REDISTRIBUTION OF FISHES IN THE EASTERN NORTH PACIFIC OCEAN IN 1957 AND 1958

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Anomalies of fish distribution may be regarded as an effect of variations in ocean climate. During the extremely warm years of 1926 and 1931 there was a heavy influx of southern species into the waters of California (Hubbs and Schultz 1929 and Walford 1931), and again in 1957 and 1958, there has been a mass northward movement of southern species. Examples of the northward distribution of southern fish have been listed in Table 1.

TABLE 1

Some of the Warm Water Fish Species Collected in California Waters During 1957 and Early 1958

No. taken	Common name	Scientific name	Years formerly reported	Location of capture in 1957
1	Bullet mackerel	*Auxis* sp.	1918 1919 1935	Coronado Island
2	Sharpchin flying fish	*Fodiator acutus*	1931	Long Beach
1	Tai or Porgy	*Calamus brachysomus*	1953?	Oceanside
1	Shortnose spearfish	*Tetrapturus anguistirostris*	(Never previously taken off California)	60 mile bank
1	Spiny trunkfish	*Lactoria diaphanus*	1932 1933 1949 1951*	Santa Monica Bay
2	Pilotfish	*Naucrates ductor*	1926 1936 1945	San Clemente Island
5	Triggerfish	*Verrunculus polylepis*	1924 1931 1946 1950 1951 1956*	Santa Monica Bay, Laguna Beach and San Diego Paradise Cove Dana Point
1	Monterey spanish mackerel	*Scomberomorous concolor*	1931 1937 1939 1944 1947 1948 1949 1951 1952 1953 1954 1956*	Santa Barbara
1	Green jack	*Caranx caballus*	1858 1924 1945 1953 1955*	Belmont Shore
1	Razorback scabbardfish	*Assurger anzac*	1951	Coronado Island
1	Thread herring	*Opisthonema libertate*	1947 1948 1954*	Belmont Shore

* Probably other years, also.

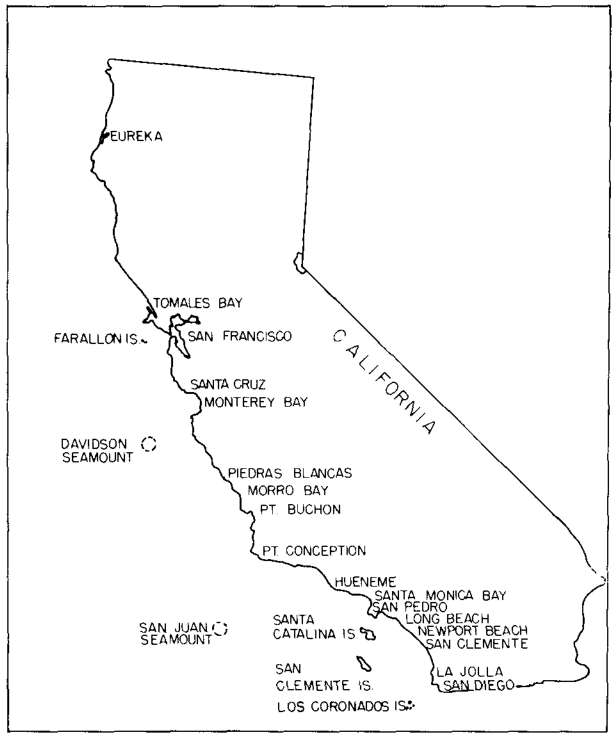

FIGURE 148. Location chart of the coast of California.

Since preparation of this table reports of southern species of fish have continued to come in to the California State Fisheries Laboratory. Another pilot fish *(Naucrates ductor)* was collected at San Clemente Island (Fig. 148) during August of 1957. A razorback scabbord fish, *(Assurger anzac)* was caught off North Coronados Island in May. This species had not been taken locally since 1950 when one was collected from Santa Monica Bay. Incidentally, some of these occurrences are of rare species and do not necessarily represent northward extensions. A yellow snake-eel *(Ophicthus zophochir)* was collected at Newport Beach, California, in December 1957. Another trigger fish *(Verunculus polylepis)* was collected in March of 1958 off Dana Point (north of San Clemente City). A thread herring *(Opisthonema libertate)* was caught off Belmont pier (south of Long Beach) on May 29, 1958. In August of 1957 an ocean white fish *(Caulolatilus princeps)* was caught off the Farallon Islands.

Among the conspicuous invertebrates, *Velella* Sp. have been abundant from San Francisco to Alaska. The pelagic red crab *(Pleuroncodes planipes)* was abundant in December of 1957 from La Jolla to San Pedro. Its last occurrence in real abundance was in April of 1941, another year of high water temperatures. Green sea turtles were seen by albacore fishermen, during 1957, as far north as Oregon and Wash-

