

# The State of the Marine Environment

Trends and processes



# **The State of the Marine Environment**

**Trends and processes**

## Foreword

Recognising the significance of the risks posed by human development activities on the coastal and marine environment, 108 governments and the European Commission adopted the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) in 1995. They made a commitment to deal with nine land-based threats to the marine environment, namely sewage, persistent organic pollutants (POPs), radioactive substances, heavy metals, oils (hydrocarbons), nutrients, sediment mobilization, marine litter and the physical alteration and destruction of habitats.

The GPA calls for periodic reviews and in response to this mandate the UNEP/GPA Coordination Office commissioned this report: *The State of the Marine Environment: Trends and processes*. Its purpose is to give a broad global perspective on the situation, providing regional and sometimes national examples. The report provides an overview of the current state of the coastal and marine environment in relation to the nine categories of threats outlined by the GPA.

The report often relies on information that dates back farther than the adoption of the GPA, largely because of limited contemporary data. At the same time, there exists a considerable time lag between the pressures imposed on the environment, the subsequent development of policies, the implementation of measures and, eventually, the visible manifestation of the impact of such responses. While the findings of the report may not be based on as current information as we would like, the resulting analysis is indicative of trends in the state of the marine environment as they relate to the GPA.

The report indicates that legal and institutional arrangements have been strengthened and now cover most regions of the world. In addition, ongoing programmes, including GEF supported large marine ecosystems (LME) programmes, contribute to the implementation of the GPA. Despite these heightened efforts globally, coastal and marine ecosystems continue to deteriorate mainly because of pressures by human development. Progress in dealing with the nine GPA source categories has been uneven: progress has been made in Persistent Organic Pollutants, Radioactive Substances and Oils (Hydrocarbons), results are mixed in Heavy Metals and Sediment mobilization and conditions have worsened in Sewage, Nutrients, Marine Litter, and Physical Alteration and Destruction of Habitats.

This report informs and compliments the other studies we have produced for the Second Intergovernmental Review Meeting, and it provides a basis for some of the new strategic directions proposed in the Programme of Work for the UNEP/GPA Coordination Office (2007-2011). The report also aims to contribute to the Global Assessment of the Marine Environment.

The UNEP/GPA Coordination office and its partners are pleased to present this report and it is our hope that the findings presented here will further support global, regional and national efforts in implementing the Global Programme of Action.

Dr. Veerle Vandeweerd  
*Coordinator, UNEP/GPA Coordination Office*

# Table of contents

	Foreword .....	i
	Acronyms and abbreviations .....	iii
	Executive summary .....	iv
1	<i>The framework for action</i> .....	1
1.1	Legal and institutional framework .....	1
1.2	Implementation and international and regional cooperation .....	1
2	<i>The current status of action within the framework of the GPA</i> .....	3
2.1	Sewage .....	3
2.2	Persistent Organic Pollutants (POPs) .....	6
2.3	Radioactive substances .....	9
2.4	Heavy metals .....	11
2.5	Oils (hydrocarbons) .....	15
2.6	Nutrients .....	19
2.7	Sediment mobilization .....	22
2.8	Marine litter .....	26
2.9	Physical alteration and destruction of habitats .....	28
3	<i>Problems identified for priority action</i> .....	33
3.1	The issues .....	33
3.2	Emerging challenges .....	34
3.3	Important management responses .....	35
4	<i>Overall assessment and conclusions</i> .....	37
	References .....	39

# Acronyms and abbreviations

AMAP	Arctic Monitoring and Assessment Programme
Billion	1000 x million
CEP	Caspian Environment Programme
CO <sub>2</sub>	Carbon dioxide
CSD	Commission on Sustainable Development of the UN
DDT	Dichlorodiphenyltrichloroethane
DPSIR	Driver-Pressure-State-Impact-Response framework
EEA	European Environment Agency
EMAP	Environmental Monitoring and Assessment Programme of the us
ESCAP	Economic and Social Commission for Asia and the Pacific
G	giga = 10 <sup>9</sup> = billion = 1000 x million
GEMS	Global Environmental Monitoring System
GEO	Global Environment Outlook
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP)
GIWA	Global International Waters Assessment
GMA	Global Assessment of the Marine Environment
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
HELCOM	Helsinki Commission/The Baltic Marine Environment Protection Commission
IAEA	International Atomic Energy Agency
ICARM	Integrated Coastal Area and River Basin Management
ICES	International Council for Exploration of the Seas
IHE–Delft	International Institute for Infrastructural, Hydraulic, & Environmental Engineering
IUCN	World Conservation Union
LOICZ	Land-Ocean Interactions in the Coastal Zone
MAP	Mediterranean Action Plan
MDG	Millennium Development Goals
NGO	non-governmental organization
OECD	Organisation for Economic Cooperation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PADH	Physical Alteration and Destruction of Habitats
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PBq	pétabequerel
PCB	Polychlorinated biphenyl
Po	Polonium
POP	Persistent Organic Pollutant
ppm	parts per million
PTS	Persistent Toxic Substances
RAMSAR	Convention on Wetlands of International Importance, especially as Waterfowl Habitat
ROPME Sea Area	Regional Organization for the Protection of the Marine Environment of the sea area surrounded by Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates
SOE	State of the Environment
t	tonne (1000 kg)
T	tera = 10 <sup>12</sup> = trillion
TBT	tributyltin
UK	United Kingdom
UN	United Nations
UNEP	United Nations Development Programme
USA	United States of America
USDA/NRCS	us Department of Agriculture/Natural Resources
USEPA	us Environmental Protection Agency
WET-WASH	Wastewater Emission Targets – Water, Sanitation and Hygiene
WRI	World Resources Institute
WSSCC	Water Supply and Sanitation Collaborative Council
WSSD	World Summit on Sustainable Development
WCMC	World Conservation Monitoring Centre



## Executive summary

### Progress has been made in the framework of the GPA in...

1 Thirty-eight per cent of the world's population live within a narrow fringe of coastal land, only 7.6 per cent of the Earth's total land area (UNEP 2006) and largely depend on coastal resources for their livelihoods. As a result, coastal and marine ecosystems are rapidly deteriorating because of human pressure, almost 80 per cent of which originate on land. In recognition of this, governments adopted the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) in 1995. This report provides an overview of the current situation and of progress in the protection of the marine environment in the GPA framework. Although the information presented here may not be comprehensive, it is indicative of the present State of the Marine Environment.

### ...legal and institutional arrangements, implementation and cooperation...

2 Since the adoption of the GPA, the legal and institutional arrangements that support action have been expanded and strengthened and now cover most regions of the world. The implementation of plans and programmes is underway and is increasingly seen as a contribution to the achievement of the targets set by the international community, such as the Millennium Development Goals and the Johannesburg Plan of Implementation (WSSD). Cooperation both within the framework of the GPA as well as with other conventions and programmes is also well established.

### ...covering nine degradation source categories:

3 The current status of action for the nine source categories within the framework of the GPA has been reviewed. Current trends vary for each category, as does progress in controlling deterioration. The picture that emerges shows that although much has been achieved, still more needs to be done. Briefly, the situation is as follows:

#### Sewage

- Discharge of untreated domestic wastes is a major source of marine pollution, and perhaps the most serious problem within the framework of the GPA. Globally, in spite of action, the problem is growing worse, mainly because of growth in population and rapid urbanization. The problems are worse in developing regions, where only a fraction of sewage is treated; the main constraint to progress there is not technical but financial.

#### Persistent Organic Pollutants

- These highly toxic and stable organic chemical substances (pesticides, industrial chemicals and associated by-products) can accumulate in organisms and persist for years and even decades in the environment. In the two decades since international controls were instituted, the situation has improved considerably, although problems still remain in developing regions dependent on agriculture and in fragile ecosystems such as the Arctic. Even in these areas steady improvements are likely, in view of the regulatory system currently in place.

#### Radioactive substances

- Energy generation and other civilian and military activities that could possibly release radioactive substances are highly regulated. Some countries feel there is cause for concern about the danger posed by nuclear accidents; however, the IAEA Safety has concluded that there is no support for the contention that maritime shipments of radioactive materials, as currently carried out, are unsafe. The 2005 Mauritius Strategy notes that States should maintain dialogue and consultation, in particular under the aegis of

the IAEA and IMO, with the aim of improving mutual understanding, confidence building and enhanced communications in relation to safe maritime transport of radioactive materials

#### Heavy metals

- Heavy metals are essential to life in minute quantities, but become toxic in higher concentrations; mercury, lead and cadmium are considered the most dangerous. These pollutants are by-products of industrial and mining activities, and from burning of fossil fuels for energy and transport. The current situation is not clear-cut. Most developed regions have instituted control measures, but this progress is offset by new sources of pollution in emerging economies. Overall, growing awareness of the danger is having a positive effect on putting control measures in place.

#### Oils (hydrocarbons)

- Significant amounts of oil and oil by-products are released into the environment, mainly as a result of activities related to energy production and use. Oil contamination damages habitats and wildlife as well as posing a threat to human health. There has been significant improvement since 1985, mainly in marine transportation of oil, although the danger of an oil-spill remains. However, because of growth in population and industrialization, it is expected that land-based oil runoff will increase.

#### Nutrients

- Imbalances in nutrient ratios cause widespread changes in the structure and functioning of ecosystems, which, in turn, have generally negative impacts on habitats, food webs and species diversity, including economically important ones. The potential seriousness of the problem was not foreseen some decades ago when it first emerged. Both the frequency and intensity of so-called 'coastal dead zones' are rapidly increasing. Control of land-based sources of nutrients has been uneven. Relative success has been achieved with point sources but diffuse sources are proving more difficult to curtail.

#### Sediment mobilization

- Increase or decrease in sediment flows seriously disrupts coastal ecosystems and habitats, including wetlands, coastal lagoons, estuaries, sea grass beds and mangroves. These changes result from modifying land-use and/or the hydrological regime. Overall, the situation appears to be worsening, with progress in some areas being offset by deterioration in others. In the future, growing populations and increased development can only make current trends more pronounced.

#### Marine litter

- Ecosystems and wildlife, human health and safety, cultural and aesthetic values and economic activities all suffer as a result of litter. Since most of this litter is non-degradable, or only breaks down very slowly, it inevitably accumulates over time. Thus, the problem is continually worsening, in spite of both national and international efforts to control it. As the problem has largely cultural roots (current attitudes and behaviour demonstrate that people do not feel responsible), building awareness and providing information offers some hope for the future.

**Physical alteration and destruction of habitats**

- Damage to coastal habitats and wildlife is increasingly becoming more severe as a result of human population growth and increased economic and development activities. The most affected coastal systems include wetlands, mangroves and coral reefs. While deterioration is worse in regions that have faster growth in population, no area is spared. Overall, the situation is worsening and will most likely continue to worsen in future.

**Progress has been uneven, but real impacts will only show in the longer term**

4 An overall assessment of the situation concerning land-based sources of pollution and progress in implementation of the GPA shows that while the framework for action is solid, progress in dealing with the nine source categories has been uneven. There are three areas where good progress has been made (Persistent Organic Pollutants, Radioactive Substances, Oils (Hydrocarbons), two areas where results are mixed (Heavy Metals and Sediment mobilization) and yet a third group where conditions have worsened (Sewage, Nutrients, Marine Litter, Physical Alteration and Destruction of Habitats). On the one hand success is directly related to factors such as the regulatory system, institutional structures, technology or funding, all areas of concern to the GPA. On the other hand there are factors that are outside the scope of the GPA but that nevertheless have a determining influence, as is the case of population growth and development. The conclusion is that, while progress has undoubtedly been made and continues to be feasible, there is still a long way to go. Bearing the framework of the GPA in mind, it is important to realise that these processes often take 15 to 20 years before meaningful commitments to joint management can be secured, and an even longer time before the environment actually begins to respond.

**Four priority problems, six emerging challenges, two important management approaches**

Four priority problems were identified from within the source categories of the GPA, namely sewage and management of municipal wastewater, nutrient over-enrichment, marine litter and physical alteration and destruction of habitats. These problems have been designated as an area for priority attention in most regions, and are the subject of novel approaches. Six emerging challenges deserve special attention: nutrient over-enrichment in relation to coastal dead zones, depletion of freshwater flows, the importance of coastal and freshwater wetlands, the abundant stream of new chemicals, the importance of resilient coastal habitats for coastal protection, and sea level rise. Two topics were recommended as being of major importance for the way forward: the coordination with other international indicator efforts in the development of a set of indicators to assess changes in the state of the environment relevant to the GPA, and the need for integrated management approaches for river basins and coastal areas.



# The framework for action

## 1

**The adoption of the GPA in 1995 signalled the beginning of the first global programme for the protection of the marine environment that focussed on the effects of land-based activities from nine specific categories. It reconfirmed general principles already contained in various global or regional agreements, either in the form of broad conventions or more restricted protocols, and stimulated the development of more comprehensive agreements, cooperation and partnerships.**

### 1.1 Legal and institutional framework

**First generation regional agreements typically concern conventions**

A first generation of regional agreements, developed before the 1995 adoption of the GPA, concern conventions applying to a specific jurisdictional area of the marine environment as well as a land area determined by the contracting parties (such as the freshwater limit, inter-tidal zones and salt-water marshes). Agreements existing prior to 1995 include those for the North-East Atlantic; the South-East Pacific; the Baltic Sea; the Mediterranean Sea; the Black Sea and the ROPME Sea Area.

**Second generation regional agreements also provide for action plans and programmes**

The recommendations of the 1995 GPA, among others resulted in revisions of various agreements, or adoption of new ones, including for the Mediterranean Sea, the Wider Caribbean, the Red Sea and the Gulf of Aden. Revisions and/or new agreements are in progress, including those for the Black Sea, the Caspian Sea and the Western Indian Ocean, under the Nairobi Convention. Action plans and programmes have been developed for East Asia; South Asia, the South Pacific; the Upper South-West and North-East Atlantic; East Africa; West and Central Africa; ROPME; the Mediterranean; the Arctic; the Baltic; the Red Sea and the Gulf of Aden. These second generation agreements are more comprehensive in terms of jurisdiction and more specific in terms of the activities and polluting substances included. They typically contain provisions for national plans and programmes as well as regional or sub-regional cooperation.

**In addition relevant regional and national legislation was adopted**

Regional and national legislation is also contributing significantly to the improvement of the state of the coastal and marine environment, and includes, among others, the Water Framework Directive (WFD) of the European Union, the Clean Water Act in the USA and equivalent legislation in Canada.

**Overall, legal and institutional arrangements have been strengthened and expanded**

#### **Assessment:**

In the past decade both the legal and institutional arrangements have been strengthened and considerably expanded, and now cover most regions. They are functioning satisfactorily, with the Secretariats to the Conventions playing an important role.

### 1.2 Implementation and international and regional cooperation

**A holistic approach**

The GPA recommends modalities for identifying priorities as well as the steps necessary for developing the most appropriate sequence of actions for dealing with problems. In the past decade, a clear trend towards a holistic approach to implementation has emerged, moving from coastal area management towards a more complex one that also includes the management of entire river basins (Integrated Coastal Area and River Basin Management – ICARM).

**Synergy****Cooperation and  
partnerships****Assessment:**

Cooperation and partnerships are seen as appropriate vehicles for addressing land based sources of pollution. There are many examples of effective cooperation, including the Waste-water Emission Targets – Water, Sanitation and Hygiene (WET-WASH) Campaign; the Programme of Action for the Sustainable Development of Small Island Developing States (BPOA/SIDS); the Mauritius Strategy for the further Implementation of BPOA/SIDS; and the WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP). International financial institutions such as CEF and the World Bank, as well as regional investment banks, bilateral donors and others are instrumental in their implementation. Furthermore, implementation increasingly functions in a synergistic manner with many programmes, making a contribution to the implementation of global initiatives such as the Millennium Development Goals and the relevant targets of the Johannesburg Plan of Implementation of the World Summit on Sustainable Development (WSSD). Cooperation, both within the framework of the GPA as well as under other conventions and programmes, is well established.

