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Biological collections and hydrographic data obtained from 5-
165 nautical miles off the southern coast of Oregon were analyzed to

learn (1) if seasonal variations in the abundance of primary producers,

herbivores and primary carnivores occur and how they are related,

in time, to upwelling and (2) if there are geographic differences in

the maxima of different trophic levels as a result of the offshore

advection of upwelled water.

The mean standing stock of trophic level I (primary producers),

estimated from chlorophyll "a" concentrations, was highest inshore

during active upwelling and offshore during late winter and spring.

Mean standing stocks of trophic levels II (herbivores) and III (primary

carnivores), estimated from dry weights, were highest in the fall

after upwelling had begun to subside. The highest standing stocks

of trophic level III tended to be found successively seawards as the

upwelling season progressed.

The standing stocks of phytoplankton, herbivores, and primary carnivores were considerably higher inshore than they were offshore. The seasonal fluctuations were large and inverse relationships between trophic levels were sometimes observed inshore. Smaller amplitudes in standing stocks of phytoplankton, herbivores, and primary carnivores were observed offshore implying that the food-chain offshore tends to be more "balanced" than that found inshore.

Upwelling, resulting from periods of northerly wind stress, caused marked changes in hydrographic conditions inshore. Coastal upwelling decreased surface temperature and dissolved oxygen and increased salinity and phosphate-phosphorus content.

Major changes in the inshore portion of the oceanic frontal layer, delimited by the 25.5-26.0 sigma-t surfaces, were related to coastal upwelling; the frontal layer sloped upward, intersected the surface, and formed a surface front between the light water offshore and the heavier upwelled water inshore. During non-upwelling periods the inshore portion of the frontal layer was relatively horizontal and was found at about 25-75 meters depth.

During periods of upwelling abrupt changes in concentration of phosphate-phosphorus and in relative abundance of the standing stocks of phytoplankton, herbivores and usually primary carnivores were apparent across the surface front; the values were considerably higher inshore than they were offshore. During periods of

non-upwelling, when no surface front was present, there was relatively little difference between the inshore and offshore standing stocks of phytoplankton and phosphate-phosphorus. After upwelling had subsided, the relative abundance of trophic levels II and III were highest at about the location where the frontal layer had intersected the surface during upwelling.

COASTAL UPWELLING AND THE ECOLOGY
OF LOWER TROPHIC LEVELS

by

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COASTAL UPWELLING AND THE ECOLOGY
OF LOWER TROPHIC LEVELS

INTRODUCTION

Increased phytoplankton production is often associated with coastal upwelling, but the response of lower trophic level consumers to this enrichment is only partially understood. Biological collections and hydrographic data collected off Brookings, Oregon between 1962 and 1964 have been studied to discover some of these responses. This study has endeavored to learn (1) if there is an increase in the biomass of herbivores and carnivores, as well as the primary producers as a result of upwelling, (2) if there are geographic differences in the maxima of different trophic levels as a result of the offshore advection of upwelled water, and (3) if seasonal variations in the abundance of consumer trophic levels occur and how they are related, in time, to the occurrence of upwelling.

Coastal upwelling is strongly developed along the Oregon coast from late spring to early fall as the result of prevailing northerly winds and the Coriolis effect. The upwelled water is rich in nutrients resulting in high primary productivity throughout the summer (Anderson, 1964; Stephánsson and Richards, 1964; Curl and Small, 1965). An unique opportunity to study the effects of increased primary productivity is thus provided.

Several investigations have shown that increases in primary
productivity occur as the result of coastal upwelling (Michael, 1921;
Moberg, 1928; Gunther, 1936; Sverdrup and Allen, 1939; Allen, 1945;
Sargent and Walker, 1948; Steeman Nielsen, 1954; Bolin and Abbott,
1963; and Smayda, 1966). However, the response of consumer tro-
phic levels to primary productivity enrichment has not been adequa-
tely studied, except for limited studies relating commercially impor-
tant fishes with nutrient enriched areas. The distribution and abun-
dance of yellow fin tuna, <u>Neothunnus</u> <u>macropterus</u>, has been linked
to mid-ocean upwelling in the Central Pacific through biota in the
tuna food "web" (Sette, 1955, 1957; King, 1953). In these studies
and in one by Vinogradov and Voronina (1962), who worked in the
Indian Equatorial Current area, the bulk of the phytoplankton, her-
bivores, and carnivores were found at successively greater distances
"downstream" from the area of upwelling.

Forsbergh (1963) obtained an "almost" significant positive cor-
relation between the standing stock of zooplankton during coastal
upwelling and the mean annual catch per unit effort of skipjack tuna,
<u>Katsuwonus</u> <u>pelamis</u>, in the Gulf of Panama. Also working in the
Gulf of Panama, Smayda (1966) found a correlation among coastal
upwelling winds, phytoplankton, zooplankton, and anchoveta, <u>Ceten-</u>
<u>graulis</u> <u>mysticetus</u>.

In recent years there have been several studies dealing with

upwelling off the coast of Oregon. Chemical properties of upwelling were discussed by Park, Pattullo, and Wyatt (1962). Increases in dissolved silicate in nearshore waters during the spring and summer were attributed to upwelling by Matson (1964). The distributions of euphausiids and copepods were related to environmental features, including upwelling (Cross, 1964; Hebard, 1966).

Smith, Pattullo, and Lane (1966) computed the offshore transport during an early stage of upwelling off Brookings, Oregon. Smith (1964) prepared a model for coastal upwelling, and Collins (1964) discussed the effects of upwelling on the permanent oceanic front off the Oregon coast. Pattullo and Denner (1965) studied local processes, including upwelling, affecting seawater characteristics. The role of upwelling in modifying the climate and heat exchange in the adjacent oceanic region was discussed by Lane (1965). Burt, Pattullo, and Kulm (in prep.) studied the effects of upwelling in relation to seasonal heat storage variations of the oceanic waters. Panshin (1967) studied the relationship between sea level and wind stress and related the findings to upwelling.

METHODS AND MATERIALS

The study was conducted off Brookings, Oregon at latitude 42°00'N between June 1962 and April 1964. Observations were made during eight cruises of the Oregon State University oceanographic research vessel ACONA and one cruise of the United States Coast Guard Cutter MODOC. During cruises aboard the R/V ACONA 11 hydrographic and trawling stations were occupied at 10-nautical mile intervals from 5 to 45 nautical miles offshore, and thereafter at 20-nautical mile intervals out to 165 nautical miles offshore (Figure 1). Bathythermograph observations were made every 10 miles. During the MODOC cruise, 33 stations were occupied on a 10-mile by 10-mile grid extending 50 miles north and 50 miles west of Brookings, Oregon (Figure 10). At each station hydrographic observations of temperature, salinity, dissolved oxygen, phosphate-phosphorus, and on some cruises dissolved silicate, were made from the surface to 1000 meters on ACONA cruises, and to 300 meters on the MODOC cruise, depth permitting. Weather observations were taken at all stations. On ACONA cruises 12 drift bottles were released at each station.

Oxygen determinations employing the modified Winkler method were made at sea (Stickland and Parsons, 1960). Salinity samples were analyzed using a Hytech Inductive Salinity and Conductivity

Meter Model 621 in the shore laboratory (Brown and Hamon, 1961).

Phosphate-phosphorus and dissolved silicate were analyzed by colori-

metric methods involving the formation of phospho-molybdate and

silico-molybdate complexes, respectively, whose concentrations

were measured with a Beckman Model DU Spectrophotometer (Strick-

land and Parsons, 1960). Phosphate determinations were carried out

aboard ship during the first three ACONA cruises; phosphate samples

from other cruises and silicate samples were quick-frozen at sea

and later analyzed in the shore laboratory.

Water samples for chlorophyll concentrations were collected

during all cruises with plastic samplers and filtered through HA

Millipore filters (pore diameter 0.45 microns). Samples were col-

lected from 0, 5, 10, 15, 25, 50, and 100 meters, depth permitting.

The chlorophyll extracts were prepared by the method of Creitz and

Richards (1955), and the concentrations were determined by the

method of Richards and Thompson (1952). Light measurements were

made during daylight hours using a Clarke submarine photometer

with a Weston photocell.

On ACONA cruises zooplankton hauls were made with one-

meter plankton nets six meters long constructed of "0" mesh netting

(0.571 millimeter aperture) and equipped with flowmeters. Small

nektonic animals were collected with a six-foot Isaacs-Kidd midwater

trawl (IKMT) (Isaacs and Kidd, 1953) of uniform 0.635 centimeter

aperture netting, which was equipped with a flowmeter and depth-distance recorder or pressure-depth recorder. The meter-net was attached to the towing wire above the IKMT. Both nets were towed obliquely between the surface and 200 meters, depth permitting, as the ship followed a given compass heading at about six knots. The IKMT was launched from the forward port side of the ship and,after about 25 meters of cable was out, the winch was stopped. The tow-cable was lifted into a snatch-block at the port-stern, and the meter-net attached to the tow-cable by means of a "BG" cable clamp (Renshaw and Pearcy, 1964) so that it fished about six meters above the IKMT. Both nets were then lowered at 50 meters per minute until 800 meters of wire were paid out, depth permitting, and retrieved at 30 meters per minute. All collections were taken between dusk and dawn to minimize catch variations caused by vertical migrations and net avoidance.

On the MODOC cruise no one-meter net or IKMT collections were taken. Instead, a vertical zooplankton haul was taken at each station using a one-half meter net constructed of No. 6 netting (0.239 millimeter aperture) and equipped with a flow meter. The net was lowered at about 50 meters per minute until enough wire was out to reach 300 meters, taking in account wire angle, depth permitting, and retrieved at about 30 meters per minute. All biological net collections were preserved at sea in ten percent buffered sea-water

formalin.

The biological net collections were sorted in the shore laboratory. All fishes, shrimps, cephalopods, and heteropods present in IKMT collections were identified and measured. Fishes and other large forms were removed from the meter-net collections which were then subdivided into two approximately equal parts with a Folsom Plankton Splitter (Mc Ewen, et al., 1954). One half of each meter-net sample was sorted into taxonomic groups consisting of euphausiids, copepods, shrimps, amphipods, chaetognaths, medusae, salps, annelids, pteropods, etc.; and the other half retained for future studies. When a particular taxonomic group was abundant, the sample was further divided to facilitate sorting. In most cases each taxonomic group was sorted from more than one fraction. For example, if a moderate number of large chaetognaths and a very large number of small chaetognaths were present in a sample, the small individuals were sorted from a subsample subsequently split after the large specimens were removed.

When possible each taxonomic group, except the chaetognaths and medusae, was identified to species. Dry weights were used to estimate the biomass for each major taxonomic group. Samples were dried to uniform weight in drying ovens at 60°C (Lovegrove, 1962).

Paired observations on 17 samples were made to obtain an

estimate of error due to the combined effects of splitting, sorting, and drying (Table 1). The mean and 95 percent confidence limits (Mode, 1961) for the percent difference between each paired observation were 14.9$\pm$5.4, respectively.

Table 1. Paired observations of dry weights.

Weight (gr/m^3)		Percent Difference
A	B	
34.62	34.38	0.7
6.68	6.35	4.9
8.27	7.74	6.4
1.14	0.70	38.6
0.06	0.07	14.3
5.09	5.35	4.9
4.02	3.57	11.2
19.61	15.06	23.2
7.73	7.41	4.1
10.54	7.50	28.8
14.15	11.95	15.5
1.23	1.53	19.6
1.14	0.97	14.9
0.57	0.23	23.3
1.06	0.98	7.5
1.49	1.09	26.8

LOCATION OF HYDROGRAPHIC AND MIDWATER TRAWLING STATIONS OFF BROOKINGS, OREGON.
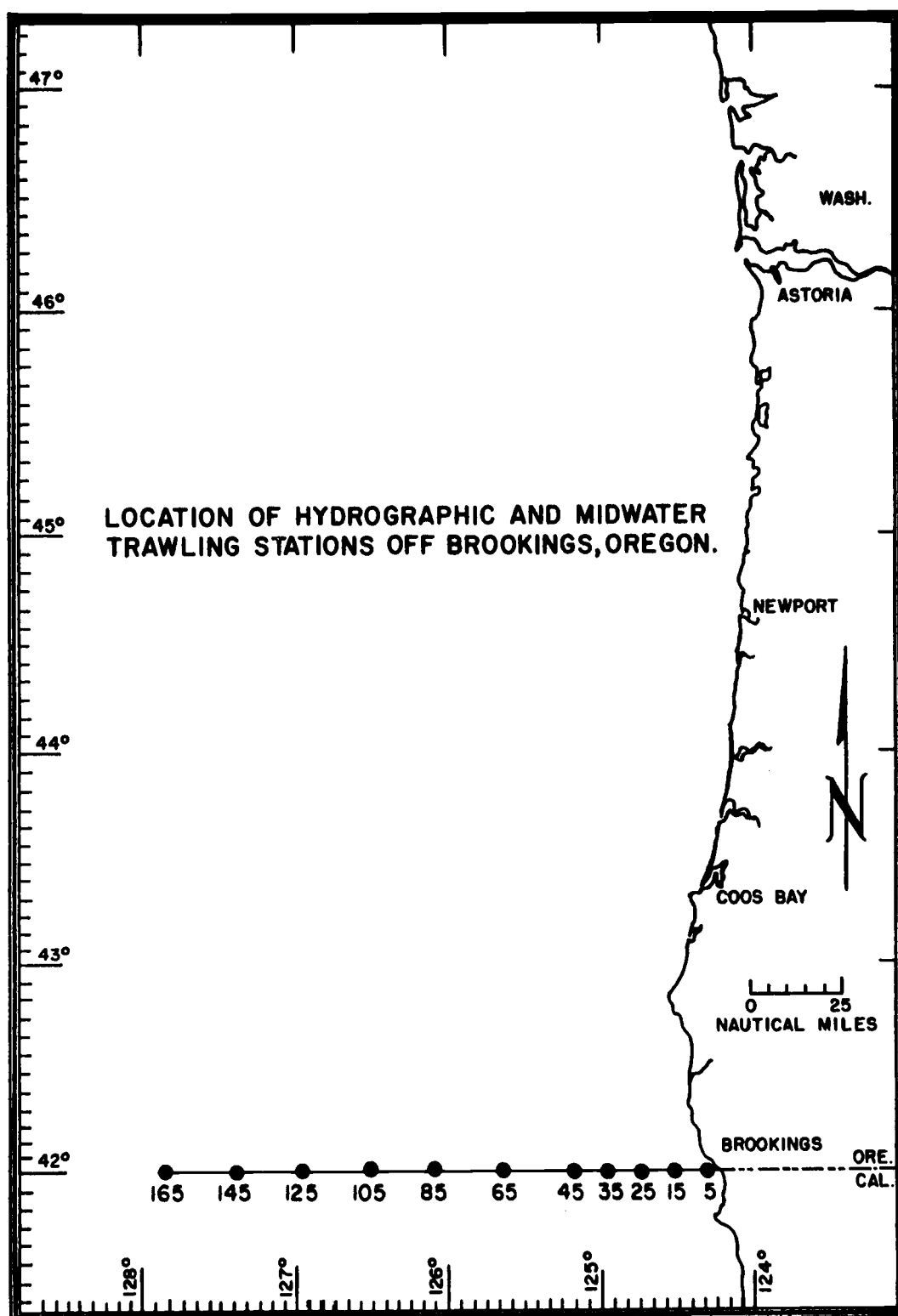
Figure 1. Location of sampling stations.

SEASONAL DISTRIBUTION OF NORTHERLY
AND SOUTHERLY WINDS

Coastal upwelling along the Oregon coast is associated with a
northerly wind stress (Smith, 1964). To determine the seasonal
distribution of winds, observations of wind direction and velocity,
made every six hours at Cape Blanco, Oregon, were obtained from
the U. S. Weather Bureau, National Weather Records Center (1962-
64). The "number of miles of wind" (Shaefer et al., 1958) for each
day for each of eight compass directions was found by multiplying
the velocity by the number of hours of blowing. The "number of
wind miles" between 315° and 45°, 135° and 225°, 45° and 135°, and
225° and 315° were summed separately to give northerly, southerly,
easterly, and westerly values, respectively.

The total "wind miles" from the northern and southern sectors
for 1962-1964 are shown in Figures 2 and 3. In general, winds were
predominantly northerly during summer months and southerly during
winter months. The total northerly "wind mileage" was greater in
the summer of 1962 than in the summer of 1963. Northerly winds
were also predominant from February 1964 through April 1964. The
total southerly "wind mileage" was about the same in the winter of
1962-63 as it was in the winter of 1963-64. See Table 2 for total
seasonal "wind mileages". The easterly and westerly "wind mile-
ages" totaled less than two percent of the total "wind mileage" for

all directions and were not analyzed further.

Table 2. Total northerly and southerly "wind mileages" during
          seasons.

Date	Total Wind Miles	
	Northerly	Southerly
May 62 - Sept. 62	46,770	8,940
Oct. 62 - Apr. 63	21,762	50,414
May 63 - Sept. 63	22,206	11,334
Oct. 63 - Jan. 64	7,092	32,692
Feb. 64 - Apr. 64	17,946	6,496
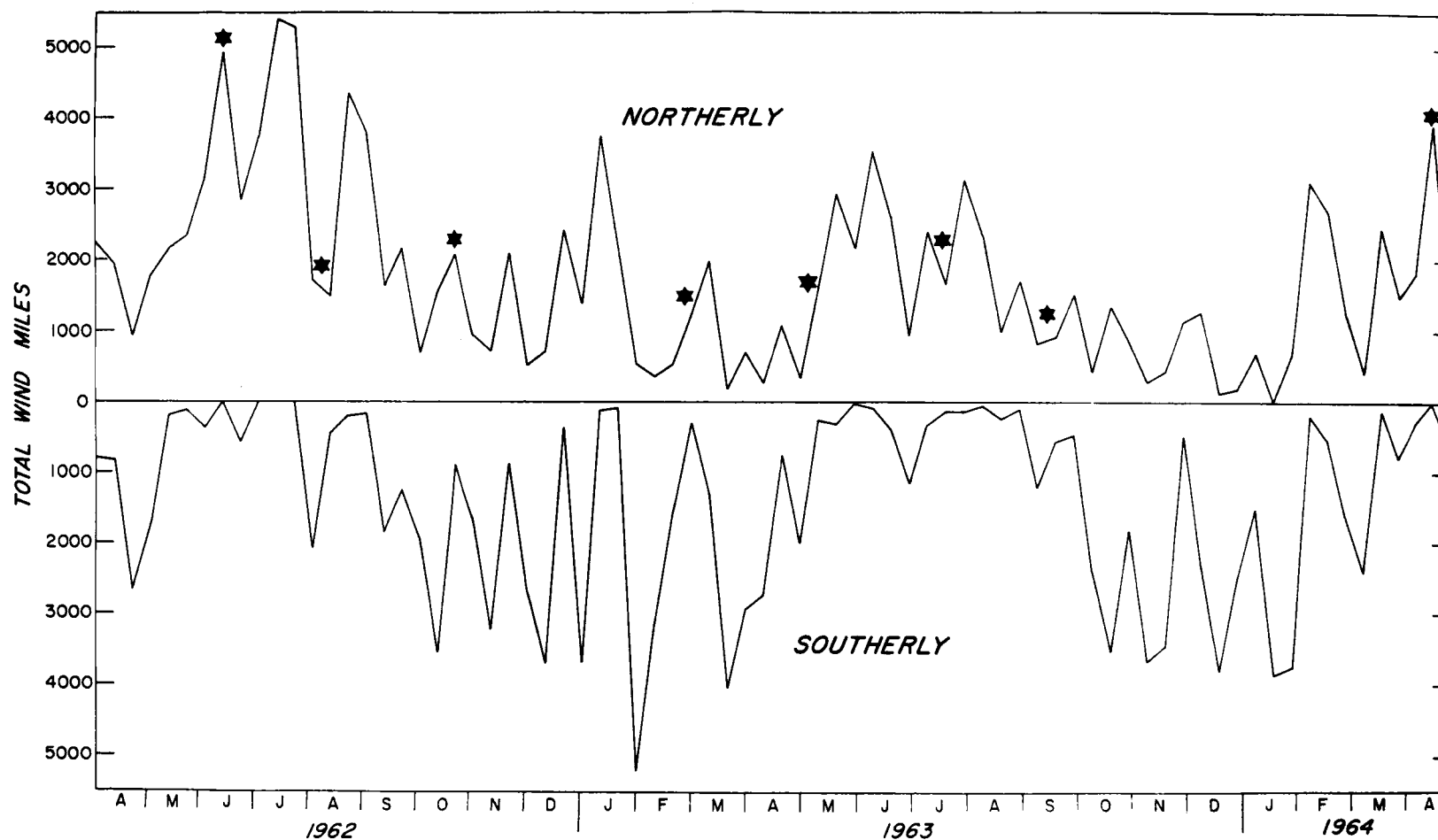
Figure 2. Ten-day northerly and southerly "wind mileages" observed
at Cape Blanco, Oregon between April 1962 and April 1964.
Stars denote when cruises were made.

INSHORE VS OFFSHORE HYDROGRAPHIC CONDITIONS

Since coastal upwelling is limited to within about 100 kilometers off the coast (Yoshida, 1955), the effects of upwelling may be approximated by comparing the relatively narrow upwelling zone with the offshore zone. This assumes that coastal upwelling is the dominant process taking place inshore and that other processes are of secondary importance. Differences in oceanographic properties at ten meters depth at two stations, 5 and 85 nautical miles offshore, indicate modifications of the coastal environment which were related to winds and coastal upwelling (Figure 3).

The greatest temperature differences between the inshore and offshore station, indicating colder temperatures inshore, always occurred during sampling periods when northerly winds were predominant. The temperature differences were least when observations were made during periods of southerly winds. The salinity was higher at the inshore station during each sampling period, except May 1963, and the greatest salinity differences were observed during periods of northerly winds. The salinity differences were small during sampling periods when southerly winds were predominant. The dissolved oxygen content was much lower inshore than offshore during June 1962 and April 1964 when winds were northerly; but it was only slightly greater at the inshore station during the 1963 summer

sampling periods when northerly winds were observed. In general,
the phosphate-phosphorus content was higher at the inshore station
than at the offshore station during sampling periods when winds were
northerly.

In summary, differences in inshore and offshore hydrographic
conditions were greatest during periods of active upwelling. During
periods of northerly winds the temperature and dissolved oxygen
were lower and the salinity and phosphate-phosphorus were higher
at the inshore station than at the offshore station at ten meters depth.
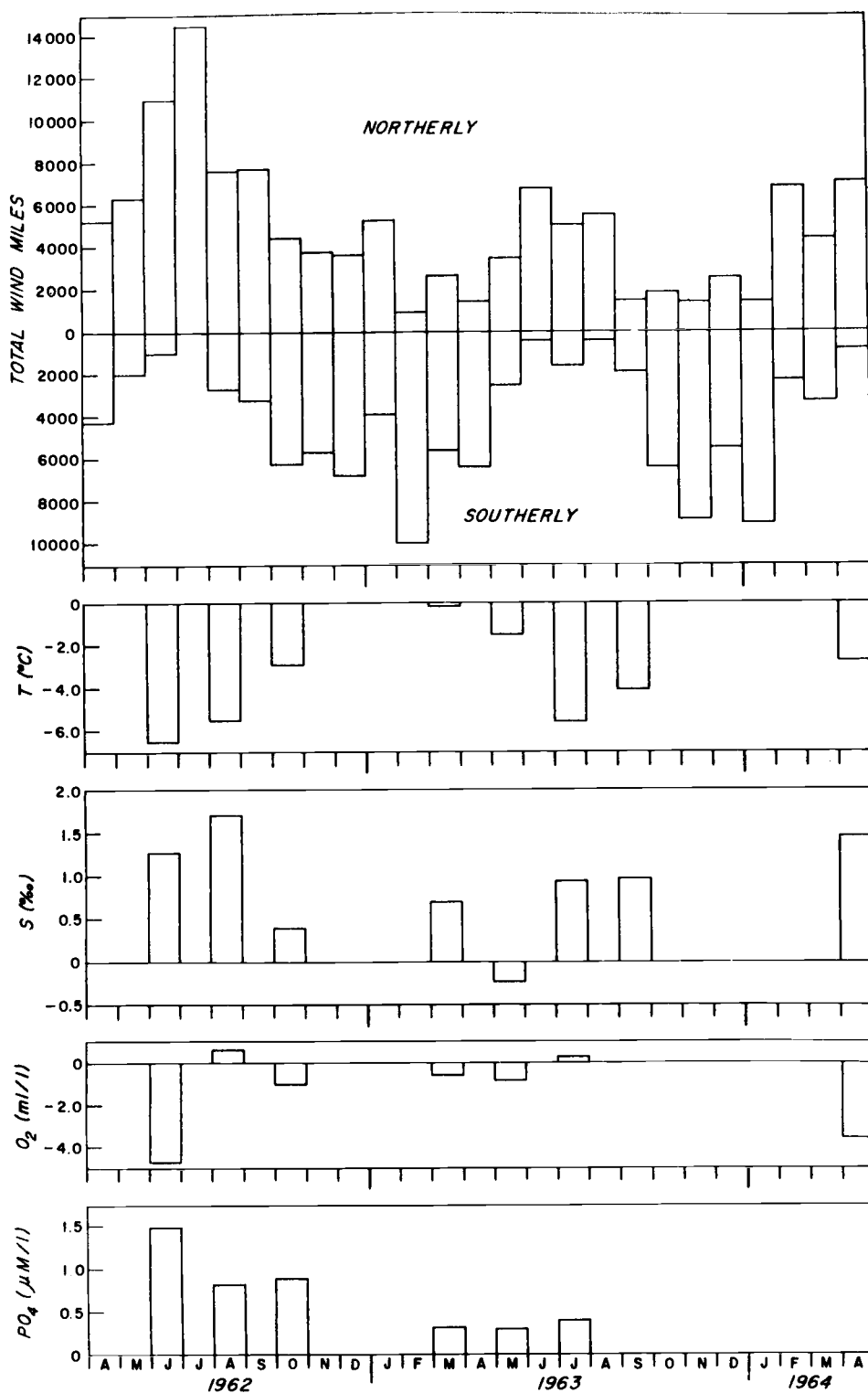
Figure 3. Differences between temperature, salinity, dissolved oxygen, and phosphate-phosphorus at ten meters depth at 5 and 85 nautical miles off Brookings, Oregon and the total northerly and southerly "wind mileage" at Cape Blanco, Oregon.

