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A PERSPECTIVE OF A MULTI-SPECIES FISHERY

OSCAR E. SETTE, Director
Ocean Research Laboratory
U.S. Bureau of Commercial Fisheries
Stanford, California

This perspective takes the viewpoint that the fishery resources of the California Current region offer a base for a large multi-species fishery, examines the nature of this base, explores the advantages of multi-species over single-species fisheries, discusses some of the problems required to be solved, and suggests the direction research might take to contribute to the solution of the problems.

The quantity of living material any part of the ocean can support depends primarily on its content of essential nutrient salts and on the radiant energy it receives from the sun. Thanks to the relatively high content of nutrients in the subarctic water brought southward in the California Current, some in solution and some bound in the tissues of the plankton, and the additional dissolved nutrient salts brought up from the depths in the locally upwelled water, the basic biological productivity in the waters off the California coast is relatively high. Here is the base for support of an unusually large quantity of resource species such as the pelagic Pacific sardine, *Sardinops caeruleus* (Girard); northern anchovy *Engraulis mordax* (Girard); jack mackerel, *Trachurus symmetricus* (Ayres); Pacific mackerel, *Scomber japonicus* (Houttuyn); Pacific saury, *Cololabis saira* (Brevoort); and the hemipelagic Pacific hake, *Merluccius productus* (Ayres); and squid, *Loligo opalescens* (Berry).

The waters off the California coast, with their chemical and biological content, can be viewed as an ecological system, in which basic productivity oscillates as the inputs of nutrient salts and of solar energy pulse with the season and are irregularly disturbed when the weather deviates from the normal, or climate average, for short and long periods of days, weeks, or years. This will cause deviations from basic productivity appropriate to the normal "underwater climate" of the region and set up oscillations in the biomass the region contains. Just as the weather oscillates with limited amplitude about its climatic average, we can expect the biomass to oscillate with limited amplitude about an equilibrium level appropriate to the underwater climatic pattern. Taking this viewpoint, we may postulate an inherent though imperfect stability in the quantity of living matter supported by the waters off the California coast.

In contrast to the postulated relative stability of the total quantity of living matter (biomass) we may expect less stability in the species composition of the biomass. Each species has its own set of optimal environmental conditions and its own seasonality in spawning and feeding. The seasonality is especially marked among those having an annual reproductive cycle, as do most of our resource species. Accordingly each can be expected to respond differently than the others to even a moderate oscillation in the physical or chemical environment. A set of environmental conditions unfavorable to reproduction, larval survival, or growth of one species may be favorable to one or more of the other species. Furthermore, the several species occupying the same habitat interact with each other as predators, prey or competitors.

As the combined result of species-specific physical and chemical environmental requirements and of interactions among species, a disfavored species may be reduced substantially while one or more of the others increase substantially in population and biomass.

If, during such an alteration of relative numbers and biomass among the species, the basic biological productivity of their common habitat has remained relatively stable, limitation of foodstuff will place a bound on the increase of any one or more favored species. Thus the individual species can oscillate widely while the aggregate biomass oscillates only moderately.

This view is offered as a hypothesis of the nature of processes in an ecological system in the absence of fishing pressure. As such the hypothesis cannot be tested. However, Andrew Soutar's studies of historical variations of scales of pelagic fishes deposited in sediments and reported in this symposium tend to support the belief that the abundance of certain of the pelagic fishes fluctuated very widely long before fishing pressures could have significantly affected abundance. Whether or not such sediments could also yield an index of total biomass remains to be discovered.

That environmentally caused fluctuations in the abundance of particular species do occur is shown by the history of the sardine. This story has been well-documented by the scientists of CalCOFI and their predecessors over a period of nearly 50 years. Most obvious and incontrovertible is the evidence that the numbers of sardines surviving through infancy to reach commercial size from each year's spawning season vary widely. Poor survival resulting in small year classes occurs more often than good survival producing large year classes. More often than not, several small year classes occur in succession. The more small year classes in succession that fail to offset annual adult mortality, the more the adult population declines.