## The current status of action within the framework of GPA

# 2

In the review that follows, all regions have been covered as far as possible. Significant examples have been highlighted. Current trends vary for each GPA source category, as does progress in controlling deterioration. Some areas show a positive trend as a result of – amongst others – successful implementation of measures undertaken in the framework of the GPA. Other areas show mixed results, because improvements in some aspects are offset by an acceleration of human impacts and resulting negative environmental trends. Finally, some areas show a clear deterioration, in some cases in spite of action, and in others because action is insufficient.

### 2.1 Sewage

#### The problem:

Sewage generally contains organic carbon, nutrients and human pathogens, as well as industrial chemicals, oils and greases (GESAMP 2001). Discharge of untreated domestic wastewater has been identified as a major source of environmental pollution in most of the UNEP Regional Seas programmes. The problem occurs mainly in developing countries; at present, only a fraction of domestic wastewater is being collected there, and of existing water treatment plants, most do not work efficiently or reliably.

Effects of discharging raw sewage into water bodies are generally local, with transboundary implications occurring in certain areas. However, the commonality of sewage related problems throughout coastal areas of the world is significant (UNEP 1995). The effects include:

- disturbances in the ecosystem, including destruction of habitats, damage to biota and biodiversity as well as possible eutrophication (such as green, brown and red tides and algal blooms);
- effects on human health from polluted water, including swimming (see picture below), bathing, drinking and eating contaminated aquatic foodstuffs;
- impacts on economic activities, principally fisheries and tourism.

Sewage problems mainly occur in developing countries



Children swimming near sewage outflow pipes

Source: BIZZARRI/UNEP/Still Pictures

Sewage treatment, degree of action, and priority accorded vary considerably per region

### The current situation globally:

Sewage treatment varies considerably, as does the degree of action and the priority accorded to the problem. The call by the UNEP Governing Council to give greater attention to the environmental aspects of sanitation (GCSS/GMEF IX, Dubai 2006) may help in focussing attention on this aspect. Highlights of the situation in various regions give a picture of the range of conditions:

In **North America**: the USA Clean Water Act enacted in 1948 and totally revised in 1972 regulates pollution and imposes uniform federal standards, based on the best available technology, for municipal and wastewater treatment. The Clean Water Act has resulted, in a significant reduction of pollution loads in US waters. The US has also focused specifically on coastal waters through the Coastal Non-point Pollution Program, implemented by coastal states and administered jointly by EPA and NOAA. (See Coastal Zone Act Reauthorization Amendments of 1990, Section 6217).

In the **Baltic Sea**: 14 per cent of the wastewater discharged is untreated (UNEP 2004a); however, in the last decade, biological treatment plants have reduced microbial concentrations in wastewater (GIWA 2005).

In **Western Europe** the percentage of population served by treatment plants increased between 1979 and 1990, and remained constant at a level of 80-90 per cent through to 2000; overall pollution levels have decreased due to improvements in treatment. Phosphorus, for example, decreased by 30 per cent and nitrogen by 60 per cent (EEA 2003). In the **Mediterranean Sea** on the other hand 53 per cent of wastewater discharged remains untreated (UNEP 2004a).

In **Central and Eastern Europe** the situation varies. Some 25 per cent of the population is connected to treatment plants, with most of the water receiving secondary treatment; however, many large cities discharge wastewater virtually untreated.

Also in the **Caspian Sea** 60 per cent of wastewater is discharged untreated (UNEP 2004a).

For **Latin America and the Caribbean** tourist facilities tend to operate their own treatment plants, but of these, only 25 per cent are in good operating condition (UNEP 2001), and 86 per cent of wastewater is discharged untreated (UNEP 2004a).

The same source (UNEP 2004a) indicates that in:

the **North Atlantic** only 10 per cent of wastewater is discharged untreated;

**East Asia** 89 per cent;

**Southern Asia** 85 per cent;

the **South East Pacific** 83 per cent;

**West and Central Africa**: 80 per cent;

the **ROPME Sea Area** sewage treatment plants exist in all countries, but the level of treatment varies and capacity is not sufficient to deal with existing loads.

### Financial aspects:

Wastewater pollution can prove costly in human, ecological and financial terms (UNEP 2004) (see box next page). Pollution is associated with direct costs to the economy, as well as the costs of missed opportunities; preventive action can generate substantial benefits while avoiding future expenditures (IHE 2000). The economic, social and environmental benefits

Benefits of improved sanitation and hygiene go beyond individual households

from improved sanitation and hygiene range from us\$3 to us\$34 per us\$1 invested; benefits extend well beyond individual households (CSD 2005).

### The cost of Inaction

- The total global health impact of human infectious diseases associated with pathogenic micro-organisms from land-based wastewater pollution of the sea is estimated to amount to 3 million 'Disability-Adjusted Life Years', with an estimated economic loss of some us\$12 billion per year (Shuval 2003).
- The 1991 cholera epidemic in Peru was the consequence of poor sanitation and water provision. It is estimated that it cost the government us\$1 billion: half of that from loss of life and productivity, a further us\$147.1 million from reduced income from tourism, us\$29 million from medical expenses and us\$27.7 million from reduced exports (Panisset 2000).
- Seafood contaminated by harmful algal blooms causes significant health problems. The socio-economic impact in 3 European Union countries (Greece, Italy, Spain) is around €329 million annually, affecting mainly commercial fisheries (€59 million) and tourism (€265 million) (EEA 2005). <

Many alternative sanitation systems exist, adapted to specific situations in a country

At present, conventional water supply and sanitation systems are costly, particularly for low-income regions. Increasingly, however, there is a wide range of alternatives, going from technically sophisticated, large-scale, costly systems to simple, small-scale and inexpensive ones (CSD 2005). Effective methods now focus on sustainable wastewater management that encompasses an enabling policy environment, efficient institutional and financial arrangements, sustainable, cost-effective technologies and social participation. This follows suggestions in the Strategic Action Plan on Municipal Wastewater and associated Management Guidelines and contributes to the achievement of MDG and WSSD targets on Water and Sanitation (UNEP/WHO/HABITAT/WSSCC 2001 and 2004).

At the global level estimates of the costs of water supply and sanitation are that an additional us\$89-100 billion is required annually for all aspects of water management (us\$72 billion for household sanitation, of which us\$56 billion for wastewater treatment alone). Although governments and the international community are committed to action, challenges still remain on how to mobilize investment (CSD 2005). Examples of current investments include an estimate of €152 billion in wastewater infrastructure during 1990-2010 and €5 billion annually by the European Commission for implementation of the Urban Waste Water Treatment Directive (European Commission 2004). In the USA, us\$125 billion has been spent between 1972-1992 in construction or expansion of publicly owned infrastructure (Pew Oceans Commission 2001).

### Assessment:

Sewage is the most serious problem with the least progress, hampered by financial constraints

Overall, control of pollution from sewage continues to be a major problem, particularly in developing countries and is continually getting worse. Treatment facilities and infrastructure have not kept pace with population growth and the number of people without the benefit of wastewater treatment will continue to increase, unless the means are found to overcome existing constraints. These constraints are mainly financial rather than of a technical nature. On balance, it is perhaps the most serious of all the problems within the framework of the GPA. It is also the area where least progress has been achieved.



The number of known ‘dead zones’ (areas deprived of oxygen and devoid of life) has doubled since 1990 and is spreading as a result of accelerating urbanization and agricultural and related activities (see section 2.6 on nutrients and section 3.2 on emerging challenges).

## 2.2 Persistent Organic Pollutants (POPs)

### The problem:

POPs are highly toxic and stable organic chemical substances that can last for years or even decades before breaking down. Through a repeated and often seasonal process of evaporation and deposit, they can migrate to regions far away from the original source. The effects can be exacerbated by a combination of harsh climatic conditions, differences in the gradient of ambient temperature between the poles and the equator, and physico-chemical properties. This accounts for the prevalence and even higher concentrations of POPs in polar regions than in originating regions (AMAP 1997). In addition, large stocks of expired or banned pesticides threaten the environment and health of millions of people in almost all developing countries and in countries in transition.

**POPs threaten the environment and health of millions of people...**

**...in most developing countries, countries in transition and the Arctic**

POPs can become magnified up to 70 000 times background levels and are readily absorbed by fatty tissue where they concentrate in living organisms through bioaccumulation. They have a range of biological effects, and, in some regions may pose risks to human health, principally through ingestion of marine food. Fish, predatory birds, mammals and human beings are high on the food chain and as a result absorb the highest concentrations. POPs are found in both people and animals living in the most exposed regions such as the Arctic (GESAMP 2001).



**Lack of oxygen due to water pollution caused the death of millions of fish**

Source: Joao P. Engelbrecht/UNEP/Still Pictures



There is much variation in concentrations, causes and effects. For example:

#### The current situation:

In response to the problems caused by POPs the international community adopted the Stockholm Convention in 2001, with the objective of eliminating production and use and restricting exports of specific POPs. The Convention identifies an initial set of 12 chemicals, of which 9 are pesticides. These chemicals fall into three categories, namely:

- pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene;
- industrial chemicals (HCBs and PCBs) and
- unintended by-products (including dioxins and furans).

The situation in respect of POPs varies in the different regions, but tends to be worse at high latitudes. The highlights of the situation in different regions illustrate variations in environmental conditions.

In the Arctic indigenous people are particularly exposed because of their diet

**Arctic** has a relatively uniform distribution of POP levels in various sites (Norstrom and Muir 1994). Indigenous people are particularly exposed because of their diet (see Box below). There are many examples of local PCB contamination, including in Svalbard, the White Sea, the Kara Sea, the eastern Barents Sea, Alaska, Canada, Greenland and Norway (AMAP 2003). New contamination by DDT in the Barents region and of toxaphene in the White Sea is also occurring. Other pollutants (brominated flame retardants, polychlorinated paraffins and perfluoro-organic compounds, some of which are produced in large quantities, have started to reach the Arctic. The Arctic regions of Canada have the highest concentrations of toxaphene and PCBs in fish, but DDT and chlordane compounds are also important. Samples of turbot in the eastern areas and the eastern Beaufort Sea have mean toxaphene concentrations 3 to 5 times higher than in ocean char and 15 to 20 times higher than in Arctic cod (Jensen and others 1997).

#### POPs in human breast milk

Fish is the primary food source of indigenous people in the Canadian Arctic. Many of the fish stocks are heavily contaminated by POPs and, as a consequence, high concentrations of toxaphene have been found in breast milk of indigenous mothers, significantly higher than in women living in large Canadian cities (GESAMP 2001). In East Greenland, 100 per cent of the population has levels of blood contamination of concern and 30 per cent have levels where a change of diet is advised (AMAP 2003a) <

Near Greenland old chemical stocks are leaking

**Greenland:** in the northern and eastern regions, concentrations of toxaphene are high in narwhal and walrus blubber (ICES 2003). This indicates that old chemical stocks are leaking into the environment.

Concentrations in Northeast Atlantic estuaries are above EU limits

**Northeast Atlantic:** concentrations of DDT, lindane and PCBs have decreased in most stocks, including fish and mussels, PCB concentration in cod increased (EEA 2003). However, concentration of contaminants, such as PCB is still above European Union (EU) limits in river estuaries such as the Seine in northern France, the Scheldt and the Rhine on the border of Belgium and the Netherlands, and the Ems in northern Germany.

**Pollution loads in the Baltic Sea have decreased, but regional variation exists**

**Baltic Sea** over the last 50 years, there have been substantial inputs of POPs from various sources. However, since several POPs were banned in the 1980s, there has been a decrease of up to 50 per cent in pollution loads. A sharp decrease occurred between 1983 and 1993, levelling off slightly until 1999, when a downward trend began, leading to a further decrease of more than 30 per cent by 2001. Direct and river inputs of organochlorine contaminants have generally decreased over the last two decades (ICES 2003). However, concentrations of DDT in seals are still high, as is the concentration of dioxins in fish, which exceed new EU limits. Considerable regional variation exists, with the most contaminated fish being found in the Gulf of Bothnia. Dioxin concentrations in sediments peaked in the 1970s, and transfer of dioxins up the food chain have decreased to one third of their 1970 levels, rapidly until the mid-1980s, subsequently levelling off (HELCOM 2001).

**The Western part of the Mediterranean has higher PTS levels than the other parts**

**Mediterranean Sea:** Data are scattered but local levels of PTS reach toxic thresholds for plants and animals near industrial areas and estuaries; in the Northern countries there already is evidence of clear contaminations by PCBs, PAH and solvents (Blue Plan 2005). So far PTS levels are consistently higher in the Western portion than elsewhere in the basin but the risk is expected to increase everywhere (Blue Plan 2005). Marine mammals (seals) in particular exhibit higher levels than elsewhere (UNEP 2003).

**In the Caspian agrochemicals are a serious problem**

**Caspian Sea:** levels of agrochemicals, particularly DDT and endosulphan, are a serious problem. Organochlorines (particularly DDT and its breakdown products) have been detected in seals, sturgeon and bony fish at levels thought to impair fertility and immune systems, thus affecting entire populations (especially in seals, where bioaccumulation is 10-1000 times background levels). Other organochlorines detected, in decreasing order of importance, include PCB, HCH and HCB; this is one of the main transboundary concerns in the region.

**Data for South-East Asia suggest recent use of PTS**

**South-East Asia and the South Pacific:** levels of endosulphan and lindane are high in river waters and sediments, especially in Malaysia and Thailand, suggesting recent use of these substances. In the Pacific Islands, levels of PST in the environment appear to be relatively low for most samples. Overall, the highest concentrations were found for DDT and its derivatives, especially in Papua New Guinea and the Solomon Islands, where it was used to control malarial mosquitoes (UNEP 2003).

**Around South America agrochemical levels fell below accepted thresholds**

**Eastern and Western South America** although there are some problem areas in most countries in the region, decreases in some substances are occurring, especially for DDT and pesticides, which have fallen below accepted thresholds in the last few years (UNEP 2003).

**Technical solutions to the POPs and PTS problem exist, but costs can be high**

#### **Financial aspects:**

Estimates (World Bank 1992) indicate that industrial pollution – and, presumably associated POP emissions – would be reduced significantly if spending on pollution control reached 3 per cent of investment costs. Technically this is not difficult, but costs can be relatively high at the level of individual enterprises; in this case, government policy and compliance mechanisms are a determining factor. Other estimates show that us\$2.5 billion would be

necessary in order to destroy stocks of approximately 500 000 tonne of obsolete or unused pesticides. In this context, it should be noted that sales of pesticides earn companies over US\$30 billion a year (FAO 2001).

**Good progress is made, but more action is required**

#### **Assessment:**

The overall situation has improved considerably since international controls on production and use of a small number of POPs were introduced over 20 years ago. Atmospheric concentrations of controlled substances have decreased in remote areas of the northern hemisphere. In the Arctic, the situation is also likely to improve now that regulation is in place (AMAP 2003). More needs to be done, though, now and in the future (GESAMP 2001). Pesticides falling into the PTS category are still a problem in regions that are heavily dependent on agriculture, including Sub-Saharan Africa, the Indian Ocean and Central and South America, as well as in regions where the chemicals are produced, such as East Asia (UNEP 2003). The Global Programme of Action on International Chemicals Management, adopted during the UNEP Governing Council (GCSS/GMEF IX 2006) may contribute to limiting chemical releases.

## **2.3 Radioactive substances**

### **The problem:**

**Nuclear fuel reprocessing is the most significant activity releasing radionuclides**

Radioactive substances have been entering the coastal and marine environment from a variety of activities, including nuclear power generators, radioactive materials used in medicine, industry, research and space exploration as well as military operations. Nuclear weapons testing in the atmosphere (mainly prior to 1964) and fuel reprocessing plants are main contributors, the first as a source of global impacts, the latter of local ones.

Approximately 85 PBq of radioactive waste has been deliberately dumped into the oceans at over 80 locations worldwide. The first sea disposal operation took place in 1946 off the coast of California. Between 1946 and 1991, Belgium, France, Germany, Italy, Japan, Netherlands, New Zealand, Republic of Korea, Sweden, Switzerland, the former Soviet Union, the UK and the USA maintained sea disposal as a waste management option (see IAEA database on nuclear waste management). During this period, about 46 PBq of low-level nuclear waste was dumped at sea, mostly in the North-East Atlantic. This included waste from research, medical, industrial and military activities, approximately 43 per cent of which was spent nuclear fuel from reactors in the former Soviet Union, disposed of in the Kara Sea.

