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OREGON STATE UNIVERSITY

PROGRESS REPORT

**Ecological Studies of Radioactivity
in the Columbia River Estuary and
Adjacent Pacific Ocean**

Norman H. Cutshall
Principal Investigator

Compiled and Edited by
Karla J. McMechan

U.S. Energy Research and Development
Administration

Contract AT(45-1)-2227, Task Agreement 12
RLO-2227-T12-54

Reference 75-2

1 April 1974 through 31 March 1975

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ECOLOGICAL STUDIES OF RADIOACTIVITY IN THE COLUMBIA
RIVER ESTUARY AND ADJACENT PACIFIC OCEAN
(USERDA Contract AT(45-1)-2227, Task Agreement 12)

PROGRESS REPORT
1 April 1974 through 31 March 1975
RLO-2227-T12-54

Compiled and Edited by
Karla J. McMechan

Submitted to
Division of Environmental and Biomedical Research
U.S. Energy Research and Development Administration

By

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ACKNOWLEDGMENTS

A major expense in oceanographic research is "time at sea." Operations on the R/V YAQUINA, R/V CAYUSE, R/V PAIUTE, and R/V SACAJAWEA were funded by several agencies, with the bulk coming from the National Science Foundation and Office of Naval Research. Certain special cruises of radiochemical or radioecological import were funded by the U.S. Energy Research and Development Administration, as was much of the equipment for radioanalysis and stable element analysis. We gratefully acknowledge the role of these agencies in support of the research reported in the following pages.

We also wish to express our thanks to the numerous students and staff who contributed to the preparation of this progress report.

NOTICE

The progress report that follows includes research results ranging from unproved ideas to scientific papers published during the tenure of this contract. The end of the contract year finds several facets of our work in various states of preparation, therefore the reader is cautioned that all except the published papers are subject to revision.

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INTRODUCTION

This report represents progress in "Ecological Studies of Radioactivity in the Columbia River Estuary and Adjacent Pacific Ocean" during the period 1 April 1974 to 31 March 1975. This research has been supported with funds from the Division of Biomedical and Environmental Research, U.S. Energy Research and Development Administration through Contract AT(45-1)-2227, Task Agreement 12.

Early sections of this report are devoted to our most current activities and deal descriptively with research underway. The Research Completed section of the report includes manuscripts which have been submitted for publication during the reporting period. This section also includes reprints of papers published during the reporting period.

SCIENTIFIC BACKGROUND

The oceans and, particularly, the coastal zones are destined to be the site of increasingly intense development of energy generation facilities. Nuclear facilities seem particularly adaptable to advantages of coastal sites. It is imperative that this imminent development proceed with maximum possible understanding of how the coastal and oceanic ecosystems function.

It has been apparent for some years now that location of electrical generating plants, especially nuclear plants, would be increasingly oriented toward the coastal ocean. Not only are many power users, i.e. industrial and population centers, already sited in the coastal zone, but the access to marine transportation and to abundant coolant water are of compelling importance. Offshore sites on artificial islands or floating platforms, and even submerged sites, have gained prime consideration during recent years. By moving large generating facilities offshore, dose interaction with people is lessened with relatively little diminution of the qualities that make the coastal zone attractive for such facilities.

Great force drives this move to the coastal zone and offshore. Increase of energy demand has brought 1960's forecasts of impending shortages to fact even in the mid-1970's. Already it appears that both the rate of increase of energy generating (converting) capability and the rate of shift toward the coastal zone are increasing. The oil crisis must cause a greater share of our energy to come from alternative sources such as nuclear fission and, eventually, fusion. The scale and scope of man's activities in the near-shore ocean during the remainder of the twentieth century will be substantially greater than it has been to date.

It is important that this development be undertaken with the greatest possible insight into the operation of coastal ecosystems. Not only is there a potential for alteration of natural community structures or loss

of economic species, but the very success of installed facilities may be at stake. Our program probes into the mechanics of coastal marine ecosystems. It is directed research because we seek to make it as responsive as possible to foreseeable needs for knowledge arising as coastal zone development progresses. It is basic research because we are seeking to learn what fundamental processes control the coastal ecosystem. Our efforts are focused upon learning rates and routes of material transport and transfer. We have seen that "artificially" introduced materials are often useful in studying these processes. We have found radionuclides from the Columbia River and from atmospheric fallout to be especially useful tracers because of their characteristic time constants and because they can be measured at extremely low levels.