That this statement can be made without equivocation is owing to the foresight of N. B. Scofield and Will F. Thompson, who recognized the need ". . . to establish a logical and adequate system of observation of the important fisheries of the state. . . ."[1] Thanks to this recognition, systematic observation of the sardine fishery began in the season of 1919–20.[2]

Early in the system of observation, when fishing effort could not be measured because processors imposed limits on the size of catch they would accept from the fishing vessels, and before a technique for determining age from scales or otoliths was developed, the fishery was systematically sampled for size composition of the fish in the catch. By following the progression of modal groups in length-frequency distributions of the landings sampled during the period 1919–33, it is possible to identify the incidence of small year classes as contrasted with large ones. From Clark (1939, Figures 4 and 5) it is readily seen that the sequences of small year classes intervening between large year classes were 2 or 3 years in length and averaged 2.5 years. This evidence comes from the length composition of the fish in catches landed during 1919–33. Age composition during this period is lacking because techniques of determining age had not been developed at that time. We now know that sardines first enter the commercial catch in substantial numbers at age 2 and can conclude that the year classes recognized by length composition during 1919–33 reflected the variations in infant survival during 1917–31.

In contrast are the longer sequences of small year classes between large ones after 1931. Thanks to the advances in research during the 1930's, the information on year-class size is more explicit from 1930 onward. The development by Clark (1939) of a measure of fishing effort, and by Walford and Mosher (1943) of a technique for determining age from scales and otoliths, provided the means for computing apparent relative abundance and relative year-class size from collections of samples from the sardine catch from 1932 onward. On the other hand, large fluctuations in year-class size, apparently unrelated to size of spawning stock and almost certainly governed by environmental variations from year to year, coupled with considerable year-to-year variations in catchability, proved to be unsurmountable obstacles to the successful application of the simple density-dependent model of population dynamics of 30 years ago. The recent study on the sardine population problem by Murphy (1966) circumvented the obstacles. He estimated sardine population sizes for the period 1932–59 by using the nearly 30-year-long series of data on catch, effort, and age composition, together with independent estimates of total population size afforded by the tag and recapture experiment of the 1930's (Clark and Janssen, 1945) and by the sardine egg and larval surveys of the 1950's (Ahlstrom, 1966).

[1] This quotation is taken from the foreword to Fish and Game of Calif. Fish Bull. No. 11, 1926, entitled The California Sardine, by the Staff of the California State Fisheries Laboratory.

[2] Throughout most of its history the fishing season has extended from midsummer of one year to late winter of the next. In the following pages, each season is designated by the year in which it started.

Pertinent to this perspective are his estimates of year-class size and population biomass. These data are reproduced graphically in Figure 1. In 1933–37 there was a 5-year sequence of small year classes. Depending on whether the 1940 class is considered large or small, the next sequence of small year classes occurred between 1939 or 1940 and 1946, and was 6 or 7 years long. Thus the period of successive small year classes averaged over twice as long in 1932–49 as in 1917–31.

After 1948 the sequences of small year classes were shorter. Following 1948 came a 2-year sequence and, following 1952, a 3-year sequence of small year classes. According to Murphy (1966) the fishery drew mainly on the northern subpopulation until about 1950 and thereafter mainly on the southern subpopulation. The latter occupies the waters off Baja California, Mexico, and extends northward into waters off southern California a variable distance, but probably not beyond Santa Barbara. Murphy found it necessary to analyze separately the segment of data following 1949. This requirement complicates the interpretation of events following 1949 and I shall not attempt it.

These ratings of year classes are relative. Those rated as "small" are small relative only to the adjacent "large" year classes. Alternatively, ratings can be regarded as being based on deviations from the trend of absolute year-class size. Although Figure 1 includes no trend line, it can readily be seen that year-class size showed a strong downward trend after the large year classes of 1938 and 1939. The year classes rated as small would lie below the trend line whereas those rated as large would lie above it. This method of rating is intended to distinguish the spawning years of unfavorable environmental conditions from those of favorable environmental conditions for survival of the young. For considering absolute year-class size, it is necessary to turn to the record of biomass.

