CHAPTER 7 CONSERVATION OF MARINE HABITATS AND THEIR BIOTA

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INTRODUCTION

The title of this book is provocative. The term 'threatened habitats' is defined elsewhere in this volume, but it is one thing to arrive at a definition, quite another to identify such habitats. The nature of threat, particularly within the three-dimensional space of the sea, is even more difficult to determine. Therefore, I ask: on what basis can we circumscribe marine threatened habitats? Are not all habitats threatened, taking interconnecting ecological processes into account? On what basis may management proceed? Finally, how does the concept of habitat relate to the broader entity of the ecosystem, which has lately come to be recognized as the objective unit for management?

Clearly, there is a need for conservationists to define better how habitats may be selected for protection. I will attempt this chore for marine ecosystems and their biota by focusing attention on critical habitats. But at the outset, I must draw attention to the obvious fact that decisions about conservation and resource use will most often be made well in advance of acquisition of data necessary to predict the impacts of human activities. For example, a primary goal of conservation is the long-term maintenance of resources and their ecological support systems. This immediately and inevitably involves value judgements on at least three levels - individual preferences, social norms, and ecological functions (Andrews and Waits 1978). First, judgements must be made about what elements of the environment we may choose to identify as resources. Then, the threats to those identified elements must be determined, their habitats delineated, and management practices established. Obviously, conservation of a climax ecosystem-resource will involve different management practices from a sub-climax ecosystem resource; one manages habitats for caribou andmoose quite differently. Equally obviously, management practices will be in conflict if different values are judged to be of equal merit within the same geographical area. The nature of threat, thus, directly emanates from priorities for conservation - ie threat to what?

Living resource protection and the identification of threat are, certainly, not simple tasks. Geist (1978) points out that: 'We need to conserve resources in order that economic activities may continue. Alas, this is a false start. Resources are always defined by a given economic system, and only it determines what is not a resource.

Therefore, conserving resources implies only the perpetuation of the appropriate economic system.... We have to start, therefore, at a more basic level'. In my opinion, this should be the level of ecological process and evolutionary adaptation. This is especially important for marine conservation. In the first place, the definition of marine resources mostly revolves around what is commercially exploited. Secondly, economics dominate marine resource-use to a far greater extent than for terrestrial resources. These facts strongly alter the essence of conservation in the sea compared with that of the land. For example, conservation action in the sea often is restricted to limitations on commercial take, and little else. The fact that marine fishes also need resources, both food and space, hardly enters the picture.

Any definition of conservation involves the interaction of human society, as a whole, with resources and their habitats. Conservation, thus, refers to an entire scope of activities ranging from natural resource development to strict protection and includes research, ecological assessment, legislation, value judgements, habitat acquisition and restoration, etc. Holt and Talbot (1978) point out '... the need for conservation arises essentially because any group of users usually will give relatively greater weight to present values with respect to future values, than does the larger group of which the user group is a part'. Thus, conservation should be a means for adjusting short-term uses and needs so as not to jeopardize longer-term values and future options. Holt and Talbot have provided a summary of a workshop that concerned both marine and terrestrial resources and that evolved the following principles:

'The privilege of utilizing a resource carried with it the obligation to adhere to the following four general principles:

1. The ecosystem should be maintained in a desirable state such that:

   a. consumptive and non-consumptive values could be maximized on a continuing basis;

   b. present and future options are ensured; and

   c. risk of irreversible change or long-term adverse effects as a result of use is minimized.

2. Management decisions should include a safety factor to allow for the fact that knowledge is limited and institutions are imperfect.

3. Measures to conserve a wild living resource should be formulated and applied so as to avoid wasteful use of other resources.

4. Survey or monitoring, analysis, and assessment should precede planned use and accompany actual use of wild living resources. The results should be made available promptly for critical public review.

The workshop did not go beyond principles into strategies or tactics specifically, but the implications of these principles are very far-reaching. It is significant that much legislation and several international agreements agree with these principles, at least in part.

Examples include conventions for Antarctica and use of many ocean resources, as well as national park and fisheries legislation of many states. However, it is also significant that few government bureaus or other institutions are ecologic or integrative by nature. Most are limited to specific issues, making difficult or impossible the task of living resource long-term protection in the face of interacting, diverse, and often subtle threats to sustainability.

This paper is concerned with the applicability of such principles, as are quoted above, to the seas and their resources. It will examine a strategic approach toward marine conservation and present a method - that of 'critical habitats' - for the identification of resource values and the threats to them. In order to do so, however, we must first examine the essential nature of the sea itself, and our approach to it.

THE MARINE DIFFERENCE

Reichle et al (1975) state, in considering the characteristics of ecosystems, that: 'A system is a complex of interacting subsystems which persists through time due to the interaction of its components. The system possesses a definable organization, temporal continuity, and functional properties which can be viewed as distinctive to the system rather than its components... The ecosystem possesses a definite organization in its trophic structure and, indeed, this structure remains relatively constant in spite of disturbances.'

Reichle et al also point out that essential to the function and persistence of ecosystems are:

1. Establishment of an energy base,

2. Development of an energy reservoir,

3. Recycling of elements, and

4. Regulation of rates.

Further, ecosystems evolve towards 'maximum persistent biomass'. Material cycling, energy transfer, and other ecological processes are thus dependent upon the biota.

With these considerations kept in mind, it should be obvious to those familiar with ecological processes that marine ecosystems are quite different from terrestrial ones, and their management must, consequently, be so adjusted. Also consider approaches towards preservation of species diversity. At the species level, the land is about 4 times as diverse as the sea, but at the class level, it is some 20 times less so. This represents a striking difference in both perception and analysis, which will have major management consequences.

Ray and Norris (1972) emphasized that 'the human view of the sea is, in general, the top of it'. They contrast aquatic and terrestrial habitats as follows: '... while rather little life exists in the atmosphere, the hydrosphere contains the major variety of mass of life on this planet. Instead of there being a skim of life as we find on land, usually less than a few metres thick, in the sea life occupies the whole water column, in addition to forming a skim on the sea bottom. This is true whether there is light or not, and most of the sea is utterly black, except for occasional flashes of biological light'.

'While the winds of the atmosphere sweep around the earth, they carry rather little with them; dust, aerosols; a few insects and spiders and some birds, all of which utilize the atmosphere only for transport. The air is not an ecosystem; there is no nutrient recycling there. Even populations of airborne micro-organisms are attenuated in the atmosphere by rain. The sea is the opposite. It's a bouillabaise of animals and plants, of uncountable microscopic organisms, of nutrients, of degradation products of life, of inorganic contributions from land, from chemical precipitation, and of dust from the atmosphere. Its 'winds', which are the ocean currents, move at all levels from the surface to the deepest sea where water generally creeps northward from the Antarctic Convergence. With them move nutrients and life and clouds of reproductive products, and of larvae, so that no part of the sea is ever free of the replenishing supply of life suited to it, save those places where man has so altered the conditions of life that occupancy is not possible'.

