DEPARTMENT of OCEANOGRAPHY

SCHOOL of SCIENCE

OREGON STATE UNIVERSITY

RESEARCH ACTIVITIES

1 April 1969 through 30 September 1969

Edited by
Beverly Knapp

Progress Report 24 Reference 69-32
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Atmospheric Effects on Incoming Solar Radiation over Tropical Oceans - Quinn, Burt

In a paper now in press, "Prediction of Abnormally Heavy Precipitation over the Equatorial Pacific Dry Zone," a simple method for using the barometric pressure changes associated with the Southern Oscillation to predict abnormally heavy rainfall over the Pacific equatorial dry zone is discussed.

Recent information from the U. S. Weather Bureau indicates that the recording of insolation data in support of this project will start by the latter part of 1969.

Development of Forecast Techniques for Wave and Surf Conditions over the Bars in the Columbia River Mouth and at the Entrance to Yaquina Bay - Quinn, Neshyba, Burdwell

This study, under contract with ESSA, was initiated June 1, 1969. Mr. Norman Kujala, who received his master's degree in oceanography at OSU, was selected to observe oceanographic conditions in the vicinity of the Columbia River Bar and to obtain additional information on such conditions from the Columbia River Bar Pilots, the U. S. Coast Guard and the ESSA-Weather Bureau Station at Astoria. The OSU buoy TOTEM I will be instrumented to obtain wave and weather data in support of this study. All information will be transmitted to Mr. Burdwell at the OSU/ESSA-Weather Bureau marine weather station at Newport for use in forecast preparation and research.

Model Study of Double Kelvin Waves - Caldwell

We have obtained sequences of streak photographs of oscillatory modes trapped on the edge of a circular sill in a rotating basin. The dispersion curve is now being constructed from measurements of wavelength and phase speed (derived from those photographs) as functions of the generator frequency. So far agreement with the Longuet-Higgins theory is quite good. The attenuation seems to be greater than would be expected from bottom friction.
Modification of Precipitation on the Oregon Coast - Elliott, Burt

Measurements of nuclei content of marine and continental air were made at Yaquina Head Lighthouse. These data indicate a diurnal variation of nuclei counts and give some indication the ratio between cloud nuclei and Aitken nuclei is less variable than the variation of either one. Analysis of the data also brought out some problems with the instrument and these are being rectified at present.

Statistical analyses of the rainfall data were started. The problems of describing the intensity patterns are being attacked but no completely satisfactory transformations have been found yet. Preliminary results seem to indicate the possibility of a frequency-amplitude correlation which could be exploited in a future model.

To test the hypothesis that rainfall is increased at the shoreline, a rain gauge was designed to be installed on the Totem based off Cascade Head. The system will be capable of telemetering its information to shore as well as recording on strip charts. The gauge will be sent to sea in October, 1969.

Physical Oceanography of Shelf and Slope Waters - Pattullo, Smith, Pillsbury, Muller, Bottero, Cutchin, Enfield

The past six months have produced significant progress in the processing of the 1967 and 1968 current meter data. A new compilation of observations should be issued in the next three month period. The past summer's observational program is completed. The three point array installed between Newport and Depoe Bay functioned well. The Depoe Bay string was partially lost for undetermined reasons. Data analysis is continuing in cooperation with the chemists and biologists.

Carl Fisher has completed his M.S. thesis and Dale Pillsbury is completing his Ph.D. work with a detailed analysis of the current structure using the 1967 and 1968 data.

Upwelling Study - Peru Coast - Smith, Pillsbury, Enfield

The processing of the time-series current, wind, and temperature data has been completed. Dave Enfield is completing his M.S. thesis studying the complex interaction of the biological and physical system.
Monthly hydrographic cruises were continued off Oregon with particular emphasis on the Newport Line. Cruises were made jointly with Biological and Chemical Oceanography sections in order to obtain greater station coverage. In June, July and August lines of stations were made of the northern and southern Oregon coasts. The large variety of samples obtained on these cruises are listed in the table below.

**Samples Taken to 185 Miles off the Oregon Coast**

<table>
<thead>
<tr>
<th></th>
<th>Hydro casts</th>
<th>BT casts</th>
<th>Drift bottles</th>
<th>Drogue current measurements</th>
<th>T, S, O$_2$</th>
<th>NO$_3$</th>
<th>SIO$_3$</th>
<th>PO$_4$</th>
<th>pH</th>
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<td>6</td>
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<td>11</td>
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<th>IK Mid-water trawl tows</th>
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**Optical Oceanography** - Beardsley, Pak, Plank, Carder

**Optical signature of marine scatterers**

The volume scattering functions and particle size distributions of several phytoplankton species and marine sediments were determined using a Brice-Phoenix Light Scattering Photometer and a Coulter Counter in the hope of developing a rapid *in situ* technique for classifying
marine hydrosols. A plot of specific volume scattering coefficient against mean particle surface area shows (Figure 1) that different types of particles display characteristic light scattering properties. The diagram is explained in terms of Mie scattering theory. The particles used in this study are listed in the table below.

<table>
<thead>
<tr>
<th>Particles</th>
<th>Estimated mean diameter in µ</th>
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<tbody>
<tr>
<td>Rhod</td>
<td>4.60 → 4.88</td>
</tr>
<tr>
<td>Isocrisis</td>
<td>4.32</td>
</tr>
<tr>
<td>Mono-crisis</td>
<td>4.46 → 4.66</td>
</tr>
<tr>
<td>Cartera</td>
<td>7.52 → 8.79</td>
</tr>
<tr>
<td>Cocolith</td>
<td>9.25 → 13.15</td>
</tr>
<tr>
<td>Syc</td>
<td>8.08 → 11.33</td>
</tr>
<tr>
<td>Thalossiosira</td>
<td>13.5</td>
</tr>
<tr>
<td>Pacific clay</td>
<td>3.37 → 3.48</td>
</tr>
<tr>
<td>Quartz</td>
<td>.947</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>3.64</td>
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<tr>
<td>Kaoline</td>
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During the past quarter, a number of techniques were developed which are auxiliary to the problem of obtaining modulation transfer functions. Experiments were performed with a variety of films and a new low contrast developer, POTA. The use of this low contrast developer will allow photographs (of edge gradients) to record luminance ratios of $10^5$: 1. A Joyce Mark III microdensitometer was located on campus, and although it is not perfectly suited for our application, it has been used to evaluate various film/developer combinations including the POTA developer. The high resolution telephoto lens (Questar) was received in early September and a few edge gradient experiments were performed. Figure 2 is a record of an edge gradient and its derivative derived from photographs taken with the Questar. It is interesting to note the slight asymmetry in the line spread function when measured in this way. Experiments using true line sources will be performed to determine the amount of distribution.
An analytic method for determining the rate at which the apparent optical properties of daylight in sea water approach the near asymptotic limit has been developed for the symmetrical case, and a program for obtaining numerical results is in preparation.

Figure 1. Characteristic light scattering vectors of some living phytoplanktons and inorganic particles formed by the specific light scattering coefficient and mean cross-sectional area of the particles.
Figure 2. Transmitted edge gradient and equivalent line source regime taken with Questar/Nikon through ~1 meter of sea water.
Light scattering and suspended particles in the eastern equatorial Pacific - Beardsley, Pak, Carder

The following abstract based on YALOC 69 data was accepted for the AGU meeting, December 1969, in San Francisco:

The total light scattering coefficient, the volume scattering function at 45°, and the suspended particle size distribution have been determined at the surface, depth of maximum turbidity, and 100 meters at several stations in the eastern equatorial Pacific. Total scattering coefficient and volume scattering function were also measured at several other depths. Total light scattering was measured in situ with a b meter, volume scattering was measured in the ship's laboratory with a Brice-Phoenix light scattering photometer, and particle size distributions were determined in the ship's laboratory with a Coulter Counter. The total scattering coefficient is directly proportional to the volume scattering function at 45°. The total number of observed particles, total particulate surface area, and total particulate volume per cc. of sea water were computed from the measured particle size distributions. Both the total scattering coefficient and the 45° volume scattering coefficient are proportional to these three properties of the suspended particles. The linear regressions derived from these data can be used to estimate particle properties from optical measurements.

Wind Wave Properties - Beardsley, Earle

Surface wave height, two mutually perpendicular surface wave slopes, and subsurface wave pressure have been measured simultaneously for several hours in deep water. Similar measurements will later be made in conjunction with subsurface velocity measurements.

Two three component spherical drag probes have been built and preliminary calibrations have been made. The associated electronics utilize simple variable inductance circuits and are entirely contained within the probe support. The spherical probe head is 5 cm. in diameter and is sensitive to both fluid drag forces and to fluid acceleration forces. The output voltage $G_i$ is proportional to the force in the $i$th direction and is given by

$$G_i = A_i \left| u \right|^{0.86} u_i + B_i u_i'$$

where $i = 1, 2, 3$, $A_i$ and $B_i$ are experimentally determined constants, $u_i$
is the \(i\)th component of water velocity with respect to the probe, \(u_i'\) is the \(i\)th component of water acceleration with respect to the probe, and \(|u| = (u_1^2 + u_2^2 + u_3^2)^{1/2}\). The response time is less than 0.1 sec. and the dynamic range is 30 to 1. If the probes are used to measure wave orbital velocities near the surface, the acceleration term is less than 10% of the drag term for wave amplitudes greater than 45 cm.

A technique has been developed to remove from the probe outputs the effects of wave orbital velocities as predicted by linear wave theory from the surface height and slope records. From the residual output, velocities due to turbulence or second order wave effects may be determined.

Figure 3. Totem two-point moor installed 30 miles off the Oregon coast
The Two-Point Mooring of TOTEM Buoy - Neshyba, Nath, Young

1) The U.S. Coast Guard provided their buoy tender CGC Magnolia for the week of 9 September - 15 September to install TOTEM buoy.

2) On Wednesday September 10, the Magnolia arrived on station with the complete mooring components. Weather was bad and seas rough, and the ship returned to Newport.

3) On Friday September 12, the Magnolia again arrived on station 45° 02.6'N, 124° 44'W (that's about 30 miles west of Cascade Head in 550 meters of water) at 8:00 A.M. and by 4:00 P.M. had installed the basic TOTEM mooring, as shown in Figure 3.

4) On Sunday, September 14, the Magnolia arrived on location with TOTEM in tow. By 10:00 A.M. the TOTEM had been uprighted and made ready for attachment to the mooring; the Magnolia had taken the CG can buoy aboard and had the two ends of chain ready for transfer to TOTEM, as shown in Figure 3.

5) By 11:00 A.M. TOTEM transfer to the mooring was completed. The task remained for the Magnolia to "stretch" out the mooring. This was accomplished as exactly to dimensions shown as possible and required about 2 hours time. In all, the Magnolia adjusted the anchor 5 times.

The buoy carries navigational aids and is instrumented with a five element wave sensor array and a tensiometer unit in each line. In November, an automatic Meteorological Station will be placed aboard together with magnetic tape recording device for recording wave sensor and line tension data on command from shore.

The Interaction of an Internal Tide with the Frontal Zone in a Coastal Upwelling Region - Mooers, Smith

C.N.K. Mooers has completed his Ph.D. dissertation. The question of how an internal tide interacts with the frontal zone in a coastal upwelling zone was discussed from a theoretical viewpoint and supplemented with field observations taken in the late summer of 1966.
Geomagnetic Electrokinetograph - Curtin, Neshyba

T. Curtin has completed a thesis titled "Towed Electrodes in the Sea - Theory and Use." Several interesting facets of the GEK signal have been found in the records taken on YALOC 69. One involves the strong evidence that internal waves in a shallow thermocline region produce a signature on the GEK record. A preliminary treatment is contained in Mr. Curtin's thesis, and a paper is being prepared.

The solutions to Maxwell's equations as they apply to an ocean current which is rectangular have been published by Longuet-Higgins and others. Mr. Curtin has plotted these solutions as families of curves for various scale lengths of the rectangular current in a deep ocean. He has developed a method of interpreting GEK signals based on these curves. A paper is being prepared.

Arctic Oceanography - Neal, Neshyba, Amstutz, Jeter, Hansen

The Geodyne CTD has been modified to yield conductivity sensing to a resolution of ± 0.001 millimho/cm. The system is now en-route to the Arctic for a two-week cruise on T-3. With this system we hope to get an accurate look at 1) Stability in the laminae 2) Velocity shear in the transition zones 3) Overall velocity profiles to 500 meters 4) Time series of temperatures and conductivity within the laminae 5) Oxygen profiles. Two papers have been published.

Crater Lake Oceanography - Neshyba, Neal, Amstutz, Jeter, Hansen

Four cruises were made on Crater Lake this summer to discover if microstructure in water temperature is found in a salt-free lake. The data in Figure 4 show conclusively that this is the case. These data were taken with a XBT on a conducting wire winch, a crude rig but one light enough to be hand carried down to the lake.

The phenomenon seems extremely short-lived, but the true picture will not emerge until better-controlled experiments can be run. We plan these experiments for next summer.

Progress and Outlook for the Telemetering Oxygen Probe - Neshyba, Jeter

Since the last report, the telemetering oxygen probe has been deployed at sea on four cruises, and at Crater Lake on two occasions.
Several of the trials yielded no result other than to point out changes which were needed for shipboard use. These difficulties have been corrected, however, and the probe has yielded some reliable and interesting data.

Of primary importance was to check the probe's output against standard chemical analyses, in order to verify the data. Figure 5 shows a comparison made at a station 65 miles off the Oregon coast. The left-hand plots are the oxygen probe data, and the remaining plots are derived from a Nansen cast with bottles spaced 5 meters apart. It is clear that the oxygen maximum shown by the probe is also shown by the chemical

![Temperature Profiles](image)

Figure 4. Temperature profiles taken of Crater Lake, Oregon by XBT, August 1969.
analyses. The plot also shows that the resolution of the probe is on the order of 0.01 ml/l, and that high data density profiles can be made.

The computer program used in analyzing the oxygen data has been improved in versatility. Calibration data can be typed into the shipboard computer at any time, allowing rapid analysis when the sensor's membrane is replaced or has drifted. This is especially important because the sensor has been observed to drift even between casts, perhaps due to the effect of hydrostatic pressure on the membrane. As presently used, the sensor is re-calibrated at each station, using in situ chemical data obtained at several points along the water column from the electrically-actuated sample bottles fastened to the CTD.

The oxygen maximum shown on Figure 5 was discovered using the oxygen probe, and was located on several different cruises. To our knowledge, this is the first time this feature has been found, probably because routine hydrographic casts have a bottle spacing of 50 meters in this depth region. Successive casts have shown that the feature oscillates over a depth interval of about 50 meters, as if by internal wave activity. A weak salinity minimum which accompanies the oxygen maximum suggests that this feature is caused by advection of a water layer, rather than by a decomposition process. A recent cruise was made to trace this feature, using the oxygen probe and the CTD, in order to find its source and sink. This data, now under analysis, may add to the knowledge of the circulation pattern off the Oregon coast.

