NOAA Technical Memorandum NMFS-NWFSC-74

# Neustonic Mesozooplankton Abundance and Distribution in the Northern California Current, 2000 and 2002

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**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service

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# Neustonic Mesozooplankton Abundance and Distribution in the Northern California Current, 2000 and 2002

Suzan S. Pool* and Richard D. Brodeur

Northwest Fisheries Science Center
Fish Ecology Division, Newport Research Station
Hatfield Marine Science Center
2032 Southeast OSU Drive
Newport, Oregon 97365

* Oregon State University
Cooperative Institute for Marine Resources Studies
Hatfield Marine Science Center
2030 Southeast Marine Science Drive
Newport, Oregon 97365

February 2006

**U.S. DEPARTMENT OF COMMERCE**
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# Executive Summary


Most plankton surveys off Oregon and northern California have focused along one transect off Newport, Oregon, or only on the ichthyoplankton in the water column and at the ocean surface. Therefore as part of juvenile salmonid (*Oncorhynchus* spp.) ocean sampling funded by U.S. Global Ocean Ecosystem Dynamics, a study was undertaken to collect neustonic mesozooplankton from Crescent City, California, to Newport, Oregon, during four cruises in June and August 2000 and 2002.

These collections were made for comparison with stomach contents of juvenile salmonids; however this technical memorandum does not include that comparison. It contains the results of our analysis of the species composition, relative abundances, and spatial distributions of the neuston on a point-by-point basis for both years instead of using geostatistics as previously done for only 2000 by Reese et al. (2005). In addition to regular sampling we conducted two diel studies in 2002 to examine temporal variations of the neustonic mesozooplankton population.

Overall 347 samples were collected, 144 taxa were identified, and 38,325 specimens were counted. Our findings show that:

- Dungeness crab (*Cancer magister*) megalopae, Oregon cancer (*C. oregonensis*) and red rock crab (*C. productus*) megalopae (not identifiable to either species), *Thysanoessa spinifera*, Pacific krill (*Euphausia pacifica)*, *Hyperoche medusarum*, *Themisto pacifica*, and *Sagitta* spp. were the dominant taxa.
- Species diversity was higher in 2002 than in 2000, but it was not significantly different between years or seasons.
- Species cluster groupings based on station assemblages included:
    - Dungeness crab megalopae, Oregon cancer and red rock crab megalopae, and Pacific rock crab (*C. antennarius*) and graceful crab (*C. gracilis*) megalopae (not identifiable to either species);
    - terrestrial insects and benthic gammarids;
    - pelagic euphausiids and hyperiids;
    - chaetognaths; and
    - shrimp larvae.
- In the diel studies more taxa were collected at night than during the day.
- In 2000, 1-m water temperatures were warmer, 3-m chlorophyll *a* concentrations were lower, and neustonic mesozooplankton abundance was lower than in 2002. In 2000 and

2002 salinity was lower, density was lower, and sample biovolumes were larger in June than in August.

## Surveys

Each of the four cruises lasted 14–18 days and primarily surveyed over the continental shelf with occasion sampling beyond the shelf break. Six major transects were sampled first, then additional stations on these or other transects based on fine-scale oceanographic features were sampled. Samples were collected using a surface-towing neuston net.

In addition to regular sampling, two diel studies were conducted in 2002 to examine temporal variations of the neustonic mesozooplankton population. A conductivity, temperature, and depth profiler was deployed to measure physical characteristics of the ocean water. Chlorophyll *a* was collected from 3 m deep and analyzed by cold-acetone extraction and fluorescence. Zooplankton were collected with a surface-towing neuston net, then identified and enumerated in the laboratory.

## Results

Of the 144 taxa identified in the four cruises, Dungeness crab megalopae, Oregon cancer and red rock crab megalopae, *Thysanoessa spinifera*, Pacific krill, *Hyperoche medusarum*, *Themisto pacifica*, and S*agitta* spp. were dominant. Decapods dominated both years in June whereas euphausiids dominated in August 2000 and chaetognaths dominated in August 2002. Other taxa caught included crab zoeae, shrimp larvae, mysids, insects, fish larvae and juveniles, copepods, polychaetes, squids, heteropods, pteropods, cumaceans, isopods, and caprellids. Variations in species composition were observed in the spatial distribution, cross-shelf distribution, and diel patterns. Inshore-offshore distribution of the five most abundant taxa varied among and within cruises along the six main transects. Spatial variability also was apparent from north to south.

Species diversity was higher in 2002 than in 2000, but it was not significantly different between years or seasons. Analysis of species cluster groupings based on station assemblages included 17 taxa in June 2000, 20 in August 2000, 33 in June 2002, and 17 in August 2002. Cluster groupings included:

1) Dungeness crab megalopae, Oregon cancer and red rock crab megalopae, and Pacific rock crab and graceful crab megalopae;
2) terrestrial insects and benthic gammarids;
3) pelagic euphausiids and hyperiids;
4) chaetognaths; and
5) shrimp larvae.

In the diel study more taxa were collected at night than during the day. The region surveyed covers a highly dynamic environment due to the strong upwelling that characterizes the California Current. The changing oceanographic conditions, compounded with variable life history patterns of zooplankton, influence the species composition and abundance of neustonic mesozooplankton.

Over the survey area the coldest water was nearshore and over Heceta Bank during all cruises. Salinity on the shelf was significantly lower in June than in August of 2000 and 2002. Density was higher over the shelf than offshore and higher in August than in June both years. Chlorophyll *a* concentrations were higher nearshore or over Heceta Bank than elsewhere. Biovolumes of samples were larger in June than in August of 2000 and 2002.

# Acknowledgments

The authors thank Jacqueline Popp Noskov, Robert Emmett, Joseph Fisher, Todd Miller, Douglas Reese, Paul Bentley, Todd Sandell, Rebecca Baldwin, Marcia House, Cynthia Anderson, Emily Locke, Tracy Wenham and the crews of the fishing vessels FV *Sea Eagle* and FV *Frosti* for their help with the field sampling. In addition the authors thank Cathy Potts for processing the June and August 2000 zooplankton samples, John Chapman for identification of gammarids and isopod *Acanthamunnopsis milleri*, Cheryl Morgan for assistance with early identifications of specimens, Mak Terazaki for identifying the *Sagitta* species from the June and August 2000 zooplankton samples, and Maria Parnel for identifying some of the larval and juvenile fishes. This study was partly funded by the U.S. GLOBEC Northeast Pacific Program and supported by a grant to the Cooperative Institute for Marine Resources Studies at Oregon State University in Corvallis.

# Introduction

It has long been known that certain organisms have an affinity for the near-surface or neustonic zone in marine waters, and these organisms are called neuston (Zaitsev 1970). Some of these organisms are associated through morphological or physiological adaptations to the neustonic layer and are termed euneuston. Others occur there by chance or as a result of diel vertical migration patterns and are called facultative or pseudoneuston (Hempel and Weikert 1972). Neuston are important prey items for some fish species, including juvenile salmonids (*Oncorhynchus* spp.) (Brodeur 1989).

Although there have been many plankton surveys in the northern California Current off Oregon and northern California, most were focused on zooplankton or ichthyoplankton occupying the entire water column. Ahlstrom and Stevens (1976), however, sampled the ichthyoneuston from California to northern Washington. Richardson and Pearcy (1977) sampled for fish larvae, including those in the neuston, along one transect off of Newport, Oregon (lat. 44.7$^{o}$N), and at a station to the north but no stations to the south. Shenker (1988) studied neustonic larval and juvenile fishes and Dungeness crab (*Cancer magister*) megalopae on the Newport line only. Richardson et al. (1980) collected larval fish with a bongo zooplankton net along the Oregon coast in March and April 1972–1975. Brodeur et al. (1987) completed the only comprehensive study of the entire neustonic mesozooplankton community in the northeast Pacific Ocean, which includes the central to southern Oregon coast, in 1984.

U.S. Global Ocean Ecosystems Dynamics (GLOBEC) commissioned further oceanographic research in the northeast Pacific Ocean, including the California Current. As a component of the GLOBEC Northeast Pacific sampling program (Batchelder et al. 2002), extensive surveys were conducted in 2000 and 2002 in the northern California Current off the Oregon and northern California coasts. To complement the juvenile salmon and other pelagic fish sampling (Brodeur et al. 2004), neuston net tows were made at every trawling station. Reese et al. (2005) used geostatistical techniques that entail interpolation to estimate abundance between the data points to describe the neuston community from 2000. Instead of using geostatistics we analyzed neuston community data on a point-by-point basis. In addition we examined data from 2000 and 2002, whereas Reese et al. (2005) focused on 2000. In this technical memorandum our purpose is to describe the mesozooplankton species composition, abundance and distribution patterns, and species associations in the neuston during four cruises, two in each year.

# Methods

## Survey Area

The survey area covered the continental shelf from Newport (lat. 44.7°N) to Crescent City, California (lat. 41.9°N) (Figure 1). Four research cruises were conducted:

- 29 May 2000–11 June 2000,
- 28 July 2000–12 August 2000,
- 1 June 2002–18 June 2002, and
- 1 August 2002–17 August 2002.

(Hereafter these dates are referred to as June 2000, August 2000, June 2002, and August 2002, respectively.) During each cruise mesoscale transects were sampled first and additional stations were selected based on fine-scale oceanographic features such as eddies or fronts (Figure 1).

In addition a diel study was conducted twice in 2002 to sample designated stations every 4 hours within a 24-hour period. The purpose was to examine diel patterns in and possible correlations between salmonid abundance and other oceanographic parameters, including possible salmonid prey in the neuston. Two stations were selected for the diel study based on high salmonid catches during mesoscale trawling. A station on the Newport Hydroline (NH) denoted as NH-5 (lat. 44.7°N, long. 124.2°W) was chosen for June 2002 and a station on the Heceta Head (HH) transect denoted as HH-2 (lat. 44.0°N, long. 124.4°W) was chosen for August 2002 (Figure 1).

## Sample Protocols

Conductivity, temperature, and depth (CTD) profiles were collected at each station. An SBE 19 SEACAT profiler (Sea-Bird Electronics, Bellingham, Washington) was used in 2000, whereas an SBE 19*plus* SEACAT profiler, which also measured light transmittance and fluorometric chlorophyll, was used in 2002. Temperature, salinity, and density at 1-m depth were analyzed.

Replicate samples for in vitro chlorophyll *a* were collected at 3-m depth with a 1-l Niskin water sampler (General Oceanics Inc., Miami, Florida). Samples were filtered immediately through grade GF/F glass fiber filters (with particle retention down to 0.7 micrometer [μm; $10^{-6}$ meter]), then frozen for analysis in the laboratory. One of the two replicates was processed, and the other was kept as a reserve sample. Chlorophyll *a* was processed using the cold-acetone extraction method and measured with a 10-AU fluorometer (Turner Designs Inc., Sunnyvale, California) (Arar and Collins 1997).

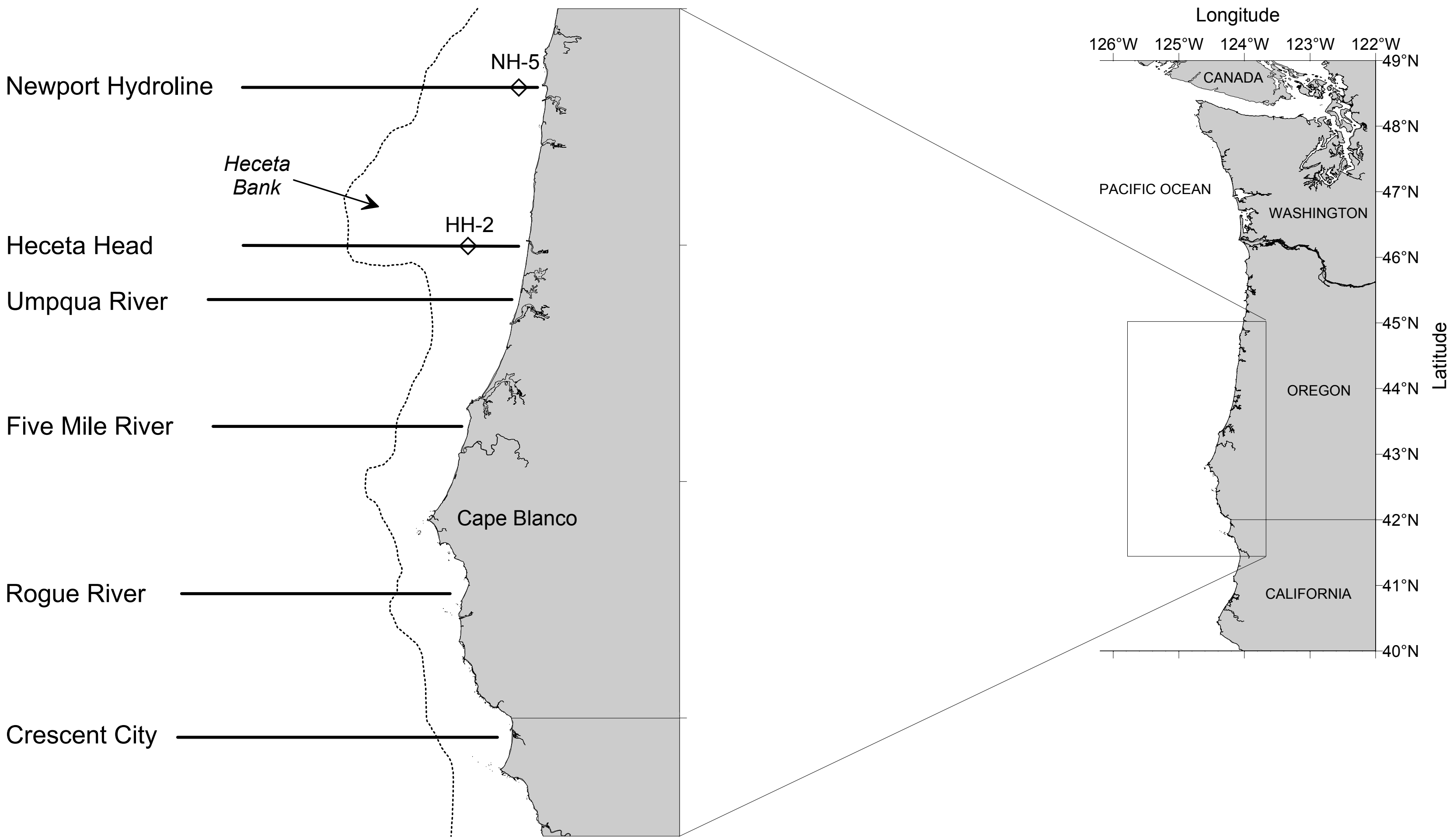


Figure 1. Pacific Northwest coastline (right), with survey area (left). Major transects are indicated by the six horizontal lines accompanied by names of geographical features. Additional transects are not shown. Stations NH-5 (June 2002) and HH-2 (August 2002) were the locations of a diel study. The dotted line to the west of the coastline is the 200-m depth shelf break.

A neuston net with a 1-m wide by 0.3-m high mouth and 333-µm mesh was utilized for collection of all zooplankton samples. A General Oceanics flowmeter was attached in the mouth of the net to estimate the volume of water filtered during each tow. The net was towed out of the ship's wake for 5 minutes at approximately 2 knots (3.7 kilometers per hour [km/h]). Upon retrieval the net was hosed down, and contents of the cod end were transferred to a sample jar. Large jellyfish[1] and flotsam were rinsed with seawater to remove any attached plankton and discarded at sea. The sample was preserved with formalin in ambient seawater to make a 5% formalin solution.

In the laboratory samples were washed with tap water over a 320-µm mesh sieve to remove the formalin then transferred to water. Additional extraneous contents subsequently were removed. To obtain displacement volumes, samples were allowed to settle overnight in Imhoff settling cones or graduated cylinders depending on the sample volume. Biovolumes (milliliter per 100 cubic meters [ml/100 $m^3$]) were calculated from displacement volumes and flowmeter readings.

Samples were transferred to a clear Pyrex dish on a white background for sorting and removing zooplankton greater than or equal to 5 millimeters (mm) using a lighted magnifying glass. This size fraction was chosen based on prey size selected by juvenile coho salmon (*O. kisutch*) and Chinook salmon (*O. tshawytscha*) in previous trophic analyses (Brodeur 1991, Schabetsberger et al. 2003). Occasionally large samples with many mesozooplankton were subsampled with a Folsom plankton splitter, and the counts were estimated. The mesozooplankton were enumerated and identified to the lowest practical taxon using a dissecting microscope, and life stages of the specimens were determined when possible. Completed samples were transferred to 70% ethanol. Counts were standardized into concentrations expressed as numbers per 100 $m^3$.

## Data Analysis

Sampling occurred most often during daylight hours, but several samples were collected after dark. Daytime samples are defined as having been collected between 0600 hours and 2000 hours Pacific daylight time. Excluding the diel study samples, the numbers of nighttime samples per cruise were: 10 in June 2000, 4 in August 2000, 12 in June 2002, and 4 in August 2002. Analysis of physical parameters, chlorophyll *a* concentrations, zooplankton biovolumes, and neustonic mesozooplankton concentrations were from daytime and nighttime samples, and included the first sample taken during each diel study. Distribution of physical parameters and chlorophyll *a* concentrations was examined utilizing Surfer 7 software (Golden Software, Inc., Golden, Colorado). Because of the scattered spacing of sampling locations, point kriging, with anisotropy ratio and angle of 1 and 0, respectively, was selected as the gridding method for its flexibility. Although this generates surficial contours using interpolated values along with actual data points, the objective simply was to show the possible spatial patterns of these parameters.

Six mesoscale transects were used to examine the spatial variability in neustonic mesozooplankton from the northern to southern ends of the survey area (Figure 1). Occasionally

[1] Five species of jellyfish, egg yolk jelly (*Phacellophora camtschatica*), *Aequorea* spp., lion's mane jelly (*Cyanea capillata*), moon jelly (*Aurelia labiata*), and sea nettle (*Chrysaora fuscscens*), were captured in the surface rope trawl used for catching salmonids and other fishes.

a transect could not be completed during the mesoscale leg because of rough weather conditions; therefore, the same transect was resampled and completed during the fine-scale leg several days later and was used in the spatial variability analysis. This was necessary to compare the cross-shelf distribution of five taxa abundant and common to all six transects within a cruise and to reduce the effects of temporal variability.

Species diversity was calculated using the Shannon-Wiener diversity index ($H'$) (Levinton 1982, Valiela 1995, Spellerberg and Fedor 2003). The formula was:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad (1)$$

where $s$ is the number of species and $p_i$ is the proportion of species $i$.

For statistical analysis, nighttime samples were excluded to minimize the effects of diel patterns commonly observed in zooplankton. Data transformations on several variables were necessary because of a skewed frequency distribution. Zooplankton concentrations and sample biovolumes were transformed with $\log_{10}(x + 1)$. Chlorophyll *a* data were transformed with a square root. Water density, temperature, salinity, and diversity data were not transformed. To test for a possible difference between seasons (i.e., June vs. August) in 2000 and 2002, the two-sample t-test was used. One-way analysis of variance (ANOVA) was run to examine differences between all four cruises while considering the variations within each cruise. Because of a few outliers in the transformed data despite normalization, the nonparametric Kruskal-Wallis test was run to justify the use of ANOVA.

Potential species associations were examined using the agglomerative hierarchical cluster analysis method. Data for this analysis excluded nighttime stations, samples without mesozooplankton, and taxa occurring in less than 5% of the stations within a cruise (i.e., frequency of occurrence was three in June and August 2000 and four in June and August 2002). The Sørensen (Bray-Curtis) distance measure and flexible beta negative 1.0 group linkage method were chosen for the cluster analysis, producing the least amount of chaining.

Examination of diel patterns in the neustonic mesozooplankton included all diel samples. The five most abundant taxa were chosen to examine temporal variation in numerical concentrations. Species diversity ($H'$) and the number of taxa collected over time also were analyzed.

# Results

## Physical Parameters

The 1-m depth water temperature was warmer in 2000 than in 2002 (ANOVA, $p < 0.0001$), and it was warmer in June than in August. The seasonal difference in 2000 was not significant (t-test, $p = 0.6$); whereas the seasonal difference in 2002 was significant (t-test, $p < 0.0001$). For appropriate and easier comparisons between cruises, August 2000 stations west of long. 125.3°W were excluded from the analysis of temperature. The temperature ranges were 10.0°C–14.6°C in June 2000, 8.7°C–16.6°C in August 2000, 7.8°C–14.2°C in June 2002, and 8.1°C–13.3°C in August 2002 (Table 1). The coldest water was in the nearshore region and over Heceta Bank during all cruises (Figure 2 and Figure 3). In June 2000 the 1-m temperature was colder over Heceta Bank than along Cape Blanco (Figure 2). In August 2000 there was a greater increase in 1-m temperature from near the coast to the offshore region than during the three other cruises (Figure 2). The water was coldest at the most-nearshore stations on the Newport Hydroline (lat. 44.7°N) and Heceta Head (lat. 44.0°N) transects (Figure 2). In June 2002 the coldest 1-m temperatures were recorded from nearshore stations on transects from Cape Blanco to Crescent City (Figure 3). In August 2002 the 1-m temperatures were colder than on all three other cruises (Figure 3). Cold water in the nearshore region to the north of Cape Blanco indicated upwelling (Figure 3). Upwelling in August 2002 also occurred south of Cape Blanco to a greater extent than observed in June 2002 (Figure 3). In August 2000 four stations west of long. 125.3°W had temperatures above 17°C (Figure 2).

The 1-m depth salinity over the continental shelf was significantly lower in June than in August of 2000 and 2002 (both years: t-test, $p < 0.0001$) (Figure 4 and Figure 5). Not including stations west of long. 125.3°W, 1-m salinity ranges were 28.9–33.0 practical salinity units (psu) in June 2000, 31.8–33.9 psu in August 2000, 29.6–33.8 psu in June 2002, and 31.7–33.7 psu in August 2002 (Table 1). In June of both years most stations over the shelf were between 31.0 psu and 33.0 psu (Figure 4 and Figure 5). In August of both years many stations over the shelf had greater than 33.0 psu, but some stations over Heceta Bank were between 32.0 psu and 33.0 psu (Figure 4 and Figure 5).

The 1-m depth water density had a similar distribution as salinity (Figure 6 and Figure 7). Density ranges were 21.5–25.3 kilograms per cubic meter ($kg/m^3$) in June 2000, 23.5–26.2 $kg/m^3$ in August 2000, 22.2–26.2 $kg/m^3$ in June 2002, and 23.8–26.2 $kg/m^3$ in August 2002 (Table 1). The density was higher over the shelf than offshore and higher in August than in June of both years (Figure 6 and Figure 7). The seasonal difference (t-test, $p < 0.0001$) and the interannual variation (ANOVA, $p < 0.0001$) were highly significant.

Table 1. Data ranges of physical parameters and chlorophyll *a* by cruise.

| | **June 2000** | | **August 2000** | | **June 2002** | | **August 2002** | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| Temperature (°C) | 10.00 | 14.60 | 8.70 | 16.60 | 7.80 | 14.20 | 8.10 | 13.30 |
| Salinity (psu) | 28.90 | 33.00 | 31.80 | 33.90 | 29.60 | 29.60 | 31.70 | 33.70 |
| Density (kg/m$^3$) | 21.50 | 25.30 | 23.50 | 26.20 | 22.20 | 26.20 | 23.80 | 26.20 |
| Chlorophyll *a* (µg/l) | 0.11 | 10.29 | 0.07 | 14.21 | 0.20 | 45.44 | 0.00 | 37.76 |

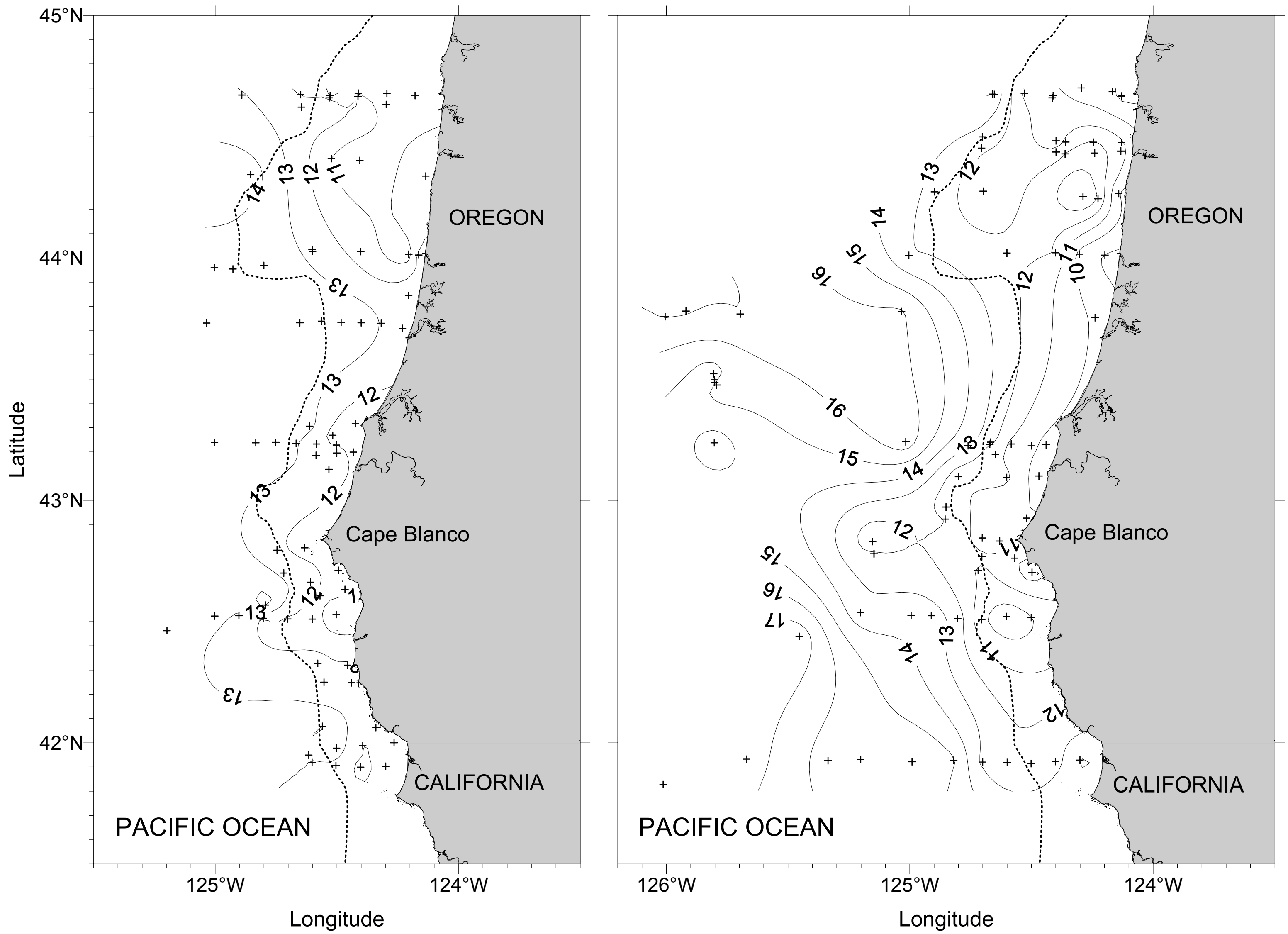


Figure 2. The 1-m depth temperature (°C) in June (left) and August (right) 2000. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

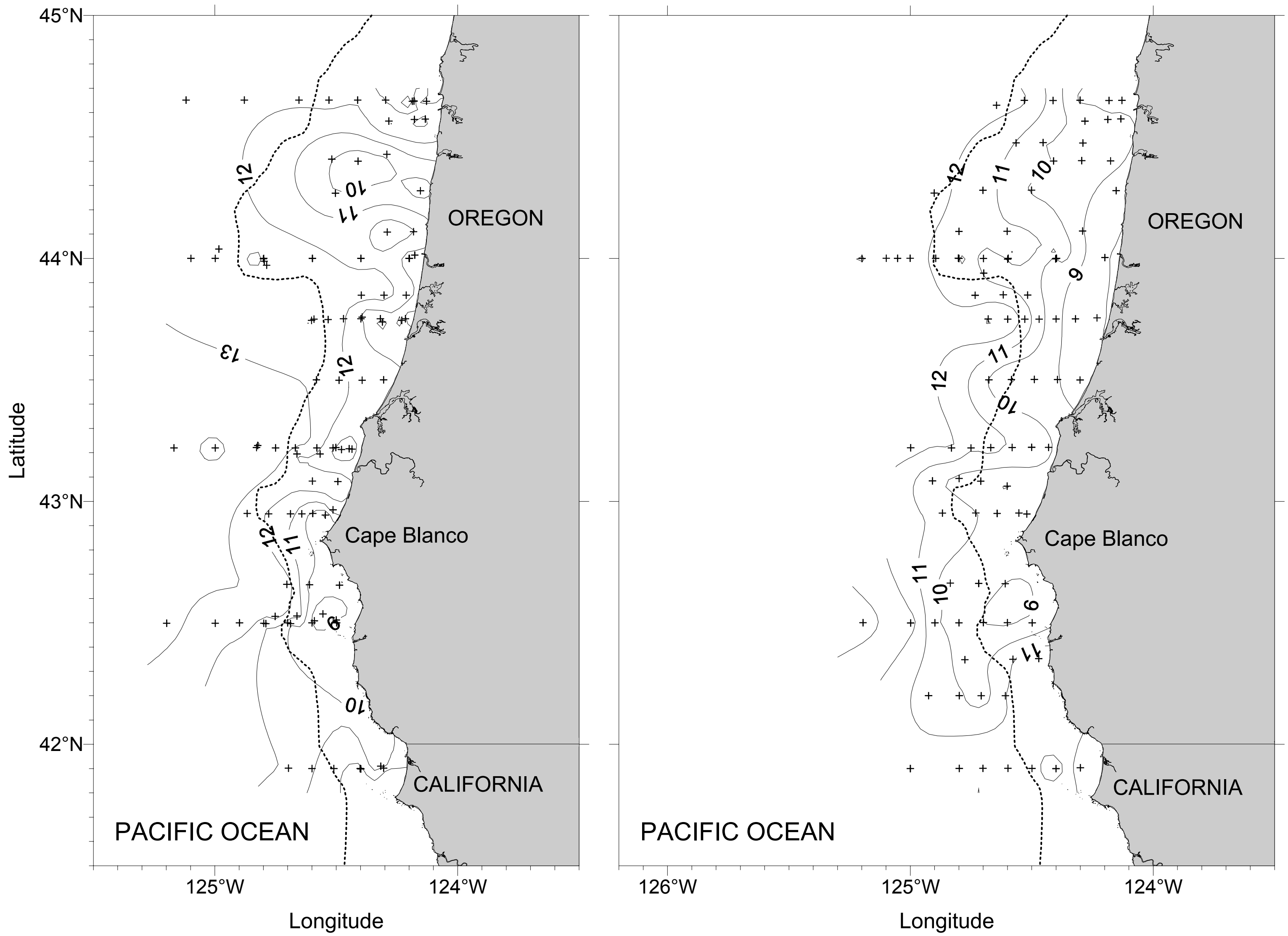


Figure 3. The 1-m depth temperature (°C) in June (left) and August (right) 2002. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