VERTICAL DISTRIBUTIONS OF HYDROGRAPHIC PROPERTIES

Coastal upwelling along the Oregon coast leads to changes in the distribution of mass which are reflected in the vertical distribution of hydrographic properties. Inshore, isopleths in the upper 250 meters slope upward toward the coast during active coastal upwelling, but isopeths are comparatively level when upwelling is not actively taking place. The effect of coastal upwelling in the California Current system is to decrease surface temperature and dissolved oxygen and to increase surface salinity and nutrient content (Wooster and Reid, 1963).

To illustrate the vertical distribution of hydrographic conditions during various seasons of the year off Brookings, sections of temperature, salinity, dissolved oxygen, and phosphate-phosphorus were constructed (Figures 4-7). March 1963 was chosen to represent conditions prior to upwelling, May 1963 to represent early upwelling, June 1962, July 1963, and April 1964 to represent active upwelling, August 1962 to represent late upwelling, and October 1962 and September 1963 to represent conditions after upwelling had subsided. These are admittedly arbitrary and are to be considered only as examples and may not depict average conditions.

Temperature

In March 1963, thermal conditions above 100 meters were nearly the same inshore as they were offshore and there were no indications of upwelling (Figure 4E). The isotherms were nearly horizontal and a weak thermocline was observed at about 100 meters. Below this depth, the isotherms were relatively flat offshore, but inshore they tended to fall toward the coast.

The distribution of the isotherms in May 1963 (Figure 4F) indicate that upwelling recently had been initiated. The isotherms above 250 meters, which were more-or-less level offshore, sloped weakly upward toward the coast inshore. A weak thermocline was evident at about 100 meters, except very near the coast.

The distribution of the isotherms in June 1962, July 1963, and April 1964 (Figures 4A, G, and D) suggest active upwelling. Near the coast the isotherms slanted sharply upward toward the surface and there was no distinct thermocline. The near-surface water was 3 to 5 $^{\circ}$C warmer offshore than inshore. Temperature data indicated that upwelling was more intense in June 1962 and April 1964 than in July 1963. For example, inshore in June 1962 and April 1964 the 7 $^{\circ}$C isotherm, which was found at depths of 250 meters or greater offshore, rose acutely upward and intersected the surface about five nautical miles off the coast. Inshore in July 1963, the 7 $^{\circ}$C isotherm

tended to slope downward and near the coast was found at about 250 to 300 meters depth.

Thermal conditions observed in August 1962 (Figure 4B) implied that upwelling had recently declined. Inshore, the isotherms above 250 meters tended to have a general slope upward toward the shore, except very near the coast. Here they were nearly level or sloped downward toward the shore. Offshore, the isotherms were relatively horizontal, and a well-developed thermocline was apparent at about 75 meters depth. The thermocline was not well-defined inshore.

The distribution of the isotherms in October 1962 and September 1963 (Figures 4C and H) indicated that upwelling had subsided. Temperatures in the upper layers were warm and nearly the same inshore as they were offshore. The isotherms were almost horizontal and a thermocline was well-defined at about 75 to 100 meters depth. The isotherms at intermediate depths were relatively level offshore, but inshore sloped strongly downward toward the coast.

Salinity

The vertical distribution of salinity in May 1963 (Figure 5F) suggested that upwelling had begun recently. Very near the coast, the isohalines were weakly inclined upward toward the shore, but did not intersect the surface. Offshore, the isohalines were

comparatively horizontal.

Active upwelling was indicated by the vertical distribution of salinity in June 1962, July 1963, and April 1964 (Figures 5A, G, and D). The isohalines in the upper layers sloped sharply upward toward the coast inshore, but were relatively level offshore. A halocline was distinct offshore between the depths of about 75 and 175 meters. No halocline was found near the coast. The salinity data indicate that upwelling was more intense in June 1962 and April 1964 than in July 1963. The 34.00 o/oo salinity isohaline, found at about 300 meters depth offshore, tilted sharply upwards and intersected the surface at about five nautical miles off the coast in June 1962 and April 1964. However, in July 1963 it shoaled only to about 150 meters depth. The low salinity water observed far offshore in July 1963 was found with high temperatures (Figure 4G), indicating Columbia River as its origin (Budinger, Coachman, and Barnes, 1963).

In August 1962 (Figure 5B), the isohalines inshore generally sloped upward toward the coast, but tended to be flattened near the surface, showing that upwelling had begun to subside. The halo-cline, not distinct inshore, was well-defined offshore at about 200 meters depth. Also offshore, the isohalines were horizontal and a shallow lens of Columbia River was indicated by the 32.00 o/oo salinity water.

The vertical distributions of salinity before upwelling had be-

gun (March 1963, Figure 5E), and after upwelling had subsided

(October 1962 and September 1963, Figures 5C and H), were very

similar. The isohalines were relatively horizontal both inshore

and offshore, and a halocline was found at about 100 to 150 meters

depth in both regions. A lens of low salinity Columbia River was

found offshore in September 1963.

Dissolved Oxygen

In March and May 1963, the concentration of dissolved oxygen

in the upper layers was high and the isopleths were about horizontal,

except very near the coast (Figures 6 E and F). Here some of them

ascended toward the shore. According to Wooster and Reid (1963),

isopleths of dissolved oxygen ascend toward the coast in eastern

boundary currents.

Inshore in June 1962 and April 1964 the isopleths of oxygen

were tilted sharply upward toward the coast and oxygen concentra-

tions of less than 2.0 ml/l were recorded in the surface layer,

indicating active upwelling (Figures 6A and D). Offshore the iso-

pleths were comparatively level and the oxygen content in the surface

layer was 4.0 to 4.5 ml/l higher than in the surface layer inshore.

In August 1962 and July 1963 the isopleths of oxygen rose up-

ward toward the shore, but near the surface they tended to be level.

(Figures 6B and C). The oxygen content was high in the upper layers

inshore and in August was correlated with high standing stocks of

phytoplankton (Table 5). The isopleths tended to fall toward the coast

at intermediate depths in August. Offshore, the isopleths were about

level and an oxygen maximum layer was distinct between about 25 and

100 meters depth. This subsurface maximum layer was continuous

with the oxygen maximum layer found at the surface inshore.

Upwelling had subsided in October 1962 and September 1963,

and the isopleths of oxygen in the upper layers were about horizontal

(Figures 6C and H). The oxygen concentration was high in the near-

surface waters both inshore and offshore. However, a subsurface

maximum layer was present offshore in September 1963. Below

about 350 meters, the isopleths sloped downward toward the coast.

Phosphate-Phosphorus

In general, the vertical distribution of phosphate-phosphorus

was similar during all sampling periods, except in June and August

1962. (No phosphate data is available for April 1964).

Inshore in June 1962, the isopleths of phosphate sloped acutely

upward toward the coast and the phosphate content of the inshore sur-

face waters was very high, suggesting active upwelling (Figure 7A).

The non-upwelled water offshore presents a sharp contrast. The

isopleths were nearly horizontal and the phosphate content of the

near-surface water was low.

In August 1962 the isopleths of phosphate were sloped upward toward the coast, but near the surface they were flattened, suggesting that upwelling had begun to subside (Figure 7B). The phosphate concentration in the near-surface waters was high at intermediate distances off the coast and low offshore and adjacent to the coast. High standing stocks of phytoplankton were also found adjacent to the coast (Table 5), indicating that the low phosphate content at the surface was due to utilization by the phytoplankton.

During other sampling periods (Figures 7C - G) the isopleths of phosphate-phosphorus were comparatively horizontal, except sometimes very near the coast. The phosphate concentration in the near-surface waters was usually low, although in the late fall and winter somewhat higher values were observed.

Discussion of Vertical Distributions of Hydrographic Properties

Seasonal changes in the distribution of temperature, salinity, dissolved oxygen and phosphate-phosphorus observed during this study were similar to those reported from other studies of coastal upwelling (Currie, 1953; Defant, 1961; Gunther, 1936; Hart and Currie, 1960; Reid, 1960; Reid et al., 1958; Sverdrup, 1938; and Sverdrup and Fleming, 1941).

Some of the vertical sections show that the isopleths in the upper layers above 100 to 200 meters conspicuously rise toward the coast, while those in the lower layers below the depth of 200 to 500 meters fall toward the coast. Defant (1961) interpreted this feature as an onshore flow in a certain sub-surface layer, which as it strikes the coast, gives rise to upwelling in the layers above and sinking in the layers below. However, according to Yoshida and Tsuchiya (1958), who studied upwelling off the coast of California, the fall of isotherms and isopycnals toward the coast, in the layers over several hundred meters above the 1000 meter level, indicates the presence of a northward current at and somewhat above these depths. According to Reid (1965) a poleward counter-current, beneath the eastern boundary current at the surface, is indicated along the coast of North America by the distribution of hydrographic properties.

Stephánsson and Richards (1964) reported on the distributions of dissolved oxygen, density and nutrients off the Washington and Oregon coasts. They were of the opinion that offshore movement and sinking along isentropic surfaces of water, which had been photosynthetically enriched in oxygen in the nearshore area, largely contributed to the formation of the offshore subsurface oxygen maximum present in the summer. However, Reid et al., (1958), Reid (1962) and Pytkowicz (1964) concluded that this maximum could be accounted for by seasonal variations in thermal structure.
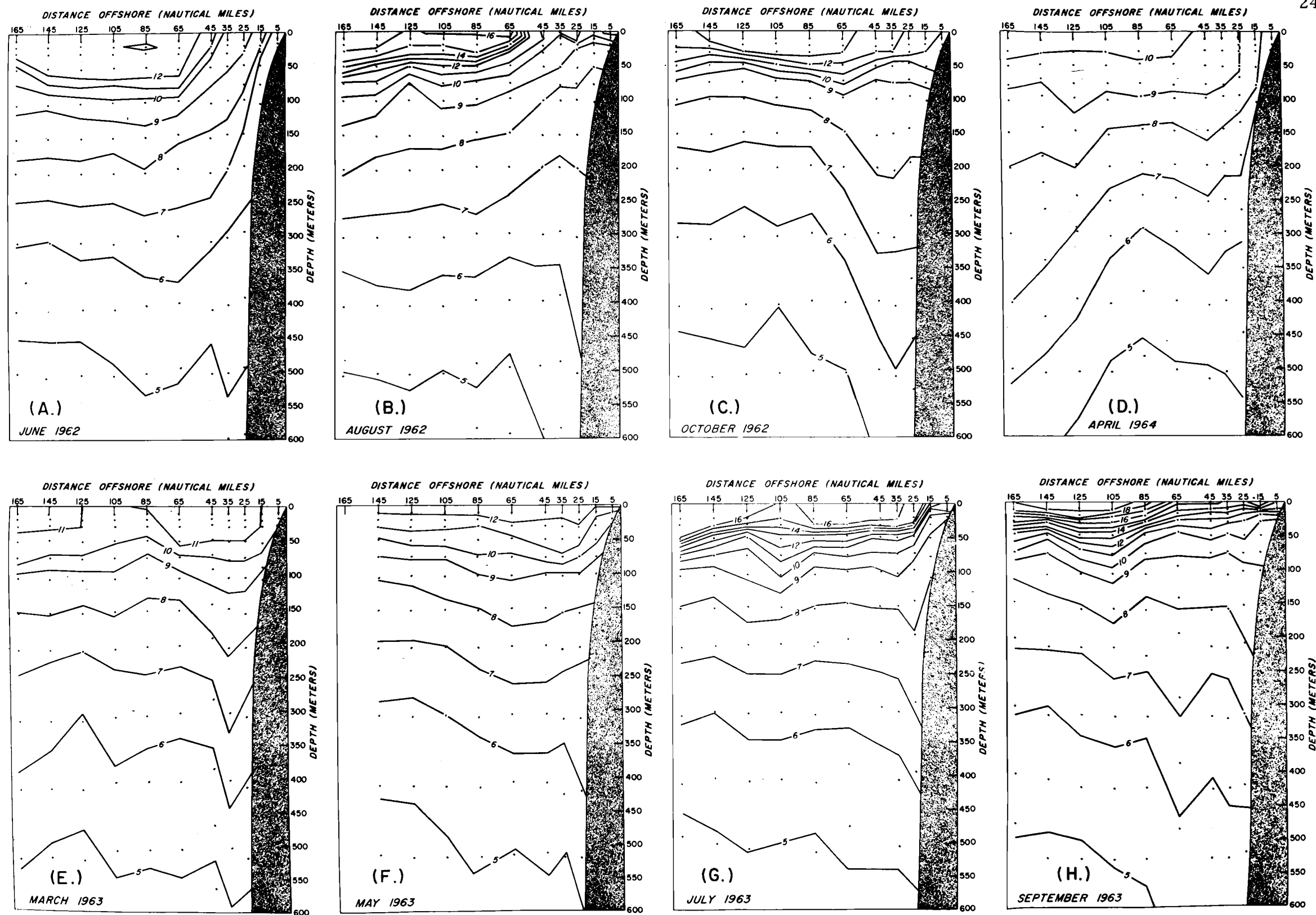
Figure 4. Vertical distribution of temperature ($^\circ$C) observed off Brookings, Oregon.
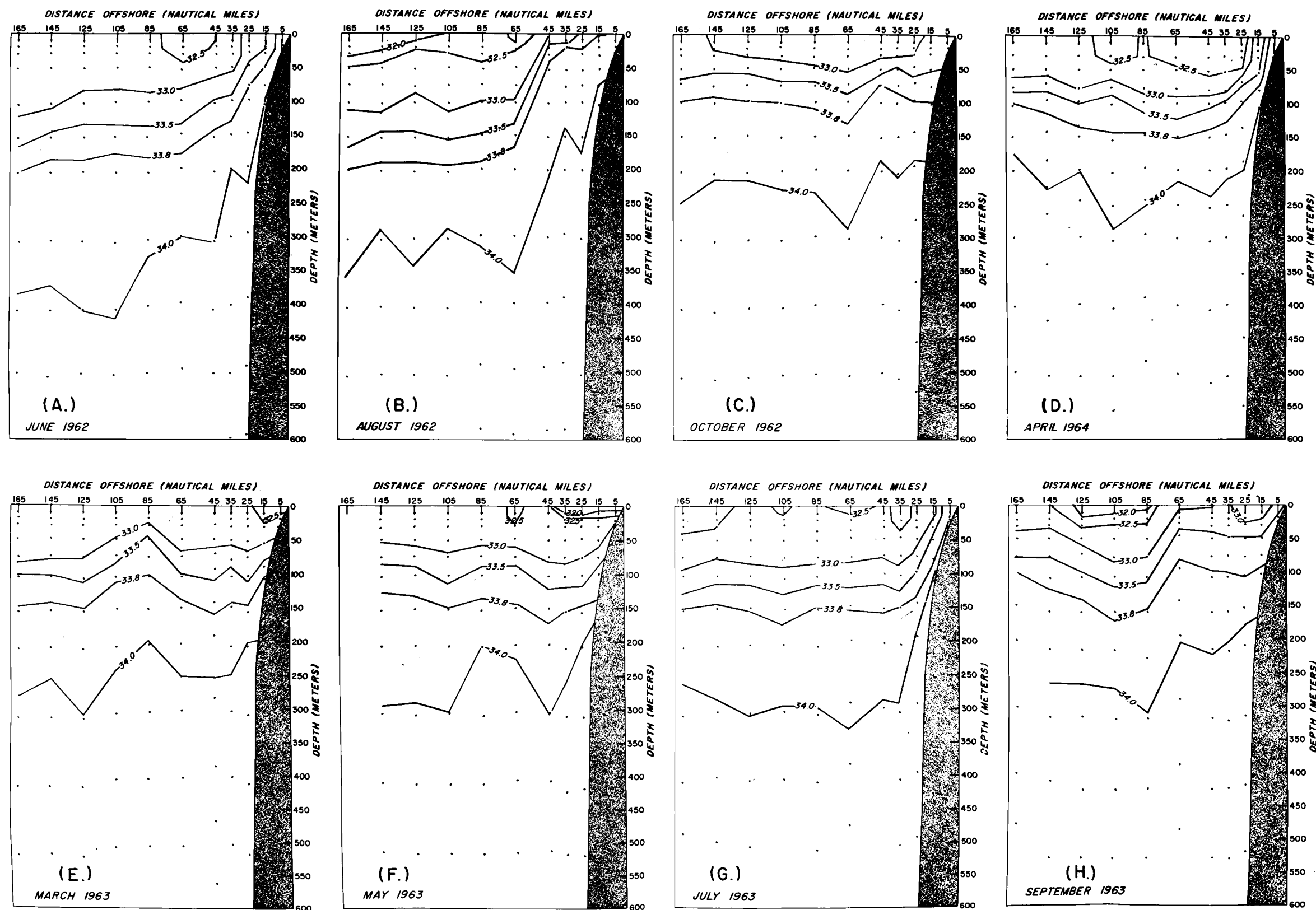
Figure 5.   Vertical distribution of salinity (o/oo) observed off Brookings, Oregon.
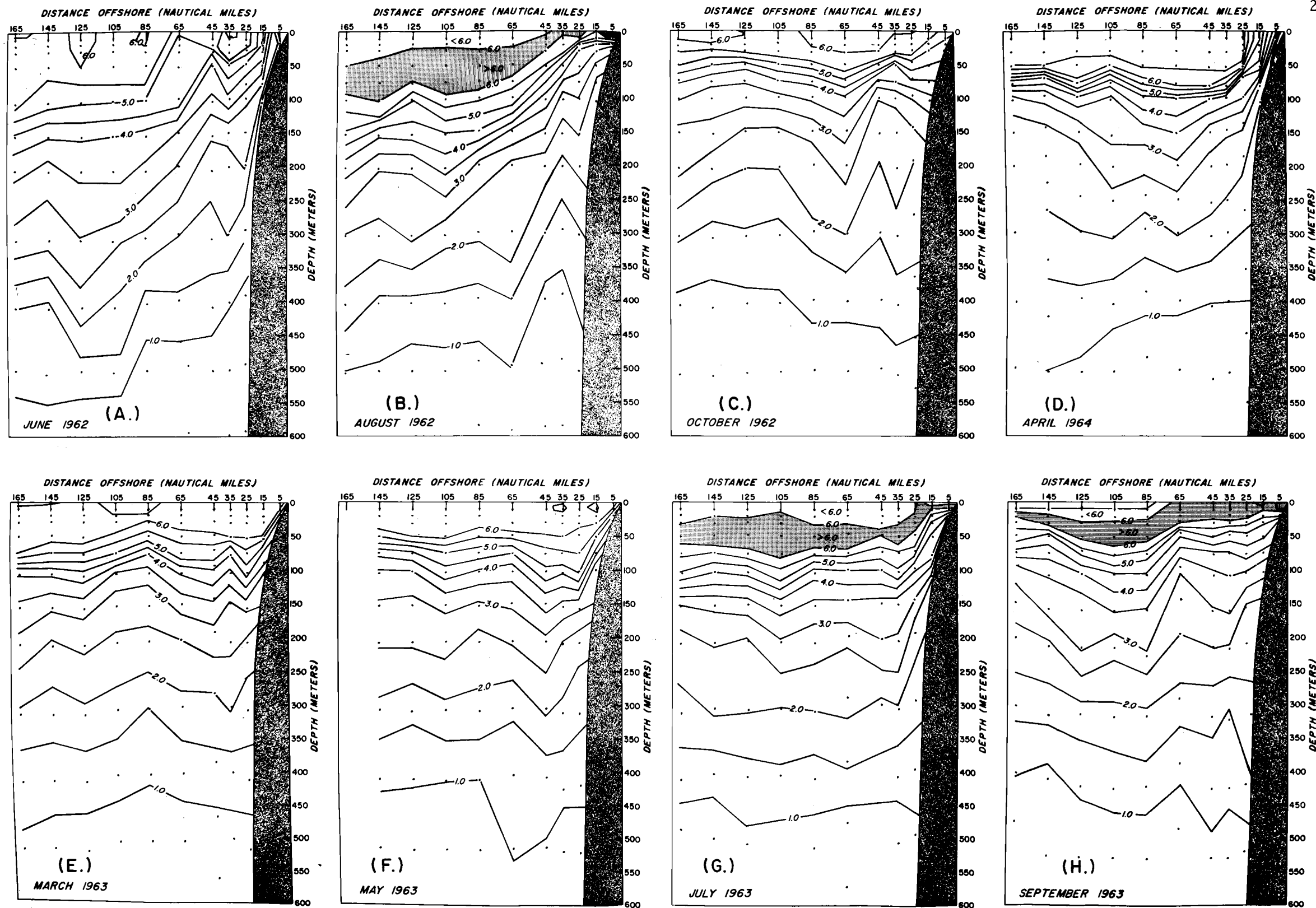
Figure 6.   Vertical distribution of oxygen (ml/l observed off Brookings, Oregon.
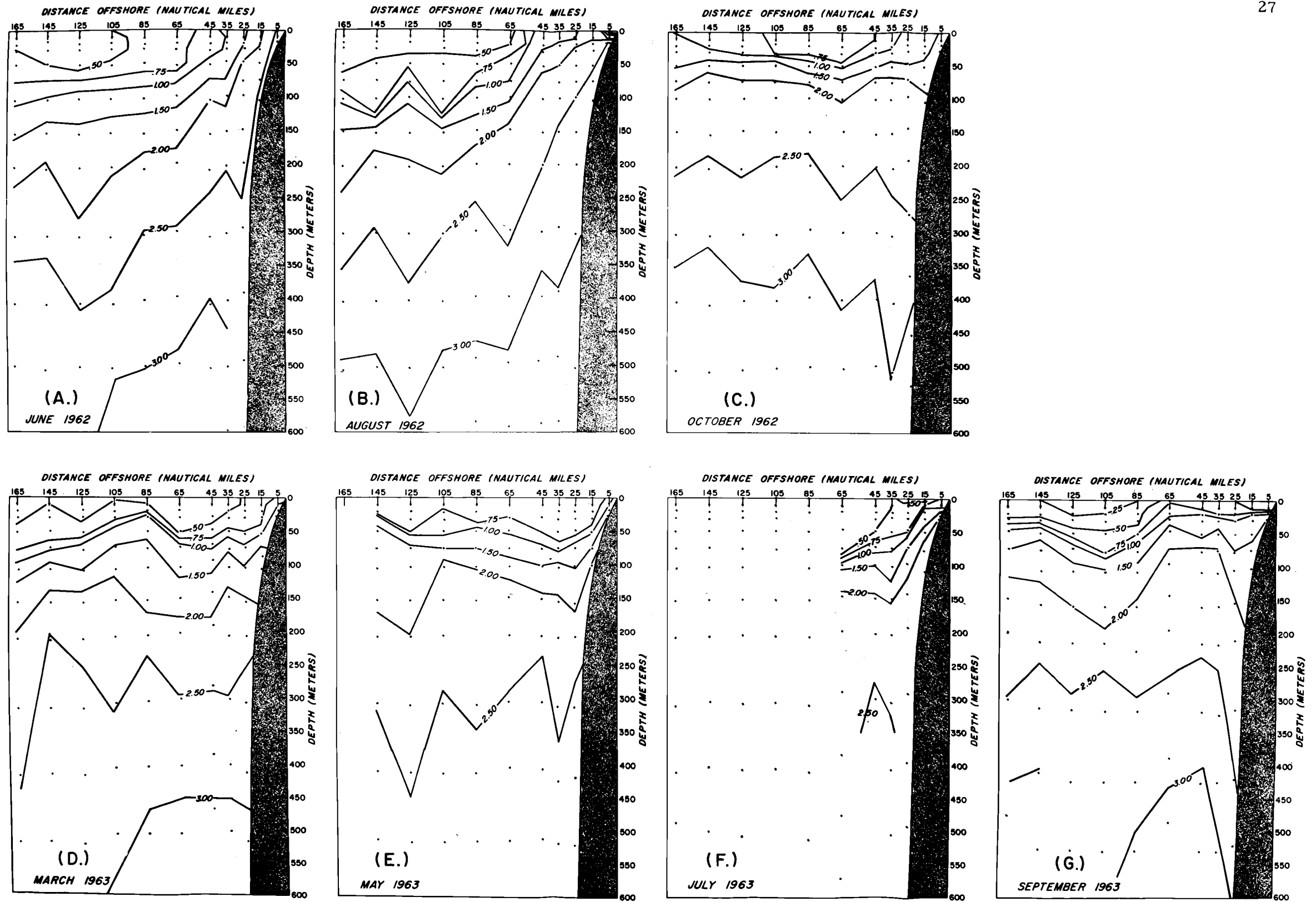
Figure 7. Vertical distribution of phosphate-phosphorus (μM/l) observed off Brookings, Oregon.

STRUCTURE OF THE OCEANIC FRONTAL LAYER

The interface between two water masses of different density is termed an oceanic front (Cromwell and Reid, 1956). The term "water-mass" is used loosely and does not imply the specific definition given by Sverdrup, Johnson, and Fleming (1942). The frontal structure off Brookings was studied to learn if the distributions of lower trophic level biota were related to the boundary between upwelled and non-upwelled water. The frontal structure off Brookings is shown by plotting the depths of the 25.5 and 26.0 sigma-t surfaces (Collins, 1964) versus distance from shore (shaded portion of Figure 18). These profiles clearly indicate major changes in frontal layer shape due to upwelling; the inshore portion of the frontal layer slopes upward, intersects the surface, and forms a surface front (Figures 18, A, B, D, and G). During periods of non-upwelling the frontal layer was relatively horizontal and found below the surface (Figures 18 C, E, and H). Collins (1964) found similar results.

Pre-upwelling. The distribution of the frontal layer in March 1963 (Figure 18 E), shows conditions prior to upwelling. The frontal layer was found below 50 meters depth and was relatively level, except for a sudden rise and an almost equally sudden deepening offshore. Collins (1964) attributed such "noise", superimposed on the trends of the frontal layer, to internal waves.

Early upwelling. The upward slope of the frontal layer adjacent to the coast in May 1963 indicates that upwelling had been recently initiated. No surface front was observed (Figure 18 F).

