

## WHAT MIGHT BE GAINED FROM AN OCEANWIDE SURVEY OF FISH EGGS AND LARVAE IN VARIOUS SEASONS

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This presentation is an extension of the talk I made 2 years ago, which was published in CalCOFI Reports, Vol. X. The first talk, presented at the Symposium on Larval Fish Biology was titled, "Kinds and abundance of fishes in the California Current region, based on egg and larval surveys."

We know a great deal about the kinds of fishes and their relative abundance in the California Current region off California and Baja California. Most of these fishes have a more widespread distribution than we cover on CalCOFI surveys. However, it is the exceptional species whose distribution is completely delimited by our surveys. *Bathylagus wesethi*, a deep sea smelt, is an example of a species that may occur wholly within our survey area. The eggs and larvae of the Pacific sardine and the Pacific mackerel have been effectively delimited in Pacific waters but both have sizeable populations in the Gulf of California that we have not surveyed regularly. The Gulf sardines are now known to be genetically distinct and resident only in the Gulf; hence they have not complicated our problems. In all probability this also will prove true for other fishes found in and out of the Gulf, e.g. Pacific mackerel, hake.

I would like to raise a basic consideration in conduct of egg and larva surveys. CalCOFI surveys initially were oriented to the studies of the Pacific sardine. This species was found to have a widespread and variable distribution, especially off southern California and along the length of Baja California. We had to survey a wide area of ocean frequently. From the standpoint of evaluating other pelagic fish resources from egg and larval surveys, this was a fortunate circumstance. Fortunately, we began the systematic identifications and enumerations of all our egg and larva material, at the inception of the CalCOFI cruises. We soon came to realize that we were investigating a complex of interacting species. Each had its own season of maximum abundance and distributional range. Furthermore, nothing was static. Temporal and areal distributions of each species changed in response to varying ocean conditions.

It is now my firm conviction that fish egg and larva surveys should never be oriented to a single species or genus. They should be ecologically, rather than species oriented. The whole complex of species should be evaluated. I have no sympathy or rapport with studies that specialize in a particular group of fishes, such as tuna, to the neglect of everything else. It

costs so much money to conduct surveys at sea that, in comparison, the monies needed to fully work up the collections of fish eggs and larvae, once obtained, are quite modest sums.

I have gone through several changes of mind in thinking about my topic. At first, I was thinking principally of how informative Norpac had been. Norpac was the Joe Reid inspired, oceanwide survey of the North Pacific (from 20° N lat.) made principally in August 1955. If I were to place a subjective value on Norpac, I should say that it gave me insights that were worth many CalCOFI surveys. I am not derogating our systematic CalCOFI surveys. From these we have not only learned a great deal about our fishery resources, but also have documented changes in their abundance, such as the remarkable increase in the anchovy population. Although informative, limited surveys have to be placed in perspective. We are looking at a small fraction of the Pacific Ocean on our CalCOFI surveys and at partial distributions of most fishes. It takes wider-ranging surveys to delimit these.

But not exclusively oceanwide surveys. We could learn a great deal by increasing our coverage, both to the north and south of the CalCOFI area. I would like to illustrate this by discussing two species, the northern anchovy and the Pacific hake. As you see, I choose to lead gradually to the subject of oceanwide surveys.

Our CalCOFI surveys have pinpointed the importance of two pelagic fishes, the northern anchovy and Pacific hake. The larvae of these two species consistently have been the most abundant in the CalCOFI survey area. However, neither of the distributions of these species is completely delimited by our surveys.

### *Anchovy:*

The distribution of the northern anchovy is "open-ended" at the northern end of our survey pattern. We have fenced it in very well at the southern end of its distribution and at its offshore extent. Unlike the sardine, it does not occur as far north as British Columbia. Furthermore, in 1949 and 1950 we sampled anchovy larvae in moderate abundance off Oregon. We have not been north of California since then on CalCOFI cruises, except on Norpac, so we do not know from larva surveys what the state of the anchovy population is off Oregon, Washington and British Columbia.

It is difficult to generalize from our survey data. For example, we know that abundance of anchovy larvae in plankton hauls decreases markedly as one goes from southern California to northern California. I would like to look for a moment at the data on numbers of anchovy larvae obtained from various parts of California. We usually divide the CalCOFI pattern off California into three areas that we simply term the northern, central and southern California areas. The northern California area extends from the Oregon border to just above San Francisco (station lines 40-57); the central California area extends from San Francisco to Point San Luis (station lines 60-77); the southern California area from Point Conception to the Mexican border (station lines 80-93).

Inasmuch as anchovy abundance has increased over the years, it is necessary to take such increase into account. For this example I am doing this simply by dividing the time span of surveys into two equal periods, the first is the 7 years of 1951-1957 and the second is the 7 years of 1958-1964.