Figure 1 makes it impressive that two years following the onset of each sequence of small year classes the biomass of the sardine population declines. The new year class, if small when recruited into the fishery at age 2, was not adequate to fully replace the mortality suffered annually by the sardine population. If followed by another small year class, the biomass continued to decline. From the peak of biomass preceding a sequence of small year classes to the following lowest point in biomass for the first four small year-class sequences enumerated above, the total declines in population biomass were 67, 81, 43 and 70 percent in successive cycles. The first decline, reducing the stock to one-third of its previous biomass, still left a stock sufficient to produce the two large 1938 and 1939 classes. Apparently this condition did not hold after the severe decline of 81 percent. For examination of conditions surrounding this decline we may turn to the record of fishing effort in relation to biomass and catch.

The record (Figure 2) gives evidence not only on the fluctuations in year-class size but also on the total effect of these fluctuations under light and under heavy fishing pressure. When the data given by Murphy (1966) are plotted as a time series, it is readily

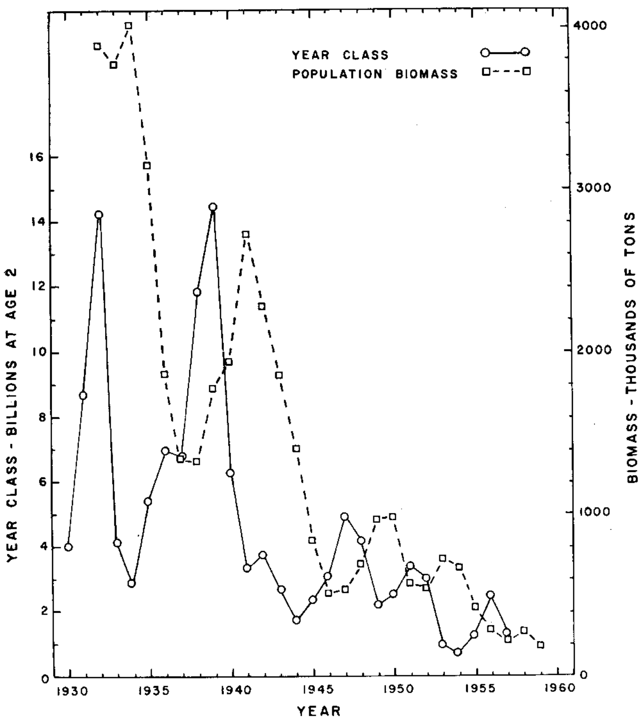

FIGURE 1. Year-class size and population biomass of the sardine population of the west coast of North America, exclusive of the Gulf of California. Data drawn from Murphy (1966, Tables 14 and 15, pp. 41 and 46).

