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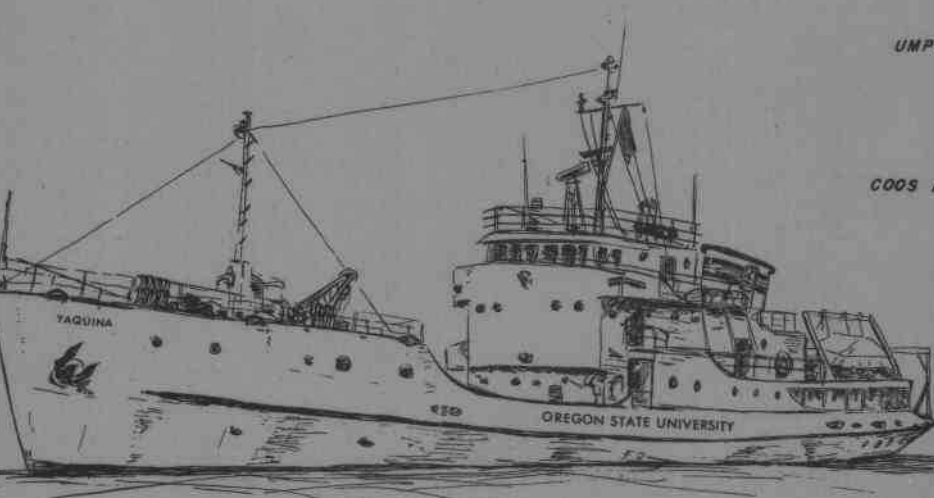
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# DEPARTMENT of OCEANOGRAPHY

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OREGON STATE UNIVERSITY



NEHALEM R.

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UMPQUA R.

COOS BAY

## RESEARCH ACTIVITIES

1 April through 30 September  
1966

Edited by  
Sally Kulm

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Department of Oceanography  
School of Science  
Oregon State University

Wayne V. Burt  
Chairman

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## PHYSICAL OCEANOGRAPHY

### Atmospheric Effects on Incoming Solar Radiation in a Tropical Marine Environment - Quinn, Burt

This study has been directed to the tropical region; the tropics have been greatly neglected from the standpoint of quantitative evaluations of incoming solar radiation as affected by atmospheric factors. The few marine studies made of this nature were based on data from middle and high northern latitude locations.

The tropical Pacific was selected for this investigation, because it contained two small atoll islands (Wake and Canton) which had essential atmospheric and radiation data (hourly and special surface weather observations, 12-hourly atmospheric soundings, and solar radiation records) available. Also, these islands are of such size, configuration, and vertical relief as to cause very little disturbance to the air-sea environment. Wake Island (located at  $19^{\circ} 17' \text{N}$ ,  $166^{\circ} 39' \text{E}$ ) data are being used primarily to investigate the trade wind region. Canton Island (located at  $2^{\circ} 46' \text{S}$ ,  $171^{\circ} 43' \text{W}$ ) data are being used primarily to investigate conditions in the equatorial trough. Although the trough migrates considerable distances with the seasons, it is frequently in the vicinity of Canton Island during its summer and early fall seasons.

Data from July 1957 through June 1958 are being used in this study since the IGY Tropical Zone Analyses are available for this period. These daily synoptic weather analyses allow one to determine the positions of the equatorial trough and tropical disturbances in relation to the islands and their atmospheric and radiation data. Climatological data indicate this selected period is highly favorable for studying disturbance type weather effects over Canton Island. Almost three times the normal amount of precipitation, nearly twice the normal number of days with precipitation, and about five times the normal number of days with thunderstorms were recorded during this 12-month period.

The ultimate goal of this study is to develop a suitable relationship for determining incoming solar radiation in the tropical marine environment through the use of meteorological data alone; many small islands record and transmit meteorological data but exceedingly few record radiation data.

The following factors appear to be quite diagnostic for this investigation and are at present being computed and tabulated for each daylight hour of the selected site record periods:

Solar altitude (angle in degrees and sine of angle)  
 Optical air mass  
 Solar radiation received at the top of the atmosphere  
 Solar radiation recorded at the observing site  
 Low cloud cover  
 Total cloud cover  
 Total opaque cloud cover  
 Precipitable water content surface to 850 millibars  
 Precipitable water content surface to 700 millibars  
 Precipitable water content surface to 400 millibars

Inter-relations between solar radiation received and cloud and precipitable water factors will be investigated in detail when the above computations and tabulations are completed.

#### Subsurface Currents Off the Oregon Coast -- Stevenson, Pattullo, Wyatt

The major results of the work with drogues have been rewritten in preparation for publication. The revised abstract follows:

Currents were measured by parachute drogues set at selected depths from the surface to 500 m. Linear regression of distance on time was used to determine the mean current for each drogue trajectory. An auto-correlation method was used to identify the dominant periodic motion.

The subsurface motions appeared to be grouped into three distinct domains: low frequency motions (no change observed over 25-50 hours), periodic fluctuations of frequency close to that of the semi-diurnal tide, and small random fluctuations. The mean longshore current, surface to 500 m was toward the south, with speeds of 5 to 10 cm sec.<sup>-1</sup> Mean transport was  $484 \times 10^9$  cm<sup>3</sup> mo<sup>-1</sup> per cm of distance perpendicular to the mean south-southeastward flow, or approximately 1.87 sverdrups in the area within 100 km of the coast. The mean zonal transport was onshore above the pycnocline, offshore below the pycnocline, but small (less than  $130 \times 10^9$  cm<sup>3</sup> mo<sup>-1</sup> per cm). Surface flow was variable. Some northward movement was observed during winter.

Semi-diurnal tidal flows of 5 to 12 cm sec<sup>-1</sup> dominated the periodic motions, but some inertial and diurnal periodicities were observed.

Upwelling, Winds, and Sea Level Changes - Panshin, Pattullo,  
Woodruff, Smith

Mr. Panshin wrote his master's thesis on this research. The abstract follows:

The relationship between sea level and wind stress in a region of known upwelling was studied for an eleven-month period during 1933-34.

Sea level data, obtained from observations taken by the Coast and Geodetic Survey, were processed to remove astronomic tidal constituents and inverted barometer effect. Regression analysis was used to establish the relationship between the resultant daily mean sea levels and the north and east components of wind stress. Sea level and wind stress were significantly related. The highest correlation for sea level of a given day was with the north component of wind stress summed over the given day and the three days preceding. Sea level was next most highly correlated with the east component of wind stress summed over the given day and the two days preceding. The sea level-wind stress relationship is consistent with what is known about upwelling along the Oregon coast.

The relationship between sea level and rainfall was also examined. Sea level and rainfall were significantly associated, but not in such a marked fashion as were sea level and wind stress. The rainfall effect may be due both to local addition of mass and to augmentation of wind stress by heavy rain.

This study is being continued by Lt. Roger Woodruff, ESSA, with Dr. Pattullo and Dr. Smith.

Oceanic Heat Storage - Burt, Pattullo, Kulm

This paper has been rewritten in preparation for publication. A revised abstract follows:

Heat content, surface to 100 m, was computed for stations within 165 nautical miles of the Oregon coast. Mean content, 1962 through 1965, was 101 kg cal.  $\text{cm}^{-2}$ , with a root mean square deviation of 12.7 kg cal.  $\text{cm}^{-2}$ . The principal fluctuation around the mean was seasonal; the seasonal range was twice as large beyond 100 miles from the coast (30 kg cal.  $\text{cm}^{-2}$ ) as the range within 65 miles offshore (15 kg cal.  $\text{cm}^{-2}$ ). The cause of the seasonal variation offshore



is shown to be local heating, but inshore advection reduced observed ranges in storage to only one-third of the computed local heating. The results are consistent with inshore currents from the south in winter and coastal upwelling associated with offshore transport of water and heat in the summer.

#### Evaporation Over Yaquina Bay - DeRycke, Pattullo

Lt. DeRycke wrote his master's thesis on the results of this research. His abstract follows:

A weather station was established on the dock of the Oregon State University Marine Science Center, Yaquina Bay, Oregon. A total of 197 weather observations was made from 30 June 1966 to 23 September 1966, with emphasis on the determination of the rate of evaporation from an evaporation pan and from atmometers.

Sources of observational error were investigated and corrections applied as necessary. The daily variation in evaporation was determined. The correlation between wind, vapor pressure, and evaporation was found. Atmometers were used to estimate the evaporation from the surface of Yaquina Bay, and the possibility of using atmometers at sea was investigated.

#### Continental Shelf Waves - Mooers, Smith

The statistical search for the presence of continental shelf waves off Oregon with periods greater than one day is continuing. Hamon (CSIRO Australia) has reported waves of several day period traveling along the Australian shelf. Robinson (Harvard University) has given a theoretical model of continental shelf waves as a class of resonant-forced-barotropic wave motion, where the resonance is determined by slope of shelf and the periodic structure of the atmospheric forcing function.

The data being used in the study at Oregon State are tidal records from four Oregon coastal stations, atmospheric pressure data, and geotrophic wind data for a period of 11 months during 1933-34. The tidal records were low pass filtered by the Doodson filter and by a convolution of Lancos and cosine tapers. The present effort has been devoted to correlation and spectral analysis of the data for summer and winter 100 day record lengths as well as the 11 month record.

Results indicate the barometric factor is not 1 cm to 1 mb (1 cm decrease in sea level to 1 mb increase in pressure) for all frequencies. Strong correlations remain between atmospheric pressure and sea level adjusted with 1 cm/1 mb barometric factor. Periods of the order of one to three weeks present in both atmospheric pressure and adjusted sea level are complicating the search for continental shelf waves of several day periods. We plan to employ a high pass filter to help resolve this difficulty. Cross correlation between the four sea level records is being used in the search for coherent motion along the coast. The possibility of complications resulting from coupling of adjusted sea level to wind stress is being tested. Future work will also consider the discrimination between barotropic continental shelf waves and baroclinic internal Kelvin waves of possibly similar characteristics.

Correspondence with B. Hamon of CSIRO, Australia, and L. Mysak at Harvard University, is continuing in this area of mutual interest.

#### Oceanography of Shelf Waters - Pattullo, Smith, Mooers, Pillsbury

An array of current meters and thermographs was installed for over a month on the Oregon continental shelf on 15 August. The purpose was twofold: (1) investigate the coastal oceanography and currents on the shelf near the end of the summer upwelling seasons and (2) study the internal tidal wave regime in the vicinity of the upwelling front. The sensor array units consisted of current meters at 20m and 60m below the surface and a recording thermograph at 20 meters. The array units were moored at 5, 10, and 15 n. miles from Depoe Bay on bearing 300° True in depths of 80, 140, and 200 m, respectively. An additional thermograph at 20m depth was placed 5 miles to the southeast of the line at 11 miles off the coast. Hydrographic stations were made at each installation.

A series of hydrographic stations 5 miles apart with dense bottle spacing were made from 26 August through 2 September to define the hydrography on the shelf in the vicinity of the array. The 25-hour anchor stations were made 25 n. miles and 40 n. miles off Depoe Bay, latitude 45°N, and 65 n. miles off Newport, latitude 44° 39'N. Current meter observations were made from the ship at selected stations off Depoe Bay, including both anchor stations.

The sensor arrays were all successfully recovered on 23 and 24 September. A surface marker float for the unit 15 n. miles off coast was missing, but the unit was successfully recovered intact. A portion

of the previous hydrographic stations was repeated with current meter observations being taken from the ship, including the 25-hour anchor stations at Db-25 (25 miles off Depoe Bay). A detailed time series of a temperature inversion and subsurface flow was made at the anchor station. A study of the latter and a comprehensive cruise report are in preparation.

We plan to install the array again in the spring at the onset of the upwelling season.

Mooers is continuing the development of a hydrodynamical model, consistent with our data, for internal tidal waves on a continental shelf. The sloping shelf, continuous variation of density with depth, and the horizontal variation in density are included. Ultimately, the model will be studied by numerical means; one of the areas of current study is that of various orthogonal expansions of the density structure, hoping to achieve a portion or the approximate solution in closed form. One of the major objectives is to model the propagation of an internal tide wave into the region of an upwelling front and to examine stability conditions there.

#### Seiching in Yaquina Bay - Gilbert, Pattullo

Tide-gauge records taken at the dock of the Marine Science Laboratory showed frequent oscillations of water level of small amplitude (a few centimeters) and short periods (5 to 20 minutes). We have studied these fluctuations and the physical characteristics of Yaquina Bay to determine whether the oscillations appear to be related to seiching in the bay. The standard tide gauge records available were somewhat inadequate; therefore, a special, portable, staff-in-tube gauge was constructed. Fifteen sets of data have been collected with this portable device.

De-trending and spectral analysis by computer have been applied to the data whenever feasible. The results suggest that there are two principle domains of periodic oscillations, both possible seiches. During winter short period oscillations (periods less than six minutes) were observed during about one-half of the instances when observations were made. Such short oscillations were much less prevalent in summer; they were observed only about one-sixth of the time. From geometrical and physical considerations, it appears these could be either multi-nodal seiches oriented along the main channel of the bay or cross-channel standing waves. Oscillations of longer period (tens of minutes) dominate during summer. Spectral analysis yields 20

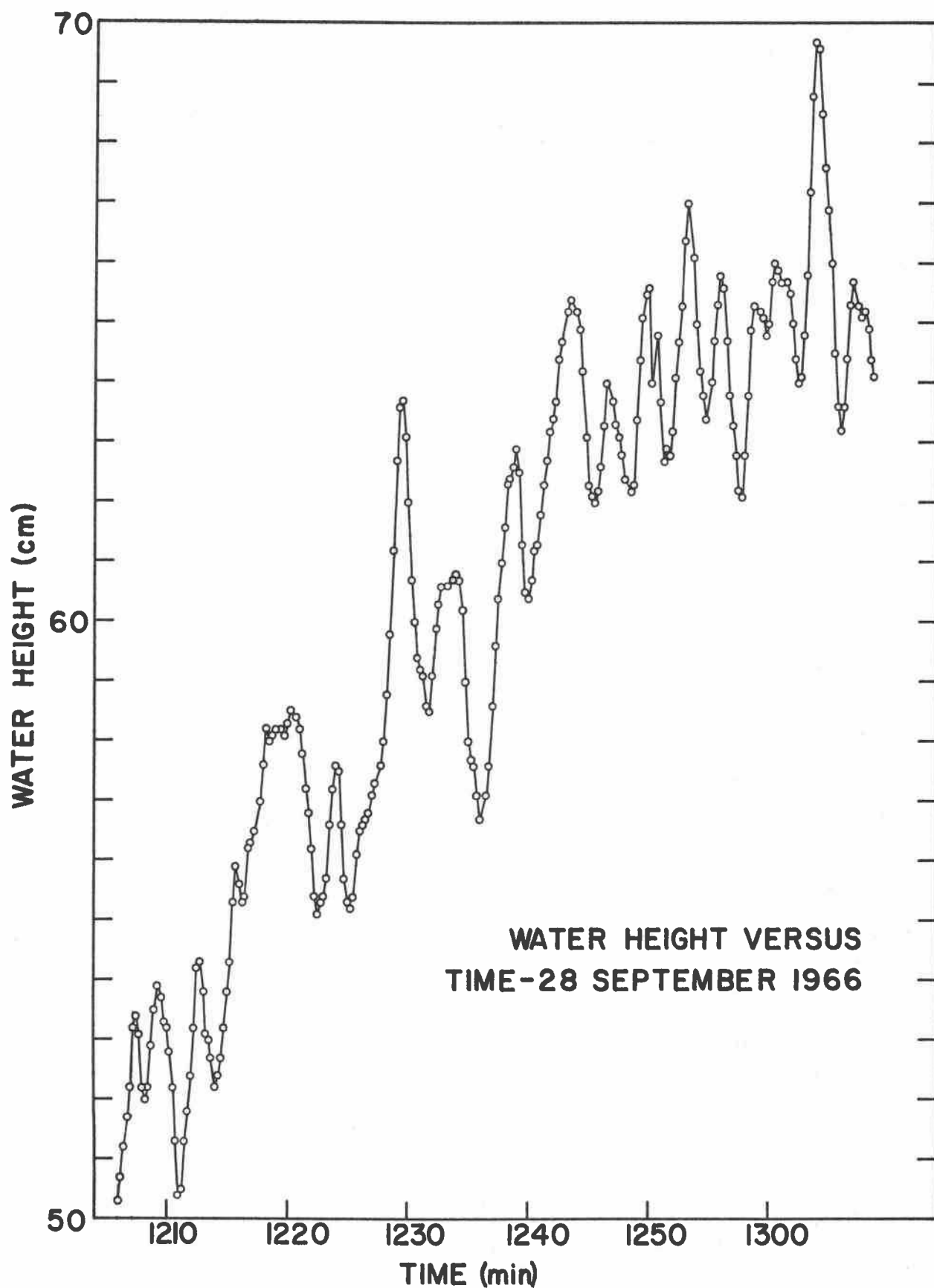


Figure 1. Water Height versus Time in Yaquina Bay, Oregon

minutes as the period most frequently observed. This is interpretable as a long-channel oscillation between the Coast Guard Station and Buoy 19. No large amplitude oscillations were observed; displacements were the order of centimeters to tens of cm throughout.

#### Current Measurements Over the Continental Shelf - Collins, Pattullo, Pillsbury

Data Report No. 23, Reference 66-11, is currently being printed by the Oregon State University Press. It is the first Data Report of a program to study physical processes in Oregon shelf waters by means of moored instrument arrays. Various statistics and plots of smoothed data are presented for time series of current velocity and of temperature. Data were collected in July, August, September, and October of 1965 and in January and February of 1966.

Correlation functions and power spectra have been computed for these time series as well as sea level and local wind. These are being analyzed presently.

Figure 2 shows a progressive vector diagram from 25 September through 19 October 1966. Speed and direction are given in the form of bar graphs in Figure 3.