Our studies extend as far inland in the Columbia River as Hanford because operations there have provided a major source of radioisotope tracers. In other rivers our efforts terminate where oceanic salt water is lacking. We emphasize estuarine and continental shelf problems in our studies. We have a limited effort underway in laboratory studies. Our program has always included a component of research oriented toward the open ocean, far from land and we hope to maintain such a component. Large scale oceanic systems are thought to operate relatively slowly compared to coastal systems. Thus, although their remoteness from most of our daily lives and their vast scale lessen concern for acute contamination problems, the relative permanence of problems once they are created in the open ocean requires careful attention to "blue water" processes. Within the scope of this program it is not possible to conduct major open ocean research. Rather we seek to perform limited experiments designed to answer questions we think are significant

RELATED PROGRAMS

This program interacts with and benefits from numerous other programs at OSU. Some of these are especially closely related, however, both by geography, subject and investigators. In cooperation with Dr. L.S. Slotta in Ocean Engineering, Drs. R.L. Holton and N.H. Cutshall have directed "Physical, Chemical and Biological Studies in Youngs Bay". This work has been supported by AMAX Aluminum as part of their preparation to construct an aluminum reduction plant near Youngs Bay. Youngs Bay is an appendix off the south side of the Columbia River estuary and has long been a scientifically interesting portion of that larger system. The principal product of the AMAX study has been baseline data. These data are also useful for gaining scientific insight into processes and the acquisition of such insight is a goal of our ERDA research.

In addition Drs. Holton and Cutshall have joined with Drs. L.F. Small and L.I. Gordon in a study of the impact of open ocean disposal of dredged materials. This program, sponsored by the U.S. Army Corps of Engineers is concentrated on disposal off the Columbia River Mouth and is, therefore, geographically akin to previous ERDA research. Its focus is more narrow, however, in terms of goals and extent.

Dr. Holton has directed a project with Dr. W.P. Elliott on the development of methods for studying biological and physical processes in the nearshore zone of the Pacific Ocean. This program has enhanced our ability to obtain samples in this zone and has provided us with some data on the abundance and distribution of certain species in this area. This work was sponsored by three Oregon electrical utility companies.

FACILITIES

Counting Laboratory

A great deal of effort has been devoted to acquisition and setup of our new low level gamma-ray spectrometer. This system has been designed to provide both a sophisticated state-of-the-art unit and a foundation for further development. Figure 1 shows essential components of the system in block form and Figure 2 shows the data recording and processing hardware. All signals from the primary detector are recorded in analyzer 2 while analyzer 1 is anticoincidence gated by signals from the NaI(Tl) annulus and plug. Thus only Ge(Li) events which are not coincident with NaI(Tl) events are recorded in analyzer 1. This spectrum excludes many external background counts, annihilation radiation counts, Compton continuum counts and counts from gamma rays emitted in cascade. The photopeaks for gamma-rays emitted by such nuclides as ^{137}Cs or ^{54}Mn or ^{65}Zn are therefore recorded above a substantially lower baseline. Two advantages accrue: 1) lower limits of detection are afforded, 2) more precise quantitative analyses are possible. The normal spectrum recorded in analyzer 2 is advantageous for analysis of isotopes with cascade decay schemes such as ^{60}Co , ^{106}Ru - ^{106}Rh or $^{108\text{m}}\text{Ag}$.

Data from each of the 4096 channel analyzers are processed by the 16K PDP-11 processor and can be output to magnetic tape or X-Y plotter. Reduced data are output from the processor via teletype.

The detectors are housed in a lead shield as shown in Figures 3 and 4. Also mounted within the cave is the annulus lift and support mechanism shown in Figure 5. The support mechanism includes a gear arrangement and three ball-bearing lift screws so that the annulus may be lifted evenly. By varying the annulus elevation the size of the sample counting chamber can be adjusted. Access to the counting chamber is made by raising only the plug detector. A counterbalance is used to hold the plug at any desired position.

Alternatively the annulus may be lifted entirely away from the Ge(Li) detector (Figure 5D) so that a Marinelli beaker or other large sample jar can be placed on the Ge(Li) detector. When operated in this mode the system does not require two analyzers.

The most logical system expansion seems to be addition of another Ge(Li) detector. Potentially the PDP-11 may be converted into a dual role as a "software analyzer" and processor. Alternatively, more hard-wired analyzers could be interfaced to the PDP-11. The present mainframe can accommodate another 8K of core after which either an extender will be required or, perhaps, disc storage may be added.

