# THE OCEANOGRAPHIC SITUATION IN THE VICINITY OF THE HAWAIIAN ISLANDS DURING 1957 WITH COMPARISONS WITH OTHER YEARS

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During the past three years POFI initiated a number of temperature and salinity monitoring stations in the Central Pacific as follows: Oahu, Hawaii; Johnston Island; French Frigate Shoals; Midway Island; Wake Island; Christmas Island; and Weather Station "Victor." The purpose of this network is to develop time series that can be related to variations in the oceanic circulation which, we anticipate, can in turn be related to variations in the distribution of skipjack and other tunas. At the present only the Christmas Island and Oahu stations have been established long enough to provide material suitable for discussion. The Christmas Island station is reported on elsewhere, leaving the Oahu station and other pertinent observations in the vicinity of Hawaii for consideration here.

## SURFACE TEMPERATURE AND SALINITY AT OAHU

The Koko Head station is occupied each Tuesday morning about 9 a.m. A bucket of water is dipped from the cliff, temperature measured and the salinity sample returned to the laboratory for titration. There are no coral reefs at the station; the depth drops off abruptly to about thirty feet below the cliff and then quickly falls off to deep water. There are no nearby streams either, and thus the location is close to ideal with respect to non-interference of shallow water warming and run-off. Offshore surveys conducted simultaneously with the shoreside observations give us further confidence that water samples taken there are representative of general conditions off that portion of Oahu.

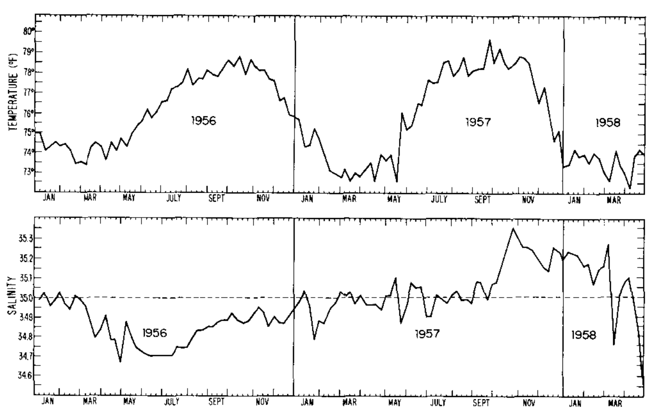


**FIGURE 41. Surface temperature and salinity at Koko Head, Oahu.**

Two and one-half years' records from this station are plotted on Figure 41. Since primary comparisons will be between 1957 and 1956, it is of some interest to consider the representativeness of the 1956 material. Though not herein documented, our accumulation of records suggests that 1956 was very close to an average year with respect to temperature and with respect to salinity. Weather patterns and biological patterns were also reasonably representative of average conditions during that year. We can then with some confidence treat 1956 as a base and proceed with intercomparisons between 1956 and 1957.

With respect to surface temperature, the pattern in 1957 was similar to 1956 insofar as maximum and minimum temperatures are concerned. However, it is clear that spring warming was accelerated in 1957 and the winter cooling was also more accelerated. These data in themselves are not clear evidence of a significant change in the advection pattern.

Surface salinity (Fig. 41) shows 1957 to be markedly different from 1956. The March-May decline in salinity followed by a gradual rise in salinity from about the first of July onward did not occur in 1957. Instead, salinity in 1957 remained almost constant until mid-September when it rose abruptly to levels higher than those ever recorded. This was followed in the spring of 1958 by an abrupt decline to what might be regarded as normal spring salinities. The decline however was short-lived, and during the first week of April salinities again rose to about 35.0‰ and remained at that level, at least through the third week in May (not included in plot on Fig. 41).

The major trends in the salinity data can only be accounted for by advection; for instance, the March-May decline illustrated by 1956 occurs at a time of decreasing rainfall. Each of the other major trends illustrated either were contrary to what might have been expected from rainfall and isolation, or could not be accounted for by these factors. However, at least some of the short-term changes in salinity can be correlated with rainfall, the most graphic example being the mid-March, 1958 decline; this occurred coincidental with a rainfall of about two feet within a 24-hour period.

