



# A Sea of Troubles



United Nations

(New York)



**UNEP**  
United Nations  
Environment  
Programme

(Nairobi)



Food and  
Agriculture  
Organization  
of the  
United Nations  
(Rome)



United Nations  
Education,  
Scientific and  
Cultural  
Organization  
(Paris)



UNESCO

Inter-  
governmental  
Oceanographic  
Commission



World  
Health  
Organization

(Geneva)



World  
Meteorological  
Organization

(Geneva)



International  
Maritime  
Organization

(London)



International  
Atomic Energy  
Agency

(Vienna)

In cooperation with:

Coordination Office of the Global Programme of Action for the Protection of  
the Marine Environment from Land-based Activities (UNEP) - The Hague  
Division of Environmental Conventions (UNEP) - Nairobi  
Advisory Committee on Protection of the Sea (ACOPS) - London

# A Sea of Troubles

Printed by GRID-Arendal for the  
United Nations Environment Programme



UNEP

15 January 2001

## Notes

1. GESAMP is a advisory body consisting of specialized experts nominated by the Sponsoring Agencies (IMO, FAO, UNESCO-IOC, WMO, WHO, IAEA, UN, UNEP). Its principal task is to provide scientific advice concerning the prevention, reduction and control of the degradation of the marine environment to the Sponsoring Agencies.
2. This study is available in English only from any of the Sponsoring Agencies.
3. The report contains views expressed or endorsed by members of GESAMP who act in their individual capacities; their views may not necessarily correspond with those of the Sponsoring Agencies.
4. Permission may be granted by any of the Sponsoring Agencies for the report to be wholly or partially reproduced in publication by any individual who is not a staff member of a Sponsoring Agency of GESAMP, or by any organization that is not sponsor of GESAMP, provided that the source of the extract and the condition mentioned in 3 above are indicated.

Cover photo: "Clean Circle", UNEP/Denjiro Sato (Topham Picturepoint)

ISBN 82-7701-010-9

© UN, UNEP, FAO, UNESCO-IOC, WHO, WMO, IMO, IAEA 2001

For bibliographic purposes this document should be cited as:

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and Advisory Committee on Protection of the Sea. 2001. A sea of troubles. Rep. Stud. GESAMP No. 70, 35 pp.

# A Sea of Troubles

## Contents

Chapter 1   <b>The Changing Relationship</b>	1	Pressures and Effects	1	Changing Perspectives	3						
Chapter 2   <b>The State of the Waters</b>	5	Pollution	5	Eutrophication	8	Altered sediment flows	9				
Chapter 3   <b>The Life of the Seas</b>	10	Fisheries	10	Biodiversity	12	Alien Species	13	Habitats	14	Coral reefs	15
Chapter 4   <b>The Oceans and the Atmosphere</b>	16	Global Warming	16	Ultraviolet Light	18	Nitrogen	19				
Chapter 5   <b>Land and Sea</b>	19	Urbanisation	19	Industry	20	Agriculture, forestry and aquaculture	21				
Hydrological changes	22	Commerce and Transport	22	Tourism	22	Military activities and social conflict	25				
Chapter 6   <b>Action</b>	26	The causes of failure	28	Science and policy	29	Risks and benefits	29	An integrated approach	30		
<b>Problems and Solutions</b>	32	About this Publication	35								

## 1

# The Changing Relationship

If it were not for the sea, the Earth would just be one more small, dead planet, another desert island adrift in the limitless black ocean of space. Life began in its waters, and no animal could clamber out of them onto dry land before algae in the primaeval oceans released oxygen to provide a welcoming atmosphere. And without the water from the sea that falls as rain, the continents would become barren again.

The world's cultures also owe much to the seas. They nurtured its early civilisations, clustered around their shores, and spread trade and ideas in the ships that came to ply them. Wealth and knowledge continued to travel mainly by water until the very dawn of the modern era, and the oceans still retain enormous, if largely unrecognised, economic importance. They cover 71 per cent of our planet's surface, regulate its climate, and provide its ultimate waste disposal system, yet our myopic, terrestrial species still insists on naming it after the land.

Humanity's future, just like its past, will continue to depend on the oceans, on the intricate interchanges between land and water. Yet the relationship has changed. Over most of human history it has been dominated by the sea's influence on people. But from now on humanity's effect on the state of the sea is probably at least as important. And, by and large, this is getting worse.

The state of the world's seas and oceans is deteriorating. Most of the problems identified decades ago have not been resolved, and many are worsening. New threats keep emerging. The traditional uses of the seas and coasts - and the benefits that humanity gets from them - have been widely undermined.

All this is happening because human activities are increasing and extending over ever wider areas. The closer the seas come to people, the greater is the damage. Ill-planned (and often unplanned) coastal development is one of the main driving forces behind the environmental problems of the oceans. Apart from overfishing, the greatest harm is caused by what we do on land - and particularly at the coasts - rather than at sea.

The picture is not universally bleak. There has been considerable progress, in some places, in reducing harm to the marine environment. But this is continually being outstripped by the pace and scale of the deterioration.

More hopefully, perhaps, there is a dawning realisation that neither individual problems, nor the crisis of the seas as a whole can be dealt with in isolation. They are intricately interlinked both with themselves and with social and economic development on land. Policy decisions, research, and management programmes are all shifting their focus accordingly.

## PRESSURES AND EFFECTS

The nearer you get to land, by and large, the greater is the hurt to the sea, its life and resources. The crisis is deepest where the waters are shallowest. It is here that pollution is at its worst, habitats are most readily destroyed, and much of the depletion of fisheries takes place.

The open oceans suffer some contamination and ecological damage, but compared to coastal areas they are still in a relatively healthy state. Pressures have been increasing on the seas above continental shelves, as drilling for oil and gas has ventured into deeper waters, and fisheries have expanded. But it is the waters nearest to the shores - and particularly those in estuaries and in semi-enclosed seas and bays - that have suffered the steepest decline over the last decade.

More and more of the narrow strip of land along the world's coasts - and its habitats - has been ruined by a host of poorly planned and badly regulated activities, from the explosive growth of coastal cities and towns to the increase in tourism, from industrialisation to the expansion of fish farming, from the development of ports to measures taken to try to control flooding. The pressures are particularly exacerbated along the coasts of many developing countries, where rapid population growth combines with persistent poverty, and there is little capacity to manage the situation. But developed country coastlines are often overdeveloped too, as people and businesses demand ocean-front properties.

### Vulnerable areas and systems - and the sources of their problems

The intensity of pressures vary from place to place, as does the vulnerability of different ecosystems

- *Coral reefs* - eutrophication, sediments, overfishing, destructive fishing, reef mining, the aquarium and curio trade, diseases.
- *Wetlands* - reclamation and development, including landfills.
- *Seagrass beds* - siltation, coastal development, eutrophication, physical disturbance.
- *Coastal lagoons* - reclamation, pollution.
- *Mangroves* - excessive exploitation, clearing for reclamation, development and aquaculture.
- *Shorelines* - development, modification of habitats, erosion.
- *Watersheds* - deforestation, soil erosion, pollution, loss of habitats.
- *Estuaries* - reduced water flows, siltation, pollution.
- *Small islands* - changes in sea level, waste management, pollution.
- *Continental shelves* - pollution, fishing, dredging, navigation.
- *Semi-enclosed seas* - pollution, coastal development, fishing.

Nevertheless, the seas and coasts worldwide are being used more and more to provide the basics of life, and for commerce and recreation. Growing demand is putting increasing pressure on the resources of the oceans. The burden of waste sent out to the sea is growing worldwide, even though it has been lightened in some places by better technology and practices. The use of pesticides, fertilisers and other agrochemicals is rising worldwide, as is the amount of them that is washed and blown off the land into the oceans. Fisheries are a shambles, grossly mismanaged and overexploited almost everywhere. Coasts are overdeveloped. Habitats are increasingly being destroyed. And the introduction of species, either intentionally or accidentally, to habitats far from their own is now taking place on a large scale, often disrupting both ecosystems and economies.

On the positive side, there is convincing evidence that better management in some areas has cleaned up beaches and bathing waters and made seafood safer to eat. Concerted national and international action has cut the amount of oil discharged from tankers in their ballast waters. Ship-

ping is believed to have reduced its pressure on the health of the oceans over the past decade - major oil spills now occur infrequently. In some countries, many coastal industries - such as oil refining, pulp and production, and chemical and food manufacturing - have made major strides in controlling discharges to the sea. On the other hand, coastal developments, such as expanding and maintaining harbours, damage and destroy habitats and have important effects on the environment. Even the increase in ports taking wastes from ships - a welcome development - often raises problems over what to do with the wastes afterwards.

The nature and extent of pressures on the seas differ from place to place, and can arise far inland. But, apart from the threats arising from predicted global warming, the most serious ones worldwide are:

- **The destruction and alteration of habitats** is common and widespread. Rivers, lakes, estuaries and coastal waters are the hardest hit - and wetlands, mangroves, seagrass beds and coral reefs are particularly vulnerable. At least half of the world's mangrove forests have been lost over the last century, for example, and 70 per cent of coral reefs are threatened. Pollution is not the only culprit, or even the greatest one. Reclaiming land, felling forests, mining, building on coasts and other activities that directly damage and destroy the land are just as important, as are destructive ways of fishing, such as using poison, explosives, or catch-all nets.
- **Overfishing and the effects of fishing on the environment.** Overfishing has brought an end to 40 years of increases in the harvest from the seas, and now threatens to cut world catches sharply over the next decade. It denudes both seas and freshwaters. Intensive fishing removes vast amounts of biomass from the middle of the food chain, with largely unknown effects. Destructive fishing methods add to the crisis, as do poor management and social and economic measures in support of unsustainable practices.
- **The effects of sewage and chemicals on human health and the environment.** The amounts of some pollutants have been reduced, and some forms of pollution are now thought to pose less of a threat than before. But new work, reported in these pages, suggests that sewage pollution has a massive effect on health worldwide, ranking with some of the most feared diseases afflicting humanity. And some chemicals are suspected of causing cancer, disrupting reproduction and altering behaviour.

- **Increasing eutrophication.** The excessive growth of marine plant life, is seriously disrupting ecosystems and threatening health throughout the world: coral reefs, seagrass beds and other vital habitats are suffering. And it can trigger explosive blooms of toxic algae which can blight tourism, contaminate seafood and poison people.
- **Changes to hydrology and the flow of sediments** - caused by such developments as building dams and causeways, creating reservoirs, establishing large-scale irrigation schemes and changing the way land is used - often seriously degrade habitats and significantly change ecosystems. These developments change the flow of rivers, and so cut the amount of sediment being carried down them which, in turn, can alter coastlines. Felling forests, by contrast, can increase their sediment burden, damaging wetlands, deltas and coral reefs.

## CHANGING PERSPECTIVES

Over the last decade - since GESAMP last produced a report of this kind - the emergence of new issues has placed the protection of the seas in a new perspective, and heightened their economic value. There has also been a new realisation that the problems of the oceans can only be tackled in an integrated way, rather than piecemeal.

Global warming, predicted by the scientific community over the last decade, will both be heavily influenced by the oceans, and have profound effects upon them. The seas' massive ability to store heat will do much to govern the rate at which the Earth warms up, and will make the process, once started, extremely hard to stop. Meanwhile the climate change is expected to alter the pattern of currents, with far-reaching effects both on sea and land, to disrupt fisheries, change ecosystems and cause the seas to rise, inundating low-lying islands and coastal areas.

Some contaminants - such as lead, mercury and oil - are now seen as much less threatening than in the past. Similarly radionuclides pose a relatively minor threat to health and the environment, even though the public often sees them as a major one. By contrast, other pollutants - like sewage - have now been found to damage health much more than had been realised.

It has become ever clearer that activities on land (or based on it) are the major source of pollution - and that the main problems may come less from fixed points, like factories, on the coasts than from diffuse practices like agriculture. However, pollution - the introduction of substances that damage the environment or human health - is now recognised to be not the only, or even necessarily the most severe, threat to the oceans. Direct physical damage to ecosystems and habitats, and overexploitation of the resources of the sea, have even greater worldwide effects.

There is also a new appreciation of the rich biodiversity of the sea, and a new realisation that it has so far suffered much less from destructive human activities than the land. Until now this has been a relatively neglected field; there are powerful arguments for paying much more attention to it.

As new understanding of the environmental problems of the seas has grown, so has the recognition that they cannot be tackled in isolation. Many authorities have been arguing for decades that the seas and coasts - and the river basins that run down to them - must be protected and managed together in an integrated way. Some countries practice this successfully, but it has taken longer for this vital principle to be enshrined in international agreements.

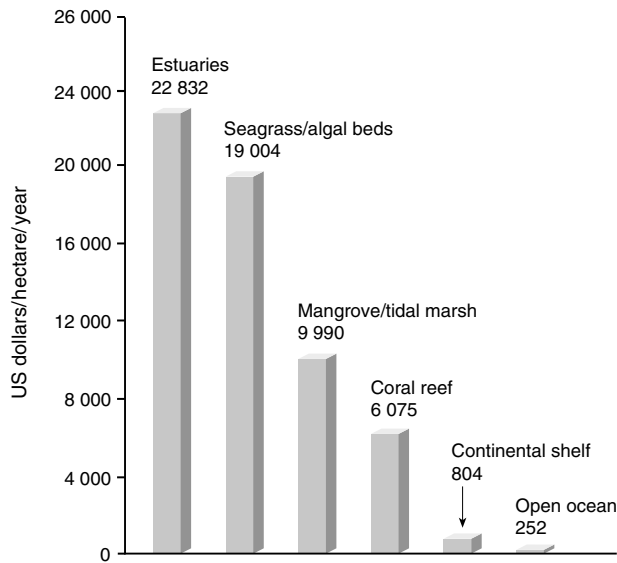
In many ways, the greatest progress has been made in some regional and subregional programmes, which have recognised that one of the best ways of solving the environmental problems of the seas is to manage development on the coasts, and their hinterlands, properly. The signing of the UN Convention on the Law of the Sea, in 1982, marked the first major - if timid - political step towards extending this worldwide. But the crucial global turning points came only with the adoption of Agenda 21 at the 1992 Earth Summit (the United Nations Conference on Environment and Development - UNCED) and, three years later, of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. Both recognise that freshwater (including groundwater), the coasts and the seas are inseparably linked. And they specifically ask that conflicting interests over the seas, coasts and river basins be resolved through integrated management of resources and environmentally sound economic development.

### Regional successes

Over the last few decades, several regions - the Baltic, the Mediterranean and the North East Atlantic - have developed successful programmes to use and protect the environment of their coasts and seas. They conduct scientific assessments, identify causes of environmental problems, set standards and objectives for emissions and the environment, find and eliminate hot-spots, employ managerial tools for using and developing coastal regions and resources, build administrative and technical capacity, develop public awareness and participation, and pursue sustainable development. They demonstrate that, despite difficulties, groups of countries can take concerted and effective multinational action to protect and develop coastal regions and their seas. The experience gained from their achievements and failures should be used to develop new programmes and improve existing ones.

FIGURE 1

## Estimated mean value of some marine biomes



Source: Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1998. The value of the world's ecosystem services and natural capital. *Ecological Economics* 25:3-15.

Even more importantly, perhaps, managers and policy makers are gradually recognising the value of the services that the oceans provide for the Earth and its people. In the past, the worth of the seas has usually been weighed in the resources it provides, whether sand and gravel, oil and gas, or fish. But these *resources* are dwarfed by the value of the unrecognised *services* that the oceans provide, from recreation to regulating the earth's climate, from supplying rainfall to receiving and treating waste. Many lie outside the conventional market economy, but life on Earth could not continue without them.

The value of these services, it is generally agreed, must be brought into mainstream economic and social calculations. Ways of valuing them are improving, but still have limitations - though not as great as the reluctance of existing institutions to take them into account. The best estimate from one recent calculation, which drew on over 100 studies over the past two decades, suggest that ocean services may be worth about US \$23 trillion a year, only slightly less than the world's GNP. It suggests too, that the seas and oceans provide two thirds of the value of all the natural services provided by the entire planet. Whatever the exact figure, it is clear that the health of the oceans is vital for the world's economic - as well as its ecological - well being.