Foremost, in the sea, the resource use situation is very different from that on land where man has learned to harvest (the gathering of a cultivated crop) living resources. There is very little true harvest or aquaculture that includes habitat management) in the sea; rather, humans are still largely hunter-gatherers of living marine resources, relying on the natural productivity of marine and coastal ecosystems for food and other living products. Advanced technology for the increasing use of ocean and coastal resources is developing rapidly, but institutional and legal frameworks for management of habitats have not yet matured. This paradoxical situation is a striking component of what I earlier termed the 'marine revolution' (Ray 1970).

Second, the need is obviously great for addressing conservation problems on the scale at which they occur. For most marine conservation needs, even many coastal ones, the most appropriate scale is regional or multi-national in order to reflect both the wide distribution of species populations and the effects of man's use on those areas. The eventual goal, therefore, is no less than the understanding of coastal and ocean ecosystems and the effects of human activities on them as a whole.

This matter of the huge scale of marine ecosystems has led, in fact, to statements that marine ecosystems differ from those on land by their lack of boundaries. The sea's habitats and ecosystems are no less encompassed than terrestrial ones; their boundaries are simply less discernible and less geographically stable than those of the land. Isotherms, water masses, salinity differences, etc, are true barriers, but are indeed difficult for terrestrially-oriented mentalities and land-derived legal and management systems to deal with. The sea's habitats differ from those on land largely due to relative inconstancy in space and time. A tropical forest doesn't move much; water masses vary not only seasonally, but also among years, often quite unpredictably.

For example, the sea ice of the boreal and austral seas is largely seasonal. The movements of krill, whales, seals, and walruses are dominated by it. Even primary productivity varies in a major way in accord with its extent, type, and percent of ocean that it covers. Yet, from year to year, the sea ice may display large differences in all these respects, in accord with meteorologic and oceanic processes. Predicting where and when biota may be most abundant is akin to predicting the weather! For temperate, inshore seas, the seasonal and temporal variations are notorious. Of course, some habitats - coral reefs, for example - are relatively stable. The point is that all habitats vary in time and space, but the scale is very different between marine habitats and terrestrial ones. The result is that both science and management must be placed on similarly different scales. This very often presents formidable problems for managers, in particular those that deal with habitat 'protected areas'.

Finally, most of the world's people, variously estimated at between 50 and 70 percent of the total billions, live in what is termed the coastal zone - at once the most peopled, most productive, and most polluted and perturbed biome of our planet. The coastal zone is a true ecotone, or transition zone, which includes the ocean zone over the continental shelf. Such transition zones are among the most dynamic and most difficult to comprehend in all the natural world. In the sense used here, the coastal zone includes the entire continental margin, ie the area of land and sea where terrestrial and oceanic processes strongly interact, both now and into the recent glacial past. Ray et al (1980) define it as follows: 'The coastal zone is a broad band of land and water where ecological processes - such as biological production, consumption, and the exchange of materials - occur at very high rates. Human activities on land directly and strongly influence these processes in the marine environment and vice versa. The landward boundary can be defined in several ways because of the inland influences of the marine environment. The seaward boundary is also variable because of the changing influences of human activities and terrestrial processes in the marine environment'.

Obviously, it is necessary in defining this zone to consider both national policy and international law; that is, a purely biophysical definition is not complete for management purposes. The coastal zone includes many of our most immediate marine conservation problems. A serious consideration concerns whether to treat it as a separate entity - neither land nor sea, but with characteristics of both.

The general tendency has been to treat the coastal zone as an extension of land and from a local perspective, but this surely is an oversimplification. For example, would one treat a terrestrial watershed as a province of forestry or of hydrology? Or can one treat estuarine species apart from the seas where they may live the greater portions of their lives? Obviously, there is no simple answer. About all we can do is to combat a disciplinary approach in favour of integrating ecological processes, and with great sensitivity for the similarities of habitats, as well as for their differences.

A STRATEGIC APPROACH THROUGH CRITICAL HABITAT ANALYSIS

It is especially true in the sea - and along our coasts - that we are still largely ignorant about the structure and dynamics of natural systems and the effects of our activities upon them. This not only makes very difficult the task of predicting consequences of threat, but also the perpetuation of what is 'desirable'. It is becoming increasingly apparent that human activities often result in unexpected and far more extensive consequences than anticipated, due to 'cascade' effects or 'residuals' that may result from seemingly innocuous activities. Therefore, human activities must be better planned and managed so as to protect the natural systems of which humans are a part and on which they heavily depend. Moreover, most resource management and conservation decisions are made on single issues (eg single species), for single sites (eg a threatened area), often on an ad hoc basis which ignores the cumulative, synergistic, and regional consequences of human activities and which does not result from any analytical process. Single-issue or site-specific decisions often lead to inefficient, incomplete and ineffectual results. Thus, there is a need to re-orient the tactics of single-issue, site-specific decisions towards comprehensive strategies for regions as a whole. This is no less true for management or development than for conservation.

The World Conservation Strategy (IUCN-UNEP-WWF 1980) states three main objectives:

- To maintain essential ecological processes and life-support systems

- To preserve genetic diversity; and

- To ensure the sustainable utilization of species and ecosystems'.

The second of these objectives has had the overwhelming attention of conservationists; the other two are still relatively neglected. Yet, these other two are at the heart of marine conservation. It is my belief, in fact, that over-concentration on species preservation, which is not as great a problem by sea as by land, save for certain higher vertebrates, has actually distracted attention from the overwhelming need to launch a meaningful marine conservation effort based on ecological processes and habitat maintenance, recognizing sustainable utilization. But whatever our individual perceptions, the need should be clear for a strategic approach as contrasted with the ad hoc emphasis of the past.

What is strategy?

Dasmann et al (in prep) summarized strategy by stating that its goal: '... is to provide a systematic overview that can help guide and complement present and future ... 'tactical' actions. Strategic assessment is useful for short-term decisions, but is essential for long-term planning, especially where it is desired that conservation and development accompany one another. Strategic assessment should result in a synthesis of presently available information that may be used, for example, to:

1. Identify potential conflicts and compatibilities among economic development projects and natural resource sustainability ...

2. Reveal the residual and cumulative or synergistic effects of a wide array of human activities ...

3. Select 'core' and 'buffer' areas for special management status ...

4. Identify research needs, data gaps, and monitoring requirements in order better to safeguard natural resources through an increasing data base; and

5. Allow wider participation in decision-making through explicit analyses and syntheses of data.

At the outset, it must be recognized that strategic assessment can be extremely cost-effective, as it can reveal ways to avoid costly duplication and it can predict where future problems are likely to occur. Furthermore, strategic assessments ... are highly 'adaptive; that is, they are dynamic allowing for adjustments to be made according to altered circumstances, rather than being static and fixed in time and space.'

The last point is important; Holling (1978) presents an especially useful treatment of the concepts and methods of adaptive environmental assessment and management.

