8662

REVIEW OF THE BIOLOGICAL RATIONALE FOR IDENTIFYING SUBPOPULATIONS IN FISHERIES

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In looking through the literature for definitions of "stock," I felt that what I read did not address the subject very well. There are two important questions we have to answer in defining a stock. First, what do we want to use the definition for? I call this the operational consideration. The second question is, what do we know about the presumed stock? This is the informational consideration.

Often the first, or operational, consideration is the main one. If we consider the operational question exclusively, we can wind up with some biologically inappropriate, but nonetheless functional, stock definitions. For example, consider Ecuador's management of tuna in its territorial sea. Although the fish come and go from that area, the Ecuadoran government believes that this tuna is its stock, to manage however it wants. So Ecuador's definition of "stock" is purely operational and has very little biological basis. Similarly, an operational definition sometimes is necessary simply because of lack of knowledge. A good example comes from the multispecies trawl fishery in the Gulf of Thailand where a single trawl may bring up several dozen different species simultaneously, making it difficult to manage any single species. Several years ago during his work on this trawl fishery, John Gulland calculated the catch per effort and determined a production curve for all the species lumped together. Although people said, "You can't do that," his solution was, as a matter of fact, probably the best that could be achieved, and it did give an answer. His technique did relate the abundance and the productivity of the stock (in this case, made up of many species) to the rate of fishing.

These are extreme cases; we hope that most often there will be a balance between the operational and the informational components in the definition of a stock. I think some of the uncertainty about the utility of the stock concept has been the result of overlooking the first question. If we only look at biological considerations in an abstract case, we might formulate definitions of stock that have no use in the real world of management. My definition of stock is a modified version of Peter Larkin's definition[1] in which the operational and informational considerations are well-balanced. Stock is a population of organisms, [ideally] sharing a common gene pool, that is *sufficiently* discrete [and nominally identifiable] to warrant consideration as a self-perpetuating system that can be managed. (Emphasis and inserts are mine.)

I believe that all fishery management is based implicitly on the concept of a stock. The stock simply is that entity from which the catches are taken, and the problems of definition often reduce to a question of appropriate geographic scale. In many fisheries, the stock is simply defined by the method used to assess it. For example, virtual population analysis, sometimes called cohort analysis, defines the historical abundance of a stock simply by adding up the catches that were taken from it, with correction for mortality and other variables. There is a problem in deciding which catches to include, but, nonetheless, the method defines the stock. Similarly, in production modeling we plot the abundance in the form of a catch per unit effort against the effort. Presumably, the abundance declines as the rate of removal increases. In doing a production model, the question again is whether to put geographically dispersed populations together or to keep them separate. Perhaps the key is whether reproduction by one segment contributes to recruitment to the other segment. One way to answer that kind of question is to do a tagging study and see if the fishes actually move. Again, we wind up with a concept of a *de facto* stock, because the stock is simply defined by where the tags go. This leads to a fairly typical problem though: we have fuzzy edges.

I can demonstrate the nature of fuzzy edges from a tagging study of Pacific mackerel conducted from 1939 to 1941. There were five regions: Monterey Bay, southern California, northern Baja California, Sebastian Vizcaino Bay, and southern Baja. Quite a few tags were released in all of those locations—32,000 in southern California. We plotted the per thousand tags returned from various areas by the two major areas of release, southern California and central California.[2] In southern California we got 28 per thousand tags back, so that was designated unity, to which all the other areas' results were scaled. In northern Baja California, we got only 72% of unity back; in Sebastian Vizcaino Bay, 47%; and in southern Baja California, only 25%. As distance increased, the fraction of tags we got back decreased, but there isn't any place where the tagged fish just disappeared. This points up a continuing problem in stock definition; stocks slowly trail off with distance.

Although such tagging studies provide useful information about fisheries, they are very expensive because the researcher has to go to where the fish are. What we really prefer is some sort of simple, natural tag—an obvious morphological characteristic—so that we can bring the fish to us and figure out which ones they are. Such "tags" do exist, but are often concealed by natural variability among stocks or subpopulations. For example, off New Zealand, some scientists thought there might be two species of *Trachurus*, while others believed there was only one. The taxonomy was completely confused until about ten years ago when R. W. Gauldie used electrophoresis to demonstrate that there were two distinct electrophoretic patterns. This pattern was used to separate these fish into two groups, which then were seen clearly to differ morphologically. The position of the termination of the accessory lateral line differed considerably between the two species, although up to that time this was seen simply as a variable characteristic.[3]

To use a natural tag we must know enough about a species to identify an appropriate, variable characteristic. Often we have little knowledge about subpopulations or species, and about all we can do is to look at different geographic areas—let geography do the separating in a sense. For example, a study of the northern anchovy revealed that its length at a specified age is really quite variable in different areas along the Pacific coast, with variations of about one standard error. This difference is fairly direct evidence that mixing is limited. We do not know whether this is a genetic or an environmental characteristic, but once the fish are past a very small stage, their growth apparently is determined and they are not mixing.

