PROGRESS IN PACIFIC OCEANIC FISHERY INVESTIGATIONS 1950–53

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 116

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

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Department of the Interior, Douglas McKay, Secretary
Fish and Wildlife Service, John L. Farley, Director

PROGRESS IN PACIFIC OCEANIC FISHERY INVESTIGATIONS 1950 - 53

M/V HUGH M. SMITH

By

Oscar E. Sette and the
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WASHINGTON: FEBRUARY 1954

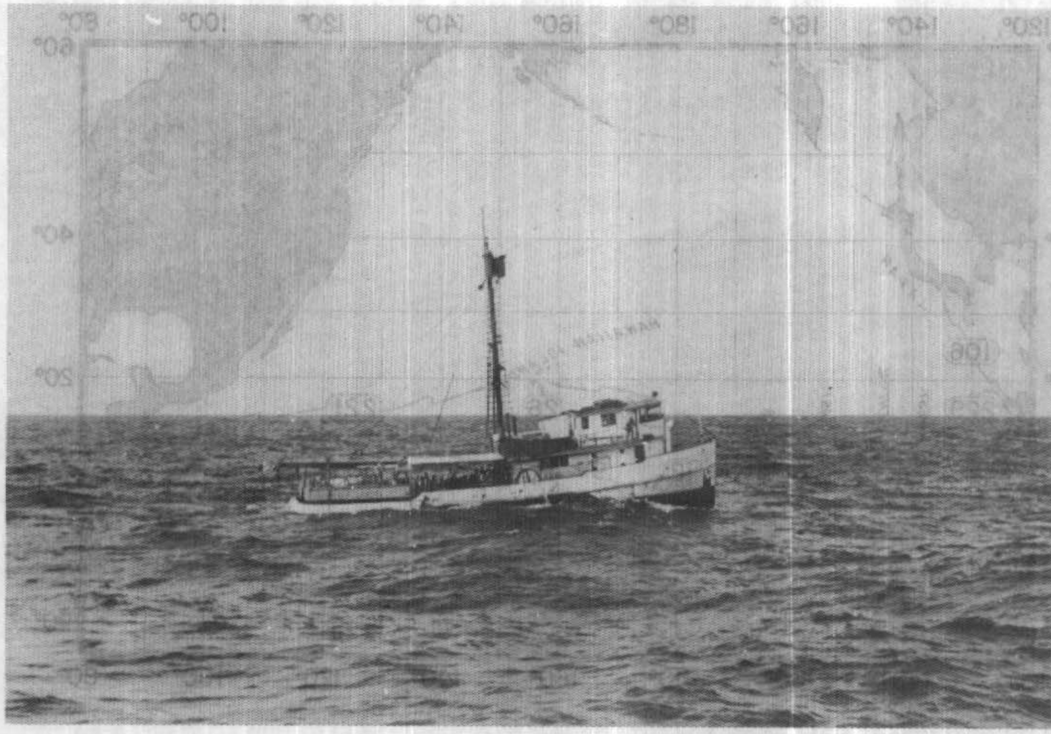


Figure 17. Equatorial Commercial Fishing. To test the commercial possibilities of the equatorial region, we chartered the West Coast purse seiner, CAVALIERI, to fish on a semi-commercial basis with longline gear in the equatorial Pacific. Although a catch of only 48 tons of tuna was realized in 33 days of fishing, we learned that the west coast purse seine boat is readily adaptable to longlining. It was also evident from this trial that at least twice the gear must be fished if we expect an American vessel to profit from such a venture. This will probably require improvements in the design of the gear and increased mechanization in setting and hauling.

The Pacific Oceanic Fishery Investigations of the Fish and Wildlife Service is based at Honolulu, Hawaii, for the purpose of carrying out Public Law 329--80th Congress, which was enacted August 4, 1947. This law declares:

"That it is the policy of the United States to provide for the exploration, investigation, development, and maintenance of the fishing resources and development of the high seas fishing industry of the Territories and island possessions of the United States in the tropical and subtropical Pacific Ocean and intervening seas, for the benefit of the residents of the Territory of Hawaii and Pacific island possessions and of the people of the United States."

Following the appropriation of funds in 1948 and the subsequent acquisition and conversion of three seagoing vessels, construction of a laboratory, and a preliminary reconnaissance of the problem, sea work began early in 1950.

The reconnaissance had determined that the several kinds of tuna, notably yellowfin and skipjack, formed the most promising mid-Pacific high-seas fishery resource. A semi-private and several private attempts to develop mid-Pacific tuna fisheries had failed during the several years prior to 1950. These had been undertaken with the idea of obtaining quick results by simply sending skilled fishermen on California-type tuna fishing vessels to fish for tuna at a number of places presumed to be favorable. Some tuna were caught during each of the ventures but not in paying quantities.

With this proof of the difficulties involved, we approached our task on a longer-term basis and from the viewpoint that fish stocks large enough to support a high-seas fishing industry could exist only where ocean conditions specially favored the production of plentiful foodstuff for the fish. This involved study of the oceanography, of the fish, and of the animals they feed upon, combined with fishing surveys designed to estimate the abundance of fish and to determine the methods by which they can be caught in commercially adequate quantities.

After 3 years of sea work results are emerging which appear to have immediate practical fishery significance and to constitute substantial scientific contribution. Some reports on separate phases have been published and others are being prepared. Pending their completion, our findings are summarized here briefly and pictorially in what we hope is a clear, simple, and useful form. To avoid the distraction of interspersing references to sources, a summary of the kind and quantity of data underlying the several charts, graphs, and statements is appended, together with a list of the publications resulting from our work.

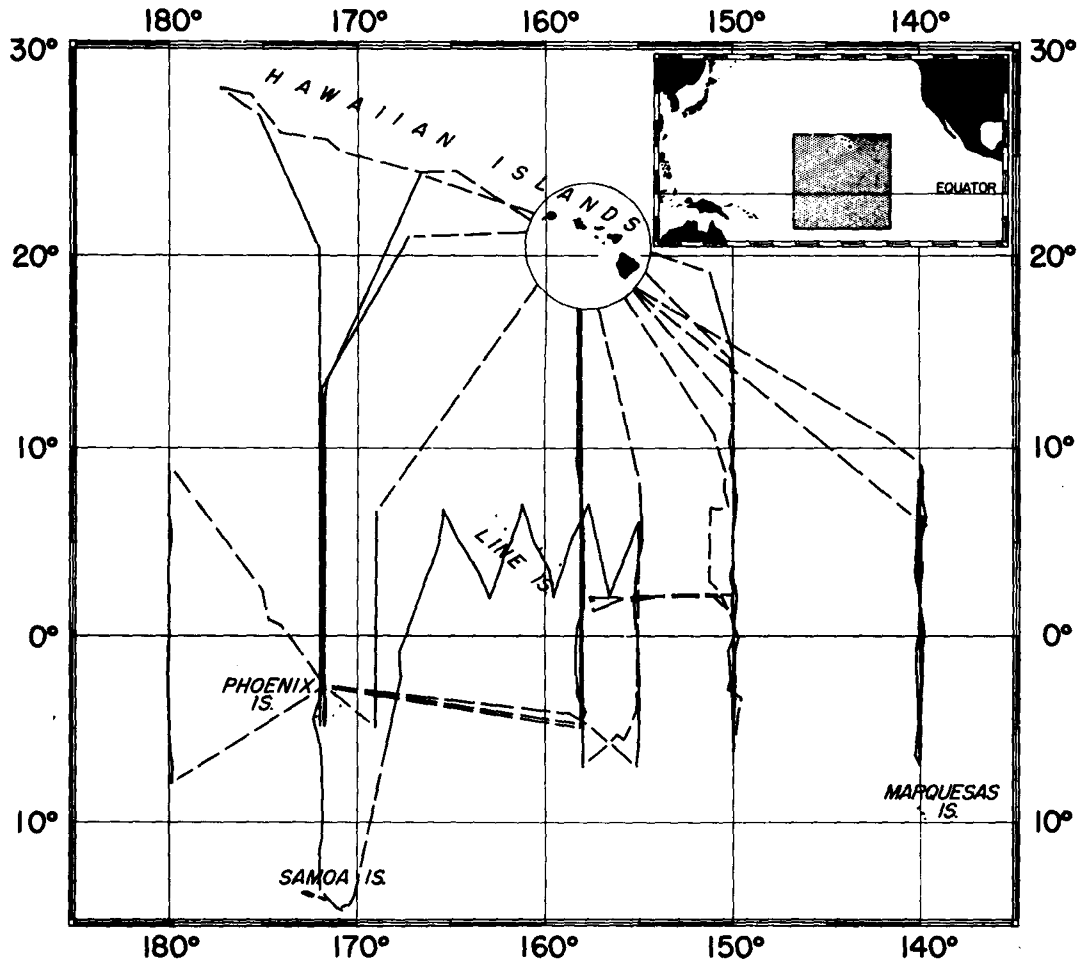


Figure 1. Equatorial Hydrographic Cruises. Our method of investigating high seas fishery resources is to first understand the seas in which the fish have to make their living. Since January 1950 we have crossed and recrossed the ocean area lying south of the Hawaiian archipelago along the tracks shown in this chart, taking temperatures, salinities, phosphates, and plankton samples at 60-mile intervals along the solid lines.

From these observations and measurements we have been able to determine the general circulation features as shown on the next figure. Also, we learned where the surface waters are enriched, undoubtedly providing more abundant food for the tuna. These surveys have shown that the oceanic conditions change with time and the indications are that these changes may be on the order of but a few days.

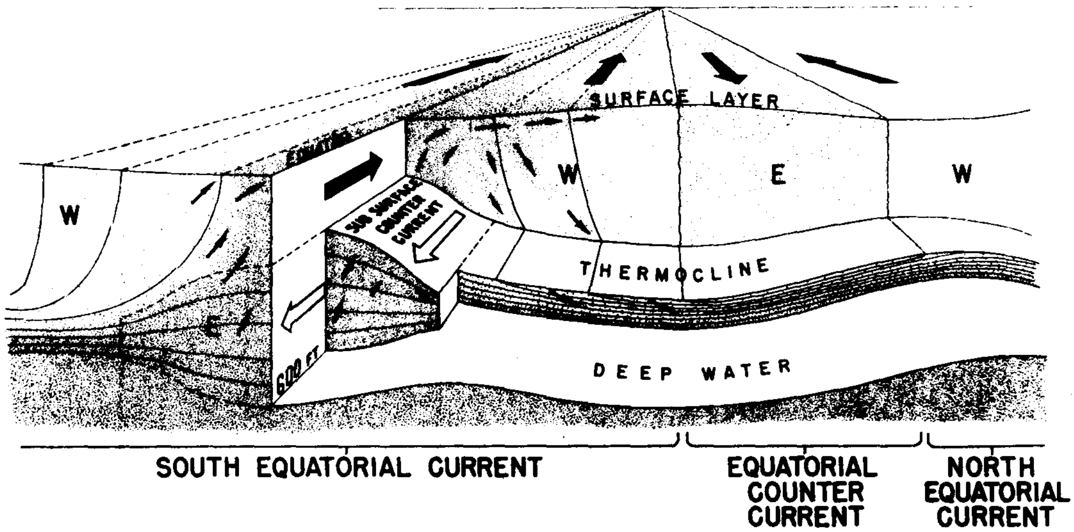


Figure 2. 1953 Concept of Equatorial Circulation. As a result of our studies we now have an idea why the equatorial waters are more productive than those to the north and south. This idea has been illustrated in the "slice" of the ocean shown above. Visualize that we have sliced the ocean along longitude 150° and are looking towards the west with north to our right and south to our left. The surface currents are shown by broad arrows and the vertical temperature structure by the fine lines of equal temperature. However, we wish to focus your attention on the waters at the Equator. Under the influence of the steady southeast tradewinds the deep water comes to the surface and moves northward as shown by the smaller solid black arrows. This sets up a chain of events that ends with good tuna fishing. The upward moving water brings phosphates, nitrates, and other nutrients to the lighted zone and phytoplankton (one-celled plants) multiplies rapidly. The zooplankton (tiny animals) feeds on the plants and in turn multiplies, drifting slowly north with the water. Larger crustacea, squids, and small fish gather to feed on the zooplankton. The tunas, the final step in the oceanic production line, concentrate here where there is good feeding much more of the time than elsewhere.

The eastward flowing subsurface countercurrent was recently discovered in our work. Its significance to the circulation and to the productivity of the system is not yet known.

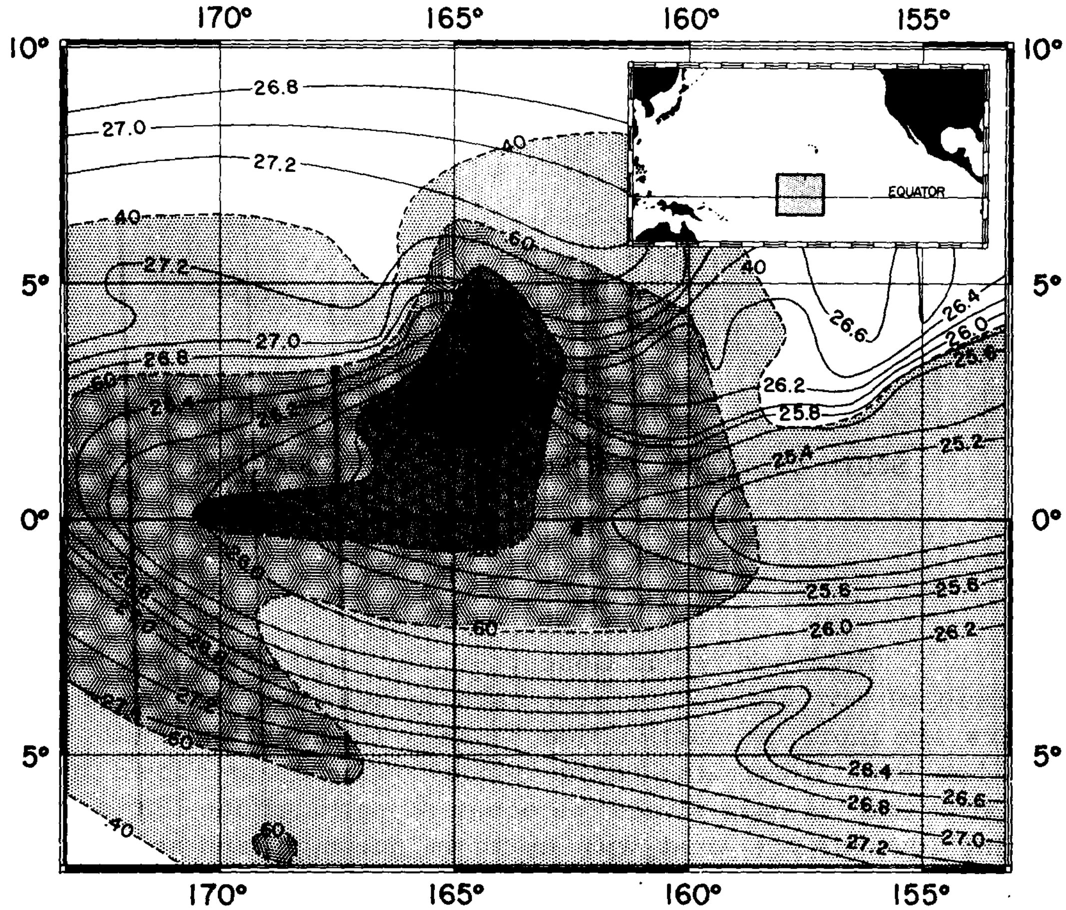


Figure 3. <u>Surface Temperature and Phosphate</u>. This oceanographic production line does not run steadily. In this picture we see evidence of a spurt at the beginning of the chain of events. The lines follow equal temperatures and the shading indicates the variation in nutrients (phosphate). The tongue of cold water can be seen along with the dark shading indicating masses of high nutrient waters. Such masses of enriched water are of primary interest since the genesis of the abundance of tuna must be related to them. Strong winds have given a push to the circulation system and we think that this will soon be followed by an extra good concentration of tuna. We have no idea how many days or how many miles separate the push of the wind from the bunching of the tuna, but figure 8 proves such bunching of the tuna does occur.

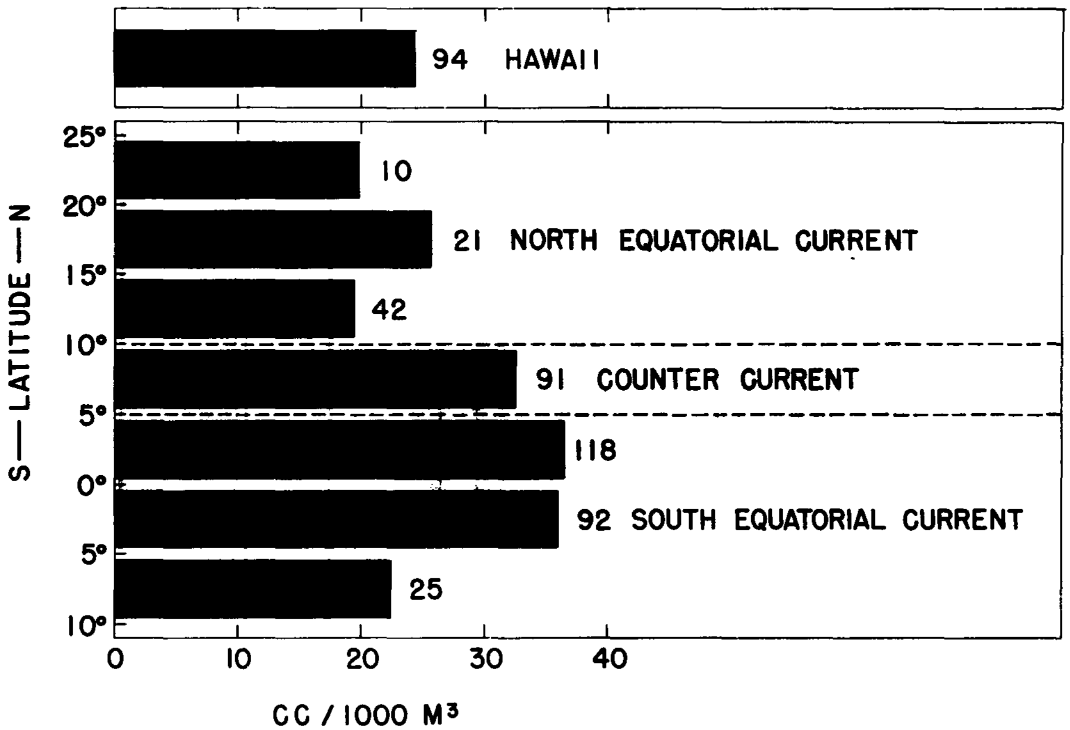


Figure 4. Zooplankton Abundance by Latitude. Since the waters immediately north and south of the Equator contain enriched subsurface water, it is interesting to note that zooplankton, which must have a rich "pasturage" to thrive, is particularly abundant near the Equator. The amount of zooplankton at various latitudes both north and south of the Equator is shown in the bar diagram above. The numbers at the end of the bars indicate number of net hauls made for each of the latitude categories. The longer bars near the Equator indicate greater amounts of zooplankton; the top bar, representing waters around Hawaii, suggests that the Island waters may be less productive than equatorial waters.

