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The instability of ocean populations

Large-scale fluctuations occur naturally in marine populations; sustained and widespread monitoring over years, even decades, will be necessary to detect the biological effects of pollution in the open ocean

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Two pitfalls await the student of man's influence on life in the oceans: first, to consider any such effects in the open ocean as inherently improbable because of the ocean's vastness or, secondly, to regard populations of marine organisms as inherently stable and to assume that any changes in them reflect the effects of man and his technology. Man's chemical invasion of the ocean does, we believe, pose a real and serious threat to marine life, despite the great volume of the oceans, despite their chemical buffering systems, and despite the probable elasticity of their complex food webs. Research on such effects must be pressed forward urgently, but unsubstantiated statements should not be made concerning "eco-catastrophes". We must remember the fable and make sure that the wolf does not make a meal of us later on.

Fishery biologists long ago discovered that the biggest problem in monitoring man's effects on life in the ocean is to separate these effects from those induced by natural climatic changes in the physical environment. We want to draw attention to the magnitude and ubiquity of natural changes in marine populations which seem, on the time-scales we can measure, to be the rule rather than the exception. Our examples tend to be drawn from fisheries data or from the data of biological monitoring programmes designed to support fishery research, because these provide almost the only source of data that have been taken in a sustained way over several decades.

The effects of climatic changes or trends may be manifest in biological trends continuing over many years, or as drastic population explosions or collapses. The classical case of a population collapse is that of the tilefish, a deepwater species discovered near the edge of the continental shelf off the east coast of the United States in 1879. A fishery developed quickly, but within three years the stock met with disaster. In March and April of 1883 vessel after vessel reported sighting dead tilefish floating on the surface, and exploratory fishing soon afterwards did not yield a single fish of this species in its normal habitat, but by 1898 the stocks were again abundant enough to support a fishery. This destruction was apparently caused by a temporary flooding of the continental edge by abnormally cold deep water.

Events of this nature may be caused by temporary instabilities in ocean systems in which longer-term trends cannot be demonstrated. Such, for instance, are "El Ninos" that occur in the eastern boundary currents in both Atlantic and Pacific oceans. The name "El Nino" (the child) originates from Peru where this phenomenon occurs around Christmas time. El Nino, associated with a slackening of the normal trade winds, is heralded by a reduction in the intensity of the normal coastal upwelling, and an incursion of tropical surface water. Off Peru, El Nino causes dramatic changes in the availability of anchovies to fishermen and to fish-eating birds, because these cold-water fish stay deeper than normal, and the guano birds are unable to dive deep enough to feed effectively. The population of 28 million birds (about 80 per cent guanay cormorant and 20 per cent brown pelican) crashed during the 1957-59 period to a little over 5 million; from a recovery by the mid-1960s to 16-18 million, they again crashed in the 1966 El Nino to about 4 million, and were slowly recovering again until the current 1972 El Nino, to which the population is again responding. Marine climatic data for the Pacific Ocean demonstrate that this must have occurred on at least 10-12 occasions during the present century, and one can infer that the catastrophic deaths of sea-birds off Peru are one manifestation of major, ocean-wide anomalies in atmospheric circulation.

However, although data on the ocean climate of the eastern Pacific does not indicate any sustained trends, such can be found in biological data taken by the CalCOFI (California Cooperative Oceanic Fisheries Investigations) programme, although these are restricted to fish populations affected by fishing operations, and are not mirrored in other biological or in the climatic data. Over the years from 1940 to the present, the population of anchovy (Eugraulis mordax) has greatly increased, while those of sardines (Sardinops coerulea) and mackerel (Scomber japonicus) have dwindled almost to extinction; the decline of the latter two species due to the stress of overfishing and to the failure of young fish to survive in several years of anomalous climate in the 1950s may have sustained the five-fold increase in the anchovy population. Even within the highly urbanised and smog-ridden Los Angeles bight, where very heavy pollution by crude oil spills and leaks, by pesticides and heavy metals have been well documented, the anchovy population shows the same increase as elsewhere off California and the amount of zooplankton still varies from year to year within the same limits as two decades ago (Figure 1).

Further to the north, routine observations have been made for many years at Ocean Weather Station "Papa" to monitor biological changes in the north-east Pacific Ocean. An example of the data derived from Station "Papa" is that for zooplankton biomass in standard 0-150 m vertical hauls; within the 12-year sampling period there are three distinct periods (see Figure 2). The factors causing the anomalously low biomass in 1962-1964 have not yet been identified, but in the absence of any long-term change in the total crop of zooplankton in the north temperate mid-Pacific Ocean, the observed fluctuations in zooplankton standing stock can be reasonably supposed to result from environmental effects. In fact, the variations in biomass have been related to surface salinities, which may be a measure of vertical mixing in the area—a process dependent on the shifting Aleutian atmospheric low pressure cell. This shift could also explain the major sea surface anomalies in temperature which characterise this part of the ocean.

