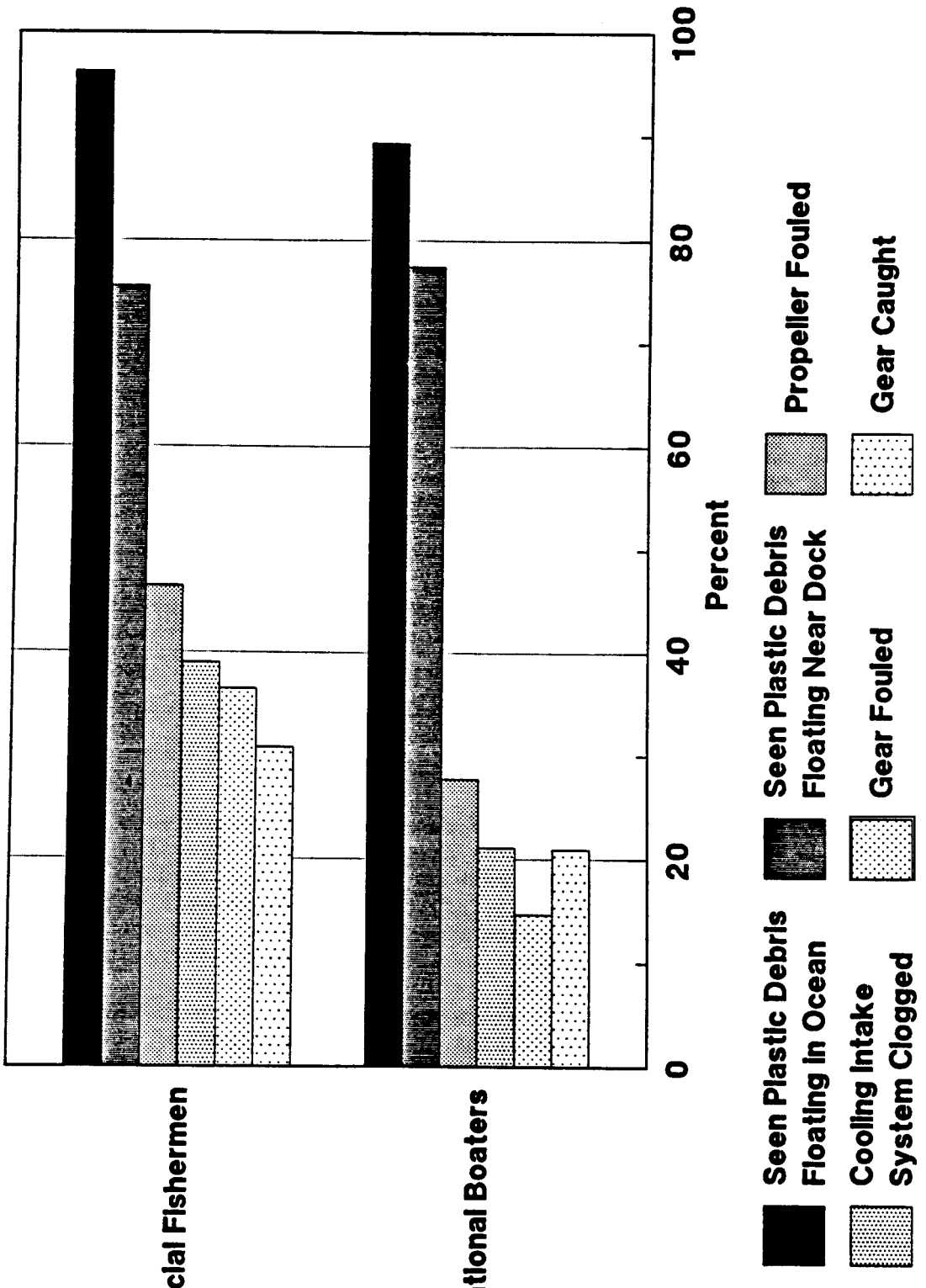



Figure 2.--Experience with plastic marine debris (based on percent of responses to the question).

plastic debris. Almost 40% have had their boat's cooling intake systems clogged by plastic debris.

About 94% of the respondents said they think plastic trash in the ocean, bay, or sound can kill marine animals, create safety hazards for mariners, and wash ashore as beach litter. Personal experience was cited most frequently as the basis for their opinion.

### Recreational Boaters

Figure 2 also summarizes the experience of the recreational boaters with plastic marine debris. About 90% of the respondents said they have seen plastic trash floating in the ocean, bay, or sound. This was also cited most frequently as the most important problem. The recreational boaters responding to the survey have also had personal experience with plastic marine debris, but not to the extent of the commercial fishermen. About 28% of the respondents have had their boat's propeller caught in plastic debris. Between 15 and 20% have had their gear caught or fouled by plastic debris. About 21% of the respondents said that their boat's cooling intake systems have been clogged by plastic marine debris.

Almost all of the respondents (97%) said they think that plastic trash in the ocean, bay, or sound can kill marine animals, create safety hazards for mariners, and wash ashore as beach litter. Like the commercial fishermen, personal experience was cited most frequently as the basis of the respondents' opinion.

## KNOWLEDGE OF LAWS ON AT-SEA GARBAGE DISPOSAL

### Commercial Fishermen

Just over half (51%) of the commercial fishermen said they know there is a Federal law which prohibits disposal of plastics from vessels and restricts the other types of garbage that may be dumped into the ocean, bays, or sounds. The remainder of the respondents were evenly split between those who were unsure and those who did not know about such a law. Word of mouth was cited most frequently as the source of information on this law, followed by magazine articles, television, and newspapers. Among the sources of information on the law specified by the respondents were training by offshore oil and gas companies for their workers and tickets received from the U.S. Coast Guard or marine patrol. Only 5% of the respondents said they have heard of MARPOL Annex V.

### Recreational Boaters

Thirty-eight percent of the respondents said they know there is a Federal law which prohibits disposal of plastic trash from boats and limits the dumping of other types of garbage into the ocean, bays, and sounds. About 33% of the respondents were unsure whether there is such a law, and 30% did not know about the law. Like the commercial fishermen, word of mouth was cited most frequently as the source of the respondents' information. This was followed by television, newspapers, and magazine articles.

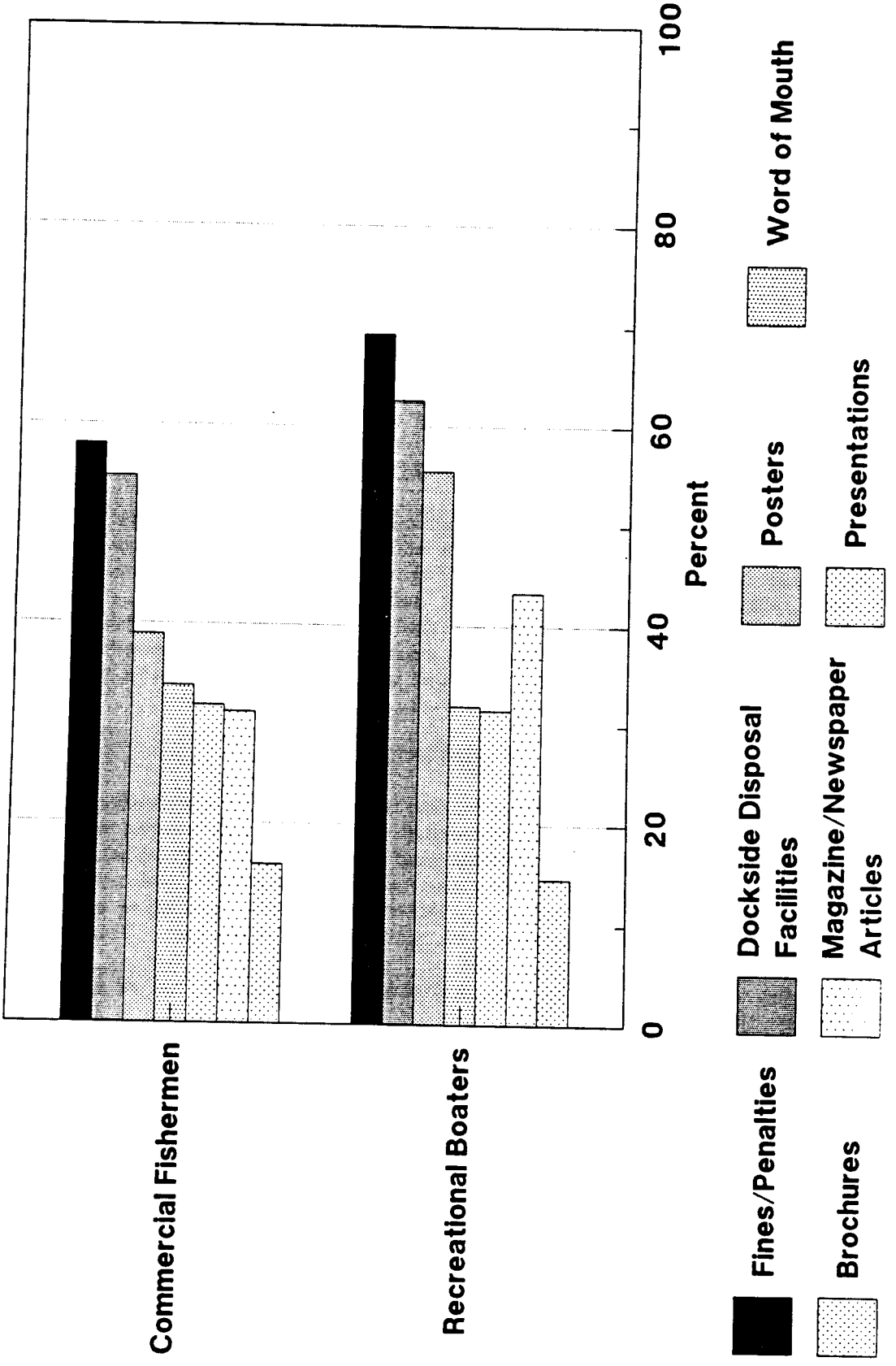



Figure 3.--Best ways to encourage shoreside disposal (based on percent of responses to the question).

The Coast Guard, marine patrol, and training by offshore oil and gas companies were also cited as sources of information on this law. Only 3% of the respondents said they have heard of MARPOL Annex V.

## OPINION ON THE BEST WAYS TO ENCOURAGE SHORESIDE DISPOSAL OF PLASTIC TRASH

### Commercial Fishermen

Commercial fishermen were asked which of seven techniques are the best ways to encourage commercial fishermen to return their plastic trash to shore for disposal. A summary of their responses is shown in Figure 3. Dockside disposal facilities and fines were the most frequent responses. There was some support for each of the techniques. Among the suggestions from the respondents were reminders on the marine radio channel, incorporation of information on proper garbage disposal into the licensing procedure, and use of advertisements and stickers.

### Recreational Boaters

Figure 3 summarizes the responses of recreational boaters on which of seven techniques are the best ways to encourage recreational boaters to return their plastic trash to shore for disposal. Like the commercial fishermen, there was some support for each of the techniques, but dockside disposal facilities and fines were cited most often. The recreational boaters also suggested the following techniques: television advertisements and programs, educational material sent with license renewals, information broadcast on the marine weather channel, and peer pressure.

## RESULTS

The results of this survey provide a baseline of knowledge on the garbage disposal practices of commercial fishermen and recreational boaters at four sites, and on their opinions and experiences with plastic marine debris. The results indicate that the problem of marine debris is not new to those responding to the survey. Further, the results show there are responsible commercial fishermen and recreational boaters. From the many comments written in the margins and on the backs of the survey form, it is also evident that many of the respondents think the source of marine debris is a group other than their own.

# THE OREGON EXPERIENCE--FOUR YEARS LATER

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## ABSTRACT

The fifth annual Oregon coastwide cleanup, held 10 October 1988, attracted 2,200 volunteers who collected 14.2 tons of debris. Similar fall cleanups were held in 22 coastal states of the United States, Costa Rica, and Puerto Rico. This paper reviews personal observations about the effectiveness of volunteer beach cleanups and discusses the evolution of data gathering, media coverage of the marine debris problem, changes in attitudes, and advancement in plastic recycling.

I am pleased to be here to share my knowledge on my favorite subject--"floatable trash." I became interested in this subject just 5 years ago. At the time, it was a challenge to find information on the subject at all. Let me tell you how I became involved.

In 1984, the May-June issue of the Alaska Fish and Game Department's magazine was delivered to my office by mistake. Flipping through it, I was drawn to an article by free-lance writer Tom Paul. Entitled "The plague of plastics," it discussed the proliferation of plastic debris in the natural environment and the resulting ingestion and entanglement by fish and wildlife.

At the time, I had worked at the Oregon Department of Fish and Wildlife for 10 years and been an active birdwatcher for 25 years. I knew birds got entangled in monofilament fishing line and six-pack beverage rings, but I didn't know they had an appetite for polystyrene foam and small bits of plastic.

In talking to birdwatchers, scientists, and friends, I realized others were also unaware of the problem. Since 1984 was the "Year of the Ocean" and we Oregonians love our coast, I had the idea to organize a cleanup of plastic debris on our 563 km (350 mi) of coast to see what we could find.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

I put together a small working group; we divided our coast into 14 zones and found people willing to serve as "zone captains." The captains were biologists from the Department of Fish and Wildlife and local residents of the coastal communities. Zone captains coordinate refreshments for celebration parties, assign volunteers to specific stretches of beach, arrange for the pickup of the collected debris, and work with the news media.

We spread the word of that first cleanup and invited the public to the coast to see how much marine debris we could collect on the 241 km (150 mi) of accessible beach.

Saturday, 13 October, was a very cold, wet, dark, blustery day. To my amazement, 2,100 volunteers showed up and collected 26.3 tons of debris in just 3 h. They filled out questionnaires documenting the quantity of fishing gear, six-pack yokes, polystyrene foam, plastic bags and bottles, rope, and strapping bands. We recorded the event on video film and produced a 12-min film entitled "Get the Drift."

Word of the cleanup spread quickly, and that November I was invited to report the results at the Workshop on the Fate and Impact of Marine Debris in Honolulu, Hawaii. Those attending were government scientists and concerned citizens from around the world working on marine mammal entanglement problems. I felt like an imposter with my citizen involvement project results, but the scientists welcomed me with open arms. They came up to me afterwards and thanked me for documenting the volume of trash in a large given area. Many had wanted to do beach surveys for years but were unable to spend time and money on that kind of research.

A number of recommendations came out of the workshop, and one was that beach cleanups are a valid way to document the amount and sources of marine debris. As a result, I was asked to organize and report on the findings of cleanups along the west coast and New England states in 1985.

I prepared the "Nuts and Bolts Guide to Organizing a Beach Cleanup the Easy Way." A "Dear Coastal Colleague" letter was mailed to over 200 organizations and government entities listed in the National Wildlife Federation Conservation Directory. They were asked to take an active part in organizing a cleanup in the study area states. Firm commitments were received from eight states.

State coordinators were mailed a copy of the Nuts and Bolts Guide as a "starter kit" but were encouraged to use special creativity to organize the cleanups. Some interesting logos, posters, and mottos resulted: "Lend a hand in the sand," "Don't be a litter boat," "Be a beach buddy," and "Debris-a-thon," to name a few. The main focus of the national cleanup was to determine the amount of derelict fishing gear, both sport and commercial, which makes its way to the coastal beaches, and to help educate the public.

Following the cleanups, I compiled the results in a report to the U.S. National Marine Fisheries Service.

The coastal cleanup program has grown by leaps and bounds. In 1986, we had 14 states participating. In 1987, there were 19 states. During September and October of 1988, all 22 coastal states, 7 inland states, and Costa Rica and Puerto Rico participated. All of the cleanups were held during Coastweeks, produced by a citizens' network of groups, agencies, and individuals who focus attention on that special place where water meets the land. During the period of Coastweeks, agencies and organizations in coastal states have beach walks, bird identification seminars, beach cleanups, and various activities to call attention to coastal issues. Five years ago it was simply Coastweek, but to accommodate the many states participating, with different weather and tide patterns, the annual campaign now stretches from the middle of September to the middle of October.

So after five cleanups, what are my thoughts about this whole business? I feel the number one value of beach cleanups is raising public awareness. Almost to a person the volunteers remark, "I never realized how much stuff was out there until I had to spend time leaning over to pick it up." And it sticks with them when they go back home. One friend told me that after working on a beach cleanup he couldn't enjoy playing golf because he kept seeing all the polystyrene cups in the ponds on the golf course. In areas where beach cleanups have occurred, government agencies responsible for monitoring trash containers indicate an increase in the amount of plastic debris which is disposed of properly.

Each year, our data gathering gets a little more sophisticated. As you might imagine, turning loose thousands of volunteers for 3 h with no "form-filling-out training" doesn't result in precise accounting of specific materials or number of pieces. But it does give an index of the type of debris and the probable source. The first 4 years we had a very general, short questionnaire. It gave us bulk figures, because volunteers would write "some," "many," "lots," "a few," under number of pieces. In 1988, we worked with the Center for Marine Conservation and used the questionnaire and guide which was used by approximately 43,000 volunteers nationally. The new questionnaire is more complex and specific. Prior to the cleanups, there was virtually no documentation on the amount or source of marine debris. So we have come a long way!

Our volunteers show up to work, are given a large collection bag, questionnaire, reminders about beach safety, and turned loose. Three hours later they come back laden with trash, enthusiasm, and stories of the weird things they found. We treat them to a free lunch to give them an opportunity to share their stories.

In years past, all of the debris from Oregon's cleanup went directly into landfills, thanks to the generosity of the Oregon Sanitary Service Institute. This year we introduced a "beach buddy" system. We asked volunteers to work in pairs and separate the plastic from other debris and place it in a special bag. After the cleanup, all the plastic and polystyrene foam was picked up by Environmental Pacific Corporation, taken to Portland, and analyzed to see how much of it could be recycled. We invited the press to watch us rip open the sacks, not knowing for sure what we would find. Much to my relief, all of it was plastic and most was

recyclable. On the minus side, I think we asked too much of the volunteers. It is not possible for one person to carry two sacks, a clipboard, writing tools, and also to pick up debris. So the system still needs refinement.

Many of our volunteers have participated in all five cleanups, and we are beginning to see more groups who charter buses for the trip from inland cities to the coast. Private industries sponsor employee trips, schools use the cleanup as an official school function, and civic groups organize carpooling and their own potluck picnics on the cleanup day.

Going after marine debris as "litter" on the beaches does not have the same public appeal as focusing on the issue of entanglement and ingestion by fish and wildlife. That focus has attracted the media and gotten new people interested and involved. I am sure everyone in this room knows the risk in getting people stirred up and emotionally involved. All of a sudden, the statistics you gather are used in very creative ways to prove a point on all sides of the marine debris and plastic recycling issues.

One of my earlier recommendations was to get a media blitz in the popular press, not just in obscure technical or professional journals. I am pleased to report there is hardly a week goes by that I don't run across a marine debris article in a commercial fishing industry magazine, conservation organization newsletter, or the newspaper. The state natural resource agency magazines and Sea Grant publications have also done an excellent job to further document the problem through feature articles complete with color photographs of injured wildlife.

I hope this trend continues. There should be repeated articles in newspapers, not just in the outdoor section but in business and science. Even the special newspaper supplements available to tourists along the coast should have articles on marine debris. The amount of trash on beaches has an adverse economic impact for coastal communities and states competing for tourism dollars. That fact was brought home to us in 1988 with the hospital waste showing up on New York and New Jersey beaches.

The publications which have not picked up on the severity of marine debris are those targeted for the sport fishing and recreational boating public. Because of the way licenses and permits are issued, recreationists have been missed by traditional Federal agency notices. We have found a larger percentage of bait containers and recreational gear during our cleanup since commercial vessel owners are better informed. For instance, I don't think the recreational fleet knows about the adoption of Annex V to the International Convention for the Prevention of Pollution from Ships (MARPOL).

A major value of the cleanups is networking with people in coastal states working on marine debris. The networking provides a vehicle to communicate findings and the status of state and Federal legislation; compare how the cleanups are organized; and share artwork, slogans and campaign strategies, what works with the media, and how to get donated materials or funding. Having the cleanups clustered during 1 month in the fall gives everyone higher visibility with the public and news media.

Now that we have the new questionnaire, we can get a better handle on how to identify items that cause the majority of entanglement or ingestion problems and focus our efforts on their source.

One of the most exciting things to come along is the pilot project conducted by the Port of Newport here in Oregon. They set up a recycling program for commercial fishermen and other marine users to separate their trash at the dock. They gave the wood to senior citizens and sold the scrap paper, glass, and metal, and only a small portion was left over for the landfill. The net fragments were recycled by tourists wanting decorations for their patios or local citizens needing supports for their vegetables or backstops for their softball fields. That 1-year program gained support and energy from a small commercial fishing community which has radiated enthusiasm and interest to the entire Pacific Rim fishing industry. Its coordinator, Fran Recht, has a new grant to implement similar projects in Alaska, California, Oregon, and Washington this year and continue educational programs with the commercial fishing industry and port officials. As long as ocean users continue to dump trash overboard, beach cleanups have a transitory value in ridding the beaches of debris. The Newport project has directly reduced the amount of debris on Oregon's central coast.

The adoption of Annex V to MARPOL has provided strong incentives for improved port facilities and less dumping at sea. I suspect it will foster accelerated plastic recycling programs.

In Oregon we have good news. On 8 October 1988, we attracted 2,200 volunteers. But they were only able to collect 14.2 tons compared to the 26.3 tons in 1984. Each year we have seen a steady decline in the amount collected, and there are several contributing factors. Our weather has been mild each fall with no major storms depositing new trash before the cleanup. Luck of the currents, no doubt. Also, the Oregon State Parks Department has held a "Company's Coming" cleanup in the spring for the past 3 years, so we didn't have an entire year's accumulation. As a general rule, beach users are carrying out their own trash and debris they see washed on shore, and on Oregon's central coast, adjacent to the Port of Newport pilot project, there was simply less debris available. The increased public awareness through the cleanups has made a big difference in Oregon.

As an extension to the regularly scheduled cleanups, we launched an "adopt-a-beach" program patterned after the State of Texas, inviting Oregonians to choose a section of the Oregon coast they want to "adopt." All we ask is that they clean it three times a year and tell us what they find.

I am really pleased to visit with you and share my enthusiam about how one person's idea can make a change. Since being involved in cleaning beaches, I am better informed about entanglement and ingestion by wildlife, environmental monitoring using citizen volunteers, how plastic is made and recycled, and best of all how valuable trash can be.

Thank you.

# THE TEXAS ADOPT-A-BEACH PROGRAM: A PUBLIC/PRIVATE APPROACH TO CLEAN BEACHES

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## ABSTRACT

The Texas Adopt-A-Beach Program, founded in 1986 by Texas Land Commissioner Garry Mauro, is made up of private citizens who volunteer to clean Texas beaches three times a year, and is managed by the Texas General Land Office. The program was conceived both as a short-term solution to the problem of trash on Texas beaches and as a means of advancing long-term, permanent solutions to the problem of marine debris: the ratification of Annex V of MARPOL, the International Convention for the Prevention of Pollution from Ships, and the implementation of effective enforcement measures.

The Adopt-A-Beach Program organizes two coastwide beach cleanups a year. The success of these cleanups--nearly 25,000 volunteers have removed 1,000 tons of garbage from Texas beaches--has enabled the program to shift its emphasis to public education about the tremendous economic and environmental damage caused by ocean dumping of garbage. Children are the focus of educational projects that include a coloring book and puppet show featuring the program's mascot, Lucky the Dolphin, and the development of a marine debris curriculum for public schools. The program has also produced videotaped public service announcements for statewide broadcast and has sponsored special awareness events in conjunction with cleanups.

Data collected by volunteers during cleanups were instrumental in building support in Congress for Senate ratification of the international MARPOL Annex V and implementation legislation for the annex in the United States. Annex V prohibits the dumping of plastics in the ocean and sets strict limits on dumping of other solid wastes overboard. The volunteer-collected data are also being used in support of making the Gulf of Mexico a special area under the annex. Dumping of any kind is prohibited in special area waters.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## INTRODUCTION

Texas Land Commissioner Garry Mauro founded the Texas Adopt-A-Beach Program in 1986 after taking part in a coastwide beach cleanup organized by the Center for Environmental Education (now the Center for Marine Conservation). In the course of this 3-h event, 2,700 volunteers collected 124 tons of trash from 196 km (122 mi) of beach. It was clear that this volume of trash could not be attributed to beach littering alone; the quantity and the nature of the debris indicated that most of it had washed ashore in tides of waterborne refuse.

Astonished at the quantity of trash on Texas beaches, and recognizing the heavy environmental and economic penalties of this pollution, Commissioner Mauro decided to investigate the problem and determine what role the General Land Office could play in solving it. He began by forming an in-house task force to study the sources of beach debris, to research existing legal and institutional remedies, and to map out an action plan.

Both a 1985 Texas Coastal and Marine Council report and the Center for Environmental Education's report on the 1986 beach cleanup concluded that some 75 to 90% of the trash on Texas beaches originates offshore, about two-thirds of it dumped from ships. Refuse discarded in the Gulf of Mexico is not washed out to sea. What fails to sink is held in gulf waters by loop currents until oblique alongshore currents carry it to shore. For this reason, the beach cleaning efforts of cities and counties along the Texas coast have provided only temporary relief, and at great cost: the State's coastal communities spend about $14 million each year on the endless task of cleaning their beaches.

### The Texas Approach

Two needs were immediately apparent: the need to raise public awareness of the magnitude of the beach garbage problem in Texas, and the need for a broad-based, unified approach to its solution, concentrating on the sources of beach debris.

