OCEANOLOGICA ACTA, 1983, N° SP

Fluctuations in the ecosystem of the Western Channel : a summary of studies in progress

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Phytoplankton
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ABSTRACT

There have been long-term fluctuations in plankton, fish, and benthos off Plymouth during the past 60 years. The changes form a biological cycle, involving the whole ecosystem, related to recent variations in climate of the northern hemisphere.

Oceanol. Acta, **1983.** Proceedings 17th European Marine Biology Symposium, Brest, France, 27 September-1 October, 1982, 187-189.

RÉSUMÉ

Les fluctuations de l'écosystème de la Manche occidentale : un résumé des travaux en cours

Près de Plymouth, pendant les 60 dernières années, des fluctuations à long terme ont été observées dans les organismes du plancton et du benthos, et parmi des poissons. Ces fluctuations constituent un cycle biologique qui concerne tout l'écosystème, en relation avec les fluctuations climatiques récentes de l'hémisphère Nord.

Oceanol. Acta, **1983.** Actes 17[e] Symposium Européen de Biologie Marine, Brest, 27 septembre-1[er] octobre 1982, 187-189.

INTRODUCTION

There is a strong tradition at the Plymouth Laboratory for study of long term changes. Present researches fall into four groups according to frequency and continuity : 1) the most complete series is of macroplankton and young fish, from 1924 ; 2) there is a less continuous series on phytoplankton and productivity from 1903 ; 3) a shorter series on intertidal barnacle communities, from 1950, but with single observations in 1930 and 1934 ; 4) more intermittent surveys, separated by periods of 10 or 20 years, of the demersal fishes close to Plymouth and of the infauna and epifauna of the seabed near Plymouth.

ENVIRONMENTAL DATA

A constant effort has been maintained to measure sea temperature, salinity and chemical constituents. A fairly complete series exists for st. E1, 20 nm SSW of Plymouth Sound, 1903-1911, 1921-1938 and since 1947. Less complete series exist for many other stations in the W. Channel and Celtic Sea. For inshore waters there is a complete series of observations in Plymouth Sound from 1905 (Plymouth City Council). These sources have been collated and published (*see* Armstrong *et al.*, 1970 ; 1974 ; Maddock, Swann, 1977 ; Pingree *et al.*, 1977 ; Butler *et al.*, 1979, for references).

Macroplankton and young fish

Oblique hauls of 1 m or 2 m nets are made weekly at st. L5, 2 nm west of the Eddystone (Southward, 1970). This station is near the front between coastal and offshore water, and is usually well-mixed.

This series showed the now well-known dramatic change in the ecosystem in the 1930 *s.* A plankton community of great diversity, characterized by *Sagitta elegans*, was replaced by a poorer community characterized by *S. setosa*. Zooplankton numbers and young of demersal fish declined by an order of magnitude, and spawning intensity of pilchard increased by several orders of magnitude. These changes were preceded by a

period of rising sea temperature and accompanied by a fall in the winter maximum of inorganic phosphate. There was a collapse of the Plymouth herring fishery at about the same time. From 1965 onwards these changes reversed, at first associated with a period of falling sea temperatures. Zooplankton abundance increased, young of demersal fish returned in large numbers, and pilchard spawning ceased in the summer months. The change appeared to be complete by 1979, although herring had not returned in any great quantity, its place as the dominant pelagic fish being taken by mackerel from 1968, following the decline in pilchard. Recent publications give references to the earlier studies (Russell *et al.*, 1971; Russell, 1973; Southward, 1974; Southward *et al.*, 1975; Southward, 1980). Present interpretation of this cyclic change is that there is an overall relationship with the secular trend in climate.

Phytoplankton and productivity

Qualitative samples with townets have been analysed for species presence or absence from 1903-1911, 1923-1930, 1938-1939 and 1964 to date. This includes several-times-a-week samples from the Plymouth fishing grounds as well as less frequent stations in the Western Channel. From 1964 quantitative water bottle samples from st. E1 and other places in the W. Channel have been analysed by sedimentation and the numbers converted to volumes. Primary production (fixation of ^{14}C) has been measured several times a year since 1964 at st. E1 and two other stations in the W. Channel (see Boalch *et al.*, 1978; Maddock *et al.*, 1981).

The preliminary analyses show big changes in individual species, which appear and flourish for some years then decline again (*e.g.* Boalch, Harbour, 1977). Probably for this reason, statistical analysis of the 1964-1974 series does not show any marked trends, even though the same period saw the return phase of the zooplankton cycle (Maddock *et al.*, 1981). Correspondingly there were no massive changes in primary production (Boalch *et al.*, 1978). Some doubts are being expressed about the role of primary production in controlling long-term trends (Southward, 1980) and the *Gaia* hypothesis has been quoted (Butler, Southward, 1981).

