FISH SPAWNING IN 1957 AND 1958

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The title on the program suggests that I should report on the spawning of various species of fish in 1957 and 1958, but I will have to confine my remarks mainly to sardines, because the identification and counts of eggs and larvae of other species from our plankton surveys has not been completed beyond the July 1957 cruise. However, the sardine material has been studied through April 1958 and shows striking changes under the warm conditions during the 1958 spawning season.

Before discussing this, we need to have the background of sardine spawning during previous years as it is known from the eggs taken in plankton nets during our systematic surveys. Figures 155 and 156 are charts giving yearly distribution of sardine eggs from 1951 to 1958. In our surveys the fish eggs and larvae are obtained in oblique plankton hauls made from a depth of approximately 140 meters to the surface. The net employed is 1-meter in diameter at the mouth by approximately 5 meters in length. It is constructed of No. 30 xxx silk grit gauze (mesh openings 0.55 mm.). The amount of water strained during each haul is recorded by a current meter, fastened in the mouth of the net. Based on the amount of water passing the current meter the number of eggs per haul was standardized to represent the numbers per 10 square meters of sea surface. Stations in the spawning area were occupied at approximately monthly intervals during the spawning season. The distribution charts (Figs. 155, 156, 157), which I will show you, were drawn from the sums of the standardized egg numbers taken at each station during each season. Sardine spawning that occurs in the Gulf of California is not taken into account in the charts; it has been investigated, however, particularly in 1956 and 1957.

Outside of the Gulf, sardine spawning in recent years has occurred mainly between Point Conception, California, and Point San Juanico, Baja California. For convenience I have divided the sardine spawning area into four subareas which are numbered in figure 157. Area two is Southern California, from Point Conception to San Diego. Area three is northern Baja California, extending down to about San Quentin Bay. Central Baja California has been divided into two areas: upper central Baja California, extending between Punta Baja and Point San Eugenio, and lower central Baja California, between Turtle Bay and San Juanico. Areas two and three together comprise the "northern spawning center," and the two central Baja California areas (areas four and five) the "southern spawning center." In comparing the series of years 1951 to 1958, shown in figures 155, 156, I would note that the most spectacular change that occurred during the last eight years did not take place in 1957 or 1958, but between 1953 and 1954. You will note from figure 155, that in 1952 and 1953 the center of spawning was in the southern spawning area off central Baja California. In fact, in 1952 only three percent of the sardine eggs were taken in the northern spawning center, and in 1953 only one percent. The percentage in the northern center in 1951 was six percent. The decline was progressive for these three years.

It is difficult to imagine a greater contrast between two seasons than occurred between 1953 and 1954. Sardine eggs were obtained in only 20 hauls in 1953 in the northern center; they were found in 149 hauls in 1954. In only two instances were sardine eggs taken at adjacent stations in 1953. In 1954 they spread continuously over most of the northern spawning area. We estimate that in 1953, 4×10^{12} eggs were spawned in the northern center, while 137×10^{12} eggs were spawned in 1954. Literally interpreting these figures, there was 35 times as much spawning in the northern center in 1954 as in 1953.

Furthermore, this difference in egg distribution was directly reflected in adult fish distribution as shown by the California commercial catch. In the 1952-53 and the 1953-54 seasons (the sardine fishing season, by law, began in November and continued through February 1st in these years), less than 5,000 tons of sardines were landed. When spawning became widespread in the northern spawning center in 1954, the catch immediately jumped to 67,000 tons. In years following 1954, spawning continued to be widespread in the northern center and the commercial catch also has continued fairly good.

As background for describing what happened in 1957, I should like to discuss the seasonal distribution of sardine spawning of the previous six years, which is illustrated in figure 157. In the northern spawning center (areas two and three in figure 157), eggs were taken mostly between February and July. Eighty percent occurred in May and June off Southern California and in April to June off northern Baja California. You will note that in the southern spawning center (areas four and five) the seasonal distribution is definitely bimodal. It builds up to a peak in March, then falls off to a minimum in June, and then there is again quite heavy spawning in July and August. This late-season spawning has no counterpart in the northern spawning center.