An obvious objective was to work for U.S. ratification of Annex V to MARPOL 73/78 to prohibit ocean dumping of plastic and restrict the discharge of other types of solid waste at sea. The severity of the beach pollution problem in Texas led to a second: to persuade the International Maritime Organization to designate the Wider Caribbean Region (the Gulf of Mexico and the Caribbean Sea) as a special area where virtually all dumping would be banned. But the General Land Office began with state-level action that would yield positive results more quickly.

As manager of the state's surface and mineral interests in about 1.62 million ha (4 million acres) of submerged land on the Texas gulf coast, the General Land Office issues leases, easements, and permits for a variety of activities. The agency's first step was to adopt emergency rules prohibiting the dumping of solid waste from offshore platforms and seismic vessels operating in Texas waters under state permits. These were later followed by no-dumping rules (and parallel contract provisions) for marinas, wharves, piers, fishing cabins, and all other structures on state-owned coastal land.

Next, to draw public attention to the amount of trash and garbage accumulating on Texas beaches, to augment existing beach cleanup efforts, and to involve citizens in the crusade against marine debris, the General Land Office instituted the Texas Adopt-A-Beach Program.

The program was modeled after the Adopt-A-Highway Program organized by the Texas Department of Highways and Public Transportation. The Adopt-A-Highway Program has proven highly successful both as a cleanup program and as a public awareness campaign to discourage roadside littering. It was felt that the adoption format, already familiar to Texans, would work equally well for the state's beaches. The Highway Department's slogan, "Don't Mess with Texas," was expanded to "Don't Mess With Texas Beaches" for the beach cleanup campaign.

### Response to the Program

The Adopt-A-Beach Program won immediate enthusiastic support in Texas. Adopters were secured for all 172 easily accessible Texas beach miles within the first year of the program, and even some segments accessible only by boat or four-wheel-drive vehicle found sponsors. Most adopting groups have renewed their adoption agreements annually. Businesses, philanthropic foundations, entertainers, advertisers, and private citizens have made generous contributions of funding, supplies, services, and promotional assistance.

Since the program's first coastwide cleanup in April 1987, nearly 25,000 volunteers have removed more than 1,000 tons of trash from Texas beaches. An analysis of data collected during coastwide cleanups, prepared by the (then) Center for Environmental Education, was presented to the U.S. Congress and to the International Maritime Organization as evidence documenting the need for U.S. ratification of MARPOL Annex V, the passage of national enforcement legislation, and designation of the Wider Caribbean Region as a special area under the annex.

The spirit of the Adopt-A-Beach Program has spread beyond state boundaries and beyond U.S. borders. The Texas program has been emulated by other coastal states, and it is now spreading to Central America. In September 1988, Texas, Louisiana, Mississippi, Alabama, and Florida joined forces in a "Take Pride Gulfwide" beach cleanup sponsored by the U.S. Minerals Management Service. A symbolic beach adoption agreement entered into by the students of Flour Bluff Junior High School near Corpus Christi, Texas, and the children of Costa Rica in the spring of 1988 immediately led to the establishment of a national Costa Rican beach cleanup program.

## PROGRAM STRUCTURE AND OPERATION

The Adopt-A-Beach Program takes its direction from State Government, but it is operated at the county level by an all-volunteer work force and is dependent upon private funding and in-kind donations of supplies and services.

An Adopt-A-Beach Task Force appointed by Commissioner Mauro developed guidelines for the program and oversees its operations. This advisory

body, whose members now number about 55, represents a broad range of coastal interests: Federal, state, and local government; oil, gas, and chemical production; tourism; shipping; agriculture; waste disposal and recycling; scientific research; and conservation. The task force meets periodically in full session for program review and planning. Three subcommittees--Finance, Education, and Legislation--hold independent meetings.

The General Land Office, as administrator of the Adopt-A-Beach Program, coordinates all program activities with the assistance of the Adopt-A-Beach task force. It oversees beach adoptions, promotes the program statewide, solicits funding, organizes two annual coastwide cleanups, and develops educational materials and programs. The agency also maintains a toll-free number for in-state inquiries about the program and publishes a quarterly newsletter, the Texas Beach Bulletin,

The Texas Conservation Foundation, a state agency empowered to manage and expend donated funds, is financial trustee for the Adopt-A-Beach Program. It manages a special fund established to receive tax-deductible contributions for the support of program activities. Monies from the fund are used for:

- the purchase and shipment of cleanup supplies, including trash bags, data cards, and pencils;
- the purchase and installation of beach signs marking adopted beach segments and crediting adopting groups;
- printing and mailing of the program's newsletter, certificates, posters, brochures, and other promotional and educational materials;
- operation of the program's toll-free telephone line; and
- promotional events to publicize the program and to recruit sponsors and cleanup volunteers.

A network of volunteer county coordinators provides grassroots leadership for the program. They recruit and register adopting groups, handle local cleanup logistics, and promote the program within their communities. This structure is not only practical, but also capitalizes on community pride--a powerful force in sustaining the program's momentum.

To join the program, groups sign an adoption agreement that commits them to cleaning a designated beach segment (usually 1.6 km (1 mi)) three times within a 1-year period, participating in the program's two coastwide cleanups and conducting a third cleanup independently. The agreement also releases the Adopt-A-Beach Program from liability for any injury incurred during a beach cleanup. Each adopting group receives an adoption certificate, and the group's name is listed on a sign installed at the access road nearest its adopted beach segment.

Groups now enrolled in the program include civic clubs, sporting clubs, chambers of commerce, large corporations, small businesses, conservation organizations, public schools, colleges, Scout troops, state agencies, cities, property owners' associations, and families.

The program's two annual coastwide cleanups are cosponsored by nonprofit organizations. The "Great Texas Beach Trash-Off," held in April of each year, is cosponsored by Keep Texas Beautiful, Inc. The "Texas Coastal Cleanup," held in September during Coastweeks, is cosponsored by the Center for Marine Conservation. Participants in these cleanups include independent volunteers as well as affiliates of the Adopt-A-Beach Program. Local coordinators distribute trash bags, data cards, and pencils to all cleanup volunteers.

The data cards provide spaces for the tabulation of items within seven broad categories (plastic, glass, Styrofoam, metal, paper, wood, and rubber), for the notation of labels that might indicate the sources of items collected, for recording the number of trash bags filled, and for reporting sightings of stranded or entangled animals.

## PROGRAM PROMOTION

The Adopt-A-Beach Program employs a variety of means to publicize the adoption program, advertise coastwide cleanups, and recruit volunteers and sponsors. The program carries its promotional efforts statewide to remind noncoastal Texans that they are residents of a coastal state, that they benefit from the coastal area both directly and indirectly, and that they should share the responsibility for protection of coastal waters and beaches.

### Recruitment

When the program was first organized, the General Land Office recruited county coordinators through telephone calls, letters, and personal visits to community leaders and known environmentalists along the coast. The same procedures were used by the General Land Office Adopt-A-Beach staff and county coordinators to enlist adopters. Lists of prospective adopters were compiled from target groups such as garden clubs, 4-H clubs, local branches of oil and gas companies, and waste disposal companies.

Early recruitment was greatly facilitated by television and newspaper coverage of press conferences preceding the program's first coastwide beach cleanup in the spring of 1987 and by establishment of the program's toll-free telephone number (1-800-85-BEACH). Now that the program is well known, it has become less necessary to engage in aggressive recruitment of participants. New county coordinators, new adopting groups, and sponsors often initiate contact with the program.

### Solicitation of Financial and In-Kind Support

All public information materials produced by the Adopt-A-Beach Program emphasize that the program is dependent upon private donations for its

operation and that such donations are tax-deductible. The program solicits contributions of money, supplies, or services through direct appeals to companies that have a reputation for supporting environmental causes or that are likely to appreciate the benefits of association with an environmental improvement program. It has also sought grants from foundations known to support conservation efforts.

Financial donations to the Adopt-A-Beach Program have included a 3-year grant of $50,000 from the Moody Foundation of Galveston, a $5,000 grant from the Fondren Foundation of Houston, and a contribution of $10,500 from Browning-Ferris Industries, a waste disposal company. Other contributions have come from oil and gas companies, law firms, and numerous private individuals.

In-kind donations to the program have included bumper stickers, trash bags, celebrity promotions, refreshments for cleanup participants, and pickup of filled trash bags after beach cleanups. The Mobil Corporation donated 100,000 garbage bags valued at $13,000 to the program in 1988, and Maryland Club Foods donated 9,700 bags for the 1989 Great Texas Beach Trash-Off. One of the first in-kind donations to the program was 15,000 "Don't Mess With Texas Beaches" bumper stickers, provided by a beer distributor.

In 1988, 23 outdoor advertising companies donated space along major routes to the coast for 300 billboards displaying the "Don't Mess With Texas Beaches" slogan and the program's toll-free number. Most of the billboards were printed with money from the Adopt-A-Beach fund and posted by companies that donated the advertising space, but some companies painted billboards free-of-charge.

## Media Coverage

The Texas Adopt-A-Beach Program has benefited from both local and national media attention. After the April 1987 coastwide cleanup, articles appeared in the New York Times and the Los Angeles Times, and both Time and Newsweek magazines featured articles about the status of beaches in America as front-cover stories. In August 1987, Commissioner Mauro discussed the problem of beach trash in Texas as a guest on the ABC television news program Good Morning, America.

Press coverage of program activities is invaluable in advertising the program, mustering volunteers for coastwide cleanups, and publicizing cleanup results. Press releases are issued to newspapers, radio stations, and television stations in advance of cleanups and as soon as statistics on the number of volunteers participating and the tons of trash collected are available afterward.

The adoption of a mascot, an Atlantic bottlenose dolphin named Lucky, enlivened the Adopt-A-Beach Program's promotional campaign and gave the program a symbol with appeal for children. Lucky, a performer at Sea-Arama Marineworld in Galveston, Texas, is an especially appropriate mascot for the program because he was a victim of marine debris, barely surviving

entanglement in an abandoned fishing net. He was given his fitting name by the veterinarians of the Marine Mammal Stranding Network who nursed him back to health.

Public service announcements are produced for radio and television broadcast before every coastwide beach cleanup. The program's first videotaped public service announcement featured Lucky and Texas rock musician Joe "King" Carrasco. The second video, featuring actor Randy Quaid, was produced to advertise the 1989 Great Texas Beach Trash-Off. A third was produced to publicize the MARPOL Annex V regulations. All public service announcements are distributed statewide.

### Printed Materials

The program produces brochures and posters to advertise coastwide cleanups. These are sent to county coordinators, adopting groups, coastal chambers of commerce, public libraries, hotels and motels, and other businesses for distribution. Cleanup brochures list the names and telephone numbers of county coordinators, the locations of designated beach check-in points for volunteers, and the names of hotels and motels offering discounts to cleanup workers.

The quarterly Texas Beach Bulletin, with a current circulation of about 3,300, summarizes Adopt-A-Beach Program activities, announces cleanup dates, reports results of coastwide cleanups, and acknowledges donations to the program. It serves as an educational as well as a promotional tool, containing articles about national and international efforts to combat marine debris. The newsletter is sent to Adopt-A-Beach Program participants and supporters and is included in the information packet mailed to anyone who calls or writes to inquire about the program.

## PUBLIC EDUCATION

With the beach cleanup program well established in all coastal counties, the Adopt-A-Beach Program is concentrating on public education projects, including educational materials and programs for children, an awareness drive targeting recreational boaters, and a campaign to promote recycling. An important element of all these efforts is publicizing the requirements and expected results of MARPOL Annex V.

### Outreach to Children

Children are the primary target of educational efforts. In the summer of 1988, the Adopt-A-Beach Program introduced an educational program for preschool and primary-grade children. Its components are a slide show, a puppet show, and a "Don't Mess With Texas Beaches" coloring book.

The slide show contrasts clean and littered beaches, shows how trash reaches the beach and how it can harm birds and marine animals, and tells the story of Lucky the Dolphin. In the puppet show, called "Joey Saves the Day," a boy fishing from a boat rescues Lucky and his friend Clipper the Crab from the Trash Monster. In the 11-page coloring book, Lucky points

out the hazards of beach litter and floating trash and urges children to help keep beaches clean. Simple lyrics for a series of beach cleanup songs set to familiar tunes are printed in the back of the book.

The educational program has been presented to an estimated 4,000 children at day-care centers, public libraries, museums, and elementary schools in Austin and coastal cities and has proven very effective in interesting children in the cause of beach protection. Because the puppet show has been so well received by teachers, librarians, and children, it is being videotaped for distribution throughout the state. Coloring books have been given to all children attending the program, and at least 20,000 more have been distributed by mail. Five hundred Spanish-language versions of the coloring book were sent to children in Costa Rica.

The Adopt-A-Beach Program is now working on a formal marine debris curriculum for kindergartens and elementary schools. It will include lessons about the nature and importance of marine and coastal resources; the damage caused by marine debris, particularly plastics; and recycling as a solution to the problem of solid waste in the environment.

The program staff is preparing a curriculum outline in consultation with the Education Subcommittee of the Adopt-A-Beach Task Force. To ensure that the curriculum meets state requirements for public school use, the staff is also coordinating development of the project with the Texas Education Agency. It is anticipated that the actual writing of the curriculum will be contracted to an educational consultant.

### Promoting Awareness Among Recreational Boaters

The Adopt-A-Beach Program is working with the Boating Trades Association of Texas and the Marina Association of Texas to make boaters aware of the need for their cooperation in the battle against marine debris. The program's first public service video was directed at recreational fishermen and boaters, urging them not to discard trash overboard. The Boating Trades Association and the Marina Association have distributed "Stow It--Don't Throw It" bumper stickers that include the Adopt-A-Beach Program and Center for Environmental Education logos.

### Recycling Campaign

The Adopt-A-Beach Program is broadening its mission by promoting recycling as a practical means to reduce solid waste in the environment and alleviate the burden on landfills. The focus of the recycling campaign is plastic, which makes up some 60% of the trash collected in coastwide beach cleanups.

General Land Office staff helped draft container-coding legislation for introduction in the 1989 session of the Texas Legislature. Information about the proposed law, which would require coding of plastic containers by resin type to facilitate recycling, has been published in the program's newsletter.

In conjunction with the April 1988 coastwide cleanup, the Society for the Plastics Industry sponsored a plastics recycling demonstration for cleanup volunteers at South Padre Island. In September 1988, Shell Oil Company sponsored a "Trash Bash" for volunteers who brought glass, paper, aluminum, and plastic to Sea-Arama Marineworld in Galveston for pickup by recycling companies.

To further encourage beach cleanup volunteers to become recyclers, and to take advantage of the opportunity to recycle large amounts of beach debris, participants in the 1989 Great Texas Beach Trash-Off were asked to separate the trash they picked up from the beach, putting recyclable materials into orange bags, and nonrecyclable trash into white bags. Keep Texas Beautiful, Inc., cosponsor of the cleanup, made arrangements for collection of the recyclable trash by local companies.

In conjunction with the 1 April 1989 Great Texas Beach Trash-Off, the Texas Arts Council and Business Volunteers for the Arts/Houston joined the Adopt-A-Beach Program in sponsoring a juried beach trash sculpture contest in Galveston. The contest was conceived as a means of publicizing the sources and types of debris found on Texas beaches, drawing attention to the program's cleanup and recycling campaigns, and adding the arts community to interests endorsing the beach cleanup program.

A brochure containing contest guidelines and an entry form was distributed to members of the Texas Arts Council and to artists on a mailing list supplied by the Texas Commission for the Arts. Posters advertising the contest, called "Trash for Art's Sake," were sent to art museums and galleries. Cash prizes were awarded to the top three winners, and other contestants received honorable mention. Ten prize-winning entries will tour art museums throughout the state before being donated to coastal museums for permanent display.

## FUTURE OF THE PROGRAM

### Special Area Designation

Data collected by Texas volunteers in future beach cleanups will permit evaluation of the effectiveness of MARPOL Annex V regulations in reducing the amount of plastic and other floating debris reaching Texas shores. The data will also support the Texas Adopt-A-Beach Program's ongoing effort to secure special area designation for the Wider Caribbean Region under the annex.

The Adopt-A-Beach Program will continue to encourage the establishment of parallel beach cleanup programs throughout the Caribbean region. The success of the Costa Rican beach cleanup program has inspired both Panama and Honduras to establish similar programs, and it is hoped that other countries will follow suit. The demonstration of widespread, serious concern about marine debris in the Wider Caribbean should benefit the cause of special area designation.

## Continuing Educational and Awareness Projects

The program will continue to stress the importance of recycling as a solution to the solid waste problem and will work to promote the expansion of recycling efforts throughout the state. The Adopt-A-Beach staff is cooperating with the Bryan and College Station, Texas, independent school district in a program that will combine classroom education with an active recycling project for public school students next year.

An expanded awareness campaign will be undertaken to educate recreational boaters about the hazards of marine debris, to inform them about MARPOL Annex V regulations, and to encourage all marinas on the Texas coast to provide garbage reception facilities like those the General Land Office now requires for marinas on state-owned land. The Adopt-A-Beach Program will supply boaters with garbage bags and award certificates of appreciation to volunteers who pledge to participate in an aquatic version of the beach cleanup program.

## Research and Planning

The Adopt-A-Beach Program is helping Texas ports prepare to contend with the plastic refuse that will be off-loaded by ships in accordance with MARPOL Annex V regulations. The program is helping the ports locate researchers, waste management companies, and recycling companies that can supply needed planning assistance, equipment, and services.

The Adopt-A-Beach Program is also represented on the Marine Debris Technical Subcommittee of the U.S. Environmental Protection Agency's Gulf of Mexico Program, assisting with data collection, data analysis, and exploration of methods to alleviate both marine and beach debris throughout the gulf region.

## Addressing Land-Based Sources of Beach Debris

The reduction--and, it is hoped, eventual elimination--of marine debris in the Gulf of Mexico will not entirely solve the problem of solid waste pollution of Texas beaches. Though offshore sources are to be blamed for most of the trash fouling the state's shoreline and nearshore waters, land-based sources make a substantial contribution. For this reason, the utility of the Adopt-A-Beach Program will not soon be diminished.

Land-based sources--onshore dumping, river-transported trash, and persistent littering--will be the target of future Adopt-A-Beach Program awareness efforts. Data collected by beach cleanup volunteers can provide estimates of the amount of beach trash attributable to these sources and can help to identify chief offenders.

## CONCLUSION

The rapid success of the Adopt-A-Beach Program in establishing a strong alliance between government and the private sector in the crusade against marine debris, in stirring citizen activism both within and beyond

Texas, and in becoming a catalyst for the statewide expansion of solid waste control efforts exceeded 1986 expectations. The program's influence can be largely attributed to timing: it was inaugurated at a time when Americans had at last begun to realize that pollution of coastal waters and shorelines had reached a critical stage.

But it cannot be assumed that no one among the volunteers who rallied to the cry "Don't Mess With Texas Beaches" would have been willing to participate in a coastal cleanup effort years earlier. In fact, many program volunteers were already participants in, or supporters of, other conservation efforts. Those who were not may just have been waiting for direction.

The Adopt-A-Beach Program provided that direction. It has succeeded because it offers an easy avenue for citizen participation, enabling citizens from all walks of life to make an important contribution to the coastal cleanup effort. Those who cannot provide hands-on assistance at the beach can support the program by donating money, supplies, or services. Those who can offer neither physical nor financial support for program activities can be of equal help by simply spreading the word--by helping to heighten public awareness of the environmental and economic costs of marine debris. The program's design has facilitated development of the broad base of informed support essential to genuine progress against so widespread and complex a problem.

# MARINE DEBRIS DEMONSTRATION AND EDUCATION PROJECT AT SQUALICUM HARBOR, BELLINGHAM, WASHINGTON, U.S.A.

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## ABSTRACT

Washington Sea Grant's North Puget Sound Office in Bellingham, Washington, began a demonstration and education project about marine debris in January 1988. The objectives of this project were:

1. to develop a demonstration project to collect and recycle vessel-generated wastes from commercial and recreational vessels at Squalicum Harbor, Bellingham, Washington; and

2. to develop an educational program to teach commercial fishermen and boaters about marine debris through a variety of extension education techniques.

Squalicum Harbor provides moorage for about 1,750 boats, of which 1,050 are recreational and 700 are commercial. The commercial fishing fleet is composed mostly of gillnetters (7.6-10.8 m long) and purse seiners (15.3-18.4 m long) that fish in Puget Sound and Alaska. The recreational fleet has about equal numbers of sail and powerboats, and 75-100 boats are used as live-aboard homes.

The demonstration project was coordinated with the Port of Bellingham, which owns and manages Squalicum Harbor. The function of Washington Sea Grant staff in this project was to act as technical advisors to the port staff. They surveyed the boaters, analyzed waste collection facilities and alternatives, and offered suggestions on improvements that could be accomplished in a cost-effective and realistic manner. The educational program focused on using traditional extension education techniques. A poster and three publications on marine debris were developed. These materials were important components of the extension education portion of this project. Because of the time it has taken to implement the changes proposed in the demonstration project, no measurements of their effects have yet been made.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## INTRODUCTION

For years, people aboard boats and in coastal areas threw their garbage into the water. Items such as tin cans, food waste, cardboard, and cotton fishing gear and lines quickly sank. These materials generally degraded and caused relatively few problems in the marine environment. Also, as a rule marinas had dumpsters or litter barrels near the docks for garbage disposal, but no specialized waste collection systems.

Today, however, much of the material that is thrown overboard or lost in Puget Sound and in the oceans is made of plastic. Plastics are very useful aboard vessels because they are lightweight, strong, and do not degrade when wet. However, these same qualities can cause problems when plastics are disposed of in the marine environment. Studies from many parts of the world have shown that serious problems result when wildlife encounters plastic marine debris (Shomura and Yoshida 1985; Center for Environmental Education 1987; Alaska Sea Grant 1988; Alverson and June 1988).

As more U.S. and worldwide attention focused on plastic marine debris, Annex V of the MARPOL Convention was ratified internationally in 1987, and to implement that convention in the United States, Congress passed the Marine Plastic Pollution Research and Control Act (MPPRCA) in 1987. The MPPRCA, which became effective on 31 December 1988, prohibits the dumping of plastics at sea and regulates the dumping of other wastes at sea (U.S. Department of Transportation 1988). With the implementation of MPPRCA, boaters and fishermen now must return boat wastes to port, and ports and marinas must have facilities to accept those wastes.

Within Puget Sound, the volume and sources of marine plastic debris and the problems it causes are not well known. Because of Washington's extensive recreational and commercial fishing fleets, one would expect to find debris common to those vessels and activities. Some negative impacts of derelict fishing gear within Puget Sound have been observed (High 1985), but the extent of the problem is unknown.

Despite a lack of specific data about the extent of the marine debris problem within the Puget Sound region, it was felt that marine plastic debris was causing problems in the area. Also, as a result of MPPRCA, boaters were prohibited from disposing of their wastes into Puget Sound, and marinas were mandated to have facilities to accept boat garbage. In general, however, few boaters, fishermen, or marina operators were familiar with the MPPRCA and its provisions. The Squalicum Harbor project was developed with two primary goals:

1. to develop a pilot project to collect and recycle vessel-generated wastes from commercial and recreational vessels at Squalicum Harbor, and

2. to develop an educational program to teach commercial fishermen and boaters in the Puget Sound region about marine plastic debris and its proper disposal.

The Port of Newport (PON), Oregon, had developed a pilot marine debris collection and education project that was fairly successful. With grant funding from the U.S. National Marine Fisheries Service, the Newport project was able to develop a successful waste collection system that was used by the commercial fishing fleet for nets, rope, wood, metal, and other materials (Recht 1988).

The Squalicum Harbor project hoped to build on the experiences of the Newport project. However, four major differences between the projects were evident. First, the PON project was organized as a staff project of the PON. The Squalicum Harbor project was being developed by people outside the Port of Bellingham staff. Second, the PON project provided funding for facilities and maintenance staff, whereas the Squalicum Harbor project did not. (For the project to be successful in the long run, it had to work within the operational budget of Squalicum Harbor.) Third, the types of debris at the harbors were different. In each harbor, the debris reflected the boats that use the marinas: Newport has more trawlers, and Squalicum has more purse seiners, gillnetters, and recreational boats. Fourth, the physical layouts of the harbors are different: Newport has separate marinas for the commercial and recreational fleets, whereas Squalicum Harbor has these fleets within the same marina.

## METHODS

Squalicum Harbor is located some 144.8 km (90 mi) north of Seattle on Bellingham Bay. It provides moorage for about 1,750 boats, of which 1,050 are recreational and 700 are commercial. The commercial fishing fleet is composed mostly of gillnetters (7.6-10.8 m long) and purse seiners (15.3-18.4 m long) that fish in Puget Sound and Alaska. The recreational fleet has about equal numbers of sail and powerboats, and 75-100 boats are used as live-aboard homes. Squalicum Harbor has three water entrances and nine ramps to the docks.

Existing waste-handlng and collection facilities and procedures were analyzed using: 1) a personal informal interview survey of boaters and fishermen who use the harbor; 2) discussions with Squalicum Harbor staff; 3) a visual survey of the waste-handling facilities; and 4) contacts with waste collection companies, recycling companies, and community agencies.

Educational materials were developed and written by Washington Sea Grant (WSG) staff working on the marine debris project. Original plans called for writing one extension education publication for each of four different audiences: Squalicum Harbor boaters and fishermen, commercial fishermen, recreational boaters, and marina operators. Additionally a poster, a slide show, and a display area were to be developed.