Active upwelling. The frontal structures observed in June 1962, July 1963, and April 1964 indicate active upwelling (Figures 18 A, G and D). Within the inshore region during each of these periods, the frontal layer sloped markedly upward, intersected the surface, and formed a surface front. In June 1962 the frontal layer was nearly vertical inshore and intersected the surface at about 30 nautical miles off the coast, suggesting intense, active upwelling. The frontal layer intersected the surface at about seven nautical miles off the coast in July 1963, indicating that upwelling was not as intense as in the summer of 1962. This weaker upwelling is correlated with lower northerly "wind mileages" in the summer of 1963 (Figure 3 and Table 2). In April 1964 the frontal layer rose sharply upward and formed a surface front at about 20 miles offshore, indicating intense, active upwelling.

Late-upwelling. Although a surface front was found at about 30 nautical miles off the coast in August 1962, the flattened distribution of the 26.0 sigma-t surface near the coast suggests that upwelling had recently begun to subside (Figure 18 B). The strongly

upcurved portion of the frontal layer between 45-65 miles offshore was due to warm, low-salinity Columbia River water abutted to colder, more-saline ocean water, rather than to active upwelling. (Temperature and salinity distributions are shown in Figures 4 and 5).

Post-upwelling. The frontal structure observed in October 1962 and September 1963 (Figures 18 C and H), indicate that upwelling had subsided. The frontal layer was more-or-less horizontal inshore and found between about 25 to 75 meters depth. Temperature and salinity characteristics (Figures 4 and 5) indicate that the depression of the frontal layer found offshore in September 1963 was due to a lens of warm, low-salinity Columbia River water.

AMOUNT OF WATER UPWELLED AND TRANSPORTED OFFSHORE

The amount of water upwelled and transported offshore was computed using a method given by Smith (1964) based on the relationship:

$$\pm M_{x}\Big|_{x=-L} = \int_{x=-L}^{o} \rho\, w_{-h}\, dx$$

where

$\pm M_{x}$ = zonal mass transport offshore (onshore)

L = width of the coastal upwelling region

ρ = density of the water

w_{-h} = vertical velocity at the base of the surface layer

and the results are expressed as gr/cm/unit meridional length in a unit time.

Smith stated that,

> In practice, the total transport between cruises was obtained by computing the volumetric changes in the surface layer due to the translation of the 25.5 sigma-t surface. The change in area between observations was found for the section in the xz-plane defined by the coastline, the vertical at 45 nautical miles off the coast, the sea surface, and the 25.5 sigma-t level.

Smith noted that the computed transport is likely to be an underestimate. He estimated the uncertainty to be 3×10^{9} gr/cm.

The values for the total surface layer transport between sets of observations are given in Table 3. These values represent

quantitative estimates of the amount of water upwelled between two sets of observations, only if the upwelling continues uninterupted and the upwelled water is transported zonally offshore. When upwelling stops, there may be flow onshore (Collins, 1964; Smith, 1964). So this method may underestimate the amount of water upwelled. If upwelling is intermittent between sets of observations and there is transport of water both offshore and onshore, the computed transport gives the net amount of water transported.

The winds were predominately northerly between 14 May and 17 May 1963, and between 23 July and 20 August 1963 (Figure 2), and it was assumed that upwelling was continuous during these periods. The computed offshore transport during each of these periods is probably a relatively good estimate of the amount of water upwelled. However, between 15 June and 3 August 1962, northerly and southerly winds predominated at different times (Figure 2), and it was assumed that upwelling was intermittent. The computed offshore transport does not, then, give a true estimate of the total amount of water upwelled.

In general, the net surface flow during summer months was offshore and during other months was onshore (Table 3). These findings are similar to those found off the central Oregon coast by Collins (1964) and Smith (1964), who computed zonal surface layer transport, and by Maughan (1963) and Stevenson (1966), who

measured currents in the surface layer with parachute drogues.

Returns from drift bottles released off the Oregon coast, in-
cluding Brookings, indicated a northward surface flow from October
through March, varying surface currents to both the north and south
during April, May, and September, and a southward surface current
in June, July and August (Burt and Wyatt, 1964).

Table 3. Zonal surface layer transport through meridional plane
at $42^\circ 00'$ N lat , $125^\circ 13'$ W long. (+ indicates onshore
flow, - indicates offshore flow)

Dates 1962	Total transport 10^9 gr/cm
15 June - 3 Aug.	- 3. 0
3 Aug. - 23 Oct.	1.. 0
23 Oct. - 3 Mar.	6. 5
1963 3 Mar. - 14 May	1. 4
14 May - 17 May	-7. 2*
14 May - 23 July	-4. 2
23 July - 20 Aug.	-10. 7
20 Aug. - 15 Sept.	5. 9

*From Smith (1964) based on - L= 35 nautical miles offshore.

AREAL VARIATION IN UPWELLING

Originally I had planned to estimate the changes in the biomass of lower trophic levels with increasing distance from shore. Knowledge of velocity and age of the upwelled water as it was transported offshore would hopefully provide insight into rates of trophic level succession. This would make it necessary to learn where along the coast the upwelled water found off Brookings had come to the surface and its mean rate and direction of flow. To answer these questions, stations were occupied on a 10-mile by 10-mile grid extending 50 miles north and 50 miles west of Brookings (Figure 10).

Results from the cruise indicated (1) that upwelling was not taking place all along the coast, (2) that in one case, upwelled water may have come to the surface at some distance offshore, (3) that the circulation pattern was too complicated to estimate a mean "age" of the upwelled water found at various distances off Brookings, and (4) that there were good correlations among the standing stock of phytoplankton, estimated by chlorophyll "a", and environmental features.

The vertical and horizontal distributions of temperature and salinity (Figures 8-11) indicate that upwelling was taking place between latitudes $43^{\circ}20'N$ and $43^{\circ}40'N$, but not on the other sampling lines. Also upwelling was best developed off latitudes $43^{\circ}20'N$ and $43^{\circ}30'N$ (Table 4).

Table 4. Distance offshore where isopleths which may indicate up-
welling intersected the surface during MODOC cruise, 16-20
August 1963 (nautical miles).

Latitude	Salinity 33.8 o/oo	Temp. 10°C	Oxygen 5ml/l	Phosphate 1.5µ M/l	Silicate 20µM/l	Sigma-t 26.0
43°10'	--	2.5	--	--	--	--
43°20'	12.5	12.0	16.5	7.5	9.5	15.5
43°30'	15.5	9.5	2.5	15.5	15.5	14.3
43°40'	--	between 2.2 & 5.5	--	between 2.0 & 7.8	between 3.5 & 6.7	between 4.3 & 4.6
43°50'	--	--	--	--	--	--
42°00'	--	--	--	--	--	--

Colder, higher salinity upwelled water, found at the surface
off Cape Sebastian, was separated from the shore by a band of war-
mer, lower salinity water (Figures 8-10, also see Table 4). This
gives the impression that the upwelled water had come to the surface
about 2-3 miles off the coast. However, runoff from the Rogue
River may have masked the upwelled water at the surface near the
shore.

The geopotential topography of the sea surface relative to the
250-decibar surface (Figure 12) (dynamic heights in shallow water
were found using methods described by Groen, 1948) indicates a
complicated circulation pattern. A well-defined surface front was

located offshore from the region where upwelling was taking place. Geostrophic calculations indicate that a strong current, about 50 cm/sec., directed southerly and westerly, was associated with the surface front. South of the surface front region, there was an anti-cyclonic eddy. A sluggish current flowing southerly, at about 5 cm/sec., was indicated inshore of 125°W longitude. Ship's drift while on station corroborates the circulation pattern deduced from the geopotential topography.

Attempts to measure the currents in the surface layer with parachute drogues were not successful. Drogues were put at 10, 75, and 200 meters depth about 55 nautical miles off Brookings. However, after they had been in the water about 15 hours, it was discovered that the parachutes had chaffed off at an unknown time. Each of the drogues traveled southeasterly and then southwesterly at about 0.3 knots.

Standing stocks of phytoplankton were low in the freshly upwelled water near the coast between Cape Blanco and Cape Sebastian (Figure 13). Newly upwelled water is at first poorly populated as regards to both phytoplankton and zooplankton (Steeman Nielson, 1937). The high standing stock of phytoplankton nearest the coast off Cape Sebastian and the much lower standing stock just seaward of it, suggests that the water nearest the coast may have been at the surface longer than that a few miles offshore. Temperature and

salinity profiles (Figures 8-10) indicate that upwelling may break

the surface 2-3 miles offshore rather than at the coast off Cape

Sebastian, possibly explaining this difference.

The highest standing stocks of phytoplankton were observed at

the inshore side of the front and in the region of the anti-cyclonic

eddy. According to Uda (1958) large populations of marine organisms

may be found near anti-cyclonic eddies possibly because of the con-

vergence associated with anti-cyclonic eddies. Sargent and Walker

(1948) found concentrated populations of diatoms closely related to

cyclonic eddies which are associated with upwelling off southern

California.
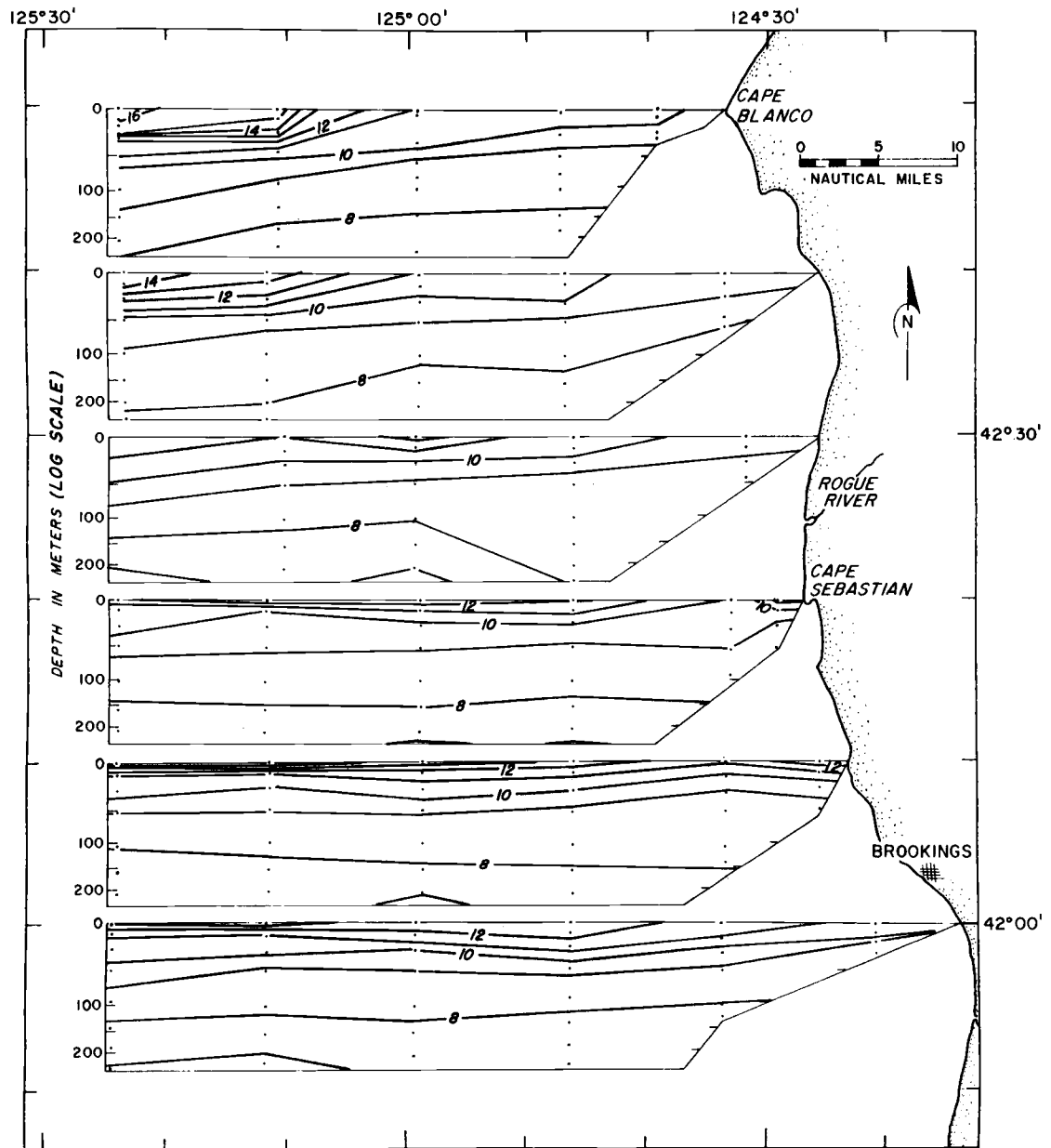
Figure 8. Vertical distribution of temperature ($^\circ$C) observed on MODOC cruise, 16-20 August 1963.
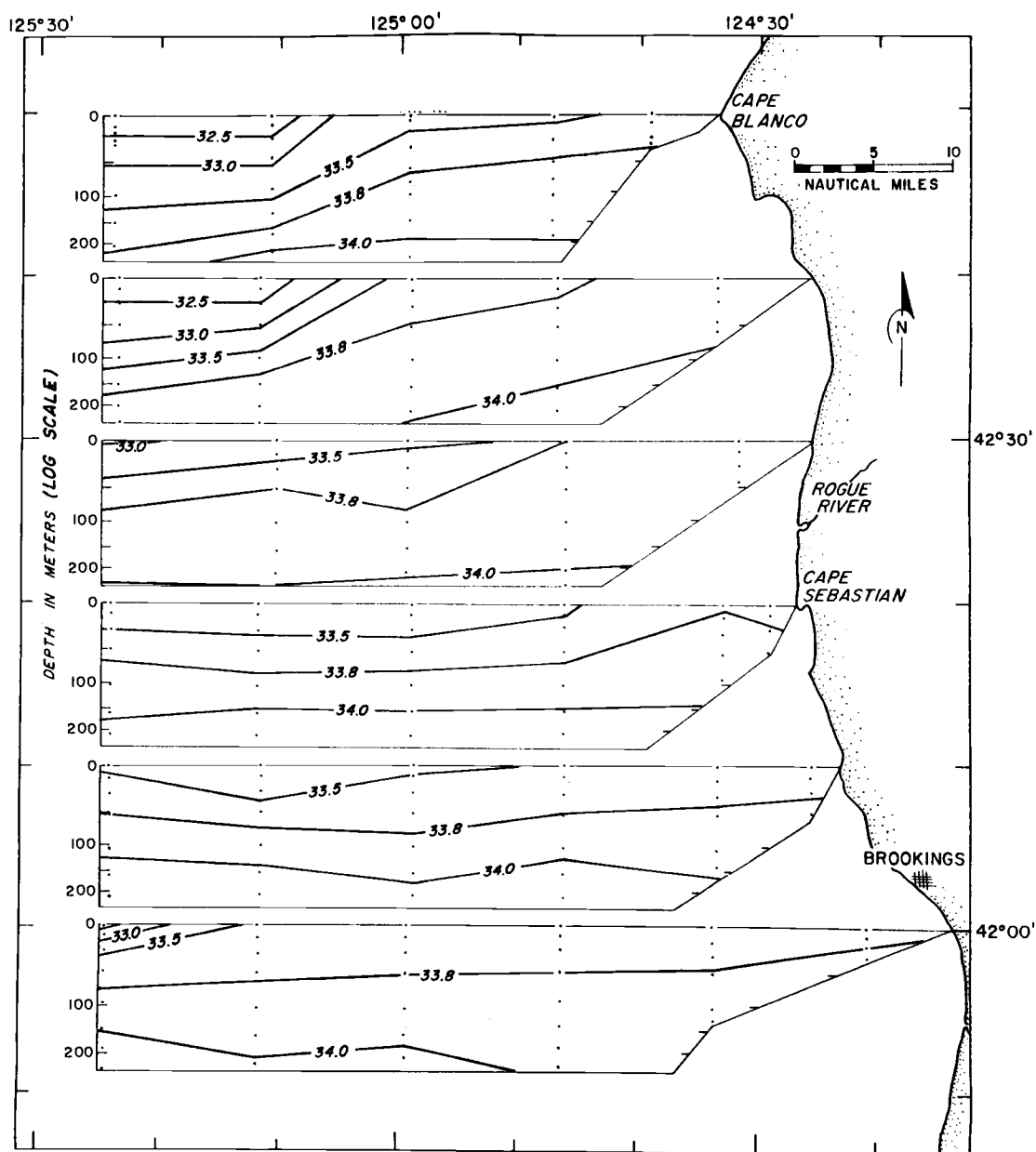
Figure 9.   Vertical distribution of salinity (o/oo) observed in MODOC
cruise 16-20, August 1963.
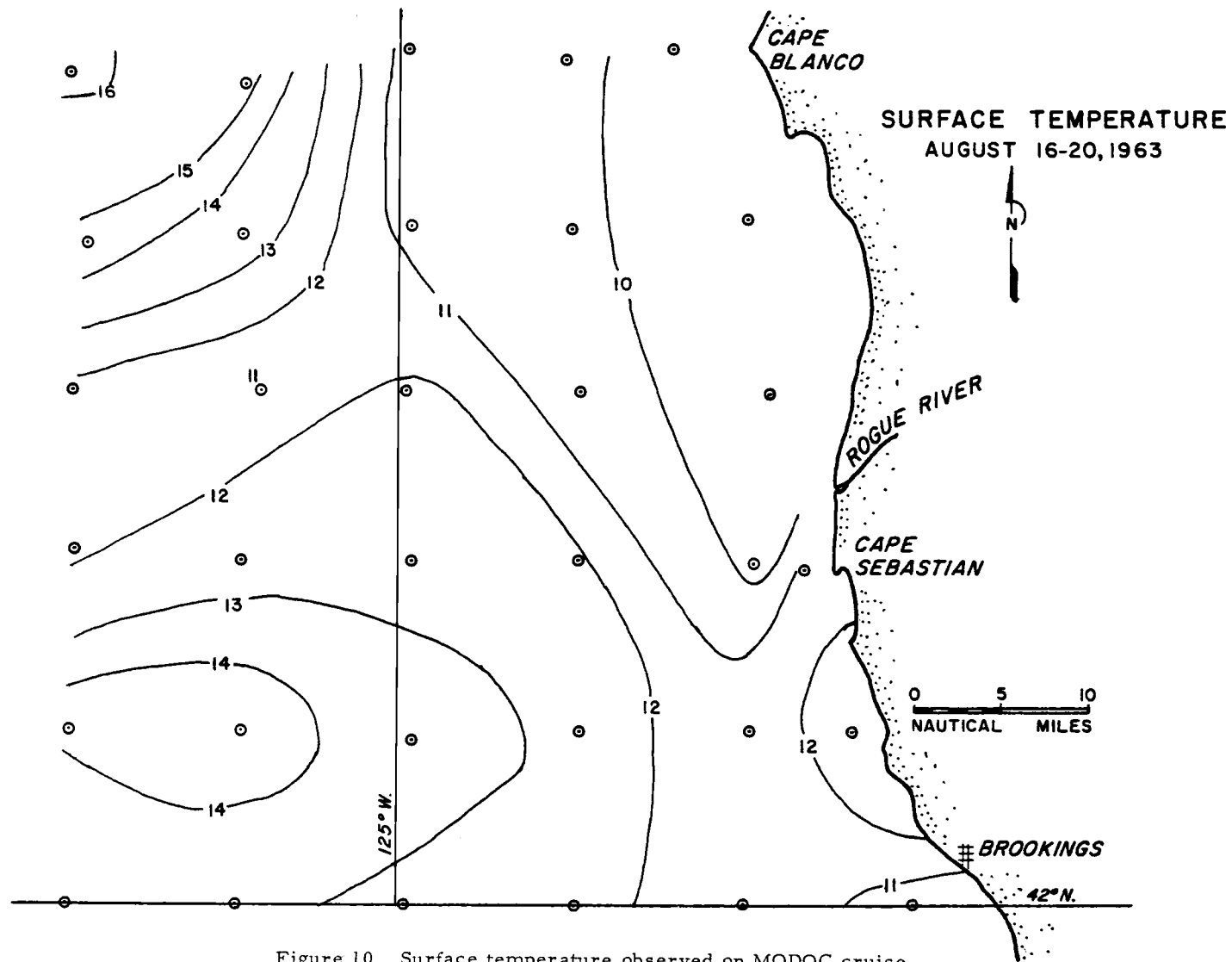
Figure 10. Surface temperature observed on MODOC cruise.
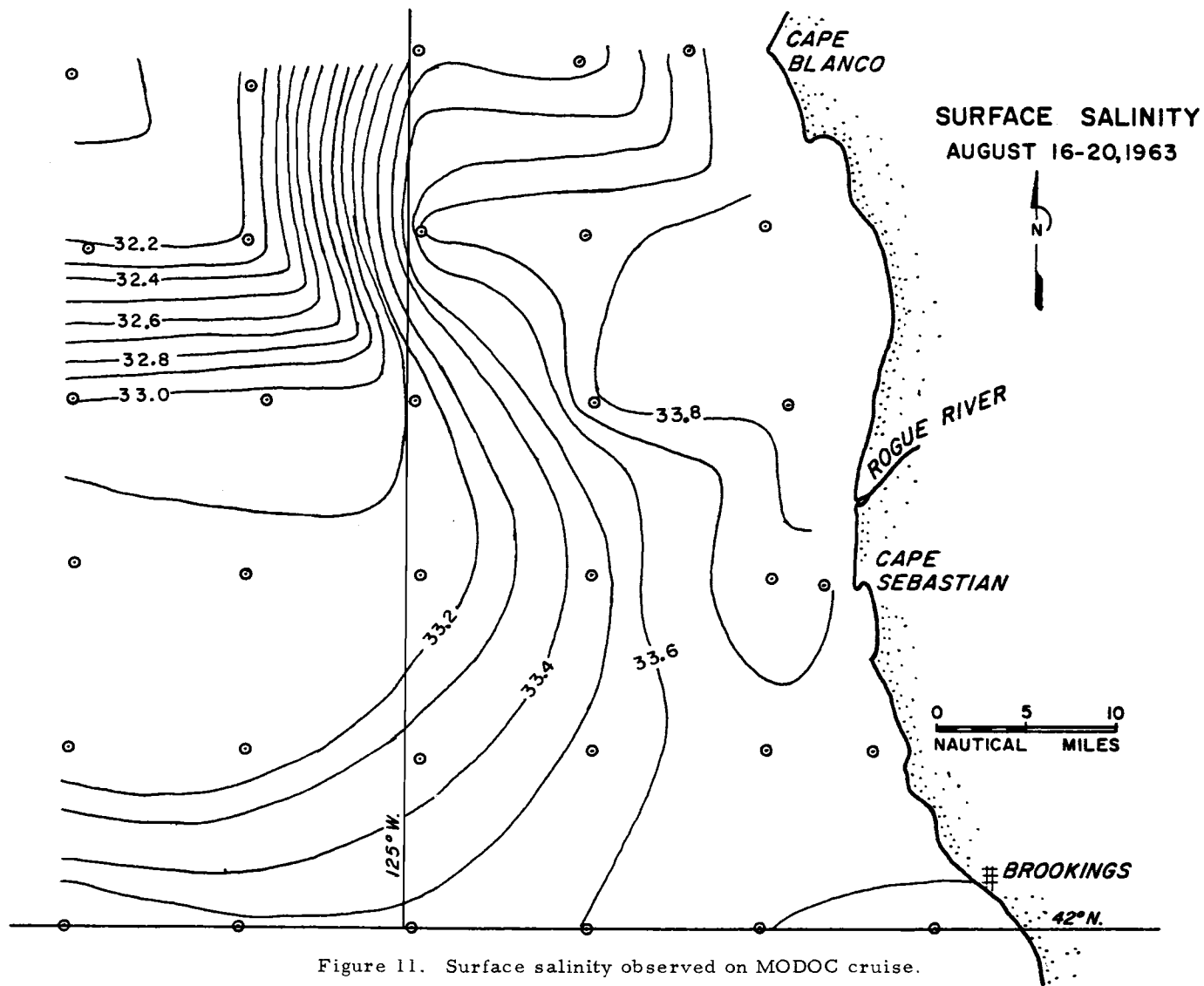
Figure 11. Surface salinity observed on MODOC cruise.
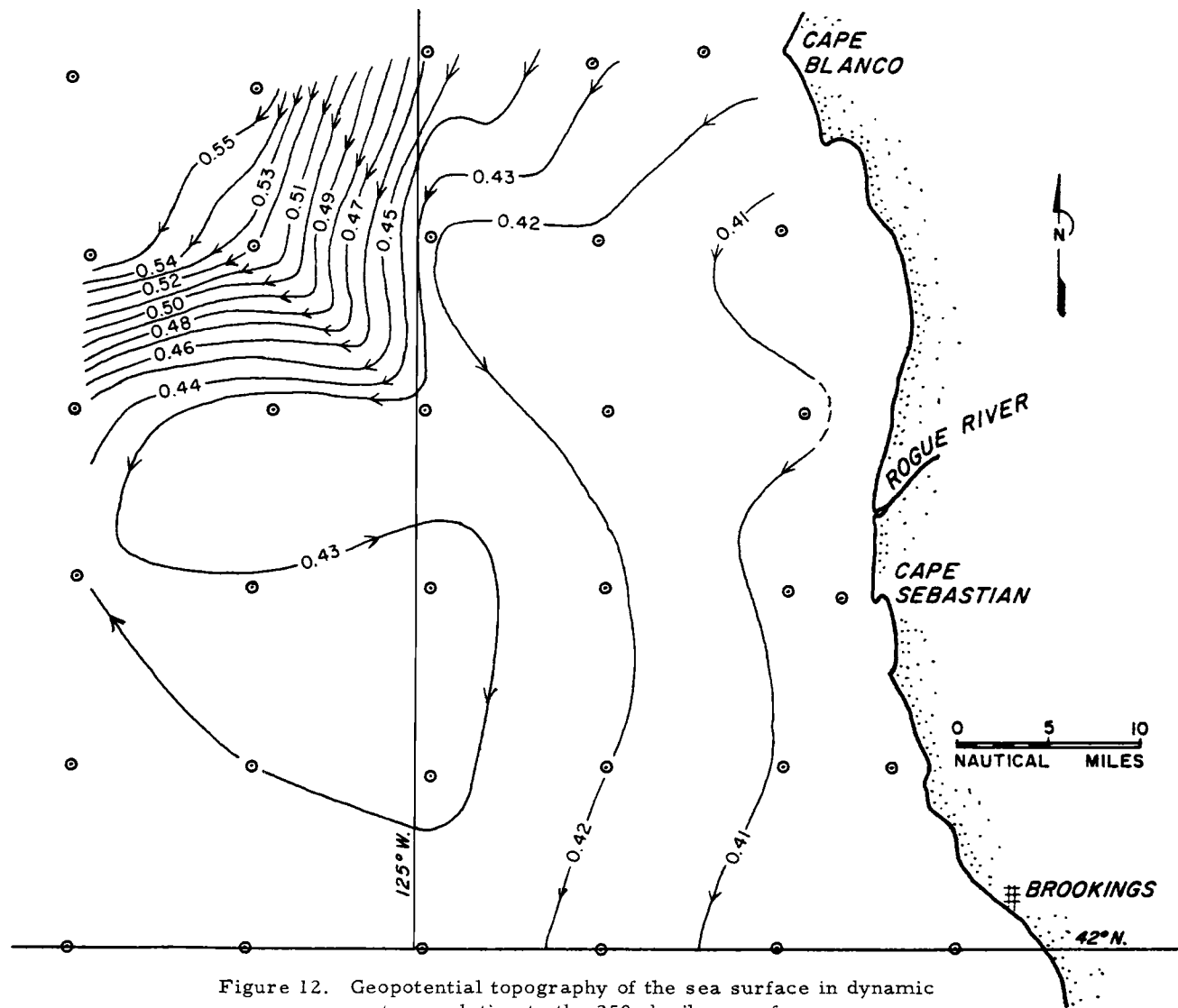
Figure 12.   Geopotential topography of the sea surface in dynamic
meters relative to the 250-decibar surface.
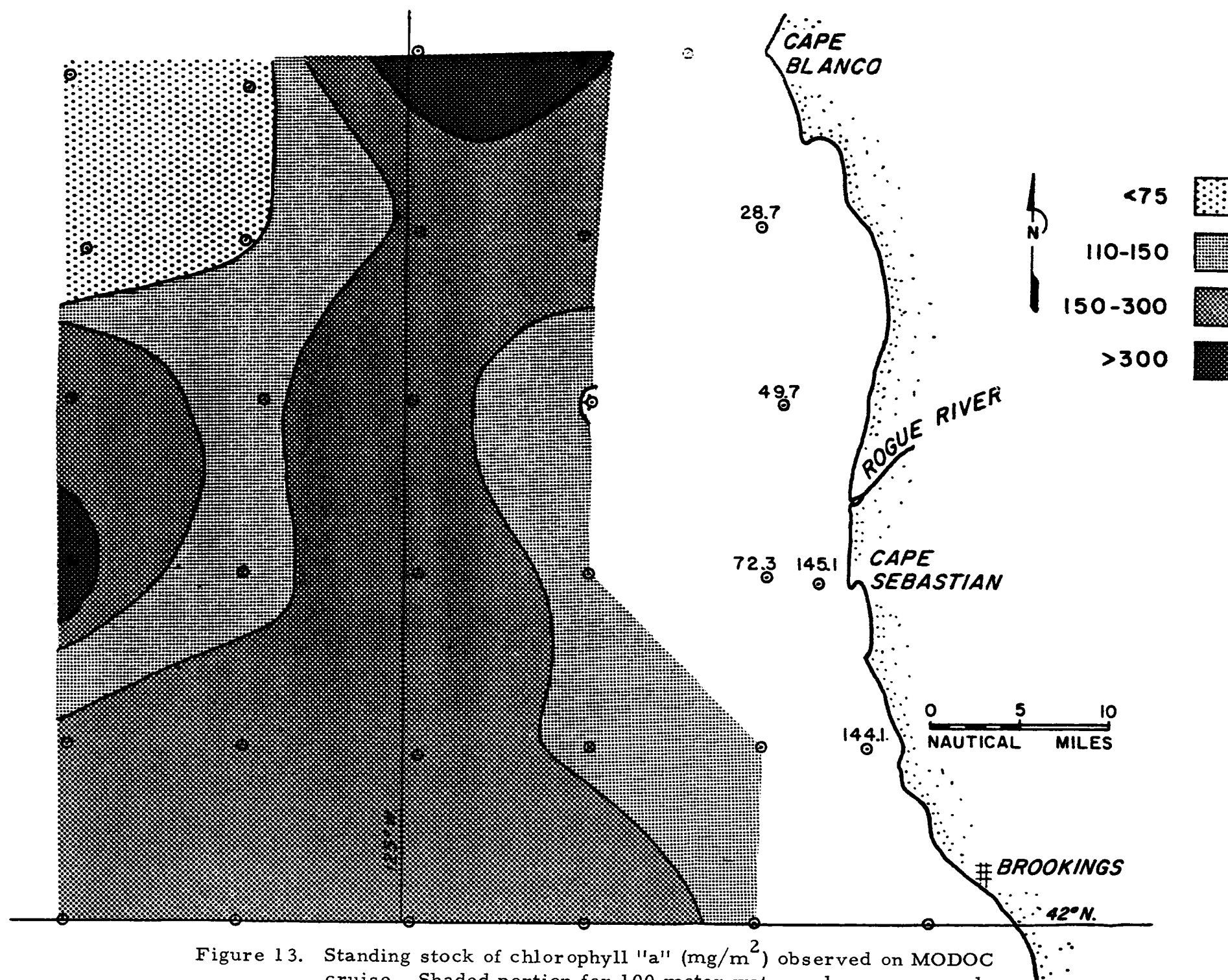
Figure 13. Standing stock of chlorophyll "a" (mg/m^2) observed on MODOC cruise. Shaded portion for 100 meter water column, numerals for 25 meter water column.