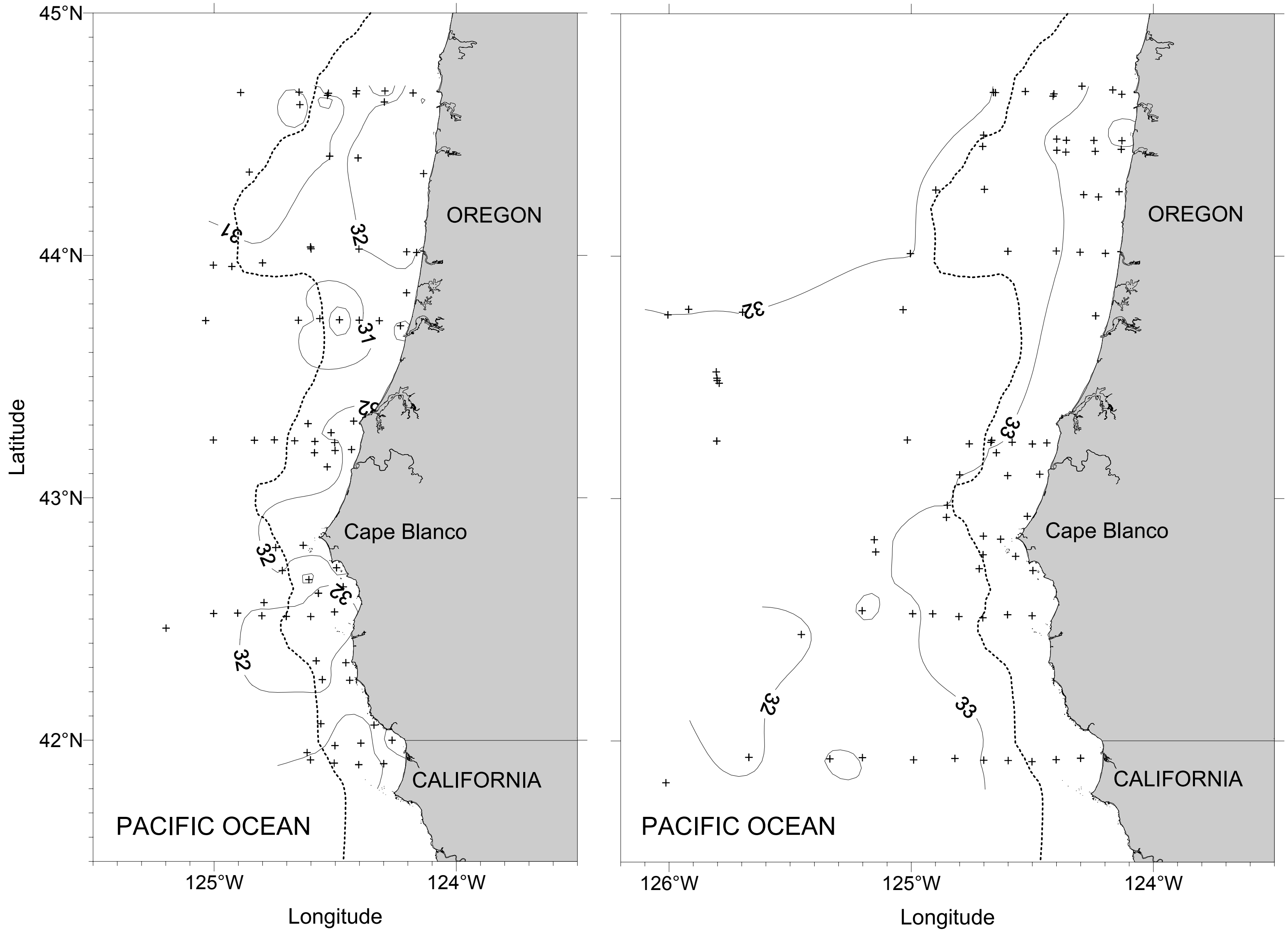


Figure 4. The 1-m depth salinity (psu) in June (left) and August (right) 2000. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

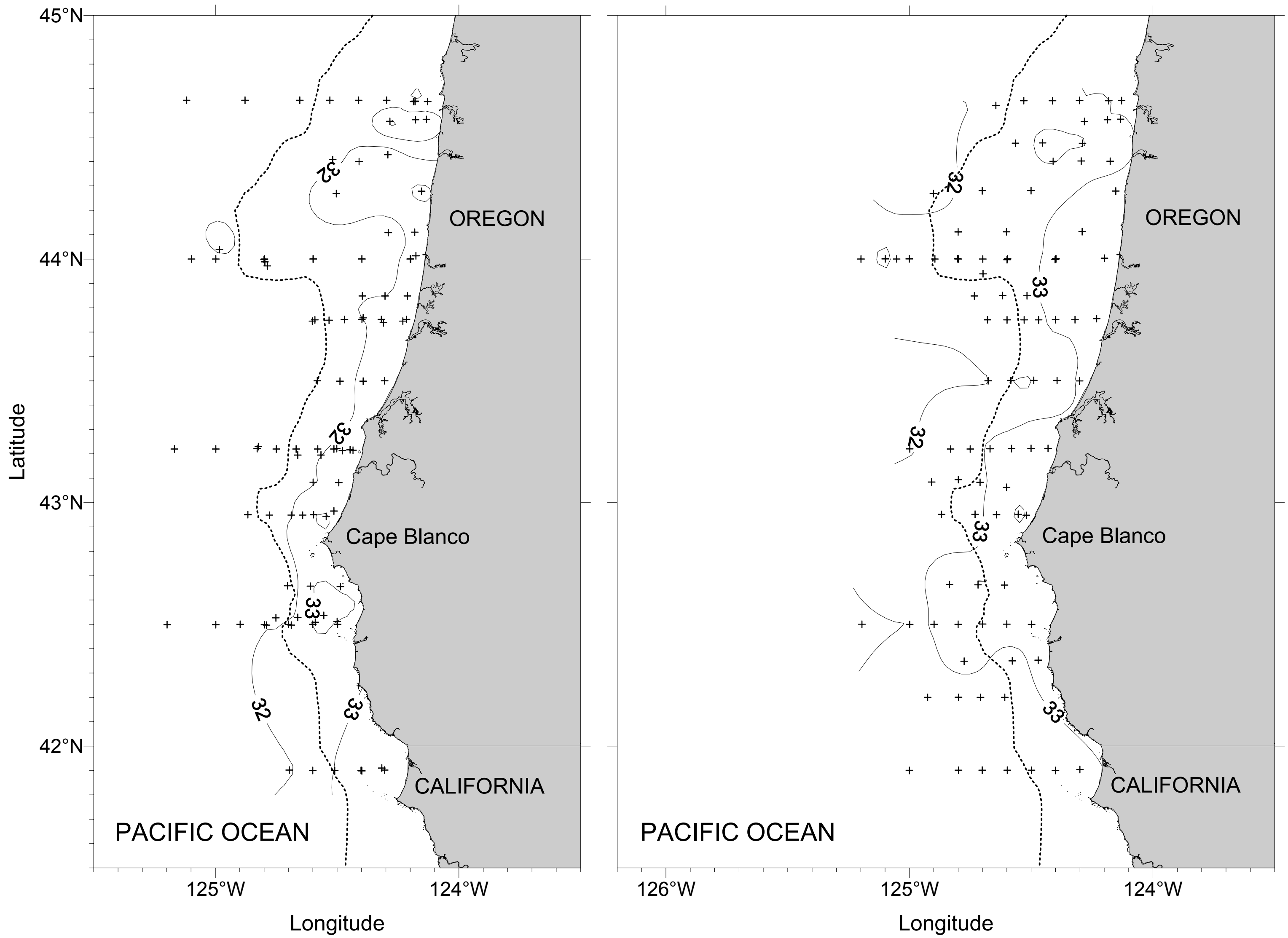


Figure 5. The 1-m depth salinity (psu) in June (left) and August (right) 2002. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

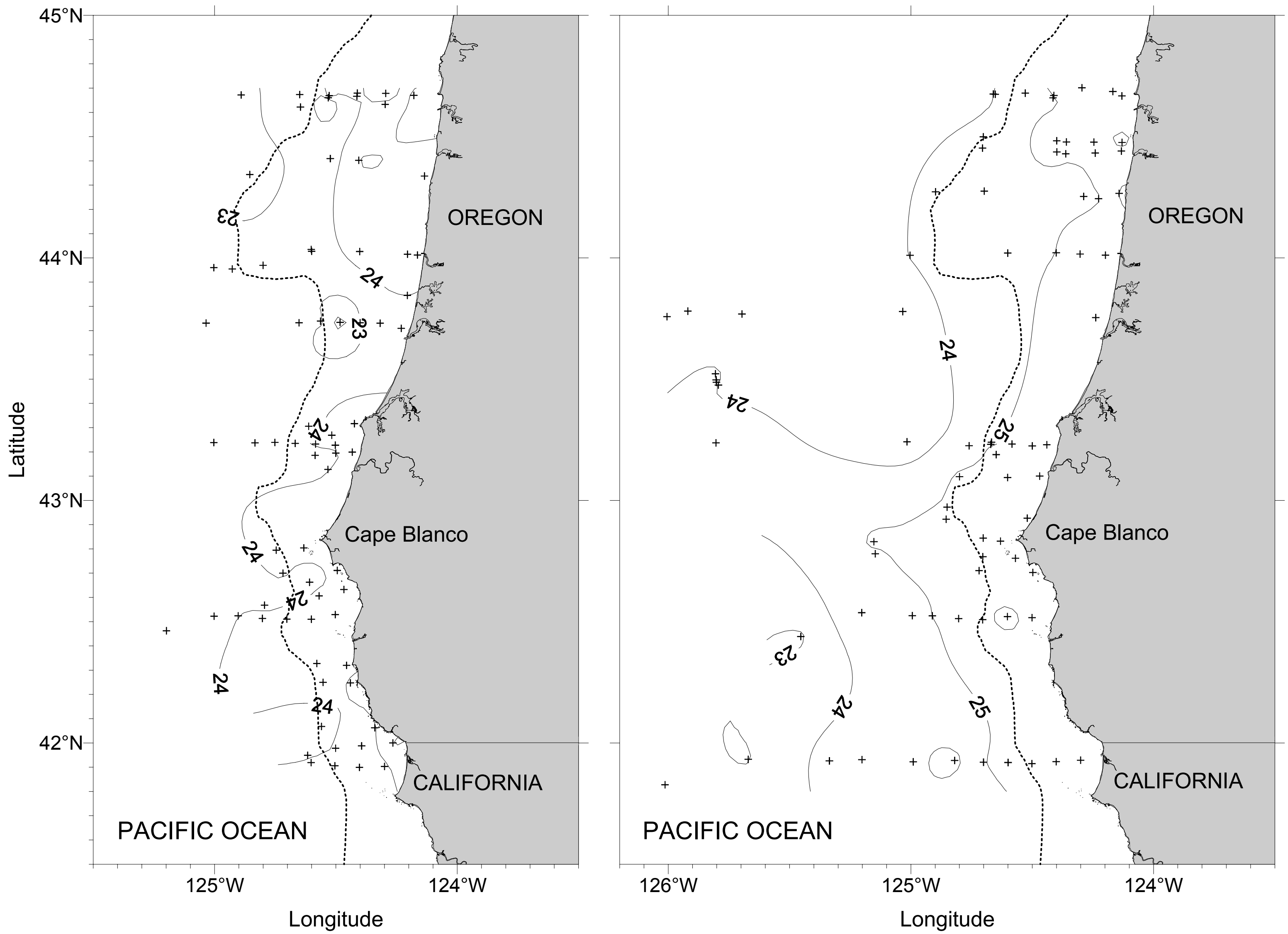


Figure 6. The 1-m depth water density (kg/m$^3$) in June (left) and August (right) 2000. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

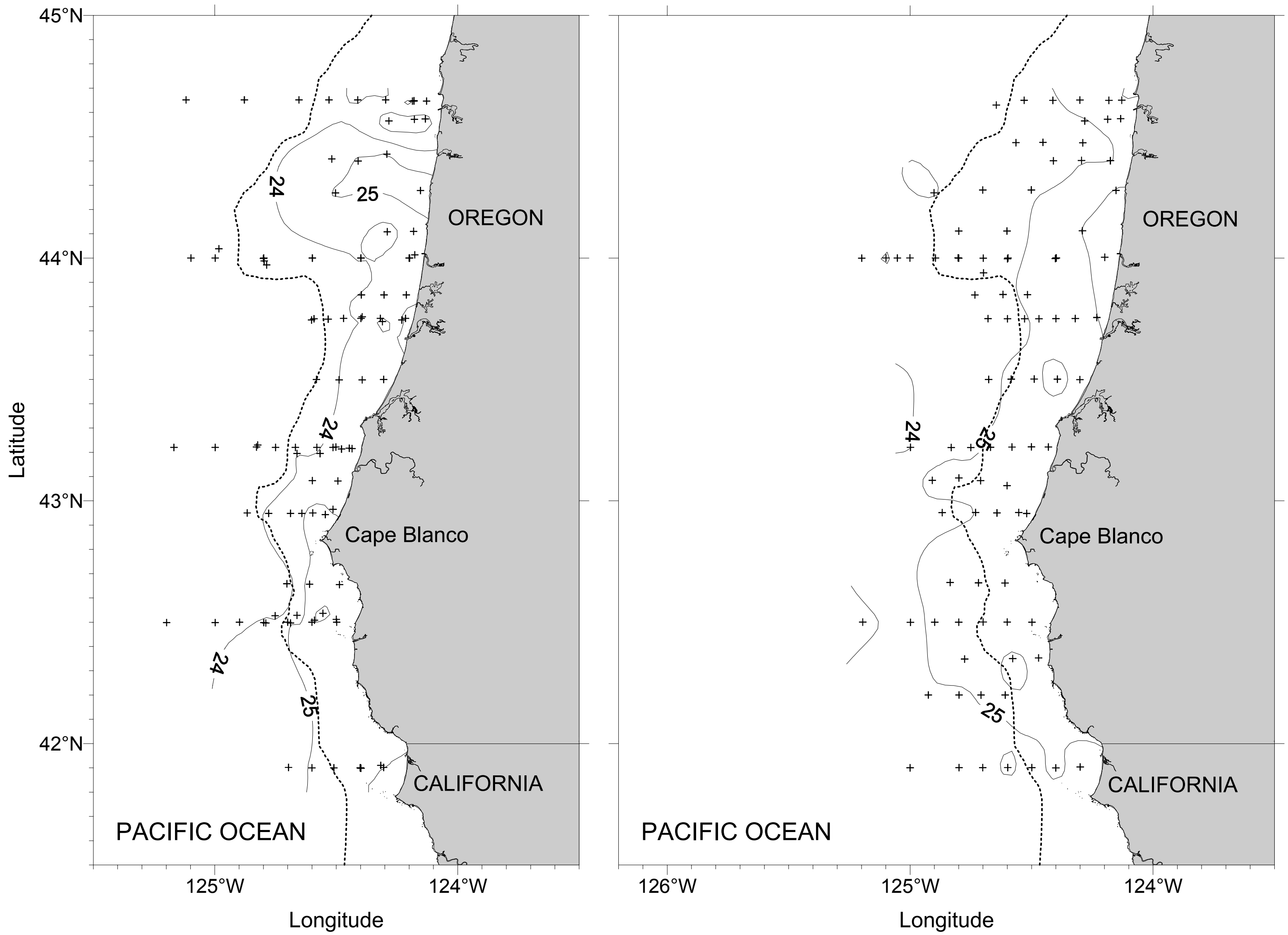


Figure 7. The 1-m depth water density (kg/m$^3$) in June (left) and August (right) 2002. Contour labels are oriented in an uphill direction. Plus signs are locations where measurements were made. The dotted line is the 200-m depth contour.

# Chlorophyll *a*

Chlorophyll *a* data from two stations in June 2000 and five stations in August 2000 were removed from analysis, because their fluorescence values exceeded the fluorometer's detection limit. Chlorophyll *a* concentrations were lower in 2000 than in 2002 (Figure 8 and Figure 9). The ranges were 0.11–10.29 micrograms per liter (µg/l) in June 2000, 0.07–14.21 µg/l in August 2000, 0.20–45.44 µg/l in June 2002, and 0.00–37.76 µg/l in August 2002 (Table 1). In June 2000, chlorophyll *a* was highest on the nearshore part of the Crescent City transect (lat. 41.9°N). Most stations had less than 2.0 µg/l (Figure 8). In August 2000 high concentrations were observed over Heceta Bank and around Cape Blanco, and all but two stations west of the shelf break had low chlorophyll *a* (Figure 8). In June 2002 chlorophyll *a* was abundant nearshore north and south of Cape Blanco (Figure 9). In August 2002 Heceta Bank had the highest concentrations, exceeding the normally observed maximum of 20 µg/l (Figure 9). One station had no chlorophyll *a* (0.00 µg/l), because it had converted completely to phaeophytin *a*; whether this was a natural occurrence or caused by sampling or processing error was uncertain. The difference in chlorophyll *a* concentrations between June and August was significant in 2000 (t-test, $p < 0.0001$) but not in 2002 (t-test, $p = 0.5$). The sample variation among all four cruises was highly significant (ANOVA, $p < 0.0001$).

# Biovolumes

Biovolumes of samples were larger in June than in August of 2000 (t-test, $p = 0.8$) and 2002 (t-test, $p < 0.0001$) (Figure 10 and Figure 11). There was a significant difference in biovolumes between all four cruises (ANOVA, $p < 0.0001$). The largest biovolume, 987.80 ml/100 $m^3$, was observed in June 2000 at a nearshore station at lat. 42.3°N (Figure 10). The maximum and mean biovolumes were higher in June than in August (Table 2). In 2000 the larger biovolumes were nearshore and around Cape Blanco (Figure 10). In August 2000 several oceanic stations had a higher biovolume than some shelf stations (Figure 10). In June 2002 larger biovolumes were distributed widely over the shelf and offshore (Figure 11). In August 2002 some of the offshore stations had larger biovolumes than those over the shelf, and biovolumes generally were lower over the northern part of Heceta Bank than elsewhere (Figure 11).

# Mesozooplankton Abundance

A total of 347 samples were collected, 144 taxa were identified, and 38,325 specimens were enumerated (Table 3). Samples were taken from 81 stations in June 2000, 77 stations in August 2000, 98 stations in June 2002, and 91 stations in August 2002. Of these samples, 10 in June 2000, 4 in August 2000, 12 in June 2002, and 4 in August 2002 were collected at night. Total concentrations were 1,629.91/100 $m^3$ in June 2000, 1,466.64/100 $m^3$ in August 2000, 16,057.94/100 $m^3$ in June 2002, and 3,267.49/100 $m^3$ in August 2002. The difference in concentrations between June and August was not significant in 2000 (t-test, $p = 0.5$), but it was significant in 2002 (t-test, $p = 0.0067$). Interannual variations were highly significant (ANOVA, $p < 0.0001$).

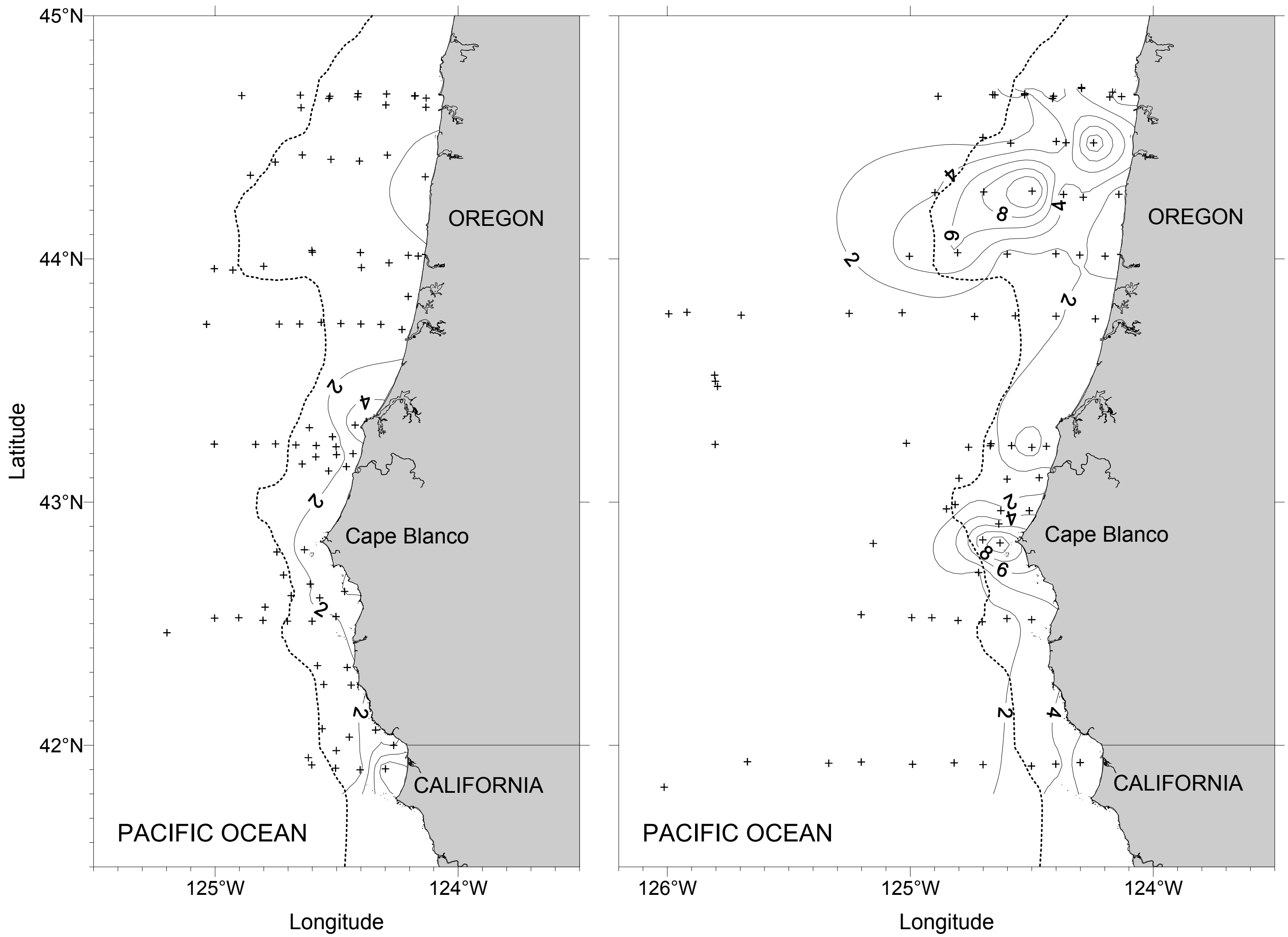


Figure 8. Chlorophyll *a* (µg/l) at 3-m depth in June (left) and August (right) 2000. Contour labels are oriented in an uphill direction. Plus signs are locations of chlorophyll *a* sample collections. The dotted line is the 200-m depth contour.

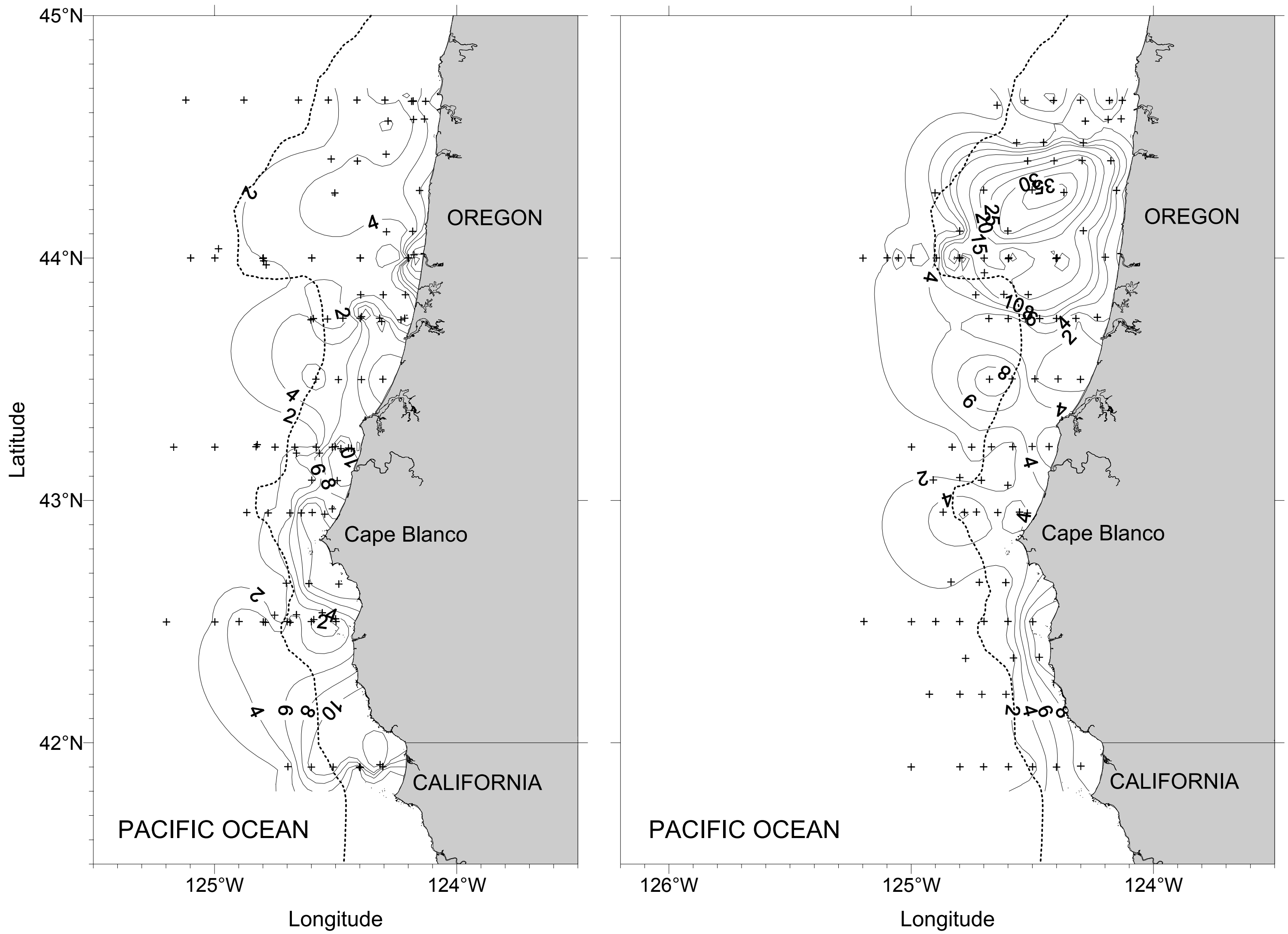


Figure 9. Chlorophyll *a* (µg/l) at 3-m depth in June (left) and August (right) 2002. Contour labels are oriented in an uphill direction. Plus signs are locations of chlorophyll *a* sample collections. The dotted line is the 200-m depth contour.

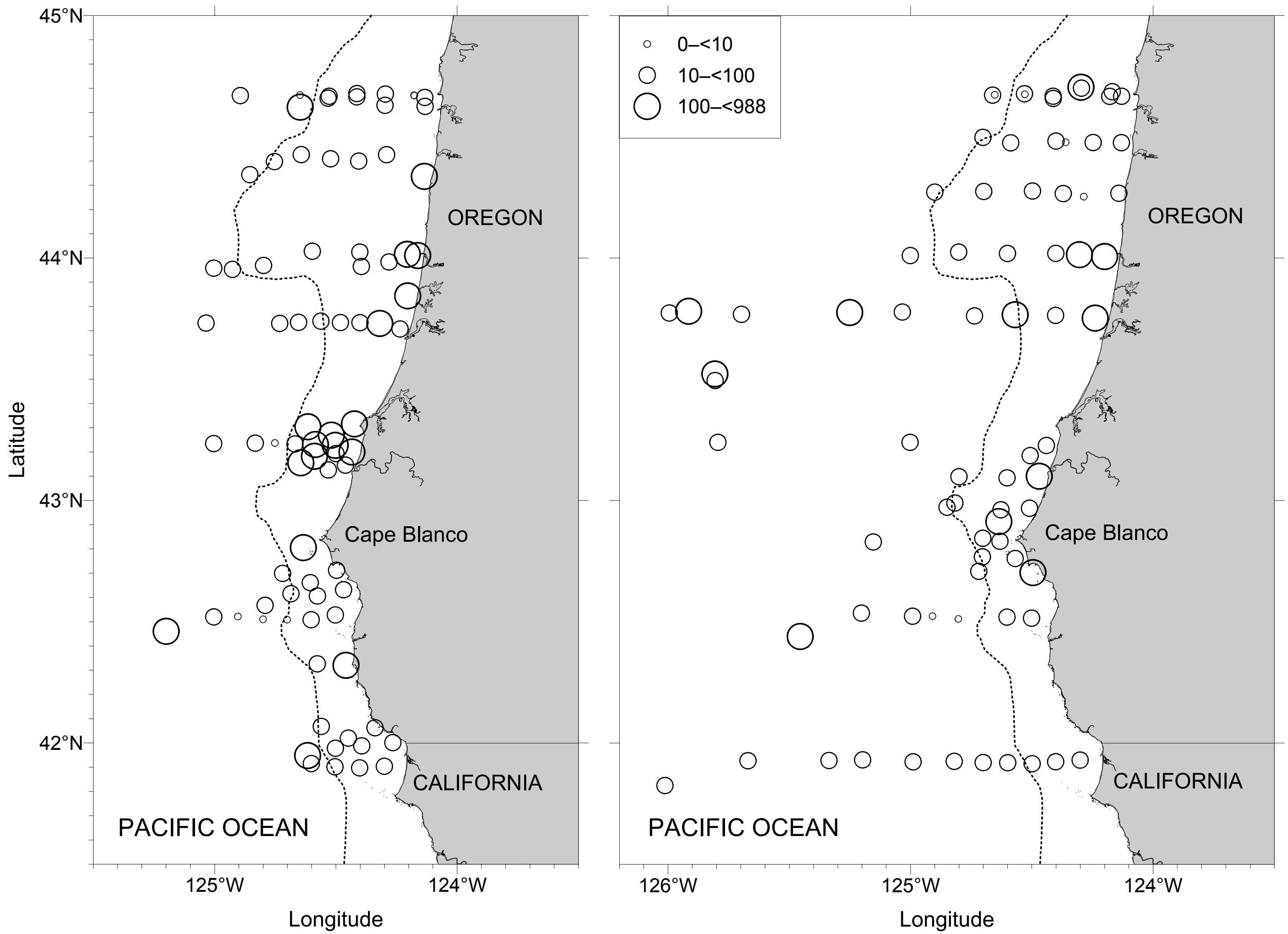


Figure 10. Biovolumes (ml/100 m$^3$) of neuston samples in June (left) and August (right) 2000. The dotted line is the 200-m depth contour.