## 2

# The State of the Waters

Vast and awe-inspiring, seemingly limitless and indestructible, the oceans have been the ultimate depository for humanity's wastes since before the dawn of civilisation. For even longer, their waters and coasts have provided an apparently inexhaustible bounty of fish and other resources. And for thousands of years they did indeed seem able to absorb everything that was done to them, though some relatively small areas were overwhelmed. But as the world's population and wealth have increased, as industries have grown, fishing has intensified, and people have crowded to the coasts, the seas have been plunged into crisis.

A host of problems have now been on the political and environmental agenda for decades - and persist there, unresolved. They, and their main causes, are fairly well understood. So are the technical, economic, social and political options for solving them. The solutions are generally available, if at a cost. But, while improvements are being achieved in a growing number of places, the complexity of the problems - and of the conflicts of interest surrounding them - has prevented managers and decision makers, for all their labour, from resolving them.

New issues have emerged during the last decade - either in response to new developments (or ones that can be predicted) or as a result of better insights into old problems. They, too, now demand closer attention.

This chapter, and the following two, review the threats to the world's oceans under three categories: pollution and alterations in the flow of sediments; threats to the life of seas and coasts; and interactions between the oceans and the atmosphere. This one examines pollution, with particular emphasis on new evidence of the effects of contamination by sewage; the increase in eutrophication and blooms of algae; and the effects of altering the flows of water and sediment down rivers.

## POLLUTION

Historically, concern about the state of the oceans has mainly been generated by pollution. Over the last decades, increasing understanding of the seriousness of other threats - such as overfishing and the destruction of habitats - and of the damage they cause, has tended to overshadow it. But it has enormous effects on health and the environment.

Sewage pollution of the sea is, of course, as old as civilisation. It provides nutrients which, in moderation, can benefit sea life. The problem arises when there is too much of it in too small an area. Even in ancient times some stretches of sea, such as the Bosphorus, became badly polluted. Now with the rapid growth of the world's population (doubling since the 1960s), and its increasing concentration around the coasts - especially in developing countries - many inshore waters have become overwhelmed.

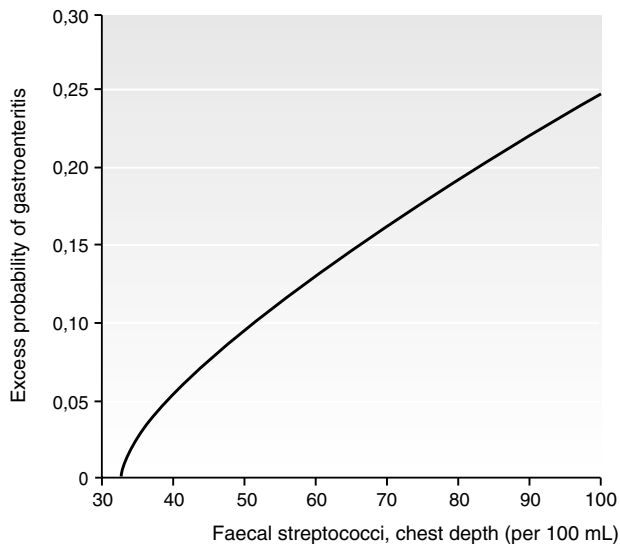
This is more than just an aesthetic nuisance. Sewage pollution ruins large areas for fisheries, recreation and tourism, causing major economic loss. Eutrophication and blooms of algae, stimulated by too much nutrition from sewage and agricultural chemicals and wastes, does widespread and serious damage to the life of coastal waters. And there are frequent outbreaks of gastrointestinal disease such as cholera, typhoid and infectious hepatitis caused by contaminated seafood and bathing water - particularly in areas where there are many carriers of the pathogens, and sewage treatment and disposal is inadequate. A major outbreak of cholera in Naples in 1973, for example, came from eating shellfish. An even greater epidemic of the disease which affected many millions of people in Latin America from 1991 to 1995 - and took 10,000 lives - started in the coastal cities of Peru.

Yet such dramatic outbreaks are responsible for only a small part of the toll of disease caused by sewage pollution. A new study sponsored by GESAMP and the World Health Organisation (WHO), now shows that - far from just causing isolated, local problems - microbiological contamination of the sea has precipitated a health crisis with massive global implications.

Many studies show that respiratory and intestinal diseases and infections among bathers rise steadily in step with the amount of sewage pollution in the water. They demonstrate, too, that bathers are at risk even in lightly contaminated waters that meet the pollution standards laid down by the European Union and the US Environmental Protection Agency. A recent WHO report has estimated that one in every 20 bathers in “acceptable waters”, will become ill after venturing just once into the sea.

FIGURE 2

Probability of gastroenteritis amongst bathers exposed to increasing faecal streptococci densities from samples taken at chest depth



Model is adjusted for following significant non-exposure related risk factors identified between bathers reporting gastroenteritis and those not reporting gastroenteritis post exposure:

- Predisposition to diarrhoea (diarrhoea at least once per month versus less than twice a year)(site A).
- Diarrhoea lasting over 24 hours within 3 weeks before exposure (all sites).
- Usual fatigue lasting over 23 hours within 3 weeks before exposure (site B).
- Gastroenteritis in family members preceding illness experienced by individual bathers (all sites).
- Gender (all sites).
- Age (10 unit categories)(all sites).
- Hamburgers or take-out food consumed within 3 days before and 7 days post exposure (site B).
- Purchased sandwiches consumed within 3 days before and 7 days post exposure (site A).

A value of 32 per 100 mL on x axis for faecal streptococcal density is the approximate density at which predicted probability of gastroenteritis equals observed proportion of non-bathers reporting gastroenteritis (ie. the excess is 0).

Source: Kay, D., J.M. Fleischer, R.I. Salomon, F.Jones, M.D. Wyer, A.F. Godfree, Z. Zelenauch-Jacquotte and R. Shore. 1994. Predicting likelihood of gastro-enteritis from sea bathing: results from randomized exposure. *Lancet* 344: 905-909.

The GESAMP/WHO study - based on global estimates of the number of tourists who bathe, and WHO estimates of the relative risks at various levels of contamination - estimates that bathing in polluted seas causes some 250 million cases of gastroenteritis and upper respiratory disease every year. Some of these people will be disabled over the longer term. The global impact can be measured by adding up the total years of healthy life that are lost through disease, disability and death using a new measurement - the Disability Adjusted Life Year (DALY) - developed by WHO and the World Bank. When this is done, the world-wide burden of disease incurred by bathing in the sea, adds up to some 400,000 DALYs, comparable to the global impacts of diphtheria and leprosy. It is estimated to cost society, worldwide, about US \$1.6 billion a year<sup>1</sup>

The toll from consuming contaminated shellfish is even greater. One study suggests that seafood is involved in 11 per cent of all the outbreaks of disease carried in food in the United States, 20 per cent of them in Australia, and over 70 per cent in Japan, which has a particularly strong tradition of eating raw fish and shellfish.

Pathogenic bacteria can survive in the sea for days and weeks; viruses can survive in the water - or in fish and shellfish - for months. The particularly virulent infectious hepatitis virus - which has caused many outbreaks of the disease associated with eating shellfish - can remain viable in the sea for over a year. Shellfish, like oysters, mussels, clams and cockles, feed by filtering huge amounts of seawater - and can concentrate viruses and bacteria a hundredfold from the water in which they live.

A series of studies has found viruses in about a fifth of the shellfish taken from waters that meet US bacteriological standards for growing and harvesting them. There is strong evidence that fresh shellfish - on sale for food - frequently contain enough viruses to make many of those who eat them ill. They are often eaten raw, or after only a light steaming which is not enough to kill most of the viruses or bacteria.

One US study suggested that one in every hundred people eating relatively lightly contaminated raw shellfish will be infected with a moderately serious intestinal virus disease; the risk rises to up to 50 in a 100 if the virus is highly infectious. Other studies in both the United States and the United Kingdom suggest that a quarter of those who are taken to hospital suffering from infectious hepatitis - a disease that can confine sufferers to bed for two to three months - have caught it from eating raw or lightly steamed shellfish.

<sup>1</sup> Throughout this document ‘one billion’ signifies one thousand million.

TABLE 1

Global human health burden and associated economic cost of selected diseases in relation to exposures to marine waters and shellfish contaminated with enteric micro-organisms

Disease or cause	Disability adjusted life-years DALY	Corresponding economic losses (rounded) in US million dollars
<b>Disease</b>		
Tuberculosis	38 000 000	115 000
Malaria	31 000 000	95 000
Diabetes	11 000 000	35 000
Trachea, Brachia and Lung cancer	8 800 000	26 000
Stomach cancer	7 700 000	23 000
Intestinal nematodes	5 000 000	15 000
Upper respiratory tract infections	1 300 000	4 000
Trachoma	1 000 000	3 000
Onchocherciasis	900 000	2 700
Dengue fever	750 000	2 200
Japanese encephalitis	740 000	2 200
Chagas disease	660 000	2 000
Leprosy	380 000	1 100
Diphtheria	360 000	1 100
<b>Marine exposures</b>		
Contaminated bathing water	400 000 - 800 000	1 200 - 2 400
Contaminated shellfish	3 500 000 - 7 000 000	10 000 - 20 000

Source: Shuval, H.I. 1999. Scientific, economic and social aspects of the impact of pollution in the marine environment on human health - a preliminary quantitative estimate of the global disease burden. Unpublished report prepared for the Division on the Protection of the Human Environment, World Health Organization and GESAMP, 28 pp. (14 August 1999).

Some eight billion meals of shellfish are thought to be eaten worldwide each year. The GESAMP/WHO study estimates that eating sewage-contaminated shellfish raw causes some 2.5 million cases of infectious hepatitis each year. Some 25,000 of the victims die, and another 25,000 suffer long-term disability from liver damage. The global burden on human health equals some 3.2 million DALYs a year - comparable to the worldwide impact of all upper respiratory infections and intestinal worm diseases - and costs world society some US\$ 10 billion annually.

This new evidence of the dangers of sewage pollution is just one example of a general reappraisal of the relative importance of different pollutants of the sea. Some of those once thought to be the most damaging worldwide are now believed to be much less important, either because more is known about them or because they have been brought under control.

The supposed effects of man-made radionuclides discharged into the sea still loom large in the minds of the general public and politicians. Although threats from accidental releases cannot be ruled out, radionuclides now probably worry scientists less than any other category of marine pollutants. Similarly, highly publicised and exaggerated concerns about the extent of contamination of the seas and their life by heavy metals cannot be justified; it is probably far less serious than pollution by nutrients and some persistent organic chemicals. The effects of even the most dramatic oil spills are generally localised; gross pollution from them disappears relatively rapidly, though some

subtle effects may last for decades, with enormous economic costs.

Until recently, most attention concentrated on pollutants which directly or indirectly poisoned sea life and those consuming it - or were suspected of doing so. Less attention was paid to the potential effects of the persistent organic chemicals, some of which may have much more subtle, but possibly even more damaging effects. These include changes in the structure and function of communities of marine life, through disrupting reproduction and altering behaviour, and effects at the molecular level, such as causing cancer or mutations or disrupting endocrine systems. Evidence that concentrations of these substances now in the marine environment are causing such effects is mostly inconclusive. Risks to human health usually only occur where concentrations are high, or where people are exposed to them in unusual ways, such as in the Arctic where fish and seafood form an extremely high percentage of the diet.

It is now well-established that some chemicals can harm the endocrine systems of a wide range of wildlife species, both on land and at sea, and may give rise to strange 'gender-bending' effects. Tributyl tin, for example - which has been widely used in anti-fouling coatings on ships and in fish farming - appears to have made female sea snails grow false penises, and to have severely affected oyster fisheries in some areas. Its use has now been restricted in most developed countries, but it is still being traded in some markets. It is possible that other environmental contaminants could 'sneak up on us', causing further unexpected effects.

## EUTROPHICATION

Excessive growth of marine plant life - eutrophication - is potentially one of the most damaging of the many harmful effects that humans have on the oceans, both in its scale and its consequences. It can turn parts of the sea into wastelands.

Plants in the oceans, as on land, need adequate nourishment from minerals and organic substances if they are to grow well. Life is far more profuse in coastal waters, which are rich in these nutrients, than in the open oceans. Areas with poor supplies of nutrients support little life; their transparent and apparently 'clean' blue waters may be aesthetically attractive, but biologically they resemble deserts on land.

Waters, however, can have too much nutrient. When this happens, usually because of pollution from the land, plant life - phytoplankton or algae - proliferates. Long-term increases in phytoplankton, and their decay near the

seabed, can deplete oxygen over large areas, either periodically or permanently - and dramatically alter ecosystems. Coastal areas with relatively little circulation of their waters are particularly vulnerable. A "dead zone" with far too little oxygen, for example, appears off Louisiana in the Gulf of Mexico each summer; excessive nitrogen from agricultural fertiliser used upstream, and flushed down the Mississippi River, has been blamed.

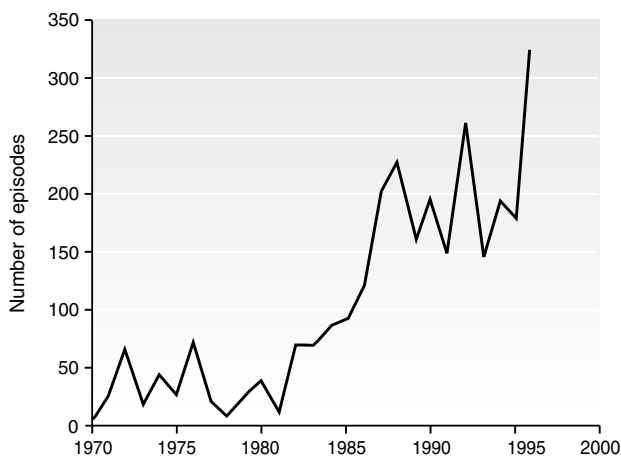
Increases in the abundance of phytoplankton also make water less transparent, and thus reduce the penetration of sunlight into the sea. Coral reefs, seagrass beds - and other ecosystems that depend on light, can suffer - And the reefs can be threatened in another way too. Eutrophication can cause seaweeds on the ocean floor to grow so fast that they outstrip the corals and smother them; the reefs stop growing and start to erode, and much of the diversity of the ecosystem is lost.

Eutrophication can also cause explosive blooms of algae - such as 'red tides' - which cover the surface of the sea. And changes in the relative amounts of different nutrients can stimulate the growth of toxic or otherwise harmful algae. The toxins can accumulate in shellfish and poison people who eat them. One explosion of algae in Chesapeake Bay, for example, killed thousands of fish, made dozens of people ill, and sent sales of crabs, oysters and fish plummeting. The poisons can also be blown to land, at times causing eye irritation, respiratory problems, and other complaints.

Toxic algae can also harm other marine life - including whales, dolphins and other marine mammals - and cause hundreds of millions of dollars worth of damage to commercial fisheries. They devastate tourism in areas like the Adriatic, and damage aquaculture, with massive economic and social costs. There are indications that the blooms, toxic or otherwise, are increasing.

FIGURE 3

Harmful algal blooms in the West Central Atlantic, 1970-96



Source: Safeguarding the Health of the Oceans (Worldwatch).

