FISHERIES OCEANOGRAPHY

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This symposium has emphasized the importance of two concepts in fisheries biology: 1) that of *population abundance* including the *fluctuations* to which populations are subject, and 2) that of availability including those factors which result in the aggregation or dispersal of a species. By interest and preference I am going to speak principally about the first of these—population abundance.

Dr. Sette, in the introductory speech at the symposium, outlined very lucidly the problems of fluctuations in marine fish populations. He gave instances of the magnitude of such fluctuations. You will recall that in the Atlantic mackerel the observed fluctuations in year class size were of the order of 15,000 to 1. Instances of such fluctuations could be drawn from most fish populations that have been studied. In the Pacific sardine, with which I am better acquainted than other kinds of fish, the most successful year class on record was several hundred times as large as the least successful. The only exception that has been advanced is the population of yellowfin tuna, a tropical species. Dr. Schaefer indicated that there was no evidence of marked fluctuations in success of year classes of yellowfin. Differences between year classes were of the magnitude of 4 or 5 to 1.

Certainly in temperate latitudes, large fluctuations in the success of individual year classes is the rule for any species that has been investigated over a period of years.

There have been a number of attempts to account for fluctuations in fish populations. Among the causal factors that have been suggested are the following seven:

winds
currents
temperature
salinity
general productivity
competition, either interspecific or intraspecific
predation

Dr. Blackburn discussed the emphasis placed by Carruthers on "winds". Winds are important indirectly in effecting transport of larvae into favorable or unfavorable conditions. Rollefson postulated another effect of winds on the success of year classes—that of direct injury to eggs through turbulence resulting from strong winds. Rollefson was led to this conclusion by observing the high proportion of "abnormal" appearing eggs that are taken in most plankton hauls. Rollefson was working with cod eggs, but this observation applies to pelagic fish eggs in general. It is one of our vexing problems with sardine eggs. Rollefson noted that there was a higher percentage of abnormal eggs among young stage eggs, in which the embryo had not yet completely encircled the yolk mass. He found that by dropping eggs from a height he could produce this condition in eggs that were normal before dropping. He was led to the conclusion that the injury was mechanical and that it could be produced in the sea.

Temperature has often been suggested as an important factor in year class fluctuations. Garth Murphy has pointed out the effects of warmer water on success of sardine survival, and in this hypothesis he is following in the footsteps of various other workers. Dr. Sette prepared a paper some 20 years ago which stressed the relation between warmer temperatures and good year broods of sardines. Unfortunately this paper was never published, but it has been commented upon fairly frequently. Although successful year classes are more frequent during warm periods, yet there have been middling or poor ones during such periods also. 1941, for example, was one of the warmer years on record—yet the 1941 class was only middling large. There is no evidence as yet that the 1958 year-class of sardines was at all successful, yet 1958 was a year of unusually high water temperatures.

Walford postulated a correlation between salinity and successful year-classes of sardines. His model was actually an attempt to correlate good year broods with high productivity. High salinity was assumed by Walford to have resulted from intense upwelling with the attendant enrichment and increased productivity. There are quite positive ways of identifying upwelled water, but a combination of several observations are needed: temperature, salinity, oxygen, and nutrient concentrations such as phosphate. Upwelled water is characterized by its high salinity and phosphate content and its low temperature and oxygen content. Walford obtained an excellent correlation over the period of years he was using—which were the years between 1934 and 1941. The correlation breaks down entirely in more recent years.

If any hypothesis can be laid at rest it is that which associates successful year broods of sardines with high productivity. Productivity, as measured by plankton volumes, has been high during the past ten years; success of sardine survival has been low.

In fact, if productivity is a major consideration in the success of a year-class of fishes, one would expect that the increased food should result in better than average survival of all species which are primarily plankton feeders. This has not taken place. In fact the northern anchovy, a direct competitor

with the sardine, has prospered during a period when the sardine has had unusually poor survival. This contrast is so marked that one is justified in posing the problem in another way: What is there in the environment or the response of these two species to the environment that has favored successful year broods of anchovies at a time when the success of sardine year-classes has been unusually low? The differences in survival may result from inherent physiological differences between the two species. The threshold temperature for sardine spawning is approximately 13°, that of the anchovy is approximately 1° lower. Is the adjustment of an organism to its environment so critical that a decrease of say 1° C. in average water temperatures can mean the difference between successful and unsuccessful year-classes? I am only going to pose this question—not attempt to answer it.