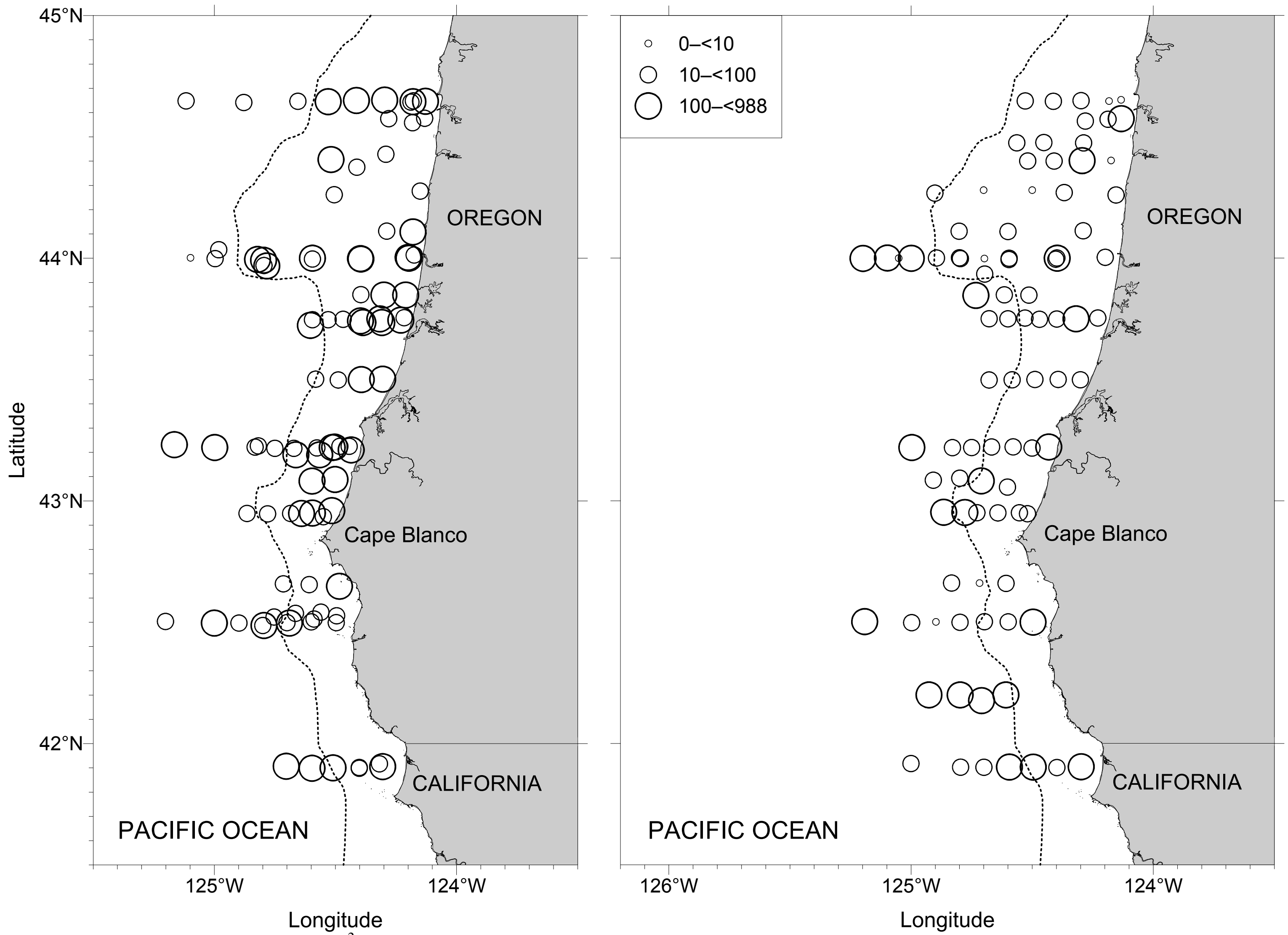


Figure 11. Biovolumes (ml/100 $m^3$) of neuston samples in June (left) and August (right) 2002. The dotted line is the 200-m depth contour.

Table 2. Biovolumes (ml/100 m$^3$) of neustonic mesozooplankton samples in June and August 2000 and 2002. SD = standard deviation.

| Cruise | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|
| June 2000 | 4.65 | 987.80 | 96.69 | 153.29 |
| August 2000 | 1.46 | 342.57 | 62.03 | 71.04 |
| June 2002 | 9.77 | 685.98 | 124.06 | 104.71 |
| August 2002 | 0.14 | 400.80 | 69.77 | 67.56 |

In June 2000 decapods comprised 49.4% of the neustonic mesozooplankton taxa, followed by amphipods (31.3%). Dungeness crab megalopae and Oregon cancer (*C. oregonensis*) and red rock crab (*C. productus*) megalopae[2] dominated the decapods, while *Lycaea pulex*, *Vibilia australis*, *Themisto pacifica,* and *Hyperoche medusarum* were the primary amphipods (Figure 12). The eight most abundant taxa comprised 90% of the total concentration (Table 3). Sample concentrations were higher nearshore than near the shelf break (Figure 13). Six stations beyond the shelf break had higher abundance than those around the shelf break (Figure 13). Three samples had no mesozooplankton.

In August 2000 euphausiids were 27.4% of the taxa, followed by decapods (26.7%) and amphipods (21.3%) (Figure 12). Pacific krill (*Euphausia pacifica*) and *Thysanoessa spinifera* dominated the euphausiids, and Dungeness crab megalopae and Oregon cancer and red rock crab megalopae dominated the decapods. *Themisto pacifica* was the most abundant amphipod, followed by *Hyperoche medusarum* (Table 3). Stations around Cape Blanco, in the northern part of the survey area, and far offshore had somewhat more mesozooplankton than elsewhere (Figure 13). Ten stations did not contain neustonic specimens in the greater than or equal to 5-mm size fraction.

In June 2002 decapods were 64.1% of the taxa, followed by euphausiids (26.6%) (Figure 12). Dungeness crab megalopae, *T. spinifera*, then Oregon cancer and red rock crab megalopae dominated and comprised 87.5% of the total concentration (Table 3). All samples had mesozooplankton.

In August 2002 chaetognaths were 38.5% of the taxa, followed by decapods (29.4%) and amphipods (16.9%) (Figure 12). *Sagitta* spp. were the primary chaetognaths. Dungeness crab megalopae and Oregon cancer and red rock crab megalopae were the most abundant decapods. *Hyperoche medusarum* was the most abundant amphipod. The 10 most abundant taxa comprised 91.0% of total concentration (Table 4). Sample concentration was lower in the northern part of the survey area and moderate over Heceta Bank and over the shelf south to Cape Blanco (Figure 14). Four samples had no neustonic mesozooplankton.

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[2] Megalopae of Oregon cancer crab and red rock crab are not distinguishable because morphological characteristics are similar.

Table 3. Frequency of occurrence (FO), mean concentration (Mean, no./100 m$^3$), and standard deviation (SD, no./100 m$^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common name | Scientific name[a] | F0 (n=81) | Mean | SD | F0 (n=77) | Mean | SD | F0 (n=98) | Mean | SD | F0 (n=91) | Mean | SD |
| Segmented worm | Annelida | | | | | | | | | | | | |
| Bristle worm | Polychaeta | | | | | | | | | | | | |
| | Alciopidae (unidentified) | — | — | — | — | — | — | 2 | 0.54 | 0.02 | — | — | — |
| | *Autolytus* sp. | — | — | — | — | — | — | 3 | 0.76 | 0.46 | — | — | — |
| | *Nereis* sp. | — | — | — | 2 | 1.30 | 1.21 | — | — | — | — | — | — |
| | Syllidae (unidentified) | — | — | — | — | — | — | 1 | 0.56 | — | — | — | — |
| | *Tomopteris* sp. | — | — | — | 2 | 7.55 | 9.17 | 21 | 2.64 | 3.50 | 5 | 4.32 | 4.65 |
| | *Travisiopsis* sp. | — | — | — | — | — | — | 1 | 0.67 | — | 1 | 0.74 | — |
| Mollusc | Mollusca | | | | | | | | | | | | |
| Gastropod | Gastropoda | | | | | | | | | | | | |
| Pyramid clio sea butterfly | *Clio pyramidata* | — | — | — | 3 | 1.42 | 1.19 | 1 | 10.05 | — | — | — | — |
| Clio sea butterfly | *Clio* sp. | — | — | — | 3 | 2.25 | 0.93 | — | — | — | — | — | — |
| Sea butterfly | Clionidae (unidentified) | 1 | 0.47 | — | — | — | — | 3 | 0.61 | 0.07 | 4 | 2.91 | 3.73 |
| Sea slug | *Dendronotus* sp. | — | — | — | 1 | 5.20 | — | — | — | — | — | — | — |
| Nudibranch | Eolidoidea (unidentified) | — | — | — | 1 | 0.54 | — | — | — | — | — | — | — |
| Naked pteropod | Gymnosomata (unidentified) | — | — | — | — | — | — | — | — | — | 1 | 0.55 | — |
| Octopus, squid | Cephalopoda | | | | | | | | | | | | |
| | *Chiroteuthis* sp. | — | — | — | 1 | 0.38 | — | — | — | — | 1 | 1.98 | — |
| Market squid | *Loligo opalescens* | — | — | — | — | — | — | — | — | — | 1 | 1.40 | — |
| Arthropod | Arthropoda | | | | | | | | | | | | |
| Crustacean | Crustacea | | | | | | | | | | | | |
| Copepod | Copepoda | | | | | | | | | | | | |
| Parasitic copepod | Copepoda (unidentified parasitic) | — | — | — | — | — | — | 1 | 0.65 | — | — | — | — |
| | *Eucalanus* sp. | — | — | — | 1 | 0.49 | — | 32 | 5.75 | 12.85 | 25 | 8.19 | 10.06 |
| | *Euchaeta* spp. | — | — | — | 2 | 1.26 | 1.25 | — | — | — | — | — | — |
| | *Neocalanus cristatus* | — | — | — | — | — | — | 10 | 12.76 | 21.37 | 7 | 3.60 | 4.05 |
| | *Neocalanus plumchrus* | — | — | — | — | — | — | 5 | 1.31 | 0.71 | 1 | 0.69 | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 $m^3$), and standard deviation (SD, no./100 $m^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name**[a] | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| Cumacean | Cumacea | | | | | | | | | | | | |
| | *Diastylopsis* sp. | — | — | — | — | — | — | 1 | 2.07 | — | — | — | — |
| | *Hemilamprops* spp. | — | — | — | — | — | — | 2 | 9.61 | 5.79 | — | — | — |
| | *Oxyurostylis* sp. | — | — | — | — | — | — | 1 | 0.69 | — | — | — | — |
| Opossum shrimp | Mysida | | | | | | | | | | | | |
| | *Alienacanthomysis macropsis* | 3 | 0.71 | 0.52 | 1 | 11.47 | — | 3 | 0.92 | 0.32 | 1 | 0.56 | — |
| | *Archaeomysis grebnitzkii* | 1 | 0.43 | — | 1 | 4.47 | — | — | — | — | — | — | — |
| | *Neomysis kadiakensis* | — | — | — | 1 | 1.56 | — | — | — | — | 1 | 0.45 | — |
| | *Pacifacanthomysis nephrophthalma* | — | — | — | — | — | — | — | — | — | 1 | 0.79 | — |
| Pill bug | Isopoda | | | | | | | | | | | | |
| | *Acanthamunnopsis milleri* | — | — | — | — | — | — | — | — | — | 1 | 0.56 | — |
| | *Excirolana linguifrons* | — | — | — | 1 | 0.45 | — | — | — | — | — | — | — |
| | *Idotea fewkesi* | 10 | 2.74 | 2.80 | 5 | 1.09 | 0.68 | 2 | 1.55 | 0.16 | — | — | — |
| | *Idotea rufescens* | — | — | — | 2 | 1.03 | 0.83 | — | — | — | — | — | — |
| Eelgrass isopod | *Pentidotea resecata* | 1 | 0.43 | — | — | — | — | — | — | — | — | — | — |
| Vosnesensky's isopod | *Pentidotea wosnesenskii* | 1 | 0.40 | — | 2 | 0.76 | 0.45 | 1 | 0.60 | — | — | — | — |
| Amphipod | Amphipoda | | | | | | | | | | | | |
| Gammarid | Gammaridea | | | | | | | | | | | | |
| | *Allorchestes angusta* | 8 | 0.76 | 0.64 | 4 | 0.58 | 0.34 | 7 | 1.22 | 0.83 | 2 | 1.20 | 0.92 |
| | *Ampithoe* sp. | — | — | — | — | — | — | 1 | 0.53 | — | — | — | — |
| | *Aruga oculata* | — | — | — | 1 | 0.45 | — | — | — | — | — | — | — |
| | *Atylus tridens* | 3 | 0.40 | 0.03 | 18 | 2.66 | 4.19 | 8 | 1.33 | 1.00 | 1 | 0.66 | — |
| | *Calliopius* cf *C. columbianus* | 1 | 0.40 | — | 2 | 8.02 | 10.71 | 14 | 2.79 | 4.78 | 4 | 0.55 | 0.14 |
| | *Eobrolgus chumashi* | — | — | — | — | — | — | — | — | — | 2 | 84.97 | 116.13 |
| | *Eogammarus confervicolus* | 1 | 0.40 | — | — | — | — | — | — | — | — | — | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 m$^3$), and standard deviation (SD, no./100 m$^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name**[a] | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| | Gammaridea continued | | | | | | | | | | | | |
| | *Gnathopleustes simplex* | 1 | 0.46 | — | — | — | — | — | — | — | — | — | — |
| | *Heterophoxus* sp. | — | — | — | — | — | — | 1 | 1.26 | — | — | — | — |
| | *Hyale anceps* | — | — | — | — | — | — | 1 | 0.54 | — | — | — | — |
| | *Hyale frequens* | 5 | 0.45 | 0.02 | 10 | 2.50 | 3.45 | 1 | 0.57 | — | — | — | — |
| | *Microjassa* sp. | — | — | — | 1 | 0.46 | — | — | — | — | — | — | — |
| | *Monoculodes* sp. | — | — | — | — | — | — | 1 | 0.63 | — | — | — | — |
| | *Peramphithoe humeralis* | 1 | 0.47 | — | 4 | 2.76 | 2.73 | — | — | — | — | — | — |
| Hyperiid | Hyperiidea | | | | | | | | | | | | |
| | *Brachyscelus crusculum* | 11 | 0.69 | — | — | — | — | 1 | 0.56 | — | — | — | — |
| | *Hyperia medusarum* | 5 | 0.57 | 0.25 | 6 | 2.60 | 3.92 | 6 | 1.57 | 1.02 | 11 | 3.80 | 4.85 |
| | *Hyperoche medusarum* | 22 | 1.48 | 1.28 | 28 | 1.77 | 1.94 | 42 | 4.90 | 9.55 | 58 | 3.82 | 5.63 |
| | *Lycaea pulex* | 25 | 11.35 | 45.29 | — | — | — | — | — | — | — | — | — |
| | *Paraphronima crassipes* | — | — | — | 1 | 0.44 | — | — | — | — | — | — | — |
| | *Primno brevidens* | — | — | — | 1 | 0.66 | — | — | — | — | — | — | — |
| | *Primno macropa* | — | — | — | — | — | — | 1 | 0.59 | — | — | — | — |
| | *Streetsia challengeri* | — | — | — | — | — | — | — | — | — | 1 | 0.60 | — |
| | *Themisto pacifica* | 6 | 10.14 | 22.24 | 10 | 13.27 | 20.02 | 10 | 4.20 | 4.94 | 10 | 9.55 | 27.02 |
| | *Tryphana malmi* | 4 | 1.38 | 1.15 | — | — | — | 8 | 2.16 | 2.50 | 6 | 1.83 | 2.32 |
| | *Vibilia australis* | 18 | 6.20 | 19.40 | — | — | — | — | — | — | — | — | — |
| | Hyperiidea (unidentified) | 2 | 0.41 | 0.01 | 1 | 0.38 | — | — | — | — | — | — | — |
| Skeleton shrimp | Caprellidea | | | | | | | | | | | | |
| | *Caprella ferrea* | 1 | 0.46 | — | — | — | — | — | — | — | — | — | — |
| | *Caprella incisa* | — | — | — | 1 | 10.40 | — | — | — | — | — | — | — |
| | Caprellidea (unidentified) | — | — | — | 1 | 0.54 | — | — | — | — | — | — | — |
| Krill | Euphausiacea | | | | | | | | | | | | |
| Pacific krill | *Euphausia pacifica* | 30 | 1.69 | 2.13 | 24 | 10.34 | 33.44 | 22 | 11.14 | 25.48 | 16 | 3.60 | 6.11 |
| | *Thysanoessa inspinata* | 1 | 1.31 | — | 1 | 0.46 | — | — | — | — | 1 | 3.53 | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 $m^3$), and standard deviation (SD, no./100 $m^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name**[a] | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| | Euphausiacea continued | | | | | | | | | | | | |
| | *Thysanoessa raschii* | — | — | — | — | — | — | — | — | — | 1 | 0.57 | — |
| | *Thysanoessa spinifera* | 13 | 1.17 | 1.72 | 17 | 9.07 | 20.04 | 40 | 100.79 | 587.84 | 39 | 3.28 | 6.65 |
| Crab, lobster, prawn, shrimp | Decapoda | | | | | | | | | | | | |
| Hermit crab, sand crab, mole crab, porcelain crab, squat lobster, stone crab | Anomura | | | | | | | | | | | | |
| Tubeworm hermit crab | *Discorsopagurus schmitti* | — | — | — | — | — | — | 6 | 0.95 | 0.99 | — | — | — |
| Pacific sand crab | *Emerita analoga* | — | — | — | — | — | — | 1 | 0.94 | — | — | — | — |
| Alaskan hermit crab | *Pagurus ochotensis* | 1 | 0.43 | — | 1 | 0.52 | — | 2 | 1.17 | 0.96 | 3 | 0.73 | 0.23 |
| | *Pagurus* sp. C [*sensu* Lough 1975)] | — | — | — | — | — | — | 2 | 1.37 | 0.86 | 1 | 0.79 | — |
| True crab | Brachyura | | | | | | | | | | | | |
| Pacific rock crab and graceful crab | *Cancer antennarius* and *C. gracilis* | — | — | — | — | — | — | 7 | 2.37 | 1.60 | 6 | 1.60 | 1.60 |
| Dungeness crab | *Cancer magister* | 34 | 14.47 | 29.24 | 13 | 16.97 | 31.04 | 67 | 116.58 | 357.27 | 37 | 15.79 | 37.52 |
| Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 27 | 11.26 | 25.39 | 7 | 18.79 | 40.85 | 34 | 64.98 | 155.78 | 12 | 27.57 | 77.26 |
| Cancrid crab | *Cancer* sp. | 1 | 0.47 | — | — | — | — | 4 | 0.73 | 0.17 | 1 | 1.29 | — |
| Grooved mussel crab | *Fabia subquadrata* | — | — | — | — | — | — | 6 | 6.27 | 7.06 | — | — | — |
| Purple shore crab | *Hemigrapsus nudus* | 1 | 0.40 | — | — | — | — | — | — | — | — | — | — |
| Shrimp | Caridea | | | | | | | | | | | | |
| Snapping shrimp | Alpheidae (unidentified) | — | — | — | 2 | 0.75 | 0.32 | — | — | — | — | — | — |
| Crangon shrimp | *Crangon* sp. | — | — | — | — | — | — | — | — | — | 1 | 0.65 | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 $m^3$), and standard deviation (SD, no./100 $m^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name**[a] | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| | Caridea continued | | | | | | | | | | | | |
| Sand shrimp, bay shrimp | Crangonidae (unidentified) | — | — | — | — | — | — | 10 | 6.02 | 14.14 | 4 | 0.97 | 0.50 |
| | Crangonidae sp. A[b] | 1 | 3.92 | — | 2 | 0.48 | 0.05 | 8 | 2.45 | 2.82 | 3 | 0.90 | 0.42 |
| Broken-back shrimp | Hippolytidae (unidentified) | 3 | 1.19 | 0.74 | 5 | 7.67 | 16.11 | 12 | 7.85 | 11.97 | 5 | 1.86 | 0.91 |
| | *Pandalus* spp. | — | — | — | — | — | — | 6 | 1.42 | 1.25 | — | — | — |
| Ghost shrimp, mud shrimp, sponge shrimp | Thalassinidea | | | | | | | | | | | | |
| Ghost shrimp | *Neotrypaea californiensis* | — | — | — | — | — | — | 7 | 2.30 | 1.81 | 2 | 0.72 | 0.10 |
| | Sergestoidea | | | | | | | | | | | | |
| | Sergestidae (unidentified) | — | — | — | — | — | — | — | — | — | 1 | 1.29 | — |
| Insect | Insecta | | | | | | | | | | | | |
| Beetle, weevil | Coleoptera (unidentified) | 4 | 0.41 | 0.03 | 5 | 0.80 | 0.76 | 3 | 0.77 | 0.27 | 2 | 0.68 | 0.03 |
| True fly | Diptera (unidentified) | 12 | 0.86 | 0.71 | 3 | 0.52 | 0.06 | 11 | 1.13 | 1.24 | 5 | 0.96 | 0.60 |
| True bug | Hemiptera (unidentified) | 1 | 0.40 | — | 3 | 0.46 | 0.07 | 1 | 0.68 | — | 1 | 0.64 | — |
| Cicada, leafhopper, aphid | Homoptera (unidentified) | 1 | 0.40 | — | 1 | 0.46 | — | — | — | — | — | — | — |
| Ant, bee, wasp, sawfly | Hymenoptera (unidentified) | 1 | 0.37 | — | 3 | 0.68 | 0.35 | 1 | 2.04 | — | 2 | 0.61 | 0.00 |
| Butterfly, moth | Lepidoptera (unidentified) | — | — | — | 2 | 0.49 | 0.07 | 5 | 0.72 | 0.20 | 2 | 0.50 | 0.11 |
| Lacewing, ant lion, mantispid, etc. | Neuroptera (unidentified) | 8 | 1.01 | 0.92 | — | — | — | 12 | 1.49 | 1.35 | 4 | 1.77 | 2.34 |
| Dragonfly, damselfly | Odonata (unidentified) | — | — | — | 1 | 0.51 | — | — | — | — | — | — | — |
| Stonefly | Plecoptera (unidentified) | — | — | — | 1 | 0.46 | — | — | — | — | — | — | — |
| Caddis fly, water moth | Trichoptera (unidentified) | 1 | 0.37 | — | — | — | — | — | — | — | — | — | — |
| | Insecta (unidentified) | 1 | 0.42 | — | — | — | — | — | — | — | — | — | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 m$^3$), and standard deviation (SD, no./100 m$^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name[a]** | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| Arrowworm | Chaetognatha | | | | | | | | | | | | |
| | *Eukrohnia* sp. | — | — | — | — | — | — | 10 | 3.32 | 6.65 | 9 | 7.70 | 11.61 |
| | *Sagitta elegans* | 1 | 108.91 | — | 7 | 1.22 | 1.77 | — | — | — | — | — | — |
| | *Sagitta euneritica* | — | — | — | 3 | 36.54 | 61.98 | — | — | — | — | — | — |
| | *Sagitta minima* | | 0.42 | — | 1 | 66.53 | — | — | — | — | — | — | — |
| | *Sagitta scrippsae* | — | — | — | 4 | 1.31 | 0.52 | — | — | — | — | — | — |
| | *Sagitta* spp. | — | — | — | — | — | — | 57 | 8.87 | 16.39 | 51 | 15.24 | 31.64 |
| | Chaetognatha (unidentified) | — | — | — | 1 | 0.52 | — | 13 | 5.47 | 6.57 | 20 | 19.72 | 39.74 |
| Chordate | Chordata | | | | | | | | | | | | |
| Bony fish | Osteichthyes | | | | | | | | | | | | |
| Poacher | Agonidae | | | | | | | | | | | | |
| Blacktip poacher | *Xeneretmus latifrons* | — | — | — | — | — | — | 1 | 0.62 | — | — | — | — |
| Sand lance | Ammodytidae | | | | | | | | | | | | |
| Pacific sand lance | *Ammodytes hexapterus* | — | — | — | — | — | — | 5 | 2.28 | 2.80 | — | — | — |
| Sablefish | Anoplopomatidae | | | | | | | | | | | | |
| Sablefish | *Anoplopoma fimbria* | — | — | — | — | — | — | 2 | 0.56 | 0.07 | — | — | — |
| Ronquil | Bathymasteridae | | | | | | | | | | | | |
| Ronquil | *Bathymaster* sp. | — | — | — | — | — | — | 1 | 1.26 | — | — | — | — |
| Northern ronquil | *Ronquilus jordani* | — | — | — | — | — | — | 2 | 0.83 | 0.42 | — | — | — |
| Brotula | Bythitidae | | | | | | | | | | | | |
| Red brotula | *Brosmophycis marginata* | — | — | — | — | — | — | 2 | 1.55 | 1.55 | 2 | 0.73 | 0.00 |
| Clupeid | Clupeidae | | | | | | | | | | | | |
| Pacific herring | *Clupea pallasii* | — | — | — | 9 | 0.68 | 0.43 | 1 | 0.63 | — | — | — | — |
| | Clupeidae (unidentified) | — | — | — | — | — | — | 1 | 0.63 | — | — | — | — |
| Sculpin | Cottidae | | | | | | | | | | | | |
| Padded sculpin | *Artedius fenestralis* | — | — | — | — | — | — | 1 | 1.26 | — | — | — | — |
| Calico sculpin | *Clinocottus embryum* | 1 | 0.43 | — | — | — | — | — | — | — | — | — | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 $m^3$), and standard deviation (SD, no./100 $m^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name**[a] | **F0 (n=81)** | **Mean** | **SD** | **F0 (n=77)** | **Mean** | **SD** | **F0 (n=98)** | **Mean** | **SD** | **F0 (n=91)** | **Mean** | **SD** |
| | Cottidae continued | | | | | | | | | | | | |
| Coastrange sculpin | *Cottus aleuticus* | — | — | — | — | — | — | 1 | 0.63 | — | — | — | — |
| Brown Irish lord | *Hemilepidotus spinosus* | 1 | 0.47 | — | — | — | — | 7 | 1.28 | 0.90 | — | — | — |
| Slim sculpin | *Radulinus asprellus* | 1 | 0.47 | — | — | — | — | — | — | — | — | — | — |
| Puget Sound sculpin | *Ruscarius meanyi* | — | — | — | — | — | — | 3 | 1.57 | 0.85 | — | — | — |
| Cabezon | *Scorpaenichthys marmoratus* | 1 | 0.69 | — | 2 | 0.47 | 0.08 | 9 | 1.38 | 1.95 | 1 | 0.49 | — |
| Anchovy | Engraulidae | | | | | | | | | | | | |
| Northern anchovy | *Engraulis mordax* | — | — | — | — | — | — | 3 | 0.61 | 0.17 | 1 | 0.55 | — |
| Cod, haddock | Gadidae | | | | | | | | | | | | |
| Pacific tomcod | *Microgadus proximus* | — | — | — | — | — | — | 2 | 0.78 | 0.44 | — | — | — |
| Stickleback | Gasterosteidae | | | | | | | | | | | | |
| Threespine stickleback | *Gasterosteus aculeatus* | — | — | — | — | — | — | — | — | — | 1 | 0.62 | — |
| Greenling | Hexagrammidae | | | | | | | | | | | | |
| Kelp greenling | *Hexagrammos decagrammus* | 1 | 0.39 | — | — | — | — | 2 | 1.85 | 1.85 | — | — | — |
| Lingcod | *Ophiodon elongatus* | — | — | — | — | — | — | 1 | 0.56 | — | — | — | — |
| Snailfish | Liparidae | | | | | | | | | | | | |
| Slimy snailfish | *Liparis mucosus* | — | — | — | — | — | — | 1 | 0.63 | — | — | — | — |
| Lanternfish | Myctophidae | | | | | | | | | | | | |
| Northern lampfish | *Stenobrachius leucopsarus* | — | — | — | — | — | — | 2 | 0.52 | 0.03 | 3 | 1.02 | 0.64 |
| Blue lanternfish | *Tarletonbeania crenularis* | 1 | 0.69 | — | 5 | 4.56 | 3.40 | — | — | — | — | — | — |
| | Myctophidae (unidentified) | 1 | 0.45 | — | — | — | — | — | — | — | — | — | — |
| Smelt | Osmeridae (unidentified) | 1 | 0.43 | — | 1 | 2.16 | — | 7 | 1.06 | 1.22 | 3 | 1.82 | 1.96 |
| Barracudina | Paralepididae | | | | | | | | | | | | |
| Slender barracudina | *Lestidiops ringens* | — | — | — | 1 | 0.42 | — | — | — | — | — | — | — |

Table 3 continued. Frequency of occurrence (FO), mean concentration (Mean, no./100 m$^3$), and standard deviation (SD, no./100 m$^3$) of taxa present in samples from June and August 2000 and 2002.

| | | June 2000 | | | August 2000 | | | June 2002 | | | August 2002 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common name | Scientific name[a] | F0 (n=81) | Mean | SD | F0 (n=77) | Mean | SD | F0 (n=98) | Mean | SD | F0 (n=91) | Mean | SD |
| Righteye flounder | Pleuronectidae | | | | | | | | | | | | |
| Rex sole | *Glyptocephalus zachirus* | — | — | — | — | — | — | 2 | 0.72 | 0.31 | — | — | — |
| Starry flounder | *Platichthys stellatus* | — | — | — | — | — | — | 1 | 0.56 | — | — | — | — |
| Sand sole | *Psettichthys melanostictus* | 1 | 0.43 | — | — | — | — | 1 | 0.60 | — | — | — | — |
| Fathead | Psychrolutidae | | | | | | | | | | | | |
| Blob sculpin | *Psychrolutes phrictus* | — | — | — | — | — | — | — | — | — | 1 | 0.59 | — |
| Saury | Scomberesocidae | | | | | | | | | | | | |
| Pacific saury | *Cololabis saira* | 28 | 2.79 | 3.30 | 17 | 1.67 | 2.43 | — | — | — | — | — | — |
| Scorpionfish | Scorpaenidae | | | | | | | | | | | | |
| Pacific ocean perch | *Sebastes alutus* | — | — | — | 1 | 1.08 | — | — | — | — | — | — | — |
| Splitnose rockfish | *Sebastes diploproa* | — | — | — | 3 | 4.66 | 1.37 | — | — | — | — | — | — |
| Yellowtail rockfish | *Sebastes flavidus* | 1 | 0.69 | — | — | — | — | 2 | 1.31 | 0.83 | 1 | 0.73 | — |
| Shortbelly rockfish | *Sebastes jordani* | — | — | — | — | — | — | 1 | 0.62 | — | — | — | — |
| Canary rockfish | *Sebastes pinniger* | — | — | — | — | — | — | 1 | 0.50 | — | 1 | 1.94 | — |
| Bank rockfish | *Sebastes rufus* | 1 | 0.50 | — | 1 | 0.33 | — | 2 | 0.49 | 0.00 | — | — | — |
| Sharpchin rockfish | *Sebastes zacentrus* | — | — | — | 4 | 1.79 | 1.72 | — | — | — | — | — | — |
| Rockfish | *Sebastes* spp. | — | — | — | — | — | — | 4 | 0.62 | 0.17 | — | — | — |
| Prickleback | Stichaeidae | | | | | | | | | | | | |
| High cockscomb | *Anoplarchus purpurescens* | — | — | — | — | — | — | 1 | 0.45 | — | — | — | — |
| | Stichaeidae (unidentified) | — | — | — | — | — | — | 2 | 0.59 | 0.07 | — | — | — |
| | Osteichthyes (unidentified) | — | — | — | 2 | 0.54 | 0.12 | 1 | 0.60 | — | 1 | 0.45 | — |

[a] Indentation patterns do not follow strict taxonomic classification. Taxonomic levels are indented to indicate a subcategory that is identified with a commonly recognizable scientific name. Within the lowest subcategories, species and other taxa with data are indented the same. This resulted in species not being indented the same between high taxonomic levels such as phyla.

[b] A distinct single species in the family Crangonidae that could not be identified to genus or species with the available taxonomic keys. Crangonidae (unidentified) has one or more unidentified species and does not include Crangonidae sp. A.