TABLE 2

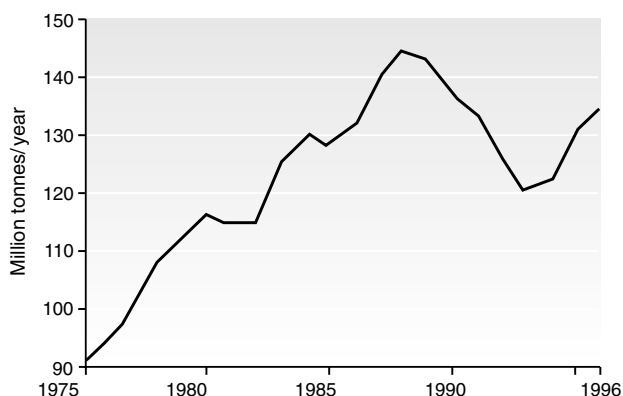
Economic losses from red tides in fisheries and aquaculture facilities, 1972-1978

Date	Location	Species	Loss (million US \$)
1972	Japan	Yellowtail	~ 47
1977	Japan	Yellowtail	~ 20
1978	Japan	Yellowtail	~ 22
1978	Korea	Oyster	4,6
1979	Maine, USA	Many species	2,8
1980	New England, USA	Many species	7
1981	Korea	Oyster	> 60
1985	Long Island, NY USA	Scallops	2
1986	Chile	Red salmon	21
1987	Japan	Yellowtail	15
1988	Norway and Sweden	Salmon	5
1989	Norway	Salmon, rainbow trout	4,5
1989-1990	Puget Sound, WA USA	Salmon	4-5
1991	Washington State, USA	Oyster	15-20
1991-1992	Korea	Farm fish	133
1996	Texas, USA	Oyster	24
1998	Hong Kong	Farmed fish	32

Source: Vital Signs 1999, Worldwatch Institute, Washington DC.

FIGURE 4

## Global fertilizer consumption



Source: FAOSTAT 1997.

Humanity mainly adds nutrients to the sea through agriculture (for example from fertilisers and animal wastes), in sewage, and by nitrogen oxides from burning fossil fuels, which fall out onto the waters. Naturally, municipal sewage tends to be the main source near cities, while agriculture predominates in rural areas. Worldwide most nutrients reach the seas down rivers (the main route for in-shore areas) and by being blown in the winds (the main one for the open ocean).

### Reducing eutrophication pays

Tackling eutrophication by reducing the amount of nutrients reaching the sea can bring big economic rewards. A study which examined the costs and benefits of cutting nitrogen and phosphorous pollution of the Baltic by half - roughly equivalent to targets adopted by international agreements on the Sea - found that the economic returns just from the effects on improving amenity and recreation on beaches were twice as high as the cost of the abatement measures.

The balance of costs and benefits varied from country to country. The economic returns to Russia, Sweden, Denmark and Finland ranged from about five to about three times the cost, whereas in Estonia, Latvia and Lithuania the costs outweighed the benefits gained in this one area. This suggests that imposing uniform targets is not the best policy either economically or environmentally, but that they should be varied to concentrate on the areas where the greatest net benefits can be gained.

The study concluded that reducing nitrogen and phosphorous pollution from existing sewage works, schemes to restore and create coastal wetlands and changes in agricultural practices, seemed to be a particularly effective combination of measures. It was better to concentrate on sewage works that did not meet acceptable standards, rather than to try to make further improvements to those that already treated their effluents well.

Cutting the amounts of nutrients that naturally reach the oceans can also do damage. Building dams and reservoirs, and withdrawing and diverting water for industry and agriculture, all reduce the natural contribution of nutrients from rivers to the sea. This can reduce the productivity of marine life, change the diversity of ecosystems, and hit fisheries. Building the Aswan High Dam in Egypt, for example, reduced the flow of the Nile by 99 per cent, cutting the nutrients and sediments travelling down the river. As a result catches of sardines slumped by 90 per cent, those of shrimp by 75 per cent.

### ALTERED SEDIMENT FLOWS

Reducing the flow of rivers also cuts the amount of sediment flowing down them to the sea. This can wreak major changes on coastlines and has led to serious coastal erosion in many parts of the world. The shores of the Nile Delta were swept away much faster when the completion of the Aswan High Dam reduced the flow of sediments down the river to less than 3 per cent of what it had been: the effects were felt throughout the Eastern Mediterranean. The same thing happened to the Delta of the Indus after the construction of barrages cut the sediment carried by the river by 80 per cent, and to the Colorado River after it was dammed. The Akosombo dam on the Volta in Ghana has reduced the amount of sediment reaching the coast by 60 per cent, while a dam on the Mono river in Togo has almost entirely eliminated it. The sediment starvation caused by these and other dams in West Africa is helping to cause widespread erosion along the coasts. There are now at least 36,000 dams and barrages on rivers worldwide.

Other activities, by contrast, *increase* the flow of sediment down rivers. Felling forests causes more soil to run off the land, especially during storms; it is washed into rivers and streams and eventually finds its way into the sea. Some agricultural practices also cause soil erosion. The amount of sediment in rivers can rise during the building of dams and roads, and other large earth-moving projects, and the diversion of watercourses.

Increased sediment makes the water cloudier, cutting down the light reaching life that depends on it. Coral reefs and other communities on the sea-bottom suffer both from losing light and because they become covered in silt. And increased sedimentation along the shore can change wetland and delta habitats. The Korlee lagoon in Ghana is one of many worldwide that have been silted up by increased sediments, while the Koba rice field in Guinea is also suffering from excessive siltation.

## 3

# The Life of the Seas

The world's people have depended on the life of the oceans for millennia, and for just as long humanity has largely taken it for granted. Great harvests of fish were wrested from the waves, only to be replenished as stocks constantly renewed themselves through reproduction. Mangrove forests, coral reefs and wetlands have formed a vital buffer zone, sheltering the land against many of the worst ravages of the sea, and providing essential nurseries for fish and other life. But now it is becoming increasingly clear that, far from being inexhaustible, much of the life of the sea is being pushed close to its limits.

This chapter reviews the main threats: overfishing on a world-wide scale; the loss of biodiversity; the introduction of alien species; and the destruction and alternation of habitats, including coral reefs.

## FISHERIES

The world's fisheries - on which about a billion people, mainly in developing countries, depend for their primary source of protein - are in crisis. Many are now in decline, many more may follow. The effects on the environment, and on economies and societies, are probably causing more concern than those of any other offshore activity.

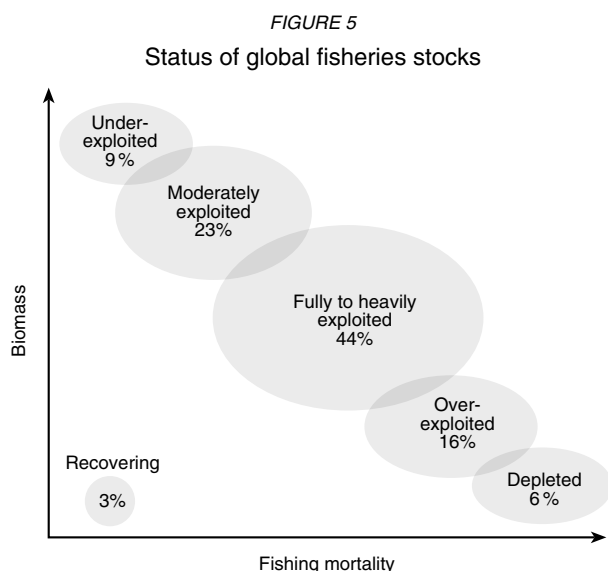
The last decade has seen the end of a 40 year fishing boom. The worldwide catch increased more than four times over between 1950 and 1989; but has since stayed at around the same level. In 1997, 86 million tonnes of fish were caught at sea (catches from inland waters, and rapidly increasing aquaculture, increased total fish production to 122 million tonnes): 40 - 50 million tonnes of this marine catch are eaten directly by people, while much of the rest goes to feed poultry, farmed fish and other animals raised for human consumption.

Fishing more intensively will not do much to increase the catch. Indeed the boom ended because it went too far; the levelling off is mainly the result of overfishing. And, in some ways, it was illusory even while it was continuing, for while the total catches went on growing, their composition was changing. Catches of high-value fish were declining, and being replaced with larger landings of low value ones.

Catching fish faster than they can reproduce reduces stocks, and thus causes the harvest of the seas to falter and

then fall. The decline has reached serious proportions in many coastal waters - particularly inshore areas with dense populations, a high demand for fish, and little employment - and has also affected many fisheries on the high seas. One of the most dramatic examples is the Grand Banks of Canada, where once plentiful stocks of cod were so depleted that the fishery had to be closed, throwing thousands of people out of work. Over 30 per cent of the ocean's productivity, and 70 per cent of the fish caught, are in coastal waters.

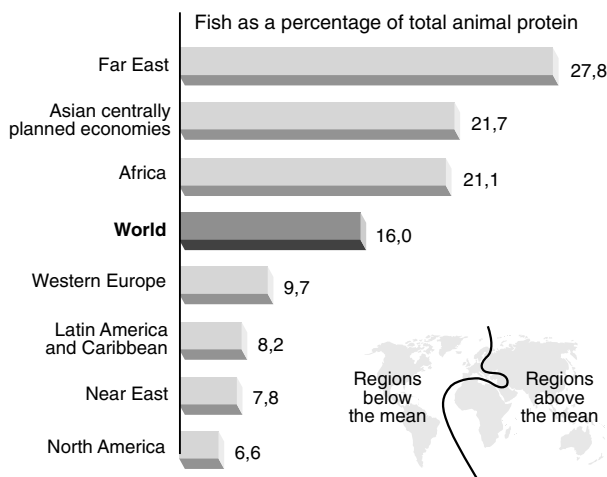
In the early 1950s, 55 per cent of the world's fish stocks were under-exploited. By the mid 1990s catches of about 35 per cent of the world's stocks were decreasing, and those of another 25 per cent had stagnated at a high level of exploitation: only the remaining 40 per cent were continuing to yield more fish.



Source: Botsford et al., 1997 in FAO.

FIGURE 6

## Contribution of fish to human diet, 1987-89



Source: Food and Agriculture Organization of the United Nations (FAO), *Marine fisheries and the law of the sea: a decade of change*, FAO Fisheries Circular n°853 (FAO, Roma, 1993).

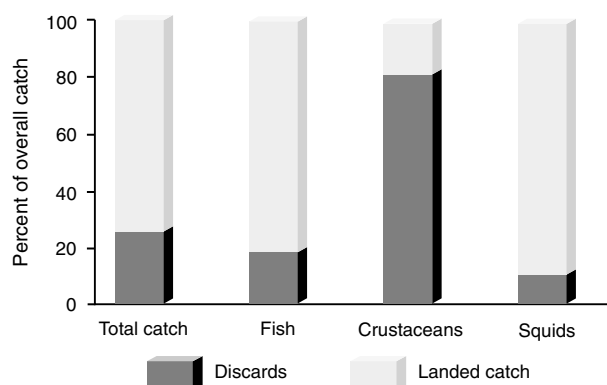
Putting more effort into fishing most of the stocks now being exploited will only lead to further falls in catches. Indeed, if widespread overfishing continues - and there is no sign of it abating - worldwide food supplies from the sea may well decline sharply over the next decade. It has been estimated that the amount of fish caught for direct human consumption may fall by a fifth by 2010, from the present 50 million to 40 million tonnes.

Overfishing does not just deplete fisheries and reduce catches. It makes fishing very expensive, reducing its economic benefits, as boats have to go further, stay at sea longer, and burn more fuel to gather their harvest.

Much of what is caught - whether fish, shellfish or other marine life - is thrown away. Every year, it is estimated, the “by-catch” of unwanted fish - including those thrown back into the sea - amounts to 27 million tonnes worldwide. Usually these are undersized or unmarketable fish, accidentally caught in the nets. But sometimes perfectly useable fish are thrown away, through the practice of

FIGURE 7

## Discards as percent of overall catch, 1988-1992



Source: Food and Agriculture Organization of the United Nation (FAO) ; Bycatch database: *A global assessment of fisheries bycatch and discards*, FAO, Rome, 1994.

“highgrading”. This can happen, for example, when quotas are set on the number of fish to be caught, ironically as a conservation measure: fishermen may then discard part of their catch in order to make space for bigger or more valuable fish. There is also an enormous, if little regulated, by-catch of seabirds, turtles and marine mammals.

Traditionally, the most intensive fisheries have been near coasts, but now fleets are venturing out into deeper waters in search of new stocks as the more accessible fisheries are increasingly overexploited. Over the last decade, in particular, tuna, salmon and other ocean fish have come under growing threats from new fishing technologies. Fishing on continental slopes in depths below 500 metres for predators at the top of the food chain is becoming more common. These fish are long-lived and grow slowly, and so are particularly vulnerable to overfishing, as the story of the orange roughy demonstrates (see box).

### Rough times for the orange roughy

Fishing for the orange roughy began on New Zealand’s continental slope in 1984. The fish became very popular, partly because of its excellent taste and partly because it has a high concentration of healthy fatty acids. It was soon fetching a high price in export markets. As a result, fishing for the orange roughy and catches both increased rapidly; 63,000 tonnes of it were landed in 1988.

This haul, however, proved to be the high point - just four years after fishing began. For the fishery grew much faster than did knowledge about it. The orange roughy - unlike most commercially harvested fish - is very long lived; some scientists believe they can survive for 150 years. It grows slowly, takes 20 to 30 years to reach sexual maturity and reproduces at a leisurely pace. So it can only sustain a low level of catches, much lower than took place while the fishery was growing. Catches fell after 1988, as the stock declined, even though new areas were constantly being opened up for fishing. Stringent measures have now been imposed to try to rebuild the stock, but this will take decades.

Deep sea ecosystems are very vulnerable, recovering only very slowly once they have been disturbed; so there is particular concern that trawling them may do grave damage. Fishing can severely deplete them by removing large amounts of their life, both in the intended catch and in the by-catch. Meanwhile intensive fishing removes vast tonnages of biomass from the middle ranks of the food chain, with largely unknown effects on the ecology of the seas.

Other practices endanger ecosystems nearer to the shore. Excessive trawling and dredging and illegal fishing with explosives, poisons or drift-nets have a major ecological impact. Irreparable harm is done to many habitats. Pollu-

tion can pose a severe threat to marketing shellfish. Eutrophication can choke near-shore waters important to young fish, though it does not seriously affect fish stocks. And some fish are particularly vulnerable to environmental changes - like those related to the El Niño phenomenon in the Pacific - which may become more frequent and severe as global warming increases.

Increasing genetic modification presents a new challenge. New strains of fish, invertebrates and microalgae that grow fast and resist disease have been developed for fish farming. There is increasing concern that if these are released, intentionally or not, into the seas they could threaten the health - and even the survival - of populations of their wild relatives.

The fisheries crisis is driven by three main failings:

- Many of the world's fisheries - and particularly those on the high seas - are still a free-for-all. For all our civilisation, we are still hunter-gatherers at sea. Free and open access encourages overfishing, as each boat, and each nation, tends to catch what it can - like our remote ancestors - without taking care, as a farmer would, to maintain and increase the stock. Fisheries bodies and agreements are not particularly effective, largely because their members are only weakly committed to co-operating on conserving stocks and have failed to fulfil even those commitments that they have made.
- Many nations heavily subsidise their fishing fleets; one recent study estimated that subsidies total up to \$20 billion worldwide every year. By encouraging unprofitable and unsustainable fishing, they make overfishing even worse. Removing and reducing them, however, would have short to medium term economic and social consequences that governments and the fishing industry are reluctant to accept. Meanwhile many developing countries are struggling with an increasing demand for food from their growing coastal populations, can offer little alternative employment to people now working in the fisheries sector, and do not have the capability or resources to enforce sustainable fishing.
- Some attempts to conserve fisheries - like introducing closed seasons, or setting limits on the total catch but not on the amount that can be caught by each boat - may unintentionally allow fishing fleets to grow too much. If a fishery is profitable enough, owners will continue to build and operate boats even if they have to be tied up during part of the year. And they will therefore work all the harder during the period when they are allowed to go to sea.

In all, the present system adds up to a massive waste of capital and fishery resources. And this looks like continuing. Unless governments - and the fishing industry - take effective action, overfishing, and long-term declines in catches, will inevitably continue.

## BIODIVERSITY

A decade ago the oceans were thought to be less biologically diverse than the land. Now they are known to be more so. Thirty three of the 34 major categories of animals (*phyla*) are represented at sea, compared to only 15 on land. Studies suggest that even the deep seas, once thought to be almost devoid of life, may contain more species than all the Earth's landmass.

Research into the biodiversity of life at sea has been relatively neglected, but there is a great deal to be gained from protecting it. Fish catches depend on it; the species caught by fishermen are sustained by the biodiversity of their food chains and habitats. Marine species are probably the greatest untapped source of chemicals that could be used in new pharmaceutical drugs. The genetic material of some species may prove to be useful in biotechnology. And species found near the hot vents on the deep ocean floor have shed light on some of the basic processes of evolution.

