THE CALCOFI ATLAS SERIES

This is the twentieth in a series of atlases containing data on the hydrography and plankton from the region of the California Current. The field work was carried out by the California Cooperative Oceanic Fisheries Investigations, a program sponsored by the State of California under the direction of the State's Marine Research Committee. The cooperating agencies in the program are:

- California Academy of Sciences
- California Department of Fish and Game
- Stanford University, Hopkins Marine Station
- National Oceanic and Atmospheric Administration, National Marine Fisheries Service
- University of California, Scripps Institution of Oceanography

CalCOFI atlases are issued as individual units as they become available. They provide processed physical, chemical and biological measurements of the California Current region. Each number may contain one or more contributions. A general description of the CalCOFI program with its objectives appears in the preface of Atlas No. 2.

This atlas was prepared by the Data Collection and Processing Group of the Marine Life Research Program, Scripps Institution of Oceanography.

CalCOFI Atlas Editorial Staff:
Abraham Fleminger and John G. Wyllie, Editors

CalCOFI atlases in this series, through June 1974, are:

No. 7. Fleminger, A., 1967. Distributional atlas of calanoid copepods in the California Current region, Part II.


1 Usually abbreviated CalCOFI, sometimes CALCOFI or CCOFI.
2 Formerly called U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries.
3 For citation this issue in the series should be referred to as CalCOFI Atlas No. 20.
Library of Congress Catalog Card Number 67-4238.
CALCOFI BASIC STATION PLAN
SINCE 1950
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CalCOFI Atlas No. 20
A. Fleminger and J. G. Wyllie, Editors
Data Collection and Processing Group
Marine Life Research Program
Scripps Institution of Oceanography
La Jolla, California
June, 1974
DISTRIBUTION OF NITRATE, NITRITE, PHOSPHATE AND SILICATE
IN THE CALIFORNIA CURRENT REGION, 1969

W. H. Thomas and D. L. R. Seibert

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Introduction

Nutrient levels are important in controlling the productivity of phytoplankton in the sea and in turn the other biota that are dependent on phytoplankton as a food source. Coastal regions where nutrient concentrations are high are areas of major fishing activity. An example is the Peru Current where nutrient replenishment due to widespread upwelling supports the world’s largest fishery.

In the California Current region thousands of nutrient determinations have been made since the CalCOFI program commenced in 1949. Sources of data on nutrient concentrations off California prior to 1969 are summarized in Table 1.

Phosphate data are abundant for the years 1949 to 1951 and moderately so for 1955. However, for nearly all years from 1951 to 1960, no nutrient data were collected by CalCOFI cruises. In 1961, the collecting of chemical data increased with the advent of newer, more reliable methods of analysis, and other nutrients in addition to phosphate were measured. In 1964 to 1966, five nutrients were analyzed during an extensive series of cruises carried out off southern Baja California by the Scripps Tuna Oceanography Research (STOR) project. Chemical nutrients were not measured by the CalCOFI program in 1966 and 1967, but the Food Chain Research Group (FCRG) of the Institute of Marine Resources carried out an extensive time series of analyses at three nearshore stations off La Jolla. Other nearshore data are available for 1959 and 1960.

In 1969 nutrient measurements off California was greatly expanded. A more complete suite of nutrients was analyzed and measurements were obtained in almost every month of the year. It is especially useful that one of the principal nitrogen sources, nitrate, was measured since it has been shown to limit phytoplankton production off Baja California and southern California (Thomas, 1969; Thomas et al, 1974).

In this atlas we present charts of the horizontal distribution of major phytoplankton nutrients, nitrate, nitrite, phosphate and silicate in the California Current region during 1969.