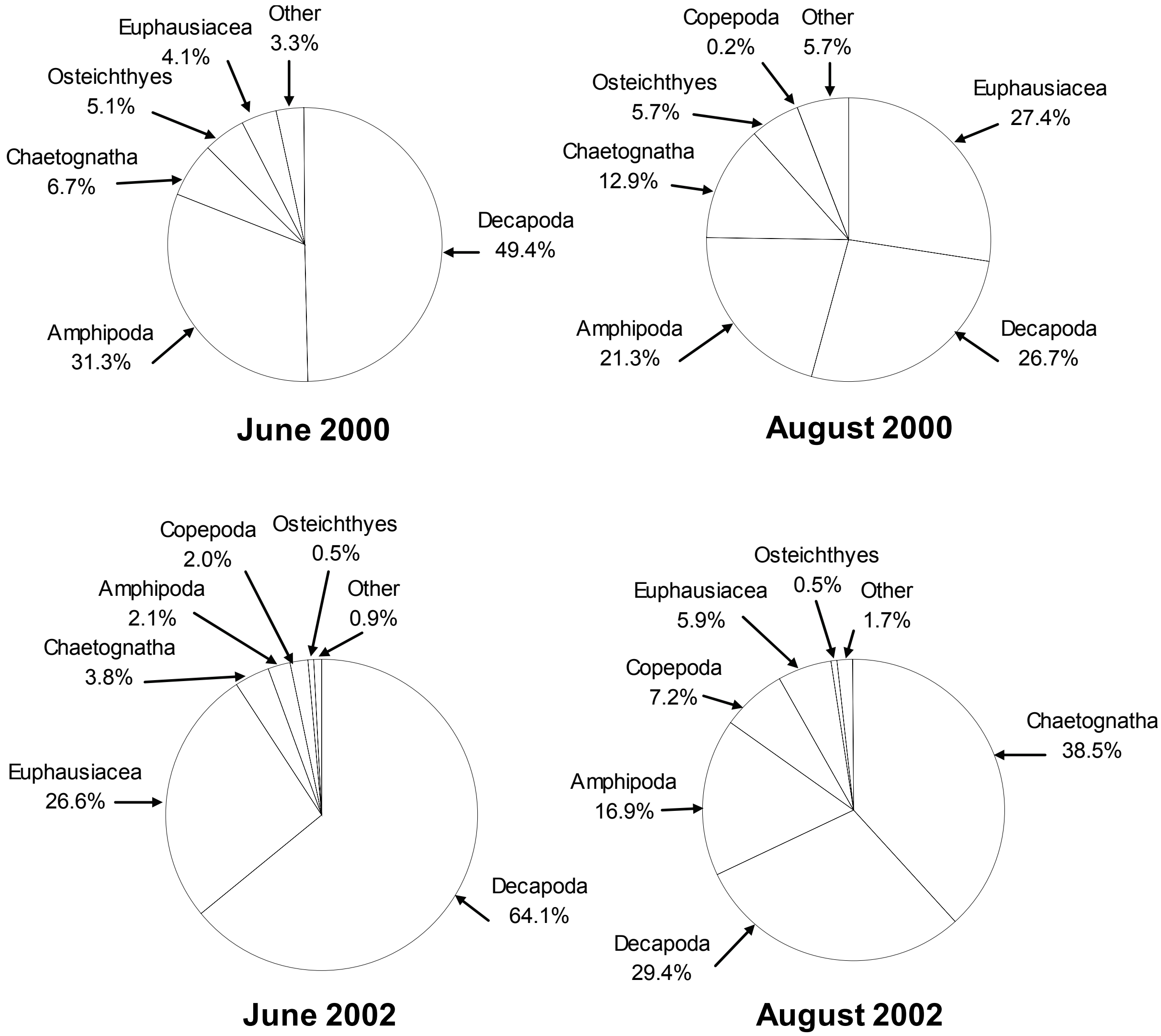


Figure 12. Composition of major neustonic mesozooplankton taxonomic groups collected during four cruises.

## Copepoda

Copepods comprised 0.2% of total abundance in August 2000, 2.0% in June 2002, and 7.2% in August 2002 (Figure 12). No copepods greater than or equal to 5 mm were in any June 2000 samples. *Eucalanus* sp. and *Neocalanus cristatus* were more abundant and occurred more frequently than other copepods (Table 3). *Eucalanus* sp. sample concentration was 0.49/100 $m^3$in August 2000 and ranges were 0.49–69.59/100 $m^3$ (mean = 5.75/100 $m^3$) in June 2002 and 0.45–40.40/100 $m^3$ (mean = 8.19/100 $m^3$) in August 2002. *Neocalanus cristatus* concentration ranges were 0.49–67.52/100 $m^3$ (mean = 12.76/100 $m^3$) in June 2002 and 0.50–11.88/100 $m^3$ (mean = 3.60/100 $m^3$) in August 2002. This species was absent in the 2000 samples.

Table 4. Ten most abundant neustonic mesozooplankton taxa in June and August 2000 and 2002.

| Cruise | Common name | Scientific name | Total concentration (no./100 $m^3$) | Cumulative % of total |
|---|---|---|---|---|
| June 2000 | Dungeness crab | *Cancer magister* | 491.81 | 30.17 |
| | Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 303.93 | 48.82 |
| | | *Lycaea pulex* | 283.71 | 66.23 |
| | | *Vibilia australis* | 111.68 | 73.08 |
| | | *Sagitta elegans* | 108.91 | 79.76 |
| | Pacific saury | *Cololabis saira* | 78.20 | 84.56 |
| | | *Themisto pacifica* | 60.86 | 88.29 |
| | Pacific krill | *Euphausia pacifica* | 50.80 | 91.41 |
| | | *Hyperoche medusarum* | 32.59 | 93.41 |
| | | *Idotea fewkesi* | 27.43 | 95.09 |
| August 2000 | Pacific krill | *Euphausia pacifica* | 248.14 | 16.92 |
| | Dungeness crab | *Cancer magister* | 220.59 | 31.96 |
| | | *Thysanoessa spinifera* | 154.16 | 42.47 |
| | | *Themisto pacifica* | 132.66 | 51.52 |
| | Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 131.56 | 60.49 |
| | | *Sagitta euneritica* | 109.61 | 67.96 |
| | | *Sagitta minima* | 66.53 | 72.50 |
| | | *Hyperoche medusarum* | 49.50 | 75.87 |
| | | *Atylus tridens* | 47.93 | 79.14 |
| | | Hippolytidae (unidentified) | 38.34 | 81.75 |
| June 2002 | Dungeness crab | *Cancer magister* | 7,811.04 | 48.64 |
| | | *Thysanoessa spinifera* | 4,031.59 | 73.75 |
| | Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 2,209.41 | 87.51 |
| | | *Sagitta* spp. | 505.76 | 90.66 |
| | Pacific krill | *Euphausia pacifica* | 245.02 | 92.18 |
| | | *Hyperoche medusarum* | 205.97 | 93.47 |
| | | *Eucalanus* sp. | 183.85 | 94.61 |
| | | *Neocalanus cristatus* | 127.55 | 95.41 |
| | | Hippolytidae (unidentified) | 94.20 | 95.99 |
| | | Chaetognatha (unidentified) | 71.17 | 96.44 |

Table 4 continued. Ten most abundant neustonic mesozooplankton taxa during the June and August 2000 and 2002 cruises.

| Cruise | Common name | Scientific name | Total concentration (no./100 m$^3$) | Cumlative % of total |
|---|---|---|---|---|
| August 2002 | | *Sagitta* spp. | 777.43 | 23.79 |
| | Dungeness crab | *Cancer magister* | 584.06 | 41.67 |
| | | Chaetognatha (unidentified) | 394.45 | 53.74 |
| | Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 330.86 | 63.87 |
| | | *Hyperoche medusarum* | 221.43 | 70.64 |
| | | *Eucalanus* sp. | 204.79 | 76.91 |
| | | *Eobrolgus chumashi* | 169.94 | 82.11 |
| | | *Thysanoessa spinifera* | 127.79 | 86.02 |
| | | *Themisto pacifica* | 95.46 | 88.94 |
| | | *Eukrohnia* sp. | 69.29 | 91.06 |

## Amphipoda

Amphipods were the second largest major taxon in June 2000. Fourteen gammarid and 11 hyperiid species were identified (Table 3). In 2000 and 2002, *Allorchestes angusta*, *Atylus tridens*, and *Calliopius* cf *C. columbianus* were the most common gammarids. *Hyale frequens* was common only in 2000. All but one of the remaining gammarid species occurred once (Table 3). During all four cruises gammarids were caught over the shelf and beyond the shelf break. *Eobrolgus chumashi* was the seventh most abundant gammarid in August 2002, and it was collected from two shelf stations at lat. 43.1°N with concentrations of 167.09 and 2.86/100 m$^3$.

Hyperiids were present in 56% of the June 2000, 48% of the August 2000, 49% of the June 2002, and 66% of the August 2002 samples. *Hyperoche medusarum* and *T. pacifica* were the most abundant hyperiids.

*Hyperoche medusarum* concentration ranges were 0.40–4.67/100 m$^3$ (mean = 1.48/100 m$^3$) in June 2000, 0.42–7.95/100 m$^3$ (mean = 1.77/100 m$^3$) in August 2000, 0.49–44.47/100 m$^3$ (mean = 4.90/100 m$^3$) in June 2002, and 0.46–32.88/100 m$^3$ (mean = 3.82/100 m$^3$) in August 2002 (Table 3). *Hyperoche medusarum* distribution was scattered in 2000 and widespread in 2002 (Figure 15 and Figure 16).

*Themisto pacifica* concentration ranges were 0.47–55.51/100 m$^3$ (mean = 10.14/100 m$^3$) in June 2000, 0.33–54.31/100 m$^3$ (mean = 13.27/100 m$^3$) in August 2000, 0.53–14.54/100 m$^3$ (mean = 4.20/100 m$^3$) in June 2002, and 0.46–86.43/100 m$^3$ (mean = 9.55/100 m$^3$) in August 2002 (Table 3). In 2000 stations with the highest *T. pacifica* concentrations were far offshore, whereas in 2002 they were over the shelf (Figure 17 and Figure 18).

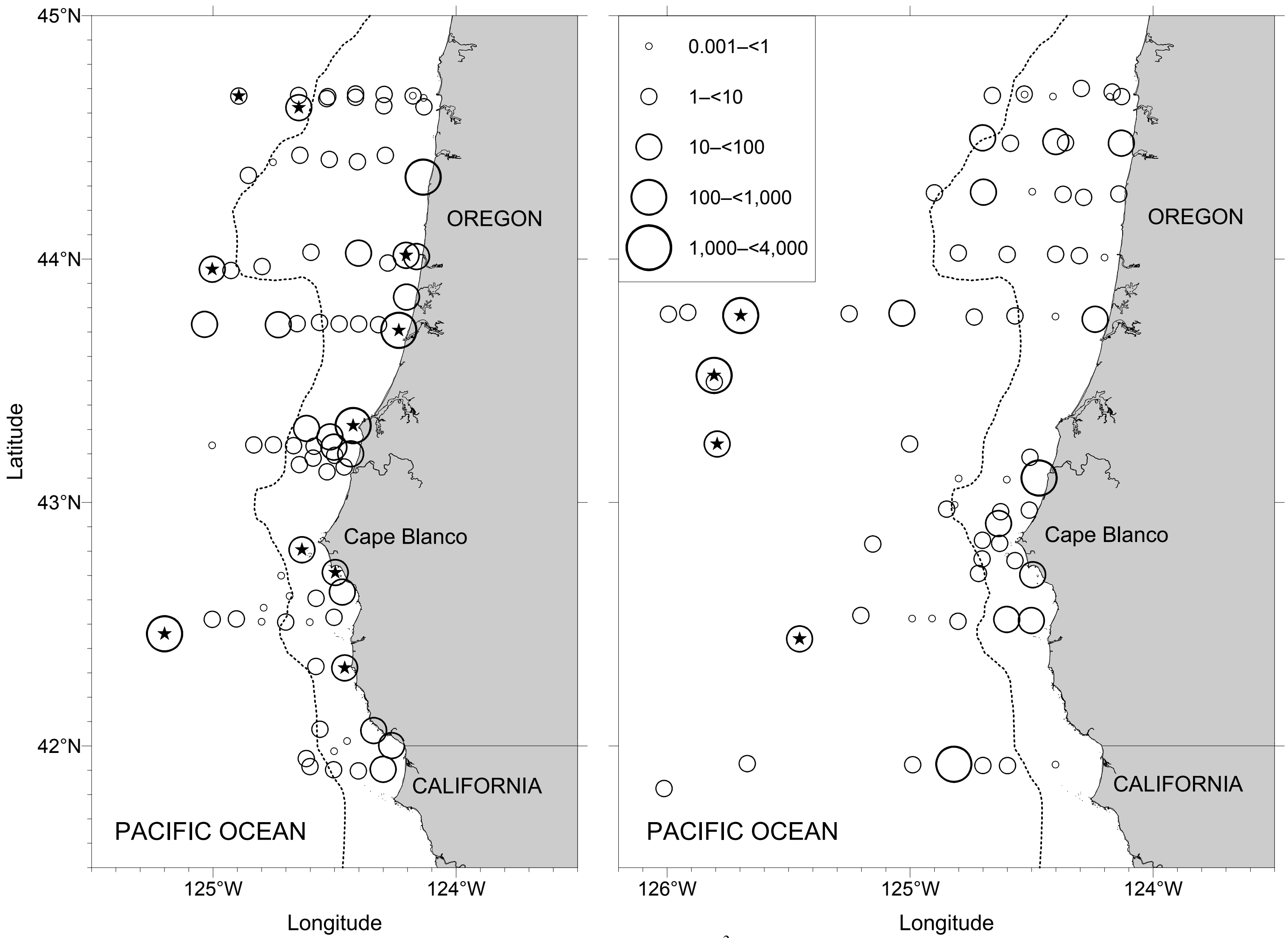


Figure 13. Distribution of neustonic mesozooplankton concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Stars are night samples. The dotted line is the 200-m depth contour.

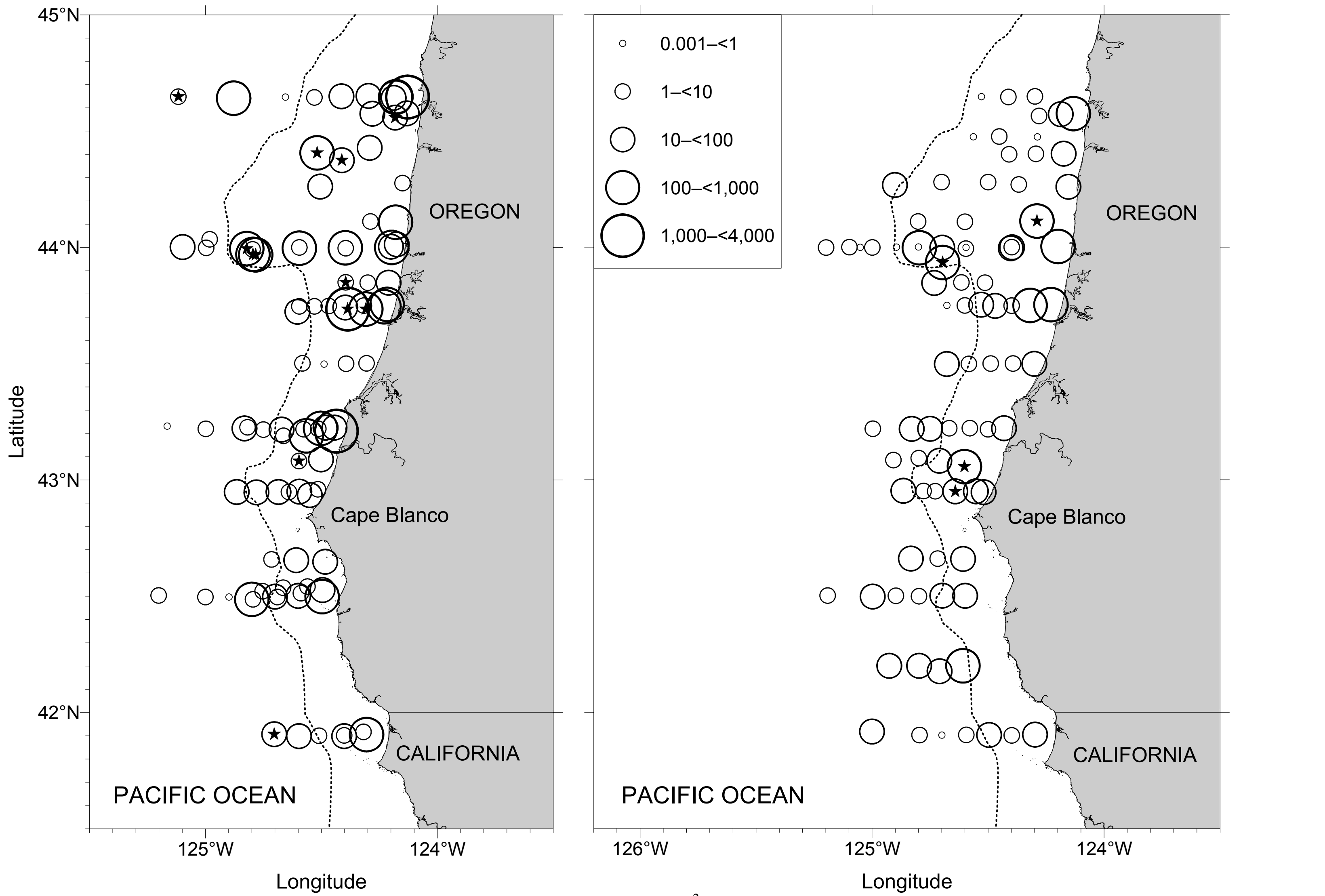


Figure 14. Distribution of neustonic mesozooplankton concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Stars are night samples. The dotted line is the 200-m depth contour.

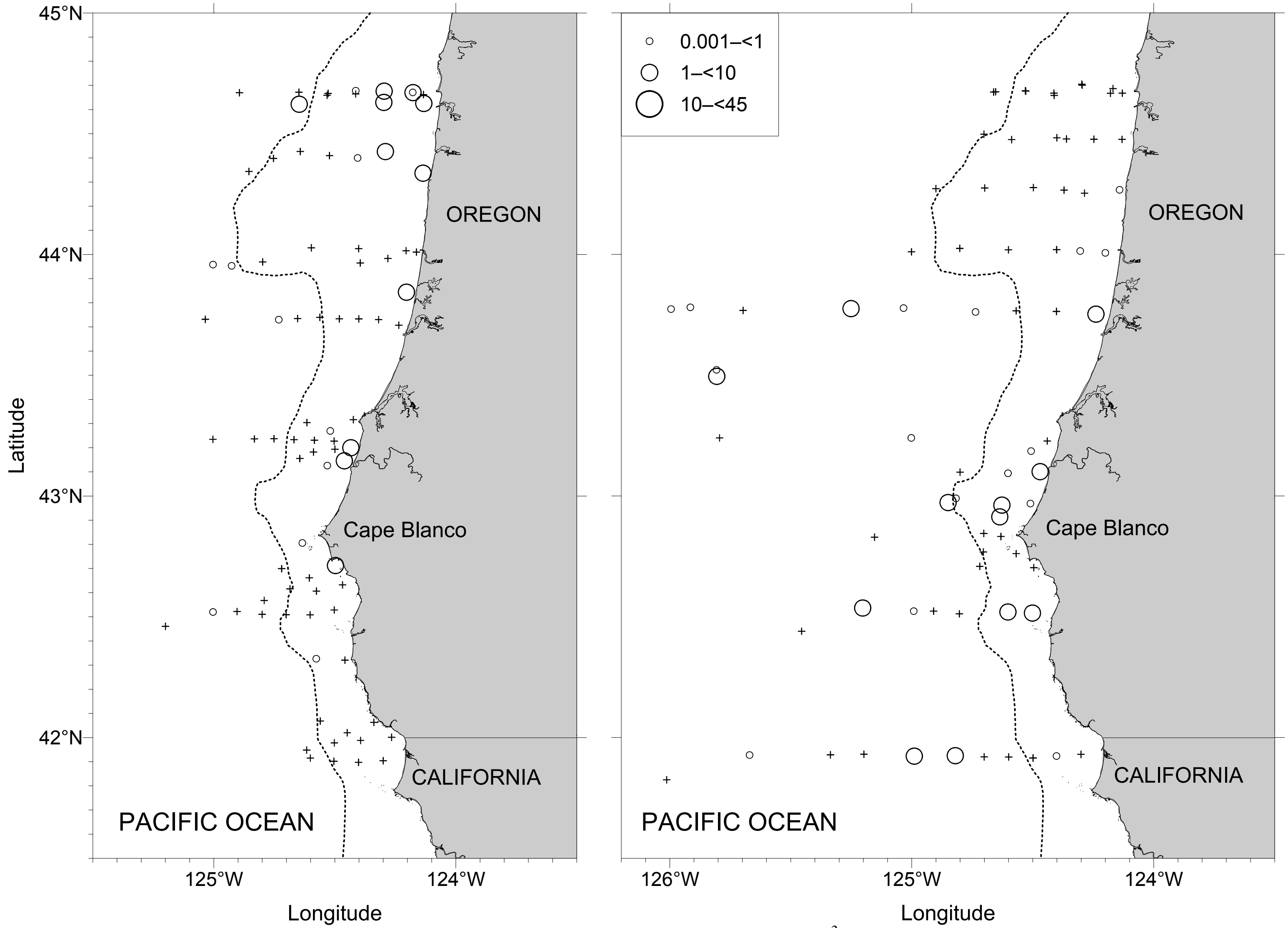


Figure 15. Abundance and distribution of *Hyperoche medusarum* concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

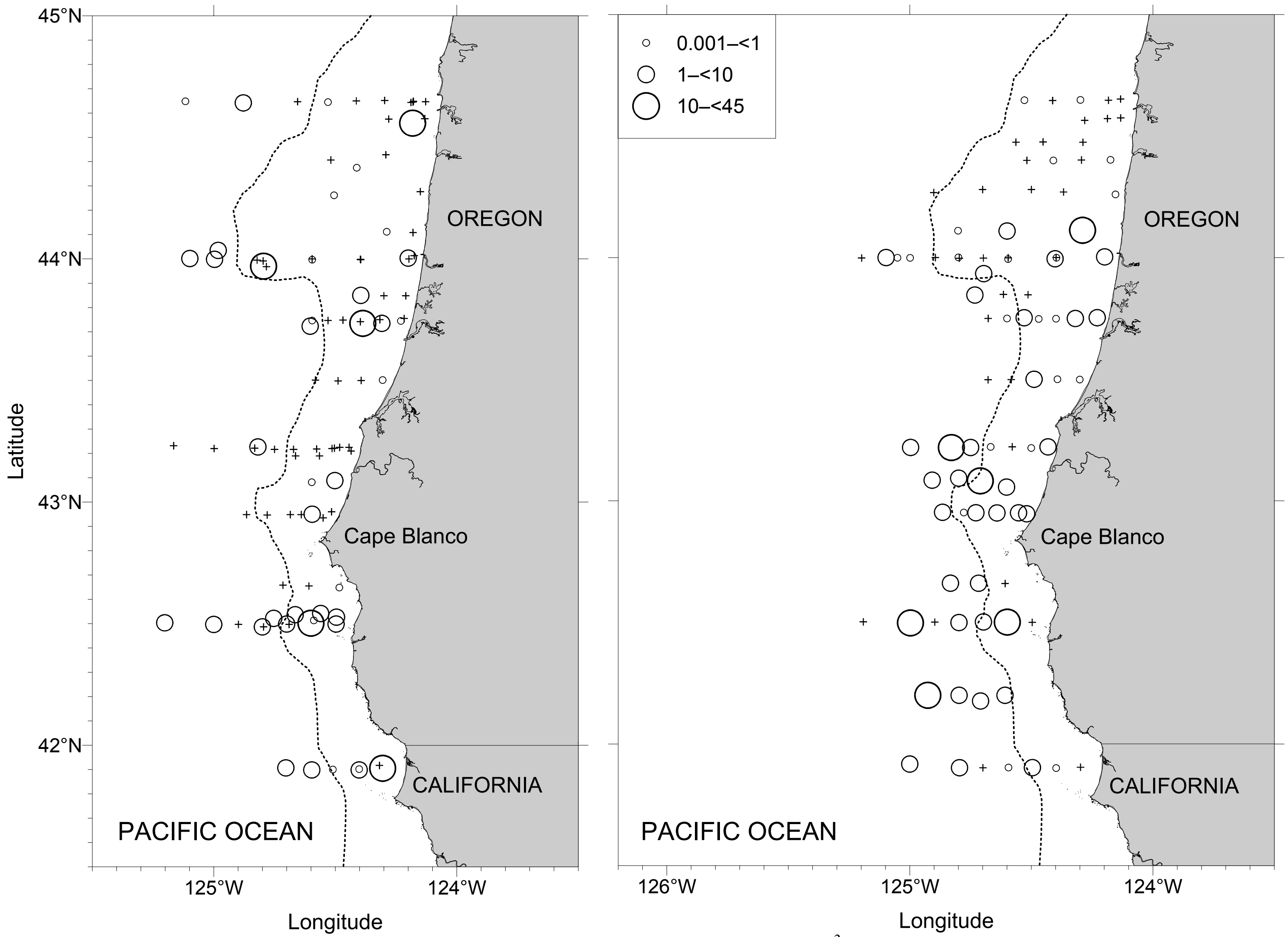


Figure 16. Abundance and distribution of *Hyperoche medusarum* concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

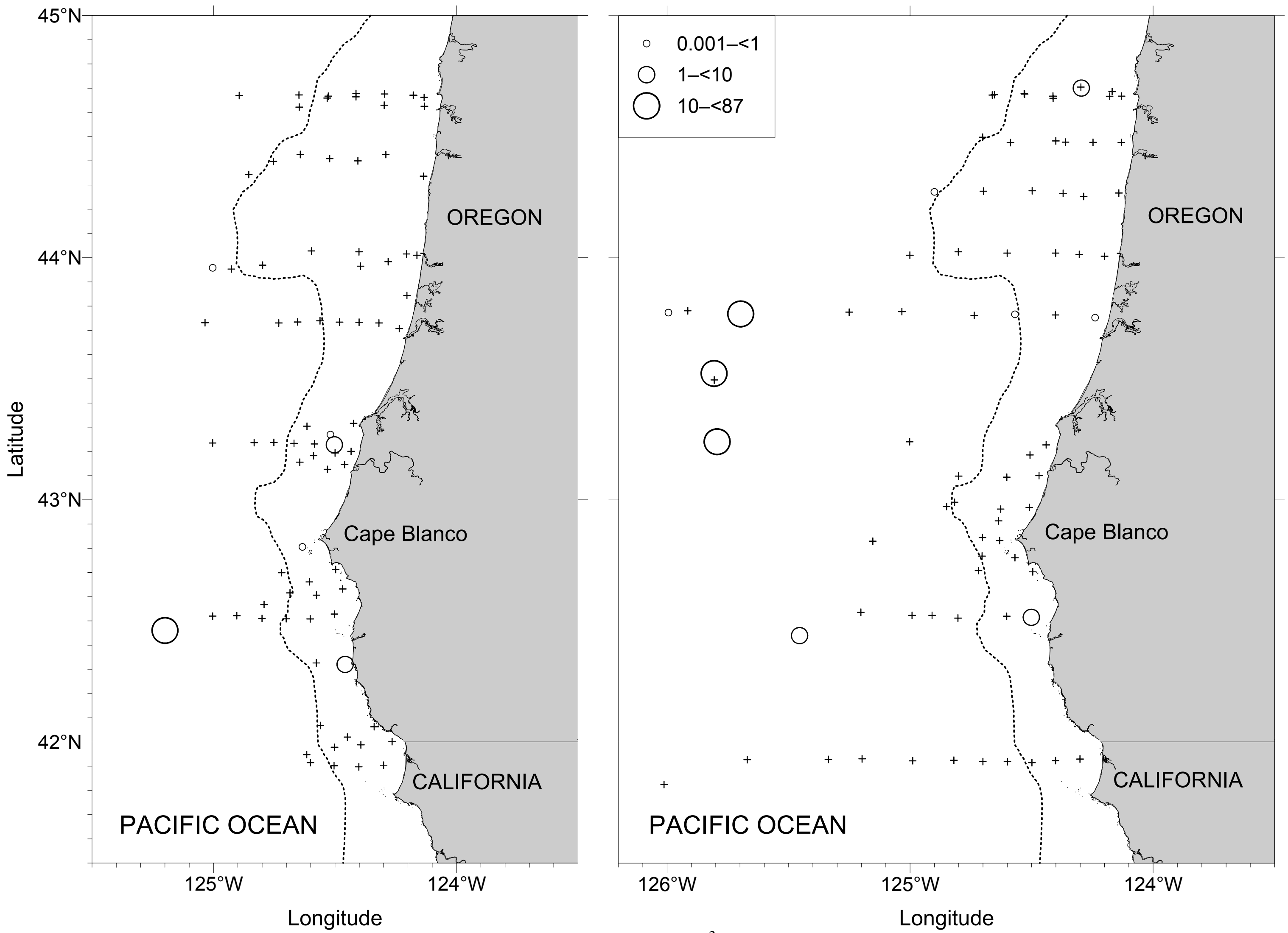


Figure 17. Abundance and distribution of *T. pacifica* concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

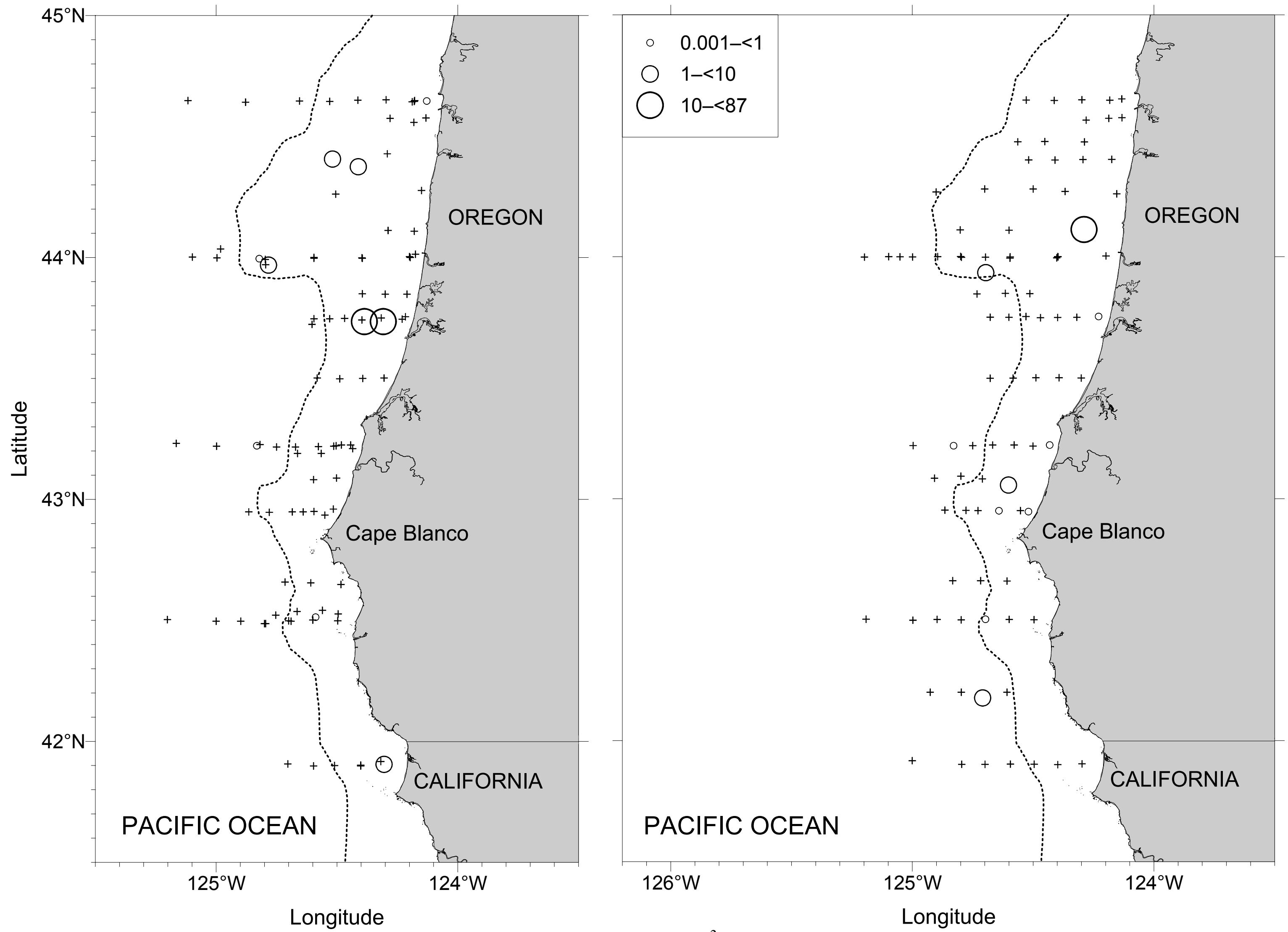


Figure 18. Abundance and distribution of *T. pacifica* concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

In June 2000 *Lycaea pulex* (range = 0.36–227.59/100 $m^3$) and *V. australis* (range = 0.36–83.26/100 $m^3$) were the most common hyperiids. In all four surveys *Hyperia medusarum* and *Tryphana malmi* also were caught several times but at lower concentrations than *T. pacifica* (Table 3). Remaining hyperiid species were collected only once (Table 3).