In another study of anchovies, Jerry Spratt of the California Department of Fish and Game noticed that the size of anchovy otoliths relative to the size of the fish seemed to vary up and down the coast.[4] He compared otolith weight to fish length for various areas and found that, although for the very smallest fish there was no difference, as the fish got larger, the difference in otolith weight to fish length between the two groups was 1.5 standard errors apart, which is quite a solid difference. He projected that, based on that characteristic alone, there is about an 80% chance of categorizing a fish into the right group. Again, this strongly suggests that mixing is limited.

Based on tagging studies that showed that some fish actually do travel long distances along the coast, we originally had assumed that the population of anchovies was fairly thoroughly mixed. However, more recent evidence from the studies on length at age and other specific characteristics indicates that the fish in one geographic area are not mixing into other areas. Perhaps the whole population moves up and down to some extent, but there is limited mixing as far as we can tell.

In the case of major coastal pelagic fisheries, such as anchovies, sardines, and Pacific mackerel, the operational considerations are quite important, and for that reason we define our stock by fixed geographic boundaries. These boundaries are well defined operationally, and are particularly suited to fishery independent surveys, such as acoustic surveys, or egg and larvae surveys. The location of those geographic boundaries is based on genetic work done 10 to 20 years ago that indicated that there was a fairly sudden shift in the genetic composition in those areas. The work was limited, however, and we need to know more. One of the most difficult problems with a fixed geographic boundary is that the fish do move north and south seasonally; during oceanic anomalies such as El Niño, the movements are even stronger. Certainly the fish are not respecting our boundary. We do not know how much they move because we do not have good morphological characteristics by which to identify these stocks. In addition, even if the stocks are genetically distinct, they still may mix physically, so that in the vicinity of our boundary we may be able to catch either stock. We might know that two stocks are separate, but we cannot say where the separation occurs.

The boundaries, or clines, can be very strongly affected by fishing pressure, causing general shifts simply as a result of differential removals on one side of the boundary. A good example is the sardine fishery in which there was continuous northward migration of sardines all during the 1950s; as fishing removed sardines from southern California, they seemed to be steadily replaced by fish moving up the Baja California coastline.[5] We had reason to believe from blood serological research that there was a northern and a southern stock of sardines.[6] However, because fishing steadily removed the northern stock and there was a continual influx of southern stock, we may have totally annihilated the northern stock. Now there is a possibility of a resurgence of the sardine; we have evidence that the population is increasing. For a person like me who is going to have to write a management plan for this fish, it is rather important to determine whether the northern stock still exists. Is the new sardine stock going to be the same as the old or is it going to be something different? If the genetic composition is different, can we expect the productivity to be the same as for the old stock? If it looks as if it is the same stock as it used to be, we would feel more confident that the productivity would be the same. On the other hand, we might want to be more conservative if we see that the genetic composition is actually different than it used to be. Presumably, fish from the south are not as well adapted to reproducing in the colder waters to the north.

In the case of the sardine fishery, as in many cases in the United States, the answer to the first question I posed, "What do we want to use it for?" is clear. The Fishery Conservation and Management Act tells us that we are to manage these fisheries for optimum yield. The major problem is question number two, "What do we know about it?" Our ability to answer that question is limited by politics, money, and all of the usual constraints of scientific research.

[1]Larkin, P. A. 1972. The stock concept and management of Pacific salmon. *In* R. C. Simon and P. A. Larkin, eds., *The Stock Concept in Pacific Salmon.* H. R. MacMillan lectures in fisheries. Univ. of British Columbia, Vancouver, B.C. Pp. 11–15.

[2]Parrish, R. H. and A. D. MacCall. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. Calif. Dept. Fish and Game, *Fish Bull.* 167.

[3]Stephenson, A. B. and D. A. Robertson. 1977. The New Zealand species of *Trachurus* (Pisces: Carangidae). *J. Royal Soc. New Zealand* 7:243-253.

[4]Spratt, J. D. 1972. The use of otoliths to separate groups of northern anchovies. Calif. Dept. Fish and Game, *Mar. Res. Tech. Rep.* 1.

[5]Felin, F. E. 1954. Population heterogeneity in the Pacific pilchard. U.S. Fish Wildl. Serv., *Fish. Bull.* 86: 201–255.

[6]Sprague, L. M. and A. M. Vrooman. 1962. A racial analysis of the Pacific sardine (*Sardinops caerulea*) based on studies of erythrocyte antigens. *Ann. New York Acad. Sci.* 97:131–138.