#### Hydrography - Neshyba

The special hydrographic techniques developed for the YALOC-66 cruise (see p. 59) were not employed on that cruise due to a loss of ship time. These techniques involve the use of rapid-launch taut-wire buoys, drogues, shallow and bottom current measurements, and continuous BT measurements, all in support of executing a given hydro cruise through the use of 24 hydro stations. These techniques were again attempted on Cruise 66-10, November 1966, but were only partially successful due to rough weather. On this cruise, three 24-hour stations were made in a triangular pattern. The objective is to process the data and obtain a vanishing net mass transport into the volume enclosed. The primary interest is to determine whether time series of BT data can be successfully used to remove uncertainty in the vertical distribution of mass due to internal motion in the water column. If this can be done, we expect to develop a buoy supported thermistor string to record temperature structure for 24 hours. The use of such a device would free the ship from the necessity of remaining on station

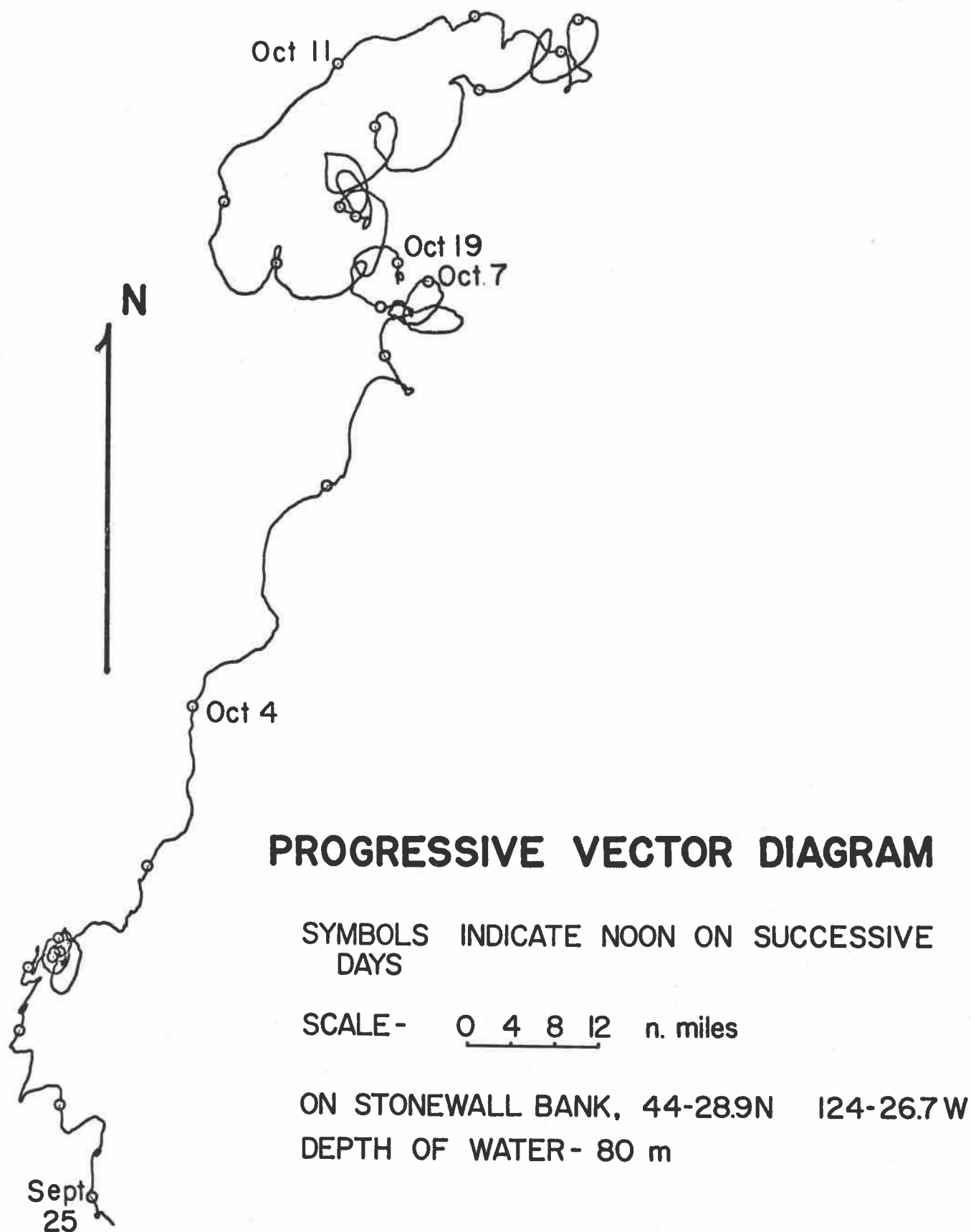


Figure 2. Progressive vector diagram from 25 September through 19 October 1966.

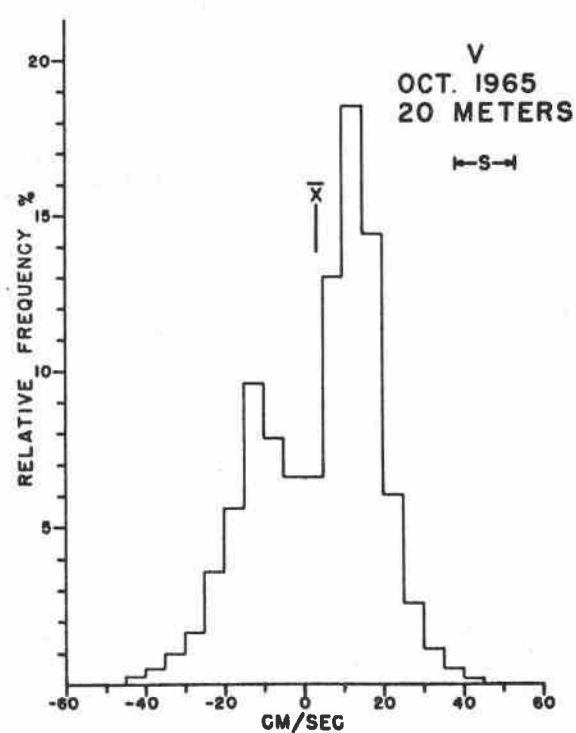
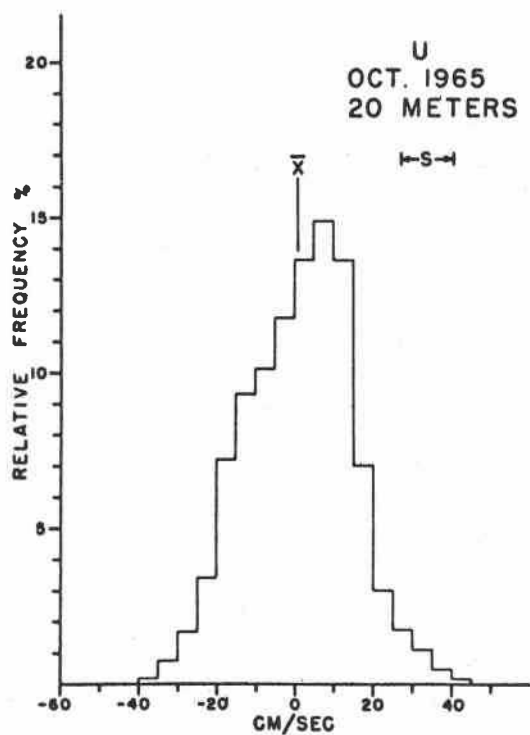
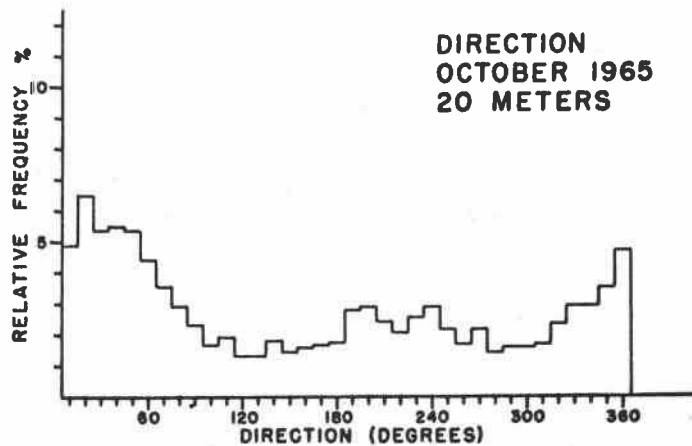
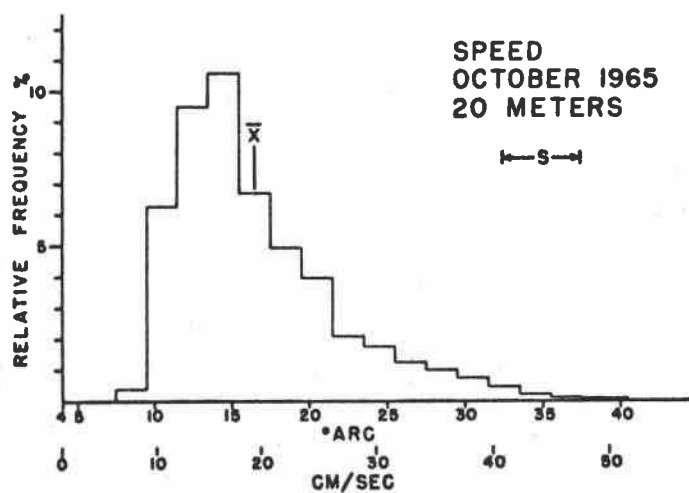


Figure 3. Speed and direction at 20 meters below the surface

for the total 24 hours required to access the uncertainty in vertical distribution of mass.

The taut bouy developed for YALOC-66 performs satisfactorily but requires excessive time in launch and retrieval. Development is underway for a more rapid system using expendable piano wire instead of poly-braid line.

A computer program for the processing of BT's and density data into internal tide amplitudes and phases, using the Fjelstod process, has been completed but has not been employed in the reduction of real data.

Measurements of back radiation taken during YALOC-66 have been reduced; however, the presence of extreme scatter in the data precludes its use. At the present time the cause of the scatter has not yet been isolated.

#### Optics - Neshyba, Carder

Work is progressing toward the measurement of direct forward scatter using interferometric techniques. An optics laboratory has been formed, and an optical bench installed. A small laser has been purchased, and work is underway on the construction of sample holders.

#### Hydrological Optics - Beardsley, Zaneveld, Tucker

The objective of the hydrological optics program is to develop a systematic method of interpreting optical and radiometric measurements and relate them to physical and biological process in the ocean. Using the available instruments, we have begun a base line study of the optical properties of the water off Newport. An approximate method of computing the apparent optical properties has been developed and programmed for the CDC 3300 computer. Construction has begun on an in situ spectrophotometer.

#### Boundary Kinematics - Beardsley, Plank

A buoy system for measuring the internal structure of wind waves has been assembled and will be used this spring. A collection of wave pressure data off the mouth of the Umpqua River is under study. Results should provide a first estimate of local wave conditions and will be used to plan further measurements.



Moored Instrument Platform - Wyatt, Burt

On 12 June 1966, an eight-foot diameter torroid float built by Geodyne Corporation was anchored at  $44^{\circ} 38'N$ ,  $125^{\circ} 35'W$ . The float was moored to test its stability as an instrument platform. A series of fouling experiments (see Tipper and McCauley, p. 44 ) were also attached to the mooring line. On 31 August the mooring was broken in an attempt to retrieve equipment and the station was temporarily discontinued.

## GEOLOGICAL OCEANOGRAPHY

### Coastal and Estuarine Geology

#### Oregon Coastal Sediments - Kulm, Byrne

Data from the heavy mineral investigation of the coastal rivers of Oregon and northern California are in the final stages of reduction. These data will be useful in determining the sources of coastal sands, as well as continental shelf and deep sea sands, and directions of sediment transport.

#### Nearshore Carbonate Sands of Bermuda - Kulm, Byrne, Carlson, MacKenzie\*

The study of textural aspects of beach and nearshore carbonate sediments of Bermuda is in the final stages of preparation for publication.

On Bermuda beaches seasonal trends in beach-face slope are more consistent than seasonal changes in particle size. Foreshore slopes of beaches during the winter along the south shore are either as steep or steeper than the foreshore slopes in the summer. Foreshore slopes of the northern beaches are more inconsistent. Winter beaches there are characterized by a wide range of foreshore slopes; whereas summer beaches, with one exception, are marked by a very narrow range of slopes. This narrow range in slopes suggests that more constant energy conditions prevail during the summer; however, these conditions are occasionally upset by hurricane storms striking the Island of Bermuda.

On the basis of median diameter and beach-face slope, most beaches investigated in August 1963 and March 1964 fall into the category defined by Wiegel (1964) as being indicative of protected beaches; even though they are considered, at best, to be only moderately protected. A similar trend was noted by the writers in data collected by other investigators on the beaches of the island of Kauai, in the Hawaiian Islands.

Although it is difficult to compare the degree of protection from one area to another, we do not believe it to be responsible for the

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Wiegel, Robert L., 1964. Oceanographical Engineering. Prentice-Hall, Inc., Englewood Cliffs, N. J., 532 p.

\*Bermuda Biological Station, Bermuda.

differences in particle size and beach-face slope that exist between the Hawaiian and Bermudian carbonate beaches and the largely terrigenous beaches discussed by Wiegell.

### Estuarine Foraminiferal Ecology - Fowler, Manske

During the period covered by this report 42 samples were collected in Yaquina Bay (Figure 1). These bring the total to 401 collected samples. One hundred ninety-three have been analyzed for their foraminiferal faunas.

The highest values for both living and total number of specimens have been found in the mid-bay to lower-bay channel, the most "marine" regime represented in the estuary (Figure 2). A correspondingly high number of species also occurs at these stations. A progressive decrease is apparent in the values for both species number and number of specimens with increase in distance upstream in the channel. The farthest upstream channel station is approximately 11 miles from the bay mouth; species number and number of specimens here establish the minima for the channel station ranges to the extent of this study.

Consistently high values for both live and total number of individuals, and relatively low species numbers, are found in the high marsh areas. In general, the sand flat environment is characterized by a higher standing crop and greater species diversity than the mud flat environment. Values for upstream mud flat stations group closely with those from the lower bay area.

During the summer months, calcareous species of nearshore marine types are present in the main estuary channel at least five nautical miles upstream from the bay mouth. Agglutinated/calcareous ratios range from 0.23 near the mouth of the bay to 1.33 five miles upstream. No calcareous species were noted in the channel six miles upstream, although occasional calcareous specimens are found in the marsh assemblages upstream from that point.

The lower bay channel fauna is generally characterized by the numerical dominance of species of Elphidium; also important are Elphidiella, Buliminella and Buccella. The lower bay sand flats are also characterized by a faunal assemblage numerically dominated by Elphidium spp. A further similarity to the channel suite is the relative importance of Buccella and Buliminella. Unlike the channel area, the porcelaneous Quinqueloculina and the agglutinated Trochammina charlottensis are generally present in some abundance. In further contrast to the channel suite, Elphidiella is not common on the sand flats.

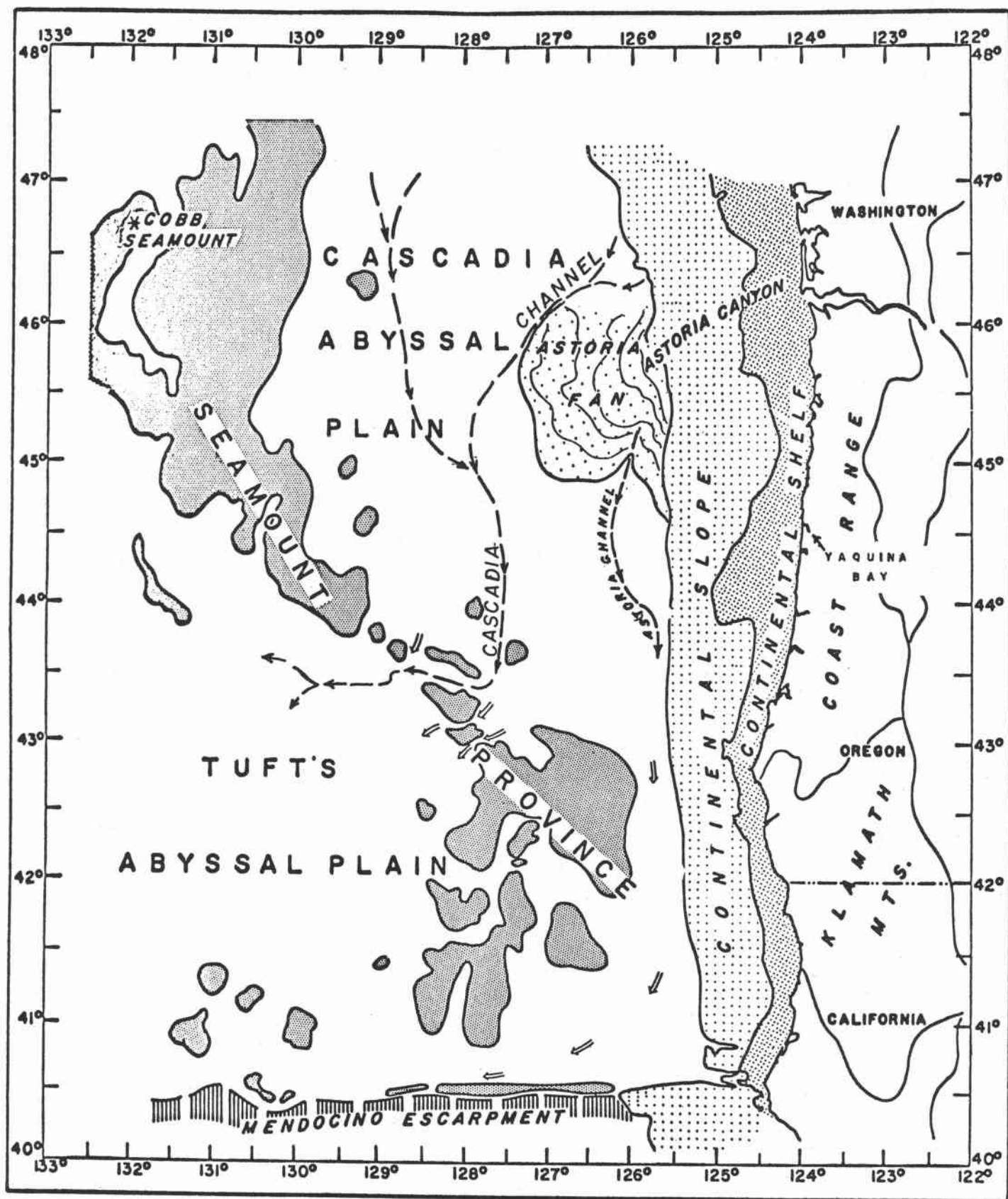


Figure 1. Location map, physiographic provinces off Oregon.

