ANTHROPOGENIC IMPACTS ON THE STRUCTURE AND FUNCTION OF THE COASTAL BIOTA

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Summary

There are major fluctuations in the natural environmental factors influencing the coastal biota, so that an anthropogenic impact that may seem tolerable for a population during benign environmental conditions can have a disastrous effect when environmental conditions are unfavorable. Fish stocks may sustain an intense level of exploitation when environmental conditions are favorable, but may collapse when there is an interaction between unfavorable environmental conditions and the same intensity of exploitation. It is believed that by these standards 35% of the world's major stocks are overexploited and another 25% are fully exploited, with the possibility of collapse under unfavorable environmental conditions.

Coral reefs are delicately balanced communities of corals, coralline algae and fleshy seaweeds. The balance is maintained by the grazing of herbivorous fish and invertebrates on the algae, and by the controlling action of predators on the herbivores. Exploitation of fish and invertebrates often damages the coral by disturbing the natural balance.

Coral reefs can be physically damaged by direct action, as in the mining of coral rock, smothering with silt, or inappropriate methods of fishing. They can also be damaged indirectly by allowing heavy runoff of silt from the land, or input of anthropogenic nitrogen which stimulates the growth of algae, thereby smothering the corals. In the Caribbean, almost all the coral reefs are strongly impacted, and in southeast Asia it is estimated that more than 50% are in poor condition. Almost all the anthropogenic effects on coral reefs can also be seen acting on kelp beds and seagrass beds.

The most important anthropogenic effects on mangroves are over-harvesting of the trees for their wood, and clearance of mangrove forests to make way for aquaculture. Mangrove forests are disappearing at a rate of about 1% per year in the Indo-Pacific region.

1. Introduction

In much of the current international literature, there is a consensus that the most important anthropogenic effects on the biota of the coastal zone are:

- Overexploitation
- Habitat destruction
- Pollution
- Sea level rise

To these we should probably now add:

- Rise in seawater temperature

The first three effects are clearly seen as direct consequences of human action. The fourth is a prediction about the future consequences of human action. The fifth has recently become a problem, particularly as it affects coral reefs.

1.1. Overexploitation

The effects of overexploitation are seen most clearly in the fish stocks of the continental shelves. A stock that is being exploited in a sustainable manner is able to replace the biomass harvested, by growth of the individual fish and by recruitment of young fish to the stock. When a stock is overexploited, natural growth and recruitment is not able to keep up with removals, and the total biomass decreases.

This in turn leads to a decrease in catch per unit effort. The response of the fishers is often to increase their effort, thus maintaining total landings, until the size of the stock is reduced to very low levels and the fishery collapses. A 1997 assessment by the Food and Agriculture Organization of the United Nations concluded that 30% of the world's major fish stocks are overexploited, while another 20% are fully exploited with no possibility of expansion of effort.

1.1.1 Interactions between anthropogenic and natural causes of variation in stocks

For many types of biota, it has only recently become clear how strong are the natural variations in population size resulting from changes in environmental factors. Most populations have evolved over a long period of time to withstand the range of environmental fluctuations occurring naturally in their habitat, but when anthropogenic stresses coincide with natural environmental stresses, sudden and unexpected reduction in numbers of organisms can occur.

Hence, managers of stocks often find that a level of exploitation, or a level of contamination in the environment that seems to be acceptable to the organisms over a long period, can suddenly become unacceptable and cause a collapse of the stocks. Most often this is because the environmental conditions have become adverse, causing the stock to fail under the combined anthropogenic and environmental stresses. The idea that for a given stock there is one level of exploitation or one level of pollution that is sustainable under all conditions is now seen to be mistaken.

The present state of coral reefs is a particularly clear example of the result of interactions between anthropogenic and natural impacts. Coral reefs occur in areas where major storms, hurricanes, or typhoons are not uncommon. The view has been widespread that an ecosystem that can survive such strong natural disturbance must be very robust and that most anthropogenic impacts must be mild by comparison. Coral reefs have had their biota heavily exploited, their structures impacted by mining and by use of destructive fishing practices, and they have been subject to eutrophication, pollution and siltation. When these anthropogenic effects are added to the natural stresses to which reefs are subject, large scale deterioration results. It is estimated that the majority of the reefs in the Caribbean and more than half of the reefs in southeast Asia are in poor condition.