The oxygen probe is presently being shipped to Fletcher's Ice Island (T-3), to be used in the study of the unique layering structure observed there. Other plans include the environmental study of concentrations of animal life, such as the Deep Scattering Layer, in hopes of being able to locate and characterize respiration and decomposition processes through their oxygen signature.

Structure of Oceanic Currents over the Continental Slope - Sakou, Neshyba, Still, Gilbert

An array of moored buoy stations has been established and in operation for sensing oceanic currents over the continental slope off Oregon. The resolution of the spatial, temporal and frequency structure of the ocean's motion over the continental slope is being sought in the analysis of the data acquired by the array. Some of the notable features observed to date include the shift in the energy level from high frequency to low frequency bands along the vertical profile downward and the lack of coherence at the discrete spectral lines in the low frequency range.
Temperature Variability over the Borderland - Mesecar, Neshyba, Still, Pawley, Sakou

Three sets of thermistor array have been fabricated and are being field-tested. The positioning of the array is coordinated with that of current meter array in order that a broad range of correlation among the variables defining the environment may be studied. The initial phase of the study is confined to measuring the entire spectral range of temperature variation in the upper 300 meters where the variation may be correlated with the propagation of internal waves, transient features of upwelling, frontal activities, etc.

Numerical Analysis of Meso-scale Oceanic Model - Paquin, Sakou

Preliminary investigation was started as Mr. Paquin's thesis research. The evaluation of principal variables, scales and boundary configuration is in progress. Three-dimensional model is studied to simulate the meso-scale interaction, specifically for the boundary ocean.

Figure 5. Comparison of oxygen probe profiles to chemical analyses.
Some additional cruises and verification tests for CTD capability study were conducted. Detailed features of large temperature inversion that remained as late as July (for the first time since the regular hydrography-BT-cast survey was initiated here) were recorded. CTD data reduction program package was completed. Since the stability of the temperature inversion layers (they are found in general to be very stable) needs to be resolved on real time basis, the program for sigma-t calculation was added to the package for PDP-8-S.

The area of study, the ocean sewer outfall area off Newport, Oregon (Figure 6) is bounded on the south by the north jetty of Yaquina Bay, on the north by Yaquina Head, on the east by the beaches of Newport and Agate Beach. Yaquina Reef acts as a partial boundary to the west. Current measurements were made just south of Yaquina Head, off Big Creek, at the sewer outfall and near the north jetty. Temperature and salinity measurements were taken at the surface and near the bottom over the outfall, in the effluent plume, outside the effluent plume, and outside Yaquina Reef. Dissolved oxygen samples were also taken where salinity and temperature measurements were taken. Waves and longshore currents were measured from the beach at Newport and near Big Creek. Winds were usually measured from the Newport jetty.

The marine environment in the sewer outfall area near Newport is significantly different from other coastal areas of Oregon due to the topographic features mentioned above. The weather and sea conditions as well as the mixed semi-diurnal tides and summer upwelling make the area particularly interesting since it is different than most coastal environments found in the United States.

Temperature, salinity and dissolved oxygen values were measured from October 1968 through August 1969. The temperatures measured are shown in Figure 7. Maximum temperatures occurred in June and early July. Minimum temperatures were recorded in early February (about 8°C) and in late July (also about 8°C). The water temperature dipped in mid-May when upwelling temporarily was in effect. The major upwelling season began July 1st. The transition from thermal stratification (June 30th) to cold isothermal water (July 1st) was readily detected on BT traces taken on those dates.

The upwelling season is also readily apparent in the graphs
Figure 6. Chart of the nearshore region, Newport, Oregon.
Figure 7. Water temperatures from October 1968 through August 1969. The upper traces (a) show surface and bottom temperatures at the sewer outfall. The lower traces show the deviations from temperatures at the outfall: (b) in the plume (c) out of the plume and (d) outside the reef.
of salinity (Figure 8), density (Figure 9) and dissolved oxygen (Figure 10). The salinity water at the surface became more saline (about 33%) during upwelling. The density graph shows greatest stratification during the months of May and June before upwelling had definitely set in. Once upwelling became well established the sigma-t values were definitely higher (on the order of 26.0). Dissolved oxygen values were generally near saturation until upwelling lowered them to less than 4 ml/liter.

Pertinent features of the wave data and longshore current data obtained follow. The significant wave periods measured ranged from as low as 5.2 seconds (July 21) to as long as 17.8 seconds (February 11) with some waves having periods up to 21 seconds during the winter months. The average wave period measured for the entire year was 10.5 seconds. Breaker heights ranged from a low of 4 feet (June 19) to a high of 16.1 feet (February 20.) The significant breaker heights average 9.5 feet for the entire period of measurement. The deep water wave heights ranged from 2.8 to 14.6 feet, with an average of 7.2 feet.

The direction of wave approach was most frequently from 270° to 290°. Longshore currents were about evenly divided between north and south flow during fall, winter and spring. During the summer months (June, July and August) the longshore currents predominantly flowed south. There was a wide variation in longshore currents from one place on the beach to another. Longshore velocities ranged from zero to over 100 feet/minute.

Currents were measured by dye marker floats released from aircraft. The dye marker movement was measured by photographs and by visual means. The average current strength was approximately 25 ft/min while the extremes ranged from 0 to over 100 ft/min. The flow directions varied considerably between stations even on the same day. For example, the current off Big Creek was sometimes 180° out of phase with the current at the sewer outfall. The currents at the sewer outfall, although also extremely variable in direction, did have a greater tendency to flow in the northeast-southwest directions. The northeasterly flow carried the effluent toward Agate Beach. A comparison of winds and currents shows no readily apparent correlation. In spite of the seeming lack of correlation between wind and current the equations derived below were generated by the computer program **STEP**, a stepwise multiple linear regression analysis program.

The current and related variables (winds, waves, and tides) were separated into north-south components and east-west components. Combinations of the possible driving forces were also used. The north-south components produced the following prediction equation
Figure 8. Salinity at the outfall during the period October 1968-August 1969. The three lower lines show deviations from outfall salinities (b) in the plume (c) outside the plume and (d) outside the reef.
Figure 9. Sigma-t values (a) at the outfall, (b) outside the plume and (c) outside the reef (October 1968-August 1969).
Figure 10. Dissolved oxygen concentrations at the outfall in ml/liter (October 1968-August 1969). The dashed line in the upper plot indicates saturation values. The lower traces are deviations from outfall concentrations (b) inside the plume, (c) outside the plume and (d) outside the reef.
V = 3.87 - 0.72 x_1 + 0.0196 x_2 + 0.54 x_3 - 0.17 x_1 x_3 + E

where x_1, x_2, and x_3 are the linearized wave, wind and tidal components respectively. The term x_1 x_3 is the product of the wave and tidal components while E is an error term. The multiple correlation coefficient for this equation is 48%. The variance explained by each variable is wind 40%, tide 6%, waves 1% and all component products negligible.

For east-west components the equation became

V = 6.408 - 0.0087 x_2 + 1.60 x_3 + 0.0020 x_1 x_2 + 0.00065 x_1 x_3 + E.

The symbols are as indicated for the first equation. The multiple correlation coefficient for this equation is 28%. The variance explained by each variable is wind 1%, tide negligible, waves negligible, wind and waves (product) 23% and wind and tide (product) 2%.

**Generation of Longshore Currents - Longuet-Higgins**

Following a seminar given in Corvallis by Dr. Paul Komar of the Scripps Institution of Oceanography, the author developed a new theory to explain the generation of longshore currents by waves which fall obliquely on a straight coastline. Following is an abstract of a paper which has been prepared for publication:

By using known results on the radiation stress associated with gravity waves, it is shown rigorously that the total lateral thrust exerted by incoming waves on the beach and nearshore zone, is equal to

\[
\frac{1}{4} E \sin 2 \sigma
\]

per unit distance parallel to the coastline, where E denotes the energy density of the waves in deep water, and \( \sigma \) their angle of incidence.

The local stress exerted on the surf zone in steady conditions, is shown to be given by

\[ (D/c) \sin \sigma \]

per unit area where D is the local rate of energy dissipation, and c the phase velocity.

These relations are independent of how the energy is dissipated; but because breaker height is related to local depth in shallow water,
it is argued that ordinarily most of the dissipation is due to wave breaking, not to bottom friction. Under these conditions the local mean longshore stress in the surf zone will be given by

\[ \frac{5}{4} \rho \frac{u}{u_{\text{max}}}^2 \sin \phi \]

where \( \rho \) is the density, \( u_{\text{max}} \) the maximum orbital velocity in the waves, the local beach slope and \( \phi \) the angle of incidence.

The profile of the longshore current, as a function of distance from the swash line, is calculated on the assumption that the horizontal eddy viscosity \( \mu_e \) has the form

\[ \mu_e = N \rho \left( \frac{x}{\sqrt{gh}} \right) \]

where \( x \) denotes the distance off shore, \( g \) the acceleration of gravity, \( h \) the local mean depth and \( N \) is a numerical constant. The assumption gives rise to a family of current profiles whose form depends only on the nondimensional parameter

\[ P \equiv \frac{\pi}{2} \frac{N}{\alpha C} \]

where \( \alpha \) is a constant characteristic of breaking waves (\( \alpha = 0.41 \)) and \( C \) is the drag coefficient on the bottom. The current profiles are of simple analytic form, having a maximum in the surf zone and tending to zero at the swash line. Comparison with the laboratory experiments of Galvin and Eagleson (1965) shows remarkably good agreement if the drag coefficient \( C \) is taken as 0.010. The theoretical profiles are insensitive to the exact value of \( P \), but the experimental results suggest that \( P \) never exceeds a critical value of 2/5.

Long-Period Fluctuations in Ocean Currents - Longuet-Higgins

One paper previously described: "On the reflexion of wave characteristics from rough surfaces" has been published in the Journal of Fluid Mechanics, 37, 231-250 (1969).

A second paper describing the trapping of long-period oscillations round an island with vertical sides, has been published as follows,

"On the trapping of long-period waves round islands". J. Fluid Mech. 37, 773-784.

This describes how Kelvin waves will follow a curved,
vertical boundary, so long as the radius of curvature is not less than a certain critical limit. If this condition is satisfied, then it is possible for the island to trap free energy with certain characteristic frequencies of oscillation, calculated in the paper.

In a third paper, to be submitted for publication shortly, it is shown how periodic oscillations, such as tides or inertial oscillations, generate forced motions in the neighborhood of an island with vertical or sloping sides, and how these are associated with a steady rectified current circulating the island. The theoretical prediction that a steady current circulates the island is verified by a simple model experiment. The result may help to explain some earlier observations by Stommel (1954) on the drift velocities of free floats in the neighborhood of Bermuda.

A calculation of the free oscillations of fluid on a hemisphere bounded by meridians of longitude, undertaken in collaboration with Dr. S. Pond, has now been completed and accepted for publication in Phil. Trans. Roy. Soc. A. This calculation shows, by a particular example, some of the unexpected types of oscillation that can occur in a large ocean basin of dimensions comparable to the Pacific or Atlantic Oceans. Following is an Abstract:

A precise calculation is presented of the normal modes of oscillation of an ocean of uniform depth which is bounded by two meridians of longitude separated by an angle of 180°. The calculation takes full account of the horizontal divergence of the motion, and so is applicable to both barotropic and baroclinic modes of oscillation.

At small values of the parameter \( \varepsilon \equiv 4 \Omega^2 R^2 / gh \) (defined fully in Section 1) the calculation yields both the familiar gravity waves and also the nondivergent planetary waves computed in an earlier paper (Longuet-Higgins, 1966). At large, positive values of \( \varepsilon \), corresponding to baroclinic waves, new types of oscillation appear in which the flux of energy is concentrated near the equator, the circuit being completed by Kelvin waves along the meridional boundaries. The calculated frequencies are compared with a symptotic expressions derived from a recent \( \beta \)-plane analysis by D.W. Moore.

Solutions are also found corresponding to negative values of \( \varepsilon \). These must be included in a complete calculation of the response of the ocean to external forces. At small values of \( \varepsilon \) these solutions resemble the planetary waves. At large (negative) values of \( \varepsilon \) they represent almost-inertial motions concentrated near the poles, having a phase-velocity towards the east and an amplitude modulated so as to vanish at the boundaries.
The calculations are relevant to the real ocean insofar as they show the kinds of oscillation that might be expected in any ocean basin including any section of the equator (or including a pole). They also indicate the degree of accuracy to be expected in computing the frequencies of the normal modes by $\beta$-plane methods.

This work has been described in a seminar given at the National Center for Atmospheric Research in Boulder, Colorado.

A paper describing theoretically the drift currents associated with waves propagated along straight ledges or sea scarps - or more precisely the difference between the currents as measured by free floats and by fixed current meters respectively - has now been published in Deep Sea Research:


Following is an Abstract:

In order to calculate the mean mass flux past a given recording station it is necessary to know more than the mean velocity in a fixed, vertical section. One must add the additional term - 'Stokes velocity' which depends also on the time and distance scales of the fluctuating currents. In typical circumstances, where the fluctuations are larger than the mean current, the Stokes velocity may dominate the mass transport, and lead to the mass transport being opposite in direction to the mean current.

Some general expressions are given for the Stokes velocity, and these are studied in detail for the particular case of waves propagated along a sloping sea bed (double Kelvin waves). Such waves are always propagated with the shallower water to their right in the northern hemisphere. It is shown that in regions of small bottom gradient the Stokes velocity is in the same direction as the phase velocity, but in the region of large bottom gradient the sign of the Stokes velocity is reversed. The mean Stokes velocity is in the direction of wave propagation. However, the total transport (integrated with respect to the depth and width) is in the opposite direction.
Air - Sea Interaction - Pond, Phelps

In May measurements were made of humidity and temperature fluctuations and waves on board FLIP as part of the BOMEX program. Other measurements include velocity fluctuations by the University of British Columbia personnel and of temperature, humidity, and wind speed profiles and wet and dry bulb temperature fluctuations by University of Washington personnel. These measurements were made on an almost continuous basis (about 20 hrs/day) for ten days. The humidity equipment continued to be operated for another ten days along with the velocity and temperature equipment of University of British Columbia by University of British Columbia personnel. These data are probably the most complete set of microscale air-sea interaction data presently available. OSU will use them to investigate the sensible and latent heat fluxes.

In June we made a short cruise on board RV CAYUSE to test our instrument tower on a taut mooring in deeper water than in August 1968. It was found that this method of using the tower was not nearly as satisfactory as the free floating method tested in February 1969. We decided to use the tower free floating in the future with the ship anchored.

In August we took the completely instrumented tower to sea for the first time using RV CAYUSE. After some minor difficulties the whole system was operated satisfactorily. Measurements were made of temperature and humidity fluctuations, the wind speed and wet and dry bulb temperature profiles, wind direction and tower motion (three components of acceleration, pitch and roll with a vertical gyro and orientation with a compass). At the same time Mr. Marshall Earle (a student of Dr. George Beardsley) measured wave height and slopes and pressures at two depths below the surface. About six hours of usable data were recorded.