*Caprella ferrea*, *C. incisa*, and an unidentified caprellid occurred once in 2000. No caprellids were found in the 2002 samples (Table 3).

## Euphausiacea

Pacific krill and *T. spinifera* were the most frequent and abundant euphausiids for all cruises. *Thysanoessa inspinata* and *T. raschii* also were present. Only one *T. raschii* was caught during all four cruises; it was collected in August 2002 from a station nearest to shore at lat. 42.95°N.

Pacific krill was more frequent than *T. spinifera* in 2000, whereas it was less frequent than *T. spinifera* in 2002 (Table 3). Life stages of furcilia to adults were present. Pacific krill concentration ranges were 0.37–7.94/100 $m^3$ (mean = 1.69/100 $m^3$) in June 2000, 0.42–162.70/100 $m^3$ (mean = 10.34/100 $m^3$) in August 2000, 0.43–101.14/100 $m^3$ (mean = 11.14/100 $m^3$) in June 2002, and 0.51–19.15/100 $m^3$ (mean = 3.60/100 $m^3$) in August 2002 (Table 3). Pacific krill distribution mainly was scattered in all cruises (Figure 19 and Figure 20). In August 2000 it was found mainly beyond the shelf break (Figure 19).

*Thysanoessa spinifera* concentrations ranges were 0.37–6.81/100 $m^3$ (mean = 1.17/100 $m^3$) in June 2000, 0.44–64.80/100 $m^3$ (mean = 9.07/100 $m^3$) in August 2000, 0.41–3,722.73/100 $m^3$ (mean = 100.79/100 $m^3$) in June 2002, and 0.42–40.76/100 $m^3$ (mean = 3.28/100 $m^3$) in August 2002 (Table 3). *Thysanoessa spinifera* was collected mainly over the shelf, and it rarely was caught beyond the shelf break (Figure 21 and Figure 22). In August 2000 and during both 2002 cruises, *T. spinifera* appeared to be more common and abundant south of Heceta Bank (Figure 21 and Figure 22).

## Decapoda

Decapods comprised a large portion of the survey-wide species composition (Figure 12). Dungeness crab megalopae and Oregon cancer and red rock crab megalopae were the most abundant and frequent decapods in all four cruises. Dungeness crab megalopae concentration ranges were 0.39–147.46/100 $m^3$ (mean = 14.47/100 $m^3$) in June 2000, 0.44–93.34/100 $m^3$ (mean = 16.97/100 $m^3$) in August 2000, 0.43–2,572.30/100 $m^3$ (mean = 116.58/100 $m^3$) in June 2002, and 0.49–175.68/100 $m^3$ (mean = 15.79/100 $m^3$) in August 2002 (Table 3). Dungeness crab megalopae were more abundant in June than in August of both years (Figure 23 and Figure 24). The distribution in June 2000 was mainly nearshore (Figure 23). In August 2000 most specimens were collected from north of Heceta Bank (Figure 23). In June 2002 the distribution was across the shelf (Figure 24). The August 2002 distribution also was shelf wide with most specimens collected from the Heceta Bank region (Figure 24).

Oregon cancer and red rock crab megalopae generally were more abundant nearshore than offshore in June of both years (Figure 25 and Figure 26). It was less frequent and more scattered in August (Figure 25 and Figure 26). Concentration ranges were 0.44–131.22/100 $m^3$

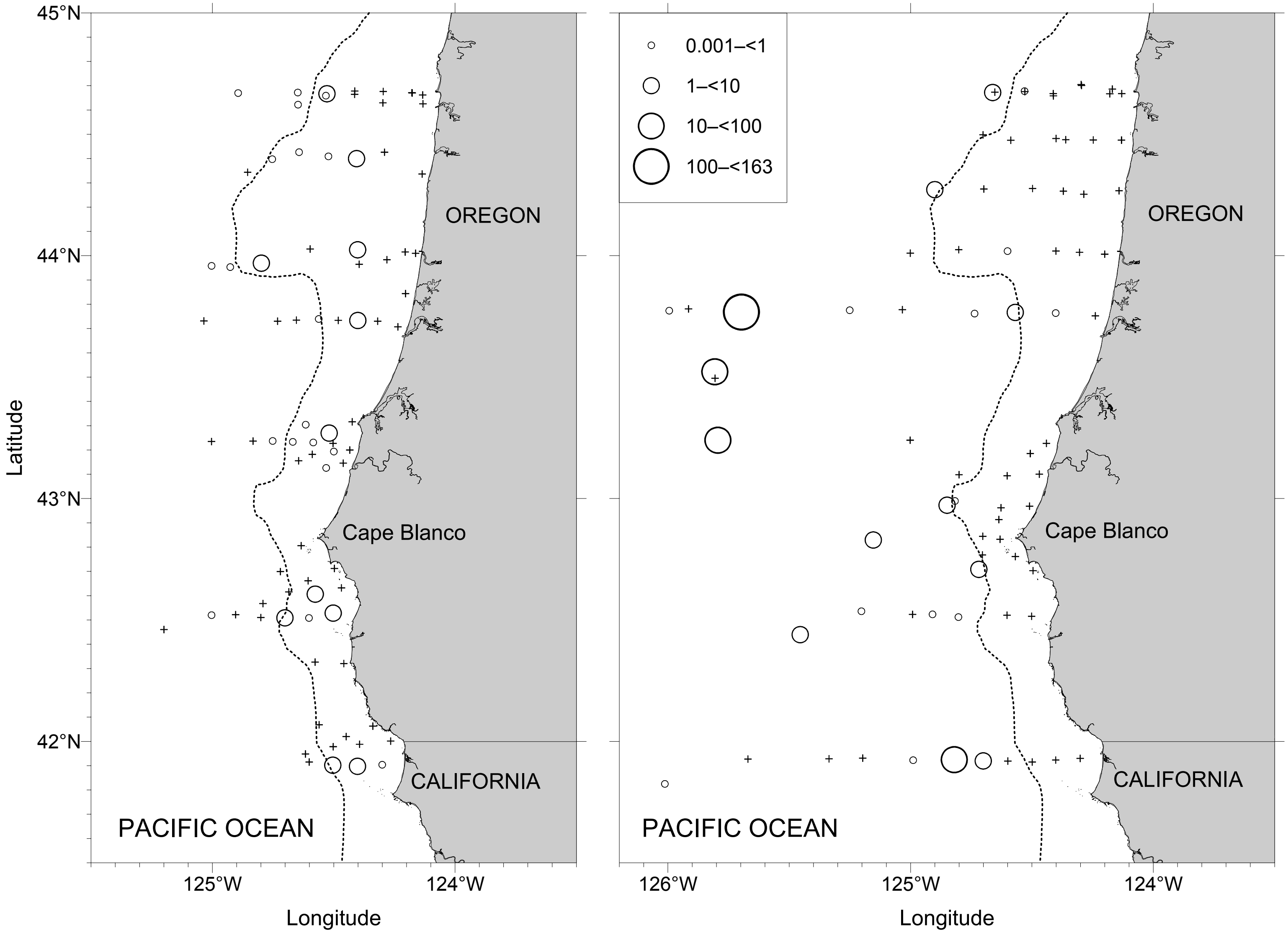


Figure 19. Abundance and distribution of Pacific krill concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

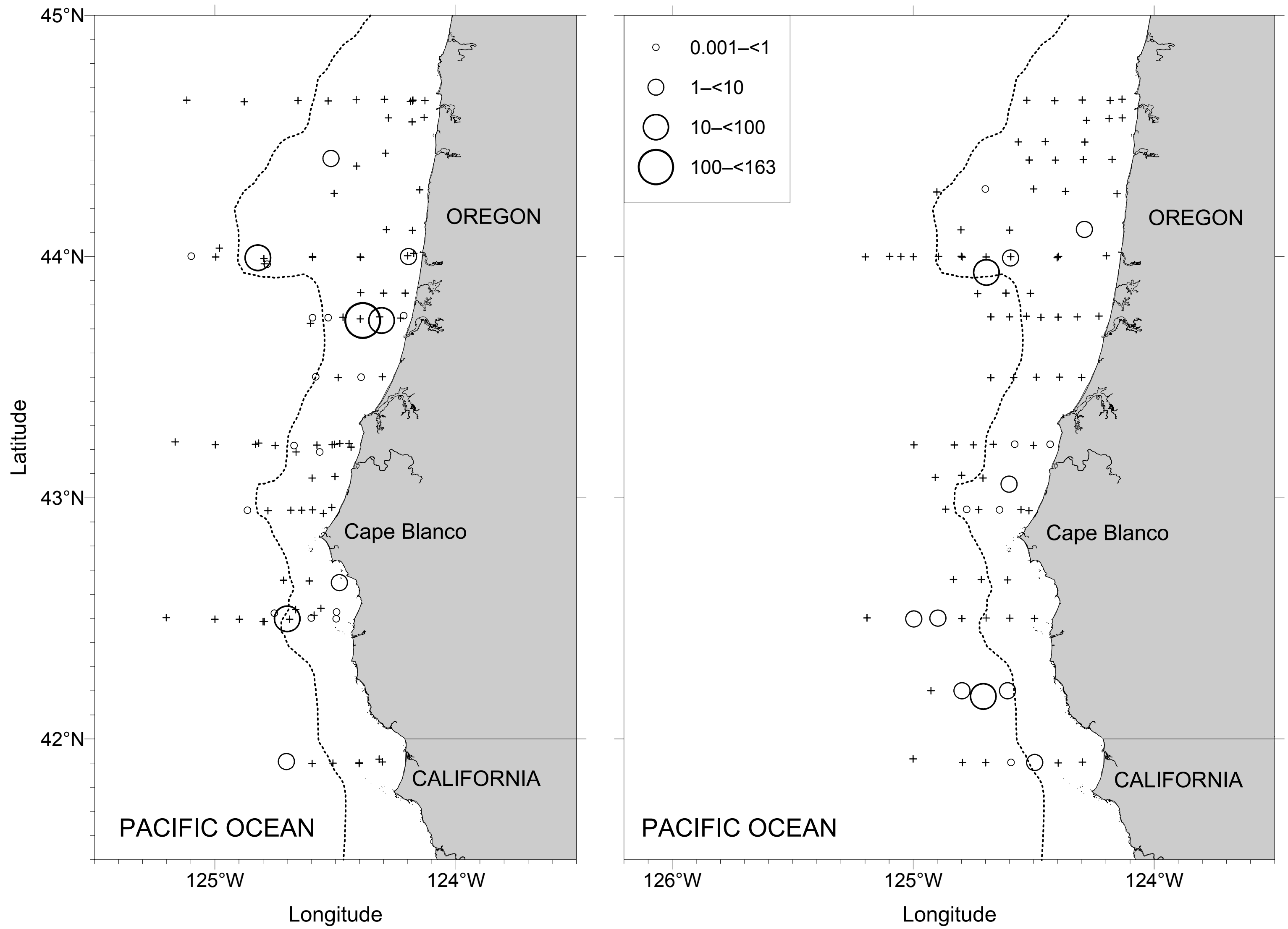


Figure 20. Abundance and distribution of Pacific krill concentrations (no./100 m$^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

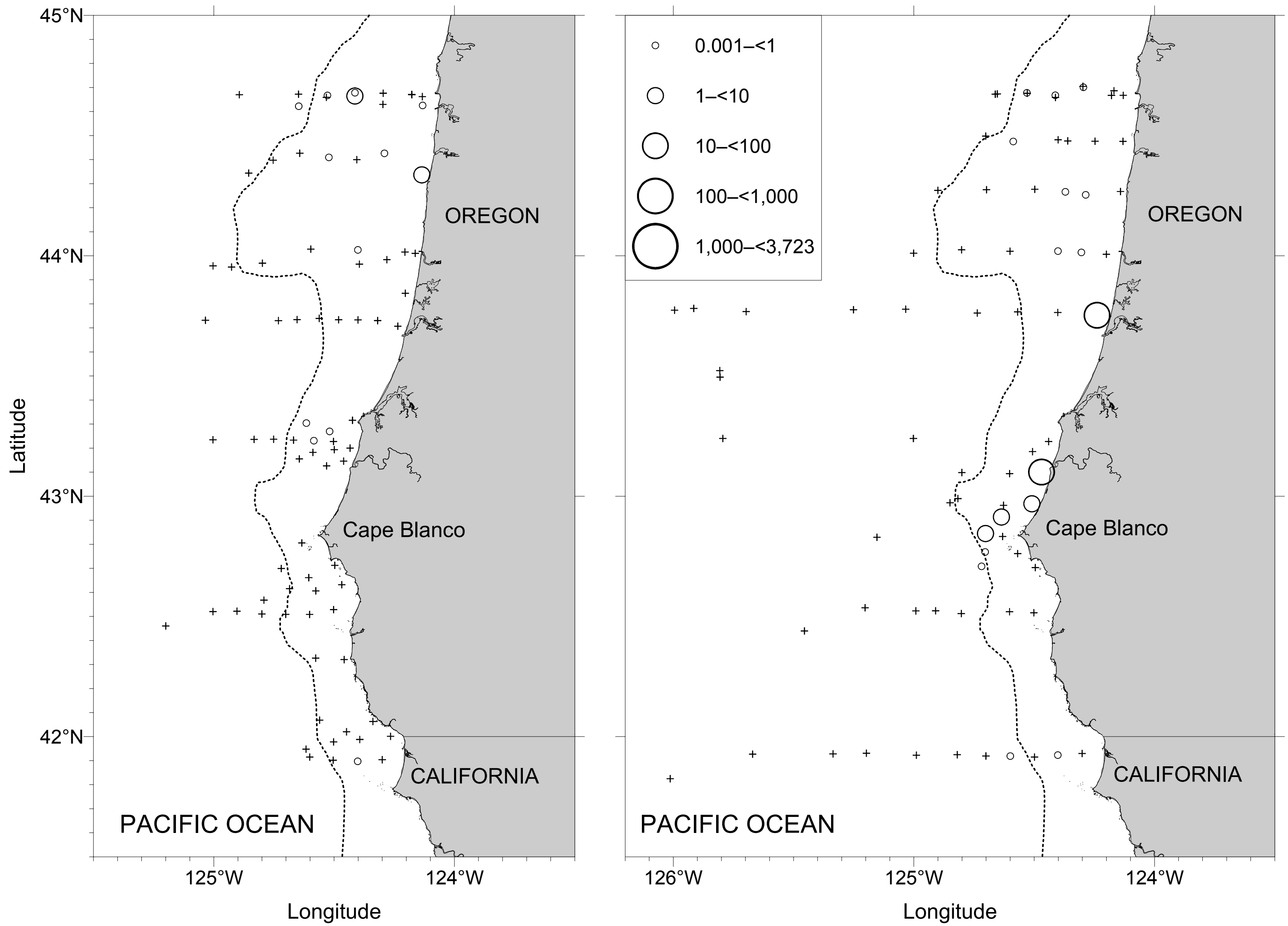


Figure 21. Abundance and distribution of *T. spinifera* concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

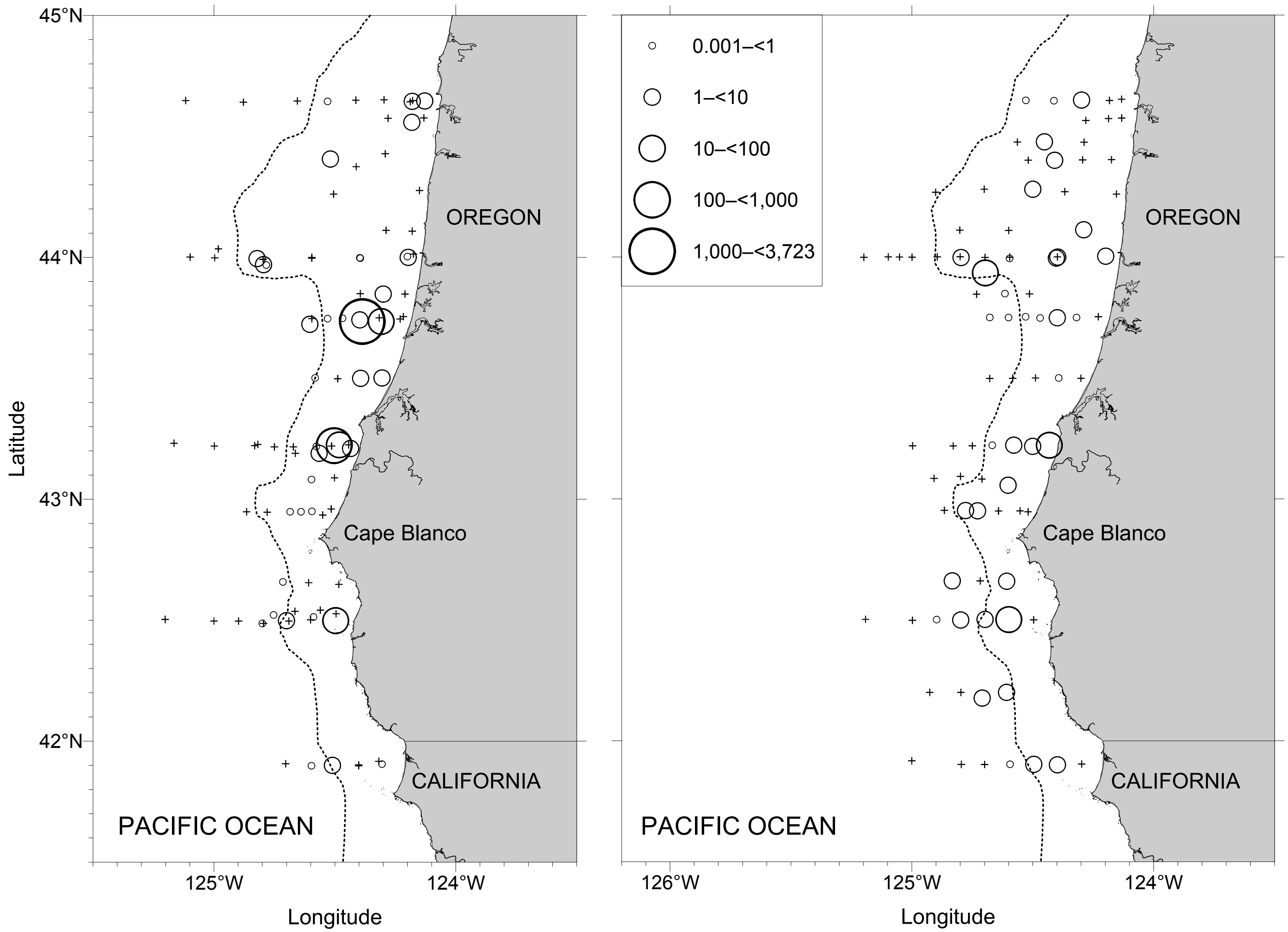


Figure 22. Abundance and distribution of *T. spinifera* concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

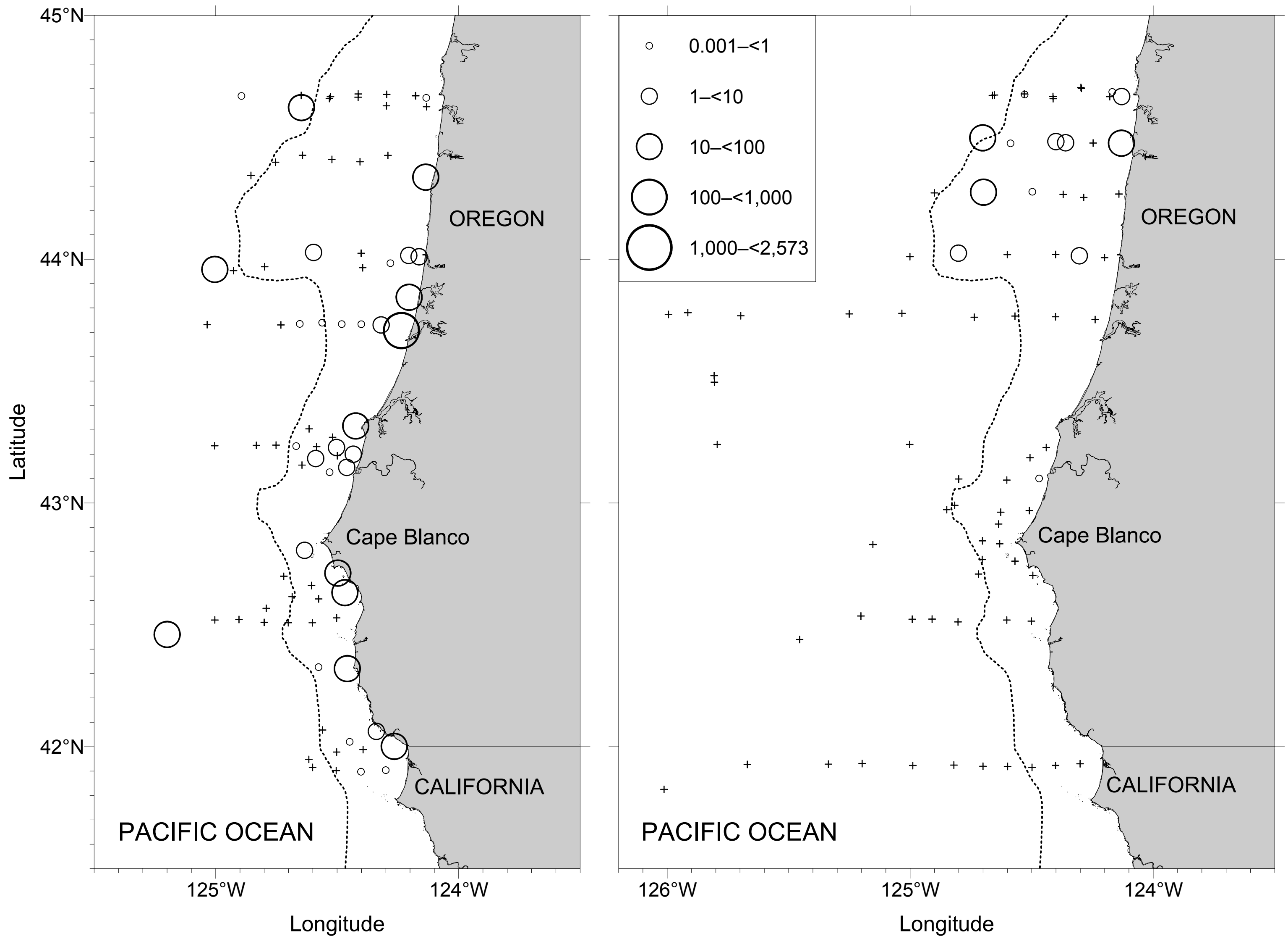


Figure 23. Abundance and distribution of Dungeness crab megalopae concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

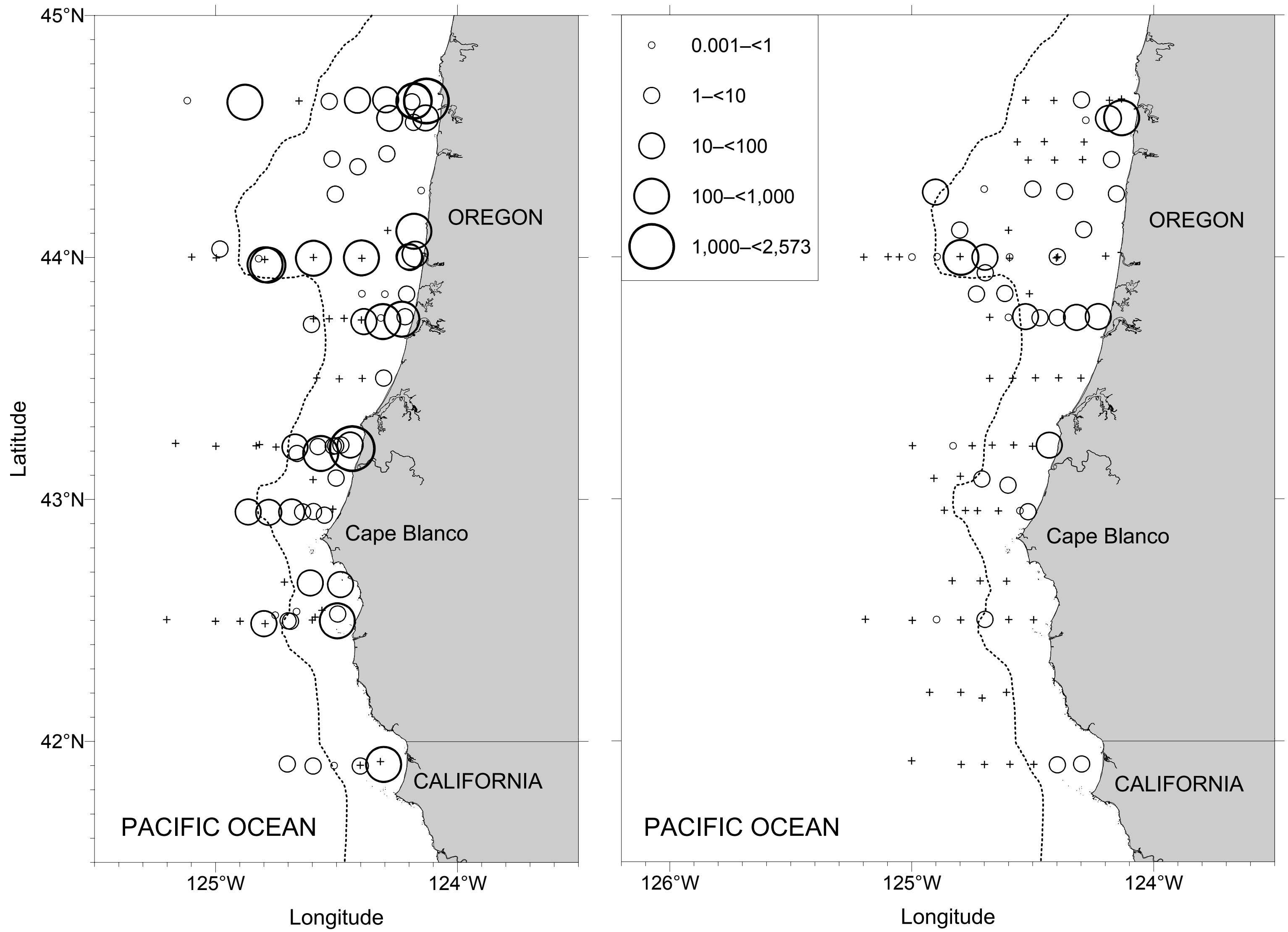


Figure 24. Abundance and distribution of Dungeness crab megalopae concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

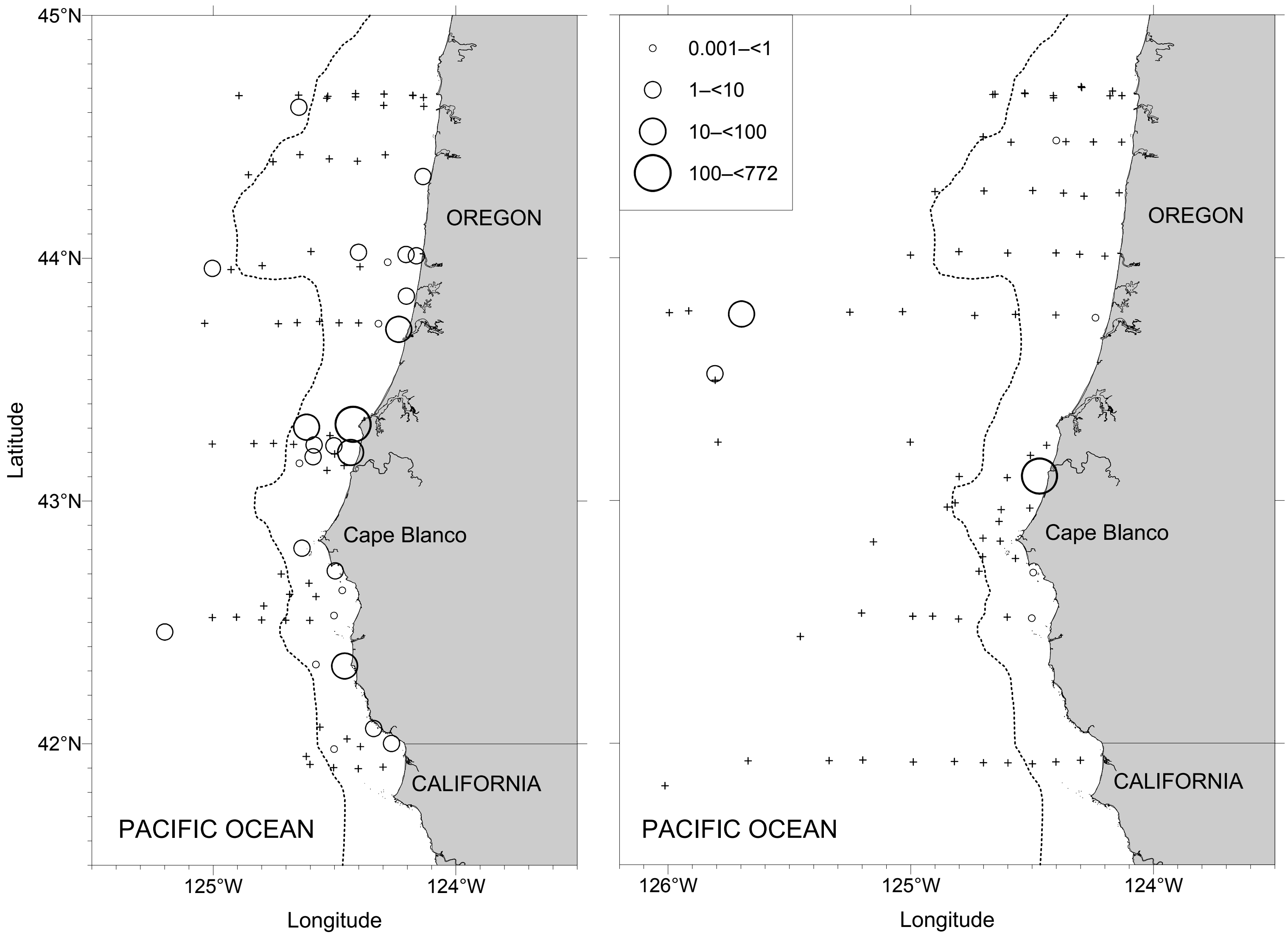


Figure 25. Abundance and distribution of Oregon cancer crab and red rock crab megalopae concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