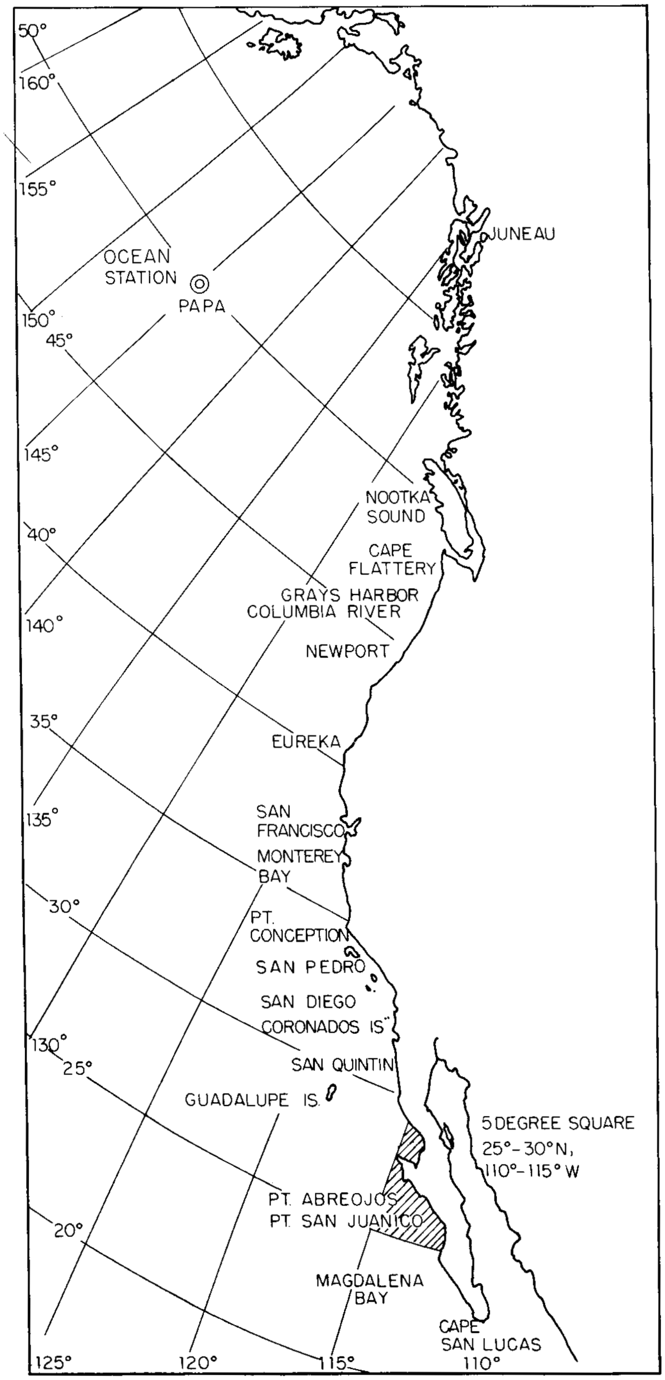

FIGURE 149. Location chart of the Pacific Coast of Alaska, Canada, United States, and Baja California, Mexico.

ington and off British Columbia as far as Nootka Sound in April and May of 1958.

In addition to these species, Dr. Hubbs has called to my attention the fact that a large number of tropical sea birds were seen far north of their usual range, including southern skuas; frigate birds; and black, ashy, and leach petrels. Also, I received a note from British Columbia indicating that at ocean station "PAPA" at 50°N. Lat. and 145°W. Long. (Fig. 149), black-footed albatross were less abundant than usual during late summer of 1957, while Laysan albatross were more numerous; becoming even more common than the black-footed albatross.

One of the first unusual events that was called to our attention was a die-off of sea gulls in May of 1957. Although we were able to confirm the fact that there was a widespread die-off, we did not find out why the gulls were dying, however, concurrently red water, which usually occurs during warmer months, was noticed off the coast. During the same month, sea otters were reported to have been observed in an area just north of Piedras Blancas, for the first time in the last three decades. They were eating quantities of abalone. The California Department of Fish and Game abalone diving crew investigated the reports and found many broken abalone shells showing typical sea otter breakage patterns.

Probably the first real clue the California Department of Fish and Game had of the changed ocean climate came from the popular sportfish, the yellowtail, (*Seriola dorsalis*). Yellowtail catches at Los Coronados Islands were exceptionally good in March. By the end of April, when we became alerted to the fact that certain events were unusual in 1957, the yellowtail sport catch had exceeded the total of the previous year. In May, more yellowtail schools were observed during the Department's aerial surveys than on any during the previous three years. Some schools were seen as far north as Catalina Island. Through May and June sports fishing continued good and by the end of July the yellowtail catch had exceeded 100,000 fish. By the end of August, the catch was more than double the next best recorded year, 1947. In September, sport fishing continued good throughout Southern California and the October catch of yellowtail exceeded all other species taken on party boats. Some yellowtail were caught in the Los Angeles-Long Beach area during November and December, while the catches off Los Coronados Islands remained good. From January to April of 1958, yellowtail continued to be caught off Southern California and on May 4th 1958 several small yellowtail between two and three pounds were caught outside the Long Beach breakwater. They were mixed with a school of bonito. Another small yellowtail was also caught on May 4th from kelp off Long Beach. It was twelve inches long and weighed only 16 oz. These were the first juvenile

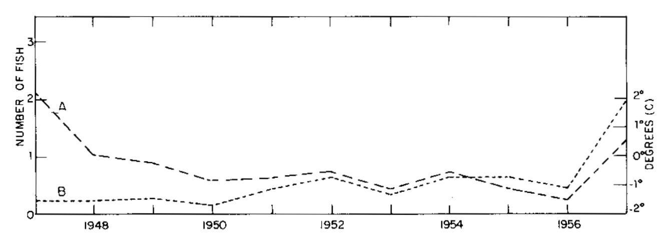

FIGURE 150. Party boat catch per angler day (1947-1957) of (A) barracuda off Southern California, and (B) yellowtail off the Los Coronados Islands, Baja California.

yellowtail recorded from Southern California by the California Department of Fish and Game.