1. Scripps Tuna Oceanography Research Program
Institute of Marine Resources
Scripps Institution of Oceanography, La Jolla,
California.
<table>
<thead>
<tr>
<th>Date</th>
<th>Cruise</th>
<th>Nutrients Analyzed</th>
<th>Remarks:</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>CCOFI</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations. Seasonal coverage.</td>
<td>Rakestraw et al. (1957)</td>
</tr>
<tr>
<td>1950</td>
<td>CCOFI</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations. Seasonal coverage.</td>
<td>Rakestraw et al. (1960)</td>
</tr>
<tr>
<td>1951</td>
<td>CCOFI</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations. Seasonal coverage.</td>
<td>Reid et al. (1963 a)</td>
</tr>
<tr>
<td>1953</td>
<td>Transpac</td>
<td>PO₄-P SiO₃-Si</td>
<td>1 station within California Current Area</td>
<td>Reid et al. (1965 a)</td>
</tr>
<tr>
<td>1955</td>
<td>NORPAC</td>
<td>PO₄-P SiO₃-Si</td>
<td>Moderate number of stations</td>
<td>Rakestraw et al. Norpac (1960)</td>
</tr>
<tr>
<td>1956</td>
<td>SCOPE</td>
<td>PO₄-P SiO₃-Si</td>
<td>1 station off southern Baja California</td>
<td>Reid et al. (1963 b)</td>
</tr>
<tr>
<td>1959</td>
<td>STOR TO59-1</td>
<td>PO₄-P SiO₃-Si</td>
<td>3 stations off southern Baja California</td>
<td>Reid et al. (1965 b)</td>
</tr>
<tr>
<td>1959</td>
<td>Allan Hancock</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nearshore surface stations in Southern California Bight, October-November</td>
<td>Chambers (1965)</td>
</tr>
<tr>
<td>1960</td>
<td>Allan Hancock</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nearshore surface stations in Southern California Bight, April</td>
<td>Chambers (1965)</td>
</tr>
<tr>
<td>1961</td>
<td>CCOFI</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations in July and August</td>
<td>Anon., SIO Ref. 62-16 (1962)</td>
</tr>
<tr>
<td>1962</td>
<td>CCOFI 6210-11</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations in October and November</td>
<td>Anon., SIO Ref. 63-25 (1963 a)</td>
</tr>
<tr>
<td>1963</td>
<td>CCOFI 6301-2,6304, 6311</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations in January, February, April, May, November, December (latter 2 months with only a few nearshore stations off southern Baja California)</td>
<td>Anon., SIO Ref. 64-2 (1963 b) Anon., SIO Ref. 64-13 (1964 a) Anon., SIO Ref. 65-1 (1964 b)</td>
</tr>
<tr>
<td>1964</td>
<td>CCOFI 6401,6404, 6407</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations in January, February, March, April, July</td>
<td>Anon., SIO Ref. 65-7 (1965 a) Anon., SIO Ref. 66-20 (1966)</td>
</tr>
<tr>
<td>1965</td>
<td>CCOFI 6501,6504, 6507</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available for many stations in January, February, March, April, June, July, August</td>
<td>Anon., SIO Ref. 66-4 (1965 b) Anon., SIO Ref. 67-16 (1967 a) Anon., SIO Ref. 67-17 (1967 b) Thomas (Unpublished data)</td>
</tr>
<tr>
<td>1965</td>
<td>STOR TO64-1</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available from many stations off southern Baja California in June and August</td>
<td>Anon., SIO Ref. 69-4 (1969) IMR Ref. 69-8</td>
</tr>
<tr>
<td>1965</td>
<td>STOR TO65-1</td>
<td>PO₄-P SiO₃-Si</td>
<td>Many stations off southern Baja California in September</td>
<td>Thomas (Unpublished data)</td>
</tr>
<tr>
<td>1966</td>
<td>STOR TO66-1</td>
<td>PO₄-P SiO₃-Si</td>
<td>Many stations off southern Baja California in November</td>
<td>Thomas (Unpublished data)</td>
</tr>
<tr>
<td>1967</td>
<td>FCRG</td>
<td>PO₄-P SiO₃-Si</td>
<td>3 stations off La Jolla occupied weekly for 5-month period April-September</td>
<td>Strickland (1968)</td>
</tr>
<tr>
<td>1968</td>
<td>CCOFI 6804,6806</td>
<td>PO₄-P SiO₃-Si</td>
<td>Nutrient data available for many stations in April, May, June</td>
<td>Anon., SIO Ref. 71-3 (1971)</td>
</tr>
</tbody>
</table>
Methods

Water samples were collected by Nansen bottles or with a Niskin sampler. Hydrographic casts to 1000 meters were made at selected stations. The data from these stations were used for estimating the abundance of nutrients in the upper 50 meters, by integration, and for the distribution at 100 meters. In addition to the hydrographic stations intermediate positions were sampled at 10-meter depths.

Most of the samples were analyzed immediately after collection by means of the autoanalyzer technique (Strickland and Parsons, 1968). The limits of detection of nitrate, nitrite, phosphate and silicate using these procedures are 0.1, 0.01, 0.03 and 0.1 μg-atoms/liter respectively. In the lattermost cruises of 1969 samples were frozen and processed ashore using the autoanalyzer.

Integration of the data from 0 to 50 meters and the plotting of the 10 meter, 100 meter and integrated values was carried out with the aid of a CDC 3600 computer; contours were fitted by eye.

10 Meter Nutrients

To illustrate near-surface mixed layer nutrient distributions charts are presented showing contoured values from a depth of 10 meters. Especially high nutrient values were found during periods of seasonal upwelling along the central California coast, Point Conception, Punta Eugenia and Punta Abreojos. Generally lower values were found farther offshore.

Nutrients Integrated 0 - 50 Meters

These data provide a general idea of the nutrients available to phytoplankton in the euphotic zone. Their distributions are similar to those at 10 meters.

100 Meter Nutrients

These charts show the distribution below the mixed layer. They may vary more due to physical than to biological processes. The distributions show the nutrient levels that might enter the euphotic zone as a result of upwelling or vertical mixing.

Acknowledgements

Technicians of the Data Collecting and Processing Group, Marine Life Research Program, Scripps Institution of Oceanography were responsible for collecting and analyzing the samples and for computing the results. The preparation of these charts was partially supported by the Oceanography Program, National Science Foundation, Grant GA32529X.

REFERENCES CITED


CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
10 METER NITRATE-N
CONTOUR INTERVAL 2 μg-at/liter
(0.1 μg-at/liter contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
10 METER NITRATE-N
CONTOUR INTERVAL 2μg-at/liter
(0.1μg-at/liter contour dashed)

CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
10 METER NITRATE-N

CONTOUR INTERVAL 2 μg-at/liter
(0.1 μg-at/liter contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969
10 METER NITRATE-N
CONTOUR INTERVAL 2 µg-at/liter
(0 µg-at/liter contour dashed)
CALCOFI CRUISE 6907
10-29 JULY 1969
10 METER NITRATE-N
CONTOUR INTERVAL 2 μg-at/liter
0.1 μg-at/liter contour dashed