TROPHIC LEVEL RELATIONSHIPS

The "trophic level" concept (Lindeman, 1942) has considerable appeal to the ecologist studying complex natural communities (Hedgepeth, 1957). However, there are difficulties inherent in the concept (Ivlev, 1945). It is well-known that in natural communities food chains tend to become intermeshed into complex food "webs" (Odum, 1959). The latter is especially true of the higher elements of the food chain (Darnell, 1961; Riley, 1963; and others). "Nevertheless, food patterns do exist and some division into trophic levels is possible." (Osterberg, Pearcy, and Curl, 1964).

In the pelagic environment the first trophic level (I) consists of phytoplankton. Filter-feeding herbivores comprise the second trophic level (II) and carnivores form the higher trophic levels (III, IV, etc.).

Trophic levels I, II, and III are considered in this study.

Trophic Level I

Chlorophyll "a" concentration was used as a relative measure of the standing stock of trophic level I. Chlorophyll measurement is probably a useful index of the size of the standing stock of phytoplankton under uniform conditions, but Krey et al., (1958), questions comparisons of chlorophyll measurements from one kind of water

with those from another, or one season with those from another. The

ratio of chlorophyll to cell volume, or cell constituents, will vary as

a result of variations in light intensity, nutrient concentrations,

physiological state of the organisms, and species composition (Krey

et al., 1958). Errors may also be introduced by the presence of

detrital chlorophyll (Strickland, 1960). Nonetheless, chlorophyll

measurement is one of the most valuable and convenient methods for

estimating phytoplankton standing stock (Raymont, 1963), and has

been utilized in this research.

Trophic Level II

Euphausiids, copepods, salps, thecosomatous pteropods, crab

zoea, and pyrosomes were included in trophic level II.

Euphausiids. About 16 species of euphausiids were identified

from the collections taken off Brookings (Hebard, unpublished data;

species list given in Appendix I). Euphausia pacifica was most

abundant. Thysanonesa longipes, T. spinifera and Nematoscelis

difficilus occurred seasonally and in much smaller numbers.

Euphausiids may feed on phytoplankton, small crustaceans

such as copepods, protozoans such as globigerina, radiolarians,

and tintinnids, or detritus (Hickling, 1925; Marshall, 1954; Pono-

mareva, 1954, 1963; Tchinodonova, 1959). Although E. pacifica

may occasionally feed on crustaceans (Ponomareva, 1954), it is

primarily a filter-feeding herbivore (Osterberg, et al., 1964). On

the other hand, animal food may form a considerable portion of the

diet of T. longipes and Nematoscelis spp. (Marshall, 1954; Pono-

mareva, 1963).

Copepods. Over 60 species of adult and about 25 genera of

copepodite copepods were identified from the Brookings collections

(Hebard, unpublished data; species list given in Appendix II). Nu-

merically, Metridia pacifica, Eucalanus bungii, Calanus finmar-

chicus, M. lucens, and C. pacificus were most abundant. Only cope-

pods larger than about three millimeters were included in the bio-

mass determinations. Thus, probably not all of the 75 species of

adults and only the larger copepodites, such as Calanus spp., were

represented in the estimates of copepod biomass. The dominant

species of copepods contributing to biomass measurements were

probably E. bungii and C. finmarchicus. Both of these species are

primarily herbivores (Marshall and Orr, 1955; Beklemishev, 1954;

Wickstead, 1962).

Salps. Four species of salps were identified from the collec-

tions (Hubbard, unpublished data; see Appendix III for species list).

Salpa fusiformis (Salpidae) was the most abundant. According to

Marshall (1954), Yount(1958), Foxton (1961), and Fraser (1962),

Salpa spp. are principally phytoplankton grazers.

Miscellaneous. Thecosomatous pteropods, crab zoea, and pyrosomes formed less than one percent of the total biomass of trophic level II. Each of these groups are herbivores (Younge, 1926, 1928; Lebour, 1928).

Trophic Level III

Fishes, chaetognaths, medusae, siphonophores, ctenophores, shrimps, amphipods, polychaetes, cephalopods, gymosomatous pteropods, and heteropods were included in trophic level III.

Fishes. Over 40 species of pelagic fishes were identified from the collections (see Appendix IV for species list). Lampanyctus leucopsarus, L. ritteri, Diaphus theta, Tarletonbeania crenularis, (Myctophidae) and Tactostoma macropus (Melanostomiatidae) were most abundant.

Myctophids feed primarily on euphausiids, calanoid copepods, and amphipods (Marshall, 1954; Osterberg et al., 1964). Euphausiids, sergestid prawns, and lantern fish were found in stomach contents of T. macropus by Osterberg et al. (1964).

Chaetognaths. The species composition of the chaetognaths was not determined. According to data available in the literature,

all chaetognaths are carnivorous, feeding on copepods, amphipods,

ostracods, small euphausiids, other chaetognaths, and larval herring

(Lebour, 1922, 1923; Bigelow, 1924; Parry, 1947; Marshall 1954;

Hardy, 1956; Tchinodonova, 1959).

Medusae, Siphonophores, and Ctenophores. These groups were

lumped together for biomass measurements. No species identifica-

tions were made. All of the medusae, siphonophores, and cteno-

phores are carnivorous and may feed on copepods, euphausiids,

chaetognaths, and small fishes (Lebour, 1922, 1923; Bigelow, 1924;

Marshall, 1954; Hardy, 1956; Nicol, 1960; Fraser, 1962).

Shrimps. Seven species of shrimps were identified from the

collections (Forss, unpublished data; species list given in Appendix

V). Only two species were important biomass contributors. These

were Sergestes similis (Penaeidea), which was collected at all sta-

tions and dominated nearly all catches, and Pandalus jordani (Cari-

dea), which was found only at the two inshore stations and frequently

comprised the entire catch of shrimps at these stations. Renfro and

Pearcy (1966) found that small crustaceans, calanoid copepods, and

euphausiids form the diet of S. similis off Oregon.

Amphipods. About 16 species of pelagic amphipods were identi-

fied (Van Arsdale, unpublished data; species list given in Appendix VI).

Numerically, Parathemisto pacifica (Hyperiidae) was most abundant.

Although there is little precise information on the feeding habits of

hyperid amphipods (Raymont, 1963), copepods, other amphipods,

crustacean debris and larval fish debris has been found in their

stomach contents (Lebour, 1922; Bigelow, 1924; Kane, 1963).

Polychaetes. Although detailed identifications of the polychae-

tes were not made, casual inspection indicated at least four species

of Tomopteris. Tomopteris spp. may feed on diatoms, copepods,

chaetognaths, and larval herrings (Lebour, 1922, 1923; Bieglow,

1924; Nicol, 1960).

Cephalopods. Abrailiopsis sp. (Enoploteuthiade) was the dom-

inant cephalopod found off Brookings. About 12 additional cephalopod

species were also identified (Pearcy, unpublished data; species list

is given in Appendix VII). Cephalopods are presumed to feed on

fishes, crustacea and other squids (Marshall, 1954; Pearcy, unpub-

lished).

Heteropods and Gymnosomatous Pteropods. These two groups

formed only 0. 3 percent of the total biomass of trophic level III.

Both groups are carnivores (Bigelow, 1924; Raymont, 1963).

TEMPORAL AND SPATIAL DISTRIBUTIONS OF TROPHIC LEVEL I

The standing stock of trophic level I was high in the spring and late winter, intermediate in the summer, and low in the fall (and in the summer of 1963) (Table 5). Seasonal differences in the mean standing stocks were small, only 2-3 fold. However, at individual stations the seasonal variation was larger, up to 8-9 fold.

In the summer (and in the spring of 1964) the standing stocks of trophic level I were considerably higher inshore than they were offshore. However, in the fall and the winter the standing stocks observed inshore were about equal to those found offshore. In the spring of 1963 the standing stocks found offshore were higher than those recorded inshore (Table 5).

The mean standing stocks of trophic level I observed at the inshore stations were approximately equal and about 1.2 to 1.8 times higher than the mean values found at offshore stations. Standard deviations of measurements at each station indicate rather small seasonal variations. The greatest variation was recorded at inshore stations (Table 5).

Anderson (1964) examined the seasonal and geographic distributions of primary productivity and chlorophyll "a" off the Washington and Oregon coasts. He found that although there was little change in standing stock, production was quite variable, with minima in winter and summer, a large spring bloom, and a smaller autumn pulse.

Table 5. Standing stocks of chlorophyll "a" (milligrams per m^2).

Date	5 *	15	25	35	45	65	85	105	125	145	165	$\bar{x}$ *
June 62	ns	ns	136.60	186.88	56.66	57.19	48.80	53.13	43.19	45.88	56.80	76.13
Aug. 62	262.10	74.82	99.90	189.03	138.37	63.14	41.77	59.16	48.20	61.76	27.25	80.34
Oct 62	9.43	35.50	54.57	52.16	84.78	46.33	69.60	41.25	51.14	55.54	64.36	55.52
Mar. 63	19.92	64.15	93.18	92.38	92.50	96.14	86.70	104.56	82.70	85.57	86.60	88.45
May 63	27.18	119.80	73.09	73.63	67.42	93.41	92.90	123.49	122.69	107.49	ns	97.10
July 63	57.98	75.10	37.95	34.66	33.00	22.55	38.13	45.29	31.37	26.53	17.97	36.26
Sept. 63	88.28	36.47	28.01	39.77	37.20	48.78	20.66	44.41	43.52	41.73	56.88	39.74
Apr. 64	ns	230.84	134.23	38.57	36.88	56.05	41.84	49.75	37.66	27.63	49.00	70.25
$\bar{x}$	78.48	90.95	82.19	88.39	68.35	60.45	55.05	65.13	57.56	56.62	51.27	
s	86.66	50.74	38.47	60.32	33.73	22.83	23.70	29.09	28.48	26.31	21.29	

* Values recorded at 5 nautical miles offshore are not included in the computation of the mean standing stock of chlorophyll "a" for each sampling period. Chlorophyll "a" standing crop values for the 5 nautical mile station are for a 25-meter water column, while those for all other stations are for a 100-meter water column.

TEMPORAL AND SPATIAL DISTRIBUTIONS OF TROPHIC LEVEL II

Pronounced seasonal differences in relative abundance of trophic level II, indicated by mean catches, were not apparent. With the exception of one low value for July 1963, all monthly means were from 14-22 grams dry weight per $10m^2$ (see $\bar{x}$ in Table 7). The small temporal variation is probably not real, but apparently due to a dampening effect caused by averaging large winter-catches taken at the 15-mile station and catches taken further offshore. The mean values for standing stocks measured at stations seawards of 15 miles (see $\bar{x}_1$ in Table 7), in general indicate a seasonal pattern with high biomass in the fall, intermediate in the spring and late summer, and low in the midsummer and late winter.

The standing stocks of trophic level II were higher at the 15-35-mile stations than they were further offshore. The mean standing stock at 15 miles was about 11 times higher than the mean value at 105 miles offshore (Table 7). Seasonal variation in the relative abundance of trophic level II was also greater inshore than it was offshore. The standard deviation for catches taken at 15 miles was 14.5 times higher than the standard deviation for catches taken at 105 miles offshore (Table 7).

The biomass of euphausiids formed a dominant portion of the biomass of trophic level II in all seasons, however, copepods and

salps contributed significantly in July 1963.

Euphausiids

Euphausiids comprised 72.0 percent of the total biomass of trophic level II. They formed a lower percentage of the biomass of trophic level II in the spring and midsummer than in other seasons (Table 6).

The relative abundance of euphausiids was low in the midsummer, intermediate in the spring, late summer, (and fall of 1963), and high in the late winter (and fall of 1962) (Table 8). The size and seasonal variation of catches were substantially greater inshore than they were offshore. At the 15-mile station the mean catch was about 5 to 7 times higher than at other inshore stations, and about 15 to 35 times higher than at offshore stations; the standard deviation was more than 50 times higher than for catches taken at 105 nautical miles offshore (Table 8).

Copepods

Copepods constituted 14.3 percent of the total biomass of trophic level II. A larger fraction of the biomass of trophic level II was formed by the copepods in the spring and midsummer than in other seasons (Table 6).

The relative abundance of copepods was low in the late winter,

intermediate in the summer (and in the fall of 1963), and high in the spring (and fall of 1962) (Table 9). The highest mean catches were taken at intermediate distances offshore. The greatest seasonal variation, indicated by standard deviations of catches at each station, was also observed at intermediate distances offshore (Table 9).

The data suggest possible inverse temporal and spatial relationships between the standing stocks of copepods and euphausiids. The relative abundance of the copepods was lowest when that of the euphausiids was highest, and the relative abundance of the copepods was highest when that of the euphausiids was reduced. Also, the relative abundance of the copepods was highest at intermediate distances offshore, whereas, that of the euphausiids was highest very near to the shore (Tables 8 and 9).

Salps

Salps formed 13.1 percent of the total biomass of trophic level II (Table 6). The relative abundance of the salps was low in the summer, winter, (and fall of 1962), and high in the spring (and fall of 1963) (Table 10).

In general, catches of salps were higher inshore than offshore. The highest mean catches were taken at 25 and 35 miles offshore. The seasonal variation in catches was higher inshore than it was offshore (Table 10).

Table 6. Percent of biomass of trophic level II formed by constituents.

	Aug. 62	Oct. 62	Mar. 63	May 63	July 63	Sept. 63	Apr. 64	$\bar{x}$
				Sampling Periods				
Euphausiids	87.0	82.5	93.6	60.7	43.9	50.9	57.2	72.0
Copepods	11.0	14.3	4.4	15.8	30.5	6.3	31.7	14.3
Salps	2.0	3.2	0.0	24.2	25.5	39.7	10.2	13.1
*Miscellaneous	0.0	0.0	2.0	2.8	0.1	3.1	0.9	0.6

*Includes zoea, megalops, pyrosomes, and thecosomatous pteropods.

Table 7. Standing stocks of trophic level II (dry weight in grams per 10 m^2).

Date	Distance Offshore (Nautical Miles)											$\bar{x}$	$\bar{x}_1$
	5	15	25	35	45	65	85	105	125	145	165		
Aug. 62	ns	72.34	29.72	20.36	8.74	2.68	4.03	3.26	1.93	1.50	2.65	14.72	8.32
Oct. 62	0.58	ns	52.28	40.76	45.16	19.90	10.80	6.96	6.20	13.54	13.92	21.10	26.19
Mar. 63	1.72	174.48	4.86	4.06	ns	6.32	5.06	4.82	4.70	11.90	3.32	22.12	5.63
May 63	0.47	53.34	9.86	6.44	8.36	11.24	17.84	13.71	27.82	ns	ns	16.56	13.61
July 63	6.57	2.78	4.50	3.48	2.88	3.04	1.76	6.04	3.28	2.10	ns	3.64	3.39
Sept. 63	3.17	27.09	47.70	57.09	25.82	7.00	9.35	1.18	3.02	2.98	4.54	17.18	17.63
Apr. 64	10.94	110.83	2.48	17.62	4.72	11.82	12.80	9.86	ns	ns	14.80	21.76	10.59
$\bar{x}$	3.91	73.48	21.63	21.40	15.94	8.86	8.81	6.55	7.83	6.40	7.85		
s	3.76	56.50	19.87	18.93	15.09	5.58	5.19	3.88	8.81	5.20	5.36		

Table 8. Standing stocks of euphausiids (dry weight in grams per 10 m^2).

Date	Distance Offshore (Nautical Miles)											$\bar{x}$
	5	15	25	35	45	65	85	105	125	145	165	
Aug. 62	ns	72.34	26.80	16.70	6.89	0.34	0.45	1.67	0.81	0.76	0.74	12.80
Oct. 62	0.05	ns	52.20	39.56	34.86	10.66	5.08	2.68	5.52	11.12	11.62	17.34
Mar. 63	0.09	174.48	4.22	1.90	ns	5.40	1.44	2.20	3.56	11.20	2.54	20.70
May 63	0.00	53.33	2.32	0.62	5.26	4.36	9.16	3.58	11.90	ns	ns	10.06
July 63	4.77	1.93	2.62	0.90	1.72	0.98	0.56	1.44	0.34	0.74	ns	1.60
Sept. 63	1.89	22.40	17.26	27.59	13.19	4.95	8.78	0.30	0.92	0.52	2.24	9.09
Apr. 64	0.06	105.05	1.46	0.90	0.18	0.60	0.88	2.06	ns	ns	0.84	12.45
$\bar{x}$	1.14	71.59	15.27	12.60	10.35	3.90	3.76	1.99	3.29	4.87	3.60	
s	1.76	56.73	17.49	14.64	11.72	3.41	3.53	0.95	3.74	5.14	4.08	

Table 9. Standing stocks of copepods (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	$\bar{x}$
						Distance Offshore (Nautical Miles)							
Aug.	62	ns	T	2.80	2.68	1.66	1.10	3.08	1.59	0.89	0.55	1.87	1.62
Oct.	62	0.53	ns	0.08	1.20	10.30	5.60	5.38	1.62	0.68	2.42	2.30	3.01
Mar.	63	0.63	T	0.52	1.96	ns	0.84	2.12	1.60	0.58	0.70	0.78	0.97
May	63	0.47	T	1.70	1.78	1.86	4.40	2.42	3.50	7.46	ns	ns	2.62
July	63	0.92	0.86	1.40	1.26	1.16	1.06	0.58	0.90	1.62	1.36	ns	1.11
Sept.	63	0.16	0.27	2.14	1.48	1.75	2.05	0.57	0.02	0.52	1.30	1.72	1.09
Apr.	64	10.39	5.34	0.64	16.54	2.28	10.18	8.04	5.00	ns	ns	3.70	6.90
$\bar{x}$		2.18	1.08	1.33	3.84	3.17	3.60	3.17	2.03	1.68	1.27	2.07	
s		3.68	1.93	0.90	5.20	3.21	3.18	2.50	1.50	2.30	0.66	0.95	

Table 10. Standing stocks of salps (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	$\bar{x}$
						Distance Offshore (Nautical Miles)							
Aug.	62	ns	0.00	0.07	0.97	0.19	1.24	0.00	0.00	0.23	0.19	0.00	0.29
Oct.	62	0.00	ns	0.00	0.00	0.00	3.64	0.34	2.64	0.00	0.00	0.00	0.66
Mar.	63	0.00	0.00	T	0.00	ns	0.00	0.10	0.00	0.00	0.00	0.00	T
May	63	0.00	0.00	3.64	3.96	6.20	2.40	5.04	6.54	8.46	ns	ns	4.03
July	63	0.87	0.00	0.48	1.30	0.00	1.00	0.62	3.70	1.32	0.00	ns	0.93
Sept	63	1.11	4.42	28.30	28.30	11.20	0.00	0.00	0.86	0.16	0.11	0.60	6.82
Apr.	64	0.00	0.00	0.00	0.00	2.22	0.84	3.88	2.80	ns	ns	10.20	2.22
$\bar{x}$		0.33	0.74	4.64	4.93	3.30	1.30	1.43	2.36	1.70	0.06	2.16	
s		0.47	1.64	9.74	9.63	4.15	1.22	1.96	2.17	3.06	0.10	4.03	

TEMPORAL AND SPATIAL DISTRIBUTIONS OF TROPHIC LEVEL III

The relative abundance of trophic level III was high in the spring and fall, and low in the early summer and late winter (Table 13). A large biomass of mesopelagic fishes was mainly responsible for the fall maximum; whereas, large biomasses of shrimps, and medusae, siphonophores, and ctenophores (measured collectively) contributed significantly to the spring maximum (Table 11).

The highest mean standing stock of trophic level III was observed 45 miles offshore. Seaward of this the mean standing stocks were reduced by about one-half and were nearly uniform. The lowest mean standing stocks were found at the two stations nearest the coast (Table 13).

There was a trend for the standing stocks to increase in a seaward direction as the upwelling season progressed. The highest standing stock of trophic level III observed in August 1962 was found at 25 miles offshore, in October 1962 at 45 miles offshore, and in March 1963 at 145 miles offshore (Table 13) (Figures 17 and 18).

The temporal variations in trophic level III were considerably greater inshore than they were offshore. The standard deviations of inshore catches were approximately 1.5 to 5.5 times higher than for offshore catches (Table 13).

Fishes

Fishes comprised 47.1 percent of the total biomass of trophic level III. Fishes formed a larger portion of the biomass of trophic level III in the fall than in the spring (Table 11).