## DISCUSSION

### Squalicum Harbor Analysis and Proposal

Twenty-seven fishermen and boaters from Squalicum Harbor were interviewed during spring 1987. Tabulation of the respondents' answers

showed that 78% thought Bellingham had a marine debris problem, 52% had experienced problems such as fouled propellers or clogged water intakes caused by plastic debris, 74% indicated that the existing waste facilities at Squalicum Harbor were adequate, and 67% expressed a willingness to sort some of their wastes for a recycling program. Respondents also indicated that management of an oil recycling facility maintained for boaters' use needed improvement.

Squalicum Harbor provided one 4.58 $m^3$ (6 $yd^3$) dumpster at the top of each float ramp, additional dumpsters in the area where commercial fishermen work on their gear, and a 15.29 $m^3$ (20 $yd^3$) dumpster near the dock used for provisioning vessels.

The visual survey of dumpster contents and interviews with Squalicum Harbor staff showed that the composition of the garbage varied with the season and the type of harbor use near that dumpster. For example, the percentage, by volume, of cardboard boxes ranged from 5 to 100%, with a mean of 52%.

Squalicum Harbor had a contract with the local garbage disposal company to empty the dumpster at the harbor. Seasonal fluctuations in quantity and composition of garbage were reflected in different pickup schedules for different dumpsters (Table 1). Rates varied with the frequency of pickup, the size of the dumpster, and whether the garbage went to landfill or to incineration (Table 2). The cost of garbage service at Squalicum Harbor rose dramatically from 1983 to 1987 (Table 3). This increase was caused by marina growth, boater population growth, and increases in garbage pickup rates over the time period.

On analysis, Squalicum Harbor's waste-handling facilities were judged to be adequate. Increased volumes of waste materials generated because of heightened awareness of the facilities could be easily accommodated by increasing the frequency of dumpster pickup. Any attendant cost increases could be minimized by developing a collection and recycling system for cardboard and aluminum. As in the PON project, a significant volume of the wastes in dumpsters at Squalicum Harbor was cardboard.

With this analysis completed, a proposal was written and presented to the Squalicum Harbor staff in August 1988. This proposal provided a detailed plan to improve the waste-handling system at Squalicum Harbor. The major elements of the plan were to maintain all existing dumpsters in the harbor; provide collection boxes or cleared space for netting, cardboard, scrap metal, wood, and aluminum; organize free pickup of materials by local recycling companies; and advertise the program through signs, pamphlets, news articles, presentations, displays, and word of mouth.

Figure 1 locates the proposed waste collection facilities at Squalicum Harbor. These facilities would:

- Provide a central location at the harbor for recycling scrap metal, wood, and netting. This would be a cleared space with signs indicating where to stack different materials.

Table 1.--Frequency of dumpster pickup at Squalicum Harbor.

| Season | Size of container | Frequency of pickup |
|---|---|---|
| Winter (Oct.-May) | 4.58 $m^3$ (6 $yd^3$) | 1 per week |
| Winter | 15.29 $m^3$ (20 $yd^3$) | 1 per month |
| Winter | 15.29 $m^3$ (20 $yd^3$) (trash compactor) | 1 per month |
| Summer | 4.58 $m^3$ (6 $yd^3$) | 3 per week |
| Summer | 15.29 $m^3$ (20 $yd^3$) | On-call basis |
| Summer | 15.29 $m^3$ (20 $yd^3$) (trash compactor) | On-call basis |

Table 2.--Monthly rates for hauling and disposal of trash from Squalicum Harbor.

| Dumpster size | Frequency of pickup | | |
|---|---|---|---|
| | 1 per week | 2 per week | 3 per week |
| 4.58 $m^3$ (6 $yd^3$) | 149.27 | 276.15 | 403.03 |
| 15.29 $m^3$ (20 $yd^3$) | [a]130.75 | [a]205.11 | [a]279.47 |
| 15.29 $m^3$ (20 $yd^3$) (trash compactor) | [a]107.20 | [a]214.40 | [a]321.60 |

[a]Additional charges for hauling and disposal fee.

Table 3.--Total costs of garbage service in Squalicum Harbor.

| Year | Cost |
|---|---|
| 1983 | $18,794 |
| 1984 | $22,394 |
| 1985 | $30,456 |
| 1986 | $34,492 |
| 1987 | $41,758 |
| 1988 | $50,000 (estimated) |

- Provide collection boxes for sorting and recycling of cardboard at five of the nine dumpsters at the harbor, dumpsters used primarily by the commercial fishing fleet. Used wooden fish totes were donated by local seafood companies for collection boxes. Removing the cardboard was expected to reduce the rate at which the dumpsters filled up and thus reduce garbage costs.

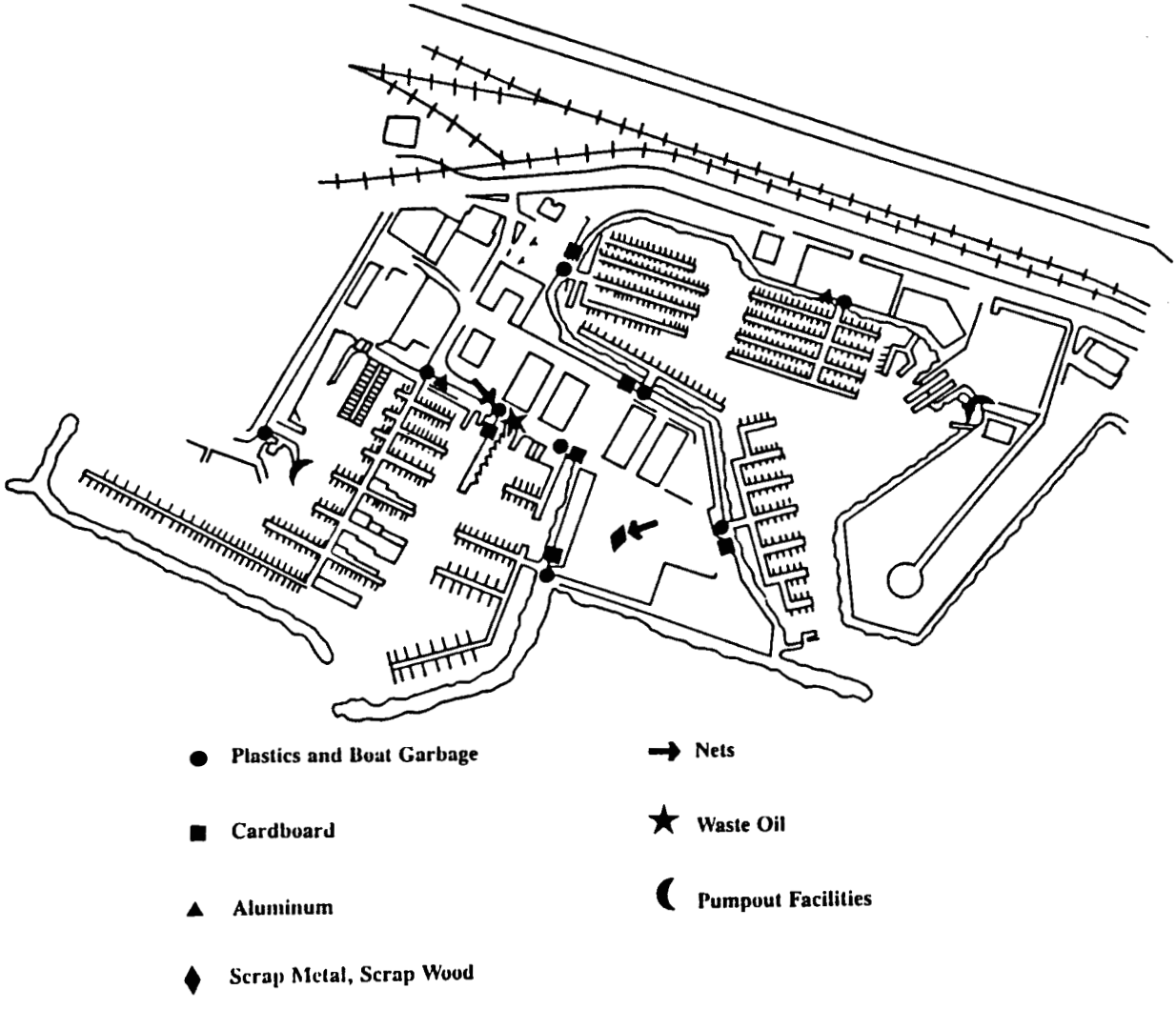



Figure 1.--Proposed waste collection facilities at Squalicum Harbor.

- Provide three aluminum recycling facilities at the harbor adjacent to the dumpsters used by the recreational boating fleet. Aluminum is a high value recyclable item, and these recycling revenues could help offset the cost of waste disposal.

The proposed facilities could be used by boaters and fishermen with a minimum of sorting. As a result, use of the facilities was expected to be heavy.

In addition, only materials that had ready markets were included in the recycling program. At no charge to the port, companies in the Bellingham area would pick up one or more of the materials being collected. This was expected to help reduce maintenance needs.

Glass was excluded from the recycling program for two reasons: 1) glass has a low market value and local companies would not pick it up at Squalicum Harbor, and 2) because of the weight of glass, specialized equipment would have been needed to handle it.

The Newport project found that blue color-coding of their recycling facilities was very useful, and the Squalicum Harbor project also color-coded the recycling facilities blue. Many fishermen and boaters travel frequently from port to port on the U.S. west coast and Alaska, and WSG suggests that for ease of recognition blue be adopted as the color for recycling facilities in all ports.

### Educational Program

The educational portion of the program was multifaceted and involved working with the Washington State Task Force on Marine Plastic Debris. This task force had representatives from some 40 different governmental, environmental, industrial, educational, and community groups who worked together to develop a Washington State Marine Plastic Debris Action Plan (Washington State Department of Natural Resources 1988). As task force participants, WSG staff developed a logo for statewide marine debris cleanup (Fig. 2). This logo and the slogan "Get a Grip on Marine Debris" are being used throughout Washington State.

The educational portion of the Squalicum Harbor project also included developing and printing a marine debris poster; writing pamphlets directed at Squalicum Harbor boaters, commercial fishermen, and recreational boaters; providing presentations to various community and school (K-12) groups on marine debris; developing a liaison with Western Washington University's plastics technology program; and being available to the media on marine debris-related matters. Using these educational materials, WSG reached a total of 585 people at workshops and other meetings, and distributed more that 2,500 posters and pamphlets.

## RESULTS AND CONCLUSIONS

The analysis and proposal conducted by WSG staff were provided to the Squalicum Harbor staff much the way a consultant would provide information.

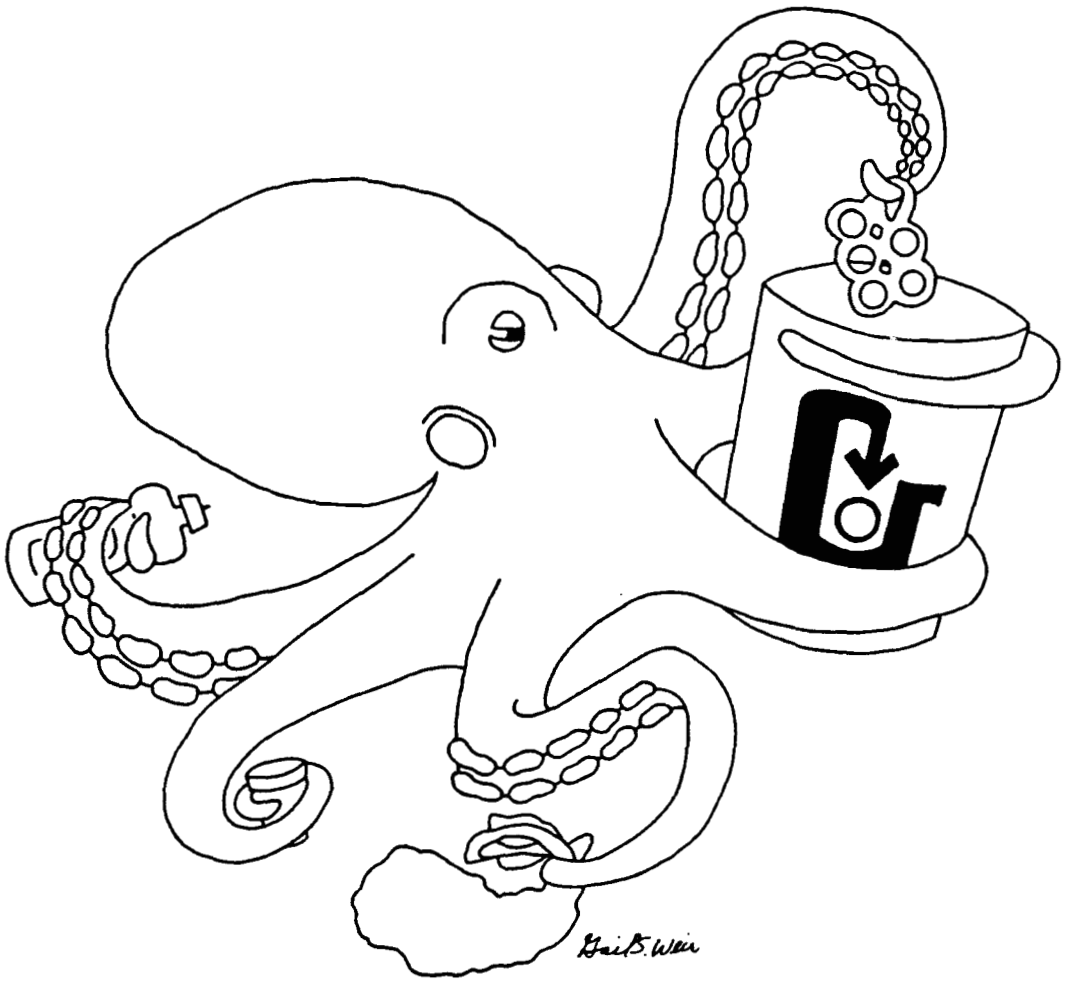


Figure 2.--Washington State marine debris logo.

However, the Squalicum Harbor staff had to make the actual changes. Six months after receiving the recommendations, they were just beginning to implement the physical changes. The first cardboard collection boxes were installed in early March 1989, and they were immediately used by the boaters and fishermen. The installation of the other facilities were expected to occur shortly thereafter.

We can only theorize about why implementing the proposal took so long. First, the Squalicum Harbor staff appeared to be already working at their maximum level. When a staff is already working at or near capacity, a new project is difficult to start. Second, in spite of the analysis and proposal, the staff appeared reluctant to implement the project for fear of generating more maintenance work for themselves. Third, this project may

have been viewed with some resentment because it was promoted by people outside of the Squalicum Harbor staff.

Because of the time it took to have physical changes made at Squalicum Harbor, no measurements have yet been made on the effects of the changes. This project points out the difficulty of setting up a demonstration project as an "outsider," and should caution others to expect to go slowly in similar projects.

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# MARINE DEBRIS: NORTH CAROLINA'S SOLUTIONS THROUGH EDUCATION

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## ABSTRACT

North Carolina began its campaign against marine litter in June 1987. The success of the program has been due largely to an emphasis on interagency cooperation and on education of the public. Five cooperating state agencies have been the University of North Carolina Sea Grant Program, and North Carolina Division of Coastal Management, Division of Parks and Recreation, 4-H, and Office of Marine Affairs. Educational activities have included slide programs given by a Sea Grant marine education specialist to power squadrons, fishing clubs, school groups, and service clubs, and ongoing exhibits and talks on marine debris by the state's three coastal aquariums. The program has also stressed youth-oriented activities relating to marine debris.

## INTRODUCTION

North Carolina has nearly 560 km (350 mi) of coastline and 931,500 ha (2.3 million acres) of estuaries, bays, and sounds. Without question, the beaches and coastal waters are vital to the aesthetics and the economy of the state.

But litter and plastics could change this.

That is why North Carolina began its marine litter program in June 1987. Now, 21 months later, the state can show evidence of change and the promise of regulations and educational programs that ultimately will help solve litter problems at the coast.

## METHOD AND DISCUSSION

On one Saturday in September 1987 and another in September 1988, the state marine debris program held Beach Sweep, a 1-day coastwide cleanup. Over 4,500 volunteers came to the coast and picked up more than 54 metric tons of trash. The volunteer participation, the amount of litter collected, and the extensive media exposure for Beach Sweep were the result of educational efforts by program coordinators and volunteers.

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

## Interagency Cooperation

North Carolina patterned Beach Sweep after similar cleanups in other states, but organizer Lundie Spence, Sea Grant's marine education specialist, took a different approach. Like the director of a play, Spence pulled in talent from many of the state agencies to play different roles in Beach Sweep and the marine debris program.

The 1987 Beach Sweep organization committee was composed mainly of representatives from four state government agencies. They were Sea Grant, the North Carolina Division of Coastal Management, Division of Parks and Recreation, and Office of Marine Affairs, which oversees the state's three coastal aquariums. In 1988, North Carolina 4-H Clubs joined the committee.

Full cooperation and contributions of time, money, and services from each agency helped spread the word to thousands of North Carolina citizens.

For example, Sea Grant's Spence kept state government leaders informed of activities concerning marine debris. She sent information on marine debris and Beach Sweep through a Sea Grant newsletter to 2,000 North Carolina teachers, and she gave slide programs to power squadrons, fishing clubs, school groups, and service clubs.

Sea Grant's communications staff handled all of the major publicity for Beach Sweep. This included issuing press releases, writing features and newsletter articles, compiling press kits, and scheduling radio and television interviews.

The Division of Coastal Management took on other tasks. As the state's coastal regulatory agency, this division was able to work closely with the governor's office, legislators, the state's Coastal Resources Commission, and the Marine Science Council to garner support.

Parks and Recreation contributed manpower at the coast for the cleanups and helped with fund-raising and contributions of garbage bags and pencils for tallying data.

The three North Carolina aquariums offered staff that served as regional coordinators for Beach Sweep. Each aquarium provided special exhibits and programs on marine debris to tourists and other interested visitors.

As the state's marine debris program grows, an increasing number of state government agencies, private nonprofit groups, corporations, small businesses, and volunteers are participating.

Targeting groups of all kinds with coastal and environmental interests provides not only a rich pool of talent and services, but also an unlimited resource for ideas.

In this case, the more the merrier.

This year, Beach Sweep and the North Carolina marine debris program still operate with no major corporate funding. The shoestring budget has gotten a bit fatter, but the shoestrings are not yet long enough to help accomplish all of the goals. Therefore, interagency cooperation is even more important to help carry out a comprehensive educational program.

## Public Education

### Emphasis on Youth

A special emphasis in North Carolina has been placed on creating awareness for the state's youth. Within the school system, the state's marine debris program coordinators have worked with science, environmental, and gifted-and-talented classes. In this area, copies of the marine debris slide and talk program from the Center for Marine Conservation have been made available to the schools.

Teachers have found out about other reference materials through a special newsletter from Sea Grant. In response, children from the fourth to twelfth grades have written Sea Grant for information. This exercise gives younger children the experience of writing for and receiving information on their own. Taking this action is one more step toward increasing awareness by personal involvement.

The North Carolina aquariums, the state maritime history museum, and the parks and recreation system have offered special youth programs on marine debris. Typically, leaders give a short talk or slide show on marine pollution and then take the group out on the beach to collect trash. After 30 to 40 min, they stop and discuss their findings and reactions.

This program has been modified to assist Boy Scout troops at the coast in earning a badge relating to environmental awareness. One troop expanded the idea during Beach Sweep and separated its trash for recycling.

Another excellent idea for increasing youth awareness has been a permanent display on marine debris erected at the North Carolina Maritime History Museum. One panel of the display is just for children. On it are photos of volunteers during Beach Sweep, an award-winning 4-H poster concerning plastics, and a pad and pen for comments. Pages and pages of ideas and comments have told museum educator Patricia Hay that children's eyes are open to the problems at the coast.

Probably the most far-reaching involvement originated with the state 4-H Club. This national youth organization has programs in each of North Carolina's 100 counties. Within this structure, Beach Sweep was promoted through newsletters and electronic mail as a good community service project for its members.

In addition, 4-H implemented a statewide marine debris poster contest for youths ages 9 to 11, and 12 and older. As schools already employ many such contests, this gave the young people a different avenue. The 4-H Club raised $255 for cash prizes in each category.

Most importantly, 4-H and Sea Grant helped devise five activities for youths concerning plastics and litter. They are currently being used by 4-H Clubs and school teachers throughout the state. But since they are new, 4-H education specialists are still conducting tests on the usability and viability of these activities as a curriculum.

The five projects include:

1. Living labels. This icebreaker invites students to become aware of types of plastic items around them. Students either act out the item they have chosen or give 10 words describing it. Other class members try to guess the item.

2. Why do we use plastics? By listing different kinds of plastics we use daily and discussing them, young people gain a better idea of how much plastic is used and why.

3. How strong is a six-pack ring? Youths test the strength of six-pack rings and correlate this with their durability in the environment. The objective is for them to realize how little chance an animal or fish has of freeing itself after entanglement.

4. Can we make plastics disappear? By comparing degradable and nondegradable six-pack rings, youths

   a. understand the meanings of photodegradable and biodegradable,

   b. learn that most plastics are not degradable, and

   c. learn that plasticlike materials can be made degradable.

5. Turning trash around. By simulating paper and plastics recycling, youths gain a better understanding of the process of and need for recycling in our society.

Other

The Beach Sweep effort has helped make many of North Carolina's citizens aware of marine pollution. Each volunteer that attended the cleanup has seen firsthand what litter can do to our beaches and how he or she can help keep them clean. The social, environmental, and economic impact of cleaner beaches is affecting the behavior of tourists. And pollution has become a political issue because people are concerned.

Since our cleanup began, certain public beaches have been kept cleaner year-round. Municipalities added more trash cans to beach access areas, and some of them added to their cleanup crews. Also, North Carolina is currently considering legislation on degradable six-pack rings.

Public education has not stopped with Beach Sweep, however. Each of the involved agencies has initiated programs concerning marine debris.

## CONCLUSION

With these projects and our other efforts, North Carolina has begun its fight against marine pollution. By working together and focusing energies on the state's youth, much has been done.

For the past 2 years, North Carolina Sea Grant has been part of a national Sea Grant marine debris network. Each of the nation's 30 coastal states has contributed toward educating commercial fishermen, teachers, boaters, and the public about pollution and its effects.

Until the problem is conquered, however, much remains to be accomplished.

# DESIGNING EFFECTIVE EDUCATIONAL PROGRAMS: THE ATTITUDINAL BASIS OF MARINE LITTERING

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## ABSTRACT

The worldwide concern with marine and coastal debris has sparked recommendations for various abatement interventions. Popular among them have been educational programs. Effectiveness of educational interventions directed toward changing environmental attitudes and behavior has, however, been found wanting, according to some recent assessments. It is argued that problems with educational abatement programs may stem from the lack of appreciation and lack of application of social science knowledge about the basis of environmental beliefs, attitudes, values, and human behavior which affect the environment.

Marine debris abatement efforts can be enhanced by basing them on social science knowledge in three relevant areas: 1) paradigms and the nature of environmental attitude formation; 2) the nature and constraints of the desired nonlittering behavior; and 3) research on attitude and behavior change, including recycling and land litter abatement. Each of these topics is reviewed, with recommendations about its application to marine debris abatement.

## INTRODUCTION

At the conference on the topic of fisheries-generated marine debris and derelict fishing gear held approximately 1 year ago in Portland, Oregon, educational programs were assessed by one participant as the most popular marine debris abatement approach. He stated that they are "politically attractive, do not cost much and meet other favorable criteria." However, the author also noted that such programs "often have only modest effectiveness and lack permanence" (Alaska Sea Grant Program 1988, p. 7).

The thesis of this paper is that one of the reasons for the limitation of these educational programs is the failure to understand fully the human and social causes of the problem. It is proposed that this shortcoming is due to the limited participation by social scientists in addressing the

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

problem. Physical scientists have assessed the extent and nature of the impact of marine debris. From this data base has evolved a determination that a "problem" exists. But the definition of the problem has remained too strongly physical because it lacks the additional perspective of environmental issues provided by the social scientist.

An example of this lack of appreciation of the social component of the marine debris problem is seen in the recommendations made by the Interagency Task Force on Persistent Marine Debris formed by the White House Domestic Policy Council. The task force recommended that 1) the (marine debris) problem be quantified, 2) the sources be determined, and 3) ways be found to reduce plastic debris from all sources.

The phrasing of the document suggests that the "source" of the problem is merely a physical location or use or particular economic activity seemingly devoid of human imput. Review of this and other documents similarly phrased revealed that there was a missing step in these recommendations. Simply put, the missing step is to ask, "Why do litter and debris exist in the marine and coastal environments?"

The goal of adding this question is to refocus the problem-solving to recognize that human behavior is the cause of the litter and debris and not just a "source." If the human nature of the problem is not addressed in the problem-solving efforts, educational interventions cannot be effective but appear as an afterthought because "something must be done." It is contended that answers to the question of why debris exists must be determined and understood before and if "ways [are to] be found to reduce plastic debris from all sources."

## SOCIAL SCIENCE FINDINGS RELEVANT TO MARINE DEBRIS ABATEMENT

With the goal of addressing this issue of the human cause of marine debris, three relevant social science topics will be briefly examined. The three topics are:

1. paradigms and the nature of environmental attitude formation,

2. the nature and constraints of the desired nonlittering behavior in the marine environment, and

3. research on attitude and behavior change including recycling and land litter abatement.

Each of these topics is reviewed with recommendations about its application to marine debris abatement.

### The Nature of Environmental Attitude Formation

#### Societal Paradigm

Members of a society share a common world view embodied in beliefs, attitudes, and values. This world view, frequently referred to as a

paradigm, emanates from the experiences of the members of the society and is functional to the society in that it supports the society's efforts to survive. While the paradigm does not necessarily answer important questions, "it tells us where to look for answers" (Babbie 1989). It also becomes the basis for choosing problems that can be assumed to have solutions (Kuhn 1970). When the existing paradigm no longer serves the members of society, it changes as the established agreed-upon paradigm is modified in favor of a new one(s).