Rising seawater temperature, an indirect anthropogenic effect, interacts with the natural fluctuations associated with El Nino, and with many other direct anthropogenic effects, to cause extensive coral bleaching and eventual death.

1.2. Habitat destruction

Coastal biota are adapted over long periods of evolution to life in particular kinds of habitat. Anthropogenic destruction of a habitat leads to collapse of the populations that depend on it. Examples of destruction of fish habitat are the strong modification of certain types of seafloor communities by trawling, and destruction of salmon spawning habitats by damming rivers, or by siltation of river beds associated with agriculture, forestry or construction projects in the watersheds.

The land lying between high tide and low tide is particularly vulnerable to anthropogenic effects from coastal development. On soft muddy bottoms the characteristic ecosystems are salt marshes in temperate climates and mangroves in the tropics. Both types of habitat are important as nursery grounds for many species of fish and shellfish, and for providing food for fish stocks living in the adjacent coastal waters. For hundreds of years salt marshes have been modified to support agriculture, by constructing mud walls to keep the salt water out.

More recently, salt marshes have been "reclaimed" in this way to provide land for industrial, residential or recreational developments. The residential developments have generated a demand for control of mosquitoes, which has often been achieved by making gross changes in the drainage patterns of the remaining salt marshes. In the USA, the State of Connecticut has lost three quarters of its original salt marshes, California has lost two thirds and most other coastal states have lost a significant proportion.

About 75% of the world's coastline between 25^{o}N and 25^{o}S was originally colonized by mangroves occupying an area of approximately 170 000 km^{2}. The wood of mangrove forests is exploited for construction, for fuel and for a modern wood chip industry. Large areas of mangrove have been cleared to make way for shrimp aquaculture and other industrial developments. In the Indo-Pacific region it is estimated that mangrove forests are being destroyed at a rate of about 1% per annum.

In shallow water below the low tide level, seagrasses colonize soft bottoms worldwide. They stabilize sediments and support dense populations of invertebrates, which in turn provide food for a wide variety of coastal fishes. Seagrass habitat is often destroyed directly during residential or industrial development of waterfront property, but seagrasses are also very susceptible to indirect effects, such as smothering with silt or sewage solids.

1.3. Pollution

Anthropogenic addition of nitrogen has been recognized as the most serious and widespread pollution problem in coastal waters. Globally, the nitrogen is derived from the runoff of croplands, from atmospheric fallout, and from sewage from man and animals, in that order of importance. The nitrogen stimulates the growth of excessive phytoplankton, a process known as eutrophication. It can also lead to the growth of dense populations of toxic algae.

When the growth of phytoplankton is stimulated to levels beyond the ability of the animals to consume it, large amounts sink to the bottom and are subject to bacterial decay, which causes an excessive demand for oxygen from the water and creates anoxic conditions that are fatal to many organisms. The most serious and spectacular example is an anoxic area of over 16 000 km^2 off the mouth of the Mississippi River, in the Gulf of Mexico.

Fishes and other mobile organisms are able to escape the anoxic area but millions of valuable bottom-dwelling invertebrates such as clams and worms are killed, leading to a major loss of feeding area to the local fish stocks. At least 50 other large anoxic areas are known around the world. Since the nitrogen comes from many essential human activities such as agriculture, manufacturing and transportation, reduction of input from these sources is a very intractable problem.

Dense growths of toxic phytoplankton, known as toxic algal blooms, are being reported with increasing frequency in the world's coastal waters. Some cause deaths in marine fish or mammals, and others lead to the accumulation of toxins in shellfish, which cause problems for people eating them. The exact conditions leading to the outbreak of a toxic bloom are different for each species, but a common factor in all the outbreaks seems to be the presence of large amounts of anthropogenic nitrogen.

Space does not permit a review of all the toxic substances entering coastal waters, and their effects. Some are toxic to biota and their effect is obvious, but many others produce sublethal effects which reduce the viability of coastal biota by reducing growth or reproductive capacity. Often several substances interact in the same organism. Many polluting substances are accumulated in the food web, as a the result of one organism ingesting another, until animals high in the food web become loaded with sufficient contaminants to make them unfit for human consumption.