Also, the late-season spawning occurs at quite different temperatures than the early spawning. The earlier spawning during recent years has occurred at temperatures of about 15.5°C on the average, while the late-season spawning has been at an average temperature of somewhat over 18°C, or about 2.5° difference in temperature. These are the temperatures measured at the 10-meter level. Sardine eggs are confined to the upper mixed layer and usually are most abundant in the upper 20 meters of this layer. The 10-meter temperature is usually a good indicator of the temperature of the whole upper mixed layer.

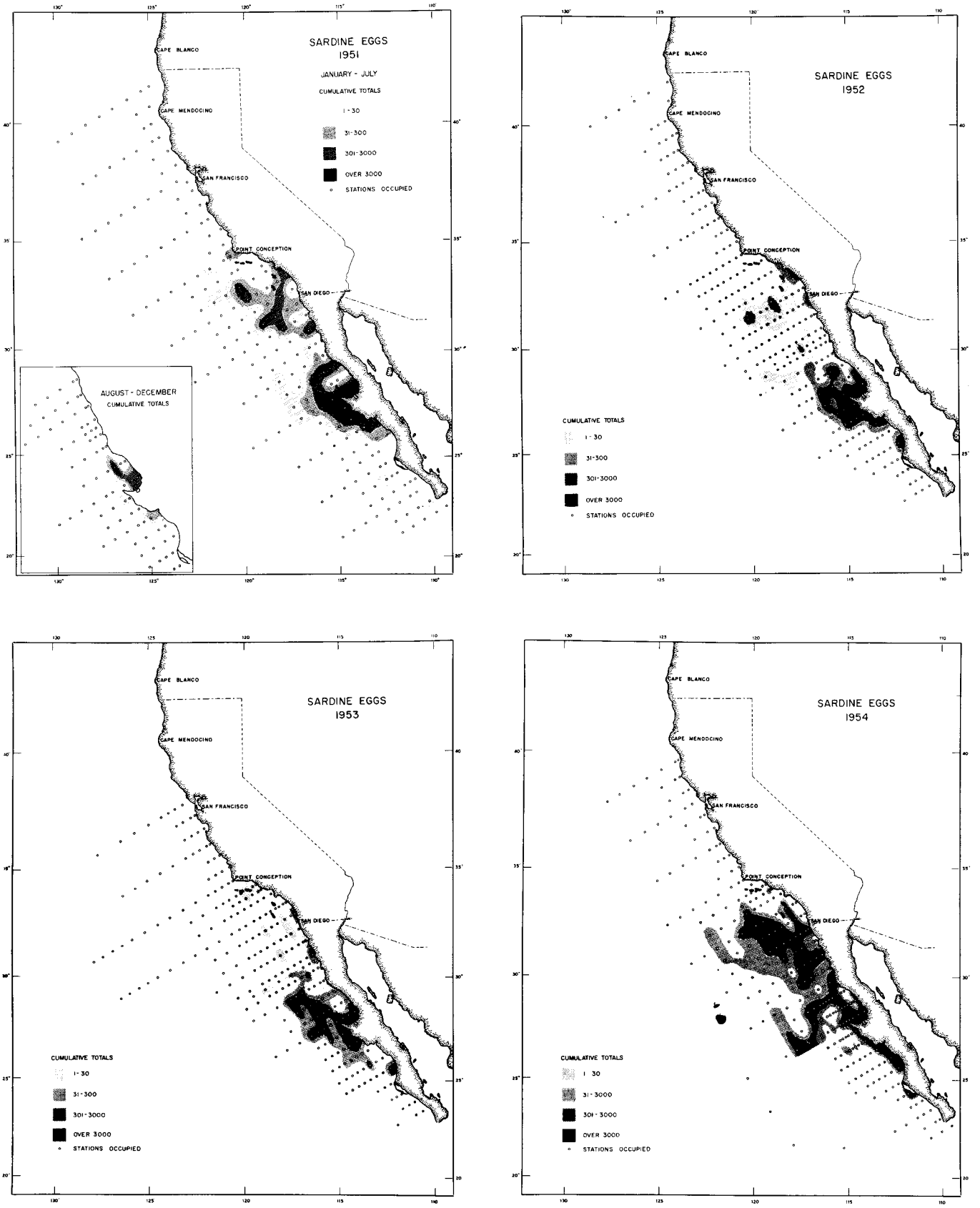

FIGURE 155. Distribution and abundance of sardine eggs.