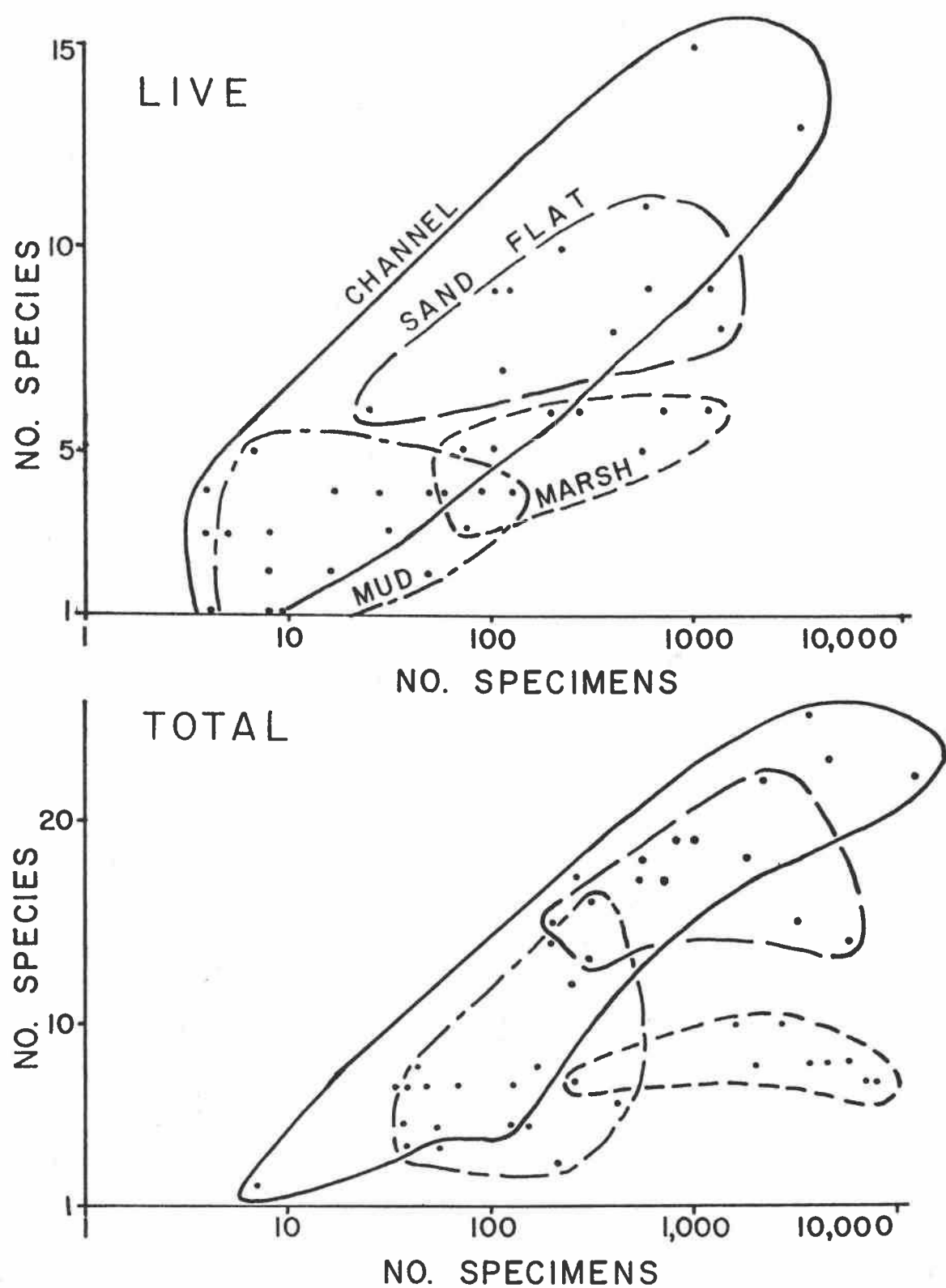


Figure 2. Comparison of the number of species and number of specimens of the live and total foraminiferal populations, Yaquina Bay.

Trochammina charlottensis is usually the most abundant species in the fauna of the lower bay mud flats. Ammobaculites, Elphidium spp. Haplophragmoides, Eggerella and Miliammina are generally present in dominantly agglutinated fauna. Miliammina and Ammobaculites are generally dominant in the fauna of the upstream, mid-bay mud flats.

The high marsh fauna is also composed primarily of agglutinated species. Miliammina is usually the most abundant, followed by Trochammina inflata and Haplophragmoides. Jadammina polystoma and Trochammina macrescens form a significant part of the suite in some areas. Calcareous species are uncommon although Elphidium incertum and Ammonia beccarii are occasionally noted.

### Continental Margin

#### Shelf Sedimentation - Kulm, Fowler, Allen

The survey of shelf sediment texture and mineralogy is being extended south of Cape Blanco to the Oregon-California border. Textural analyses have been completed for 87 samples and the data reduced by computer.

#### Astoria Canyon - Byrne, Carlson

Laboratory analyses have been completed on the core and dredge samples collected from Astoria Submarine Canyon (Figure 1). The characteristics studied include textural parameters, composition of the sand fraction, mineral variations of both heavy and light fractions of selected coarse layers, and foraminiferal trends in representative sediment types. The sediments within and adjacent to Astoria Canyon grade from dominantly terrigenous at the upper end to chiefly biogenous constituents in the coarse fraction at the lower end. The number and thickness of sand and silt layers increase with depth in the cores. This is probably due to the lower stand of sea level during the Pleistocene when sand and silt were transported to the edge of the shelf by the Columbia River. A detailed bathymetric chart of the Astoria Canyon region has been completed. This detailed survey shows that Astoria Canyon and Astoria Channel are parts of an interconnecting submarine drainage system. A publication on the marine geology of Astoria Submarine Canyon is being prepared.

### Foraminiferal Ecology - Fowler, Boettcher

The study of foraminiferal trends on the shelf between 43° 16' and 43° 50' N. latitude off the southern Oregon coast is nearly completed. One hundred fifty-five benthic species and nine planktonic species have been identified. Benthic species can be grouped into faunas (Table 1) based on observed species distributions. Faunal breaks occur at 50, 100, and 150 meters; the breaks and faunal groups are better defined in shallower waters. A rocky area off Cape Arago supports different species than present in sediments at comparable depths farther to the north (Table 1). The number of benthic species, percent agglutinated, standing crop, percent planktonic, and percent live vary in significant trends with increasing depth across the shelf (Figure 3). Variability among species, from replicate samples only a few centimeters apart, reaches a maximum value of approximately 35% but is commonly 15%. Possible causes of the variability are being examined. A generalized statistical treatment of in-station vs. between-station variability of abundant species indicates that station density is not too close.

### Carbon Content of Sediments - Fowler, Kulm, Allen

Total carbon, carbonate carbon, and organic carbon data have been obtained from 35 shelf and slope samples collected off southern Oregon. Organic carbon content increases across the shelf to a maximum of 1.50% on the upper slope at a depth of approximately 550 meters. This trend is followed by a decrease into deeper water and then a second, slightly higher maximum at about 1500 meters. The maxima appear to correspond to areas of maximum benthic productivity.

### Deep Sea

#### Astoria Fan - Byrne, Kulm, Nelson, Russell

The sedimentary and bathymetric data for Astoria Fan (Figure 1) are in the final stages of reduction and analysis. A report of the results is being prepared.

A definite correlation exists between the stratigraphy of the fan and the bathymetry and geographic position on the fan. Both a Recent section and a Pleistocene section (of unknown thickness) occur on the fan. These can be differentiated on the basis of color, faunal changes, lithologies, and radiocarbon dating (of similar deposits in adjacent areas by other investigators).

Table 1. Foraminiferal species characteristic of central Oregon shelf faunas.

Fauna A (< 50m)

*Buccella frigida depressa*  
*Buccella frigida frigida*  
*Buccella tenerrima*  
*Elphidiella hannai*  
*Elphidium incertum*

Fauna B (50-100m)

*Buliminella elegantissima*  
*Elphidium magellanicum*  
*Elphidium microgranulosum*  
*Nonionella labradorica*  
*Nonionella miocenica stella*  
*Recurvoides turbinatus*  
*Rosalina columbiensis*

The above species are largely replaced in the Cape Arago rocky area by:

*Cassidulina californica*  
*Cassidulina limbata*  
*Cibicides fletcheri*  
*Cibicides lobatulus*  
*Dendrophyra arborescens*  
*Trochammina pacifica*

Fauna C (100-150m)

*Eilohedra levicula*  
*Saccamina atlantica*  
*Spiroplectammina biformis*  
*Textularia earlandi*  
*Trifarina angulosa*

Fauna D (>150m)

*Bolivina pacifica*  
*Cassidella* sp.  
*Eggerella advena*  
*Epistominella exigua*  
*Nonionella turgida digitata*  
*Uvigerina juncea*



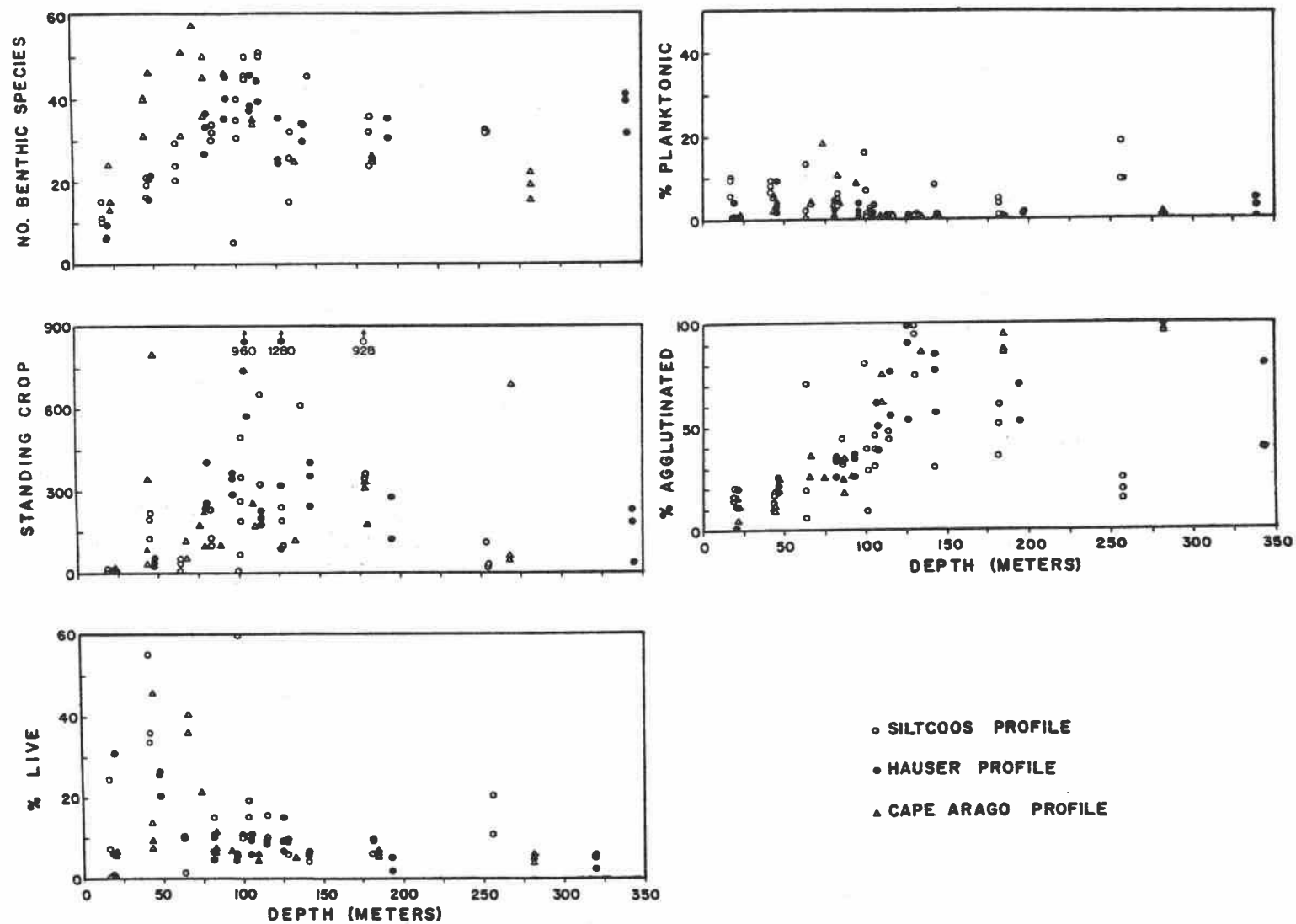


Figure 3. Foraminiferal trends with depth on the south central Oregon shelf.

Recent sediments on the fan are about one meter thick in the inter-channel areas and probably several meters thick in the channels, particularly Astoria Channel. With the exception of the interchannel areas on the outer fan, these deposits contain varying quantities of volcanic ash which is distributed throughout the upper one-half of the Recent section. Ash is present in the sediment of Astoria Channel, even on the outer fan. There is a general lack of coarse layers in the Recent sediments in the interchannel areas, while the channels exhibit numerous coarse layers.

A Pleistocene section was cored only in the interchannel areas of the fan. This section on the upper fan is characterized by a lack of coarse layers and the only ice-rafted sediments found. Pleistocene sediments on the middle and outer fan are marked by the presence of coarse layers, which become more numerous and thicker on the outer fan.

The highest rates of sedimentation apparently occur in the channels, while somewhat lower rates are associated with the inter-channel areas.

X-ray analyses of clay minerals from 66 samples indicate a typical sample composition of 40% montmorillonite, 30% illite, and 30% chlorite. Kaolinite is not present. No horizontal variation in clay mineral distribution has been observed. However, a change in the concentrations of the clay minerals is visible at the end of the last epoch of glaciation. The change in clay mineralogy consists of an increase of about 5% in the chlorite concentration in the older sediments. Because such a change is less than the possible error of the determination, it is recommended that this change be used for stratigraphy only along with other criteria.

Cascadia Abyssal Plain (Cascadia Basin) - Kulm, Fowler, Duncan, Griggs

The bathymetric and sampling survey of Cascadia Channel (Figure 1) is being continued. Approximately 850 nautical miles of echo sounding tracks have been run along the channel to date. A total of 18 piston cores have been collected in the axis of Cascadia Channel and its tributaries, and six cores have been collected on the walls and banks of the main channel. The cores range up to 9 meters in length.

All cores studied in the channel, except one, consist of thick, silty turbidite units alternating with thin pelagic clay layers. Cores taken from the walls of the channel contain somewhat thinner silty layers alternating with the pelagic clay layers. Criteria used to distinguish turbidite and pelagic sediment types include color, texture, coarse fraction composition, and carbon content.

Cross-channel Precision Depth Recorder profiles show that the right side (west and north) of Cascadia Channel is from 2 to 70 meters higher than the left side on almost all crossings (Figure 4). Few Precision Depth Records south of 45° N latitude exhibit any evidence of submarine levee development. A core taken on the bank of the channel in this area has the typical thin covering of Recent sediments overlying a Pleistocene section of undetermined thickness; this is usually the case on the abyssal plain to the west of Cascadia Channel. Why the right side of the channel is higher in the absence of levees is not known at the present time.

Total rates of Recent sedimentation in the channel, based on two radiocarbon dates, range from 15 to more than 100 cm per 1000 years. The highest rates calculated thus far are found midway along the length of Cascadia Channel.

Seven more piston cores have been taken in the southwestern portion of Cascadia Abyssal Plain, bringing the total to 10. Six of the cores were taken in two unnamed channels. A more detailed investigation of this portion of the plain is planned, particularly for the interchannel areas.

The sampling program for a sedimentation study in southern Cascadia Abyssal Plain and adjoining Blanco Fracture Zone has been completed. We have collected 23 piston cores varying in length from 1 to 10 meters, 4 dredge-hauls of rock, and more than 3300 miles of echo sounding tracks. All cores have been opened, photographed, and logged. Core samples are presently being processed to determine textural, mineral, and microfaunal trends.

The ratio of radiolarians to planktonic foraminifers has been determined for approximately 1400 samples taken from cores at 10 to 20 cm intervals. Several oscillations in the ratios with depth in the cores are thought to be due to Paleoclimatic fluctuations. A greater production of planktonic foraminifers compared to that of radiolarians seems to have occurred during the glacial advances of the Pleistocene, while radiolarians predominated during glacial retreats. At least four

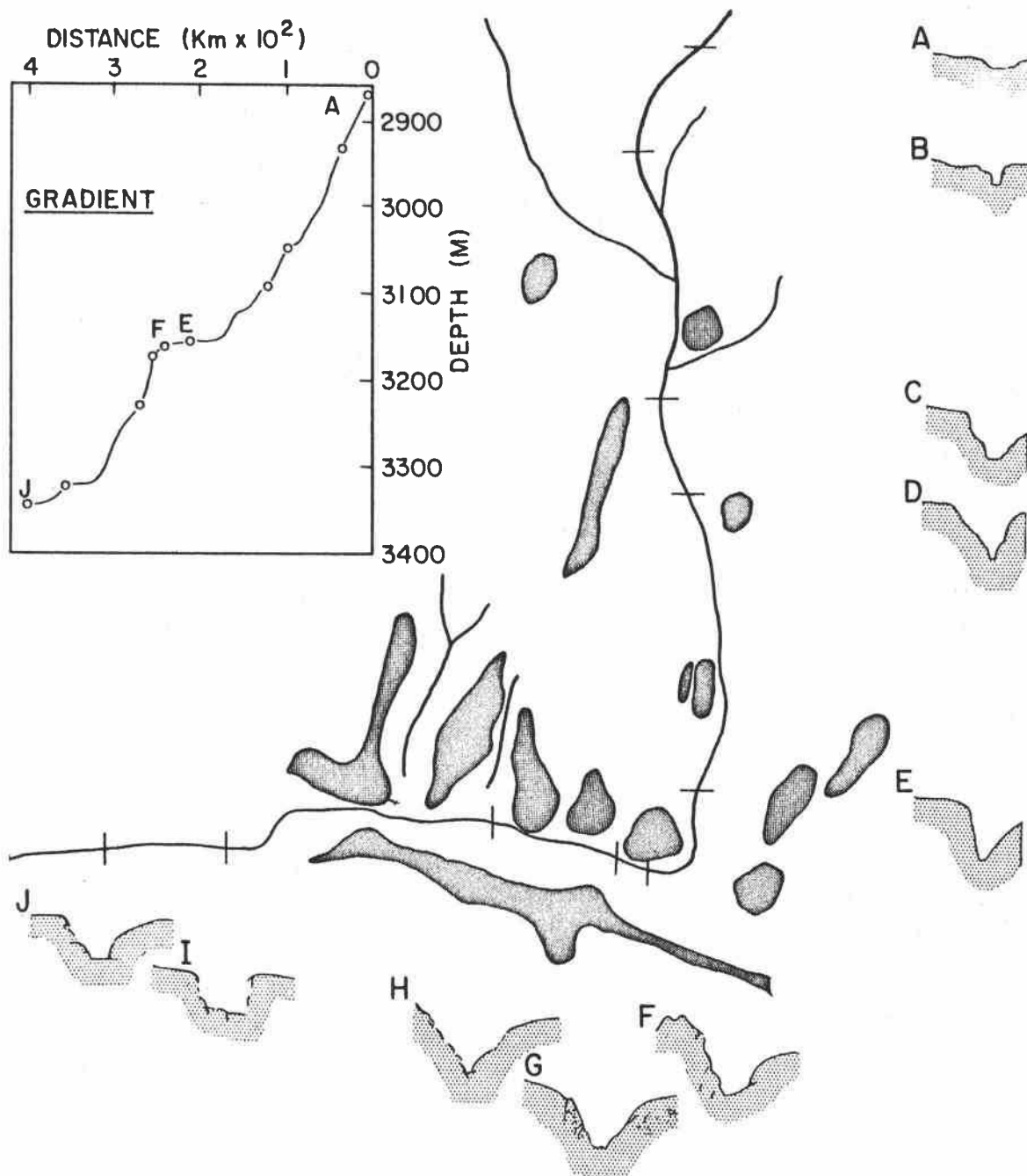


Figure 4. Transverse and longitudinal profiles of Cascadia Channel. Dark areas indicate the seamount province.

intervals are evident in the deep sea sediment record of the last 50,000 to 70,000 years. Based on radiocarbon dates, these intervals correspond approximately to Late Wisconsin glacial advances and retreats as defined for the Puget Lowlands of Washington.