Barracuda *(Spyraenia argentia)* fishing was also phenomenal, but it did not start until a little later. On figure 150 you will note that the catch per angler day was high in 1957 for both the yellowtail and the barracuda. In addition, the manner in which the sport catch of these two species has varied since 1947 is similar, indicating that sportfishing for both species might be related to the same oceanic conditions.

To examine this more closely, let us look at what is known about the distribution of these two species. In general, the Southern California area represents the northern limit of the yellowtail population, which extends southward along the Baja California coast and into the Gulf of California. While the yellowtail is, perhaps, the most popular marine sport fish in Southern California, most of its population is far south of the sport fishery. On the other hand, the barracuda population does not extend nearly as far southward as does the yellowtail. Its biological range extends only to Magdalena Bay. South of Pt. Abrejos, the population tapers off rapidly and barracuda are encountered only occasionally south of Pt. San Jaunico. In the past six or eight years, barracuda have been plentiful in the area just north of Pt. Abrejos. Although their abundance drops off abruptly at the southern end of their range, they extend northward a considerable distance and gradually diminish in numbers. This suggests that they prefer the warmer waters of their range, but have a broad tolerance for cold water. Apparently they do not tolerate the warmer water south of Magdalena Bay but are most abundant near the warmest part of their range.

The barracuda fishery usually develops in the late spring or summer off Southern California. Yellowtail show up during the early spring. Both are caught every summer by sportfishermen and neither remain all winter except perhaps, during years of unusually warm water. Therefore, Southern California is a fringe fishing area for both species.

Since both species begin to spawn around July, a preference for a narrow range of temperatures during their spawning period could influence their movement northward.

The barracuda catch per angler day for all anglers fishing on party boats off Southern California, and the yellowtail catch per angler day for all anglers fishing on party boats at Los Coronados Islands, for each year since 1947, are shown on Figure 150. Since these are the preferred species, I am assuming that whenever party boats fished, they were fishing for the two species. When large numbers of other fish are caught, it is usually because the two preferred species are less available. Prior to 1957 the yellowtail sportcatch was predominantly from the Los Coronados Islands area, but in 1957-1958, yellowtail were caught throughout Southern California waters. The graphs of catch per angler day for the two species are similar. In fact, allowing for the difference in trends, the variations correspond closely. If barracuda favor the warm waters of Baja California, and abruptly cease to

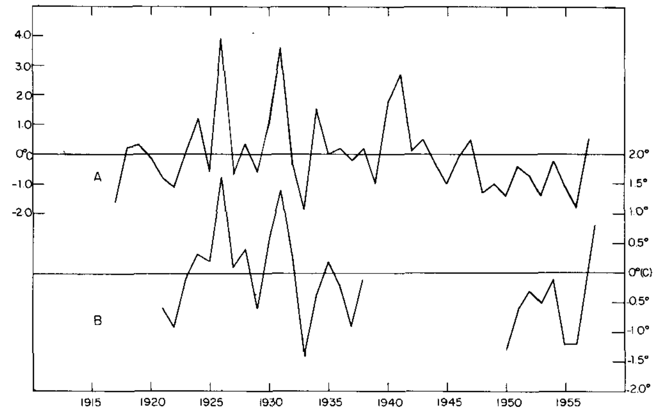

FIGURE 151. Average monthly deviations of sea surface temperatures from January to June at (A) La Jolla, and (B) 5 degree square 25°-30°N latitude, 110°-115°W longitude.

exist at the southern end of their range, then a rise of water temperature in the south may thrust the population northward. Since the fish seem to be more tolerant of colder water, they may not be pushed southward as rapidly by a drop in temperature. Eventually, they may return to the warmer water they prefer, but over a longer period of time.

Figure 151 shows the La Jolla monthly surface temperature deviations from the 1917-1955 monthly means, averaged for January through June of each year, and the January to June average of monthly deviations of surface temperatures from the 1921-38 means, of the five degree square 25°-30° N. Lat., 110°-115° W. Long. The five degree square (Fig. 149) encompasses the southern limit of the barracuda population, and the center of the yellowtail distribution. Unfortunately there are no temperature data for this area from 1939 through 1949. However, since the La Jolla temperature deviations so closely resemble those of the five-degree square, they may be used to indicate changes which occurred during this time. You will note that the warmest January through June temperatures occurred during 1926, 1931 and 1941. The coldest temperature occurred during 1933 and the water temperatures since 1947 have been below the 1917-1955 mean, until 1957.

