

# SEASONAL AND GEOGRAPHIC CHARACTERISTICS OF FISHERY RESOURCES

## California Current Region--VIII. Zooplankton

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Plankton is defined in most dictionaries simply as the passively floating or weakly swimming animal and plant life of a body of water (zooplankton and phytoplankton, respectively). Such an uninteresting definition in no way acknowledges the important roles of such organisms in the food chains in bodies of water and their tremendous variety in species and morphology.

In the California Current region alone, it has been estimated that, for zooplankton only, there are at least 546 invertebrate species (Isaacs, Fleminger and Miller, 1971) and approximately 1,000 vertebrate species, that is, as fish larvae. Such larvae and, in some instances, their eggs were the bases of the first seven reports in this series (Kramer and Smith, 1970a, b, c, d, 1971a, b, c). The variety of species in this region, just for a part off central Baja California, was shown by Ahlstrom and Thraillkill (1963, Table 5). They listed about 145 invertebrates and 36 vertebrates in only 12 plankton samples. Another example of variety of species found near our survey pattern was reported by McGowan and Fraundorf (1966, Table 7) for a small area southeast of Cabo San Lucas near the northern limits of the zooplankton fauna of the equatorial water mass. This report on zooplankton diversity listed 69 species of invertebrates and 81 species of fish larvae collected in 24 plankton samples.

### Zooplankton's Essential Role

Zooplankton is not reported here as a fishery, but in recognition of the essential part its vast community plays in relation to the fish resources. In worldwide fisheries, its supply forms the entire diets of plankton feeders such as anchovies, herrings, pilchards, and menhaden. Certain of its constituents, possibly including some phyto-

plankton, are essential foods for most stages of larval fish development. One of the greatest phenomena of marine-animal development is that of the growth of baleen whales, which feed exclusively on plankton, sometimes only on the shrimplike plankter "krill", a large euphausiid. One example in particular is the blue whale's growth. At birth, this whale is about 7 m long and 2,000 kg in weight (21-23 ft, 2+ tons). Seven months after birth, it is about 16 m long and weighs 23,000 kg (48-52 ft, 25 tons)--feeding only on krill! (Rice, 1972.)

This report deals with the seasonal and geographic characteristics and variations of zooplankton biomass in the California Current region. Organizations, area of investigation, and treatment of data were presented in the first report of this series (Kramer and Smith, 1970a). In addition, we will discuss the annual cycles (variation) for different parts of the survey area north to south and inshore-offshore.

### Data Processing

Our previous descriptions of processing data did not include discussion of the methods used to collect and process plankton. Detailed descriptions of the methods for collecting and processing data in the California Current region were described by Kramer, et al. (in press) and in some detail by Smith (1971).

For the data 1951-60, the following methods were used to collect plankton. Each sample was taken with the standard CalCOFI net constructed of silk mesh (bolting cloth), mouth diameter 1 m, and mesh size approximately 0.55 mm. Occasionally a nylon net of the same mouth opening and mesh size was used. A flow meter in the mouth of the net

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permitted calculation of the amount of water strained. Each tow was made by sinking the net at 50 m per minute to a depth of about 140 m (200 m of wire out, depth permitting) and retrieving it at 20 m per minute while maintaining a wire angle of 45 degrees. The ship's speed during a tow was about 2 knots.

Each sample was preserved in 5% formalin and buffered with sodium borate. The samples were brought back to the laboratory and measured by the displacement method described by Ahlstrom and Thraikill (1963), or by a method developed by Thraikill, described by Kramer, et al. (in press). Both methods are accurate to  $\pm 1$  ml. Smith (1971) discussed the variations due to shrinkage and interstitial liquid as previously reported by Ahlstrom and Thraikill (1963). Two volumes, reported as ml/1,000 m<sup>3</sup> water strained, were determined for each sample: first, the total volume and, second, the total volume less large organisms--5 ml or greater--usually jellies or jellylike organisms. (Juvenile and small adult fishes captured by the net are not considered planktonic.) Each sample was then sorted for all fish eggs and larvae. The sorted sample was studied further for selected invertebrates (e.g., Isaacs, et al., 1969, 1971). Also see their Table 1 in each volume, which cites investigators, their publications, and interests.