The area off southern California has had the best coverage of any in the CalCOFI pattern. During the decade of the 50's, the area was covered on 9 to 12 cruises a year—average 10.7. The area off central California was covered on seven cruises per year, on the average. The northern California area has been surveyed only about 30 times since the inception of CalCOFI, and the last surveys made in this area were in 1960.

The number of anchovy larvae taken off southern California were 86 larvae per occupancy during the first 7 years, and 210 larvae per occupancy during the second 7 years. The number taken off central California was lower in both periods, but a marked increase in abundance has been evident on the station lines adjacent to the southern California area. Numbers of larvae taken on lines 70-77 averaged seven larvae per occupancy in the earlier period, but 100 larvae per occupancy during the latter period. The upper portion of this area, off San Francisco to Monterey, has been less productive—the increase being from less than one larvae per occupancy on the average to just over 10 larvae per occupancy.

Few larvae have been taken off northern California at any time. During the decade of the 1950's, anchovy larvae were taken in 17 of the 267 hauls made in the area; the average number per occupancy was only about 0.4 of a larva.

Since we have not surveyed this area since 1960, we do not know if numbers are now increasing there. Also it is dangerous to assume that because numbers are low off northern California they will also be correspondingly low off Oregon and Washington. Anchovy larvae could be markedly more abundant in the water off Oregon and Washington than off northern California. There is even the possibility that anchovies in the Pacific northwest constitute a separate genetic stock. We are looking into the latter possibility using blood antigens. The former can only be determined by systematic surveys for fish eggs and larvae off Oregon and Washington.

We are intensifying our surveys in the CalCOFI area during this coming year (1966) in order to have a base year of data about fish egg and larva abundance at the same time that a controlled anchovy fishery is begun. The surveys will not cover any area north of San Francisco. Obviously, to know the state of the anchovy population over its whole distribution we would have to survey the ocean off the Pacific northwest as intensively as we have between San Francisco, California and Magdalena Bay, Baja California. I would like very much to stimulate such coast-wide surveys.

The Pacific hake is of more immediate interest in the Pacific northwest. A fishery for that species is getting underway there. Hake are only seasonally present in the shelf waters off Washington. There is still speculation as to where they go during the off season. Do they move south to spawn in waters off California and Baja California? Or do they merely move offshore to spawn in waters off Washington and Oregon?

Since there is a large population of hake in shelf water of Washington in the summer and fall months, it should be an easy matter to determine if they move offshore to spawn. If they do, there should be plenty of eggs and larvae to sample. I would like very much to see this point resolved. My guess is that hake will not be found to spawn off Washington in most years, but that they may spawn there when the ocean is unusually warm.

This educated guess is based on several lines of evidence:

One of these is the distribution of hake eggs and larvae within the CalCOFI survey area. In most years, the greatest number of hake larvae are taken off Baja California rather than off California. The percentage of the CalCOFI total of hake larvae taken off Baja California has been as high as 97.6%. This was in 1956, a year colder than average. In contrast, 70% of hake larvae were obtained off California in 1958 and 90% in 1959, during warmer-than-average years. Hence, it appears that the distribution of hake spawning shifts markedly in response to ocean conditions.

Another line of evidence is the temperature range over which hake eggs and larvae are collected. Our data are from vertical distribution studies and from regular CalCOFI surveys. Hake larvae have been taken over a wide temperature range—8-16° C with most occurrences between 10.5-15° C.

As part of our study for the Atomic Energy Commission, we have looked at our larva from the Point Arguello area fairly intensively. Point Arguello is immediately north of Point Conception. We define the Point Arguello area as that within a 75-mile radius of the Point. Hake larvae were common in the Arguello areas only during years with warmer-than-average temperatures, especially 1958 and 1959. During these 2 years most temperatures, at depths where hake larvae occurred, were above 10° C.

I have spent some time looking at water temperature data from off Oregon and Washington at 75 and 100-meter depths—the depth range at which we take most hake larvae in the CalCOFI area. In a cold year, such as 1956, winter and spring temperatures at these depths ranged between 6 and 8° C. In 1958, water

temperatures occasionally were above 10° C, but most observations were between 7° and 9° C. It seems to me that water temperatures in the Pacific northwest ordinarily are too low for hake spawning. To substantiate or disprove my conclusion, we need only systematic surveys for fish eggs and larvae off Oregon and Washington.

I have given my argument for more extensive egg and larva surveys in the eastern North Pacific which raises an interesting point. Such surveys are not particularly needed for hydrographic observations which have been made with fair frequency. The problem is simply that systematic collections of fish eggs and larvae were not an integral part of those surveys. There is an education problem here. We must sell fishery oceanographers on the value of egg and larva surveys for resource-evaluation.