### **The current situation:**

**Impacts on human health and the environment are generally of minor significance**

All contemporary practices involving large amounts of radionuclides are authorized in conformity with the International Safety Standards for Protection Against Ionizing Radiation and the Safety of Radiation Sources (IAEA 1996). Although accidents can occur, the impacts on human health and the environment are generally of minor significance (GESAMP 2001), as also illustrated in the box on the next page.

### Radioactive substances: the comparative risks

The comparative risks of ingesting radionuclides and chemical carcinogens through consumption of seafood have been evaluated (IAEA 1993). The objective was to place the risks associated with disposing of low-level radioactive wastes at sea in a suitable context. The conclusion was that:

- the effect of naturally occurring radionuclides (principally Po-210) poses a greater risk than the dose limits set by the International Commission on Radiological Protection for production, use and disposal of radioactive materials;
- naturally occurring Po-210 and Pb-210 provide the major dose to marine organisms, and in turn, dietary intake of Po-210 is a major contributor to the background dose for populations consuming fish and shellfish (Livingston 2004);
- the presence of PCBs represents a risk similar to that arising from naturally occurring radio nuclides, other chemicals (DDT, HCB, chlordane, benzo(a)pyrene and dieldrin) present lower risks; however both of these risks are two times larger than those arising from disposal at sea of radioactive wastes (GESAMP 2001).

&lt;

The most significant authorized releases of radionuclides to the sea are from nuclear fuel-cycle installations, particularly spent fuel reprocessing plants located at Sellafield (UK), La Hague and Marcoule – now closed – (France), Trombay (India), and Toki-Mura (Japan). Areas of direct influence from discharges from Sellafield (Irish Sea) and La Hague (North Sea) have been subject to comprehensive evaluation for many years. Nuclear power reactors discharge small amounts of radionuclides at point sources along the coasts or within river catchment areas; generally these are well regulated and are not of concern, even locally, under normal operating conditions. Atmospheric deposition (fallout) is still a significant pathway on land and at sea, but is becoming less important as the atmospheric reservoir of fission products from weapons testing is reduced by radioactive decay (GESAMP 2001). A voluntary moratorium on disposal of low-level radioactive waste at sea was introduced in 1985 by the Contracting Parties to the London Convention and in 1993 a new resolution prohibiting disposal of radioactive waste at sea was adopted (Livingston 2004). Disposal of low-level liquid and solid waste in the Arctic Ocean makes up less than 1.6 per cent of total global activity and wastes disposed of in the Pacific Ocean amount to around 1.7 per cent.

Two regions of the world are highlighted here:

**The Arctic is vulnerable to radioactive contamination but current levels are relatively low**

**The Arctic** is more vulnerable to the consequences of radioactive contamination than other parts of the world because of the characteristics of its land and land cover, food webs and the diet of its inhabitants. The main sources of contamination are fallout from atmospheric nuclear weapons testing from 1945 to 1980, discharges from European spent nuclear fuel reprocessing plants and the fallout from the 1986 Chernobyl accident (AMAP 2004). A potential future problem is the decommissioning of the Russian nuclear fleet and associated infrastructure (Sarkisov 2004) as well as civil facilities containing spent nuclear fuel. These tasks are receiving priority attention through bilateral, multilateral and international programmes (GESAMP 2001). Monitoring suggests that current levels of contamination are relatively low and pose no immediate radiological concern (Livingston 2004). The exception is the amount of long-lived water-soluble fission products present in seawater, originating from nuclear fuel reprocessing in Western Europe (AMAP 2004).

**North-East Atlantic:** the main sources of radioactive contaminants are from nuclear reprocessing plants and the Chernobyl accident, which is mostly a secondary input from the Baltic. Scientific evidence suggests that these pose low risks to human health and the environment (GESAMP 2001). Liquid discharges from nuclear installations from 1989-2002 show a downward trend in both the total alpha and beta activity, excluding tritium, which releases have increased, mainly from discharges from La Hague, France (OSPAR 2004).

#### Assessment:

the situation concerning radioactive substances in the marine environment is stable and controls on routine discharges are generally stringent. However, accidents such as the one in Chernobyl in 1986 have increased radioactive contamination and are a legitimate cause for concern (GESAMP 2001). In spite of incidents such as this, most of the contamination comes from natural sources rather than human activities and public concern on the subject is not generally supported by objective risk assessments (Livingston 2004).

Public concern on radio activity is not supported by objective risk assessments

## 2.4 Heavy metals

### The problem:

Although metals (such as copper, zinc and selenium) are essential to life, they can become toxic through accumulation in organisms, so that even small amounts in seawater or sediments may become a problem at the top of the food chain. Relatively volatile heavy metals and those that become attached to air-borne particles can be widely dispersed (UNEP 1995). Organic and inorganic metals and metallic compounds are released into the environment as a result of a variety of human activities. The main point sources are industrial and mining activities, while diffuse sources include metal structures and products as well as by-products of combustion, particularly coal and transport.

Mercury, lead and cadmium are highly toxic and easily transported through air over large distances

Impacts of heavy metals are most pronounced near factories and in industrialized estuaries

Mercury, lead and cadmium are metals of concern, because of their high toxicity in certain forms, and relatively high volatility (transported over large distances in the atmosphere). Because of its toxicity, especially in its methylated form, mercury has become an issue of international concern and has led many countries to implement strict controls on emissions and its phasing out. Seafood contaminated with mercury that poisoned both people and animals in Minamata, Japan, is a striking example of its toxicity (GESAMP 2001). Leaded gasoline has been a major historic source of contamination and human exposure. Cadmium accumulates in aquatic organisms such as shellfish and crustaceans and in the liver and kidneys of mammals. Itai itai disease (bone brittleness related symptoms which occurred in Japan) was partly caused by consumption of seafood contaminated with cadmium (GESAMP 2001). Other metals of concern are arsenic, copper, nickel, selenium, tin and zinc. Some – such as tin – are not highly toxic by themselves but can form compounds with organic substances to produce highly toxic substances. Tributyltin and its derivatives, for example, have endocrine disrupting properties and have proven to be much more persistent in the environment than expected. It is used in anti fouling paints and has been banned in some countries in mariculture and on small vessels. It continues to be used elsewhere for certain categories of ships (GESAMP 2001), but on large vessels its use will be phased out between 2003 and 2008 (ICES 2003).



**Chemical outflow into the sea and the atmosphere**

Source: B.Blume/UNEP/Still Pictures

At the local level the most pronounced effect of heavy metals is in the vicinity of point sources and in estuaries in industrialized countries. In the open ocean, atmospheric contamination is more important. For example, 96 per cent of mercury in the ocean originates from atmospheric input, 97 per cent of lead, 92 per cent of cadmium, 76 per cent of copper and 94 per cent of zinc (GESAMP 2001).

#### **The current situation:**

An increasingly serious problem globally is that of 'electronic waste', particularly the disposal of computers and mobile phones, which contain over 1000 different materials, many of them toxic. Recycling (such as valuable component materials like gold) and disposal, when done without the necessary controls, have serious environmental and health impacts. In 2004 an estimated 100 million personal computers were either recycled or disposed of (Hilty 2005).

In more general terms, governments agreed at the 2005 UNEP Governing Council to establish partnerships with international organizations, NGOs and the private sector to take steps to control pollution from mercury, cadmium and lead. The Global Programme of Action on International Chemicals Management (GCSS/GMEF IX, Dubai, 2006) may be instrumental in this regard. The situation regarding heavy metals varies somewhat in different regions, as illustrated below.

**Electronic waste is a major new source of toxic metals**

**Arctic: high mercury levels**

**decreased lead deposition but still high concentrations in soils and sediments**

**Arctic** is still affected by high levels of mercury pollution, both in the environment and in marine mammals. This is occurring in spite of reduction in emissions and concentrations in Europe and North America, because the reductions are being offset by increased emissions in Asia. It is believed that the Arctic may, in fact, be acting as a sink for atmospheric mercury of which around 5 000 t are present at any one time. Levels of mercury in Arctic ringed seals and beluga whales have increased 2 to 4 times over the past 25 years in some areas of the Canadian Arctic and Greenland (UNEP 2002). This gives rise to concerns for indigenous people in the region, as marine mammals are an important component of traditional diets (ICES 2003). Atmospheric lead deposition has decreased dramatically since the introduction of unleaded gasoline; however levels of lead in wildlife and fish has not measurably declined,

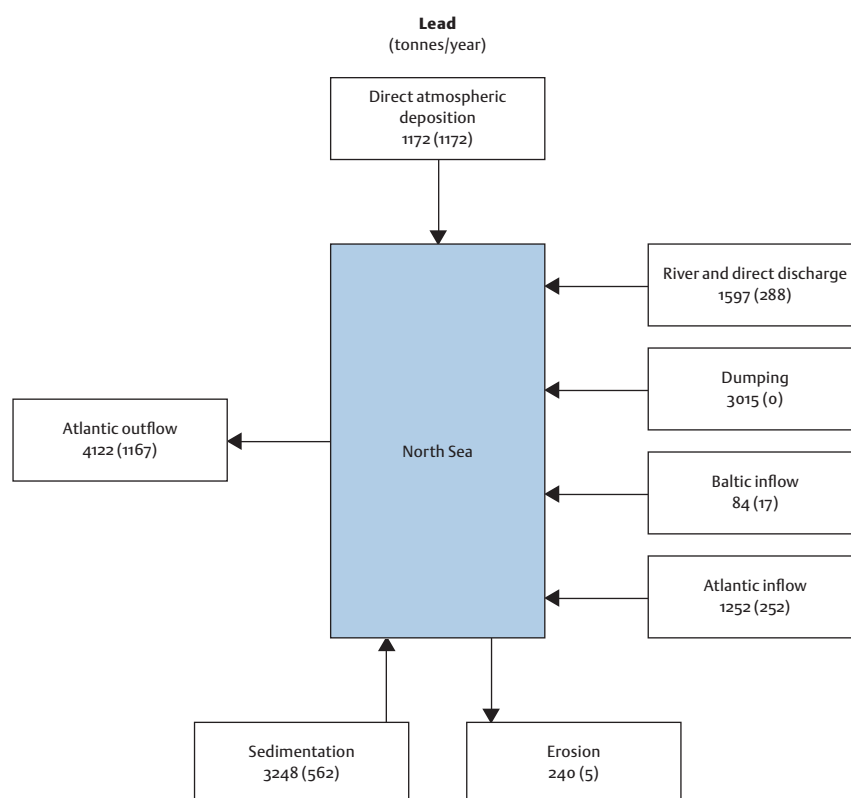


**unclear cadmium levels**

probably because of continued uptake from the large reservoir of lead deposited in soils and sediments. Lead levels in the environment are expected to diminish over time if present trends continue. The significance of current levels of cadmium remain unclear; they are high enough to threaten fish, birds and mammals, but the actual effects have not been documented here, although the effects in other regions are known. Platinum, palladium and rhodium, – used in catalytic converters in cars –, as well as other rare earth metals are present in low concentrations, which are nevertheless many times higher than they were some decades ago. The environmental and health effect of these metals is not well known (AMAP 2003).

**North Sea:  
large decreases in lead,  
cadmium and mercury**

**North Sea:** a comprehensive study considered direct input of heavy metals into surface waters, as well as deposition in the watershed, river input, Baltic Sea and Atlantic Ocean inflow and outflow and exchange of metals with sediments. The figure below shows results in respect of lead. Atmospheric input is important in this larger context; it is roughly equal to inflow from the Atlantic Ocean (which in itself includes around 20 per cent from the atmosphere), although smaller than that from direct dumping (GESAMP 2001). Lead cadmium and mercury inputs have decreased by up to 70 per cent in most countries in the region, although targets for substances such as copper and tributyltin have not been met (EEA 2003).

**Input of lead to the North Sea**


Source: GESAMP 2001, after Van den Hout 1994

Values in parenthesis denote atmospheric contribution to the total input from that source.

**NE Atlantic:**  
less cadmium,  
mercury and lead

**North East Atlantic:** aggregated results of time-trends in concentrations of heavy metals per sea area over the past 15 years show falling levels for cadmium, mercury and lead in blue mussels and fish (EEA 2003).

**Baltic:**  
Polish rivers make up  
90 per cent of mercury  
loads

**Baltic Sea:** a few major rivers account for a large proportion of total river-borne loads of heavy metals. These have largely decreased during the period between 1994-2000, particularly cadmium and lead. Rivers in Russia – mainly the Neva – make up 60 per cent of lead and 40 per cent of copper loads, while rivers in Poland make up 90 per cent of total mercury loads (HELCOM 2004). The Gulf of Finland received the highest cadmium, lead and copper loads, while mercury inputs were highest in the Baltic proper. However, overall concentrations of mercury in fish are at background levels.

**Europe:**  
Contamination above  
EU limits occurs in major  
estuaries

**Europe:** concentrations of contaminants above the limits set by the EU for fish and shellfish for human consumption are found mainly in mussels and fish in estuaries of major rivers. Examples include cadmium (Seine), lead (Elbe), cadmium near industrial point discharges (Sørfjord, Norway) and lead in some harbours (inner Oslo Fjord). In spite of being far away from point sources, some areas have high concentrations of hazardous materials. Examples include cadmium in northern Iceland and mercury in northern Norway. Concentrations of mercury in blue mussels between 1995 and 1999 were slightly higher than background levels in most areas, indicating a widespread, diffuse exposure, presumably from atmospheric deposition, but with no real hot spots; only four locations showed increasing concentrations in both mussels and fish (EEA 2003a). A 50-90 per cent reduction in discharges has resulted in improved surface water quality; sediment quality is still a problem in designated hot-spots.

**Mediterranean:**  
Cadmium, mercury and  
lead levels are falling

**Mediterranean Sea:** the flows of industrial heavy metals, such as mercury, increased by 300 per cent between 1950 and 1990 (UNEP/MAP/MEDPOL 2003), but aggregated results of time trends in concentrations of heavy metals per sea area over the past 15 years show falling levels for cadmium, mercury and lead in blue mussels and fish (EEA 2003). It was estimated (UNEP/MAP 1996) that river discharge is the largest source of mercury (92 per cent), lead (66 per cent), chromium (57 per cent) and zinc 72 per cent, although direct industrial discharges from coastal zones are also significant for chromium and lead (around 30 per cent of the total (EEA 2003).

**Black Sea:** oil spills caused by inadequate handling of mining effluents containing cadmium, zinc have caused serious fish kills.

**Caspian:**  
Some heavy metals occur  
due to geology, others to  
pollution

**Caspian Sea:** an estimated 17 t of mercury and 149 t of cadmium are discharged annually into the sea, and originate in rivers or from industry and municipal sources. The distribution of concentrations of certain heavy metals such as aluminium, cadmium, cobalt, copper and nickel indicate that they are due to local geology rather than pollution, while elevated levels of mercury and chromium indicate local pollution superimposed over regional characteristics (EEA 2003).

**Nine million batteries are dumped each year in East Asian seas**

**East Asian Seas:** pollution from heavy metals (mainly cadmium, nickel, and cobalt) in electric and electronic equipment and batteries, is an increasing problem, as 9 million batteries are dumped annually. In order to deal with this problem, Thailand has placed at least 5,000 containers for hazardous wastes in convenience stores and electric and electronic goods shops (Fortes 2005).

**Progress in industrialized countries is off-set by new pollution in emerging economies**

#### **Assessment:**

The situation regarding heavy metals is not clear-cut. While most developed countries have taken the necessary steps to deal with the problem, progress at the global level is off-set by new sources of pollution in emerging economies. The picture is complicated by the effects of atmospheric circulation of pollutants, the time-lag in the dispersal of pollutants deposited in the past as well as unexpected persistence of certain compounds in the environment. Added to this, is the emergence of new problems, such as the disposal of electronic wastes. Overall however, there appears to be progress because of the increasing awareness of the dangers posed.

## **2.5 Oils (hydrocarbons)**

### **The problem:**

Significant quantities of oils (hydrocarbons) derived from human activities find their way into the marine environment. These oils:

- damage habitats;
- smother aquatic communities and are generally toxic to aquatic life (when ingested, by coating skin, fur and feathers and by interfering with the respiratory system);
- taint seafood, contaminate water supplies and generally affect human health; and
- foul coastlines and beaches.