10 m NITRATE-N
6907
CALCOFI CRUISE 6908-9
6 AUG - 8 SEPT and 11 SEPT - 7 OCT 1969
MENDOCINO

IO METER NITRATE-N
CONTOUR INTERVAL 2µg-at/liter
(0.1µg-at/liter contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969

10 METER NITRATE-N

CONTOUR INTERVAL 2μg-at/liter
(0.1μg-at/liter contour dashed)
CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
10 METER NITRITE - N
CONTOUR INTERVAL 0.1 µg-at/liter
(0.05 µg-at/liter contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
10 METER NITRITE - N
CONTOUR INTERVAL 0.1 µg-at/liter
(0.05 µg-at/liter contour dashed)
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
10 METER NITRITE - N
CONTOUR INTERVAL 0.1 μg-at/liter
(0.05 μg-at/liter contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

10 METER NITRITE-N
CONTOUR INTERVAL 0.1μg-at/liter
(0.05μg-at/liter contour dashed)
CALCOFI CRUISE 6908-9
6 AUG - 8 SEPT. and 11 SEPT. - 7 OCT. 1969

10 METER NITRITE - N
CONTOUR INTERVAL 0.1 µg-at/liter
(0.05 µg-at/liter contour dashed)

10m NITRITE-N
6908-9
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
10 METER NITRITE - N
CONTOUR INTERVAL 0.1 μg-at/liter
(0.05 μg-at/liter contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
10 METER NITRITE - N

CONTOUR INTERVAL 0.1 μg-at/liter
(0.05 μg-at/liter contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
10 METER PHOSPHATE - P
CONTOUR INTERVAL 0.25 μg-at/liter
CALCOFI CRUISE 6904
2 - 26 APRIL 1969

10 METER PHOSPHATE - P
CONTOUR INTERVAL 0.25μg-at/liter
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969
10 METER PHOSPHATE-P
CONTOUR INTERVAL 0.25µg-at/liter

10m PHOSPHATE-P
CALCOFI CRUISE 6908-9
6 AUG.-8 SEPT. and 11 SEPT. - 7 OCT. 1969
10 METER PHOSPHATE - P
CONTOUR INTERVAL 0.25 µg-at/liter
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
10 METER PHOSPHATE - P
CONTOUR INTERVAL 0.25μg-at/liter
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
10 METER SILICATE - Si
CONTOUR INTERVAL 5µg-at/liter
(2µg-at/liter contour dashed)
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
10 METER SILICATE - Si
CONTOUR INTERVAL 5µg-at/liter
(2µg-at/liter contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

10 METER SILICATE - Si
CONTOUR INTERVAL 5 μg-at/liter
(2 μg-at/liter contour dashed)
CALCOFI CRUISE 6908-9
6 AUG. - 8 SEPT. and 11 SEPT. - 7 OCT. 1969
10 METER SILICATE - Si
CONTOUR INTERVAL 5μg-at/liter
(2μg-at/liter contour dashed)

10m SILICATE - Si
6908-9
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969

10 METER SILICATE - Si
CONTOUR INTERVAL 5 µg-at/liter
(2 µg-at/liter contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969

10 METER SILICATE - Si

CONTOUR INTERVAL 5 μg-at/liter
(2 μg-at/liter contour dashed)
CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
NITRATE-N
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 100 mg-at/m²
(10 mg-at/m² contour dashed)
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
NITRATE-N
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 100 mg-at/m²
(10 mg-at/m² contour dashed)

SAN FRANCISCO
 Point Conception
 SAN DIEGO
PUNTA EUGENIA

INTEGRATED NITRATE-N
6904
INTEGRATED NITRATE-N

CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969
NITRATE-N
INTEGRATED 0-50 METERS

CONTOUR INTERVAL 100 mg-at/m²
(10 mg-at/m² contour dashed)

INTEGRATED NITRATE-N

6905-6
CALCOFI CRUISE 6907
10-29 JULY 1969

NITRATE-N
INTEGRATED 0-50 METERS

CONTOUR INTERVAL 100 mg-at/m²
(10 mg-at/m² contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
NITRATE - N
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 100 mg-at/m²
(10 mg-at/m² contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969

NITRITE - N
INTEGRATED 0 - 50 METERS

CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
NITRITE - N
INTEGRATED 0 - 50 METERS

CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

NITRITE - N
INTEGRATED 0 - 50 METERS

CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)

INTEGRATED NITRITE - N
6905-6
CALCOFI CRUISE 6907
10-29 JULY 1969
NITRITE - N
INTEGRATED 0-50 METERS

CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)
CALCOFI CRUISE 6908-9
6 AUG. - 8 SEPT. and 11 SEPT. - 7 OCT. 1969

NITRITE - N
INTEGRATED 0-50 METERS

CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)

INTEGRATED NITRITE - N

6908-9
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
NITRITE - N
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
NITRITE - N
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 2 mg-at/m²
(0.5 mg-at/m² contour dashed)

INTEGRATED NITRITE-N
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
PHOSPHATE - P
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 10mg-at/m²
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

PHOSPHATE - P
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 10mg-at/m²

INTEGRATED PHOSPHATE - P
6905-6
CALCOFI CRUISE 6908-9
6 AUG. - 8 SEPT. and 11 SEPT. - 7 OCT. 1969
PHOSPHATE - P
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 10mg-at/m²

INTEGRATED PHOSPHATE - P
6908-9
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
PHOSPHATE - P
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 10 mg-at/m²