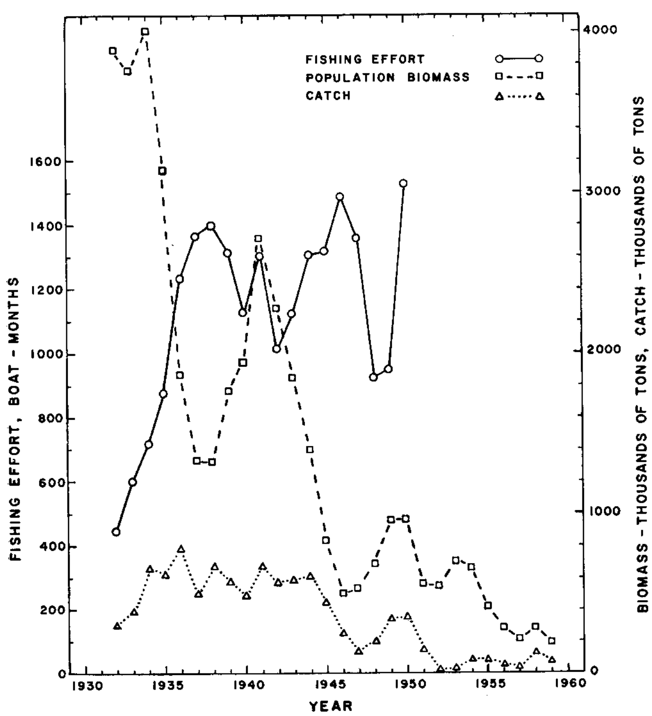

FIGURE 2. Total catch, fishing effort and population biomass of the sardine population of the west coast of North America, exclusive of the Gulf of California. Data drawn from Murphy (1966, Tables 1, 10 and 14, pp. 4, 5, 37 and 46).

seen that the fishery was still in its growth stage in 1932, and that the fishing effort nearly tripled between 1932 and 1936. During this growth period the population biomass, averaging 3,700 thousand tons, was high; the effort, averaging 650 boat-months was low; and the annual catch, averaging 500 thousand tons, was only 14 percent of the biomass. In 1936, the end of the growth period of the fishery, when the effort had reached nearly 1,200 boat-months, the level about which it was to fluctuate for a number of ensuing years, the population was already in a decline due to the diminished recruitment during 1935–39 from the 1933–37 sequence of small year class. The combined effect of poor recruitment, natural mortality, and an annual catch averaging about 600 thousand tons brought the biomass down to 1,300 thousand tons. At this level the population was still able to produce the two large year classes of 1938 and 1939, which were even a little larger than the large year classes of 1931 and 1932 produced by the 4-million-ton population of those two years (Figure 1).

The outcome of the next cycle of events was far different. The fishery had grown to a size sufficient to exert an effort of about 1,200 boat-months. This general level, with some fluctuation, was sustained throughout the cycle. The recruitment from the large 1938 and 1939-classes restored the population to the 2,700-thousand-ton level. But under the substantial catch mortality imposed by the high fishing effort, the ensuing recruitment from the 1941–46 sequence of small year classes replenished the stock so inadequately that the biomass fell to 700,000 tons before the next large year classes of 1947 and 1948 were recruited to the population in 1949 and 1950. By the time the second, third, and fourth in the 6-year sequence of small year classes were being recruited to the population in 1945, 1946, and 1947, the vigorous fishing during these 3 years averaged nearly 1,400 boat-months and was taking an annual average of 430 thousand tons from the population in the fishery area. This catch amounted to 49 percent of the population biomass. The 1947 and 1948 year classes, though rated as large relative to the adjacent year class, were so small and fished so vigorously that their recruitment in 1949 and 1950 raised the population biomass only to 970 thousand tons. These two year classes came from the spawnings of 1947 and 1948, when the population biomass averaged 600,000 tons.

From this sequence of events it is obvious that the great decline of the sardine population between 1941 and 1946 took place when (i) there had been a long sequence of 6 or 7 years when the environment had been continuously unfavorable for survival of year classes to the age of recruitment in large numbers, and (ii) the fishery was catching an annual tonnage amounting to 25 to 50 percent of the population biomass, taking the larger percentages in the years when the biomass was sinking toward its lowest levels.

For purposes of this perspective, the events after 1948 are germane only as evidence that the sardine population in waters off California has not recovered from the severe decline in the middle 1940's. With some fluctuation, the sardine catch of the California fleet has dwindled almost continuously until in 1966 only a few tons were landed for processing. These fish were incidental to catches of mackerel with which they were mixed. In 1967 California imposed a moratorium on sardine fishing for delivery to processors. They are still fished for bait in California, and the Baja California fleet still delivers sardines to processing plants there.