In September we attempted to make a second cruise with all the previous measurements and two additions. One was a two component sonic anemometer prototype (development of a final three dimensional model was not possible due to supplier problems). The second was a three dimensional drag probe to measure velocities in the water (Mr. Earle). Due to very bad weather it was only possible to get to sea for part of the last day. Some wave, profile, and motion data were recorded. We did not have time to get the tower oriented so that fluctuation measurements could be made. However on the basis of this test we are confident that we can finish the development of the sonic anemometer and so have a complete set of equipment for future experiments.
A search for seasonal trends in foraminifera populations in the Oregon sublittoral region is underway as part of the Benthic Environment subproject, Marine Fisheries Resources project, OSU Sea Grant Institutional Program. To date 107 samples have been collected at 17 stations during five cruises.

Of particular interest are the tentative observations that sediment type or some related parameter or set of parameters exerts control on seasonal variation of foraminifera populations. At two stations (SG-2 and SG-8), both at 200 m water depth but with significantly different sediment type, total foraminiferal standing crop differs by a factor of more than two at a given season. The higher standing crops occur on the very fine silt substrate of SG-8 in contrast to the very fine sand at SG-2. Highest standing crops also occur during the summer when there is deposition of muds on the bottom over portions of the middle and outer shelf.

A stepwise multiple linear regression analysis has indicated that for Bolivina pacifica sediment median grain size appears to be a more important control than water depth. There tends to be an increase in population size and a decrease in specimen length with a decrease in grain size indicating an approach toward optimum conditions. There is also an increase in specimen size from spring to summer conditions indicating a growth cycle.

Seasonal changes in the faunal composition at each station is being tested by calculating similarity coefficients (weighted Jacard Index of Faunal Affinity) for each pair of samples. Similarity coefficients for stations SG-2, -22, and -8 show that station subsamples collected at a given time have the highest faunal affinities. Trellis diagrams of these coefficients comparing seasonal collections at a given station show a progressive increase from lowest affinity in January to highest in August.

When analyses are completed seasonal variation in foraminifera may be more sensitively illustrated by individual species or groups of species than by the total foraminiferal assemblage. Preliminary analyses show several interesting trends. For example, analyses of variance of length measurements of 57 individuals of Bolivina pacifica at station SG-2, 70 individuals of B. pacifica at SG-8, and 50 individuals of Uvigerina juncea at SG-8 show significant seasonal changes in test size indicating reproductive cycles a year or more in length.
Foraminiferal Biostratigraphy and Paleoecology, Continental Terrace - Fowler, Muehlberg

During June and July, approximately 50 samples were obtained at rock coring stations on Nehalem Bank and vicinity, Heceta Bank, and the shelf and slope between Coos Bay and the Oregon-California border. Most of the samples contain well-preserved, diagnostic foraminiferal assemblages. A biostratigraphic and paleoecologic study of these and similar assemblages from the approximately 160 rock samples already in our collections forms an essential part of a comprehensive geologic investigation of the Oregon continental terrace.

The rocks range in age from Late Miocene to Pleistocene (?); the great majority is Pliocene. Paleoenvironmental analyses require relative uplift of up to approximately 1000 m of most of the sedimentary units from their depositional sites.

Using evidence from foraminiferal faunas, lithologic characteristics, and structural relationships, four stratigraphic units have been defined. In two instances, east to west facies variations are demonstrated within given stratigraphic units.

Deep-Sea Biostratigraphy, Planktonic Foraminifera - Fowler, Sumich

Continuing investigations of deep-sea piston cores taken from the western flank of Juan de Fuca Ridge in the vicinity of Cobb Seamount have extended our knowledge of paleoclimates and deep-sea sedimentation in the northeastern Pacific off Oregon by nearly an order of magnitude.

Two cores have yielded evidence of a warm interval from 55,000 to 127,000 years B.P. The dates are based upon extrapolated sedimentation rates from a dated interval near the top of the cores. Nevertheless, these dates are comparable to those given by Blackman and Somayajulu (1966) and Frerichs (1968) for a warm interval in cores from the equatorial Pacific and the Indian Ocean, respectively.

One core (6709-20; 46°04.0'N, 131° 0.00'W) apparently penetrated the Sangamon-Wisconsin boundary. This conclusion is based upon an abrupt shift from 80 percent dextral populations of Globigerina pachyderma below to 95 percent sinistral populations above the boundary. There is also an abrupt change to a dominance of radiolarians over planktonic foraminifers below the boundary, although the two shifts do not exactly coincide. Further evidence of warming is given by the presence in significant numbers of Globorotalia inflata.
Variations in the percentage of calcium carbonate in 6709-20 show a clear relationship to the paleoclimatic trends outlined above. Carbonate maxima occur during cool intervals, minima during warm intervals. This relationship agrees with that previously suggested by Arrhenius (1952), Emiliani (1966), and Hays et al. (1969).

**Marine Stratigraphy - Moore**

The investigation and correlation of the stratigraphy of radiolarians and calcareous nannoplankton is continuing. The present collections under investigation are 1) samples from the South Atlantic taken during the CIRCE expedition of Scripps Institution of Oceanography; 2) samples from the Panama Basin taken during various expeditions of the Lamont-Doherty Geological Observatory, Scripps Institution of Oceanography, and the Oceanography Department at Oregon State University; samples from the Atlantic Ocean taken by Dr. V. T. Bowen during various cruises of the Woods Hole Oceanographic Institution; samples taken from the tropical Pacific Ocean during Leg 8 of the Deep-sea Drilling Project.

**Core and Dredge Collection - Byrne and Moore**

Efforts are now being made to obtain funds for a marine sample laboratory. This proposed laboratory would house all our rock and sediment samples as well as provide space for the initial description, sub-sampling, sample preparation, and study of samples in our collection.

**Data Reduction and Laboratory Methodology - van Andel, Heath and Moore**

At the beginning of the reporting period, we were faced with a large backlog of geophysical data resulting from CIRCE cruise in the South Atlantic and YALOC 69 cruise in the eastern equatorial Pacific, while our data reduction programs were in an embryonic state. Addition of Mr. K. Keeling as a programmer on our staff and considerable effort from the Geophysics group have resulted in the completion of an excellent package of programs for the reduction and plotting of bathymetric, magnetic and gravity data, and at this time our backlog has been reduced to less than two months work. Mr. Keeling, with the aid of a consultant, has also completed the necessary programs for reduction and processing of the routine data yielded by the sediment laboratory, including conversion of the massive FAST program for factor analysis of large data matrices.
During the same period, we put into operation a standard X-ray diffraction system, based on equipment generously made available to us by Esso Production Research Co., and Chevron Oil Field Research Co., let the contract for the acquisition of a large automated and digital controlled X-ray diffraction system funded by the National Science Foundation to be installed in the new building, and constructed a falling drop apparatus which will speed up and render more precise and detailed our grain size analyses of fine fractions. A procedure for the standard description, logging and curating of all cores obtained by the Department was established. All cores resulting from cruises in the last 18 months have been logged according to this system, and headway is being made in reducing the backlog. We also developed a design for a core storage and curating facility. The procedures now adopted are equivalent to those used at Scripps, Miami, and the Deep-sea Drilling Project.

Geophysical and Geological Studies in the South Atlantic - van Andel, Heath and Moore

The geophysical results of the Mid-Atlantic Ridge portion of CIRCE cruise in the fall of 1968 have now been processed. The Mid-Atlantic Ridge in this area has had a complex history resulting from several changes in spreading rates and possibly directions. Each accompanied by deformation of the ridge resulting in extensive normal faulting and an increase in the relief. The results are being reported in a paper on the geomagnetic data, now in press, and a paper on the structural history in advanced preparation. The core and rock samples obtained during the same cruise have all been processed; the rock samples have been analysed for trace elements but the data have not been reduced as yet.

Sediments and Stratigraphy of the Equatorial Atlantic west of St. Paul’s Rocks - Dinkelman

The reconnaissance study in a few cores of the usual Foraminiferal stratigraphy has been completed. It compellingly indicates that this approach to the late Pleistocene stratigraphy is not adequate in the region, and also suggests that a better stratigraphy based on nannoplankton is possible. The next phase in this program will consist of the development of such a stratigraphy.

Sedimentation in the Panama Basin - Heath, Beer, Nelsen and van Andel

Work on this project has consisted mainly of an analysis of the seismic reflection records obtained on YALOC 69 cruise in the spring
of this year. The data have all been reduced and plotted on bathymetric profiles. In addition, all cores have been opened, described and sampled. Additional samples have been obtained from Lamont and Scripps cores in the area, giving a total of nearly 200 surface samples to be analysed. A procedure and flow sheet for a comprehensive laboratory analysis has been established, and laboratory analysis, carried out by Franklin and Drake, is well underway.

Mineral Resources of the Oregon Continental Margin - Bowman

A beginning has been made with an analysis of the economics of prospecting, resource delineation and recovery of heavy mineral concentrates on the Oregon shelf. This project will serve as a M.S. thesis for K.C. Bowman.

Trace Elements in Atlantic Oceanic Basalts - Corliss

With the completion of a last radiation at the Radiation Center, and the completion of analysis of Uranium contents and some other trace elements, the data collecting and processing stage of this project, designed to study the distribution of trace elements and rare earths in oceanic tholeiites of the Mid-Atlantic Ridge crest, is nearing completion.

Deep Sea Studies in the Northeast Pacific

Near-bottom Currents and Water Chemistry in Cascadia Channel - Kulm, Pytkowicz, Culberson and Harlett

The "free-vehicle" bottom current meter was tested in the axis of Cascadia Channel at a depth of 3100 m. Velocities ranging from between 3 and 7 cm/sec. were measured at a distance of 1 meter off the bottom. These velocities are somewhat higher than those of observed by B. Korgen on the abyssal plains on either side of the channel. Although the orientation of the instrument was lost in the test, the current direction did not deviate during the two-hour test period. The flow direction is believed to be either up channel or down channel. A more detailed analysis of the near-bottom currents is planned.

Water chemistry was also obtained in the axis of the channel as well as several hundred meters above it. The water in the channel axis is well mixed and has a salinity of about 0.01 % higher than the water directly above the channel on the abyssal plain. Oxygen values in the
axis of the channel are from 0.1 to 0.2 ml/L higher than the waters on
the plain above.

Laminated Deep-Sea Sands and Silts - Allen

A Ph. D. dissertation entitled "Sedimentary Texture -- A Key to
Interpret Deep Marine Dynamics" was completed in September 1969 by
D. Allen. Based on a detailed study of 8 laminated sequences ranging
in age from Holocene to Pleistocene, a model for the origin and develop-
ment of these sequences is proposed. Textural evidence indicates that
the lower division of parallel lamination (division B of Bouma) is de-
posited entirely from suspension in a turbidity current. Pairs of dark
and light laminae are deposited as a pene-simultaneous development in
a two-layer system, and a limited and critical set of dynamic conditions
must be present in the suspension current for lamination to accrete.

During deposition of the entire sequence of course laminae, the
current must maintain an average velocity adequate to support a dis-
persed traction carpet. This critical velocity just exceeds the suspension
competency of medium silt. Eddies superpose their velocity on the
average current flow, either increasing shear and thereby affecting
more efficient shear sorting in the bed load or lowering current velocity
below the critical and collapsing the dilated carpet. Maximum eddy
velocity just exceeds a suspension competency of fine sands. Sediment
deposited while shear sorting operates forms a well-packed dark layer.
The dark layer continues to accrete at the bottom of the traction carpet
as long as current velocity maintains a dispersed bedload. The upper
light layer forms instantaneously when the carpet collapses in situ and
displays less effective packing and appears light in color when partially
dry. As average current velocity reimposes itself on the regime, the
cycle begins again and another pair of light and dark layers begins to
form. The rapidity at which deposition occurs at this stage of current
flow permits a thick accumulation of coarse lamination during what must
be an exceeding transient stage in the current regime. Division-B does
not begin to form until the critical current velocity is approached so
closely that an eddy rotating counter to it can locally collapse the dis-
persed carpet. Lamination gives place to a different structure when
current-induced shear is finally unable to disperse the bedload into
laminar flow.

Calcium Carbonate, Organic Carbon and Quartz in Hemipelagic
Sediments - Peterson and Kulm

An analysis of the amounts of calcium carbonate, organic carbon,
quartz, and the rates of accumulation in hemipelagic sediments off Oregon has revealed that the accumulation rates of the total sediment, organic carbon, and quartz were at least twice as high in the late Pleistocene as they were during the Holocene. The accumulation rate of calcium carbonate was at least eight times as high. There may have been a short transition period at the end of the last glacial stage from about 14,000 to 12,500 years BP, when the sedimentation rates were very high -- up to 75 cm/1000 years.

There is evidence that the amount of organic carbon in deep-sea sediments is a function of terrigenous influx, preservation, and possibly of depth of burial and the sediment. Turbidite sequences in the deep-sea environment off Oregon contain much higher amounts of organic carbon in the upper fine-grained portion of the sequence than in the coarser basal sediment of the sequence, indicating that organic carbon is concentrated in the finer and slower-settling parts of the flow. In lower continental slope sediments, the greatest amounts of organic carbon are found in the less than 4 micron size fraction.

Ash Deposits - Scheidegger and Kulm

A study of the volcanic ash layers in the sediments of the Northeast Pacific was initiated this summer. Various techniques, such as x-ray fluorescence and neutron activation analysis, will be used to determine the composition of the ash. An attempt will be made to correlate ash layers from one region to another and to determine the parent sources.

Sediments and Structure of Cascadia Channel, Basin and Vicinity - Kulm, Griggs, Phipps and Fowler

A manuscript entitled "Deep-sea Gravel from Cascadia Channel" has been prepared for publication. Layers of coarse Pleistocene gravel have been cored in Cascadia deep-sea channel up to 750 km along its course. Petrographic study of the pebbles indicates a very close lithologic similarity to a number of rock types exposed from the Columbia River and its tributaries in Oregon and eastern Washington. Late Pleistocene glacial floods which scoured this area transported coarse material derived from these outcrops down the river to the marine environment. These catastrophic events are believed to have generated high velocity and high turbidity currents which transported the coarse sediment for many hundreds of kilometers along the sea floor.

Continuous seismic profiles have been obtained for more than 600 km of Cascadia Channel. The records show that the channel has a complex
history of development. It is both erosional and depositional. Slumping on the walls occurs in some areas. Near the head of the channel acoustically transparent levees are common. A piston core from one of these levees consists of silts and clays. Two camera surveys of the walls failed to reveal any erosional features. The volcanic basement exerts some control on the channel course, but it is not believed to be a major factor. Where the channel continues on Tufts Abyssal Plain a similar structure is noted.

Several seismic profiles across Cascadia Basin show a thick accumulation of sediment in the eastern one-half of the basin, near the continental margin. This section is thickest, perhaps several kilometers, near Astoria Fan and thinnest (1-2 km) to the south near Cape Blanco. In the western portion of the basin the sediment accumulation thins towards the eastern flank of the Juan de Fuca Ridge.