Our treatment of the data is for zooplankton only in terms of total volumes of all organisms with no separation by constituents or groups. Isaacs, et al. (1969) reported on the seasonal and annual variability among 17 functional groups of zooplankton for the spring (April cruises) and fall (October cruises) for 1955 through 1959. In 1971, they reported on winter variability for January in 1955 through 1959.

#### Seasonal and Geographic Distribution

The variations in seasonal and geographic distributions for 1951-60, shown in Figures 1 and 2, are similar even though the diagrams are from two sets of data and are presented in somewhat different ways. Figure 1 shows summaries of plankton volumes only for organisms less than 5 ml, expressed as medians of volumes per 1,000 m<sup>3</sup> of water strained--the medians represent the central values of suites of samples. Figure 2 summarizes plankton volumes only for organisms greater than 5 ml, expressed as percentages of occurrences in plankton hauls. Smith (1971,

Figure 2) presented the same data in a figure of relative abundances in an atlas of plankton volumes for every survey conducted by the CalCOFI from 1951 through 1960. The basic data for all surveys, 1951 through 1966, were reported by the Staff, South Pacific Fisheries Investigations (1952, 1953, 1954, 1955, 1956) and Thraikill (1957, 1959, 1961, 1963, 1969, MS).

Each figure indicates the trends to be expected during a year's production of plankton, wherein peaks of abundance occur from spring to summer and decreases occur in fall and winter. (Data were insufficient for summaries to be made for August, September, and November.)

#### Temperature and Zooplankton

Temperatures at 10 m, summarized for the 10 years in the same pooled areas (Figure 3)--see Kramer and Smith, 1970a, Figure 2--indicate the trends of centers of greatest plankton abundance within a particular range of low temperatures, 12<sup>o</sup>-15<sup>o</sup> C. (The 10-m depth is regarded as mid-depth or average of stratum between surface and thermocline. Ten-meter temperatures have been published in atlases for 1949 through 1969 for all CalCOFI surveys (Anonymous, 1963; Wyllie and Lynn, 1971).)

Zooplankton production in "warm" and "cold" years bear out the trends to be expected from the data depicted in Figures 1, 2, and 3. Reid (1962, Figure 5) showed that for each year, 1949 through 1960, plankton volumes were high with low temperatures and low with high temperatures. He also depicted two figures from Thraikill (1959, 1961) showing averages of high volumes in 1956, a cold year, and low volumes in 1958, a warm year. Ahlstrom and Thraikill (1963) cited the warm year 1959 and the fact that plankton volumes then were the lowest in a decade.

#### Annual Cycles

Another illustration of seasonal and geographic changes is in the summarization of data to show annual cycles by region and pooled area (Figure 4). Here, monthly median volumes are presented for six regions, north to south, at 40-mile intervals onshore-offshore. Each curve is an annual cycle beginning in each January (J), summarized over the 10 years, 1951-60. Each