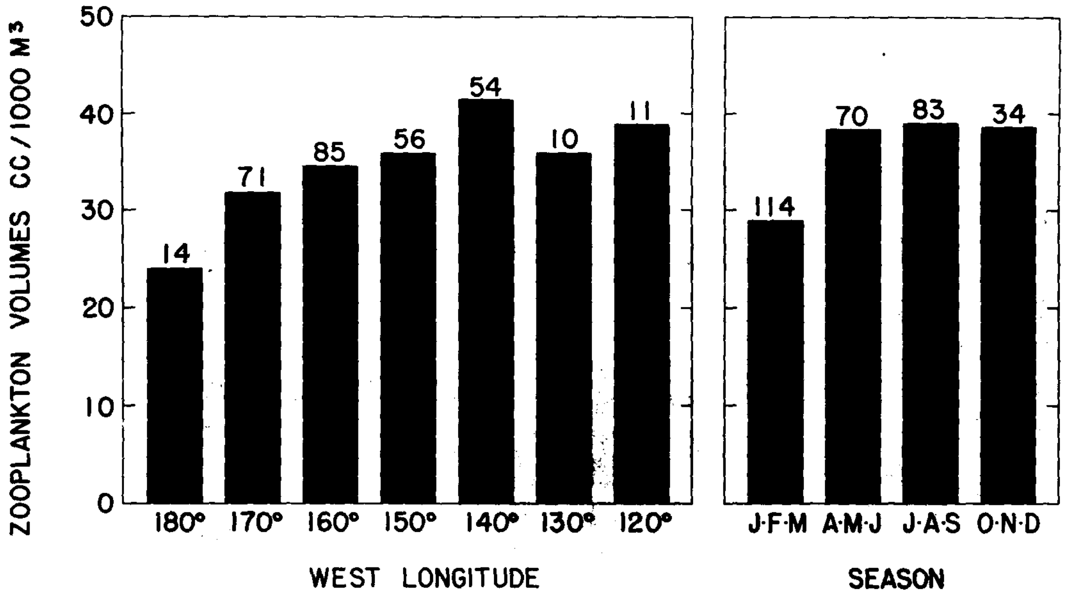


Figure 5. <u>Zooplankton Abundance by Longitude and Seasons</u>. We think that the productivity at the Equator increases from west to east. The diagram at the left confirms this at least between 180° and 140° W. longitude. It appears that plankton production levels off in the eastern sector of our survey area, but our surveys east of 140° W. have not been comprehensive enough to be sure of this.

The diagram to the right shows that some parts of the year are more productive than others. We expect that further analyses will show that these changes in productivity are related to the fluctuation in tuna abundance.

While plankton is an important indicator of richness, most plankton animals are too small for tuna food. Instead they are fodder for the small fish and squid which in turn are eaten by the tuna.

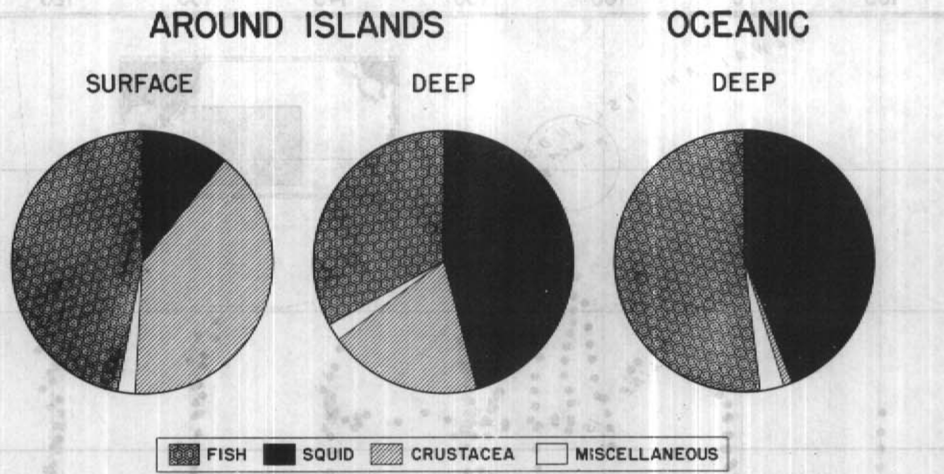


Figure 6. Food of Yellowfin Tuna. To find out what the tuna eat we have identified the material in the stomachs of many tuna caught on our fishing surveys. Apparently yellowfin tuna eat almost anything they encounter that is active, large enough to be noticed, and small enough to swallow. The variety of sea animals in their diet is outstanding and many are of surprisingly small size. Over 75% of the stomachs contained organisms weighing less than one-tenth of an ounce. Occasionally quite large animals are eaten too, the largest being a 16-inch skipjack found in the stomach of a 53-inch yellowfin. This simplifies the problem of finding their feeding grounds. They should be anywhere in warmer waters where general biological productivity is high. There is no need to find concentrations of a particular kind of feed.

Consistent with this are the different proportions of the various kinds of food in tuna taken from island and oceanic areas. Within 5 miles of islands the surface tuna eat almost equal parts of small reef fish and crustaceans such as the free-swimming young stages of crabs and mantis shrimp, which in their adult form live on the reef and on the bottom in shoal water. Somewhat farther offshore but still within 10 miles the crustaceans diminish and the squids become a much larger element in the food of deep-swimming tuna caught with longlines, and in truly oceanic areas the diet is made up of almost equal parts of small fish and squid with very few crustaceans.

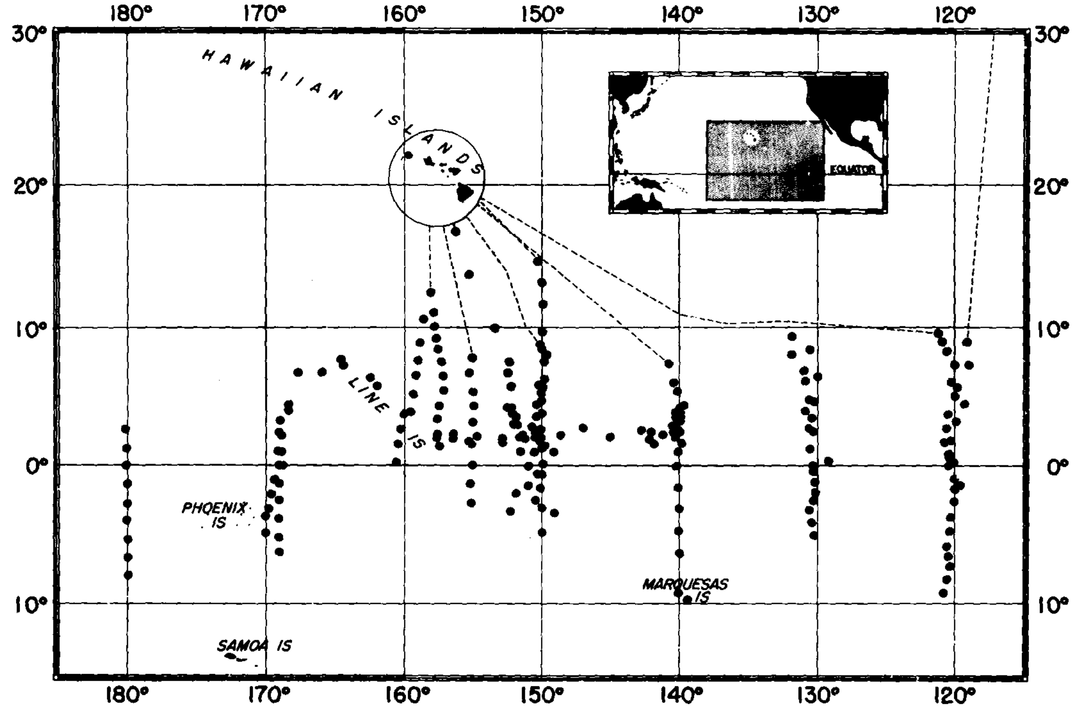


Figure 7. Equatorial Longline Fishing Cruises. After finding a rich zone near the Equator south of Hawaii, we fished this area using the Japanese longline method. We have tried to cover a broad expanse of the equatorial region, as can be seen from the above chart. Our plan was to fish across the Equator on selected longitudes at various times of the year and in about another year we will have completed this phase of the program. From our long-line station data, the positions of these stations being indicated by the black dots, we detect quite drastic changes in tuna abundance and we plan to relate these fluctuations to the hydrographic conditions and information about the fish food and, finally, attempt to predict the best time and place to fish.

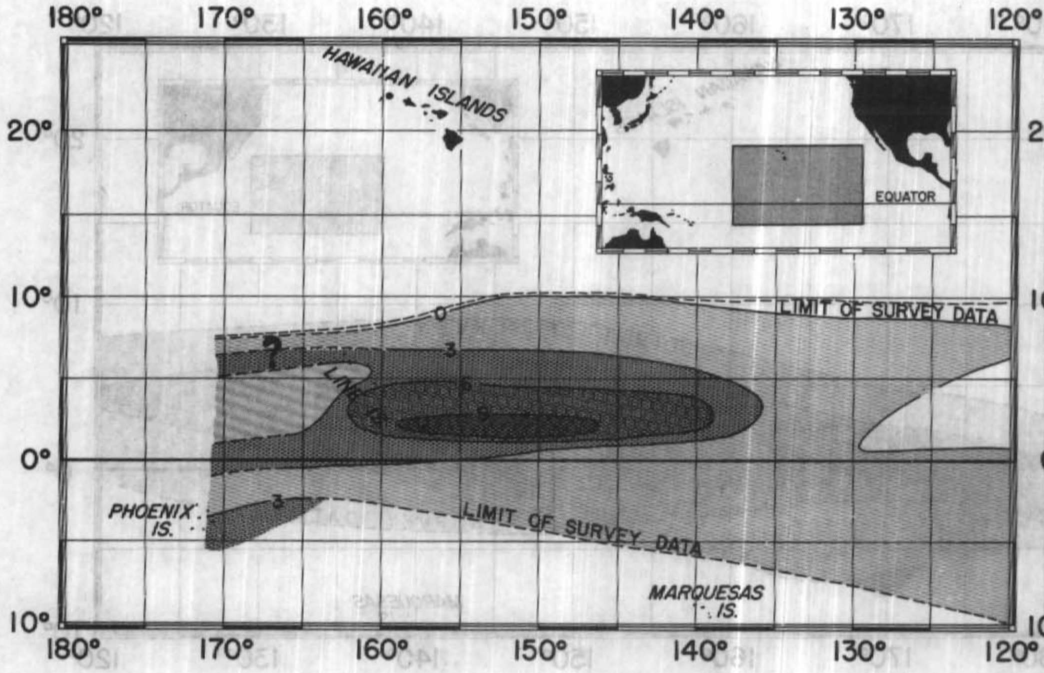


Figure 8. Yellowfin Tuna Catch/100 Hooks (July-November). As mentioned previously, we do not yet have enough crossings to plot the distribution for all times of the year. However, when we group together a set of 10 crossings made in August, September, October, and November (of three different years), we can draw a very generalized picture of the concentration in terms of number of yellowfin tuna caught per hundred hooks per day. We have drawn lines through equal catches. The "9-line" encloses the area yielding 9 or more yellowfin per hundred hooks; between the 9-line and the 6-line the catches averaged 7 to 8 per hundred hooks, etc. You can see that at 150° W. longitude the fishing was best in a zone centering at about 2° N. latitude running east to about 145° W. longitude and west to 160° W. longitude. It tapers off rapidly going north or south and more gradually going east or west.

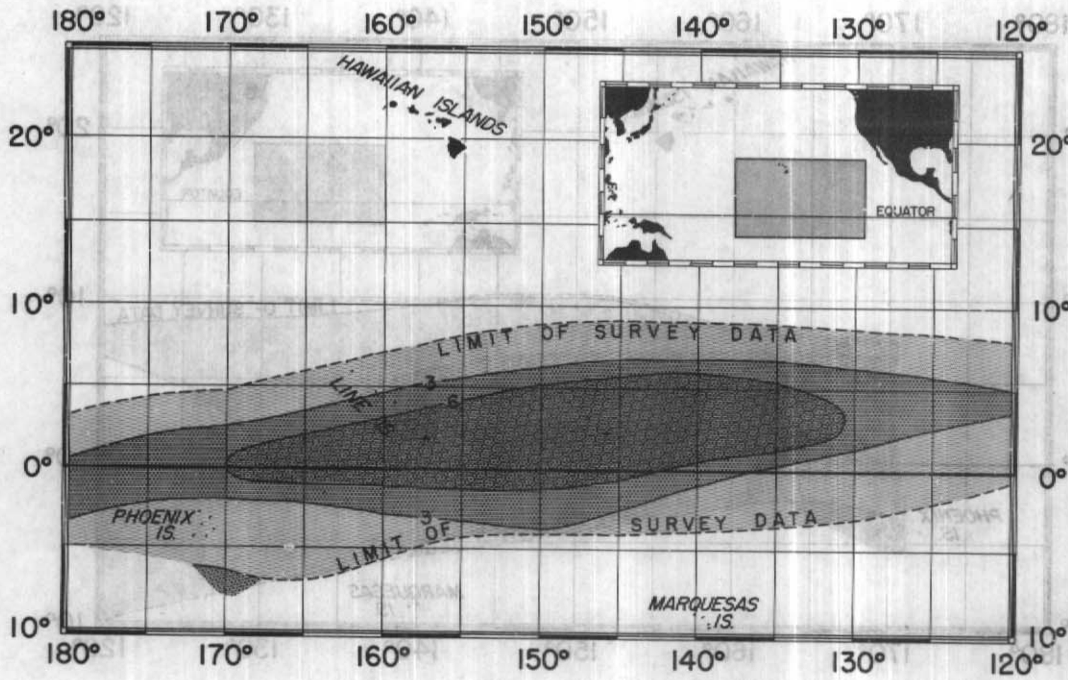


Figure 9. Yellowfin Tuna Catch/100 Hooks (January-June). Another group of four fishing sections in February, March, May, and June suggests a wider spread of medium concentrations and no really high concentrations of yellowfin tuna. Otherwise the pattern is very much the same. We do not consider the above or the previous chart as being very accurate. Too many different months are grouped together and there are not enough repeated fishing trials for the same months. Until our survey plan is completed, these should only be regarded as tentatively describing the distribution. Even so, it is becoming clear that certain areas along the tuna-rich equatorial belt contain more tuna than others and during some periods of the year the tuna are more concentrated.

Translating these concentrations in to commercial fishing yields, a vessel fishing on the grounds that average 6 tuna per hundred hooks would catch 180 tons per month, if it fished the same amount of gear (2,000 hooks) as is normally operated by Japanese longline vessels. But without lavish use of manpower, it is difficult to handle daily this much gear. The American vessel shown in figure 17 set less than 500 hooks per day.

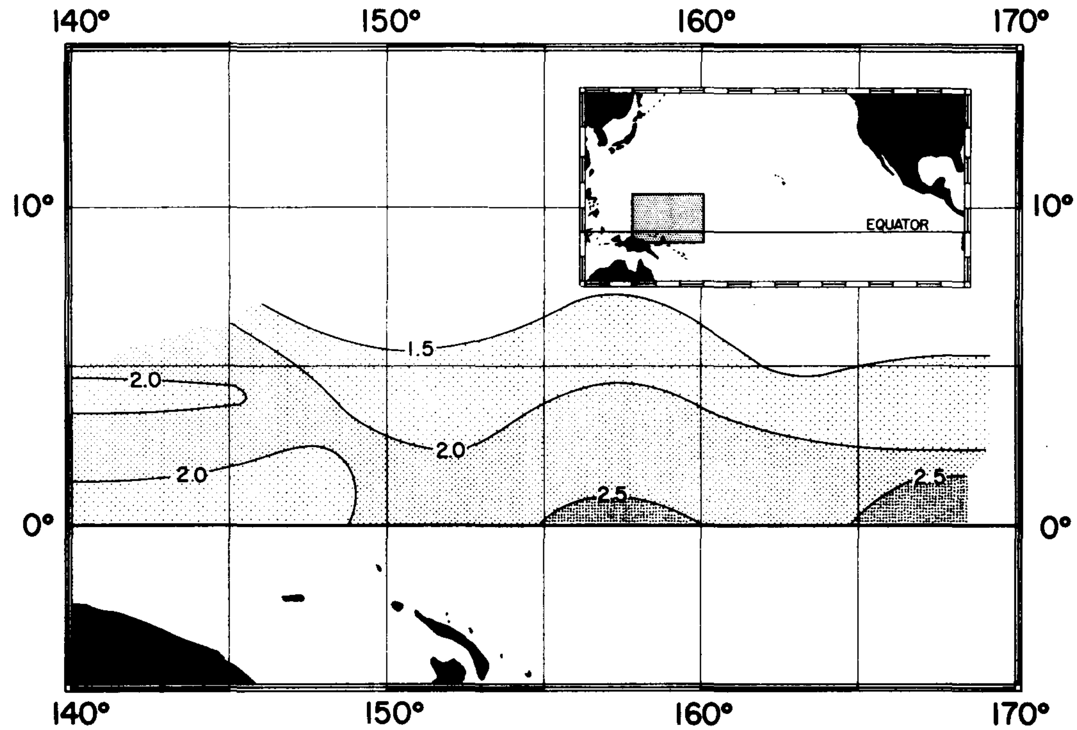


Figure 10. Relative Abundance of Yellowfin Tuna in the Western Equatorial Pacific. To obtain information on the distribution of yellowfin tuna throughout the Pacific Ocean, we have obtained data from the nine Japanese mothership expeditions to the western equatorial Pacific in 1950 and 1951. These fishing trials were restricted by SCAP to the area from 130° to 180° E. longitude and from the Equator to 24° N. latitude. Our observers went along on five of the expeditions to collect biological data and production records.