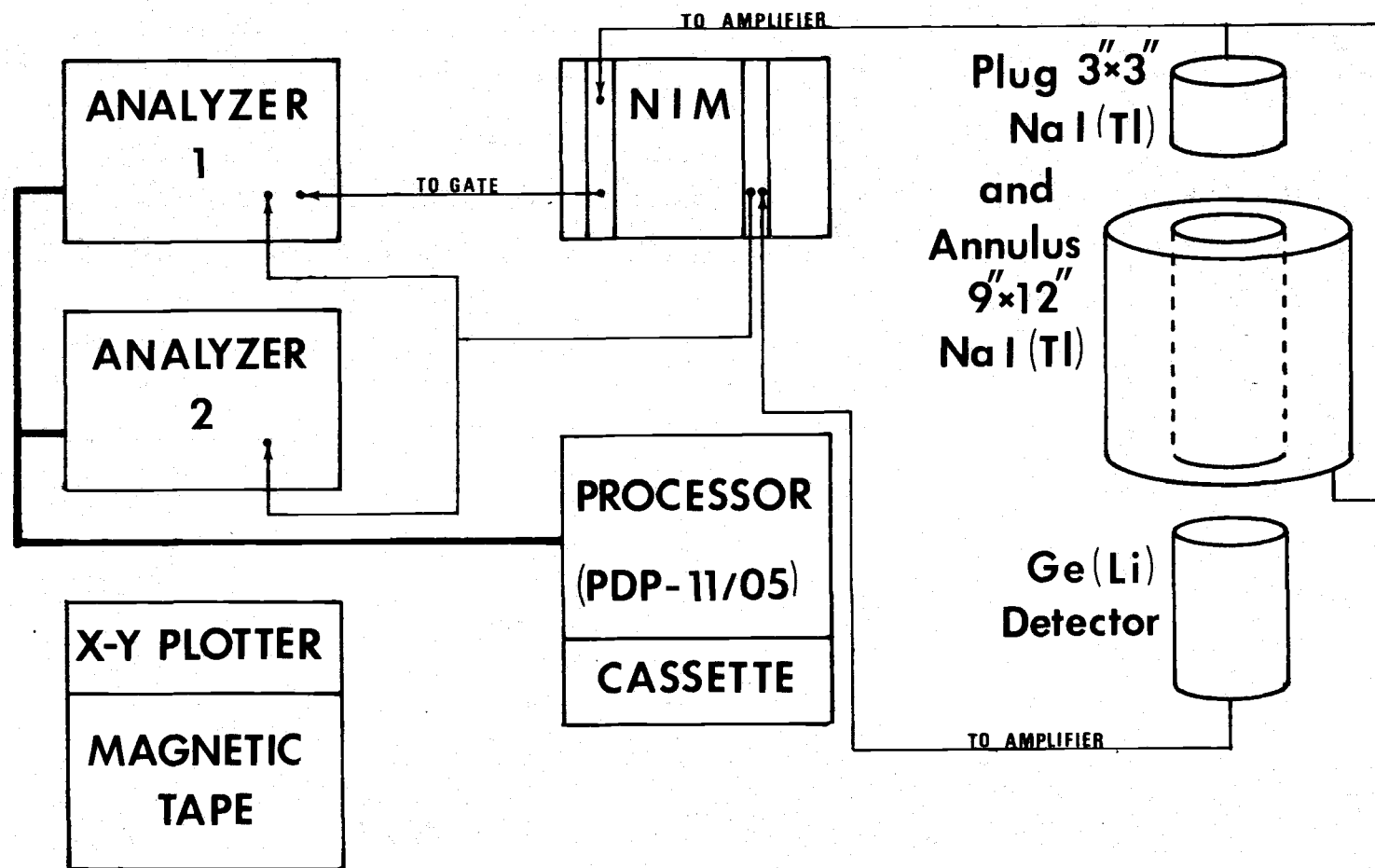


Figure 1. Block Diagram of Anticoincidence Shielded Gamma Ray Spectrometer

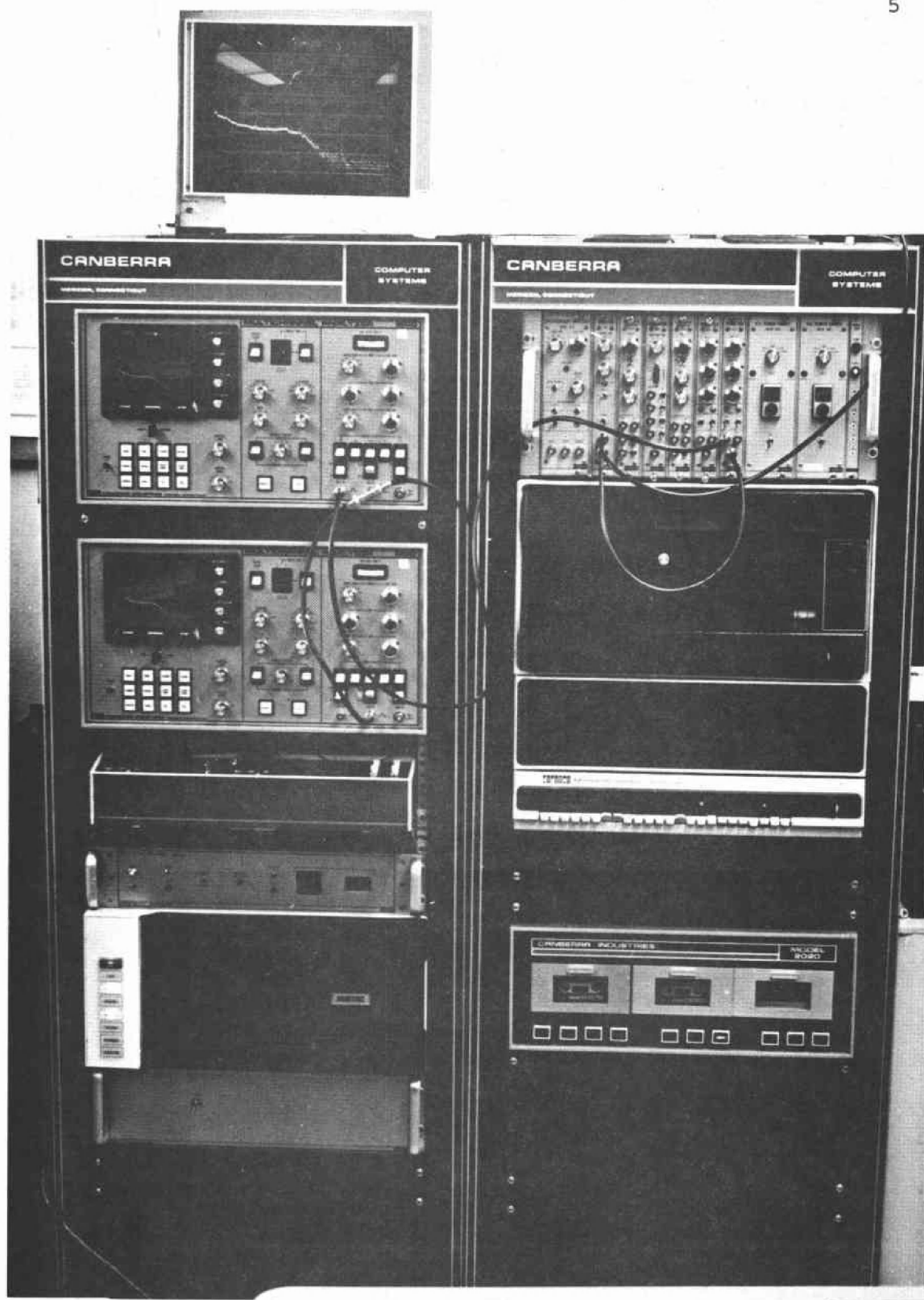