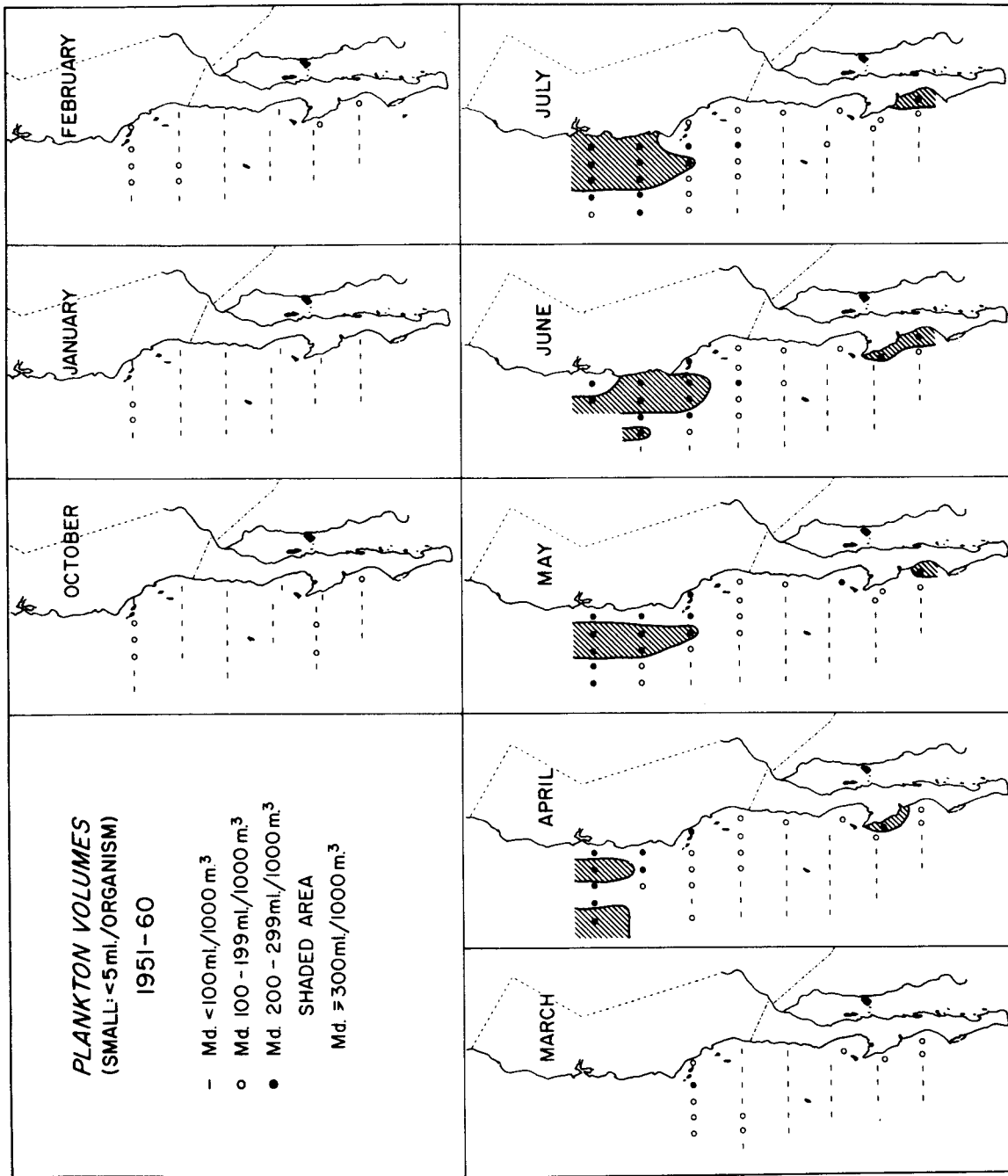


Fig. 1 - Medians of plankton volumes consisting of organisms less than 5 ml. collected on survey pattern of California Cooperative Oceanic Fisheries Investigations (CalCOFI), 1951-60. Each circle, line, or dot represents a pooled statistical area (see Kramer and Smith, 1970a).