Intertidal barnacles

Rocky shore traverses are counted annually : in the spring at up to 40 stations around the SW peninsula; and in the autumn at several places of differing exposure to wave-action and insolation close to Plymouth (Southward, 1967). The same survey now includes the follow-up of the " Torrey Canyon " disaster (Southward, Southward, 1978).

Comparison with surveys in 1930 and 1934 showed that by 1951 there had been increases in the proportion of warm-water species and decreases in cold-water species (Southward, Crisp, 1954). Since 1962 a cold-water species has returned and there have been decreases in the warm-water species (Southward, 1967; Southward, Southward, 1977). Two components are present : a long-term rise and fall (or fall and rise) agreeing with the secular trend in temperature; and a smaller component corresponding to the 11 y solar cycle, but with a 2 y phase lag (Southward *et al.*, 1975). The 11 y trend is still present in the records but correlation with sea temperature is less significant, suggesting mediation through other climatic factors.

Demersal fishes and benthos

Similar-sized otter trawls are towed for a measured time at the same stations (up to 130) at approximately the same time of year over a period of 3 to 4 years (Southward, 1963). Fish are identified and lengths measured. Records for 1920-1922, 1950-1952 and 1976-1979 are now available.

Major changes occurred between 1920 and 1950, corresponding to the change in plankton. Warm-water species increased in relative abundance and cold-water species declined (Southward, 1963). The reverse has happened since 1952 and there have been marked increases in certain cold-water species (Southward *et al.*, 1975; Southward, Mattacola, 1980). During the whole period the catch of angler fish and scad has increased, whereas spur-dogs, rays and some gurnards have decreased. The total number of fish taken per hour fishing has not changed significantly, but the proportion of commercially valuable species has declined. These very long term changes appear to be related to fishing intensity, and probably represent a change in balance between species that could influence plankton and benthos (Brander, 1981; Southward, 1981).

Intermittent surveys of benthos off Plymouth have been made since the turn of the century. The results and trends are described by Holme (1983, this volume).

PREDICTION OF CHANGE

Biological prediction contains many elements of stock-market " chartism ", but it is tempting to try. The return of the pre-1930 plankton system ought to have been accompanied by build-up of a fishable population of herring, but what we got was mackerel, and the predicted effect of inorganic nutrients was shown to be an illusion. In 1975 attention was drawn to the fit between some of the biological data and the solar cycles of 11 y and 180 y duration (Southward *et al.*, 1975). If the latter can be predicted from planetary movements, and if the effect is mediated through sea temperature, then there ought to have followed several more decades in which cold-water communities flourished in the Western Channel. In some respects this 1975 prediction came true, and there have been further increases in cold-water species (Southward, 1980; Southward, Mattacola, 1980). But sea temperatures are no longer falling, and the correlation with the 11 y solar cycle is less significant. It may be that an overall trend is imposed

on random fluctuations only when one environmental factor is stronger than usual, as sunspots and temperature may have been at the top of the 180 y cycle in 1921-1971. Even if this short term correlation is no longer clear, the existence of the 180 y cycle could still mean a dominance of cold-water species into the next century. On the other hand, if what we are seeing now is the " greenhouse effect " due to accumulating anthropogenic CO_2 (Hansen *et al.*, 1981 ; Wigley, Jones, 1981), then rising temperatures will tend to cancel out the 180 y trend, and either produce stability at the present level or favour return of warm-water communities. The return of warm-water communities to the Western Channel would mean a fall in zooplankton standing crop, a decline in mackerel, and increases in pilchard. Replacement of cold-water demersal fish by warm-water species would reduce the yield from the commercial fishery.

FUTURE

The surveys carried out since 1900 have shown the existence of important biological changes in the Western Channel, changes perhaps more obvious than those detected in other regions in Northern Europe. The program begun recently to study the " frontal " region at the mouth of the Channel, and the corresponding area of mixing along the continental shelf edge to the west, is capable of providing additional evidence of changes in hydrographic and biological conditions (Grall *et al.*, 1971 ; Pingree, 1978 ; Pingree, Griffiths, 1978 ; Pingree *et al.*, 1978 ; 1979 ; Le Fèvre *et al.*, 1983 *a* ; 1983 *b*). Satellite imaging is an essential part of this program, supplementing and extending the biological data. A combination of the older surveys with studies of " frontal " regions will give greater information on long term changes in the Channel and approaches.

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