Figure 2. Data Accumulation and Processing Hardware

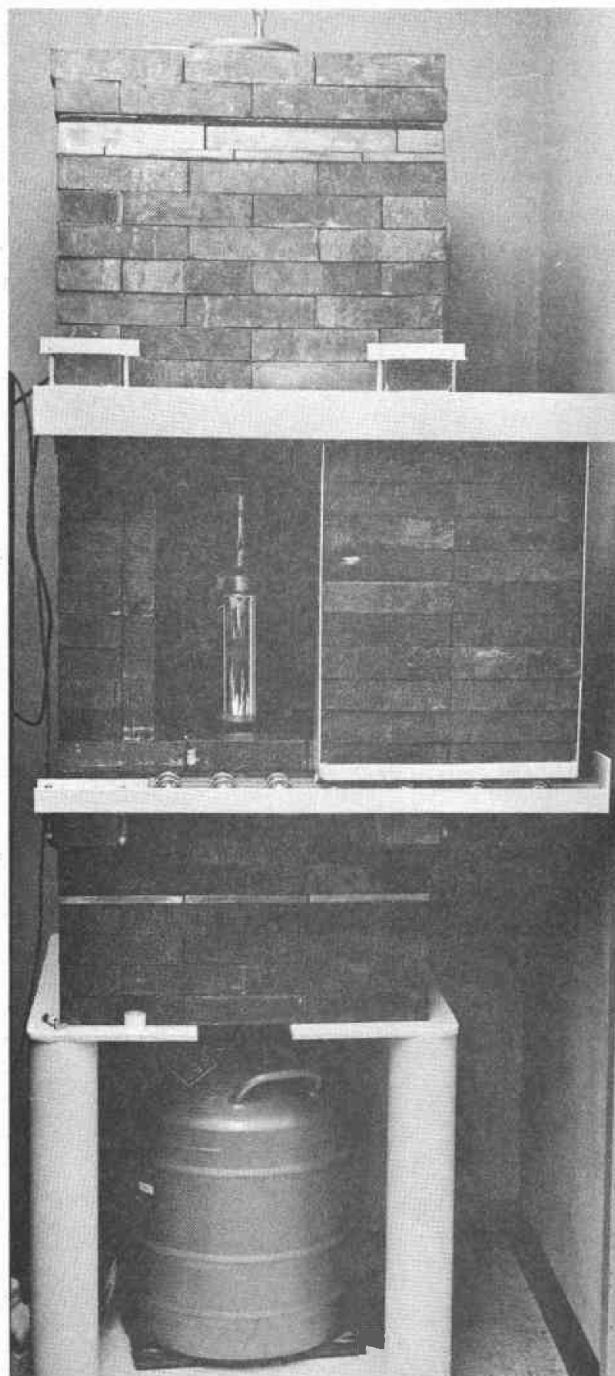


Figure 3. Lead Shield with Access Door Open Showing Detectors Inside.