For example, an important current concern is with the concentrations of chlorinated hydrocarbons in the tissues of arctic marine mammals that are a staple part of the diet of the Inuit people.

1.4. Sea level rise

It is now widely believed that the accumulation of “greenhouse gases” in the atmosphere is resulting in increase in the global average temperature and that one result will be a rise in the average sea level relative to the land. Intertidal systems such as salt marshes, mangroves, and corals are capable of keeping pace with sea level rise provided that the rate of rise is not excessive.

For example, current predictions suggest that there could be a rise of 18 cm in 35 years, but mangroves growing on low limestone islands with little opportunity to colonize higher ground cannot adjust to rates higher than about 4 cm in 35 years. For mangroves growing on the fringe of a land mass, there is the possibility of shrinking on the seaward side and colonizing new ground on the landward side. For this to be possible there must be an absence of development on the land adjacent to the mangrove forest. Similar considerations apply to salt marshes, seagrass beds and fringing coral reefs.

In many cases a particular population of interest is adversely affected by more than one of the factors listed above, so the material in this section is arranged by types of biota. They will be taken in the following order:

- fish and shellfish stocks of the continental shelves
- coral reef communities
- kelp bed communities
- seagrass communities
- mangrove forests
- salt marshes

1.5. Rise in seawater temperature

When seawater temperature rises a few degrees above their accustomed maximum, corals eject the microscopic algae living within them, giving them a bleached appearance. The coral metabolism is impaired and if the condition persists, the corals die. For example, during the El Nino of 1983 there was extensive coral bleaching in the coral reefs of Costa Rica, Panama, Colombia and the Galápagos Islands.

Surface waters were 30 to 31 ^{o}C for 5 to 6 months. In the worst affected regions 90 to 95% of the corals died. With the current global warming, it seems that the effect on corals has now spread to areas not directly affected by El Nino, such as the coast of East Africa. Here, the proportion of coral damaged by bleaching in the 1997 to 98 El Nino varied from <1% in South Africa to >80% on the reefs of northern Tanzania and Kenya.

There is some evidence that corals that recover from an episode of bleaching may become colonized by symbiotic algae that are more resistant to heat damage. In the strong El Nino of 1997/98 the damage in Costa Rica, Panama, Colombia and the Galápagos Islands seemed less than in earlier episodes. In general the rate of recovery is very variable, depending on the severity of exposure to high temperatures and on the amount of collateral stress from pollution and disturbance.

2. Anthropogenic effects on fish and shellfish stocks of the continental shelves

The strongest anthropogenic effect on fish stocks of the continental shelves is undoubtedly overexploitation. The discussion of the problems of overexploitation that follows is equally applicable to fish (sometimes distinguished as finfish) and to commercially exploited invertebrates such as crustaceans and mollusks, collectively called shellfish.

2.1. Problems of overexploitation

2.1.1 The global picture

The continental shelves are the site of over 90% of the world's marine fish production. The global marine catch was valued in 1999 at about $US80 billion per year, with fish farming adding another $24 billion. About 200 million people are employed. Just after World War II the total landings of all kinds of fish worldwide were less than 20 million metric tonnes (MMT). Since that time, about 50 major new stocks have been exploited, larger and more powerful vessels have been used, satellite navigational aids have permitted fishing in waters previously considered too dangerous, and underwater acoustic aids have made it much easier to locate shoals of fish. As a result, world landings of fish from all sources reached 100 MMT by 1989. Since then, landings, while fluctuating, appear to have reached a plateau, raising the question of whether exploitation has reached a global limit.

A 1997 analysis by the Food and Agriculture Organization concluded that 35% of the world's major stocks are overexploited, while another 25% are fully exploited, with no possibility of expansion. Hence, 60% of the world's stocks are being exploited at or beyond their limits. In the light of world population growth and increasing demand for high-protein food, this situation is a cause for concern. The roots of the present crisis may be attributed primarily to overfishing, with additional problems created by disruption of food webs, habitat destruction and pollution.

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Biographical Sketch

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