Thus the events in the California sardine fishery give an example of a species disfavored by relatively unfavorable environmental conditions during its early life history through two sets of successive years. Each set produced a large fluctuation in population size. Following the first set, under relatively light fishing pressure, the population was still large enough to produce, when favorable environmental conditions ensued through 2 years, year classes fully as large as formerly. Following the second, somewhat longer set of unfavorable years, under heavy fishing pressure, the sardine population seems to have lost its capacity for producing really large year classes. Instead, the combination of unfavorable environment and heavy fishing appears to have set off an irreversible downward trend. How has the ecological system of the California Current region responded to the extreme dimunition of a once major component in the system?

That the sardine probably was a major component in the ecological system of the California Current region in the early 1930's has been documented by Murphy (1966). Using energy-requirement data furnished by Dr. Reuben Lasker, the energy contained per-unit wet-weight in the plankton, the average zooplankton content of the water off California and Baja California in 1952 as reported by U. S. Fish and Wildlife Service (1953), and the quantity of zooplankton in the waters flowing from the north in the California Current and the quantity outflowing at the south, Murphy estimated that the sardine population alone, at its level of about 4 million tons in the early 1930's would have required for its growth and activity about 2.5 standing crops of zooplankton. The turnover rate of plankton in the California Current region has not been measured. Murphy (1966) gave his opinion that ". . . it is no greater than five times per year. . . ." Because neither the sardine nor the plankton is distributed evenly or randomly throughout the waters under consideration, it is probable the schools of sardines continuously consumed well over half of the standing crop of plankton wherever they aggregated for feeding in the early 1930's.

When the sardine population was reduced to one-twentieth of its former size in the late 1950's and withdrawn to the southern end of its range, it became a trivial consumer of plankton everywhere north of southern California. This change released a tremendous food mass for the support of any zooplankton-feeding pelagic species occupying the practically vacated area.

Evidence now exists that the anchovy was the species that benefited most from the bounteous food supply left unconsumed by the decimated sardine population. It is not known how large the anchovy population was when the sardine population was at its high size of 4 million tons. A thorough egg and larva survey of the waters off southern California in 1939 showed anchovy and sardine larvae to be about equally abundant, but the area surveyed was too small a portion of the habitat of both species to provide a dependable estimate of the whole population of either species. It was not until after the war-interrupted civilian fishery-oceanography programs could get under way again in 1949 that fish egg and larva surveys were resumed. These surveys were designed to discover the environmental requirements causing the year-class size of the sardine to fluctuate as widely as they had been observed to do up to that time. As yet they have not been successful in accomplishing this purpose.

Yet they have accomplished an equally significant purpose—that of furnishing year-by-year estimates of the size of spawning populations of the sardine; and when the scientists of CalCOFI decided to broaden their efforts, estimates were made also of the spawning populations of other important fish species of the California Current region from San Francisco to the southern tip of Baja California. As result of these surveys and the analyses of samples of eggs and larvae by Dr. Elbert H. Ahlstrom and his staff, it is now known that the numbers of anchovy larvae in the survey area increased spectacularly from 1951, the year of the first definitive survey, until in 1962 they were nearly 20-fold more numerous than in 1951 (see Messersmith, Baxter and Roedel, this symposium). They appear to have remained at about this high level since 1959. Translated to quantity of parental anchovy biomass by means of data from fecundity studies by MacGregor (1968) and by comparison with sardine biomass and larvae (Ahlstrom, 1966), the anchovy spawning biomass since 1962 has equalled or exceeded that of the 4 million tons of sardine biomass of the early 1930's.

Parenthetically, it also may be surmised that the anchovy biomass may be substantially larger than this estimate. The CalCOFI surveys extended northward only to the waters off San Francisco whereas the anchovy ranges northward in substantial but unestimated numbers into waters off the coasts of Oregon and Washington. One may conjecture that the waters off Vancouver Island and northward the anchovy may be replaced as the major plankton-feeding clupeoid by the Pacific herring (*Clupea pallasi* Valenciennes).

The 50-year history of the sardine population and fishery based upon it, and the much shorter history of the anchovy population as it has been revealed by the estimates of larval abundance have been reviewed in some detail because the events recorded by these histories have generated the ideas leading to the concept of a multi-species fishery. Before I proceed to the advantages and problems associated with a multi-species fishery, I shall examine the concept of the maximum sustainable yield in the light of these histories.