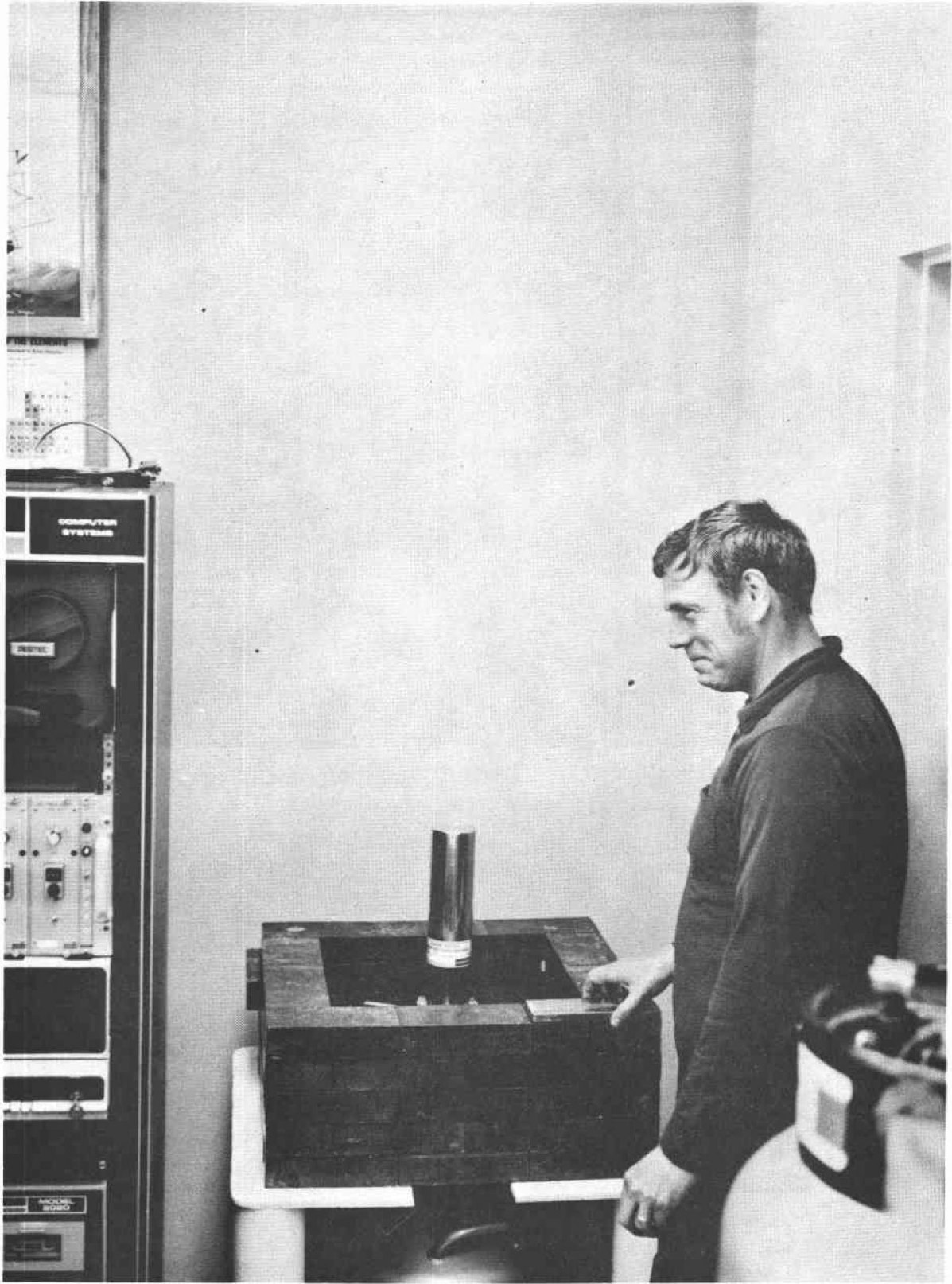
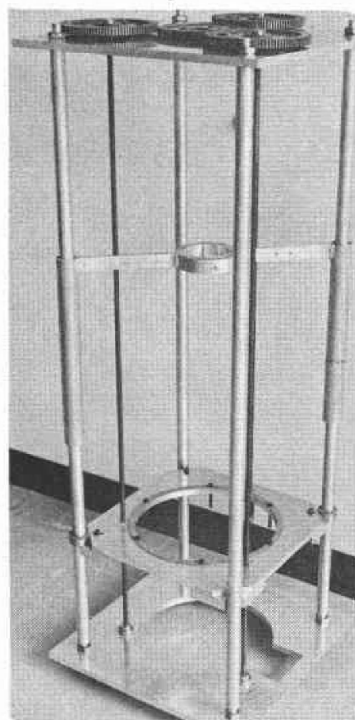
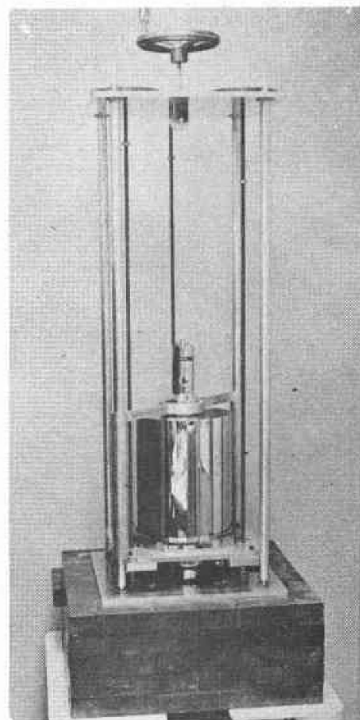


