Atlantic
Circulation
Fish
Secular changes
Production

Atlantique
Circulation
Poissons
Tendances séculaires
Production

Fluctuations in North Atlantic fish populations

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ABSTRACT The distributions of some pelagic fish in the North Atlantic are described in the eighteenth century and compared with the present situation. Attention is drawn to parallel changes in their natural history. The differences may have been brought about by changes in the circulation, operating through production mechanisms.

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Fluctuations chez quelques espèces de l'Atlantique Nord

RÉSUMÉ La distribution au XVIII[e] siècle de quelques espèces pélagiques est décrite et comparée avec la situation actuelle. Des changements parallèles dans le cycle annuel de leurs populations sont soulignés. Les différences observées peuvent avoir été induites par des modifications de la circulation océanique, agissant par l'intermédiaire des mécanismes de la production.

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CHANGES IN THE DISTRIBUTION OF FISH SINCE THE EIGHTEENTH CENTURY

There is sufficient evidence concerning the fisheries of the eighteenth century to indicate that the distribution of stocks in the North Atlantic was then quite different from the situation which prevails today. The Norwegian cod fishery of the eighteenth century was prosecuted far to the south of its present location (Friele, 1879). This fishery diminished after 1796, and the cod has since been sought farther north, mainly in the region of Vestfjord and the Lofoten Islands, but also as far to the north and east as Finnmark, whence it had disappeared in 1629. Following the decline of the cod in western Norway, the return of the spring herring took place in 1808. There was a partial return to eighteenth century conditions in the late 1860s and 1870s. After about 1930, the main spring herring fishery in Norway moved to the north as far as Trondheimfjord (Runnstrom, 1941).

The year in which the spring herring fishery returned to western Norway (1808) also marked the end of a period of rich herring fishing on the Bohuslän coast of Sweden, which lasted from 1755 to 1808, and was especially good from 1775 to 1800. The years 1699 to 1754 had been poor herring years there (Ljungman, 1882). In the late 1860 *s*, when the Norwegian spring herring fishery failed, the Bohuslän fishery returned, and lasted until about 1922. This apparent alternation between the Norwegian and Swedish spring herring fisheries has been traced as far back as the tenth century, but the Swedish fishery of the eighteenth century is regarded as the richest on record.

The Norwegian spring herring fishery, is based on the Atlanto-Scandian herring, which overwinters to the Southeast of Iceland. The Swedish fishery is more complex; three races are probably involved, but the Atlanto-Scandian stock is not (Andersson, 1958). There is some indication in nineteenth century catch statistics that the success of the Norwegian and western Scottish yields alternate in relative abundance, and that the eastern Scottish fishery, based on a North Sea race, and the relative contribution of spring spawners to the Swedish catch do likewise (Storrow, 1922; 1930). Furthermore, when the late eighteenth century catches to the west of Scotland declined, the catches in the west and north of Ireland became very abundant (Blake, 1868).

At the end of the eighteenth century pilchards (large sardines) were found in the Firth of Forth in equal abundance in certain localities as the common herring (Parnell, 1838). They had disappeared from the Forth by 1816, and have rarely been seen off eastern Scotland since, though large quantities were taken with herring and sprat in the 1860 *s* (Fulton, 1904). In the 1780 *s* and 1790 *s*, pilchards were unusually abundant off Yarmouth (Couch, 1840), and in 1868 off Harwich (Murie, 1903). In that year too, a " biggish lot " were found off Dungeness and Rye (September 1868), though pilchards were at that time considered rare to the east of Portland Bill. The disappearance of pilchards from the Forth coincided with an increase in Cornish catches, and a change in the size of fish taken at St Ives, which between 1781 and 1791 at least had been very small, sardines in fact (Couch, 1840).