In figure 152, the yellowtail and barracuda catch per angler day may be seen to vary closely with the January to June average temperature deviations. Therefore, it appears that even during the "monoton-

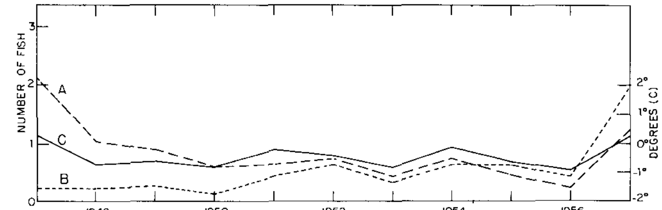

FIGURE 152. Party boat catch per angler day (1947-1958) of (A) barracuda off Southern California, and (B) yellowtail off the Los Coronados Islands, Baja California, and (C) the average of the January-June deviations of surface temperatures from the 1917-1955 mean at La Jolla.

ous, cool'' years since 1947, variations in the environment have elicited a response by barracuda and yellowtail.

To carry the barracuda extension still further, in 1958, for the first time in several years barracuda were caught in Monterey Bay. During April of 1958, many were caught as far north as Santa Cruz by sportfishermen and some were reported from the Farallon Islands. We have considered that Southern California is a fringe fishing area for barracuda, but the waters off central California are in even more of a fringe area. California Department of Fish and Game commercial catch records reveal that; in 1926, about 67,000 pounds of barracuda were delivered to fish markets in the Monterey Bay area; in 1927, about 2600 pounds were delivered; and in 1928, only about 1000 pounds. Water temperatures were high during 1926, yet in 1927 and 1928, when temperatures were not particularly high, some fish still remained in the Monterey area. Apparently, they were lingering in the northern waters for a couple of years after they had been pushed up by the warmer waters. No barracuda were caught, commercially, in Monterey Bay during 1929 and 1930; but in 1931, when the water temperatures rose markedly, 140,000 pounds were caught in Monterey Bay. Although the water cooled in 1932, 2000 pounds were caught; and in 1933, the year of the coldest water temperatures of the series (1917-1955) 29 pounds of barracuda were caught in Monterey Bay. Following two years which were colder than normal, a catch of 58 pounds in 1934 indicated that some barracuda were still present in the Monterey Bay area.

From 1935 to 1940 no barracuda were caught in this area, but in 1941 the water temperatures rose again, and 1550 pounds of barracuda were landed. Since

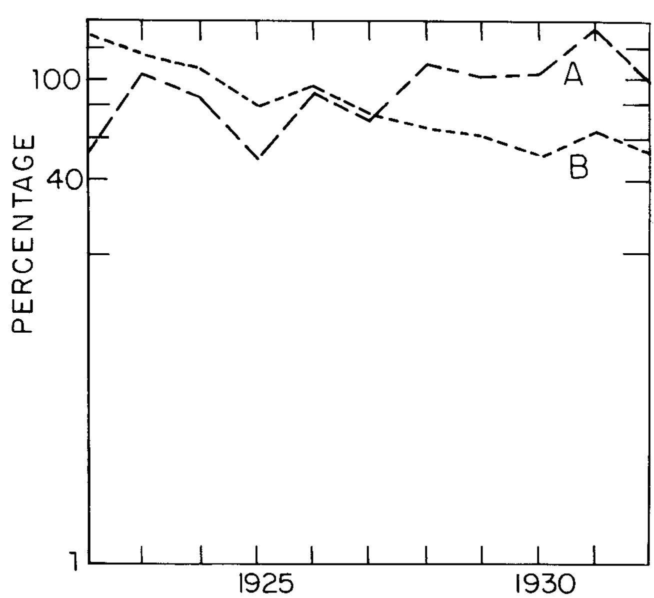

FIGURE 153. Graph showing a comparison of the relative average daily boat catches of (A) barracuda, (B) yellowtail. Reproduced from Whitehead, S.S., Condition of the Yellowtail Fishery, vol. 19, no. 2, *California Fish and Game*, where it appears as Fig. 66.

1941, no barracuda have been delivered at Monterey, however in April of 1958, following high winter surface temperatures, barracuda again appeared in the Bay. In a paper by S. S. Whitehead (1933), a graph appears which is here reproduced as figure 153. From this graph, it is apparent that the yellowtail catch per effort, of the small commercial boats fishing in the vicinity of San Diego and Los Coronados Islands, declined steadily during the period 1922 through 1932. Only during two years of this period was there an increase in catch per effort for yellowtail. These were the two warm water years of 1926 and 1931.

Although the primary effort of these boats was for yellowtail, and their barracuda catches probably were strongly influenced by the availability of yellowtail, the trend of the barracuda catch per effort is upward while the trend for yellowtail is downward. This is just the reverse of the situation during the period from 1947 through 1957 when the trend for yellowtail is upward and for barracuda, downward (Fig. 150).

Unfortunately, no data appeared in Whitehead's paper, nor was there a clear explanation of how the daily boat catch was calculated, however, the basic data from which his calculations were made can still be evaluated, since they have been kept in the files of the California State Fisheries Laboratory.

Isaacs: Could the reverse trends for the two species be the complementary effects of a preference by the fishermen for one over the other?