Temporal and Spatial Distributions

Seasonal differences in relative abundance of fishes, indicated by mean catches for each sampling period, were small. However, a consistent pattern was found. Catches of fishes were 2-3 times higher in the fall than in the summer and intermediate in the spring (Table 14). Changes in the availability of fishes will be discussed further in conjunction with dominant species.

The small temporal variation, indicated by mean catches, is probably not real, but apparently due to a dampening effect caused by averaging inshore and offshore catches. Greater differences in catches among cruises are evident if individual stations are compared.

The seasonal variation in catches of fishes was considerably greater inshore than it was offshore. The standard deviation of catches taken 45 miles offshore was nearly seven times higher than that for catches taken 105 miles offshore (Table 14). The highest mean catch was taken 45 miles offshore.

Change in Species Composition

Lampanyctus leucopsarus, L. ritteri, Diaphus theta, Tarle-
tonbeania crenularis (Myctophidae) and Tactostoma macropus (Mela-
nostomiatidae), which are mainly Sub-Arctic -- Transitional forms,
comprised more than 90 percent of the biomass of fishes in each
sampling period except in July 1963 when the value fell to 70.4 per-
cent (Table 12).

A change in the species composition of fishes was evident in
July 1963 in the offshore region. The Sub-Arctic -- Transitional
species, whose numbers were intermediate inshore, were nearly
absent offshore. For example, the number of L. leucopsarus col-
lected per 1000 m^3 of water was 1.67 at 25 miles offshore, 0.12 at
125 miles offshore, and 0.0 at 145 miles offshore. The Sub-Arctic--
Transitional forms were replaced offshore by small numbers of
fishes apparently of southern and/or western waters. These in-
cluded Lampadena urophaos (Myctophidae), Nansenia sp. (Argen-
tinidae) and Leuroglossus sp. (Bathylagidae). These latter species
were collected only in July 1963 and only in the offshore region.

Availability of Fishes

The seasonal differences in catch indicate changes in avail-
ability of the fishes. These changes in availability may be due to

changes in actual abundance or to changes in vulnerability to capture. In either case, the differences could be related to the life histories of the species.

Histograms of the size-frequency distributions of L. leucopsarus, L. ritteri, and D. theta are shown in Figures 14-16, respectively. The smallest length groups always occurred in the fall. A mode comprised of small individuals and representing the 0 age-group usually is predominant for each species. This implies that breeding of these species is mainly seasonal.

Seasonal differences in the size-frequency distribution of each species may result from growth, mortality, and movement of the populations. The fall increase in small individuals is due to the increased susceptibility of small individuals to capture after they have grown enough to be retained by the mesh of the trawl. However, other factors appear to be involved in the fall increase of large individuals. Not only did the large individuals constitute a greater proportion of the total catch during the fall than in other seasons, but the catch of large individuals during the fall was greater than that of small individuals during other seasons. These differences indicate that large individuals probably migrated into the study area.

It is concluded that the increase in relative abundance of fishes during the fall is due to (1) recruitment of small individuals into the population, and (2) migration of large individuals from without.
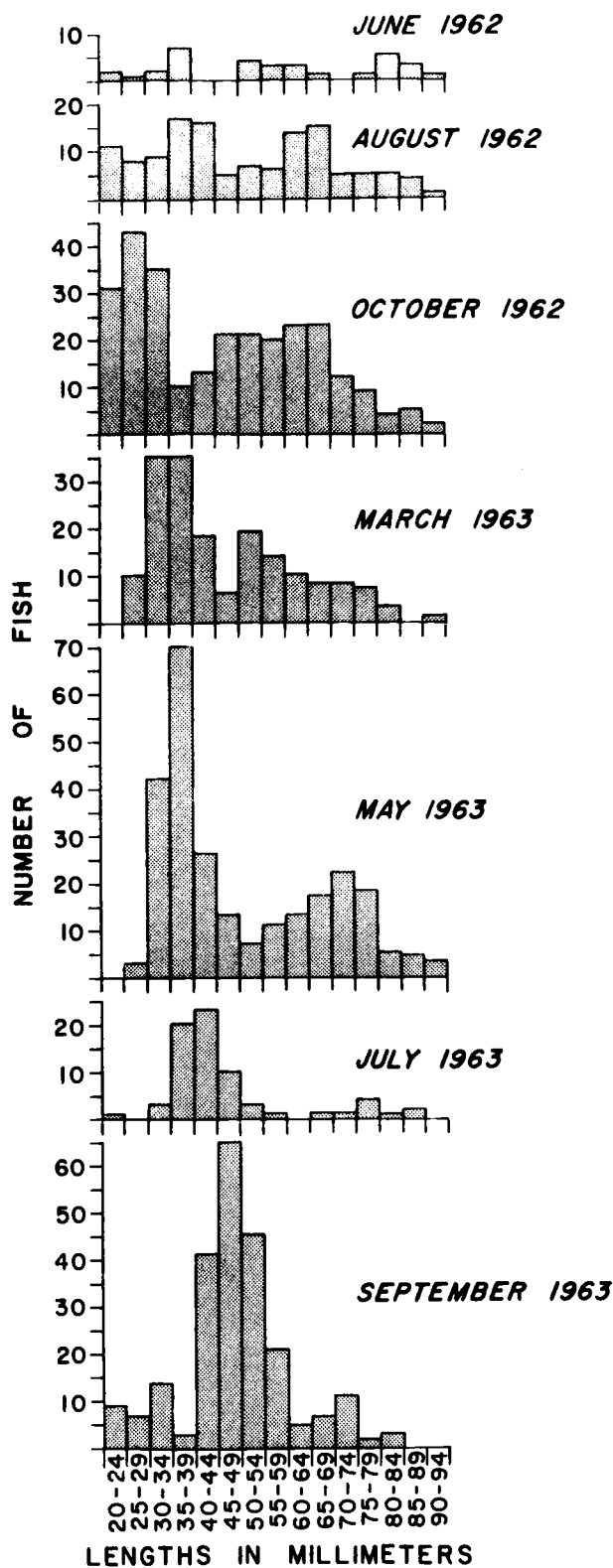
Figure 14. Length frequency distribution for Lampanyctus leucopsarus.

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LENGTH FREQUENCIES FOR LAMPANYCTUS RITTERI
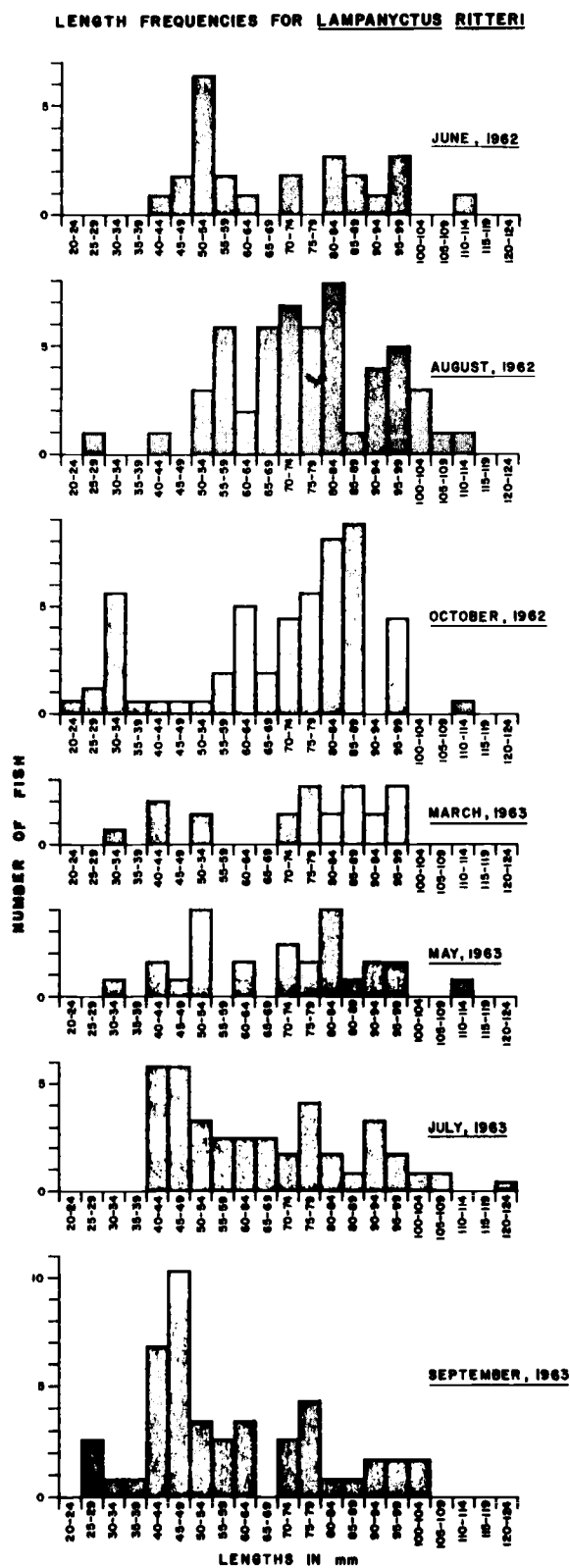
Figure 15.   Length frequency distribution for Lampanyctus ritteri.
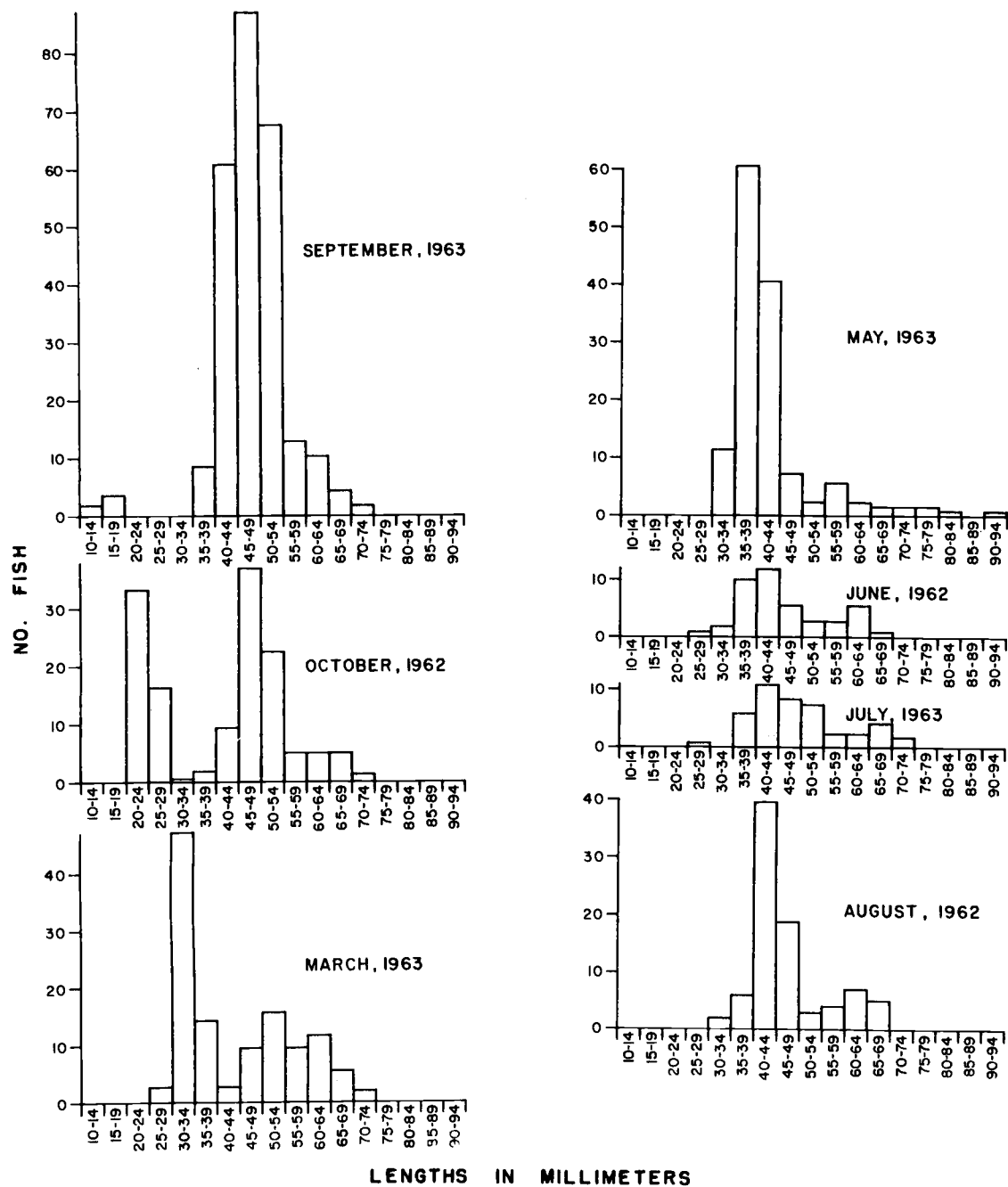
Figure 16. Length frequency distribution for Diaphus theta.

Chaetognaths

Chaetognaths formed 15.3 percent of the total biomass of trophic level III (Table 11). The relative abundance of the chaetognaths exhibited annual variations. Standing stocks were minimum in the spring, intermediate in the summer and late winter, and maximum in the fall (Table 15).

In general, standing stocks were higher at intermediate distances offshore in the fall and far offshore in other seasons. The highest mean catch was taken 45 miles offshore (Table 15), and the greatest seasonal variation in catches was also observed at this station.

Medusae, Siphonophores, and Ctenophores

The standing stocks of the medusae, siphonophores, and ctenophores were measured collectively. Their biomass comprised about 30 percent of the biomass of trophic level III in the spring, but only about 10 percent in the fall. The total biomass of these groups formed 14.4 percent of the total biomass of trophic level III (Table 11).

The relative abundance of these groups, taken together, was lowest in the summer and late winter, intermediate in the fall, and highest in the spring (Table 16). The greatest seasonal variation in

catches of these groups occurred offshore.

Shrimps

Eleven percent of the total biomass of trophic level III was formed by shrimps (Table 11). The relative abundance of the shrimps was lowest in the summer and late winter, intermediate in the fall, and highest in the spring (Table 17).

Mean catches of shrimps were two to five times higher inshore than offshore; the highest mean catch was taken 25 miles offshore (Table 17). The standard deviations of catches taken at each station indicate that the seasonal variation in the relative abundance of shrimps was greatest inshore (Table 17).

Amphipods

Amphipods constituted 5.8 percent of the total biomass of trophic level III (Table 11). The relative abundance of amphipods was lowest in the late winter and spring, intermediate in the summer, and highest in the fall (Table 18).

The sizes of catches were variable spatially. However, in general, catches taken offshore were larger than those taken inshore, except in September 1963 (Table 18).

Polychaetes

The relative abundance of pelagic polychaetes was highest in the spring and lowest in the fall when they comprised five and one percent of the biomass of trophic level III, respectively (Tables 19 and 11).

In the late winter and spring, catches of polychaetes were larger offshore than inshore, whereas in other seasons, except in the fall of 1962, largest catches were taken inshore. The standard deviations of offshore catches were as much as an order of magnitude greater than for inshore catches (Table 19). This suggests that the seasonal variation in relative abundance of polychaetes is greater offshore.

Cephalopods

Cephalopods constituted 2.4 percent of the total biomass of trophic level III (Table 11). Although catches of cephalopods were small, seasonal differences in relative abundance were suggested. Catches were lowest in the summer, intermediate in the late winter and spring, and highest in the fall, except fall 1963 (Table 20).

There were relatively few differences in inshore--offshore catches. However, the mean catches were slightly higher inshore than they were offshore; the seasonal variation was greatest 25 miles offshore (Table 20).

Table 11. Percent of biomass of trophic level III formed by constituents.

| | Sampling Periods | | | | | | | |
	Aug. 62	Oct. 62	Mar. 63	May 63	July 63	Sept. 63	Apr. 64	$\bar{x}$
Fishes	48.7	52.3	53.9	32.7	39.4	55.6	47.3	47.1
Chaetognaths	13.0	17.5	13.9	10.1	20.9	14.9	16.5	15.3
Med., Siph. & Cten.	9.3	11.4	10.9	30.3	12.4	10.8	16.0	14.4
Shrimps	12.6	8.4	8.9	15.1	12.5	8.7	9.8	10.9
Amphipods	8.3	5.9	2.6	4.5	9.7	7.0	2.8	5.8
Polychaetes	2.1	1.1	6.1	5.3	4.3	1.1	2.9	3.3
Cephalopods	3.3	3.3	3.4	1.7	0.7	1.0	3.8	2.4
Heter. & Ptero.	2.6	0.1	0.2	0.3	0.3	0.8	0.8	0.3

Table 12. Percent of fish biomass formed by Sub-Arctic -- Transitional species.

| | Sampling Periods | | | | | | |
	June 62	Aug. 62	Oct. 62	Mar. 63	May 63	July 63	Sept. 63
Percent	94.0	94.2	96.3	92.3	91.4	70.4	91.4

Table 13. Standing stocks of trophic level III (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
Aug.	62	0.10	3.22	11.34	9.29	7.99	7.32	10.17	5.14	4.98	4.65	5.48	6.33
Oct.	62	0.74	ns	4.08	11.44	20.40	8.24	7.12	4.66	6.36	13.40	11.70	8.81
Mar.	63	0.45	T	5.44	4.44	ns	4.66	4.54	5.94	6.16	11.34	6.34	5.16
May	63	1.59	ns	15.18	5.04	12.10	6.44	7.80	6.40	14.42	ns	ns	8.62
July	63	1.54	0.44	7.08	4.26	4.86	5.92	3.56	6.70	5.76	4.46	ns	4.46
Sept.	63	1.83	2.08	16.32	22.04	17.24	9.16	6.08	4.54	3.96	3.86	2.96	8.25
Apr.	64	1.10	0.08	8.20	8.78	ns	4.82	ns	3.46	ns	ns	5.24	4.88
x̄		1.05	1.16	9.66	9.33	12.52	6.65	6.55	5.26	6.94	7.54	6.34	
s		0.65	1.42	4.75	6.25	6.40	1.69	2.29	1.15	3.77	4.48	3.24	

Table 14. Standing stocks of fishes (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
June	62	ns	ns	1.50	3.42	4.02	0.96	0.90	2.18	2.02	2.40	0.94	2.04
Aug.	62	T	1.35	6.79	4.21	3.20	4.41	4.54	2.24	3.24	1.58	2.35	3.08
Oct.	62	0.36	0.08	3.12	7.64	8.70	5.92	3.32	2.76	4.70	3.18	6.38	4.20
Mar.	63	0.14	T	2.70	1.58	1.98	2.22	0.70	3.42	4.14	6.80	4.82	2.59
May	63	0.36	ns	3.38	1.98	5.90	3.12	1.82	2.16	3.82	ns	ns	2.82
July	63	0.13	0.02	2.94	1.56	1.62	2.26	1.06	2.76	3.28	1.96	ns	1.76
Sept.	63	1.03	0.03	8.94	14.00	14.06	3.53	4.67	1.62	1.42	0.26	0.86	4.58
Apr.	64	0.39	0.08	5.50	3.72	ns	2.90	ns	1.08	ns	ns	1.38	2.15
x̄		0.34	0.26	4.36	4.76	5.64	3.17	2.43	2.28	3.23	2.70	2.79	
s		0.34	0.54	2.50	4.23	4.44	1.51	1.72	0.72	1.07	2.23	2.30	

Table 15. Standing stocks of chaetognaths, (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
Aug.	62	T	0.13	0.76	0.92	0.70	1.08	1.53	0.78	0.68	1.65	0.86	0.83
Oct.	62	0.35	ns	T	1.48	8.62	0.64	0.42	0.40	0.32	0.92	2.32	1.55
Mar.	63	0.14	T	0.64	1.12	ns	0.70	1.34	0.90	0.38	1.24	0.54	0.67
May	63	0.00	0.00	0.96	0.70	0.62	0.84	0.56	0.20	3.08	ns	ns	0.77
July	63	0.11	0.09	1.36	0.58	1.06	1.18	0.84	1.44	1.32	1.36	ns	0.93
Sept.	63	0.24	0.32	1.92	2.87	1.85	2.88	0.27	0.48	0.56	1.38	0.74	1.23
Apr.	64	0.28	0.00	1.08	1.76	0.66	0.62	0.69	0.46	ns	ns	1.06	0.73
x̄		0.16	0.09	0.96	1.35	2.25	1.13	0.81	0.65	1.06	1.31	1.10	
s		0.13	0.13	0.56	0.87	2.88	0.74	0.47	0.37	0.96	0.24	0.63	

Distance Offshore (Nautical Miles)

Table 16. Standing stocks of medusae, siphonophores, and ctenophores (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
Aug.	62	0.00	0.00	0.94	0.81	1.62	0.38	1.24	0.41	0.28	0.59	0.19	0.59
Oct.	62	0.00	ns	T	0.08	0.22	0.28	1.26	0.50	0.08	7.24	0.40	1.01
Mar.	63	0.00	0.00	0.24	0.28	ns	0.56	1.44	0.82	0.34	1.36	0.34	0.54
May	63	0.00	0.00	4.86	1.48	4.20	1.38	3.10	0.54	5.32	ns	ns	2.32
July	63	0.65	0.15	1.22	1.08	0.50	0.60	0.54	0.14	0.20	0.44	ns	0.50
Sept.	63	0.37	0.15	1.70	2.34	0.60	0.52	1.14	1.16	0.90	1.14	0.30	0.94
Apr.	64	0.02	0.00	0.52	1.72	0.30	0.64	0.44	0.56	ns	ns	1.62	0.65
x̄		0.15	0.05	1.35	1.11	1.24	0.62	1.31	0.59	1.19	2.15	0.57	
s		0.24	0.08	1.53	0.74	1.40	0.33	0.88	0.30	1.87	2.57	0.53	

Distance Offshore (Nautical Miles)

Table 17. Standing stocks of shrimps (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
							Distance Offshore (Nautical Miles)						
Aug.	62	0.00	1.52	1.26	1.64	1.12	0.52	0.59	0.59	0.42	0.46	0.67	0.80
Oct.	62	0.00	ns	0.62	0.94	1.26	0.80	1.22	0.34	0.82	0.68	0.72	0.74
Mar.	63	0.17	T	1.48	0.80	0.28	0.38	0.34	0.40	0.46	0.24	0.12	0.42
May	63	1.23	ns	5.66	0.50	0.80	0.48	0.42	0.98	0.32	ns	ns	1.30
July	63	0.00	0.00	1.02	0.20	1.02	0.78	0.68	1.10	0.18	0.58	ns	0.56
Sept.	63	0.17	1.32	1.24	0.84	0.63	2.11	0.30	0.54	0.46	0.02	0.30	0.72
Apr.	64	0.41	0.00	0.78	0.96	ns	0.42	ns	0.84	ns	ns	0.22	0.45
x̄		0.28	0.57	1.72	0.77	0.85	0.78	0.59	0.68	0.44	0.40	0.41	
s		0.41	0.70	1.63	0.43	0.33	0.56	0.31	0.27	0.19	0.24	0.24	

Table 18. Standing stocks of amphipods (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
							Distance Offshore (Nautical Miles)						
Aug.	62	0.00	0.07	0.14	0.32	0.37	0.41	1.71	0.93	0.21	0.27	1.37	0.53
Oct.	62	0.03	ns	0.26	0.84	0.98	0.30	0.44	0.36	0.22	0.36	1.40	0.52
Mar.	63	0.01	0.00	0.06	0.06	ns	0.30	0.22	0.12	0.10	0.32	0.10	0.13
May	63	0.00	0.00	0.16	0.06	0.22	0.16	0.96	0.72	0.80	ns	ns	0.34
July	63	0.63	0.13	0.18	0.56	0.40	0.58	0.36	0.96	0.54	T	ns	0.43
Sept.	63	0.02	0.23	1.98	1.48	0.02	0.02	0.11	0.46	0.52	0.90	0.62	0.58
Apr.	64	T	0.00	0.24	0.26	0.04	T	0.18	0.20	ns	ns	0.20	0.12
x̄		0.10	0.07	0.43	0.51	0.34	0.25	0.57	0.54	0.40	0.31	0.74	
s		0.22	0.09	0.64	0.47	0.32	0.19	0.58	0.31	0.24	0.29	0.56	

Table 19. Standing stocks of pelagic polychaetes (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
						Distance Offshore (Nautical Miles)							
Aug.	62	0.00	0.14	0.20	0.43	0.10	0.16	0.20	0.11	0.04	0.04	0.02	0.13
Oct.	62	0.00	ns	0.00	0.18	0.00	0.06	0.14	0.14	0.04	0.32	0.12	0.10
Mar.	63	0.00	0.00	0.16	0.42	ns	0.46	0.24	0.10	T	1.34	0.28	0.30
May	63	0.00	0.00	T	0.16	0.28	0.32	0.38	1.48	1.06	ns	ns	0.41
July	63	0.02	0.04	0.20	0.16	0.26	0.52	0.08	0.28	0.24	0.10	ns	0.19
Sept.	63	0.00	0.00	0.06	0.21	0.05	0.09	0.08	0.22	0.10	0.16	0.06	0.09
Apr.	64	T	0.00	0.08	0.28	0.06	0.20	0.00	0.30	ns	ns	0.06	0.11
x̄		T	0.04	0.10	0.26	0.13	0.26	0.16	0.38	0.25	0.39	0.11	
s			0.06	0.05	0.11	0.11	0.16	0.13	0.46	0.37	0.56	0.09	

Table 20. Standing stocks of cephalopods (dry weight in grams per 10 m^2).

Date		5	15	25	35	45	65	85	105	125	145	165	x̄
						Distance Offshore (Nautical Miles)							
June	62	ns	ns	T	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	T
Aug.	62	0.10	0.01	1.26	0.31	0.39	0.16	0.04	0.02	0.02	0.00	0.02	0.21
Oct.	62	0.00	0.00	0.08	0.28	0.62	0.24	0.32	0.16	0.18	0.70	0.36	0.27
Mar.	63	T	T	0.16	0.18	0.16	0.04	0.26	0.24	0.64	0.02	0.14	0.17
May	63	0.00	ns	0.10	0.02	0.06	0.10	0.56	0.32	T	ns	ns	0.15
July	63	T	0.02	0.16	T	T	0.00	0.00	0.00	T	0.02	ns	0.02
Sept.	63	0.00	0.02	0.46	0.30	0.00	0.02	T	0.04	T	0.00	0.08	0.08
Apr.	64	0.00	0.00	T	0.56	ns	0.00	ns	0.00	ns	ns	0.66	0.15
x̄		T	0.01	0.32	0.24	0.18	0.07	0.17	0.10	0.12	0.12	0.21	
s			0.01	0.40	0.18	0.22	0.08	0.20	0.12	0.22	0.26	0.23	

RELATIONSHIPS AMONG TROPHIC LEVELS

The relationships among the standing stocks of trophic levels I, II, and III were studied to determine if changes in the relative abundance of one trophic level were correlated with changes in the relative abundance of others.