In western France, the sardine changed its distribution during the same period, withdrawing from Vendée in the 1760 *s*, and occurring in greater numbers then in Brittany (Odin, 1894). In the mid-eighteenth century, sardines were taken in large quantities along the north coast of Brittany (Encyclopédie Méthodique, 1751) where they have subsequently been rare. About 1810, the reverse occurred (Le Maître, 1977). In southwest Ireland, Pococke (1758, cited by Coombes, 1958) thought that the pilchard had been replaced by mackerel, while in Cornwall, the mackerel was thought to be more abundant in the eighteenth century than later (Couch, 1851). The failure of the sardine at St Jean-de-Luz is sometimes compensated by increased catches of mackerel and other species (Arné, 1928). The changing fortunes of the hake fishery in Cornwall and Ireland paralleled those of the pilchard (Carew, 1811; Went, 1946). The herring extended farther south along the French coast in the eighteenth century, and was then abundant in the Loire Estuary and off La Rochelle (Duhamel du Monceau, 1769-1784; Hembel, 1912; Dardel, 1941). Only twice since, in the last months of 1891 and 1892, have herring been recorded in large concentrations as far south as La Rochelle (Anonymous, 1893).

CHANGES IN THE HABITS OF FISH

The changing distributions of fish in the last three centuries have been accompanied by changes in their natural history, some of which have been incorporated into the folklore of the dependent fishing communities (see *e.g.* Sébillot, 1901). These have included changes in the time of arrival of the shoals at the traditional fishing grounds, in their migration routes, in their spawning seasons, and in their condition. The beginnings and ends of Bohuslän herring periods have been marked by the late arrival of the fish, and by a northward shift in their port of arrival (Ljungman, 1876; 1882). The fishery of the eighteenth century began about two months sooner than at any subsequent time (Ljungman, 1886). Similar trends have been noted in the herring fisheries of the Shetlands and eastern Scotland (*e.g.* Millikan, 1907; Fulton, 1907). In the present century at least, this type of shift in Norway has been accompanied by a change in the mean date at which the fish reached sexual maturity (Rasmussen, 1942). Similar trends have been described in the Swedish sprat fishery (Molander, 1924; 1940).

Partial failures of the Lofoten cod fishery are accompanied by the late arrival of the fish, by the postponement of spawning, and by the poor quality of the liver and underdeveloped sexual organs (Pettersson, 1905; Helland-Hansen and Nansen, 1909). The mackerel is said to have changed its habits at the end of the eighteenth century in Brittany (Trévédy, 1888) and Cornwall (Couch, 1851). In both Cornwall (Bolitho, 1851) and Brittany (Baudouin, 1893) too, the time of the fishery changed markedly around 1800-1810, and to a lesser extent subsequently in parallel with lesser fluctuations in the yield (*e.g.* Fox, 1878). Low catches in Vendée have been associated with the location of the shoals at greater distances from the coast (Amieux, 1912). There have been changes too in the spawning season of the sardine (*e.g.* Arné, 1929).

The eighteenth century was marked in Iceland by large changes in the distribution of cod and herring, which deserted their traditional grounds. These changes first became apparent in the late seventeenth century (around 1690), and lasted until the 1780 *s* (Svabo, 1959; Kristjànsson, 1971). In the western Atlantic, the tautog was replaced in southern New England by the scup and porgy, the herring declined in abundance in the Gulf of Maine, menhaden left the Bay of Fundy, and the mackerel probably moved farther to the North (Baird, 1873; Goode, 1884). There is at least suggestive evidence that the changes listed as having occurred in the eastern Atlantic were accompanied by changes in the west as well.

To summarize, there have been major changes in the distributions of the important pelagic fish on both sides of the Atlantic Ocean, which have been accompanied by profound changes in their natural history. The most notable changes seem to have occurred around the beginning of the nineteenth century (1800-1820), but changes have continued to occur since. The partial return to eighteenth century conditions in the 1870 *s* has already been mentioned. Equally striking are the changes linked with the "climatic amelioration" of 1930-1960, which included the dramatic invasion of West Greenland by the cod.