Murphy (1966, pp. 68–69) estimated that during the period 1932–49 the sardine population size ". . .

for a maximum sustained yield was 975,000 tons, and the yield was 470,600 tons annually. . . ."; and pointed out that "During the 1937–1945 period when the population was near that expected to yield the maximum catch, i.e., 1,000,000 tons, the actual annual harvest was 570,000 tons. This suggests that the population was 'overharvested' by about 20 percent. . . ."

It appears, however, that during most of this period the stock was well above the 1,000,000-ton level, dipping below it only in 1945; it thus could provide a yield in the order of 100,000 tons greater than 470,000 tons during those years without driving the stock below the size needed to produce a large year class, whenever environmental conditions were favorable for good survival. On the premise that it is socio-economically impractical to curtail suddenly, perhaps severely, a fishery which supports many people in both the fishing and processing industry, the concept of a fixed maximum sustainable yield is sound and Murphy's estimate is valid, provided of course that the future will never have an even longer sequence of small year classes; and provided also that the sacrifice of large amounts of yield of a single species is really the best use that can be made of the potentials of the ecological system of which the single species is a part.

If we can hypothesize, as has been done at the outset of this perspective, that the productivity in the California Current area fluctuates much less than the sizes of year classes of a single species, and if a socio-economic condition can be created within which the various species can be fished, processed and sold in proportion to their ascendency in the ecological system, then it should be possible to harvest yields continuously equal to or exceeding those of the heyday of the sardine fishery. That is to say, a multi-species fishery, processing industry, and marketing system offers the probability of full and prudent use of the fishery resources in the waters off California, and perhaps a total yield much larger than any one species is capable of supporting.

This approach would not be abandoning the principle of maximum sustainable yield, whether it be measured in tons or in dollars, or in one or the other of these plus the value of recreational satisfaction. Instead, it expands this principle from its focus on a single species to embrace the aggregate of harvestable species supported by the ecological system being fished.

For instance, by hindsight we can see in Figure 1 that the mediocre year class of 1940, succeeded by the small year class of 1941, portended a decline, perhaps severe, of the sardine population. If this sequence could have been foreseen and if a substantial portion of the fishing effort could have been shifted from the sardine to other species, the sardine decline would have been lessened and perhaps halted while the population was still at a size capable of producing large year classes such as those of 1932, 1938, and 1939. This view, though conjectural, illustrates the type of adjustments that might be made in a multi-species fishery managed under the multi-species concepts.

A shift toward spreading the fishery over more species did take place in the past, but it was too little, too late, and not in accordance with the concept of maximizing the yield of a multi-species resource. In the late 1940's, as the sardine and Pacific mackerel landings failed to supply the demand for canning, the acceptance of jack mackerel and anchovy for this purpose increased. By 1952, eight years after the sardine population had lost its capability of producing a year class large enough to sustain the population, the landings of each of these four species converged at a level that averaged about 30,000 tons per year or 121,000 tons for all four species during the period 1952–57 (Anderson and Power, 1955–57; Power, 1958–59). A combination of foreign competition in the canned fish market from the post-war resurgence of the Japanese and South African sardine and mackerel fisheries, lack of consumer acceptance of the anchovy pack, and California regulation against the processing of fish for meal and oil soon drove the processing demand down until in 1965, the latest year for which final statistics are available, the California landings of all four species totaled less than 41,000 tons (Lyles, 1967).[3]

This set of events is mentioned here only because, on the surface, it might appear as if there had existed, at the fishing and processing level, a multi-species fishery industry. Indeed, in a loosely defined sense this was one, but it lacked the most essential attribute set forth in this perspective. If it were not so lengthy, the multi-species fishery concept would be better named "the management of a fishery for achieving maximum sustainable yield of a multi-species resource," or better yet, the "management of a fishery for achieving the optimal utilization of a multi-species resource considering commercial and recreational values."