Radovich: It could during the earlier period, but I feel the chart of the recent period reflects the local abundance of both species.

Isaacs: One interesting thing is the reported occurrence of yellowtail in Monterey in the years of 1915, 1916, 1917, and 1918. Were they from yellowtail present in 1914 and 1915 which persisted until 1918?

Radovich: Yellowtail may have been present in those years, however, water temperatures were not high in 1917 or 1918. I do not know whether the water temperatures were warm or cold prior to 1917. Although barracuda tend to remain in Monterey Bay for a couple of years following a warm year, I do not know if this holds for yellowtail. When it gets cold, they may go south immediately.

Isaacs: Such incidental reports, going back in the past might enable us to reconstruct the occurrences of the kinds of anomalous years that we recognize in the more immediate past. This is a very valuable thing to have.

Hubbs: Do you find it difficult to explain why the barracuda were abundant in 1947? This is one year the barracuda were abundant when there was not much reason for it, except that perhaps they had not been fished down from former abundance.

Fleming: This is just following the war. Was not all fishing stopped during the war?

Radovich: It was slowed down. We do not have any party boat records during the war. The discrepancy in 1947 indicates that the picture is not perfect, but in general, I think the relationship of the local abundance of both species with water temperatures is pretty good.

The barracuda data for 1947 and 1948 are not as reliable as for the following years. There was a tendency for some of the party boat operators to exaggerate their catches of certain species, particularly barracuda, but this condition was improved considerably.

The collection of party boat records began in 1936 and stopped in 1941. Mr. Parke Young, who is in charge of the Department's sportfish project (responsible for the maintenance of party boat records), believes that the data collected between 1936 and 1940 are unreliable. They may not be comparable to data collected since 1947. Figure 154 shows the catch per angler day for yellowtail around Los Coronados Islands, and for barracuda off Southern California, and the January to June average surface temperature deviations from the long term mean at La Jolla, during the period 1936-1940. Even considering that the data are not reliable, I have no explanation, at the present time, for the poor correlation of barracuda abundance with temperature deviations during this period.

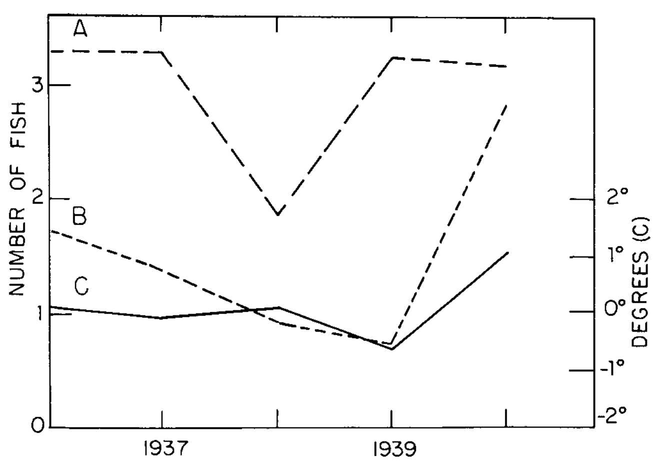

FIGURE 154. Party boat catch per angler day (1936-1940) of (A) barracuda off Southern California and (B) yellowtail off the Los Coronados Islands, and (C) the averages of the January to June deviations of sea surface temperatures at La Jolla from the 1917-55 mean.

Revelle: Would not this be affected by the number of anglers on a boat regardless of how many fish there are?

Radovich: There are variations here, of course, but in general, between years, the number of anglers per boat is fairly constant. Boats were filled to capacity then as well as now.

Isaacs: In which year does the yellowtail catch per angler reach its lowest point while the barracuda catch per angler goes up?

Radovich: That was in 1939, which was an unusual year. There was an extreme range of water temperatures during the year.

Isaacs: There was an extremely cold spring, which may have affected the yellowtail, and an extremely hot fall, which might have affected the barracuda.

Radovich: Looking at the average of the annual temperatures, one does not really get a very good picture. Since both species come into the fishery during the spring or early summer, the January to June average temperatures should be more important.

Murphy: In terms of cause and effect of these relationships, this picture might be more convincing if you had some data on some other species of fish that were repelled from here by warm water—something other than stragglers and something that was fished here during the years when it was cold—some fish that presumably belonged in the north and would go north to get away from the warm water.

Radovich: I have data on several other species. The white sea bass *(Cynoscion nobilis)* is another fish whose range extends into California waters from the south. It lives in the Gulf of California and it is also found along the outer coast of Baja California and off Southern California. In former years it was abundant off San Francisco, but in recent years, except for a small and erratic fishery in Tomales Bay and an occasional fish caught in the southern part of Monterey Bay, it is rare north of Point Conception.

In 1957 white sea bass began moving northward. It is not a species which party boat anglers primarily fish for, but it is a desirable fish and many are caught. During September of 1957 many white sea bass were caught off Morro Bay by sportfishermen, and in Monterey Bay and off San Francisco by sport and commercial salmon trollers, and gill net fishermen. Six white sea bass weighing an average of about forty pounds were caught five miles north of the Columbia River by salmon trollers and one twenty-eight pound fish by a dragger; several weighing up to forty-five pounds were caught off Gray's Harbor, Washington; and two white sea bass weighing between thirty and forty pounds were caught off Juneau, Alaska.