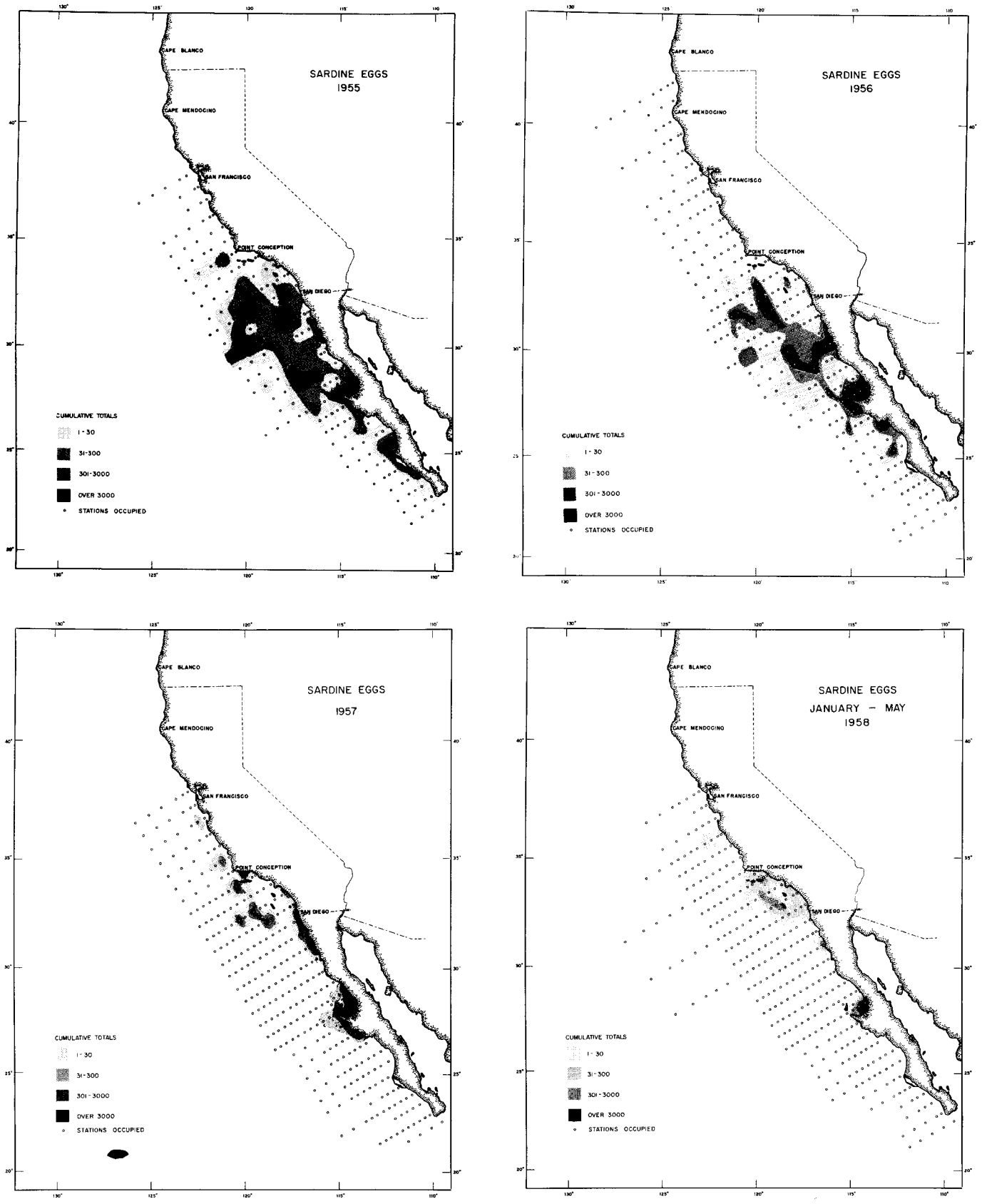

FIGURE 156. Distribution and abundance of sardine eggs.