This figure gives the catch rates as averages for yellowfin tuna from all expeditions. The contour lines in the figure separate zones of like catch rates. The Japanese fishing in the western Pacific agrees with POFI's in the central Pacific by showing yellowfin to be most abundant near the Equator and tapering down to the north; however, the abundance is very much lower. The best western areas produced only 2.5 yellowfin per hundred hooks whereas the best areas in the central Pacific produced over 9 and there was a very large area that averaged 6 fish per hundred hooks.

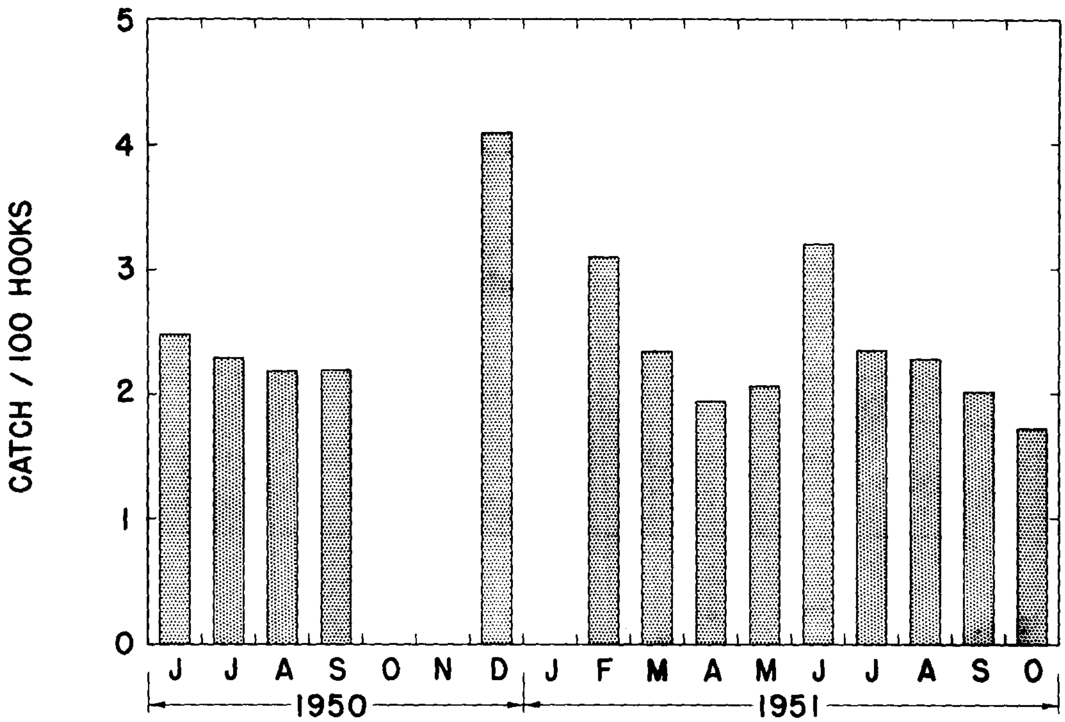


Figure 11. Seasonal Fluctuations in the Longline Catch Rate in the Western Pacific. It is of interest to know the times of the year when the Japanese mothership expeditions experienced the best fishing. The above diagram shows how the catch varied from month to month during 5 months of 1950 and 9 months of 1951. There appear to be two peaks of abundance in this western region; one in midwinter and one in midsummer. The fluctuations in the monthly catch rates are of much smaller magnitude than generally experienced in temperate zone fisheries and there is no month when the catch sags as low as one-third of the peak value. In this instance the average rate of capture by the Japanese was between two and three yellowfin per 100 hooks in most months.

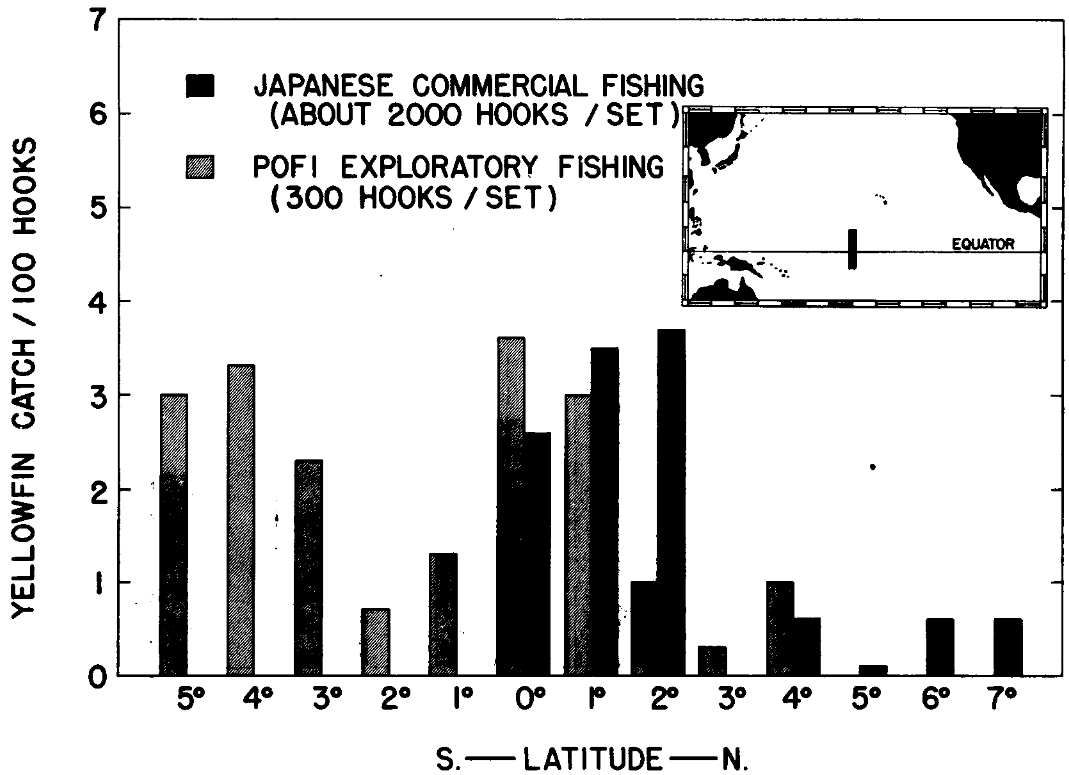


Figure 12. Comparison of Catch Rates from Japanese Commercial and POFI Experimental Fishing. In the two previous figures we discussed the catch rate from Japanese longline fishing in the western Pacific. Until recently we did not know definitely whether our small-scale experimental fishing was sufficiently like the Japanese full-scale commercial fishing to give the same measure of yellowfin concentration. In 1952 we had a chance to make a direct comparison when the JOHN R. MANNING and a Japanese vessel were fishing at nearly the same time in the same place, near the western boundary of our survey area (along 170° W. longitude). Plotting the catch per hundred hooks of each vessel against latitude shows that our gear gives catching rates that are comparable to the Japanese commercial operations.

This is the first instance of Japanese fishing as far east as our survey area. There is no evidence that they have come as far as the relatively richer area south of Hawaii.

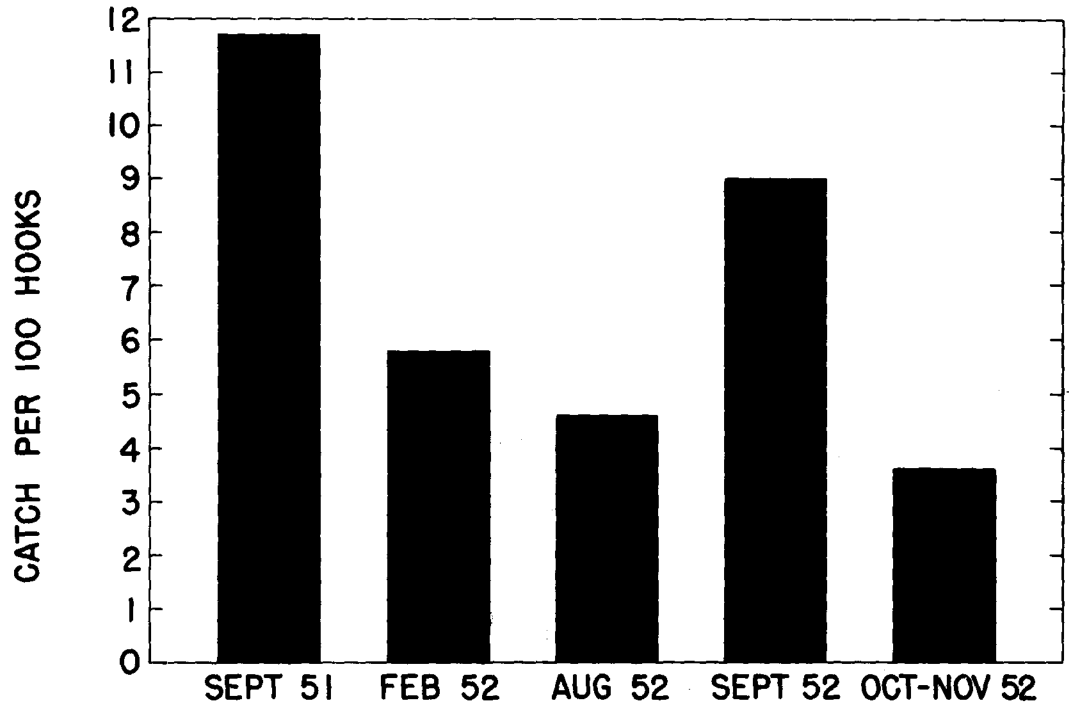


Figure 13. Abundance of Yellowfin at 150° W. Longitude on Successive Cruises. While the results of succeeding fishing surveys are consistent in most respects and show the same rich zone near the Equator, some of the details are puzzling. Here we have grouped the results of successive surveys along 150° and 155° W. longitude. You can see that a downward trend in catch rate is suggested and superimposed on this are fluctuations from one cruise to another. These fluctuations may be the result of the spurts and halts in the oceanographic production line mentioned a few pages back. It is less easy to see why there should be a downward trend. The fish of the more recent trips, however, have been larger as well as fewer and we may be witnessing the passing of a successful year class. If so, the numbers should go up again with another successful spawning. We are hopeful that studies of a biological nature, such as those related to larval abundance and distribution, may yield clues concerning these fluctuations.

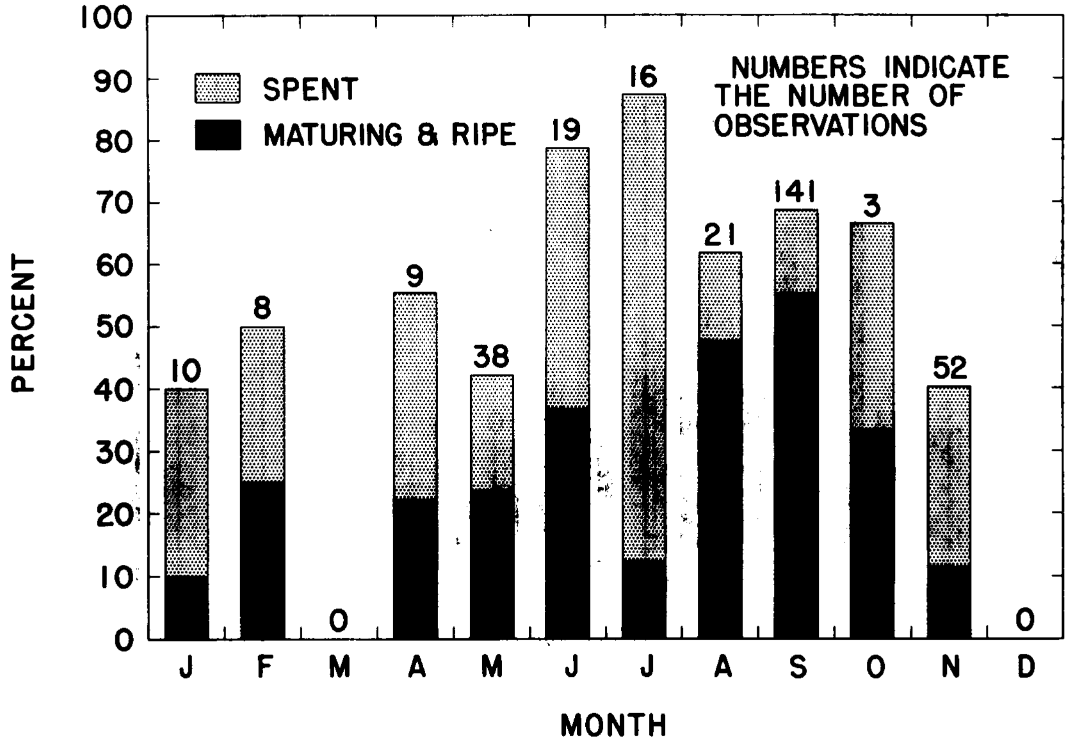


Figure 14. Tuna Spawning Near the Equator. In addition to knowledge of the abundance of yellowfin tuna in the central Pacific it is essential to understand the distribution of the different populations found throughout the Pacific. One method of accomplishing this is to study the spawning habits of tuna found near the Equator. We have examined the roes in a large number of the yellowfin captured during our fishing trips. A high percentage of these fish caught during all months sampled were either nearly ready to spawn or were spent. Somewhat more spawning activity is suggested during the summer and fall months than at any other time of the year, but some spawning yellowfin were obviously present throughout the year.

Although the condition of the roe proves that the yellowfin would spawn in the near future or had done so in the recent past, very few actually running ripe fish are caught. This leaves some doubt as to the exact spawning place. Much of this doubt is removed by our finding the very young tuna larvae in our plankton hauls from the equatorial area.

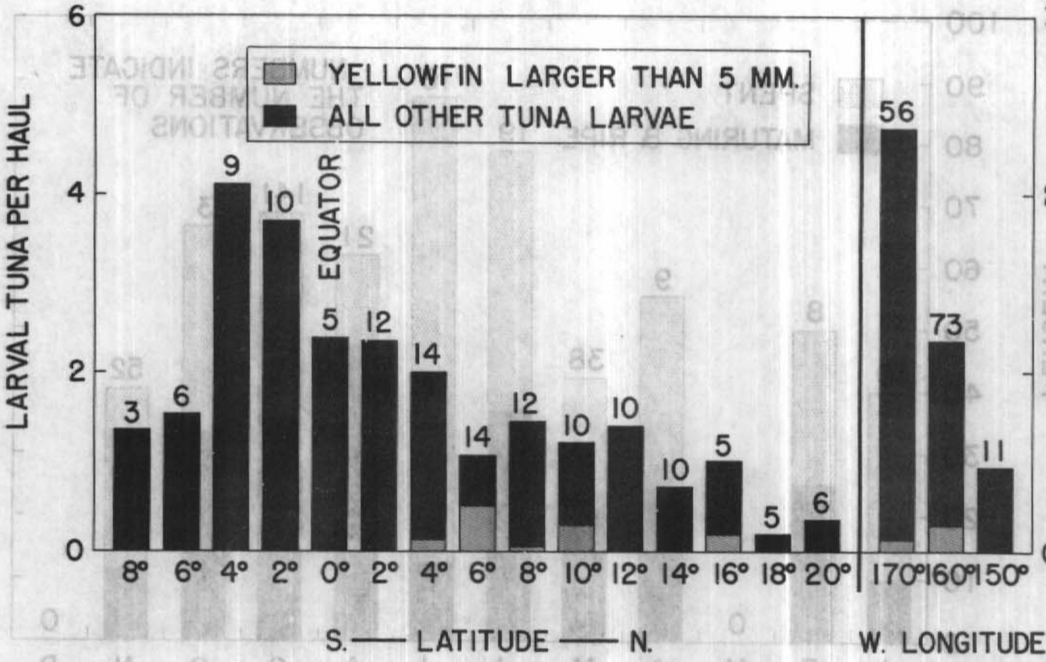


Figure 15. __Distribution of Tuna Larvae in Central Pacific.__ Counts of the number of tuna larvae in a portion of our plankton samples show them to be most numerous in the hauls taken near the Equator, not far from the places in which we found the near-ripe and the recently spent females. Regrettably too few of our hauls have been sorted for larvae to give a reliable distribution diagram. Also, it is difficult to tell the different kinds tuna apart when they are smaller than 5 millimeters (one-fifth of an inch) long. This leaves the definite yellowfin larvae records quite scanty and the indication of more larvae at 170° than at 150° W. longitude must be taken with reservation. However, these very preliminary results give hope that the work on planktonic larvae, as it progresses, will indicate whether the tuna spawn over the entire east-west range of adults or whether spawning is concentrated in one or more separated localities. This bears on the question: Does the Pacific have one large interbreeding stock of tuna or a number of separate self-perpetuating stocks?