Oregon Continental Margin Studies

Geological and geophysical data were collected on the continental margin during two R/V CAYUSE cruises in June and July 1969. Approximately 2800 km of continuous seismic profiles were made over the entire margin and 56 rock samples were collected with the gravity corer.

Structure - Kulm, Bales, and Ness

The major structural elements of the Oregon margin are being mapped. This map will be useful in determining the tectonic framework of the continental shelf and slope. A geologic map is also being constructed for the continental shelf between Coos Bay and the Oregon-California border.

Sediments - Kulm, Roush, Spigai and Buehrig

An investigation of the unconsolidated sediments and sedimentary structures of the central Oregon shelf was completed in September 1969 by R. Roush. The textural characteristics of these deposits were compared with those of the adjacent coastal beach and dune sands and with those of the deposits on the continental shelf in the vicinity of the Rogue River off southern Oregon. The well-defined mud facies found off the Rogue is generally absent on the central shelf and fine silts and clays that do deposit in this area are reworked into the underlying basal transgressive sands by benthic organisms. A mixed sediment facies is the end product of this activity. Relict sand deposits are also common in
this area. Shelf muds accumulate in areas where there is a fairly high supply of silt and clay from nearby coastal rivers. Because of the small drainage basins and low runoff of the coastal rivers of central Oregon, little fine-grained sediment is contributed to the adjacent shelf.

The sediments on the continental slope off southern Oregon (Cape Blanco to Oregon-California border) have been analyzed for the texture, composition, and faunal stratigraphy. The accumulation of Holocene fine-grained sediment on the upper slope and its benches is thin and patchy. Sediments on these benches consist mostly of relict sand, or a thin veneer of stiff gray clay of Pleistocene age; sedimentation rates average less than 10 cm/1000 years. In contrast, the lower slope is characterized by more rapid accumulation of Holocene olive-gray silty clay, with sedimentation rates varying between 15 and 65 cm/1000 years. The upper Rogue Canyon also shows little Holocene sediment accumulation, and the sedimentation rates range from 8 to 12 cm/1000 years. In the lower Rogue Canyon, however, the Holocene section thickens, which suggests that this portion of the canyon is filling. The pattern of Holocene sedimentation on the continental slope results from several interacting factors. These include: 1) a low sediment supply due to trapping in bays and estuaries, 2) topographic effects, 3) the possible existence of a southerly current winnowing fine sediments and 4) sediment bypassing on the upper continental slope, and the subsequent down-slope movement of sediment by bottom currents from the upper to lower slope.

Sedimentary Rocks - Kulm and Spigai

Approximately 90 rock samples have been collected from 40 different sites on the continental shelf and upper slope. Thirty of these samples have been thin sectioned and the rocks classified. Since the majority of the rocks are mudstones and siltstones, they are being x-rayed for their clay mineralogy. The distribution of clay minerals in the unconsolidated sediments on the margin indicates there are several different continental sediment sources. The clay minerals of the rocks will be compared with those of the sediments to determine if similar trends exist.

Sedimentary Processes - Neudeck and Kulm

The investigation of the sedimentary processes operating on the Oregon continental shelf is in the final stages of completion. A seasonal underwater camera survey has shown that the fine-grained sediments move across the shelf as a turbid layer seeking the topographically low features, such as submarine valleys, and are deposited on the continental slope and abyssal plain below. The volume of material transported is
larger during the winter when surface gravity waves stir the bottom at depths of at least 80 m and when river discharge is highest. During the summer oceanographic conditions, including upwelling, preclude sediment transport across the shelf. River discharge is also lowest at this time. A model for continental shelf sedimentation has been developed.
Geophysical Data Reduction Computer Programs - Gemperle, Keeling

In cooperation with the Marine Geology group, a mutually compatible set of computer programs has been written for the reduction and presentation of bathymetric, gravimetric and magnetic data. All data, including navigation, is first checked for time sequence errors. The bathymetric data is then converted to meters and merged with the navigation data. The magnetic data is converted to gammas if necessary, and the regional field subtracted, if desired, to obtain magnetic anomalies. The regional field is computed using the spherical harmonic coefficients of the International Geomagnetic Reference Field. Magnetic anomalies are then merged with the navigation data. The gravity data are merged with the navigation data and reduced to a free-air anomaly. Programs have been written to plot the merged data as profiles or on map grids of selectable scales.

Marine Magnetics - Banks, Couch, Gemperle, Heinrichs, Lu

The following magnetic data has been corrected for the regional magnetic field using the International Geomagnetic Reference Field, and the resulting anomalies plotted as profiles for further interpretation:

1. 1000 km of magnetic data from the Straits of Juan de Fuca and Puget Sound.
2. 10,000 km of magnetic data from the Panama Basin (YALOC-69 Legs 4 and 5).
3. 6000 km of magnetic data from Puntarenas to San Diego (YALOC-69 Leg 6).

The magnetometer failed completely during the July 1969 Explorer Ridge cruise.

Heat Flow - Banks, Couch, Gemperle, Johnson

Heat flow values have been computed from measurements made in 1968 and 1969 at 17 locations. The 6 heat flow values in the Strait of Juan de Fuca range from 2.0 to 3.0 µcal/cm² sec with a mean of 2.6 µcal/cm² sec.
A value of 1.3 µcal/cm²·sec was obtained in the Scott Island Fracture Zone and one of 4.16 µcal/cm²·sec in the median valley of the Explorer Ridge. Three measurements across the Juan de Fuca Ridge resulted in values from west to east of 1.3, 1.51, 8.62 µcal/cm²·sec. The extremely high value of 8.62 µcal/cm²·sec on the east side of the ridge and the rather low value of 1.3 µcal/cm²·sec on the west side agree with previous measurements in this region.

Four values obtained along a line perpendicular to the coast off the northern tip of Chichagof Island increased from 1.5 µcal/cm²·sec on the abyssal plain to 3.9 µcal/cm²·sec at the entrance of Cross Sound. A value of 1.4 µcal/cm²·sec was obtained in Icy Strait and one of 2.0 µcal/cm²·sec at the northern end of Chatham Strait.

Marine Gravity - Banks, Couch, Gemperle, Heinrichs, Kim

Gravity measurements made along approximately 1400 km of trackline west of Washington and British Columbia during July 1969 have been reduced to free-air anomalies. These data will be used to update existing maps and to interpret geophysically Explorer Ridge and the Scott Island Fracture Zone.

Approximately 10,000 km of gravity measurements from the Panama Basin and 6500 km of gravity measurements between Puntarenas and San Diego were obtained during YALOC-69. These measurements have been reduced to free-air anomalies and plotted as profiles for further interpretation.

Seismic Profiling - Banks, Couch, Gemperle, Heinrichs, Johnson

During July 1969 approximately 820 km of seismic profiling data were obtained west of Washington, off the north end of Vancouver Island and over the Juan de Fuca Ridge. Preliminary evaluation of the seismic records obtained over the Scott Island Fracture Zone south of Quatsino Sound indicates relatively undisturbed sedimentary hills whose structures appear dependent on both depositional processes and the very irregular structure of the acoustical basement. Northwest of Quatsino Sound, ridges of acoustical basement, aligned approximately NW-SE, disturb, tilt and penetrate the most recent sedimentary layers. The structures portrayed by seismic profiling are suggestive of a large active shear zone.
Refraction Seismology - Couch, Johnson

Seismic waves produced during the Project EDZOE experiment in British Columbia were recorded along two lines extending southwest from the shot point (50°46.9'N lat., 118°20.6'W long.) across the northern Cascade Mountains of British Columbia and Washington. The crustal velocity (p) along a line of azimuth 210° obtained from first and second arrivals at 9 stations is 6.13 km/sec. Travel time equations obtained from a least squares fit to Pn arrivals at six stations along a line of azimuth 211.0° and five stations along a line of azimuth 223.2° are \( T = 6.21 + \Delta/7.91 \) sec and \( T = 6.85 + \Delta/8.06 \) sec respectively. If a constant Pn velocity of 7.9 km/sec is assumed for the northern Cascade Mountain region, a depth to the Mohorovicic discontinuity of approximately 30 km is indicated.

Land Gravity - Banks, Couch

Ten established gravity stations in the Puget Sound area were re-occupied with LaCoste-Romberg gravity meter G12 to establish, if possible, a rate of change of gravity with time \((\partial g/\partial t)\) for each station. Stations at Seattle, Tacoma, Olympia, Bremerton, Port Gamble, Port Townsend and Port Angeles, originally established in 1916 were re-occupied in 1958, 1966 and 1969. The stations at SEA-TAC airport, Toledo and Corvallis were established about 1958 and were reoccupied in 1963, 1966 and 1969. The reduction of the 1969 gravity measurements is in progress.

Earthquake Seismology - Couch, French, Johnson, Lowell, Whitsett

The World-Wide Standard Seismograph Station at Corvallis was operated continuously during this report period. The satellite seismic station at Klamath Falls, Oregon experienced intermittent timing problems during this period. The seismograph records of the Corvallis, Klamath Falls and Portland (OMSI) stations have been read and catalogued.

An earthquake of magnitude 3.5 occurred approximately 30 km north of Baker, Oregon, near the Thief Valley Reservoir on August 14, 1969. In the valleys covered with fluvial deposits - particularly in the vicinity of Haines and North Powder, Oregon - intensities were near V to IV on the Modified Mercalli Scale. The focal depth, determined with a technique recently developed by Mr. William French based on post Pn arrivals, is 32 km. An independent method based on arrivals at the Blue Mountain Seismological Observatory yields a focal depth of
30.5 km. First motion indications suggest right lateral strike-slip motion. The depth of focus and method of faulting in this relatively aseismic area suggest a subcrustal tectonic cause rather than isostatic adjustment due to load removal.

Direct Interpretation of Potential Field Data - Bodvarsson

A paper by Emilia and Bodvarsson on the application of direct interpretation methods to marine magnetic data is in print. Previous methods are now being improved by the use of more suitable representations for the field intensities. In particular, a new surface integral type formula for the fields due to bodies with a homogenous magnetization has been derived.

Bottom Current Studies - Bodvarsson, Pietrafesa

Methods are being developed to interpret and process the bottom-current data obtained by Korgen during 1968. The mathematical technique is based on recent results by Longuet-Higgins on long waves in rotating basins.

Theoretical Geophysics - Bodvarsson, Lowell, Rands

Work on convection phenomena in the earth and on the mathematical theory of guided waves has been continued. A report on the influence of earth tides on the pressure within subsurface fluids was completed.

Physics of Geothermal Areas - Bodvarsson

The work carried out in cooperation with Dr. Don E. White of the U. S. Geological Survey, Menlo Park, California, is being continued. New data from geothermal areas in Central America have been obtained.
CHEMICAL OCEANOGRAPHY

Seasonal Nutrient Distribution Off Oregon - Park, Ball and Gordon

Using a Technicon Autoanalyzer and manual methods, seawater samples collected monthly along the Newport hydrographic line were analyzed for phosphate, silicate, and nitrate. In January, phosphate is slightly greater than 0.5uM at the surface, increasing to a 3.3uM maximum at 1000 m. (A phosphate maximum occurs at 1000 m throughout the year). With the onset of photosynthetic activity, there is a general decrease in surface concentrations. In summer (July) a slight minimum occurs at 10-20 m. At the end of the productive season, from October on, no minimum exists and the surface concentrations increase, reaching the seasonal maximum in January. Concentrations increase from 0.1uM offshore to 0.5uM shoreward in November.

Silicate concentration is approximately 170uM at 2600 m during the entire year. In January, silicate shows a slight minimum offshore at 60 m shallowing immediately offshore to 5 m; its depth fluctuates. Surface silicates increase from less than 5uM offshore to 13uM nearshore. In March nearshore surface concentrations are greater than 15uM due to increased river runoff; the silicate levels of Oregon coastal rivers are 300-500uM. A July minimum occurs at 40-50 m with a concentration less than 2uM. Summer minima are more pronounced than any time during the year. Summer surface concentrations are less than 2uM offshore, increasing to 40uM nearshore as a result of upwelled water from 200-300 m. October surface concentrations are generally less than 5uM along the Newport line with increased nearshore concentrations again due to river runoff.

The nitrate monthly maxima are 40-45uM at 1000-1200 m. January surface concentrations range from 3uM offshore to 7uM nearshore. March values are lower, ranging from 1uM offshore to 5uM immediately offshore. From January to March a slight minimum occurs at 10-20 m. The July minimum is more pronounced (like silicate) at 40-50 m offshore and rising to the surface at NH-25 as a result of the influence of upwelling. Late in the season (October) nitrites are higher (5-6uM) near the coast dropping to less than 0.1uM offshore with no minimum apparent. Patches of zero nitrate water are found from May to November.

Low nitrate concentrations indicate that this is the limiting nutrient for phytoplankton productivity. The silicate minimum and oxygen maximum indicate that the most intense biological activity occurs below or near the bottom of the Columbia River plume. (Ball, M.S. Thesis, in preparation)
Chemical Features of the Subarctic Boundary - Park, Alvarez and Gordon

We are continuing to analyze the data from cruises aboard the USC&GSS SURVEYOR and the CNAV ENDEAVOUR during 1968 and 1969. Mr. Alvarez is investigating features of the dissolved oxygen distribution in the salinity minimum layer of this region. Mr. Gordon is examining the air-sea exchange of oxygen and carbon dioxide.

A detailed study of Oregon coastal oceanography is in progress. The field data have been obtained on eleven cruises aboard the YAQUINA and CAYUSE. These cruises began in March and will end the last week of October. The cruises were intended to survey conditions prior to, during, and after the presence of the Columbia River plume and coastal upwelling off the Oregon coast.

During the summer there were two-ship operations and aircraft-ship operations designed to provide more nearly synoptic observations covering a large portion of the region of study. The task has brought together our nekton, phytoplankton, physical oceanography, radiochemistry, and chemistry groups in a concerted study.

The chemistry program has included salinity, dissolved oxygen, and nutrient measurements on all the cruises. The dissolved oxygen analyses have been performed at sea during the cruises. The salinity and nutrient measurements have been done in part at sea and in part ashore, after the cruises. All the salinities measurements have been completed as of this writing. All of the nutrients measurements except those from the last two cruises have been completed and are ready for computer processing.

Air-Sea Exchange of Gases off Oregon - Park, Byrne and Gordon

During two of the coastal oceanography cruises in the summer we measured pH, alkalinity, and PCO₂. This was in addition to the measurements of dissolved oxygen and nutrients that we made on all the coastal oceanography cruises. The cruise tracks were planned to cover summer conditions in the Columbia River plume and lower estuary, offshore waters, and the coastal upwelling region. We made repeated observations across the front between the plume and upwelling waters.
submersible pump system was successfully employed in making our first $\text{PCO}_2$ measurements at depth.

We have completed the data reduction on the pH, alkalinity, and dissolved oxygen measurements. The first computer runs on the CO$_2$ and nutrient data have been made. We are proceeding to analyze the data.

Our seasonal observations are continuing; the autumn picture has just been obtained on the last of the Coastal Oceanography cruises the last two weeks of October; two additional short cruises are planned for January and early spring to complete an annual cycle.