Critical habitat analysis

The critical habitat approach is a strategic attempt to cut through the problem of making decisions about areas which require special protection, even though we may be largely in ignorance of the details of species biology or ecosystem function, as is all too often the case in the sea. It is designed specifically to show relationships among diverse sets of information, including gaps in data that must be addressed as a matter of high priority. Analysis of habitats, biota, and threats to them must often be based upon the best use of available data in advance of engendering large-scale research and monitoring schemes which usually cannot influence decision-making from the start. At the very least, it highlights areas within regions deserving special protection status. It also directs research towards the highest priority needs. At best, it helps direct our attention towards the cumulative, pervasive, long-range effects of our actions and to integrative ways and means that can help resolve conflicts between living resources and the demands that human activities place upon them.

There are several aspects to critical habitats analysis, incorporating two basic processes - that of identifying highest priority habitats and that of selecting, from the identified areas, those for immediate conservation action. I will now review each briefly, leaving the detail of methods to the references cited.

Classification: The first task is to place habitats within a regional context, that is, to make an effort towards regional classification and characterization. Every marine or coastal habitat may be placed within an oceanic realm or specific coastal zone. The continental United States, for example, falls between the eastern North Atlantic and western North Pacific Realms. Alaska's northern coasts are within the Arctic-Boreal Realm. The Gulf of Mexico is a sub-province of the West Indian region. Each of these units has its own peculiar features, which may be revealed by 'characterization', for which resource use conflicts are often quite specific. There is not adequate space here to go into detail on characterization; suffice it to say that there are several multivariate techniques (eg principal component analysis or biotic analyses of various sorts) capable of pointing out the principal covariant features of an environment. Such analysis is capable of revealing how the basic realms of the seas or coasts are subdivided. For example, for the USA continental coastal zone five basic regions have been identified. These are: 1. East Coast, 2. Gulf Coast, West Coast 4. Gulf of Alaska - North Pacific, and 5. Alaskan Ice-stressed Coasts.

Each of these may, in turn, be sub-divided into subregions, eg the East Coast's boreal-Acadian, north temperate-Virginian, south temperate-Carolinian, and West Indian-Floridian. The biota of each of these has its own central features and may react to human perturbation quite differently for physiological, behavioural, or ecological reasons; that is, temperature changes have quite different effects in cold versus warm habitats. The result of 'characterization' is a classification scheme to which the criteria of 'representativeness' or 'uniqueness' may be applied (see the Selection Process, below).

The terrestrial 'biotic province' scheme of Udvardy (1975) is primarily based on analysis of floristic components. There is no strictly analogous system for the sea, principally because rooted vegetation does not occur in much of the sea (exceptions are sea-grasses, estuarine 'pond weeds', mangroves, and algal beds). The classic work of Ekman (1953) has been modified by Briggs (1974) and Ray (1975), but the basis is zoogeographic. Hayden et al (in prep) are attempting a biophysical marine and coastal classification which incorporates these zoogeographic schemes with physical features of coasts and seas. The point to be emphasized is that without any classification, a systematic approach to habitats on a world or regional scale is not possible, and no banking of representative habitats - threatened or not - can be accomplished. A classification, based on characterization, thus allows discrete and defensible ecological units to be addressed.

<u>Species for analysis:</u> As the term habitat is preferable to species, by definition, it is essential to examine species which have aspects of being indicators of the specific habitat types that fall within the regions and subregions of the classification scheme. However, our state of knowledge of the sea, and the great variety of taxa involved, often makes choices difficult. For example, certain commercial species of great economic importance may be indicators of specific subregions (eg the Atlantic lobster, <u>Homarus</u>, of boreal waters). Others migrate widely throughout regions, or even over whole oceans (eg swordfish, tuna, etc). Although a strategic approach should be based upon the characteristics of regions, their subregions, and identification of indicator species which are representative of these, we are immediately confronted by questions such as: 'indicators of what?' or 'on what habitat does a species really depend?'. Therefore, as a practical matter, species should be chosen for analysis if they meet most of the following criteria: 1. economically important, 2. depleted, 3. ecologically important, 4. regionally representative, and 5. adequate of data.

The first two criteria identify species for which society ascribes some economic or aesthetic value. The third criterion is most important, but often most difficult to apply; forage species (eg those lower on the food chain that are eaten by commercial species) are an example. The fourth refers back to the classification scheme. The last is simply a matter of assuring that there is some minimum data level for analysis.

Two forms of data sets should now be compiled. The first is a data compendium that treats each species in terms of its life history and other essential information. Table 7 presents a format. The second is a map, drawn from the compendium, that treats the spatial aspects of life history. Ray et al (1980) have presented an example of this second aspect, in atlas form for a specific region, but which, regretably, did not include supporting compendia. However, the literature abounds with examples of this 'natural history' treatment. The purposes of this exercise are twofold. First, a list of species is created which is broad enough to be representative of a region or subregion, as derived from a classification, and for which data are compatible both in form and content. Second, the choice of species and information gathered is such that ecosystem relationships and habitat analysis may realistically proceed. For example, Ray (1981) has proposed the following points as essential for determining the ecological role of such large organisms as marine mammals: 1. food and feeding as an ecological process, 2. social behaviour, 3. reproductive rates and strategies, and 4. distribution in terms of ecosystem maturity and stability.

On these bases, it is possible to relate species functions to oceanographic, meteorological, coastal, food web, benthic, and ice-dynamics habitat features, once data described in the following section are compiled. Without such an approach, the determination of threat to the species' habitat, and especially the formulation of an ecologically realistic management scheme, would be impossible. Such a statement is, perhaps, obvious to those familiar with terrestrial game management; it is far from the practice for marine species.

Supporting data: The species level is most basic, as it is directly referable to habitat. But it is only one of five categories of information that are required. The categories are:

1. Species; described above;

2. Physical factors, comprising data of ecological importance which determine the distributions of species (eg oceánic currents, water temperature, salinity, bathymetry, storms, tides, etc);

3. Biotic factors, comprising such factors as distributions of coral reefs, sea grass beds, mangroves, wetland types, productivity, etc;

4. Economic and social factors, comprising the human activities that affect species and environments (eg pollution, shipping, fisheries, etc); and

5. Legal and jurisdictional factors, comprising various responsibilities for regulation and management from public health restrictions to various forms of environmental use and protected areas, to law of the sea.

The elements of these categories are important for the analysis of habitats and threats. Their scope is imposing, but in actuality, the number of elements is not large; experience with strategic assessments of the coastal zone (covering both land and sea portions) has shown that 100-200 elements might be involved for any region (cf Ray et al 1980). With respect to all categories, data compendia and maps must be developed. Table 8 suggests a format for categories 2 and 3. Finally, included with the data compendia, for species as well, should be 'evaluations'; this exercise assesses data and should be held discrete from the data themselves as it is a judgement of data relevance and adequacy. Table 9 suggests how evaluations of data might be composed.