INTEGRATED PHOSPHATE-P
6912
CALCOFI CRUISE 6907
10-29 JULY 1969

SILICATE - Si
INTEGRATED 0 - 50 METERS

CONTOUR INTERVAL 200 mg-at/m²
(100 mg-at/m² contour dashed)
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969

SILICATE - Si
INTEGRATED 0 - 50 METERS

CONTOUR INTERVAL 200 mg-at/m²
(100 mg-at/m² contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969

SILICATE - Si
INTEGRATED 0 - 50 METERS
CONTOUR INTERVAL 200 mg-at/m²
(100 mg-at/m² contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
100 METER NITRATE-N
CONTOUR INTERVAL 5μg-at/liter

100m NITRATE-N

6902
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
100 METER NITRATE-N
CONTOUR INTERVAL 5μg-at/liter

100m NITRATE-N
CALCOFI CRUISE 6907
10-29 JULY 1969

100 METER NITRATE-N
CONTOUR INTERVAL 5 μg-at/liter

CAPE MENDOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
PUNTA EUGENIA

100m NITRATE-N
CALCOFI CRUISE 6908-9
6 AUG - 8 SEPT. and 11 SEPT. - 7 OCT. 1969

100 METER NITRATE-N
CONTOUR INTERVAL 5 μg-at/liter
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
100 METER NITRATE-N
CONTOUR INTERVAL 5 µg-at/liter

100 m NITRATE-N
6910
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
100 METER NITRATE-N
CONTOUR INTERVAL 5μg-at/liter
CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
100 METER NITRITE-N
CONTOUR INTERVAL 0.05μg-at/liter
(0.01μg-at/liter contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
100 METER NITRITE-N
CONTOUR INTERVAL 0.05 µg-at/liter
(0.01 µg-at/liter contour dashed)
CALCOFI CRUISE 6904
2-26 APRIL 1969
100 METER NITRITE—N
CONTOUR INTERVAL 0.05μg-at/liter
(0.01μg-at/liter contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

100 METER NITRITE - N

CONTOUR INTERVAL 0.05 µg-at/liter
(0.01 µg-at/liter contour dashed)

100m NITRITE - N

6905-6
CALCOFI CRUISE 6907
10-29 JULY 1969

100 METER NITRITE-N

CONTOUR INTERVAL 0.05 μg-at/liter
(0.01 μg-at/liter contour dashed)
CALCOFI CRUISE 6908-9
6 AUG - 8 SEPT. and 11 SEPT. - 7 OCT. 1969
100 METER NITRITE - N
CONTOUR INTERVAL 0.05 µg-at/liter
(0.01 µg-at/liter contour dashed)
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
100 METER NITRITE-N
CONTOUR INTERVAL 0.05 µg-at/liter
(0.01 µg-at/liter contour dashed)

SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
PUNTA EUGENIA
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
100 METER NITRITE-N
CONTOUR INTERVAL 0.05μg-at/liter
(0.0μg-at/liter contour dashed)
CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
100 METER PHOSPHATE - P
CONTOUR INTERVAL 0.5µg-at/liter

SAN FRANCISCO
CAPE MENDOCINO
POINT CONCEPTION
SAN DIEGO
PUNTA EUGENIA
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
100 METER PHOSPHATE-P
CONTOUR INTERVAL 0.5 µg-at/liter

100m PHOSPHATE-P
CALCOFI CRUISE 6904
2 - 26 APRIL 1969
100 METER PHOSPHATE - P
CONTOUR INTERVAL 0.5μg-at/liter
CALCOFI CRUISE 6905-6
5 – 29 MAY and 9 – 28 JUNE 1969
100 METER PHOSPHATE – P
CONTOUR INTERVAL 0.5 μg-at/liter
CALCOFI CRUISE 6907
10 - 29 JULY 1969
100 METER PHOSPHATE - P
CONTOUR INTERVAL 0.5 \( \mu \text{g-at/liter} \)

100 m PHOSPHATE - P

6907
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969

100 METER PHOSPHATE-P
CONTOUR INTERVAL 0.5 µg-at/liter

100 m PHOSPHATE-P
6910
CALCOFI CRUISE 6901
6 - 30 JANUARY 1969
100 METER SILICATE - Si
CONTOUR INTERVAL 10μg-at/liter
(5 μg-at/liter contour dashed)
CALCOFI CRUISE 6902
13 FEBRUARY - 11 MARCH 1969
100 METER SILICATE - Si

CONTOUR INTERVAL 10µg-at/liter
(5µg-at/liter contour dashed)
CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969
100 METER SILICATE-Si
CONTOUR INTERVAL 10 µg-at/liter
(5 µg-at/liter contour dashed)
CALCOFI CRUISE 6907
10-29 JULY 1969
100 METER SILICATE - Si
CONTOUR INTERVAL 10μg-at/liter
(5μg-at/liter contour dashed)
CALCOFI CRUISE 6908-9
6 AUG - 8 SEPT. and 11 SEPT. - 7 OCT. 1969
100 METER SILICATE - Si
CONTOUR INTERVAL 10μg-at/liter
(5 μg-at/liter contour dashed)
CALCOFI CRUISE 6910
9 OCTOBER - 8 NOVEMBER 1969
100 METER SILICATE - Si

CONTOUR INTERVAL 10μg-at/liter
(5μg-at/liter contour dashed)
CALCOFI CRUISE 6912
13 NOVEMBER - 17 DECEMBER 1969
100 METER SILICATE - Si

CONTOUR INTERVAL 10µg-at/liter
(5µg-at/liter contour dashed)
The charts presented in the phytoplankton section of this atlas summarize measurements obtained systematically in the California Current region during 1969. Together with subsequent measurements, the data assume special significance since they are the only extant source for estimating seasonal cycles, annual changes, and spatial variations in the region. As phytoplankton supports the natural marine food resources available to man, the postulated sensitivity of potential fish yield to phytoplankton variations and the sensitivity of these variations to more easily measured and perhaps predictable environmental changes may be confirmed through these measurements.