Chemistry of the Columbia River Estuary - Park, Forster, Gordon, Renfro, Barstow and Haertel

Our survey of the seasonal distributions of nutrients, pH, alkalinity, total carbon dioxide and oxygen continues. Haertel has completed a Ph.D. thesis correlating chemical data with areal and temporal plankton distributions in the estuary.

Park and Gordon reported on the carbon dioxide system in the river noting that the river is undersaturated with respect to calcite. Columbia River water carbon dioxide tension exceeds the partial pressure of carbon dioxide in the atmosphere by 200 to 870 ppm-attn. Concurrent pH, total carbon dioxide, alkalinity, temperature and $\text{PCO}_2$ measurements indicate equilibrium is attained between carbon dioxide tension and pH. Henry's Law is obeyed for carbon dioxide.

Sulfate Complexes - Pytkowicz and Kester

Our laboratory results on sulfate ion association were used, in conjunction with those of Garrels and Thompson for carbonate and bicarbonate ion association, to calculate a chemical model of seawater at 25°C and one atmosphere (Kester and Pytkowicz, in press). The model, that is, the speciation in seawater, is being extended to the low temperatures and high pressures found in deep oceanic waters.

Carbonate and Bicarbonate Complexes - Pytkowicz and Hawley

The determination of carbonate and bicarbonate ion pairs by a new potentiometric procedure is continuing. The work is being done at atmospheric pressure and 25°C initially.
Calcium Carbonate - Pytkowicz and Hawley

The degree of saturation of the Pacific Ocean with respect to calcium carbonate was determined using low temperature measurements of the pressure coefficient of the solubility of calcium carbonate. The South Pacific was found to be saturated to greater depths than the North Pacific; however, the mechanism of formation of the compensation depth could not be ascertained because the field data available does not reach the bottom of the ocean (Hawley and Pytkowicz, in press).

Factors that control the inorganic precipitation of calcium carbonate were examined (Pytkowicz, in press).

Nearbottom studies - Pytkowicz, Culberson and Hawley

A computer program was prepared to process the data obtained during cruises of the R/V YAQUINA with the near-bottom sampler and with the titration alkalinity procedure developed in our laboratory (Culberson, Pytkowicz and Hawley, in press). Values of the AOU, preformed phosphate, total carbon dioxide, in situ pH will be completed prior to the interpretation of the data.

NASCO Report - Pytkowicz and Kester

In collaboration with R. M. Garrels, Scripps Institution of Oceanography, we reviewed the physical-chemistry of seawater and prepared a report for the NASCO Panel on Marine Chemistry.
Specific Activity Studies of $^{65}\text{Zn}$ in Various Soft Body Parts of Mytilus californianus - Larsen and Forster

The specific activity of Zn-65 for various organs of mussels is being determined. Detection of Zn-65 was by a NaI(Tl) detector coupled to a 512 multichannel analyzer. Stable metal analysis is by atomic absorption spectrometry and neutron activation analysis for comparison.

Preliminary results show higher specific activities of Zn-65 at locations closer to the Columbia River than those stations further away, as expected. Specific activity values for Zn-65 ($\mu$Ci Zn-65/gm Zn) ranged for a low value of 0.00190 to a high of 0.794. These distances from the Columbia River were 357 miles south and 19 miles south respectively.

Radioanalysis - Larsen

Radioanalysis is accomplished by Gamma Ray Spectrometry. Samples conforming to a standard geometry are counted in one of three NaI(Tl) well detectors, each coupled to a 512 multichannel analyzer. Environmental samples are generally counted for 100 or 400 minutes, depending upon the level of radioactivity present. After counting, the background is subtracted and the count rate of the various radionuclides is converted into units of radioactivity (picocuries) by use of a CDC 3300 computer. Complex spectra (those spectra which have overlapping photopeaks) are reduced by means of a least squares program. This procedure measures up to nine radionuclides in one sample. Simpler spectra are reduced by comparing the counts under a photopeak to that of a standard count rate. Calculations for decay and sample size are made to give units of radioactivity per unit sample size at the time of collection.

Plankton and Nutrient Ecology of the Columbia River Estuary - Haertel

Analysis of monthly data on nutrients, phytoplankton, and zooplankton in the Columbia River estuary was finished in July with the completion of Dr. Haertel's thesis. Estuary levels of phosphate and nitrate reflect seasonal variations in river and ocean waters. In winter, phosphate concentration in river and ocean waters is about equal while summer upwelling greatly increases the levels in ocean water. Nitrate in ocean water similarly increases during upwelling. Minima in both phosphate and nitrate in river water occur in late summer. Silicate is always much higher in river than in ocean water.
The phytoplankton of the estuary is dominated by species characteristic of eutrophic lakes. *Melosira italica* is dominant in spring and early summer, with *M. granulata* and *Fragilari crotonensis* becoming important in late summer. Regression analysis shows correlation between temperature and the succession of species. The phytoplankton is probably light-limited during most of the year although low nitrate and phosphate levels may become limiting during late summer.

The principal zooplankter of the estuary is *Eurytemora affinis*, a species which reaches great abundance at low salinities. Peaks of abundance characteristically occur in late April, late July and late autumn. The exact cause for this seasonal distribution is unknown; it may reflect the generation time of the species. The large size of the *Eurytemora* population and the close correlation between *Eurytemora* abundance and phosphate levels is believed to indicate regeneration of phosphate by the zooplankton.

Radionuclide Transfer through Food Webs - Renfro and Steinfeld

Estimates of the total inventories of gamma-emitting radionuclides in Alder Slough were made on four occasions during 1968 and 1969. The levels of $^{65}$Zn, $^{51}$Cr, and $^{46}$Sc in the water, plants, animals, and sediments of this small section of the Columbia River Estuary were separately measured in several seasons. Regardless of season, most of the radioactivity present was associated with the sediments.

An item of particular interest was the much higher winter levels of $^{51}$Cr in detritus strained from the top cm of sediment. Not only was there much more detritus present in winter, but also the levels of $^{51}$Cr per unit weight were much higher. This suggests that the decaying material present on the bottom during fall and winter provides a reducing environment which may change hexavalent $^{51}$Cr to its trivalent state. Such a change would cause $^{51}$Cr$^{III}$ to readily sorb to the detrital particles. This process, previously considered by Jennings, Cutshall, and Osterberg, is undergoing further examination.

Columbia River Estuary Fishes - Renfro and Farrow

Analyses of the $^{65}$Zn specific activity levels in various organs from juvenile starry flounders have revealed interesting relationships. Since specific activity ($\mu$Ci $^{65}$Zn/g zinc) indicates the fraction of zinc atoms in the organ which are radioactive, it reflects the rate at which $^{65}$Zn atoms in an organ with slow turnover spend a relatively long time in the organ, hence are subject to greater chance for decay. The result is that slow
organs have relatively low $^{65}\text{Zn}$ specific activities. When the $^{65}\text{Zn}$ specific activities of organs from the same individual or group of fish comprising a sample were compared, the organs ranked as follows: Liver > Alimentary Tract > Gills > Muscle and Bone > Skin. A mathematical model of this system has been tentatively devised.

Trace Element Analyses of Estuarine Waters - Wagner, Forster and Wu

Extraction and concentration of trace elements in the Columbia River Estuary have previously been accomplished by co-precipitation with Fe(OH)$_3$, solvent extraction, or scavenging with MnO$_2$. More recently, a general chelating agent, ammonium pyrrolidine dithiocarbonate (APDC), has been tested using a method developed by Brooks, Presley, and Kaplan at U.C.L.A. To adopt the procedures to our needs, extraction efficiency tests involving seven common radionuclides were run. The results are shown below:

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Pre-Extraction Activity mCi</th>
<th>Activity in Extractant mCi</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{51}\text{Cr}$</td>
<td>9.85</td>
<td>7.95</td>
<td>83.2</td>
</tr>
<tr>
<td>$^{46}\text{Sc}$</td>
<td>7.67</td>
<td>7.80</td>
<td>101.8</td>
</tr>
<tr>
<td>$^{54}\text{Mn}$</td>
<td>13.45</td>
<td>0.25</td>
<td>16.0</td>
</tr>
<tr>
<td>$^{59}\text{Fe}$</td>
<td>10.58</td>
<td>10.6</td>
<td>100.0</td>
</tr>
<tr>
<td>$^{60}\text{Co}$</td>
<td>124.50</td>
<td>124.5</td>
<td>100.0</td>
</tr>
<tr>
<td>$^{65}\text{Zn}$</td>
<td>15.20</td>
<td>15.2</td>
<td>100.0</td>
</tr>
<tr>
<td>$^{125}\text{Sb}$</td>
<td>6.66</td>
<td>1.52</td>
<td>27.4</td>
</tr>
</tbody>
</table>

Antimony - 124 in the Columbia River - Pope, Forster and Renfro

The levels of ionic and particulate $^{124}\text{Sb}$ were determined by gamma ray spectrometry using a sodium iodide well crystal and by measurement in a coincidence counting system specially assembled for this project. To evaluate the conservative nature of $^{124}\text{Sb}$, it was compared with $^{51}\text{Cr}$, which has been shown to behave as a conservative element in the river. The ratio of ionic $^{51}\text{Cr}$ to ionic $^{124}\text{Sb}$ was relatively constant regardless of season or location. Hence $^{124}\text{Sb}$ is concluded to be a conservative element in the river.
The movement of sediments from the Columbia River along the continental shelf near Washington and Oregon has been studied with the use of the activity ratio of $^{65}\text{Zn}/^{60}\text{Co}$. One assumption which must be made is that this activity ratio is constant at the river mouth. In unsorted sediment samples taken at various stations in the estuary the $^{65}\text{Zn}/^{60}\text{Co}$ ratio varied widely. Hence, it was necessary to study the ratio in the clay, silt, and sand fractions and the results are still being analyzed.

Studies of the mechanisms responsible for retention of Hanford induced activity by Columbia River sediment have been resumed. The previously identified specifically sorbed fraction is being further characterized by batch treatment of sediment samples with dilute solution of divalent transition metals.

Plans are also being made to determine the relative importance of the organic and inorganic fractions in retention of radionuclides by Columbia River sediment.

Studies of $^{65}\text{Zn}$ Uptake by Phytoplankton at Three Temperatures - Tomlinson, Renfro, Forster

Studies of the uptake and retention of radionuclides by species of motile, unicellular algae have various inherent problems due to the inadequacy of existing experimental systems. These difficulties include the inability of workers to efficiently separate radionuclide adsorption from radionuclide assimilation, without subjecting the cells to stresses that may alter the characteristics of radionuclide uptake and transfer. On this basis, a study was completed using an electronic particle counter (Coulter Counter Model A) to obtain statistical parameters related to changes in particle size distributions. An attempt was made to correlate these parameters with the extent of radionuclide accumulation or loss. Although inorganic precipitation in the experimental media partially obscured the results of these pioneer experiments, the system and general technique for determination of physical cell parameters and their relationship to radionuclide uptake and loss seem to be sound, and hold considerable promise for future experimentation.
Vanadium Distribution in the Water, Sediments, and Biota of the Columbia River Estuary and Plume Waters - Dyer, Forster, Renfro

Geochemical action of the Columbia River has introduced large amounts of vanadium into the sea, yet sea water concentration values obtained in this study indicate that vanadium is present in very low concentrations of 3-5µg/kg (ppb). Biological mechanisms appear to be the most effective removal agents at present. Atomic absorption analysis shows enrichment factors

\[
\left( \frac{\text{conc. in organism (ppb in ash)}}{\text{conc. in sea water (ppb)}} \right)
\]

in some marine and estuarine organisms ranging from a high of approximately 27,000 in algae to an average of 13,000 in selected invertebrates.

Sediments are being analyzed for sulfur to determine whether sulfide coprecipitation could be a significant chemical removal agent of vanadium.

Trace Element Equilibrium in the Vicinity of Sulfite Liquor Outfall - Hennebry, Forster, Cutshall

Assuming that a dynamic equilibrium exists between particulate and ionic states of dissolved metallic elements in river water, changes in particulate/ionic ratios in the presence of Kraft mill effluent are being investigated in the Columbia River at Camas, Washington. Neutron Activation Analysis is the principal tool for determining abundances. This study will provide additional information regarding the fates of such radionuclides as $^{54}\text{Mn}$ and $^{65}\text{Zn}$.

Specific Activities of $^{32}\text{P}$ in Columbia River Fish - Romberg, Renfro, Forster

An unusual opportunity to measure uptake of $^{32}\text{P}$ by young chinook salmon occurred during May 1969, when 200,000 fingerlings (6-11 cm long) were released 22 km downstream from the Hanford reactors. Samples of these fish taken at The Dalles Dam during the ensuing three weeks were furnished through the courtesy of Bureau of Commercial Fisheries biologists. In the laboratory the fish were processed to quantitatively extract phosphorus and $^{32}\text{P}$. Total phosphorus concentration was determined gravimetrically, while $^{32}\text{P}$ activity was measured in a low background beta counter.
The increase of $^{32}$P specific activity (in mCi $^{32}$P/gP) of young salmon continued for three weeks, appearing to approach an equilibrium value of 17 mCi $^{32}$P/gP. Calculations based on this rate of increase suggest that the biological half-life of phosphorus in these fish was about 8 days.

**Trace Elements in Bottom Sediments off Southern Oregon Coast - Forster, Naidu**

Samples taken from the Black Sands area off the southern Oregon coast were analyzed for V, Pb, Cu, Ru, Co, Cr, Mn, Ni, Zn, and Fe, as part of a program to evaluate potential offshore mineral and metal deposits. Concentrations of all trace elements, with the exception of manganese and vanadium, were higher than the average crustal values.

**Specific Activities of Zn$^{65}$ in Salmon from the Pacific Ocean - Naidu, Forster**

Coho salmon collected by the Bureau of Commercial Fisheries as part of a program to study the migration times and routes with Coho of known origin were analyzed for Zn$^{65}$ specific activities. This radioactive tag served as an internal marker and helped to group the population on a latitude basis, which is perhaps a first step towards evaluating large scale and large area migratory patterns.

**Zinc-65 Distribution in Tissues of the Pacific Hake - Naidu, Forster**

The Pacific Hake - *Merluccius productus* (Ayres) which is today harvested for animal food, promises to be a food source for man. It was therefore analyzed for Zinc-65 specific activities with a view of tracing radioactive elements through the aquatic food chain to man. The specific activities of the various tissues identify themselves with the biological activity of the tissue in question. In view of this a new program has been started wherein hake is being caught all along the west coast of the United States and is currently being analyzed for radionuclide and stable element content. Mercury and lead are receiving special attention in these analyses.
Radiochemistry of the Columbia River Water Plume - Forster, Naidu, Wagner

During the COOC Cruises of Summer 1969, sea water samples were filtered through specially constructed filter beds. These beds were equipped with glass fiber filter papers and activated aluminum oxide beds. The glass fiber filter papers filtered off the particulate matter while the aluminum oxide beds trap Cr when activated with SnCl₂. Ra is trapped when the beds are activated with BaSO₄. By this method very large water samples - 2000 to 4000 liters could be analyzed. The samples are being analyzed for their radionuclide and stable element content. The Cr⁵¹ so determined could serve as an excellent indicator of this Columbia River water plume.