Table 7. Species compendium format

1. CATEGORY: (Fish, Birds, Invertebrates, Mammals, etc)

2. CLASSIFICATION: Class: Order: Family: Subfamily

3. NAME: Common name(s): scientific names

4. LEGAL STATUS: International protection: Federal protection; State protection

5. RANGE:
   a. Worldwide: General geographic range of the species
   b. Region of Concern: The general geographic range of a particular region of concern

6. DISTRIBUTION:
   a. Discrete Populations: General location of recognized discrete populations
   b. Concentrations:
      i. Natural: Locations of large aggregates of a species found as year round residents or as seasonal visitors (include dates)

      ii. Commercial: Locations where commercial concentrations of a species are harvested (include tonnage)

7. HABITAT:
   a. Type: General habitat type(s) the species prefers, eg marsh, benthic, littoral, pelagic
   b. Physical/Chemical: Specific tolerances of the species, including water depth, temperature, salinity, sunlight, turbulence, shelter needs

8. LIFE HISTORY
   a. Social Behaviour: Characteristic behaviour of the species, eg solitary or colonial, diurnal or nocturnal, secretive, adaptable or intolerant of change or human encroachment
   b. Biological Association: Dependence on species associations for survival
   c. Nutrition:
      i. Feeding Type: General class of feeding, eg predator, scavenger, filter feeder, carnivore, omnivore
      ii. Food: Preferred to tolerable food for adults and young, including seasonal foods and requirements
      iii. Feeding Behaviour: Special conditions or characteristics of feeding, eg food size, stimulus, group or solitary
      iv. Feeding Location: Where the animal feeds, eg coastal benthic, pelagic, etc

Table 7 continued

d. Reproduction:
   i. Mode: Manner in which reproduction occurs, eg sexual or asexual, internal or external fertilization, dioecious or monoecious
   ii. Location: Geographic and habitat location specific to mating, nesting, or courting areas
   iii. Behaviour: Important aspects of the reproductive process, eg pair bonds, territorial defence, colonial or solitary breeding or nesting, promiscuous or monogamous, special requirements, tolerance for humans
   iv. Biology: Important considerations of reproductive biology, eg stimuli conditions, seasonal time and duration

e. Development: Important aspects in the development and maturation of young, the degree of parental care, environmental needs of the developing young, age of maturity, stages of growth (eg larvae, juvenile, etc), and nursery areas

f. Growth: Rate of growth, size and weight of adults, life span

g. Movements: Migratory routes, date, duration and critical aspects, including important resting areas and seasonal areas outside of the region of concern

9. FACTORS INFLUENCING POPULATIONS:
   a. Natural: Environmental and community interactions that would increase or decrease species abundance, eg predators of young and adults, weather conditions
   b. Man-Related: Human activities that threaten or enhance a species or a population, eg habitat destruction or alteration, food availability, chemical or pollution intolerances
   c. Potential: Known threats that have yet to occur that will affect species abundance, eg lack of proper management, potential use of known carcinogens or intoxicants, synergisms, etc

10. POPULATION SIZE: Estimates or counts of species in the region of concern; worldwide population status, including historical and future trends in the poplation size and structure

11. MANAGEMENT: Present and proposed management, highlighting particularly sensitive aspects

12. PERSONS CONSULTED: Name and address of person(s) reviewing information

13. REFERENCES: Sources consulted in preparing this compendium

14. SUPPLEMENTARY READING: References for greater depth in understanding the species

Table 8. Environmental data compendium format

1. ELEMENT NUMBER

2. CATEGORY: eg "physical oceanography", "habitat"

3. ELEMENT NAME: eg "currents", "wetlands"

4. GEOGRAPHIC DISTRIBUTION: General statement of distribution of element

5. DESCRIPTION:
   a. Characteristics:
      i. Physical/chemical
      ii. Biological
   b. Processes:
      i. Physical/chemical
      ii. Biological

6. VARIABILITY: ie the dynamics related to the element
   a. Spatial
   b. Temporal

7. INFLUENCING FACTORS:
   a. Natural
   b. Man-Related
   c. Potential

8. PERSONS CONTACTED

9. SOURCES: ie referenced

10. SUGGESTED READING: ie not referenced but useful for further information

Critical habitat identification

The data compendia and supporting maps form the basis for habitat analysis, critical habitat identification, and at least an initial evaluation of threat. The evaluations indicate state of the art and point toward further needs; as such, they are especially important from the strategic point of view. The immediate purpose is to identify where each of the indicator species' critical habitats occur so that areas in need of species protection status can be at least initially identified. First, critical habitat must be further defined. The USA Endangered Species Act of 1973 is the only USA legislation that mentions critical habitat specifically:

'The purposes of this act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved.... Federal departments and agencies shall... insure that actions, authorized, funded, or carried out by them do not jeopardize the continued existence of such... species or result in the destruction or modification of habitat of such... species determined... to be critical.'

Critical marine habitat was defined by Ray (1976) as those identifiable areas which are vital to the survival of a marine species at some phase in its life cycle, or of a marine habitat, community, or ecosystem, because of the ecological processes that occur within it. Emphasis was given to ecological processes due to downstream effects, which are of such importance on a regional level. At about the same time, the USA Fish and Wildlife Service and the National Oceanic and Atmospheric Administration adopted the following operational definition (Federal Register, 50 Code of Federal Regulations Sec. 424.02 (c)):

'Critical habitat means

(1) The specific area occupied by a species, at the time it is listed (as endangered or threatened)... on which are found those physical or biological features

  (i) Essential to the conservation of the species and

  (ii) Which may require special management consideration or protection; and

(2) Specific areas outside the geographical area occupied by a species... upon a determination... that such areas are essential for the conservation of the species.'

However, as for the principles elucidated by Holt and Talbot (see above) methods were not included with any of these definitions. Consequently, the USA Marine Mammal Commission supported an attempt to develop such a method (Ray, Dobbin and Salm 1978, 1981; Ray, Salm and Dobbin 1979). The species chosen to exemplify the method was the Pacific Walrus, Odobenus rosmarus. The study required examination of:

1. The species' vulnerability in terms of functions such as breeding, feeding, etc;

2. The ecological processes necessary for habitat maintenance; and

3. The threats to species directly (biologically) or indirectly (ecologically).

The result of the study was a regional, graphic representation of the complex interactions between human activities and the biology and ecology of an important species which is representative not only of its environment, but also of other species and of human conflicts with living resources occuring in the region. That is to say, the walrus is important for itself alone, but also represents regional living resource management problems in the Beringian ecosystem in general. Ray and Miller (1982) have

Table 9. Evaluation format

1. WHAT DATA AND MAP SHOW: single source, compiled, new?

2. JUSTIFICATION:

   a. Value: of subject matter, of itself and for analyses
   b. Choice: of data mapped - why presented as it is

3. COMPLETENESS AND QUALITY OF DATA:

   a. Mapped Data: result of comprehensive analysis, partial, etc
   b. Scale: adequate for element, too generalized, etc
   c. Confidence: poor - excellent, obvious data needs
   d. Problems Encountered: data availability, form

4. NEED FOR ADDITIONAL STUDY:

   a. As a part of this analysis:
      i. Specific sites and/or problems
      ii. Specific data gaps
   b. As a consequence of this project
      i. Specific sites and/or problems
      ii. Specific data gaps

5. RELATIONSHIPS TO OTHER CATEGORIES:

   a. For analysis and/or synthesis:
      i. Possible conflict and/or compatibility
      ii. cumulative and/or synergetic effects
   b. Seasonal needs or problems
   c. Other

6. REFERENCES

re-examined this case. Their analysis is as follows:

'The walrus is a gregarious animal. Its distribution appears to be determined principally by bathymetry, sea ice dynamics and benthic food supply. Winter concentrations occur in the north central and south-eastern Bering Sea; summer concentrations occur in the north-western and north-eastern Chukchi Sea. Most of the northward migrants are females, sub-adults, and young; most males occur on or near land haulouts in the Bering Sea.