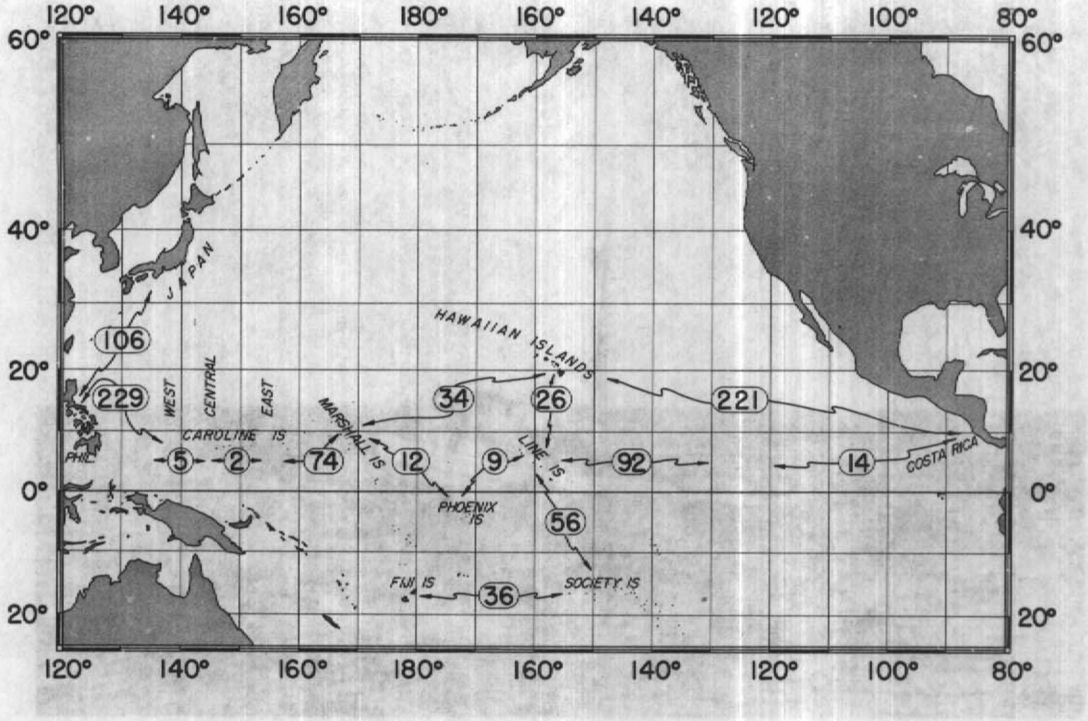
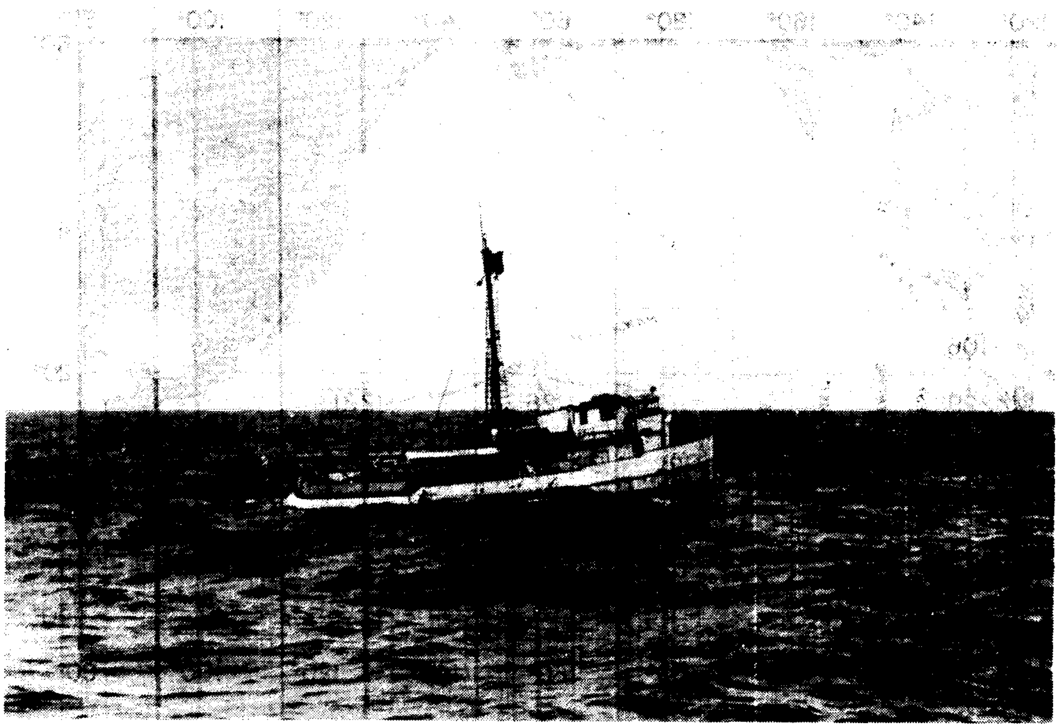


Figure 16. <u>Index to Racial Difference of Yellowfin Between Sample Localities.</u> To understand the relationship between tuna stocks we have compared the body proportions of yellowfin tuna from various parts of the Pacific. When the differences in body proportions between two samples is great, the index number appearing on the above chart is large, and when the tuna from the two sample areas are similar, the numbers are small. This analysis shows that west coast yellowfin differ widely from those of the central Pacific, and that the yellowfin of the central Pacific differ considerably from those farther west toward Asia. Unfortunately no one knows how large an index number is required to prove complete separation of stocks or conversely how small it should be when there is complete mixing. Firm conclusions require evidence from other sources.



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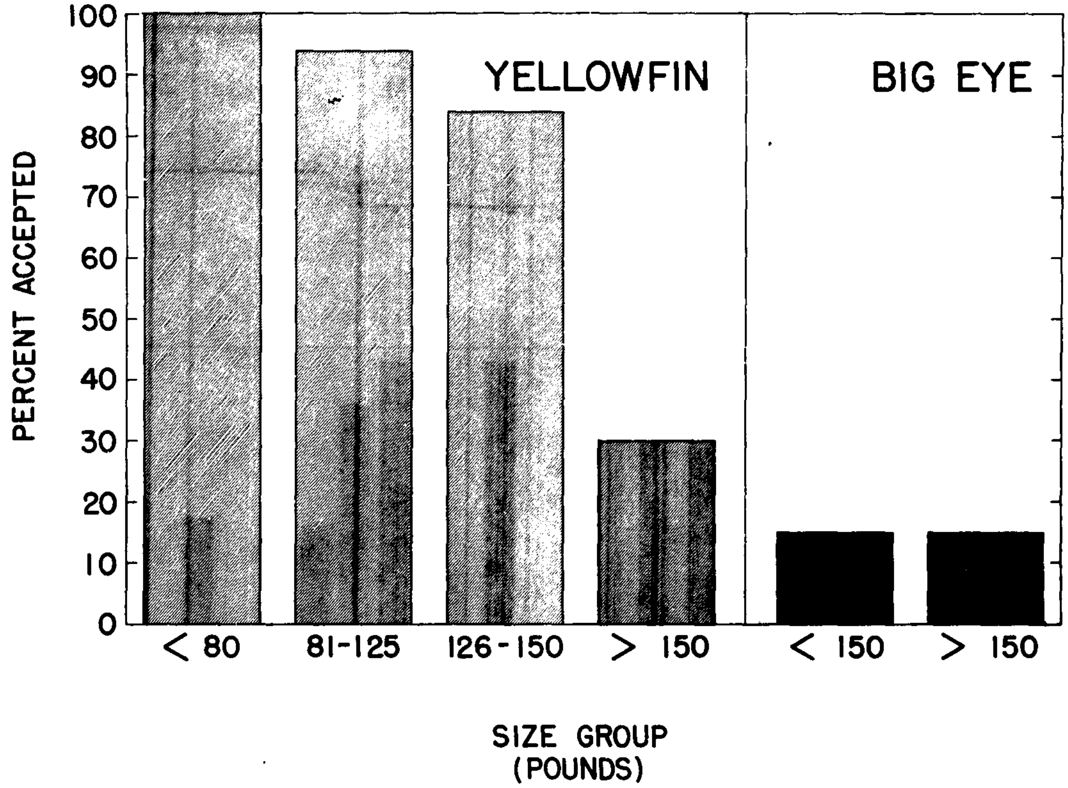


Figure 18. Acceptance of CAVALIERI Longline Tuna for Canning. Since the CAVALIERI catch of tuna consisted of large fish from an untried area, we were vitally interested in the percentage acceptance by the cannery. The above figure shows that a very small percentage of the small and medium sized fish were rejected by the cannery, while only 30 per cent of the yellowfin tuna above 150 pounds were acceptable. The rejection at the cannery was primarily on the basis of the color of the flesh, the larger fish being generally darker than the smaller. Later observations of fish of various sizes canned especially for us indicated that flavor was not noticeably affected by size.

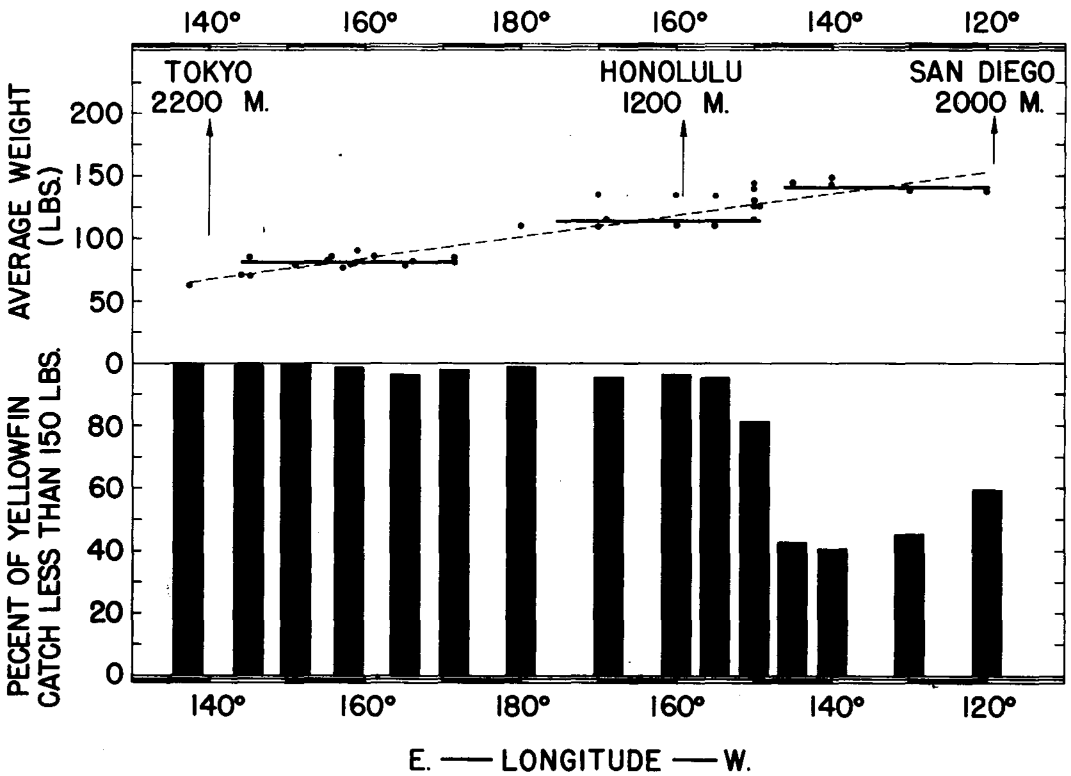


Figure 19. Variation in Size of Yellowfin Along the Equator. The commercial venture stressed the importance of increasing our knowledge of the distribution of tuna with respect to size. The upper panel shows the change in size of the yellowfin along a 6,000-mile stretch of the equatorial Pacific. To the west of 180° each point represents a sample taken by POFI observers while on board Japanese motherships, while to the east of 180°, the measurements are from POFI catches. The size appears to increase in steps rather than in a steady progression and there is an indication that the tuna are smaller east of 140° W.

The lower panel shows the percentage of fish that weighed less than 150 pounds. Since a size of about 150 pounds is the upper limit for having most of the catch accepted under the "light meat" canning label, it is of interest to note that most of the yellowfin caught west of 140° W. longitude have been under 150 pounds.

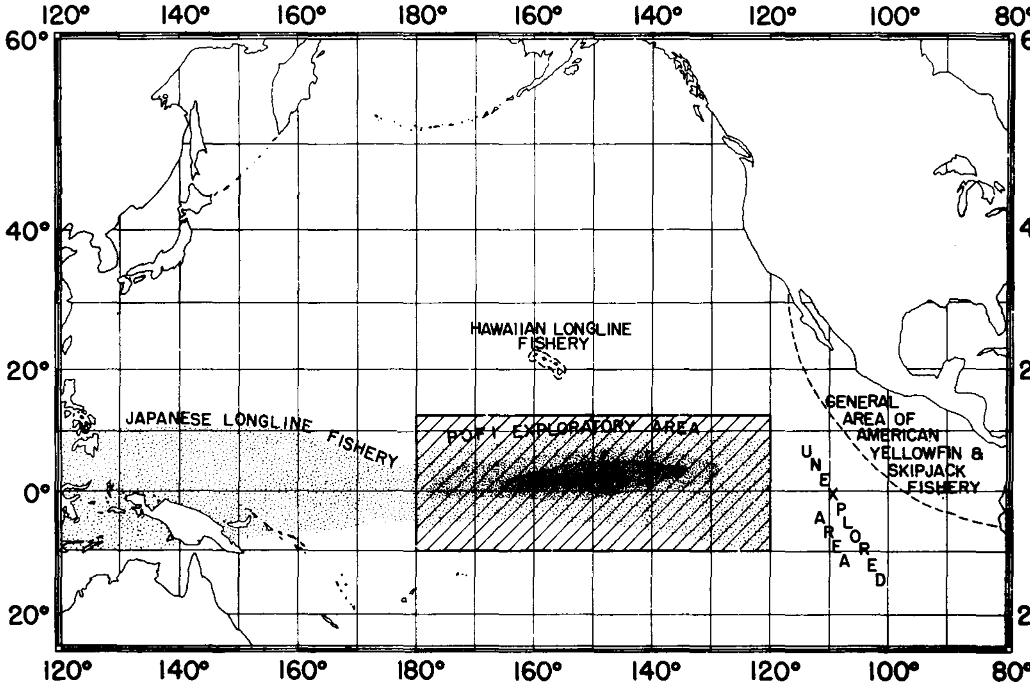


Figure 20. Known Trans-Pacific Distribution of Yellowfin Tuna. Summarizing all our yellowfin data collected since the start of the POFI equatorial longline fishing and adding other data from various sources, we constructed the above chart. It appears quite certain that abundant yellowfin stocks are to be found continuously across the Pacific from 120° W. to the Asiatic mainland with the greatest concentration in the broad band south of Hawaii between 140° W. and 170° W. No catch records are presently available for the 1,500-mile stretch between 120° W. and the Galapagos. We do not know yet whether the band of tuna is continuous through the area designated as "unexplored" in the above figure.

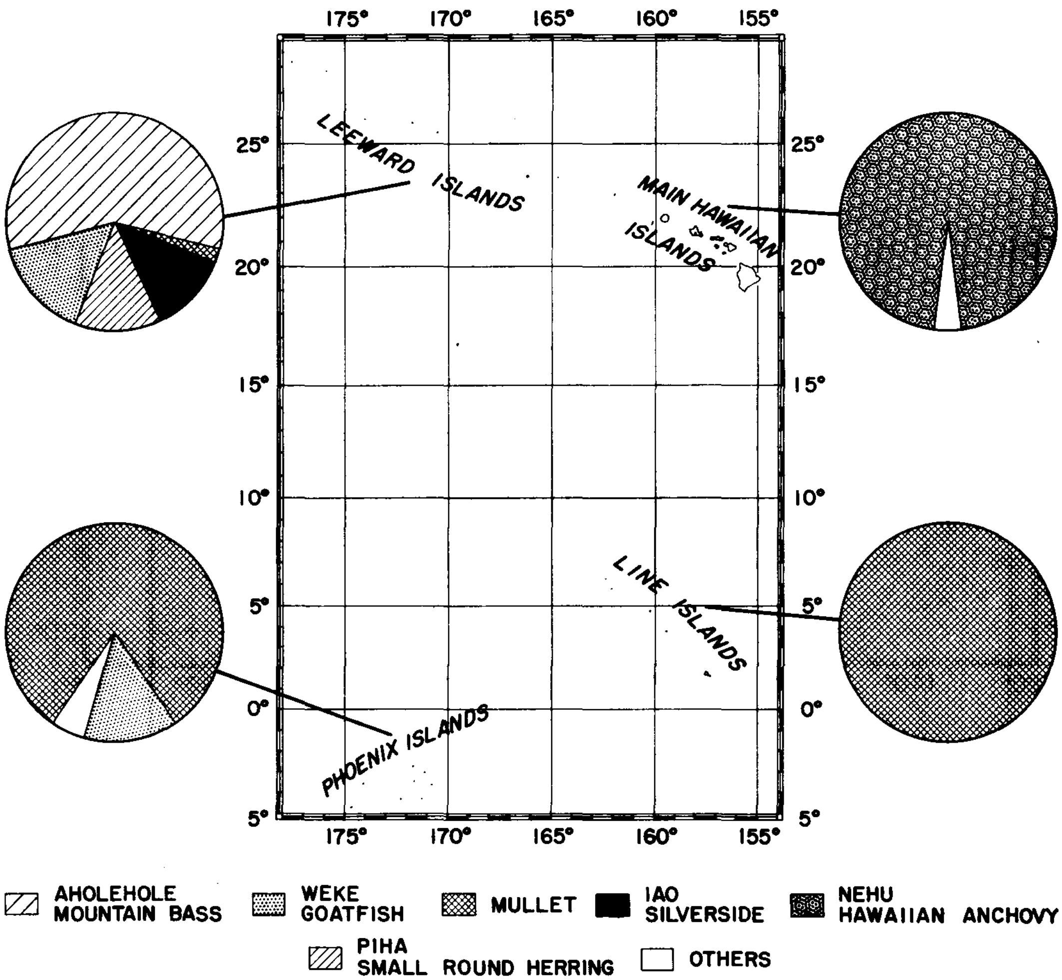
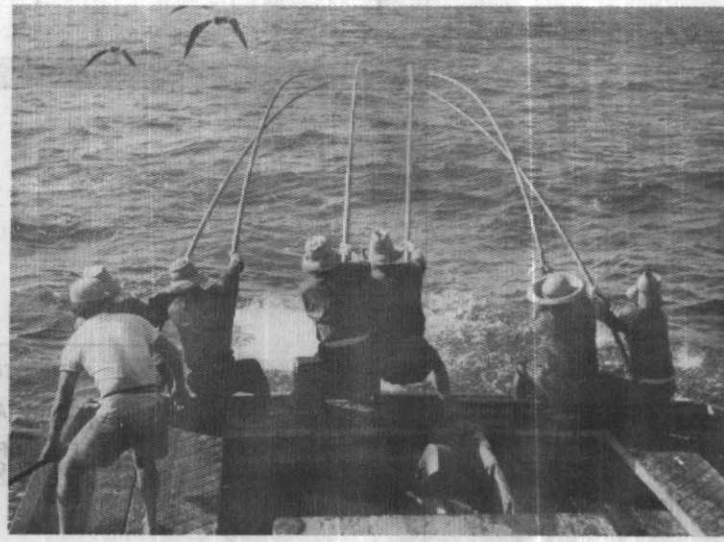


Figure 21. Bait Resources in the Central Pacific. Extensive bait surveys have been made in most of the island possessions of the United States in the central Pacific to determine the availability of live bait. The Hawaiian anchovy, the nehu, is the major bait species used in the Hawaiian Islands. The available supply is inadequate for local fleet of tuna sampans. In the leeward Hawaiian Islands bait can be found in moderate quantities at certain times of the year. The kinds are aholehole, iao, piha, weke, and some mullet. However, these were not found consistently and there probably is not enough to supply more than a small fleet of sampans. In the Line and Phoenix islands the major bait species is young mullet. A few weke, pronounced "vecky", are also there. Despite their considerable lagoon areas, these islands probably can supply only a small fleet of sampans during part of the year.