Five species generally make up 90% or more of the planktonic foraminiferal assemblages within the cores from Cascadia Abyssal Plain. Globigerina pachyderma and Globigerina bulloides together compose more than one-half of the assemblages. In grain size fractions, less than 177 microns (Globigerina quinqueloba and Globigerinita uvula predominate. Occasional specimens of Globoquadrina hexagona, Globigerina digitata, and Globigerinoides ruber have been observed.

The species composition of planktonic foraminifers does not appear to reflect the change from glacial to post-glacial climates. Neither does the coiling habit of Globigerina pachyderma. This species is dominantly left-handed throughout the sections examined. Right-handed forms reach a maximum of 13% and average 2.7%.

#### Mineralogy of Silts - Kulm, Deffeyes, Allen

Silt as a size class (62-4 microns) has been neglected in detrital mineral analyses. Occasionally workers with sand-size material extend their optical examination to include coarse silt (62-44 microns), while x-ray diffraction of clay frequently is continued up into the fine silt range, especially in soil analyses. Little is known about the mineralogy of silt as a coherent unit.

Silts comprise a large portion of the unconsolidated marine record, as well as the lithified geologic record, even in areas remote from terrigenous sources. If silt mineralogy is a function of provenance, as is sand mineralogy, and if silts are transported at least partially in suspension, then each silt sample should reflect its source. This would be a useful tool in delimitating current patterns and the extent of a given river's influence on marine sedimentation. Clay minerals are of limited value, because they usually are not diagnostic of specific sources. Within the silt range a wide spectrum of mineralogic change apparently occurs. Common minerals of the sand fraction disappear and are replaced by the distinctive mineral suite which dominates the clay fraction. Exactly where this change in mineralogy occurs within the silt-size range is not known.

Procedures are being developed at Oregon State University to obtain optimum information from silts by x-ray diffraction. Nine samples of marine sediment were selected from cores taken off Oregon representing three provenance sources; the Frazer, Columbia, and Klamath drainage basins. The silt-size fraction of each sample was separated by particle settling techniques, and its percent of the total sediment was determined. Each silt-size sample was further subdivided into 10 micron size increments. Light and heavy mineral separates of each increment were then taken by magnetic and heavy liquid methods. Experiments using differential mineral solution with acid is in process. A total of 87 subsamples is currently being analyzed by x-ray diffraction.

## GEOFYSICAL OCEANOGRAPHY

### Marine Gravity - Dehlinger, Couch, Gemperle, Banks

Gravity anomalies have been determined for 7400 stations along 5800 miles of trackline off the coasts of Washington and British Columbia. Approximately 1660 gravity measurements along 2250 miles of the Inside Passage of Alaska and British Columbia have been reduced to free-air anomalies. This work has been submitted for publication in the Journal of Geophysical Research. Isostatic anomalies at 100 selected points along the Inside Passage are being determined.

A statistical analysis of errors in sea gravity measurements has been made and the results submitted for publication in the Journal of Geophysical Research.

Geophysical measurements were made during the YALOC cruise of 1966. Gravity readings were made at approximately 550 stations along 1000 miles of trackline north of Hawaii; 750 stations along 1200 miles of trackline across the Aleutian Trench near Adak; and 640 stations along 810 miles of trackline in the Dixon Entrance area. A continuous record of the total magnetic field was obtained along the same tracklines. Anomalies for these data are being determined.

### Earthquake Seismology - Dehlinger, French, Gallagher, Skorpen

The World-Wide Seismic Station at Corvallis and satellite station at Klamath Falls, Oregon, have been operated continuously during this period. Seismological Bulletin No. 7 has been completed and Seismological Bulletin No. 8 is being prepared.

The investigations of earthquake focal depths and source mechanisms have been continued in extended studies of crustal and subcrustal structures in the Pacific Northwest states.

### Land Gravity - Berg, Heinrichs, Thiruvathukal

Free air and Bouguer anomaly maps of Oregon and a free air anomaly map of off shore Oregon have been constructed. The maps have been submitted for publication.

A preliminary report of the results has been written and detailed analysis of the regional and residual anomalies is being completed.

### Magnetics - Berg, Heinrichs, Emilia, McKnight, Bales

The magnetic data from measurements made off the Pacific Northwest coast has been analyzed. Field results have been submitted to The Ore Bin for publication. In the near future the anomaly maps and interpretations will be submitted to a national journal for publication.

An additional collection of paleomagnetic samples was made from a section of Recent High Cascade lava flows. The directions and intensities of remanent magnetization have been measured for all the flows. The data are currently being analysed. Preliminary results indicate a smooth consistent change in direction of the geomagnetic field with a magnitude similar to observed rates of secular variation.

### Thermal Studies - Berg, Bodvarsson, Mesecar, Shih, Vossler

The new thermal probes for recording long time variations in the temperature at the sea-bottom interface were tested in a few locations off the coast of Oregon at depths about 3,000 meters. The first records obtained proved to be satisfactory and gave information on the temperature and eddy diffusivity at the bottom interface. This work is in progress.

The laboratory experiments on temperature coring were continued with satisfactory results. The technique is now being adapted to field work at sea.

A theoretical study of all published ocean-floor heat-flow data was initiated. The purpose is to obtain estimates of the depth and nature of the sources of heat flow anomalies. This work is now in progress.

### Theoretical Studies - Bodvarsson, Berg, Maloof, Emilia, Vossler

The work on direct interpretation methods was continued; a paper on this subject was published. A new method of solving the direct problem for lumped relaxation ladders was developed. Work on direct problems in electromagnetic scattering theory is in progress.

The work on potential fields and the filtering of potential field data was continued. A new project of solving the direct problem in potential field theory was initiated.

Eddy diffusion models for the transport of heat above the ocean-bottom interface are being studied with regard to the influence of terrestrial heat flow anomalies on the temperature microstructure in the ocean.



The work in geothermology was continued, and a paper was published on the energy and power of geothermal areas.

The theoretical study of two-phase critical flows in collaboration with Dr. D. J. Ryley at the University of Liverpool, England was continued. A joint paper was completed and submitted for publication.

## CHEMICAL OCEANOGRAPHY

### Chemical Reactions in Seawater - Pytkowicz, Culberson, Kester

Existing apparent dissociation constants of carbonic acid at high pressures, used to determine the Beta correction of the pH and to calculate the distribution of carbon-dioxide carbonate species in deep oceanic waters, are questionable because of determination in distilled water.

We have developed electrodes for the in situ determination of the pH at high pressures and have redetermined the constants in seawater of 19.21 ‰Cl at 22° C. The results are:

Pressure (atm)	$(K'_1)_p / (K'_1)_1$	$(K'_2)_p / (K'_2)_1$
1	1	1
217	1.21	1.13
435	1.46	1.27
652	1.75	1.44
1000	2.30	1.72

These measurements will be extended to lower temperatures.

In addition to the determination of coefficients such as the Beta correction factor which is of routine use in oceanography and to fundamental studies in the geochemistry of carbonates, the in situ electrodes have a potential application in time series studies and continuous scans of the fine structure of seawater.

### Oxygen-phosphate Reactions - Pytkowicz, Kester

The results of the water mass analysis that were recently published (Pytkowicz and Kester, 1966) are being extended further west and south. We are searching for the sources of water masses A, B, and C present between 1000 and 2000 meters in the Northeast Pacific Ocean. The presence of three water masses at 1000 meters, moving in different directions, may affect the results of geostrophic computations using the 1000 decibar surface as a reference level. The magnitude of this effect is not known at present, because the speed of the deep-intermediate waters is not known.

### Partial Equivalent Conductance of Salts in Seawater - Connors, Weyl

Research on the partial equivalent conductance of salts in seawater has been completed. Eight salts were run ( $\text{NaCl}$ ,  $\text{KCl}$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{K}_2\text{SO}_4$ ,  $\text{KHCO}_3$ ,  $\text{MgSO}_4$ ,  $\text{Ca}(\text{NO}_3)_2$  and  $\text{NaNO}_3$ ), and the partial equivalent conductance was determined as a function of salinity and temperature. Thesis, part of Mr. Connor's Ph. D. work, is in progress.

### Improvement of Shipboard Techniques - Park, Catalfomo, Latimer

1. Alkalinity -- Conductometric technique has been frequently tested at sea. Maximum precision of the conductometric method has been in the order of 1%. An inductive salinometer has been permanently converted to enable conductometer titration.
2.  $\text{CO}_2$  -- A Beckman Infrared  $\text{CO}_2$  analyzer has been purchased to construct a total  $\text{CO}_2$  analyzer.
3. Nutrients -- A Technician Autoanalyzer has been ordered. We plan to assemble a sea-going analyzer a la Strickland's group of Scripps.

### Estuarine Chemistry - Park, Kujala, Catalfomo, Webster\*, Reed\*

A study of the nutrient and alkalinity budgets of the Columbia River continues. Monthly water samples are taken at Astoria (12 samples) and upstream stations (14 samples). The Pacific Northwest Water Laboratory is cooperating with the sample collection in upstream waters.

### Offshore Chemistry - Park, Erdmann, Catalfomo, Wyatt, Still, Barstow

Seasonal distribution of nutrient matter (phosphate, silicate, nitrate) off Oregon is being studied. The nutrient data are compared with the oxygen and carbon dioxide data to show the nutrient-gas relationship off the coast.

Abnormally low surface pH of 7.8 was observed 9 km off Newport, Oregon, on 29 July 1966, as a result of intensive summer upwelling.

Preformed nutrient levels off Oregon have been established. Preformed phosphate is  $0.9 \mu\text{M}$  at near surface and  $1.1 \mu\text{M}$  at 2500 m. Preformed nitrate equivalent is about  $8 \mu\text{M}$  at near surface and  $10 \mu\text{M}$  at 2500 m.

\*Pacific Northwest Water Laboratory

Members of the chemical oceanography group performed the following investigations during the YALOC-66 cruise:

#### Deep-Sea pH -- Park

In the northeastern Pacific Ocean, where R/V YAQUINA occupied deep-sea hydrographic stations, we frequently found a deep-sea pH maximum of about 7.9 existing near 4000 m. A report on this finding will appear in Science shortly.

#### Surface pH -- Park, Glooschenko, Curl

A latitudinal, differential pH distribution is observed in the northeastern Pacific Ocean with a pH range of 8.15 at high latitude to 8.29 at low latitude. These pH values are generally greater than the calculated equilibrium pH with respect to atmospheric CO<sub>2</sub>.

A high surface pH value of about 8.26 observed immediately south of the Subarctic boundary zone near 170° W appears to be biogenic. We find a positive correlation between surface pH and chlorophyll content.

#### Chemical Study of Subarctic Boundary -- Park, Erdmann, Wesman

σ<sub>t</sub>-AOU relationship and specific alkalinity pattern was used to study the upward divergence of intermediate water on the north side of the subarctic boundary. Preformed phosphate profile across the boundary was used to study the origin of the salinity-minimum water located south of the boundary in the Subarctic region.

#### Gas Chromatography - Hansen, Latimer, Park

Dissolved nitrogen and total carbon dioxide were routinely measured by gas chromatography. The cruise data are being analyzed.

#### Deep-Sea Nutrients - Park, Erdmann, Catalfomo, Gunnings

Phosphate, silicate and nitrate profiles for the entire YALOC-66 cruise are being prepared.

## RADIOCHEMISTRY AND RADIOECOLOGY

### Radiochemistry - Osterberg, Johnson, Jennings, Beasley

A paper based on V. Johnson's M.S. thesis, dealing with the exchange properties of Columbia River sediments, has been accepted for publication by the Journal of Water Resources.

A new study on  $\text{Fe}^{55}$  has been inaugurated by D. Jennings and T. Beasley, with the assistance of H. E. Palmer, Battelle-Northwest Laboratories. Levels of  $\text{Fe}^{55}$  in marine organisms are running two to three orders of magnitude greater than any of the radionuclides we have previously measured.

Mr. Beasley is beginning work on alpha emitters in the marine environment. Initial analyses will be made at Richland, Washington with instrumentation provided by Battelle-Northwest Laboratories.

### Columbia River Studies - Kujala, Haertel, Forster, Osterberg

Monthly collections are being made with otter trawls at three stations in the Columbia River Estuary. Results of the first two years work will appear in a forthcoming edition of Ecology.

A report on the radioactivity of Pacific Salmon, abstracted from the thesis of N. Kujala, is being prepared for publication.

### Relation of Radioactivity to Turbidity - Hanson, Osterberg

An instrument package capable of measuring salinity, temperature, turbidity (transmissivity), and collecting water samples for analysis of particulate and nonparticulate radioactivity was used successfully in the Columbia River Estuary. Data provided by this system will be incorporated into a M.S. thesis.

### Dissolved Organics in Seawater - Cronin, Burger\*, Martin\*, Osterberg

Analyses of dissolved organics removed from seawater by solvent extraction are nearing completion. This was the first use of a reverse-flow, pulse-jet, extraction column at sea. Data from this experiment will be included in the doctoral dissertation of Mr. Cronin. Two papers describing certain aspects of this research are being prepared for publication.

\*Battelle-Northwest Laboratories

### Radiosensitivity Studies - Holton, Osterberg

Populations of brine shrimp (*Astemia*, sp.) are being subjected to high levels of radioactivity from a cobalt-60 source to observe radiosensitivity. Mr. Holton has begun this work as part of his Ph.D. research problem.

### Trace Element Analysis - Forster, Buffo

Our major interest is in the determination of trace elements (3d transitions) in all phases of the marine environment--water, sediments, and biota. Each area has unique problems associated with metal ion analysis.

Sediments show an overall natural radioactive background which must be removed before the gamma spectrum is meaningful, relative to the transition ion in question. Separations are being made by refluxing the sediments in dilute hydrochloric acid. Evaporation of the filtrate to dryness is made with infrared. Counting the ions of concern is preformed by the gamma spectrometry.

The main problem in the trace analysis in seawater is the low concentration of these transition metals in the high concentration of conservative elements. The highly specific and sensitive method of atomic absorption spectroscopy (AAS) is used for zinc and manganese, after a concentration of 100 x has been affected by extraction techniques. Table 1 gives the sensitivity of the other transition elements that will also be done with the Perkin Elmer Model 303 and their average concentrations in seawater.

Table 1. Elements--Sensitivity and Average Concentrations in Seawater.

Element	Avg. Conc. in seawater (ppb)	P. E. -Model 303 Sensitivity (ppb) for 1% absorption	Neutron activation Sensitivity (ppb)
Cr	0.05	150	1.00000
Mn	10.00	100	0.00005
Fe	50.00	300	100.00000
Co	0.50	200	0.10000
Ni	3.00	200	0.50000
Cu	5.00	150	0.00100
Zn	10.00	40	0.10000

The total element analysis of the above trace ions will also be determined by A. A. S. after drying, ashing, and then dissolving the sample that contains the constituent element. The method of standard additions is used throughout.

The most sensitive tool available for trace analysis is neutron activation, see Table 1. Zinc enriched seawater samples have been sent to Washington State University for activation by their University's reactor to determine the feasibility of using this method without a preconcentration step. A TRIGA reactor will be available on the Oregon State campus in early 1967, and many of the above transition elements will be tried.

#### Radioecology of Oceanic Animals -- Percy, Eagle, Larsen.

During the past quarter 70 samples of benthic fishes, 16 samples of pelagic animals, and 12 samples of albacore tuna have been radioanalyzed. Samples of ash of all the above samples are being prepared for atomic absorption spectrometry so that specific activities can be calculated.

#### Radioecology of Pelagic Animals - Percy, Eagle, Larsen, Osterberg

Results of a two-year study of the variations of radioactivity in nekton with depth and season were presented in a paper by Percy and Osterberg (submitted to International Journal of Oceanography and Limnology). Seasonal differences in  $\text{Zn}^{65}$  were most pronounced in surface waters, somewhat damped at 500 m, and essentially constant at 1000 m. No lag in  $\text{Zn}^{65}$  levels was apparent in samples from mid-depth, indicating rapid vertical transport. Samples from 1000 m contained more  $\text{Zn}^{65}$  than surface samples from over 500 km offshore, indicating that the Columbia River is the probable source of this radionuclide.

#### Radioecology of the Benthos - Carey, McCauley, Hancock, Alspach, Larsen, Osterberg, Tennant

During this report period 173 samples representing 36 animal species and 12 sediment types have been radioanalyzed for gamma-emitting radionuclides. In addition, 90 of these samples were analyzed by atomic absorption spectrometry for total zinc content, to be used in the computation of specific activity for radiozinc. A chemical separation for extracting zinc from sediments was investigated. This method will isolate radiozinc from the confusing background of natural radioactivity of the sediments. Seasonal samples from the standard AEC trawling stations were obtained.

## BIOLOGICAL OCEANOGRAPHY

### Distribution of Pelagic Amphipods - VanArsdale, Percy

Hyperiid amphipods have been examined from meter net plankton collections over a two-year period at stations 15, 25, 50, and 65 nautical miles off Newport, Oregon. Twenty species were identified.

The frequency of occurrence of Parathemisto pacifica, Paraphronima gracilis, Hyperia hystrix, Tryphana malmi, and Primno abyssalis increased with distance from shore while that of Streetsia challengerii decreased.

The occurrence and distribution of hyperiid amphipods were related to several oceanographic features. A high proportion of Subarctic water usually corresponded to a low frequency of occurrence. Species diversity was often greater when the heat content was large. Inshore occurrence of hyperiid amphipods appeared to be correlated with onshore movements of water.

Species diversity and average abundance of oblique and vertical meter nets were compared. Slightly higher numbers were found in oblique than vertical tows.

### Deep Scattering Layer Studies - Donaldson, Percy

During the past year a large series of echo-traces of the DSL (Deep Scattering Layer) have been analyzed. Daily and seasonal changes in the numbers of layers and amount of scattering present are being examined. An effort will be made to determine if daily fluctuations are large enough to mask seasonal fluctuations.

Work is also continuing on the analysis of data from the YALOC-66 cruise. On the leg from Hawaii to Adak a marked increase in fish and plankton biomass was noted at 42° 35' North, the approximate latitude of the Subarctic Convergences. The catches of cephalopods and shrimp showed no marked increase at northern stations. The DSL was almost entirely absent North of 47° 44.2', although biomass values were high in this region.

### Ecology of Oceanic Animals - Percy, Coleman, Heeter

The catches of common oceanic and mesopelagic micronekton, made during the past five years, are being studied to learn the extent and regularity of seasonal variations in number and biomass. Some species demonstrated obvious seasonal fluctuations in number that are



repeated every year. Other species showed irregular variations. Year to year variations and variations related to distance from shore are also apparent. Both oceanographic features and size structure of the populations will be analyzed and correlated with changes in population abundance.