Phosphate-Phosphorus and Trophic Level I

The relationship between the standing stock of trophic level I and phosphate-phosphorus was studied to determine if changes in standing stock of phytoplankton were related to changes in concentration of phosphate-phosphorus.

The standing stocks of trophic level I and phosphate-phosphorus were low and usually directly related offshore in the summer and fall, (Figures 18 A,B, G, and H). Offshore in the fall 1962, however, phosphate-phosphorus was high and trophic level I was low (Figure 18C). In the late winter and spring, standing stocks of trophic level I and phosphate-phosphorus were intermediate and directly related (Figures 18 E and F).

Inshore in the summer and spring, increases in the standing stock of trophic level I were correlated with increases in phosphate-phosphorus, except very near the coast, where trophic level I decreased and phosphate-phosphorus continued to increase (Figures 18 A, B, G, and F). High phosphate-phosphorus concentrations inshore
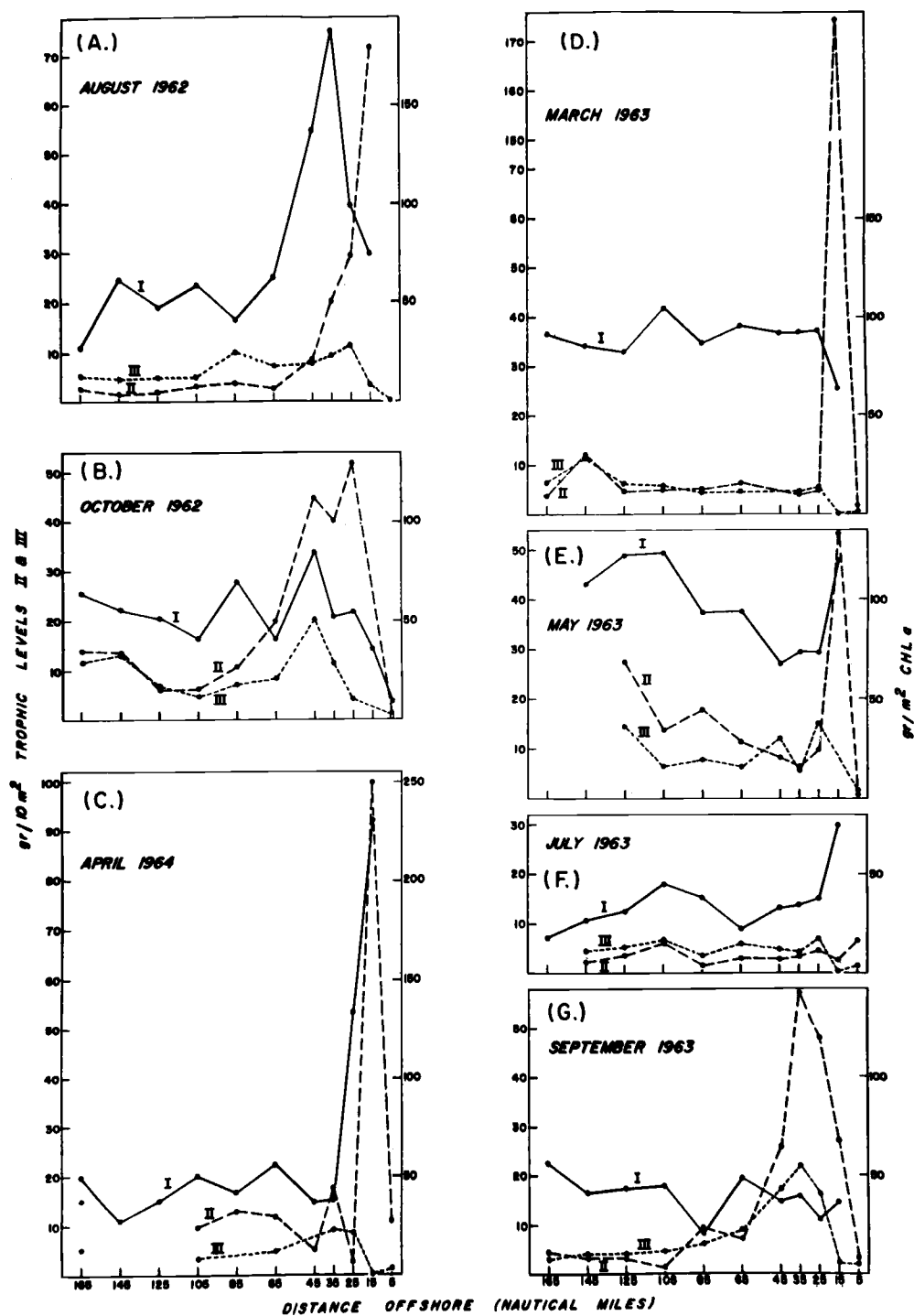
Figure 17. Spatial distributions of the standing stocks of trophic
levels I, II, and III observed off Brookings, Oregon.
Values for trophic level I based on 100-meter water
column, for trophic levels II and III for 200-meter
water column.
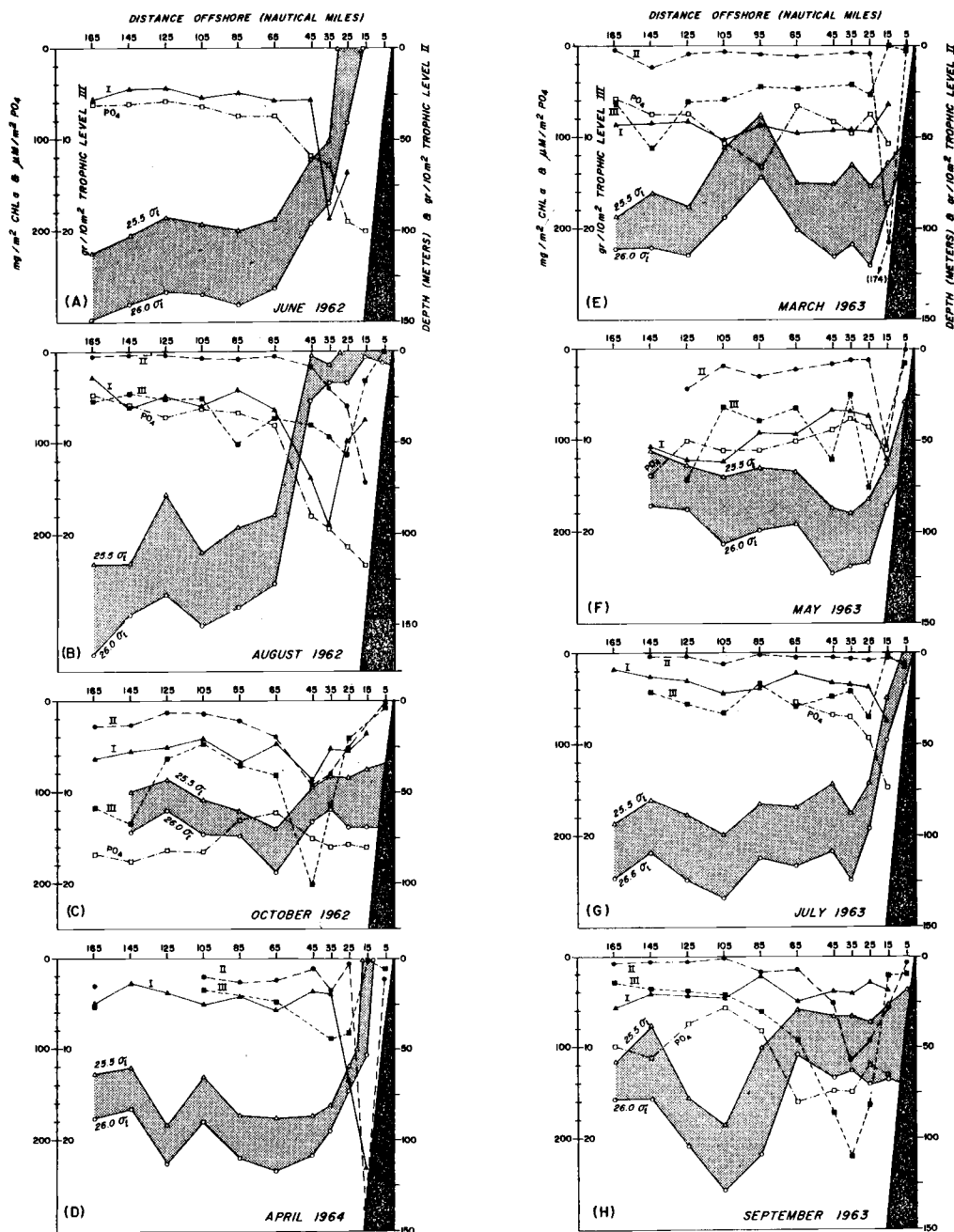
Figure 18. Spatial distributions of the oceanic frontal layer, concentration of phosphate-phosphorus, and standing stocks of trophic levels I, II, and III. Shaded area denotes frontal layer between 25.5 and 26.0 sigma-t values. Values for phosphate-phosphorus and trophic level I based on a 100-meter water column; values for trophic levels II and III based on a 200-meter water column.

in other seasons were not correlated with high standing stocks of trophic level I (Figure 18 C, E, and H).

Based on Ketchum (1939) a phosphate-phosphorus concentration of less than about 55 mg-atoms P/m^2 for a 100-meter water column, or about 0.55 mg-atoms P/m^3, would be limiting to phytoplankton growth. It is the rate of supply of nutrients, however, which determines how much organic matter can be formed by the phytoplankton (Ketchum, 1962). Nutrient data (Figures 7 A, B, and G; Figures 18 A, B, and G) suggest that the low standing stocks of trophic level I observed offshore in June and August 1962 and in July 1963 may have been due to reduced phytoplankton production as a result of nutrient deficiency. However, trophic level I minima observed very near the coast in June and August 1962 and in March 1963 were correlated with high phosphate-phosphorus concentrations (Figures 7 A, B, and E; Figures 18 A, B, and E). Hence these low phytoplankton standing stocks were probably due to causes other than nutrient deficiency.

The low standing stock of trophic level I observed both inshore and offshore in October 1962 may have been the result of reduced phytoplankton growth due to the seasonal reduction of solar radiation (Table 21).

These results corroborate those of Anderson (1964), who concluded that low concentrations of nutrient salts and low light

Table 21.   Mean solar radiation at $42°00'N$ lat., $124°13'W$ long. *

| | (Langleys Per Day) | | |
	1962	1963	1964
Jan.	140	170	90
Feb.	215	175	265
Mar.	330	340	345
Apr.	505	475	510
May	545	550	
June	650	595	
July	650	655	
Aug.	575	600	
Sept.	455	450	
Oct.	230	275	
Nov.	145	170	
Dec.	95	100	

* Taken from U.S. Weather Bureau Climatological Data.

intensities limit phytoplankton production in summer and winter,

respectively, off the Washington and Oregon coasts.

Relationships Between the Standing Stocks of Trophic Levels I and II

The standing stocks of trophic levels I and II were low and dir-

ectly related offshore (Figures 17 A, B, C, D, F, and G; and Figures

18 A, B, C, D, E, G, and H), except in May 1963, when trophic level I

was relatively high and trophic level II was low (Figures 17 E; and

Figure 18 F). Inshore in the spring, increases in trophic level II

were correlated with increases in trophic level I (Figures 17 C and

E; and Figures 18 D and F). Near the coast in other seasons, in-

creases in trophic level II were usually correlated with decreases

in trophic level I (Figures 17 A, B, D, and G; and Figures 18 B, C,

E, and G).

The inverse relationship between trophic levels I and II obser-

ved near the coast during most seasons suggests that the phytoplank-

ton was grazed down by the herbivores. For example, high standing

stocks of herbivores adjacent to the coast in August 1962 indicate

that intense grazing probably was taking place (Figures 17 A and 18

B). Grazing may also explain the decrease in trophic level I obser-

ved near the coast in June 1962 (Figure 18 A). Unfortunately meter

net samples were not taken in June 1962 so there is no estimate of

the relative abundance of trophic level II, however, large

concentrations of euphausiids, taken in inshore IKMT collections,
indicate that the standing stock of trophic level II was high adjacent
to the coast.

Translocation losses of phytoplankton exceeding the growth
rate may also explain the trophic level I minimum sometimes obser-
ved near the coast (Figure 13; Figures 18 A and B). If the response
of phytoplankton to nutrient replenishment by upwelling was slow
relative to the rate at which the upwelled water was advected off-
shore, the highest phytoplankton growth would be expected to have
taken place at some distance off the coast. Strong vertical turbu-
lence near the coast might also have been important in reducing
phytoplankton production by mixing the phytoplankton out of the
photic zone.

As a result of upwelling, the frontal layer intersected the sur-
face forming a surface front between the upwelled water inshore and
the non-upwelled water offshore (Figures 18 A, B, D, and G). The
highest standing stocks of trophic level I were found at the inshore
side of the surface front. This may have been the result of a con-
centration of phytoplankton caused by convergence at the front or it
may have been the result of increased phytoplankton production.

Relationships Between Trophic Levels II and III

The standing stocks of both trophic levels II and III were usually higher inshore than offshore. Inshore, the standing stocks of trophic level II were higher than those of trophic level III (Figure 17 A, B, D, D, E, and G). Offshore, the standing stocks of trophic level II were lower than those of trophic level III (Figure 17 A, B, D, F, and G), except in the spring when biomasses of trophic level II were slightly higher than those of trophic level III (Figure 18 C and E).

The peak in relative abundance of trophic level III was usually found seawards of the peak in relative abundance of trophic level II. Grazing of trophic level II by trophic level III could explain why the peaks in relative of abundance of the two trophic levels did not coincide. The spatial separation between the peaks in relative abundance of trophic levels II and III may have been also depended on the greater time interval required for the populations which comprise trophic level III to develop in the upwelled water. Since the upwelled water is advected offshore, the relative abundance of trophic level III would be expected to be highest seawards of where trophic level II is highest.

Sette (1955) and King (1958) postulated that trophic level succession also explains the downstream displacements of the maxima

of successively higher trophic levels in the equatorial Pacific.
Since many of the animals sampled off Oregon have relatively long
life spans and generation times, lateral movements or immigration
may be important in explaining the high inshore catches during cer-
tain seasons.

During some of the cruises the highest standing stocks of tro-
phic level II were taken at the 15-mile station and the highest
standing stocks of trophic level III were taken further offshore. The
abundance of the populations which comprise trophic level III may
have been restricted at the 15-mile station by the shallowness of the
water-depth, about 130 meters. This may have been especially true
in the case of vertically migrating animals such as the mesopelagic
fishes.

RELATIONSHIPS BETWEEN TROPHIC LEVELS
AND THE OCEANIC FRONTAL LAYER

Major changes in the inshore portion of the oceanic frontal layer were related to coastal upwelling. Upwelling caused the inshore portion of the frontal layer to slope upward, intersect the surface, and form a surface front between the light offshore water and the heavier upwelled water. During non-upwelling periods the inshore portion of the frontal layer was relatively horizontal and was found at about 25 to 75 meters depth.

The frontal layer shape inshore was found to be an important feature in the spatial and temporal distributions of phosphate-phosphorus and lower trophic level biota. During periods of upwelling abrupt changes in concentration of phosphate-phosphorus and in relative abundance of the standing stocks of phytoplankton, herbivores, and usually primary carnivores were apparent across the front; the values were considerably higher inshore than they were offshore (Figure 18 A, B, D, and G).

During periods of non-upwelling, when there was no surface front present, there were relatively few differences between the inshore and offshore standing stocks of trophic level I and phosphate-phosphorus (Figure 18 C, E, F, and H). After upwelling had subsided the relative abundances of trophic levels II and III were

highest at about the location where the frontal layer intersected the surface during upwelling (Figure 18 C and H). A plot of the number of fishes collected and the heat content at each station indicates that the fishes remained in the cooler upwelled water even after the surface front had disappeared (Figure 19, October 1962 and September 1963).

The high standing stocks of lower trophic level biota observed at and just inshore of the surface front raises the question of whether high standing stocks of marine organisms are caused by concentration of biota or by creating conditions favorable to the production of a high standing stock. Where upwelled water breaks the surface there is a divergent surface front (Uda, 1959). At the interface between two water masses of different density there is a convergent front (Cromwell and Reid, 1956). A convergent front is believed to mechanically aggregate plankton (Beebe, 1926; Uda, 1938, 1959; Cromwell and Reid, 1956; and Uda and Ishio, 1958). A divergent front, where nutrient-rich water might be brought to the surface, may increase plankton growth (Uda, 1959).

The surface front referred to in this study is a convergent front between upwelled water inshore and non-upwelled water offshore. Curl (personal communication) believes that the high standing stock of phytoplankton observed at the inshore side of the surface front during upwelling off Oregon probably results from the
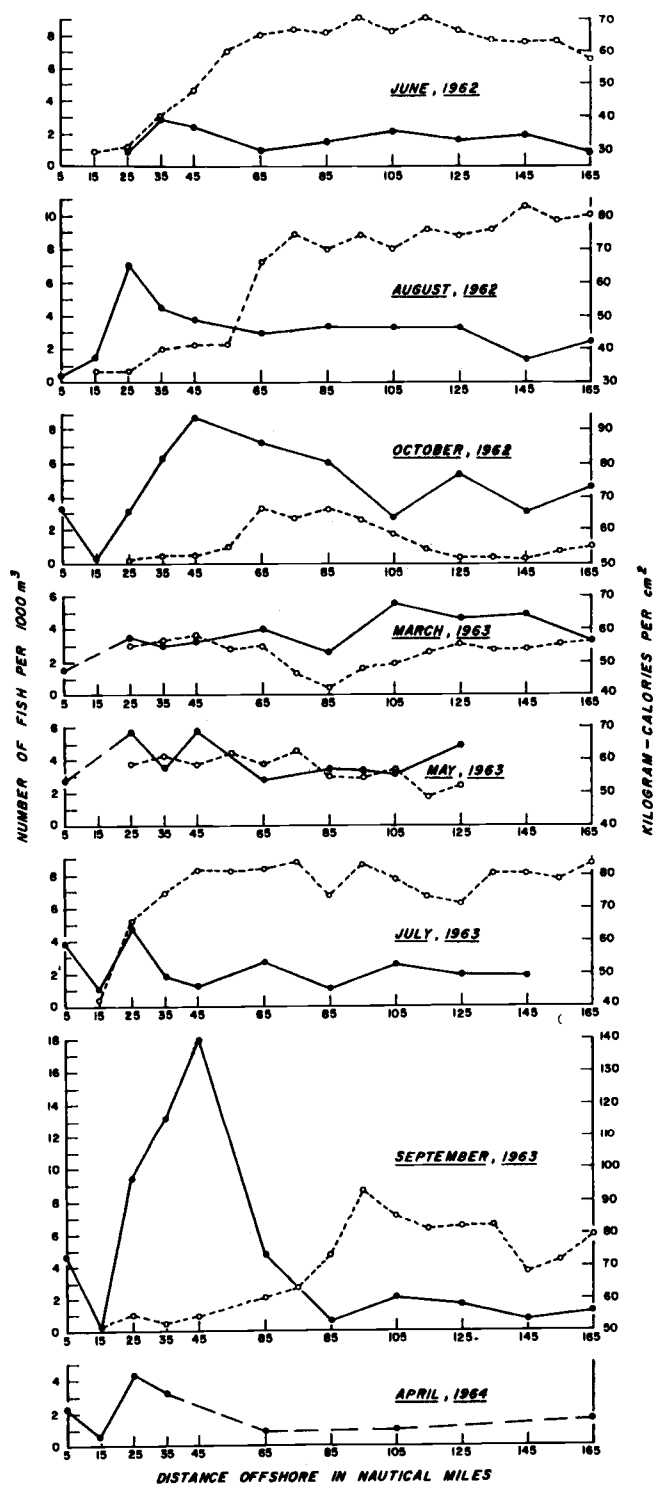
Figure 19. Number of fish per 1000 m^3 and heat content (kilogram-calories per cm^2 for the upper 100-meters) observed off Brookings, Oregon. Closed circles represent number of fishes and open circles denote heat content.

concentration of phytoplankton by the convergence. Feebly swim-

ming zooplankton may also be concentrated there by the convergent

surface flow. The nektonic animals, which can to a large degree

select their environment, may aggregate near the surface front be-

cause of the abundance of food.

In order to determine why the high standing stocks of marine

organisms are found at the surface front, it will be necessary to

know the production rates of the organisms involved.

SUMMARY

In general, winds were predominantly northerly during summer months and southerly during winter months. The total northerly "wind mileage" was greater in the summer of 1962 than in the summer of 1963. Northerly winds were also predominant from February 1964 through April 1964. The total southerly "wind mileage" was about the same in the winter of 1962-63 as it was in the winter of 1963-64. The easterly and westerly "wind mileages" totaled less than two percent of the total "wind mileage" from all directions.

Differences in inshore and offshore hydrographic conditions at ten meters depth were greatest during periods of active upwelling. During periods of northerly winds the temperature and dissolved oxygen were lower and the salinity and phosphate-phosphorus were higher at 5 than at 85 nautical miles offshore.

Changes in the distribution of mass associated with upwelling were reflected in the vertical distribution of hydrographic properties. Inshore, the isopleths in the upper 250 meters sloped upward toward the coast during active upwelling, but isopleths were comparatively level when upwelling was not taking place. The effect of coastal upwelling was to decrease surface temperature and dissolved oxygen and to increase surface salinity and phosphate-phosphorus content.

Major changes in frontal layer shape were correlated with

upwelling.   Upwelling caused the inshore portion of the frontal layer to slope upward, intersect the surface, and form a surface front. During periods of non-upwelling the frontal layer was relatively horizontal and found below the surface.

Distributions of hydrographic properties and the oceanic frontal layer suggest that upwelling was more intense during the summer of 1962 than it was during the summer of 1963.

Computations of zonal transport indicated that the net surface flow during summer months was offshore and during other months was onshore.   Returns from drift bottles indicated a northward surface flow in the summer, and varying surface currents from both the north and south in the spring and early fall.

A special cruise was made to learn where along the coast the upwelled water found off Brookings comes to the surface and its mean rate and direction of flow.   The results indicated that (1) upwelling was not taking place all along the coast, (2) upwelled water may come to the surface at some distance offshore, (3) the circulation pattern was too complicated to enable estimation of a mean "age" for the upwelled water found at various distances off Brookings, and (4) there were good correlations between the standing stock of phytoplankton and environmental features.

Trophic levels I, II, and III were considered in this study. Chlorophyll "a" concentration was used as a relative measure of the

standing stock of trophic level I. Dry weights were used to estimate the biomass of trophic levels II and III.

Euphausiids, copepods, salps, thecosomatous pteropods, crab zoea and pyrosomes were included in trophic level II. Euphausiids comprised 72.0 percent of the total biomass of trophic level II. About 16 species of euphausiids were identified; Euphausia pacifica was most abundant. The relative abundance of euphausiids was lowest in the midsummer, intermediate in the spring and late summer (and fall of 1963), and highest in the late winter (and fall of 1962). The size and seasonal variation of catches were substantially greater inshore than they were offshore.

Copepods constituted 14.3 percent of the total biomass of trophic level II. Over 60 species of adult and about 25 genera of copepodite copepods were identified. However, since only copepods larger than about three millimeters were included in biomass determinations, not all of these were represented in the estimates of copepod biomass. The relative abundance of copepods was lowest in the late winter, intermediate in the summer (and fall of 1963), and highest in spring (and fall of 1962). The highest mean catches and greatest seasonal variation were observed at intermediate distances offshore.

Salps formed 13.1 percent of the total biomass of trophic level II. Four species were identified; Salpa fusiformis was most abundant.

The relative abundance of salps was lowest in the summer and winter (and fall of 1962) and highest in the spring (and fall of 1963). In general, catches and seasonal variations were higher inshore than offshore.

Fishes, chaetognaths, medusae, siphonophores, ctenophores, amphipods, polychaetes, cephalopods, gymnosomatus pteropods, and heteropods were included in trophic level III.

Fishes formed 47.1 percent of the total biomass of trophic level III. Over 40 species of pelagic fishes were identified; five species of myctophids and one species of melanostomiatid were most abundant. The relative abundance of fishes was lowest in the summer, intermediate in the spring, and highest in the fall. The size and seasonal variation of catches was greater inshore than offshore.

A change in the species composition of fishes was evident in July 1963 in the offshore region. The Subarctic--Transitional species, whose numbers were intermediate inshore, were nearly absent offshore. The Subarctic--Transitional forms were replaced offshore by small numbers of fishes apparently of southern and/or western waters.

Size-frequency analyses for L. leucopsarus, L. ritteri, and D. theta indicated (1) that the breeding of these species is mainly seasonal, (2) that the increase in relative abundance of fishes during the fall is due to recruitment of small individuals into the population

and migration of larger individuals from without.

Chaetognaths formed 15.7 percent of the total biomass of trophic level III. Standing stocks were minimal in the spring, intermediate in the summer and late winter, and maximal in the fall. In general standing stocks were higher at intermediate distances offshore in the fall and far offshore in other seasons.

The biomass of the medusae, siphonophores, and ctenophores, which were measured collectively, formed 14.6 percent of the total biomass of trophic level III. The relative abundance of these groups was lowest in the summer and late winter, intermediate in the fall, and highest in the spring. The greatest seasonal variation in catches of these groups occurred offshore.

Amphipods constituted 6.2 percent of the total biomass of trophic level III. About 16 species of pelagic amphipids were identified; Parathemisto pacifica was most abundant. The relative abundance of amphipods was lowest in the late winter and spring, intermediate in summer, and highest in the fall.