Some species, like corals and fish from coral reefs, are threatened by trade. They are much in demand in rich countries as curios, for aquariums and for luxury foods - as is shark fin, for soup. They therefore fetch high prices, providing a strong incentive to trade in them. The trade is poorly regulated and largely uncontrolled. So they are often severely overexploited, and sometimes their habitats are destroyed in the process. Some coral reefs have been degraded both by having too much coral taken from them and by being damaged by people catching the fish. But, by and large, outright destruction of habitats - like the mining of reefs for construction materials, as in South Asia - has a much more serious effect on biodiversity.

TABLE 3  
Marine species on the IUCN «red list»  
and the CITES appendices

Species	Red list	CITES appendix I*	CITES appendix II**
Whales, dolphins	13	22	All cetaceans
Marine otters	1	1	1
Seals, sea lions	12	3	9
Sirenians	3	3	1
Birds	61	4	1
Reptiles (sea turtles)	9	7	1
Fish	111	2	-
Mollusks	10	-	10
Coral	2	-	All stony and black corals

\* Risk of extinction, international trade prohibited

\*\* Vulnerable to exploitation but not yet at risk of extinction, international trade in permitted manner

Source: Safeguarding the Health of the Oceans (Worldwatch).



The good news is that species are not becoming extinct at anything like the same rate as on land. But though less attention has naturally been paid to the reduction of the biodiversity of the oceans, it is gradually being recognised that this is a potentially important issue. Marine species, like sea turtles, monk seals and giant clams, have been driven to local extinction because they have been overexploited or because their habitat has been destroyed. There is particular concern about the effects of killing off 'keystone' species, which hold ecosystems together; when they disappear the structure and functions of the whole ecosystem may change. And there is increasing evidence that many marine species are less widely distributed, and therefore more vulnerable to extinction, than has been previously thought.

### ALIEN SPECIES

As the world shrinks, through growing travel and transport, marine species are frequently ending up, breeding and thriving, far from their original habitats. They can have devastating effects on their new environments and ecosystems, and could end up costing economies many billions of dollars.

Of course, people have taken other species with them since they first began to travel, introducing them to their new homes to provide food or sport, or even merely for aesthetic reasons. There have also been major invasions of species from one sea to another when humanity has artificially connected them, as by the Suez Canal and the St Lawrence Seaway. There are cases where they have done grave ecological and economic damage, while introductions of toxic algae have even harmed human health.

What is happening now, however, is on a much bigger scale. Every day, it has been estimated, 3,000 species of animals and plants are being transported around the world in the ballast water of ships, or on their hulls. They join the ship when the ballast is taken on board at the start of the journey, and leave it when it is discharged at the destination, possibly on the other side of the world. Other species get into the sea after being released from aquaria and fish farms.

Most of these alien species are introduced near coasts, and these waters are particularly vulnerable to them. Many do no damage to their new habitats, but some have threatened the survival of native species or even driven them to extinction, damaged fisheries and aquaculture, and changed whole ecosystems. European zebra mussels have done damage worth many millions of dollars in the Great Lakes of North America, the European green crab has had a similarly costly impact in Latin America and the United States, and so has the North Pacific seastar from Japan in Australia. One of the most damaging of all such invasions has been the spread of a jellyfish, *Mnemiopsis leidyi*, in the Black Sea. (see box)

### The Nemesis of the Black Sea

The effects of a jellyfish invasion on the Black Sea is one of the best documented examples of the far reaching - almost catastrophic - economic and ecological consequences that can follow the introduction of an alien species into an environment favouring its almost unlimited expansion.

*Mnemiopsis leidyi*, a comb jellyfish, originates on the Eastern seaboard of both North and South America. It abounds in their ports and harbours, and is pumped in ballast water into cargo ships. Enough food to sustain the jellyfish on the 20 day voyage to the Black Sea may well be pumped in too. But they will survive anyway, because they can live for three to four weeks without nourishment, by reducing the size of their bodies. They were first found in the Black Sea, off the south-east Crimea, in 1982.

Damaging human activities - including overfishing, pollution, water extraction and barrages on rivers running into the sea - had set the stage for its entrance. Overfishing and eutrophication seem to have combined to remove top predators like turbot, bluefish, and monk seals and to cut the numbers of plankton-eating fish severely, opening up a niche for the jellyfish. Meanwhile plankton proliferated.

Hermaphroditic and self-fertilising, the numbers of jellyfish exploded from 1988 onwards. The populations of plankton crashed as the invaders ate them. Fish stocks collapsed, partly because the jellyfish deprived them of their food and ate their eggs and larvae. The catch of the former USSR states plummeted from 250,000 tonnes to 30,000 tonnes a year, and it was much the same story in Turkey. At least \$300 million was lost in falling fishery revenues between the mid 1980s and the early 1990s, with grave economic and social consequences. Fishing vessels were put up for sale, and fishermen abandoned the sea.

The problem is bound to get worse. Increasing trade and coastal development - and greater commerce in sea life - will make introductions of alien species even more common. They are hard to control. It usually takes a long time - often decades - before an introduced species has multiplied enough for its presence, and effects, to become obvious; in some cases damage worth billions of dollars has occurred before the first attempts at control have been worked out. And, with present technology, control measures are insufficient and haphazard, even when implemented.

## HABITATS

The greatest of all threats to biodiversity, and the most widespread human impact on coastal zones, comes from the destruction and alteration of habitats. This can happen through a wide variety of means; physical, such as draining or 'reclaiming' land, extracting sand or gravel, or the deposition of sediments from soil erosion or deforestation; chemical, such as pollution; and biological, such as invasions of alien species. Habitats, of course, have changed naturally since long before the appearance of humanity, but the sheer scale of the present onslaught is unprecedented.

Half of the world's wetlands were lost during the course of the twentieth century, mostly in the last decades. Up to two thirds of those in Europe and North America have been destroyed, and 85 per cent of those remaining in Asia are threatened. These figures include inland wetlands as well as coastal ones, but these are usually important for watersheds, rivers and thus, ultimately, for coasts and seas.

Over half of the world's mangrove forests have been lost, too. Sixty per cent of them in Guinea and the Ivory Coast have been cut down, mainly for firewood and housebuilding: about seventy per cent of them have been destroyed in Liberia. Seventy per cent of coral reefs worldwide are threatened, while only about five per cent of Europe's coastline still remains undisturbed.

Destroying habitats often has dramatic knock-on effects. Take the widespread destruction of mangrove forests to provide wood and wood chips or to make way for such developments as aquaculture, road building and the spread of towns and cities. This hits fisheries, as mangroves are vital breeding areas and nurseries for many fish, crustaceans and molluscs. It increases the flow of sediments, normally trapped by mangrove roots. And it makes coasts and their peoples more vulnerable to storms - turning natural events into human disasters - as intact forests provide effective buffers against them. The loss of wetlands leads to a similar cascade of effects.

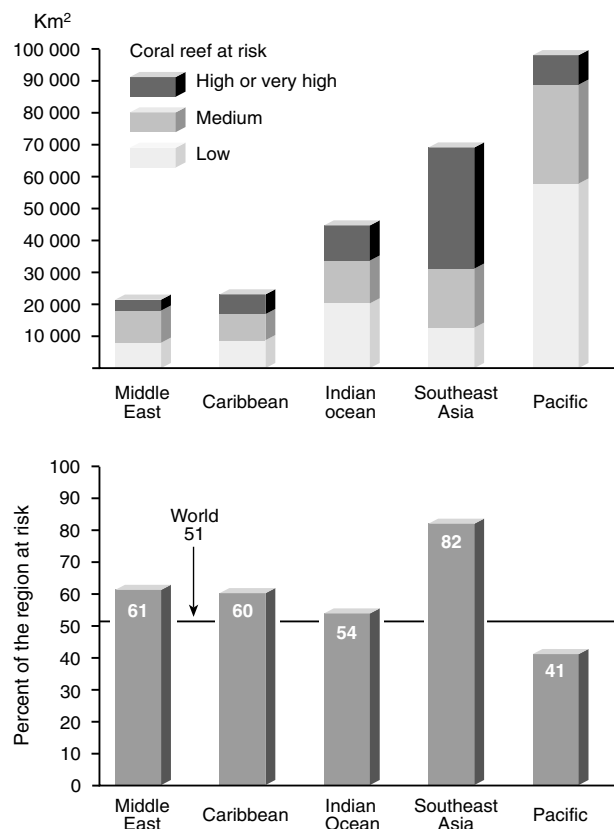
### Disaster follows mangrove loss

Tens of thousands of people died in October 1999 when a cyclone hit the eastern coast of India, with winds of up to 300 kilometres per hour. It brought a tidal surge and torrential rain, causing rivers to break their banks. The flat land near the coast was flooded and slums as far as 50 kilometres from the coast were destroyed. The tragedy would have been much smaller if the coastline had still been covered in mangrove forests, as they would have dissipated the energy of the waves and greatly reduced the damage and loss of life.

## CORAL REEFS

Coral reefs, arguably the richest of all the ecosystems in the sea, have been damaged in 93 of the 110 countries in whose waters they are to be found. Some 27 per cent of the world's reefs are at high risk of degradation: this figure rises to 80 per cent in populous areas. The damage comes from a wide range of causes, ranging from sedimentation and eutrophication, to ships' anchors and trampling by tourists. They are blasted to make way for ports or navigation, and mined for building materials and lime. Overfishing reefs can profoundly disrupt their ecosystems, while fishing with dynamite and poisons does further damage. Collecting coral for the curio trade has done great harm in some places, but is now increasingly being managed as a sustainable activity.

FIGURE 8  
Coral reefs at risk from human activities



Note: Reefs classified as low risk are not considered in imminent danger.

Source: Laurretta Burke et al. *Reefs at Risk: a map based indicator of potential threats to the world's coral reefs*, World Resources Institute, Washington DC, 1998.

There is increasing concern about outbreaks of disease which, over the last decade, have seriously reduced the number of corals and other key organisms in places, and badly affected the ecology and productivity of reefs. Some of these diseases, presumably, are natural: they have been known since the 1970s, and occur on reefs far from the impact of human activities. Yet there is reason to believe that they are becoming both more frequent and more serious. There is particular concern about corals in the Caribbean and off the Florida Keys.

Many uncertainties remain, but nevertheless there is a strong suspicion that these diseases are linked to increasing pollution of coastal waters. If this is so, the very future of the reefs and their ecosystems is in doubt: if there are fewer corals to build the reefs, they may erode away and eventually be destroyed altogether.

Coral reefs are also increasingly affected by bleaching. The overall effects of diseases and bleaching may have far reaching economic and social consequences. Fisheries and tourism are both likely to be particularly badly hit, resulting in serious losses of income and jobs.

### **Coral Bleaching**

Mass bleaching of corals was discovered on reefs all over the world between 1996 and 1998. In 1998, it was found on two thirds of all the world's reefs; in some places, such as around the Maldiv Islands, the proportion rose to 90 per cent. It is caused by the water at the sea surface getting warmer. These outbreaks took place at the same time as a strong El Niño event, but there is evidence that global warming over the longer term may also be having an effect. One recent long-term study in the remote Chagos Archipelago in the Indian Ocean indicates that widespread and severe coral death during the 1988 El Niño were a continuation of a trend in coral decline that had been taking place over the previous quarter of a century, probably caused by steadily increasing water temperatures . There is increasing concern that reefs will not be able to recover if bleaching becomes more frequent, particularly when they are already stressed by pollution and other human activities.

## 4

# The Oceans and the Atmosphere

Much of the future of human civilisation will be shaped by the intimate interactions that takes place where air and water meet on the surface of the sea. The oceans play a vital role in global warming, which is likely to be one of the main determinants of the fate of the planet, its peoples and its other life, over the next centuries and millennia. This chapter examines the seas' part in this process, and its effects on them, and then reviews the impact on the oceans of increased ultraviolet radiation through the thinning of the ozone layer, and the problem of the enormous amounts of nitrogen, released by using fertilisers and burning of fossil fuels, that reach the waters through pollution of the air.

## GLOBAL WARMING

Global warming - predicted to take place faster than at any time in the last 10,000 years - is probably the best known phenomenon affecting the world's seas and coasts. It is likely greatly to exacerbate many of the problems they face.

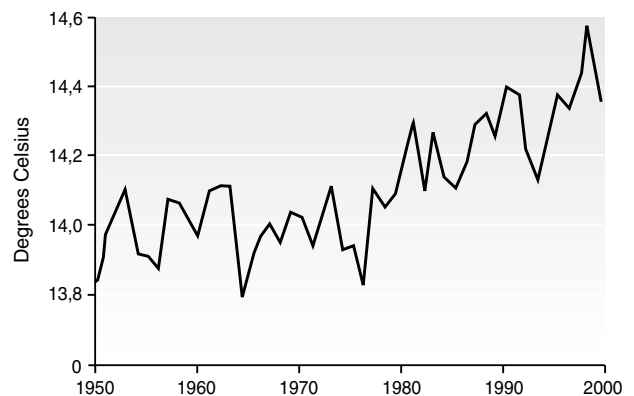
Although the effects of human activities on the climate are still debated, the best scientific assessment is that the steady and accelerating increase in concentrations of carbon dioxide and other greenhouse gases in the atmosphere over the last century - mainly from emissions in industrialised countries - is rapidly altering the Earth's heat balance. Evidence is mounting that, as a result, the world's climate is already changing.

The most recent estimates suggest that, unless preventive measures are taken, the Earth's temperature will rise by between 1 and 3.5 degrees Celsius over the next century. At the same time, according to the Intergovernmental Panel on Climate Change, average sea level is expected to rise between 13 and 94 centimetres: 50 centimetres is seen as the most probable figure.

The oceans will both profoundly affect the rate of climate change and be profoundly affected by it. They can absorb a thousand times as much heat as the atmosphere. In this way they create a massive inertia in climate change, which delays its onset, but ensures that, once it begins, it cannot be reversed in anything less than several centuries.

FIGURE 9

Average temperature at Earth's surface, 1950-1999



Source: Goddard Institute for Space Studies (GISS)

Most concern over global warming has focused on its effects on land - and on the species, including *homo sapiens*, that live on it. Relatively little attention has been paid to its impact on the seas and oceans. But it threatens to cause a whole series of changes to the marine environment.

The flow of major currents, one of the driving forces of the oceans, may change. This would alter the make-up of marine ecosystems, and the way they are distributed through the seas, with far reaching consequences both for the ecology of the oceans and for the economies of the nations that surround them. It may also have dramatic repercussions on climate; for example, if global warming alters the flow of the Gulf Stream, as some scientists predict, North West Europe could rapidly get very much colder.

Commercial fisheries are a product of finely-balanced ecosystems, and are bound to be affected as these are disrupted. There are already instances when the abundance of fish has been affected by changes in the oceans linked to the climate; the El Niño phenomenon of the South Pacific, for example, has helped bring about crashes in Peruvian fisheries.

Hurricanes, flood, droughts and other extreme climate events are expected to get fiercer and more frequent with global warming: the US National Oceanographic and Atmospheric Administration is already reporting that the number of heavy rainstorms and blizzards has increased by a fifth since 1990. This is bound to have a serious impact at sea as well as on land. For example, major storms can do devastating damage to ecosystems in the intertidal zone, destroy structures, and create breeding sites for carriers of infectious diseases.

### The Impact of El Niño

El Niño is a natural phenomenon, which occurred long before concern arose over global warming. But its ill-effects around the world - killing people, destroying homes and other buildings, disrupting transport and devastating agriculture - may give a foretaste of what can be expected from the greater and more frequent extreme weather expected as the world warms up. The World Meteorological Organisation reports that the extreme climates caused by the last El Niño in 1997-8 seriously affected some 117 million people worldwide, killed more than 21,000, and made around 540,000 ill. It drove 4.9 million people from their homes, did US \$14 billion worth of damage to buildings and other structures worldwide and, in all, cost the world's economies US \$33 billion.