From the data on figure 41 we can safely conclude that there are seasonal changes in advection in the vicinity of the Hawaiian Islands and that the typical seasonal changes did not occur in 1957; rather, the island area was brought under the influence of water masses that do not normally influence the area.

The data on figure 41 replotted in smooth form on figure 42, graphically illustrate the difference between the two years. The treatment on figure 42 is in essence a T/S curve, time being the third and non-linear variable, rather than depth. It is interesting to note that many features of the basic pattern were similar during the two years, very possibly reflecting similar patterns

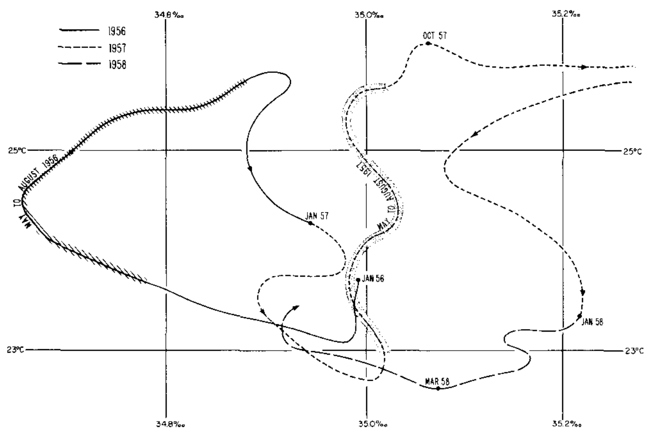


FIGURE 42. Surface temperature and salinity at Koko Head, Oahu (data smoothed by eye).

of temperature and rainfall between the two years. Many details are, however, different between the years and it is clear that the basic temperature-salinity relationship was very dissimilar between the two years.

In summary, the normal seasonal pattern in Hawaii involves high salinity and low temperatures in October-February, and low salinity and high temperatures during the summer. In 1957 the temperature regime resembled the normal except that the rates of increase and decrease associated with the September-October maximum were greater. In 1957 the salinity regime was very different from normal. The May-July low salinity did not develop and the ensuing winter saw salinities rise to higher than normal levels. The regime for 1958 has not clearly established itself. These differences in salinity and temperature can only be explained on the basis of changes in advection pattern in the island area.

## DISTRIBUTION OF SALINITY NORTH AND SOUTH OF OAHU

One of the authors (Seckel) is in the process of summarizing and analyzing all available oceanographic data from the portion of the Central Pacific outlined in figure 43. This chart depicting certain surface isopleths shows that the mean position of the 35.0 isopleth during the period, April to July, is about 2½ degrees north of Oahu. During the contrasting season, November to February, this isopleth lies about three degrees south of Oahu. This migration is quite compatible with the results of the salinity changes with time at Koko Head during 1956, which we believe to be close to an average year but is quite dissimilar from 1957.

A north-south profile of surface salinities during 1957 (April to July) figure 44 shows the 35.0 isopleth to be almost coincidental with the latitude of Oahu, rather than 2½ degrees north of Oahu, Interestingly enough, the surface salinities that should have prevailed during 1957 at Oahu were located almost exactly 2½ degrees south of Oahu. Figures 43 and 44 suggest that the normal spring north-south profile of surface salinity had about the same shape in 1957 and 1956, but was simply displaced about 2½ degrees south in 1957.

The sum total of our observations suggest that normally during the winter the vicinity of Hawaii is under the influence of cool, high-salinity water of northern origin. Normally during the summer this high-salinity water seems to be displaced to the north-

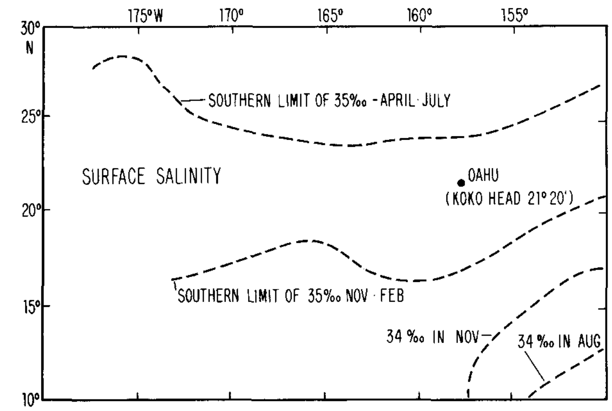


FIGURE 43. Mean Seasonal Locations of 35⁰/₀₀ and 34⁰/₀₀ Isopleths (Approximately 700 surface observations 1957 data not included).