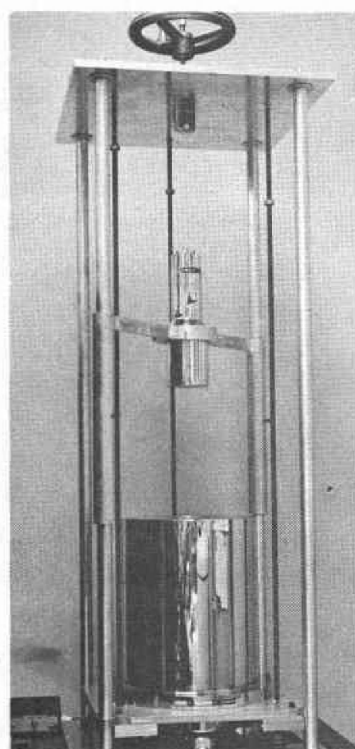
Figure 4. Partially Assembled Lead Shield



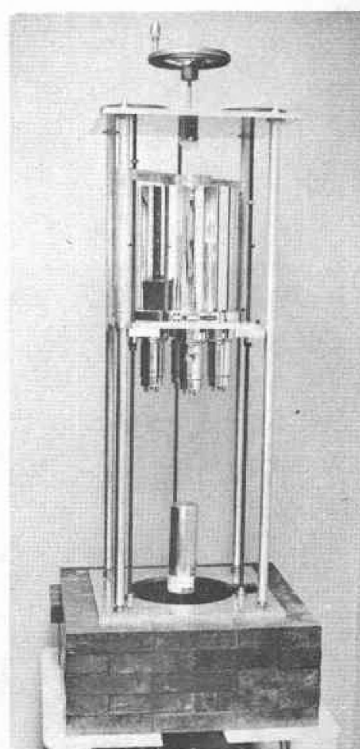
A.



B.



C.



D.

Figure 5: Views of Annulus Support and Lift Mechanism. A. Lift mechanism showing gears and ball bearing screws. B. Annulus and plug lowered into counting configuration. C. Plug lifted for access to sample chamber. D. Annulus raised.

Routine data reduction includes search of the spectrum for peaks, determination of total peak areas (Baedecker, 1971) and standard deviations. A reference library is searched to identify isotopes present by energy. Finally, a quantitative analysis of selected isotopes is performed.

The processor is available for other applications except when actually reducing gamma-ray spectra (i.e. during the counting periods). We are using the processor and digital cassettes for mass storage and statistical analyses, curve fitting, etc., of data from a number of projects. For example, we have three years of radioactivity and trace element data from McNary reservoir filed and accessible on cassette. As we develop programs for reduction of data from the atomic absorption spectrophotometer (which has punched paper tape output) we are using the PDP-11 more and more for AAS data. By combining cassette storage, high speed paper tape input and teletype control, rather diverse data processing options are available.

Analytical Laboratory

Three new pieces of equipment have been added to our analytical laboratory with a fourth item being constructed.

A digital electrometer/pH meter (Orion Model 801) provides us with the capability to measure specific ion activities such as fluoride, chloride and sulfur dioxide directly.

A digital wavelength-scanning UV-VIS spectrophotometer (Varian Model 635D) provides us with an alternative method for determining a broad range of elements and compounds such as total fluoride, cupric ion, phosphate and nitrate solution concentrations.

An electronic indicator and control module (Varian Model IM-6) was purchased to up-date our Atomic Absorption Spectrophotometer (AAS) by replacing three modules of the original AA5-R system. The new module has several advantages and improvements over the original equipment. Increased signal expansion capability combined with the improved signal-to-noise ratio provides a lower detection limit for the AAS system. A peak signal detector and hold circuit permits recording peak heights digitally instead of by a manual graphic interpretation. This function is especially important when using the flameless "carbon rod" technique for analyzing very low levels of trace metals. Selectable time integration periods from 3 to 30 seconds improves the analytical precision of the measurement when working with low-level metal concentrations by flame AAS. A two control curvature correction capability greatly improves the speed with which calibration curves may be linearized electronically during an analysis. Formerly it was necessary to have solution concentrations corresponding to every 0.1 change in absorbance over the range to be analyzed, requiring the adjustment of ten potentiometer controls. An improvement in the digital readout circuitry now provides us with the capability to record negative values, formerly unavailable.