El Niño can also devastate fisheries. Normally, deep water rises to the surface near the West coast of South America, bringing plentiful supplies of nutrients and making this part of the ocean among the most productive in the world. During El Niño events, this process stops and the amount of nutrients in coastal waters falls sharply. Plankton populations drop dramatically, disrupting the whole food chain, including anchoveta and birds. During the 1957/8 El Niño event about half of the 30 million guano-producing birds in the area starved to death, while the effects of the 1972/3 event - together with overfishing - reduced the fish catch from 14 million to two million tonnes, nearly causing an economic catastrophe in Peru.

The seas will rise, mainly because the oceans will expand as they warm up, inundating coastal areas. Some cities - like Bangkok, New Orleans and Amsterdam - have all, or much, of their land below sea level.

The rising seas will not just affect cities, towns, villages, industry and infrastructure. They, and the changing currents and wave patterns they will bring, will also profoundly change key natural habitats like wetlands, estuaries, deltas, mudflats, mangroves, and coral reefs. These are particularly vital to the life of the sea, as fish and other species breed in them, providing food for birds, reptiles, amphibians and mammals, including humans.

Rising temperatures and sea levels may also increase the incidence of other diseases, such as cholera and shellfish poisoning. Some scientists have suggested that global warming will increase the frequency of blooms of algae, which will in turn lead to more cholera outbreaks as they may harbour the pathogen that causes the disease; but this has not yet been firmly established. Diseases may also take hold more readily in the future because of increasing malnutrition due to falling fish catches, and due to damage to immune systems caused by extra ultraviolet light penetrating a thinner ozone layer.

Some measures that are proposed for tackling global warming might also pose threats to the oceans. There have been suggestions, for example, that fertilising relatively barren areas of the seas could increase phytoplankton, which would then take up more carbon dioxide from the atmosphere, and might even lead to richer fisheries. Experiments suggest, for example, that adding iron to large areas of the southern and tropical Pacific, where a shortage of the metal is limiting plankton growth, could have dramatic effects of this kind. But such a big, deliberate, artificial intervention in the life of the oceans may also have ill-effects, such as favouring the growth of certain species at the expense of others. We just do not know enough to be able to predict the consequences, and should desist until we do.

Another idea is to inject carbon dioxide, emitted by burning fossil fuels, directly into the deep oceans, rather than letting it escape to the atmosphere. This would effectively create a short cut as the gas would eventually be absorbed by the oceans anyway. Keeping it out of the atmosphere altogether would modify climate change. Nevertheless, studies that have examined the proposal conclude that (apart from obvious technical, legal and economic difficulties in putting it into practice) we do not yet know enough about the natural biological, geochemical and physical processes in the deep seas - or about the effects that injecting the carbon dioxide may have on nearby life - to be able to work out whether it would be feasible or desirable. But at least, in this case, studies are being undertaken before anything is done.

## ULTRAVIOLET LIGHT

As the ozone layer high in the atmosphere gets thinner, the amount of harmful ultraviolet light getting through to the Earth greatly increases, and so does its effect on the life of the planet. Specifically, there is a rise in short wavelengths of ultraviolet radiation, especially at the poles. Damage to life, generally speaking, increases exponentially as wavelengths get shorter. So small decreases in the amount of ozone in the stratosphere lead to big increases in biologically dangerous radiation. Its effects on marine life - either by itself or in combination with traces of contaminants in surface waters - are as yet poorly understood.

Ultraviolet radiation affects the top few metres of the ocean. There is evidence that relatively small increases in it can affect photosynthesis, growth or reproduction in some marine species. The eggs and larvae of many fish (including those caught commercially) and bottom-living species float near the surface of the sea, and so may be threatened.

This may become even worse because ozone depletion may also interact with the lessening of polar ice cover, brought about by global warming, to cause major changes in the spectrum and intensity of the light falling on the waters. This could affect the productivity of the marine plants and phytoplankton on which the food chains of the seas depend. It may have its gravest effects on ecosystems in high, polar latitudes - and polar bears may be particularly sensitive to it.

## NITROGEN

Enormous amounts of nitrogen reach the seas from the air. Two fifths of all the nutrient's contamination of Chesapeake Bay, in the United States, for example, reaches it in this way - either through the rain falling directly on its waters, or through rainfall running off the land in rivers to the sea. Thus air pollution fertilises the bay almost as much as farmers do the fields around it; the amount of nitrogen reaching each square metre of water from the air is almost identical to the amount applied to each square metre of cropland. Nor is this an isolated example: similar results have been found in other estuaries and coastal waters in, for example, the North, Baltic and Mediterranean seas.

There is also growing concern about nitrogen being blown out to the open oceans, particularly where - as in vast areas of the central North and South Pacific - lack of the nutrient limits or controls biological productivity. Current estimates suggest that the nitrogen that reaches these areas by air is only a small percentage of the total amount in their surface waters, but that is recognised not to be the whole story. Great pulses of it arrive all at one time, when storms sweep it out from the continents to the oceans, and then it may play a much more important role.

These processes will almost certainly increase as more and more fossil fuels are burned and more and more fertilisers are put onto the land. And its distribution around the world is likely to change. Over the next 20 years or so, most developed countries are expected to increase their emissions of nitrogen to the air only moderately, if at all. In many rapidly developing regions, by contrast, they will rise significantly. Emissions of nitrogen oxides from energy use are predicted to increase fourfold in Asia, and sixfold in Africa, between 1990 and 2020, accounting for 40 per cent and 15 per cent respectively of their worldwide growth. And nitrogen from fertiliser use is expected to more than double in Asia over the same time, contributing about 90 per cent of its increase worldwide. These predictions suggest - and computer models agree - that there should be big increases in the amount of airborne nitrogen reaching the seas and oceans downwind of Asia, South and Central America and Africa. These increases could possibly lead to changes in the life of the waters in these areas.

## 5

## Land and Sea

Almost all of the problems of the oceans start on land. It is here that virtually all of the pollution originates, whether from factories and sewage works at the coasts, from fertiliser or pesticides washed into rivers and down to the sea, or from metals and chemicals emitted from car exhausts and industry and carried by the winds far out to the oceans. Human activities on land - from covering wetlands with rubbish to selling curios from coral reefs, from felling mangrove forests to changing coastlines - put most of the pressure on the ecosystems and habitats of seas and coasts. Land-based activities are responsible for almost all the emissions of greenhouse and ozone-depleting gases that have such an effect on the oceans. And even the decisions that guide the fishing fleets and other ships that roam the seas are mostly taken on land.

None of this, of course, is new. Scientists have long been voicing concern about the effects of such land-based activities on seas and coasts. But more and more data over the last decade have shown that these have been growing - both in scale and type - and are increasingly damaging the environment. They are now a major focus of international attention.

The effects on the seas cannot generally be blamed on individual sources or activities. They mostly result from the cumulative effect of a whole variety of them, which vary in importance from place to place, and cannot always be traced with great certainty. Indeed, it can be difficult to measure the amounts even of single pollutants reaching the oceans, particularly when they come from such diffuse sources as agriculture or traffic. But it is possible to describe the nature and consequences of particular categories of land based activities in qualitative - and sometimes in quantitative - terms. The following sections of this chapter set out to do this, looking, in turn, at urbanisation; industry; agriculture, forestry and aquaculture; hydrological changes; commerce and transport; tourism; and military activities and social conflict.

#### URBANISATION

Humanity is increasingly gravitating towards the coasts. About one in every three people on the planet now live within 100 kilometres of the sea, and 44 per cent of the

world's population - more people than inhabited the entire globe in 1950 - are within 150 kilometres of it. Two thirds of all the cities with over 2.5 million inhabitants are on the coast, and they are growing fast. Casablanca's population soared from 600 in 1839 to 29,000 in 1900, and to almost 5 million today. Dar Es Salaam is growing by 7.8 per cent a year, well over twice as fast as population growth in Tanzania as a whole. The rate of population growth in coastal areas is accelerating and increasing tourism adds to the pressure on the environment.

The more people that crowd into coastal areas, the more pressure they impose both on land and sea. Natural landscapes and habitats are altered, overwhelmed and destroyed to accommodate them. Lagoons and coastal waters are 'reclaimed', wetlands are drained and covered with rubbish, the floodplains around estuaries are built over and reduced, and mangroves and other forests are cut down. Ecosystems are damaged, frequently lost forever. Fish stocks, fresh water, soils and beach sands are often overexploited, at great economic and ecological cost.

Increasing volumes of waste, particularly sewage, are sluiced out into coastal waters: this can cause eutrophication and endanger public health. Garbage is often dumped on important habitats, like wetlands, and mangroves; they are destroyed, and contaminants leach from the rubbish into coastal waters. The waste itself is increasingly getting into the sea, either by accident or design, in



what is a growing worldwide problem. Litter is common in coastal waters and is strewn across many beaches, even in remote areas, though public education is reducing it in some places.

Much progress has been made by many countries over the past decade in identifying and banning environmentally damaging chemicals, or reducing their use. Nevertheless, many industrial and household chemicals are also discharged to sea, directly and indirectly, accidentally and deliberately. The commonest are soaps, detergents and other cleaning products; oils, paints, batteries, and other products containing hydrocarbons and metals; and gases used in sprays and cooling systems. A wide range of chemicals also gets into the sea by being washed off land by rain or storms.

Of course, it is not just coastal cities that pollute the sea. Population increases and industrial development in river basins or groundwater catchments can do so too, and also merit attention.

## INDUSTRY

Industry is also attracted to coasts, estuaries and large rivers. Many industrial plants depend on their waters for feedstock or cooling - and to transport raw materials. They may also need the markets and labour forces provided by such well populated areas. About 60 per cent of the industries in the Gulf of Guinea States of West Africa, for example are at the coasts.

All the world's oil comes from land or the continental shelves. Exploratory drilling, extracting oil, and transporting and refining petroleum all produce waste, but this has relatively minor effects on coastal and seabed ecosystems. Pollutants can reach the sea from refineries, either directly or through emissions to the air. Large-scale oil spills have had serious - if local and temporary - effects, but most of the oil reaching the oceans comes from much less dramatic sources, such as routine discharges from ships, air pollution, and engine oil put down the drains. Oil pollution can kill seabirds: at times severe spills have affected whole populations of them.

Many people believe that obsolete oil platforms, such as oil rigs, should not be disposed of at sea. But abandoning them, toppling them over, or dumping them (after removing any hazardous materials) in ways that do not increase hazards to fishing or shipping, give little cause for environmental concern.

## Deep sea minerals

So far, drilling for oil and gas has largely been restricted to shallow waters near coasts and to continental shelves. Recent technological developments, however, make it possible to explore for oil and gas - and to exploit them - from ever deeper waters; the current limit is about 2000 metres. The potential contamination - for example, from the release of oil or gas - could damage large areas of the oceans and their ecosystems. And a blow-out in deep water could be difficult to control quickly, and have serious ecological effects.

In 30 to 50 years time - as conventional oil and gas reserves are depleted - oil companies may turn to extracting gas hydrates from the ocean floor. This would have the advantage of producing a much cleaner fuel than coal, oil or oil shale. The drawback is that the main constituent of gas hydrates is methane, a quick-acting, high-impact greenhouse gas, at least ten times as powerful over the short term as carbon dioxide. Methane released from gas hydrates, as sea levels fluctuated with the coming and going of ice-sheets in geological time, may have had enormous effects on the climate: it will be important strictly to limit any release of the gas if the hydrates are ever exploited.. Extracting gas hydrates will also disturb the seabed far more than conventional oil and gas exploitation.

Extracting minerals from the floor of the deep sea is not commercially viable at present - but it could become so if technologies improve and the value of the minerals increases. Exploitation on a large scale could extensively degrade ecosystems on the ocean bottom by directly disturbing them, through resuspending sediments and, possibly, through pollution from the operation itself. And if processing is done at sea, the whole water column could be affected.

Exploring for minerals and exploiting them in areas under the jurisdiction of developing countries is increasingly dominated by multinational interests. These companies often do not make the same effort to meet environmental standards in those countries where they are less effectively enforced. And the dire need for foreign exchange can easily compromise national environmental policies.



Power plants burning fossil fuels are often built on the coast, and beside estuaries and rivers, because they then have plenty of water for cooling: coastal sites near harbours are particularly attractive as it is then easier to supply them with fuel, especially coal. The warm water they put back in return can have some beneficial effects, such as enhancing the potential for aquaculture; but it may also alter the composition of ecosystems. These plants are, of course, a major source of the carbon dioxide emitted to the atmosphere and - depending on the fuel they burn, and the devices they use to control pollution - can also be major contributors of nitrogen and sulphur compounds, and of metals.

Nuclear power stations are often similarly sited so that they can get cooling water. Despite a widely held belief that they are dangerous, they are a relatively minor source of radionuclides. They are generally well regulated, and their environmental record is relatively good. Plants that reprocess spent nuclear fuel - such as those at Sellafield in the United Kingdom and Cap de la Hague in France - discharge many more radionuclides both to air and water. However, so long as they are well operated and regulated (not always the case) their routine emissions are thought to present relatively minor risks to human health on a regional or global scale.

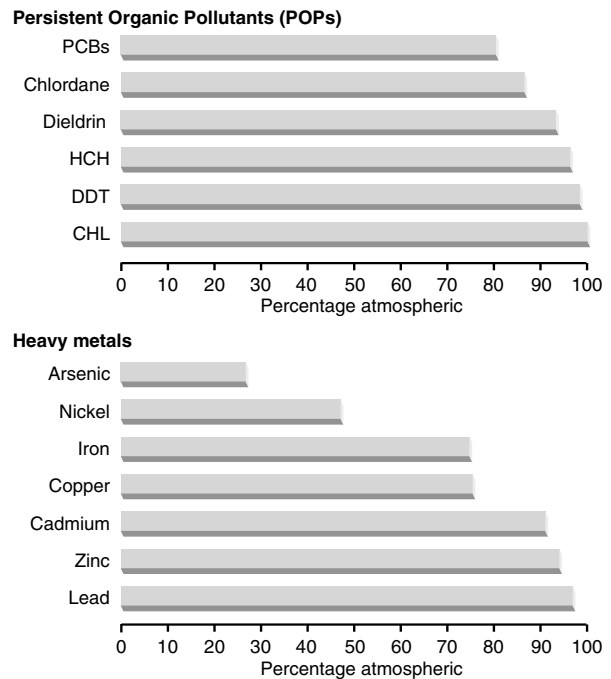
Pulp mills, also often sited on the coast, discharge a wide range of particulates and chemical compounds, sometimes including chlorinated dioxins and furans. Textile and food processing plants, and those refining metal ores are also among the most common industrial polluters of the sea, discharging organic and particulate matter, and chemicals including nutrients, oils and other compounds.

Meanwhile the chemical industry is becoming increasingly globalised. More and more installations are being built in developing countries, Eastern Europe and the former Soviet Union. Over 100,000 chemicals are produced commercially; over 1,000 in quantities of over a thousand tonnes a year. Large volumes of them are shipped by sea and river, road and rail; this inevitably leads to discharges from operations like tank washing, and poses a risk of accidental spills as the cargos are transferred from one means of transport to another. But as regulation gets more rigorous and pollution is more tightly controlled, coasts and estuaries become progressively cleaner and support a more diverse array of life.

Globally, air pollution is as important as rivers in contaminating the open ocean with dissolved copper and nickel - and more important for cadmium, mercury, lead, zinc and, particularly, for synthetic organic compounds. Once emitted, many of these compounds stay in the air for weeks or more, and this is the major route by which they reach the open oceans. Once in the sea they may be taken up by the air again and despatched to the polar regions by a process of global distillation, which boils the chemicals off the ocean in hotter areas, and allows them to condense out of the air again in colder ones.

FIGURE 10

Inputs of heavy metals and synthetic compounds to the global ocean from the atmosphere



Source: after Duce et al., 1991; Hg data from Mason et al., 1994.

### Air pollution and the sea

Air pollution can be important in contaminating coastal waters as well as the open ocean. Nearly 40 per cent of the lead in the waters of Chesapeake Bay gets there directly from the air (though only one per cent of the manganese arrives by this way). Similarly more than 80 per cent of the pesticide, lindane, reaches the North Sea by air - and this is typical for many such synthetic organic compounds. The North Sea also gets as much lead by this route as flows in from the Atlantic Ocean, though less than from dumping.