The walrus is polygynous, mating in mid-winter, and the males are hierarchical and probably semi-territorial. Pregnancy lasts 15 months and birth occurs just before and during the spring migration. Nursing lasts for up to two years (occasionally longer). Females in late pregnancy and during nursing can be presumed to feed heavily. The walrus is a benthic feeder; it locates food by rooting on the bottom with its muzzle, mostly for soft-bodied invertebrates.

These features of walrus natural history suggest that the greatest vulnerability of the walrus population occurs when both reproduction and least food supply occur together. That is when the animals are concentrated in winter and engaged in reproductive activity, with many females near term and feeding heavily, walruses might be subject to severe stress if food supply was low. Areas of low benthic biomass occur within walrus winter concentration areas.

The Pacific walrus exhibits features of K-selection (low reproductive rate, moderately long life, etc), but it is moderately facultative in selection of food. It is not an endangered species. In fact, there is evidence that its population may be near carrying capacities. It occupies all of its former range and may now be having a strong impact on its food supply, some components of which may themselves be K-selected. In addition, recent data indicate that population productivity declined during the late 1970's. Crude birth rates were about 14-17% from the 1950's to the early 1970's, contrasting with estimates of a third as much from the mid 1970's to 1981. In this regard, it is important to note that subsistence hunting by Alaskan natives may not have made a measurable impact on the population. Also, it is not correct that the walrus is considered a 'pest' because of possible conflict with proposed fisheries; quite the contrary, there is concern among natives of Alaska and elsewhere about the health of the population and its habitat.

It is apparent that consideration of the ecological processes responsible for walrus concentrations is essential to any consideration of this species' critical habitat. Unfortunately, very little is known about processes responsible for food supply. For example, it is possible that walrus bioturbation of the benthos during feeding induces 'feedbacks'; that is, walrus rooting patterns in sediments might release nutrients to the water column in significant quantities. Thus, walruses might actually enhance local productivity. A corollary is that a reduction in walrus numbers could result in lowered ecosystem productivity, either generally or locally, with unforeseen - but quite possibly extensive - consequences. The distribution of walruses is also strongly influenced by sea ice dynamics ...'

Even if the walrus population is near carrying capacity, there is little likelihood that it will undergo severe oscillations under natural conditions. That is, it is probably not out of equilibrium with its ecosystem, as its food supply has not been exploited by man. Future human-caused impacts within walrus habitat are related principally to possible exploitation of shellfish on which the walrus feeds, and to oil and gas exploration. Disturbance to food supply could have disastrous consequences, by analogy to the case of the elephant.

We see from this description that there are three levels of critical habitat:

1. Areas where species are biologically vulnerable, whether the species are depleted or not;

2. Areas which contribute ecological support processes; and

3. Either of the above sorts of areas that are threatened by human activities. Separating these three allows analytical procedures to be used, rather than intuitive guesses, on any of these levels or on all three together, as a synthesis. There is, however, one cautionary restraint that deserves mention. The walrus critical habitat analysis for the USA Marine Mammal Commission (referenced above) was presented in simplistic, graphic, 'overlay' terms which has obvious shortcomings. Population ecology is much more complex than graphics alone can show; it tends to highlight spatial correlations at the expense of functional ones, and can lead to false conclusions. Careful interpretation by biologists and ecologists thoroughly familiar with the species and area involved, is necessary to avoid the many pitfalls involved.

The community/ecosystem level

It is possible and instructive to combine species information so that a composite or community representation of the region and its subregions is achieved. For this purpose, the critical habitats for several important indicator species should be combined. For example, selected and important species' habitats, as defined by their breeding and nursery areas, in comparison with environmental and economic data, will indicate areas of very high priority that should be considered critical on each or all of the three levels described above. Also, one would suspect that there is a hierarchy of areas, some more critical than others. For example, core areas may be derived from a species biology approach. Buffer areas could be derived from an ecological approach. Highest priority habitats may be those of endangered species, of great species richness or productivity, or in particular need of relief from human perturbation. It is important that analysis towards these ends be performed on as objective a basis as possible. Unfortunately, identification of critical habitat is as often highly prejudiced as not. A problem lies in acquiring sufficient quantitative data for the purpose.

The approach here, through identification of critical habitats of a few species only, rests on the assumption that data for a few representative and relatively well-known species will yield as much, or even more, insight into environmental conflicts than will analysis of data for a great many species, some of which are bound to be poorly understood.

The rationale for this is that niche variety is expressed well enough by a few selected species, in the absence of detailed information on a great number of species, to determine major habitat patterns and the threats to them. Also, one would wish to avoid undertaking complete inventories as they rarely reveal a level of information that justifies the expenditure of time and effort involved.

THE SELECTION PROCESS

If the process described above for identification of areas of special significance is followed, many critical habitats will inevitably emerge. Further, a diversity of critical habitat types and threats will require an equal diversity of objectives for conservation, eg resource sustainability, continuance of species diversity, assurance of appropriate biological productivity, pollution abatement, maintenance of ecological processes, strict protection of breeding areas, etc. Strategic decisions for living resource conservation of large assemblages of critical marine habitats will most often have to be made in the context of multiple use, particularly given the size of marine ecosystems. For example, both commercial and endangered species may inhabit the same or adjacent areas; utilization of commercial species, restoration of habitats, and strict protection of depleted species at the same time and within the same region or subregion requires multiple management objectives, as well as sophisticated techniques that are subject to continued improvement, as indicated by scientific study and management experience.

Priorities for conserving critical habitats will vary according to the perceived value of the habitat, its ecological importance, and the amount of human caused threat. A comprehensive set of priorities has been developed for selection of a regional system of protected areas for the Mediterranean by IUCN (1980); these criteria are listed in Table 10. A method for employing the criteria was implicitly suggested, but how criteria may be applied is still a subject of considerable debate. The point is that a great variety of factors must be considered and that priorities will vary accordingly. Also worthy of note is that there are two levels of criteria, the generic and the specific. This implies that ratings are to be made on each of these levels, separately. That is, ratings are first made for specific criteria, then separately at generic levels, ie all ecological criteria are assessed first and an overall ecological rating stated. Then, the generic levels are assessed together, ie the ecological compared with the economic or cultural. Obviously, various levels of value judgements, some quantitative and some qualitative will be involved.