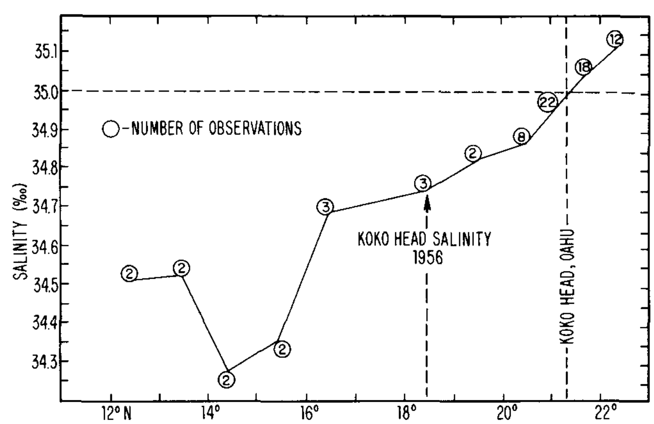


FIGURE 44. Mean surface salinity by latitude at the longitude of Oahu during the period April to July 1957.

ward and the islands are influenced by lower-salinity, warm water that possibly originates to the southeast. Perhaps the high-salinity water is downstream, or is influenced by downstream Kuroshio flow, and signals advection from the west. During March-May this easterly-flowing water is displaced to the north and tends to be replaced by lower-salinity water from the southeast. Perhaps the water is related to California Current water. In 1957 this warm, low-salinity water persisted through spring, summer and the subsequent winter.

## SKIPJACK

The skipjack season in Hawaii undergoes marked seasonal, as well as annual variations. Though the annual variations may be large, they have not during any year of record been great enough to suppress the seasonal pattern. July is almost invariably the peak month and December, January and February are almost invariably low points in the annual cycle. Typically, landings begin to rise in April, rise precipitously in May and June, peak in July, and fall off fairly precipitously to October. Variations in effect may serve to accentuate the peaks and valleys, but by and large effort is constant throughout the year so the catch must be interpreted in terms of immigration and emigration of fish through the Hawaiian region. (The Hawaiian tuna fishery generally operates within 20 miles of land so that fishery is in effect a point fishery, unlike the Southern California tuna fishery, which roams over a vast expanse of ocean.) In addition to the seasonal shift in the magnitude of the catches there is a change in the size composition with winter or off-season catches generally comprised of small individuals, five to ten pounds in weight, and the bulk of the season or summer catches comprised of large individuals ranging from 15 to 25 pounds in weight. This change in the composition of the fishery lends further weight to the assertion that the basic changes in landings are functions of the movements of the fishes rather than changes in effort or economic factors.

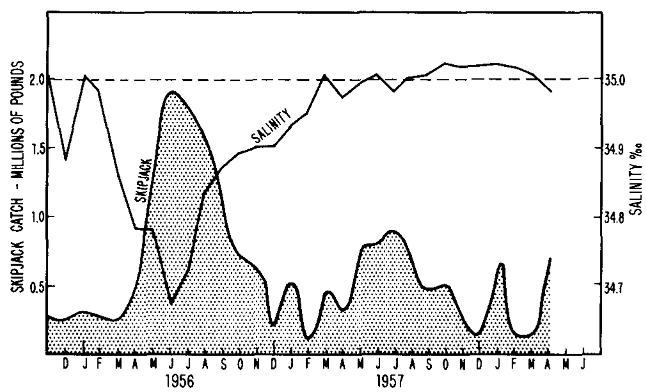


**FIGURE 45. Monthly Skipjack landings and mean monthly salinity at Koko Head.**

There is now a substantial body of evidence that shows the development of the season, that is the immigration of skipjack to Hawaii is related to the impingement of the warmer, less saline waters from the southeast into the island area. The first indication we had of this came in 1956 from a comparison of our Koko Head monitoring records and the skipjack landings. These data are shown on figure 45, together with similar data from 1957. As already demonstrated, and again indicated on figure 45, the low-salinity water did not impinge on the islands in 1957, and this is associated with failure of the fishery in 1957. The 1957 catches also differed from the 1956 catches in respect to size of fish; the large 15 to 25 pounders were almost entirely absent, the fishery being supported by smaller, typical winter skipjack. This sequence of events led us to examine the catches, that is the summer catches, during earlier years together with such records on salinity as we could assemble. These are tabulated below. It is clear from these figures that, at least during the five years' records, good or average season catches were associated with the presence of lower salinity water while poor catches, including the lowest on record since the war, were associated with higher salinity water.

