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, their chemical buffering systems, and despite the probable elasticity of their complex food webs. Research on such effects must be pressed forward urgently, but unstatisticised 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 1979. A fishery developed quickly, but within three years the stock met with disaster. In March and April of 1983 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 1986 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 the "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 guany cormorant and 20 per cent brown pelican) crashed during the 1957-59 period, fell from a recovery by the mid-1960s to 16-18 million, they again crashed in the 1966 El Nio 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 and 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 (Engraulis mordax) has greatly increased, while those of sardine (Sardinops caerulea) 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, sewage and oil from 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 0-350 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
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 popula-
tion size and because of their great import-
ance 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
dearliest 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 microps). 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” ocean-
ographic conditions obtain, that is, when the
influence of the warm Kuroshio water is
greatest around the Japanese islands; rela-
tively “good and poor” decades in the past
half-century are correlated with warm and
cool oceanographic conditions. Although over-
exploitation 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 1956-41 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 modi-
fied and spawning occurred in areas where
the young fish would be vulnerable to the
effects of winter cooling. The changed loca-
tion of the present centres of the sardine
population tends to confirm the effect of en-
vironmental, rather than fishery, changes.

Failures to recruit young fish because of
anomalous environmental conditions have
been demonstrated for at least three other
species of sardine: the Californian Sardinops
cærulea 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-com-
positions 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 migra-
tion from the Icelandic stocks, on the coast of
Greenland for the first time in living memory
in 1917. By 1980 they had built up a popula-
tion 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 dis-
appearance 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 inter-
vals for the last 25 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 indica-
tions, based on geographical and species rela-
tionships, 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
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.