Uptake, Retention and Concentration of Phosphorus-32 in Juvenile Starry Flounder - Bolen, Forster, Renfro, Lyford

The objectives of this study are to determine (1) the rate of uptake and loss of phosphorus-32 by field retention and uptake experiments, (2) the importance of food versus water in contribution to the young flounder's concentration of this radionuclide and (3) the radionuclide's concentration in the animal's immediate environment (water, prey, organisms, etc.) in Alder Slough, a small water body connected to the Columbia River Estuary.

Retention experiments transferring juvenile starry flounder from the Columbia River Estuary to a caged environment in the Yaquina River were unsuccessful because of large variations in phosphorus-32 concentrations between individual animals. Possible sources of these large variations between animals are being investigated. Uptake studies in which non-radioactive starry flounder have been transferred to a caged environment in Alder Slough are underway. Maximum phosphorus-32 specific activities observed in selected environmental media in Alder Slough during the summer, 1969, were 26.5 and 13.5 nCi P/gm P and 0.8 pCi/l for juvenile starry flounder, amphipods (Corophium) and water respectively.

Activable Water Tracer - Hanson

Research on the application of soluble, metal chelates for water tracing using thermal neutron activation analysis for tracer determination has led to the development of several tracers with promising solution stabilities (conservative behavior) and determination sensitivities. The solution stabilities of the ethylenediamine tetaacetic acid (EDTA)
and the diethylenetriamme pentaacetic acid (DTPA) chelates of the activable elements Cr, Co, Eu, In, Sb, Sc, and Tb were evaluated in a series of laboratory radiotracer experiments conducted under simulated field conditions. They showed that (1) chelation of metals produces highly conservative solution behavior, (2) DTPA is generally better than EDTA for improving tracer behavior (3) non-chelated metals are rapidly sorbed onto sediments and (4) chelation reduces sorption of metals onto sediments.

Field tests of EuDTPA, TbDTPA, InDTPA and Rhodamine B fluorescent dye in a small Eastern Washington stream demonstrated that the metal chelates have significantly improved solution stabilies in natural water compared to widely used Rhodamine B. The high sensitivity of neutron activation and gamma-ray analysis allows activable tracers to be detected at concentrations below 1ppb.

Benthonic Radioecology - Carey, F. Pope, Kyte

During this report period samples for radioanalysis were collected by otter trawl, beam trawl, Smith McIntyre grab, and multiple corer. Two hundred thirteen samples, representing sediment and 46 animal species from 14 stations were prepared and analyzed for gamma-emitting radionuclides. Those samples containing significant quantities of $^{65}$Zn were also analyzed for total zinc by atomic absorption spectrometry. Wherever possible specific activities were calculated.

Zinc Radioecology of Benthic Fish - Vanderploeg, Pearcy

This study examines the zinc-65 radioecology of benthic fishes caught off Oregon. During the early phases of this study, emphasis was placed on differences in specific activity among species as they related to depth and season. Now, our purpose is to elucidate variations in specific activity among the species caught at a single depth as they relate to season, distance south of the Columbia River and species ecology.

Each species is analyzed both by gamma-ray and atomic absorption spectrometry. Picocuries of $^{65}$Zn and µg of total Zn are calculated for each gram of ash-free dry weight. From these values, specific activity is calculated.

A deterministic equation that expresses the relationship between specific activity of a fish and its prey was derived. This model suggests
that size may significantly effect an individual's specific activity. A preliminary analysis of the data supports this hypothesis.

Special effort is being extended to capture the prey of these fishes. Information about the specific activities in the fishes and their prey may throw light on the question of whether zinc enters the fish from the water or from the food chain. Assuming uptake through the latter, this information may be used to calculate uptake and excretion of zinc.
BIOLOGICAL OCEANOGRAPHY

Yaquina Bay Plankton Studies - Frolander, Bergeron, Flynn, Zimmerman

The weekly zooplankton sampling program at Yaquina Bay has been combined with the bongo net sampling program now being conducted in nekton research. Clarke-Bumpus samples along with bongo net samples are being collected simultaneously for comparative purposes at five stations in the bay. Chemical and physical data is also being collected at each station.

Early Life of Boreal Fishes - Pearcy, McNeil, Satterlee, Zimmerman, Spring

Since June 1969 we have collected samples every week at a series of stations from inside Yaquina Bay to a distance of 10 miles off Newport with Bongo and Clarke-Bumpus plankton samplers. Over 100 samples have been collected to date.

Fish eggs and larvae from Dr. Frolander’s Yaquina Bay survey are also being studied. Over 400 samples from one station, collected from 1960-1969, have been sorted. An example of the seasonal variation of the total number of eggs and larvae is shown in Figure 11.

Benthic Environment - Sea Grant - Kulm, Fowler, Pearcy, Bertrand, Gunther, Stein

Invertebrates

To date, a total of 262 Smith McIntyre grabs have been taken, with 207 of these from the 8 stations sampled seasonally. This is probably the most complete set of combined quantitative faunal and environmental data for any continental shelf of U.S.A.

The infaunal samples are washed on board through a .42 mm sieve and preserved in formalin. In the laboratory they have been separated in macro- and microfractions with .42 mm and 1.00 mm sieves. The larger fraction of the infauna, that greater than 1.00 mm and available to demersal fish as food, will be completely analyzed for this project. The species numbers, abundances, and weights are being combined
Figure 11. Number of fish eggs and larvae collected in Yaquina Bay (Buoy 21 Station) during 1968.
with the environmental data such as sediment particle size and composition and water chemistry and will be analyzed by a computer program for factor analysis.

One of the primary applications of this study is an evaluation of the food source of demersal fish stocks. Preliminary analysis of the infauna shows that over 90 percent, by weight, of each sample is composed of polychaetes and bivalve mollusks. These groups are known to be a basic food for young bottom fish in other areas.

**Demersal Fishes**

Sixty-four samples of fish have been collected by quantitative beam trawls at nine stations on the four seasonal cruises. The species composition, abundance, and feeding habits have been examined for 12 collections. There appears to be a correlation with sediment type for four of the most common species.

Stomach content analyses of four species indicate different food habits. The primary components of the diet of most species are crustaceans, polychaetes and bivalve mollusks.

**Pelagic Fisheries Environment**

Pearcy, Panshin, Gordon, Small, Curl, Wyatt, Mueller, Evans, Barstow, Smith, and Beardsley.

**Coastal Oceanography**

This is an interdisciplinary research program to learn more about the interactions of ocean conditions, the pelagic food chain and albacore tuna off the Oregon Coast. Upwelling and the Columbia River plume, phenomena that dominate the ocean off Oregon during the summer, received special attention. This study consists of several interdependent projects:

1. Remote Sensing of the ocean off Oregon (BCF, NASA)
   The data collection phase of this study was virtually completed during the last quarter. Three different aircraft were used to obtain oceanographic data by remote sensors: (1) University of Michigan's C-47 provided 2640 data miles from July 3-13 and 1747 data miles from September 14-24; (2) The U.S. Coast Guard, Port Angeles, Washington
HU-16E provided 3500 data miles on flights July 24 and 28, August 25 and September 3 and 4; and (3) NASA's Convair 240-A provided 2280 data miles August 14-24.

Flights consisted of triangular patterns from the coastline up to a distance of 150 miles offshore. Sea surface temperature was measured with a Barnes Precision Radiation Thermometer (PRT-5) on all flights. Color and black and white photographs were taken on overflights. Multi-spectral scanners, used only on the C-47, included twelve channels from 0.40-13.5µ. An altitude of 500 or 1000 feet was maintained, except when scanner coverage was obtained at 10,000 feet on two flights. Three rendezvous between aircraft and surface ships were completed for "ground truth" calibrations.

In addition to the above, an RB-57 overflight on July 16 provided extensive photographic coverage of the entire Oregon coast out to 50 miles offshore. Various film and filter combinations were used.

Sea surface temperature maps were prepared from aircraft and shipboard measurements, and information on thermal structure was broadcasted to albacore fishermen on a near real-time basis. The areal temperature pattern was complex and changed rapidly. Temperature and color fronts were common. Upwelling often appeared as a zone of cold water along the coast, and the Columbia River water appeared as a warm "plume." (Figures 12, 13)

Preliminary results of the remote sensing flights were presented at the Sixth International Symposium on Remote Sensing of the Environment, in the paper "Upwelling, Columbia River Plume and Albacore Tuna" by W.G. Pearcy and James L. Mueller.

(2) Coastal Oceanography: Studies of Upwelling, Columbia River water, fronts, and associated chemical and biological features from research vessels.

Coastal Oceanography - Curl, Forster, Gordon, Pearcy, Small, Smith, Wyatt

Eight cruises of the YAQUINA and CAYUSE totaling approximately 80 days at sea, were completed since April. Standard hydrographic measurements, nutrients, plankton and midwater trawl samples were collected on each cruise. On certain cruises, pCO₂, pH, and alkalinity measurements were taken, and 30-hour drogue studies were accomplished on two cruises. Extensive ¹⁴C production studies were
Figure 12. Sea surface temperature from airborne PRT-5 radiometer survey. University of Michigan C-47 on 13 July 1969, - temperature front; .... color front.
Figure 13. Infrared sea surface temperature (above) along two flight lines at 1000 feet off the Central Oregon coast. These lines form a triangle with the apex 150 miles offshore and the base separated by 60 miles along the coast. (Below) The total number of albacore and hours of fishing reported by fishing vessels. Each pair of histograms applies to the distance between tick marks (Loran Lines) and represents nearly equal areas of sea surface.
carried out on one cruise. Samples of water and animals for radio and chemical analyses were also collected in the vicinity of the plume on two cruises. Sampling stations were often more closely spaced nearshore in areas of upwelling and near the inshore Columbia River plume boundary.

A plot of surface temperature, surface salinity and mixed layer depth (Figs. 14, 15, and 16) illustrate areal patterns found during June 18 - July 3, 1969. The plume is obvious as a tongue of warm, low salinity water with a shallow mixed layer. The shallow mixed layer depths explain why plume waters are heated more rapidly than surrounding waters. Upwelling during this period was localized along the southern Oregon coast where temperatures were below 13°C.

The many biological, chemical, and radiochemical collections are currently being processed. A complete, synoptic description of the Oregon coastal environment in 1969 should result when all data are evaluated.

(3) Cooperation with Albacore Fishermen: Near real-time environmental information was broadcasted to the fleet in a series of 92 daily radio messages by the Marine Advisory Program of Sea Grant. Primary information was sea surface temperatures obtained from aircraft, research vessels, and fishing boats. Other information included mixed layer depth, water color, locations of color and thermal fronts, and marine weather.

The Marine Advisory Program also prepared a series of 13 weekly bulletins and accompanying temperature charts. These were widely distributed along the Oregon coast.

Eleven fishing boats were equipped with bathythermographs (8 mechanical, 3 expendable). These boats provided data on thermal structure for the broadcasts and charts. These data will also be valuable for correlation with albacore catch rates.

Close to 500 logbooks were distributed to albacore fishermen. Through the logbooks fishermen are providing detailed catch data in both time and space, plus concurrent information on sea surface temperature and water color (as well as such other information as abundance of birds and forage animals). To date, more than 100 fishermen have reported nearly 300 trips.
Figure 14. Coastal Oceanography Cruises 4 and 5.
Figure 15. Coastal Oceanography Cruises 4 and 5.
Figure 16. Coastal Oceanography Cruises 4 and 5.
Growth and Reproduction of the Lanternfish Stenobrachius leucopsarus
Smoker, Pearcy

Growth and reproductive patterns of the common lanternfish, Stenobrachius leucopsarus, are described by length frequency analysis, otolith analysis and examination of ovaries.

Length frequency analysis, employing the probability paper method of analysis of polymodal distributions, of three and one-half years of monthly midwater trawl collections off Oregon showed that fish in the fourth year of growth and younger form distinct length classes in collection. Growth is approximately linear during the second, third, and part of the fourth year of life. The average rate of growth during this time is 1.59 mm (standard length) per month. Fish on their first birthday average 23 mm long, on their second birthday 41 mm long, and on their third birthday 59 mm long.

Otolith analyses indicated that some fish live to be eight years old, but confidence in this method is limited to fish five years old and younger. By fitting mean lengths of age groups defined by otolith analyses with the von Bertalanffy equation, the asymptotic length was estimated to be about 85 mm, and the rate at which growth to the asymptote decreases to be about 0.34.

Back calculation of lengths at the times of annulus formations gave another set of estimated mean lengths of age groups. Fitting the von Bertalanffy equation to these data described a growth curve comparable to the one described by otolith analyses. Transforming the growth curve to growth in weight by a length-weight relationship indicated that the inflection in growth occurs at about age four years.

Spawning, determined from egg measurements, is thought to occur from December to March. Reproductively mature individuals are four years old and older. Recruitment of young size groups was also seasonal, 20-25 mm individuals appearing in largest numbers in trawl samples in the winter, presumably about eight months after spawning.

Comparison with previously unpublished information from collections made in Monterey Bay, California, indicates that spawning may occur earlier there than off Oregon, but growth rates and sizes in age groups V and younger are very similar. Comparisons with published results of otolith analyses show similar age determinations for the younger age groups.
Current research underway deals with the possible changes in the metabolic pathway in *Vibrio marinus* MP-1 when subjected to various temperatures and salinities. Since there is a difference in maximum growth temperature of this organism at different temperature-salinity conditions it can be expected that certain metabolic pathways are altered by these conditions. Our data has demonstrated that salinity-temperature relationships are very important in protein synthesis on *Vibrio marinus* - MP-1. It appears from the data obtained in this lab that in marine biological systems one cannot talk about temperature alone but must take into consideration the temperature-salinity relationship in salt-requiring organisms. Research is also being conducted on the effect of salinity and temperature on the induction of certain enzymes. Continued effort is being made on purification and physically characterizing aldolase of *Vibrio marinus*.

**Physical oceanographic investigations of inshore waters with special reference to thermal alterations** - Bourke, Glenne, Adams, Renfro

This project is part of a comprehensive literature survey of oceanographic factors which may be important in establishing the location of outfalls, especially thermal outfalls, on the open coast. To determine the dispersion patterns of heated water discharged into the nearshore zone, critical physical processes are being studied by physical oceanographers and ocean engineers. Among the important oceanographic and meteorological parameters being evaluated are: seasonal surface temperatures, wave and swell statistics, wind vectors, surface currents, density profiles, effects of large rivers, solar insolation, and evaporation. In addition, critical analyses of the various relevant heat dispersion models are underway.

**Biological investigations of inshore waters with special reference to thermal alterations** - McCauley, Hancock, Renfro

This project is part of a comprehensive literature survey of oceanographic factors which may be important in establishing the location of outfalls, particularly thermal ones, on the open coast. To consider the effects of heated effluents on nearshore organisms, it is first necessary to know the plants and animals inhabiting the area. This information
is being systematically compiled with extensive annotations of geographic distributions, seasonal abundances, temperature relations, and other biological characteristics of more than 4,000 species endemic to the area.