Phytoplankton Pigments

Pigment concentrations were determined by fluorometry using water samples from prescribed regular and special CalCOFI stations. More than 10 levels were usually sampled between the surface and 150m depth in 1969. A secchi disc measurement was usually used to determine appropriate sampling depths at each station. Where no Secchi reading was possible, standardized depths were sampled. Methods of pigment analyses were used consistent with procedures recommended by the Biological Methods Panel Committee on Oceanography, National Academy of Science (1969).

Samples in 270-ml plastic bottles were filtered under low vacuum (not exceeding -7 inches of mercury) through Whatman GF/C glass fiber filters (2.4-cm diameter) having a thin magnesium carbonate coating. Filtration was usually completed within a half hour after sample collection. In some instances, however, samples were chilled and stored in darkness up to 12 hours before processing.

Filters were placed in 90%-v/v-spectral-quality acetone, ground for 30 seconds in a motor-driven tissue grinder and stored dark for 10 minutes to permit full extraction of the pigments. Filters and extract were separated by centrifuging for 10 minutes. Extract volume was brought up to 10.0 ml; about 5 ml was placed in a cuvette and submitted to a Turner fluorometer, Model 111, for fluorometric analysis by the method of Holm-Hansen, Lorenzen, Holmes and Strickland (1965). A blue-pass Corning 5-60 primary filter and a red-pass Corning 2-64 secondary filter were used in conjunction with the light source and the detector, a red-sensitive multiplier phototube (Hamamatsu R 136).

On occasion, a fluorometer failure occurred and sample filters were folded, stored dark in a freezer,

1. National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, California 92037
and analyzed later aboard ship or returned frozen to La Jolla for analysis. Values so obtained were multiplied by 1.1 to account for the consistent 10% loss that occurs when samples are stored for more than a day (Author's data: Lorenzen, pers. comm.).

All phytoplankton data were card punched, verified, and submitted to the CDC 3600 computer for calculation of basic phytoplankton parameters. Computed and listed by cruise, station and depth were chlorophyll a concentration, phaeo-pigment concentration, total pigment concentration, phytoplankton production per unit volume and several parameters for use in editing and interpreting these basic values. Also printed were interpolations and vertical profiles of pigment and production values.

Pigment concentrations were calculated from the equations given by Lorenzen (1966):

\[
\text{chlorophyll } a \text{ (mgm}^{-3}) = \frac{F_o/F_{a \text{ max}}}{(F_o/F_{a \text{ max}} - 1) (k_x) (F_o - F_a)} \text{ liters filtered}
\]

\[
\text{phaeophytin } a \text{ (mgm}^{-3}) = \frac{F_o/F_{a \text{ max}}}{(F_o/F_{a \text{ max}} - 1) (k_x) [F_o/F_{a \text{ max}} (F_a - F_o)]} \text{ liters filtered}
\]

where:  
- \( F_o \) = fluorescence before acidification  
- \( F_a \) = fluorescence after acidification  
- \( F_o/F_{a \text{ max}} \) = maximum acid factor which can be expected in the absence of phaeophytin  
- \( k_x \) = calibration constant for a specific sensitivity scale

The \( k_x \) factors were determined by submitting known concentrations of chlorophyll a to each fluorometer and observing fluorescence units. Linearity of each instrument was checked by serial dilution of pigment extracts. The maximum acid factor was determined by observing fluorescence before and after acidification of extracts of diatom and dinoflagellate cultures sampled in logarithmic phase of growth when phaeo-pigments are absent.

Field measurements were examined station-by-station. Constancy of the shape of each vertical profile was considered and in the few cases where a second deep maximum occurred that was defined by a single observation, a scale reading error was presumed to have occurred and the value was rejected. In addition, the vertical profile of the acid factor (the proportional change of pigment fluorescence upon acidification of the extract) was examined. This factor normally decreased monotonically from surface layer values near 2 to deep values near 1. Where single significant departures from this pattern occurred, sample values either were justified from the original data, or, if no simple change of values could be supported in terms of analyst error, the observation was rejected. Both apparent errors and rejections were rare, never exceeding 1% on most cruises.

Plant pigments, both chlorophyll a and phaeopigment concentrations, were integrated to 150 m to express the total pigment under a square meter of sea surface. Only minute quantities of plant pigment occur below 150 m except in the extreme, offshore portion of the survey tracks. The integration programs were based on Simpson's Rule for irregular areas and therefore use a linear interpolation between observations. Where water depth was too shallow to permit sampling to 150 m depth, integration was performed to the deepest sample. Integration values at such stations probably underestimate water column pigment totals since the deepest sample may not be close to the bottom.