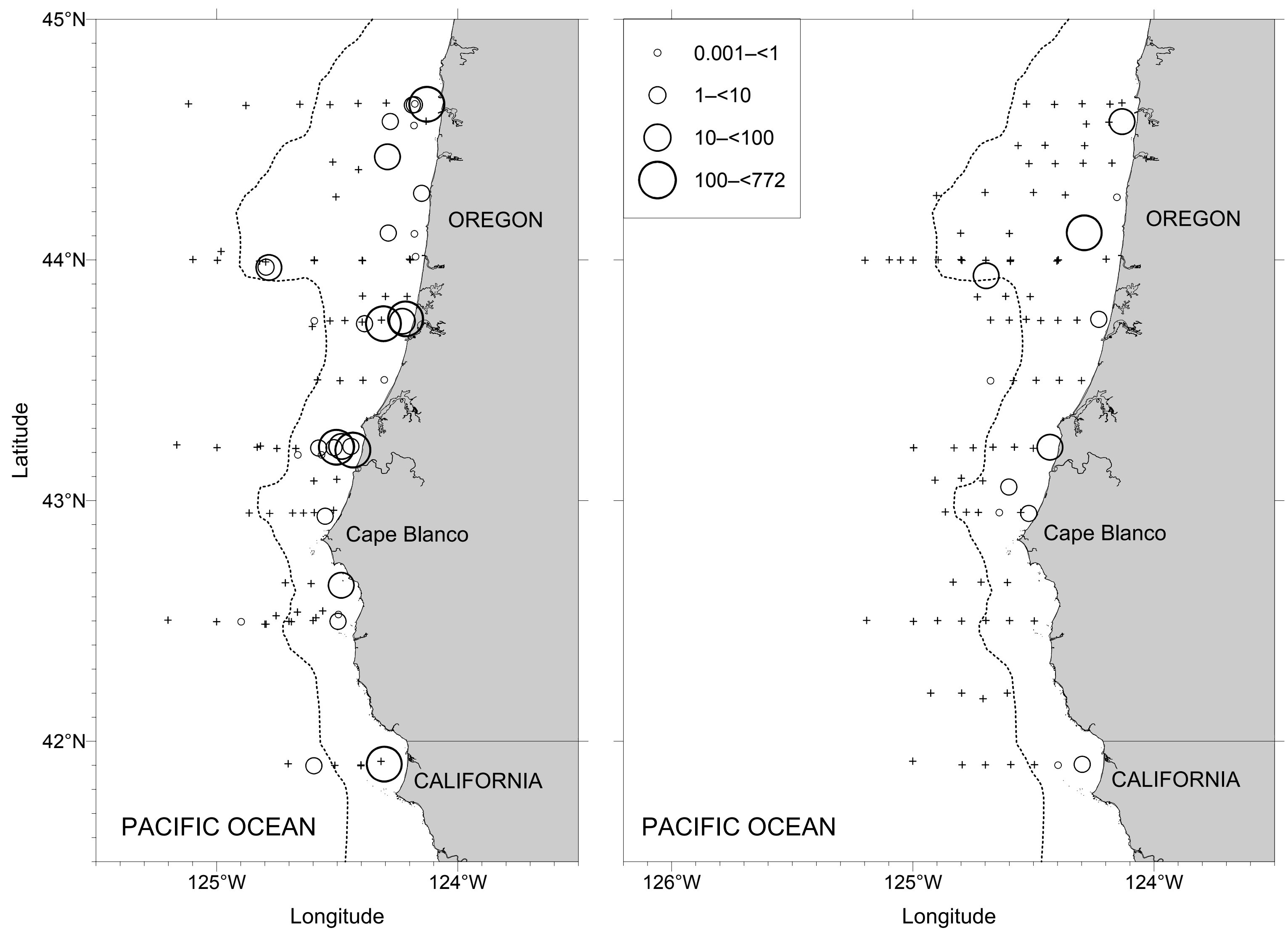


Figure 26. Abundance and distribution of Oregon cancer crab and red rock crab megalopae concentrations (no./100 m$^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

(mean = 11.26/100 $m^3$) in June 2000, 0.45–110.83/100 $m^3$ (mean = 18.79/100 $m^3$) in August 2000, 0.47–771.27/100 $m^3$ (mean = 64.98/100 $m^3$) in June 2002, and 0.55–271.98/100 $m^3$ (mean = 27.57/100 $m^3$) in August 2002 (Table 3).

In addition to Dungeness crab megalopae and Oregon cancer and rock crab megalopae, there were 16 other decapod taxa. These included pagurid zoeae and megalopae, three additional species of brachyuran crabs, caridean shrimp zoeae and megalopae, ghost shrimps, and pelagic sergestid shrimps (Table 3). All taxa were more frequent and more abundant in June 2002 than other periods (Table 3). Crangonids and hippolytids dominated in frequency and mean abundance (Table 3).

### Chaetognatha

Chaetognaths were collected during all four sampling periods. Chaetognaths were the most abundant taxon in August 2002 (Figure 12). *Sagitta* spp. were the most common chaetognaths. In the 2000 samples four *Sagitta* species were identified: *S. elegans*, *S. euneritica*, *S. minima*, and *S. scrippsae*. In the 2002 samples it was not feasible to identify *Sagitta* to species; therefore, all *Sagitta* species were grouped together for analysis of chaetognaths. *Sagitta* spp. were more widespread and more frequent in 2002 than in 2000 (Figure 27 and Figure 28). *Sagitta* spp. concentration ranges were 0.42–108.91/100 $m^3$ (mean = 54.67/100 $m^3$) in June 2000, 0.44–174.63/100 $m^3$ (mean = 17.27/100 $m^3$) in August 2000, 0.39–97.64/100 $m^3$ (mean = 8.87/100 $m^3$) in June 2002, and 0.43–177.48/100 $m^3$ (mean = 15.24/100 $m^3$) in August 2002 (Table 3). In addition to *Sagitta* spp., *Eukrohnia* sp. and unidentified chaetognaths also were present. *Eukrohnia* sp. was present only in 2002 with a sample concentration range of 0.49–34.70/100 $m^3$.

### Osteichthyes

Larval and juvenile fish were caught during all four surveys. A total of 42 taxa in 20 families was identified (Table 3). The number of taxa per cruise was 12 in June 2000, 11 in August 2000, 31 in June 2002, and 10 in August 2002. The fish comprised 5.1 % of the taxonomic composition in June 2000, 5.7% in August 2000, 0.5% in June 2002, and 0.5% in August 2002 (Figure 12). Pacific saury (*Cololabis saira*) juveniles dominated the fish composition in 2000 (Table 3). No one species dominated in 2002. Only cabezon (*Scorpaenichthys marmoratus*) and unidentified osmerids were present in all four cruises. Mean concentrations did not exceed 4.66/100 $m^3$ (Table 3). Except for the sauries, the frequency of occurrence was no more than nine stations during any one cruise (Table 3). Pacific saury occurred at 28 stations in June 2000 and 17 stations in August 2000 (Table 3). Spatially, the distribution of larval and juvenile fish was beyond the shelf break in 2000 and over the shelf in 2002 (Figure 29 and Figure 30).

### Others

Polychaetes were not caught in June 2000 and rarely were found during the other three cruises (Table 3). The pelagic polychaete *Tomopteris* sp. was most common in June 2002 when it was identified in 21 samples. *Autolytus* sp. and unidentified syllids were in epitoke stages.

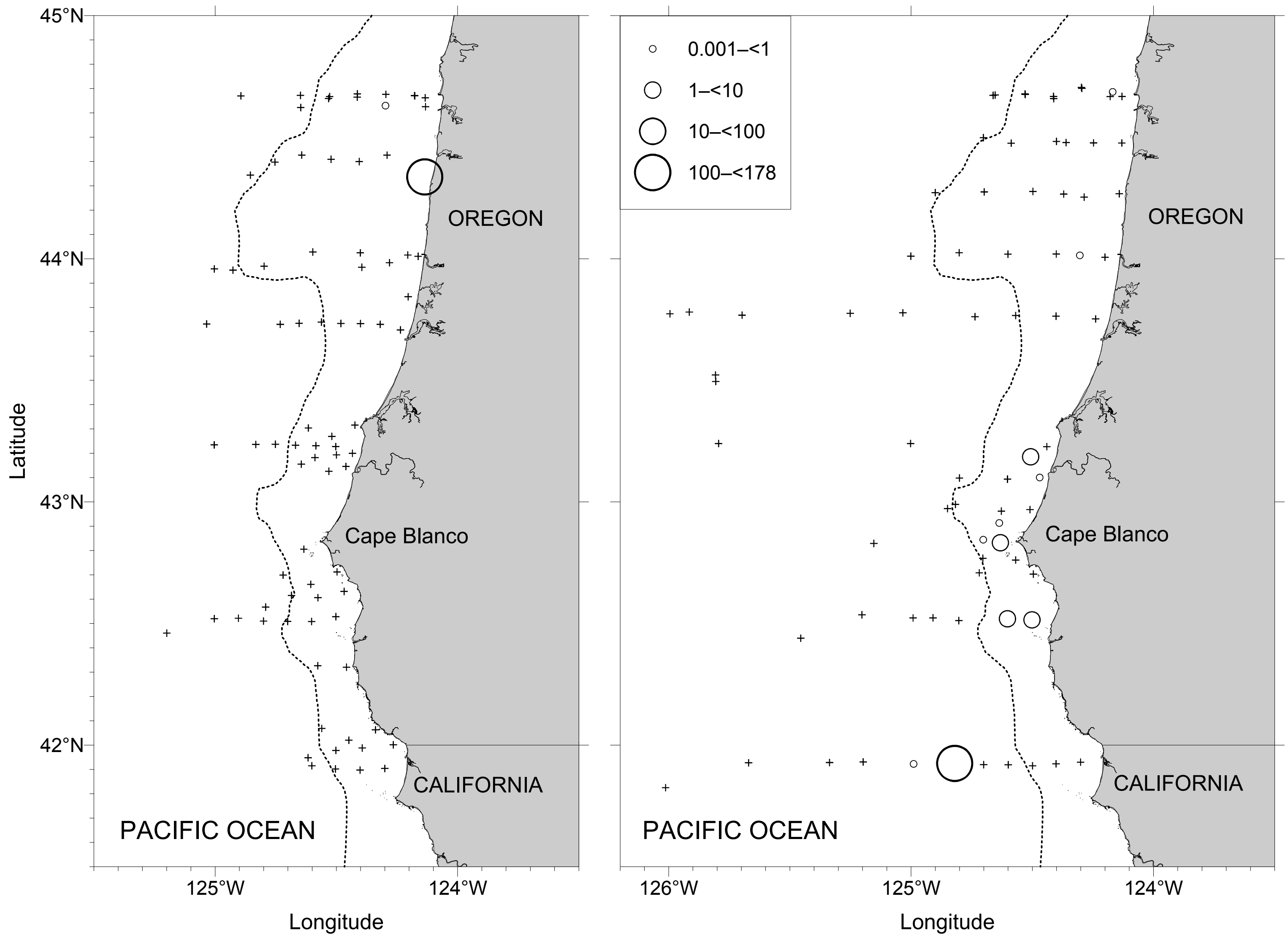


Figure 27. Abundance and distribution of *Sagitta* spp. concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

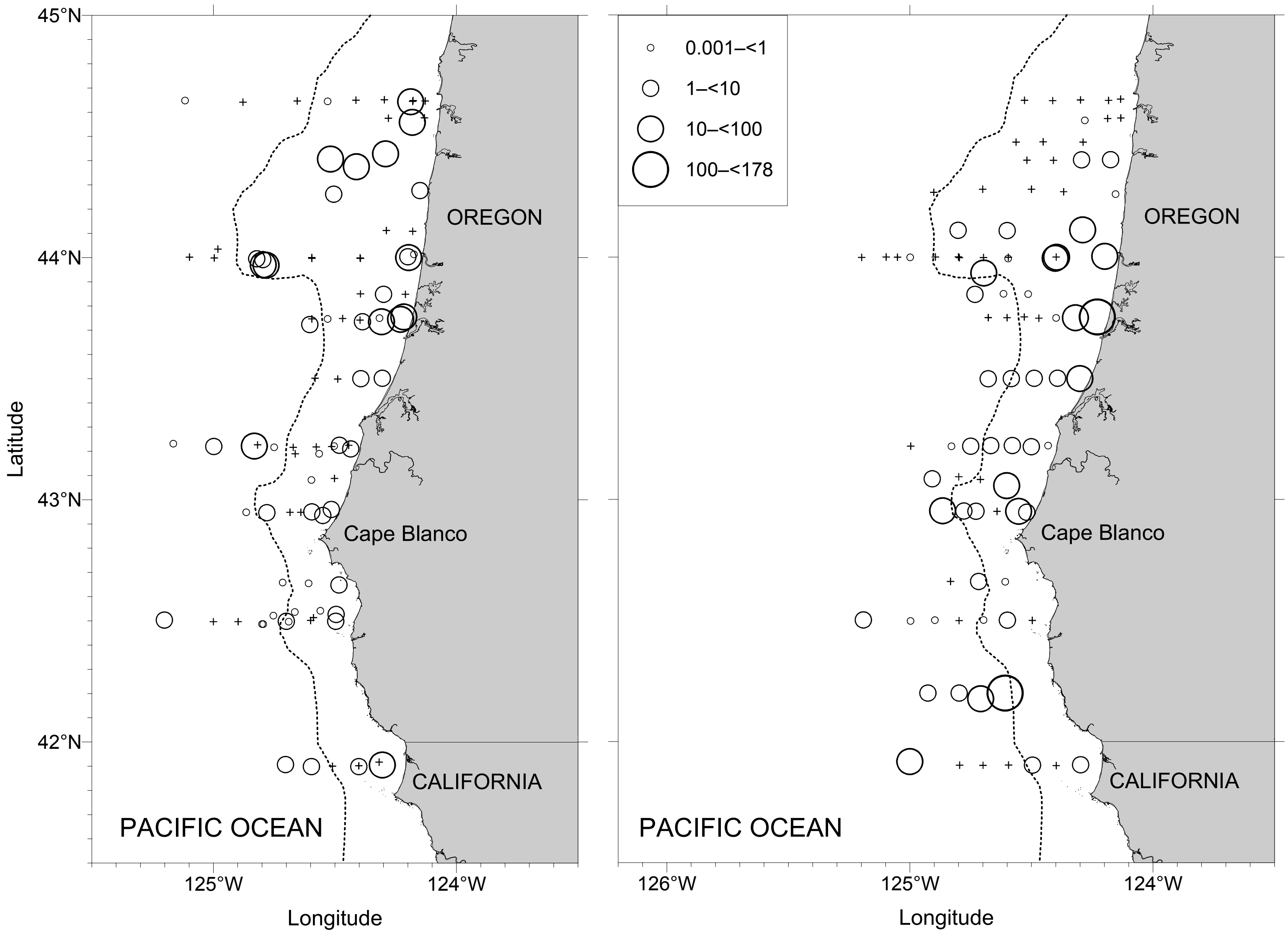


Figure 28. Abundance and distribution of *Sagitta* spp. concentrations (no./100 m$^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

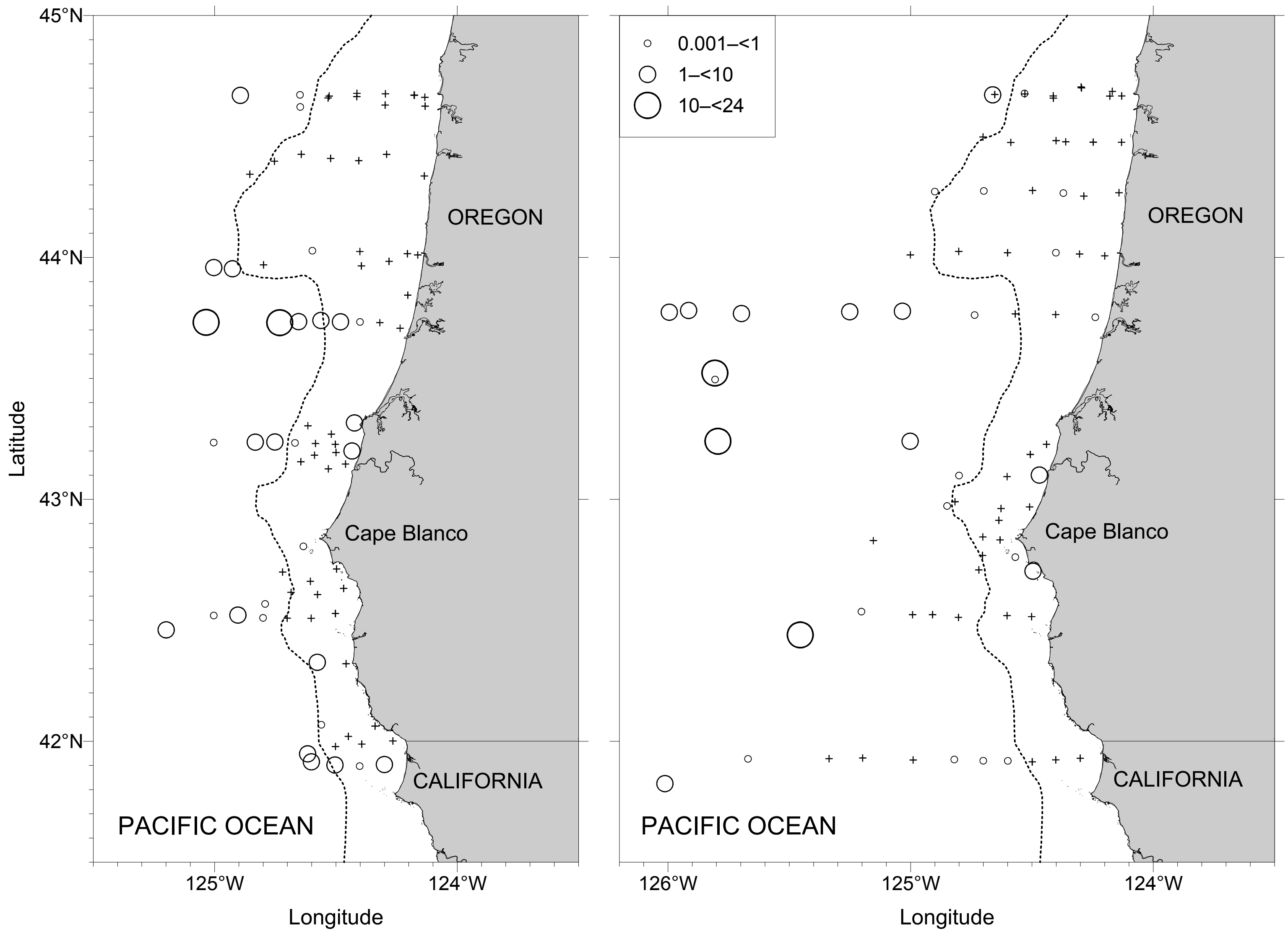


Figure 29. Abundance and distribution of larval and juvenile fish concentrations (no./100 $m^3$) in June (left) and August (right) 2000. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

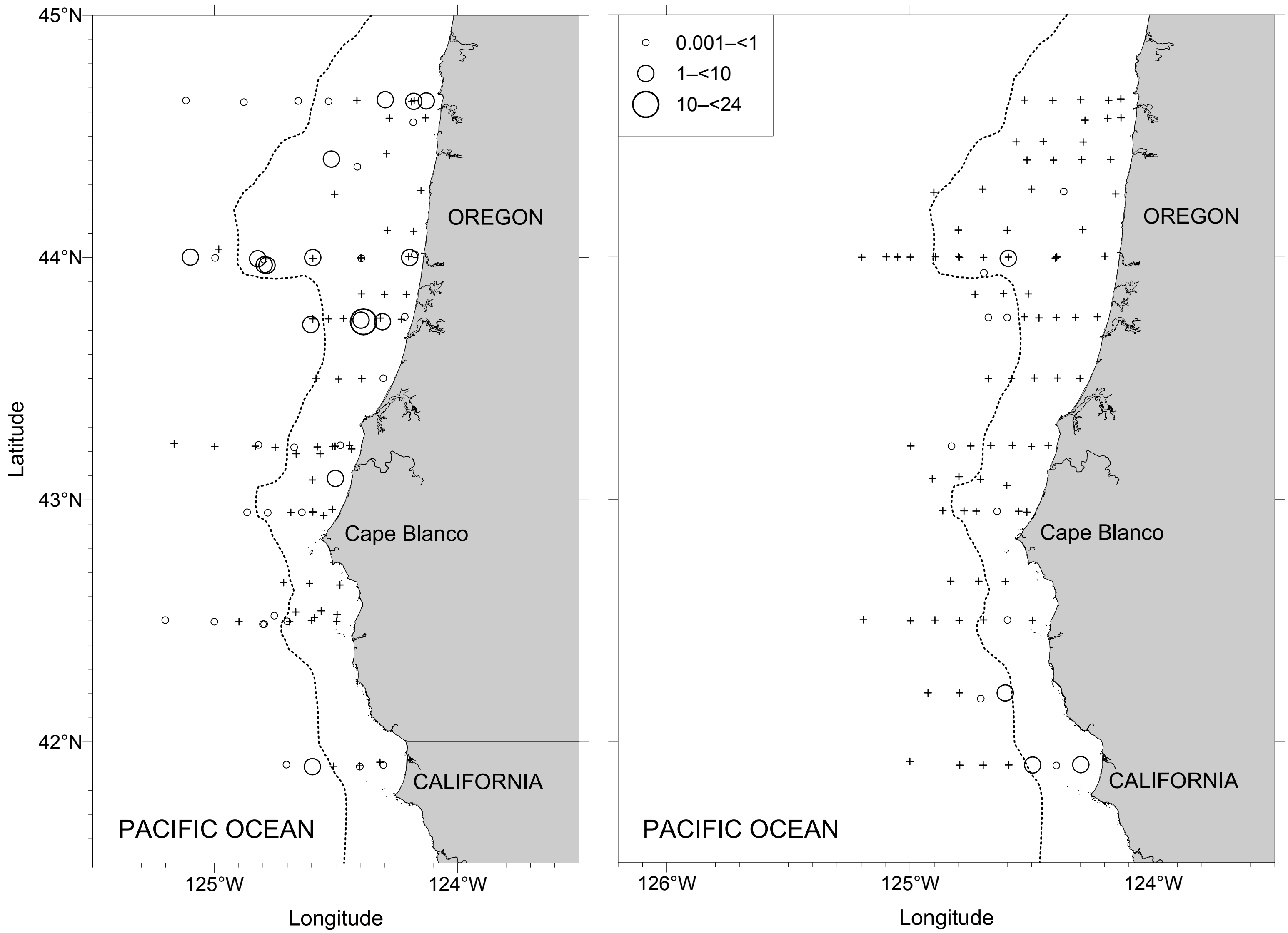


Figure 30. Abundance and distribution of larval and juvenile fish concentrations (no./100 $m^3$) in June (left) and August (right) 2002. Plus signs represent zero concentration. The dotted line is the 200-m depth contour.

Heteropods and pteropods were present in the 2000 and 2002 samples, whereas the nudibranchs were found only in the 2000 samples (Table 2). An early life stage of *Chiroteuthis* sp. was caught in August 2000 and August 2002, whereas market squid (*Loligo opalescens*) was collected only in August 2002. In August 2000 one individual *Chiroteuthis* sp. was seen in a sample from lat. 43.0°N immediately beyond the shelf break. In August 2002 the second station west of the shelf break at lat. 42.2°N had three *Chiroteuthis* sp. individuals.

Cumaceans were found only in the June 2002 samples (Table 3). *Diastylopsis* sp., *Hemilamprops* spp., and *Oxyurostylis* sp. were collected on 8 June 2002 on the 2A transect at lat. 44.4°N.

Four mysid species were in the samples (Table 3), and *Alienacanthomysis macropsis* was the only species identified in samples from all four cruises. Its highest mean abundance was 11.47/100 $m^3$ in an August 2000 sample. The other species occurred in one or two cruises.

Six isopod species were identified (Table 3). *Idotea fewkesi* was the most common isopod but was not collected in August 2002. Vosnesensky's isopod (*Pentidotea wosnesenskii*) was collected in June 2000, August 2000, and June 2002. Eelgrass isopod (*P. resecata*) and *I. rufescens* were not in any of the 2002 samples. *Excirolana linguifrons* occurred once in August 2000. A single specimen of *Acanthamunnopsis milleri* was caught on 4 August 2002 at the second station from shore on the Rogue River transect south of Cape Blanco.

Ten orders of insects were identified. Diptera and Neuroptera were the most frequent orders in June 2000, June 2002, and August 2002 (Table 3). In August 2000 Coleoptera had the highest mean abundance of 0.80/100 $m^3$. In June 2002 Hymenoptera occurred only once, but had the highest abundance at 2.04/100 $m^3$. Homoptera, Odonata, Plecoptera, and Trichoptera were in the 2000 samples but not the 2002 samples.

## Spatial Variability

Inshore-offshore distribution of the five most abundant taxa varied among and within cruises along six main transects (Figure 1):

1) Newport Hydroline,
2) Heceta Head,
3) Umpqua River,
4) Five Mile River,
5) Rogue River, and
6) Crescent City.

Spatial variability also was apparent from north to south.

In June 2000 Pacific saury juveniles were more abundant beyond the shelf break along all six transects (Figure 31). Except along the Heceta Head and Rogue River transects, Dungeness crab megalopae generally were more abundant inshore (Figure 31). Oregon cancer and red rock crab megalopae were most abundant at the nearshore station on the Umpqua River Transect

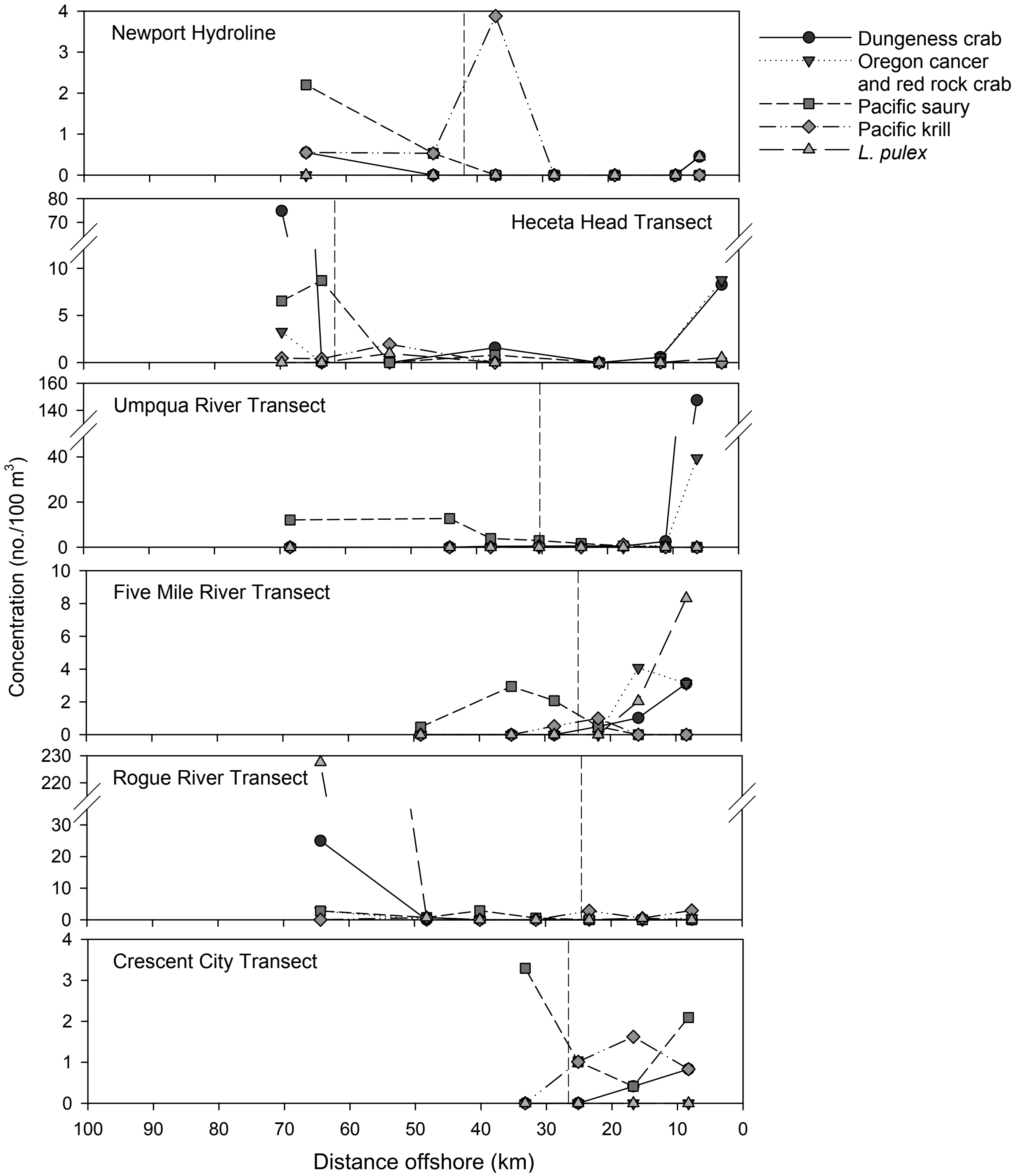


Figure 31. Inshore-offshore distribution of five most abundant neustonic mesozooplankton taxa along six main transects from north (Newport Hydroline) to south (Crescent City Transect) in June 2000. Vertical dashed lines represent shelf break at 200-m depth. Diagonal slashes in y-axes are breaks in data range.

(Figure 31). The hyperiid *L. pulex* was most abundant beyond the shelf along the Rogue River Transect and inshore on the Five Mile River Transect (Figure 31). Pacific krill concentrations were low over and beyond the shelf (Figure 31).

In August 2000 the Umpqua River Transect had the highest concentration of neustonic mesozooplankton because of high *T. spinifera* concentrations at the station closest to shore (Figure 32). As in June 2000 Pacific saury also was more abundant beyond the shelf (Figure 32). *Hyperoche medusarum* was common nearshore, but it also was caught beyond the shelf from the Umpqua River to Crescent City transects (Figure 32). Pacific krill was caught more often beyond the shelf (Figure 33). *Atylus tridens* was distributed inshore and offshore (Figure 32).

In June 2002 all five taxa, particularly Dungeness crab megalopae and Oregon cancer and red rock crab megalopae, were most abundant nearshore from the Newport Hydroline to the Five Mile River Transect (Figure 33). They were more distributed over the shelf on the Rogue River Transect and beyond the shelf break on the Crescent City Transect (Figure 33). It is worth noting that the Newport Hydroline to Rogue River transects were sampled one day apart from 1 June to 5 June 2002 during the mesoscale leg of the cruise. Only two nearshore stations on the Crescent City Transect could be sampled before sea conditions became too rough to continue. Data for the Crescent City Transect are from the fine-scale leg when five stations were sampled successfully in one day, eight days after the end of the mesoscale study. Data examination from these two stations during the mesoscale leg showed that spatial distribution along the transect was similar to that seen in the other five transects.