**Chemical investigations of inshore waters with special reference to thermal alterations - Renfro, Hager**

This is part of a comprehensive literature survey of oceanographic factors which may be important in establishing the location of outfalls, especially thermal outfalls, on the open coast. To better understand the chemical environment of the nearshore area, the distributions and concentrations of various toxic trace metals and other chemicals are being compiled. In addition, baseline values for pertinent radioactive elements are being determined.

**Echinoid Biology Studies - Brownell, Sumich, McCauley**

General biological studies on *Brisaster latifrons* and *Allocentrotus fragilis* are continuing.

For study of the variability on *B. latifrons*, twelve measurements were made on each of about 200 specimens taken from 39 stations off Oregon. The measurements were converted into ratio form, the ratios were corrected for the effects of allometric growth, and the corrected values for each specimen were plotted against depth. Depths were arbitrarily divided into four ranges: 100-155 m, 200-245 m, 400-600 m, and 800-840 m. The results indicate that specimens from the deeper end of the animal's bathymetric range exhibit consistent morphological features that set them apart from shallower specimens. Differential growth patterns appear to be related to the oxygen in the water. Respiratory organs enlarge in low oxygens forcing distortion in the growth patterns.

**Diversity and similarity of benthic fauna off Oregon - Stander, Carey**

Samples of benthic organisms off the coast of Oregon from depths of 50-2900 meters have been analyzed in terms of diversity at a given station, and in terms of similarity and ecological distance from other stations. Diversity, abundance, and variety indices are considered independent pieces of information relevant to the ecological structure of the population of interest.
Simpson's index was used; the measure of similarity and ecological distance are related. These calculations are simple to use and may be interpreted as estimates of well-defined population parameters which have straightforward probabilistic interpretation.

Gregarine parasites of Echinoids - Brownell, McCauley

At least five sporozoan parasites are present in the caelomic cavity of Brisaster latifrons and, in the case of two of these, enough life cycle stages are identifiable to permit the description of two new species. Both belong to the gregarine species Lithoceptis and occurred in about 25 out of 600 urchins examined. These are the first parasites to be reported from B. latifrons.

Benthic ecology and systematics - Carey, McCauley, Kyte, F. Pope

The study of Cascadia Abyssal Plain initiated in January was continued. Sixteen otter trawls, 16 beam trawls, 10 Smith-McIntyre grab samples, 9 bottom water samples, and 17 multiple core samples were taken on the Cascadia Abyssal Plain and Continental Shelf. Sampling of the first north-south transect line on the Cascadia Abyssal Plain will be completed in October. All of the faunal samples have been processed. The sediment samples are being analyzed for organic carbon and nitrogen.

A systematics paper on the Ophiuroidea of Oregon is in preparation. Also, a paper relating the distribution of Ophiuroidea to sediment is in preparation.

Studies on Crinoidea, reproductive periodicity and benthic zooplankton have been begun.

Deep-Sea Fish Trematodes - McCauley, Brownell, Pequegnat

A new digenetic trematode from the genus Gonocerea is being described from the stomachs of several deep-sea fishes. The worm occurs in Chalinura pectoralis and other macrourid species, and in ophidiid species Parabassogigas grandis. Its depth ranges from 1530 to 3000 meters. Additional trematodes are also being studied.
This research is directed toward detecting the occurrence and cause of fluctuations in populations of marine intertidal biota and the relation of these fluctuations to various environmental factors. The temperature regime of the intertidal habitat and its biota is currently receiving emphasis. Separate phases of the project are as follows:

1. Daily surf temperature and salinity measurements at Agate Beach, Oregon are taken once daily in fall, winter and spring and twice daily in summer. This data forms the basis for comparisons of local inshore oceanic conditions with low tide intertidal conditions.

2. During the summer of 1969, a vertical chain of eight shielded thermistors was installed in a device attached to the laboratory dock which covers the intertidal range from -2 ft. to +8 ft. above MLLW. Temperature is recorded continuously from this installation, and the data will be used as the basis of a model study of temperature fluctuations during intertidal immersion and exposure.

3. Work on the temperatures experienced by the intertidal biota at low tide continued in the summer of 1969. Animal internal temperatures were measured in situ at low tide to acquire data on temperature levels and heating rates experienced, so that an assessment of the summer heating rate, level and duration can be made. Continuous measurements of the temperature of individual animals from the time of tidal emergence to re-submergence supplements the population data usually taken. Differences produced by minor habitat variations are being investigated.

4. Laboratory experiments on the thermal properties of intertidal invertebrates and their thermal and desiccation tolerances were conducted. These experiments are based on the temperature levels, heating rates and duration of tidal exposure measured in the field, and demonstrate the role of heating and drying in limiting the level of intertidal occurrence of the species being studied.

5. Population size and density are studied at Boiler Bay, Oregon by periodic resurvey of study sites established in previous years.

The mechanisms by which reproductive periodicities of marine invertebrates of fisheries significance are entrained to seasonal
cycles in the sea are being investigated. Gonad development and spawning and population synchrony is being followed by monthly sampling of populations in the field in order to describe the nature and fluctuations in the reproductive cycle of several bivalves. Construction of an apparatus for studying the long term effect of temperature and photoperiod regimes on gonadal cycles is underway.

**Larval Biology - Gonor, Lough**

During this report period, Mr. Lough completed a MS thesis entitled "The effect of temperature and salinity on the early development of *Adula californiensis* (Pelecypoda-Mytilidae)." Laboratory experiments of a factorial design were used to investigate the effects of temperature and salinity on the survival, growth and respiration of these clam larvae during development. Development rate is temperature dependent from 7 to 20°C. Optimum conditions for larval survival estimated by response surface techniques occur between 12 and 16°C. and 8 to 32‰ for 3 day larvae and between 10 and 15°C. and 29 to 34‰ for 15 day old larvae. Larval oxygen consumption increases from 7 to 18°C. and then sharply decreases. Since the early development of this bivalve requires temperature and salinity conditions near oceanic for survival, successful recruitment of this species in the Yaquina estuary depends upon the release of a large number of eggs at a critical summer period of optimum conditions. Adults are tolerant of extremely varying conditions.

**Energy Relationships in a Common Intertidal Herbivore - Gonor, Caplan**

Doctoral thesis research by Mr. Caplan on the intertidal chiton, *Katharina tunicata*, was continued. Monthly samples are separated into six components and the dry weight and percentage of each component of total body dry weight measured. Cyclic fluctuations with season are being studied. Annual gonadal growth and spawning is demonstrated. The relationship between cycles in the digestive gland and gonad is being studied. All tissue components show significant annual cyclic changes. An attempt to calculate an energy budget for the species, and the partitioning of the energy between various body components is being made by determining the caloric values of the different components at different seasons. Growth is being investigated in the field on marked animals on San Juan Island, Washington, and on the central Oregon coast. The data will be used in several growth models in an effort to predict seasonal and annual growth. The field data also permits five size classes to be distinguished, probably representing year classes. Experiments on growth in the laboratory under known feeding conditions are being conducted.
Assimilation of Organic Matter by Marine Second Trophic Level Grazers -
O'Connors, Menzies, Small

A preliminary investigation of the summer zooplankton of Auke Bay, Alaska was completed by Mr. O'Connors. Data concerning the taxa present and their temporal and spatial distribution were gathered and are being used to formulate a more comprehensive sampling plan for these zooplankton for implementation next summer. Copepod fecal pellet samples were gathered and examined, and evidence for selective feeding was found. A proposal for a comprehensive investigation of the grazing relationships of the Auke Bay copepods on the indigenous phytoplankton has been prepared and preliminary laboratory work is in progress.

Mr. Menzies has copepod grazing experiments in progress, with several laboratory phytoplankton cultures employed as food. The ultimate aim of the project is a comparison of radiotracer, gravimetric, numeric and chemical methods of determining grazer assimilation efficiency. Ingestion will be measured by 1) changes in Coulter Counter cell counts, 2) changes in particulate carbon and nitrogen, using a C-H-N analyzer, 3) changes in $^{14}$C incorporation, using an ionization chamber and vibrating reed electrometer, and 4) changes in weight, using a microgram electrobalance. Egestion measurements will be done by the same methods on clean fecal pellet samples. Assimilation will be assessed as ingestion minus egestion.

Phytoplankton-Zooplankton Relationships in Different Hydrographic Regimes - Pequegnat, Ramberg, Vogel, Small

Field and laboratory research for Mr. Ramberg's MS thesis has been completed, and he is in the process of writing. Chlorophyll, particulate nitrogen, and the particulate carbon-nitrogen ratio have shown several significant relationships to each other, to nitrate concentration in the water, and to hydrographic conditions. Upwelling and the Columbia River plume are particularly distinguishable by the pigment and elemental composition of particles. The various relationships are being presented in the thesis as a means to understanding the processes and factors involved in biological productivity off the coast of Oregon. Hydrographic features exert the greatest effect on essential nutrient supplies and, consequently, on biological conditions.

Freeze-dried samples of grazers off the Oregon coast are being collected monthly by Mr. Pequegnat for microanalysis of proteins and lipids. Phytoplankton (particulate carbon) samples, collected by filtration through glass fiber filters, are also being made for microanalysis of proteins and lipids. In addition to the organic and carbon analyses,
trace element studies have been initiated. Results of trace element studies on "clean" phytoplankton samples are being prepared for publication. The report includes data on Au, Cr, Cu, Fe, Mn, Ni, Pb, Sn and Zn and an evaluation of the standard addition method for Cu, Fe, Mn and Zn.

Mr. Vogel is preparing pumping equipment to collect large volumes of phytoplankton at sea, for trace element analysis and attendant species distribution studies. Trace elements will be done by atomic absorption spectrophotometer. One collection has been made, and equipment adjustments were found to be needed.

Photoperiodism in Phytoplankton Carbon Assimilation - Donaghay, Small

Equipment has been constructed for a controlled, uniform-condition study of photoperiodic effects on carbon assimilation. Experiments using Skeletonema costatum, a common coastal diatom, will begin as soon as equipment testing and stabilization is completed. From the results, photoperiod correction factors will be estimated for particulate carbon, particulate nitrogen, chlorophyll "a", and C\textsuperscript{14} uptake.

Antarctic Activities - Hedgpeth

During this period sorting of the ecological collections was completed in Washington under the supervision of John McCain, and negotiations are now under way to have the material analyzed by appropriate specialists. Preliminary identifications of the species of Colosendes collected by ELTANIN were completed by William E. Stout, and data for meristic analysis of species of Pallenopsis were obtained from the various Antarctic collections available. Contributions for the Antarctic symposium were completed for the press.

Dinoflagellate Bioluminescence - Esaias, Curl

The nature of the bioluminescence of Gonyaulax catenella is similar to that observed for other dinoflagellates in culture, showing a photoperiod-entrained rhythm of luminescence and stimulability with relatively constant luminescent capacity during scotophase. G. catenella is very sensitive to stimulation and photo inhibition. The nature of the response to stimulation by bubbling appears similar to that of G. polyedra, and comparisons of the total stimulable light with G. polyedra indicate
that G. catenella emits approximately $6 \times 10^7$ photons per cell, during exhaustive scotoptic stimulation.

Over a range of cell concentrations, the rates of cell removal and filtration for Calanus pacificus when grazed on G. catenella were consistently lower when the dinoflagellates were in a relatively non-luminescent phase as opposed to a highly luminescent and sensitive phase. These differences could not be attributed to differences in particle size, culture age, distribution of dinoflagellates, ambient light intensity, or rhythms in copepod feeding activity, or other factors reported to affect copepod grazing.

It is proposed that bioluminescence in dinoflagellates serves as a Protean display type of defense mechanism against copepod grazing, has selective value, and is of adaptive and ecological significance.

Physiological Ecology of Phytoplankton - Larsen, Zakar, Brown, Curl

Two species of phytoplankton diatoms, Skeletonema costatum and Thalassiosira nordenskioldi, are being grown in chemostats under controlled light and temperature to estimate growth rate as a function of nutrient concentration at initial conditions and at steady state. These data will be used to test the hypothesis that the seasonal succession of phytoplankton species in Auke Bay, Alaska, is controlled by nutrient concentration and the growth response of individual species, as well as other variables. Additionally, we are determining this relative activity of nitrate reductance in various species to test the hypothesis that this step is the rate limiting process defined as "growth response."

Pelagic Biological Production in Auke Bay, Alaska - Iverson, O'Connors, Curl

We proposed to correlate the abundance and distribution of phytoplankton and zooplankton with hydrographic and chemical features of Auke Bay. The data are to be used in computer simulation to develop a predictive model for estuarine systems such as Auke Bay. This year's field sampling program and data reduction has been completed.

Physiological Ecology of Cryophilic Algae - Curl, Sutton

In the course of measuring the effect of light and temperature regimes on photosynthesis of Chromulina we noticed that cultures of the
organism did not freeze at 0°C when distilled water and culture medium froze under identical conditions. It appeared possible that the organisms were secreting substances that acted as "anti-freeze." The ecological implication of such a mechanism is obvious: cells in interstitial water would be less subject to freeze-thawing damage.

We measured the molality of frozen culture media, old cultures, and cultures with the cells filtered out, by comparison with the melting points of salt solutions of known molality (shown in table below). Contrary to expectations, cultures with or without cells were more dilute than fresh media. We tentatively conclude that the cells remove inorganic solutes but may secrete enough organic material to prevent formation of freezing nuclei but not enough to compensate for the assimilation of ions. We are now conducting a few simple experiments to study the effect of dilute organic solutes on freezing point as opposed to thawing point.

Molality of Various Solutions
Measured by Thawing Point.

<table>
<thead>
<tr>
<th></th>
<th>Molal</th>
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</thead>
<tbody>
<tr>
<td>Holm-Hansen medium (HH)</td>
<td>0.041</td>
</tr>
<tr>
<td>Chlamydomonas culture in (HH)</td>
<td>0.029</td>
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<tr>
<td>Pringsheim medium (P)</td>
<td>0.024</td>
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<tr>
<td>Filtrate from Chromulina culture in (P)</td>
<td>0.014</td>
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<tr>
<td>Chromulina culture in (P)</td>
<td>0.010</td>
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</tbody>
</table>

We visited Dutchman's Flats, at the base of Mount Bachelor in May 1969 and marked the location of algae blooms as the last snow remnants were about to melt. A maximum-minimum thermometer was buried 5 cm beneath the surface and has been read periodically to determine the temperature extremes to which the algae resting stages are exposed in this environment. For May through September the range increased (shown in table below). The highest temperature noted was 51.5°C which is close to the melting temperature of DNA at one atmosphere. Dry pumice soil is a good insulator and the extremes must be considerably less a few centimeters deeper.

Solar insolation has been measured since September 1968 at the 7000 foot level on Mount Bachelor. Clear sunny days yield an instantaneous value of 1.2 ly min⁻¹ at noon during midsummer.