Let us consider a species with a different distribution, albacore *(Thunnus germo)*. The albacore range across the Pacific from the waters of Japan and Hawaii to the North American continent. They generally appear along this coast in June about sixty miles southwest of Guadalupe Island, and off northern Baja California. In general, the fishery begins in this area, and as the season progresses, it moves northward. When the fish are closer to shore, their movement northward is slower. When the fishery develops farther offshore, the northward movement is more rapid. The sport fishery depends on fish close to shore, and the offshore fast moving schools are less available to the angler. The commercial fishery is also influenced by the proximity of albacore to the coast and the speed of the northerly progression of the fish. About 65 percent of the albacore caught off this coast are caught from water between 60 and 64 degrees Fahrenheit.

In June of 1957, the California Department of Fish and Game research vessel, N. B. Scofield, made an exploratory fishing cruise in an attempt to intercept the incoming albacore schools well offshore. As the vessel sailed southward, unseasonably warm water was encountered south of Guadalupe Island and the cruise was shifted to the north. On June 9, the first albacore of the season were caught by the N. B. Scofield about 80 miles WNW of Guadalupe Island in 62°F. water The albacore fishery, subsequently began about forty miles off the coast, between San Quentin and San Diego. The season's first albacore landings were made during June and sport catches were good out of San Diego.

In July, the fishery ranged farther north than during the Julys of the past six years when they had been taken primarily south of Catalina Island. A few catches were made north of Monterey. On July 15, some were taken 140 miles off the Oregon Coast. Fish as large as fifty pounds were taken inshore off Baja California.

By the end of August, a major fishing area had developed between San Juan and Davidson Seamounts, and the catch was about one million pounds behind the 1956 catch for the same period. Up to this time, the fish appeared inshore farther north than usual. They moved closer to shore off northern Baja California, and then suddenly shifted offshore and northward. It looked as if the 1957-58 season's catch would be a poor one. However, the albacore again did the unexpected—they remained in the area between Point Conception and San Francisco through the entire month of September. They were extremely available to the fishery during September, and by the end of the month, the catch was about three million pounds ahead of the 1956 catch through September.

In October and November, fishing dropped off in the central California area as the fish moved northward. Some sport catches were made off Avila and Morro Bay.

During the first week of December, fair catches were made about 300 miles west of San Diego. By the end of the month, most fishermen had returned to port.

Murphy: May I comment on the albacore? They are a case in point.With respect to temperature, albacore are found in water of 62° and 65°F here. In Japan, it is known from tags that they have the same population of fish, the same fish, in fact. There, the bulk of the catch is taken between 68° and 72°F, quite a bit over the optimum temperatures here. In our POFI surveys north of Hawaii, also fishing on the same population, we got our best catches at 58°F by gill netting. To be sure the Japanese catches are by live bait and yours are by trolling. Therefore, with our present state of knowledge I do not see how temperature alone can be used as an index—it seems more complicated. There may or may not be some relation to extreme temperatures.

Isaacs: When they get to central California do they usually head north?

Murphy: That is not quite correct. Your tagging pattern suggests that normally they go north from Southern California to waters off San Francisco. I think they turn off at about San Francisco because the Oregon fish are a different group according to tags.

Isaacs: As Giff Ewing pointed out, the junctions between currents and boundaries between water masses are waters in which organisms tend to concentrate. Their location would be influenced by the currents. If these discontinuities are evident from isotherms, there would be a correspondence between temperature and albacore, though the absolute value of the temperatures might differ in different regions of the ocean.

Radovich: Albacore fishermen reported running into 70°F water from the Davidson Seamount to the Farallon Islands. This was the area in which the fishery picked up albacore inshore, and skipjack and dolphinfish, also.

Murphy: They do get pretty nice catches up to San Francisco, then they do not get much up beyond that.

Stewart: Not implying a cause and effect relationship, I could not help but be struck by the parallel in your albacore data and the water temperature anomaly as recorded, for example, at Los Angeles. You said, as I recall, the albacore stopped dead at the end of August and then stayed there through September and then started off in October, November, December, which parallels exactly the water temperature anomaly of Los Angeles (Fig. 91) or even the mean temperature anomaly for all stations along the coast (Fig. 100).

Sette: In other words, the points where the travel of the albacore was checked, correspond with a change from the warm temperature anomaly for August toward temperatures more nearly normal in September.

Radovich: Aside from the close relationship of barracuda and yellowtail to temperature, most of the material I am presenting represents anomalies of fish distribution that may or may not be correlated with temperature anomalies. They should be critically evaluated.

Another example of an anomalous distribution is bluefin tuna, which usually is caught only south of Pt. Conception. Nothing seemed unusual as the bluefin season began in June, but later they were caught off Monterey. Between July and October, bluefin tuna were caught from 80 to 100 miles north of Cape Flattery, off Eureka, and off Newport, Oregon.