Some oils are volatile or easily degraded and disappear rapidly from aquatic systems; other may persist for long periods in the water column or sediments. Natural seeps can provide valuable insights into the behaviour of crude oil in the environment and the response of marine organisms to introduction of oil. Polycyclic Aromatic Hydrocarbons (PAHs) are a special natural constituent of oils and are also produced by combustion of fossil fuels which are subsequently dispersed in the atmosphere; lubricating oils are also an important source. Coastal sediments in most industrial areas and ports frequently have concentrations well above regional background levels. PAHs affect human health mainly by ingestion of seafood (GESAMP 2001).

Land-based sources of oils include:

- urban, industrial and agricultural runoff;
- operational and accidental discharges and emissions from oil exploration, exploitation, refining, storage and transport;
- inappropriate disposal of used oil, mainly lubricating oil, and
- transport in general.



**Stricken oil tanker burning oil**

Source: J. Ledesma/UNEP/Still Pictures

The main pathways for contamination (UNEP 1995) are:

- atmospheric dispersion of volatile fractions,
- storm sewers and
- sewage treatment plants and rivers

#### **The current situation:**

The incidence of oils in the environment can be considered at various levels.

*Globally*, the most reliable estimates are based on comparisons of data for 1983 and 2003.

The latter is expressed as a percentage of the earlier values. All amounts of oil inputs from different sources have decreased significantly, except one category – natural seepage, which is much higher, having increased by 200 per cent. Total oil inputs decreased to 37 per cent of 1985 levels, oil inputs from atmospheric deposition to 17 per cent; from land-based sources to 12 per cent; from tanker accidents to 25 per cent and from tanker operations to five per cent. The table below presents an overview. Two factors, which are difficult to separate, need to be taken into account when interpreting the data, namely improvements in data collection and the degree of success in efforts to stem pollution. Furthermore, the environmental effects of oil releases are a complex function of the local and physical environment, the nature of the oil and rates of release (NRC 2003).

**Data on oil input into oceans need to be interpreted with care**

**Annual (average) worldwide input of oil into oceans (in thousands of tonnes and in percentages)**

	2003 report	1985 report
Natural seeps (marine seeps)	600 000 (47 %)	200 000 (6 %)
Operational discharges of vessels (larger than 100 Gt)	270 000 (21 %)	not available
Land-based sources (municipal and industrial wastes and runoff)	140 000 (11 %)	1 180 000 (36 %)
Tank vessel spills (tanker accidents)	100 000 (8 %)	400 000 (12 %)
Atmospheric deposition	52 000 (4 %)	300 000 (9 %)
Produced waters (offshore production)	36 000 (3 %)	50 000 (2 %)
Operational discharges (tanker operations)	36 000 (3 %)	700 000 (22 %)
Sum of minor categories of inputs	34 600 (3 %)	120 000 (4 %)
Bilge and fuel oils	not available	300 000 (9 %)
Total	1 268 600	3 250 000

Source: adapted from NRC 2003

**The Arctic:** Rivers in Russia (such as the Ob) that drain into the Arctic are severely contaminated. Oil exploration and production is a significant source of pollution. Water from drilling operations accounted for 76 per cent of pollution on the Norway shelf between 1990-95. Levels of PAHs in seawater and marine sediments (particularly in the Beaufort Sea) are above background levels elsewhere (GESAMP 2001). Findings suggest that in the next few decades the sea routes through the Arctic could become virtually ice-free during summer due to climate change, which would have profound implications for development and shipping, and oil and gas exploration in the region (ACIA 2005).

**Baltic Sea:** ecosystems and wildlife are severely threatened by oil pollution. Coastal areas are contaminated by oil-spills, but even clean-up operations may do harm to ecosystems and wildlife. Around 10 per cent of oils originate from deliberate discharges from vessels (HELCOM 2003). The effects include immediate contamination of seabirds and beaches, while long-term ones include greater concentration in sediments (HELCOM 1996). Continuing oil transportation will increase the likelihood of large (over 10 000 tonne) oil-spills by 35 per cent in the Baltic itself and by 100 per cent in the Gulf of Finland (HELCOM 2003).

**Caspian Sea:** intensive exploration and production of oil and gas has been taking place since the mid-1990s. Rising water levels between 1978-92 caused flooding, including in oil wells and production facilities, resulting in widespread pollution of coastal waters. It is estimated that by 2001 160 000 t were being discharged annually into the sea. Rivers contribute 47 per cent of total oil inputs and pollution, erosion and various industries 21 per cent, natural seepage 13 per cent and oil industry activities 5 per cent (EEA 2003). Oil spills are also occurring as a result of the development, by international companies, of the shelf zone (CEP 2002).

**Black Sea:** total oil inputs are estimated to be 110 000 t, of which 53 000 t (48 per cent) arrive via the Danube River. A further 30 000 t derive from domestic sources and 15 400 t from industry; only 136 t come from accidental oil spills, and this does not include the discharge of oily residues from ships, which is believed to be considerable (GESAMP 2001).

**Asia and the Pacific:** accidental oil spills from ships, both along transport routes from the Gulf across the *Arabian Sea* and at loading points, coupled with increasing offshore exploration, make the Indian Ocean vulnerable to oil pollution. Oil spills cause severe contamination in ports in Bangladesh, Indonesia, Malaysia and Pakistan (UNEP 2002).

**North America:** inputs of oil from all sources is estimated at 260 000 t annually, originating in natural seeps (160 000 t/y), land based sources (54 000 t/y), atmospheric discharges (21 000 t/y), tanker spills (5 300 t/y), oil extraction (3 000 t/y), pipeline spills (1 900 t/y) and spills in coastal facilities (1 900 t/y) (NRC, 2003). Natural seeps are responsible for over 60 per cent of oils entering North American waters, the largest and best known natural seeps being in the Gulf of Mexico and off southern California, both of which also harbour extensive oil and gas production. Spills from vessels between 1990-99 decreased by two thirds compared to the previous decade; releases from oil and gas exploration and production have also decreased dramatically in this period (NRC 2003).

**South America:** oil exploration and production in river basins is a key factor in pollution in coastal areas. Oil spills originating in the Andes also contribute considerable amounts of heavy metals (LOICZ 2005).

**Africa:** oil exploration and production along the coasts causes widespread pollution and degradation of both coastal and marine ecosystems, as shown by the case of Nigeria.

**ROPME Sea Area:** is considered to have one of the greatest pollution risks in the world due to the large number of offshore installations, tanker loading terminals, and high volume and density of marine transportation of oil. Around a third of oil spills larger than 10 million gallons occur here. Smaller scale incidents such as pipeline rupture and well blowouts are more frequent here than elsewhere. Roughly 2 million barrels of oil are spilled annually from routine discharges of ballast, tanker slops and from 800 oil and gas platforms (Butayban 2005). The high assimilative capacity of the ecosystem means that the general effects of oil leaks are minor, and contamination is almost entirely on beaches (GESAMP 2001).



**Oil input from marine transportation has significantly reduced...**

**...but land-based run-off is expected to increase**

### **Assessment:**

The general situation concerning anthropogenic inputs of oil into the marine environment has improved significantly since 1985. The greatest success has been achieved in curbing inputs from marine transportation of oil, the associated discharge from tankers and oil spills. Improvements in technology (design and operation of tankers) and legislation and regulation, particularly at the international level, are the main factors in improvement. However, the danger of a large oil spill is significant, particularly in areas without stringent safety procedures and inspection practices. With the population growth and industrialization experienced over the past two decades, it is expected that the current trends in land-based oil runoff (urban runoff, municipal wastes, industry and refineries, disposal of lubricants) will move upwards.

## **2.6 Nutrients**

### **The problem:**

**Imbalances in nutrient ratios cause major negative changes in coastal ecosystem**

Nutrient over-enrichment of oceans is probably one of the most important worldwide problems in the context of the GPA. Imbalances in nutrient ratios cause changes in the entire structure and functioning of an ecosystem. This includes:

- stimulation of growth of phytoplankton and benthic algae, often favouring toxic or otherwise harmful species, as well as reduced penetration of light;
- large-scale oxygen depletion from decomposition of excess organic matter;
- general degradation of habitats, including destruction of coral reefs and sea-grass beds;
- alteration of marine food-webs, including damage to larval or other life stages;
- mass mortality of wild or farmed fish and shellfish as well as of mammals, seabirds and other animals.

**Land-based activities are the dominant source of nutrients**

Nutrient inputs are often localized but added up they are a major factor in global marine pollution. Land-based activities are the dominant source of nutrients, especially for fixed nitrogen, and include (GESAMP 2001):

- agricultural runoff (fertilizer);
- atmospheric releases from fossil fuel combustion, and, to a lesser extent, from agricultural fertilizers and manure;
- sewage and industrial discharges

**Nitrogen flow towards oceans is strongly increasing, a trend that is expected to continue**

Nitrogen flow towards the oceans are a good illustration of the magnitude of changes in anthropogenic nutrient inputs since the industrial revolution. These flows have increased 15 fold in North Sea watersheds,<sup>11</sup> fold in the north eastern USA;<sup>10</sup> fold in the Yellow River basin, 5.7 fold in the Mississippi River basin, 5 fold in the Baltic Sea watersheds, 4.1 fold in the Great Lakes/St Lawrence River basin, 3.7 fold in South-Western Europe (MEA 2005). It is expected that global river nitrogen exports to the oceans will continue to rise. Projections for 2030 show an increase of 14 per cent compared to 1995. By 2030 global river nitrogen exports is projected to be 49.7 Tg/yr, with natural sources contributing 57 per cent of the total, agriculture 34 per cent and sewage 9 per cent (Bouwman and others 2005).

### Coastal dead zones and eutrophication are of particular concern

While most of the effects of nutrient enrichment are negative, in some areas they have led to increased production in commercial fisheries, as has happened in the some parts of the Mediterranean (GESAMP 2001). Two general problems of concern are:

- 'coastal dead zones' (areas of oxygen deprivation and devoid of life) of which there are currently 146, having doubled every decade since 1960 (Larsen 2004);
- increasing agricultural runoff and consequent eutrophication of coastal waters, a worrying trend not foreseen three decades ago (UNEP 2002).

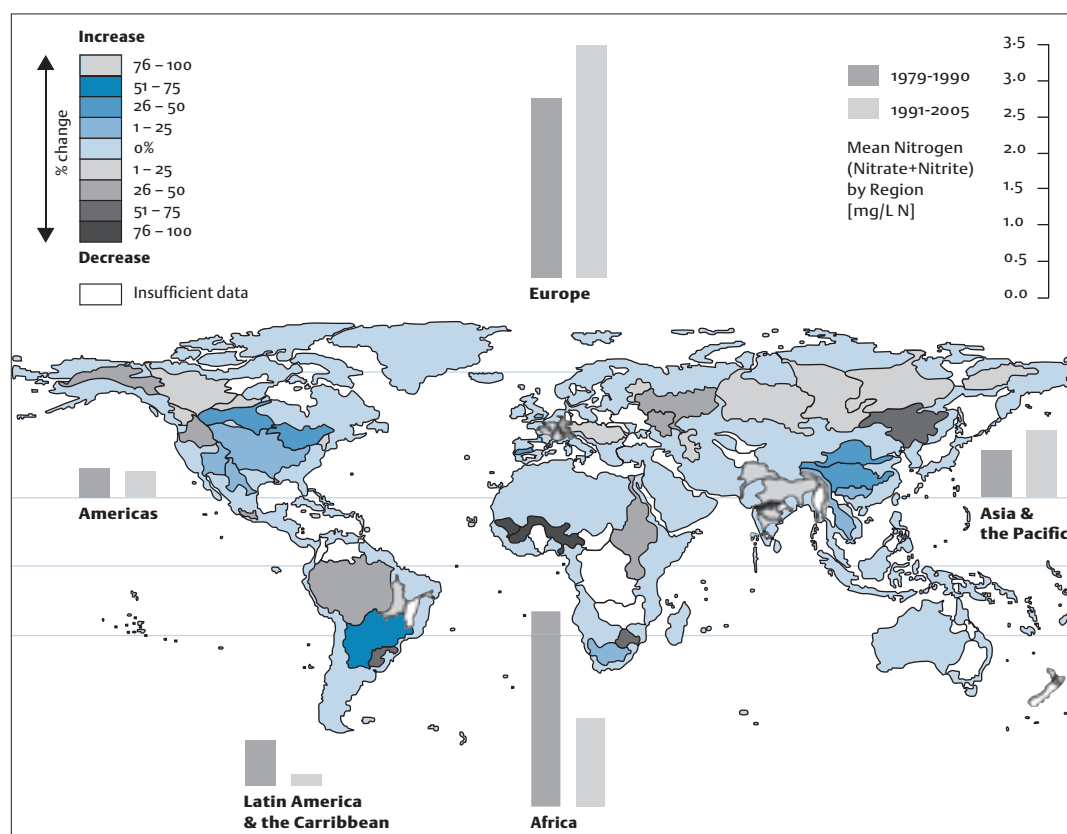
Projections indicate that this could lead to major ecosystem degradation (Tilman and others 2001). Nutrient over-enrichment also interacts synergistically with other human activities, contributing to ever increasing degradation.

### The current situation:

The amount of nutrients entering the oceans tend to vary significantly over time and from region to region (see map below), as do the actions to control the problem. Nutrient enrichment between 1960-1980 in the developed regions of Europe, North America, Asia and Oceania resulted in major changes in coastal ecosystems. Estuaries and bays are most affected, but eutrophication is also apparent over large areas of semi-enclosed seas, including the Baltic, North Adriatic and Black Seas in Europe, the Gulf of Mexico and the Seto Inland Sea in Japan. Significant reduction in phosphorus loading from discontinuing the use of polyphosphate detergents has occurred in Europe, North America and Japan (NRC 2000). Highlights below illustrate other regional trends.

### Amount of nutrients entering oceans vary significantly per region

### Changes in nitrogen concentrations for significant global watersheds (percentage) and by region (concentration): 1979-1990 and 1991-2003



**North Sea:** more than 90 per cent of the current annual inflow of both nitrogen and phosphorus come from the North Atlantic; atmospheric inputs of nitrogen are 23 per cent of total inputs.

**North Atlantic:** is the major source of sea nutrients on the western margin of Europe. Nutrient concentrations in river water are often 50 times higher than in Atlantic waters; rivers contribute 65-80 per cent of total nitrogen and 80-85 per cent of total phosphorus.

**Irish Sea:** rivers contribute 56 per cent of total nitrogen inputs; atmospheric nitrogen deposition contributes 31 per cent.

**Baltic Sea:** nitrogen from rivers constitutes 69 per cent of total nitrogen inputs; atmospheric inputs are 31 per cent of totals and have decreased by 20 to 30 per cent.

**Mediterranean Sea:** concentrations of nutrients in rivers are generally at least four times lower than rivers in north-west Europe, but there is evidence of an upward trend in both nitrogen and phosphate concentration (ICES 2003).

**Black Sea:** nitrogen levels are four times higher than they were in the 1960s. However, important reductions have taken place since the political and economic changes to the centrally planned economies in the region occurred. Within seven years of reduced economic activity, the levels of nitrogen and phosphorus entering the sea had dropped to half the previous levels, dead zones largely disappeared and fisheries rebounded (Mee 2001). Nitrogen from rivers are 65 per cent of totals, and 70 per cent of this comes from the Danube River alone.

**East Asian Seas:** urban areas and agriculture produce such large amounts of organic waste that coastal ecosystems are unable to filter and neutralize them (ESCAP 1999). Rivers running through Cambodia, China, Malaysia, Thailand and Vietnam deliver at least 636 840 t of nitrogen to the waters above the Sunda Shelf; China contributes at least 55 per cent of the total, Vietnam 21 per cent and Thailand 20 per cent (Talaue-McManus 2000). In 2001, 77 'red tide' events affected 15 000 km<sup>2</sup> offshore waters of China, where pollution is serious. Major eutrophication occurs only in estuaries and coastal areas in the Philippines and Thailand; impacts are most significant in enclosed bays, harbours and lagoons with limited circulation, such as Manila Bay (Fortes 2005).