By the same token, cleaning up the source of the pollution can have positive effects at sea. Lead in both the water and the air around Bermuda has dropped by about three quarters over the last 20 years, as the metal has been removed from petrol in North America and Europe, showing that reducing or stopping air pollution by metals that have a short lifetime in the sea can allow even the open ocean to recover quite quickly.

### AGRICULTURE, FORESTRY AND AQUACULTURE

Agriculture has an even greater effect on the sea than industry. Fertilisers and animal wastes - escaping from farms, and working their way into rivers and the sea - are major causes of eutrophication. Pesticides reach the ocean in a similar way. Soil eroded from fields adds greatly to the particulate load of rivers and coastal waters, increasing sedimentation - a problem that gets worse as forests are cut down to make way for farming.

Poor forestry also mobilises sediments. The soil of forests that have been recently logged or burned is particularly likely to suffer heavy erosion, silting up watercourses and coastal waters. The cost of the damage done to reefs by sediment from one logging project in the Philippines - in terms of lost income from tourism and fishing - was found to be four times the revenue gained by selling the logs. Industries associated with forestry produce wood fibre wastes, and release chemicals, including dioxins and furans, during pulping

Marine aquaculture grew at a rate of about 9.2 per cent a year between 1988 and 1997. By the end of this period it was producing 18.4 million tonnes of fish, molluscs, crustaceans and seaweed worth US \$26.6 billion a year. It amounted to just over half of all aquaculture, and about 14 per cent of all the world's harvest of fish. But badly managed aquaculture has destroyed key habitats like mangrove forests and has allowed selectively bred fish to escape to open waters and interbreed with their wild relatives, with unknown consequences

## HYDROLOGICAL CHANGES

Diverting rivers and other watercourses, building dams, increasing irrigation and using water in industry - all widespread practices - have had major effects on coastal areas. Dams, and other impoundments, are constructed to provide water for irrigation, control floods, and develop hydroelectric power, among other purposes. Unless special measures are taken, they interrupt the migration of fish like salmon and eels between the sea and rivers and so impair their reproduction and life cycles. They also cut the amount of silt and nutrients carried by rivers to the sea; this increases the erosion of coasts and the loss of wetlands, hits ecosystems that depend on the nutrients, and changes the shape of coasts. And they can alter the way that river flow changes with the seasons, affecting habitats and ecosystems that are attuned to it; indeed most damage is caused by the fact that nutrients no longer reach the sea at the time of year when they are needed rather than by their reduction *per se*.

By contrast, carrying out other water engineering works - including straightening or deepening rivers and streams, diverting them, building levees to try to stop them flooding, and destroying wetlands for development - can increase the amount of sediment reaching the coast. These practices can also change the seasonality of river flows. The results are seen in cloudier water and greater sedimentation, increases in the nutrients discharged to the sea, and changes in the circulation, mixing and salinity of water in estuaries. This, in turn, leads to the destruction of coral reefs, the smothering of seagrasses and other severe effects on the environment.

## COMMERCE AND TRANSPORT

Building causeways and roads along the coast often destroys valuable habitats. Developing ports imposes par-

ticular stress on coastal habitats, which can be completely destroyed by dredging, reclaiming land, and construction. Just as much damage may be done by the jetties, navigation channels, basins for turning and anchoring ships, and all the other infrastructure that ports require. These dramatically alter flows of water, sediments and nutrients - as well as other processes in ecosystems - and thus can have as severe an impact as the direct physical destruction of habitats, and affect a much larger area. The construction of ports is, together with dam building, the main cause of the erosion which is the biggest coastal problem in West Africa. Victoria Beach, Lagos has been losing up to 25 to 50 metres a year, as the result of port development and there is a similar situation in Cotonou, Benin, and Lome, Togo.

Unfortunately, the places most favoured for ports are often home to particularly valuable habitats. These wetlands, lagoons, mangroves, seagrass beds and coral reefs are as biologically diverse and productive as any ecosystems on earth, and are critically important breeding, nursery, feeding and migration sites for fish and other wildlife. They are also often prime sites for fishing, recreation and tourism. So developing ports can have effects that are out of proportion to the area involved. There is even more need than usual for good planning and management - including a thorough and integrated environmental cost-benefit analysis.

These pressures will increase, for an ever-increasing growth in maritime commerce and traffic is demanding the development of more ports and the expansion of existing ones. And it is not just the volume of traffic that is growing. Bigger ships, with much deeper drafts, are on their way: so even the ports that can handle more ships will need deeper and larger channels, basins and docks to accommodate these new classes of vessels. In some places, action is being taken to ensure that very large vessels only go to ports with the channels, basins and facilities that can handle them, thus reducing damage.

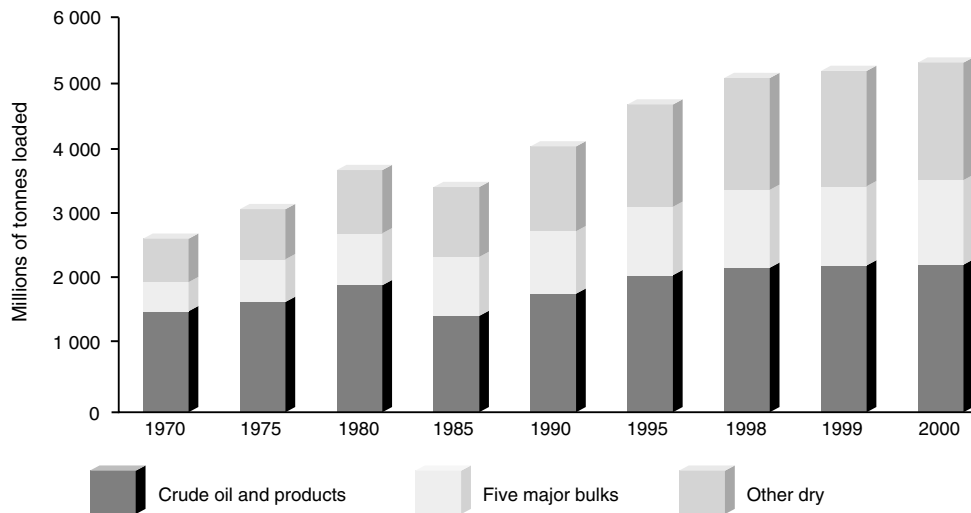
More and more facilities are being provided at ports to receive waste from ships, as part of a global drive against pollution from vessels. But, desirable as this is, it creates the risk of pollution when the measures taken to manage the wastes received are inadequate. Many small islands, for example, simply do not have enough safe places to put large volumes of them.

## TOURISM

Tourism is the world's biggest industry - indeed the biggest the planet has ever seen - and it is growing rapidly. The number of international tourists worldwide grew from 170 million in 1971 to 635 million in 1998, while the amount they spent soared from US\$21 billion to US \$439 billion. By 2020, the World Tourism Organisation predicts, 1.5 billion of them will be spending \$2 trillion a year - or over \$5 billion every day. Meanwhile, at least three times as many people take holidays within their own countries,

FIGURE 11

## International seaborne trade for selected years



Source: Review of Maritime Transport in UNCTAD, various issues.

predominantly in developed nations. Tourism is a big, sometimes dominant, contributor to the GDPs of many nations, such as small island developing countries. It already accounts for a quarter of the total economy of the Caribbean, and provides a fifth of all its jobs.

If tourism is well planned, and is appropriate to local circumstances, it can do much for the sustainable development of coastal areas. Tourists are attracted to pristine seas, so there is a strong incentive to manage the environment properly. Tourism provides a renewable source of

income for coastal communities, and can be used directly to subsidise environmental management; a fee specially levied on visitors to the Great Barrier Reef National Park, for example, produced over 28 per cent of the revenue of the authority managing it in 1999, while its public aquarium and bookshop (used mainly by tourists) provided another 4.6 per cent.

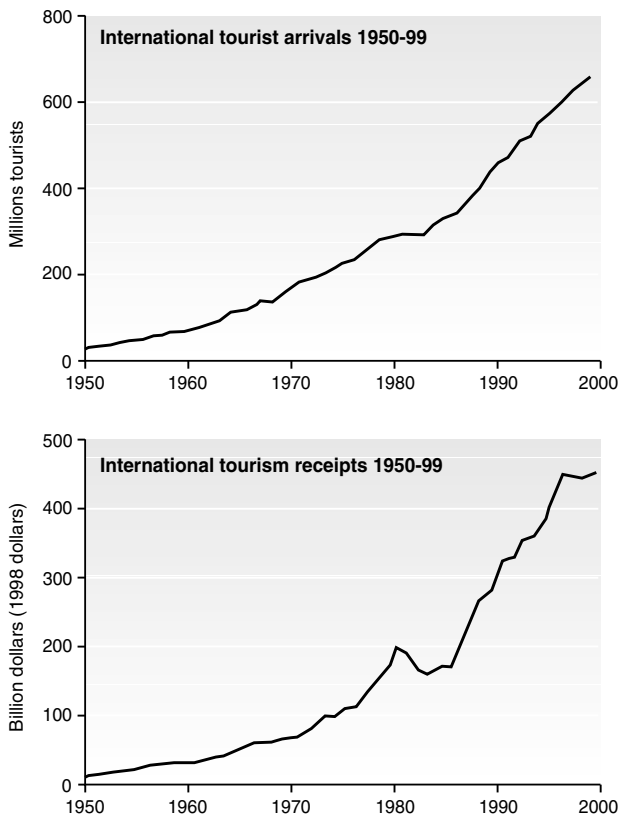
However, tourism is usually not managed well from an environmental perspective. There are strong economic incentives to site hotels and other tourist facilities as near to attractive spots as possible, regardless of the aesthetic and environmental damage that may result. Building hotels, marinas and their supporting infrastructure - roads, airports, car parks, harbours, jetties, breakwaters, sea walls, restaurants, golf courses etc. - often greatly changes natural coastlines and their habitats. In extreme cases, whole ecosystems - such as wetlands, estuaries, mangroves and coral reefs - are destroyed or reduced to insignificance and, as a result, the very survival of key economic or ecological species is thrown into doubt.

The sewage and rubbish that tourists produce add to the difficulties resident populations already have in managing their own debris, especially as the visitors each usually generate more solid waste than local people. The extra sewage they produce often ends up in the sea, with little treatment. This adds to eutrophication, and can increase the incidence of pathogens in waters used for swimming, boating and aquaculture. Large amounts of fertilisers and pesticides are used on coastal golf courses, and may get into the sea. Some far-sighted developers have solved both problems by using treated sewage to irrigate and fertilise their greens and fairways.

Tourists want to eat local seafood and buy local curios, and so indigenous species are often overexploited to try to satisfy them. In many places habitats are commonly destroyed by people walking on reefs, diving or snorkelling - or by the anchors and propellers of boats.

FIGURE 12

## Tourism growth



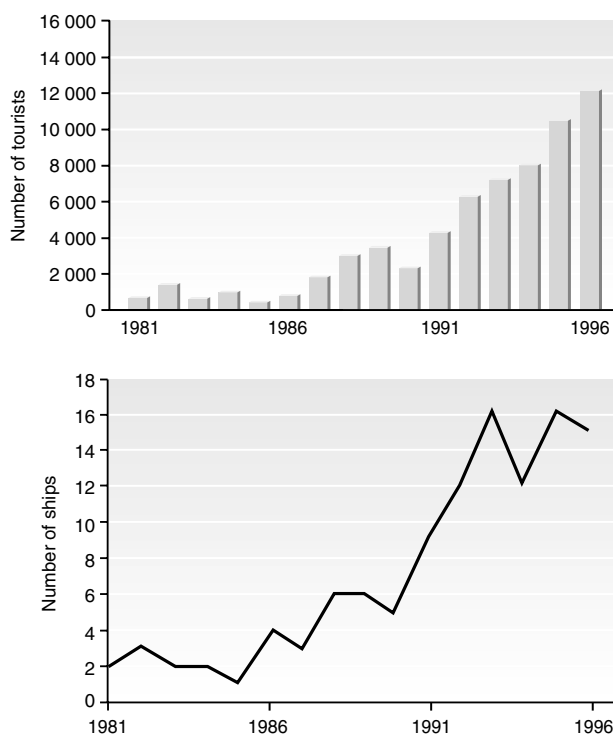
Source: Vital Signs 2000 ; World Tourism Organization (WTO).

Maritime tourism is increasing, posing special problems. Pleasure boat marinas are often built in attractive places, with no regard for the damage they do to wetlands, lagoons, coral reefs and other local habitats. Often they do not have adequate facilities for receiving, treating and disposing of wastes. Meanwhile many of the cruise ships' favourite destinations cannot cope with the vast amount of wastes they generate. It is, indeed, often questionable whether the countries most visited by the ships get enough of an income from them to outweigh such costs.

### Cruising into trouble

The number of people who go on a cruise each year more than trebled - from 1.4 to 4.5 million - between 1980 and 1993. The largest cruise ship built so far, the Carnival Destiny, carries 3,400 passengers and 1,040 crew, and is taller than the Statue of Liberty and longer than three football fields. Cruise ships, on average generate about 4,400 kg of waste a day, compared to the 60 kg a day produced by cargo ships and 10 kg a day by fishing vessels. About a third of the waste from cruise ships visiting the Caribbean is deliberately dumped, because many ships do not have incineration units (or they are faulty) or because ports do not have adequate facilities for unloading it. Indeed, even when the waste is properly received by ports, this is often only the beginning of the problem: many countries, particularly small islands, do not have enough disposal sites to deal with it.

FIGURE 13  
Tourism in the Antarctic



Source: <http://www.gridc.org.nz/images/tour.gif> in Global Environment Outlook 2000, UNEP, 1999.

On the positive side, the emergence of eco-tourism and cultural tourism has begun to introduce a new dynamic into the industry. People who choose such holidays encourage sustainable development by putting a high value on well-preserved environments and cultures, and undertaking to do as little damage as possible themselves. There are encouraging signs that environmental concerns are spreading from this niche market to big tour operators. Several now go out of their way to stress their green credentials, and check out the hotels and resorts they use for their impact on the natural world - and there are some well-supported award schemes. But if tourism is to become truly sustainable these initiatives will have to spread much wider: the presumption must be that no part of the environment has an unlimited capacity to accommodate visitors or their activities.

### Greening tourism

The Seychelles has taken steps to integrate environmental concerns into the development of the tourism industry. During the initial stages, the focus was mainly on sun, sand and sea, but even then the Government adopted policies to limit the size of hotels and to develop harmonious architecture and styles. More recently all new tourism establishments have had to undergo Environmental Impact Assessments, and international certification is being explored.

Despite these good intentions and some concrete progress, there have been shortcomings, causing ill-effects. In some cases, habitats have been damaged, sewage treatment plants have malfunctioned, land has been used inappropriately, and large amounts of water and fossil fuels have been consumed. Until now there has been no clear policy for tourism in general, and eco-tourism in particular, and no overall detailed master plan for tourism and land use in the Seychelles.

A draft Tourism Master Plan, to be finalised in the year 2000, will now devote a specific chapter to environmental concerns. These are highlighted in the country's second Environment Management Plan - covering the period 2000-2010 - as follows:

- Facilitating the establishment of eco-tourism as a prime tourism product of Seychelles.
- Reducing the environmental impacts of tourism.
- Promoting sustainable design and managing resources more sustainable within the tourism sector.
- Improving the capacity of institutions to deal with issues of environmental sustainability.

## **MILITARY ACTIVITIES AND SOCIAL CONFLICT**

War and social conflict also affect the sea. Intensive military activities on coasts cause large-scale destruction of their habitats and ecosystems. Damaged factories, sewage treatment plants and oil installations - rigs, pipeline and terminals - pollute the sea, as do destroyed or damaged ships and aircraft, both military and civilian. And wars increase poverty, making it much harder for countries to address their environmental concerns.