Within each society, subgroups share paradigms useful for supporting their experiences and position in society. For example, different scientific disciplines have different paradigms as do other occupational groups. In order to understand the basis of behavior of members of a society, it is important to appreciate both the general world view of the larger society and those views of the subgroups about which you have specific interest. Both the general and the subgroup will be discussed below.

The paradigm common to the American society has been characterized as the "dominant Western world view" (Dunlap and Van Liere 1984), the "technocratic" paradigm (Drengson 1980), or the "human exemptionalist" paradigm (Catton and Dunlap 1980). This paradigm sees the relationship between humans and the environment as one in which humans utilize the environment for their betterment, even at the expense of the environment. Based on the Judeo-Christian heritage, this paradigm assumes a human superiority over other organisms bequeathed to humans by their special relationship with God. Contained in this perspective of superiority is the belief that any problems which befall the environment during its exploitation can be remedied by humans through technology. A society which holds this paradigm believes that it is exempt from conformity to the natural ecological laws because of its ability to overcome any environmental problems.

The American extension of this paradigm divides the environment into parts which are privately owned for the gain of the owner and parts which are publicly, or commonly, owned (Hardin 1968). The "commons" is shared for the betterment of all members of the society. However, as Hardin (1968) notes, such a common betterment for all becomes impossible once the ratio of the population to the environment surpasses its "carrying capacity." At that point the common good suffers as the individual benefits from use of the commons.

Industrial pollution and littering behavior represent the use of the common for the betterment of individuals and their economic interests. Belief in the right of individuals to so use the commons for their interest is an important belief contained in the American paradigm. Throwing something "away" means simply putting it into the commons when it no longer serves the person's needs.

The strength of this tenet within the western paradigm is evident when we consider the "absurdity" of the idea that all pollution, every single bit, should be totally banned from the commons. To paraphrase, what general societal support would there be for the total prohibition of environmental degradation in all commonly shared environments--air, water,

and public lands? The economic interests would argue that such a position would cause mass bankruptcies. Average citizens would also resist such a ban when they came to realize how it would affect the consumer-oriented lifestyle which has also evolved from the paradigm.

Discarding refuse into the ocean becomes an obvious extension of this paradigm. A series of studies done by sociologists Dunlap and Van Liere (1978, 1984) sought to determine to what extent such a degrading orientation toward the environment was linked to subscription to the western paradigm. In other words, does a person's belief in the dominant western paradigm affect his or her attitudes (and behavior) toward the environment? Van Liere and Dunlap (1980) broke the paradigm down into eight dimensions:

- support for laissez-faire government,
- support for the status quo,
- support for private property rights,
- faith in science and technology,
- support for individual rights,
- support for economic growth,
- faith in material abundance, and
- faith in future prosperity.

Three of these dimensions of the dominant western paradigm were associated negatively with the environmental attitudes scales they also developed. The greater the support for the following, the less the support for the environment:

- support for private property,
- support for economic growth, and
- faith in material abundance.

We may, thus, propose from these research findings that individuals who subscribe closely to the dominant western paradigm--particularly support for private property, economic growth, and belief in material abundance--will more likely not hold proenvironmental attitudes. If such proenvironment attitudes are not held, it is more likely that littering behavior, such as that which results in marine debris, will be exhibited.

An alternative paradigm is evolving as the current paradigm becomes less functional. The paradigm which would reduce the stress on the environment is called the "new environmental paradigm" (Catton and Dunlap 1980) or the "person-planetary" paradigm (Drengson 1980). This paradigm accepts the fact that humans are subject to the same ecological laws as other organisms, and when humans degrade the environment, they are not always able to repair it with technology.

A "paradigm shift" (Kuhn 1970) by the majority of the populace may occur more rapidly than might be anticipated given the escalating environmental problems. Recent political deliberations in southern California were directed at reducing air pollution conditions that are no longer acceptable. The proposal included restricting each family to owning one car and requiring that the family members work near where they live. A

recent proposal by the U.S. Environmental Protection Agency directed toward reducing acid rain indicated that the solution could come with a required dropping of interior household temperature during the winter. While the dominant western paradigm still prevails, the fact that "responsible, mainstream" public officials were making these proposals suggests that the paradigm is shifting.

Educational interventions directed toward antilittering in the marine environment can benefit from an awareness of the target population's paradigm. If it is determined that they subscribe to the traditional paradigm, efforts toward modifying their world view should be included in the communication along with the message directed toward the specific change in littering behavior. If on the other hand, they are shifting their paradigm, then the communication can benefit from "tapping" this new orientation in the message.

**Subgroup Paradigms**

Besides the general societal orientation toward the environment, subgroups of the population have been found to vary in their attitudes toward the environment depending on their relationship to it. Awareness of these subdifferences can also benefit educational interventions directed at target populations.

For example, Louisiana has both the most active offshore oil extraction activities in the United States and some of the most prolific spawning grounds for fish and shellfish in the United States. Thus, coastal users include large groups of fishermen and offshore oil rig employees. Should we expect to find these groups different in their attitudes toward marine littering or the same? Popular opinion might argue that the oil rig employees would be likely to have less concern for the environment than fishermen whose livelihood depends on a healthy environment.

Research findings, however, suggest the contrary. Rural residents have been found to be less proenvironment than urban residents because they work in agricultural and mining activities which approach the environment in a more utilitarian, exploitative fashion (Lowe and Pinhey 1982). It is thus likely that the fishermen and oil workers will be more similar than different in their environmental attitudes. Louisiana fishermen have a reputation for considerable littering, as do oil rig employees. They also have strongly resisted steps taken by the Federal Government to protect the environment, such as the requirement that they use turtle excluder devices (TED's) while shrimping to protect the Kemp's ridley sea turtles.

The exploitative orientation toward the environment of some jobs may not be the only influence which engenders human exemptionalist attitudes in those whose livelihood depends on the environment. Companies for which such individuals work may themselves have company "cultures" reflecting similar orientations. It may be more cost-effective to use the commons for refuse, and this belief is learned as employees learn what is expected of them on the job. Personal worker economic motivation to perform well on the job compounds their own inclinations to litter.

Other individual characteristics have been found to affect attitudes and behavior toward the environment. Small town residents appear to also be less proenvironment. Van Liere and Dunlap (1980) explain this observation with the "progrowth" orientation of small towns. Urban residents have, to the contrary, been found to be more proenvironment. Environmental deprivation theory is used to explain this finding: Urban residents experience higher levels of pollution and environmental degradation and can thus make a comparison between the existence and nonexistence of pollution, which results in developing a proenvironment orientation (Dillman and Christenson 1972). In addition, urban residents are more likely to appreciate a "social solution" to environmental problems because they experience control over their built environment (Lowe and Pinhey 1982). Thus, they are willing to accept the existence of a problem because they perceive it as solvable. Take for example the predominance of urbanites in the groups who are involved in the annual beach cleanups.

In addition to geographic location, education, race, sex (Sigelman and Yanarella 1986), social class (Buttel and Flinn 1978), and age (Hamilton 1985) have been found to predict attitudes toward the environment. Income has not been found so strongly associated (Constantini and Hanf 1972; Sigelman and Yanarella 1986). Van Liere and Dunlap (1980, p. 190), in summarizing the findings from numerous studies of social characteristics, indicate that the association between income and environmental concern is "quite ambiguous and fail[s] to support the hypothesized positive association." This ambiguity may be due to changes which are taking place in the way in which the less affluent view environmental problems. While they value the jobs that come from industry, which often pollutes, they are becoming more aware that the pollution from such activity often is discarded closer to their communities than to those of the more affluent (Bullard and Wright 1986).

Similar changes may also be occurring in some of the relationships found in the subgroups reviewed above. While fishermen may not have traditionally been inclined to be concerned with the environment, the depletion of the resource such as the threat to the Gulf of Mexico redfish population may also begin to change their orientation to the environment as well.

It is important that the educational interventions being developed to reduce beach and marine debris are oriented toward the expected attitudes which various target groups might hold toward the environment, and that support be given to maintain current information on the attitudes which coastal users hold so that the intervention is relevant to the orientation.

## Characteristics of Nonlittering Behavior

In addition to appreciating the orientation which coastal users have toward the environment, it is important to understand the nature of the behavior which the educational program attempts to change--i.e., marine littering--and the meaning given to that behavior by those who do it. Conversely, it is also important to recognize the characteristics of the desired behavior--nonlittering--which make conformity to it more difficult than other environment-oriented behaviors.

**Complexity of Desired Behavior**

Nonlittering behavior in the marine and coastal setting contains both a "don't do" and a "do" component, making its successful implementation somewhat complex. It is desired that individuals not discard that which is no longer of value to them into the commons--i.e., into the water or along the beach. Then, it is desired that individuals maintain the item in their personal space--in their pocket, on the boat, on the oil rig, with camping and fishing gear--until they are able to discard it in an appropriate refuse-collecting device or area such as a trash barrel, dumpster, junk yard, or landfill.

**Inconvenience**

Nonlittering behavior in the marine and coastal setting is an inconvenience to the individual because the appropriate refuse-collecting device is frequently not in the immediate vicinity. It may be at the beach entrance, at a nearby gas station, at home, or, for larger items, at a special location requiring an even longer trip. The inconvenience is defined by the length of time the individual may have to maintain the item which no longer has utility within his or her personal domain--often extended if out at sea--and by the fact that it is occupying part of a very limited space--fishing boat, oil rig, freighter, camper.

**Limitations of Social Control**

Littering in the marine and coastal setting is frequently done when there are no other people around to observe the behavior. Or, if others are present, they are experiencing the same need--to discard no longer useful items taking up precious space. Or, the observers are strangers or at such a distance that the litterer can maintain his or her anonymity while violating the norms. This means that the behavior can frequently not be controlled by the knowledge that someone else is observing them doing something contrary to the norm, a manner in which much desired behavior is encouraged.

An anecdote demonstrates norm-control dynamics and the way a litterer can attempt to avoid them. Last summer on a Florida beach, I watched a well-coiffured, expensively dressed beachcomber with cigar in one hand and a soft drink can in the other stop on a crowded beach to dig a small hole in the sand with his toes. He deposited the empty soft drink can in the hole, covered it over, and walked on. This behavior suggested to me that he knew littering was against the norm. If, however, he could hide the object, he would be able to avoid the possible scorn of the onlookers or rationalize that he had not littered because the object was no longer visible--one of the most commonly mentioned qualities of litter being that it is an eyesore.

**Impact Not Obvious**

The effect which the littering behavior is having on the environment is not seen or appreciated by the litterer because the discarded item frequently disappears under water or sand. Even when it does not disappear,

the beach and the ocean are so vast that the ratio of litter to commons is miniscule. It is difficult to appreciate the significance of one Styrofoam cup tossed off an oil rig into a vast ocean. Or even a piece of fishing gear or the waste from an ocean-going vessel.

**Implications for Behavior Change**

It is argued that awareness of these particular qualities of marine and coastal littering and nonlittering behavior can contribute to the development of more effective educational interventions directed toward curbing such littering behavior.

First, awareness that there is a lack of a clear antilitter norm in the marine environment and a lack of critical observers to enforce whatever norm there is should reduce emphasis on norm conformity in educational programs.

Second, it would be expected that educational campaigns which present graphic evidence of the impact of littering on wildlife--such as the ones recently developed--would improve antilittering behavior. They would help the individual become aware of the impact on the environment of even one small discarded item, albeit seemingly insignificant and invisible when the littering act is committed.

Third, educational campaigns should be implemented in conjunction with strong efforts to provide very convenient locations for disposal of marine refuse.

Examples of the linking of education and convenient refuse disposal are available in the recycling efforts of some communities. One successful pilot community recycling program in Louisiana has stackable containers for curbside pickup clearly marked for glass, aluminum, and paper. The effort to conform is thus quite minimal.

Similarly, studies should be conducted to determine the most convenient refuse disposal configuration at beaches, boat launches, marinas, and harbors. Some disposal services might best be reached from the water so that refuse does not have to be carried onto land by hand. Also, litter bag dispensers could be placed at convenient locations near boat launches and docks to encourage convenient on-boat refuse storage. With such accommodating refuse disposal facilities in place, beach or dockside antilitter signs would be encouraging a more feasible behavior. Once the marine user is practiced in such nonlittering behavior, the behavior will seem "more natural" and such attention to convenient refuse disposal will not be so important. This would be a case of learning to cope with natural hazards (this hazard being to marine life) through participation, as proposed by Sorensen and Mileti (1987).

An example of such facilitating assistance has been tried with success at several Louisiana fishing rodeos. When registering for the rodeo, each entrant was given a trash bag, with a request that it be used and returned to the registration desk at the end of the day. Those entrants who returned their bags filled with the day's refuse qualified for a special drawing for

several significant prizes. The bags were donated, as were the prizes, in return for public recognition that the companies had performed the public service. While the prize component of the activity may not be conducive to continuing the behavior after the fishing rodeo (see below), it might not have a negative effect if the bag contained a recommendation to always take along a trash bag and if trash bags were conveniently dispensed at docks and launch sites on a regular basis.

### Research on Attitude and Behavior Change Including Recycling and Land Litter Abatement

The third social science topic of relevance for improving educational programs directed toward marine debris abatement is the research on attitude and behavior change. Research has been conducted on the content of successful persuasion communication in general and on persuasion directed toward specific attitude and behavior changes. These include self-help behaviors related to health, safety, crime and natural hazards protection (see Weinstein 1987 for a useful review), and energy conservation, recycling, and litter abatement on land. A review of theories useful for attitude and behavior change with regard to solid waste demonstrates the utility of this literature.

There is little systematic theory concerning the social psychological variables which influence littering (Reich and Robertson 1979). However, several theories have been found to be useful in changing littering attitudes and behavior. These include reactance theory (Mazis 1975); cognitive dissonance theory (Weigel and Weigel 1978; Shipee et al. 1980; Cook and Berrenberg 1981) or balance theory (Winham 1972); saliency theory (Cook and Berrenberg 1981); and Bem's self-perception theory (Arbuthnot et al. 1976-77; Pedersen 1979; Pardini and Katzev 1984). Each of these theories explains behavior based on an assessment which people make about themselves or those around them.

Reactance theory asserts that "when a person believes himself free to engage in a given behavior and his freedom is eliminated or threatened with elimination, the individual experiences psychological reactance" (Mazis 1975). When this occurs, the planned intervention results in behavior opposite to what is desired. An example is the TED which has been so strongly resisted by shrimpers in the Gulf of Mexico. While preventing all resistance to the TED's would have been impossible, a greater appreciation of the likelihood of reactance might have engendered different approaches by the environmentalists. Likewise, by knowing what coastal users believe they are free to do in the coastal environment, litter abatement interventions can be developed which will be less likely to cause such reactance.

Dissonance theory also has potential utility. It proposes that dissonance may occur for individuals among various values and beliefs which they hold and observations which they make. When this occurs, a person tries to reduce the dissonance. A person might interpret the observation such that it supports values and beliefs already held. Such dissonance may exist for the marine and coastal user with regard to littering. By determining whether it does, educational programs can be developed encouraging certain attitude and behavior change to "assist" coastal users in reducing their dissonance.

Saliency theory applied to conservation behavior "impl[ies] that the salience of proconservation attitudes will be enhanced primarily through or in anticipation of associations with others" who share proconservation attitudes (Cook and Berrenberg 1981, p. 82). When such persuasions are implemented, the presence of those holding nonlittering attitudes would be likely to increase saliency. Their presence can also be felt by presenting their proconservation statements in their absence or by asking residents to make public commitments to proconservation behavior. Beach cleanups are an example of a way to enhance the saliency of nonlittering behavior. Individuals make a public commitment to proenvironment behavior in the presence of other like-minded individuals.

Likewise, Bem's theory of self-perception can be applied to changing marine littering behavior. Bem proposes that behavior change occurs after a person changes his or her self-image to one capable of the new behavior (Arbuthnot et al. 1976-77). This self-image change can be assisted by educational programs that require small behavior change commitments to start the process of self-image change. Arbuthnot et al.'s successful experiment required minor recycling commitments which then led to a willingness to undertake more extensive recycling. Refuse disposal such as recycling at marinas and harbors could be approached in such an incremental way. Based on this theory, educational programs which encourage refuse disposal by giving prizes would not be expected to work over the long run because individuals do not have to change their self-image. The motivation to dispose correctly remains external to them, i.e., a prize given by someone else.

## CONCLUSION

It will not be easy to integrate even the few concepts and theories presented in this paper in addressing the marine debris problem. It will be even more difficult to determine and apply the appropriate theories when social science research on relevant topics is more thoroughly reviewed. However, motivation to address the existing research and to respond to it can be found in recognizing the difficulty of success with educational programs in light of resistance from the existing human exemptionalist paradigm. Human behavior is the result of very complex social psychological processes influenced by the structure of the society in which the person lives and his or her position within that society. To have a modicum of lasting success in behavior change, "one needs all the help one can get." It will require a cooperative effort of both physical and social scientists to provide the knowledge base needed by those working directly with the marine debris problem to address its solution in a timely and successful fashion.

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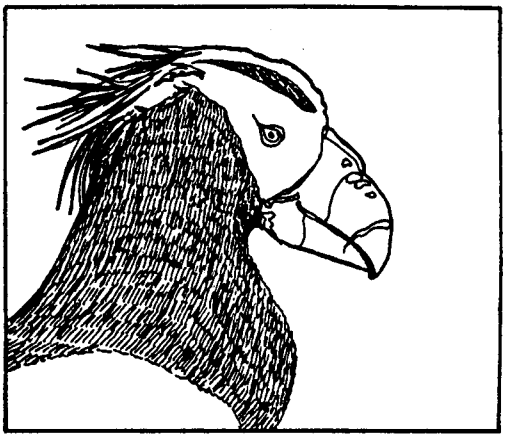
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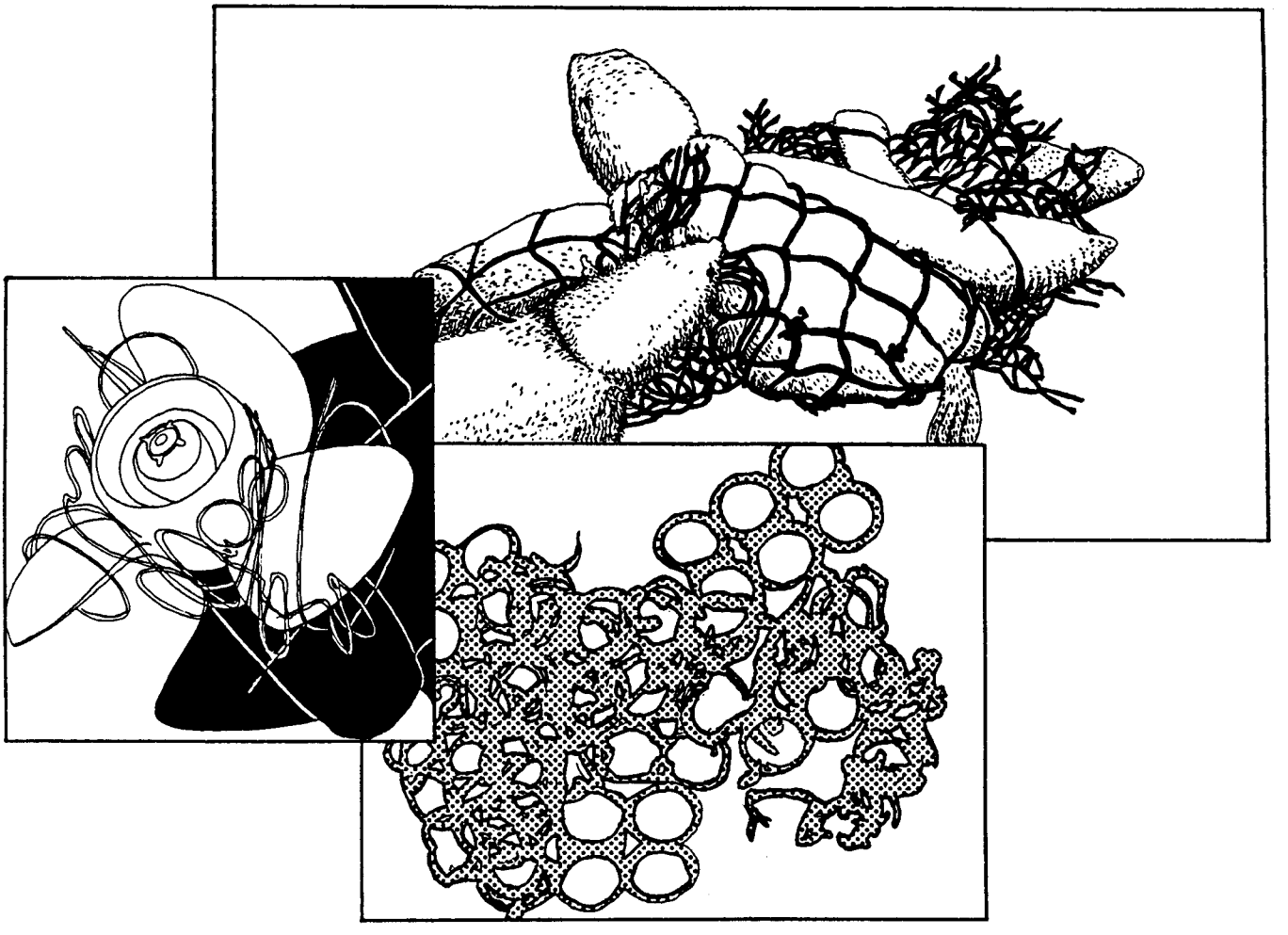
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# POSTER PRESENTATIONS



# ANIMALS AS LITTER VICTIMS AT THE GERMAN NORTH SEA COAST

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## ABSTRACT

Over a distance of 65 km at 12 beaches of the German North Sea coast, 64 entangled vertebrates belonging to 14 species (mainly gulls, gannets, guillemots) were found dead from August 1983 to April 1988.

On the island of Helgoland, furthermore, 53 living seabirds belonging to 11 species (most gannets) were observed as entangled with remains of ships' litter. In at least 46 cases, plastic material was involved, so that the chance of survival of the animals must be rated as very low.

The numbers quoted must be considered as minimums, since not all animals affected or entangled with litter reached the shore or were found there. Also those animals which died as a result of litter ingestion are not listed.

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# MARINE DEBRIS AND EPIPELAGIC FISHES

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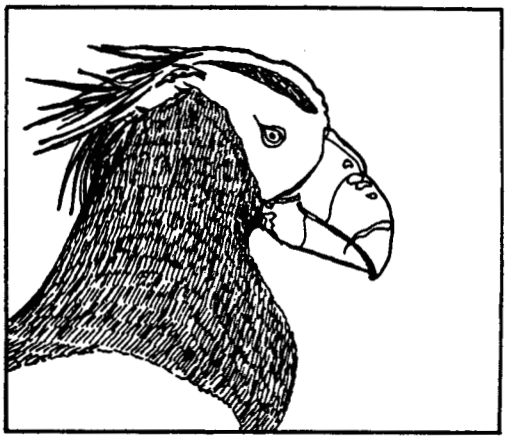
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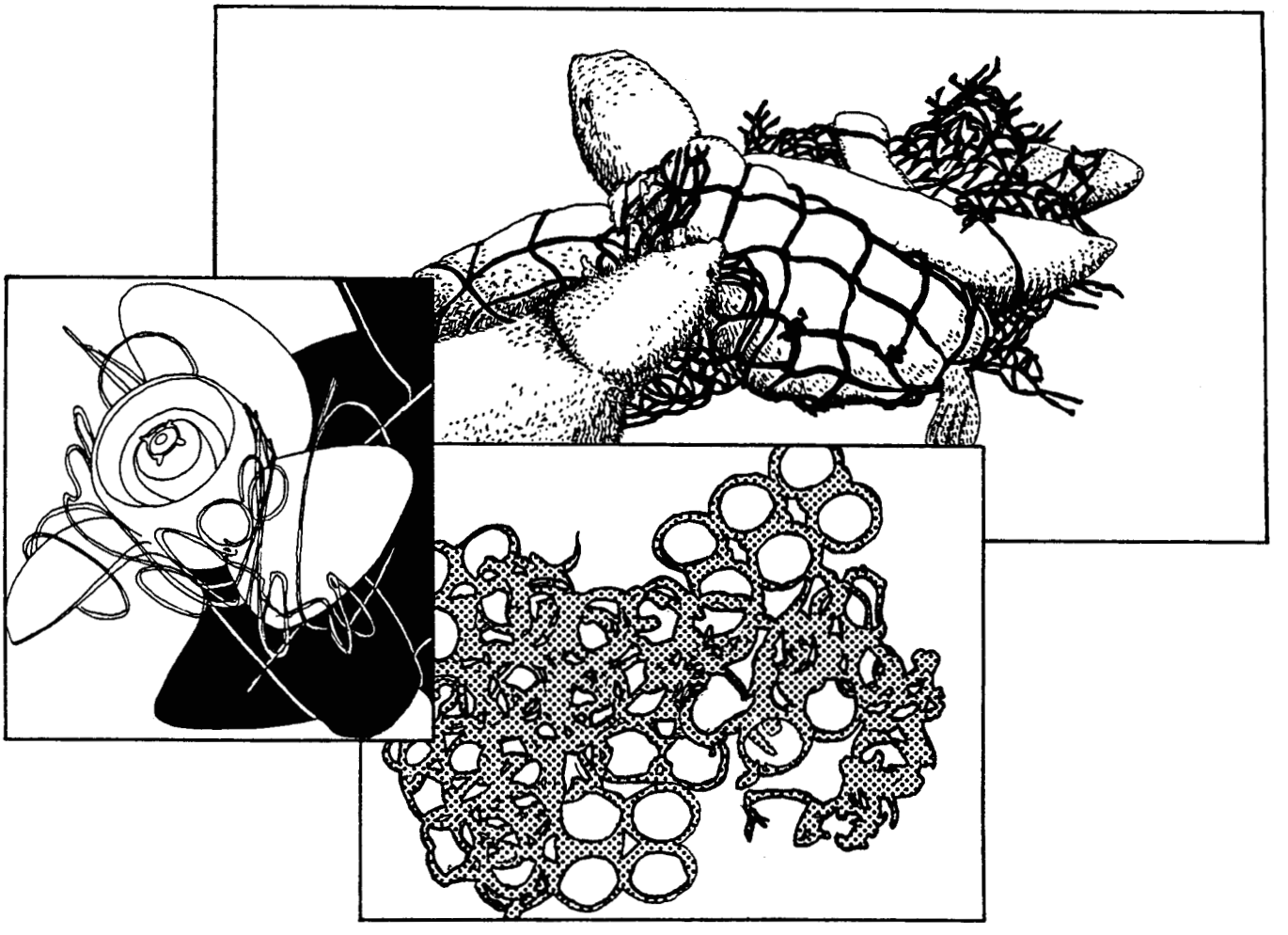
## ABSTRACT

Two species of epipelagic fish caught in 1987 and 1988 by commercial fishing vessels operating in the vicinity of the Hawaiian Archipelago display the impacts of marine debris. The first specimen is a male mahimahi, *Coryphaena hippurus*, 77.5 cm total length and weighing 2.06 kg. Captured during albacore trolling operations, the mahimahi had monofilament net fragments attached to its gills and opercular area. The other instance involves a swordfish, *Xiphias gladius*, measuring approximately 140 cm total length and weighing 10 kg caught during tuna longlining operations. A rubber band cut approximately 3 cm deep into its caudal peduncle; otherwise, the swordfish appeared normal. Presented are photographs of both specimens and speculations as to the possible origins of the impacting debris.