**North America:** in the USA diffuse inputs of nitrogen and phosphorus pollution have increased dramatically, causing eutrophication, harmful algal blooms, dead zones, coral reef destruction, loss of sea-grass and kelp beds, fish kills, shellfish poisoning and even sea-bird and marine mammal deaths (Howarth and others 2000). Around 60 per cent of coastal rivers and bays are severely degraded. Human activities have increased nitrogen flux in the Mississippi River basin four-fold and in rivers in the northeast eight-fold. The single largest coastal system affected by eutrophication is a large dead zone in the Gulf of Mexico. In the early 1990s it was estimated to be 9 500 km<sup>2</sup> and by 1999 20 000 km<sup>2</sup>. Other severely

Control of nutrient over-enrichment has been uneven and remains problematic

degraded coastal areas include Chesapeake Bay, Long Island Sound and the Florida Keys. The largest single source of nitrogen comes from animal waste leaked directly into water bodies or volatilised into atmospheric ammonia. The largest non-point source of atmospheric deposition of oxidized nitrogen comes from fossil fuel combustion (Walker 2002); phosphorus comes from agricultural activities (Jaworski 1990).

#### Assessment:

Overall, progress in the control of land-based anthropogenic sources of nutrient over-enrichment of the marine environment has been uneven. In developed regions, municipal sources are fairly well managed, but nutrient over-enrichment from agricultural runoff is emerging as a serious problem everywhere. Efforts directed at curtailing phosphorus and nitrogen inputs from point sources have been relatively successful in some cases, but need to be given higher priority; diffuse inputs have proven more difficult to control. The box below lists some management options.

#### The key to success: focussed management approaches

Science has been effective in documenting the causes and consequences of nutrient over-enrichment of the oceans. The challenge now is to determine the relative susceptibility of coastal ecosystems and devise improved methods for reducing nutrient input, enhance nutrient sinks and rehabilitate watersheds within an adaptive management framework. Various management options are currently being explored.

- Increasingly management goals are based on desired outcomes for the coastal ecosystem, determining the nutrient load reductions necessary to attain them. Examples are the Total Daily Maximum Load (TDML) in the USA and the Water Framework Directive in the EU (Boesch, 2002).
- The *proportional scenario*, which sets a uniform target (e.g. X per cent reduction) for all countries in a given region has proven problematic though, as countries that already meet high water quality standards and have already achieved reductions find it more difficult to comply. This is for example the case with goals set by the countries of the Baltic Sea region following the 1988 Ministerial Declaration on the subject (Schernewsky and Neumann 2002).
- An alternative *cost-effective scenario* has been proposed (Gren 2000), focussing on nutrient load reduction in drainage basins where it shows the highest cost-efficiency. Simulations show that goals can be met at one fourth of the cost of other approaches; however, a considerable reallocation of investments would be necessary.

<

Dramatic changes have occurred in sedimentation patterns

## 2.7 Sediment mobilization

### The problem:

Natural sediment mobilization is important in the development and maintenance of coastal habitats, including wetlands, lagoons, estuaries, sea-grass beds, coral reefs and mangroves, dunes and sand barriers. Modification of drainage basins by human activities has led to dramatic changes in the flow of water and suspended sediments and nutrients.

Anthropogenic modifications arise from:

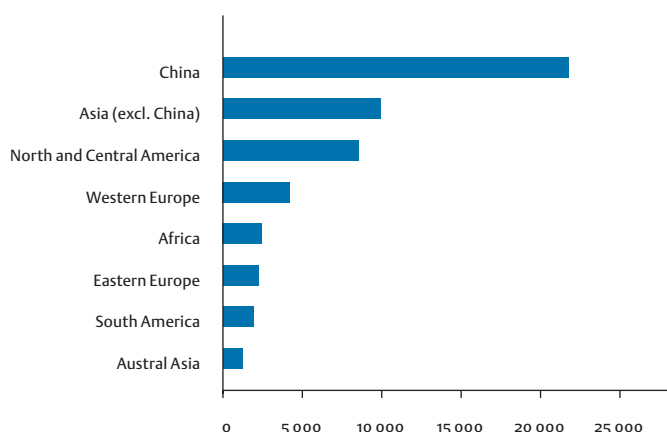
- changes in land use, including land clearance for agriculture and settlement development, forestry and mining activities; and
- hydrological modification through building of reservoirs, dams (see graph next page) and causeways, dredging of water bodies and establishing large-scale irrigation schemes.

The effect of these human activities is that either sediment input into the sea increases, smothering marine communities, or both water and sediment flows decrease, causing erosion and damage to ecosystems (LOICZ 2005). Land clearance and deforestation have increased sediment yields. At a global scale, however, this effect is overshadowed by the reduction of sediment flow caused by damming (see graph below). Storage of sediments in large reservoirs has decreased the global flux of sediment to coastal zones by some 30 per cent over the past 50 years (LOICZ 2005). In future, these flows will continue to decrease, mainly because of continued construction of large dams (WCD 2000, LOICZ 2005). It is assumed that a decrease of 5 per cent in total sediment flux represents a threshold beyond which a coastal system is likely to show considerable deterioration.

**Dams are the most important factor in sediment mobilization**

Some historical examples can give an idea of the magnitude of changes that have taken place. Land use and sediment discharge in the eastern seaboard of the USA, for example, have come full circle (Pasternack and others 2001). After European settlement (post 1740) agriculture and deforestation caused sedimentation rates to increase eight-fold up to 1820, and a further three-fold increase occurred in the period of peak deforestation and intensive agriculture up to 1920. From then onwards sedimentation rates were reduced to nearly the original levels, because of urbanization and dam construction (LOICZ 2005). In the Nile Delta, water input has decreased by 80 per cent and sediment input by 98 per cent since the construction of the Aswan High Dam in 1964 (Stanley and Warne 1993; El-Sayyed 1996). Currently 98 per cent of sediments are trapped behind the dam and fresh sediment that does reach the coast these days arrives with the wind and through transport along the shore. As a consequence, there has been erosion along parts of the coastline, salinization of cultivated land and declines of 95 per cent in sardine yields (LOICZ 2005).

**Number of dams in some major sub-regions of the world**



Source: World Commission on Dams (<http://www.dams.org/docs/report/wcdch1.pdf>)

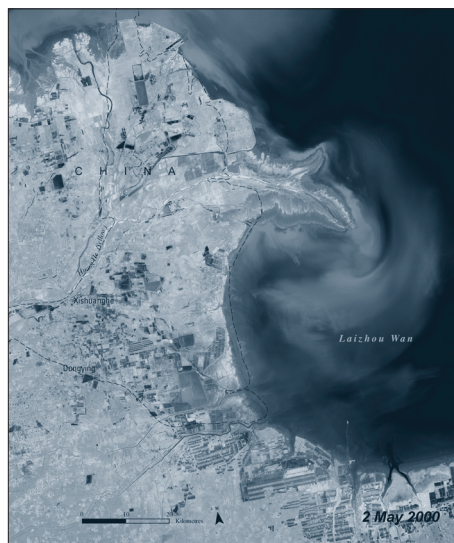
**The current situation:**

Many of the examples highlighted have their origin in events occurring years or even decades ago. However, because human intervention and ecosystem response usually occurs with a delay, impacts are only now becoming apparent.

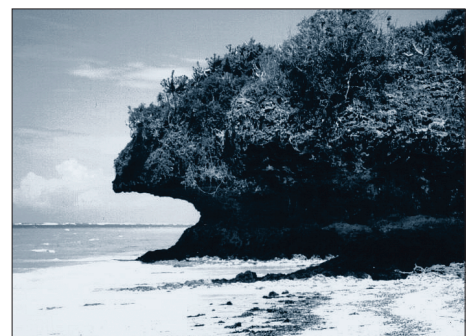
**Europe:** sediment yields differ markedly throughout the region, with the lowest values in the Baltic Sea (12.5 t/km<sup>2</sup>/yr) and the highest in the Mediterranean Sea (300 t/km<sup>2</sup>/yr). Relatively low to medium rates occur in the Atlantic Ocean (131 t/km<sup>2</sup>/yr), the northern Black Sea and the Arctic (48 t/km<sup>2</sup>/yr) and the North Sea (38 t/km<sup>2</sup>/yr) (LOICZ 2005). In the Mediterranean about 75 per cent of the average sediment yield in its river basins can be attributed to human activity; the most important factor affecting sediment mobilization is reduction in water flow resulting from damming, which currently stands at 50 per cent, so greatly reducing sediment inputs into coastal systems. Particle fluxes from the Ebro in Spain, for example, have been reduced by 95 per cent and from the Rhone in Southern France by 80 per cent (Dedkov and Mozzherin, 1992).

**Red Sea/Gulf of Aden:** the main source of degradation is dredging and infilling associated with urban expansion, tourism and industrial development; this causes excessive sedimentation, which in turn leads to suffocation of benthic communities and ecosystem damage (GESAMP 2001).

**Asia:** sediment transport is a real issue in Asia as well. The sediments of the Yellow River, for example, have over the years gradually built up a huge delta (see image below). Between 1979 and 2000 the delta expanded dramatically. Several hundred square kilometers of newly formed land were added to China's coast during this period. It is a dynamic process though. Between 1989 and 1995 the delta has grown, but between 1995 and 2000 it shrank in area (UNEP 2005b). The Atlas does not report on the causes of this dynamic sediment regime, but it is clear that there are multiple causes at work influencing the sediment load and transport. As in the rest of the world dams play their part (China currently has 22 000 dams, representing some 46 per cent of all dams in the world, see graph previous page), as do changing land uses in urban development, agriculture, silviculture and rural development.



**The delta of the Yellow River with a parrot-headed peninsula**  
Source: UNEP 2005b



**Undercut cliff bounding a back reef limestone terrace at Diani, Kenya**  
Source: R.S. Arthurton



**South Asia:** sediment load from erosion in coastal areas is high, mainly as a result of poor land-management and construction activities. Annually, 1.6 billion tonnes of sediment reach the Indian Ocean from rivers in the Indian sub-continent. Total sediment load in rivers in Bangladesh alone amounts to 2.5 billion tonnes, of which the Brahmaputra carries 1.7 billion tonnes and the Ganges 0.8 billion tonnes (UNEP 1987).

**East Asian Seas:** the load of silt per km<sup>2</sup> of drainage basin is 3 to 8 times higher than the world average and contributes to the high turbidity of coastal waters (ESCAP 2000). Two thirds of the world's total sediment transport to oceans occurs here and in South Asia, due to a combination of active tectonics, steep slopes, erosion-prone soils and heavy rainfall, all of which are affected by agricultural and logging practices. Increased damming and diversion of river courses are linked with erosion and sedimentation problems along the coast (LOICZ 2005). Studies in Indonesia (Cesar 1996) and the Philippines (Hodgson and Dixon 1988) indicate that the costs of environmental damage to coral reefs due to sedimentation from logging far exceed the economic benefits derived from this activity. The benefits of improved logging practices outweigh monetary costs to loggers by 3:1 (GESAMP 2001).

**The Wider Caribbean:** annual sediment loads are estimated at 1 Gt, or approximately 12 per cent of global sediment input from rivers. Deforestation is the most important factor in erosion and increases in sediment loads (UNEP 2001).

**South America:** the Mississippi, Amazon, La Plata, Orinoco and Santa Marta river systems discharge large amounts of sediment that move across thousands of kilometres, as seen in satellite images (UNEP 2002). Along both the Pacific and Atlantic coasts serious problems of increased sedimentation and eutrophication, as well as erosion occur. Along the Atlantic coast, siltation and severe erosion has affected mangroves and beaches in Brazil and Argentina (LOICZ 2005).

**Africa:** during the past five decades, water diversion and extraction and construction of dams have been the most important causes of disruption to ecosystems, contributing to salinization (as in the Incomati River in Mozambique), nutrient depletion and loss of biodiversity (as in KwaZulu-Natal in South Africa). Agriculture and associated deforestation are contributing to increased erosion and sediment flux (as in the Tana and Sabaki Rivers in Kenya). Coastal erosion and sedimentation are significant and affect nearly all areas of the continent, the problem being most acute in the Nile Delta and the West African lagoon system (LOICZ 2005) (see picture previous page).

#### **Assessment:**

As changes in sediment mobilization continues because of development, negative impacts have increased, and will probably continue to do so in future. The pattern of change varies from region to region (decrease or increase in sediment flow), with improvements in some areas being offset by deterioration in others. It is therefore difficult to determine the exact balance of the situation; it appears to be relatively stable in the developed regions of the world, while problems are increasing elsewhere.

**Sediment mobilization problems are increasing outside the developed regions**

## 2.8 Marine litter

### The problem:

Litter is found in coastal areas and oceans across the world, even in remote places far from human population centres, dispersed by marine currents and wind. Litter in the marine environment:

- damages ecosystems and wildlife;
- threatens human health and safety,
- has a negative influence on the cultural, aesthetic and amenity values of society, and
- adversely affects economic activities such as tourism and fisheries.

**More litter is produced, which accumulates because of its slow or non-degradable nature**

Marine litter consists mainly of slowly degradable or non-degradable substances, which inevitably accumulate in the environment, causing an ever growing problem. It is difficult to estimate the total amount of marine litter in the oceans, but it is believed that around 70 per cent of litter entering the oceans lands on the seabed, 15 per cent on beaches and 15 per cent remains floating on the surface. Litter originates from two sources: Sea-based litter includes:

- trash from all manner of vessels;
- oils from offshore platforms or from boats and transport ships;
- refuse from aquaculture installations;
- discarded ships, fishing equipment and nets.

Land-based sources of litter include:

- municipal wastes from trash dumps, untreated sewage or storm water; and the special category medical waste;
- various types of wastes from industrial installations and military activities;
- wastes originating from tourism and leisure activities (UNEP, 2005a).



**Marine litter**

Source: Shirley Richards/UNEP/Still Pictures

**Impacts of marine litter can be devastating, both for animals and men**

Marine litter is a complex problem. Examples of specific effects are entanglement in nets and plastic bags, and ingestion of various objects. In addition plastic litter kills more than 1 million birds and 100 000 marine mammals and sea turtles each year. Plastic litter is believed to be a source of persistent toxic substances and pieces of litter can transport exotic invasive species over large distances. Items such as glass, plastic, rope, fishing lines and medical waste also pose immediate risks to human safety. Bathers and divers can become entangled in submerged or floating debris or injured by syringes and medical waste can transmit pathogens. Contact with such polluted water can result in a variety of infections, including skin rashes, diarrhoea, bacillary dysentery, hepatitis and even typhoid and cholera. Military debris is a particularly serious problem: millions of tonnes of munitions, including explosives, incendiary devices as well as weapons containing arsenic, phosphorus and mustard and nerve gas have been dumped in the oceans, sometimes washing-up on beaches, posing a serious hazard (GESAMP 2001).

**Some 58 per cent of litter comes from recreational activities**

**The current situation:**

The annual 'International Coastal Cleanup', organized by the NGO 'Ocean Conservancy' gives an indication of the amount of marine litter existing globally. In the 2002 campaign, 390 000 volunteers in 100 countries removed litter from more than 21 000 km of coastline and waterways, collecting 6.2 million pieces of refuse weighing 4 000 tonne. Almost 58 per cent of the litter could be attributed to recreational activities along the shore. Estimates from various regions include:

**Europe:** between 1992-2002, over 73 000 m<sup>3</sup> of marine litter were collected along 300 km of Sweden's beaches (6 000-8 000 m<sup>3</sup>/yr). In the **Baltic** plastic debris has greatly increased in the last decades and now accounts for over 90 per cent of the total. In Poland, annual clean-ups collect 50-100 m<sup>3</sup> of waste (HELCOM 2003). Nevertheless, solid waste is not a big problem as beaches are cleaned regularly and litter from ships is limited (GIWA 2005).

**Pacific Islands:** in 2002 107 tonnes of nets and fishing gear were gathered from the northern islands in Hawaii (NOAA 2002); a further 90 tonnes were collected in 2003.

**Australia:** in northeast Arnhem Land, around 200 turtles were found ensnared in fishing nets over a period of four years; apparently around 80 per cent of the nets were foreign. A beach survey in the same area in 2000 found 7 561 items, including 500 derelict fishing nets along only 8.5 km of coastline (DEH 2001).