There is little sign of war abating; 20 out of the 45 sub-Saharan African countries, for example, are involved in conflicts, or affected by them, a level not seen since the fight for independence decades ago. Meanwhile war returned to Europe in the 1990s after decades of peace.

Harm is done by the military even in peacetime. Wastes, hardware, ammunition and weapons are frequently lost or dumped - deliberately or accidentally - in the sea. They range from the usual wastes generated by ships to radioactive effluents, from conventional explosives to nuclear warheads and chemical and biological warfare agents, and include entire aircraft, ships and submarines - some complete with the nuclear reactors that propelled them.

Yet most worldwide and regional agreements on the environment have only limited application to military activities. Governments reserve to themselves the right to apply the rules to their own armed forces and military equipment - immune to enforcement by other countries - but rarely take this responsibility seriously. And if conflict does break out the laws of war often override international agreements.

# 6

## Action

Action to protect and conserve the oceans - and remedy damage - is not keeping pace with the ubiquitous threats to them, their resources and amenities. There have been some notable successes in the past decade in improving the quality of the environment of the coasts and seas. But, in general, their degradation has continued and, in many places, intensified. While the open ocean remains still relatively unaffected, impacts on coastal areas - both land and sea - are growing, particularly as the world's population and consumption increases, and as coastal megacities grow in both developed and developing countries.

### Success stories

There are many examples around the world of where timely and effective action has brought success.

International regulations have greatly cut routine discharges of oil from ships. Reduction and banning lead in automobile fuel has caused levels of the toxic metal in ocean waters to fall, particularly in the North Atlantic. Similar controls on pesticides have allowed seabird populations, once decimated by them, to make dramatic recoveries. Bans on testing nuclear weapons in the atmosphere and increased controls on discharges from European nuclear fuel reprocessing plants have reduced the contamination of the sea by radionuclides, and lessened the risks they pose to human health. And many communities worldwide have controlled their discharges of sewage and industrial wastes, gaining safer seafood and bathing waters, cleaner beaches and healthier coastal habitats as a result.

A quarter of a century ago, Jacques Cousteau, predicted the imminent death of his beloved Mediterranean Sea. In 1975, however, the developed and developing countries

surrounding it adopted the Mediterranean Action Plan, addressing pollution, the sustainable use of resources and the management of coastal areas. Although there are still acute problems, and though continuing action is needed, the Plan can be considered a success.

Similar action has led to marked improvements in Chesapeake Bay and other large estuaries. The increased quality of the environment in Britain's Thames Estuary, the United States' Boston Harbour, and China's Xiamen Harbour, for example, shows the effect that determined, co-ordinated action can have, even around big cities where the pressures from population and development are greatest.

Successes, of course, are far from being confined to the industrialised world. To take just two examples: innovative, and locally appropriate, management measures in Namibia have increased the sustainability of the hake fishery and the economic benefits it bestows: marine reserves, set up by coastal communities on Apo Island in the Philippines, increased local fishers' catches.

The most serious problems, apart from the threats arising from predicted climate change, are:

- alteration and destruction of habitats and ecosystems;
- effects of sewage and chemicals on human health and on the environment;
- widespread and increased eutrophication;
- decline of fish stocks and other renewable resources;

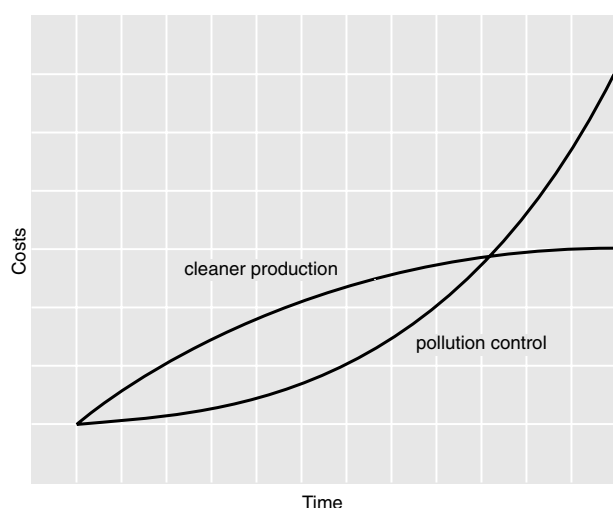
and

- changes in sediment flows due to hydrological changes.

Most of these problems are old ones. They continue to be so serious because they have not been addressed adequately nationally, regionally or globally. Effective action is needed both to deal with acute, short-term threats and with the long term trends of environmental decline, but it remains

FIGURE 14

## The economics of cleaner production



Source: Global Environment Outlook 2000, UNEP, 1999.

the exception rather than the rule in many parts of the world. And even where countries have made progress, damage to the marine environment continues from activities which do not even provide overall economic benefit over the long term.

This is all the more unfortunate because the threats to the world's seas and oceans - and the effects that they can have - are now widely recognised by people around the world. Many governments are fully aware of the dangers,

both now and in the future, of failing to tackle them properly. They also accept that there will have to be a concerted political, social, economic, technical and scientific effort to counter and reverse them.

This growing awareness has led to a remarkable number of political initiatives during the last decade. (*see box*). They have an extraordinarily broad scope and may seem, at first sight, to be impressive. But, in fact, most of them fall short of their goals and are not being implemented in a co-ordinated way. They are long on ringing rhetoric, short on effective action.

Governments as a whole are not putting their money where their mouths are, and the relatively low level of engagement in these issues by the public and other stakeholders has done nothing to counter their lack of resolve. The Secretariat of the 1992 Earth Summit (the UN Conference on Environment and Development) estimated that the world's seas would need about \$12.9 billion a year between 1993 and 2000 - \$900 million of it in overseas aid - if the recommendations it made in Agenda 21 were to be implemented. Nothing like this sum has been forthcoming. Many governments in developing countries are hamstrung by a critical lack of the financial, human and institutional resources they need to address environmental problems effectively.

Governments will have to become much stronger in preventing and controlling environmental damage if the

### Major global political initiatives

**1992.** The Earth Summit - the United Nations Conference on Environment and Development (UNCED) - adopted **Agenda 21** (the Programme of Action for Sustainable Development). Chapter 17 is devoted to "protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas, and the protection, rational use and development of their living resources."

**1993.** The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal**, the **Convention on Biological Diversity**, and the **United Nations Framework Convention on Climate Change** entered into force.

**1994.** The **United Nations Convention on the Law of the Sea** came into force. It was recognised by UNCED as "the international basis upon which to pursue the protection and sustainable development of the marine and coastal environment and its resources."

**1995.** The **Global Programme of Action for the Protection of the Marine Environment from Land Based Activities** was adopted.

**1995.** The **Code of Conduct for Responsible Fisheries** and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of December 1982 Relating to the **Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks** were adopted.

**1996.** The **Protocol to the London Convention** was adopted. Once in force it will replace the 1972 Convention on the Protection of Marine Pollution by Dumping of Wastes and Other Matter, and will ban the dumping of most wastes, except dredged material.

**1997.** Negotiations began to formulate an **international agreement on controls of Persistent Organic Pollutants (POPs)**. This will address the so-called 'dirty dozen' compounds of predominant contemporary concern and may include measures for other Persistent Toxic Substances.

**2002 - 2003.** Planned adoption of a **new international instrument on ballast water control and management**.



seas are to be protected systematically and comprehensively. They should devote a greater share of their budgets to developing and supporting national institutions dealing with environmental issues. Funds for environmental protection can be raised through charges on emissions, fines, and other economic instruments and incentives, such as taxes. State facilities can also be sold or let to the private sector, but only if the capacity for government control is increased and the process is transparent and open to public scrutiny.

Poor coordination and rivalry between donors and between recipient ministries often cause work and programmes to be duplicated and people and money to be deployed inefficiently. This places a tremendous burden on developing countries' limited institutional and human resources, and co-ordination must be improved considerably if there is to be effective environmental protection. It is particularly important that the activities of international financial institutions - such as the World Bank, International Monetary Fund and the regional development banks - are better co-ordinated, since their lending policies largely determine the route that development takes in many countries.

## THE CAUSES OF FAILURE

The root causes of the problems afflicting the world's seas and coasts lie partly in the failure of governments to provide enough political and financial commitment - and in the lack of capability that many have to take effective action even if they wanted to. But they are also deeply embedded in powerful social, political and economic driving forces. These are constantly confronting governments, particularly in developing countries, with short-term needs that have to be satisfied, thus limiting their ability to adopt and implement effective long-term solutions.

Not all environment investment, however, necessarily requires public financing, and so it need not present governments with difficult decisions on where to spend scarce funds. The private sector can do much to provide environmental services, particularly those like ports and sewage treatment works where new investment and technological updates may be needed. There is plenty of evidence that many people, even in developing countries, are willing to pay to have water and sanitation in their homes, and for their rubbish to be taken away. Encouraging private investment and management to provide such services can create new ones or improve those that already exist; governments may often have to do no more than to ensure that they are regulated properly.

No effective long-term solutions to any problems - whether long-standing, emerging, or potential - can be found without dealing with their social and economic root causes. Most, if not all, developing countries are under increasing economic and social stress and are confronted with widespread poverty. They must meet the needs of their

## Failings that impede action

A wide range of failings reflect, and help to reinforce, the lack of commitment and capability to address and solve the environmental problems of the seas in a comprehensive way. They include:

- the poor governance of the seas, nationally and internationally, including a widespread failure to understand the need to approach their inter-linked environmental problems in an integrated way, rather than sector by sector, and to involve different stakeholders meaningfully in designing and implementing environmental programmes. One result is often unwise competition for the limited funds available for tackling the problems of the oceans;
- the fragmentation, and lack of co-ordination between international programmes and institutions. Their broad objectives are often not well translated into specific actions and their priorities are poorly defined;
- economic constraints, including the low priority that is given to financing measures to protect the environment, and the failure to recognise the economic value of the natural services that the seas and oceans provide;
- weaknesses of national structures and deficiencies in national policies and practices which seriously hamper the participation of many countries in international efforts designated to protect and develop institutions, policies and practices;
- scientific uncertainties and deficiencies in information and its management. In many countries the scientific infrastructure is weak, and scientists are little involved in decision-making processes;
- ineffective communication between scientists and government policy-makers and the public alike; and
- insufficient public awareness about environmental problems. There is also too little public involvement in - and support for - attempts to solve them.

people as soon as possible. Thus, many are forced to give a relatively low priority to protecting the environment and conserving natural resources - even though this may undermine their long-term, sustainable development. They need to achieve development without neglecting the environment if they are adequately to address the problems of the seas. One of the most promising solutions may lie in developing countries working together to address what are often common problems within a spirit of global solidarity.

Developed countries are not bedevilled by such harsh constraints, but they too are reluctant to adopt responsible



environmental policies. They sometimes use immediate economic need as an excuse for inaction. But in fact their reluctance may spring from an unwillingness to alienate powerful economic interests or to modify the institutional arrangements already set up to address the issues, from a lack of constituencies lobbying for proper conservation and management, from failure to understand how to implement responsible policies, from a perception that implementing them is costly and provides too small an economic return, and from a fundamental misunderstanding of the economic value and benefits of coastal ecosystems.

## SCIENCE AND POLICY

Scientists, managers and policy-makers must work together effectively if the seas and coasts are to be protected and developed, and if their resources are to be used sustainably. When they do not interact in a balanced way - or public emotions or media outcries dominate decision-making - it is hard to develop rational solutions. For example, the bans on dumping wastes at sea have not been justified as protecting either the environment or public health. Indeed sea disposal may be the best option for some materials on both grounds; but this important option has been foreclosed.

Most decisions affecting the environment are made for social and economic reasons, heavily influenced by politics. It is right that these decisions should be political; but they should be informed by science, and be not driven by short term financial considerations. The oceans and their resources cannot be managed wisely without the reliable and timely information which only interdisciplinary scientific research and observation can provide. The need for it is increasing as environmental change accelerates - and it should be seen as valuable, even in economic terms.

Scientific method is the only rational basis for estimating gaps and uncertainties in our knowledge and for working out the probabilities of the risks involved in different decisions about policies and management. An increasingly interdisciplinary approach among scientists is opening up new vistas and making it possible better to understand the oceans - and how they can benefit humanity. But a cautionary note must be sounded. Uncertainties are inherent and unavoidable characteristics of scientific research; it can rarely deliver the certainty politicians and the general public expect. So decisions will often have to be taken with less than complete information. It is important that neither they, nor proper management measures, are delayed in the hope that more data may become available.

Unfortunately, managers and policy makers receive only a tiny proportion of existing scientific knowledge in a useable form - and they do not use, or use properly, much of what they do get. Scientists, for their part, do not involve them enough in designing their research and in defining what information they expect to get from it. Much of the fault lies in the inadequacies of the system; the issues to

be addressed, and the research priorities, need to be established by both parties, acting in concert.

Major programmes aimed at providing information for the management of the marine environment - such as the Global Ocean Observing System - need to respond better to environmental management demand in both developed and developing countries. Other major initiatives - particularly the Global International Waters Assessment and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities - are focused on addressing needs and on ways to intervene to solve outstanding environmental problems; it remains to be seen whether they can effectively guide action to achieve the greatest benefits in environmental improvement.

## RISKS AND BENEFITS

Caution should be a cornerstone of economic and social development because this inevitably risks degrading the environment and natural resources. A precautionary approach helps to avoid unwanted results - or at least limits the likelihood of them occurring. This approach means that the possible consequences of actions should be evaluated when their objectives are drawn up. It means, too, that authorities should take pre-emptive action whenever there is an unacceptable risk of severe and irreversible damage to human welfare, resources or the environment - even if the effects, or causes, are not certain. If there is doubt about the risks, they should still err on the safe side, taking action to prevent or remedy the damage, in so far as the economic and social consequences warrant.

Common sense dictates that activities posing the greatest risks should get the most attention. But this demands objective assessments of risk - and of the magnitude of the consequences should the worst occur. Such assessments are predominantly the domain of the natural and social sciences. Though they have long been used as a way of determining priorities in safeguarding health, they have not been used adequately for protecting the environment. These assessments - which take into account the degree of uncertainties involved - often produce a different ranking of risks from that perceived by the general public, policy makers and managers. When they take decisions, politicians naturally put more weight on the perceptions of the public they represent than on scientific assessment.

The objective of policy and management should be to achieve the greatest long-term benefit to society by making wise and consistent choices in the trade-offs between economic development and environmental protection. There are a number of techniques for establishing such 'societal net benefits'; the most important element in all of them is to value the benefits that a healthy environment gives society which at present do not carry a market price or are priced too low. Often this involves value judgements that only society can make, usually through governments and elected leaders.

## AN INTEGRATED APPROACH

Many of the environmental problems of the seas and coasts cannot be addressed in isolation. They are intricately interwoven with each other. The environments of land and sea are interdependent, linked by complex atmospheric, geological, physical chemical and biological interactions. The human activities that affect, and arise from, these environments also depend on economic and social factors. And the problems cross physical and institutional boundaries, so that there has to be international co-operation to set common objectives and implement compatible policies and programmes.

Nowhere is the interdependence of the seas and coasts with their hinterland - a linkage that is economic as well as environmental, historical and cultural - as obvious as where large rivers enter the sea. Many of the world's oldest, largest and most prosperous cities - centres both of culture and commerce - stand where fresh and salt waters meet. Rivers were, and still are, liquid highways carrying people, goods and ideas from the coasts deep into the land and *vice versa*. River basins and the flat land around estuaries are fertile ground for producing food and raw materials for the peoples of the coast. The accelerating environmental problems of the river basins, coasts and seas are still generally seen as separate, and treated as such, instead of being addressed together and as a whole. But some countries, such as France, have developed a successful integrated system for managing river basins that is now being extended to coasts.

Fortunately, old perceptions that the problems could be solved in isolation, by specific measures addressing single sectors, or just by "technological fixes", are beginning to wane. Today's environmental managers and policy makers are increasingly realising that lasting solutions can only be achieved through a comprehensive, systematic and sustained approach - and that management plans for the sea and those for the coastal strips and rivers and their basins, must be co-ordinated.