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.



# VIDEO PRESENTATIONS



# PORTRAIT OF A BARRIER ISLAND BEACH

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## ABSTRACT

Spanning a period of 11 years, 1,800 transects have been made along a 12-km stretch of beach on Mustang Island, Texas, to observe the seasonal and long-term changes to this barrier island beach bordering the northwest Gulf of Mexico. Documented in the ongoing study are bird populations, human disturbance, beach morphology, local oceanographic and weather conditions, stranded marine mammals, turtles, birds, oil spills, fish kills, effects of severe weather, and occurrence of marine debris and litter. This talk illustrates visually the tremendous impact, both aesthetic and as a danger to wildlife, of marine debris and increasing human usage on this otherwise beautiful beach. Also illustrated are several environmental and other factors that complicate efforts to understand the seasonal and long-term trends in the distribution of marine debris.

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

# U.S. OIL INDUSTRY EFFORTS IN ADDRESSING BEACH DEBRIS PROBLEM

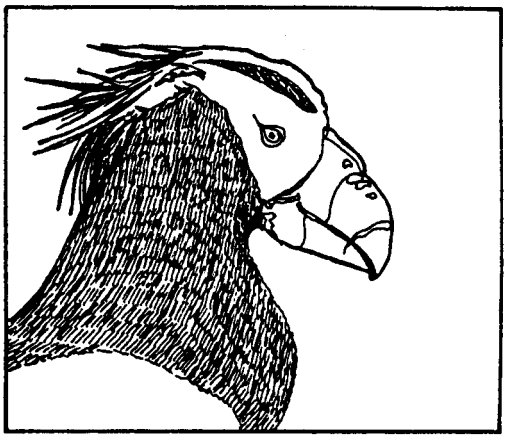
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## ABSTRACT

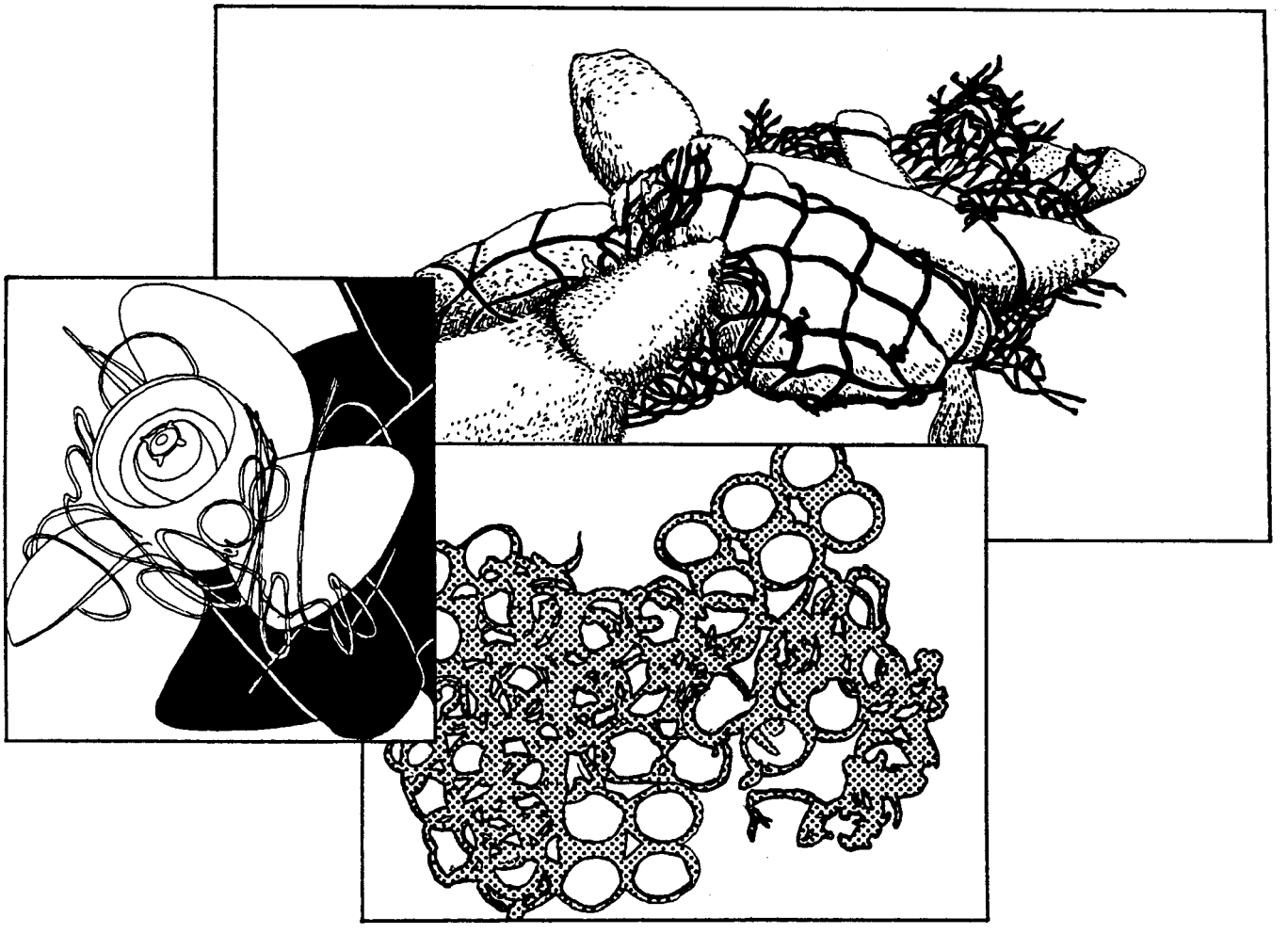
The United States Gulf of Mexico offshore oil and gas industry has, over the past 2 to 3 years, embarked on an industry-wide effort to eliminate its contribution to marine debris. Beach debris surveys on gulf coast beaches previously identified a significant percentage of the debris originating from offshore exploration and production operations. As regulations which prohibited the discharge of trash from these facilities were already in place, it was thought that carelessness and possibly ignorance were involved.

It was evident that education would be the best way to approach this problem. This presentation will focus on a 12-min video developed by the offshore operators' committee, along with some individual efforts undertaken by companies, which we have used in the education process.

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# WORKING GROUP REPORTS



# REPORT OF THE WORKING GROUP ON METHODS TO ASSESS THE AMOUNT AND TYPES OF MARINE DEBRIS

(Christine A. Ribic, Chair)

## INFORMATION NEEDS AND METHODOLOGIES

For the determination of the amount and types of marine debris, the working group distinguished between two types of studies: baseline, studies with low sampling frequency made over large geographic areas; and assessment, studies of a more limited area and having more intensive sampling effort over time. Baseline studies describe existing marine debris and seek to identify the magnitude of a problem. Assessments study the level of pollution.

The group considered various methodologies now in place for determining the amount of debris in the ocean (nearshore, open ocean, and bottom) and on beaches. They agreed that the beach survey is appropriate for assessment studies on a large scale. For limited-scale studies, dedicated surveys using visual observations and neuston tows in nearshore areas (e.g., bays, harbors, and estuaries) or limited ocean areas such as offshore dumping areas can be used for assessment.

Table 1 summarizes the current utility of survey techniques. Use of aircraft, while experimental, is feasible for baseline studies. Techniques to study bottom debris are needed; currently bottom debris studies are categorized as baseline.

Figure 1 is a proposed outline of the stages of a marine debris pollution assessment plan.

## GEOGRAPHIC AREAS

The vastness of the oceans makes it necessary to select areas of interest for more intensive studies. On an international level, the working group suggested MARPOL special areas as appropriate geographical areas for more intensive study. On a national or a regional level, special areas of local interest must be developed. Examples of national level areas were the Pribilof Islands, because of the impact of debris on northern fur seals (United States), and national marine sanctuaries (United States). A regional area of interest cited was the Caribbean. Freshwater systems, including estuaries, were not discussed by the working group for lack of time.

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Table 1.--Summary of survey techniques.

| Survey techniques | Type of study | |
|---|---|---|
| | Baseline | Assessment |
| Nearshore/open ocean | | |
| Surface debris: | | |
| Visual observation (strip/line transect) | Platforms of opportunity | Dedicated surveys in well-defined areas of importance |
| Neuston nets | Oceanographic surveys | Dedicated surveys in well-defined areas of importance |
| Photography | Aircraft/helicopter (limited to large debris items) | |
| Bottom debris: | Limited to certain types of communities | |
| Survey of fishermen | Questionnaire (limited to certain types of debris) | |
| Bottom trawl | Limited to certain types of communities | |
| Remote operating vehicles | Expensive to use | |
| Beach surveys | Volunteer efforts (educational/ public relations) | Planned surveys Estimates of amounts on beaches--random sampling |
| | | Changes over time--same beach or transect |
| | Low-flying aircraft | |

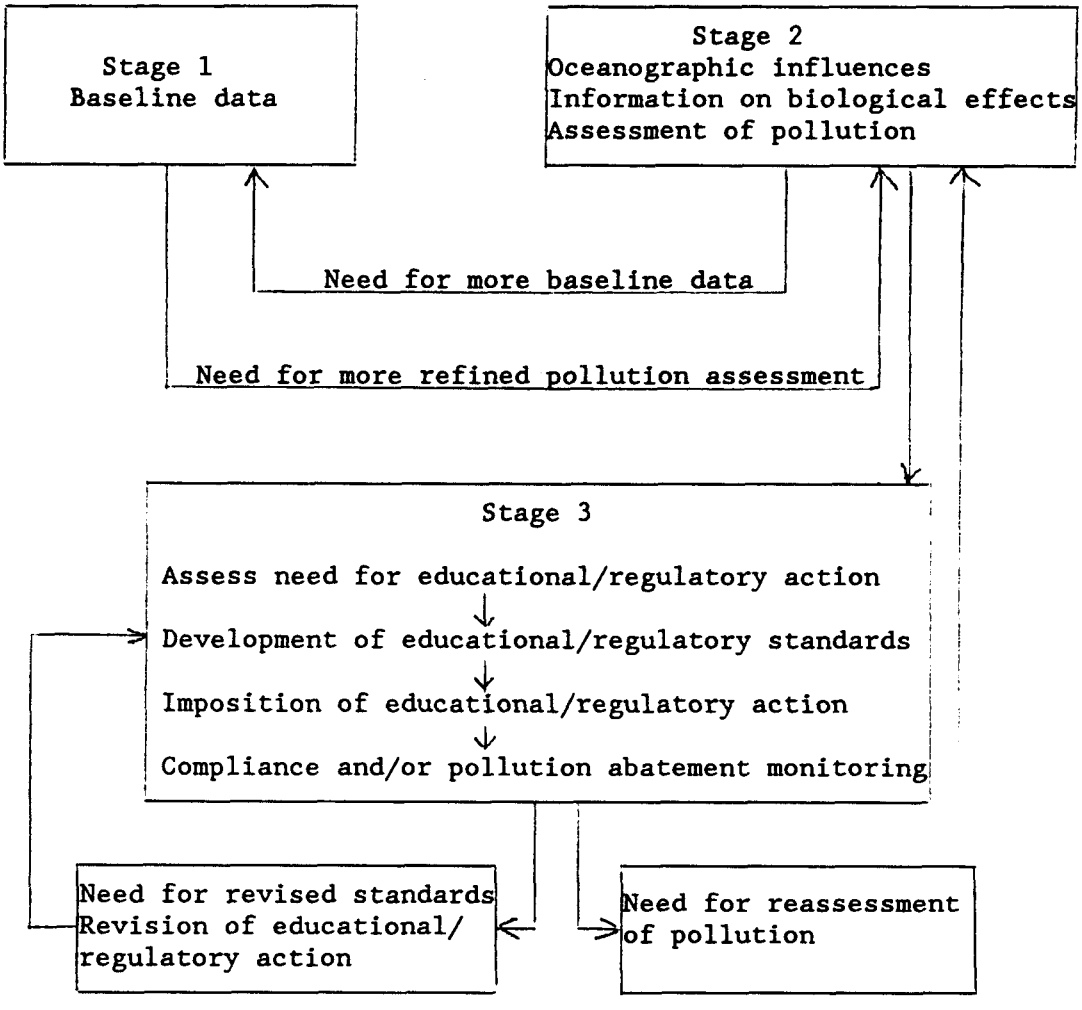



Figure 1.--Components of a marine debris assessment plan (after G. Kullenberg et al. (1986) Mar. Pollut. Bull. 17:341).

## Floating Debris at Sea

At sea, counts of floating debris are made using platforms of opportunity and dedicated surveys.

Visual observation from a viewing platform such as the flying bridge of a vessel is used when counting large debris. Most studies employ a strip transect method and count all debris sighted within a certain distance of the ship, using the glare-free side of the ship for observation. The width of the strip depends on the height of the viewing platform as well as on survey conditions (e.g., Beaufort sea state), and may change during the survey. All debris in the strip is assumed to be sighted. No one has done work on the probability of sighting different debris objects, and there are potential size and color biases that need to be evaluated. The length of a single transect varies as does final total transect length. The variable considered is usually a density estimate, number per square

kilometer or number per square nautical mile. The group recommended that two or three observers be employed in the survey. A single observer should use a strip width of 25 m or less. Calibration runs were recommended to estimate strip width, and experiments were recommended to investigate color and size biases and the probabilities of sighting different debris types.

There has been limited line transect work, but no formal analysis has been published. Problems persist with inaccuracies in the data, notably in the accurate determination of the distance of debris perpendicular to the ship. When accurate distance measurements can be made, the working group recommended the use of the line transect.

Neuston tows (necessarily strip transects) appear to be the most extensively used method for the study of particulate plastic and tar balls. The group agreed on the usefulness of such tows when made from dedicated survey vessels, but questioned whether neuston tows could be made successfully using platforms of opportunity. They require certain speeds--some devices can be used at speeds of only 3 kn or less; others at up to 7 kn--and the group questioned a captain's willingness to slow the ship down sufficiently to accommodate the towing device. Important to the success of a neuston tow is the estimate of time actually towing, or sweep efficiency.

The working group noted the possibility of using low-flying aircraft to survey nearshore areas for debris.

## Debris on the Sea Floor

Little is known about bottom debris. Bottom trawls may be used from either dedicated survey vessels or platforms of opportunity to sample sea floor debris. The working group discussed bottom trawls for sampling debris, noting that this area has seen little work. They agreed that composition of debris is measurable using bottom trawl gear, but estimates of density are thought to be questionable.

Remote Operating Vehicles (ROV) were mentioned as a possible sampling tool, but it was agreed that this approach is too expensive for widespread use. Bottom drifter studies were also mentioned.

A potential source of information are fishermen whose gear has become entangled in sea floor debris. The working group recommended the development of a survey form to collect bottom debris from fishermen. This could be a starting point for collecting baseline information on bottom debris.

## Debris on Beaches

Beach debris surveys can be carried out in designed or in volunteer programs. Standardization of beach surveys has been attempted for Alaskan beaches and English beaches, with the major difference being the sampling unit. In Alaska the sampling unit is the entire beach (at least 1 km in length). The sampling unit for the English beach is one transect per beach. Based on the working group discussion, it appears that the difference in sampling strategy stems from the types of debris found on the beaches. Entire Alaska beaches have to be surveyed in order to count the trawl web

that dominates the debris. In England, where most of the debris is plastic, transects are used because there is too much debris to count.

To avoid as much as possible counting debris that has originated on land, both approaches emphasize surveying beaches that are away from urban areas and have little recreational use. Beaches of sand and small gravel substrates with moderate slope were selected because they tend to collect debris. In England back beach areas were included; in Alaska they were not. Alaskan beaches facing the open ocean were used. Beaches with complicated topographic features such as partly sheltering reefs should be avoided, as should beaches known to be cleaned periodically. Other variables to consider are prevailing winds and accessibility.

If the intent of the study is to estimate the amount of debris on beaches in a given area, then random beach selection is important. In England a two-stage stratified random sampling scheme was used successfully. To detect changes over time, the majority of the group felt that selected beaches should be sampled repeatedly over time. The kind of change expected should be predicted, an appropriate variable defined to measure that change, and data collected to support or refute the prediction.

For baseline and some assessment studies, total amount, weight, and composition of the debris should be measured. Volume measurements were considered, but the working group felt that they would not be possible in all situations. For studies of changes in debris type over time, there was general agreement that the type of debris would determine whether changes in total amount or changes in composition were of more importance. In Alaska it was considered important to detect a change in the amount of trawl web. In England, composition and age structure of plastic containers were of prime interest. The important point in addressing the question of change over time is to define a variable of interest that can be measured.

For assessment studies, more work is needed to understand beach debris dynamics--for example, local currents and sinks for the debris as well as debris sources.

A suggestion was made to utilize low-flying aircraft, as some current surveys in Alaska are doing.

### Debris Emanating From Land

The working group disagreed about the ease of distinguishing debris of land origin from debris originating on board ship. The accuracy of identification may vary from area to area. After some time in the water, debris items lose any paper labels and may acquire encrusting biota. Some items obviously originating on land may include plant seeds.

## CATEGORIZATION OF DEBRIS

One suggestion was to categorize debris sizes as follows:

Mega - >2-3 cm
Macro - 5 mm to 2-3 cm

Meso - <5 mm (granule size)
Micro - powdered (generally unseen).

The working group also made a list of some more common or important types to track. Suggested were:

Nets (by type)
Other fishing gear
Strapping bands (open/closed) (cut/uncut)
Granulated plastic (recycled plastic)
Particulate plastic
Fragmented plastic
Plastic bags
Plastic containers (country of origin, age)
Styrofoam
Medical waste
Rope
Entanglement remains (e.g., bones)

Due to the time limitation, the group was unable to decide on broad categories for use in comparing data on an international scale, but recommended a review of existing categories in order to develop a common list that could be tailored to fit individual areas of interest.

## MONITORING PROGRAM

Also because of a time limitation, the working group did not address the topics of sampling frequency and sample size requirements. A seasonable variation in the amount of floating debris was noted.

## PROCEDURES MANUAL

The working group generally agreed that a procedures manual detailing survey techniques should be written. This manual would provide ideas for those interested in initiating marine debris studies.

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# REPORT OF THE WORKING GROUP ON ENTANGLEMENT OF MARINE LIFE

(William R. P. Bourne, Chair)

## TERMS OF REFERENCE

It was reported at the first conference on marine debris in 1984 that individual seals, turtles, birds, and fish, some belonging to endangered species, become entangled at times in marine debris. The frequency and severity of these interactions were usually unknown, and no conclusive evidence was demonstrated for any effects on populations. This working group was asked to review the problem and identify the information needed to fill the gaps in current knowledge, notably by devising a model in the light of which current information could be assessed. This should include 1) age, 2) sex, 3) population, 4) numbers, 5) distribution, 6) legal status of victims, 7) activities and materials causing problems, 8) information that is needed to complete the picture and monitor its future development, and 9) the priority that should be given to different aspects of the investigations.

## THE WORKING GROUP

The findings at the 1984 conference still seemed valid, so in order to avoid repeating preconceived ideas, the working group first considered materials which cause problems and their impact on different animals. The previous working group reports were then reviewed to see what progress has been made. The first conclusion is that, despite the accumulation of circumstantial evidence that marine debris may have an adverse effect on all sorts of marine wildlife (including cetaceans, which did not receive much attention previously), the information is still insufficient to show clearly the magnitude of the problem.

## LIMITATIONS OF THE DATA

Care is needed in the interpretation of the available information. It is substantial only for the most common species of two out of the four main groups affected, pinnipeds and birds. These spend long periods on land at breeding sites, where they can be counted and marked. Even here information is deficient for the important period spent at sea. Much less is known about the turtles, which spend most of their time at sea, and the cetaceans, which never come ashore at all. Owing to the way in which the information is collected, it still remains difficult to distinguish between the effects of a variety of interacting factors. These include oceanic fluctuations, disturbance while breeding, the impact of fishing on both the animals and their food supply, disease, and pollution.

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## THE NATURE OF THE PROBLEM

Human artifacts must have caused hazards for wildlife since man first went to sea. They cause two types of problem: killing animals in unpleasant ways, a problem whose nature is self-evident so it will not be discussed further here, and harming the status of species and ecosystems. Both uncontrolled hunting or fishing and the incidental capture of unintended animals while taking other species (by-catches) potentially cause conservation problems. Although such factors lie outside our terms of reference, it must be remembered that not only may the losses of marine animals from hunting and fishing be only a fraction of the losses from natural causes, but losses due to marine debris may also be only a fraction of those from hunting and fishing. In such cases, entanglement may be important as a separate entity only to man, because the animals that it kills are deducted from his catch. The situation starts to acquire a wider significance only when the mortality of any animal becomes large enough to affect the welfare of the species and the ecosystem as a whole as well.

### Nets

In the past, netting was made of natural materials which were not very durable, so that lost nets were noticed to cause a problem only by fouling vessels. Following the introduction of nylon and other synthetic netting after World War II, there have been growing problems with both lost or abandoned nets and the fragments torn from them by obstructions, discarded during repairs, or used to make small traps which subsequently disintegrate. Some reference collections of different types of netting have been made in the hope of identifying their origin--for example, where strange net which presumably comes from the tropical Atlantic washes ashore in the West Indies. It was thought that it might be useful to consult the fishing industry about the preparation of a guide to different types of fishing gear and its likely origin.

It was considered whether nets should be constructed of, or fastened together with, more rapidly degradable material, so that they would break up and sink sooner when lost. However, it was thought that this would lead to the production of more small fragments of net on the sea floor and along the shore, which would add to the problem. Experiments suggest that, if left intact, whole nets tend to bunch up and may cause less problem for wildlife. Thus it may be better to try and keep the net in one piece so that it is more easily removed or immobilized. It has been reported that floats of unequal size drift at different rates with the wind and current, keeping the net open, so the effect of the buoys and weights used on the performance of nets may deserve more attention.

There still appears to be a need for further study of the way in which animals are caught in nets and the fate of lost nets, using marked trial specimens to see how long they continue ghost fishing at sea and whether they catch more or different animals as they come ashore.

### Hooks and Line

These are one of the commoner agents ensnaring wildlife and, occasionally, people. Discarded angling gear often hooks or ensnares birds. Fishing has been banned from some North Sea oil platforms because lost gear has caused problems for divers. Here also the situation has been made worse by the adoption of durable nylon line. It seems likely that the longlines used at sea, which may extend for up to 96.5 km (60 mi), with several thousand hooks and few buoys, may present a more serious problem. Little appears to be known about this, and it deserves more study.

### Loops, Sheets, and Sharp Objects

Other potentially dangerous objects may appear occasionally at sea. They range from wrecks and heavy machinery and construction material discarded by the oil industry, through nautical gear and packing materials and containers, to clothing and household equipment. It seems easier to consider the nature of the hazard that they present than the identity of the object concerned.

Anything which incorporates a loop or ring is potentially hazardous. This includes knotted rope, uncut packing bands, containers with holes, loose webbing or fabric, plastic sheeting, and, of course, netting. These present lethal threats to any marine animal up to the largest whale, should their head, jaws, or limbs become ensnared while hastily seizing mobile prey, or hunting and playing around drifting material. Such objects should be disposed of ashore or by incineration.

Anything which includes, or can break down to form, a sharp point or cutting edge also presents a hazard, especially if it is concealed among innocuous materials. Such objects include wrecks and dumped heavy equipment which may catch nets on the sea floor, lesser metalwork, woodwork with projecting nails, tins opened to leave sharp edges, and fragile glass containers. In addition to being a threat to wildlife, these are also a threat to people who are diving, hauling nets which have collected debris, or walking along the shore. All such objects should also be disposed of carefully.