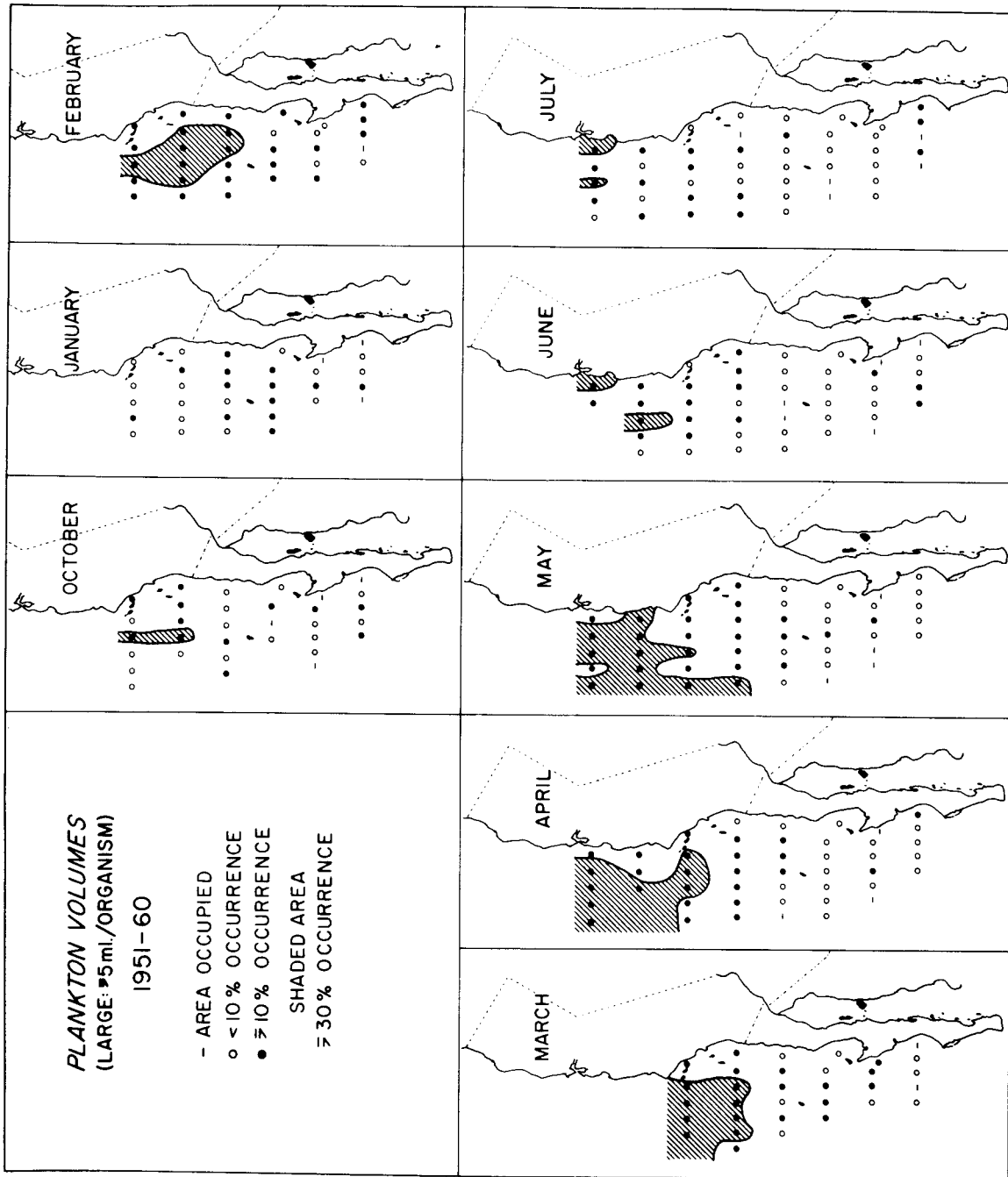


Fig. 2 - Percent occurrence of plankton volumes, consisting of organisms equal to or greater than 5 ml, collected on survey pattern of California Cooperative Oceanic Fisheries Investigations (CalCOFI), 1951-60. Each circle, line, or dot represents a pooled statistical area (see Kramer and Smith, 1950a).