In August 2002 *Sagitta* spp. were abundant nearshore on the Heceta Head and Umpqua River transects and offshore on the Rogue River and Crescent City transects (Figure 34). Dungeness crab megalopae abundance peaked inshore and near the shelf break (Figure 34). *Hyperoche medusarum* and *T. spinifera* were more abundant on the Five Mile River and Rogue River transects (Figure 34). Unidentified chaetognaths peaked inshore on the Heceta Head and Umpqua River transects and offshore on the Crescent City Transect (Figure 34).

## Species Diversity

Species diversity (*H'*) was higher in 2002 than in 2000, but it was not significantly different between years (ANOVA, $p = 0.4497$) or seasons (t-test, $p = 0.8$, 2000; t-test, $p = 0.5$, 2002). Maximum diversity was 2.15 (mean = 0.78) in June 2000, 2.11 (mean = 0.80) in August 2000, 2.32 (mean = 0.95) in June 2002, and 2.01 (mean = 0.85) in August 2002. The diversity was not concentrated in any particular area of the survey, but it was evenly distributed. The maximum number of taxa in any one sample was 12 (mean = 3.8) in June 2000, 25 (mean = 3.6) in August 2000, 25 (mean = 6.2) in June 2002, and 18 (mean = 4.3) in August 2002.

## Species Associations

Analysis of species cluster groupings based on station assemblages included 17 taxa in June 2000, 20 in August 2000, 33 in June 2002, and 17 in August 2002. Within each cruise, the number of clusters was determined by cutting the resulting dendrograms at 50% of the remaining information. Then station locations and habitat preferences (i.e., pelagic, benthic, and terrestrial) of specimens were considered.

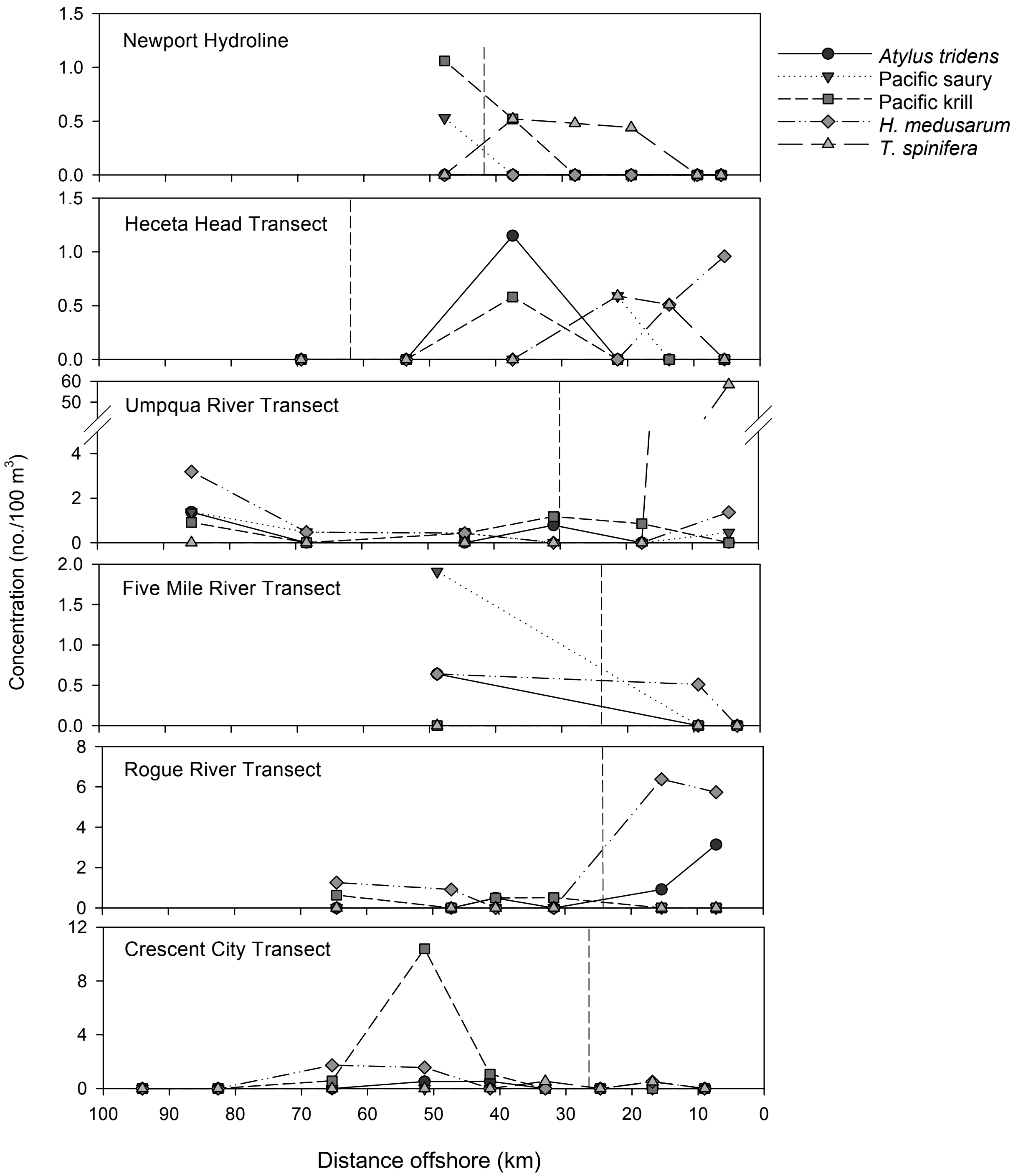


Figure 32. Inshore-offshore distribution of five most abundant neustonic mesozooplankton taxa along six main transects from north (Newport Hydroline) to south (Crescent City Transect) in August 2000. On the Crescent City Transect, two stations beyond 100 km were omitted. Vertical dashed lines represent shelf break at 200-m depth. Diagonal slashes in y-axes are breaks in data range.

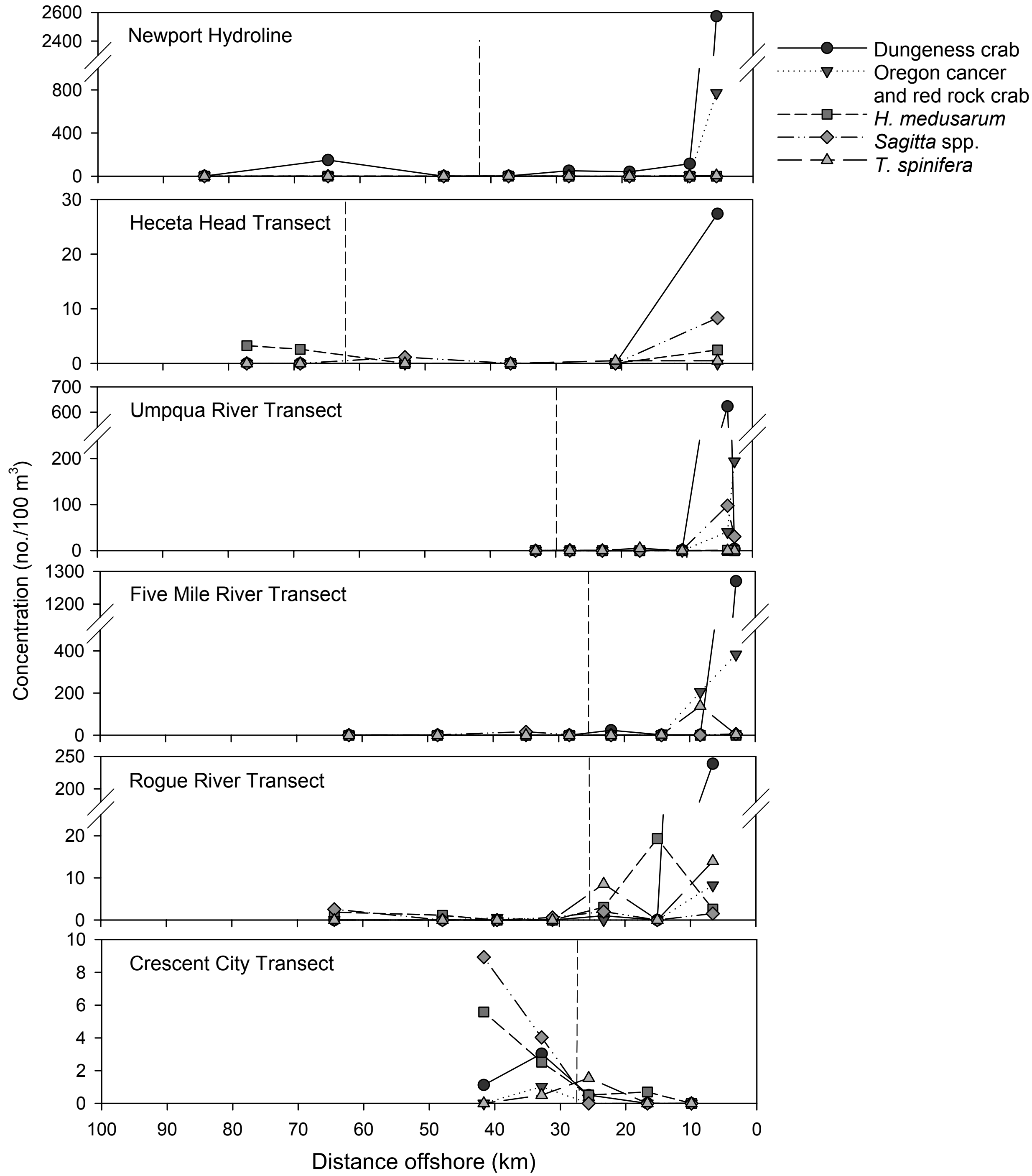


Figure 33. Inshore-offshore distribution of five most abundant neustonic mesozooplankton taxa along six main transects from north (Newport Hydroline) to south (Crescent City Transect) in June 2002. Vertical dashed lines represent shelf break at 200-m depth. Diagonal slashes in y-axes are breaks in data range.

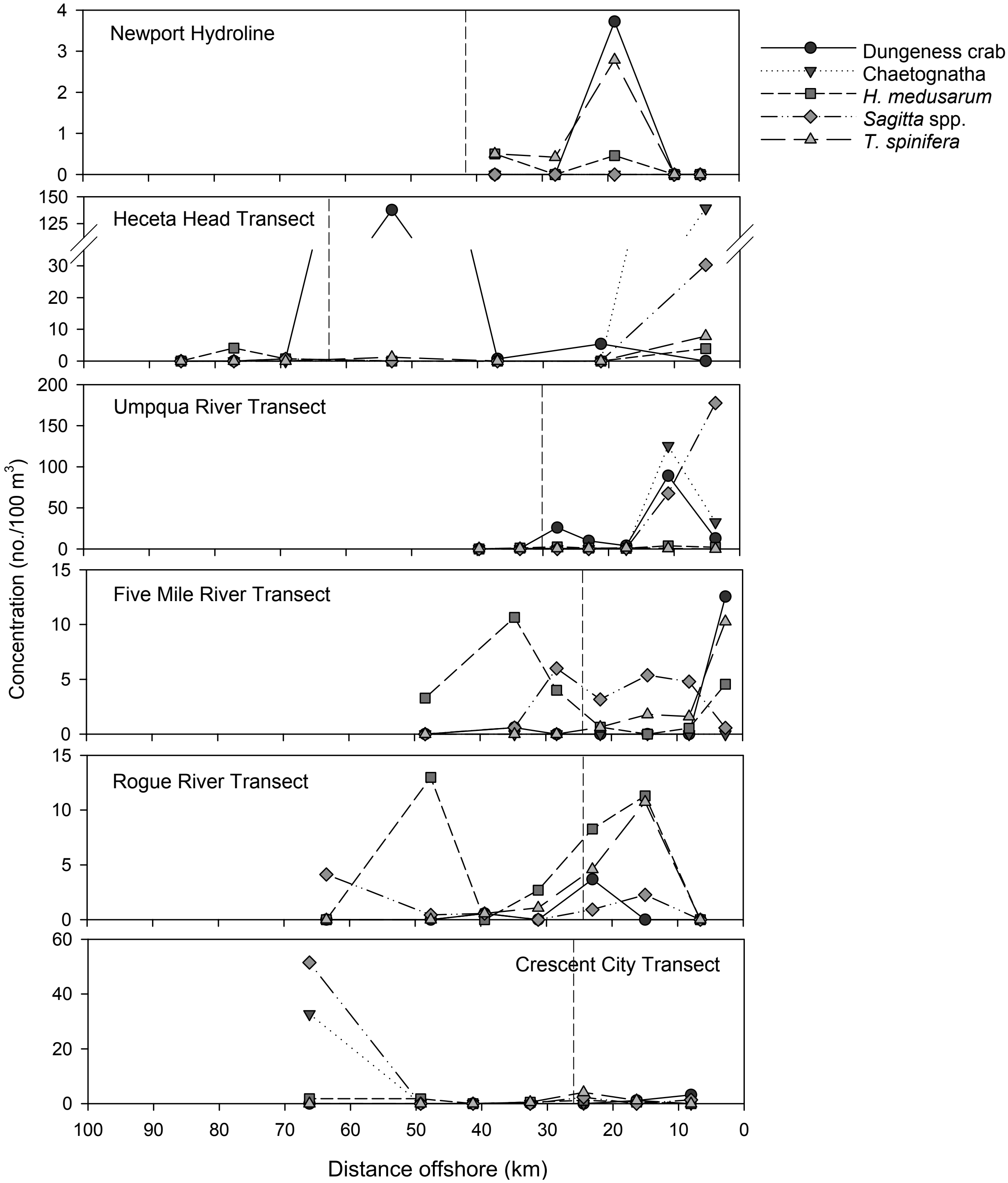


Figure 34. Inshore-offshore distribution of five most abundant neustonic mesozooplankton taxa along six main transects from north (Newport Hydroline) to south (Crescent City Transect) in August 2002. Vertical dashed lines represent shelf break at 200-m depth. Diagonal slashes in y-axes are breaks in data range.

Dungeness crab megalopae and Oregon cancer and red rock crab megalopae were associated with each other in June of 2000 and 2002 (Figure 35 and Figure 36). In August Dungeness crab megalopae were clustered with chaetognaths, fish, hyperiids, hippolytids, and *Eucalanus* sp. (Figure 35 and Figure 36). Oregon cancer and red rock crab megalopae were clustered with *T. spinifera* in August 2000 and with Pacific rock and graceful crab megalopae, hippolytids, *Tomopteris* sp., hyperiids, and krill in August 2002 (Figure 35 and Figure 36).

Terrestrial insects (Diptera, Neuroptera, Lepidoptera, and Coleoptera) generally were clustered with benthic gammarids (*A. angusta*, *H. frequens*, *A. tridens*, and *Peramphithoe* sp.) and isopods (*I. fewkesi*) in 2000 (Figure 35). However, in 2002 they associated with the copepod *N. cristatus* (Figure 36). A cluster of hyperiid *Hyperia medusarum*, *T. malmi*, *T. pacifica*, and *V. australis* was found for June 2000 and August 2002 (Figure 35 and Figure 36).

Common pelagic taxa such as *T. spinifera,* Pacific krill and *Hyperoche medusarum* were in the same cluster groupings in June of 2000 and 2002 and in August 2002 (Figure 35 and Figure 36). In August 2000 *T. spinifera* was not found to cluster with Pacific krill and *Hyperoche medusarum* (Figure 35). In the 2000 survey Pacific saury juveniles were associated with pelagic euphausiids and hyperiids (Figure 35).

Unidentified chaetognaths and *Eukrohnia* sp. were clustered together for both cruises in 2002 (Figure 36). Grooved mussel crab zoeae and megalopae and *Tomopteris* sp. were grouped with the unidentified chaetognaths and *Eukrohnia* sp. in June (Figure 36). Dungeness crab megalopae, *Eucalanus* sp., and *Sagitta* spp. were associated with the unidentified chaetognaths and *Eukrohnia* sp. in August (Figure 36). *Sagitta* spp. associated more closely with *T. spinifera,* Pacific krill, and *Hyperoche medusarum* in June 2002 (Figure 36).

Ghost shrimp (*Neotrypaea californiensis*) zoeae and megalopae and unidentified zoeal crangonids were clustered with Pacific rock and graceful crab megalopae in June 2002 (Figure 36). In another subcluster Crangonidae sp. A zoeae and hippolytids grouped with *Eucalanus* sp. (Figure 36).

## Diel Studies

During both diel studies in 2002, seven sets of samples were collected. Forty taxa were identified, 32 in June and 22 in August (Table 5 and Table 6).

During the June diel study, water temperature, salinity, zooplankton biovolume, and chlorophyll *a* concentrations fluctuated over time (Figure 37). Although the biovolume peaked at 1800 hours, total mesozooplankton concentration was low and did not peak until 0204 hours (Figure 37). Dungeness crab megalopae and *Sagitta* spp. were in all seven samples. Oregon cancer and red rock crab megalopae, *Eucalanus* sp., and *Pandalus* spp. megalopae occurred in four or more samples (Table 5). Most taxa were collected at night (2205 hours and 0204 hours), when total sample concentrations also were high. The total sample concentrations were 97.38/100 $m^3$ at 2205 hours and 255.68/100 $m^3$ at 0204 hours. The midday (1141 hours) sampling collected 5.95/100 $m^3$, the lowest concentration (Figure 37). The five most abundant taxa were *Diastylopsis* sp., Dungeness crab and Oregon cancer and red rock crab megalopae,

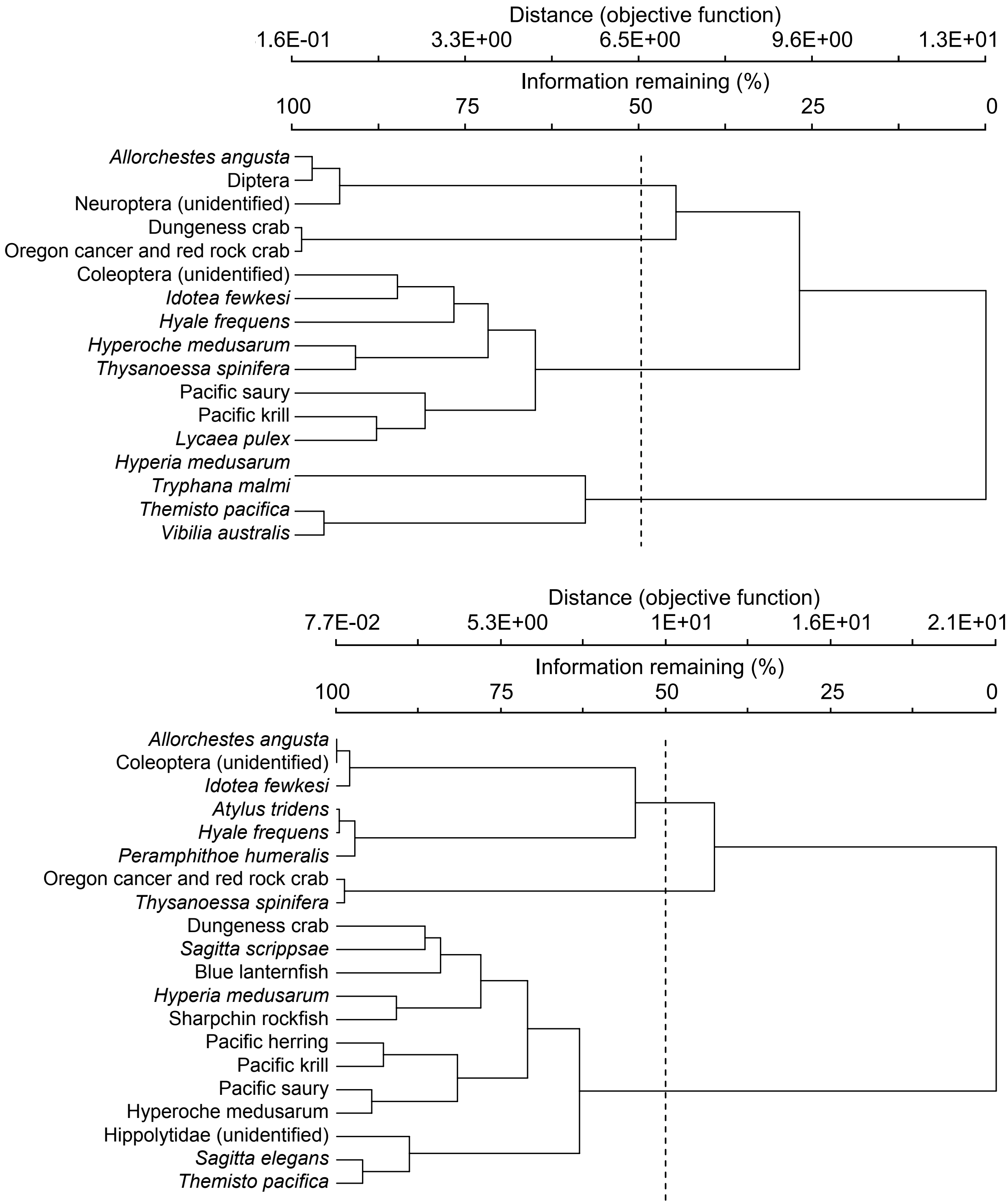


Figure 35. Dendrograms of neustonic mesozooplankton taxa cluster groupings for June (top) and August (bottom) 2000. Vertical dashed lines represent cutoff level.

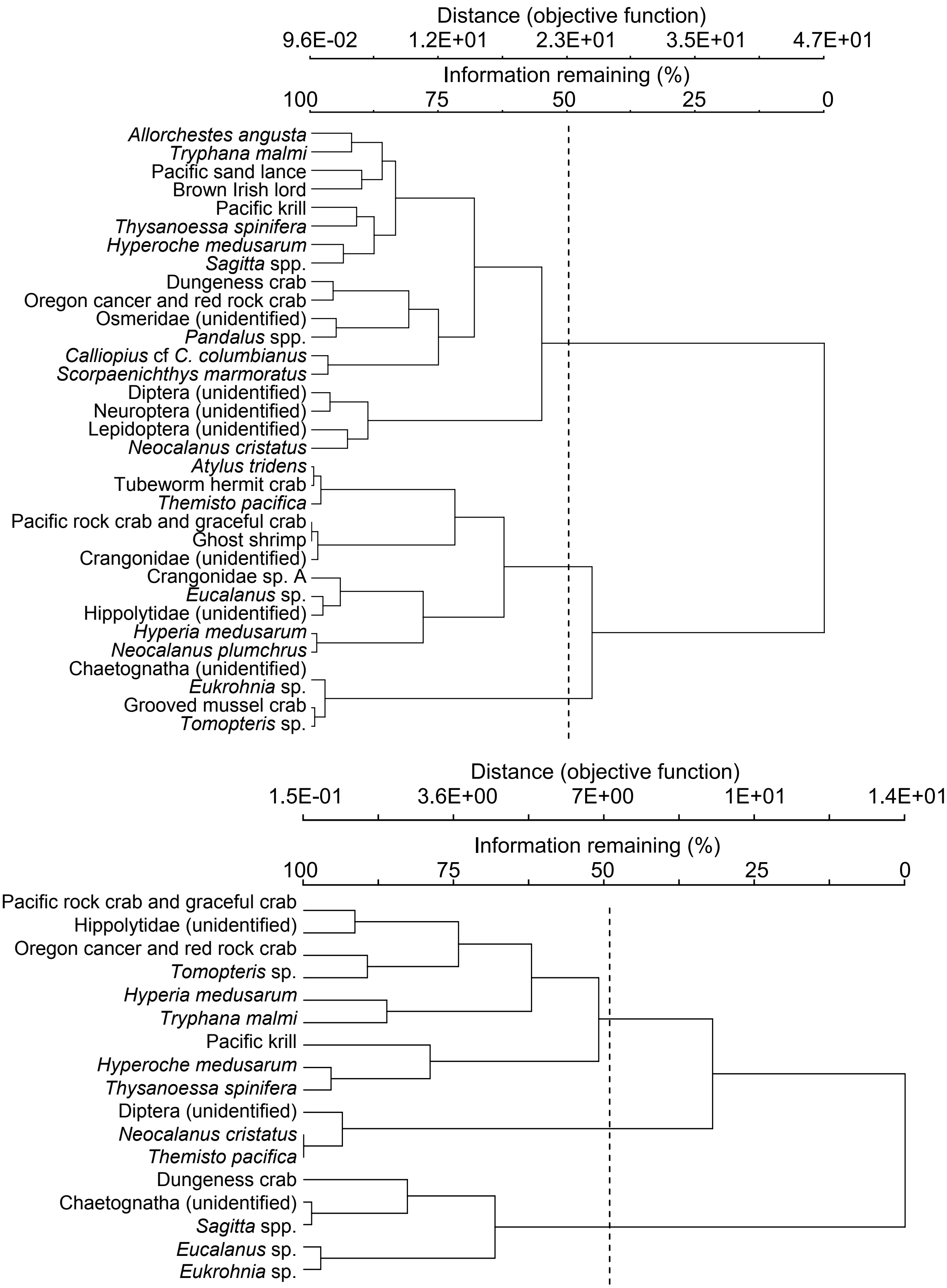


Figure 36. Dendrograms of neustonic mesozooplankton taxa cluster groupings for June (top) and August (bottom) 2002. Vertical dashed lines represent cutoff level.

Table 5. Concentrations (no./100 m$^3$) of taxa in the June 2002 diel study at station NH-5 (lat. 44.7°N, long. 124.2°W).

| Common name | Scientific name[a] | Time of day 1012 | 1411 | 1800 | 2205 | 0204 | 0606 | 0932 |
|---|---|---|---|---|---|---|---|---|
| Segmented worm | Annelida | | | | | | | |
| Bristle worm | Polychaeta | | | | | | | |
| | Spionidae (unidentified) | — | — | — | — | 0.57 | — | — |
| Arthropod | Arthropoda | | | | | | | |
| Crustacean | Crustacea | | | | | | | |
| Copepod | Copepoda | | | | | | | |
| | *Eucalanus* sp. | 1.04 | — | 0.63 | 0.98 | 1.14 | — | — |
| | *Lophothrix frontalis* | — | — | — | — | 0.57 | — | — |
| Cumacean | Cumacea | | | | | | | |
| | *Colurostylis* sp. | — | — | — | 0.49 | 2.86 | — | — |
| | *Diastylopsis* sp | — | — | — | — | 50.34 | — | — |
| | *Lamprops* sp., *Hemilamprops* sp., or *Mesolamprops* sp. | — | — | — | — | 10.30 | — | — |
| | *Leptostylis* sp. | — | — | — | 0.49 | 1.14 | — | — |
| | *Oxyurostylis* sp. | — | — | — | — | 0.57 | — | — |
| Opossum shrimp | Mysida | | | | | | | |
| | *Alienacanthomysis macropsis* | — | — | — | 1.97 | 8.01 | — | — |
| | *Neomysis kadiakensis* | — | — | — | — | 1.14 | — | — |
| | Mysida (unidentified) | — | — | — | — | 0.57 | — | — |
| Amphipod | Amphipoda | | | | | | | |
| Gammarid | Gammaridea | | | | | | | |
| | *Atylus tridens* | — | — | — | 3.44 | 6.86 | — | 0.56 |
| Hyperiid | Hyperiidea | | | | | | | |
| | *Hyperoche medusarum* | — | — | — | 1.48 | — | — | — |
| | *Themisto pacifica* | — | — | — | 1.48 | 0.57 | — | — |
| Krill | Euphausiacea | | | | | | | |
| | *Thysanoessa spinifera* | — | — | — | — | — | 0.50 | — |
| Crab, lobster, prawn, shrimp | Decapoda | | | | | | | |
| Hermit crab, sand crab, mole crab, porcelain crab, squat lobster, stone crab | Anomura | | | | | | | |
| Tubeworm hermit crab | *Discorsopagurus schmitti* | — | — | — | 0.49 | 1.72 | — | — |
| Alaskan hermit crab | *Pagurus ochotensis* | — | — | — | — | 1.72 | — | — |
| | *Pagurus* sp. C [*sensu* Lough (1975)] | — | — | — | — | 0.57 | — | — |

Table 5 continued. Concentrations (no./100 m$^3$) of taxa in the June 2002 diel study at station NH-5 (lat. 44.7°N, long. 124.2°W).

| Common name | Scientific name[a] | Time of day | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1012 | 1411 | 1800 | 2205 | 0204 | 0606 | 0932 |
| True crab | Brachyura | | | | | | | |
| Pacific rock crab and graceful grab | *Cancer antennarius* and *C. gracilis* | — | — | — | 0.98 | — | — | — |
| Dungeness crab | *Cancer magister* | 3.65 | 4.63 | 3.77 | 16.72 | 0.57 | 25.91 | 7.79 |
| Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | 4.69 | — | 0.63 | 1.48 | 0.57 | 1.50 | 24.48 |
| Grooved mussel crab | *Fabia subquadrata* | — | — | 2.51 | 1.48 | 1.72 | — | — |
| Shrimp | Caridea | | | | | | | |
| Stout crangon | *Crangon alba* | — | — | — | — | 1.14 | — | — |
| Sand shrimp, bay shrimp | Crangonidae | — | — | — | 29.02 | 8.58 | — | — |
| | Crangonidae sp. A[b] | — | — | — | — | 1.14 | 0.50 | 1.11 |
| Broken-back shrimp | Hippolytidae (unidentified) | — | — | 1.26 | 6.39 | 8.58 | — | — |
| | *Pandalus* spp. | 0.52 | 0.66 | 0.63 | 2.46 | 0.57 | — | — |
| Ghost shrimp, mud shrimp, sponge shrimp | Thalassinidea | | | | | | | |
| Ghost shrimp | *Neotrypaea californiensis* | — | — | — | — | 1.14 | — | — |
| Blue mud shrimp | *Upogebia pugettensis* | — | — | — | — | 1.72 | — | — |
| Arrowworm | Chaetognatha | | | | | | | |
| | *Sagitta* spp. | 12.52 | 0.66 | 28.25 | 27.54 | 114.97 | 16.94 | 22.81 |
| | Chaetognatha (unidentified) | — | — | — | — | 9.15 | 0.50 | — |
| | Osteichthyes | | | | | | | |
| Smelt | Osmeridae (unidentified) | — | — | — | — | 0.49 | 17.16 | — |

[a] Indentation patterns do not follow strict taxonomic classification. Taxonomic levels are indented to indicate a subcategory that is identified with a commonly recognizable scientific name. Within the lowest subcategories, species and other taxa with data are indented the same. This resulted in species not being indented the same between high taxonomic levels such as phyla.

[b] A distinct single species in the family Crangonidae that could not be identified to genus or species with the available taxonomic keys. Crangonidae (unidentified) has one or more unidentified species and does not include Crangonidae sp. A.

unidentified crangonid zoeae and megalopae, and *Sagitta* spp. Crangonids dominated at 2205 hours whereas *Sagitta* spp. dominated at 0204 hours (Figure 37). Generally the number of taxa and species diversity ($H'$) followed a similar temporal pattern (Figure 38).

