ON THE NATURALNESS OF CHANGE IN MARINE POPULATIONS *

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"Industry need not fear that overfishing will deplete a resource; no habitat long remains vacant, and like populations may be expected to replace extinguished links of a food chain". Extraordinary notes of optimism are sometimes voiced when a fluctuating supply of fish is in a phase of decline—when justification must be offered to industry or government for pursuing a profitable fishery. Such optimism, recently put forward in a lecture by Dr. M. Tweit of the Indo-Norwegian Project, is fuel for healthy controversy, but where, if anywhere, might the above principle be expected to apply? Furthermore, is the fishery biologist ever justified in blaming overfishing for acute reduction in the availability of a stock?

Let us first consider possible sources of the species or population which will not only serve as the ecological replacement for a depleted population, but will also satisfy the needs of the fishery. Evolutionary adaptation to the habitat is far too tedious, and cannot be expected to provide a replacement at the same rate as that of the decline of the exploited stock. However, it is inherent in evolutionary theory that species will continually adapt so as to expand their geographical range, as well as to compete successfully with sympatric species. Thus, a fish which has already developed a capacity to live in habitats marginal to its locally observed range, may, in a given locality, be geographically restricted only by the presence of a competitor for its food. The potential *replacement species* must, therefore, live in a fringe environment—it may long have been one of the natural competitors of the depleted species.

The possibility of such replacement is greater in the tropics than elsewere. Warm-water ecosystems are complex, and consist of large numbers of species. Multiple pathways are therefore available for the transfer of trophic energy. If one species is locally depleted, and the local area happens to be its centre of distribution and reproduction, then a second species—sympatric, in the sense that part of its broader range overlaps the habitat of the first—may conveniently (for Man, the fisherman) expand its area of dominance to include the place in which its erstwhile competitor was overfished.

In this connection, we may look at the composition of the Kerala prawn catch. Fishery biologists have pointed out that at least six species, belonging to three genera, are caught commercially along this coast. Mixed catches are common, but the numerical dominance of *Metapenaeus dobsoni* is obvious. As with all marine populations, year to year fluctuations in the availability of *M. dobsoni* are observed. However, the period of these fluctuations would be

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expected to agree with the period shown for other species (e. g. *Metapenaeus affinis* and *M. monoceros*) only if overfishing were established as the cause of the fluctuations, *and* the distributional ranges of the species coincided and were centered in the area of the fishery. We knew that the latter is not the case with the different kinds of prawns. It is therefore possible that other species, similar in migratory habit to *M. dobsoni*, but ranging more broadly geographically, will proliferate locally in the event of a catastrophe to the now-dominant species.

But might not the decline of an important species effect other balances among the communities of organisms,—or within the coastal ecosystem as a whole? It has been argued by M. J. Dunbar of McGill University (in papers before the International Oceanographic Congresses) that classical selection theory, which explains evolution of species, may be extended to the level of the ecosystem—and that ecosystems may compete! This thinking assumes that ecosystems evolve toward stability. The species which comprise stable ecosystems characteristically produce few larvae at a time and have extended breeding periods, tending toward year-round production. It is optimal for the community for larvae to be nonpelagic, and be thus, to a degreo, independent of irregularities in primary production. The theory argues that spawning that is synchronized with bursts in the production of plants—as is well known for barnacles, plankters etc—is optimal only in single-species selection, where the species is considered to struggle alone. But because species are ecologically inter-dependent in a community, survival of the community should also favor survival of the separate species.

How does selection take place at the level of the ecosystem? Population oscillations whether seasonal or longer term, may sometimes be too extreme, leading to the extinction of a vital component of the community. An adjacent, adaptable, more complex system then moves in.

There is little doubt that tropical ecosystems are relatively complex because of their large number of species. They therefore are expected to be better able to tolerate artificially induced oscillations, such as might be brought on by overfishing, than ecosystems of high latitudes. Whether or not populations in the tropics are generally more stable than elsewhere, is not answerable in general terms. Conditions along tropical upwelling coasts, such as the Somali and Peru Currents, are certainly characterized by enormous natural osillations in population sizes, including those manifested by the mass mortalities of squids, fishes, and sea birds.