It seems desirable to redesign some objects which regularly cause serious problems. These include perforated plastic six-pack yokes, cans which normally have sharp edges when opened, and openers which leave cans with sharp edges.

## VULNERABLE ANIMALS

There is accumulating anecdotal evidence that virtually all marine animals are occasionally entangled in debris, but quantitative data are available for few of them. The main cases where it appears important follow.

### Cetaceans

Entanglement appears to be unusual and to be reported most often among the smaller species which are found near the shore. Its impact might be most serious with the North Atlantic right whales, *Eubalaena glacialis*. This is a large whale population reduced to a remnant of a few hundred by commercial fishing which has failed to recover despite half a century of protection, and some are known to be entangled occasionally in nets (Report of the International Whaling Commission, Special Issue 10, p. 116-119, 1986). Nearly a third are also said to be scarred from unknown causes, which might include other whales (notably killer whales), rocks, collisions with ships, and fishing gear, since they frequent areas with concentrations of plankton and these areas are often important fisheries. It seems time that these whales received more study.

### Phocid Seals

While these seals are occasionally entangled in netting, the incidence is not usually high. It appears to be worst in the endangered warm water monk seal, *Monachus* sp. The only surviving species in the Mediterranean and North Pacific are both reduced to hundreds. A number of Hawaiian monk seals, *M. schauinslandi*, are known to have been killed by net fragments along the shore, and nearly a quarter of the mortality reported in Greece was also found to be due to fishing gear (J. Jacobs and A. Panou, Conservation of the Mediterranean monk seal, *M. monachus*, in Kefalonia, Ithaca and Lefkada Islands, Ionian Sea, Greece, Institute of Zoology, University of Munich, Seidlstrasse 25, D-8000 Munchen 2, Federal Republic of Germany, 221 p., 1988, per D. E. Sergeant). These species clearly deserve more attention.

### Otariid Seals

While many populations of these seals were reduced by exploitation for skins and oil in the past, most now appear to be recovering. Possibly owing to their large numbers, their tendency to feed in areas with important fisheries, and their active behavior and slender physiques, they are also among the marine mammals most prone to entanglement. Young animals which play around nets seem particularly vulnerable. While most species are maintaining their numbers, the northern fur seal, *Callorhinus ursinus*, has been declining in some areas in recent years. A number of other factors which are difficult to study, such as overfishing and climatic change, may also be involved. It seems desirable to continue monitoring the breeding populations, investigate the animals' movements and relationship to nets at sea, and compare the results with those for increasing populations.

### Chelonians

Most of the turtles now appear to be endangered, but while they do become entangled occasionally, there appears to be no evidence that this is having any impact on their numbers comparable to such factors as overexploitation for shell, meat, and eggs, disturbance of the breeding

habitat, losses in fishing nets, and ingestion of plastic material. Pelagic ridley turtles, *Lepidochelys* sp., may be the most vulnerable. The depleted Kemp's ridley turtle, *L. kempi*, is confined to one breeding beach in the Caribbean; the olive ridley turtle, *L. olivacea*, has been found entangled in the Pacific.

### Birds

Birds become entangled in nets, hooks and line, and other debris occasionally, and the reported incidence in British Trust for Ornithology (BTO) banding recoveries of the common guillemot or murre, *Uria aalge*, has increased from 5% before 1970 to 37% since 1987 (C. Mead, BTO News 163, 1989). There is no evidence yet, however, that entanglement is having an important impact on bird numbers when compared with disturbance by man and introduced predators at the breeding places, or losses due to active fishing gear or oil pollution. Some species, especially the Pelecaniformes, are also vulnerable when, to make their nests, they collect floating material which may ensnare either the old birds or their young. The species for which there is the most evidence of damage from pollution of all kinds, the northern gannet, *Sula bassana*, is nonetheless increasing explosively in most areas, even at a small colony on Flamborough Head, England, where more than half the nest material is composed to nylon netting, and where many birds also become entangled at sea.

### Fish and Shellfish

While other marine animals may become entangled in debris occasionally, there is no evidence that the resulting mortality amounts to more than a small fraction of that due to fishing. Debris-related mortality therefore seems most important as a loss from fisheries, as discussed by the working group on ghost fishing.

## PRIORITIES

The group was asked to arrange its recommendations in order of their importance. Of highest priority is the collection of more information, arranged to cover as many areas and aspects of the subject as possible. There are still many important gaps in the available information, including several inadequately studied major groups of animals where the losses may be important, such as the cetaceans, sirenians, and chelonians. There are also several inadequately studied potential problems, such as longlines and sharp objects. A large part of the world is still inadequately covered--this conference has lacked any direct representation from not only the Communist and developing nations, but also South America and Australia.

### Organization

It was thought that a more permanent organization is required to obtain information from more places. This should be composed of a limited number of representatives who are active in research on different animals, on different aspects of the problem, and in different areas. Its purpose

should be to expand the sphere of activity and maintain more continuity and consistency in recording methods. This would require the identification and enlistment of suitable people, whether in government organizations with their own resources, or voluntary bodies. Providing limited help with administrative expenses and the cost of attending meetings would be useful.

## Information

Even in areas where there is already an interest in problems caused by marine debris, there is still a need for more means of circulating information and advice. This could include such matters as the identification of the materials and species encountered, the examination of stranded animals, and the best ways to record comparable observations. It would be useful to have a simple field guide to introduce more people to the subject, supplemented with a newsletter to report further progress and results. (The Marine Pollution Bulletin would be happy to assist.)

## Research and Conservation

For purposes of economy it seems desirable to devise proposals that will cover several objectives simultaneously. These should include as far as possible the most vulnerable species in each of the main groups of animals, the most sensitive areas, the most critical threats, and mitigating measures. Five projects which between them might cover most aspects of the subject are monk seals, fur seals, right whales, sea turtles, and man.

### Monk Seals

The marine animal for which entanglement appears to pose the worst threat is the Hawaiian monk seal in the Northwestern Hawaiian Islands (NWHI), where several are known to have died as a result of entanglement in stray fragments of net along the shore and where there appears the best chance of practical action to alleviate the threat of entanglement. This area is also important in several other respects. It is one of the first nature reserves of international importance. In addition to studying the impact of entanglement on this most vulnerable phocid seal, investigations there could also cover the impact of debris on a variety of other wildlife, including entanglement of sea turtles and ingestion by albatrosses and other seabirds, in a remote situation in the tropical Pacific. Measures should include the regular collection, evaluation, and destruction of debris on both the beaches and outlying reefs, the liberation of all live entangled animals, and studies of dead ones. The situation of the even rarer Mediterranean monk seal also needs further study, which could also be integrated with a study of related issues in a much more heavily developed area.

### Fur Seals

The other marine animal where there is already evidence of serious mortality from entanglement is the northern fur seal. It also inhabits

established nature reserves of international importance. The recovery of its original vast numbers was previously a cause for general satisfaction, and any continuation of its recent decline would cause wide concern. It differs from the preceding species in its more migratory behavior, and may be encountering its most serious problems at sea away from the breeding places. At present it still has a much larger population than the endangered phocids, representing the other main group of otariid seals, so it can be studied more actively with less risk of serious disturbance and might provide interesting comparative results. It is important to continue monitoring the breeding populations, and investigations should be extended out to sea on a larger scale, both tracking animals on their feeding movements and migrations (notably by satellites), and studying their reaction to nets at sea. Such investigations should also yield useful general information about the welfare of other wildlife and the impact of marine debris further north in the Pacific.

**Right Whales**

The cetaceans for which there is possibly most cause for concern are the North Atlantic right whales (though most right whale stocks are depleted). These provide an instructive contrast to the previous species, since they are much larger, yet feed on plankton in an area with active fisheries in another ocean. Although they were originally very numerous, they were the first species seriously reduced by modern whalers and have failed to recover after half a century of protection. A certain amount is already known about them, such as the location of a small population with many scarred individuals, some of which are occasionally killed in nets. Humpback whales are regularly caught (and sometimes killed) in coastal nets in the same area, so the right whales may be encountering similar problems out at sea. It therefore seems desirable to learn more about the extent to which entanglement is a problem for this species. This might also reveal useful general information about the impact of marine debris on the most important fishing grounds in the northern Atlantic.

**Sea Turtles**

It is doubtful that entanglement is as important a cause of mortality for turtles as ingestion of debris, and it might be better to investigate the two problems together. One approach might be to study the behavior of turtles in captivity when confronted experimentally with debris. It might also be useful to try to trace individuals from satellites. The most vulnerable species, which might merit attention at an early stage, appear to be the ridley turtles. Any investigation of Kemp's ridley turtle might also yield useful general information about debris-related problems in the Caribbean. It might also be possible to integrate any investigation of the green turtle with research on the Hawaiian monk seal to obtain a better picture of events at sea in actively exploited tropical waters.

**Man**

It is surprising that there seems to have been little attention paid to the animal whose welfare is of the widest general interest. A certain

amount of harm must be caused to people by marine debris such as netting, hooks, lines, and sharp objects. It seems time for an assessment of the risks posed by various categories of debris on beaches, in shallow waters, and brought up by trawls. It might prove instructive to carry out a trial survey among medical personnel, sailors, fishermen, and divers to discover whether they can supply any information about the incidence, nature, and cost of human injuries due to marine debris. It is possible that marine debris may also cause occasional human fatalities, either directly or by disabling boats, and if so it seems desirable to assess their frequency.

## RECOMMENDATIONS

Specific recommendations included:

- Continued monitoring, removal, and destruction of lost or discarded nets and other debris presenting a hazard to monk seals, green turtles, and other wildlife in the NWHI, extending the work to the outlying reefs.

- Continued monitoring of the numbers, survival, breeding success, and incidence of entanglement of northern fur seals, extending the observations out to sea.

- Investigation of the impact of entanglement and other possible hazards on right whales in the northwest Atlantic and Kemp's ridley turtles in the Caribbean.

- A review of the long-term evidence for entanglement provided by bird banding and beach surveys.

- A survey of the injuries caused to man by marine debris.

- Observations of the movements and behavior of seals and turtles at sea using satellites.

- Collection of more information about net use and losses, and means of identifying the origin of different types of net.

- Studies of the movements and fate of marked debris, including nets, with further observations of the way in which animals react to debris at sea.

- Reviews of experience with voluntary beach cleaning, artificial reefs, and material left on the sea floor by the oil industry.

- The use of models to determine the population dynamics of different animals, the way in which processes affecting them are likely to operate, and the best data to collect to elucidate them.

- The formulation of standard recording techniques for different types of debris and victims of entanglement in order to facilitate the more systematic collection of records of entangled animals and fouled vessels.

- The preparation of a guide to types of lost or discarded nets and other debris, and the best ways to examine and treat entangled animals and record observations.

- The dissemination of warning against the particular hazards posed by rings and loops, especially uncut packing bands.

- The redesign of six-pack can yokes, so that they are broken up in use, and methods of opening cans, so that they do not leave sharp edges.

- It was concluded that, in view of the number of problems that require investigation and the wide area that needs to be covered, there is a growing need for the establishment of a representative international organization to coordinate the systematic collection and circulation of information about the occurrence and impact of artificial marine debris and possible conservation measures to mitigate its ill effects.

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# REPORT OF THE WORKING GROUP ON GHOST FISHING

(Paul A. Breen, Chair)

## OVERVIEW

Ghost fishing is a potentially serious problem because of the very large volumes of fishing gear now in use. Only a small percentage of this gear lost annually would amount to a very large loss. The increasing use of nondegradable materials such as plastic, vinyl-coated wire, and fiberglass means that lost fishing gear may persist in the marine environment for a long time.

Of the many gear types in use worldwide, the working group considered traps and gillnets to be of primary interest. Ghost fishing is well documented in coastal gillnets and in a few studied trap fisheries; it is much less well documented in pelagic gillnet fisheries. For most trap fisheries, no directed work has been done and whether ghost fishing takes place is not known. Much more work is required to study ghost fishing in specific trap fisheries and in pelagic gillnet fisheries.

Trawls and longline gear types probably cause smaller ghost fishing problems than do traps and gillnets. For other gear types, no evidence exists that ghost fishing takes place.

For American lobsters, the estimated economic waste is several million dollars annually. In other trap fisheries where it has been measured, the loss to ghost fishing appears to be a significant percentage of the reported catch. It seems certain that if other trap fisheries were examined further, serious ghost fishing situations would be discovered.

Mitigation of ghost fishing is technologically simple for traps, but requires situation-specific materials research, legislation, and industry education. Mitigation of ghost fishing by nets is more difficult. Both timed-failure devices and degradable meshes should be developed and tested for nets.

The lower priority problems of ghost fishing by trawls and longlines are poorly documented.

## GEAR TYPES

The working group reviewed the various gear types in use with respect to their potential for ghost fishing. Traps, tangle nets, and pelagic gillnets were considered to have the highest potential for ghost fishing because of their passive mode of fishing and the very large quantities

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

presently in use. Bottom trawls and coastal gillnets were considered to have the next priority. Longlines, both benthic and demersal, and lures were considered at a third level of importance.

With the many other gear types in use, the working group has no reason to suspect significant ghost fishing problems.

## FRAMEWORK

The working group devised the following framework for summarizing and evaluating the existing information on ghost fishing impacts. The following questions apply to each species, gear type, and location problem. The working group recognized dangers in generalizing or extrapolating from one species or trap type to another.

- Does ghost fishing take place in a particular situation; i.e., for a particular species/gear type/location combination?
- At what rate does lost gear catch and kill target and nontarget species?
- How is gear lost?
- At what rate is gear lost, or alternatively, how much lost gear is there?
- At what rate does lost gear cease to fish?
- What actions have been taken to reduce gear loss?
- What actions have been taken to reduce the ghost fishing life span of fishing gear?
- What actions have been taken to enhance the recovery of lost gear?

## ANALYSIS

The working group reviewed the existing data and analyses by gear type in the context of the framework devised. The analysis is presented in the format outline above. Further information on traps and gillnets can be found in the review by Breen (1990 [this document]).

### Traps

#### Does Ghost Fishing Take Place?

Ghost fishing has been documented in traps in the fisheries for American lobster and Dungeness crab through simulated lost trap studies. For the Western Australian snapper fishery, ghost fishing is suggested by a preliminary lost trap study. Ghost fishing seems likely from observations in fisheries for king crabs, snow crabs, and Pacific sablefish.

Observations and short-term escapements have been used by some workers to suggest that ghost fishing does not occur, for instance in Western Australian snapper. However, the working group considers the published evidence inadequate to reject the hypothesis that lost traps ghost fish for any species.

For most of the world's trap fisheries, the question of ghost fishing is not addressed by published reports. From studies of the few species so far examined, it seems likely that many more trap fisheries suffer from ghost fishing.

**At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?**

The rate of capture by lost gear has been measured in American lobsters at 10% of the catch rate by the commercial fishery. For Dungeness crabs in a sheltered British Columbia bay, lost traps killed 10 crabs per trap year. For Atlantic snow crabs, a lost trap fishes only for the life of the bait, then stops fishing. No capture rate estimates are available for other species.

**How Is Gear Lost?**

Trap gear is lost in a myriad of ways. Vessel traffic and tow boating sever buoylines or drag traps into deep water. Buoylines chafe and break. Buoys may become detached, or can be attacked by marine birds or mammals.

Storms and strong currents may "drown" traps. Traps may be snagged on rocky bottom. Traps are carried away by trawlers or gillnetters. Buoylines are cut by vandals or in fishing disputes.

**At What Rate Is Gear Lost, or How Much Lost Gear Is There?**

Estimates of annual trap loss rates vary from 5 to 30% based on estimates made from surveys of fishermen (see Breen 1990). For Dungeness crabs annual estimates vary from 11 to 18%. These rates are probably typical of most trap fisheries. In two surveys of Dungeness crab fishermen, it was estimated that about 50% of lost traps continue to ghost fish.

In the Alaska king crab fishery, it is estimated that 30,000 lost traps remain on the fishing grounds. In the U.S. portion of the American lobster fishery, it was conservatively estimated in 1978 that 187,000 traps could be ghost fishing.

No estimates are available for other trap fisheries.

**At What Rate Does Lost Gear Cease to Fish?**

Traps without timed-failure devices might ghost fish for years. Treated wooden lobster traps may last 2 years; metal king crab traps may last 10-15 years. No experimental results are available.

### What Actions Have Been Taken to Reduce Gear Loss?

To reduce trap loss rates, some jurisdictions have regulations that require traps to be buoyed with marked buoys. In some areas, seasonal and area closures create temporal or spatial separation of trap and other fisheries. In Washington State, buoys must be foam-filled and buoylines weighted to prevent losses from buoys sinking or vessels running over buoylines. In Washington State, trap fishermen are notified of potential gear conflicts. High technology navigation systems allow trap gear to be relocated with more precision. Educational programs have reduced gear loss.

All these actions are taken from American lobster and Pacific west coast jurisdictions. Apart from buoyage and marking requirements, little is known about actions to reduce trap loss in fisheries outside North America.

### What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

Devices to reduce the ghost fishing life span of a trap are required in all traps in Alaska, Washington, Oregon, and California; in Pacific sablefish traps in Canada; and in American lobster traps in Connecticut.

Actions taken to prevent ghost fishing outside North America have not been published.

### What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

The working group is aware of no programs to recover lost traps, except that a small-scale commercial operation once operated in Canada to recover Dungeness crab traps. In Alaska, king crab traps caught by domestic trawlers are slashed before being discarded. Trap recovery is probably opportunistic.

## Pelagic Gillnets

### Does Ghost Fishing Take Place?

Ghost fishing in a pelagic salmon gillnet was reported in a lost net recovery, and ghost fishing was documented in a simulated lost net study.

### At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

In one experimental simulation of lost pelagic gillnets, two fish were caught by 1,500 m of net in the first 3 days.

### How Is Gear Lost?

Pelagic gillnets may be lost when cut by vessel traffic, broken by storms or large marine mammals, or when the fishing vessel fails to relocate her gear.

**At What Rate Is Gear Lost?**

The rate of gillnet loss has been estimated in one study at 0.05% per set. This estimate, from the Japanese salmon mothership fishery, appears to be the only available estimate.

Density of lost gillnet fragments observed from passing vessels has been estimated in several studies presented at this conference.

**At What Rate Does Lost Gear Cease to Fish?**

Two studies suggest that nets less than 2 km long fish for only a short time after loss and then rapidly aggregate into a solid mass. The net tends to remain open longer when attached to a large buoy.

**What Actions Have Been Taken to Reduce Gear Loss?**

Japan requires gillnets to carry radar reflectors at each end of the unit to prevent cutting by vessel traffic. Radio communication is used to direct vessel traffic around nets. To prevent loss in bad weather, shorter sets are made. Japan requires nets to be marked with radio transmitters, and old gillnets to be recycled. No information is available from other countries.

**What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?**

No actions have been developed to reduce the ghost fishing life span of a pelagic gillnet.

**What Actions Have Been Taken to Enhance the Recovery of Lost Gear?**

Japan requires nets to carry radio buoys and radar reflectors, and requires old nets to be recycled. Japanese research vessels pick up fishing debris.

## Coastal Gillnets

**Does Ghost Fishing Take Place?**

Ghost fishing by Pacific salmon gillnets has been documented, and observations of ghost fishing by Pacific herring gillnets have been reported. Experimental results confirm ghost fishing in demersal gillnets in Newfoundland, New England, and New Zealand.

**At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?**

Catch rates of lost gillnets have not been estimated in any published study.

**How Is Gear Lost?**

Coastal gillnets are lost when nets become fouled on the bottom or on snags; broken by storms, marine mammals, or large fishes; cut by vessel traffic; or carried away by trawlers.

**At What Rate Is Gear Lost?**

Rates of gear loss for coastal gillnets are not immediately available. A submersible survey in a known area in New England found a density of 0.23 nets/ha. A Newfoundland study reports numbers of gillnets retrieved in direct retrieval operations.

**At What Rate Does Lost Gear Cease to Fish?**

Lost gillnets may become tangled (leadline over corkline) or balled up (tangled in the horizontal plane). Fouling increases visibility and reduces catches. No precise estimates of the rates of these processes are available. Ghost fishing has been observed in Pacific herring gillnets 7 years after net loss.

**What Actions Have Been Taken to Reduce Gear Loss?**

Most jurisdictions require proper marking and lighting of gillnets to prevent cutting by vessel traffic. Radar reflectors are required on gillnets in New England.

**What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?**

Recent New England experiments have examined degradable corklines and the effect of degradable panels along the net.

**What Actions Have Been Taken to Enhance the Recovery of Lost Gear?**

A Newfoundland program was conducted in 1975-76 to recover lost gillnets with specially designed recovery gear. In the British Columbia herring fishery, efforts are made to ensure that all gear has been recovered at the end of an open fishing period.

## Bottom Trawls

**Does Ghost Fishing Take Place?**

Ghost fishing has been reported where trawl netting was stretched across bottom features or snags.

**At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?**

No estimates of catch rates by lost trawls are available.

**How Is Gear Lost?**

Trawls are lost when the net or doors become snagged on bottom obstructions. Snagging incidents may result in partial loss of the net. Trawls have been lost when fouled by submarines.

**At What Rate Is Gear Lost?**

No rates of trawl loss are immediately available. Some logbook programs may contain this information.

**At What Rate Does Lost Gear Cease to Fish?**

No information.

**What Actions Have Been Taken to Reduce Gear Loss?**

Snag charts reduce the incidence of net loss on wrecks or other obstructions. High technology navigation systems allow trawls to be set more accurately in known areas.

**What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?**

There appear to be no actions taken with respect to trawls.

**What Actions Have Been Taken to Enhance the Recovery of Lost Gear?**

The working group uncovered no information on this question.

## Longlines

**Does Ghost Fishing Take Place?**

Pacific halibut are reported to strike and be caught on bare hooks. Lost halibut longlines may thus ghost fish.

**At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?**

No estimate of the rate of ghost fishing by longlines is available.

**How Is Gear Lost?**

Longlines are lost when snagged on bottom features.

**At What Rate Is Gear Lost?**

No estimates of loss rate or density of lost gear are immediately available. Some logbook programs may contain information.

**At What Rate Does Lost Gear Cease to Fish?**

There appears to be no information with respect to longlines.

**What Actions Have Been Taken to Reduce Gear Loss?**

There appears to be no information with respect to longlines.

**What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?**

There appears to be no information with respect to longlines.

**What Actions Have Been Taken to Enhance the Recovery of Lost Gear?**

There appears to be no information with respect to longlines.

## RECOMMENDATIONS

The working group made recommendations at three levels of priority: high, medium, and low. Within each level no attempt was made to assign priorities.

**High Priority Recommendations**

1. Fishery agencies responsible for trap and tangle net fisheries should conduct lost gear simulations to determine whether ghost fishing occurs and, if it does, the rate at which target and nontarget species are killed. If a ghost fishing problem is discovered, the rates of gear loss should be estimated through logbook programs or questionnaire surveys. In some situations, useful information might be obtained from surveys of fishing gear manufacturers.

2. Where ghost fishing has been demonstrated or is suspected in a trap fishery, the fishery agency should decide what timed-failure mechanism would be most appropriate to reduce the life span of traps and how soon to cause timed failure to happen. Research under actual fishing conditions should then be conducted to determine the most appropriate regulation for timed-failure devices. Industry should be consulted and involved in this research.

3. Further studies with simulated lost pelagic gillnets should be conducted. In order to simulate the loss of an entire net, studies should use nets approximating the length of commercial nets. More studies on smaller sections are also required. These studies should examine whether ghost fishing takes place and, if it does, then the rate of ghost fishing and the rate at which the nets form a tangled mass or otherwise cease to fish.

4. Direct observations should be made of lost pelagic gillnets to determine their shape and to determine the apparent rate at which ghost fishing for fish, birds, sea turtles, and marine mammals is taking place. These observations should be collated, made available, and distributed by a central agency such as the Food and Agriculture Organization of the United Nations.

**Medium Priority Recommendations**

1. Research should be continued and new programs developed to examine potential timed-failure mechanisms in gillnets and tangle nets. Both degradable net components and degradable mesh should be considered. In the former case, possible ghost fishing by sunken gillnets must be evaluated with appropriate experiments. In the latter case, the consequences of generating many small fragments must be examined. This research should also address the costs of timed-failure mechanisms for gillnets and tangle nets.

2. Fishery agencies should examine existing data or undertake new programs to estimate the rate of gear loss in fisheries using pelagic or coastal gillnets, trawls, or longlines.

3. Where ghost fishing has been demonstrated or is suspected with any gear type, the responsible fishery agencies should conduct research into the fishing life span of gear after loss.

4. In those fisheries for which an estimate of the impact of ghost fishing is available, ghost fishing should be examined as a mortality source in stock assessments and incorporated in fishery management plans.

5. In those jurisdictions where timed-failure devices are already required in traps, the rate of compliance with such regulations and attitudes of industry should be examined.

**Low Priority Recommendations**

1. Studies should examine whether ghost fishing takes place by longline gear, especially for Pacific halibut and tunas but also for other species as appropriate. If ghost fishing does occur, then studies should be conducted to measure the rate at which hooks of various kinds cease to catch fish.

2. Where it has not been done, charting of snags should be carried out to help vessels prevent net loss.

3. The possibility of encouraging or requiring vessels to retain recovered lost fishing gear for disposal on land should be explored.

4. Research should be initiated on possible positive effects of lost gear, especially lost traps acting as habitat for American lobster and floating masses of pelagic gillnet acting as fish aggregating devices.

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# REPORT OF THE WORKING GROUP ON INGESTION

(Louis Sileo, Chair)

This report includes a summary of the information about ingested plastic presented during the technical sessions and a summary of the working group's discussions. Both are organized by taxa and deal with the prevalence and effects of ingested plastic.