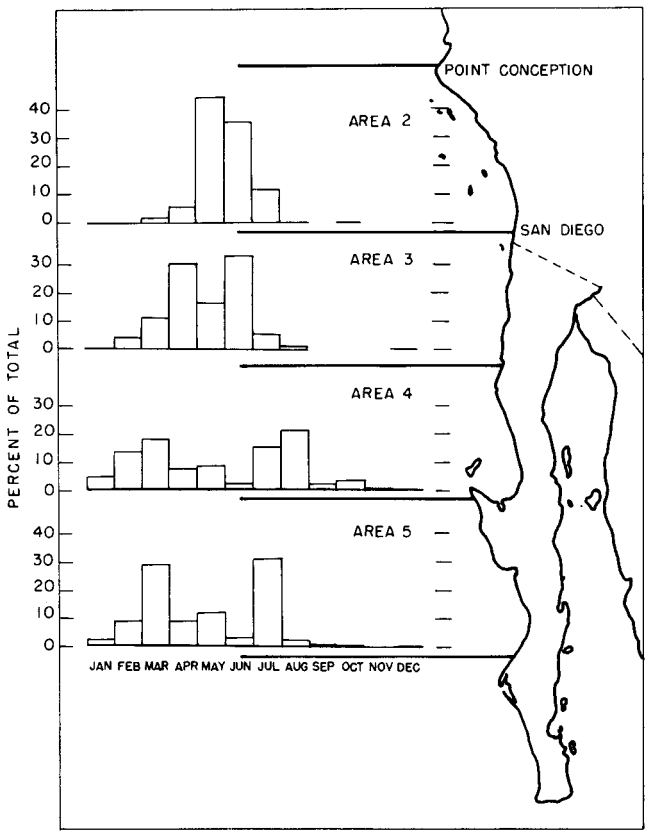

FIGURE 157. Seasonal distribution of sardine spawning, as indicated by the monthly mean number of eggs for the six-year period 1951 to 1956, by major areas.

It might be pertinent to give some information on the temperature at which sardine spawning has occurred in the different areas. In the Southern California area during the six-year period 1951 through 1956, the average temperature at all stations yielding sardine eggs was 14.7°C. There was then a gradual progression in temperature going southward. In the northern Baja California area the average was 15.1°, or 0.4° higher; in the upper central Baja California area it was 15.4°, and in the lower central Baja California area it was 15.7°.

In 1957, spawning in the Southern California area which occurred from March to July, was at an average temperature of 14.9°. This is quite close to the average of the preceding six years. Off northern Baja California, the 1957 temperature was 15.4°, as compared with the average of 15.1° during the preceding six-year period. In the upper central Baja California area the temperature was 16.4°. This was a degree higher than the average of the preceding six years. In the southernmost area it was 16.2° at the only two stations where eggs were taken.

These temperatures I have given were the averages for January through June, that is, the earlier months of the season. The fall spawning temperature had a still more marked difference. For fall, the six-year average was 18.1° (areas four and five combined). Last year it was 21.2°. During the latter part of 1957 we know that temperatures increased all along the coast. The increase occurred after July, mostly. Spawning in the northern center was over by July, so it was not much influenced by the change in temperature.

By 1957 spawning was light compared to some of the preceding years. The most striking thing is that there were practically no spring spawners off central Baja California in 1957. In this area the spring spawning was only about 2 percent as large as the fall spawning in 1957. In preceding years, the spring spawning had been (with one exception) considerably larger than the fall spawning. We are pretty much convinced that the early spawners of central Baja California are the same group of fish that spawn off Southern California and northern Baja California. The fall spawning group may be a distinct subpopulation or race. I think the evidence of 1957, when we had practically no spawning in the southern center during the first six months and heavy spawning during the last six, is good support for considering this group to be a separate subpopulation. As I said earlier, the fall spawning was at a higher temperature than usual, the average being over 21°.