**ROPME Sea Area:** an estimated 1.2-2.6 kg of litter is generated on board ships per person per day, most of which is dumped overboard. In Kuwait, 18 fishing nets weighing more than three tonnes and measuring more than 3 000 m<sup>2</sup> were recently collected (Butayban 2005).

**Financial aspects:**

Few assessments of the economic impacts and costs of marine litter have been carried out. The costs for the clean-up of 900 km of coastline, gathering 10 000 tonnes of waste, in 56 communities in the UK was estimated at US\$3.9 million. The total cost of marine litter in the

Shetlands (assuming all parties involved were damaged equally) was estimated at US\$9.9 million annually, of which some US\$8.7 million for the fishing industry (Hall and Nickerson 2000).

**Cost of cleaning-up marine litter and of damage incurred is enormous**

Municipalities on the west coast of Sweden spend an estimated US\$1.6 million annually to clean beaches along 3 600 km of coastline. The cost to the fishing industry in Sweden on the Skagerrak coast has been estimated to be over US\$1.1 million per year (Hall and Nickerson 2000). Extrapolating from these figures it is possible to imagine the magnitude of global clean-up costs and of the damage incurred.

**The marine litter problem has cultural roots; awareness programmes can help to tackle it**

#### **Assessment:**

The problem of marine litter has steadily grown worse, despite both national and international efforts to control it. The largely non-degradable nature of litter in the marine environment causes it to accumulate and a constant increase in the amounts discarded only adds to the problem. Legislation and improved management practices have a limited effect, because the problem has cultural roots (people do not really feel responsible). Information, education and public awareness programmes are proving useful, but there is still room for improvement (UNEP, 2005a).

## **2.9 Physical alteration and destruction of habitats**

### **The problem:**

**Coastal degradation is worst in regions with fast growing populations, but no area is spared**

Direct physical alteration or outright destruction of coastal and marine ecosystems is coupled to growth of population and economic activities. Thirty-eight percent of the world's population lives on only 7.6 per cent of the Earth's total land area, a narrow fringe of coastal land (UNEP 2006). Projections indicate that the numbers will increase considerably over the next few decades; increases will be larger than for in-land areas. Average population density in the coastal zone increased from 77 persons per square kilometre in 1990 to 87 p/km<sup>2</sup> in 2000. It is projected that this trend will continue resulting in population densities of 99 p/km<sup>2</sup> in 2010, 115 p/km<sup>2</sup> in 2025 and 134 p/km<sup>2</sup> in 2050 (UN data at [www.gpa.unep.org/PADG](http://www.gpa.unep.org/PADG)). This growth has a clear bearing on the amount of physical alterations and consequent destruction of coastal areas. The most damaging actions are:

- changes in land use, including draining wetlands and mangroves for use in agriculture or settlements, building dams, ports, seawalls and aquaculture installations as well as tourist facilities, and
- overuse of resources, including over-fishing, water, sand and gravel extraction and other similar practices.

**Much damage is caused by activities in coastal zones ...**

The effects of these actions are inextricably linked and problems in one area set off chain reactions in others. The most important effects are:

- imbalances in ecosystems,
- outright physical or habitat destruction and
- damages to wildlife and fish-stocks.

... but activity in the hinterland also has severe negative impacts

In addition to the activities in the coastal area itself, the effects of increased freshwater use and human activities in the bordering river basins have to be mentioned as major drivers for coastal change. Damming of rivers during the last decades has caused a decline of sediment transport to the coastal areas by 30 per cent and a decline of freshwater flows by 15 per cent.

Some 35 per cent of mangroves disappeared in the past 20 years...

Examples of the type of physical alterations currently occurring in coastal environments give an idea of the magnitude of the problem. Trawling grounds cause significant damage to the sea bed; data from 24 countries indicates that trawling grounds cover around 8.8 million km<sup>2</sup>, of which 5.2 million km<sup>2</sup> are located on the continental shelf, representing 57 per cent of the total continental shelf of those countries (WRI 2000). Of all wetlands 50 per cent have been lost over the past century and of mangroves even more than 50 per cent (OECD and IUCN 1996); 35 per cent of mangroves disappeared over the past 20 years alone (Valiela and others 2001). Already 30 per cent of the world's coral reefs are seriously damaged and it has been predicted that 60 per cent of coral reefs will be lost by 2030 (Wilkinson 2004). RAMSAR estimated in 1999 that the main threats are overexploitation (36 per cent of the total) and habitat destruction (64 per cent of the total, of which 30 per cent through coastal development, 22 per cent through land-based pollution and erosion and 12 per cent through marine pollution) (RAMSAR 1999). More local figures on habitat destruction are documented in UNEP-WCMC 2006. Recent FAO data show the seriousness of over exploitation of fisheries: in 12 of the 16 FAO statistical regions at least 70 per cent of stocks are already fully exploited or overexploited, suggesting that the maximum fishing potential has been (FAO 2004).

...and 60 per cent of the remaining coral reefs will be lost by 2030

#### **The current situation:**

The driving forces responsible for the physical alteration and destruction of habitats vary from region to region, but all show deterioration of some kind.

**North Sea:** sand and gravel extraction is widespread, and is particularly intense in the southern part damaging benthic communities, which can take up to 10 years to recover. Intensive trawling activities affect the seabed in sub-regions such as the Irish Sea (GESAMP 2001).

**Baltic Sea:** approximately 90 per cent of marine and coastal biotopes are threatened to some degree, either by loss of area or reduction in quality (HELCOM 1998 and 2001).

**Mediterranean Sea:** In the section on sediment mobilization the example of the Nile River has already been given. Many other examples exist. After a new fishing harbour and commercial port were built in the 1990-s near Tangier in Morocco, for example, the Tangier beach nearly disappeared as the sediment transport regime changed. As a result Tangier lost 53 per cent of its international night-stays, local tourism transport was reduced by 40 per cent and local craftsmen lost 25 per cent of their income. On the other hand, continued growth in tourist facilities and settlements in coastal areas also contributes to a disturbance of ecosystems and destruction of coastal habitats in most countries of the region (Blue Plan 2005).



**Caspian Sea:** the transgression of the sea in the last two decades has resulted in a sharp increase of water levels of around 2.5 m, which has displaced wetlands and other shallow habitats; this has been accompanied by ecosystem instability and a decline in bio-diversity, particularly in the Caspian lowland in Kazakhstan and Russia, in lowland deltas in Azerbaijan and offshore shallows (GIWA 2005a).

West Asia is suffering from increasing deterioration of coastal areas, mainly because of land reclamation (dredging, infilling) and construction; the problem is severe along the western coasts of the Gulf countries (Bahrain, Qatar, Saudi Arabia, United Arab Emirates). Habitat destruction is exemplified by the case of Dubai, where the expansion of the tourism industry is damaging the marine habitat, burying coral reefs, oyster and sea-grass beds, threatening other marine species, increasing the turbidity of coastal waters and disrupting natural currents. Much of the damage has been caused by one single development project through which a series of artificial islands are being created. Part of the project is located in a formerly protected marine reserve (Butler 2005). Restoration efforts in the marshlands of Lower Mesopotamia do show some positive signs (see box below).

#### **A wetland reborn: the marshlands of Lower Mesopotamia**

The most significant changes in the Lower Mesopotamia wetland ecosystem have occurred here in the past three decades. Satellite images show that 93 per cent of the lakes and marshes that existed in 1970 had disappeared by 2002 (UNEP 2002). This is attributable in part to the construction of a large number of dams in the headwaters of the Tigris-Euphrates system, but the principal change came from large drainage works in southern Iraq, notably the Main Outfall Drain (formerly the Third River or Saddam River), the Mother of Battles River (sealed in 2003), and the Glory River, all of which redirect marsh waters to the Persian Gulf.

In May 2003 action was taken by the local population and the Ministry of Water Resources to re-establish the marshlands. By May 2005 an estimated 20-25 per cent of the area had been flooded again, either seasonally or permanently. Re-flooding, however, is not necessarily equivalent to restoration. Some areas have experienced a rapid return to original conditions, others are recovering more slowly, and some areas have not returned to wetland conditions but have become akin to reservoirs or evaporation ponds.

Full recovery of the ecosystem will not be easy. It may even be impossible in some parts. However, the social fabric does show signs of recovery, with as many as 42 000 Marsh Dwellers returning to their age-old traditional lifestyle (Eden Again 2005).

The Marshlands play an important role as spawning and nursery area for the north western Persian Gulf aquatic ecosystem, while juveniles are migrating via the 190 km long Shatt Al-Arab, the connection between the Marshlands and the sea. It is estimated that 40 per cent of Kuwait's shrimp catch originates from the marshes.

&lt;

**South East Asia** probably has some of the most degraded wetland in the world, caused in part by population pressure, deforestation (Indonesia), ecosystem fragmentation and large numbers of dams (India); 88 per cent of the coral reefs (among the most species rich in the world) are potentially threatened by human activities, of which 50 per cent at high or very high risk (Burke and others 2002). Mangroves, also among the most bio-diverse in the world (Burke and others 2001), are under increasing pressure from land clearance for agriculture, aquaculture and logging, despite the widely documented value of these ecosystems in terms of coastal protection, water purification, CO<sub>2</sub> absorption and as breeding grounds



for fish. Also the 2005 tsunami caused a great deal of destruction, but, there are signs of recovery in some areas.

**North America:** About a third of North America's threatened and endangered species depend on wetlands (UNEP 2002). A wide mix of land use changes have resulted in large wetland losses, with urban development responsible for 30 per cent, agriculture for 26 per cent, silviculture for 23 per cent and rural development for 21 per cent (American Rivers 2000). Overall losses in wetlands have decreased in the last three decades (USEPA 2003). Key areas of the USA continue to lose valuable wetlands, though. The destruction of Louisiana's coastal wetlands caused by Hurricane Katrina provides part of the explanation for the continued losses. More than 1 million acres have been lost there over the past decades. Before the alteration of the ecosystem, millions of tonnes of sediment from the Mississippi replenished the wetlands and barrier islands in the delta on a regular basis. The canals that were built to accommodate the oil and gas installations in the area led to salt-water intrusion though, and this destroyed the freshwater marsh-grasses, all of which formed a protective buffer (Waite and Pittman 2005).

**Wider Caribbean:** more than 300 million hectares of land has been degraded and almost two-thirds of the reefs are potentially threatened from human activities, of which over 40 per cent are at high or very high risk (Burke and Maidens 2004). A marked deterioration has taken place over the last two decades. By the late 1990s the condition of reefs was considered poor, and live coral cover averaged only 20 per cent or less, except in north Barbuda (Smith and others 2000). Between 1995 and 2001 reefs in the Soufriere region lost an average of 47 per cent coral cover in shallow waters and 48 per cent in deeper waters. North-west of Saint Lucia 82 per cent of the reefs has either died or is in poor condition (Department of Fisheries of Saint Lucia 2003). In many Caribbean countries intensive mining of beach sand and coastal construction (breakwaters and seawalls) have led to increasing deterioration of the coastal environment. The USA Virgin Islands have lost 50 per cent of their mangroves in the last 70 years (DPMR/DEP and USDA/NRCS 1998).

**Latin America:** loss of habitats along the coastline is wide-spread, as is evidenced by declines in fisheries. Annual catches have historical monitoring records which provide reliable 'critical threshold estimates' for many sites. Extreme cases of deterioration include the 90 per cent reduction in commercial fisheries in the Magdalena River delta in Colombia over the last two decades and a 90 per cent decline in viviparous shark catches in the Patos Lagoon estuary in Brazil (Haimovici and others 1997). Extensive losses of mangroves in Ecuador and Colombia, and salt marsh areas in southern Brazil have been reported (Cardona and Botero 1998); (PMRC 1993; Seeliger and Costa 1997).

**Africa:** extensive changes to the geomorphology of coastal areas are taking place, particularly through erosion of major deltas such as those of the Nile, Volta and Zambezi River or, more rarely, by accretion, as occurs around the Sabaki River in Kenya, which is threatening the Watamu Marine Park. Generalized disturbances in the ecosystem due to agriculture and extensive deforestation are acute in small to medium river catchment areas

in Morocco (Sebou and Moulouya) and East Africa (Tana, Sabaki, Rufiji) (LOICZ 2005). Agricultural and urban development and other pressures are resulting in a loss of up to 50 per cent of wetlands in Southern Africa (DEAT 1999) and Western Africa (Armah and Nyarko 1998; Oteng-Yeboah 1998), while some 80 per cent of the Upper Guinea forest has been cleared, leading to widespread environmental deterioration (Conservation International 1999).

#### **Assessment:**

Physical alteration and destruction of coastal ecosystems has continued to increase in the last decade as a direct result of population growth and associated growth in economic and development activities, in particular those associated with infrastructure and tourism. Coastal ecosystems and habitats, particularly wetlands, mangroves and coral reefs, are fast disappearing; this in turn affects biota, with grave consequences for bio-diversity and food supplies. While deterioration is worst in regions with the fastest rates of population growth, no area is spared. An emerging factor is the growing incidence of catastrophic natural events, sometimes exacerbated by previous weakening of natural systems brought about by human action.

**Infrastructure and tourism increase coastal alteration and destruction, ...**

**...and the consequences for biodiversity and food supply are grave**

## Problems identified for priority action

# 3

Among the nine GPA source categories four issues have emerged as requiring priority, namely sewage and management of municipal waste water, nutrient over-enrichment, marine litter and physical alteration and habitat destruction. A number of resulting challenges have come forth, which are not all new, but are clearly putting increasing pressure on the marine environment. Here the importance of freshwater systems, wetlands, and land use practices in catchment areas requires special mention. This points to the urgent need for integrated management and ecosystem-based approaches.

### 3.1 The issues

Management of waste-water is identified as a priority in six of the ten regional seas assessed

**Management of municipal wastewater:** Due to a variety of factors, in particular the rapid urbanization and growth in population along the coast, traditional approaches to dealing with this problem are no longer effective, and the overall situation steadily grows worse. In an attempt to find a solution, governments are increasingly turning to alternative approaches. This entails various streams, from giving priority to the issue in the framework of national and international strategies, to dealing with the problem in an integrated manner, as well as using simpler methods and technologies that are more cost effective. This problem was identified as a priority in six of the ten regions where UNEP carried out assessments of land-based sources of pollution in 1997-98 (GESAMP 2001) and has also been recognized by the MDG, WSSD and CSD-12 as a priority. Increasingly, a series of international programme initiatives address the problem, including the UNEP/WSSCC WET-WASH initiative.

New understanding is emerging of the dynamics of nutrient over-enrichment and control measures

**Nutrient over-enrichment:** The potential seriousness of this problem was not foreseen only a few decades ago, when it was first emerging. Over the past few years, the magnitude and intractability of the problem has become apparent. Increased demands for food for an expanding global population, intensified agriculture and an estimated 2.4-2.7-fold increase by 2050 in nitrogen and phosphorus-driven eutrophication of terrestrial, freshwater and near-shore marine ecosystems are all elements of a worrying picture of the future (Tilman and others 2001). This eutrophication and habitat destruction would cause unprecedented ecosystem simplification, loss of ecosystem services, and species extinction. It is now clear that, while there has been continuous action to deal with this problem, it is not yet having the desired effect. A new understanding is now emerging of the dynamics of the problem and the kind of approach and control measures that can be effective. In particular, focussing on an outcome based approach rather than on arbitrary goals of nutrient reduction seems to offer some promise. However, this presents scientific and technological challenges that will not be easy to overcome.

PADH must be approached in an integrated manner with a specific geographical focus

**Physical alteration and destruction of habitats in the coastal zone:** This problem, and the related problem of changed sediment mobilization regimes, is now perceived as being of extreme seriousness, given the sheer magnitude of the destruction and the changes taking place. Increasingly it is understood that the problem cannot be dealt with in an isolated manner, but must be approached on a broad front, in an integrated manner, not only at the level of activities (such as tourism, aquaculture and infrastructure development),

but also applying a geographical focus (such as coastal areas, associated river basins and hinterland). Systematic, integrative management approaches are being considered and it is accepted that all relevant actors (industry, policy makers, and the private sector) must embrace them.