During the past quarter, a total of 69 Isaacs-Kidd midwater trawls and 38 meter plankton net collections have been made. Most of these were in conjunction with systematic sampling off Oregon although some were made on the YALOC Cruise. Collections were made to over 2000 m depth using opening-closing devices.

#### Upwelling and Biomass of Trophic Levels - Laurs, Percy

A program to study the biological effects of coastal upwelling was conducted between June 1962 and April 1964 off Brookings, Oregon. Observations were made during eight cruises at 11 stations extending from 5 to 165 nautical miles offshore. In addition to standard hydrographic observations, tows were made with a six-foot Isaacs-Kidd midwater trawl and a one-meter plankton net. Water samples for chlorophyll concentrations were also taken.

Laboratory analysis of all biological samples collected has been completed. All fishes, shrimps, cephalopods, and heteropods present in IKMT collections were sorted, identified, and measured. The fishes and micronekton were removed from the one-meter net collections. Samples were then divided into two approximately equal parts. One-half of the sample was sorted into taxonomic groups consisting of euphausiids, copepods, shrimps, amphipods, chaetognaths, medusae, salps, annelids and pteropods; the other half was retained for future studies. Dry weights were determined to estimate the biomass for each major taxonomic group. (A total of 1623 dry weight determinations were carried out.) The weights of herbivore and carnivore groups were summed separately to give estimates of the standing stocks of trophic levels II and III, respectively. Chlorophyll concentrations were determined in the laboratory of Dr. H. C. Curl, Jr. and were used to give estimates of the standing stocks of trophic level I.

Analysis of hydrographic data show that major changes occur in the inshore portion of the permanent oceanic front off Oregon (pycnocline) due to upwelling. Upwelling causes the inshore portion of the front to slope upward, intersect the surface, and form a surface front. Frontal slope was found to be an important feature in the spatial distribution of lower trophic level biota. Abrupt changes in relative abundance of the standing stocks of phosphate-phosphorus and trophic levels I and II are apparent across the surface front; standing stocks are considerably

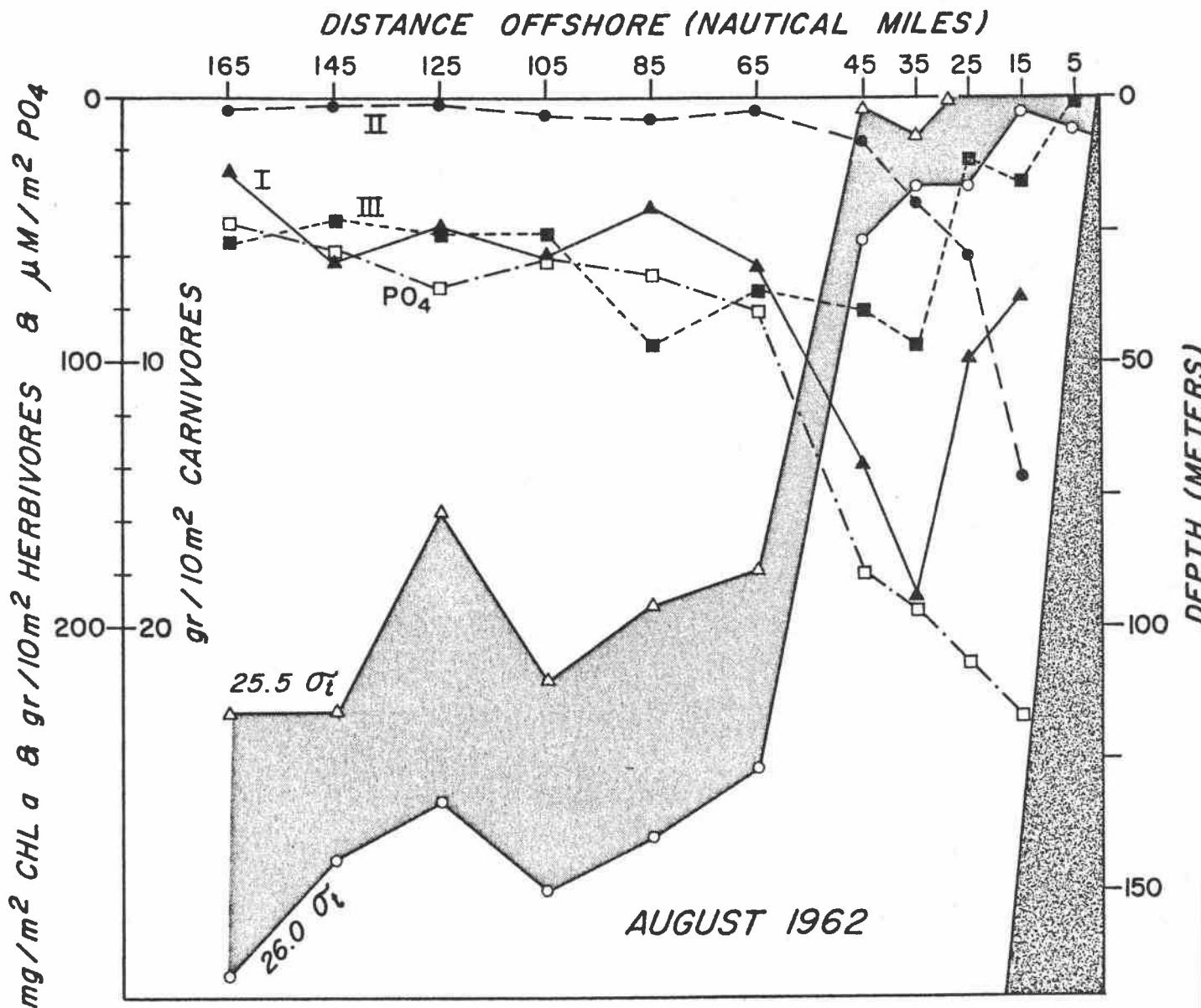


Figure 1. Spatial distributions of the oceanic frontal layer and standing stocks of phosphate-phosphorus and trophic levels I, II, and III. Light shaded area denotes frontal layer, between 25.5 and 26.0 sigma-t values. Lines represent standing stocks of PO<sub>4</sub> and trophic level I based on a 100 meter water column and standing stocks of trophic levels II and III based on a 200 meter water column. Note that scales for standing stocks increase downward.

higher inshore than they are off shore of the front. Peak relative abundance of trophic level III is at and just seaward of the surface front.

During periods of non-upwelling, when there is no surface front present, standing stocks of phosphate-phosphorus and trophic level I are nearly the same in both the inshore and offshore regions. However, relative abundance of trophic levels II and III is often higher inshore than offshore.

Results also indicate an offshore shift in the peak relative abundance of trophic levels II and III as the upwelling season progresses.

The spatial distributions of the oceanic frontal layer and standing stocks of phosphate-phosphorus and trophic levels I, II, and III observed during August 1962 are summarized in Figure 1. These data exemplify abiotic and biotic conditions during late upwelling. The inshore portion of the frontal layer slopes upward, intersects the surface, and forms a surface front. (Columbia River water may also be important in determination of frontal layer shape during late summer.) The standing stocks of phosphate-phosphorus and trophic levels I and II, which are low offshore, increase sharply across the surface front. Trophic level I is maximum just shoreward of the surface front but decreases closer to the coast. Grazing is apparently responsible for the inshore decrease. The standing stock of phosphate-phosphorus, and presumably other nutrients, is high inshore. Similarly, the maximum standing stock of trophic level II is found inshore. The standing stock of trophic level III is highest at and just seaward of the surface front.

#### Benthic Ecology - Carey, Alspach, Hufford, Everitt

Benthic ecology (and benthic radioecology) participated in three cruises during this period: 13 otter trawl, 4 anchor-box dredge, and 9 Smith-McIntyre bottom grab samples were collected. The majority of the samples were collected from the continental shelf and continental slope on the Newport station line. Two of the otter trawls and the four anchor-box dredge samples were collected during the Department of Oceanography's long cruise, YALOC-66 during the late spring and early summer.

The four YALOC-66 dredge hauls were made at two 48-hour primary production study stations on the cruise track between Hawaii and Adak, Alaska. The numbers and biomass of the small benthic macrofauna from these stations will be correlated with primary production in the overlying waters and will be compared with the abyssal fauna nearer the coast of Oregon. The YALOC-66 otter trawl samples were obtained between

Ketchikan, Alaska, and Newport, Oregon. These will provide a closer comparison between the fauna in the semi-enclosed, close to shore, Cascadia Basin and the Alaskan and Tufts Abyssal Plains beyond the Ridge and Seamount Province. Samples are presently under investigation in the laboratory.

Laboratory analyses of the Newport station line samples continue. Polychaete homogeneity at 12 stations has been studied as an initial step in the analysis for ecological communities along the station line. Polychaete species groups with high affinities were demonstrated at five of these stations.

#### Reproduction of Echinoderms - Hufford, Carey

A study of the reproductive activity of Paelopatides sp., an abyssal sea cucumber, has been initiated. Sampling is on a seasonal schedule to determine if the reproduction of the cucumber undergoes a yearly cycle. The gonad index (gonad volume/dry weight of animal) and egg diameter are being used to determine the reproductive state of the animal. Correlations between environmental factors (i. e. bottom water temperature and salinity and sedimentary food supply) and the reproductive activity are being investigated.

#### Distribution and Ecology of Oregon Echinoids - McCauley, Carey

The study of the distribution and ecology of Oregon echinoids has been completed and a manuscript submitted for publication. The data report in Progress Report 17 is essentially unchanged except that Brisster sp. can now be positively identified as B. latifrons. Since this study has been completed, a new pourtalisiid echinoid has been collected off Oregon, and a new cidaroid echinoid from deep water between Adak and Kodiak has been found. Neither has been identified.

#### Systematics of Deep-Sea Fish Trematodes - McCauley

More than 2300 specimens of deep-sea fish trematodes in the O.S.U. collection are being studied and identified and new species described in an effort to understand some of the ecology of deep-sea parasitism. Preliminary study has shown at least 51 species of trematodes to be present, and only eight appear to be members of previously described species.

### Deep-Sea Fouling Studies - Tipper, McCauley

The fourth in a series of sample panel arrays to be subjected to biological deterioration on the ocean floor was deployed in 2800 meters of water in April 1966.

Attempts to retrieve the sample arrays during September, 1966, proved fruitless. Grappling and complete system recovery were thwarted by structural failure in both the ground line and the mainline. Structural failure in the mainline occurred at a depth of 1000 ft. below a shackle.

An intensive study was then undertaken to analyze past methods and to improve the overall mooring system design. Several types of lines and flotation systems were studied. Actual tests on lines were carried out when possible. The sample panel array was re-designed to minimize over-the-side damage during deployment and to eliminate electrolytic corrosion between dissimilar metals in contact.

A 30-day sea trial of an improved mooring system is now underway in 200 meters of water. Evaluation of this system is planned before further deployments of moored sample arrays are conducted. D. Pillsbury is assisting with the mooring operation; he has been successful with other moors.

### Systematics of Echinoids - McCauley

Two nominal species of Brisaster have been recognized off the West Coast of North America--B. townsendi (Agassiz, 1898) and B. latifrons (Agassiz, 1898). Identification of these species has been difficult and a restudy seemed advisable. About 430 specimens collected by the R/V YAQUINA off Oregon in 1961-66 and 176 specimens collected by the Streamer ALBATROSS off the west coast of North America between 1889 and 1915 were studied. The latter were borrowed from the U. S. National Museum. Later about 300 nominal B. latifrons from Japanese ALBATROSS collections were studied at the U. S. National Museum.

All of the American specimens from both nominal species were studied and measured and no dependable characteristics could be found to separate them into two species. Measurements revealed a continuous gradient that included all specimens, and it was concluded that only one species was involved. Consequently the name B. townsendi was suppressed as a junior synonym of B. latifrons.

The Asiatic material differed from the American material and was transferred to B. owstoni (Mortensen, 1950).

### Energy Transfer in the Lower Marine Food Web - Small, O'Connors

Work on the respiration of Euphausia pacifica under different environmental conditions has been completed. One paper has been published (see Progress Report 16) and a second submitted for publication. The results of this second paper will be reported more extensively in Progress Report 19.

Mr. O'Connors has begun work on a Master's degree this fall. His thesis problem will be the measurement of assimilation rates in euphausiids (and perhaps copepods) feeding on different food sources. We hope to use  $C^{14}$  labelling techniques, as well as numerical assessment of ingestion and egestion, to measure assimilation.

### Element Transfer in the Lower Marine Food Web - Small, Fowler, Bergeron

Mr. Fowler has completed his M.S. thesis on uptake and retention of  $Zn^{65}$  from seawater by Euphausia pacifica. "Uptake and retention of  $Zn^{65}$  by live and formalin-preserved euphausiids were observed in the laboratory at three temperatures and two concentrations of radiozinc. Uptake in live animals was dependent upon temperature, size of the animal, and concentration of  $Zn^{65}$  in the water. Weight-specific uptake appeared to be linear over a  $5^{\circ}$  to  $15^{\circ}$  C range (Figure 2). Both weight-specific uptake and corrected concentration factors generally decreased as euphausiid weight increased (Figure 3). At higher temperatures, moulting accounted for great  $Zn^{65}$  loss, with exoskeletons containing about 34% of the activity prior to moulting (Figure 4). Initial rates of desorption loss and apparent biological half-lives were also dependent upon weight and temperature and upon  $Zn^{65}$  concentration in the euphausiid. Moulting accounted for about 17% of total body activity at the higher temperatures. Considering both uptake and desorption experiments, moulting probably accounted for about 25% of total body activity prior to the first moult.

Results of  $Zn^{65}$  uptake and desorption experiments with formalin-preserved euphausiids were similar to those with live animals in all respects except moulting. Evidence indicated that  $Zn^{65}$  accumulation was an adsorptive process, and that an increase in temperature might somehow alter the exoskeleton constituents, so as to present more sorption sites.

Concentration factors computed from field data were 7 to 24 times greater than those from laboratory data. Although several factors tended to show that the data were not comparable, the possibility still existed

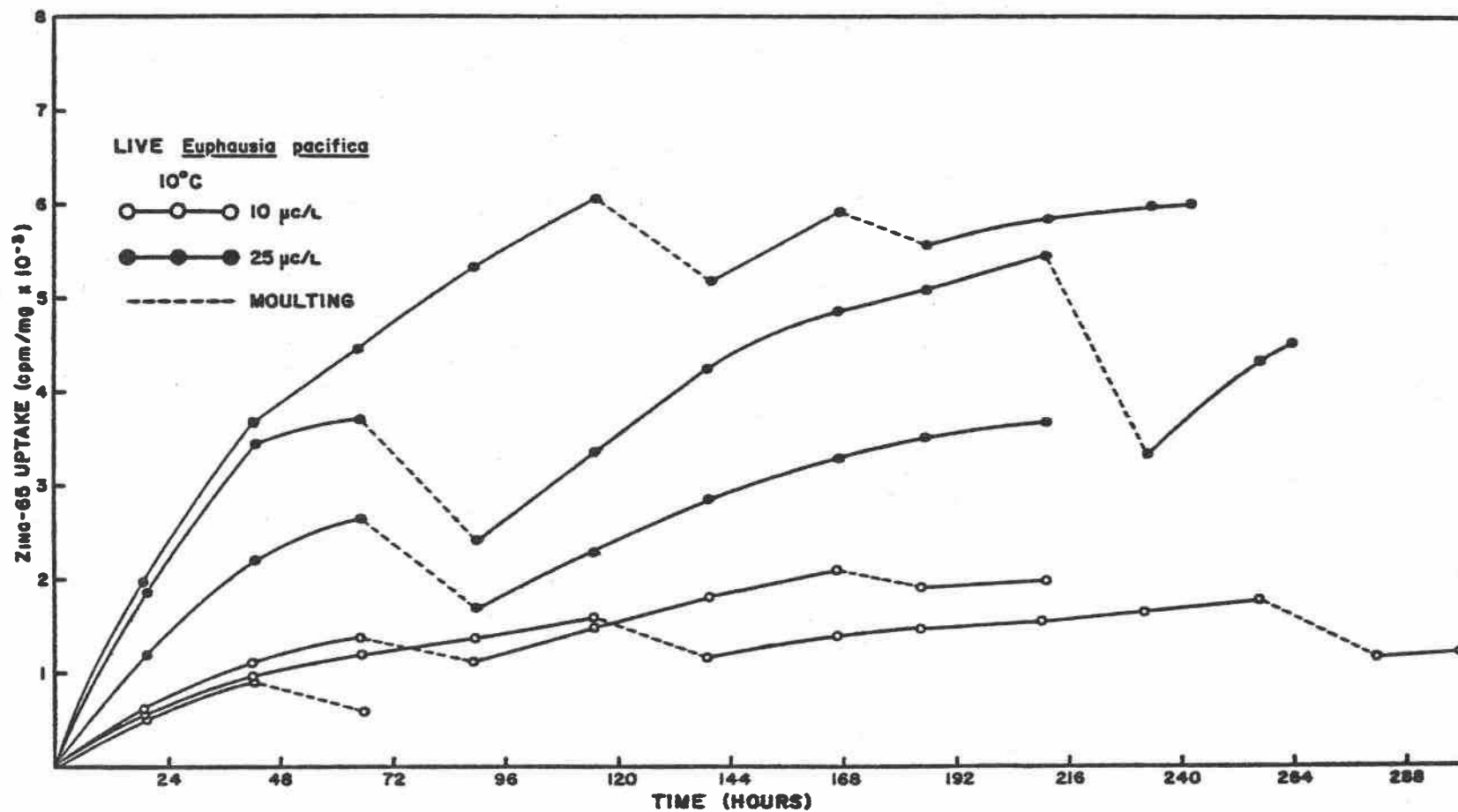


Figure 2. Uptake of two concentrations of  $Zn^{65}$  at 10° C by euphausiids. The effects of different animal weights and of moulting are shown. Euphausiid dry weights ranged from 7.7 to 12.7 mg.