Eleven percent of the total biomass of trophic level III was formed by shrimps. Seven species of shrimps were identified; Sergestes similis and Pandalus jordani were most abundant. The relative abundance of shrimps was lowest in the summer and late winter, intermediate in the fall, and highest in the spring. The size and seasonal variation of catches were larger inshore than offshore.

Tomopteris spp. formed 3.3 percent of the total biomass of trophic level III. Catches were larger offshore than inshore in the late winter and spring, whereas in other seasons largest catches were taken inshore.

Cephalopods constituted 2.4 percent of the total biomass of trophic level III. Catches were lowest in the summer, intermediate in the late winter and spring, and highest in the fall. There was relatively little difference between inshore and offshore catches.

The standing stocks of trophic level I and phosphate-phorphorus observed offshore were low to intermediate and usually directly related. Inshore in the summer and spring, increases in the standing stock of trophic level I were correlated with increases in phosphate-phosphorus, except very near the coast in the summer, where trophic level I decreased and phosphate-phosphorus continued to increase. High phosphate-phosphorus concentrations inshore in other seasons were not correlated with high standing stocks of trophic level I.

The standing stocks of trophic levels I and II were usually low and directly related offshore. Near the coast increases in trophic level II were usually correlated with decreases in trophic level I, except in the spring. Grazing of trophic level I by trophic level II may explain this inverse relationship between the two trophic levels observed near the coast. Translocation losses of phytoplankton exceeding the growth rate may also be important.

The standing stocks of both trophic levels II and III were usually higher inshore than offshore. Inshore the standing stocks of trophic level II were higher than those of trophic level III, whereas offshore the opposite was true, except in the spring. The peak in relative abundance of trophic level III was usually found seawards of the peak in relative abundance of trophic level II. Grazing, trophic level succession, immigration, and shallowness of water-depth near the coast may have been important factors contributing to the spatial separation between the peaks in relative abundance of trophic levels II and III.

The standing stocks of the phytoplankton, herbivores, and primary carnivores were considerably higher inshore than they were offshore. The seasonal fluctuations were larger and inverse relationships between trophic levels were sometimes observed inshore. Conversely the seasonal amplitudes in standing stocks were small offshore, and increases or decreases in trophic levels were usually positively correlated. Smaller amplitudes in standing stocks of the phytoplankton, herbivores, and carnivores observed offshore implies that, relative to the food-chain inshore, the food-chain offshore tends to be more "balanced."

The shape of the oceanic frontal layer inshore was found to be an important feature in the spatial and temporal distributions of phosphate-phosphorus and lower trophic level biota. During periods of upwelling abrupt changes in concentration of phosphate-phosphorus

and in relative abundance of the standing stocks of phytoplankton, herbivores, and usually primary carnivores were apparent across the front; the values were considerably higher inshore than they were offshore.

During periods of non-upwelling, when there was no surface front present, there was relatively little difference between the inshore and offshore standing stocks of phytoplankton and phosphate-phosphorus. After upwelling had subsided the relative abundance of herbivores and primary carnivores were highest at about the location where the frontal layer intersected the surface during upwelling.

The high standing stocks of lower trophic level biota observed at and just inshore of the surface front may have been due to mechanical concentration of the biota or due to conditions favorable for the production of high standing stocks. A knowledge of the production rates of the populations of animals involved will be necessary to determine why high standing stocks of marine organisms are found at the surface front.

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APPENDICES

Appendix I. Euphausiids collected off Brookings, Oregon between August 1962 - April 1964.

LARVAE
 Calyopsis
 Furcilia

ADULTS
 Euphausia pacifica
 E. gibboides

 Thysanoessa spinifera
 T. longipes
 T. inspinata
 T. gregaria

 Tessarabrachion oculatus

 Nematoscelis difficilis

 Nematobrachion flexipes

 Stylocheiron abbreviatum
 S. maximum
 S. elongatum
 S. longicorne

Appendix II. Copepods taken off Brookings, Oregon between August
    1962 - April 1964.

COPEPODITES

Calanus
Eucalanus
Rhincalanus
Pseudocalanus
Clausocalanus
Aetideus
Gaidius
Gaetanus
Euchirella
Chirundina
Pareuchaeta
Scottocalanus

Lophothrix
Scaphocalanus
Racovitzanus
Scolecithricella
Metridia
Pleuromamma
Heterorhabdus
Heterostylites
Candacia
Epilabidocera
Microsetella
Oithona

ADULTS

Calanus finmarchicus
C. pacificus
C. glacialis
C. plumchrus
C. cristatus
C. lenvicornis

Eucalanus bungii
E. elongatus hyalinus

Rhincalanus nasutus

Paracalanus parvus

Pseudocalanus minutus

Microcalanus pusillus

Clausocalanus arcuicornis

Aetideus armatus

Gaidius brevispinus
G. variabilis
G. pungens

Gaetanus simplex

Euchirella rostrata
E. pulchra
E. galeata
E. curticauda
E. sp.

Chirundina streetsi

Undeuchaeta plumosa
U. major

Pareuchaeta japonica
P. abyssalis
P. sp.

Pseudochirella polyspina

Appendix II. (cont'd.)

Scottocalanus persecans
S. sp.

Lophothrix frontalis

Scaphocalanus brevicornis

Amallothrix valida
A. vorax

Scolecithricella minor
S. ovata

Metridia lucens
M. pacifica

Pleuromamma abdominalis
P. xiphias
P. borealis
P. quadrungulata
P. scutullata
P. sp.

Tortanus discaudatus

Gaussia princeps

Lucicutia flavicornis

Heterostylites longicornis
H. major

Arietallus setosus

Microsetella sp.

Harpacticoid

Candacia columbiae
C. bipinnata

Epilabidocera amphitrites

Acartia longiremis
A. danae
A. tonsa

Oithona similis
O. spinirostris

Appendix III.   Salps collected off Brookings, Oregon between June
           1962 - April 1964.

Salpidae

>   Salpa fusiformis

>   Iasis zonaria

>   Pegea confoederata

>   Thetys vagina

Appendix IV. Fishes collected off Brookings, Oregon between June
              1962 - April 1964.

Engraulidae
    Engraulis mordax

Osmeridae
    Thaleichthys pacificus

Bathylagidae
    Bathylagus ochotensis
    B. pacificus
    B. milleri
    B. sp.

Argentinidae
    Nansenia sp.

Gonostomatidae
    Cyclothone signata
    C. microdon
    C. spp.

Sternoptychidae
    Argyropelecus lynchus
    A. aculaetus

Melanostomiatidae
    Bathophilus fleminigi
    Tactostoma macropus
    Opostomias sp.

Malacosteidae
    Aristostomias scintillans

Chauliodontidae
    Chauliodus macouni

Idiacanthidae
    Idiacanthus antrostomus

Myctophidae
    Hierops crockeri
    H. thompsoni
    Symbolophorus californiense
    Tarletonbeania crenularis
    Diaphus theta
    Lampanyctus leucopsarus
    L. ritteri
    L. regalis
    Ceratoscopelus townsendi
    Lampadena urophaos

Paralepidae
    Lestidium ringens

Scomberesocidae
    Cololabis saira

Apodes
    Unidentified Leptocephalus
    Cyema atrum

Nemichthyidae
    Nemichthys scolopaceus

Merlucciidae
    Merluccius productus

Trachypteridae
    Trachypterus rexsalmonorum

Melamphaidae
    Poromitra crassiceps
    Melamphaes lugubris

Pleuronectidae (larval)
    Microstomus pacificus
    Glyptocephalus zachirus
    several spp.

Appendix IV.   (cont'd.)

Scorpaenidae (larval)
    Sebastolobus altivelis
    several spp.

Agonidae
    1 sp.

Liparidae
    Nectoliparis pelagicus

Gasterosteidae
    Gasterosteus aculeatus

Stichaeidae
    Lumpenus sagitta

Appendix V. Shrimps collected off Brookings, Oregon between
June 1962 - April 1964.

Sergestes similis

Bentheogennema borealis

B. sp.

Gennadas propinquis

Pasiphaea pacifica

P. chacei

Pandalus jordani

Appendix VI. Amphipods collected off Brookings, Oregon between August 1962 - April 1964.

Phronimidae
    Phronima sedentaria

Hyperiidae
    Parathemisto pacifica
    Hyperoche medusarum
    Hyperia hystrix

Phrosinidae
    Primno macropa
    P. abyssalis

Lycaeidae

Paraphronimidae
    Paraphronima gracilis
    P. crassipes

Vibiliidae
    Vibilia armata
    V. propinqua

Cystisomidae

Gammarides

Lanceolidae

Oxycephalidae
    Oxycephalus clausi
    Streetsia challengeri

Tryphanidae
    Tryphana malmi

Appendix VII. Cephalopods collected off Brookings, Oregon between
June 1962 - April 1964.

Onychoteuthidae
   Onychoteuthis banksi

Enoploteuthiade
   Abraliopsis sp.

Veranyidae
   Octopoteuthis sicula

Histioteuthidae

Gonatidae
   Gonatus fabricii
   G. borealis
   G. sp.

Chiroteuthidae
   Chiroteuthis veranyi
   C. doratopsis

Cranchiidae

Octopodidae

Bolitaenidae
   Japetella sp.

Appendix VIII.   Hydrographic data collected on MODOC
cruise between 16-20 August 1963.

	OBSERVED				INTERPOLATED					DERIVED		
D	T°C	S‰	O₂ ml/l	PO₄≡	Z	T	S	O₂	PO₄≡	σ₁	∫x10⁸	Δ D

A-1   42 49.8 N   124 39.6 W   DATE 16 AUG 63 2315 GCT   WIRE -   DRY 55.0   WET 53.0
WIND DIRECTION 01 VEL 10 KTS   BAR 18 SWELL DIRECTION 30 H   2 T - CLOUD 4 AMT   8 WEATHER 2

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σ₁	∫x10⁸	Δ D
0	9.77	33.682	5.82	1.46	0	9.77	33.69	5.82	1.46	25.99	203.3	0
9	9.68	33.680	5.93	1.45	10	9.59	33.68	5.77	1.48	26.02	200.9	.020
24	8.47	33.727	3.52	1.88	20	8.78	33.70	4.17	1.65	26.16	187.3	.040
28	8.43	33.778	3.40	2.31	30	10.40	33.54	0	0	25.77	224.9	.060

A-2   42 49.6 N   124 48.0 W   DATE 17 AUG 63 0105 GCT   WIRE 15   DRY 55.0   WET 53.5
WIND DIRECTION 13 VEL 10 KTS   BAR 18 SWELL DIRECTION 30 H   2 T - CLOUD 4 AMT   8 WEATHER 2

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σ₁	∫x10⁸	Δ D
0	10.15	33.345	6.96	.98	0	10.15	33.35	6.96	.99	25.66	234.3	0
10	10.34	33.530	6.35	.93	10	10.34	33.54	6.35	.93	25.78	223.9	.023
24	9.60	33.669	5.04	1.58	20	9.87	33.64	5.41	1.36	25.94	208.7	.045
48	8.61	33.810	4.24	2.32	30	9.30	33.71	4.75	1.83	26.09	194.5	.065
72	8.35	33.893	3.48	2.19	50	8.57	33.82	4.17	2.31	26.29	176.0	.102
96	8.13	33.938	2.94	1.97	75	8.32	33.90	3.40	2.16	26.39	166.6	.145
145	7.94	33.996	2.38	2.13	100	8.11	33.95	2.87	1.98	26.46	160.6	.185
169	7.81	33.992	2.31	2.42	150	7.91	34.00	2.35	2.18	26.52	154.9	.264

A-3   42 50.1 N   125 .8 W   DATE 17 AUG 63 0320 GCT   WIRE 30   DRY 57.5   WET 55.0
WIND DIRECTION 35 VEL 11 KTS   BAR 18 SWELL DIRECTION 30 H   2 T - CLOUD 4 AMT   8 WEATHER 2

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σ₁	∫x10⁸	Δ D
0	10.85	33.372	0	.84	0	10.85	33.38	0	.85	25.56	243.8	0
4	10.66	33.361	8.27	.68	10	10.67	33.42	7.84	.70	25.63	237.5	.024
31	10.73	33.710	6.27	1.32	20	10.69	33.55	7.09	.88	25.72	228.9	.047
56	8.86	33.694	4.40	0	30	10.73	33.69	6.34	1.27	25.83	218.8	.070
74	8.75	33.767	4.22	2.12	50	9.30	33.71	4.76	1.73	26.08	195.3	.111
95	8.67	33.860	3.73	2.25	75	8.75	33.77	4.20	2.13	26.22	182.4	.158
143	8.00	33.900	3.12	1.98	100	8.61	33.87	3.65	2.23	26.32	173.6	.203
234	7.77	34.094	1.93	2.26	150	7.93	33.91	3.03	2.00	26.45	161.6	.287
					200	7.86	34.00	2.38	2.03	26.54	154.3	.366

A-4   42 47.8 N   125 16.1 W   DATE 17 AUG 63 0550 GCT   WIRE 35   DRY 61.0   WET 57.9
WIND DIRECTION 35 VEL 11 KTS   BAR 19 SWELL DIRECTION 30 H   3 T - CLOUD 4 AMT   7 WEATHER 1

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σ₁	∫x10⁸	Δ D
0	15.24	32.232	5.99	0	0	15.24	32.24	5.99	0	23.82	410.1	0
9	15.22	32.229	6.05	.37	10	15.14	32.25	6.05	.13	23.85	407.2	.041
23	13.55	32.587	6.01	.58	20	14.00	32.50	6.04	.48	24.28	366.4	.080
45	10.31	32.851	5.23	1.34	30	12.47	32.69	5.80	.82	24.73	323.4	.114
87	8.87	33.403	4.21	1.60	50	9.95	32.92	5.09	1.41	25.37	263.4	.173
132	8.34	33.633	3.35	1.87	75	8.92	33.26	4.46	1.53	25.80	223.0	.233
177	7.87	33.881	3.03	2.31	100	8.66	33.49	3.92	1.67	26.01	202.6	.287
222	7.55	34.001	2.36	2.08	150	8.14	33.74	3.21	2.08	26.29	177.2	.382
					200	7.69	33.96	2.73	2.28	26.53	155.2	.465

A-5   42 48.5 N   125 27.5 W   DATE 17 AUG 63 0835 GCT   WIRE 15   DRY 62.0   WET 58.3
WIND DIRECTION 35 VEL 10 KTS   BAR 19 SWELL DIRECTION 30 H   3 T - CLOUD 4 AMT   7 WEATHER 1

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σ₁	∫x10⁸	Δ D
0	16.24	32.037	5.86	.36	0	16.24	32.04	5.86	.36	23.45	445.5	0
10	16.11	32.231	5.58	.36	10	16.11	32.24	5.58	.36	23.63	428.8	.044
26	15.23	32.608	5.80	.44	20	15.56	32.45	5.67	.41	23.91	401.5	.085
30	12.08	32.732	5.85	.87	30	12.08	32.74	5.85	.88	24.84	313.0	.121
101	9.30	33.380	4.93	1.78	50	11.30	33.08	5.73	1.13	25.25	274.3	.180
154	8.88	33.660	4.62	1.93	75	10.32	33.33	5.43	1.45	25.62	239.7	.244
208	8.68	33.756	4.11	2.23	100	9.34	33.37	4.95	1.77	25.82	221.6	.302
261	7.86	33.930	2.83	2.12	150	8.88	33.65	4.64	1.92	26.10	195.1	.406
					200	8.72	33.75	4.22	2.19	26.21	186.2	.501
					250	8.08	33.89	3.16	2.18	26.41	167.0	.589

	OBSERVED				INTERPOLATED					DERIVED		
D	T °C	S‰	O₂ ml/l	PO₄≡	z	T	S	O₂	PO₄≡	σₜ	δ x10⁶	Δ D

B-2   42 39.6 N   124 33.3 W   DATE 17 AUG 63 2347 GCT   WIRE 15   DRY 51.8   WET 51.3
WIND DIRECTION 28 VEL 13 KTS   BAR 19 SWELL DIRECTION 28 H 3 T - CLOUD 7 AMT 3 WEATHER 5

D	T°C	S‰	O₂	PO₄	z	T	S	O₂	PO₄	σₜ	δx10⁶	ΔD
0	9.52	33.863	4.55	2.18	0	9.52	33.87	4.55	2.18	26.17	186.0	0
10	9.48	33.865	4.45	2.13	10	9.48	33.87	4.45	2.14	26.18	185.4	.019
24	8.98	33.879	3.88	2.02	20	9.15	33.87	4.08	2.05	26.24	180.1	.037
48	8.17	33.950	2.56	2.14	30	8.75	33.90	3.54	2.05	26.32	172.5	.054
72	7.98	33.974	1.95	1.80	50	8.13	33.95	2.48	2.13	26.46	159.5	.088

B-3   42 39.7 N   124 46.0 W   DATE 17 AUG 63 2103 GCT   WIRE 5   DRY 53.0   WET 52.0
WIND DIRECTION 28 VEL 11 KTS   BAR - SWELL DIRECTION 28 H 3 T - CLOUD - AMT - WEATHER 1

D	T°C	S‰	O₂	PO₄	z	T	S	O₂	PO₄	σₜ	δx10⁶	ΔD
0	10.20	33.781	4.95	1.15	0	10.20	33.79	4.95	1.15	26.00	202.9	0
10	10.30	33.783	6.09	1.11	10	10.30	33.79	6.09	1.11	25.98	204.5	.020
27	10.05	33.821	5.24	1.37	20	10.22	33.81	5.80	1.24	26.01	201.8	.041
52	8.77	33.729	4.17	1.62	30	9.91	33.81	5.09	1.41	26.07	196.7	.061
103	8.28	33.880	1.83	1.83	50	8.88	33.74	4.24	1.60	26.18	186.6	.099
157	7.76	34.003	2.30	1.98	75	8.37	33.77	3.91	1.74	26.28	177.0	.144
212	7.61	34.055	2.20	2.18	100	8.31	33.87	3.78	1.82	26.36	169.5	.188
266	7.55	34.039	2.11	2.49	150	7.82	33.99	2.48	1.96	26.53	153.9	.268
					200	7.62	34.05	2.22	2.13	26.61	147.5	.344
					250	7.56	34.05	2.14	2.39	26.62	147.4	.417

B-4   42 39.7 N   124 58.5 W   DATE 17 AUG 63 1813 GCT   WIRE 10   DRY 57.8   WET 54.2
WIND DIRECTION 01 VEL 8 KTS   BAR 20 SWELL DIRECTION 28 H 2 T - CLOUD - AMT - WEATHER 1

D	T°C	S‰	O₂	PO₄	z	T	S	O₂	PO₄	σₜ	δx10⁶	ΔD
0	10.73	33.735	5.83	1.22	0	10.73	33.74	5.83	1.23	25.87	215.0	0
11	10.56	33.737	6.55	1.29	10	10.62	33.74	6.54	1.26	25.89	213.3	.021
27	9.63	33.703	5.30	1.77	20	10.06	33.72	5.99	1.55	25.96	206.1	.042
52	9.00	33.823	4.01	2.00	30	9.52	33.71	5.11	1.82	26.05	197.9	.063
103	8.11	33.999	2.83	1.79	50	9.03	33.81	4.09	2.00	26.21	183.4	.101
157	7.72	33.992	2.70	2.18	75	8.53	33.89	3.29	1.93	26.34	170.8	.145
213	7.28	33.878	2.60	1.94	100	8.15	33.93	2.86	1.81	26.43	162.6	.187
264	7.29	34.077	1.78	2.32	150	7.76	33.98	2.72	2.13	26.54	153.7	.266
					200	7.36	33.89	2.66	1.99	26.52	155.5	.343
					250	7.29	33.99	2.07	2.16	26.61	147.8	.419

B-5   42 39.0 N   125 14.0 W   DATE 17 AUG 63 1457 GCT   WIRE 20   DRY 58.5   WET 56.5
WIND DIRECTION 01 VEL 3 KTS   BAR 20 SWELL DIRECTION 22 H 2 T - CLOUD 4 AMT 5 WEATHER 1

D	T°C	S‰	O₂	PO₄	z	T	S	O₂	PO₄	σₜ	δx10⁶	ΔD
0	13.33	32.163	6.76	.49	0	13.33	32.17	6.77	.49	24.16	377.3	0
10	12.88	32.246	6.61	.51	10	12.88	32.25	6.61	.51	24.32	362.9	.037
25	11.57	32.540	6.19	.68	20	12.05	32.43	6.34	.61	24.62	334.5	.072
50	9.50	32.935	5.63	1.15	30	11.11	32.62	6.07	.77	24.94	304.2	.104
99	8.60	33.651	4.80	1.87	50	9.50	32.94	5.64	1.15	25.45	255.2	.160
150	8.68	33.900	3.81	2.21	75	8.72	33.33	5.19	1.56	25.88	214.5	.218
202	8.02	33.940	2.94	0	100	8.60	33.66	4.78	1.88	26.16	189.0	.269
253	7.44	33.980	2.52	2.46	150	8.68	33.91	3.82	2.21	26.34	172.9	.359
					200	8.05	33.94	2.97	2.40	26.46	161.9	.443
					250	7.47	33.98	2.53	2.45	26.57	151.6	.521

B-6   42 39.0 N   125 27.0 W   DATE 17 AUG 63 1118 GCT   WIRE 20   DRY 61.0   WET 56.9
WIND DIRECTION 35 VEL 9 KTS   BAR 19 SWELL DIRECTION 30 H 3 T - CLOUD 4 AMT 8 WEATHER 1

D	T°C	S‰	O₂	PO₄	z	T	S	O₂	PO₄	σₜ	δx10⁶	ΔD
0	14.65	32.190	6.26	.39	0	14.65	32.19	6.27	.39	23.91	401.1	0
10	14.39	32.252	6.19	.46	10	14.39	32.26	6.19	.46	24.01	391.6	.040
25	12.38	32.547	6.19	.74	20	13.14	32.44	6.19	.64	24.41	353.7	.077
50	9.74	32.660	5.74	.91	30	11.76	32.58	6.13	.78	24.78	318.6	.110
99	8.90	33.356	4.38	1.67	50	9.74	32.67	5.74	.92	25.20	279.3	.170
150	8.45	33.749	3.92	2.10	75	8.93	33.00	5.03	1.28	25.59	242.7	.236
202	8.44	33.883	3.64	2.05	100	8.89	33.37	4.37	1.68	25.88	215.0	.293
253	7.40	33.940	2.90	2.16	150	8.45	33.75	3.92	2.10	26.25	180.7	.392
					200	8.45	33.88	3.65	2.05	26.35	172.0	.480
					250	7.49	33.94	2.96	2.15	26.54	154.7	.561

	OBSERVED				INTERPOLATED					DERIVED		
D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D

C-1 42 29.9 N 124 32.2 W DATE 18 AUG 63 0155 GCT WIRE 12 DRY 52.0 WET 51.8
WIND DIRECTION 28 VEL 10 KTS BAR 19 SWELL DIRECTION 30 H 3 T – CLOUD – AMT 0 WEATHER 4

D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D
0	9.62	33.853	4.85	0	0	9.63	33.86	4.85	0	26.15	188.3	0
10	9.38	33.888	4.28	1.61	10	9.38	33.89	4.29	0	26.22	182.1	.019
24	8.73	33.912	3.24	2.13	20	8.92	33.91	3.53	0	26.30	174.2	.036
43	8.24	33.947	2.43	0	30	8.53	33.92	2.91	0	26.37	167.3	.053

C-2 42 29.6 N 124 46.2 W DATE 18 AUG 63 0419 GCT WIRE 15 DRY 52.8 WET 52.1
WIND DIRECTION 32 VEL 9 KTS BAR 19 SWELL DIRECTION 30 H 3 T – CLOUD – AMT 0 WEATHER 4

D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D
0	10.42	33.799	5.53	1.61	0	10.42	33.80	5.54	1.61	25.97	205.1	0
11	10.38	33.812	5.71	1.59	10	10.44	33.81	5.78	1.58	25.98	204.8	.020
26	9.48	33.772	4.62	1.70	20	9.89	33.79	5.14	1.64	26.05	198.0	.041
51	8.36	33.860	3.23	2.16	30	9.26	33.78	4.36	1.75	26.15	188.9	.060
101	8.14	33.943	2.40	0	50	8.39	33.85	3.27	2.13	26.34	170.7	.096
154	8.07	33.951	2.30	0	75	8.25	33.91	2.62	0	26.41	164.8	.138
208	8.03	34.004	2.23	0	100	8.14	33.94	2.40	0	26.45	161.4	.179
251	8.05	33.991	2.18	0	150	8.07	33.95	2.31	0	26.47	160.5	.259
					200	8.03	34.00	2.24	0	26.51	157.3	.338
					250	8.05	33.99	2.18	0	26.50	158.8	.417

C-3 42 29.9 N 125 .2 W DATE 18 AUG 63 0645 GCT WIRE 5 DRY 55.0 WET 54.0
WIND DIRECTION 29 VEL 3 KTS BAR 20 SWELL DIRECTION 30 H 3 T – CLOUD – AMT – WEATHER 0

D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D
0	12.40	33.149	7.91	0	0	12.40	33.15	7.92	0	25.11	287.5	0
10	10.60	33.545	6.45	0	10	10.60	33.55	6.45	0	25.74	227.1	.026
27	9.75	33.491	4.63	0	20	9.92	33.51	5.27	0	25.83	218.8	.048
52	8.80	33.679	3.83	0	30	9.62	33.51	4.46	0	25.88	214.7	.070
103	8.04	33.878	3.63	0	50	8.86	33.66	3.84	0	26.12	192.1	.110
157	7.41	33.945	2.86	0	75	8.35	33.79	3.65	0	26.30	175.1	.156
212	7.02	33.992	2.50	0	100	8.06	33.87	3.64	0	26.41	165.4	.199
266	6.63	34.020	2.18	0	150	7.48	33.94	2.96	0	26.54	152.8	.278
					200	7.09	33.98	2.56	0	26.63	145.2	.353
					250	6.75	34.01	2.27	0	26.70	139.0	.424

C-4 42 29.9 N 125 15.0 W DATE 18 AUG 63 1016 GCT WIRE 3 DRY 56.1 WET 55.3
WIND DIRECTION 32 VEL 1 KTS BAR 20 SWELL DIRECTION 32 H 1 T – CLOUD – AMT – WEATHER 0