Now to discuss ocean-wide surveys. I would like very much to see the equivalent of Norpac repeated in all seasons, but with more systematic coverage and with uniform methods of sampling fish eggs and larvae. Furthermore, to answer some of the questions I am going to pose, it would be necessary for one person to examine collections from all parts of the Pacific. The studies of fish eggs and larvae should be centralized, not articulated.

Broad-scale surveys are, of necessity, cooperative. Financing for such surveys does not come easy; surveys have to be justified. If we are to launch repeat Norpacs, I think that support will have to come from major fishery investigations, such as those dealing now with temperate tunas.

In this area, fortunately, some spadework has been done. The need for such surveys was recognized in one of the resolutions agreed upon at the FAO-sponsored "World Scientific Meeting on the Biology of Tunas and Related Species," held at La Jolla in July 1962. The resolution, numbered 10, is titled "Cooperative Study of Albacore and Bluefin Tuna in the North Pacific Ocean." One of the recommendations is for "further cooperative oceanographic surveys of the North Pacific Ocean such as the Norpac and EQUAPAC expeditions, for the purpose of obtaining synoptic coverage, preferably at all four seasons of the year."

We know little about spawning season and areal distribution of eggs and larvae of the two temperate tunas. In fact, there is some question as to whether we are able to identify the larval stages of the albacore. I am certain that this is a problem that would be resolved if we had adequate material.

The bluefin and albacore are two species of North Pacific fishes that travel across the Pacific. We know this from the capture off Japan of fish tagged off California and Baja California and vice versa. We do not doubt that both species must eventually be studied on an oceanwide basis. There are other species, common as eggs and larvae in CalCOFI collections, that we suspect must also have oceanwide distributions. Two species of particular interest are jack mackerel and Pacific saury. We have taken jack mackerel eggs and larvae 1,100 miles at sea off Washington in the Norpac collections. We have looked at fish eggs and

larvae collected by the Bureau of Commercial Fisheries, Honolulu, on Norpac to see if we could extend the distribution of jack mackerel further seaward. Their samples were from the mid-Pacific. We found no jack mackerel eggs or larvae in these samples, but we did find saury eggs. Hence, present evidence supports the trans-Pacific distribution of saury, but it is inconclusive for jack mackerel. Additional systematic Norpac-like surveys, especially during the spring season, would permit better evaluation of jack mackerel distribution.

Having made my justification with bread and butter species (and, parenthetically, all of these offer very interesting problems), I will proceed to discuss taxonomic and distributional problems with some of the simon-pure species—those without any potential except their ecological role. There are many such as these, but I wish merely to select a few examples.

Among the abundant kinds of fish larvae we sample in the CalCOFI area are those of deep-sea smelts. The common deep-sea smelts belong to two families, Bathylagidae and Argentinidae. The larvae of both families are easier to identify to species than are the adults. This is one of the groups in which larval taxonomy is a distinct aid to adult taxonomy.

We had an excellent demonstration of this from material obtained on one of the first, wide-ranging cruises made by Scripps, "Northern Holiday," which worked into the Gulf of Alaska near the Aleutians. On looking over the fish eggs and larvae from the cruise, I was pleased to find eggs and larvae of a species of *Leuroglossus* quite distinct from those of the common *Leuroglossus* in the CalCOFI area. These eggs were half again as large as those of the CalCOFI. They went through a somewhat different embryonic development. The larva had more pigment than *Leuroglossus stilbius* larvae, but, most striking, they had 10 vertebrae more. They obviously belonged to a quite distinct species. These differences were not as apparent to ichthyologists working with adults. A Russian scientist first described the northern form as a subspecies of *Leuroglossus stilbius* under the name *schmidti*. An American ichthyologist proceeded to synonymize the two, finding no important differences. Neither of these scientists had looked at all trenchant characters, especially the number of vertebrae. When these characters were pointed out, the northern species was recognized as a valid one.

Interestingly, it is apparent that this northern species of *Leuroglossus* is the same fish that was described from skeletal material taken from fur seal stomachs by Lucas in 1899. He gave his skeletonized fish the name of *Therobromus callorhini*. Our northern species of *Leuroglossus* should be known as *Leuroglossus callorhini*. This first example is drawn from a problem that larva surveys helped resolve, but there are many more yet to be resolved.