Characteristics of some criteria must be pointed out. First, 'naturalness' is often troubling. There are almost no completely natural areas; even recreational fishing is a perturbation. This means that a degree of perturbation will involve highly intuitive judgements. Second, for some criteria, such as diversity, a more quantitative approach is possible. Nevertheless, even here, difficulties are encountered. I have already pointed out that the fundamental approach to diversity is quite different on land and in sea (= species vs higher taxa). But 'diversity' also refers to habitats. Further, non-diverse areas are often highly productive, so that lack of diversity is not necessarily negative. Third, the set of criteria lumped generically under 'social and economic benefit' is exceedingly difficult to assess or to apply. A considerable political influence is often evident. This is made more complex by the fact that economics is a social science, and despite its promise, has not shown itself capable of ranking social and aesthetic benefits satisfactorily; cost-benefit analysis has reached a state of great apparent sophistication, but doubts about the long range wisdom of the technique are widespread. The history of civil engineering projects, in particular some of those of the USA Army Corps of Engineers or of foreign aid agencies that have conceived of port development on estuaries and the damming or re-routing of rivers - are cases in point. The sensitivity to social and economic consequences of such projects lags far behind the mathematics!

Fourth, landscape and cultural criteria are only slightly less difficult to deal with than economics. The first often involves inter-relationships between land and sea, on an ecological basis. Seashore roads, marinas, jetties, and such developments may improve access, but may also interrupt ecological patterns (drainage, inshore current structure) that are responsible for the landscape (or seascape) value for which the area was given a high rating in the first place. As for cultural values, judgement is often in the eye of the beholder. The value of the criterion, from the habitat point of view, may lie in the fact that cultural sites are often located in biologically rich or unique areas; preservation of cultural values on the site often means preservation of biological values as well. Examples abound of cultures that hold dear certain biological values. New Guinea peoples who value, use, and protect the much depleted dugong is an example. Also, sea-faring cultures, both ancient and extinct, developed uses and traditions on sites of high ecological value and often placed their villages in close proximity to these areas (cf Dasmann et al, in prep).

Finally, the concept of productivity needs some clarification. It is mentioned under ecological criteria and implicit in several other criteria. Productivity expresses a rate; it is not the same as production, which expresses a quantity. Very often, high productivity is associated with organic pollution and eutrophy. Therefore, primary productivity should be appropriate to the ecosystem so that high productivity (resulting in production) of valuable commercial or aesthetic resources will result. Fisheries models are excellent examples of the relationship between productivity and production.

As a result of the application of these criteria, priorities among the identified critical habitats should be achieved and the management objectives for each should be made clear. For some areas, strict protection of resources or of ecological processes (eg productivity) will be necessary and for others, specification of fisheries zone wherein sustainable take is emphasized will emerge. For still others, monitoring and research on the effects of pollution will be the major objectives. For yet others, human recreation will be paramount. However, each of these objectives tends to fall within the purview of different agencies. Protection of areas of substantial size implies multiple agency management and the multiple use concept. A significant problem is the blending of the exploiting fisheries agencies with the protective parks or sanctuaries agencies, and this can only be solved on a case- or site-specific basis.

DISCUSSION

Dasmann et al (in prep) make the point that: 'There is no easy solution and there is no one solution, but at least there can be a systematic approach to decisions'. This is especially important when considering threats to marine habitats, as they are so poorly known compared with terrestrial ones - much more out of sight and out of mind to all but a very few. There are, indeed, only two basic approaches to identification of threatened habitats - intuitive and analytical. Inevitably, resource-use decisions almost always fall between these two extremes, but intuitive judgements about terrestrial habitats are likely to be an order of magnitude better than such judgements about marine habitats. Of course, this situation is rapidly changing as the 'Marine Revolution' (Ray 1970) proceeds, but the point remains. Therefore, it appears that the identification of areas requiring special protection, especially on a regional basis, can be appropriately approached by analysis of critical habitats through selected,

Table 10. Selection criteria (slightly modified from IUCN, 1980)

1. ECOLOGICAL CRITERIA: these relate to values of ecosystems and the species within them:
   a. Dependency: the degree to which a species depends on the area, or the degree to which an ecosystem depends upon ecological processes occurring in the area. If an area is critical to more than one species (or process), it should have high rating.
   b. Naturalness: the degree of perturbation of the area. Undisturbed areas should have higher rating.
   c. Representativeness: the degree to which the area is representative of a habitat type, ecological process, biological community, physiographic feature, or other natural characteristic. If no area of the type is protected, it should have high rating. NOTE: a classification system for coastal and marine areas is necessary for the application of this criterion.
   d. Uniqueness: the degree to which an area is "one-of-a-kind"; habitats of endangered species which occur in only one area are an example. These should have high rating. NOTE: a classification system for coastal and marine areas is necessary for the application of this criterion.
   e. Diversity: the degree of ecosystem, community and species variety or richness. Areas having the greatest variety should receive priority. NOTE: this criterion may not apply to simplified ecosystems, such as some pioneer or climax communities, or areas subject to disruptive forces such as shores exposed to high energy wave action.
   f. Integrity: the degree to which the area is a functional unit, that is, an effective, self-sustaining ecological entity. The more ecologically self-contained the area is, the more likely it is that its values can be effectively protected, and so higher rating should be given to such areas.
   g. Productivity: the degree to which productive processes within the area contribute to species or to human values. Productive areas which contribute most to ecosystem sustainment should receive high rating. NOTE: Exceptions are eutrophic areas where high productivity may have a deleterious effect.

2. SCIENTIFIC AND EDUCATIONAL CRITERIA: these primarily concern areas for research and monitoring. Such areas may be natural or perturbed, and may accommodate training or educational programmes:
   a. Proximity: the degree to which the area is accessible to those wishing to do research in it. Greater proximity should receive high rating.
   b. Benchmark: the degree to which the area may serve as a "control" in the scientific sense, ie as a non-manipulative area against which to measure change occurring elsewhere. Such benchmark areas are essential to the conduct of an ecological monitoring programme and should receive a higher rating.
   c. Demonstration: the degree to which the area can serve to exemplify techniques or scientiic methods. Such areas should receive higher rating.

Table 10 continued

d. Process Relationship: the degree to which the area represents ecological characteristics of regional value susceptible to research and study; these should receive a high rating.

3. SOCIAL AND ECONOMICAL BENEFIT CRITERIA: these consider benefits to human welfare, measured in economic and social terms:
   a. Economic Benefit: the degree to which protection will affect the local economy in the long term. Initially, some protected areas may have a short-lived, disruptive economic effect. Those that have obvious positive effects should have a higher rating: eg protection of feeding areas of commercial fish, or of areas of recreational value.
   b. Social Acceptance: the degree to which support of local people is assured. Should an area already be protected by local tradition, custom or practice, this should be encouraged and the area should receive a higher rating; moreover, an "official" protected area designation may not be necessary if local support is high.
   c. Public Health: the degree to which the creation of a protected area may serve to diminish pollution or other disease agents that contribute to public health problems. For example, protective status for contaminated areas such as shellfish beds or bathing beaches may result in amelioration of pollution as the polluting source is recognized and controlled.
   d. Recreation: areas which benefit the local community by providing them with the opportunity to use, enjoy and learn about their local natural environment should receive high rating.
   e. Tourism: areas which lend themselves to forms of tourism which are compatible with the aims of conservation should receive high rating.