In addition to bluefin, there were a number of tropical oceanic fish, such as skipjack, yellowfin tuna, and bonito that were caught far north of their usual range. On July 24, albacore fishermen began catching skipjack and dolphinfish off San Diego. In August many skipjack, dolphinfish, and yellowfin tuna were caught off Southern California. A fifteen pound yellowfin tuna was caught on August 18th off Pt. Buchon (above Point Conception). In September, swordfish were commonly observed around the Davidson Seamount and some were caught off Monterey. Skipjack were frequently encountered off Point Arguello. On September 25 a yellowfin tuna weighing 75 pounds was caught off Davidson Seamount. This probably is a northern record. The fishery for bonito, barracuda and yellowtail, lasted all winter, and is still continuing.

Among the small pelagic fishes, sardines, anchovies, and Pacific and jack mackerel, nothing dramatic happened until July. In July there were a number of large sardines taken by bait netters. About twenty tons of sardines were caught for bait off Monterey.

In August sardines were very abundant in the bait from Hueneme to the Mexican Border and young sardines began appearing in the bait catches. Anchovies were difficult to catch in Southern California and at Monterey there was a large number of very young anchovies. In September more young sardines that were spawned late in 1956 or early 1957 appeared and some of them showed up in Monterey Bay. Adult sardines were observed as far north as Eureka, California, for the first time in about six or seven years. The commercial sardine fishing season was hampered by a strike during the first part of the season. Only about 20,000 tons were landed during the season making it one of the poorest on record. In March of this year some six-inch sardines were caught at Monterey. At the present time, the 1957 year class of sardines is still in evidence off Monterey.

That concludes the chronology of the anomalous events related to Southern California species.

Off San Francisco the king salmon troll fishery had one of its poorest years. Another bad year for salmon was 1939. It stands out as the poorest in a forty-year period. The same year, 1939, was outstanding for sardines. In fact the 1939 year class of sardines is the largest one on record. I do not know what is significant about 1939. The average annual temperatures do not seem unusual, but a closer scrutiny at the different periods within the year might reveal anomalies significant to both salmon and sardines.

Isaacs: From the standpoint of what?

Radovich: The temperatures in 1939 were quite low early in the year, after that it was very warm. I do not know how outstanding this was.

Isaacs: It was very outstanding—the warmest fall on record.

Stewart: The lowest sea level was recorded in 1939, too.

Radovich: Salmon and sardines behaved abnormally, but very different from each other in 1939. The salmon troll fishery failed and sardines produced their largest year class.

Returning to 1957 and going farther north to British Columbia; pink salmon on their spawning migrations apparently came in from a more northerly route than usual in 1957. Actually, the 1957 pink salmon run in British Columbia was the best since 1930.

DISCUSSION

Isaacs: As far as the salmon are concerned, they are more abundant in the northern areas, whereas California is at the southern fringe of their distribution.

Radovich: This is right. We have mainly the king salmon in California.

Hubbs: This is explained by Brooks as a shift northward of the warmer temperature in the environment after the ice age.

Radovich: The spawning run in the Sacramento River system was very poor in 1957. This suggests that it was not only the availability that changed. Salmon find their way back to their own streams. Although a few sometimes stray into streams other than their own, there has never been evidence of mass straying. In some manner they are capable of detecting differences between the various streams and find the right one. It is possible that if ocean conditions changed significantly in the general area of the parent stream they might not recognize their parent stream.

Isaacs: Apropos of 1939 being inexplicable as to two cases: yellowtail and barracuda in one case, and salmon in the other, I think if you closely studied the water temperatures, you would find the lowest February temperatures in many years and the highest November temperatures. February temperatures were about 4°F below normal and those of November, about 4°F above normal.

Stewart: If you assume that sea level is a reflection of sea water temperature, San Francisco had the lowest sea level anomaly in February on record since 1897 and this would suggest an anomalously low temperature.

Radovich: There was a significant difference in temperatures, fish distribution and survival in 1939, but there are so many variables involved that I do not believe you can explain it as simply as this. For example, in 1939 there was a high survival of young sardines north of San Francisco to as far north as British Columbia. Conditions prevailing above San Francisco allowed the fish to go north; and the fact that spawning was successful in that northern area is important. However, in other years, when one considers both, the distribution and the survival of young fish in specific areas, the picture becomes a little too complex to be explained simply by temperatures.

Fleming: I think that we are jumping a long way when we try to relate distribution of very mobile fish such as you have been describing to us—yellowtail, barracuda, salmon, and so forth—with such a thing as surface temperatures. These fish can obviously move around rapidly. I feel in these cases that a more rational approach to this problem would be thorough consideration of the availability of food for some of these forms. I do not know the main food of barracuda and yellowtail for example.

Radovich: For barracuda, anchovies probably constitute one of the important constituents of their diet. This is based on the fact it is the primary bait for barracuda and that it is the most common species found in barracuda stomachs. They have large teeth and prey on small fish, usually small ones. Yellowtail eat a large variety of animals including sardines and anchovies.

Fleming: What I would like to see is some relationship between the view you have presented here with the talks earlier today, which were on planktonic forms and so on—forms that are more subject to the movement of the water and the physical chemical environment, and then see if there may be a better explanation of the distribution of some of these predators.

Radovich: There have been food studies conducted on a number of species. I do not have much faith in them, myself, for the simple reason that, in general, most fish seem to eat anything of the proper size that happens to be present.