There are a few documented instances of reduction in population size due to exploitation by man. These are mainly from seas of high latitudes. For example, the present depletions in the stocks of the great blue and humpback whales are clear cases of overfishing. It has been estimated that before 1910 half a million whales fed in Antarctic waters; today the blue whale and others are near extinction. Whalers have roamed widely across the full ranges of the species, even invading nursery areas.

The food chain culminating in the whales is simple: antarctic "krill", a single species of euphausiid crustacean, is nearly the sole item of diet of the antarctic whales. In turn, this krill is a strict herbivore that feeds directly on the primary producers, the diatoms. Man is mainly interested in the whales. He has not yet, therefore, turned his attention to the effect of over-whaling on the populations of krill. (It is noteworthy, however, that the Discovery Committee gathered a great deal of information on the size of krill populations during the years 1926-1940.) A growing whale is known to consume three tons of krill per day; however, it is not known to what extent the presence of the whale, rather than limitations in the availability of diatoms, was a check on the size of the krill populations. Again we are faced with the question: will a new predator for the krill emerge, and, if so, from where? The krill resource is too large and rich to remain long untapped. In this case we cannot look for the new kinds of whales to arrive on the scene. However, if international resolutions to curtail whaling can be implemented, stocks of humpbacks, at least, are expected to regenerate within 50-60 years. This will then thwart our prospects of observing evolution of the antarctic ecosystem!

Fluctuations in the herring populations of the North Atlantic, though more intensively studied by biologists than those of any other fish, are still not understood. The history of this ancient and vast fishery, recently reviewed by Professor A. C. Hardy, does not clarify whether or not man has become a critical part of the ecosystem of the northern seas. The British herring fishery apparently dates back to the 5th Century, but attained importance by providing export commodity only in the 1100's. The Baltic fishery, further to the east, became of great importance in the 13th and 14th centuries By controlling it. the cities of the Hanseatic League were able to control the economy of Europe for more than 200 years. But in the 16th century the herring disappeared from the Baltic, and the fortunes of the Hanseatic cities fell.

To this day, it is not known whether or not the fishery led to the decline of the Baltic herring. At the time, it was evidently believed that the herring had "migrated" westward to the North Sea, because thereafter the Dutch fishery in the North Sea became dominant. More weight must perhaps be given to the possibility that the Baltic environment changed in such a way that annual recruitment failed. Present day studies have shown that herrings in a small residual Baltic population differ meristically from North Sea herrings. This lends support to the possibility that the two populations have long been racially different, and that a general environmental change which adversely affected survival of the Baltic stock, favorably affected the North Sea stock.

In more recent years, population fluctuation, with *replacement*, has been observed along the Pacific coasts of Mexico and California. Until 1946, sardines (*Sardinops caerulea*) formed a major fishery in the California Current. The population off California, estimated to be 4 billion fish, was, however, no larger than that of the anchovy (*Engraulis mordax*) which was largely ignored because of the greater market value of the sardine. When, in the late 1940's, the sardine fishery collapsed, biologists and oceanographers sought to assemble *post facto* descriptions of the *good* years. 1939-47, in order that the cause of the collapse—whether overfishing or environmental change —might be found.

Only after eight years of intensive study and lively controversy about the ecology of the current did clues begin to emerge. The years 1939-47 had evidently been a period of environmental extremes. They had included some of the coldest as well as some of the warmest years. This alternation produced good year-classes of sardines.

The period 1948—57, on the other hand proved to be "monotonous." Water temperatures were somewhat colder than the previons decade, but winds, salinity and temperature were relatively constant. During this period the California sardine catch declined to near zero, —scarcely 4000 tons in 1953-54, The size of the anchovy population, however, appeared, to be increasing. Plankton biomass also increased to new highs. but it is doubtful that food-for-sardines was more plentiful, because the increase in plankton was at least partly attributable to large numbers of the jelly type of organism (salps, pyrosomes, medusae).

Differing explanations continued to be offered for the decline of the sardine, including, now, the upsurge of the anchovy. Both fishes are coastal, schooling species, though the anchovy is, on the average, the more near - shore of the two. The north-south ranges do not differ greatly. Both are omniverous plankton feeders. Is it not reasonable to suppose that heavy toll on the sardine population by fishing created an ecological vacuum into which the anchovy expanded? Studies of the distribution and abundance of sardine eggs and larvae argued against this. Larvae continued to be plentiful— at least plentiful enough so that with even moderate survival, bumper year-classes would have been produced.