It is true also that these events following the decline of the sardine and mackerel emphasize the economic impact of fishery management concerned with the ultimate product, e.g., canned fish versus fish meal and oil, rather than the sustainable yield of the resource.

Let us turn now to a more comprehensive consideration of the problems needing solution for establishment of a successful multi-species fishing industry based on the pelagic and hemipelagic fishery resources of the California Current region. These problems exist at the research level, the fishing level, the processing level, and the fishery-management level.

At the research level the problem is to achieve an understanding of processes operating in the ecological system that is adequate to provide foresight of events such as have been observed by hindsight as related above. This is to say that the scientists in CalCOFI

[3] In 1967, according to preliminary statistics, the California landings for canning purposes of the four species totaled only about 21,000 tons. In addition, about 30,000 tons of anchovy were landed for reduction to fish meal and oil. The terms under which this fishing was permitted apparently were discouraging to fishermen and processors at existing world price levels for meal and oil. At the time the symposium was held it was already evident that the anchovy fishing effort in the 1967–1968 season would be inconsequential.

need to develop the capability of reliably forecasting long-term, middle-term, and short-term trends and events.

For the long term, this capability has been partially achieved in the assessment if the interaction between sardine and anchovy populations. It remains to be demonstrated how reliable the assessment is. CalCOFI has proposed a cautious test of its reliability, but various complications of socio-economic nature have so far prevented the test from being performed. Since this difficulty is perhaps the main reason for this symposium and its various aspects have been and are to be discussed by other participants, I shall not dwell upon it. It will be more useful to take a viewpoint broader than just the interrelation between the two species.

That the anchovy has replaced the sardine, an event which I believe to be well substantiated, implies that the biological productivity of California Current region fluctuates much less than do some of the individual members within the biological community, as I hypothesized at the outset. But we have practically no quantitative measure of the amplitude or the periods of these oscillations in productivity. It would be logical to add productivity to the items to be observed in future survey programs. Carbon 14 suggests itself, but is expensive in ship time and manpower. Perhaps it would be simpler and cheaper to go to the first trophic level and measure chlorophyll or something proportional to it. Ultimately, once the relationships are established, it might be most efficient to rely on agents that govern nutrient input and thermal energy, such as vertical and horizontal advection and influx of radiation. These processes may be measured in the near future for a number of other purposes—not just the fishery application.

In the long term and verging on the middle term are several questions raised by the historical record.

First, why do small sardine year classes occur in sequences; and why were the sequences shorter before than after 1931?

Why was year-class size inversely correlated with parental biomass in the middle term as documented by MacGregor (1964) and visually apparent in Figure 1, and yet positively correlated in long-term trend? Murphy (1966) examined this apparent contradiction in great detail and concluded (p. 51) ". . . that the average resilience of the population is a great deal less than the 90 thousand eggs produced per female might suggest, and that really large year classes are not to be expected from small spawning stocks. . . ." Although this statement probably is true, it begs the question of what processes are involved. I tend to be haunted by the sedimentary record that suggests relatively long upward and downward trends in sardine abundance, which suggest in turn that there may be similar long trends in environmental suitability for the sardine in contemporary times.

As nearly as one can tell from the record, the increase of the anchovy population did not keep pace with the decline of the sardine population. In 1946 the sardine was reduced to one-eighth of its size in the early 1930's, but the anchovy population did not reach a size rivalling that until about 1958. What caused such a lag? One could invoke the answer given by Murphy for the sardine, i.e., that a really small anchovy population cannot produce a really large year class, but again the statement says nothing of the processes involved.

This series of questions all point to the master question: What are the environmental survival requirements for bringing the young stages of the sardine, the anchovy, and each of the other important pelagic species through their respective early life histories in numbers that can be called a large year class? What do we need to measure, or what assortment of things do we need to measure in our surveys if we are to forecast good recruitment to the fishable stock of the several species? Do these recruitments become evident far enough ahead for the manager, the processor, and the fisherman to adopt a strategy in each of their several affairs that will be appropriate for maximum yields from an assortment of species and provide assurance against jeopardizing subsequent yields of any species in this assortment?