Table 6. Concentrations (no./100 m$^3$) of taxa in the August 2002 diel study at station HH-2 (lat. 44.0°N, long. 124.4°W).

| Common name | Scientific name[a] | Time of day | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0825 | 1237 | 1637 | 2142 | 0138 | 0532 | 0936 |
| Mollusc | Mollusca | | | | | | | |
| Gastropod | Gastropoda | | | | | | | |
| Sea butterfly | Clionidae (unidentified) | — | — | — | 0.52 | — | — | — |
| Arthropod | Arthropoda | | | | | | | |
| Crustacean | Crustacea | | | | | | | |
| Copepod | Copepoda | | | | | | | |
| | *Eucalanus* sp. | — | — | — | 2.07 | 0.74 | 0.62 | — |
| | *Neocalanus cristatus* | — | — | — | 0.52 | 2.23 | — | — |
| Amphipod | Amphipoda | | | | | | | |
| Gammarid | Gammaridea | | | | | | | |
| | *Allorchestes angusta* | 1.84 | — | — | — | — | — | — |
| | *Atylus tridens* | — | — | — | 0.52 | 2.23 | — | — |
| Hyperiid | Hyperiidea | | | | | | | |
| | *Hyperoche medusarum* | 0.61 | — | — | 6.21 | 16.36 | 170.64 | — |
| | *Themisto pacifica* | — | — | — | 16.55 | 3.72 | 6.23 | — |
| Krill | Euphausiacea | | | | | | | |
| Pacific krill | *Euphausia pacifica* | — | — | — | 11.38 | 49.08 | — | — |
| | *Thysanoessa spinifera* | 1.84 | 0.80 | — | 58.97 | 1,997.39 | 16.19 | 1.25 |
| Crab, lobster, prawn, shrimp | Decapoda | | | | | | | |
| Hermit crab, sand crab, mole crab, porcelain crab, squat lobster, stone crab | Anomura | | | | | | | |
| Alaskan hermit crab | *Pagurus ochotensis* | — | — | — | 1.03 | 0.74 | — | — |
| True crab | Brachyura | | | | | | | |
| Pacific rock crab and graceful crab | *Cancer antennarius* and *C. gracilis* | — | — | — | 18.10 | 5.21 | — | — |
| Dungeness crab | *Cancer magister* | — | — | — | 15.52 | 7.74 | 8.72 | 1.25 |
| Oregon cancer crab and red rock crab | *Cancer oregonensis* and *C. productus* | — | — | — | 57.42 | 63.21 | — | — |
| Shrimp | Caridea | | | | | | | |
| Sand shrimp, bay shrimp | Crangonidae (unidentified) | — | — | — | — | 3.72 | — | — |
| | Crangonidae sp. A[b] | — | — | — | 0.52 | 1.49 | — | — |
| Broken-back shrimp | Hippolytidae (unidentified) | 1.23 | — | — | 3.62 | 0.74 | — | — |

Table 6 continued. Concentrations (no./100 m$^3$) of taxa in the August 2002 diel study at station HH-2 (lat. 44.0°N, long. 124.4°W).

| Common name | Scientific name[a] | Time of day | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0825 | 1237 | 1637 | 2142 | 0138 | 0532 | 0936 |
| Insect | Insecta | | | | | | | |
| True bug | Hymenoptera | 0.61 | — | — | — | — | — | — |
| Arrowworm | Chaetognatha | | | | | | | |
| | *Sagitta* spp. | 11.67 | — | 0.61 | 15.00 | 30.49 | 5.60 | — |
| | Chaetognatha (unidentified) | 0.61 | — | — | 2.07 | 4.46 | 0.62 | — |
| Chordate | Chordata | | | | | | | |
| | Osteichthyes | | | | | | | |
| Sculpin | Cottidae | | | | | | | |
| Cabezon | *Scorpaenichthys marmoratus* | — | — | — | — | — | 0.62 | — |
| Anchovy | Engraulidae | | | | | | | |
| Northern anchovy | *Engraulis mordax* | — | — | — | 1.03 | — | — | — |
| Snailfish | Liparidae | | | | | | | |
| | *Liparis* sp. | — | — | — | — | 0.74 | — | — |

[a] Indentation patterns do not follow strict taxonomic classification. Taxonomic levels are indented to indicate a subcategory that is identified with a commonly recognizable scientific name. Within the lowest subcategories, species and other taxa with data are indented the same. This resulted in species not being indented the same between high taxonomic levels such as phyla.

[b] A distinct single species in the family Crangonidae that could not be identified to genus or species with the available taxonomic keys. Crangonidae (unidentified) has one or more unidentified species and does not include Crangonidae sp. A.

In the August diel study, water temperature was warmer during the afternoon than during the night, and salinity fluctuated over time (Figure 39). Chlorophyll *a* concentrations peaked during the evening, and then declined during the night (Figure 39). However, there was a sharp drop in chlorophyll *a* at 1237 hours (Figure 39), which was confirmed with data recorded by the auxiliary fluorometer on the CTD vertical profiler. Sample biovolume was low during the daytime and peaked at 0138 hours before declining prior to dawn (Figure 39). The temporal pattern of biovolume resembled that of the total mesozooplankton concentration (Figure 39). Most mesozooplankton taxa occurred in one or two samples, and samples collected at night (2142 hours and 0138 hours) contained the most taxa (Table 5). The midday (1237 hours and 1637 hours) samples contained only one taxon each (Table 5). *Thysanoessa spinifera* was the most frequent and abundant species during the August diel study. The maximum *T. spinifera* concentration was 1,997.39/100 m$^3$ and occurred at 0138 hours, when the most mesozooplankton were caught. *Hyperoche medusarum*, Pacific krill, Oregon cancer and red rock crab megalopae, and *Sagitta* spp. were the more abundant species and mainly caught at night (Figure 39). *Hyperoche medusarum* peaked at 0532 hours (Figure 39). Comparison of species diversity indices and number of taxa per sampling time indicated that, while the number of taxa at 0138 hours was high, diversity was low (Figure 38). This is in contrast to that observed at 2124 hours, when diversity was much higher than at 0138 hours (Figure 38).

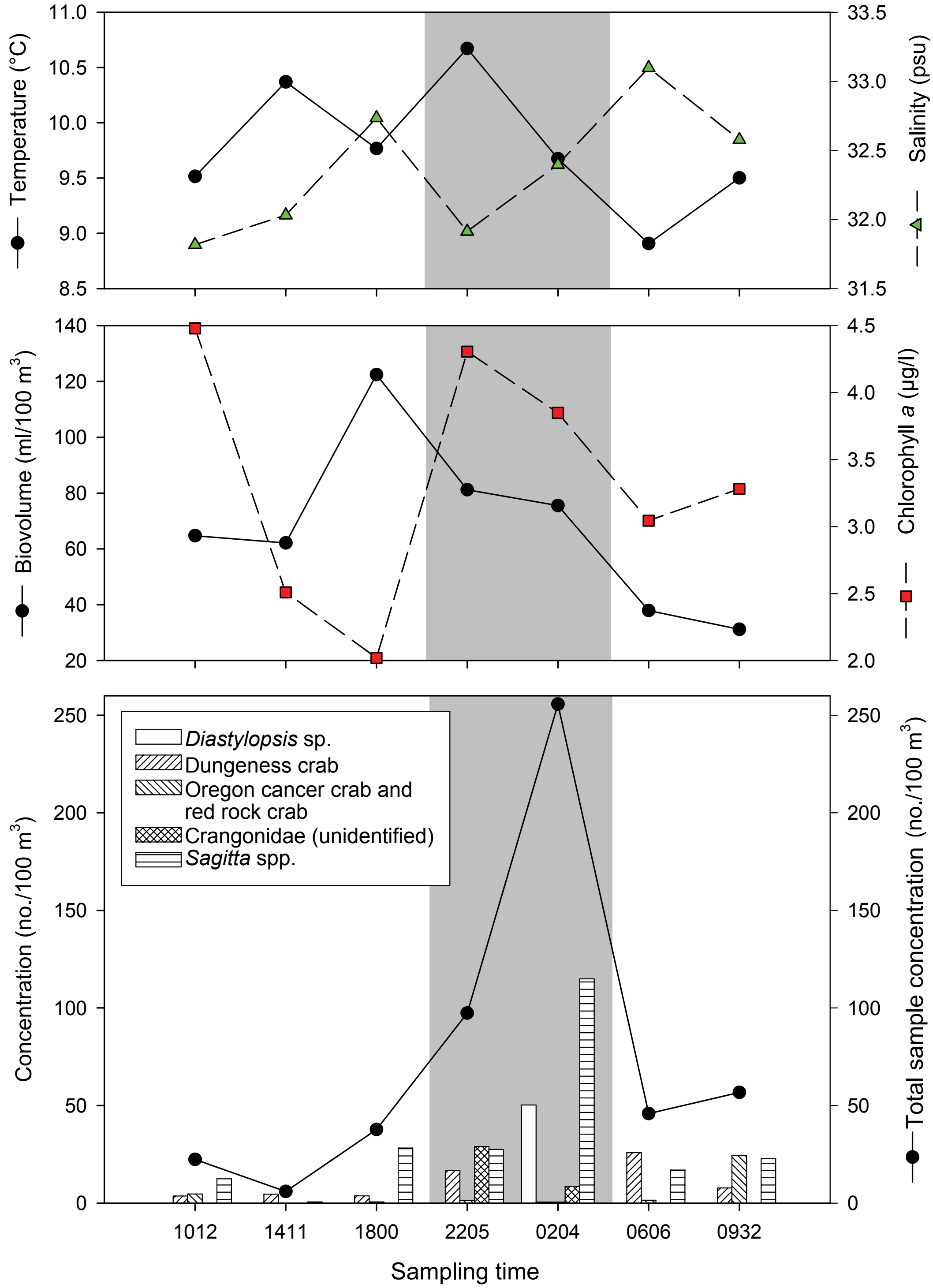


Figure 37. Temporal variations in water temperature (°C), salinity (psu), neustonic mesozooplankton biovolumes (ml /100 m$^3$), chlorophyll *a* (µg/l), and concentrations (no./100 m$^3$) of five most abundant taxa and total mesozooplankton at station NH-5 in June 2002. Gray areas indicate nighttime sampling.

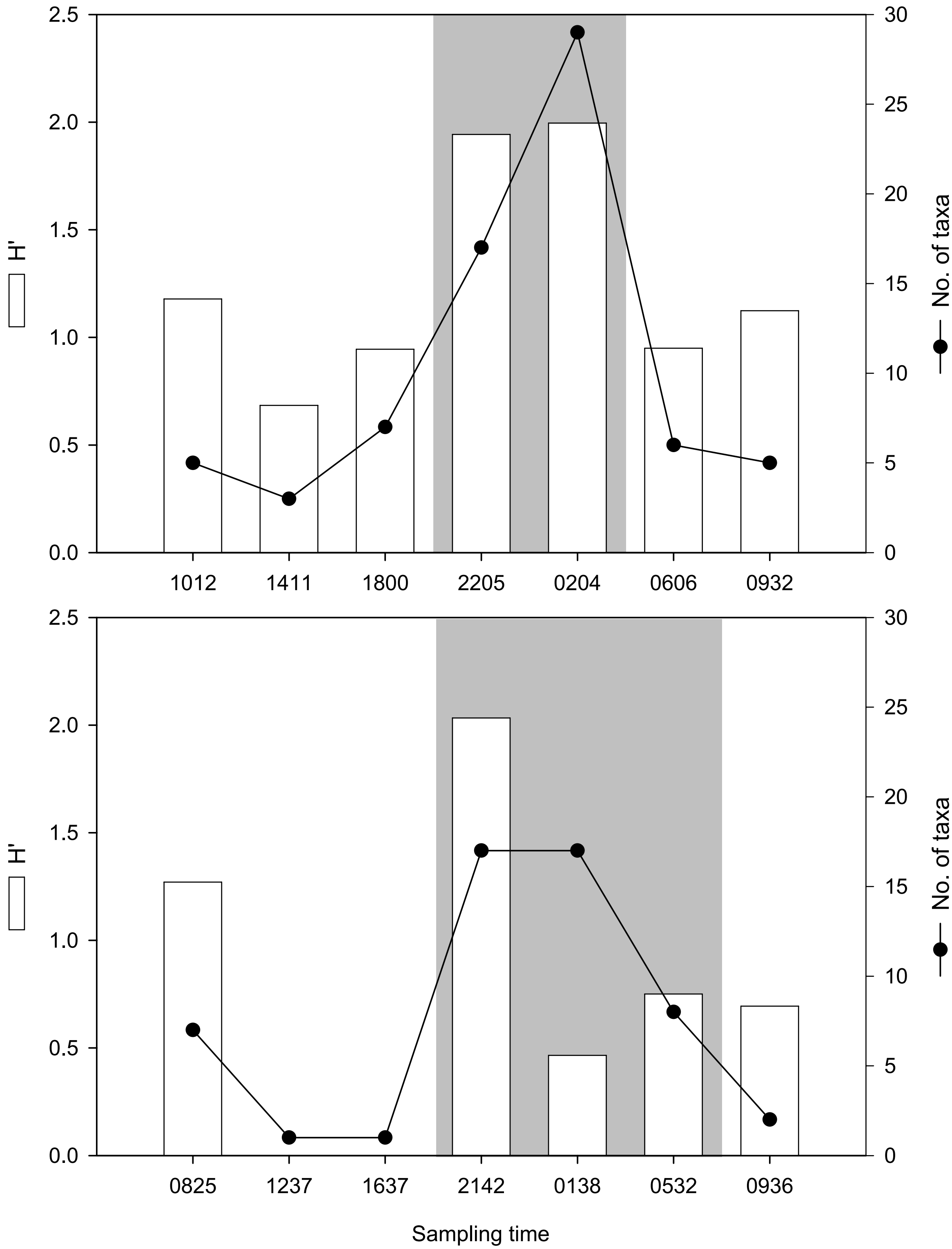


Figure 38. Diel pattern of neustonic mesozooplankton species diversity indices (*H'*) and number of taxa in June 2002 (top) at station NH-5 and August 2002 (bottom) at station HH-2. Gray areas indicate nighttime sampling.

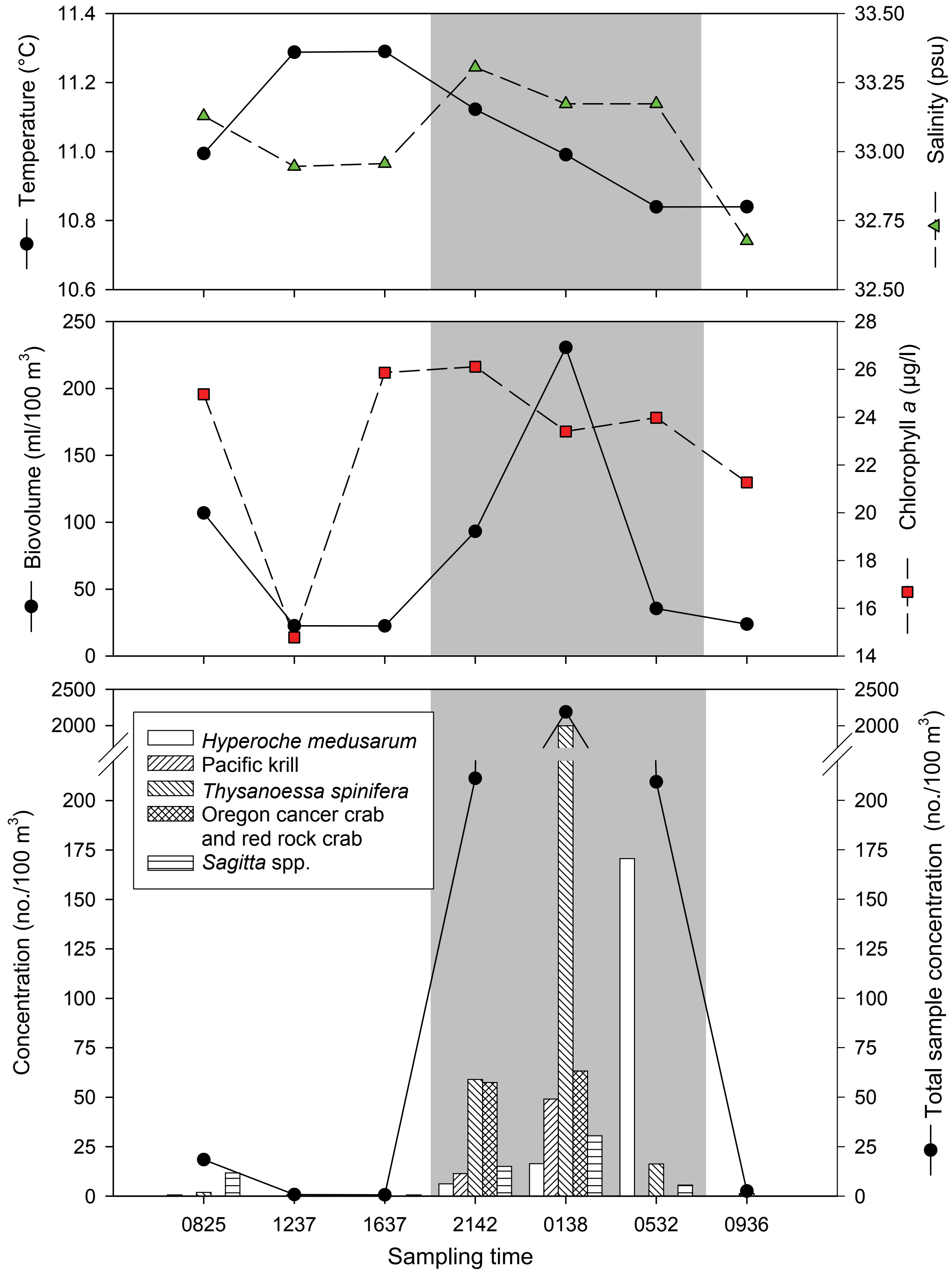


Figure 39. Temporal variations in water temperature (°C), salinity (psu), neustonic mesozooplankton biovolumes (ml/100 $m^3$), chlorophyll *a* (µg/l), and concentrations (no./100 $m^3$) of five most abundant taxa and total mesozooplankton at station HH-2 in August 2002. Gray areas indicate nighttime sampling. Diagonal slashes in y-axes are breaks in data range.

# Discussion

The variations observed in the neustonic mesozooplankton abundance and distribution may be affected by a number of factors such as predator-prey interactions, interspecific competition for space and food resources, vertical migration, current direction and speed, and water surface conditions (i.e., varied from calm with no waves breaking to large, choppy swells with waves breaking). Geomorphological features such as Heceta Bank and a coastal promontory, Cape Blanco, also could play a role. During the 2000 survey, a strong southward upwelling jet flowed along the outside of Heceta Bank, and a weaker northward current flowed inshore of the bank (Barth et al. 2005). Barth et al. (2000 and 2005) observed that Cape Blanco redirects the southward flow of the California Current offshore as it passes the cape. In addition, Peterson and Keister (2002) found that Cape Blanco separated the copepod community from the upper 100-m water column into interspecific zones north and south of the cape. Some taxa are meroplankton that spend a portion of their life cycles in the upper water column where currents could affect their seasonal occurrence and the enumeration of the different life stages (Lough 1975, Peres 1982, Holdway and Maddock 1983).

Data from the CTD casts indicated cooler water during 2002 than in 2000. Cool water nearshore was caused by coastal upwelling and the subsequent offshore advection of upwelled water during the summer season along the Oregon coast (Huyer 1983). Daily average upwelling indices showed that downwelling occurred during much of the June 2000 cruise because of an intense storm that originated from the south and was accompanied by strong southerly winds. During the cruise, northward wind stress reached nearly 0.4 Newton per square meter before subsiding (Barth et al. 2005). These conditions were anomalous for this time of year (Batchelder et al. 2002). The upwelling indices for August in 2000 and 2002 were similar, although strong upwelling occurred during July 2002 before the August 2002 cruise. Murphree et al. (2003) reported that anomalous wind stress in the Gulf of Alaska during early 2002 caused a strong equator-ward flow of the California Current, hence an intrusion of subarctic water to the California Current. The anomalous intrusion of subarctic water in our survey area also was identified by Barth (2003), Kosro (2003), and Strub and James (2003). This in turn may have influenced our observations of higher chlorophyll *a* concentrations in 2002 than in 2000, particularly over Heceta Bank. Wheeler et al. (2003) also reported high chlorophyll *a* concentrations off southern Oregon in July 2002 and attributed this to increased nutrients transported to this region as part of the subarctic anomaly.

For all four cruises, the numerically dominant taxa were Dungeness crab megalopae, Oregon cancer and red rock crab megalopae, *Hyperoche medusarum*, *T. pacifica*, Pacific krill, *T. spinifera*, and *Sagitta* spp. These taxa have been commonly caught in past surveys of this area (Lough 1975, Brodeur et al. 1987, Brodeur 1990, Schabetsberger et al. 2003, Gómez-Gutiérrez et al. 2005).

The distribution of Dungeness crab megalopae and Oregon cancer and red rock crab megalopae across the shelf and offshore mainly was because of the water circulation patterns in the survey area. The concentrations of these abundant species dropped dramatically from June to August in both years, perhaps contributing in large part to the seasonal decrease in biovolumes because of their large body size. Early in the year when downwelling occurs, both cancrid species pass through their zoeal stages while being transported offshore (Lough 1975, Shenker 1988, Jamieson et al. 1989, Hobbs et al. 1992). During the spring, the winds shift from southwesterly to northerly and upwelling begins, causing the southward flowing California Current to become stronger (Hickey and Banas 2003). This is when the last zoeal stage metamorphoses into the megalopal stage. The megalopae then are transported cross-shelf to return nearshore where they settle in shallow water (Lough 1975, Shenker 1988, Hobbs et al. 1992). Occasional southwesterly storms with accompanying winds during the upwelling season may facilitate the shoreward transport of the megalopae (Shenker 1988, Jamieson et al. 1989). However, Roegner et al. (2003) found that Dungeness crab megalopal recruitment to two Washington estuaries occurred during a wide range of wind stress and water movements. Tidally generated internal waves in convergence zones may be another mode of transport (Johnson and Shanks 2002). Surface orientation of megalopae or their practice of clinging to floating surface debris also has been proposed (Jamieson et al. 1989). Dungeness crab megalopae and Oregon cancer and red rock crab megalopae were previously caught up to 111 km offshore along the Newport Hydroline (Lough 1975, Shenker 1988). In addition, Dungeness crab megalopae and Oregon cancer and red rock crab megalopae were collected 28–170 km off the southwestern side of Vancouver Island in British Columbia, Canada (Jamieson et al. 1989). Therefore, the occurrence of these megalopae offshore and beyond the shelf break in our neuston survey was not unexpected.

The differences in Dungeness crab megalopal abundance between June 2000 and June 2002 may have been because of several effects. The timing of zoeal to megalopal metamorphosis could have differed between years (Lough 1975). This could influence whether most individuals were in the megalopal stage by the time of this sampling. Aggregation behaviors have been suggested as another effect (Lough 1975, Shenker 1988, Roegner et al. 2003). Dungeness crab was observed more often at the surface during the megalopal phase than during all zoeal stages, probably because of their photopositive response to light (Lough 1975, Shenker 1988). However, in other studies, more megalopae were caught from the ocean surface at night than at other times; this possibly was caused by vertical migration, avoidance of predators or the net, or surface orientation for onshore transport (Shenker 1988, Jamieson et al. 1989, Johnson and Shanks 2002, Roegner et al. 2003). Temperature and salinity were considered important environmental factors on Dungeness crab larval life (Lough 1975). However, Hobbs et al. (1992) (from northern California to Washington) and Roegner et al. (2003) (off southern Washington) did not find any correlations or significant relationships between sea surface temperature or salinity and Dungeness crab megalopal abundance.

Hyperiid and gammarid amphipods were collected from the ocean surface during 2000 and 2002. Gammarids may have been brought to the neustonic layer by subsurface water mixing and vertical transport, or in the case of nearshore species, many have been associated with drifting kelp or other algae. Gammarids were caught in previous zooplankton surveys off Oregon and Washington but not in large numbers or high occurrences (Brodeur et al. 1987, Schabetsberger et al. 2003). Hyperiids generally are considered to be commensal or even parasitic on gelatinous zooplankton, often inhabiting their cavities and tissues while young and riding on them while adults (Madin and Harbison 1977, Harbison et al. 1977, Laval 1980, Sorarrain et al. 2001). Therefore, the distribution of some hyperiids could be dependent on the distribution of their hosts (Madin and Harbison 1977, Harbison et al. 1977, Laval 1980, Sorarrain et al. 2001). *Hyperoche medusarum* have been associated with ctenophores (*Beroe forskali*), moon jelly and lion's mane jelly, and comb jelly (Brusca 1970, Harbison et al. 1977, Laval 1980). *Themisto pacifica* are parasites on medusae and salps (Laval 1980). The concomitant surface rope trawl catches included salps, ctenophores (*Beroe* spp.), moon jelly, and lion's mane jelly. In addition, some of the neuston tows contained many *Pleurobrachia* spp., including *P. bachei*. While direct observations of living hyperiids parasitizing on these gelatinous zooplankton were not made during this survey, the possibility remains that the abundance and distribution of gelatinous zooplankters largely influenced the capture of hyperiids in neustonic zooplankton tows. Laval (1980) indicated that abundance and distribution of hyperiids caught in plankton tows may not be representative because of associations with their gelatinous hosts.

Among the euphausiids, *T. spinifera* generally is considered a shelf species, while juvenile and adult Pacific krill are considered an offshore species; however, their distributions are stage dependent and often overlap (Gómez-Gutiérrez et al. 2005). Smiles and Pearcy (1971) reported that Pacific krill of all sizes were more abundant over the shelf than offshore, but that the larvae were more abundant inshore. Our analysis combined all life stages observed in the size fraction we examined and from the ocean surface, as opposed to deeper waters. Whereas we caught juveniles to adults, some of our samples had many furciliae within the size range from 4 to 6 mm. Diel vertical migrations of both species have been observed over the continental shelf and in the California Current (Brinton 1962, Alton and Blackburn 1972, Youngbluth 1976). During the August 2002 diel study, this phenomenon was apparent in that most of the euphausiids were caught at night. Therefore, the data may be underestimated if one limits analysis to furciliae, and biased on the temporal and vertical distributions of each life stage. *Thysanoessa raschii* is a subarctic species that is rarely observed off Oregon and the single specimen of this species found in August 2002 was probably a result of the anomalously cold water intrusion during 2002.[3]

Chaetognaths were one of the most abundant organisms during all cruises. Along the Oregon and southern Washington coasts, chaetognaths dominated over other mesozooplankters in the water column throughout the summer of 1981 (Brodeur 1990). Chaetognaths also dominated in the Gulf of Alaska, where copepods were the dominant prey (Brodeur and Terazaki 1999). The abundance and distribution of chaetognaths in this study, therefore, could be dependent on the availability of copepods as prey. However, few chaetognaths in our samples had copepods in their digestive tracts, despite many samples containing a high abundance of copepods below the 5-mm size fraction examined in this study. Off Oregon and northern California, the concentrations of neustonic chaetognaths in 2000 and 2002 were 2–8 times higher than in 1984 (Brodeur et al. 1987).

Larval and juvenile fishes have been caught from the neuston and water column in ichthyoplankton surveys along the Pacific coast from Canada to California (Ahlstrom and

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[3] J. Gómez-Gutiérrez, Departmento de Plancton y Ecologia Marina, Col Playa de Santa Rita, La Paz, Mexico. Pers. commun., 31 January 2004.

Stevens 1976, Richardson and Pearcy 1977, Richardson et al. 1980, Gruber et al. 1982, Shenker 1988, Doyle 1992, Doyle et al. 2002). Fish larvae and juveniles were not very abundant in our survey compared to other ichthyoplankton surveys in this region, though we did collect many species that had been identified in previous surveys. Net avoidance during the day and diel vertical migration of fish larvae and juveniles could affect catches of ichthyoplankton in the neuston (Gruber et al. 1982, Shenker 1988, Doyle 1992). Ichthyoplankton surveys of just the Newport transect by Richardson and Pearcy (1977) and Shenker (1988) over several time periods provide an indication of seasonal abundance patterns in the larval and juvenile stages of many fishes.

The associations among species generally appeared to be based on habitats, but they were not highly distinguishable. Many common pelagic taxa such as *Cancer* spp. megalopae, chaetognaths, *Tomopteris* sp., hippolytid larvae, *T. spinifera*, and grooved mussel crab zoeae and megalopae seemed to be clustered together. In 2000, Pacific saury juveniles and Pacific krill were grouped together, likely because of their offshore affinities, while also being associated with *Hyperoche medusarum* because all three species have similar spatial distributions. Shrimp zoeae and megalopae usually clustered together, which could be because of the timing of reproduction and the subsequent presence of larval stages at the ocean surface. Finally, terrestrial (insects) and benthic organisms (gammarids and isopods) generally were clustered, probably because of their proximity to shore. Any offshore distributions of these latter taxa could be explained by offshore dispersal caused by winds and Ekman transport.

In the one previous comprehensive survey to date, Brodeur et al. (1987) sampled four transects between lat. 42.0°N and lat. 44.7°N from shore to about long. 124.7°W during three cruises in 1984. Much of their sampling was close to shore and to the north of the present study area (one cruise extended from Canada to southeast Alaska). In contrast, we sampled up to 18 transects over a broader offshore area (i.e., to long. 126.0°W) more intensely during two summers. Therefore, direct comparison of abundance and distribution patterns of mesozooplankton in the neuston between these two studies is difficult. In a comparison between the June cruises in the present study and in the 1984 study, many dominant species were similar (Dungeness crab, Oregon cancer and red rock crab, Pacific krill, *T. spinifera,* and *T. pacifica* [*Parathemisto pacifica* in the 1984 study]). A major difference was the relative paucity of terrestrial insects during the present study compared to 1984. Winds could affect the aerial distribution of small, weak-flying insects, and hence, their ocean surface abundance and distribution (Cheng 1977, Cheng 1978). An anomalous weather pattern, with winds blowing offshore from the coast, may have contributed to the overabundance of insects in the previous sampling (Brodeur et al. 1987, Brodeur 1989). Also, the previous work encompassed the end of a strong El Niño, which led to the occurrence of some warm-water southern species such as the euphausiid *Nyctiphanes simplex*, normally found only off southern California.

Cruises during this study were 14–18 days long, covering a large area with constantly changing oceanographic conditions. The long duration of the cruises may have produced variations in the results at the fine-scale level. For instance, sampling the Heceta Head line on 2 June 2002 then again on 9–10 June 2002 showed that species composition changes rapidly. For example, Dungeness crab megalopae were not caught at four of five stations on 2 June 2002 (HH-1–HH-5), but they were found in high abundance 9–10 June 2002. The 1-m temperature, salinity, and density were similar (<1 unit of change) between these two sampling times, although chlorophyll *a* concentrations at the 3-m depth increased 2–14 times at three nearshore stations. During the August 2002 cruise on the same Heceta Head line, chlorophyll *a* concentrations changed by a factor of 5 within a 14-day period. Timing of the offshore transport of megalopae, and an increase in primary productivity as indicated by chlorophyll *a* concentrations, may have been more pronounced after we sampled the transect the first time. Therefore, the dynamics of environmental conditions and zooplankton life cycles could affect the temporal abundance and distribution of neustonic mesozooplankton at a single sampling location.

# Conclusion

Mesozooplankton in the neustonic layer off Oregon and northern California differed in numerical abundance, taxa composition, and temporal and spatial distribution between sampling periods. Abundance and number of taxa observed were higher in 2002 than in 2000 and higher in June than in August. Cooler 1-m water temperatures and higher 3-m chlorophyll *a* concentrations observed in 2002 are indicative of strong upwelling and may have positively affected neustonic mesozooplankton abundance and distribution. Dungeness crab megalopae and Oregon cancer and red rock crab megalopae, *T. spinifera*, Pacific krill, *Hyperoche medusarum*, *T. pacifica*, and *Sagitta* spp. were the commonly caught mesozooplankton during all four cruises. Fluctuations in abundance and distribution also can be attributed to zooplankton life histories, diel vertical migration, oceanographic conditions, and sampling net avoidance.

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