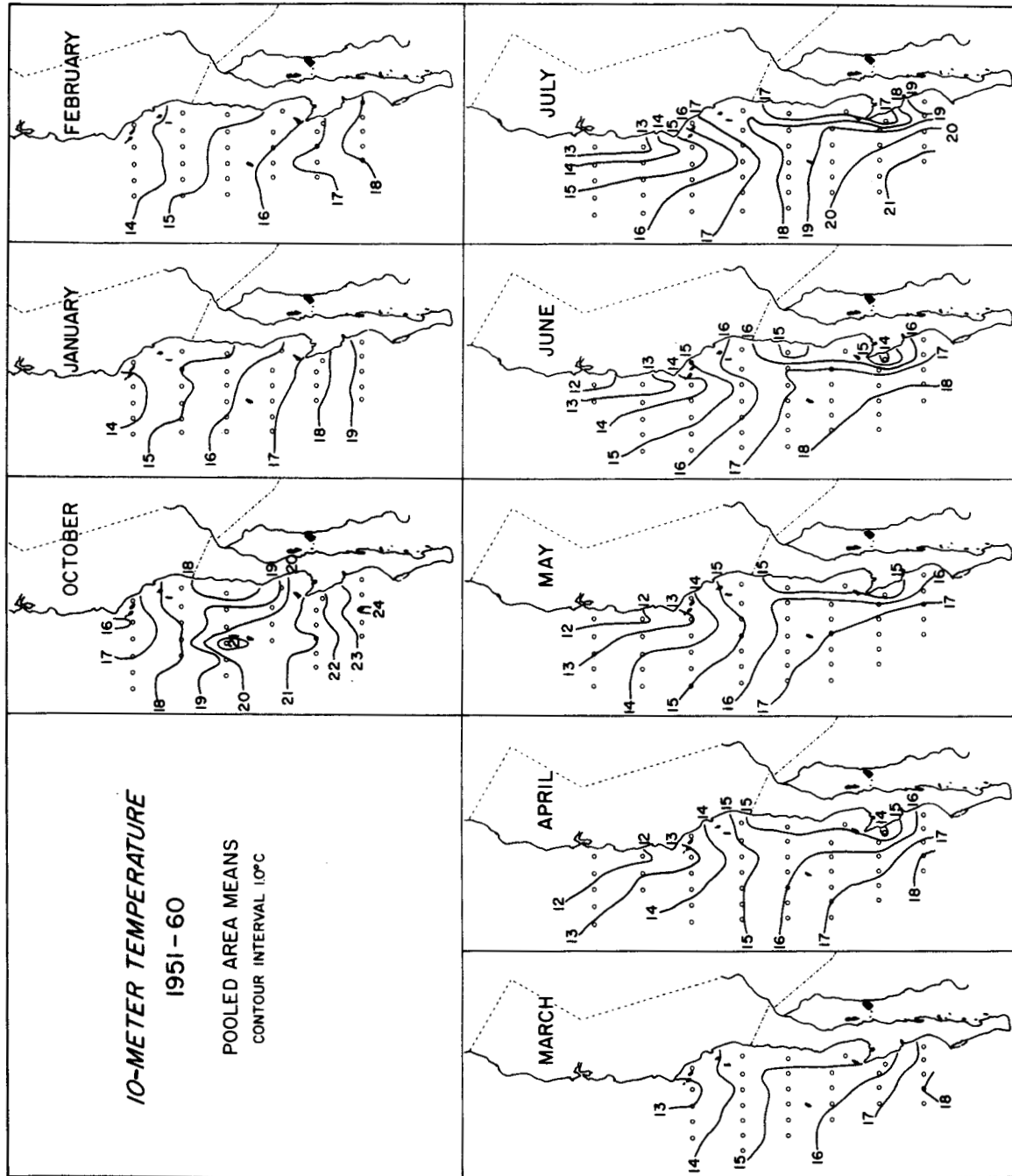


Fig. 3 - Pooled area means of 10-m temperatures in survey pattern of California Cooperative Oceanic Fisheries Investigations (CalCOFI), 1951-60. Each circle, line, or dot represents a pooled statistical area (see Kramer and Smith, 1970a).