## SUMMARY OF TECHNICAL SESSIONS

Sixteen papers concerning ingestion of plastic were presented during the technical sessions. Five of these dealt with birds, two with fish, five with marine turtles, and four with marine mammals. There was one review paper for birds and one partial review each for fish and turtles. The majority (13) of the reports were of a descriptive or anecdotal nature. The latter are very useful for gathering baseline information for hypothesis generating and for defining and attracting attention to an emerging problem. Such anecdotal reports often show associations between observations, such as emaciation and the presence of plastics in stranded marine animal carcasses. However, with anecdotal data it is not possible to determine if such an association is coincidental or cause and effect. Only 4 of the 16 papers reported work with controlled experiments designed to test a hypothesis. There is need for more such studies designed to test hypotheses about the possible cause-effect nature of associations revealed by the anecdotal studies.

Most (14) of the papers presented information about the prevalence of ingested plastics: 9 papers introduced new data about the effects, usually harmful, of ingested plastic on individual animals. There were no data about those effects on the population dynamics of any species, nor about absorption of toxins from ingested plastics.

The nature and extent of the data presented in the technical sessions were summarized by taxa (Appendixes A to D); these summaries provided a basis for the working group's discussions. Crucial knowledge deficiencies were defined by the group and then given priority (Table 1). All priorities were reached by consensus. The areas of expertise of the scientists attending the working group sessions provided an equitable representation of the various taxa.

Future studies should have statistically adequate sampling schemes designed to test hypotheses that the prevalence is increasing or decreasing in given areas or taxa. Future studies of the effects of ingested plastics should also include statistically adequate experimental designs for testing

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Table 1.--Knowledge deficiencies and informational needs arranged in order of importance.

| Priority | Information needed |
|---|---|
| First | Effects on marine turtles |
| Second | Effects on seabirds |
| Third | Prevalence in marine turtles |
| Third | Prevalence and effects on manatees |
| Fourth | Effects on large fish |
| Fourth | Prevalence in marine mammals |
| Low | Effects on larval fish |
| Low | Prevalence in fish |
| Low | Prevalence in seabirds |
| Low | Effects on marine mammals |

hypotheses. It is possible that estimates of variance from studies already completed will provide the basis for determining sample sizes required for statistical significance in future studies.

Regardless of the taxon, the same three general pathophysiological effects were proposed: (1) mechanical blockages, (2) pseudosatiety, and (3) absorption of toxins from the plastic.

## RESEARCH NEEDS

### First Priority

#### Effects of Marine Turtles

Experimental feeding studies are needed to determine (1) diagnostic criteria for interpreting the lethality or other pathologic significance of loads of ingested plastic, and (2) the entire gamut of the pathophysiology of ingested plastic in turtles.

#### Justification

There are relatively few data available on the prevalence or effects of ingested plastic in turtles, but those data which do exist suggest that the prevalence is high and that ingested plastic causes significant lesions and mortality. The endangered status of marine turtles justifies a prompt look at the role of plastics in mortality. Finally, it seems that a favorable cost/benefit ratio might result from dollars invested in turtle research. So little is known that a relatively small sum may produce considerable new information.

## Second Priority

### Effects on Seabirds

Controlled experimental work is required to determine if (1) pseudo-satiety does occur, (2) the duration of retention and erosion rates of ingested plastics, and (3) the toxicity of ingested plastics. The results of such studies will establish the need for long-term population studies of things like the postfledgling effect of plastic loading of chicks.

### Justification

The available data establish that frequency of ingestion is very high in some species of seabirds and that some individuals contain very large amounts of plastic. There are few data about the effects on individual birds or populations. The few data available show no cause for alarm, but if these preliminary data are misleading, the potential deleterious effects on seabird populations could be severe. Because of the ubiquity of ingested plastic in seabirds and the as-yet-unmeasured potential for harm, it is prudent to identify the effect. Also, this group includes several threatened or endangered surface-feeding seabirds including the short-tailed albatross, *Diomedea albatrus*, which may be at risk.

## Third Priority

### Prevalence in Marine Turtles

The working group recommends continued monitoring of the prevalence of ingested plastic and its association with lesions. The monitoring efforts should be improved to better determine how often it actually causes harm. The working group recommends that review of the Marine Animal Stranding network be conducted to determine if the network's activities could be enhanced by standardizing necropsy protocols and by including collection of data about ingested plastics. Adequate diagnostic pathology services should be provided for the biologists in the Network. Even though the anecdotal data generated by monitoring programs cannot prove cause-effect relationships, they do provide useful information data bases.

### Justification

This is the same as for first priority. Also, the Marine Animal Stranding Network is already in place; it would seem cost efficient to strengthen the program and orient it to collect and analyze data on ingested plastics.

### Prevalence and Effects in Manatees

The data presented in the technical session suggested that plastic ingestion is common and was considered the cause of death of one manatee. It is recommended that carcasses found through the Marine Animal Stranding

Network be examined to obtain as much information as possible from each animal recovered.

**Justification**

There are no data about the impact of ingested plastic on the manatee population. Since this is a remnant population near extinction, any avoidable source of death is unacceptable.

**Fourth Priority**

**Effects on Fishes**

The working group recommends that laboratory work be done first with large fish to determine under what conditions they ingest plastics and to determine further the effect of the plastics. For example, will ingested plastic be retained for long periods and cause gastrointestinal tract blockages? Will it induce pseudosatiety, or release toxic chemicals?

**Justification**

Potential losses to the commercial and recreational fisheries may occur if ingested plastics impair the health of large fish. The working group assigned fourth priority to this issue because field and laboratory evidence available to date are equivocal, and as yet there is no evidence of a significant problem.

**Prevalence in Marine Mammals**

The working group recommends that monitoring of ingested plastics in stranded marine mammals be continued and improved as much as possible, taking advantage of the Marine Animal Stranding Network.

**Justification**

The working group generally agreed that available data suggest ingested plastics are a lesser problem in marine mammals and that there are no apparent reasons to elevate this issue to a higher priority at this time. It was also stated that laboratory work might better elucidate the consequences of ingested plastics, but that laboratory work with marine mammals is impractical because of logistics and legal complications.

**Low Priority**

Low priority issues are not unimportant, but they are less pressing than those above.

**Effects on Larval Fish**

The working group recommends that additional laboratory feeding experiments be done with larval fish to determine if ingested microparticles reduce growth rates.

**Prevalence in Fish**

The working group recommends that a specific study be designed to look for plastics in the gastrointestinal tract of large, free-ranging fish and for indications that it causes harm. This might be accomplished by alerting and educating fisheries biologists about the issue. This work could be done in conjunction with other on-going studies.

**Prevalence in Seabirds**

The working group recommends continued monitoring for benefits accrued (public awareness, time-order trends), but suspects that monitoring will continue without specific, directed guidance.

**Effects on Marine Mammals**

Laboratory studies of the effects of ingested plastic would provide useful data, but the group generally agreed that such studies are impractical for logistical and legal reasons.

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## APPENDIX A

Summary of information from five reports on the prevalence and effect of ingested plastics in seabirds.

### Prevalence

Many previously unpublished data were presented at the technical sessions. Ingested plastics are present in many species and the prevalence is high in some species. Prevalence between species is influenced by feeding behavior, feeding location, season, year, resident or migrant status, and whether or not chicks are fed by regurgitation.

### Effect of Ingested Plastic on Individual Seabirds

Some die from the lesions caused by impactions. Fledging weights of one species were reduced in chicks having high volumes of ingested plastic.

### Effect of Ingested Plastic on Seabird Populations

There are no data available.

## APPENDIX B

Summary of information from two reports on the prevalence and effect of ingested plastics in fish.

### Prevalence

Ingestion does occur, but the information available suggests that this is uncommon. In one study, 20 of 3,000 larval fish contained ingested plastics. Nothing is known of the prevalence in large fish. In one study, most lancetfish contained one or more pieces of plastic.

### Effect on Individual Fish

There is no clear evidence of an effect. In one study, larval fish ate 500 $\mu$ spherules, but there was no detectable short-term effect. No data are available about the effect on large fish.

### Effect on Fish Populations

No data were presented.

## APPENDIX C

Summary of information from five reports on the prevalence and effect of ingested plastics in marine turtles.

### Prevalence

The few data available suggest the prevalence is high. In one study, 8 of 15 young pelagic turtles carcasses had intestinal compactions containing hundreds of pieces of debris. There were 3,000 pieces of plastic in 1 compaction. These compactions were the suspected cause of death. In another study, 60 of 111 beach-washed turtle carcasses contained intestinal debris, and 4 died from the effects. Yet another study reported debris in 12 of 168 stranded turtles; 5 of which had blocked pyloruses. Plastic bags or sheeting seemed to be the offenders.

### Effect on Individual Turtles

Impactions can kill turtles. The few available data suggest that this is potentially a serious problem. Laboratory studies suggest that low doses of plastic have no effect.

### Effect on Turtle Populations

There is no information available.

## APPENDIX D

Summary of information from four reports on the prevalence and effect on ingested plastics in marine mammals.

### Prevalence

The data are not completely clear. One report suggested the prevalence is low, others that it is high. Plastic was found in 15% of 63 dolphins and in 6 of 82 whales in one study. Another study reported that plastic debris was present in 67% of stranded whales. This study also reported debris in the stomachs of 23 of 86 Baird's beaked whales examined; 30% of this ingested debris was plastic.

### Effects on Individual Marine Mammals

Data from both wild and aquarium specimens show that ingested debris can kill cetaceans.

### Effects on Marine Mammal Populations

There are no data available.

# REPORT OF THE WORKING GROUP ON ECONOMIC ASPECTS OF MARINE DEBRIS

(Kenneth E. McConnell, Chair)

The problem of marine debris is a classic example of markets failing to allocate resources efficiently. When firms and individuals use materials which escape into the marine environment, they impose costs on others. These costs--external costs, as they are known to economists--may be nonmarket, as in the aesthetic degradation of beaches or the killing of noncommercial species of birds and mammals. The external costs may also be incurred by market forces; for example, fishing vessels may have their propellers entangled in abandoned gear. Regardless of who suffers the external cost, its presence indicates a problem which requires some form of public policy to solve.

The marine debris problem is dominated by plastics and other nondegradable materials. Plastics have advantages in production and consumption processes that other materials lack. The replacement of plastics will therefore impose direct or inconvenience costs on consumers and producers. There are three basic ways to reduce marine debris: (1) reduce the loss and disposal of materials that may end up in the marine environment, (2) reduce the production of plastics and other nondegradable materials by using substitutes, and (3) engage in cleanup efforts.

Currently, knowledge of the economic aspects of marine debris is quite limited. This document outlines the basic economic issues and suggests research projects which would help in the process of reducing marine debris. The research projects can also serve as terms of reference for the economic issues of marine debris.

## ECONOMIC COSTS

The economic costs of marine debris are the lost economic values that occur when the debris directly influences people and their behavior. These economic costs may be categorized as aesthetic, fouling of gear and vessels, and impact on fish stocks. Knowledge of these costs can help motivate government action. This requires information not only on the physical and biological effects of marine debris but also on the economic costs of these effects. The U.S. Office of Management and Budget, for example, is especially influenced by benefits and costs, not by physical effects. These economic effects require careful research because they do not show up in market transactions.

### Aesthetics

Debris makes beaches less attractive. It traps fish and wildlife. Each of these entails an aesthetic loss to some individuals. Currently we

*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

know practically nothing of the economic costs of either. We recommend two types of studies to help understand the magnitude of the economic costs of marine debris.

### A Study of the Economic Costs of Debris on a Specific Set of Beaches

This study would pick a set of beaches and investigate the economic value of lost services that result from different levels of debris on the beach. The techniques for undertaking this research are well known to economists, but they have not been applied to marine debris.

### A Study of the Economic Costs Incurred When Some Individuals of a Noncommercial Species (e.g., Birds, Mammals) Are Entangled in Marine Debris

Economists have some experience in estimating the loss in economic value from the threat of extinction of a noncommercial species but little or no experience when only a small number of the species are lost. This study would begin the investigation of this problem.

## Fouling of Vessels and Fishing Gear

When vessels and their gear are impaired by contact with marine debris, there are two kinds of costs. The obvious cost is the repair or replacement cost for the damaged gear. Less obvious is the opportunity cost of the vessel and gear when it is not in productive service. Very little is known of this cost in the United States. There is evidence from Japan that the cost to fishing vessels is quite substantial. We suggest the following research.

### Investigate the Incidence of Impairment and the Magnitude of Costs for One of the Following Industry Groups: Commercial Fishing, Shipping, or Recreational Boating

This research project would involve a small survey among owners or operators in one of these industry groups for a well-defined region.

## Impact on Fish Stocks

The biggest impact of marine debris on fish stocks is ghost fishing. But there is also the possibility that consumers' perception of contamination of fish stocks by marine debris can influence the demand and price of selected fish products.

### Ghost fishing

The nature of physical or biological effects of ghost fishing is well known, but the quantitative effects are hard to estimate. Ghost fishing has an economic cost in terms of the lost resource. We suggest gauging this cost with a joint project involving economists and biologists.

### The Impact of Perceived Contamination on the Price of and Demand for Fish

A project which collects and describes incidence of market effects from perceived contamination would provide especially convincing evidence on the economic costs of marine debris. We suggest a survey of literature and of knowledgeable people to gather these incidents in the form of a research report. This evidence comes in the form of market price changes induced by perceived contamination.

## POLICIES TO REDUCE MARINE DEBRIS

Economics, the study of choices and behavior, is sometimes useful, sometimes essential, in thinking about and designing policies to reduce marine debris. Research on the costs of reducing marine debris needs to investigate the direct costs of adopting different techniques, the demand for the use of nondegradable materials, and the rate of compliance with various regulations among different sectors of the public and industry.

Policies to reduce marine debris require people to change their behavior. Behavior can be changed through a variety of means: education, moral suasion, lobbying, incentives, and direct regulation.

### Incentives

In 1987, 12 U.S. senators wrote to the President expressing their concern over the marine debris problem. They urged the study of various methods of reducing debris, including instituting deposits "and other incentives for retention and retrieval of debris." Incentive schemes may be especially cost-effective in controlling debris when education and moral suasion fail. The following projects investigate the use of fees and incentives as part of the solution. These projects are not listed in the order of priority.

### Deposits on the Return of Nondegradable Products

The efficiency of deposits on beverage containers as a means of controlling land debris is well documented. This research project would investigate the potential for deposits for the return of plastic marine debris. It should focus on coastal states which have experience with deposit systems.

### Fees on the Use of Nondegradable Materials

Business firms and households are good at allocating scarce resources when they pay for them. Fees on plastics would induce substitution of other materials. This project would investigate the feasibility of fees on potential debris in the marine environment.

### Incentives at the Production Level

Debris in the marine environment is part of the larger social problem of solid-waste management. The disposal of nondegradables is a crucial component of this problem. Fees on the use of nondegradable raw materials, including plastic pellets, in the production process would guide producers to substitute other materials. Such fees would raise the relative costs of nondegradable materials and make it economically more attractive to develop degradable substitutes and to sponsor research in developing substitutes. This research should investigate the demand for raw materials at the production level and the potential for fees and incentives to spur the development of substitutes including recycled plastic materials.

## Compliance

The typical approach to solving environmental problems is: to pass a law to prohibit behavior causing the problem, to devote a small amount of money to enforcing the law, and to engage in education and public awareness campaigns to persuade people to comply. This approach frequently fails, raising demands for more enforcement funds, harsher penalties, and so on. It may be fruitful to investigate alternatives to this traditional approach to compliance.

### Investigate Alternatives to Traditional Methods of Compliance

Policies combining punishment and reward which partly subsidize the adoption of techniques to help people comply and impose clear penalties for the absence of compliance are used elsewhere. For example, sewage treatment has been enhanced by Federal subsidies to construct waste treatment plants linked to the requirement that all households hook up. Methods of linking compliance to rules and regulations for handling marine debris can be used to access to other beneficial programs. For example, the registration of boats might be linked to evidence that boats have systems for handling solid wastes. This research program would study compliance programs which include education, incentives, and penalties for a specific portion of the industry. The recreational boating industry is an especially good candidate for study because boating is so widespread and boaters so heterogeneous in attitudes.

### Evaluate the Effectiveness of Moral Suasion Programs

Public campaigns to reduce pollution by moral suasion have been attempted for other forms of pollution. A study of these campaigns would help understand their failures, which have been many, and their successes, which have been few. This study should cover different countries and different times.

## Onshore Disposal

The new laws require that vessels bring their nondegradable wastes to port. Ports are required to handle the solid waste. Within particular

regions, it may be economically very costly for all ports to handle all of the vessel-borne waste. We suggest the following research project.

**Investigate the Economic Gains That Can Accrue to a Particular Region as a Consequence of Consolidating Waste Handling Facilities**

Some ports are unable to handle wastes. Other ports may have excess capacity. An economic study of the costs of onshore waste handling would prepare ports for the resource demands and for setting port fees. When the costs differ among ports, there may be incentives to use different ports. Further, there are incentives to dump the trash if fees are based on the trash that is brought ashore.

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# REPORT OF THE WORKING GROUP ON TECHNOLOGY

(William G. Gordon, Chair)

## INTRODUCTION

The Working Group on Technology, while recognizing that further work is required to quantify the types and volumes of ship-generated debris, strongly believes that technology/methodology currently exists to address management of the majority of the wastes generated at sea. The group recognizes that a considerable portion of debris originates from such terrestrial sources as careless transportation of garbage, combined storm/sewage outfalls, storm and street drains, industrial activities, beach-goers, and at-sea disposal, and that management of these sources requires application of somewhat different technologies and methodologies. However, a large measure of the ship-generated debris ultimately will be transported ashore. Thus, satisfactory resolution of much of the marine debris issue will require rational resolution of many of the terrestrial waste management issues and problems.

## SHIP-GENERATED DEBRIS

Ship-generated debris and sources are categorized in Table 1, Sources and types of ship-generated debris.

## SHIP WASTE MANAGEMENT

Technology and/or methodologies for dealing with ship-generated wastes, and their potential application, are shown in the Table 2, available technology and methodology for handling ship-generated waste.

As displayed above, there are currently available a number of techniques for addressing ship-generated wastes. However, all ultimately require some degree of transportation of the waste ashore for disposition. On-land facilities for handling such wastes may not exist, and thus at-sea disposition will continue.

The group stressed that there is no single methodology or technology which will resolve the issue. Regardless of the size of the vessel or craft, a variety of practices will undoubtedly be employed. Brief descriptions follow.

### Source Reduction

Source reduction is the use of materials on board the vessels which will reduce both quantity and volume of waste. Such practices will vary with segments of the industry and should be encouraged for all.

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Table 1.--Sources and types of ship-generated debris.

| Sources | Clean plastic | Contaminated plastic | Fishing gear | Paper | Metal and glass | Oils | Food wastes |
|---|---|---|---|---|---|---|---|
| Merchant marine | Large | Small | -- | Medium | Small | Large | Small |
| Naval vessels | Large | Large | -- | Large | Large | Medium | Large |
| Commercial fishing | Small | Medium | Large | Small | Small | Medium | Small |
| Recreational craft | Medium | Large | Small | Small | Medium | Small | Medium |
| Cruise ships | Large | Large | -- | Large | Large | Medium | Large |
| Oil and gas operations | Large | Large | -- | Large | Large | Large | Large |

**Alternate Materials**

The use of alternative materials is a simple but effective strategy for plastic waste management at sea. This may involve the replacement of a given plastic product with either a different plastic product or a nonplastic product which is more disposable. This simple approach can have a significant impact on solid waste management options for shipboard use.

Effectiveness and feasibility of incineration of waste on board a vessel can be increased by the selection of plastics which can be safely burned for use at sea. Exclusion of chlorine-containing plastics and, perhaps, the use of compounds with high factions of fillers (to reduce BTU's per pound) are possible examples.

Recycling of plastics carried to shore is viewed as a plausible means of disposal. Plastics to be used aboard vessels might then be selected to ensure optimum blend compatibility of the disposed plastic waste stream. Alternatively, the plastics can be coded to allow easy separation into the different chemical types. Replacement of nonrecyclable material such as glass and metal (usually disposed of at sea) with recyclable material such as paper and plastic is also feasible.

Reducing the plastic content of a given product can lean to substantial improvements in disposability with minimal loss of performance. Plastic films, plates, and cups, for instance, can be replaced with plastic-coated or composite materials that are more disposable. At the extreme is the replacement of plastics and glass with paper, which can be more easily

Table 2.--Available technology and methodology of disposition of debris generated at sea.

| Type of debris | Type of disposal | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Incineration | Disposal at sea | Separation | Compaction | Recycle | Degradation | Alternate | Source reduction |
| Plastic | X | -- | X | X | X | X | X | X |
| Foamed plastic | X | -- | X | X | -- | -- | X | X |
| Fishing gear | X | -- | X | -- | X | -- | -- | X |
| Paper | X | X | X | X | X | -- | -- | X |
| Metal and glass | -- | X | X | X | X | -- | X | X |
| Oils | X | X | X | -- | X | -- | -- | -- |
| Food wastes | X | X | X | X | -- | -- | -- | -- |

disposed of. In doing so, of course, the economic factors must be taken into account to make sure that the proposed substitution of materials is realistic. Substitution of materials that are easily compacted and stored on board is stressed by the working group.

## Degradation

Deep-sea disposal of many materials remains acceptable. Waste food biodegrades, paper (unless plastic-coated) degrades, metal cans (if punctured) sink, and glass bottles (if broken or if caps are removed) sink. However, plastic materials regardless of form cannot be dealt with in this way as their rate of degradation is unacceptable for at-sea disposal.

Some common plastic and fibers can be made to photooxidize and biodegrade in a controlled fashion. In both film and fiber forms they are already in use in agriculture and some packaging applications. Olefins are among those polymers which can be engineered to degrade. Nylon and polyesters presently available do not degrade in an acceptable time. Nylon can be made to photodegrade, but photodegradable nylon is not yet commercially available. The products of degradation of most polymers are environmentally innocuous.

Photodegradable plastics are compatible with other technologies. Degradable plastics can be burned normally or can be recycled to secondary products. Degradable products can cause environmental problems in landfills, as many cease to degrade under anaerobic conditions.

Degradable plastics have potential disadvantages. For example, few of the existing degradable materials have been cleared by the Food and Drug Administration for contact with food. Some degradable plastics perform differently on land than in the marine environment, and require further evolution. Thus, industry is not yet prepared to supply economically feasible plastics which can be counted on for degradability at sea.

## Recycling

Recycling of plastics is a process by which used plastic objects are collected, identified, separated (if necessary), and melt-processed into useful items. Recycling of plastic soda bottles, fishing nets, and general plastics waste is currently being done on a commercial basis. At present, probably less than 10% by weight of the annual production of plastics is being recycled. The impetus brought about by factors such as the increasing costs of dumping at landfills, the influence of environmentally concerned groups, the inherent value of the plastics themselves, which continue to increase in cost, and the profit motive for value-added products made of recycled plastics could well increase the use of recycling to as much as 50% of yearly production.

Except perhaps aboard very large vessels, recycling at sea does not appear to be a viable solution for dealing with plastics waste. A more practical approach is the establishment of recycling centers at ports receiving large volumes of plastic debris. Unless information on how much, what type, and when will it be landed is made available, industry is

unlikely to move. Accordingly there is a need to acquire much more information on the issue in order to encourage the private sector toward a positive response.

Another aspect of recycling is the reuse of plastic items for different purposes. An example of this is the use of fishing nets for decorative or recreational applications.

Recycling of various plastics together (commingling) will result in some difficulties. Commingling will reduce the value of the resultant product as it results in characteristics that are less desirable to most users. This problem must be addressed, particularly in view of the move toward laminated products of various plastics.

## Compaction

Compaction technology as wide application for resolution of waste issues within the maritime industry. For many, compaction may be the most appropriate, as all solid waste may be reduced through compaction and stored readily aboard those craft where trips are of short duration. This would include virtually all recreational boats, coastal commercial fishery operations, and coastal maritime shippers. Obviously, on-land disposal must be economical and efficient in order to encourage the practice.

For recreational and small fishing vessels, the initial problem created by the need to retain all wastes aboard ship is that none of these vessels are designed with waste retention compartments. However, they are designed with water and fuel tanks, sleeping compartments, cargo and provision compartments, and most recently with sewage holding tanks. These vessels are designed with these various compartments because either laws require them or they are necessary for the operation of the vessel. Therefore, in a way similar to sewage holding tanks, waste retention compartments could become a necessary requirement of all vessels.

One suggestion for a type of shipboard waste retention compartment might be a "shipboard waste compactor." One could be designed to run off the ship electrical system or be hand-operated. If owner-installation were possible, then some of the burden of cost to the vessel owner would be lessened. Such a device could provide for improved sanitation as well as make transfer of wastes easier. For example, the ports could store compacted wastes more neatly and securely than "untreated wastes," which are often unsightly, cause odors, and are cumbersome to store.

## Separation

Separation of all wastes by type will become part of all successful waste management practices within the maritime industries. This methodology must be fully integrated into customary practice in combination with others. All practices must be at reasonable cost and effective.

## Combustion

Combustion includes low technology burning and incineration.

### Low Technology Burning (e.g., Use of Burners)

Low technology burning has important practicabilities and benefits:

1. It can be an attractive option for compliance with Annex V.
2. It is low in cost.
3. It needs relatively little deck space.

It also has some potential pitfalls:

1. Some separation of hazardous materials is necessary.
2. Products of incomplete combustion (e.g., dioxin, furans) of a wide range of materials (including salt from the marine environment) are environmentally hazardous. Potential hazards include toxic air emissions.
3. There are current problems concerning disposal of toxic ash (which may be resolved in the near future as a result of manufacturing modifications by the plastics industry).
4. The regulatory climate concerning air pollution emissions could change in the future.