It must, then, be environmental change that is making it difficult for the larvae to survive— so argued workers in the egg and larvae census. Indeed, one conld, after seven of the "monotonous" years, state the environmental change *had* taken place in the late 1940's. The change was from a variable water mass to a relatively constant one. Further, it was theorized that favorable conditions for the sardine are associated with rapidly changing or alternating climate; water becomes *patchy* under these conditions, and in such patchwork, patches favorable for sardine larvae are more likely to exist than under uniform conditions. (It is not to be expected that coastal waters will be generally or widely favorable to any one species, particularly on an upwelling coast). Further support for the climtological explanation was fouud in the fact that the sardine larvae were always patchily distributed, as if the fish were spawning less in response to absolute temperatures, or other absolutes, but more in response to the occurrence of gradients where opportunities for the larvae to find conditions suitable for survival are enhanced. Possibly the anchovy was inherently more tolerant of the coastal water, and survival of larvae was unaffected by the cool monotonous period.

Without warning, in 1957 the California Current reverted to its pre-1950 condition. Its average temperature increased by 1°C. and it was pocked with cold and warm patches. These conditions prevailed until 1959. The sardine, however, did *not* respond. Had the achovy by now become too numerous? Certainly it was more numerous than it had ever been observed to be before, —though a significant anchovy fishery had still not developed.

It appeared likely that the anchovy had, indeed, prevented the return of the sardine. Availablity of the large, warm-water, predaceous fishes (yellowtail, bonito barracuda) remained constant, as these utilized any available forage fish, whether anchovy or sardine. Their populations, moved somewhat northward, however, as the generally cooler part of the Current retreated northward. At the same time, sardine populations previously centered off Mexico also moved northward and 100,000 tons were caught. But a poor year-class was again produced! The *availability* of the southern population was increased, but survival of the larvae did not take place.

Clearly, the sardine larvae are delicate creatures, but their survival seems to depend on heterogeneity or instability in the environment. Like the young of many other animals, fish larvae face a "critical period" when absorption of the yolk sac is completed. A particle of food– a copepod egg or nauplius– must be found within that critical period, or else the larva will starve.

First put forward by Hjort, the "hunger theory" has been supported by the field observations of British and Japanese workers. Healthy larvae are found in the midst of patches of nauplii, and larvae in poor condition are found in water containing no nauplii. J. C. Marr, of the U. S. Fish and Wildlife Service, concluded that it is during this critical period that the bulk of the sardine larvae are dying, and that lack of suitable food is the cause of the mortality. It seems reasonable to suppose that, if a fluctuating and patchy environment is indeed favorable for survival of the larvae, the essential property of this environment is that it contain not merely ample plankton, but also a sufficient *variety* of sizes and kinds. Only then would the probability of contact between larvae and suitable food be high.

Thus we have seen, during these years, ecosystems in flux, though not, evidently, in states of collapse. The character of the community persists, but the relative importance of the species changes. The roles of stablity or instability in the environment are by no means clear. Evidence is now being unearthed that the California sardine may have been through all this trouble many times before. Professor J. D. Isaacs, of the Scripps Institution of Oceanography, has reported that sediment cores taken from varved deposits off the California coast yield long-term records of sardine-anchovy co-existence. These records are in the form of fish scales, preserved in the sediment layers corresponding to geological epochs. Data from the first of these cores to be analyzed suggest that the anchovy population has always been rather constant in size. The sardine, on the other hand, has almost always been less important numerically, but occasionally, every few hundred years, surges ahead of the anchovy. If these records prove to be typical for that coast, Californians may reasonably say good-bye to the sardine for our time, and settle for the anchovy.

It appears, therefore, that at least in temperate and polar seas natural fluctuations in "useful" marine populations are to be expected. As the recognized resources of the Arabian Sea become more fully fished, there will be oportunity to observe whether or not availablity of fish is constant or predictable in this tropical area. Prediction relies, of course, upon data collected through long periods of time. The essential data relating to this, the world's most complex ecological zone, is presently acruing at a rapid rate in India.