**Marine litter:** The problem of marine litter is continuously getting worse and posing an increasing threat to the marine and coastal biodiversity in productive coastal areas. Most of the marine litter consists of material that degrades slowly, and pieces of litter are also potential carriers of invasive species between seas. Though a wide range of marine litter-related policy instruments already exists, the threat is still growing, which suggests that much more remains to be done. According to a recent study ‘deficiencies in the implementation and enforcement of existing international and regional environment-related agreements, as well as national legislations and standards, are contributing to the problem’ (UNEP 2005a).

### 3.2 Emerging challenges

**Waters deprived of oxygen and devoid of life increase**

**Coastal dead zones** – areas of oxygen deprivation and devoid of life of which there are currently about 150 in the world. The number of known locations has doubled every decade since 1960. While many of these sites are small coastal bays and estuaries, seabed areas in marginal seas of up to 70 000 km<sup>2</sup> are also affected. Increased flows of nitrogen from agricultural runoff, deposition in coastal areas of air-borne nitrogen compounds from fossil-fuel burning, and discharges of human wastes are causing nutrient over-enrichment and excessive algae blooms. Most oxygen from the water system is then used for decomposition of the algae in the bottom layers (UNEP 2004).

**Freshwater flows into coastal waters are decreasing**

**Depleted freshwater flows** – freshwater flows are the lifeblood for estuaries and coastal zones, as they provide for the salinity gradients and nutrient flows to sustain the regenerative functions of these regions for marine aquatic ecosystems. During the last decades river flows have decreased at a global scale by about 15 per cent, mainly because of damming (Vörösmarty and others 1997 and 2003). Dramatic increase of up-stream water use and climate change are causing depletion of freshwater flows in an increasing number of rivers in arid and semi arid regions during the dry season or even all year around (such as in the Colorado, Yangtze and Ganga rivers).

**Near-coast freshwater wetlands are deteriorating**

**Downstream and near-coast freshwater wetlands**, used by migratory species as spawning and nursery area, are deteriorating while they are of major importance in sustaining marine aquatic ecosystems.

**New chemicals are released into the environment**

**New chemicals in the environment** – In addition to the few persistent and well-known POPs and metals, especially in western countries, hundreds to thousands of other, newer and less persistent chemicals are continuously released into the environment ensuring their ubiquitous presence. In this respect mention also has to be made of the problem of electronic waste.

Healthy coastal habitats provide flood protection

**Good quality and resilience** of coastal habitats (a priority component of the GPA) are of major importance for coastal protection against flood events and tsunami's.

Sea level rise is a real challenge for coastal management

**Effects of sea level rise** – Sea level rise is expected to cause salinization as well as physical alteration posing a major challenge for coastal management

### 3.3 Important management responses

There are two basic elements for environmental management. The first deals with the construction of a solid basis for understanding environmental problems, in particular with indicators that allow the assessment of changes taking place in the environment. The second is of a much broader nature and can be exemplified by the integrated management of river basins and coastal areas.

Use indicators to assess environmental change and to guide policy and management decisions

**Indicators relevant to GPA sources:** In many cases the absence of clear targets and appropriate indicators, as well as inadequate data and information make it difficult to assess in concrete terms the current situation and trends in respect of the nine source categories of the GPA. Long-term monitoring programmes are often not feasible because of constraints such as lack of financial resources and institutional capacity. This is particularly true of developing countries. However, assessments of the state of the environment are required in order to improve environmental policy and management. The use of well chosen 'smart' indicators will help streamline such assessments and guide policy setting and management choices; 'smart' referring to 'specific, measurable, achievable, realistic, and time-bound'. In addition 'proxy' indicators can be useful in the absence of other required data and information (also as a preparation of the next assessment of developments on GPA related issues). Three categories of indicators should be outlined: indicators for the *process* of GPA implementation, for *stress reduction* related to source categories and for *environmental status* of the marine environment.

Link river basin and coastal and marine management through an ecosystem-based approach

**Integrated management of river basins and coastal areas:** Although integrated approaches to planning and management have existed for decades, these have not been applied systematically to the problems dealt with by the GPA. As the perception of the nature of these problems evolves it is increasingly accepted that there would be benefit in moving away from a sectoral approach and towards a broader management framework. To consider economic, developmental, social and environmental goals together in the context of both freshwater and marine ecosystems is seen as the way forward. In order to establish linkages between river basin management and coastal and marine management an ecosystem-based, multi-sectoral approach is envisaged. The required scale is defined by the extent of the priority problems themselves, their driving forces, the extension of their impacts and the anticipated societal responses.

While adopting the Johannesburg Plan of Implementation, the global community agreed to develop integrated water resources management and water efficiency plans by 2005. They called for development and implementation of national/regional strategies, plans and programmes with regard to integrated river basin, watershed and groundwater management (JPOI, Chapter 4, para 26). This was reiterated during the UNEP Governing Council Special Session, held in Jeju, Republic of Korea in 2004, where an integrated strategy to water resources management was emphasised based on an 'ecosystem-based approach and linking the principles... (and) practice of IWRM with integrated coastal zone management' (UNEP 2004b).



## Overall assessment and conclusions

# 4

**Overall progress in protecting the marine environment from the effects of land-based activities, and in implementing the GPA has been uneven. Success in some areas has been offset by deterioration elsewhere. This uneven performance occurs at all levels, both between and within sectors and between and within regions. A distinction has to be made between whether progress can be measured in terms of actual improvements or merely in terms of arresting further deterioration. An additional distinction needs to be made in cases where the situation has deteriorated in absolute terms. In assessing the situation, it is important to understand the implications of what is occurring and the underlying reasons for progress, stagnation or regression. Although it is not possible to draw conclusions on what action resulted in which trend, and without going into details that have already been reviewed in previous sections, one can highlight the following:**

***The framework for action*** for the protection of the marine environment is established, with a good, solid institutional and legal base and global programme of action (GPA) functional in several regions. A good level of international and regional cooperation facilitates implementation of the GPA/LBA.

Relatively good levels of success exist in three of the nine GPA source categories,...

...mixed results for two out of nine, and...

...worsening conditions for the remaining four

***The degree of progress in the various sectors varies*** considerably. The following clusters can be distinguished, considering trends in the current situation and effectiveness of action taken in relation to the nine priority areas of the GPA framework:

- *Relatively good levels of success* have been achieved in relation to Persistent Organic Pollutants, Radioactive substances and Oil (hydrocarbons). Of course some problems remain, mainly in developing regions, but overall, progress has been consistent. One special issue here is the danger posed by accidents affecting radioactive substances and oil. Besides, pesticides continue to pose problems, mainly in developing regions.
- *Mixed results* have been obtained in respect of Heavy metals and Sediment mobilization. Overall, the situation appears relatively stable in developed regions, but presents problems in areas of rapid development. In respect of heavy metals, emerging problems such as that of electronic waste pose new threats.
- *Worsening conditions* are occurring in respect of Sewage, Nutrients, Marine litter and Physical alteration and destruction of habitats. In developed regions the situation is stable in respect of sewage, but because of population growth and rapidly increasing development, it is a major problem in developing regions and the situation continues to deteriorate. Agricultural nutrient run-off is a growing problem in most places. The other two problems are increasing in severity and magnitude and have a global reach.

Factors that influence progress in a positive manner

***Factors determining progress*** are related directly to the problem at hand or are part of a broader context. Factors that influence progress in a positive manner include a clear and functional regulatory system, a solid institutional framework, well-trained personnel, financial and technical resources and an informed public. Well defined or circumscribed problems appear easier to deal with, whereas diffuse or pervasive problems or complex questions appear much more difficult.

**Cultural and societal values can hamper progress**

A pervasive factor that hampers progress relates to cultural and societal values, which influence the way people act (or neglect) and are notoriously difficult to change. Public awareness campaigns have been effective, but at the same time political will on the part of governments to take appropriate action is paramount.

**Development and human well-being must be factored into any action (to be) initiated**

Finally, there are two factors that have a direct bearing on progress, but that lie outside the scope of an environmental plan. The first is the degree of economic development: a solid starting level contributes to the ability of society to deal with problems. The second is the speed at which changes occur in a society: high rates of population and economic growth can create unstable conditions that are not conducive to effective action. The implication is that, if progress is to be made, issues of the broadest concern to society, namely development and human well-being, must be factored into any action to protect the marine environment.

**To make progress innovative ways must be found**

It appears that action in the context of the GPA has been effective in several regions, but that factors outside its scope, namely the continued pressure of population growth and economic development, has made progress in absolute terms elusive. If deterioration is to be arrested and improvements made, new, different, better ways must be found. While this will not be easy, it is nevertheless possible and feasible.

**Actual results will only be obtained through long-term processes**

The length of time required to obtain results within the framework of the GPA must be taken into account. Experience from long-standing regional environmental initiatives (such as the Mediterranean Sea, North America's Great Lakes, the Mekong River, to name a few) shows that these processes often take 15 to 20 years before meaningful commitments to joint management can be secured, and an even longer time before the environment actually begins to respond. Viewed in this light, the GPA is just starting.

## References

- ACIA (2005). *Arctic Climate Impact Assessment – Scientific Report*. Cambridge University Press, Cambridge
- AMAP (1997). *Arctic Pollution Issues: A State of the Arctic Environment Report*. Arctic Monitoring and Assessment Programme, Oslo
- AMAP (2003). *AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to, within, and from the Arctic*. Arctic Monitoring and Assessment Programme, Oslo
- AMAP (2003a). *AMAP Assessment 2002: Human Health in the Arctic*. Arctic Monitoring and Assessment Programme, Oslo
- AMAP (2004). *AMAP Assessment 2002: Radioactivity in the Arctic*. Arctic Monitoring and Assessment Programme, Oslo
- AMAP (2004a). *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (ACIA)*. Prepared by AMAP, CAFF and IASC for the Arctic Council. Cambridge University Press, Cambridge
- Armah, A.K. and E. Nyarko (1998). On the faunal biodiversity of the Gulf of Guinea large marine ecosystem. In A. Chidi Ibe and others (eds.), *Integrated Environmental and Living Resource Management in the Gulf of Guinea*. United Nations Industrial Development Organization, United Nations Development Programme, National Oceanic and Atmospheric Administration and United Nations Environment Programme, New York
- Blue Plan (2005). *A Sustainable Future for the Mediterranean. The Blue Plan's Environment and Development Outlook*. Blue Plan and Earthscan, Sophia Antipolis and London
- Boesch, D. F. (2002). Challenges and Opportunities for Science in Reducing Nutrient Over-enrichment of Coastal Ecosystems. *Estuaries*, Vol. 25, No. 4b, p. 886-900
- Bouwman, A. F., G. Van Dreht, J. M. Knoop, A. H. W. Beusen, and C. R. Meinardi (2005). Exploring changes in river nitrogen export to the world's oceans, *Global Biogeochem. Cycles*, 19, GB1002
- Bryant, D., L. Burke, J. McManus, and M. Spalding (1998). *Reefs at Risk. A Map-based indicator of Threats to the World's Coral Reefs*. World Research Institute, Washington DC
- Burke, L., Y. Kura, K. Kassem, C. Revenga, M. Spalding, and D. McAllister (2001). *Pilot Analysis of Global Ecosystems: Coastal Ecosystems*. World Research Institute, Washington DC
- Burke, L., Selig, E. and Spalding, M. (2002). *Reefs at Risk in Southeast Asia*. World Resources Institute, Washington DC
- Burke, L. and Maidens, J. (2004). *Reefs at Risk in the Caribbean*. World Research Institute, Washington DC
- Butayban, N. (2005). Assessment of the State of the Environment in the ROPME Sea Area Relevant to the GPA Source Categories. Document prepared for UNEP/GPA as input into UNEP 2006
- Butler, T. (2005). 'Dubai's artificial islands have high environmental cost.' The Price of 'The World': Dubai's Artificial Future. [http://news mongabay.com/2005/0823-tina\\_butler\\_dubai.html](http://news mongabay.com/2005/0823-tina_butler_dubai.html) [Accessed on 26 June 2006]
- Cardona, P. and L. Botero (1998). Soil characteristics and vegetation structure in a heavily deteriorated mangrove forest in the Caribbean coast of Colombia. *Biotropica* 30:24-34
- Cesar, H. (1996). *Economic Analysis of Indonesian Coral Reefs*. Environment Department, The World Bank, Washington DC
- CEP (2002). *Transboundary Diagnostic Analysis for the Caspian Sea*. Caspian Environment Programme. Vol. II, Baku
- Conservation International (1999). *Conservation Priority-Setting For The Upper Guinea Forest Ecosystem, West Africa*. Conservation International, Washington DC
- CSD (2005). *Sanitation: policy options and possible actions to expedite implementation*. Report of the Secretary-General, Thirteenth Session of the Commission on Sustainable Development, E/CN.17/2005/3, New York
- DEAT (1999). *State of the Environment South Africa*. Department of Environmental Affairs and Tourism, Pretoria
- Dedkov, A. P. and V. I. Mozzherin (1992). Erosion and sediment yield in mountain regions of the world. In: Walling, D. E., T. R. Davies, and B. Hasholt (eds.): *Erosion, debris flows and environment in mountain regions* (Proceedings of the Chengdu Symposium, July 1992). IAHS Publication 209:29-36, International Association of Hydrological Sciences, Fontainebleau
- DEH (2001). *State of the Environment Australia*. Department of the Environment and Heritage, Australian Government
- DPNR/DEP and USDA/NRCS (1998). *Unified Watershed Assessment Report – United States Virgin Islands*. Virgin Islands Department of Planning and Natural Resources in cooperation with United States Department of Agriculture, Natural Resources Conservation Service, Caribbean Area, St. Croix
- Eden Again (2005). *Restoration of the Mesopotamian Marshlands*. A Project of Nature-Iraq in partnership with The Iraq Foundation
- EEA (2003). *Europe's Environment: The Third Assessment*. Environmental Assessment Report No. 10. European Environment Agency, Copenhagen