The distribution during the first four months in 1958 was very unusual. As we have seen in the average seasonal distribution chart of figure 157, practically no eggs are taken off Southern California in January or February and a small amount in March. April has only about five percent of the seasonal total. In 1958, however, fairly heavy spawning started in February and spawning in March had the distribution shown in the chart. Spawning centered in the area of the Santa Barbara Channel Islands, with a strip along the coast of Southern California and another zone offshore from Santa Catalina and San Clemente Islands. The only other center of heavy spawning was in Sebastian Viscaino Bay. Spawning did not occur offshore in the southern center, which is the usual distribution in this center during the spring months. Also, there was hardly any spawning between Sebastian Viscaino Bay and Southern California.

Spawning temperatures off Southern California in 1958 during January through May have averaged 15.1°C. This is only about 0.4° higher than the six-year average. The 1958 season has paralleled the 1941 season off Southern California in time of spawning, but not in temperature of spawning. As you will recall from a number of discussions, 1941 was an unusually warm year; the average temperature of spawning off Southern California was 16.1°C. This is not only a full degree higher than the spawning temperatures off Southern California during January-May 1958, but a higher value than that found for any of the four areas during the regular spawning period in 1951-1956. This points up the fact that one area like Southern California, over a period of time, will have a wider average temperature range than is ordinarily found throughout the spawning range of the sardine.

DISCUSSION

Berner: Is the implication here that early spawning sardines off Southern California might be the first hump in the seasonal graphs of the southern center and these fish have migrated north?

Ahlstrom: Yes.

Fleming: May I ask another: Do they spawn only once a year?

Ahlstrom: This is the kind of information that we would like to have but which is very difficult to get. When you examine the frequency distribution of diameters of ova in the gonads of maturing female sardines, you find that there are several modes. From this kind of evidence it is usually thought that three batches of eggs are destined to be spawned during the year. Whether all three actually are spawned or not is the controversial point.

Wooster: You may be going to get to this, but as I understand it, one of the uses you make of these data is to estimate the size of the spawning stock. To do this you eventually integrate these charts and multiply them by some factor which gives you the number of adult sardines. If this is true, then there was an extremely great decrease in the size of the population of sardines from 1956 to 1957, if I am integrating properly. Is this the conclusion you have drawn?

Ahlstrom: Yes. In estimating the number of spawners we have assumed that a female spawns on the average about 100,000 eggs. Allowing this figure and a 50-50 sex ratio, we estimate that the spawning population in 1956 numbered approximately five billion fish, while in 1957 it was reduced to about two billion fish.

Isaacs: What is the population drop over a period of seven years?

Ahlstrom: From twelve to two billion fish.

Wooster: To continue, in these first six charts your average population in each year is more or less the same size population.

Ahlstrom: No. The distribution charts are simple sums of eggs taken at each station through the season. For estimating the total number of eggs spawned the numbers of eggs are integrated over time and space. The total spawning population is estimated from these integrated egg numbers. There was a very big drop in spawning population between 1951 and 1952. The numbers, including both the northern and southern populations, dropped from twelve billion down to below three billion. The 1953 and 1954 values are around eight billion.

We think these variations in adult population are caused by variations in year-class strength. From the age-composition and quantity of the California sardine catch we have a very good estimate of the relative year-class strength. There was a series of three big year classes in 1946, 1947, and 1948. In 1949 and 1950 the survival to commercial size was one one-hundredths as good as in 1947. For example, the 1947 year class, produced from a relatively small population, amounted to over 3000 million fish as measured by the subsequent catch. In 1952 we were feeling the influence of the weak 1949 year-class as three-year-olds, and the weak 1950 year-class as two-year-olds. Since 1948 the only moderately good year class we have had in the fishery was the 1952 year-class. The 1951 class was somewhat better than 1949 and 1950, but not as good the 1952. In the spawning population of 1954, especially, we have this influence of the 1952 year-class, and there has been a gradual decrease in population since then, because succeeding year classes have not been very good. But as John Radovich probably mentioned yesterday, present indications are that from this small spawning population in 1957, there has been fairly good survival.