**Phytoplankton production-simulated in situ method**

Production measurements were made by a modification of the \(^{14}\text{C} \) method of Steemann-Nielsen (1952). Sampling depths were chosen to span the range of light intensities over which phytoplankton production exceeds respiration. Samples drawn from biologically inert Lexan plastic samplers were placed in 270 ml glass bottles and inoculated with 10 to 20 \( \mu \)Ci of sterile Na\(^{14}\text{CO}_2 \) solution buffered at pH 9.0. Directly after inoculation the samples were loaded into two cylindrical incubators. One incubator was completely opaque and the other was screened to transmit intensity of incident solar radiation present at each of the seven sampled depths. Once loaded, the incubators were placed under full exposure to sun and sky radiation. The time for collecting samples was arranged so that incubation could be started at local apparent noon. Incubation continued until local sunset, when the samples were recovered for filtration. Spectral quality of the light was not controlled. Surface sea water was pumped through the incubators to control temperature.

---

1. Phaeo-pigments are degradation products of chlorophyll a and represent detrital pigment.
Filtration was conducted in subdued light at a vacuum not ordinarily exceeding -7 inches of mercury using Millipore membrane filters (2.5 cm diameter) with 0.45-μm pore diameters. The filters were then glued to identified copper planchets, placed in perforated pill boxes and stored in desiccators. Upon their return to shore for radioassay, the filters were fumed over concentrated HCl for 10 minutes, sorted by station and returned to their desiccators to await beta-assay. As soon as possible after fuming, samples were turned over to the General Atomic Corporation, La Jolla, California, where they were counted on Beckman wide-beta gas flow counters. Detector end windows were of 80-μg/cm² Mylar with 5.72-cm diameters. Samples were counted for 3 minutes. Background counts, which usually did not exceed three per minute, were determined and subtracted from each sample count. Counter efficiencies were 27.0 and 34.0% during the entire period of analyses, as determined from point-source standards calibrated against those maintained by the National Bureau of Standards.

Production rate of the phytoplankton was calculated from the equation:

Production (mg C/m³/day) = \(\frac{(L - D) W}{A \times E} \times 1.05 \times 2\)

where:
- \(L\) = counting rate (counts per minute) of the phytoplankton in the light bottle.
- \(D\) = counting rate (counts per minute) of the phytoplankton in the dark bottle.
- \(W\) = weight of carbonate carbon in the water assumed to be 25,000 mg/m³.
- \(A\) = discharges per minute by the radiocarbon added to each sample; usually 4.44 \(\times 10^7\) dpm
- \(E\) = counter efficiency, determined experimentally for each counter.
- 1.05 = factor to allow for difference in uptake rate of \(^{14}\)C as compared with that of \(^{12}\)C
- 2 = correction from the half day incubation period to full day.

Criteria for rejection of production values, while applied over the whole period of the field program, were reworked frequently to ensure consistency. Averaged dark counts were submitted for a single high dark value when the latter occurred at a station, if the corresponding light count was consistent with known profile characteristics. Sets of high dark counts were accepted if they were not erratic (indicating contamination) and if they were well below the corresponding light counts. Values for entire stations were rejected if the vertical profile was so erratic as to indicate light leaks in incubators, inadvertent exposure to ambient light during filtration, or contamination of the \(^{14}\)C stock.

Production values for the water column were obtained by computer integration to the euphotic depth. As with plant pigment integrations, Simpson's Rule was used.

**Secchi Depth**

Diffuse attenuation of light in the water was estimated from the Secchi depth, determined by lowering a flat 30-cm white disc until it disappeared from sight, then raising the disc until it reappeared and averaging the corresponding depths. Euphotic depth, taken to be at 1% of surface light intensity, was assumed for experimental purposes to occur at 3 X the Secchi depth. (Author's data; R.W. Eppley and J.D.H. Strickland, pers. comm.)

**Chart Preparation**

The spatial density of phytoplankton measurements obtained in any single cruise was considered too sparse to warrant contouring the resulting values. A number of stations were sampled repeatedly, however, and sufficient internal agreement between plant pigment and Secchi depth values was obtained from one cruise period to the next to permit pooling of the data into 3-month intervals. The coherence of the contoured patterns that arise from pooling help to confirm the validity of pooling. The particular 3-month intervals presented were chosen to span chronologically the year of observations rather than to represent extremes in the variations encountered. Inspection of the time variations over the region revealed that these pooling intervals were at least as representative of the variations as any other set of 3-month intervals, although more optimal periods might be chosen to represent seasonal change in some sub-areas of the region.

For contouring the charts of plant pigment and Secchi depth distributions, values at stations occupied more than once in the pooling interval were averaged. Contour intervals were selected simply for clarity of representing the distributions: a quasi-geometric progression was necessary for the plant pigment distributions, whereas constant intervals most clearly represented the distribution of water clarity as measured by Secchi depth. In situ production observations were so sparse in time and space as to preclude meaningful contouring.
Computed values by station and cruise of chlorophyll $a$, phaeo-pigments, production and Secchi depths, from which these charts were prepared, are reported by Owen and Sanchez (1974) together with insolation and mixed-layer depth.