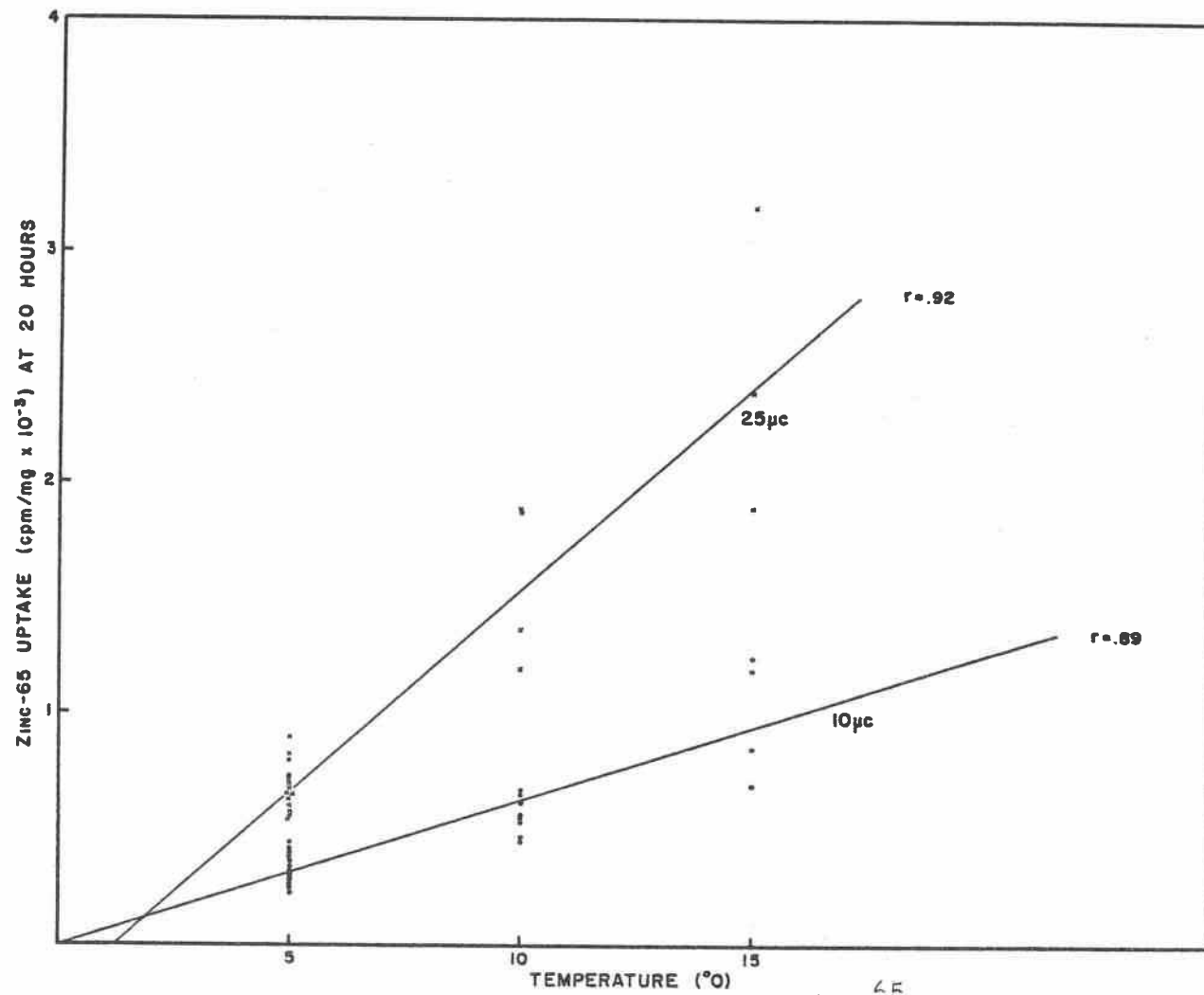


Figure 3. Relationship of weight-specific uptake of  $\text{Zn}^{65}$  by euphausiids to temperature, at two concentrations of  $\text{Zn}^{65}$ . Uptake values are cpm/mg at 20 hours. Euphausiid dry weights ranged from 7.7 to 12.7 mg.



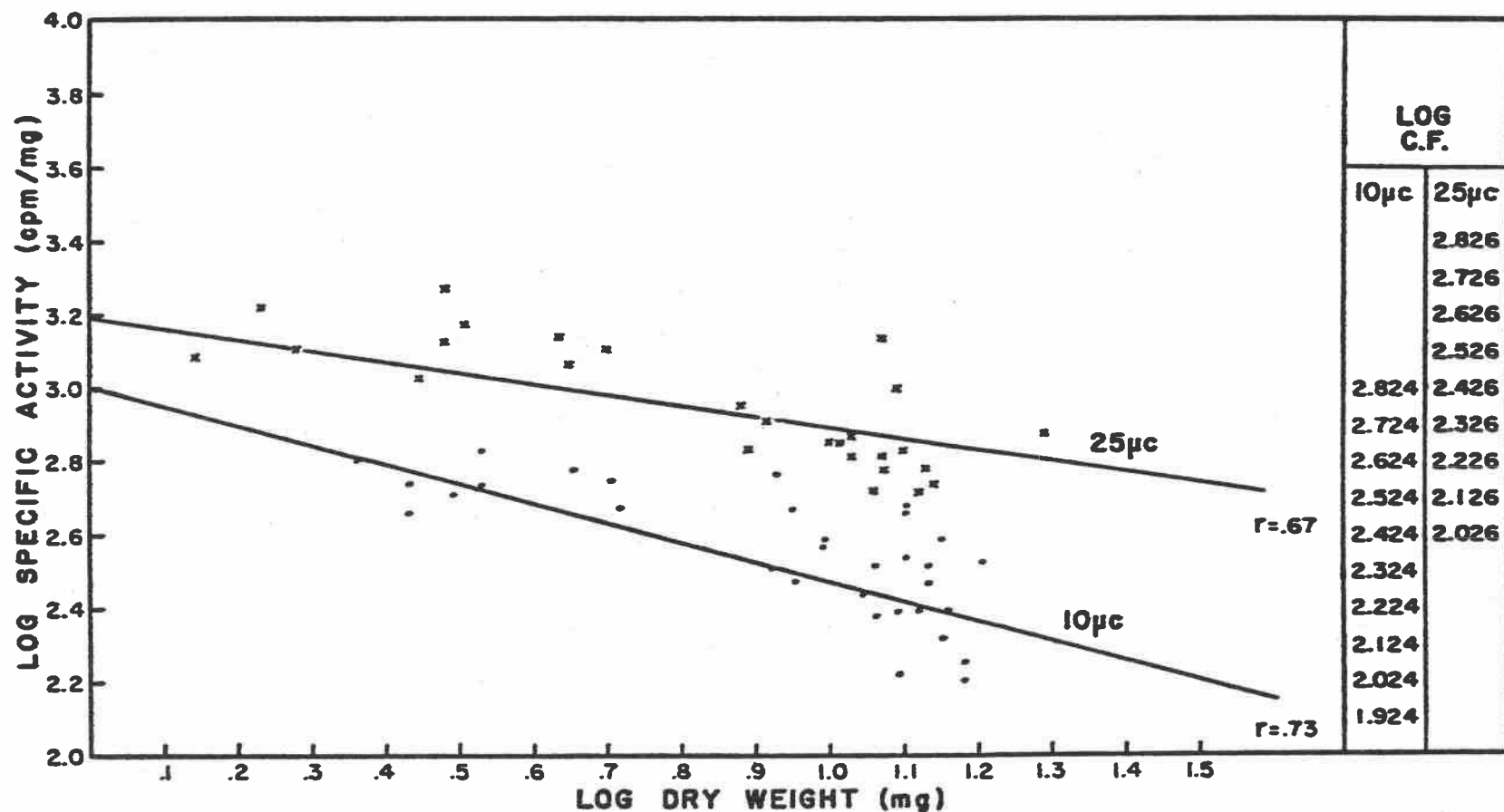


Figure 4. Relationships of weight-specific uptake and concentration factors (CF) to dry weight of euphausiids, at 5° C and two concentrations of  $Zn^{65}$ . Uptake values and concentration factors were determined at 20 hours.

that euphausiids could accumulate more  $\text{Zn}^{65}$  from low, chronic levels than from high, temporary concentrations of the isotope.

The importance of euphausiids in the transport and cycling of  $\text{Zn}^{65}$  in the sea is discussed with respect to moulting, predation, and diel migration."<sup>1</sup>

Mr. Fowler is now on an AEC predoctoral fellowship and is in residence at the Hanford Laboratories in Richland, Washington. He will be studying zinc metabolism in euphausiids.

Mr. Bergeron is completing his M.S. thesis on uptake and retention of  $\text{Zn}^{65}$  through a simple food chain by Euphausia pacifica.

#### Phytoplankton Pigments - Iverson, Curl

Column and thin-layer chromatography are being used to isolate and identify pigments from marine and cryophilic algae. Problems in identification of carotenoids have not been resolvable with our present spectrophotometric equipment; however, we are attempting to obtain more adequate instrumentation in order to continue this work.

We have calibrated our monochrometers and are determining photosynthetic action spectra of marine phytoplankton algae and cryophilic algae.

#### Physiological Ecology of Cryophilic Algae - Curl, Hardy, Iverson, Sutton

Research on the physiological ecology of cryophilic algae has continued toward five objectives:

- (1) taxonomy and identification of species of cryophilic algae
- (2) isolation and culture of cryophilic algae
- (3) ecological observations and measurements of physical factors affecting the growth of cryophilic algae in the field
- (4) the effect of environmental factors on growth and photosynthesis of cultures in the laboratory
- (5) survival of cultures of cryophilic algae under environmental extremes which are likely to be encountered extraterrestrially

The phenomenon of colored snow is now recognized as rather common and of widespread occurrence. In the spring and summer the snowfields of alpine, glacial, and polar regions often contain patches or large areas

<sup>1</sup> Abstract from M.S. thesis of S. Fowler

that appear as varying shades of green, yellow, orange, or red. Curl and Hardy have recently found red snow caused by a previously unknown species of Trachelomonas (Euglenophyta). This causative agent of red snow was found near Mt. Bachelor, Oregon, and has been reported in a paper submitted to Journal of Phycology.

Snow samples collected in Antarctica by Dr. George Llano, National Science Foundation, have been examined. A joint paper on the findings is now in preparation.

The transmission of solar radiation in snow is important to ecological investigations of snow and ice algae. Light intensity and quality may play an important role in limiting the distribution of these "cryophilic" algae with the snow pack. Therefore, measurements were made of the relative absorption of solar radiation of different wave lengths at several depths in a natural alpine snow cover. Absorption was found to vary markedly with wavelength. Results of this work have been submitted to Ecology.

#### Phytoplankton - Curl, Glooschenko, Marmelstein

Phytoplankton research was carried on during the YALOC-66 cruise between Hawaii and Kodiak Island. The work basically consisted of measurements of standing stock of phytoplankton by chlorophyll measurement every 25-30 n. m. at the surface and at depths of 10, 15, 25, and 50 meters every 50-60 n. m. Productivity measurements using the carbon-14 technique were made at these one-day stations between Honolulu and Adak. In addition, at these fixed stations chlorophyll samples were taken every two hours to determine if a chlorophyll periodicity existed, and nutrient enrichment experiments were performed. Samples were also collected for species determination and water for bioassay purposes was collected each 50-60 n. m.

Productivity was found generally to be below a latitude of 37° N. Here, the standing stock as evidence by chlorophyll determination was also low. North of 37° the standing stock increased between 5- and 20-fold to a depth of 25 meters, but decreases in standing stock were apparent beyond 46° N. Apparently, this area of increased standing stock is due to the presence of the sub-arctic convergence in this area as evidenced by hydrographic data. Nutrient enrichment with nitrate, phosphate, and iron showed that such an enrichment generally decreased productivity. Hence, it appears that the oceanic species were well-adapted to low nutrient levels.

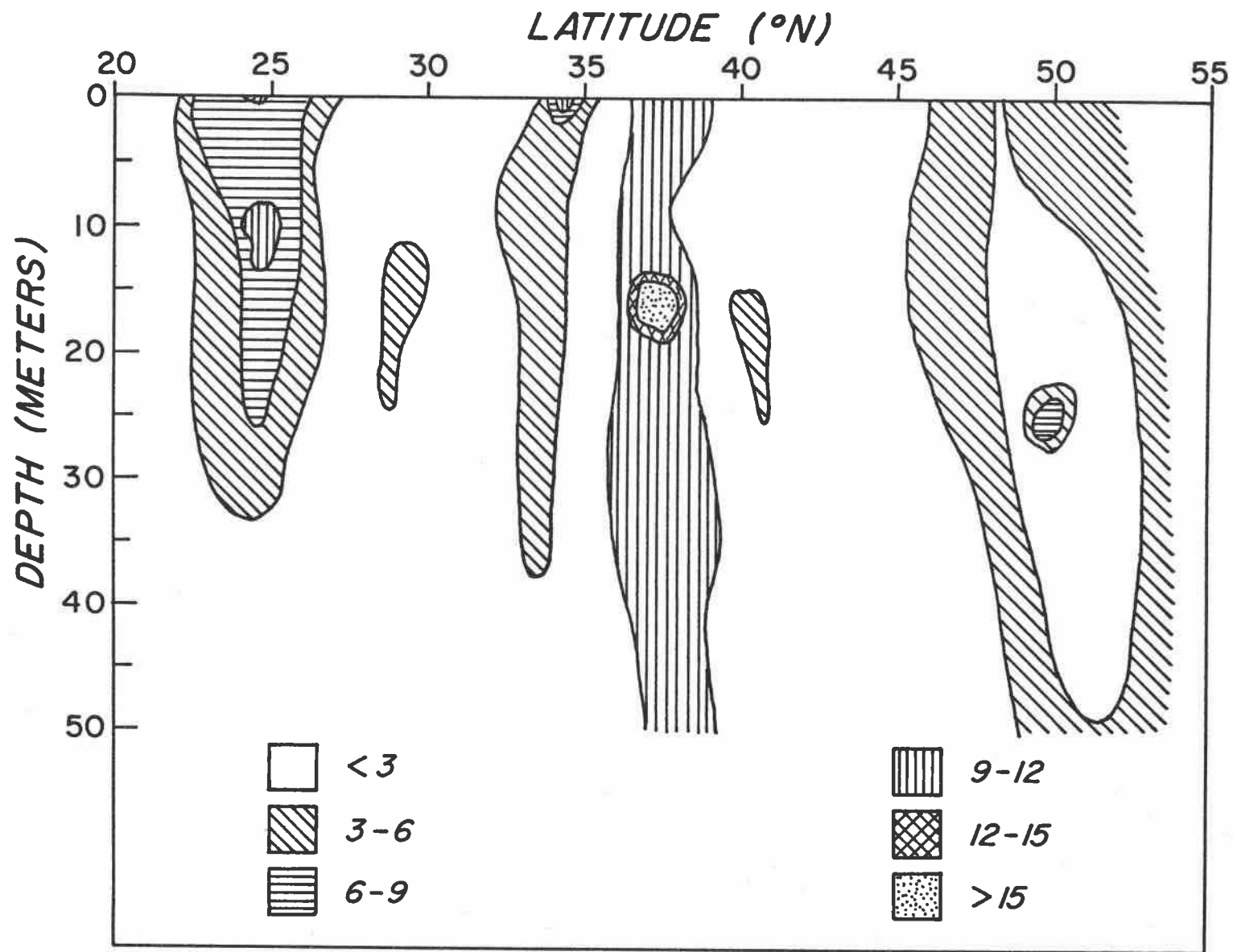


Figure 5. Total chlorophyll  $\text{mg}/\text{m}^3$  with relation to latitude and depth.

A definite chlorophyll periodicity was noticed on the fixed stations. In general, chlorophyll was highest at night and lowest in the late afternoon, the ratio of highest chlorophyll around midnight to lowest chlorophyll in the late afternoon varying from 2-4. Light intensity appears to control this phenomena, and this effect is being further investigated in the laboratory.

#### Phytoplankton Physiology - Davey, Curl

Our gas chromatograph has been modified to allow accurate calibration during analytical runs, and the sensitivity has been increased four-fold. Experiments are being performed on the effect of nitrogen-containing-nutrients, light, and temperature of photosynthesis, respiration, cell division, and intermediary metabolism.

#### Phytoplankton Ecology - Curl, Small, Glooschenko, Marmelstein

We are studying the role of chlorophyll c in photosynthesis by diatoms, hourly variations in assimilation number, and diel changes in chlorophyll concentrations with depth. We observe an increase in chlorophyll at night; whereas, other works report decreases at night.

We have completed a preliminary study of the contribution of chlorophyll and seston to extinction coefficient in local waters.

#### Plankton Inventories at Yaquina Bay - Frolander

We continued to collect samples weekly from four locations in Yaquina Bay. In addition to Clarke-Bumpus tows, we also collected surface and bottom water samples for determining temperature, salinity, and dissolved oxygen. A summary of the data collected during this period appears in Table I. All samples have been accessioned into ledgers, catalogued in card files, and deposited in chronological accessioning cases.

Table I. Data Collected at Yaquina Bay.  
1 April 1966 to 30 September 1966

Sampling Days	23
Clarke-Bumpus Tow - #6 mesh	97
Clarke-Bumpus Tow - #12 mesh	94
Clarke-Bumpus Tow - #25 mesh	3
1/2-meter net tow - #6 mesh	26
Water samples (for measurement of temperature, salinity, dissolved oxygen)	343

A 24-hour temporal survey was conducted on 11 and 12 September at Buoy 21 in Yaquina Bay. Each hour two CB Samples, one 1/2-meter net sample, and four water samples were taken. On 13 September a spatial survey of the bay was made which included water and plankton samples taken at six stations in the bay.

#### Marine Microbiology - Morita

The effect of sodium chloride on the maximum and optimum growth temperature on Vibrio marinus MP-1 is now under investigation. This study will be projected to other marine psychrophilic bacteria. Studies on the various glycolytic enzymes and TCA enzymes of V. marinus have shown that many of the enzymes are abnormally thermolabile. The data on gelatinase (an example of a proteinase) obtained from a psychrophilic vibrio have shown that this enzyme is not abnormally thermolabile since its optimum temperature of activity is between 42-45 C, approximately 20 C higher than the maximum temperature for growth of the organism. However, at low temperature (5 C) and hydrostatic pressure, the reaction rate of gelatinase is slow.

The effect of hydrostatic pressure on protein synthesis as well as on RNA synthesis is still under investigation. The hydrostatic pressure-temperature relationships are also being conducted on glucose-6-phosphate dehydrogenase obtained from a psychrophile.

The effect of moderate temperatures of 20 to 30 C on the permeability of cells of psychrophiles is being studied in terms of the penetration of acriflavine into cells as well as with thermally-induced leakage of cellular materials.

#### Marine Ecological Studies - Hedgpeth

The last six months has been devoted to necessary reconnaissance for the marine ecological studies. During the summer, records were obtained and collated. Collections have also been added to the laboratory library; these will form the nucleus of a reference collection.

#### Systematics and Evolution of Opisthobranchs - Gonor

Taxonomic and anatomical work on collections of these animals from Costa Rica and the tropical Pacific was continued during this period. Analysis of these collections is about half completed. Systematic studies on opisthobranchs have been extended by an agreement with the Smithsonian Oceanographic Sorting Center to examine the opisthobranchs occurring in the collections sorted at the Center. A consignment of

material from Antarctica has been received and a preliminary examination of the specimens made. While preservation of this material is very bad, the collections contain a few specimens of the poorly known Bathydoris group, a specialized dorid nudibranch group which come from abyssal depths.