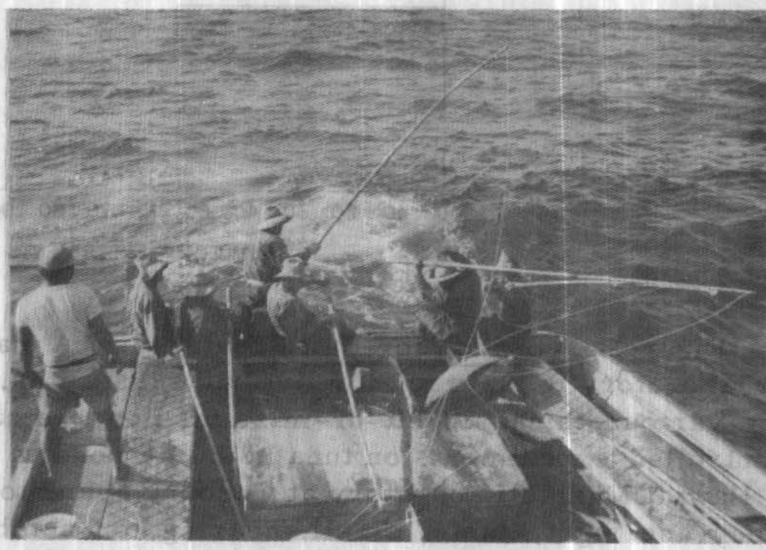


Figure 22. Midwinter Sampan Fishing in Line Islands. One trial venture to the Line Islands made by the Honolulu based sampan, TRADEWIND, was logistically supported by the HUGH M. SMITH, and fished the Line Islands area near the Equator south of Hawaii during January. This effort was the first commercial attempt to capitalize on the results of POFI live bait fishing surveys made during 1950 and 1951. In spite of a mediocre catch of 14 tons of yellowfin and about 2 tons of reef fish, the fishermen from the sampan felt that a profitable off-season fishery might be developed. The photos show TRADEWIND fishermen catching a large 6-pole yellowfin; the average size of the tuna caught by the TRADEWIND on this trip was 40 pounds (1- and 2-pole fish), considerably smaller than those taken by longline gear in that region.

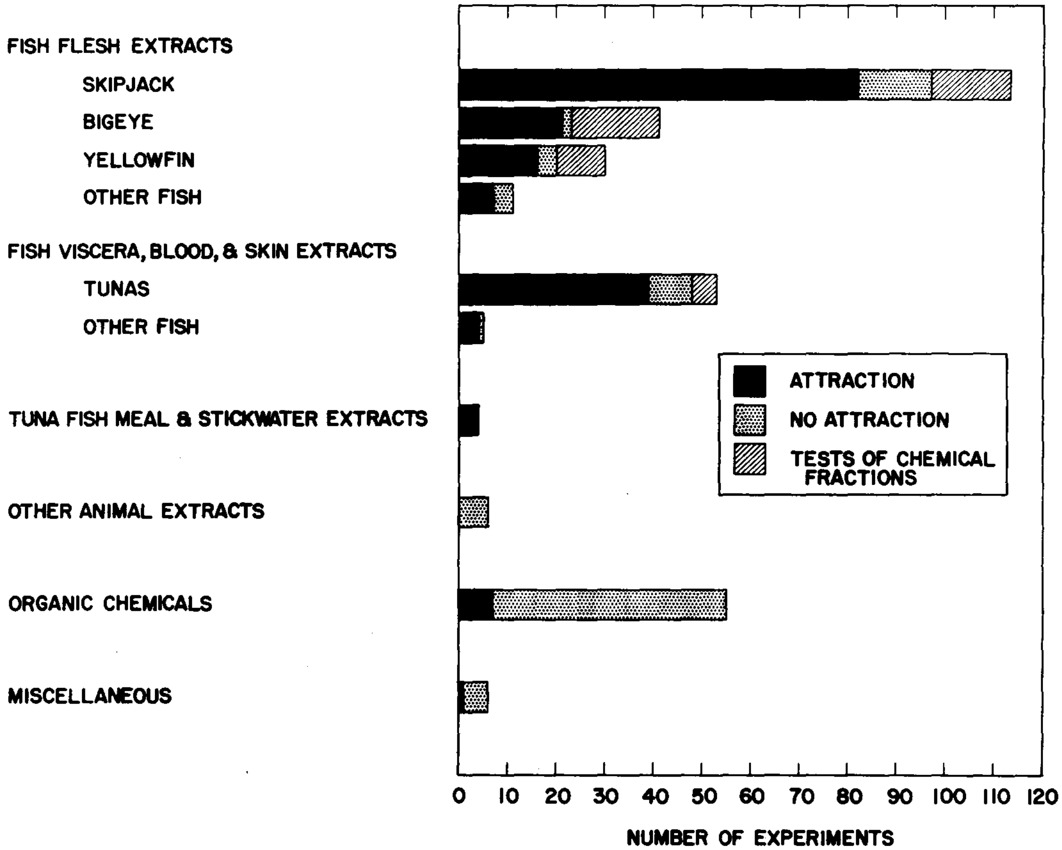


Figure 23. Search for Bait Substitutes. A major project of our laboratory is a search for live bait substitutes. Rather than trying various things in hit-or-miss fashion, we have been making controlled experiments on tuna held in a pond at the University of Hawaii Marine Laboratory at Coconut Island to find out whether they use sight, taste, smell, hearing, or combinations thereof, to locate food. In 1951 we found that tuna were sensitive to extracts made from the tissues of fish. In 1952 the taste-smell experiments were extensive as shown in the above chart. Early in 1953 we began to test the extracts on tuna schools out at sea. Results have been disappointing. It probably will be necessary to combine visual and chemical stimuli to attract and hold the fish near the stern of the vessel for pole and line fishing.

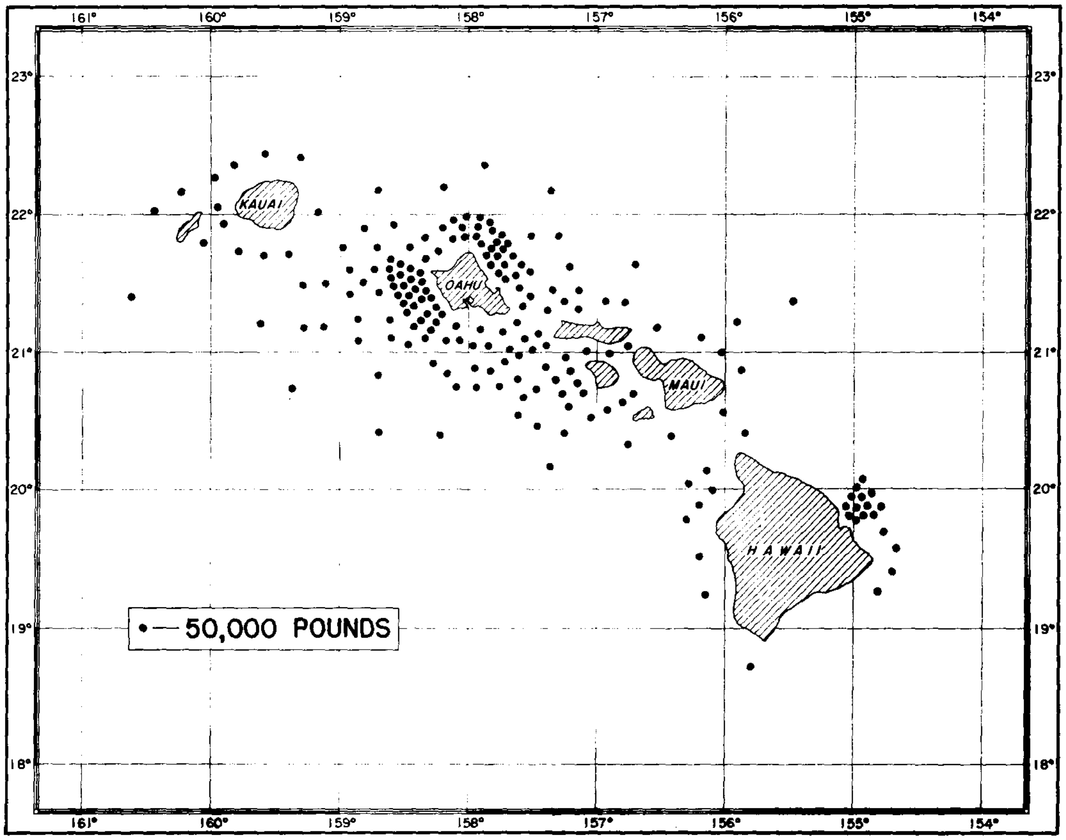


Figure 24. Distribution of Skipjack Catch Around the Hawaiian Islands. Skipjack form the basis for the principal fishery of the Hawaiian Islands. We are studying the distribution of skipjack in the Hawaiian area to ascertain whether or not the skipjack are confined to the immediate vicinity or whether there are worthwhile concentrations beyond the limits of present fishing. The above figure shows the location of the skipjack fishery during the 5 years, 1948 to 1952. The concentration of dots northeast of Oahu is near the major live bait source in Kaneohe Bay, the concentration southwest of Oahu is near the major landing port of Honolulu, and the cluster of dots northeast of the island of Hawaii is just outside of the port of Hilo where a small fleet is locally based. It is obvious that the present fishing is concentrated near the ports and near major baiting areas. This suggests that the fishery is limited by the range of the fishing boats rather than the range of the skipjack. As already noted the catch is also limited by the scarcity of bait.

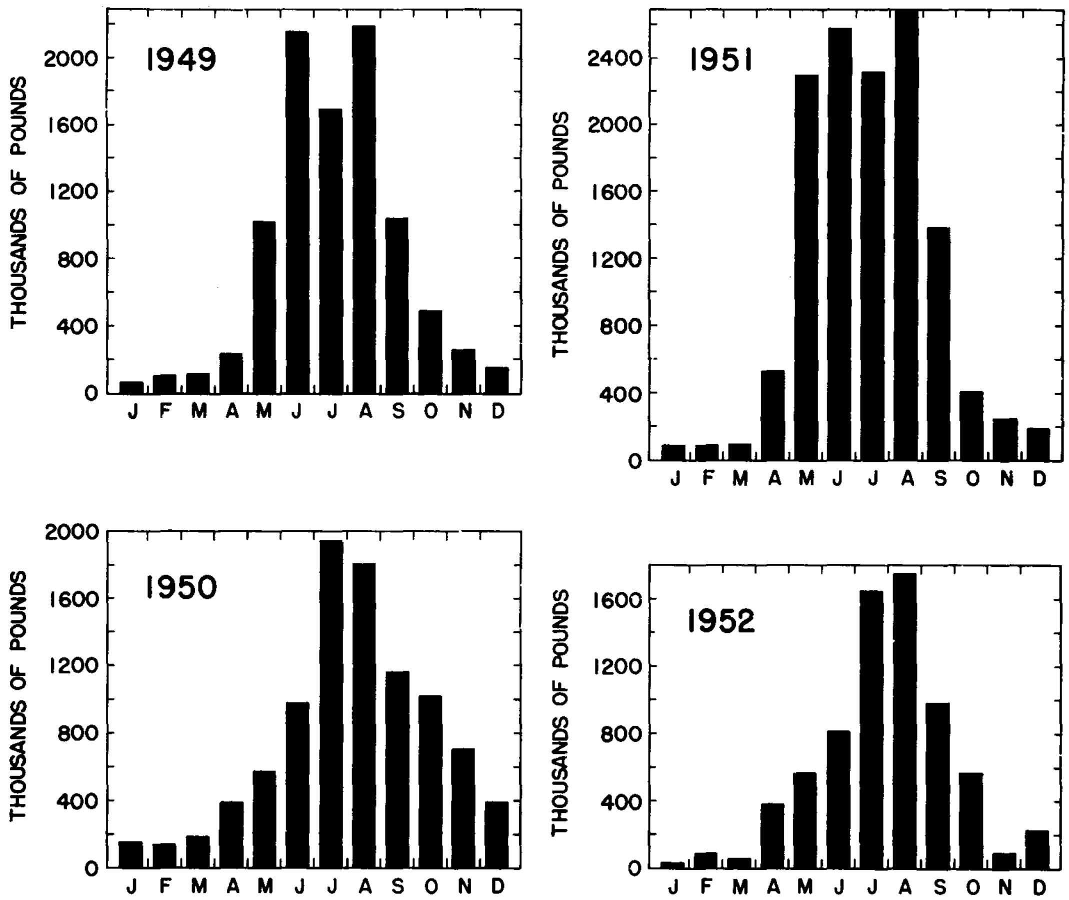


Figure 25. Hawaiian Monthly Skipjack Landings 1949-1952. The limited area of fishing and scarcity of bait are not the only restrictions on the fishery. As shown in the above diagrams, the catch during the winter season is very low with the landings seldom exceeding 200,000 pounds. Also there are large yearly fluctuations. In 1951 the total landings were 12,900,000 pounds while in 1952 they fell to 7,260,000 pounds. These highs and lows of catches prevent the development and expansion of a stable fishery industry in the Hawaiian Islands.

We do not imagine that these natural fluctuations can be controlled, but are hopeful that we can determine their causes, perhaps forecast the seasonal catch with some degree of reliability and find ways to increase or supplement the landings, especially during periods when fish are scarce.

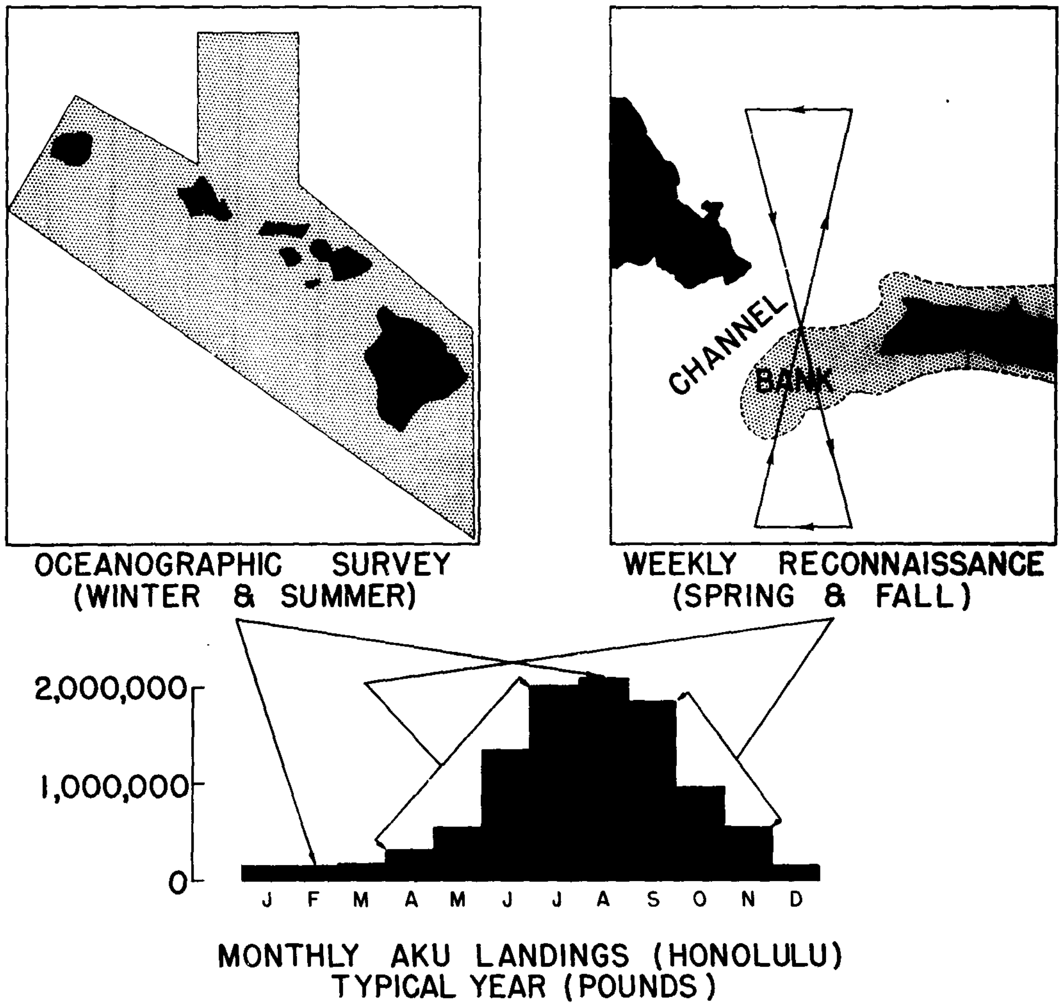


Figure 26. Survey Plan for Hawaiian Hydrography. As is true for equatorial tuna, we believe that the abundance and movements of the skipjack are controlled by events in the sea. Using the skipjack catch as a guide, hydrographic surveys have been planned and are in progress to discover the events during both the changes of the seasons and at the times of greatest and least abundance. It is hoped that these surveys of both a detailed and a reconnaissance nature will yield information which will help us understand the abundance, distribution, and movements of skipjack around the Hawaiian Islands.

