Soapstone carving by Pudlat of Cape Dorset. This is one of a collection owned by Dr. H. T. Schwarz of Montreal.

Commentary

On the West Greenland Sea-Life Area of the Atlantic Salmon

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Horsted (1971), in an account of the present state of the Greenland salmon fishery, describes that fishery as having increased considerably in 1964. Pyefinch (1972) describes the fishery as beginning to develop in the late 1950's, and records also the history of two other recent salmon fisheries which began at about the same time, one in Norwegian waters and one in the vicinity of the Faeroe Islands. It is the contention of this present note that the West Greenland salmon fishery at least, and probably the other two as well, have come into existence because the salmon themselves have quite recently shifted their sea-life feeding area in response to marine climatic change.

The salmon which now appear in west Greenland waters swim very close to the surface and are taken in surface drift nets. The West Greenland waters have been fished and hunted for some four centuries. The whalers sailed up the West Greenland coast regularly during the 19th century and into the 20th; and the Greenlanders themselves are a watchful and enterprising people. The "Tjalfe" Expeditions of 1908 and 1909 worked in southwest Greenland specifically with the purpose of exploring for possible fisheries to develop, to be followed by many other similar operations. It is entirely unreasonable to believe that, had the salmon been in these waters during such a period of time, they could have escaped detection and exploitation long since. Moreover, there is a good positive *a priori* argument to support the view that such sea-life areas of migrant euryhaline species are not permanent, but change from time to time.

Marine (hydrospheric) climates differ from atmospheric climates in that the response of the living populations associated with marine climate changes is immediate, at least as regards planktonic and nektonic communities: there is clearly a lag in the response of benthonic attached and in-faunal communities. We have abundant evidence of drastic changes in the marine climate of the North Atlantic and Subarctic area, particularly in West Greenland waters, during the past century. The increase in temperature since about 1915, which lasted into the 1940's, and brought the Atlantic cod fishery into existence in that region, is especially well documented (Jensen 1939, Dunbar 1951, etc.).

Jespersen (1954) demonstrated that the region southwest of Iceland and southeast of Greenland, in the broad North Atlantic, was highly productive. The surface water was found to be cool, the phosphate levels high throughout the summer, and the zooplankton populations very large in the surface layer, in comparison with the waters surrounding the region. Menzies (1949) suggested

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that the feeding grounds of the Scottish stocks of salmon lay "to the north of the British Isles" (Pyefinch 1972), and that probably the salmon from both Atlantic coasts used common sea-life feeding grounds. It is possible that these common grounds were in the region of high production discovered by Jespersen. Menzies' suggestion was not followed up and now in the 1960's the salmon turn up in the region west of Greenland. During this interval remarkable things have been happening to the marine climate over the entire North Atlantic and Subarctic. The warming period in West Greenland came to an end, and signs of a return to colder conditions appeared. The booming cod fishery in West Greenland began to falter. These changes in climate are not at all understood, but at least we know that they affect both the productivity and the fauna of the waters concerned, and it is not at all improbable that one of the changes during the past two decades has been a shift in the sea life area of the salmon.

The migrations of animals involve explanation of causes at both the proximate and the ultimate levels; that of the stimulus which sets off the migration to begin with, in the individual (proximate level); that of the method of navigation (also proximate); and that of the establishment of the habit of migration in the evolutionary history of the species or stock (ultimate level). The proximate level is concerned with the questions "what causes the individual to do it, and how does the individual find its way?"; the ultimate level is concerned with the question "what is the advantage to the species?". The problem of the West Greenland salmon touches upon the ultimate level, but is concerned chiefly with the proximate matter of navigation. It may be assumed that one selective advantage in the evolution of salmon migration is the attainment of marine regions of high food production; such regions are not stationary in the long term, or even in the comparatively short term, but are dependent on patterns of nutrient production and advection, which are in turn dependent on the changing pattern of wind and current. The navigational mechanism, by natural selection, becomes attuned to this objective, so that most of the population concerned (in this case apparently not including the grilse) reach the appropriate area. The means of navigation may be one or more of several (sun, moon, stars, electric field), and these are still unknown or at best controversial.

The patterns of migration, and of breeding area, of many marine animals have changed most significantly in recent decades in association with, but not necessarily directly caused by, change in marine climate; the Atlantic cod is perhaps the most spectacular and economically important example in the West Greenland region. It is therefore reasonable to search for means of navigation, in terms of information used by the migrants, which have also changed during the same period. Of the means so far considered, only two, those of the electric field and of olfactory information, change rapidly enough to be relevant in the present context. If ocean currents carry their own identifying smells and tastes, which presumably they do, then olfactory information may well be involved, but it is the possibility of the relevance of the electric field that is put forward here.

It has been suggested by several workers, recently by Royce, Smith and Hartt (1968), that oceanic electrical information may be used by migrating animals;

and Rommell and McCleave (1972) have shown that the American eel is sensitive to fields as small in intensity as those measured in the sea. The potentials developed by the passage of ocean currents through the earth's magnetic field are proportional to the velocity and transport of the current, and therefore the pattern must change as current velocities change; and changes in transport and velocity are clearly involved in changes in hydrospheric climate (see for example, Berezkin 1937). If electric fields are used in migration of fish, therefore, we should expect the migrational routes and termini to change with the climatic cycle.

(Horsted's very interesting paper also records the taking in west Greenland of a few individuals of the pink (humpback) salmon, *Oncorhynchus gorbuscha,* a Pacific species which must be assumed to have reached Greenland from Newfoundland, where they have been successfully introduced. The significance of this, in the present context, is not clear. Unless the pink salmon simply swam along with the Atlantic salmon, it might suggest that some fairly direct navigational clues, such as the electric field, were operating also for the Pacific transplants).

Shifts in the distribution and migration of marine exploitable species are of immense economic and international importance, and underline the urgent necessity for far better understanding of the processes controlling changes in marine climate. The nations of the world have organized, in the past half century, an efficient global system of weather observation, reporting, and synopsis, on which is based the weather forecasting for all regions. If we had had a similar organization to deal with the hydrospheric (subsurface) climate over the same period of years, we would now know a great deal more about the changing marine climate, and would have the beginnings at least of the means of forecasting it. To quote from the Arctic Institute of North America's Position Paper to the U.N. Stockholm Conference on the Human Environment (June 1972): "There is a need for (a) a program of routine oceanographic measurement, organized internationally, of temperatures and salinities in certain sections such as Hudson Strait, Davis Strait, the Labrador Sea, Denmark Strait, over the Wyville Thompson Ridge between Iceland and Scotland, and in the Barents Sea and Svalbard areas; between northeast Greenland and Svalbard; and (b) a broadly based investigation into the nature and causes of these events, whose causes may possibly reach beyond the global limits into our solar system as a whole, and whose effects certainly are world wide" (Arctic Institute 1972).

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