Radovich: Right now the picture is extremely confused because the samples we are getting in the 1958 bait catches contain fish about the size they should be if they were of the 1957 year-class, except they seem to have an extra ring in their scales.

Isaacs: What happened to all these fish? Two-thirds of them disappeared between 1956 and 1957. Is this explained on the year-class strength chart?

Radovich: The 1952 year-class actually supplied more than 50 percent of the catch for a period of about three years and tapered off without another year-class coming in.

Murphy: What is the typical number of year-classes in a spawning population?

Radovich: I would say, predominantly three. Only about half of the fish are spawning at the age of two.

Question: Why do you take the 10-meter temperature when it comes to spawning?

Ahlstrom: We have done a number of studies on vertical distribution of sardine eggs, and have found that the distribution varies in different places and at different times. There are several things that are constant in the vertical distribution, however. The eggs are always in the upper mixed layer above the thermocline, and where the thermocline is shallow, the vertical distribution is shallow. When there is a deep mixed layer as is true at some offshore stations, the eggs may be distributed quite deeply. But in most cases where this happens, the temperature is rather uniform throughout the mixed layer so that the 10-meter temperature is a very good representative temperature of that layer. In a situation where you have a gradual change in temperature from the surface downward, there is no single temperature that would be fully representative.

Arthur: Would you not expect to find the eggs at their density layer? I am thinking of the waters with more shallow thermocline along the coast.

Ahlstrom: In one set of the vertical distribution data we had an interesting difference in spawning. In a sample there are usually the eggs of the three previous days of spawning, and these can be distinguished by the stage of the embryo. At this station, one-day-old eggs and the three-day-old eggs had their center of distribution at about the 40-meters depth. The two-day-old eggs had their highest concentration near the surface and declined quite rapidly downward. The same distribution was found in both day and night series. So to me, at least, this suggests that sometimes the sardines may be spawning as deep as 40 meters, and at other times spawning near the surface in the

same water mass. The temperature was uniform throughout the egg-bearing stratum so that temperature did not affect the distribution.

Fleming: Can you tell us something about the frequency of the cruises here, and whether you have any time series at stations?

Ahlstrom: The cruises are roughly a month apart. The coverage has been the most intensive during the first seven months of the year, and somewhat less intensive during the later five months, so that the fall spawning has been undersampled.

Fleming: Have you ever stayed in an area for a month to see what happens?

Ahlstrom: We have stayed in an area on several occasions for a period of three to five days.

Fleming: Does this spawning seem to go on fairly regularly day after day? What I am wondering is how valid is the sampling? Could you miss a whole spawning population when you only sample once a month?

Ahlstrom: Although each station is sampled only once a month, the samples contain two or three days' eggs so that time coverage amounts to about one-tenth of the period between cruises.

Fleming: I shudder to think how little you are actually comparing.

Ahlstrom: I will point out one thing. When there is spawning of any intensity in an area, there are usually several days' eggs present. Take 1941 that you mentioned earlier. The first cruise of that year covered 41 stations off Southern California. We found eggs in every haul taken in this area, and in every haul there were all of the previous days' eggs that could have been expected from continuous daily spawning. This suggests that the spawning was continuous rather than intermittent during the month.

Johnson: Wouldn't the presence of larvae indicate whether or not you had missed spawning?

Ahlstrom: Yes, this is a nice thing about larvae; they are more conservative in time than the eggs. A sample of larvae represents the accumulation over approximately a month and a half.

Fleming: So your larvae do reassure you.

Klein: Does the spawning in Viscaino Bay follow the general pattern, or does it remain fairly constant?

Ahlstrom: Fall spawning was very heavy in 1953. In most seasons it was less than 20 to 25 percent of the total spawning.

Hubbs: Do you get any periodicity in frequency of spawning?

Ahlstrom: We have looked for this a number of times but we have not been able to see anything in our data suggesting this.