Fleming: The albacore might have hung around, in the way you described because of the availability of food.

Radovich: That is a possibility. They might have run into an abundance of food in that area. However, I do not visualize the migrations of yellowtail and barracuda (or albacore) as a chase after specific food items. They might remain awhile in a spot if an abundance of food were present, but this is not the same as moving great distances because of a change in distribution of one or more food organisms.

Hubbs: We find white sea bass where food is abundant. Show me where the white sea bass spawn in a particular time and I can predict small boats will be out catching white sea bass within about a week. You (Fleming) say we cannot ascribe the movements of these larger free-swimming fish to temperature changes? I think this view is contradicted by a lot of the evidence. If you break down the data within a year, nearly every year back for a number of years there has been a winter of low temperatures. In the spring we get northern fish suddenly appearing. We get a high peak of temperature in July or August. This high peak lasts only two or three weeks, at that time or right after it, we get southern fish suddenly popping up. These do not seem to be enormously sensitive to the temperature in their optimum area but in the fringe area they respond to it very sharply.

Radovich: Frankly, I consider that during the series of years 1947-1957 there is a good correlation. Two species (barracuda and yellowtail) respond in the same way. I feel that the correlation between the temperature and distribution of these species is real.

Murphy: Other things change in this environment when the temperature changes.

Radovich: There may be changes in oxygen, salinity, or in a combination of several things. If species, such as barracuda and yellowtail, were looking for any specific foods, it would be difficult to explain this close a correlation with temperature. Of their food items I know none which vary the same way over this period.

Fleming: One of the hypotheses is that the survival of the year class of sardine depends on availability of the proper food of the larvae. You can start way back there.

Radovich: This has been expressed, and may be a possibility of course. But it is rather a loose hypothesis which we cannot test until we know a little more. The hypothesis refers to survival of young larvae, but adult fish, particularly predators such as barracuda and yellowtail are capable of moving great distances.

Fleming: Do you admit these fish are spread over a wide band of latitude? For the barracuda and the yellowtail, I think food response is a perfectly valid hypothesis in that in this range there is concentrated a great abundance of food.

Murphy: There is additional complication in respect to tuna. Their availability to certain fishing techniques varies according to what they are feeding on. Off Japan apparently where the albacore is apparently feeding on squid, it is available to the commercial fishery. As the boat catches change, in response, I suspect, to the food supply, you might expect a change in the availabilty.

Radovich: This does not appear to be true for barracuda. They seem to be eating mostly anchovies and sardines along the coast. If there is any food preference here, it should be for those particular species, but I haven't been able to find that the catch of barracuda corresponds to abundance of anchovies and sardines.

Schaefer: May I contribute a nickel's worth? I think the data we have on the tuna in the Eastern Pacific, (that is in the tropical region), indicate that the fish respond both to food concentrations and to temperatures. We find at the two edges of range, for instance off Baja California, that tuna concentrations vary approximately with the migration of the 20 degree isotherm, yet there is practically no change in the standing crop of food. Along Baja California there is food in concentrations the year around, but the tuna come seasonally. Similarly at the southern end, off Peru, when water warms up the tuna moves south toward Chimbode. In the warm water of the intervening zone between Cape San Lucas and Cape Blanca in Peru, where the year-round temperatures are generally favorable, the tuna tends to be concentrated where the food is most concentrated, provided water is warm enough. So there are seasonal migrations at both ends of the range but no pronounced seasonal movement in the middle.

Radovich: This is the kind of relationship I would expect, rather than a close relationship to a particular type of food. During unusual years when warm water extends far north, tuna may extend far north also. For instance, last year there was a considerable amount of skipjack caught off San Diego.

Murphy: We tend to build up ideas of what the various species of tuna consider to be good temperatures. But if we go to some other place in the world, we could find the "good temperatures" were quite different. If I remember correctly, the skipjack off Australia are caught in the low 60's, which is quite strange to us.

Schaefer: Off Australia they may be fishing at the edge of a concentration. This is quite analogous to the fishing off Southern California.

Murphy: As to the albacore, we have a certain set of temperatures where albacore are found along this coast—but they are never seen at these temperatures in the area south of the Aleutians or off Japan, except in rare instances.

Radovich: I do not mean to imply that temperature by itself is the only factor that motivates the albacore. During 1957, they certainly did make their appearance along this coast well north of their usual location. The temperatures where the fishery usually begins (Guadalupe Island) were very warm. During previous years, the catches were distributed as one might expect if they were related to temperatures. With a superficial examination, I did not see a direct positive relationship between warm water and the amount of fish that was caught. What was observed, and what I have presented, was an anomalous distribution and what seemed to be an anomalous behavior during the warm year, 1957.

The albacore appeared farther north and moved in closer to shore at the beginning of the season. Then instead of moving northward slowly, as they usually do when they are close to shore, they apparently moved offshore, rapidly, went northward and stopped. They stayed north of Pt. Conception for about a month and a half, and the catch was exceptionally good for that month and a half. They could have been stopping for food rather than anything else, or they might have run into a temperature barrier, or some other kind of barrier. They behaved essentially as I have described it—whatever the explanation.

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