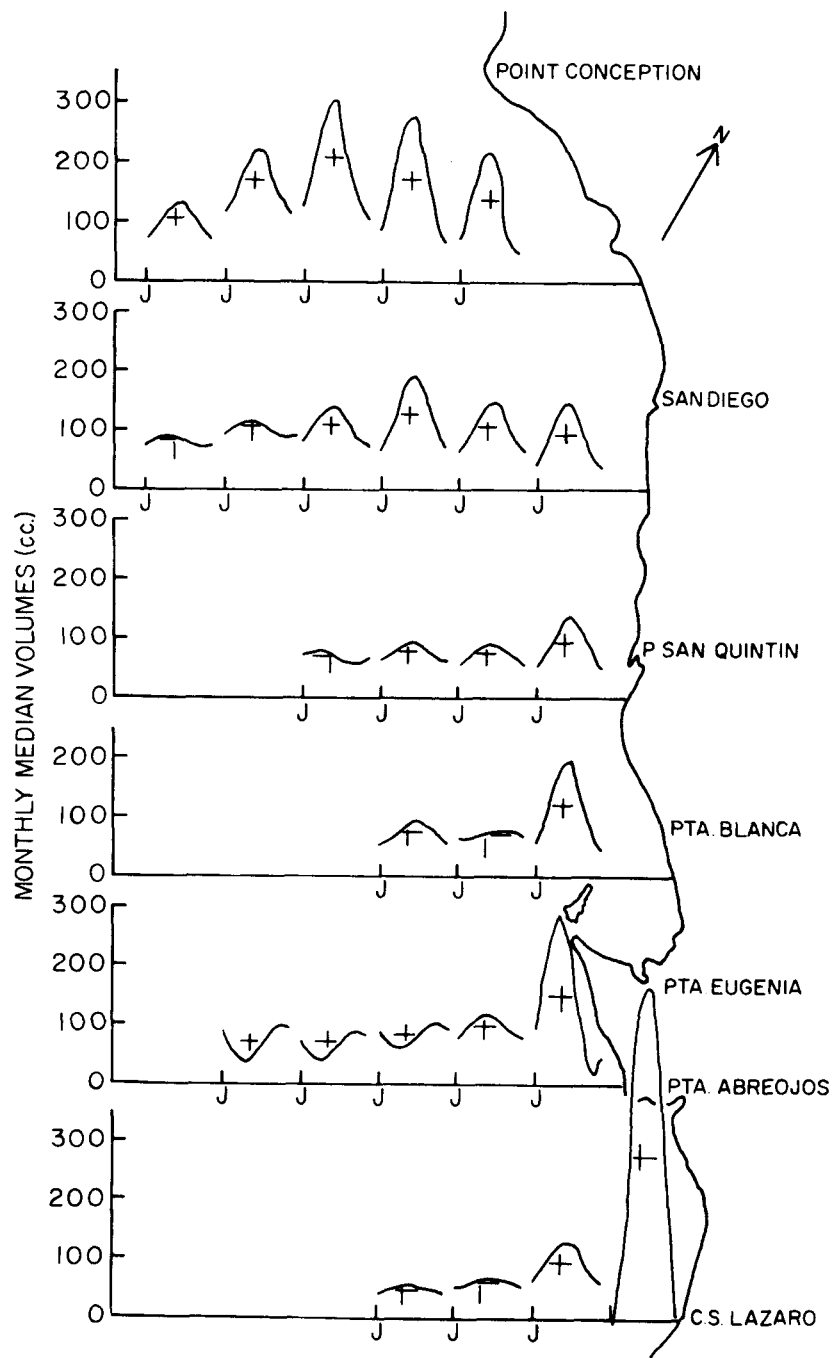


Fig. 4 - Annual cycles of plankton volumes (monthly medians) collected in survey area of California Cooperative Oceanic Fisheries Investigations (CalCOFI), 1951-60. (See text.) There are no curves shown for offshore areas, Punta San Quintin, and south because there were no significant annual cycles in monthly median volumes in those regions.

vertical line in each curve represents June and each horizontal line is the annual average. Here, as in Figures 1 and 2, high abundance occurs in mid-year when day length is longest and temperatures are low, as shown in Figure 3.

#### Determinants of Zooplankton Concentrations

Zooplankton concentrations are established by the rates of production of their components, their growth rates, their natural mortality, and predation on their populations. Very little is known about any of these since our data are based only on that proportion retained by our rather coarse-mesh net. A large part of the plankton escapes through this net--those immature stages that are smaller than our primary targets, fish eggs and larvae. It is highly probable that a very large part of the escaping plankton is the food in sizes needed by the fish larvae we

collect--for example, as listed for anchovy larvae by Kramer and Zweifel (1970, Table 2).

It has been hypothesized that high plankton concentrations are the result of (1) high nutrient content, and (2) transport of plankton during certain seasons. Reid, Roden and Wyllie (1958) observed that dense plankton in summer months and high phosphate-phosphorous ( $PO_4$ -P) content coincide with low temperatures in the California Current region. Reid reported in 1962 that dense zooplankton might be the result of its transport into the region by the west wind drift from dense subarctic populations. Our major problem in this study is that estimates and predictions of rates of water movement, and life histories of plankton that are not well known, are inadequate to show what parts in their different stages of development drift in and out of, or stay in, the region.