4. LANDSCAPE AND CULTURAL CRITERIA: these consider benefits which provide pleasure to people to enrich their appreciation of the natural or historic environment:
   a. Landscape: natural areas which also contain features of exceptional natural beauty should be given higher rating, since such areas depend upon the maintenance of the integrity of the coastal and adjacent marine systems.
   b. Cultural: natural areas which also contain important cultural, artistic or historic features should be given high rating.

5. REGIONAL CRITERIA: these criteria can best be applied if a regional approach is adopted so that it is possible to measure the contribution which an area may make to a network of protected areas:
   a. Regional significance: the degree to which the area represents a characteristic of the region - whether it be a natural feature, an ecological process or a cultural site. This involves an assessment of the role which the area plays by contributing materials, nutrients, or support for species (especially migratory ones) to the region as a whole. As both ecological processes and natural resources are shared among nations or regions, areas contributing towards maintenance of species or of ecosystems beyond national boundaries should have high rating.

Table 10 continued

b. Sub-regional Significance: within every region there are numerous sub-regions whose characteristics would be classified by a regional classification scheme. It is relevant, therefore, to determine whether an area fills a gap in the network from a sub-regional point of view. This may be done by comparing the distribution of protected areas with sub-regional characteristics. If a type of area is preserved in one sub-region, that type should also be protected in another sub-region.

c. Awareness: the degree to which monitoring, research, education, and/or training within the area can contribute knowledge and appreciation of regional values. Areas which can combine such activities as pollution monitoring and education should have high rating.

d. Conflict and Compatibility: the degree to which the area may help to resolve conflicts between natural resource values and human activities, or the degree to which compatibilities between them may be enhanced. If an area can be used to exemplify the resolution of conflicts elsewhere in the region, it should receive high rating. Protected areas which demonstrate the benefits, values or methods of protection and/or restoration should also have high rating.

6. PRAGMATIC CRITERIA: these consider whether protection can be accomplished or whether action is necessary:

a. Urgency: the degree to which immediate action must be taken, lest values within the area be transformed or lost. NOTE: lack of urgency should not necessarily be taken as low priority, however, as it is often best, and least costly, to protect well in advance of threat.

b. Opportunities: the degree to which existing conditions or actions already underway may justify further action. For example, an extension of an established protected area should have high rating.

c. Defensibility: the degree to which an area can be properly safeguarded or restored. Sites which are defensible should have high rating.

d. Availability: the degree to which the area is available foracquisition or can be managed satisfactorily by agreement; such areas should have high rating.

e. Accessibilty: the degree to which the area is accessible to those managing it or those doing research or other activities within it; such areas should have high rating. Indeed, areas of very low accessibility may be protected by that fact.

f. Restorability: the degree to which the area may be returned to its former natural state. Areas capable of having their productivity increased should receive high rating.

representative, indicator species. Obviously, such an approach can be used for any species, marine or not, depleted or not, but its use in the marine sphere is especially useful for the reasons mentioned above.

The critical habitat method involves understanding of indicator species' roles in their ecosystems. It may be presented graphically. Simplistic graphic overlay methods, particularly useful in landscape and town planning, must be taken with care, however. The totality of adaptations of species within ecosystems, expressed as an 'adaptive complex' (Bartholomew 1970) or 'bionomic strategy' (May 1978) is not easily represented by graphics. This is not to say that graphic techniques are not useful; for a first approximation or to emphasize strategic reconsiderations to a wide variety of users, graphic interpretations can be essential, in fact. The reverse side of the coin is that they can also be highly misleading and that interpretations by ecologists are essential. Nevertheless, this approach - graphic or otherwise - results in an array of justified critical habitat areas. Criteria for selection may then be applied so that, from this array, priorities for selecting and management may be established. These identification and selection processes are strategic by nature; that is they can avoid the ad hoc, issue specific, or intuitive methods which have, unfortunately, dominated conservation and development processes alike in the past.

I have not dealt with the analysis of threat which should be at the heart of this volume. In fact, the selection criterion 6(a) - urgency - should be a measure of threat. It is defined by one dictionary as 'an indication of impending danger or harm'. But how difficult assessing urgency is and how lost in the sea of criteria that I have suggested it appears to be! For example, the establishment of sanctuaries for many species is necessary, but how urgent is this and on what basis? The rationale for oceanic whale sanctuaries is presently not one of biological urgency - providing hunting is ceased - although it may be useful in other ways. On the other hand, the rationale for protection of many coastal habitats, such as mangroves, wetlands, estuaries, and coral reefs, is exceedingly urgent on biological, ecological, economic, and aesthetic bases. Use of the selection criteria should help us to achieve a better perception of why and for what purpose we must establish marine protected areas.

To illustrate how very difficult it is to perceive threats and urgency, consider the concept of residuals - ie the side effects of human activities. Human activities often affect the natural environment and, through feedback mechanisms and ecological interactions they also affect those same activities in return. For example, development associated with tourism and recreation may produce sewage, altered water circulation, discharge of solid wastes, noise, and artificial illumination. These, in turn, may affect the marine environment by causing turbidity, erosion, heavy metal pollution, and alteration of water temperature and aesthetic values. Such effects have impacts on fisheries and wildlife, as well as on tourism and recreation themselves. Thus, an analysis of the environmental threats posed by socioeconomic development involves not only conflicts among human activities and resource values, but also among those activities. Resolution of such problems involves consideration of the three value concepts mentioned at the outset of this paper - individual preferences, social norms, and ecological functions. It also involves thinking beyond single actions and single sites towards a wider ecosystem view.

It is obvious to the ecologist, but not well reflected in the generally piecemeal or bureaucratic approach to conservation and development, that our thinking and approach to environment must be integrative. This is especially necessary in the sea. Further, conservation and resolution of threat should be based upon principles which take on the role of general fundamentals of conduct. They should be planned by strategies and guidelines which indicate how policy should be carried out. Finally, they should be implemented through the application of clearly stated criteria which are standards on which implementation should be based. None of the above should, however, be rigid. They must only be clearly stated, so as to be subject to wide public participation.

Equally clear are three other factors. First, a complex array of factors controls species diversity and ecosystem function. Consequently, the critical habitats approach appears to over simplify, but I would emphasize that it involves quite complex concepts, some of which will not be readily apparent from the analysis itself. For example, the interdependence between species diversity and area size is one such valuable concept (cf J Diamond, this volume). It identifies a minimum requirement for protected areas. Whereas it emphasizes diversity, it is not so applicable to the 'other two' objectives of the World Conservation Strategy, ie ecological process maintenance and sustainable resource use. In fact, Salm (1980) has found that for coral reefs, the species-area relation may under-estimate minimum reserve size; the application of area-dependent survival probabilities may be more useful. Second, it is essential, for marine conservation, that one address both local and regional levels. Local perceptions must be placed within a regional perspective in order to grapple with insidious, cumulative alterations which may have regional consequences. It is a mistake to assume that only individual nations can take effective conservation action. As a matter of fact, the Antarctic treaty and several other regional and marine agreements of far reaching consequences (eg a whale sanctuary, recently established for the entire Indian Ocean that may not immediately affect whales, but could have other important conservation and research impacts). A regional approach to marine conservation is also required because each region has its own identity and also because shared species' movements and ecological interdependencies are inter-connected across national jurisdictions in the bouillabaisse of the sea. Further, a regional approach avoids duplication of effort and enhances information transfer. Third, habitat and ecosystem are not the same thing. Habitats may or may not be manageable functional units, by themselves alone. Threats to habitats, unless placed in an ecosystem or regional context, may not be resolvable. I do not wish to dwell on such an obvious point, but how easily and how often it is forgotten!