REFERENCES CITED


PRIMARY PRODUCTION
INTEGRATED OVER EUPHOTIC ZONE
mg C/m²/day

MAY - JUNE 1969

PRIMARY PRODUCTION
MAY - JUNE 1969
PRIMARY PRODUCTION
INTEGRATED OVER EUPHOTIC ZONE
mg C/m²/day
AUGUST - SEPTEMBER 1969
PRIMARY PRODUCTION
INTEGRATED OVER EUPHOTIC ZONE
mg C/ m²/day

NOVEMBER - DECEMBER 1969
CHLOROPHYLL g
AT THE SEA SURFACE, mg/m³
JAN. - FEB. - MAR. 1969
CONTOUR INTERVALS
0.1 mg/m³
0.5 mg/m³
(0.05 mg/m³ contour dashed)

CAPE MENOCINO
SAN FRANCISCO
POINT CONCEPTION
SAN DIEGO
PUNTA EUGENIA
CHLOROPHYLL a
AT THE SEA SURFACE, mg/m³
JUL. - AUG. - SEP. 1969

CONTOUR INTERVALS
0.1 mg/m³
0.5 mg/m³
(0.05 mg/m³ contour dashed)

SAN FRANCISCO
SAN DIEGO
PUNTA EUGENIA
CHLOROPHYLL $\mu g$
AT THE SEA SURFACE, mg/m$^3$
OCT. - NOV. - DEC. 1969

CONTOUR INTERVALS
0.1 mg/m$^3$
0.5 mg/m$^3$
(0.05 mg/m$^3$ contour dashed)
CHLOROPHYLL a
INTEGRATED TO 150 METER DEPTH, mg/m²
JAN. - FEB. - MAR. 1969

CONTOUR INTERVALS
5 mg/m²
20 mg/m²
CHLOROPHYLL a
INTEGRATED TO 150 METER DEPTH, mg/m²
APR.-MAY-JUN. 1969

CONTOUR INTERVALS
5 mg/m²
20 mg/m²

SAN FRANCISCO
SAN DIEGO
PUNTA EUGENIA

APR.-MAY-JUN. 1969
CHLOROPHYLL a
INTEGRATED TO 150 METER DEPTH, mg/m²
JUL.- AUG.- SEP. 1969

CONTOUR INTERVALS
5 mg/m²
20 mg/m²

SAN FRANCISCO
CAPE MENDOCINO
SAN DIEGO
PUNTA EUGENIA
PHAEO PIGMENTS
(PHAEOPHYTIN, PHAEOPHORBIDES)
INTEGRATED TO 150 METER DEPTH, mg/m²

APR.-MAY-JUN. 1969

CONTOUR INTERVALS
5 mg/m²
20 mg/m²

SAN DIEGO
PUNTA EUGENIA

CAPE MENDOCINO
SAN FRANCISCO
PHAEO PIGMENTS
(PHEOPHYTIN, PHEOPHORBIDES)
INTEGRATED TO 150 METER DEPTH, mg/m²

JUL. - AUG. - SEP. 1969

CONTOUR INTERVALS
5 mg/m²
20 mg/m²

SAN FRANCISCO

POINT CONCEPTION

SAN DIEGO

PUNTA EUGENIA
SECCHI DEPTH
JUL.- AUG.- SEP. 1969
CONTOUR INTERVAL 5 METERS
SECCHI DEPTH

OCT. - NOV. - DEC. 1969

CONTOUR INTERVAL 5 METERS
Introduction

This report presents contoured charts summarizing displacement volumes of zooplankton samples that were collected systematically during regular CalCOFI cruises carried out in 1969.

The sampling in 1969 differs in two details from that carried out in the years 1951 to 1966 described by Smith (1971): 1. The depth of the standard CalCOFI oblique tow was increased to approximately 210 meters by paying out and retrieving 300 meters of cable at the usual rates of release and return (50 meters per minute out and 20 meters per minute in). 2. The standard CalCOFI net was constructed of a single grade of nylon fabric with mesh apertures of 0.505 mm. Previous nets were constructed of two grades of bolting silk, the anterior section having apertures of 0.55 mm and the posterior section having apertures of 0.25 mm.

A sampling study considering the effects of the two types of nets and the two depths of tow on the displacement volume was carried out at CalCOFI station 93.30 which lies ten miles west of La Jolla (latitude 32° 50.5’ N, longitude 117° 31.0’ W, bottom depth 805 meters). The object was to facilitate comparison of the systematic measurements of zooplankton volumes obtained in 1969 with those from previous CalCOFI cruises. Sets of replicate samples were collected at 10, 6 and 2 hours before and after local apparent noon by oblique tows with silk and nylon nets deployed in randomized order from 140 m and 210 m depth. A total of 42 tows were made between 2100 PST June 28 and 0300 PST July 1, 1968 (Table 1). All other field and laboratory procedures used to obtain and process the test samples and the samples from the 1969 cruises follow those described by Kramer et al (1972). Omitting the abnormally large catch by the nylon net taken at 1020PST (838 cc/1000m³) the general results (Table 2) indicate that in the test area zooplankton concentrates above 140 meters are much greater proportionately than between 140 m and 210 m depth, in both day and night sampling periods. The day to night ratio of average volume of zooplankton remains virtually the same between the 140 meter silk net tows (D/N=0.797) and the 210 meter nylon tows (D/N = 0.803). However, in terms of cc/1000m³ the volumes from the 1969 type tows tend to be 25 - 30% less than those from the previous years (Smith 1971), a decrease that will affect the contoured abundance to a limited degree.
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<th>TIME</th>
<th>VOLUME FILTERED m$^3$</th>
<th>DEPTH m</th>
<th>DISPLACEMENT $\text{cc/1000m}^3$</th>
<th>VOL DEPTH DISPLACEMENT</th>
<th>TIME</th>
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<th>DEPTH m</th>
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<td></td>
<td></td>
<td>1.36</td>
<td>1.37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Omitted from Mean

Standard Deviation

Mult. Error Factor

181.4 37.39
56.34 12.04
1.36 1.37
TABLE 2.