"Winter" arrived approximately with the autumnal equinox this year. The monsoon-like winter storms, which arrive at four-day intervals, began. Solar insolation fell from a summer average of 550 by day⁻¹ to 150 by day⁻¹ and the first snow storm of any consequence left
ca. 19 cm on 25 September. Chemical analyses of snow after this date will be of new snow only.

Temperature Extremes Measured under 5 cm of Pumice Soil, Dutchman's Flats, Oregon

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature Range °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 June 1969</td>
<td>15.6 - 29.5</td>
</tr>
<tr>
<td>27 July 1969</td>
<td>6.7 - 30.0</td>
</tr>
<tr>
<td>6 August 1969</td>
<td>1.0 - 34.5</td>
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<tr>
<td>13 August 1969</td>
<td>1.7 - 34.0</td>
</tr>
<tr>
<td>22 August 1969</td>
<td>3.0 - 35.0</td>
</tr>
<tr>
<td>31 August 1969</td>
<td>2.0 - 43.5</td>
</tr>
<tr>
<td>6 September 1969</td>
<td>1.0 - 35.1</td>
</tr>
<tr>
<td>27 September 1969</td>
<td>3.2 - 51.5</td>
</tr>
<tr>
<td>7 October 1969</td>
<td>0.0 - 5.5</td>
</tr>
</tbody>
</table>

Sufficient snow to yield 10 liters of water was collected at approximately weekly intervals on Mary's Peak in the Coast Range, at Santiam Pass, and at 7000 feet on Mount Bachelor, as long as snow was present. The Mount Bachelor collecting area consists of a semi-permanent field which persists over a period of years.

In general, concentrations of all measured elements plus PO₄ and NO₃ was lowest on Mary's Peak. Calcium was highest in collections made early in the season closest to roads. Lead, undoubtedly from automobile exhaust after the prevailing winds had carried moisture over the Willamette Valley, was highest in the Cascades.

The effects of varying light intensity, temperature, and mineral nutrients of photosynthesis and, in some cases, the growth of selected cryophytes have been investigated. The results so far show that, of the algae tested, only Chromulina chinophila has been shown to be truly cryophilic. This alga has an optimum temperature for photosynthesis at 15°C for short duration experiments. A paradox exists here however, since the organism will not grow above 12 or 13°C. Raphidone-mus nivale has shown a photosynthetic peak at 0°C when grown and tested in Holm-Hansen's medium but has a photosynthetic peak at 25°C when grown in Holm-Hansen's medium and tested in Pringsheim's medium. The data show that with light intensity of 1.44 mWcm⁻² only in the field collection of assorted spores was photosynthesis light limited.
DEGREE REQUIREMENTS COMPLETED

ALLEN, David W.
Thesis Title: Sedimentary Texture--A key to interpret deep-marine dynamics.
Major Professor: L. D. Kulm

CARDER, Kendall Lyman
Thesis Title: Particles in the Eastern Pacific Ocean: Their distribution and effect upon optical parameters.
Major Professor: George F. Beardsley, Jr.

CURTIN, Thomas
Thesis Title: Towed electrodes in the sea--Theory and Use.
Major Professor: Steve Neshyba

DAVEY, Earl
Thesis Title: The photosynthetic and respiratory physiology of Skeletonema costatum (Greville) Cleve grown under simulated environmental conditions.
Major Professor: Herbert C. Curl, Jr.

FISHER, Carl
Thesis Title: A statistical study of winds and sea water temperatures during Oregon coastal upwelling.
Major Professor: Robert Smith

GONOR, Sue
Thesis Title: The larval histories of four porcellanid anomurans (crustacea, decapoda) from Oregon.
Major Professor: H. F. Frolander

HAERTEL, Lois
Thesis Title: Plankton and nutrient ecology of the Columbia River estuary.
Major Professor: Charles Osterberg
KESTER, Dana
Thesis Title: Ph.D. Chemical Oceanography
Ion association of sodium, magnesium, and calcium with sulfate in aqueous solution.
Major Professor: R. M. Pytkowicz

LOUGH, Robert G.
Thesis Title: M.S. Biological Oceanography
The effects of temperature and salinity on the early development of adulta californiensis (Pelecypoda - Mytilidae).
Major Professor: Jefferson J. Gonor

MA, Heau San
Thesis Title: M.S. Physical Oceanography
Sea level response to low-frequency atmospheric pressure fluctuations along the Northwestern American Coast.
Major Professor: Robert Smith

MARMELSTEIN, Allan D.
Thesis Title: Ph.D. Biological Oceanography
The effect of light intensity on the organic composition of marine phytoplankton diatoms.
Major Professor: Herbert C. Curl, Jr.

MATHEWS, Frank Samuel
Thesis Title: Ph.D. Geophysical Oceanography
The electrical conductivity of Atlantic type pyromagmas from Mount Etna, Sicily.
Major Professor: Gunnar Bodvarsson

MOOERS, Christopher N. K.
Thesis Title: Ph.D. Physical Oceanography
The interaction of an internal tide with the frontal zone in a coastal upwelling region.
Major Professor: Robert Smith

PAK, Hasong
Thesis Title: Ph.D. Physical Oceanography
The Columbia River as a source of marine light scattering particles.
Major Professor: George F. Beardsley, Jr.

PETEYERSON, Robert E.
Thesis Title: M.S. Geological Oceanography
Calcium carbonate, organic carbon, and quartz in hemipelagic sediments off Oregon: a preliminary investigation.
Major Professor: L. D. Kulm
POPE, Stephen Van Wyck  
Thesis Title: M.S. Radioecological Oceanography  
Antimony-214 in the lower Columbia River.  
Major Professors: W. C. Renfro  
W. O. Forster

ROMBERG, Patrick G.  
Thesis Title: M.S. Radioecological Oceanography  
Determination and application of $^{32}$p specific activity in Columbia River fish.  
Major Professors: W. C. Renfro  
W. O. Forster

ROUSH, Robert  
Thesis Title: M.S. Geological Oceanography  
Sediment textures and internal structures; a comparison between central Oregon shelf sediments and adjacent coastal sediments.  
Major Professor: L. D. Kulm

SMOKER, William  
Thesis Title: M.S. Biological Oceanography  
Growth and reproduction of the lanternfish Stenobrachius leucopsarus.  
Major Professor: William Pearcy

STANDER, Jeffrey  
Thesis Title: M.S. Biological Oceanography  
Diversity and similarity of benthic fauna off Oregon.  
Major Professor: Andrew G. Carey, Jr.
FACILITIES

Marine Science Center

With the addition of a new baby octopus and the advent of the summer tourist season, the public aquarium wing had a busy time. Between the first of April and the end of September 158,933 visitors went through the Center's public wing. August was the high month with visitors totaling 41,074. Other monthly totals were as follows: April 13,072, May 28,621, June 24,101, July 36,051, and September 16,014.

In April 2,900 students (K-12) participated in the Guidesheet Tours of the Museum and Aquarium. In May the total was 3,800 students.

Visitors during the two six-hour days of Open House, May 3, 4, totaled 9,600. August 24 was the day of highest attendance on a regular day with 2,053 visitors.

Some special groups used the facilities during the reference time including: (1) the American Assembly, (2) American Society of Pharmacognosy, (3) American Mathematics Society, (4) American Institute of Industrial Engineers (Student Division) and (5) Pacific Northwest Public Power Association.

This summer the MSC had the services of three work-study students in the Public Wing. The two young women and one young man were involved with collecting, aquarium displays and working with the public. With the summer film shows, the work-study students showed slides explaining the mission of the Center and describing some of the research projects being carried out in the labs and aboard ship. Public reaction was strongly positive and we hope to continue these activities next year.

RESEARCH VESSELS

R/V YAQUINA

During the past six months our 180-foot Research Vessel YAQUINA has traversed 12,517 miles of Pacific water. The Yquina returned to her home port on 26 April after completing 100 days of geological and physical research in the Panama Basin. Since her commissioning
in September 1964 scientists have spent 1253 days carrying out all phases of marine research. A time-at-sea chart and track lines of individual cruises are found in Figures 17 and 19.

**R/V CAYUSE**

R/V CAYUSE has spent 267 days conducting all types of marine research since her commissioning in April 1968. During the past 6 months, she has traveled 7946 miles carrying out all phases of marine research. A time at sea chart and track lines of individual cruises are found in Figures 18 and 20.

**R/V SACAJAWEA**

Bids for construction of R/V SACAJAWEA were opened 17 June 1969 and awarded to Matusmoto Shipyards, Ltd. located in North Vancouver, B.C. Final trials and delivery are scheduled for late October 1969.

Sacajawea is designed primarily for biological research in the Columbia River, but also is expected to provide a platform for study of estuaries near the mouth of the Columbia River.
Figure 17. Time at Sea chart of R/V YAQUINA
April through September 1969

Figure 18. Time at Sea chart of R/V CAYUSE
April through September 1969
Figure 19. Cruise tracks of R/V YAQUINA. Cross-hatched area indicates various near-shore, one day, test and trial cruises.
Figure 20. Cruise tracks of R/V CAYUSE. Cross-hatched area indicates various near-shore, one day, test and trial cruises.
Dr. Wayne V. Burt was elected by the Council of the American Meteorological Society as Fifth Councilor. The position is for a three-year term, 1969-1971.

Dr. R. Y. Morita has just returned, after one year, from Washington where he served as Program Director in the Molecular Biology section of the National Science Foundation.

Dr. P. Kilho Park has begun a one year leave to serve as Program Director for Physical Oceanography at the National Science Foundation, Washington, D.C.

Dr. Robert L. Smith is currently on leave to serve with the Ocean Science and Technology Group of the Office of Naval Research, Washington, D.C.

Dr. William O. Forster is on leave and is serving with the Puerto Rico Nuclear Center in Mayaguez, Puerto Rico.

Dr. Andrew G. Carey, Jr. is currently on sabbatical leave and is working in the Division of Echinoderms at the U.S. National Museum of Natural History, Smithsonian Institution.

Miss Beth Strong spent a portion of her sabbatical leave at the University of South Africa, Capetown.

Visiting Staff

Dr. David H. Cushing of the Fisheries Laboratory of the Ministry of Agriculture, Fisheries, and Food, in Lowestoft, England, visited the Department of Oceanography this summer as a Distinguished Visiting Professor. Dr. Cushing is a highly-regarded fisheries biologist, specializing in fisheries ecology.

Dr. Cushing presented a three-week seminar on marine ecology in the Department of Oceanography as part of the Oregon State University Summer Session Program.

Dr. Eric J. Perkins of the University of Strathclyde (Marine Laboratory, Garelochhead, Dunbartonshire, Scotland), made a two-week visit to the Departments of Oceanography and Engineering, and FWPCA
Dr. Perkins has worked on marine pollution problems involving radionuclides and waste heat for the past ten years. He visited the U.S. to learn more about pollution arising from pulp mills and from detergents.

Dr. Norman Cutshall joined the staff in Radioecology this fall as a Research Associate. He is on leave from the Atomic Energy Commission.

Dr. Lutz Hasse of the University of Hamburg, Meteorological Institute is visiting the Department for one year. Dr. Hasse is working on:

a. A translation to English of his article "On the Determination of the Vertical Transports of Momentum and Heat in the Atmospheric Boundary Layer at Sea."

b. An evaluation of the heat budget based on radiation data obtained in the vicinity of the air-sea interface while working at the Meteorological Institute.

c. A study of the feasibility of conducting various mesoscale air-sea interaction experiments over the Oregon coastal waters.

Non-resident Cruises

Dr. Moore participated in leg 8 of the Deep-sea Drilling Project. On this leg the drilling ship, the Glomar Challenger, sailed from Honolulu, Hawaii to Papeete, Tahiti and drilled a series of holes across the equatorial band of highly fossiliferous sediments. Dr. Moore is working on the stratigraphy of the fossil Radiolaria in samples from the drill cores.

As a part of the BOMEX program, Dr. Stephen Pond on board FLIP collected measurements of humidity and temperature fluctuations and waves. Other microscale air-sea interaction data collected by University of British Columbia scientists will also be available to OSU.

Dr. Robert L. Smith participated in a Spring cruise aboard the T.G. Thompson off Latin America.

Dr. G. Ross Heath participated as a sedimentologist in leg 7 of the Glomar Challenger drilling cruise in the Pacific between Guam and Hawaii, and is now engaged in preparation of the core description report for this cruise.
VISITING SCIENTISTS

April

Dr. Manuel Bass, Scripps Institution of Oceanography, La Jolla, California
"Variation or orogenesis and seafloor spreading during geologic time"

Dr. F. McIntyre, Scripps Institution of Oceanography, La Jolla, California
"The Top half of the ocean"

Dr. Paul D. Komar, Scripps Institution of Oceanography, La Jolla, California
"The Advection and Diffusion of Sand in the Nearshore Region"

Professor Maurice Rattray, University of Washington, Seattle, Washington
"Estuaries"

Dr. Wayne Cassett and Dr. Harold Busey, Center for Graduate Studies, Richland, Washington

May

Professor George E. Backus, Institute of Geophysics and Planetary Physics, La Jolla, California
"Inverse problems in geophysics"

Mr. Larry Murdock, Nereus Corp., Seattle, Washington
"Techniques of Temperature Measurement in the Oceans - A Systems Engineering Approach"

Dr. Timothy Parsons, Pacific Oceanographic Group, Nanaimo, B. C.
"Food chain and the cycle of organic carbon in the marine environment"

Mr. John Dahlen, MIT Instrument Laboratory
"MTI/ONR Oceanic Telescope"

Mr. J. V. Henry and Hugh McClellan, National Science Foundation
June

Mr. Bruce P. Luyendyk, Scripps Institution of Oceanography, La Jolla, California
"Deep-tow studies of a Pacific abyssal hill area"

Dr. Ewart Baldwin, Geologist, University of Oregon
On board R/V YAQUINA on COOC-4 cruise

Dr. Patrick Squires, Head Atmospheric Sciences Branch, Desert Research Institute, Reno, Nevada, to discuss weather modification program and the instrumentation.

July

Dr. Eric Barham, Navy Research and Development Center, San Diego
"Biology from Deep Submersibles"

Dr. Paul Maughan, Bureau Commercial Fisheries, Washington, D.C.
"Remote Sensing Research"

J. Bischoff, University of Southern California

Dr. Charles Osterberg and Dr. David Pittman of the Atomic Energy Commission, Washington, D.C.

Dr. Steven Keckes of the International Atomic Energy Agency, Monaco

August

Dr. David Menzel of Woods Hole Oceanographic Institute

September

Professor Katsuo Nishikawa, Escuela Superior de Ciencias Marinas e Instituto de Oceanologia, Ensenada, Baja California, Mexico

Commander Rybacki and Mr. Hartman of Coast Guard National Data Buoy Project
"Project Bluefin"

Beardsley, G. F. See Burt and Beardsley. 1969.


Bodvarsson, G. See Mesecar, Bodvarsson and Burt. 1969.


Burt, W. V. See Mesecar, Bodvarsson and Burt. 1969.


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Webster, George R. See Park, Catalfomo, Webster and Reid.

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