D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D
0	10.96	33.061	7.07	0	0	10.96	33.07	7.07	0	25.30	268.7	0
11	10.61	33.219	6.50	0	10	10.66	33.19	6.58	0	25.45	254.6	.026
27	9.78	33.674	5.23	0	20	10.15	33.48	5.80	0	25.76	225.3	.050
53	8.88	33.802	3.82	0	30	9.65	33.71	5.03	0	26.03	200.2	.071
104	8.21	33.931	2.93	0	50	8.96	33.79	3.95	0	26.20	184.1	.110
159	7.59	33.999	2.68	0	75	8.50	33.87	3.24	0	26.34	171.3	.154
212	7.40	34.076	2.04	0	100	8.23	33.92	2.94	0	26.42	163.9	.196
268	7.08	34.104	1.61	0	150	7.67	33.99	2.71	0	26.56	151.9	.275
					200	7.43	34.06	2.19	0	26.64	144.1	.349
					250	7.20	34.10	1.72	0	26.71	138.6	.420

C-5 42 30.2 N 125 27.0 W DATE 18 AUG 63 1258 GCT WIRE 10 DRY 54.2 WET 53.8
WIND DIRECTION 20 VEL 1 KTS BAR 20 SWELL DIRECTION 29 H 1 T – CLOUD – AMT – WEATHER 1

D	T°C	S‰	O_2 ml/l	$PO_4^\equiv$	$\bar{z}$	T	S	O_2	$PO_4^\equiv$	σ_t	$\delta \times 10^6$	Δ D
0	11.99	32.984	7.75	0	0	11.99	32.99	7.76	0	25.06	292.2	0
11	11.28	33.149	6.45	0	10	11.31	33.14	6.56	0	25.30	269.5	.028
26	10.78	33.320	4.84	0	20	10.95	33.25	5.43	0	25.45	254.9	.054
51	9.92	33.653	3.90	0	30	10.64	33.38	4.60	0	25.60	240.9	.079
101	8.38	33.877	3.46	0	50	9.95	33.64	3.91	0	25.92	210.5	.124
154	7.65	33.943	2.65	0	75	9.11	33.81	3.59	0	26.19	185.4	.174
208	6.99	33.972	2.94	0	100	8.41	33.88	3.46	0	26.36	170.1	.218
261	6.58	34.013	1.71	0	150	7.69	33.94	2.70	0	26.52	155.7	.299
					200	7.08	33.97	2.91	0	26.62	146.0	.375
					250	6.65	34.00	2.09	0	26.71	138.4	.446

	OBSERVED				INTERPOLATED						DERIVED	
D	T°C	S‰	O₂ ml/l	PO₄≡	Z	T	S	O₂	PO₄≡	σₜ	$s \times 10^8$	Δ D

0-1   42 19.6 N   124 28.5 W   DATE 19 AUG 63 1653 GCT   WIRE 0   DRY 54.2   WET 52.8
WIND DIRECTION 34 VEL 6 KTS   BAR 22 SWELL DIRECTION 24 H   2 T - CLOUD 8 AMT   1 WEATHER 1

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	11.14	33.701	6.63	1.13	0	11.14	33.71	0	1.14	25.77	224.5	0
10	9.92	33.729	5.08	1.47	10	9.92	33.73	0	1.48	26.00	202.4	.021
25	8.86	33.830	0	1.73	20	9.13	33.80	0	1.66	26.18	185.6	.041
50	8.39	33.873	2.88	2.14	30	8.64	33.85	0	1.81	26.30	174.2	.059
					50	8.39	33.88	0	2.15	26.36	169.0	.093

0-2   42 20.1 N   124 32.8 W   DATE 19 AUG 63 1535 GCT   WIRE 0   DRY 52.5   WET 51.2
WIND DIRECTION 01 VEL 3 KTS   BAR 22 SWELL DIRECTION 24 H   2 T - CLOUD 8 AMT   1 WEATHER 1

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	9.91	33.772	5.05	1.91	0	9.91	33.78	5.05	1.92	26.04	198.9	0
12	9.51	33.828	4.34	1.66	10	9.52	33.83	4.34	1.66	26.14	189.1	.019
28	9.43	33.834	4.32	1.67	20	9.45	33.83	4.33	1.67	26.16	187.8	.038
54	8.95	33.824	3.22	1.91	30	9.40	33.83	4.26	1.68	26.16	187.3	.057
80	8.40	33.942	2.08	2.15	50	9.04	33.83	3.43	1.86	26.22	182.5	.094
					75	8.51	33.91	2.30	2.10	26.37	168.7	.138

0-3   42 19.9 N   124 45.5 W   DATE 19 AUG 63 1306 GCT   WIRE 10   DRY 52.7   WET 52.1
WIND DIRECTION 02 VEL 2 KTS   BAR 22 SWELL DIRECTION 24 H   2 T - CLOUD - AMT   - WEATHER 0

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	12.04	33.465	6.57	.70	0	12.04	33.47	6.57	.71	25.42	257.7	0
10	11.34	33.408	6.49	.87	10	11.34	33.50	6.49	.88	25.57	243.1	.025
25	9.93	33.665	4.68	1.43	20	10.40	33.61	5.34	1.23	25.82	219.6	.048
51	8.69	33.760	4.13	2.11	30	9.61	33.69	4.46	1.59	26.02	200.7	.069
101	8.26	33.906	2.26	2.18	50	8.72	33.76	4.15	2.09	26.22	182.6	.107
153	7.82	34.012	2.08	1.79	75	8.32	33.84	3.20	2.14	26.34	171.4	.152
206	7.44	34.008	1.75	2.27	100	8.27	33.90	2.29	2.18	26.40	166.0	.194
259	6.89	34.041	1.97	2.62	150	7.84	34.01	2.09	1.81	26.54	153.0	.274
					200	7.49	34.01	1.78	2.20	26.60	148.5	.349
					250	7.00	34.03	1.89	2.57	26.68	140.9	.421

0-4   42 19.9 N   124 58.2 W   DATE 19 AUG 63 0957 GCT   WIRE 3   DRY 56.1   WET 54.9
WIND DIRECTION 35 VEL 2 KTS   BAR 21 SWELL DIRECTION 24 H   2 T - CLOUD - AMT   - WEATHER 0

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	12.63	33.125	8.71	1.26	0	12.63	33.13	8.71	1.26	25.04	293.4	0
11	10.98	33.318	6.89	.70	10	11.08	33.31	7.00	.72	25.48	252.5	.027
26	9.53	33.389	5.28	1.23	20	10.00	33.37	5.81	.95	25.71	230.7	.051
52	9.15	33.678	4.74	1.34	30	9.38	33.43	5.11	1.28	25.85	216.7	.074
102	8.32	33.898	3.11	1.99	50	9.18	33.65	4.78	1.33	26.06	197.3	.115
157	7.99	34.008	2.47	2.36	75	8.74	33.81	3.98	1.62	26.26	179.3	.162
211	7.45	34.050	2.08	1.93	100	8.35	33.89	3.17	1.96	26.38	167.9	.206
265	7.27	34.102	1.61	1.96	150	8.02	34.00	2.51	2.35	26.51	156.1	.287
					200	7.55	34.04	2.15	2.03	26.61	147.0	.362
					250	7.28	34.09	1.75	1.95	26.69	140.9	.434

0-5   42 20.5 N   125 12.3 W   DATE 19 AUG 63 0705 GCT   WIRE 3   DRY 57.0   WET 55.8
WIND DIRECTION 27 VEL 3 KTS   BAR 22 SWELL DIRECTION 24 H   2 T - CLOUD - AMT   - WEATHER 0

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	12.56	33.116	8.42	.24	0	12.56	33.12	8.42	.25	25.05	292.8	0
11	9.74	33.293	5.70	1.20	10	9.77	33.28	5.74	1.17	25.68	233.3	.026
27	9.21	33.448	5.03	1.66	20	9.44	33.39	5.07	1.55	25.81	220.5	.049
53	9.00	33.645	4.56	1.46	30	9.17	33.47	4.96	1.66	25.92	210.1	.071
104	8.39	33.880	3.52	1.89	50	9.01	33.63	4.60	1.51	26.07	196.8	.111
159	7.87	34.019	2.20	2.41	75	8.75	33.76	4.13	1.58	26.22	182.9	.159
213	7.60	34.096	1.95	1.98	100	8.44	33.87	3.61	1.84	26.34	171.2	.203
267	7.48	34.086	1.77	2.50	150	7.94	34.00	2.39	2.36	26.53	154.8	.284
					200	7.65	34.08	1.96	2.08	26.63	145.3	.359
					250	7.50	34.09	1.82	2.23	26.66	143.7	.432

0-6   42 20.4 N   125 26.1 W   DATE 18 AUG 63 1518 GCT   WIRE -   DRY 58.5   WET 56.2
WIND DIRECTION - VEL C KTS   BAR 20 SWELL DIRECTION 28 H   1 T - CLOUD 6 AMT   5 WEATHER 1

D	T°C	S‰	O₂	PO₄	Z	T	S	O₂	PO₄	σₜ	s×10⁸	ΔD
0	11.90	33.248	7.06	.68	0	11.90	33.25	7.07	.68	25.28	271.2	0
11	10.65	33.338	6.97	.97	10	10.67	33.33	7.04	.95	25.56	244.6	.026
27	10.29	33.494	5.91	.92	20	10.35	33.42	6.43	.94	25.69	232.3	.050
53	9.52	33.759	4.74	1.97	30	10.20	33.53	5.75	1.02	25.79	222.5	.072
105	8.35	33.907	3.31	2.07	50	9.61	33.73	4.85	1.83	26.05	198.3	.114
160	7.76	33.978	2.48	1.84	75	8.96	33.86	4.02	2.01	26.26	179.3	.162
214	7.25	34.046	2.10	2.21	100	8.44	33.91	3.41	2.06	26.37	168.4	.205
268	7.04	34.046	1.85	2.53	150	7.84	33.97	2.59	1.87	26.51	155.8	.286
					200	7.36	34.03	2.17	2.09	26.63	145.3	.361
					250	7.08	34.05	1.92	2.43	26.68	141.1	.433

OBSERVED					INTERPOLATED					DERIVED		
D	T°C	S‰	O_2 ml/l	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D

E-1 42 9.9 N 124 24.4 W DATE 19 AUG 63 1900 GCT WIRE 0 DRY 56.0 WET 54.0
WIND DIRECTION 35 VEL 3 KTS BAR 23 SWELL DIRECTION 24 H 2 T - CLOUD 8 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	12.99	33.612	8.27	.36	0	12.99	33.62	8.27	.36	25.35	264.4	0
10	10.86	33.715	6.34	1.18	10	10.86	33.72	6.34	1.18	25.83	218.9	.024
25	9.29	33.770	4.28	1.42	20	9.66	33.76	4.86	1.39	26.07	196.5	.045
50	8.66	33.861	2.96	2.39	30	8.97	33.79	3.80	1.56	26.20	183.8	.064
					50	8.66	33.87	2.97	2.40	26.31	173.8	.100

E-2 42 10.0 N 124 33.1 W DATE 19 AUG 63 2040 GCT WIRE 0 DRY 56.2 WET 55.2
WIND DIRECTION 31 VEL 9 KTS BAR 23 SWELL DIRECTION 24 H 2 T - CLOUD 8 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	11.15	33.658	5.95	1.30	0	11.15	33.66	5.95	1.30	25.73	227.8	0
15	9.87	33.688	5.45	1.69	10	10.20	33.68	5.90	1.64	25.91	211.1	.022
32	8.74	33.727	3.93	1.86	20	9.48	33.70	5.02	1.77	26.05	198.3	.042
58	8.60	33.933	2.98	1.70	30	8.84	33.72	4.12	1.85	26.17	187.0	.062
109	8.20	33.951	2.68	2.29	50	8.64	33.87	3.16	1.76	26.31	173.4	.098
140	8.13	33.965	2.22	2.46	75	8.46	33.94	2.80	1.85	26.40	165.7	.140
					100	8.26	33.95	2.73	2.16	26.43	162.7	.181

E-3 42 9.9 N 124 46.0 W DATE 19 AUG 63 2245 GCT WIRE 7 DRY 57.9 WET 56.7
WIND DIRECTION 31 VEL 8 KTS BAR 23 SWELL DIRECTION 26 H 2 T - CLOUD 8 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	12.84	33.565	6.83	.83	0	12.84	33.57	6.83	.84	25.34	265.0	0
11	11.11	33.528	6.76	.81	10	11.20	33.52	6.88	.78	25.61	239.5	.025
27	9.60	33.675	4.78	1.23	20	10.14	33.60	5.71	1.03	25.86	216.0	.048
52	8.84	33.812	4.05	1.45	30	9.45	33.70	4.62	1.27	26.05	198.0	.069
103	8.55	33.998	2.68	1.87	50	8.86	33.80	4.05	1.44	26.23	181.3	.107
157	7.84	34.003	2.73	1.75	75	8.63	33.91	3.34	1.67	26.35	170.1	.151
212	7.74	34.081	1.93	2.10	100	8.57	33.99	2.74	1.85	26.42	163.9	.192
266	7.35	34.098	1.64	1.87	150	7.93	34.00	2.70	1.77	26.53	154.6	.272
					200	7.75	34.06	2.12	2.03	26.60	148.3	.348
					250	7.50	34.09	1.67	2.00	26.66	143.4	.420

E-4 42 9.4 N 124 59.8 W DATE 20 AUG 63 0126 GCT WIRE - DRY 62.3 WET 60.0
WIND DIRECTION 26 VEL 2 KTS BAR 22 SWELL DIRECTION 26 H 2 T - CLOUD 0 AMT 3 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	13.46	33.369	7.83	.58	0	13.46	33.37	7.83	.59	25.07	291.2	0
11	11.41	33.523	6.83	.86	10	11.46	33.52	6.91	.84	25.57	243.9	.027
26	10.62	33.579	5.68	1.18	20	10.80	33.57	6.10	1.05	25.72	229.2	.050
52	9.17	33.682	4.62	1.88	30	10.38	33.59	5.46	1.30	25.82	220.3	.073
102	8.51	33.880	4.13	1.62	50	9.27	33.67	4.67	1.83	26.06	197.2	.115
157	7.79	33.976	2.63	2.35	75	8.69	33.78	4.32	1.84	26.24	181.0	.162
211	7.06	34.027	2.34	1.99	100	8.54	33.87	4.14	1.64	26.33	172.2	.206
265	6.62	34.016	2.13	2.41	150	7.88	33.97	2.82	2.26	26.51	156.4	.288
					200	7.20	34.02	2.35	2.07	26.65	143.8	.363
					250	6.71	34.03	2.18	2.22	26.72	137.7	.434

E-5 42 9.9 N 125 12.9 W DATE 20 AUG 63 0340 GCT WIRE 12 DRY 60.0 WET 58.5
WIND DIRECTION 26 VEL 5 KTS BAR 22 SWELL DIRECTION 22 H 2 T - CLOUD 0 AMT 3 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	14.51	33.110	8.14	.20	0	14.51	33.12	8.14	.21	24.65	330.9	0
10	10.81	33.088	6.85	.83	10	10.81	33.09	6.85	.84	25.35	264.3	.030
25	9.90	33.320	5.46	1.48	20	10.20	33.23	5.85	1.30	25.56	244.7	.055
50	9.04	33.694	4.64	1.78	30	9.68	33.40	5.22	1.58	25.78	223.5	.079
100	8.11	33.951	2.72	2.15	50	9.04	33.70	4.65	1.79	26.12	191.9	.120
153	7.84	34.021	2.28	2.34	75	8.47	33.88	3.61	2.00	26.35	170.7	.165
206	7.55	34.052	1.73	2.42	100	8.11	33.96	2.72	2.15	26.46	159.9	.207
258	7.23	34.089	1.72	2.46	150	7.85	34.02	2.28	2.33	26.55	152.1	.285
					200	7.58	34.05	1.78	2.41	26.61	147.0	.359
					250	7.28	34.08	1.72	2.46	26.68	141.1	.431

E-6 42 9.7 N 125 25.6 W DATE 20 AUG 63 0608 GCT WIRE 5 DRY 60.0 WET 58.8
WIND DIRECTION 26 VEL 4 KTS BAR 22 SWELL DIRECTION 22 H 2 T - CLOUD 0 AMT 3 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	$\delta \times 10^8$	Δ D
0	14.05	33.184	8.76	.30	0	14.05	33.19	8.76	.30	24.80	316.3	0
11	11.13	33.597	7.66	.86	10	11.18	33.59	7.77	.82	25.68	233.4	.027
27	10.37	33.633	5.95	1.57	20	10.45	33.62	6.67	1.29	25.82	219.7	.050
53	9.09	33.799	4.31	1.79	30	10.21	33.65	5.71	1.63	25.89	213.5	.072
105	8.06	33.961	2.81	2.03	50	9.23	33.78	4.45	1.76	26.15	188.8	.112
160	7.56	34.069	2.25	2.32	75	8.50	33.88	3.47	1.91	26.35	170.3	.157
214	7.15	34.061	2.00	2.45	100	8.10	33.95	2.88	2.01	26.46	160.1	.198
268	6.94	0	1.70	2.01	150	7.63	34.06	2.30	2.27	26.61	146.3	.275
					200	7.24	34.06	2.05	2.42	26.67	141.3	.347
					250	6.99	34.08	1.81	2.22	26.72	137.1	.416

	OBSERVED				INTERPOLATED					DERIVED		
D	T°C	S‰	O_2 ml/l	$PO_4\equiv$	Z	T	S	O_2	$PO_4\equiv$	σ_t	$\delta \times 10^5$	Δ D

F-1   41 59.0 N   124 19.5 W   DATE 21 AUG 63 0159 GCT   WIRE 20   DRY 58.0   WET 55.8
WIND DIRECTION 28 VEL 18 KTS   BAR 18 SWELL DIRECTION 28 H 3 T - CLOUD 0 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	10.91	33.716	5.70	.96	0	10.91	33.72	5.70	.97	25.82	219.4	0
9	10.77	33.708	5.82	1.04	10	10.56	33.72	5.60	1.12	25.88	214.0	.022
18	8.81	33.801	3.56	1.78	20	8.79	33.82	3.22	1.89	26.25	178.8	.041
32	8.64	33.886	2.43	2.19	30	8.66	33.88	2.59	2.19	26.32	172.6	.059

F-2   41 59.1 N   124 32.3 W   DATE 20 AUG 63 2336 GCT   WIRE 21   DRY 56.2   WET 54.8
WIND DIRECTION 28 VEL 12 KTS   BAR 20 SWELL DIRECTION 28 H 2 T - CLOUD 8 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	11.27	33.701	6.57	.91	0	11.27	33.71	6.57	.92	25.74	226.7	0
14	10.97	33.668	6.34	.93	10	11.37	33.67	6.71	.82	25.70	231.3	.023
30	9.37	33.738	4.84	1.38	20	10.39	33.69	5.82	1.07	25.89	213.6	.045
54	8.76	33.840	3.76	1.97	30	9.38	33.74	4.84	1.39	26.10	193.4	.065
102	7.98	33.985	2.75	1.75	50	8.78	33.82	3.88	1.89	26.26	178.7	.103
126	7.94	33.990	2.65	1.80	75	8.33	33.92	3.16	1.96	26.40	165.3	.146
					100	8.00	33.98	2.77	1.77	26.50	156.3	.186

F-3   41 59.2 N   124 45.6 W   DATE 20 AUG 63 2040 GCT   WIRE 30   DRY 57.3   WET 55.7
WIND DIRECTION 28 VEL 12 KTS   BAR 21 SWELL DIRECTION 28 H 2 T - CLOUD 8 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	12.49	33.634	8.03	.45	0	12.49	33.64	8.03	.45	25.46	253.4	0
9	12.34	33.636	7.63	.41	10	12.29	33.64	7.57	.42	25.50	250.0	.025
22	11.47	33.665	6.77	.72	20	11.63	33.66	6.92	.65	25.64	236.9	.050
46	9.49	33.793	4.82	1.58	30	10.78	33.71	6.10	1.01	25.83	219.0	.072
90	8.29	33.878	3.25	2.09	50	9.30	33.81	4.59	1.67	26.16	187.9	.113
138	7.78	33.907	3.16	1.94	75	8.48	33.86	3.56	2.03	26.33	171.8	.158
185	7.60	33.917	2.92	2.29	100	8.14	33.89	3.17	2.07	26.41	165.3	.200
232	7.34	33.987	2.43	1.97	150	7.72	33.91	3.12	2.04	26.48	158.7	.281
					200	7.53	33.93	2.79	2.26	26.53	154.9	.359

F-4   41 59.4 N   124 59.4 W   DATE 20 AUG 63 1609 GCT   WIRE 2   DRY 58.0   WET 56.9
WIND DIRECTION 26 VEL 9 KTS   BAR 21 SWELL DIRECTION 28 H 2 T - CLOUD 0 AMT 2 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	12.70	33.511	8.23	.46	0	12.70	33.52	8.23	.46	25.33	266.4	0
11	11.63	33.573	7.76	.57	10	11.73	33.57	7.89	.55	25.55	244.9	.026
27	10.01	33.624	5.74	0	20	10.68	33.60	6.67	.79	25.77	224.6	.049
53	8.92	33.797	4.16	1.61	30	9.82	33.64	5.49	1.03	25.95	207.8	.071
105	8.30	33.896	3.18	1.69	50	8.98	33.78	4.27	1.53	26.19	185.3	.110
160	7.69	33.980	2.53	1.96	75	8.53	33.86	3.55	1.64	26.33	172.6	.155
215	7.22	34.025	2.31	2.09	100	8.31	33.89	3.20	1.68	26.38	167.4	.197
270	6.98	34.076	1.70	2.52	150	7.79	33.97	2.62	1.91	26.52	155.3	.278
					200	7.33	34.01	2.37	2.05	26.62	146.1	.353
					250	7.04	34.06	1.97	2.33	26.70	139.8	.425

F-5   41 59.7 N   125 13.6 W   DATE 20 AUG 63 1317 GCT   WIRE 0   DRY 56.6   WET 56.0
WIND DIRECTION 28 VEL 1 KTS   BAR 21 SWELL DIRECTION 28 H 1 T - CLOUD 6 AMT 3 WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	13.40	33.546	8.36	.43	0	13.40	33.55	8.36	.43	25.22	277.0	0
11	11.02	33.603	6.49	.92	10	11.06	33.60	6.51	.91	25.70	230.9	.025
27	10.44	33.639	6.23	1.10	20	10.50	33.63	6.34	1.05	25.82	220.0	.048
53	8.78	33.755	4.14	1.57	30	10.25	33.65	6.01	1.15	25.88	214.1	.070
105	8.23	33.928	3.43	2.06	50	8.97	33.74	4.40	1.51	26.16	187.7	.110
160	7.45	33.987	2.46	1.74	75	8.33	33.84	3.57	1.86	26.34	171.3	.155
214	6.89	33.997	2.36	1.95	100	8.28	33.92	3.50	2.04	26.41	165.3	.197
268	6.81	34.078	1.65	2.09	150	7.59	33.98	2.61	1.81	26.56	151.3	.276
					200	7.00	33.99	2.37	1.87	26.65	143.2	.349
					250	6.84	34.04	1.95	2.05	26.71	138.0	.420

F-6   41 59.0 N   125 26.0 W   DATE 20 AUG 63 0850 GCT   WIRE 25   DRY 60.0   WET 58.8
WIND DIRECTION 28 VEL 1 KTS   BAR 22 SWELL DIRECTION 28 H 1 T - CLOUD - AMT - WEATHER 1

D	T°C	S‰	O_2	PO_4	Z	T	S	O_2	PO_4	σ_t	δ	ΔD
0	13.09	32.780	6.94	1.01	0	13.09	32.79	6.94	1.01	24.69	327.4	0
9	11.39	32.781	6.76	.50	10	11.30	32.82	6.76	.51	25.05	293.0	.031
24	10.69	33.416	6.64	.99	20	10.75	33.22	6.69	.78	25.47	253.6	.058
48	9.59	33.712	5.12	1.51	30	10.40	33.54	6.31	1.14	25.77	224.9	.082
95	8.38	33.845	3.58	1.97	50	9.52	33.72	5.03	1.54	26.06	197.3	.124
145	7.83	33.987	2.36	2.21	75	8.78	33.84	4.10	1.83	26.27	178.1	.171
190	7.34	34.062	1.97	1.91	100	8.31	33.88	3.43	2.01	26.37	168.4	.215
244	6.96	34.061	1.84	2.05	150	7.77	34.00	2.29	2.18	26.55	152.7	.295
					200	7.25	34.06	1.92	1.94	26.67	141.5	.368

Appendix IX.   Sampling variability.

Replicate tows at a given station were not made; however, by assuming that the offshore tows made during each cruise represent replicate samples, a basis is provided for estimates of sampling variability.   Catches of fishes taken at the 65 - 165-mile stations were examined for this purpose.   The mean, variance, and co-efficient of dispersion, $s^2/\bar{x}$ (Blackman, 1942), were calculated for each cruise, except April 1964 (Table 22).   Coefficients of dispersion have a small range (from 0. 23 to 1. 38), suggesting a fairly consistent dispersion pattern.   If the distributions were random, the variance would be approximately equal to the mean, i. e. coefficient of dispersion equal to one.   Coefficients of dispersion were considered to demonstrate a random distribution unless they were greater (or less) than the level of significance as derived from the formula,

$$ 1 \pm 2 \sqrt{[2n/(n-1)^2]} \, , $$

where n is the number of samples (Barnes and Marshall, 1951). Most of the coefficients of dispersion did not significantly depart from unity, suggesting a random distribution.

Appendix IX (cont'd.)

Table 22. Mean, variance, and coefficient of dispersion for catches
of fishes taken 65 - 165-miles offshore.

	Mean	Variance	Coefficient of Dispersion
June 62	1.58	0.41	0.26
Aug. 62	3.06	1.48	0.48
Oct. 62	4.38	1.94	0.44
Mar. 63	3.68	3.72	1.01
May 63	2.73	0.62	0.23
July 63	2.26	0.71	0.31
Sept. 63	2.06	2.85	1.38