Some of such problems are in the related family Argentinidae. From studies of larvae, we know we have four species of Argentinidae belonging to three genera in the eastern north Pacific. One of these which poses no problems is a species with a localized, neritic distribution, *Argentina sialis*. A second, *Mic-*

*rostoma microstoma*, is a widely distributed species, which occurs on both sides of the Pacific, in the Atlantic, and Mediterranean. The other two belong to the genus *Nansenia*; one has a subtropical to tropical distribution, the other a subarctic to temperate distribution. At least four species of *Nansenia* have been described from the North Pacific, two from the western Pacific, two from the eastern; one or more of these may be synonyms. Here again, larvae from both sides of the Pacific would help us resolve such problems. The larvae of *Nansenia* also are more distinctive than their adults.

Larvae are useful in helping to resolve taxonomic problems in other groups of pelagic fishes, for example, *Scopelosaurus*. This is an interesting deep-sea fish that is a curiosity as an adult. A few species have been described, from the Atlantic, South Pacific and off Japan. Adult material is limited to one or two specimens per species, these usually in poor condition. One species of *Scopelosaurus* is rather common in the CalCOFI area in larval form. It took us some time to figure out what kind of fish it was, since so little is known about adult *Scopelosaurus*. When we compared the larva material from the CalCOFI with larvae from Norpac, on Shellback, and off Peru and Chile on Step I, we found that there are some six species of *Scopelosaurus* in the eastern and central Pacific between California and Chile. This is another one of the groups of fishes that has very distinctive larval characters. The problem remains of what to call our CalCOFI species and most of the others. A species of *Scopelosaurus* was described by Mead and Taylor from a very young juvenile specimen taken off Japan. It could be the same species as occurs off California. This could be settled if larvae were available from all of the north Pacific Ocean.

Such examples could be multiplied, using larvae of myctophids, paralepidids, etc. There are a multitude of problems that could be clarified if adequate material were available for study from trans-Pacific surveys.

## DISCUSSION

*McGowan*: If the objective of your proposed program is to study the total ecology of larval fishes, won't it be necessary to include in it organisms other than fish larvae? Usually the larval fish make up a very small proportion of the total number of individuals present in a plankton tow. This indicates that larval fish are living among an overwhelming number of invertebrates which are potential predators, prey and competitors.

*J. Johnson*: The Coast and Geodetic Survey will soon start an expanded program of routine surveys of physical properties of the oceans. Recently there has been considerable discussion on what biological sampling should be included in the C&GS ocean survey program. I should like to know what the consensus of the scientists in this group is as to how worthwhile plankton sampling would be on the ocean survey program. Should samples be collected even though there might be no immediate plan for their analysis?

(The answer seemed to be that it would be worthwhile to collect the samples.)

*Stewart*: For some time now, we have been deliberating whether to barge ahead and make such tows routinely or to wait for specific requests for specific types of observations in certain areas. When we have gotten such requests, we have filled them. The special daily tows for tuna larvae and copepods made from the PIONEER at the request of the Bureau of Commercial Fisheries' Honolulu Laboratory is an example. NASCO and others have reiterated the need for data for zoogeographical studies, but requests to BCF and to individual biologists to come up with a definition of exactly what they want to have, have not yet resulted in a biological survey component of the ocean survey being developed. When I approached BCF Honolulu in 1962, the answer I got was—'Don't take any more North Pacific plankton samples for us, we have more now than we can process'—so we did nothing on it. I maintain that the samples should be stored in the ocean rather than on a shelf somewhere if nobody is going to work them up.

*Longhurst*: Isn't the problem about whether or not to take a plankton sample rather one of curating than processing? Plankton samples taken when opportunity offers may not cost much to collect on top of the cost of an expedition and should cost little to curate if properly organized; yet a library of such samples can be of enormous use to future work.

*McGowan*: Since a zooplankton sample represents an ecological situation which exists at a particular place and time, no sample which has been properly collected should be thrown out; further, no opportunities to collect samples should be missed.

*Blackburn*: The sorting of planktonic fish stages can be kept reasonably current, provided that there are people with a lively interest in the information and that they are not snowed under with other jobs. If such work is important, it should be staffed in an adequate way—qualitatively as well as quantitatively.

*M. Johnson*: With respect to (1) the accumulation of plankton samples which have not been adequately analyzed for their contents and (2) the reluctance to add to this burden by more plankton collecting because of lack of plankton sorting personnel and facilities, is it possible or practical to send samples to the Smithsonian Sorting Center in Washington, D.C., for sorting?

In light of the huge and growing plankton collection on this coast, I should like to propose that consideration be given to establishing a sorting center in this area.

*Chapman*: There is an International Sorting Center now in operation at Cochin-Ernakulam, Kerala State, India. It is working quite well. The United States has tens of millions of dollars' worth of rupees resulting from PL480 grain and other food shipments. They must be spent in India. The Sorting Center in Cochin requires additional support. Why can it not be given this from the PL480 rupee fund, plankton samples air-shipped from here to there for sorting under contract, and shipped back sorted with the only new cost to the United States being the air freight?