Attempts to answer questions of this type with respect to one species, the sardine, have so far eluded earnest, persistent, and expensive at-sea observations. It appears that we simply do not know what condition, or what set of conditions, to measure. It seems we should add to the survey effort, controlled laboratory experiments in which various physical, chemical, and biological environmental conditions of the kind and range of variation likely to be encountered at sea are imposed singly and in combination until the optimal condition or set of conditions is discovered and the various degrees of suboptimal conditions are evaluated.

Turning now to forecasting in the middle term which in my terminology means forecasts in advance of each forthcoming season, we are concerned not only with fishery management decisions but also with the economic necessity of improving the efficiency of fishing and processing. Achieving such forecasting capability is already being explored by research vessel surveys employing echosounding and echoranging, supplemented with species identification by actual catches of the schools producing the signatures on the sounder or sonar display. As these techniques become perfected, it should be possible for the management system, if made sufficiently flexible, to prescribe the tonnages to be taken of each of the several species appropriate to their pre-ascertained abundance. Foresight and flexible management would permit the fisherman to prepare the appropriate gear and the processor to tool up for handling the anticipated landings, and lay forward-looking marketing plans.

The short-range, within-season, forecasts are needed to increase the efficiency of fishing operations sufficiently for our catches to become competitive with foreign-produced fishery products. All of the latter are produced in economies that have lower costs of manpower, equipment, and supplies than are prevalent in this country's economy. Presently the California local purse seine fleet probably spends threefourths or more of its time hunting for schools and one-fourth or less catching them. Only a small decrease of hunting time in favor of an increase in catching time could make the difference between profit or loss in the fishing operation. Needed here is foreknowledge as to when and where aggregates of fishable schools are more probable than elsewhere. Research needs to be directed toward attaining this foresight.

To take advantage of the forecasting capability resulting from survey and research, the fisherman needs to provide himself with the gear and skills to catch most efficiently the several pelagic and hemipelagic species in proportion to the quantities appropriate to their prospective abundance. This not only calls for the appropriate purse seines, but also midwater or bottom trawls for such species as hake or squid, or possibly even completely novel methods of fishing.

The processor, in turn, may be alerted on a day-to-day basis to prepare for handling the amounts in the various proportions of the several species expected to be landed during the several days ahead.

Upon the fishery management under a truly multi-species fishery rests the burden of utilizing the forecasts to frame regulations appropriate to the expected relative abundances of the several species in a forthcoming season and perhaps adjusting these regulations according to events within the season.

All of these manipulations depend on (i) reliable forecasts—a responsibility of the fishery research organizations—and (ii) a regulation system that can respond to the strongly fluctuating abundances of the several pelagic and hemipelagic species of the California Current region and also permit their processing to the forms marketable in competition with foreign product—whether they be canned goods, fish-protein concentrate, fish meal and oil, or some other product not yet conceived of.

In summary, this perspective hypothesizes that the fishery resources of the California Current could yield a larger tonnage on a sustained basis than ever before realized, if the resources are researched, fished, and managed as a multi-species resource. Because the resource would be sustained at the optimal level, oscillating only moderately as the productivity of the ecological system oscillates, recreational values would be preserved. To realize these benefits, serious economic problems must be solved. A major contribution to their solution would be the attainment, through research, of forecasting capability in the long term, middle term, and short term so that the fisherman, the processor, and the resource manager could plan ahead and adopt strategy and tactics that would maximize the efficiency and reduce costs of fishery operations and maximize the yield without jeopardizing the resource. Finally, the sociological portion of the socio-economic problem calls for better communication among scientists, fishery administrators, commercial fishermen, fish processors, and recreational fishermen. As I understand it, this symposium represents an experiment in providing one kind of communication channel among five groups.

I appreciate the opportunity of participating in this experiment.

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