| $< 35.0$ ‰ | $> 35.0$ ‰ |
|---|---|
| 1951—9.9 million lbs. | 1952—4.8 million lbs. |
| 1953—7.1 million lbs. | 1957—3.2 million lbs. |
| 1956—7.2 million lbs. | |

If the skipjack are actually associated with low-salinity water, this association should be particularly sensitive during the spring, that is April and May, when the fishing season is just developing. Figure 46

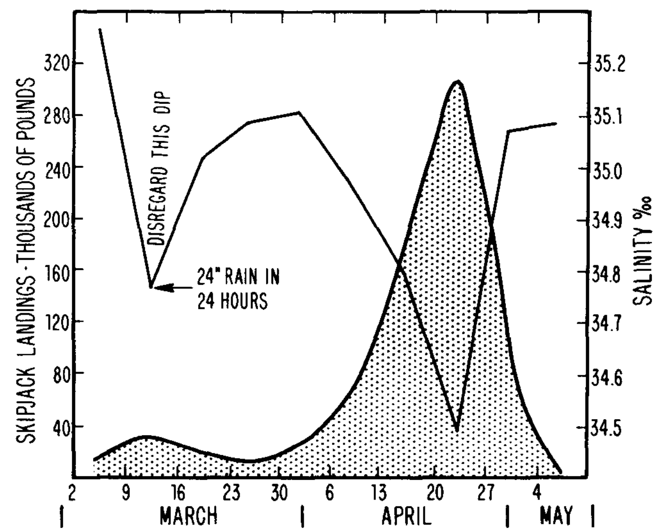


**FIGURE 46. Spring of 1958. Weekly Skipjack landings and weekly salinities, Koko Head, Oahu.**

illustrates the weekly records for the spring of 1958 during which time the ocean apparently formed a neat experiment for us. As may be seen salinities fell to an extraordinarily low level during the last week in April and this was exactly coincidental with a marked upsurge in skipjack landings; in fact, the rate of landings during the peak week was quite high for April and coincides with a typical June-July week's landings during the normal season. Following this, salinities rose abruptly to winter levels and the catch dropped to winter levels.

If the immigration of skipjack is associated with the advection of low-salinity water from the southeast, there should be corresponding evidence of directional movement of the fish. Data are available from two sources: (1) the pattern of landings along the island chain with the advance in the season and (2) the results of tagging. Unfortunately for a variety of reasons, the data from both of these sources do not provide a critical evaluation of the direction of movement of the skipjack. However, there are several indications that the fish do move into the island area from the southeast and no contradictory indications.

If we assemble all of this information into juxtaposition, it is possible to erect a relatively simple hypothesis to account for seasonal variations in skipjack landings in Hawaii, as follows. The skipjack that enter the Hawaiian fishery are a portion of a population migrating from east to west in a body of low-salinity water suggestive of downstream California Current water. If this low-salinity water impinges on the island area, skipjack in large numbers appear in the island fishery. The season is terminated either by the passage of the last wave of migrant fish, or simply by retreat of the low-salinity water, or both. The migration of skipjack entering the island area may be disrupted and delayed in response to special feeding situations that they encounter. This hypothesis relegates the islands to the role of an operating base for the fleet, rather than a base for the skipjack, and is in accord with our failure to find significant seasonal differences in the standing crop of biota in the Hawaiian Islands and our observation that during a typical season skipjack are abundant far south of the islands, well beyond the possible influence of the islands, whereas indications are that they are not abundant very far to the north of Hawaii. The problem of change in size of the skipjack with the onset of a typical season is also susceptible to explanation for many populations of tuna to arrange themselves geographically by size, the most typical picture being the small fish in a population tending to dominate the extremities of the environment. If we interject this additional factor, we can understand the absence of large fish during the 1957 ''season.''