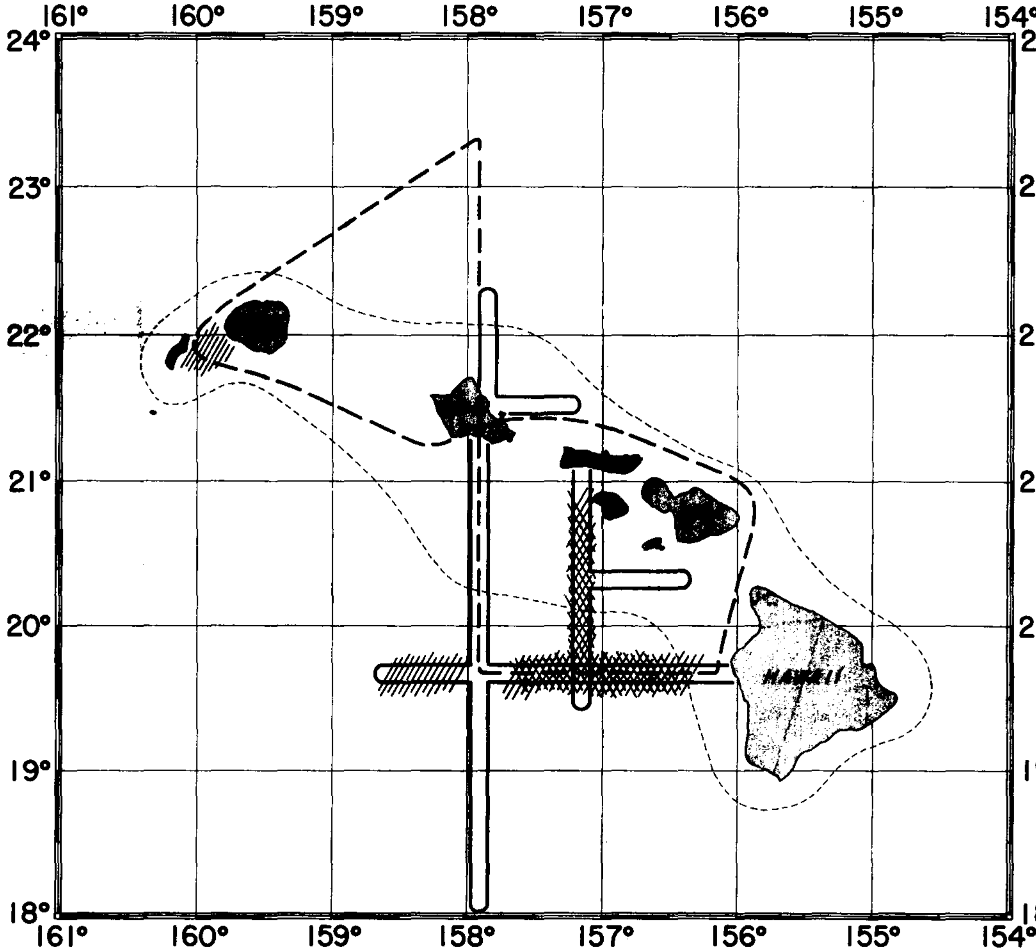


Figure 27. Winter Sightings of Skipjack. Biological studies on the skipjack and on the principal bait fishes are being carried out in cooperation with the Territorial Division of Fish and Game. POFI has undertaken as its principal contribution the study of skipjack at sea--primarily how and where to find them. As presently envisioned, this involves, in part, systematic scouting for skipjack by plane and vessel. Scouting carried on during the winter of 1951-52 and its relation to the area of local commercial fishing is summarized in the figure shown above. The heavy lines indicate some of the vessel tracks and the heavy broken lines the plane tracks; the light dashed line outlines the Hawaiian fishery. The hatched areas designate the schools of skipjack seen during the cruises. Many were seen southwest of the islands and far beyond the range of the present fishery.

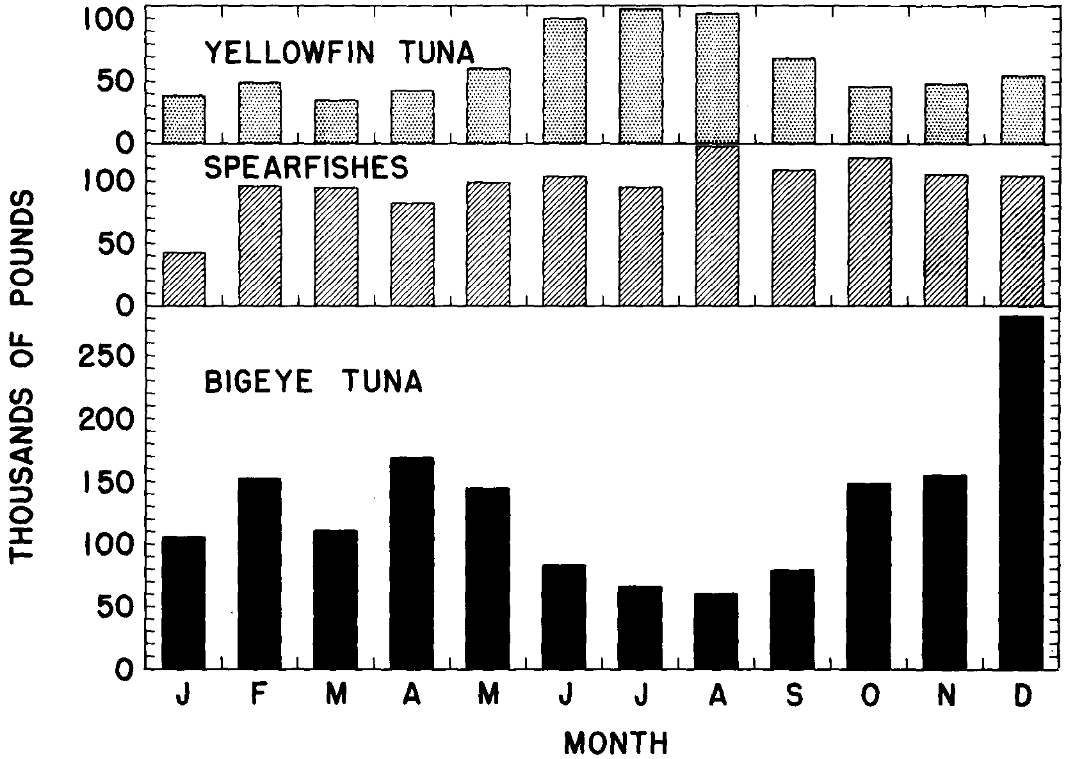


Figure 28. <u>The Hawaiian Longline Fishery.</u> The Hawaiian tuna longline or "flagline" fishery is second to the skipjack. This fishery lands about 4 million pounds of yellowfin and bigeye tuna and marlin each year. The three panels of the above figure show the average monthly landings for the three species for the years 1948 to 1952. Yellowfin are more plentiful during the summer while bigeye are abundant during the winter months. The catch of marlin does not seem to fluctuate much during the year. We do not know whether or not the variations in catch of these deep-swimming fish in the vicinity of the Hawaiian Islands are linked with the variations in the more abundant stock of tuna near the Equator.

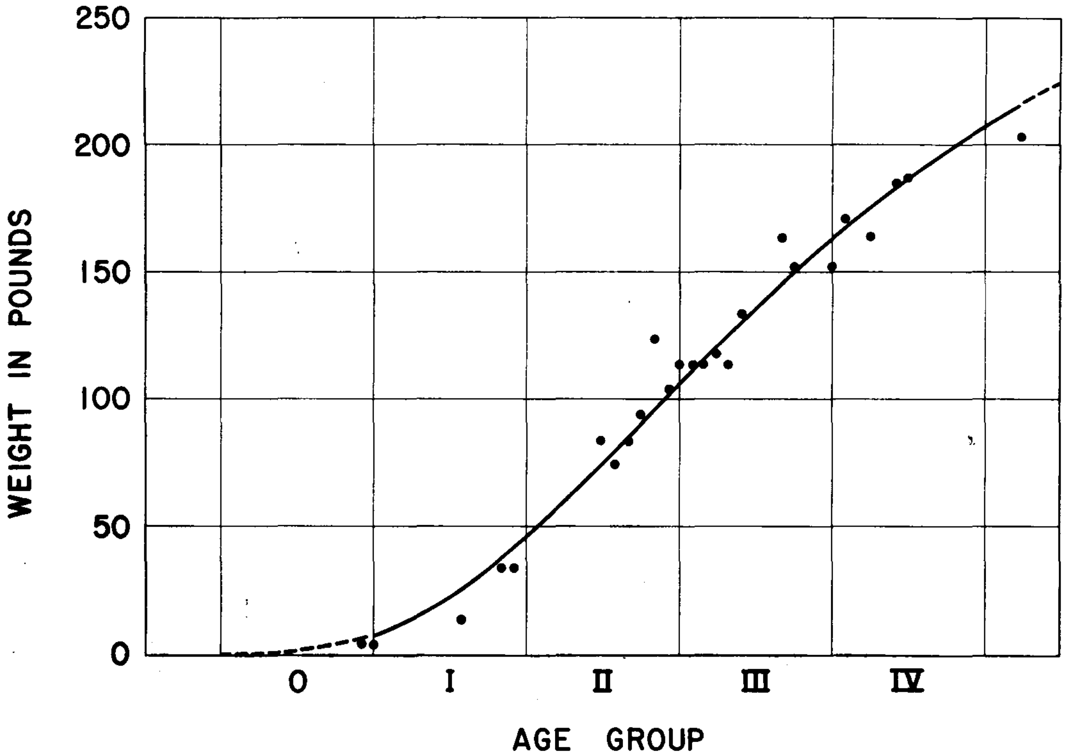


Figure 29. The Growth of Yellowfin. The local Hawaiian longline fishery affords information on the growth of the yellowfin caught near the Islands. The fish are brought into the market and weighed individually. From the records kindly made available by the marketmen, we have been able to follow size-groups in weight-frequency diagrams as they advance with growth through the months. The above curve represents the estimate by this method of the rate of growth in successive years of life. The tuna grow very rapidly during the early years of life, increasing more than 50 pounds a year in middle life. This is a very rapid growth rate but is consistent with knowledge of tuna growth obtained in other parts of the world. We expect this knowledge to help in the understanding of the peculiarities in prevalent sizes that we are finding in different parts of the Pacific.

Fishing Methods. During the early phases of our investigations we tested practically all conventional methods of fishing for tuna.

Trolling has been regularly done by POFI research vessels when underway to and from the Equator and on daylight runs between stations on hydrographic and fishing trips. During 5,525 line-hours of such incidental trolling only 15 tuna were caught; 8 were yellowfin and 7 were skipjack. In contrast, deliberate trolling close to island reefs when the vessel is maneuvered through schools at reduced speed has produced a much larger catch. In the Line and Phoenix islands we have deliberately trolled for tuna a total of 969 line-hours catching 280 tuna or 29.0 per 100 line-hours. These were practically all yellowfin tuna and most were of sizes between 16 and 60 pounds. Assuming a commercial vessel were fishing six lines, this would mean a catch of about 17 tuna or about 600 pounds per 10-hour day.

Purse seining was tried in the Phoenix Islands on two occasions, one during the summer of 1950 and the second trial during January and February 1951. During both of these attempts a number of tuna schools were sighted but rough seas and strong winds hampered the operations and no tuna were caught. Five trips were made to the Line Islands during 1950-1951. Although 75 schools of tuna were observed, most of them were too wild or too close to the reefs for setting the seine. Of the eight schools that it was possible to set on, fish were still in the circle of net when pursing began in six instances but they sounded out before the net was closed. On the other two sets the fish probably escaped before pursing began. Further purse seine trials were attempted around the Hawaiian Islands during 1951. Several schools or parts of schools were captured by engaging a sampan to chum the fish while the purse seine was set around the school. Without such chumming the fish escaped from all sets that were tried. It appears that in the central Pacific purse seining is not a practical means of capturing tuna in commercial quantities.

Surface gill nets were used in the vicinity of the Hawaiian Islands for a total of 284 hours during the summer of 1951. A report has been published on the results of these trials, most of which were carried on during the night. Fishing was confined to the lee of the larger islands because of the difficulty in handling the gear in rough waters. Some of the trials were in areas known to be productive of skipjack and during their season of abundance. A total of 28 fish were taken by the gill nets of which only 7 were tuna. It was concluded that surface gill netting also shows very little promise as a commercial fishing method for skipjack in central Pacific waters.

Fishing by the live-bait method has been attempted in the Hawaiian Islands, Phoenix and Line Islands area by our vessels HUGH M. SMITH, HENRY O'MALLEY, and by the private vessels PIONEER, OREGON, and CALISTAR. These trials covered practically all months of the year and yellowfin and skipjack tuna were taken by all of them, mostly on the leeward sides of the islands within 3 miles of the reefs around the shore. The catch per hour's scouting was superior to that obtained by the commercial fishery around the Hawaiian Islands. The catch was predominantly yellowfin tuna in the Line and Phoenix islands while around the Hawaiian Islands the catch was predominantly skipjack.

The major limitation on the live-bait fishing method for expanding the harvest of tuna in the central Pacific either by the large tuna clippers or by the small sampans is the scarcity of suitable live-bait throughout the area. The best baiting grounds are in the main Hawaiian Islands, where a commercial fleet of sampans is now utilizing the bait stocks to the maximum. The Phoenix and Line islands show the most promise with regard to the number of surface schools of tuna found, but have little bait with which to capture tuna using the live-bait method.

Although the scarcity of live bait is the major difficulty, the large tuna clippers have additional troubles in the central Pacific. The tuna schools themselves are small, fast, and quite difficult to chum. The large clipper is less successful with these schools than the much smaller sampan type of vessel used in the live-bait fishery around the Hawaiian Islands, which has the speed and maneuverability to cope with these "wild" schools. However, the sampan is handicapped by its small carrying capacity and limited cruising range.

Longlining stands out as a method with great promise for large-scale tuna production in the central Pacific. The area of good catching rate with this gear is enormous (see fig. 20). With this gear there is no need to scout for surface schools or other fish "signs". The gear is set "blind" and does not fail to catch tuna when in the proper zone, although the catching rate varies. Weather never prevents operation and bait is no problem. Frozen herring, sardine, squid, and mackerel are all suitable for bait and available from Mainland sources. Although the tuna caught by this method are near the upper size range for canning acceptability and some are beyond it, the percentage of over-sized can be reduced to almost negligible proportions by selection of fishing grounds (see fig. 19); and eventually it should be possible to find alternative markets for the few large yellowfin as well as the incidental catch of a few bigeye tuna and spearfishes. The only serious defect of this method of fishing is the large amount of hand labor involved in setting enough of this gear to make a commercially profitable catch in the American economy. Preliminary experiments warrant confidence that a few simple modifications in the design of this gear will adapt it to mechanized hauling without seriously impairing the catching rate. This should overcome the only serious deterrent to the development of a large central Pacific fishery for tuna.

APPENDIX 1 - DATA UNDERLYING THIS REPORT

To serve the technical reader, we give for each figure and its accompanying explanatory text the kind and amount of information from which it was prepared.

Figure 1. Equatorial hydrographic cruises. Along the solid-line portions of the tracks charted in this figure, the following standard plan and procedures apply:

1. Station interval was 60 nautical miles between 15° N. and 8° S., 120 miles at higher latitudes.

2. Serial oceanographic observations were made to 1,500 meters depth during cruises 2 and 5; to 1,200 meters during cruises 8, 11, and 14; to 500 meters during cruises 15 and 19; and to 400 meters during cruise 16.

3. The properties measured were temperature, salinity, oxygen, and phosphate. Oxygen determinations were omitted subsequent to cruise 11.

4. Subsequent to cruise 2, an oblique zooplankton tow from the surface to 200 meters was taken at each station with a meter net of #30xxx grit gauze.

5. Two 900-foot bathythermographs were taken at each station and at 10-mile intervals running along station lines. Casts were taken at 20- or 30-mile intervals while running other than along hydrographic station lines.

6. Surface current measurements were taken with the geomagnetic electrokinetograph (GEK) on cruises 14 and 19, and surface and deep currents were studied with the use of drags on cruise 16.

TABLE 1. TIME, LOCATION, AND OBSERVATIONS FROM OCEANOGRAPHIC CRUISES OF THE HUGH M. SMITH.

Cruise number	Dates	Location		Hydro-graphic stations	Plank-ton tows	BT casts
2	1/16/50-3/2/50	172°W[1]	24°N to 5°S	26	26[2]	269[4]
		158°W	5°S to 21°N	24	24[3]	215[5]
		Elsewhere		--	--	86
5	6/16/50-8/6/50	172°W[6]	27°N to 5°S	27[7]	27	208
		158°W	5°S to 21°N	24[7]	24	159
		Elsewhere		--	--	135
8	1/14/51-3/14/51	158°W	21°N to 7°S	24	24	96
		172°W[8]	14°S to 21°N	30	30	135
		155°W	2°N to 7°N[9])	50	50	280
		170°W	7°N to 7°S[9])			
		Elsewhere		--	--	23
11	8/20/51-10/6/51	150°W	5°S to 19°N	23	22	204
14	1/23/52-3/13/52	155°W	8°N to 7°S	16	16	127
		169°W	5°S to 7°N[10]	13	13	83
		180°W	9°N to 8°S[10]	18	18	119
		Elsewhere		--	--	126
15	5/21/52-7/1/52	140°W	9°N to 7°S[11]	60	77[12]	437
16	7/23/52-8/29/52	150°W	12°N to 7°S	30[13]	30[14]	303
19	1/8/53-2/12/53	162°W	6°N	25	20	112
TOTAL				390	401	3117

Footnotes for Table 1.

1/ At northern end of leg #1, the stations were on a line from 24°N, 167°W to 14°N, 172°W.

2/ Surface and oblique tows with a meter net of # 30xxx grit gauze.

3/ Surface and oblique tows with a meter net of #18xxx grit gauze.

4/ Includes 61 casts for internal wave study made while hove-to for 24 hours at 7°00'N, 172°00'W.

5/ This includes 24 casts for internal wave study made while hove-to for 24 hours at 2°03'N, 158°08'W.

6/ At the northern end the stations were on a line from 27°N, 175°W to 21°N, 172°W.

7/ At a few stations, the serial observations extended to 3,000 and 4,000 meters.

8/ At the northern end the stations were on a line from 21°N, 167°W to 14°N, 172°W.

9/ These stations were occupied along a zig-zag course. On 7 of the 8 legs, the serial oceanographic observations were made at 6 levels down to 300 meters, and only one BT cast was made at each station.

10/ North of 5°S, serial observations extended to 600 meters.

11/ The stations were occupied 4 times during a period of 3 weeks.

12/ Includes 17 surface phytoplankton hauls made with a 1-foot diameter net.

13/ The stations were 30 nautical miles apart between 5°N and 5°S.

14/ In addition, 30 surface phytoplankton hauls were made with a Clarke-Bumpus sampler, net of 56xxx grit gauze.

Figure 2. 1953 concept of equatorial circulation. By the broad arrows shown on the surface we indicate the long known South Equatorial Current on the left, the North Equatorial Current on the right, and the Equatorial Countercurrent between them. The small arrows indicating the transverse movement are based on isenstropic concepts applied during this past year (Townsend Cromwell, in press). The easterly flowing sub-surface current underlying the Equator was discovered by use of a drift drag technique during SMITH cruise 16 (Townsend Cromwell, R. B. Montgomery, and E. D. Stroup, in press). By this technique there was also confirmed the northerly transverse movement near the surface between the Equator and countercurrent and the complete lack of transverse movement in the countercurrent itself.

Figure 3. Surface temperature and phosphate. The data for this diagram were drawn from SMITH cruise 8 and consist of thermograph records of surface temperature and inorganic phosphate determinations of water samples from 10-meter levels. The data are lacking for the middle lower portion of this figure and the course of the isopleths as drawn may differ somewhat from the exact conditions existing at the time of survey. Owing to suspected deterioration of one of the reagents used in the chemical analysis there is some doubt as to the absolute values of phosphate concentrations. We believe the error, if it exists, is consistent throughout the determinations giving consistent relative values and hence a reliable pattern of isopleths.