- EEA (2003a). *Hazardous substances in the European marine environment: Trends in metals and persistent organic pollutants*. European Environment Agency, Copenhagen
- EEA (2005). *Priority issues in the Mediterranean environment*. EEA Report No. 5. European Environment Agency, Copenhagen
- El-Sayed, M. Kh. (1996). Rising sea level and subsidence of the northern Nile Delta. In: Milliman, J. D. and B. U. Haq: *Sea-level Rise and Coastal Subsidence*. Kluwer Academic Publishers, Dordrecht
- ESCAP (1999). *ESCAP population data sheet. Population and development indicators for Asia and the Pacific*. Population and Rural Development Division, Economic and Social Commission for Asia and the Pacific, Bangkok
- ESCAP (2000). *Policy issues in addressing critical environment and sustainable development issues of the region – Highlights and recommendations from Eco Asia (ENR/RRM/MCED/6)*. Economic and Social Commission for Asia and the Pacific, Bangkok
- European Commission (2004). Implementation of Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment, as amended by Commission Directive 98/15/EC of 27 February 1998, Report of the Directorate-General for the Environment from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Brussels
- FAO (2001). *Baseline Study on the Problem of Obsolete Pesticide Stocks*. Food and Agriculture Organization of the United Nations, Rome
- FAO (2004). *State of the World Fisheries and Aquaculture 2004*. Food and Agriculture Organization of the United Nations, Rome
- Fortes, M. (2005). Assessment of the State of the Environment Relevant to the GPA Source Categories in the Seas of East Asia. Document prepared for UNEP/GPA as input into UNEP 2006
- Gardner, T.A., I.M. Côté, J.A. Gill, A. Grant, and A.R. Watkinson (2003). Long-term region-wide declines in Caribbean corals. *Science* 301, 958-960 (published electronically in Science Express, 17th July 2003)
- GESAMP (2001). *Protecting the oceans from land-based activities – Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment*. Rep. Stud. GESAMP No. 71. United Nations Environment Programme, Nairobi
- GIWA (2005). *Global International Waters Assessment Baltic Sea*. Lääne, A., Kraav, E., and G. Titova, GIWA Regional assessment 17, University of Kalmar, Kalmar
- GIWA (2005a). *Global International Waters Assessment Caspian Sea*. Stolberg, F., O. Borysova, I. Mitrofanov, V. Barannik, and P. Eghtesadi, GIWA Regional assessment 23, University of Kalmar, Kalmar
- Gren, I.-M. (2000). *Cost-effective nutrient reductions to the Baltic Sea*. Earthscan, London
- Haimovici, M., J.P. Castello, and C.M. Vooren (1997). Fisheries. In: Seeliger, U., C. Odebrecht and J.P. Castello (Eds.). *Subtropical Convergence Environments: the Coast and Sea in the Southwestern Atlantic*. Ch. 9, p. 183-196, Springer-Verlag, Berlin
- Hall, K. and R. Nickerson (2000). *Impacts of Marine Debris and Oil, Economic and Social Costs to Coastal Communities*, Kommunes Internasjonale Miljøorganisasjon (KIMO), Grantfield, Lerwick, Shetland
- HELCOM (1996). *Third Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1989-1993; Background document*. Baltic Sea Environment Proceedings, No. 64B. Helsinki Commission, Helsinki
- HELCOM (1998). *Red List of Marine and Coastal Biotope Complexes of the Baltic Sea, Belt Sea and Kattegat*. Baltic Sea Environment Proceedings, No. 75. Helsinki Commission, Helsinki
- HELCOM (2001). *Fourth Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1994-1998; Executive Summary*. Baltic Sea Environment Proceedings, No. 82A. Helsinki Commission, Helsinki
- HELCOM (2003). *The Baltic Marine Environment 1999-2002*. Baltic Sea Environment Proceedings No. 87, Helsinki Commission, Helsinki
- HELCOM (2004). *Fourth Baltic Sea Pollution Load Compilation PLC-4*. Baltic Sea Environment Proceedings, No. 93, Helsinki Commission, Helsinki
- Hilton-Taylor, C. (2000). *IUCN Red List of Threatened Species*. The World Conservation Union, Gland
- Hilty, L.M., 2005: Electronic waste- an emerging risk? *Environmental Impact Assessment Review* 25: 431-435
- Hodgson, G. and J. A. Dixon (1988). *Logging versus tourism and fisheries: environmental and economic dimensions*. Occas. Pap. Environmental Policy Institute, East-West Center, Honolulu
- Howarth, R., D. Anderson, J. Cloern, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Marcus, K. McGlathery, A. Sharpley, and D. Walker (2000). Nutrient Pollution of coastal Rivers, Bays and Seas of the USA. *Ecological Issues* 7:2-15
- IAEA (1993). *Risk comparisons relevant to sea disposal of low-level radioactive waste*. IAEA-TECDOC-725, International Atomic Energy Agency, Vienna

- IAEA (1996). *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (jointly sponsored by FAO, IAEA, ILO, OECD/NEA, PAHO and WHO). Safety Series No. 115, International Atomic Energy Agency, Vienna
- ICES (2003). *Environmental Status of the European Seas*. International Council for Exploration of the Seas, Copenhagen
- IHE (2000). *Strategy Options for Sewage Management to Protect the Marine Environment*. International Institute for Infrastructural, Hydraulic and Environmental Engineering, Delft
- Jaworski, N. A. (1990). Retrospective of the water quality issues of the upper Potomac estuary, *Aquatic Science*, 3, p. 11-40
- Jensen, J., K. Adare, and R. Shearer (1997). *Canadian Arctic Contamination Assessment Report*. Department of Indian Affairs and Northern Development, Ottawa
- de Lacerda, L.D. and R. V. Marins (2002). River damming and mangrove distribution. *GLOMIS Electronic Journal* 2(1):1-4
- Larsen, J. (2004). *Dead Zones Increasing in World's Coastal Waters*. Earth Policy Institute, Washington DC
- Livingston, H. D. (Ed.) (2004). *Marine Radioactivity*. Elsevier, Amsterdam
- LOICZ (2005). *Coastal Fluxes in the Anthropocene*. Crossland, C. J., H.H. Kremer, H.J. Lindeboom, J.I. Marshall Crossland, and M.D.A. Le Tissier (Eds.). The Land-Ocean Interactions in the Coastal Zone Project of the International Geosphere-Biosphere Programme. Springer-Verlag, Berlin
- Mee, L. D. (2001). Eutrophication in the Black Sea and a basin-wide approach to its control, p. 71-91. In: Bodungen, B. von, and R. K. Turner (Eds.). *Science and Integrated Coastal Management*. Dahlem University Press, Berlin
- Milliman, J. D. and J. P. M. Syvitski (1992). Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. *Journal of Geology* 100(5):525-544
- NOAA (2002). *Pacific Highlight, Marine Debris Removal from the Northwestern Hawaiian Islands*. Fisheries Coral Reef Conservation Program, Hawai'i
- Norstrom, R. J., and D. C. G. Muir (1994). Chlorinated hydrocarbon contaminants in Arctic marine mammals. *Science of the Total Environment* 154: 107-128
- NRC (2000). *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution*. National Research Council, National Academies Press, Washington DC
- NRC (2003). *Oil in the Sea III: Inputs, Fates, and Effects*. National Research Council, Committee on Oil in the Sea, National Academies Press, Washington DC
- OECD and IUCN (1996). *Guidelines for Aid Agencies for Improved Conservation and Sustainable Use of Tropical and Sub-tropical Wetlands*. Organization for Economic Cooperation and Development, Paris
- OSPAR (2004). *Liquid Discharges from Nuclear Installations in 2002*. OSPAR Commission, London
- Oteng-Yeboah, A.A. (1998). Why the emphasis on conservation of biological diversity in the Gulf of Guinea? In: A. Chidi Ibe and others (eds.), *Integrated Environmental and Living Resource Management in the Gulf of Guinea*. United Nations Industrial Development Organization, United Nations Development Programme, National Oceanic and Atmospheric Administration and United Nations Environment Programme, New York
- Panisset, U.B. (2000). *Foreign Policy and Public Health Decision-Making in Peru's Cholera Epidemics*
- Pasternack, G. B., G. S. Brush, and W. B. Hilgartner (2001). Impact of historic land-use change on sediment delivery to a Chesapeake Bay subestuarine delta. *Earth Surface Processes and Landforms* 26:409-427
- Pew Oceans Commission (2001). *Marine Pollution in the United States*. Arlington, Virginia
- PMRC (1993). *Plan de Manejo de la ZEM Bahía – San Vicente – Canoa*. Programa de Manejo de Recursos Costeros, Ministerio de Agricultura y Gandería, Gayaquil
- Ramsar (1999). *Global Review of Wetland Resources and Priorities for Wetland Inventory*. 7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands, San José, Costa Rica
- Sarkisov, A.A. (Ed.) (2004). *Strategic approaches in solving decommissioning problems or retired Russian nuclear fleet in the northwest region*. Russian Academy of Sciences, Nuclear Safety Institute, Moscow
- Schernewskii, G. and T. Neumann (2002). Impact of River Basin Management on the Baltic Sea: Ecological and Economical Implications of Different Nutrient Load Reduction Strategies, In: Bernardini, F., M. Landsberg-Uczciwek, S. Haunia, M. Adriaanse, and R. Enderlein (Eds.) (2002). *Sustainable Management of Transboundary Waters in Europe, The Second International Conference*. p. 125-130.
- Seeliger, U. and C.S.B. Costa (1997). Human and Natural Impacts. In: Seeliger, U., C. Odebrecht, and J.P. Castello (Eds.). *Subtropical Convergence Environments: the Coast and Sea in the Southwestern Atlantic*. Springer-Verlag, Berlin
- Shuval, H. (2003). Estimating the Global Burden of Thalassogenic Disease-Human Infectious Disease caused by Wastewater Pollution of the Marine Environment. *Journal of Water and Health*, Vol. 1 no. 2, 2003, p 53-64



- Smith, A.H., M. Archibald, T. Bailey, C. Bouchon, A. Brathwaite, R. Comacho, S. Goerge, H. Guiste, M. Hasting, P. James, C. Jeffrey-Appleton, K. De Meyer, A. Miller, L. Nurse, C. Petrovic, and P. Phillip (2000). Status of the Coral Reefs in the Eastern Caribbean: The OECS; Trinidad & Tobago, Barbados, the Netherlands Antilles and the French Caribbean. In: Wilkinson, I. and AIMS (eds.) *Status of Coral Reefs of the World: 2000*. Australian Institute of Marine Sciences, Townsville
- Stanley, D. J. and A. G. Warne (1993). Nile Delta: recent geological evolution and human impact. *Science* 260:628-634
- Syvitski, J. P. M. (2003). Sediment fluxes and rates of sedimentation. In: Middleton, G. V. (ed.) *Encyclopedia of sediments and sedimentary rocks*. Kluwer Academic Publishers, Dordrecht
- Talau-McManus, L. (2000). *Transboundary diagnostic analysis for the South China Sea*. Tech. Rep. Ser. O. 14, Regional Coordination Unit, East Asian Seas Programme, Bangkok
- Tilman, D., J. Fargione, B. Wolff, C. D. Antonio, A. Dobson, R. Howarth, D. Schindler, H. William, H. Schlesinger, D. Simberloff, D. Swackhamer: Forecasting Agriculturally Driven Global Environmental Change. *Science*, Vol. 292, 2001, p. 281-284
- UNEP (1987). *Environmental Problems of the South Asian Seas Region: An Overview*. UNEP Regional Seas Reports and Studies No 82. United Nations Environment Programme, Nairobi
- UNEP (1995). *Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities* (UNEP (OCA)/LBA/IG.2/7),
- UNEP (2001). *Caribbean Environment Programme*. Regional Coordinating Unit, Jamaica
- UNEP (2002). *Global Mercury Assessment*. United Nations Environment Programme Chemicals, Geneva
- UNEP (2003). *Regionally-based Assessment of Persistent Toxic Substances, Global Report 2003*. United Nations Environment Programme Chemicals, Geneva
- UNEP (2004). *Financing wastewater collection and treatment in relation to the Millennium Development Goals and World Summit on Sustainable Development targets on water and sanitation*. Note by the Executive Director to the Eight special session of the Governing Council/Global Ministerial Environment Forum, Jeju, March 2004, UNEP/GCSS.VIII/INF/4. 26 pp.  
[http://www.unep.org/Ko470053\\_gcstviii\\_4.doc](http://www.unep.org/Ko470053_gcstviii_4.doc)
- UNEP (2004a). *Water Supply and Sanitation Coverage in UNEP Regional Seas, Need for Rational Wastewater Emission Targets? Section III: An Inventory of regional Specific Data and the Feasibility of developing Regional Wastewater Emission Targets (WET)*. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, United Nations Environment Programme, The Hague
- UNEP (2004b). *Jeju Initiative, President's summary of the ministerial segment of the eighth special session of the Governing Council/Global Ministerial Environment Forum*. UNEP GC/GMEF, Para 17d, e
- UNEP (2005a). *Marine Litter, an analytical overview*. United Nations Environment Programme, Nairobi
- UNEP (2005b). *One Planet Many People. Atlas of Our Changing Environment*. United Nations Environment Programme, Nairobi
- UNEP (2006). *The State of the Marine Environment: A regional assessment*. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, United Nations Environment Programme, The Hague
- UNEP/MAP (1996). *The state of the marine and coastal environment in the Mediterranean region*. MAP Technical Reports Series No 100. United Nations Environment Programme, Athens
- UNEP/MAP/MEDPOL (2003). *Transboundary Diagnostic Analysis for the Mediterranean Sea (TDA)*. United Nations Environment Programme, Athens
- UNEP/WHO/HABITAT/WSSCC (2001). *Strategic Action Plan on Municipal Wastewater*. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, United Nations Environment Programme, The Hague
- UNEP/WHO/HABITAT/WSSCC (2004). *Guidelines on Municipal Wastewater Management, Version 3*. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, United Nations Environment Programme, The Hague
- UNEP-WCMC (2006). *In the front line. Shoreline protection and other ecosystem services from mangroves and coral reefs*. United Nations Environment Programme – World Conservation Monitoring Centre, International Coral Reef Action Network, The World Conservation Union, Nairobi
- USEPA (2003). *Report on the Environment, Executive Summary*,  
<http://www.epa.gov/indicators/roe/html/roeExec2.htm>
- UNESCO (2006). *Water, a shared responsibility. The United Nations World Water Development Report 2*. United Nations Educational, Scientific and Cultural Organization, Paris
- Valiela, I., Bowen, J.L. and York, J.K. (2001). Mangrove forests: one of the world's threatened major tropical environments. In: *Bioscience* 51(10): 807-815



- Van den Hout, K. D., (Ed.) (1994). *The Impact of Atmospheric Deposition of Non-Acidifying Pollutants on the Quality of European Forest Soils and the North Sea*. Report of the ESQUAD Project, IMW-TNO Report No. R 93/329, the Netherlands Organization for Applied Scientific Research TNO, Delft
- Vörösmarty, C. J., M. Meybeck, B. Fekete, and K. Sharma (1997). The potential impact of neo-Castorization on sediment transport by the global network of rivers. In: Walling, D. E. and J-L. Probst (eds.): *Human impact on erosion and sedimentation*. IAHS Publication No. 245, International Association of Hydrological Sciences, Fontainebleau
- Vörösmarty, C. J., M. Meybeck, B. Fekete, K. Sharma, P. Green, and J. P. M. Syvitski (2003). Anthropogenic sediment retention: Major global-scale impact from the population of registered impoundments. *Global and Planetary Change* 39 (1/2), p. 169-190
- Walker, D. (2002). *Non-point Source Pollution: Reducing Its Impact on Coastal Environmental Quality*. Ocean Studies Board, The National Academies, Washington DC
- Waite, M. and C. Pittman (2005). St. Petersburg Times. 'Katrina offers lesson on wetlands protection.'
- wcd (2000). *Dams and Development. A New Framework for Decision-Making. The Report of the World Commission on Dams*. Earthscan, London
- Wilkinson, C. (ed.) (2004). *Status of Coral Reefs of the World: 2004*. Australian Institute of Marine Science, Townsville
- World Bank (1992). *World Development Report 1992: Development and the Environment*. Oxford University Press, New York
- WRI (2000). *World Resources 2000-2001: People and ecosystems: The fraying web of life*. United Nations Development Programme, United Nations Environment Programme, The World Bank, World Resources Institute, Washington DC

This report was commissioned by the Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) of the United Nations Environment Programme (UNEP).

UNEP/GPA Coordination Office  
PO Box 16227  
2500 BE The Hague  
The Netherlands  
T +31 (0)70 311 44 60  
F +31 (0)70 345 66 48  
E [gpa@unep.nl](mailto:gpa@unep.nl)  
I [www.gpa.unep.org](http://www.gpa.unep.org)

### **Acknowledgements**

The UNEP/GPA Coordination Office gratefully acknowledges the financial contribution to this publication from the Governments of Belgium, Ireland, the Netherlands and Norway.

#### *Research and compilation*

Dr. Ljubomir Jeftic

Much of the draft material for the UNEP/GPA regional assessment of the State of the Marine Environment has been used as input for this report.

#### *Research assistants*

Jennifer Laughlin and Prem Vanrompay

#### *External reviewers*

Josef M. Pacyna and Prof. Felino P. Lansigan; the draft report was also discussed in June 2005, during the LOICZ/UNEP workshop on the State of the Environment in the Regional Seas that UNEP/GPA is preparing

#### *Editing*

Andrea Matte-Baker and Mirjam Schomaker

#### *Design and typesetting*

Mijke Wondergem: Graphic designer (BNO), Baarn, the Netherlands

#### *Cover photo*

Secret Sea Visions/Lineair

#### *Printing*

Artoos Drukkerijen, Rijswijk, the Netherlands  
Printed on wood-free and chlorine-free paper

The contents of this publication do not necessarily reflect the views or policies of UNEP or the editor, nor are they an official record.

This publication may be reproduced in whole or in part and in any form of educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. UNEP would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or for other commercial purposes whatsoever without the prior permission in writing from UNEP.

For bibliographical purposes this document may be cited as:

UNEP/GPA (2006). The State of the Marine Environment: Trends and processes. UNEP/GPA, The Hague

ISBN 92-807-2708-7

© United Nations Environment Programme, 2006