This is often called integrated coastal management (ICM). It provides a framework for integrating environmental, economic, social, cultural and public health interests to ensure sustainable development. It can operate at different levels. Thus ICM, to take one example, might evolve from a local programme dealing with a few pressing issues like protecting habitats or treating sewage to more comprehensive national or regional programmes. Many countries, developed and developing, are beginning to apply the concept, if in different ways (see box).

The concept of ICM is simple enough, but implementing it is often difficult and patchy in practice. As there will be both winners and losers among different interests, policies are often effectively determined by those with big enough constituencies to ensure that their views and interests prevail. Lack of funding and skills may well constrain ICM, and many countries may need technical and financial assistance.

## ICM in practice

There are three very broad approaches towards ICM. They are:

- **An integrated institutional mechanism**, where one organisation is responsible for most, or all, aspects of coastal management. For example, the Great Barrier Reef Marine Park Authority, in Australia, is responsible for a wide range of tasks including zoning activities on the Reef, formulating a plan for the area, running education programmes, and developing, interpreting and applying comprehensive research and monitoring programmes covering not just the Reef but the water catchments on the mainland that drain into the area. But it is limited in some ways. It does not manage fisheries on the Reef, and has no executive authority for managing the way land is used on the mainland - though it can influence it.
- **An institutionally co-ordinated approach**, where one institution co-ordinates the plans and work of others. For example in the Chesapeake Bay Programme, in the United States, the federal Environmental Protection Agency co-ordinates other federal and state bodies. The programme aims at reducing pollution of the Bay by nutrients, and at recovering the abundance, diversity and productivity of its natural resources.
- **Institutional co-ordination achieved through consultation** within a legislative framework. In Zanzibar, for example, the Ministry of Lands and the Environment has taken the lead in developing a holistic strategy for protecting the coasts. This is based on working closely with other ministries on partnerships with local communities and provides the framework for managing natural resources and other activities. Some Mediterranean countries, developed and developing, are also applying this type of ICM at a national, provincial or local level.

There is a pressing need for more and better trained managers from appropriate cultural backgrounds with particular expertise in environmental planning and conflict mediation.

Much can be done to improve management within existing funds and capabilities. There are some inexpensive systems for sewage disposal, for example, which may bring great benefits until the money is available to raise standards to the levels found in many industrialised nations.

This report presents a stark picture of the deterioration of the world's seas and oceans. But all is not yet lost. There are still grounds for hope. The problems are increasingly becoming better understood: the solutions to them are increasingly being worked out. The gap between such knowledge and effective action is largely a matter of political will. What is needed is demonstrable public and political

commitment, not merely in signing agreements and conventions, but in providing the resources to implement the remedies that are now so abundantly clear. Then we shall be able, with Hamlet, to “take arms against a sea of troubles, and, by opposing, end them.”

### **A National management framework**

Countries adopt policies to meet their own particular needs. But, when it comes to conserving coasts and seas, these should be set in a framework of general development plans which contains, among others, the following elements:

- Legislation which provides a legal basis for the protection and management of seas and coasts and defines the conditions under which natural resources are to be used and conserved;
- Provision for international co-operation to identify issues of common interest, primarily at regional and sub-regional levels, and mitigate damage to shared areas;
- Principles that are central to managing the resources of the seas and coasts responsibly, including the precautionary approach, the principle of preventative action, the polluter pays principle, and principles of equity;
- A policy process to set and update goals and objectives for managing the marine environment recognising that this is a learning experience based on continuously emerging knowledge;
- A policy process that ensures adequate and meaningful information and analysis to inform decision-making, incorporates environmental costs and the value of environmental services, and sets priorities;
- Institutional arrangements that provide for devolving management to the lowest level practicable, for approaching it in an integrated way, and for consulting with resource users and other key stakeholders on decisions that affect them - and allowing them to participate in decision making;
- Procedures in the policy process that will provide timely notice of environmental change due to human activities;
- A policy process that fosters effective communication among experts, policy-makers and the public;
- A readiness to evaluate the range of available policy instruments, and apply the most appropriate ones;
- Financial mechanisms that make it possible to attain the goals and address the priorities; and
- Education programmes to ensure informed public participation.

# Problems and Solutions

The following section has been written by the Marine Environmental Assessments Working Group of GESAMP. Many of the problems and the solutions to them listed here have been widely published elsewhere. Nevertheless, they are important and no apologies are needed for repeating them.

Human impact on the oceans is most severely felt in coastal areas, including the coastal terrestrial strip and the adjacent waters. **Action:**

- protect and manage seas and coasts as an integral part of the development process, taking full account of their net benefit to society;
- integrate the management of coastal areas and associated watersheds, thereby recognising the interdependence of freshwater (including groundwater), coastal and marine systems; and
- focus management effort on physical alteration, sewage, nutrients (especially nitrogen) and sediment mobilisation in relation to land-based activities.

The open ocean is much less affected than coastal areas, although it is contaminated with substances that are widely dispersed by atmospheric transport, such as nitrogen, lead, mercury and persistent volatile organic substances. **Action:**

- reduce activities resulting in atmospheric transport of pollutants to the ocean;
- keep a watch on the exploitation of deep-sea non-living resources, oceanic responses to climate change and the delivery of nitrogen into the open ocean, and take appropriate action;
- assess the consequences of interventions likely to result in large-scale effects, such as fertilisation of oceanic surface waters and sequestration of carbon dioxide in the deep ocean, before they are implemented;
- recognise that global approaches are required to address problems in the open ocean.

Many fisheries have free and open access, encouraging overcapitalisation and overexploitation. **Action:**

- adopt and enforce measures to equate fishing capacity and effort with optimum sustainable yields of stocks;
- address artisanal over-fishing through appropriate measures including creating opportunities for alternative employment; and

- reduce by-catch and discards through, inter alia, more selective fishing methods and better enforcement of restrictions.

Coastal habitats have already been severely impaired and are threatened with further damage. **Action:**

- minimize habitat destruction and the loss of biodiversity by the development and/or enforcement of legal, administrative and economic measures appropriate to local circumstances;
- establish protected areas for habitats, sites of exceptional scenic beauty and cultural value; and
- where the degradation of habitats has already occurred, or cannot be prevented, and natural recovery is unlikely, initiate restoration where it is likely to be successful.

Risks to public health from exposures to contaminated seafood and coastal waters are more significant than previously appreciated. Existing quality standards for bathing waters and seafood do not provide adequate protection. **Action:**

- re-evaluate coastal bathing water and seafood quality standards in the light of recent evidence of risks associated with exposures;
- invest in appropriate technologies and procedures to prevent or reduce human exposures to contaminated seafood and bathing waters; and
- invest in costly treatment technologies and impose stringent quality standards only where they are needed to meet environmental and public health objectives and are appropriate to local circumstances.

Integrated coastal management (ICM) - encompassing associated freshwater catchments - is increasingly recognised as an effective approach to managing and protecting the marine and coastal environment. It merits wider application both in resolving existing problems and in dealing effectively with new ones. **Action:**

- promote co-ordinated, cross-sectoral, and holistic approaches to managing environmental resources and

amenities taking full account of environmental, public health, economic, social and political considerations;

- make environmental impact assessment (EIA), risk management, and cost-benefit analysis integral elements of the decision making process and incorporate the value of ecosystem services wherever possible;
- seek the active involvement and participation of all major stakeholders (local authorities, the private sector and particularly the interested public) in the design and implementation of ICM;
- regularly review management systems and their implementation and adjust priorities, targets and methods as necessary; and
- strengthen institutional capacities through training and retraining programmes.

If existing global and regional environmental agreements had been implemented as intended, coastal areas would not be in the deplorable state they are today. National legislative frameworks to achieve national goals and implement multilateral agreements are weak in many countries and are often inadequately enforced. **Action:**

- governments should adapt national legal instruments so that they conform with the provisions of internationally endorsed agreements;
- national and international attention should be focused on compliance with existing international agreements rather than on the development of new ones unless there is compelling justification for them;
- governments need to adopt a consistent and coordinated approach to their dealings with different international organisations and agreements;
- international bodies responsible for the implementation of global environmental agreements should improve the coordination of their secretariats and governing bodies to this end; and
- further attention should be devoted at the regional level to harmonising national approaches and measures, and to collaborating cost-effectively; the full potential of voluntary commitments and targets should be explored, including with the private sector, as well as further legally-binding instruments.

There is a need to improve the balance of attention devoted to different environmental sectors (ocean, land, atmosphere) and to ensure that full account is taken of the overall consequences of interventions designed to prevent or correct problems in individual sectors. **Action:**

- do not foreclose options for ocean disposal without due consideration of the impact on other sectors of environment and overall net benefits; and
- refrain from an unwarranted preoccupation with issues of relatively minor consequence for the marine environment (e.g. ocean disposal of oil production platforms, authorised discharges of radioactive wastes) and focus attention on issues of substantive concern (e.g. physical alterations, coastal development and habitat loss).

The economic value of goods, services and amenities provided by the environment is poorly appreciated and grossly underestimated by managers and policy-makers. It is only rarely taken into account in developmental plans and activities. **Action:**

- take account of the economic value of environmental goods and services wherever possible;
- insist that the costs of environmental degradation should be borne by those who cause it; and
- broaden user fees to include hitherto "untaxed", cost-free uses of the environment and its resources.

Public information and education on environmental problems in the ocean is inadequate; furthermore, the media and special interest groups frequently direct unwarranted attention to peripheral and trivial issues, thus diverting attention from issues of substance. **Action:**

- the media, governments, special interest groups and scientific organisations should fulfil their responsibilities to provide reliable public information and education about marine (and other) environmental issues to enable the public to assess the relative significance of problems and threats.

Every human activity involves a certain degree of risk. Risk is unavoidable: there is no "zero risk" option. **Action:**

- strive to minimise risk and, whenever in doubt, apply a precautionary approach; and
- involve natural and social scientists in the assessment of relative risk and weigh options on the basis of their net benefits.

The public sector often has difficulty in mobilising funds for investment in environmental protection, and the private sector is playing an increasingly visible and important role. **Action:**

- stimulate private sector involvement and investment by using appropriate economic incentives and creating legal and administrative frameworks to promote and protect such investments.

National capabilities to cope with the problems of the marine and coastal environment are inadequate in most developing countries. **Action:**

- governments, aided by the international community should strengthen the capabilities of national institutions to manage the marine and coastal environment effectively; and
- governments should provide national institutions with the authority and human and financial resources needed to carry out their tasks.

International cooperation and assistance, including the transfer of knowledge, experience, technology and finan-

cial resources, benefits both the industrialised and less developed countries and is essential in boosting capabilities of developing countries to protect the environment.

**Action:**

- the international community should improve the flow and quality of official development assistance to less developed countries and devote a larger part of this aid to protecting oceans and coastal areas through genuine partnerships between “donor” and “recipient” countries.

## About this Publication

The main body of the present report has been written by a professional writer/editor on the basis of a draft prepared by the Editorial Board of the Working Group on Marine Environmental Assessments, established within the framework of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). The Editorial Board has been greatly assisted by inputs received from all members of the Working Group and contributions from additional experts. The Working Group was supported and co-sponsored by all eight bodies sponsoring GESAMP (United Nations – UN; United Nations Environment Programme – UNEP; Food and Agriculture Organisation of the United Nations – FAO; United Nations Educational, Scientific and Cultural Organisation and its Intergovernmental Oceanographic Commission – UNESCO/IOC; World Health Organisation – WHO; World Meteorological Organisation – WMO; International Maritime Organisation – IMO; and International Atomic Energy Agency – IAEA) and the Advisory Committee on Protection of the Sea (ACOPS). UNEP provided the technical secretariat of the Working Group.

The draft of the report was peer reviewed by numerous specialists with different scientific backgrounds, managers and policy-makers. Their comments and suggestions were taken into account prior to endorsement of the report by the session of GESAMP in May 2000, and their contributions are hereby acknowledged with appreciation.

**Members of the Working Group:** Lawrence F. Awosika (Nigeria); J. Michael Bewers (Canada) – member of the Editorial Board; Richard G. V. Boelens (Ireland); Francisco Brzovic Parilo (Chile); Sabine Charmasson (France); Robert A. Duce (USA) – member of the Editorial Board; Danny Elder (Switzerland); Robert M. Engler (USA); Michael E. Huber (Australia) – member of the Editorial Board; David Insull (United Kingdom) – member of the Editorial Board; Ljubomir Jeftic (Croatia) – member of the Editorial Board; Terry Jones (Seychelles); Stjepan Keckes (Croatia) – Chairman of the Working Group and member of the Editorial Board; Hillel Shuval (Israel); Helen T. Yap (Philippines).

**Experts and Technical Secretaries of GESAMP during the preparation of the report:** Nik M.R. Abdullah (Malaysia); Lawrence F. Awosika (Nigeria); J. Michael Bewers (Canada); Richard G. V. Boelens (Ireland); Robert Bowen (USA); Tim Bowmer (The Netherlands); Sabine Charmasson (France); Robert A. Duce (USA); Danny Elder (Switzerland); Robert M. Engler (USA); Ong Jin Eong (Malaysia); Scott Fowler (IAEA); John S. Gray (Norway); Richard J. Gowen (United Kingdom); Robert Gruszka (UN); Ramon Guardans (Spain); Paul A. Gurbutt (United Kingdom); John Hambrey (Thailand); Richard Helmer (WHO); Michael E. Huber (Australia); David Insull

(United Kingdom); Ljubomir Jeftic (Croatia); Stjepan Keckes (Croatia); Gwenda Matthews (UN); Piamsak Menasveta (Thailand); Heiner Naeve (FAO); Manfred Nauke (IMO); Stephen B. Olsen (USA); Oladele Osibanjo (Nigeria); Velimir Pravdic (Croatia); Joan-Albert Sanchez-Cabeza (Spain); Kirsti-Liisa Sjoebloom (IAEA); Alexander Soudine (WMO); Ismat Steiner (UN); Umit Unlüata (UNESCO/IOC); Donald Weston (USA); Omar Vidal (UNEP); Helen T. Yap (Philippines); Ivan Zrajevskij (UNEP).

**Additional contributors including those who contributed through the peer review process:** Joan Albaiges (Spain); Jacqueline Aloisi de Lardere (UNEP); Edward Barbier (USA); Monica Borobia (UNEP); Peter Bridgewater (Australia); Anne Christine Brusendorff (HELCOM); Robert Buddemeier (USA); Peter Burbridge (UK); Ian Burton (Canada); Peter Cook (Australia); Antonio Cruzado (Spain); Arthur Dahl (UNEP); Mike Depledge (United Kingdom); Leo de Vrees (UNEP); Helena Freitas (Portugal); Stavros Georgiou (Cyprus); Edward Goldberg (USA); Edgardo D. Gomez (Philippines); Raymond Griffiths (United Kingdom); B. A. Hamzah (Malaysia); Yves Henocque (France); Magnus Johannesson (Iceland); Timothy Kasten (UNEP); Peter Liss (United Kingdom); Vitali N. Lystsov (Russian Federation); Lee Kimball (USA); Gunnar Kullenberg (Denmark); Tom Laughlin (USA); Jamie Machin (UNEP); Elisabeth Mann Borgese (Canada); William Mansfield (USA); Uri Marinov (Israel); Alasdair McIntyre (United Kingdom); Jeff McNeely (IUCN - The World Conservation Union); Gerald Miles (SPREP); Ulises Munaylla Alarcon (CPPS); Scott Nixon (USA); Bob Oudshoorn (The Netherlands); Arsen Pavasovic (Croatia); John Portmann (United Kingdom); Martin Preston (United Kingdom); Kelly Robinson (Caribbean Tourism Alliance); Roger Sassen (USA); Tucker Scully (USA); Viktor Sebek (ACOPS); David Smith (UNEP); Su Jilan (China); Colin Summerhayes (UNESCO/IOC); Mostafa Tolba (Egypt); Veerle Vandeweerd (UNEP); Ben van de Wetering (OSPAR Commission); John Waugh (IUCN – The World Conservation Union); Herbert Windom (USA); Per Wramner (UNEP).

**Writer/Editor:** Geoffrey Lean (United Kingdom)

**Technical Secretary:** Omar Vidal (UNEP)