Under construction is a solid-state electronic interface and timer sequenced controller, designed for transferring binary coded digital readout

information from any of the three instruments mentioned above, to an ASR33 teletypewriter. The timer sequenced controller performs multiple functions. It was designed to operate the updated AA-5R spectrophotometer in either a manual mode, in which a controlled sequence is initiated by the operator each time a sample is to be measured, or in a completely automatic mode, which controls the AA-5R sample changer. The output data format has a selectable line number which is incremented by one for every line and a variable data record length selectable from one to nine records per line. The timers can be preset from 0.1 to 99.9 seconds individually and control the time of each sample phase. The four phases controlled by the timers are: (1) settling time before the first sample reading is taken, (2) time between repeated sample readings, (3) time for sample flushing, and (4) time during which the baseline is automatically re-zeroed. Other functions provided by the controller include turntable rotation control, end of tray sensing, solenoid valve control which selects sample or reference solution alternately and switching of a fluid pump motor for filling sample chamber on the UV-VIS spectrophotometer or the cell chamber for electrometer probes.

Computer Program (PDP-11/05). Program AADATA is used for converting absorbance values from the Atomic Absorption Spectrophotometer (AAS) to concentration units. The program is written in a high level interpretive computer software language called "CLASS" (Canberra Laboratory Automation Software System) which is compatible with our PDP-11/05 computer system.

Features of the program include the ability to correct the analytical signal for non-atomic background absorption and an estimate of the overall uncertainty in the precision of the analysis.

Raw data is obtained from the AAS in the form of punched paper tape (ASCII) and transferred to the computer at a later time for data processing.

Data reduction by the computer occurs in three parts. The first part lists the coefficients of the least squares linear regression analysis of the standards (Bevington, 1969). The second part lists the mean, variance, standard deviation and number of determinations for the non-atomic background absorption blank. The third output is the sample concentration data report. It lists a line number for sample identification, net sample concentration in $\mu\text{g per ml}$, a "code", percent relative uncertainty, percent relative standard deviation, absorbance of the gross signal, accumulated variance, and accumulated standard deviation.

The "code" column informs the person examining the data report whether or not the concentration of the sample lies within the range of the standards used for calibration. If the sample concentration is less than the lowest standard concentration, an asterisk is printed in this column. If the sample concentration exceeds the highest standard concentration, a value is printed indicating the percentage by which the highest standard is exceeded. If the sample concentration lies within the range of standards used for calibration, the column is left blank.

Relative percent uncertainty is intended to mean an estimate of the overall error in precision of each sample analyzed. (Larsen, Hartmann, and Wagner, 1973). It also includes the variance of the non-atomic background signal.

Aquarium Room

We are making frustratingly slow, but steady, progress in our large batch-culture phytoplankton facility described in last year's progress report (OSU Reference 74-4). Light limitation of growth in the 350-gallon tanks has been solved by addition of high intensity quartz iodide lamps. With the lamps in operation it has been necessary to cool the tanks in order to maintain reasonable temperature and to prevent stratification. Cooling coils have been installed in the tanks and the cooling system is now being reconfigured in order to comply with health-safety considerations.

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STUDENT PARTICIPATION

Students contribute substantially to our research program. During the past year one student completed a doctorate, one completed a master's degree, and three new Graduate Research Assistants joined the project. Abstracts of theses are printed in the following section. The name of each person's thesis advisor is given in parentheses.

DEGREES COMPLETED

Janakiram R. Naidu, Ph.D.

Dr. Naidu presented his thesis "Radioactive Zinc (^{65}Zn), Zinc, Cadmium and Mercury in the Pacific Hake, *Merluccius productus* (Ayres), Off the West Coast of the United States" in May 1974. He is presently on the staff of Dames and Moore in New Jersey. (Cutshall)

Ronald Carl Scheidt, M.S.

Mr. Scheidt completed his thesis "Relation Between Natural Radioactivity in Sediment and Potential Heavy Mineral Enrichment on the Washington Continental Shelf" in August 1974. He worked temporarily with the National Environmental Research Center in Corvallis and has now joined the staff of the OSU Water Resources Research Institute, Corvallis, Oregon. (Cutshall)

Ph.D. CANDIDATES

David W. Evans, B.S. (Chemistry) UCLA; M.S. (Oceanography) OSU

Mr. Evans has spent the past two and one-half years at the Atlantic Estuarine Fisheries Center of the National Oceanic and Atmospheric Agency in Beaufort, North Carolina. During that time he has been engaged in studies of the chemical reactions of transition metals in estuarine waters under the guidance of Dr. Douglas Wolfe and Dr. Ford Cross. He plans to return to OSU this May to begin writing his dissertation. (Cutshall)

Arthur Russell Flegal, Jr., B.A. (Zoology) UCSB; M.A. (Biology) California State College-Hayward

Mr. Flegal has worked with the Corps of Engineers on environmental impacts of dredge spoil disposal and his prior research involved trace metals in coastal organisms. He joined our group in September 1974 and has not yet selected a thesis topic. (Cutshall)

Vernon G. Johnson, B.S. (General Science) OSU; M.S. (Oceanography) OSU

Mr. Johnson has completed data collection for his thesis research on radionuclide transport in the Columbia River. A portion of that work will be presented at the Fourth National Symposium on Radioecology this May. In addition to working on his thesis Mr. Johnson has worked for us on the AMAX project (see Introduction) in Youngs Bay during the past year. (Cutshall)