#### Reproductive Biology of Marine Coastal Invertebrates - Gonor

Long standing plans for initiating studies in this area were finally implemented during the summer months. A high school teacher, working under my direction in a National Science Foundation Research Participation Program, began a survey of breeding activity of local invertebrates. Twenty-five species were investigated by laboratory techniques designed to induce spawning as an indication of breeding condition. A number of species were found to be actively breeding in the summer, an off season for many species in this area which breed in winter and spring. Eggs and larvae of the breeding species were subjected to a variety of experimental procedures in order to determine their suitability as material for investigations in developmental biology. Thus, they could supplement commonly used species which do not breed in the summer.

## DEGREES GRANTED

Four students completed the requirements for the Ph. D. while 12 students earned M. S. degrees. Names, thesis titles, and major professors are listed below:

CHIBURIS, Edward F. Ph. D., Geophysical Oceanography

Thesis Title: Crustal Structures in Pacific Northwest States from  
Phase-Velocity Dispersion of Seismic Surface Waves.

Major Professor: Peter Dehlinger

DeRYCKE, Richard J. M. S., Physical Oceanography

Thesis Title: An Investigation of Evaporation from the Ocean off the  
Oregon Coast, and from Yaquina Bay, Oregon.

Major Professor: June G. Pattullo

DUEDALL, Iver W. M. S., Chemical Oceanography

Thesis Title: The Partial Equivalent Volumes of Salts in Seawater.

Major Professor: Peter K. Weyl

ENSMINGER, Henry R. M. S., Geological Oceanography

Thesis Title: Sediments and Planktonic Foraminifera of Tropical  
North Atlantic Cores.

Major Professor: John V. Byrne and Gerald A. Fowler

ERICKSON, Barrett H. M. S., Geophysical Oceanography

Thesis Title: Marine Seismic Studies Near Newport, Oregon.

Major Professor: Joseph W. Berg, Jr.

FOWLER, Scott W. M. S., Biological Oceanography

Thesis Title: Uptake and Retention of Zinc-65 from Seawater by  
Euphausia pacifica Hansen.

Major Professor: Lawrence F. Small

HEBARD, James F. Ph. D., Biological Oceanography

Thesis Title: Distribution of Euphausiacea and Copepoda off Oregon  
in Relation to Oceanographic Conditions.

Major Professor: William G. Pearcy

HUNGER, Arthur A. M. S., Geological Oceanography

Thesis Title: Distribution of Foraminifera, Netarts Bay, Oregon.

Major Professor: Gerald A. Fowler



- HUTT, Jeremy R. M.S., Geophysical Oceanography  
Thesis Title: Relationships Between Thermal and Electrical  
Conductivities of Ocean Sediments and Consolidated  
Rocks.  
Major Professor: Joseph W. Berg, Jr.
- INGHAM, Merton C. Ph.D., Chemical Oceanography  
Thesis Title: The Salinity Extrema of the World Ocean  
Major Professor: Peter K. Weyl
- KESTER, Dana R. M.S., Chemical Oceanography  
Thesis Title: Determination of the Apparent Dissociation Constants  
of Phosphoric Acid in Seawater.  
Major Professor: Ricardo M. Pytkowicz
- KUJALA, Norman F. M.S., Radioecology  
Thesis Title: Artificial Radionuclides in Pacific Salmon.  
Major Professor: Charles Osterberg
- ODEGARD, Mark E. M.S., Geophysical Oceanography  
Thesis Title: Gravity Interpretation Using the Fourier Integral  
Major Professor: Joseph W. Berg, Jr.
- PANSHIN, Daniel A. M.S., Physical Oceanography  
Thesis Title: Sea Level, Winds, and Upwelling Along the Oregon  
Coast.  
Major Professor: Robert L. Smith and June G. Pattullo
- SARMAH, Suryya K. Ph.D., Geophysical Oceanography  
Thesis Title: Attenuation of Compressional Waves in the Earth's  
Mantle.  
Major Professor: Joseph W. Berg, Jr.
- SOUDERS, Robert H. M.S., Geophysical Oceanography  
Thesis Title: Angle of Emergence of Seismic P Waves and its  
Variation with Frequency.  
Major Professor: Joseph W. Berg, Jr.

## FACILITIES

### Marine Science Center

#### Aquarium

The program of improvement and expansion of the aquarium has continued through the summer with efforts directed primarily toward replacing the temporary filters, aeration system, and plumbing with permanent and more reliable components. This program will continue through the winter with the addition of both large and small display tanks.

A very serious problem developed with the laboratory seawater system which serves the entire laboratory including the aquarium and the research wings. It was found that the flow capacity of the system had dropped to dangerous levels due to plugging by living marine growth consisting primarily of barnacles, goose-neck barnacles, and clams. After unsuccessful efforts to clear the system mechanically, it was decided to attempt chemical methods. The use of technical hydrochloric acid in moderate concentration was found to do an excellent job. Only minor revisions of plumbing were necessary to permit this treatment.

#### Small Boat Marina

The original dock facilities at the Marine Science Center made provision only for vessels of major size such as the YAQUINA. It was apparent that there was serious need for launching and mooring facilities for small craft; some 20 vessels 30-feet and under were in use or budgeted by the various groups active at the Marine Science Center. In addition, a vessel of the 80-foot class was projected.

A second consideration was the extensive debris washed downstream during winter storm conditions which threatened damage to the main dock, and required considerable labor to dislodge and remove.

A marina consisting of a causeway, 100-foot pier, and a 400-foot floating mooring platform to be located immediately upstream of the main dock will provide both small craft mooring capacity and debris protection for the dock. The pilings have been driven and a temporary log boom to provide debris protection has been installed. The grading of the causeway and construction of the pier and float will be accomplished as weather permits during the winter.

## Research Vessels

In the two years the 180-foot Research Vessel YAQUINA has been in operation for the department, she has traveled approximately 52,000 miles. All types of marine research have been performed during her 492 days at sea.

During the past year, the YAQUINA has expanded her operating distance from 1,000 miles to over 3,000 miles off the coast of the northwestern United States. The cooperation and endurance of the scientific party on a joint physical, biological, geophysical, geological, and chemical cruise have been successfully tested.

Figures 2 to 6 show the time the YAQUINA spent at sea and tracks of individual cruises taken from October 1964 through September 1966.

A 33-foot boat, PAIUTE, has been put into operation for estuarine and coastal work. Although this vessel will berth a crew of four in the bow, most trips will be of one day or less.

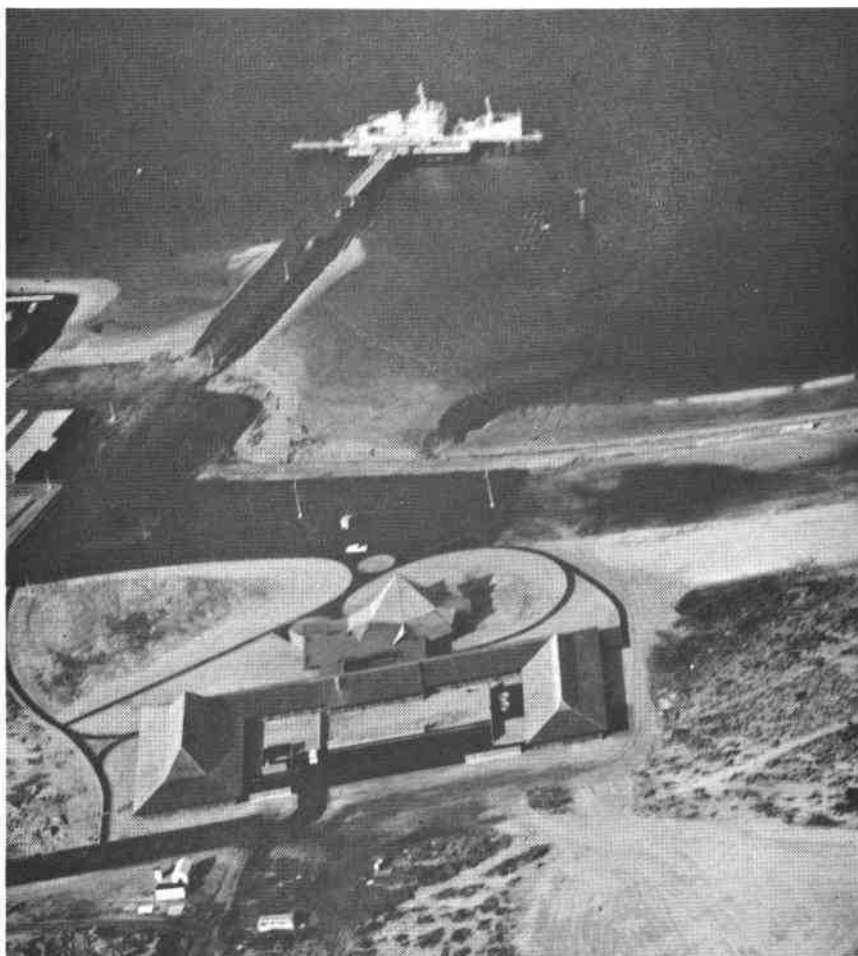


Figure 1. The Marine Science Center and YAQUINA, Newport, Oregon.

## YALOC - 66

The first extended oceanographic cruise by members of the Department of Oceanography, Oregon State University, aboard the R/V YAQUINA was made from 20 April to 29 July 1966. The cruise, track line shown in Figure 5, was divided into four legs:

- (1) Newport, Oregon to Honolulu, Hawaii  
Chief Scientist: Dr. Kilho Park
- (2) Honolulu, Hawaii to Honolulu, Hawaii  
Chief Scientist: Dr. Peter Dehlinger
- (3) Honolulu, Hawaii to Adak, Alaska  
Chief Scientist: Dr. Stephen Neshyba
- (4) Adak, Alaska to Newport, Oregon  
Chief Scientist: Dr. June Pattullo

This long cruise was primarily undertaken so that the YAQUINA could participate in Mohole investigations near Hawaii. En route to Honolulu chemical, geophysical, and physical data were collected. Before returning to home port, the YAQUINA sailed north to collect samples of deep water for physical and chemical studies. Between Honolulu and Adak, Alaska, experiments were also carried out to determine the biological activity in the area. Hydrographical and geophysical data were gathered across the Aleutian Trench. In the Gulf of Alaska, emphasis was placed on dredging the sea floor. More geophysical data were collected in Dixon Entrance near Ketchikan, Alaska. Several trawls and hydrographic stations comprised the final leg of the cruise.

The regular hydrographic stations off Oregon were occupied by the YAQUINA on departure and on return, while the R/V ACONA filled in during the YAQUINA's absence.

For a more complete description of the YALOC-66 cruise, see Cruise Report YALOC-66, Technical Report 74, Reference 66-10, Department of Oceanography, Oregon State University, September 1966.

## YALOC 66 STATISTICS

Total miles travelled 13,642

### Hydrographic station data:

Casts to 1500 m or less	81
Casts to deeper than 1500 m	46
Deepest cast	7,300 m

Determinations on board included: temperature, salinity, oxygen, nitrogen, carbon dioxide, phosphate, pH, and alkalinity. Samples for silicates and nitrates were frozen and brought home.

Bathymetromgrams: 372

Drift Bottles: 360 total at 30 stations - Newport line out to NH-165 on departure; Newport line from 600 miles offshore to coast; on return.

Pipe dredge hauls: 7

Anchor dredge hauls: 3

Gravity Measurements: 9 lines each 100 miles long over Mendocino Escarpment; 1,000 miles of track in Aleutian across trench and island chain; 2 lines each 300 miles long near Dixon Entrance perpendicular to the coast.

Magnetic profiling: Virtually at all times when the ship was underway.

Nekton: 7 collections with multiple sampling nets.

Zooplankton: 200 meter trawls each night when possible.

Phytoplankton: Primary productivity - three 24-hour stations; surface samples on hydrographic stations Adak to Kodiak.

Benthos: Anchor dredge hauls - 6 Otter trawl hauls - 3

Radiation: Short-wave radiation by recording Eppley pyrhelimeter throughout cruise. Dawn, dusk and noon sea radiation when ship was stopped at those times.

Weather: Continuous recording of sea surface and air temperature, and pressure. Normal weather schedule by bridge personnel.

# TIME AT SEA 1965-66

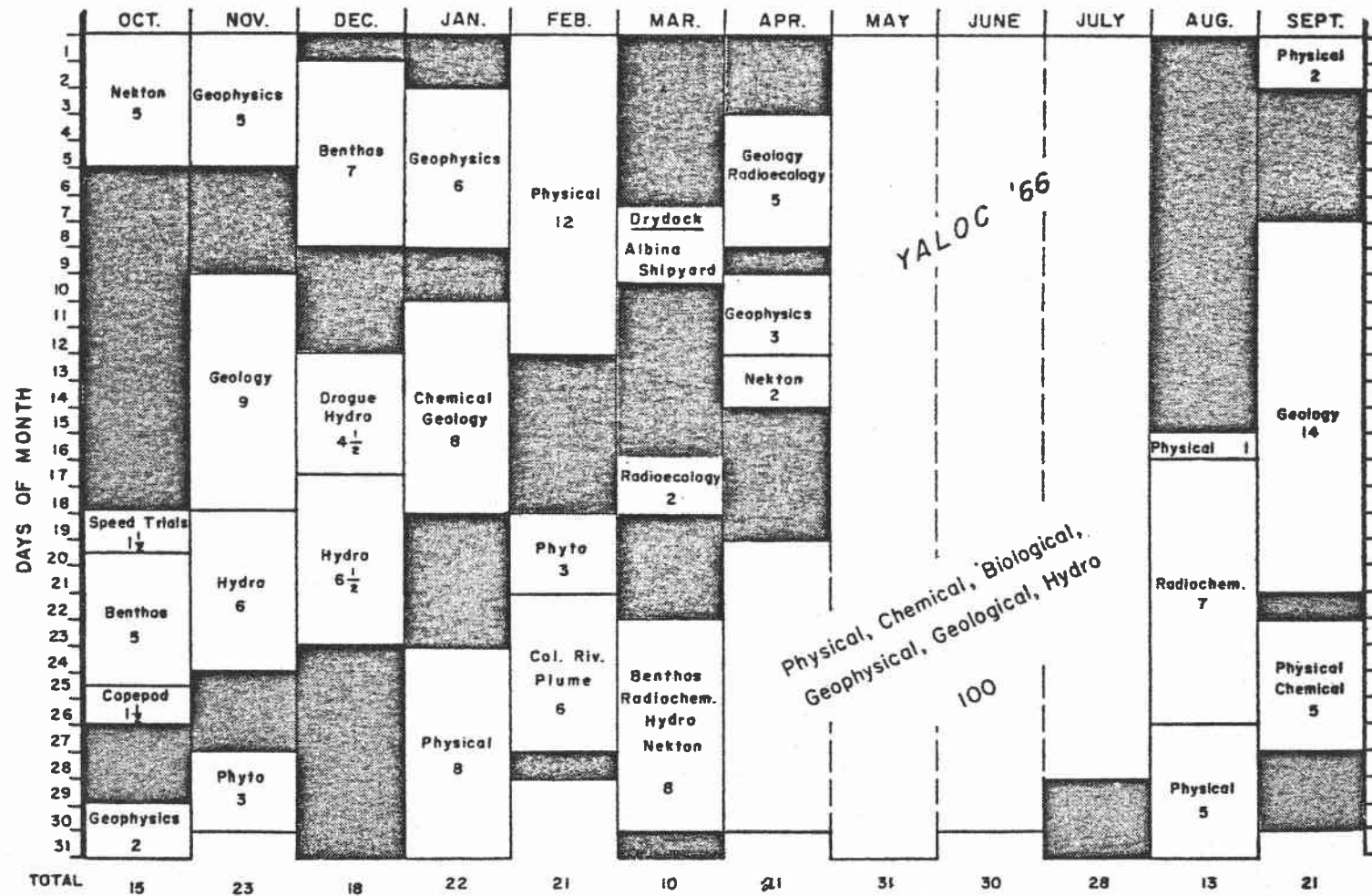


Figure 2

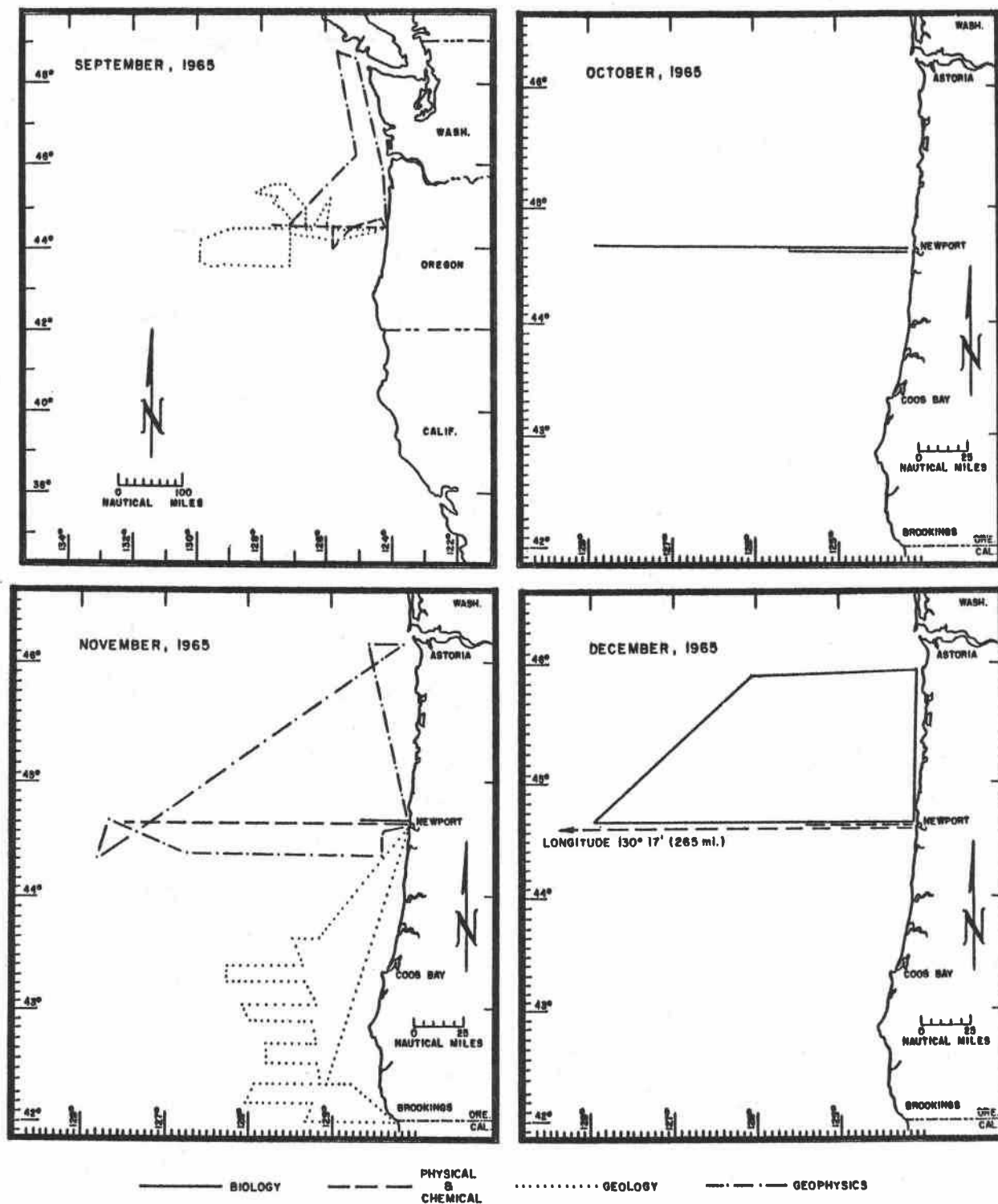


Figure 3. Cruise tracks of R/V YAQUINA, September 1965 - December 1965.