Radovich: Since sardines in Sebastian Viscaino Bay spawn in warmer waters and at a different time-space interval than the rest of the sardine population, they may be a genetically different population. Do you have any indication of fall spawning off Southern California during the time the Sebastian Viscaino Bay fish are spawning?

Ahlstrom: The 1957 material examined thus far does not show this. When we have completely worked up the 1957 collections we might find this.

Radovich: I am trying to identify these small fish that seem to be older than they should be. They may represent that southern group, which are smaller for their age than the others.

Question: What species, other than sardines, do you get in your hauls?

Ahlstrom: Eleven or twelve species dominate the material making up about 80 percent of all the larvae we take. In recent years the most abundant has been the anchovy. Also of considerable importance are jack mackerel and hake. The latter is a commercial species in some parts of the world but is not caught commercially in our area. Next to anchovy, hake larvae have always been the most abundant. In last year's collections a notable thing was the large number of the larger sizes of jack mackerel larvae. It seems that the apparent survival of the jack mackerel year-class was surprisingly good. This will have to be determined later by the fishery.

Radovich: Numerous young jack mackerel were caught in Morro Bay in 1957.

Ahlstrom: This probably is an indication that it is a successful year-class. Certainly the larval collections suggest that it should be the best year-class of jack mackerel since we began our surveys.

I might mention one other thing about the apparent relation between success in sardine spawning and temperature. It has been known for a number of years that there often is good survival in years that are warmer than usual. Mr. Sette made a preliminary study of this some years ago, I believe. It showed very well the success of the 1926 class and 1931 class during these two warm years. 1941, another warm year, was somewhat of an exception to this; it was not a bad year-class but it was not spectacular. Again, the 1957 class is a good one in a warmer than usual year. The 1939 year-class was an outstanding class that was produced during a partly very cold, and partly very warm year. The 1932 class was also very successful, although the temperature in 1932 was somewhat below normal. It is interesting to note that the years 1932, 1939 and 1957 have one thing in common. During the last half of each of these years the winds died down. This, at least, was a condition that would favor a shoreward transport of larvae and also it might have been conducive to the heating up of the water.

Murphy: Do you ever have any very striking indications of mortality among the eggs and larvae?

Ahlstrom: We almost always find abnormal looking eggs in our hauls, but as far as these might relate to unusual mortality we have found nothing noteworthy.

Hubbs: Didn't Carl Oppenheimer find tremendous numbers of diseased eggs?

Ahlstrom: There is a problem in collecting viable eggs. Among the early stage eggs there is a large proportion of abnormal appearing eggs in our plankton hauls. This does not apply to sardines alone, but to

eggs in general. In fact, this condition makes identification of fish eggs difficult because they become milky and so opaque that the embryonic features cannot be seen. Some of the later stages of eggs are in the same condition, but it is not nearly as prevalent after the embryo has encircled the yolk at the anal pore closure. I suggest that this condition may be due to rupture of the embryonic membrane and that it may be caused by mechanical injury during the collection of the eggs.

Sette: I would like to remark that this condition is quite general in fish eggs of various species in both the Atlantic and Pacific.

Hubbs: Carl Oppenheimer showed me some preparations of eggs he had recently collected locally. The milky area was swimming with bacteria. Although a little time elapsed while getting them under the microscope, there seemed to be much too much bacterial increase in a short time to be due to infection after collecting.

Ahlstrom: We have had difficulty with Carl's results. We have collected a number of fish eggs recently, sardines and other species, and have incubated them at constant temperatures. We have had good survival. We take out normal looking eggs and it is very unusual to have these die. Carl experienced a very high mortality, but ours is much better.

Hubbs: Have you picked out some milky looking eggs? This would be very interesting.

Sette: Are not the milky eggs dead when first seen?

Ahlstrom: All the live ones are translucent—transparent. You can hardly see them unless you get the light reflecting the right way.

NOTE: The editors offer their opinion that Hubbs and Ahlstrom were discussing two different phenomena. The former related Oppenheimer's findings on the nature of the "milky" eggs, i.e., whether or not they were diseased; the latter was relating his experience as to the viability of eggs other than the milky ones, i.e., normal healthy eggs.