#### LITERATURE CITED

- AHLSTROM, ELBERT H. and JAMES R. THRAILKILL  
1963. Plankton volume loss with time of preservation. Calif. Coop. Oceanic Fish. Invest. Rep., IX:57-73.
- ANONYMOUS  
1963. CALCOFI atlas of 10-meter temperatures and salinities 1949 through 1959. Calif. Coop. Oceanic Fish. Invest. Atlas, 1.
- ISAACS, J.D., A. FLEMINGER and J. K. MILLER  
1969. Distributional atlas of zooplankton biomass in the California Current region: spring and fall 1955-1959. Calif. Coop. Oceanic Fish. Invest. Atlas, 10, xxv + 252 p.
1971. Distributional atlas of zooplankton biomass in the California Current region: winter 1955-1959. Calif. Coop. Oceanic Fish. Invest. Atlas, 14, xxiii + 122 p.
- KRAMER, DAVID, MARY J. KALIN, ELIZABETH G. STEVENS, JAMES R. THRAILKILL, and JAMES R. ZWEIFEL  
In press. Collecting and processing data on fish eggs and larvae in the California Current region. NOAA Tech. Rep., Natl. Mar. Fish. Serv. Circ., 370.
- KRAMER, DAVID and PAUL E. SMITH  
1970a. Seasonal and geographic characteristics of fishery resources, California Current region--I. Jack mackerel. Commer. Fish. Rev. 32(5): 27-31. Also Reprint No. 871.
- 1970b. Seasonal and geographic characteristics of fishery resources, California Current region--II. Pacific saury. Commer. Fish. Rev. 32(6): 46-51. Also Reprint No. 876.
- 1970c. Seasonal and geographic characteristics of fishery resources, California Current region--III. Pacific hake. Commer. Fish. Rev. 32(7): 41-44. Also Reprint No. 880.
- 1970d. Seasonal and geographic characteristics of fishery resources, California Current region--IV. Pacific mackerel. Commer. Fish. Rev. 32(10): 47-49. Also Reprint No. 891.
- 1971a. Seasonal and geographic characteristics of fishery resources, California Current region--V. Northern anchovy. Commer. Fish. Rev. 33(3): 33-38. Also Reprint No. 907.
- 1971b. Seasonal and geographic characteristics of fishery resources, California Current region--VI. Rockfish. Commer. Fish. Rev. 33(7 & 8): 40-43. Also Reprint No. 915.
- 1971c. Seasonal and geographic characteristics of fishery resources, California Current region--VII. Pacific sardine. Commer. Fish. Rev. 33(10): 7-11. Also Reprint No. 922.
- KRAMER, DAVID and JAMES R. ZWEIFEL  
1970. Growth of anchovy larvae (*Engraulis mordax* Girard) in the laboratory as influenced by temperature. Calif. Coop. Oceanic Fish. Invest. Rep., 14: 84-87.
- McGOWAN, JOHN A. and VERNIE J. FRAUNDORF  
1966. The relationship between size of net used and estimates of zooplankton diversity. Limnol. Oceanogr., 11(4): 456-469.
- REID, Jr., JOSEPH L.  
1962. On circulation, phosphate-phosphorus content, and zooplankton volumes in the upper part of the Pacific Ocean. Limnol. Oceanogr., 7(3): 287-306.
- \_\_\_\_\_, GUNNAR I. RODEN, and JOHN G. WYLLIE  
1958. Studies of the California Current system. Calif. Coop. Oceanic Fish. Invest. Rep., 26-56.
- RICE, DALE W.  
1972. The great blue whale. Pac. Search, 6(6): 8-10.
- SMITH, PAUL E.  
1971. Distributional atlas of zooplankton volume in the California Current region, 1951 through 1966. Calif. Coop. Oceanic Fish. Invest. Atlas, 13, xvi + 144 p.
- STAFF, SOUTH PACIFIC FISHERY INVESTIGATIONS  
1952. Zooplankton volumes off the Pacific coast, 1951. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish 73, 37 p.

## LITERATURE CITED (Contd.)

- STAFF, SOUTH PACIFIC FISHERY INVESTIGATIONS (Contd.)
1953. Zooplankton volumes off the Pacific coast, 1952. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 100, 41 p.
1954. Zooplankton volumes off the Pacific coast, 1953. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 132, 38 p.
1955. Zooplankton volumes off the Pacific coast, 1954. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 161, 35 p.
1956. Zooplankton volumes off the Pacific coast, 1955. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 177, 31 p.
- THRAILKILL, JAMES R.
1957. Zooplankton volumes off the Pacific coast, 1956. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 232, 50 p.
1959. Zooplankton volumes off the Pacific coast, 1957. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 326, 57 p.
1961. Zooplankton volumes off the Pacific coast, 1958. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 374, 70 p.
1963. Zooplankton volumes off the Pacific coast, 1959. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 414, 77 p.
1969. Zooplankton volumes off the Pacific coast, 1960. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 581, 50 p.
- MS. Zooplankton volumes off the Pacific coast, 1961-1966.
- WYLLIE, JOHN G. and RONALD J. LYNN
1971. Distribution of temperature and salinity at 10 meters, 1960-1969, and mean temperature, salinity and oxygen at 150 meters, 1950-1968, in the California Current. Calif. Coop. Oceanic Fish. Invest. Atlas, 15, xi + 188 p.