Figure 4. Zooplankton abundance by latitude. As an indicator of relative productivity we have used the volume of zooplankton taken in hauls of a standard type described by King and Demond (1953), which sample the larger members of the zooplankton community in the upper 200-meter stratum of water. Daytime hauls caught less, on the average, than nighttime hauls. The volumes were adjusted for this variability by a method to be described by King and Hida (ms. in preparation). Thus the volumes represent the standing crop rather than the production, but owing to uniformity of the zooplankton composition and of the temperature in the waters with which we are concerned, the rate of turnover probably is fairly uniform and the standing crop proportional to the production. The summary of zooplankton abundance in the upper panel includes all of the hauls of HUGH M. SMITH cruises

Nos. 10, 12, and 17 in waters around Hawaii (See table 7). Those of the lower panel are distributed with respect to longitude and calendar quarters as shown in table 2.

Figure 5. Zooplankton abundance by longitude and season. In this figure there has been included only the hauls taken between latitudes 10° N. and 5°S. The distribution of hauls according to the range of latitude and month of each set of hauls is given in table 3.

Figure 6. Food of yellowfin tuna. The segments of the circles are proportional to the percentage of the total volume of stomach contents comprised by each of the designated constituents. The right hand circle is based on measurement of stomach contents of 775 yellowfin tuna caught by surface trolling and surface live-bait pole and line fishing within about 5 miles of islands in the Line Islands and Phoenix Islands groups; the middle circle on 97 deep-swimming yellowfin tuna caught by longline within about 10 miles of the same islands, and the left-hand circle on 214 caught in the equatorial region more than 10 miles from islands. Detailed data appear in J. W. Reintjes and J. E. King, 1953

Figure 7. Equatorial longline fishing cruises. There is summarized in table 4 the longline fishing at the stations charted in figure 7. For the most part, the fishing at each station consisted of the setting and hauling of 40 baskets of gear aggregating 8.4 nautical miles of mainline carrying 240 hooks. The only exceptions were the HUGH M. SMITH cruise when 25 to 35 baskets were set and the CAVALIERI cruise when 50 to 85 baskets were fished at each station. Except for SMITH cruise 7 the gear was constructed according to a standard plan (Niska, 1953). In addition to fishing, bathythermograph casts (BT) and plankton hauls were made as shown in the table 4.

Figure 8. Yellowfin tuna catch/100 hooks (July-November). This chart of yellowfin tuna concentration is based on HUGH M. SMITH cruises 7, 11, 18, JOHN R. MANNING cruises 12, 13, and the CAVALIERI cruise (see table 4). Where stations located within 50 miles of each other gave varying results on successive visits, the values were averaged to determine the position of the contour lines.

TABLE 2 - DISTRIBUTION OF ZOOPLANKTON HAULS BY LATITUDE, LONGITUDE, AND CALENDAR QUARTER

Latitude interval	Number of hauls, by longitude intervals							
	175°01'E-175°00'W	174°59'W-165°00'W	164°59'W-155°00'W	154°59'W-145°00'W	144°59'W-135°00'W	135°59'W-125°00'W	124°59'W-115°00'W	Total
20°00' - 24°59'N:								
Jan. Feb. Mar.		3	1					4
Apr. May, June		1	1					2
July, Aug. Sept.		2	1					3
Oct. Nov. Dec.			1					1
15°00' - 19°59'N:								
Jan. Feb. Mar.		3	2					5
Apr. May, June		2	1					3
July, Aug. Sept.		3	2	3				8
Oct. Nov. Dec.			5					5
10°00' - 14°59'N:								
Jan. Feb. Mar.		8	8					16
Apr. May, June		1	2					3
July, Aug. Sept.		4	6	8				18
Oct. Nov. Dec.			5					5
5°00' - 9°59'N:								
Jan. Feb. Mar.	5	10	15	4				34
Apr. May, June		2	2		18			22
July, Aug. Sept.		6	5	9				20
Oct. Nov. Dec.		1	9			3	2	15
0°00' - 4°59'N:[1]								
Jan. Feb. Mar.	5	19	19	3				46
Apr. May, June		1	3		17			21
July, Aug. Sept.		4	9	25				38
Oct. Nov. Dec.			3			4	6	13
0°00' - 4°59'S:[1]								
Jan. Feb. Mar.	4	17	12	1				34
Apr. May, June		6	2		19			27
July, Aug. Sept.		5	6	14				25
Oct. Nov. Dec.						3	3	6
5°00' - 9°59'S:								
Jan. Feb. Mar.	4	7	5					16
Apr. May, June					6			6
July, Aug. Sept.		1						1
Oct. Nov. Dec.							2	2
Total	18	106	125	67	60	10	13	399

Note. - In addition to the above, there have been three hauls made between latitudes 25° and 30°N and longitudes 170° and 180°W, and three between latitudes 10° and 15°S and approximately longitude 173°W.

Latitude interval	175°01'E-175°00'W	174°59'W-165°00'W	164°59'W-155°00'W	154°59'W-145°00'W	144°59'W-135°00'W	135°59'W-125°00'W	124°59'W-115°00'W	Total
20°00' - 24°59'N:								
Jan. Feb. Mar.		3	1					4
Apr. May, June		1	1					2
July, Aug. Sept.		2	1					3
Oct. Nov. Dec.			1					1
15°00' - 19°59'N:								
Jan. Feb. Mar.		3	2					5
Apr. May, June		2	1					3
July, Aug. Sept.		3	2	3				8
Oct. Nov. Dec.			5					5
10°00' - 14°59'N:								
Jan. Feb. Mar.		8	8					16
Apr. May, June		1	2					3
July, Aug. Sept.		4	6	8				18
Oct. Nov. Dec.			5					5
5°00' - 9°59'N:								
Jan. Feb. Mar.	5	10	15	4				34
Apr. May, June		2	2		18			22
July, Aug. Sept.		6	5	9				20
Oct. Nov. Dec.		1	9			3	2	15
0°00' - 4°59'N:1/								
Jan. Feb. Mar.	5	19	19	3				46
Apr. May, June		1	3		17			21
July, Aug. Sept.		4	9	25				38
Oct. Nov. Dec.			3			4	6	13
0°00' - 4°59'S:1/								
Jan. Feb. Mar.	4	17	12	1				34
Apr. May,June		6	2		19			27
July, Aug. Sept.		5	6	14				25
Oct. Nov. Dec.						3	3	6
5°00' - 9°59'S:								
Jan. Feb. Mar.	4	7	5					16
Apr. May, June					6			6
July, Aug. Sept.		1						1
Oct. Nov. Dec.							2	2
Total	18	106	125	67	60	10	13	399

Note. - In addition to the above, there have been three hauls made between latitudes 25° and 30°N and longitudes 170° and 180°W, and three between latitudes 10° and 15°S and approximately on longitude 172°W.

1/ For several stations exactly on the Equator the hauls were classed with N latitude when the vessel was proceeding northward and with S latitude when proceeding southward.

TABLE 4. SUMMARY OF SURVEY LONGLINE FISHING

Cruises and dates	Latitude	Longitude	Days fishing	BT casts	Zoo-plankton hauls
HUGH M. SMITH 7:					
10/20/50-11/1/50	12°N-3°N	157°W-158°W	11	106	12
11/6/50-11/16/50	6°N-4°N	159°W-168°W	7	89	5
11/18/50-11/27/50	11°N-0°	158°W-160°W	9	100	
Elsewhere				68	7
HUGH M. SMITH 11:					
8/24/51-9/4/51	15°N-2°N	150°W	12	109	11
9/5/51-9/19/51	2°N	151°W-157°W	10	10	10
9/20/51-9/25/51	1°N-4°S	150°W	6	69	7
Elsewhere				178	
JOHN R. MANNING 11:					
1/29/52-2/6/52	8°N-2°S	155°W	9	45	
2/16/52-2/24/52	3°N-8°S	180°W	9	44	
3/4/52-3/12/52	4°N-7°S	170°W	9	59	
CHARLES H. GILBERT 1:					
5/28/52-6/4/52	9°N-1°S	119°W-120°W	8	64	
6/8/52-6/13/52	8°N-0°	129°W-130°W	6	62	
Elsewhere				53	
JOHN R. MANNING 12:					
8/14/52-8/22/52	8°N-3°S	149°W-150°W	11	54	
8/31/52-9/4/52	0° -6°S	140°W	5	18	
Elsewhere				29	
CAVALIERI:					
8/21/52-9/6/52	7°N-1°N	140°W-141°W	17	19	
9/7/52-9/12/52	2°N-3°N	142°W-149°W	6	6	
9/13/52-9/20/52	4°N-1°N	149°W-152°W	8	8	
HUGH M. SMITH 18:					
10/18/52-11/2/52	9°N-10°S	120°W-121°W	15	116	13
11/5/52-11/15/52	9°N-5°S	130°W-132°W	11	52	10
Elsewhere				17	
JOHN R. MANNING 13:					
10/17/52-10/23/52	21°N-10°N	154°W-158°W	4	20	
10/25/52-11/7/52	7°N-3°S	151°W-152°W	11	63	
11/19/52-11/28/52	4°N-5°S	168°W-170°W	10	50	
Total			~~195~~ 194	1513	75

TABLE 3. DISTRIBUTION OF ZOOPLANKTON HAULS INCLUDED IN FIGURE 5 ACCORDING TO MONTH AND LATITUDE.

Longitude	Latitude range	Number of hauls
175°01'E - 175°00'W:		
February 1952	10°N - 5°S	14
174°59'W - 165°00'W:		
January, February 1950	9°N - 5°S	7
February 1951	7°N - 5°S	12
March 1951	10°N - 5°S	14
March 1952	7°N - 5°S	13
May, June 1951	9°N - 5°S	9
July 1950	10°N - 5°S	15
November 1950	6°N	1
Total		71
164°59'W - 155°00'W:		
January, February 1951	7°N - 0°	17
January, February 1951	10°N - 5°S	14
January, February 1952	2°N - 5°S	7
February 1950	9°N - 5°S	8
May, June 1951	8°N - 2°S	7
July, August 1950	10°N - 5°S	15
September 1951	3°N - 0°S	5
October, November 1950	10°N - 1°N	12
Total		85
154°59'W - 145°00'W:		
January 1951	6°N	1
January 1952	8°N - 4°S	7
August 1952	3°N - 4°S	14
August, September 1951	10°N - 5°S	34
Total		56
144°59'W - 135°00'W:		
May, June 1952	10°N - 5°S	54
134°59'W - 125°00'W:		
November 1952	10°N - 5°S	10
124°59'W - 115°00'W:		
October 1952	8°N - 5°S	11
Grand Total		301

Figure 9. Yellowfin tuna catch/100 hooks (January-June). This chart is based on JOHN R. MANNING cruise 11 and CHARLES H. GILBERT cruise 1 (see table 4).

Figure 10. Relative abundance of yellowfin tuna in the western equatorial Pacific. Catches of the nine Japanese mothership tuna fishing expeditions from June 1950 to October 1951 were summarized by catching area. The weighted mean number of yellowfin caught per hundred hooks fished was computed for each rectangle of 1° of latitude by 5° of longitude as the basis for drawing the contour lines of figure 11.

Figure 11. Seasonal fluctuations in the longline catch rate in the western Pacific. Each bar represents the weighted mean number of yellowfin tuna caught per hundred hooks fished between latitude 1°N. and 5°N. by all boats of the nine Japanese mothership tuna fishing expeditions from June 1950 to October 1951.

Figure 12. Comparison of catch rates from Japanese commercial and POFI experimental fishing. There are included in this graph the results of Japanese commercial fishing for 21 days at the several latitudes along longitude 170°W. during the period October 27 to November 23, 1952, and the results of 10 days' fishing by the JOHN R. MANNING along the same longitude during the period November 19-28, 1952. The Japanese fished with 390 baskets per day, on the average, whereas the MANNING set only 40 baskets per day.

Figure 13. Abundance of yellowfin at 150° W. longitude on successive cruises. This graph is based on HUGH M. SMITH cruise 11, JOHN R. MANNING cruises 11, 12, 13, and the CAVALIERI cruise. The catches are the average of the four adjacent stations with the highest catch rate along the given longitude. Thus they represent the richest 240-mile-wide band regardless of the latitudinal shifts in this band.

Figure 14. Tuna spawning near the Equator. The determinations were made by Fred C. June by measuring the diameter of ova in the gonad and classifying the degree of maturity according to criteria given in Fred C. June, 1953.

Figure 15. Distribution of tuna larvae in central Pacific. The values given in the graph are based on the plankton tows taken on HUGH M. SMITH cruises 5, 8, and 11. When tuna larvae are less than 5 millimeters (one-fifth of an inch), we have not been able to identify them as to species. However, we find it possible to identify larvae of yellowfin after they have reached more than 5 millimeters of length. It is likely that many of the larvae designated as "all other tuna larvae" are also yellowfin tuna.

Figure 16. Index to racial difference of yellowfin between sample localities. In table 5 are listed the numbers of yellowfin tuna whose morphometric measurements entered the calculations on which figure 17 is based. The numerical values given in this figure are the "reduced coefficient of racial likeness" computed according to the formula:

$$R\,C\,R\,L = 50\left(\frac{\bar{n}_1 + \bar{n}_2}{\bar{n}_1 \bar{n}_2}\right)\left[\Sigma\left\{\frac{1}{M}\left(\frac{(m_s - m_{s'})^2}{\frac{\sigma_s^2}{n_s} + \frac{\sigma_{s'}^2}{n_{s'}}}\right)\right\} - 1\right]$$

in which m_s is the mean of the sth character estimated for 100 cm. fork length, σ_s the standard error of estimate of the regression of the sth character on fork length, n_s the number of observations of the sth character, $\bar{n}$, the mean number of observations of all characters in the sample and M the number of characters. The symbols s' and n_2 refer to the characters in the second sample.

Figure 17. Equatorial commercial fishing. Because of the especial interest attached to the commercial aspects of equatorial fishing results there is given herewith in table 6 the results of each day's fishing by the CAVALIERI. Of the fish included in this table, 17.7% of the yellowfin. 16.9% of the bigeye and 10.3% of the skipjack were damaged by sharks. It is estimated that the damage on approximately half of these was slight enough not to have affected their commercial acceptability. The yellowfin taken east of 145° W. longitude averaged 148 lbs. each while those taken west of this meridian averaged only 128 lbs.

TABLE 5. NUMBER OF YELLOWFIN TUNA FOR WHICH MORPHOMETRICAL MEASUREMENTS WERE TAKEN BY LOCALITY AND LENGTH CLASSES

Locality	Length cm.												
	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-99.9	100-109.9	110-119.9	120-129.9	130-139.9	140-149.9	150-159.9	160-179.9	Total
North of 10°N lat:														
Hawaii	16	15	3	2	4	9	15	6	17	29	22	15	50	203
Japan	12	6	6	8	8	6	1							47
Off Luzon, P.I. 1/	1	59	122	62	47	19	9	6	15	11	5	2		358
10°N to 10°S lat:														
Costa Rica		2	7	3	6	11	6	5	2		2	1		46
120°-130°W						1			3	5	17	13	4	43
Line I.	1	2	9	25	30	31	31	21	17	19	24	39	6	255
Palmyra 2/		1	10	24	18	27	10	2	1		1			94
Phoenix I.		4	18	14	16	19	10	24	13	8	3		1	130
Marshall I. 3/		21	6	4	5	4	3	1						44
Caroline I.														
Eastern	1	8	23	18	19	16	6	14	12	21	9	11	1	159
Central	1	6	11	19	21	21	33	27	33	24	13	2		211
Western			2	1	1	3		2	7	1				17
South of 10°S lat:														
Society	2	15	3	2	8	1					2			33
Fiji 2/		1	2		3	1	6							13
Total	34	140	222	182	186	169	130	109	120	118	98	83	62	1653

1/ Measurements supplied by Dr. D. V. Villadolid.

2/ Godsil and Greenhood (1951).

3/ Measurements supplied by Mr. J. C. Marr, Fish and Wildlife Service, Stanford, California. Partly collected near Bikini Atoll, which is at 12°N latitude.

TABLE 6. CATCH RECORD OF THE SEMI-COMMERCIAL FISHING OF THE CAVALIERI, AUGUST 21 TO SEPTEMBER 20, 1952.

Date	Position		Baskets	Yellowfin	Bigeye	Skipjack	Marlin	Shark
	Latitude	Longitude						
Aug. 21	07°07'N	140°47.6'W	50	2	1		2	2
22	05°58'	140°30'	50	4	1		2	11
23	05°14'	140°14'	60	15	4			8
24	04°23'	139°38'	60	18		4		3
25	03°26'	139°56'	60	34	7	2		8
26	02°23'	140°02.5	61	32				5
27	01°32'	139°55'	70	49		1		12
28	00°59'	140°07'	70	12		1	1	6
29	02°05'	140°22'	70	24		1		6
30	03°37'	140°15'	70	25	1	1	1	7
31	03°39'	140°15'	76	34			1	12
Sept. 1	03°31'	140°12.5'	70	13		1		6
2	03°04.5'	139°52'	79	19		4		5
3	04°02'	139°57'	79	8				14
4	03°15.5'	139°58'	60	12	1			3
5	02°24'	140°12'	75	22	4	2		
6	02°11'	140°32'	79	23	3	1		6
7	01°51'	141°49.5'	80	18	3		1	6
8	02°25'	142°04'	80	23	4			5
9	02°30.5'	142°57'	80	21	1			7
10	02°12'	144°59'	80	15	1	5		2
11	02°45'	147°05.5'	80	20			1	5
12	02°25'	148°47'	80	9	4		1	10
13	01°17'	149°18'	80	27	4	1	2	8
14	01°34'	149°47.5'	81	27	2	2		9
15	01°57.5'	150°02'	80	24	2		2	3
16	02°23.5'	150°17'	85	15	2		2	1
17	03°19'	151°24'	80	33	3		1	1
18	03°37'	151°36'	80	61	6	3	1	8
19	03°44.5'	151°54.5'	80	43	6			4
20	04°04'	152°10.5'	80	38	5			12
Total				720	65	29	18	195

Note: Of the above the following were damaged by sharks: yellowfin, 17.7%; bigeye, 16.9%, skipjack, 10.3%.

Figure 18. Acceptance of CAVALIERI longline tuna for canning. The percentages indicated in the graph are based on a sample of the catch which was tagged prior to unloading. In this manner individual fish could be identified with their original weights after the precooking operation, which is the stage when the acceptability of fish is established. The sample consisted of 72 out of a total catch of 720 yellowfin.