The 'marine difference' revisited

The objectives of the World Conservation Strategy emphasize differences in approach and perception that have influenced conservation of habitats between land and sea. The attention to species diversity and preserving endangered species and habitats has been overwhelming by land, but is limited with respect to marine conservation. One could only venture a guess that our comparative lack of attention to the coastal zone where, after all, most people live, is biased by the lack of endangered species there - at least in the marine portion. The principles summarized by Holt and Talbot are in accord with the World Conservation Strategy and call attention, appropriately to both consumptive and non-consumptive uses.

There are many similarities between land and sea and how their ecosystems function. However, I have attempted to point out significant differences. Among these are the relative weight that must be given to shared resources and a regional approach, the different nature of threat and the comparative difficulty in interpreting it, the different definition of resources, differences in ecosystem structure, and differences in both management objectives and bureaucratic responsibilities. The single fact that, for most marine systems, high primary productivity replaces the terrestrial pattern of high plant biomass, must lead forcefully to the conclusion that we are dealing with a different set of circumstances in the sea. In addition, the management of marine systems is dominated not by aerial responsibility - most agencies generally responsible for a piece of designated land - but by multi-layered jurisdiction in which a multitude of agencies are responsible for water quality, fisheries, public health, etc within the same area. Confusion often abounds when ecological process considerations are attacked.

Also apparent, from the ecological point of view, is that 'cores' will be less useful than 'buffers' for that segment of marine conservation that is concerned with protected areas. This is so for three reasons;

(1) sanctuaries or other protected areas can be established only for very small portions of the sea, simply for reasons of manageability,

(2) identified critical habitats are often of such size as to completely dwarf even the Serengeti (cf the walrus, above), and

(3) large expanses of the seas are so ecologically interconnected that devices other than protected areas may be more useful (eg control of pollution and fisheries).

To my knowledge, the extension of protected area concepts - those by which we often attempt to 'solve' threatened habitat problems by land - have not yet been satisfactorily attacked for the sea. The useful matrix of Miller (1975) which places objectives for management against alternative management categories might, with much modification, be made applicable to coastal and marine problems and the threats to them. However, Miller (cf this volume) does not address this nor has IUCN yet expanded its own protected area/objective matrix to cover most marine threatened habitat problems. Figure 9 expresses the problem that I perceive; land derived measures can go so far towards solutions within the 'grey area'. Further, this area is, in my opinion, that of the greatest need because it is mostly concerned with protection of the larger portion of the sea that cannot forseeably fall in a protected area category, as we usually define such matters. Clearly, filling this void on a conceptual basis should be a high priority during the Marine Revolution.

We must learn to think on a different level for marine issues, even as we stand on the ecotone of the shore, not fully appreciating that our footsteps could at any moment be marine. We must look towards regional networks of 'core' (= critical habitat) protected areas so that each will represent a link in the ecological processes which sustain species and ourselves. But, we must not neglect the bulk of the sea which supports and buffers such areas. It may be especially true of marine conservation that the critical habitat is the sea itself.

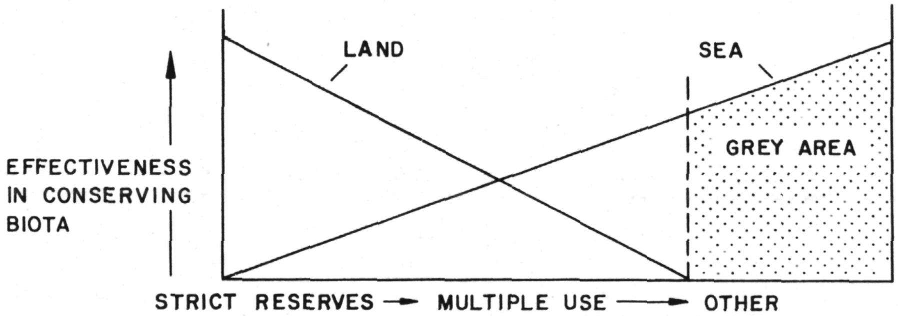

Figure 9. Effectiveness of protected area types in conserving biota. For meeting problems of threatened habitat protection, areas of many sorts may be established in which appropriate management may be undertaken. For the land, an array of protected area types has been developed and has been summarized by IUCN, from "strict" nature reserves to multiple use areas. All of these types are useful and applicable for marine habitat conservation, but their utility and effectiveness is in reverse order to the land. Further, there remains a "grey area" where land-derived methods and types are not easily applicable, if at all. This is often in direct contrast to the need to do so. Examples include such matters as pollution control, ocean dumping, and ecological process conservation, for which entire ecosystems, rather than habitats, must be treated.

SUMMARY

Land-based principles need to be adapted to the difficult problems of conservation in the sea. The sea differs from the land in having virtually invisible depths containing less species but which cover a considerably greater range of taxonomic forms. Resource-use by humanity is still almost entirely of the crude hunter-gatherer type, concentrated mainly in the coastal zone. Conservation is made more difficult by the lack of understanding of the structure and dynamics of marine systems, and the effects of human activities upon them: a serious aspect is that these systems may be linked, so that seemingly innocuous actions may have far more extensive consequences than might be expected from terrestrial management policies.

A strategic approach, linking many facets in a dynamic, holistic system, is needed. Such an approach is offered by critical habitat analysis in which the highest priority habitats are identified, and of these, those needing immediate conservation action are chosen by specifically designed methods. Habitats are classified using indicator species as the chief criteria. Other data come from physical components; biotic factors; economic and social pressures; and legal and jurisdictional aspects. These data are combined using a graphic overlay method, showing where critical areas exist for

1. Places where species are biologically vulnerable;

2. Sites which contribute ecological support processes; and,

3. Either of these which are threatened by human activities.

Care must be taken with the overlay method not to overlook the complex linkages of biological systems, as exemplified by the adaptive factor complexes that are known to rule the population sizes of many species. Data from the community and ecosystem levels are included where known.

Selection of the critical habitats that deserve prior attention is based upon a comprehensive system of rated criteria.

Once identified, priority critical habitats must be conserved, and here a host of problems exists. One is the multi-agency nature of authority over the oceans. Another is the perception of threats in a remote environment that is essentially difficult to observe. The vast sizes of ocean areas needing conservation is a further problem. There is a good case for providing a marine version of the matrix of objectives versus kinds of conservation-area, that is used for terrestrial reserve planning.