DISCUSSION

Two different types of hypothesis may be invoked to account for the changes in biogeography and ecology of pelagic fish summarized here. In one, due mainly to Iselin (1940), changing pressure gradients in the atmosphere generate either intensification or relaxation of the North Atlantic circulation, leading to alterations in the strength of the "escapement" currents (Norwegian Current, Iriminger Current, etc.). This hypothesis is a dynamic analogue of the descriptive hypothesis developed by Cleve *et al.* (1901) to account for annual changes in the distribution of plankton. An important implication is that the cold water circulation of the

Norwegian and East Greenland seas should intensify or relax at the same time.

The major atmospheric circulation features over the Atlantic are thought to have varied since the eighteenth century by 2° or more of latitude and 10-20° of longitude (Mitchell, 1977). Evidence that during the eighteenth century the North Atlantic circulation was in an intensified mode was provided by Lamb (1977 ; 1979), who showed that between 1770 and 1820, the Gulf Stream reached its most southerly course. Sea surface temperatures collected between 1791 and 1819 confirm this finding. Between 1820 and 1950 the Gulf Stream adopted a more northerly course. The redistribution of temperature brought about by such a mechanism may to some extent help us to understand the withdrawal from or penetration of different areas by fish, at least in terms of classical biogeography. It is perhaps worth emphasizing that a change in the intensity or volume transport of the escapements will be accompanied by changes in the time at which they reach given localities, and hence in the timing of associated fisheries.

A second hypothesis, promulgated by Pettersson (*e.g.* 1905 ; 1935), invokes the nodal tide of period 18.6 years to account for the changing hydrographic regimes to which the fish must adapt. Such a tide, operating indirectly through control of the time at which stabilization of the water column occurs, might lead through changes in the timing and character of the spring bloom to changes in the success of larval fish survival. It is significant that if the mean age of fish in the stocks in which an ~ 18 year signal appears is subtracted from the identified phase, we arrive at those years in which the nodal tide reached is maximum height (Wyatt, in press). The only exception to this so far identified is the French sardine, which is approximately 180° out of phase with the Cornish pilchard. Since these two fisheries are based on the same stock, this finding confirms the major shifts in the distribution which have occurred.

The amount of stabilization required to initiate phytoplankton growth is very small (Pingree *et al.*, 1976 ; Williams, Robinson, 1973), and the magnitude of the changes in surface temperature associated with the nodal tide (*e.g.* Loder, Garrett, 1978) sufficient to generate significant trends in the timing of plankton growth. Changes in the timing of spring and summer plankton growth in the Plymouth area have been related to the strength of stratification by Maddock and Swann (1977) in the context of the climatic amelioration of 1930 onwards. The difference between an early and late start may be as much as two months. Since the spawning activity of fish is very closely regulated in time, such differences may create very large changes in the success of larval survival, and subsequently in year class strength.

Recent studies have suggested that there may be a link between the nodal tide and climate (*e.g.* Bell, 1981 ; Loder, Garrett, 1978). In the French sardine fishery, the trends in yield expected upon the advent of different winds are of the same nature as those already discussed. In Brittany and Vendée for example, south and southwest winds (rumb d'aval) are believed to bring an early start and a late end to the fishing season, and southeast and north winds (vents d'amont) the reverse. This folk wisdom is confirmed by scientific studies, and the impact of the winds on the stocks is thought to operate through the changing thermal character of the sea. Similar examples can be drawn from the Swedish sprat and herring fisheries.

The somewhat eclectic approach adopted here concerning the Atlantic circulation is unfashionable. Macroscale effects may only account for a small fraction of the kinetic energy in the ocean in the short term, but populations with many year classes must adapt to these scales of motion rather than the high energy mesoscale motions. They must adjust their life cycles to the " climate " of the ocean as well as survive its " weather ".

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