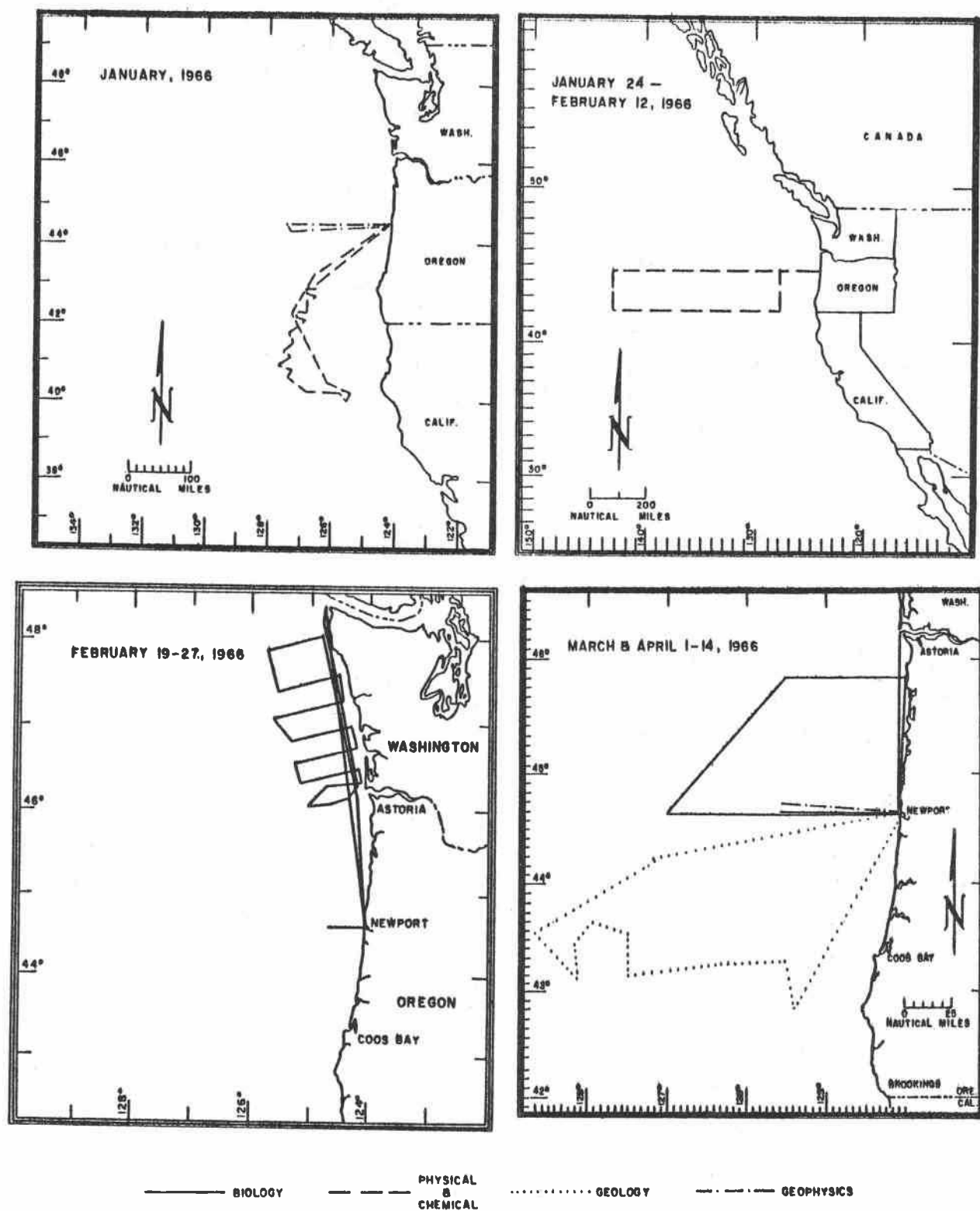


Figure 4. Cruise tracks of R/V YAQUINA, January 1966 - April 1966.



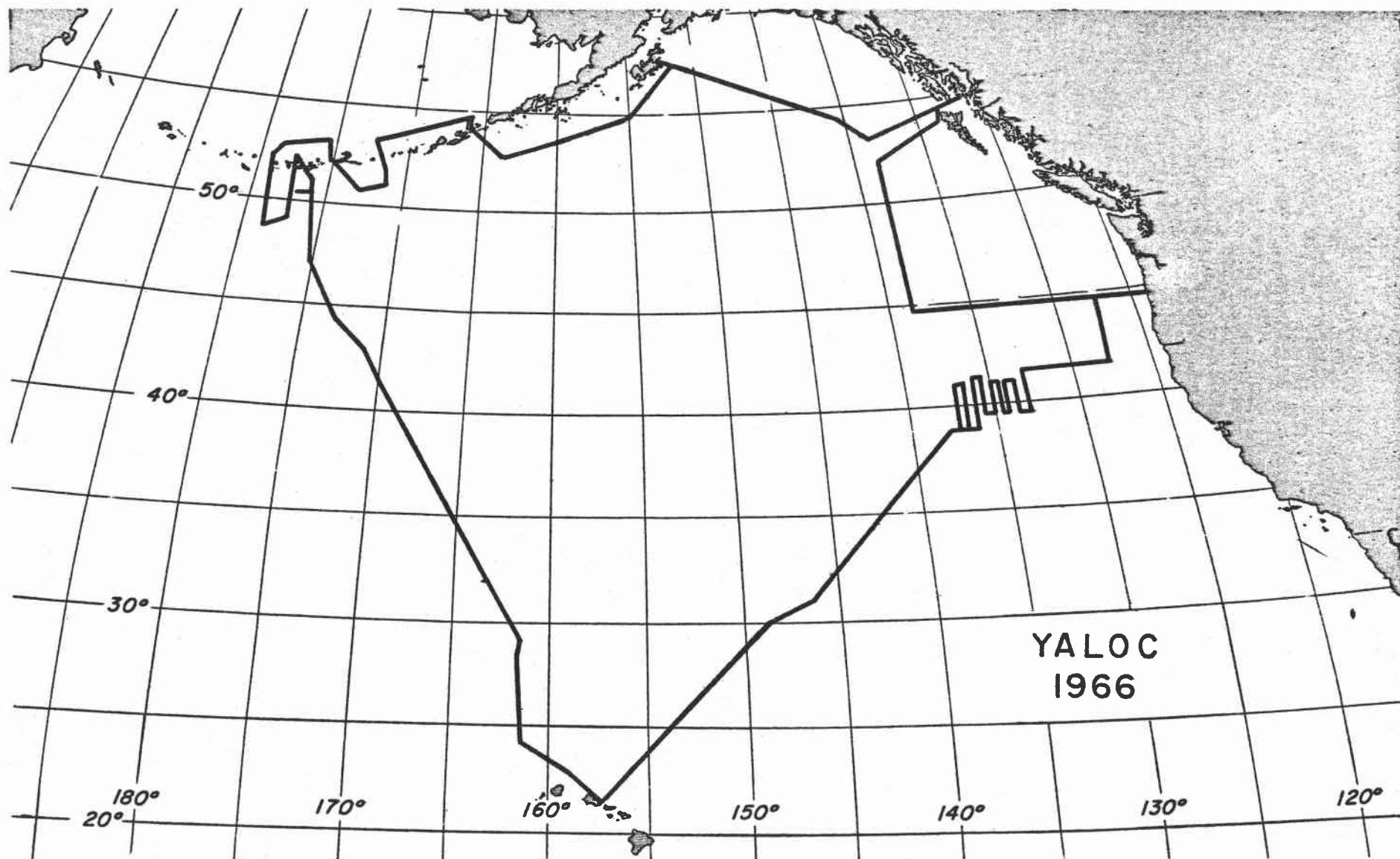


Figure 5. Cruise track of R/V YAQUINA, 20 April 1966 - 29 July 1966.

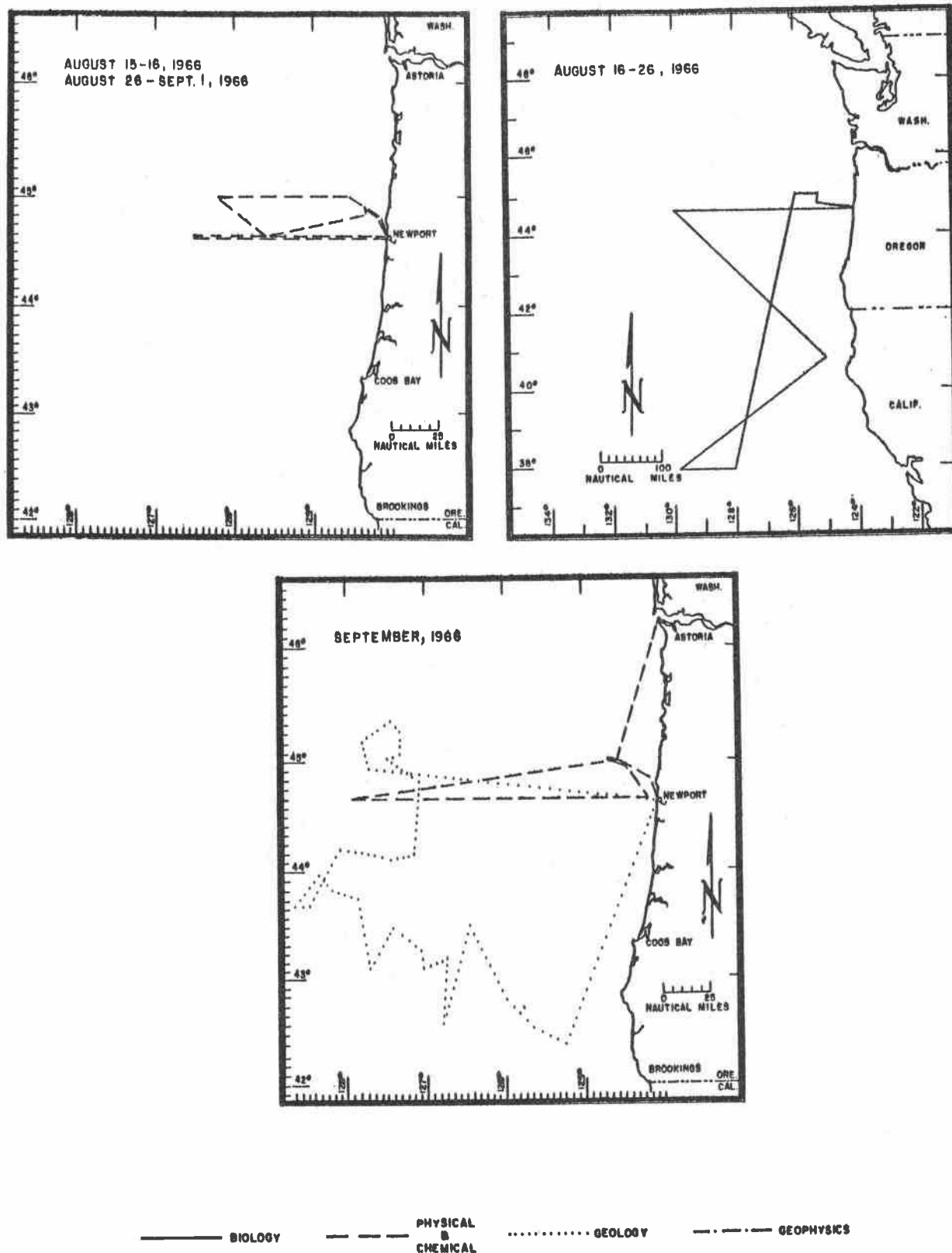


Figure 6. Cruise tracks of R/V YAQUINA, August 1966 - September 1966.

## STAFF

Dr. George F. Beardsley, Jr. has joined our staff as an Assistant Professor of Physical Oceanography. He earned a B.S., M.S., and Ph.D. from Massachusetts Institute of Technology. His doctoral dissertation is entitled "Radiative transfer in the sea."

Dr. Beardsley worked as a physical oceanographer for National Marine Consultants and as a scientist for Lockheed Missile and Space Company. Electronics and instrumentation are a strong part of his background. His main interests are in hydrological optics and waves.

Dr. William O. Forster has joined our staff as an Assistant Professor in Oceanography. He holds both B.S. and M.A. degrees from Michigan State University and a Ph.D. from the University of Hawaii. His doctoral dissertation is entitled "The seasonal changes of cobalt and nickel in seawater."

Dr. Forster has been an instructor at Henry Ford Community College and the University of Hawaii. His main interest is in radiochemistry.

Dr. Donald F. Heinrichs, Assistant Professor of Oceanography, is a new staff member in Geophysics. He received B.S. and Ph.D. degrees from Stanford University. Paleomagnetism was the subject of his doctoral thesis.

Dr. Heinrichs was employed in the summers of 1959 and 1961 as a geophysical technician for Chevron Oil Company. For the past two years he has been an instructor at Menlo College, California. He is currently investigating magnetic and gravity anomalies in Oregon.

Dr. Victor T. Neal has returned to Oregon State as an Assistant Professor in Physical Oceanography. Dr. Neal holds a B.S. degree from Notre Dame, a M.Ed. degree from North Dakota, and a Ph.D. degree from Oregon State University. His doctoral dissertation is entitled "Calculation of flushing times and pollution distribution in the Columbia Estuary."

Dr. Neal has been on the faculty at the United States Naval Post-graduate School in Monterey, California since the spring of 1964. He is currently serving as Assistant Administrator in the Oceanography Department, Oregon State University. His interests in physical oceanography include estuarine processes and air-sea interaction.

Dr. John V. Byrne began a 15-month leave of absence in September. He is currently Program Director for Oceanography, Earth Sciences Section, National Science Foundation, Washington, D. C.

Dr. Peter Dehlinger will spend the next year (starting 1 September 1966) as Head of the Geophysics Group, Ocean Science and Technology, Office of Naval Research, Washington, D. C.

Dr. Ricardo M. Pytkowicz left in September for a four-month trip to England, Belgium, and Sweden. He is spending much of his time with Professor A. Disteche of the University of Liege, Belgium. They are working together on techniques to determine the effect of pressure on the solubility of calcium carbonate in seawater.

Dr. Robert L. Smith has returned from a year's leave of absence. The recipient of a NATO fellowship for postdoctoral study, he worked with Dr. John C. Swallow at the National Institute of Oceanography, England.

Dr. Smith participated in a 50-day cruise aboard the RRS DISCOVERY. During the cruise he assisted with deep (near bottom) current measurements; an examination of patchiness of Mediterranean water northwest of Madeira; and an investigation of pressure fluctuation on Seire Bank seamount in an attempt to find trapped "shelf" waves. Dr. Smith also worked on upwelling data collected off the Arabian coast by members of the International Indian Ocean Expedition aboard the RRS DISCOVERY in 1963.

Dr. Joseph W. Berg, Jr. has left the Department to become Executive Secretary, Division of Earth Sciences, National Academy of Sciences, Washington, D. C.

Dr. Peter K. Weyl has joined the faculty of the State University of New York at Stony Brook, Long Island, New York, as a Professor in the Department of Earth and Space Sciences.

## VISITING SCIENTISTS

April	Dr. George V. Keller, Colorado School of Mines; Golden, Colorado. "Geophysical prospecting in the Soviet Union"
May	Dr. Y. Nayudu, Department of Oceanography, University of Washington. "Submarine Volcanics"
May	Dr. Stephen Pond, Postdoctoral Fellow at National Institute of Oceanography, England.
May	Dr. Philip Handler, Duke University. "Science and Public Policy"
May	Dr. Todd V. Crawford, Lawrence Radiation Laboratory, Livermore, California. "The Plowshare Program and its connection with some meteorological questions"
June	Dr. Eugene Bollay, President, E. Bollay, Associates, Inc., Boulder, Colorado
June	Dr. R. Crossett, Australian Atomic Energy Commission Research Establishment, Private Bag, Sutherland, N.S.W.
August	Mr. Feenan D. Jennings, Head Oceanographer, Ocean Science and Technology, Office of Naval Research. Dr. Donald P. Martineau, Assistant to Mr. Jennings Dr. Hugh McClellan, Assistant to Mr. Jennings
August	Mr. Ted Clausen, Westinghouse oceanographic staff
September	Laurence Draper, National Institute of Oceanography, England. "Making use of wave research"

## VISITING SCIENTISTS ABROAD THE R/V YAQUINA

### April

Dr. Burger, Battelle-Northwest Laboratories, Richland, Washington  
Mr. Swift, Battelle-Northwest Laboratories, Richland, Washington  
Mr. Aungst, Battelle-Northwest Laboratories, Richland, Washington  
Mr. Martin, Battelle-Northwest Laboratories, Richland, Washington

### April to July -- YALOC - 66 Cruise

James Dodd, Scripps Institution of Oceanography  
Timothy Francis, Scripps Institution of Oceanography  
Joseph Gettrust, University of Wisconsin  
Charles Hoskin, University of Alaska  
Alan C. Jones, Scripps Institution of Oceanography  
James Kasaloo, University of Wisconsin  
Robert Meyer, University of Wisconsin  
Lee Powell, University of Wisconsin  
George Rieck, Battelle-Northwest Laboratories, Richland, Washington  
Burt Tanner, University of Wisconsin  
William Unger, University of Wisconsin  
John Zane, Scripps Institution of Oceanography

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- Bodvarsson, G. Direct methods in applied geophysics. Geoexploration.
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- Byrne, J. V. and L. D. Kulm. Natural indicators of sediment movement in an Oregon estuary. J. of Waterway and Harbors Division, Am. Soc. Civ. Eng.
- Carey, A. G. Studies on the ecology of benthic invertebrate fauna in the Northeast Pacific Ocean off Oregon, U.S.A. Biological Station - Japan 11th Pacific Sci. Congress.
- Carey, A. G., W. G. Percy, and C. L. Osterberg. Artificial radio-nuclides in marine organisms in the Northeast Pacific Ocean off Oregon, U.S.A. Proceeding: Symposium on the Disposal of Radioactive Wastes into Seas, Oceans, and Surface Waters, Vienna, Austria, May 16-20, 1966.
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- Forss, C. A. and W. G. Pearcy. Distribution and biology of the pelagic shrimp Gergestes similis off the Oregon coast. American Society of Limnology and Oceanography, Seattle, Washington, June 1966.
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