### Incineration (e.g., Insulated Combustion Chambers With Mechanical Air Control)

Incineration also has important practical aspects and benefits:

1. It is an attractive option for compliance with Annex V for ships such as cruise ships, merchant vessels, and tankers.
2. It provides operational flexibility, given the variable availability of port reception facilities.

It, too, has potential pitfalls:

1. Trained skilled personnel are necessary for proper operation.
2. It is more costly than low technology burning or overboard dumping.
3. Combustion of plastics, salt, and other materials produces air pollution emissions.
4. There are current problems concerning disposal of hazardous ash (which may be resolved in the future as a result of manufacturing changes).

5. Regulatory climate concerning air pollution emissions at sea could worsen in the future.

## LAND DISPOSAL

The working group recognizes that ultimately ship-generated debris, particularly plastics, will be transported ashore for disposition. Land facilities, therefore, must be expanded or developed to accommodate the increased volume of such materials. Shoreside receivers must be cost effective and convenient in order to encourage maximum use. Shore-based industries should be encouraged to recycle such materials; they will require considerable information on the types, quantities, and location of the materials. Governments should implement policies and incentives permitting and encouraging such initiatives, but this, too, requires a much greater level of knowledge than is currently available.

The group stressed that marine debris is clearly linked to the land and that all efforts to encourage rational waste management must be extended globally.

## RECOMMENDATIONS

### Data

More information should be obtained about types, quantities, and distribution of the plastic materials which, under MARPOL regulations, will be brought ashore for disposal. Such information should be disseminated throughout the plastics industry to encourage reuse of such material.

### Technology

Research and development of new technologies should be encouraged.

**Low Technology Burning**

1. Research on environmental impacts of air emissions.

2. Research and development of guidelines concerning materials separation and operations.

3. Research concerning environmental implications of ash and methods of disposal.

**Incineration**

1. Research on environmental impacts of air emissions.

2. Research concerning environmental implications of ash and methods of disposal.

3. Research concerning hydrogen chloride corrosion of incinerator units and accompanying potential effects on durability. Measures to address problems, if necessary.

**Ship Design**

1. New design should accommodate waste management strategies.

2. New construction should include facilities and space accommodations for waste management.

**Plastics**

1. Development or identification of the more desirable plastic mix streams for commingled plastics.

2. Development of performance standards for alternative materials used for specific product applications.

3. Development of trade-off studies on performance versus disposability.

## Policy

No single methodology or technology will ensure compliance with waste management regulations. Accordingly, no policy should be established which prohibits technologies which have potential--keep all options open.

Governments should work together to create incentives for on-land disposal wherever feasible. Recycling, for example, will be feasible only where economic conditions are ideal for such practices. Governments should take the lead to assure that new and complementary technologies are created.

## Education

Manufacturers of items such as packaging, fiber, and netting, are not aware of the capabilities and potential of programmable degradable plastics. Efforts should be undertaken to achieve broad dissemination of such information. The working group suggests that the plastics industry undertake such efforts.

There is need for a global network to disseminate information on the impact of marine debris widely and to uniformly encourage development of modern technologies or methodologies everywhere.

There is need for education throughout the private sector, aboard all classes of ships as well as shoreside, to encourage good waste management practices.

## General Views

The working group strongly endorses the need to conduct global workshops on the issue of marine debris periodically. Sessions should include technical aspects of present and emerging technology for shipboard application. Invitees should include those potentially interested in land-based use of materials.

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# REPORT OF THE WORKING GROUP ON LAW AND POLICY

(David Cottingham, Chair)

The working group reviewed existing legal and institutional arrangements to curtail the disposal and loss of solid wastes into the marine environment. Many nations have signed various international agreements and passed domestic laws that prohibit or limit disposal of plastic and other refuse into the sea, including disposal of wastes from ships. An undetermined, though probably significant, amount of marine debris originates on land. The group, therefore, concluded that solutions to the problem of marine debris should be developed and implemented in concert with efforts to address broader solid waste management issues. The most pressing needs identified include:

1. participating in the relevant international agreements;

2. assuring that adequate reception facilities are available at all ports and harbors to receive ship-generated garbage returned to shore; and

3. adopting national policies and programs, such as recycling and innovative packaging, to reduce the quantities of solid waste generated.

## CONTROLLING AT-SEA SOURCES OF MARINE DEBRIS

The international agreement of greatest importance for controlling the discharge of plastics and other solid wastes into marine waters are:

- International Convention for the Prevention of Pollution from Ships, 1973/1978, Annex V (MARPOL Convention); and

- International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention (LDC)).

The MARPOL Annex V regulates the disposal of ship-generated garbage. The LDC restricts transporting land-generated solid wastes to sea for the purpose of dumping.

At least 10 regional conventions control various forms of marine pollution, including the disposal of plastics and other solid wastes, from both sea- and land-based sources. They include:

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- Convention on the Conservation of Antarctic Marine Living Resources, 1980.
- Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1974 (the Helsinki Convention).
- Convention for the Prevention of Marine Pollution from Land-Based Sources, 1970.
- International Convention for the High Seas Fisheries of the North Pacific Ocean, 1952.
- Convention for the Protection of Marine Pollution by Dumping from Ships and Aircraft, 1972 (the Oslo Convention).
- Convention for the Protection and Development of the Wider Caribbean Region, 1983 (the Cartagena Convention).
- Convention for the Protection of the Mediterranean Sea Against Pollution, 1976 (the Barcelona Convention).
- Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, 1978.
- Convention for Cooperation in the Protection and Development of the Marine Environment of the West and Central African Region, 1981 (the Abidjan Convention).
- Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, 1982 (the Jeddah Regional Convention).

The latter five are part of the United Nations Environment Program Regional Seas Program.

The working group concluded that these international conventions jointly prohibit the disposal of plastics and other solid materials in the sea, thereby establishing this prohibition as "customary international law."

Of 131 nations that are members of the International Maritime Organization (IMO), 36 have ratified optional Annex V of MARPOL as of April 1989. These countries account for approximately 56% of the world's total gross commercial shipping tonnage. Many signatory nations are still in the process of developing programs to implement Annex V. In particular, many ports do not have adequate or convenient facilities for accepting ship-generated garbage.

Annex V identifies five "special areas"--the Baltic Sea, Red Sea, Mediterranean Sea, Black Sea, and "Gulfs Area." Within these special areas, ships are prohibited from disposing of all solid wastes (except comminuted food wastes beyond 12 nmi from shore). Before these provisions

can become effective, however, 1) each adjoining nation must certify that it agrees to designation of the area as a special area, and 2) that its ports have adequate reception facilities for handling ship-generated garbage. All nations surrounding the Baltic Sea have notified IMO. As of 1 October 1989, special area provisions in the Baltic Sea became effective. The Marine Environment Protection Committee (MEPC) recently added the North Sea as a special area. The United States is proposing to add the Gulf of Mexico as well.

## CONTROLLING LAND-BASED SOURCES OF MARINE DEBRIS

Many items which become marine debris wash or blow into oceans and estuaries from landfills, municipal sewer systems, recreational beaches, industrial outfalls, illegal shoreline dumping, and other sources. Controlling land-based sources of persistent marine debris raises difficult problems which all nations must address domestically. International agreements are not well suited for controlling wastes from sites located on land.

Working group participants discussed the problems associated with effectively handling municipal and industrial solid waste throughout the world. Developed nations produce the largest per capita amounts of solid waste and generally have systems in place to dispose of it. Developing nations, on the other hand, frequently lack effective solid waste collection and disposal systems. Problems caused by marine debris in developing nations must be viewed within the context of their overall ability to handle all solid wastes. In such countries, marine debris may be a relatively small component of problems associated with handling solid wastes.

In the United States, responsibility for controlling nonhazardous wastes rests with the state and local governments. State and local agencies throughout the country have antilittering and dumping laws. However, enforcing these laws is difficult and penalties for violating them are not severe. Most local agencies, like the municipally operated Keep America Beautiful and Don't Mess With Texas programs, concentrate efforts on informing the public through antilitter campaigns.

Working group participants discussed the importance of reducing the volume of ship-generated solid waste by modifying ship stores purchasing and having rigorous onboard waste management. Current packaging systems often include throwaway containers, many of which could be recycled if systems and markets existed for the initial products and the recycled material. Japan, Denmark, parts of the United States and Canada, and other countries require people to separate newspapers, aluminum cans, clear and colored glass, and some plastic bottles for recycling. Seattle officials estimate that its recycling program, with curbside residential pickup of separated refuse, has reduced the volume of solid waste by 40%. Recycling has proven to be an effective way to remove aluminum and glass containers from the solid waste stream.

## IMPROVED TECHNOLOGY

Although the subject of advanced technology was addressed by another working group, the Law and Policy Working Group briefly discussed ways to encourage research on degradability of single-use items such as plastic cups, plastic eating utensils, plastic bags, and tampon applicators. Degradable products may be a partial solution to the problem of marine debris. However, application of this technology requires further consideration of what happens to them as they break down. For example, wildlife may be just as likely to ingest the smaller fragments produced as plastic items degrade.

## WORKING GROUP RECOMMENDATIONS

The Working Group on Law and Policy recommends that the following actions be taken by the IMO, national governments, and private industry:

### Loss and Disposal of Garbage From Ships

1. Nations that have not yet ratified MARPOL Annex V and any regional conventions applicable to them which restrict disposal of solid wastes into marine waters should do so as soon as possible.

2. Nations which have ratified MARPOL Annex V should accelerate efforts towards full implementation of required provisions for port reception facilities.

3. The MEPC of IMO should review its guidelines for port reception facilities for garbage to facilitate effective implementation pursuant to Annex V of MARPOL. The MEPC should give particular attention to: 1) recovering or defraying the costs of operating port reception facilities and handling wastes (e.g., through recycling and refuse separation); 2) methods for handling various types of wastes; and 3) simplifying the steps and procedures that vessel owners and operators must follow to use port reception facilities.

4. The MEPC nations should consider measures which could ensure that vessels do not leave ports with garbage on board, for example, consistent fee systems.

5. National governments should provide information and, where possible, economic incentives to help ports comply with port reception facility requirements of Annex V. National governments also should assist local port communities where significant increases in the volume of solid waste result from the installation of new port reception facilities. For example, in the United States, Federal and state officials should expedite reviews of applications and permits for landfills and incinerators in port communities in developing

recycling programs, and expedite review of applications and permits for disposal facilities made necessary by increased wastes from ships.

6. Governments and port authorities should develop incentive systems, such as requiring or including off-loading fees as part of docking fees, rather than penalties to encourage compliance with Annex V.

7. The IMO should consider expanding Annex V guidelines or developing other forms of providing advice on the development and use of vessel logs for tracking the handling and disposal of ship-generated garbage.

8. Nations adjacent to special areas of Annex V should accelerate the development of port reception facilities to enable special area provisions to become effective at the earliest possible dates. In particular, nations bordering the Gulf of Mexico should take steps to designate the gulf as a special area under Annex V.

9. Governments should consider sharing collection and refuse transportation costs.

10. Governments should consider developing uniform signage and coloration standards for refuse and recycling facilities.

**Shoreline Sources of Marine Debris**

1. Nations should examine ways to prevent garbage and litter from escaping from landfills, industrial outfalls, sewage outfalls, and harbors or washing from beaches and shorelines into coastal waters.

2. Regional seas programs should provide technical assistance to member nations on siting disposal facilities and handling solid wastes in coastal areas.

3. Industries manufacturing or transporting plastics and plastic products should ensure that plastic resin pellets are not lost into the marine environment during handling.

4. All levels of governments should encourage recycling programs to reduce the volume of material which becomes solid waste. For instance, in Japan the plastics industry, in cooperation with fishing villages, has found ways to collect and recycle gillnets and trawl nets.

5. Governments should require that ships and barges transporting solid wastes be fully covered to prevent debris from dropping or blowing into waterways. Transfer facilities should be required to have booms and skimmers in

place to remove refuse which enters waterways, and load limits and maximum heights for barges should be prescribed.

6. The Environmental Protection Agency and coastal municipalities should consider developing and requiring installation of equipment to prevent items in combined sewer overflows from entering waterways.

7. National governments should require that governmental entities preferentially purchase recycled goods.

**Compliance and Enforcement**

1. Governments party to MARPOL Annex V should develop incentives to encourage vessel owners and operators to comply with garbage disposal provisions.

2. Vessel owners and operators should be encouraged to report to national authorities and IMO those ports and harbors in Annex V signatory nations that do not have adequate port reception facilities. They should also be encouraged to report ports in nations which are not party to Annex V. For example, in the United States, the U.S. Coast Guard should publicize citizen reporting networks and encourage Coast Guard Auxiliary members to report violations of marine pollution regulations, including the absence of required port reception facilities.

3. The IMO should encourage member nations to develop innovative enforcement policies, such as requiring ships to offload plastic refuse before they sail and providing inexpensive refuse removal.

**Technology Improvements**

1. National and local governments and private industry should develop institutional arrangements for recycling fishing nets and other large items that may potentially become marine debris.

2. Fisheries agencies should require time-release devices on crab, lobster, and fish traps and pots to avoid long-term ghost fishing by lost gear. Use of degradable material for selected components of drift net gillnets and other types of fishing gear should be required.

3. Private industries should conduct research on enhanced-degradable single-use plastic items such as cups, utensils, packing materials, and tampon applicators. The research also should examine by-products of degradable plastic materials and potential impacts on marine wildlife.

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# REPORT OF THE WORKING GROUP ON MARINE DEBRIS EDUCATION

(Kathryn J. O'Hara, Chair)

Recognizing the difficulty of enforcing marine debris laws, especially at sea, education has been identified as an important way to help reduce the marine debris problem. Under the assumption that an informed public will be much less inclined to generate marine debris during both commercial and recreational activities, compliance with laws and regulations should be much higher. Education is particularly important in this issue because land-based sources of debris are primarily nonpoint, having diverse contributors that would be difficult to control under regulatory authorities alone. Moreover, longstanding, customary international law has permitted garbage discharge for ships in transit. Therefore, ethics and behavior patterns for individuals both on land and at sea must be changed, and education is the best known means for effecting such changes.

Charged with assembling a comprehensive list of the types of educational materials currently in use, the Working Group on Marine Debris Education identified more than 100 different types of educational materials. This included 21 brochures, 19 reports, factsheets and special documents, 11 posters, 10 videos, 9 curriculums and guides for educators, 6 newsletters, and more than 30 other types of educational materials ranging from public service advertisements to bumper stickers and coloring books. A complete listing of educational materials currently available may be obtained by contacting the National Oceanic and Atmospheric Administration's Marine Debris Information Office operated by the Center for Marine Conservation in Washington, D.C.

The working group was also charged with making recommendations for: (1) production of new educational materials and priority audiences for marine debris education, including the best means for delivery; (2) appropriate methods for the effective dissemination and utilization of these materials; (3) appropriate means for evaluating the success of educational programs; and (4) evaluation of lessons from the development of past marine debris educational programs and materials that may be of value in formulating environmental education programs in the future.

## TYPES OF EDUCATIONAL PROGRAMS AND TARGET AUDIENCES

Marine debris education encompasses two key elements: The implementation of educational programs and the development of educational materials. With regard to the former, the group recommended that marine debris education should be incorporated into three primary types of programs:

1. formal education in a structured academic setting;

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*In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

2. informal education outside a formal academic setting but within structured educational events such as adult education classes and organized youth groups; and

3. general public awareness.

Marine debris education has been or is presently being conducted for many groups, including: plastics manufacturers and processors, offshore oil and gas workers, commercial fishermen and processors, military personnel, politicians, solid waste managers, port and terminal operators, commercial shippers, teachers and educators, elementary, middle, and high school children, college students, recreational fishermen, recreational boaters, charter vessel operators, operators of cruise ships, cruise ship passengers, and the general public.

Several new groups would benefit from education and should be included in future efforts. These are the packaging industry; municipal sewage treatment operators; government officials; government enforcement agencies; coastal tourist industries; tackle manufacturers; operators of small ports, docks, marinas, and yacht clubs; suppliers of stores for vessels; boat manufacturers; employees of retail stores (including fast-food and convenience stores, and fishing and boating stores); environmental and conservation organizations; the media; employees of shipyards; longshoremen; and coastal hunters. Specialized efforts should be directed toward native and rural people.

Among all the groups identified above as target audiences for marine debris education, the working group concluded that five major groups are priority audiences:

1. all marine user groups;

2. the media;

3. teachers and educators;

4. school children; and the

5. general public.

A public awareness campaign is of utmost importance at the present time. Specific elements that should be addressed in developing this campaign are an initial assessment of human behavior and public perception of the marine debris problem. Using this information, a mass media public awareness campaign should then be developed. The working group felt that paramount to the success of this campaign is the development of a comprehensive strategy to use the media effectively as a tool to disseminate educational information. One suggestion was to solicit pro bono support from the National Advertising Council or a similar group. The working group also recognized that substantial funds are necessary to create this campaign.

## EFFECTIVE DISSEMINATION AND UTILIZATION OF MATERIALS

After reviewing the list of marine debris educational materials, the working group concluded that there is a wealth of materials currently available but there is a need to facilitate the dissemination of these materials to appropriate groups. In 1988, the National Oceanic and Atmospheric Administration's Marine Entanglement Research Program established two Marine Debris Information Offices, which respond to requests for information on marine debris. The working group suggested that the dissemination of marine debris educational materials would be facilitated if the function of these offices were enhanced by increasing their visibility as an international resource center and providing them with sufficient quantities of educational materials to meet the demand. It was also suggested that an informational vehicle be established to provide updated information on the development of new educational materials and programs. There was an opinion, however, that educational materials should be disseminated in a more decentralized manner.

The dissemination of educational materials could be facilitated with assistance from established education organizations such as the National Marine Educators Association.

Existing government distribution mechanisms such as licensing and registration procedures for fishing and boating should also be used to disseminate materials.

The working group recognized the difficulty of disseminating educational materials on an international level due to the diversity of cultures and languages. However, it was suggested that specific international agencies such as the United Nations Environmental Programme, Food and Agriculture Organization, and the International Maritime Organization should be encouraged to take part in information exchange.

Efforts should be made to include the marine debris issue on the agendas of international conferences and meetings that address the issues of marine pollution and education.

## EVALUATING THE SUCCESS OF EDUCATIONAL PROGRAMS

Evaluations could be conducted through long-term monitoring of beach debris and monitoring the usage of shoreside refuse reception facilities.

Formal surveys should be conducted, where possible, to assess changes in attitude and behavior.

## LESSONS LEARNED FROM THE DEVELOPMENT OF PAST MARINE DEBRIS EDUCATIONAL PROGRAMS

Specific recommendations made with regard to development of educational programs and materials included:

- Involve members of the target audience in the development of educational materials and distribution.

- Identify specific discrete tasks for the involvement of individuals.
- Set realistic goals.
- Make educational experiences positive and enjoyable.
- Be familiar with the audience.

Other experiences shared by group members who have been involved in educational efforts pertained to the content of educational materials. This included the need to:

- Use good photographic materials that show the impact of debris.
- Personalize the message to specific target audiences.
- Emphasize the benefits to a group for their involvement in efforts to reduce the marine debris problem.
- Emphasize the importance of individual efforts.
- Emphasize economic impacts where appropriate.
- Keep the information as locally relevant as possible.
- Keep the message short.
- Highlight positive steps taken by groups or individuals to reduce the marine debris problem.
- Use facts that are updated and verified.

The working group suggested that researchers who are working on the issue of marine debris should be encouraged to make photographic materials available for educational efforts.

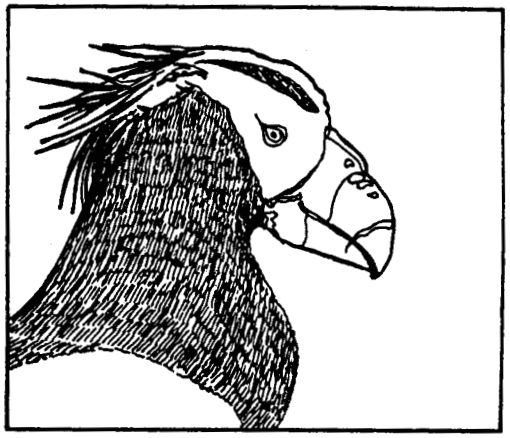
## FORMULATING FUTURE ENVIRONMENTAL EDUCATION PROGRAMS

The working group also discussed the need to expand educational efforts to include the way in which debris affects estuaries and inland waters. There was considerable discussion with differences of opinion regarding the emphasis of marine debris educational materials and programs. The majority of participants agreed that the primary focus of marine debris educational materials should be to increase awareness of the problems caused by improper disposal of man-made wastes in marine areas. Others suggested that marine debris educational efforts should also emphasize the need for source reduction and the broader issues of wasteful consumer habits. It was agreed by all working group participants that the marine debris issue is part of the larger solid waste problem and, therefore, we should incorporate lessons learned from dealing with solid waste into marine debris education materials and programs.

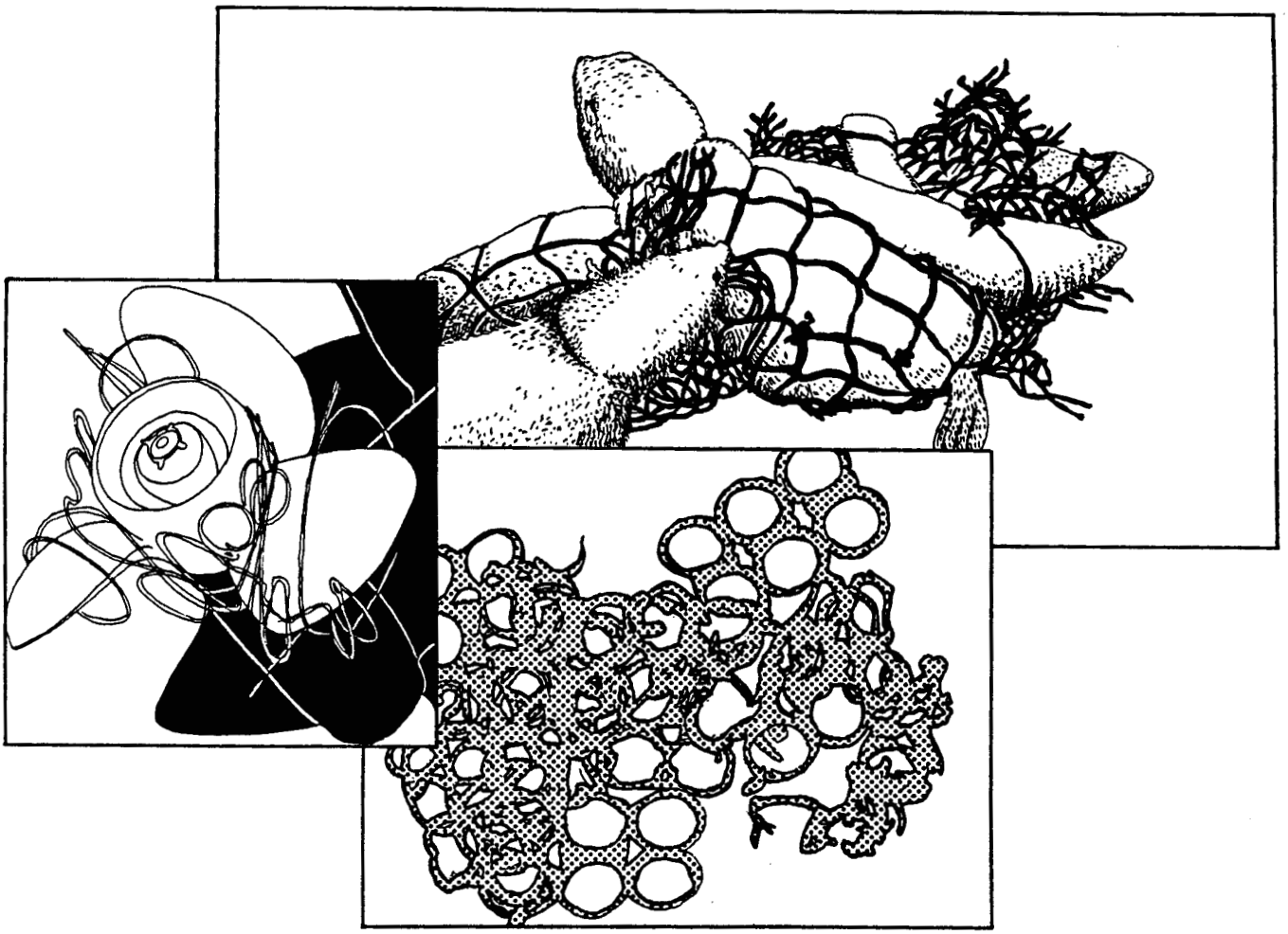
The working group recognized that the marine debris issue has elicited an unprecedented emotional response and enthusiasm to take action. Therefore, the group sees great potential for using the marine debris issue as a stepping stone to encourage citizen involvement in other environmental issues.

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## APPENDIX B

## AGENDA

1. Opening of the conference
2. Presentations
   a. Overview papers
   b. Session I - Amounts, types, distribution, and sources of marine debris
   c. Session II - Entanglement of marine life and ghost fishing
   d. Session III - Ingestion by marine life
   e. Session IV - Economic impacts on vessels and shorelines
   f. Session V - Solutions through technology
   g. Session VI - Solutions through law and policy
   h. Session VII - Solutions through education
   i. Poster presentations
   j. Video presentations
3. Working group meetings
4. Plenary session
5. Conference summary and closing

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