Figure 19. Variation in size of yellowfin along the Equator. The data plotted in this figure were taken from length measurements converted to weights according to a weight on length regression. Included are lengths of 10,048 yellowfin tuna from equatorial survey catches distributed as follows:

Japanese mothership expeditions:		POFI survey fishing:	
138°E.	195	180°W.	55
145°E.	2,699	170°W.	107
151°E.	382	160°W.	137
158°E.	3,254	155°W.	75
165°E.	1,236	150°W.	722
172°E.	730	145°W.	98
		140°W.	308
		130°W.	31
		120°W.	19

Figure 20. Known trans-Pacific distribution of yellowfin tuna. The geographical extent of the Japanese longline fishery is based on published records of pre-war Japanese fishing activities, on data from POFI observers' records on Japanese mothership expeditions from occupied Japan, and on gleanings from newspaper and trade journal accounts of post-treaty Japanese fishing. The outline indicating the area of American yellowfin and skipjack fishery follows Godsil (1938 Calif. F. B. 51, figure 3).

Figure 21. Bait resources in the central Pacific. Material of this figure and the text below it were drawn from June and Reintjes, 1953.

Figure 22. Mid-winter sampan fishing in Line Islands. The sampan TRADEWIND with a crew of 10 men sailed from

Honolulu January 8, 1953 and returned February 12, 1953. Some pertinent data are:

Running	13 days
Fishing for bait	7 days
Fishing for tuna	8 days
Fishing for market fish	4 days
Transferring fish and supplies . . .	2 days
Weatherbound	2 days
Total	26 days

Fishing for bait:

Palmyra I., 20 hauls caught 2,315 lbs. mullet.
Christmas I., 5 hauls caught 840 lbs. mixed fish.
Fanning I., 6 hauls caught 850 lbs. mullet.

Fishing for tuna:

Palmyra I., 16 schools worked, 7 tons caught.
Christmas I., 1 school worked, none caught.
Fanning I., 10 schools worked, 6-1/2 tons caught.
Incidental trolling, 71 tuna caught.

Proceeds from sale of fish	$3,809
Expenses	$2,426
Share per fisherman	$ 164

Figure 23. Search for bait substitutes. This figure summarizes experiments conducted during 1952 by contract with the University of Hawaii under the direction of Prof. Albert L. Tester at the University's Marine Laboratory on Coconut Island, Oahu. The tests of chemical fractions, shown as shaded portions of the bars, were directed toward discovery of the chemical identity of the attractive substance in the various extracts of fish tissues.

Figure 24. Distribution of skipjack catch around the Hawaiian Islands. Each dot on the chart represents a catch of 50,000 pounds made during the average year of the years 1948 to 1952 according to statistics collected by Territory of Hawaii, Board of Commissioners of Agriculture and Forestry, Division of Fish and Game.

Figure 25. Hawaiian skipjack landings 1949-1952. The data shown on these graphs are the catches of the live-bait tuna fleet of Hawaii and were furnished by the Territory of Hawaii, Board of Commissioners of Agriculture and Forestry, Division of Fish and Game. The figures for the last 2 months of 1952 are preliminary totals subject to revision.

Figure 26. Survey plan for Hawaiian hydrography. Our plans for future work are based in part on a considerable amount of hydrographic observations and plankton tows already made in Hawaiian waters and summarized in table 7.

These observations were taken as follows:

1. The station pattern was planned to cover waters immediately around the islands and extending offshore 50-100 miles in order to include the transition from conditions associated with the presence of islands to conditions that are practically oceanic.

2. At each station serial oceanographic observations were taken to 1, 200 meters except where the water was too shoal.

3. The properties measured were temperature and salinity on all cruises and included dissolved oxygen on cruises 1 and 10 and inorganic phosphate on cruises 10, 12, 17, and 20.

4. Zooplankton hauls were of approximately 1/2-hour duration and were taken with a meter net of 30xxx grit gauze in the manner indicated. Cruise 1, being the shakedown cruise, also tested nets of 56xxx and 18xxx mesh.

5. Two bathythermograph casts were made at each station and at 10-mile intervals between stations. They were to 900 feet on all cruises with the exception of the first six casts on cruise 1, which were to 450 feet.

6. Surface current measurements on station and midway between stations were taken with the geomagnetic electrokinetograph (GEK) on cruises 12 and 20.

TABLE 7. OCEANOGRAPHIC CRUISES IN WATERS SURROUNDING THE HAWAIIAN ARCHIPELAGO.

Cruise number [1]	Dates	Stations		Zooplankton Hauls		BT casts
		Number occupied	Usual spacing [2]	Type	No. taken	
S I	12/8/49-12/21/49	16 [3]	30 [4]	Surface, horizontal	14	80
S 10	7/19/51-7/31/51	33	40	Oblique to 200 m.	33	169
M 8	9/23/51-10/19/51	--	--	Oblique to 200 m.	36	69
S 12	10/23/51-11/3/51	30	40	Surface, horizontal	30	147
S 17	9/5/52-9/15/52	31 [5]	45	Oblique to 200 m.	30 [6]	160
S 20	2/25/53-4/4/53	69	40 [7]	Oblique to 200 m. [8]	69	235
Total		179			212	860

1/ Cruises made by the JOHN R. MANNING are prefixed with M, those by the HUGH M. SMITH, with S.

2/ Station spacing is in nautical miles.

3/ Serial observations were to various depths down to 1,500 meters.

4/ On lines 100 miles apart.

5/ Serial observations were to 700 meters.

6/ In addition, surface phytoplankton hauls were made at 9 stations with a 1-foot net, #25 silk.

7/ Two legs to 29° N have a station spacing of 60 miles.

8/ One surface tow on Penguin Banks, 21°-5'N, 157°36'W.

Figure 27. Winter sightings of skipjack. Charted in this figure is the track of CHARLES H. GILBERT cruise 7 and flights 2 and 3. Altogether there were four scouting cruises and four flights between September 1952 and March 1953.

Figure 28. The Hawaiian longline fishery. Statistics were furnished by the Territory of Hawaii, Board of Commissioners of Agriculture and Forestry, Division of Fish and Game.

Figure 29. The age and growth of yellowfin. This figure is adapted from Harvey L. Moore, 1951, figure 9.

APPENDIX 2 - PUBLICATIONS RESULTING FROM PACIFIC OCEANIC FISHERY INVESTIGATIONS

Bates, Donald H., Jr.

1950. Tuna trolling in the Line Islands in the late spring of 1950. U. S. Fish and Wildlife Service Fishery Leaflet 351, Oct. 1950.

Cleaver, Fred C. and Bell M. Shimada.

1950. Japanese fishing methods for skipjack (Katsuwonus pelamis). U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 12, No. 11, Nov. 1950, pp. 1-27. Sep. No. 260.

Cromwell, Townsend.

1951. Mid-Pacific oceanography, January through March 1950. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 54, July 1951.

1953. Circulation in a meridional plane in the central equatorial Pacific. Jour. of Mar. Res., Vol. 12, No. 2.

--------, R. B. Montgomery and E. D. Stroup.

1953. A newly discovered ocean current. Science.

Dung, Dorothy I. Y. and William F. Royce.

1953. Morphometric measurements of Pacific scombroids. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. 95, Feb. 1953.

Ego, Kenji and Tamio Otsu.

1952. Japanese tuna mothership expeditions in the western equatorial Pacific Ocean, June 1950 - June 1951. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 14, No. 6, June 1952. Sep. No. 315.

Ikehara, Isaac I.

1953. Live bait fishing for tuna in the central Pacific. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 107, July 1953.

June, Fred C.

1950 A. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part I-The Hawaiian longline fishery. U. S. Fish and Wildlife Service Comm. Fish. Rev. Vol. 12, No. 1, pp. 1-23, Jan. 1950. Sep. No. 244.

1950 B. The tuna industry in Hawaii. Pan-American Fisherman, 4(10) pp. 11, 19. April 1950.

1951 A. Preliminary fisheries survey of the Hawaiian-Line Islands area, Part II-Notes on the tuna and bait resources of the Hawaiian, Leeward, and Line Islands. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 13, No. 1, January 1951. Sep. No. 270.

1951 B. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part III - The live-bait skipjack fishery of the Hawaiian Islands. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 13, No. 2, February 1951. Sep. No. 271.

1951 C. Notes on the feeding habits of the giant white marlin of the Pacific. Pacific Science, Vol. 5, No. 3 July 1951.

1952 A. Observations on a specimen of bluefin tuna (Thunnus thynnus) taken in Hawaiian waters. Pacific Science, Vol. VI, No. 1, January 1952.

1952 B. An "unusual" yellowfin tuna (Neothunnus macropterus) from the waters of the northern Line Islands in the central Pacific Ocean. Copeia, No. 3, 1952, pp. 210-211.

June, Fred C.

1953. Spawning of yellowfin tuna (Neothunnus macropterus) around the Hawaiian Islands. Fishery Bulletin No. 77, Vol. 54, pp. 47-64.

-------- and John W. Reintjes.

1953. Common tuna bait fishes of the central Pacific islands. Research Report No. 34.

King, Joseph E.

1951. Two juvenile pointed-tailed ocean sunfish, Masturus lanceolatus, from Hawaiian waters. Pacific Science, Vol. V, No. 1, January 1951, pp. 108-109.

-------- and Joan Demond.

1953. A quantitative study of the zooplankton of the central Pacific. Fishery Bulletin No. 82, Vol. 54, pp. 111-144.

Matsumoto, Walter M.

1953. Experimental surface gill net fishing for skipjack (Katsuwonus pelamis) in Hawaiian waters. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 90, Nov. 1952.

McKernan, Donald L.

1953. Pioneer longlining for tuna along the Equator. Pacific Fisherman, Vol. 51, No. 8, pp. 19, 21, 23, July 1953.

Moore, Harvey L.

1950. The occurrence of a black marlin, Tetrapterus mazara, without spear. Pacific Science 4 (2) p. 164. April 1950.

Moore, Harvey L.

1951. Estimation of age and growth of yellowfin tuna (Neothunnus macropterus, Temminck and Schlegel) in Hawaiian waters by size frequencies. U. S. Fish and Wildlife Service Fishery Bulletin No. 65.

Murphy, Garth I. and Richard S. Shomura.

1952. New tuna sources. Pan-American Fisherman, Vol. 6, No. 10, pp. 14, 16, May 1952.

-------- and Edwin L. Niska.

1953. Experimental tuna purse seining in the central Pacific. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 15, No. 4, April 1953.

-------- and Richard S. Shomura.

1953 A. Longline fishing for deep-swimming tunas in the central Pacific, 1950-1951. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 98, May 1953.

1953 B. Longline fishing for deep-swimming tunas in the central Pacific, January-June 1952. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 108, August 1953.

Niska, Edwin L.

1953. Construction details of tuna longline gear used by the Pacific Oceanic Fishery Investigations. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 15, No. 6, June 1953. Sep. No. 351.

Reinjtes, J. W. and J. E. King.

1953. The food and feeding habits of the yellowfin tuna (Neothunnus macropterus) of the central Pacific. Fishery Bulletin 81, Vol. 54.

Royce, William F.

1953. Preliminary report on a comparison of the stocks of yellowfin tuna. Proceedings of the 4th meeting of the Indo-Pacific Fisheries Council, Part II. (In press.)

Schaefer, M. B.

1951. Some recent advances in the study of the biology and racial divisions of Pacific tunas. Indo-Pacific Fisheries Council Proceedings, 2nd meeting, April 1950, Cronulla, Australia, pp. 63-69. Bangkok, January 1951.

1952. Comparison of yellowfin tuna of Hawaiian waters and of the American west coast. U. S. Fish and Wildlife Service Fishery Bulletin 72, Vol. 52, 1952.

-------- and John W. Reintjes.

1950. Additional records of confirming the trans-Pacific distribution of the Pacific saury, Cololabis saira (Brevoort). Pacific Science 4 (2), p. 164, April 1950.

Sette, O. E.

1949. Pacific Oceanic Fishery Investigations, Copeia, No. 1, April 15, 1949.

1950. Methods of biological research on pelagic fisheries resources. Indo-Pacific Fisheries Council Proceedings, 1st Meeting, Singapore, March 1949. Singapore 1950.

-------- and M. B. Schaefer.

1951. Pacific Oceanic Fishery Investigations. Indo-Pacific Fisheries Council Proceedings, 2nd Meeting, Cronulla, Australia, April 1950, pp. 85-87. Bangkok, January 1951.

Shapiro, Sidney.

1950. The Japanese longline fishery for tunas. U.S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 12, No. 4, April 1950. Sep. No. 249.

Shimada, Bell M.

1951 A. Japanese tuna-mothership operations in the western equatorial Pacific Ocean. U. S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 13, No. 6, June 1951. Sep. No. 284.

1951 B. An annotated bibliography on the biology of Pacific tunas. U. S. Fish and Wildlife Service Fishery Bulletin No. 58, Vol. 52.

1951 C. Juvenile oceanic skipjack from the Phoenix Islands. U. S. Fish and Wildlife Service Fishery Bulletin No. 64, Vol. 52.

1951 D. Contributions to the biology of tunas from the western equatorial Pacific. U. S. Fish and Wildlife Service Fishery Bulletin No. 62, Vol. 52.

Tester, Albert L.

1952. Establishing tuna and other pelagic fish in ponds and tanks. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 71, Feb. 1952.

-------- P. B. Van Weel, S. C. Hsiao, and I. Miyake.

1952. Reaction of tuna and other fish to stimuli - 1951. U. S. Fish and Wildlife Service Spec. Sci. Report: Fish. No. 91, Nov. 1952.

Van Campen, Wilvan G.

1952. Japanese mothership-type tuna-fishing operations in the western equatorial Pacific, June to October 1951. (Report of the 7th, 8th and 9th Expeditions). U.S. Fish and Wildlife Service Comm. Fish. Rev., Vol. 14, No. 11, November 1952. Sep. No. 326.

Van Campen, Wilvan G.

1953. Tuna fishing at Tahiti. U. S. Fish and Wildlife Service Comm. Fish. Rev., October 1953. (In press.)

-------- and Bell M. Shimada.

1950. The Japanese albacore fishery in the north central Pacific. Pacific Fisherman, November 1950, pp. 29-33. U. S. Fish and Wildlife Service Fishery Leaflet No. 388, February 1951.

Yuen, Heeny S. H. and Joseph E. King.

1953. Sampan from Hawaii visits Line Islands. Pan-American Fisherman, Vol. 7, No. 12, July 1953.

In addition to the publications issued or in press, reports are under preparation on the following subjects:

1. Mid-Pacific oceanography, April to December 1950.
2. Mid-Pacific oceanography, January to June 1951.
3. Results of current drag experiments of SMITH cruise No. 16.
4. Variations in zooplankton abundance in Hawaiian waters, 1950-1952.
5. The variability of estimates of yellowfin tuna from longline catches.
6. Occurrence of tuna in surface waters of the Central Pacific as indicated by trolling and by sighting fish schools and bird flocks.
7. Analysis of the catches of nine Japanese mother-ship expeditions to the western tropical Pacific.
8. Longline fishing for deep-swimming tunas in the central Pacific, August to November 1952.
9. The oxygen requirements of Hawaiian tuna bait fish.
10. The tuna long-line fishery of Hawaii, 1949-1952.
11. The response of tuna to chemical stimuli, 1952-1953.

APPENDIX 3 - TRANSLATIONS

The following foreign-language fisheries publications are currently received, reviewed, and significant articles are translated. (For publications which also have English titles, the title in the original language is given in parentheses; for those which do not, the translation of the original title is given in brackets.)

Arsberetning fra Danmarks fiskeri- og havsundersøgelser [Annual report of Danish fishery and sea investigations].

Berita Perikanan [Fishery News], published by the Sea Fisheries Service of the Republic of Indonesia.

Boletín and Contribuiciones Técnicas, Instituto de Pesca del Pacífico [Bulletin and Technical Contributions, Fishery Institute of the Pacific] (Mexico).

Boletin and Trabajos, Instituto Español de Oceanografía [Bulletin and Works, Spanish Institute of Oceanography].

Bollettino di Pesca, Piscicoltura e Idrobiologia [Bulletin of Fisheries, Fish-culture, and Hydrobiology] (Italy).

Bulletin of the Faculty of Fisheries, Hokkaidō University (Hokkaidō Daigaku Suisangakubu Kenkyu Ihō).

Bulletin of the Japanese Society of Scientific Fisheries (Nippon Suisan Gakkai Shi).

Bulletin of the Tōkai Regional Fisheries Research Laboratory (Tōkaiku Suisan Kenkyūsho Kenkyū Hōkoku).

Ciencias Zoológicas and Miscelanea, Museo Argentino de Ciencias Naturales Bernardino Rivadivia [Zoological Sciences and Miscellany, Bernardino Rivadivia Argentine Museum of Natural Sciences].

Die Fischwirtschaft [The Fish Business] (Germany).

España Pesquera [Fisheries Spain].

Fishing Industry Weekly (Suisan Shūhō) (Japan).

Investigaciones Zoológicas Chileñas [Chilean Zoological Investigations].

Jahresbericht über die Deutsche Fischerei [Yearly Report on the German Fisheries].

Japanese Journal of Ichthyology (Gyoruigaku Zasshi).

Journal of the Faculty of Fisheries, Mie Prefectural University (Mie Kenritsu Daigaku Suisangakubu Kiyō).

Journal of the Fukuoka Prefectural Fishery Experiment Station (Fukuoka-ken Suisan Shikenjō Hōkoku).

Journal of the Fisheries Research Institute (Suisan Kenkyūkai Hō) (Japan).

Journal of the Shimonoseki College of Fisheries (Nōrinshō Suisan Kōshūjo Kenkyū Hōkoku).

Kanagawa Suiken Geppō [Monthly Report of the Kanagawa Prefecture Fisheries Experiment Station].

Kanagawa-ken Suisan Shikenjo Gyōmu Hōkoku [Progress Reports of the Kanagawa Prefecture Fisheries Experiment Station].

Memorie, Comitato Talassografico Italiano [Memoirs of the Italian Oceanographic Committee].

Nippon Suisan KK. Kenkyūsho Hōkoku [Nippon Suisan Co. Research Laboratory Reports].

Nippon Suisan Shimbun [Japan Fisheries Newspaper].

Pesca y Caza [Fishing and Hunting] (Peru).

Protokolle zur Fischereitechnik, Institut für Netz- und Materialforschung [Reports on Fishery Technology, Institute for Net and Materials Research] (Germany).

Publicaciones del Instituto de Biología Aplicada, Barcelona [Publications of the Institute of Applied Biology, Barcelona].

Reports of the Nankai Regional Fisheries Research Laboratory (Nankai-ku Suisan Kenkyūsho Hōkoku).

Skrifter Udgivet af Kommissionen for Danmarks Fiskeri- og Havsundersøgelser [Papers Published by the Commission for Danish Fishery and Oceanographic Research].

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