VOLUME FILTERED

<table>
<thead>
<tr>
<th>Type of Net and Tow</th>
<th>Average Volume Strained m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>140 meter Silk</td>
<td>440</td>
</tr>
<tr>
<td>210 meter Silk</td>
<td>635 increase 44.3% over 140 m Silk</td>
</tr>
<tr>
<td>210 meter Nylon</td>
<td>671 increase 52.5% over 140 m Silk</td>
</tr>
</tbody>
</table>

CONCENTRATION

<table>
<thead>
<tr>
<th>Type of Net and Tow</th>
<th>Average Concentration cc/1000m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>140 meter Silk</td>
<td>289</td>
</tr>
<tr>
<td>210 meter Silk</td>
<td>212 decrease 26.6% from 140 m Silk</td>
</tr>
<tr>
<td>210 meter Nylon</td>
<td>209* decrease 27.7% from 140 m Silk</td>
</tr>
</tbody>
</table>

*Omitting large 1020 PST day value for 210 meter Nylon net.

REFERENCES CITED


Zooplankton Displacement Volume

cc/1000 m$^3$ seawater strained

\[ N_D = 1.44 \quad N_T = 1.21 \]

CALCOFI CRUISE 6901
6-30 January 1969

STATIONS: ● NIGHT ○ SUNRISE
○ DAY ● SUNSET

MEAN DISPLACEMENT VOLUME (cc/1000 m$^3$) PER SAMPLE

Zooplankton Displacement Volume

6901
Zooplankton Displacement Volume

cc/1000 m³ seawater strained

\[ \frac{N}{D} = 1.55 \quad \frac{N}{T} = 1.56 \]

CALCOFI CRUISE 6904
2-26 APRIL 1969

SAN FRANCISCO

STATIONS: ● NIGHT ○ SUNRISE ○ DAY ● SUNSET

MEAN DISPLACEMENT VOLUME (cc/1000 m³) PER SAMPLE

70-77
90-97
100-107
110-119
120-127
130-137

Zooplankton Displacement Volume 6904
Zooplankton Displacement Volume

cc/1000 m³ seawater strained

N = 1.05  N = 0.57

CALCOFI CRUISE 6905-6
5-29 MAY and 9-28 JUNE 1969

STATIONS: ● NIGHT  ○ SUNRISE
○ DAY  ● SUNSET

Zooplankton Displacement Volume

6905-6
Zooplankton Displacement Volume

cc/1000 m³ seawater strained

N / D = 1.23
N / T = 1.16

CALCOFI CRUISE 6907
10-29 JULY 1969

STATIONS:
- NIGHT
- SUNRISE
- DAY
- SUNSET

MEAN DISPLACEMENT VOLUME (cc/1000 m³) PER SAMPLE
Zooplankton Displacement Volume

cc/1000 m³ seawater strained

N_D = 1.66
N_T = 1.29

CALCOFI CRUISE 6908-9
6 AUG. - 8 SEPT. and 11 SEPT. - 7 OCT. 1969

STATIONS: • NIGHT • SUNRISE
○ DAY • SUNSET

MEAN DISPLACEMENT VOLUME (cc/1000 m³) PER SAMPLE

LINES
60-67
70-77
80-87
90-97
100-107
110-119
120-127
130-137

Zooplankton Displacement Volume

6908-9
Zooplankton Displacement Volume

cc/1000 m³ seawater strained

N/D = 1.79  N/T = 1.37

CALCOFI CRUISE 6910
9 OCTOBER – 8 NOVEMBER 1969

STATIONS: • NIGHT  • SUNRISE
○ DAY  • SUNSET

MEAN DISPLACEMENT VOLUME (cc/1000 m³) PER SAMPLE

LINN
60-67
70-77
80-87
90-97
100-107
110-119
120-127
130-137
Zooplankton Displacement Volume

cc / 1000 m³ seawater strained

\[ \frac{N}{D} = 1.36 \quad N \times 0.96 \]

CALCOFI CRUISE 6912

13 NOVEMBER - 17 DECEMBER 1969

STATIONS: ● NIGHT ○ SUNRISE ○ DAY ○ SUNSET

MEAN DISPLACEMENT VOLUME (cc / 1000 m³) PER SAMPLE

<table>
<thead>
<tr>
<th>LINES</th>
<th>0</th>
<th>200</th>
<th>400</th>
<th>600</th>
<th>800</th>
<th>1000</th>
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</thead>
<tbody>
<tr>
<td>60-67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70-77</td>
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<td></td>
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</tr>
<tr>
<td>80-87</td>
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<tr>
<td>90-97</td>
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<td></td>
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</tr>
<tr>
<td>100-107</td>
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<tr>
<td>110-119</td>
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<td></td>
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</tr>
<tr>
<td>120-127</td>
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<tr>
<td>130-137</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
These maps are designed to show essential details of the area most intensively studied by the California Cooperative Oceanic Fisheries Investigations. This is approximately the same area as is shown in color on the front cover. Geographical place names are those most commonly used in the various publications emerging from the research. The cardinal station lines extending southwestward from the coast are shown. They are 120 miles apart. Additional lines are utilized as needed and can be as closely spaced as 12 miles apart and still have individual numbers. The stations along the lines are numbered with respect to the station 60 line, the numbers increasing to the west and decreasing to the east. Most of them are 40 miles apart, and are numbered in groups of 10. This permits adding stations as close as 4 miles apart as needed. An example of the usual identification is 120.65. This station is on line 120, 20 nautical miles southwest of station 60.

The projection of the front cover is Lambert's Azimuthal Equal Area Projection. The detail maps are a Mercator projection.
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