Herrings and herring-like fishes undergo considerable natural fluctuations in population size and because of their great importance in mediaeval economies there is at least qualitative information about their changes in abundance extending back for several hundred years in some instances. One such fishery is found around Japan. From the earliest days it has been a multi-species fishery based upon a sardine (Sardinops melanosticta), and an anchovy (Engraulis japonicus) together with some round-herring (Etrumeus micropus). The fishery reached a peak of more than 1·1 million tons in the 1930s, but has since declined to about half this figure. In the 1930s sardines accounted for the bulk of the catch but the Sardinops stock then started to decline and with it the fishery. Similar fluctuations in this fishery have been recorded in the half-millenium since it was founded about the year 1500. In fact, the present decline is the third one to be recorded during this period.

A major sardine population off Japan apparently occurs only when "warm" oceanographic conditions obtain, that is, when the influence of the warm Kuroshio water is greatest around the Japanese islands; relatively "good and poor" decades in the past half-century are correlated with warm and cool oceanographic conditions. Although overexploitation of the entire oriental sardine stock has been put forward as the sole cause of the decline, the failure to recruit young fish to the stock in the years 1938-41 as a result of environmental changes seems more likely. In the late 1930s the pattern of currents changed to such an extent around Japan that the migration patterns of the sardines were modified and spawning occurred in areas where the young fish would be vulnerable to the effects of winter cooling. The changed location of the present centres of the sardine population tend to confirm the effect of environmental, rather than fishery, changes.

Failures to recruit young fish because of anomalous environmental conditions have been demonstrated for at least three other species of sardines: the Californian Sardinops caerulea mentioned already; the South African Sardinops ocellata; and the Ghanaian Sardinella aurita. In the Californian and South African examples, perhaps because combined with altered parent stock age-compositions due to fishing pressure, such events appear to have initiated major downward population trends.

The major biological fluctuations discussed so far have been mostly "either-or" situations in which the phase-change occurs relatively rapidly. Rather different are the events of this century in the high latitudes of the North Atlantic, in which a general warming trend in the surface waters, associated with changes in the atmospheric circulation pattern, lasted for approximately 30 years from the early 1920s. Cod (whose northward distribution is limited by an inability to survive in water colder than 2°C) began to appear, by migration from the Icelandic stocks, on the coast of Greenland for the first time in living memory in 1917. By 1960 they had built up a population sustaining a fishery yielding more than 400 000 tons each year, but a reversion to the climatic conditions of the first decades of this century will, presumably, result in the disappearance again of the Greenland stock, and the collapse of this great fishery.

Long-term trends in high-latitude Atlantic plankton have also been observed in samples that have been collected from a substantial area of the North Atlantic at monthly intervals for the last 23 years, using automatic samplers towed from merchant ships and ocean weather ships. There are two major patterns in the data, first, a roughly linear downward trend which is still continuous and, second, a more complex trend with peaks in the early fifties and late sixties and a period of low abundance between (see Figure 3). The influences producing these trends have not yet been identified but there are indications, based on geographical and species relationships, that they are produced by climatic changes acting either directly on the plankton populations, or indirectly through induced changes in the strength and direction of ocean currents.

Similarly, in the western English Channel off Plymouth notable changes in the quality of the water have occurred, as indicated by a

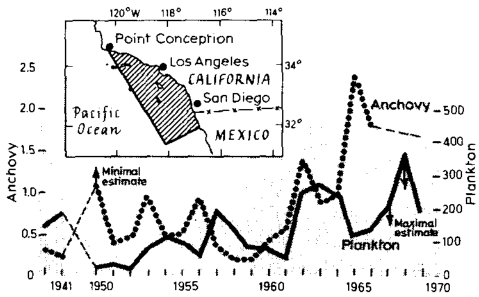

Figure 1 Fluctuations in the amount of zooplankton and anchovy eggs in the polluted Los Angeles Bight show the same increase in the anchovy population as seen elsewhere off the Californian coast

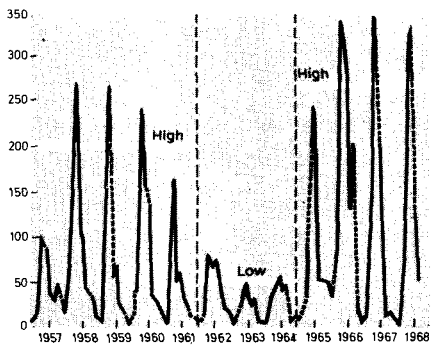

Figure 2 Records of zooplankton biomass sampled at a single ocean station show three distinct phases. The cause of the trough has not been explained, but in view of the recovery natural causes were probably responsible

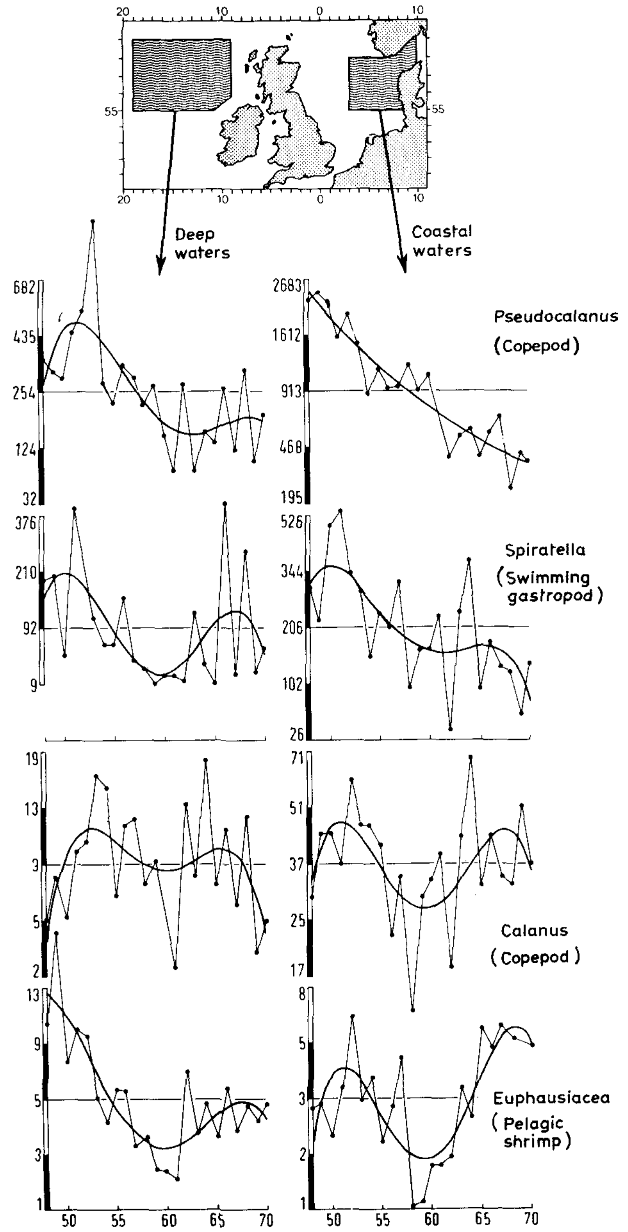

Figure 3 Annual fluctuations in the abundance of four zooplankton organisms for two areas show the dominant patterns of recent year-to-year changes. They were selected from data for about 50 species. The heavy line shows the trend derived by statistical analysis

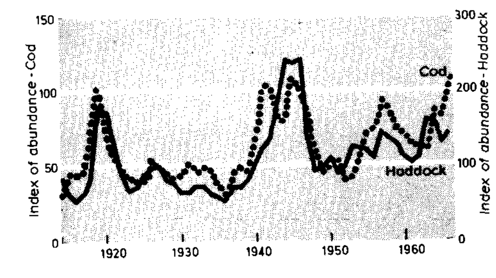

Figure 4 The increased abundance of cod and haddock in the North Sea in recent years indicates a natural increase in productivity

decrease in winter phosphate values in the early 1930s, which were manifested biologically in important ways: the massive spring population of zooplankton dominated by Calanus declined, the herring fishery collapsed because of the failure of recruitment and, instead, a population of the more southerly clupeid Sardinia became established so that its spawning products dominated the spring zooplankton. In the mid-1960s the situation reverted to that of the 1920s: herring shoals have returned, the spring zooplankton is again abundant and dominated by Calanus, and other boreal fish have reappeared.

One of the best long series of quantitative data concerning marine animals is that for the commercial fish in the North Sea, which extends back to the early years of this century. Apart from the obvious effects of the two European wars, there are other important changes that cannot be easily ascribed to man's direct influence. Some of the year-to-year fluctuations, especially in haddock, clearly result from variations in year-class strength, since the numbers of young haddock surviving from the annual spawning in each spring can vary by a factor of a thousand or more. However, the distinct increasing trend that is apparent in the last few years—not only in cod and haddock, but also in plaice and other species—indicates that there has been a succession of unusually good year-classes for all the major bottom-living species. For all three species, total catches in the last few years have been higher than ever before while the abundance has been much higher than at any other period of heavy fishing (see Figure 4). Some of the increase can be credited to the international measures for conservation—prohibition of the landing of small fish, and of the use of small meshed nets—but these do not seem to be enough to explain their magnitude and there appears to have been, during the past decade, a real increase in the natural productivity of the North Sea bottom-living fish.

This review demonstrates several basic principles that have to be understood if man is to measure his influence on the ocean environment. Perhaps most important, it is evident that the ocean is a restless and changing environment and that its changes may either be sudden and dramatic, or covert and sustained for very long periods; it is also obvious that, by their nature, these changes can only be revealed and measured by deliberately mounted and well-sustained ocean monitoring operations. Less obvious there seems to be a real lack of understanding that pollution monitoring schemes, in the ocean or elsewhere, can only succeed if the natural effects of the changing physical environment are both understood and monitored continuously and indefinitely. Natural fluctuations in animal populations have already been ascribed incorrectly to the effects of pollutants, and it would be easy for a serious impact on the environment to pass unnoticed through ignorance of natural population instability or a lack of monitoring of the oceans on a global scale.

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