MASTER OF SCIENCE CANDIDATES

John Steven Davis, B.A. (Biology) University of California-Riverside

Mr. Davis spent the summer of 1974 working in the Columbia River estuary after receiving his B.A. degree in June of 1974. His thesis research will increase our knowledge of behavioral strategies of the gammarid amphipod, *Corophium salmonis*. This species is an important constituent of several food chains in the estuary. He is currently supported by other funds. (Holton)

John N. McCall, B.S. (Biology) University of West Florida-Pensacola

Mr. McCall received a B.S. degree in June of 1974 and joined us immediately for a summer of field work in the Columbia River estuary, before starting classes in the fall of 1974.

Although he is supported by other funds, his thesis research on the feeding behavior of the starry flounder will greatly increase our knowledge of this important species, and will enable us to better predict the movement of radioactivity through this important link in the estuarine food chain. (Holton)

Katsuo A. Nishikawa, K., B.S. (Oceanography) Escuela Ciencias Marinas,
Ensenada, B.C., Mexico

Mr. Nishikawa has completed almost all of his course work and is now engaged in thesis research. He will use a radioactive tag to trace the distribution of metals after their excretion in molluscan feces and pseudo-feces. (Cutshall)

Gerhardt F. Riedel, B.S. (Oceanography), A.B. (Biology) Humboldt State
University

Mr. Riedel joined our group in September 1974. His thesis research deals with the relative utilization of different chemical forms of metals by marine phytoplankton. (Cutshall)

Thomas J. Roffe, B.S. (Biology) University of California-Santa Cruz

Mr. Roffe started his graduate program in Oceanography in the fall of 1974. He has completed the identification of cephalopods captured in opening-closing nets on a cruise made September 1974. We have also used his programming capabilities in the analysis of our data on ^{65}Zn content of pelagic animals. (Pearcy)

ABSTRACTS OF THESES COMPLETED

RLO-2227-T12-47

RADIOACTIVE ZINC (^{65}Zn), ZINC, CADMIUM, AND MERCURY IN THE PACIFIC HAKE,
MERLUCCIUS PRODUCTUS (AYRES), OFF THE WEST COAST OF THE UNITED STATES

Ph.D. Thesis by Janakiram R. Naidu*

The Pacific Hake, *Merluccius productus* (Ayres) was used to monitor the coastal waters off the West Coast of the United States, and Puget Sound for zinc (Zn), radioactive zinc (^{65}Zn), cadmium (Cd) and mercury (Hg).

This study has revealed that the Columbia River is not the source for zinc, cadmium and mercury, but was the main source for zinc-65 as of January 29, 1971. Since then with the phasing out of all the plutonium production reactors at Hanford, the zinc-65 activity in the river water, and therefore in sea water off the West Coast of the United States, has approached minimum detection levels.

The zinc-65 concentration in the hake reflect the position of the Columbia River water plume. With the decrease in sea water concentrations of zinc-65 as mentioned above, the activity of zinc-65 in the Pacific Hake has decayed to levels below the limits of detection. Specific activity of zinc-65 also follows a similar pattern and had declined with time (1969-1972).

The data on zinc and cadmium concentrations in the hake were fitted mathematically to the exponential equation:

$$Y = B_1 + B_2 e^{B_3 X}$$

where Y is the concentration of the element; X is the length or weight of the fish; and B_1 , B_2 and B_3 are parameters. Attempts were made to give these parameters biological meanings. In relating the data (zinc and cadmium concentrations) to the age of the fish (based on Bureau of Commercial Fisheries data, which relates age to length or weight of the fish), the following biological attributes could be assigned to the parameters:

B_1 : asymptotic value for zinc or cadmium or concentration at chemical maturity, that is, when the length or weight of the fish approaches a steady state;

* Major Professor: Norman H. Cutshall, Ph.D.

- B₂: location of the curve with reference to the weight or length of the fish. This is not a biological but a chemical interpretation of the growth process;
- B₃: constant pertaining to the rate of change in the concentration of zinc or cadmium.

Although zinc, cadmium and mercury all belong to group IIB of the periodic table, correlation between zinc and mercury concentrations or between cadmium and mercury concentrations were present, but the degree of correlation was a function of location, whereas the correlation between zinc and cadmium concentrations were highly correlated for all locations.

Zinc and cadmium concentrations increase with fish size approaching an asymptotic value at maturity. Mercury concentrations were linear with age and the slope was a function of sampling location. The concentration factors follow the pattern: mercury > zinc \approx cadmium. Regulation is seen for zinc and cadmium but in the case of mercury there is evidence that it is cumulative with age.

It may be significant that the age distribution of fish caught commercially coincides with the maximum concentration of zinc and cadmium. In the case of mercury the accumulation is linear and continues to accumulate with age. In terms of environmental pollution hazards, this may have important consequences based on public consumption of such fish.

RLO-2227-T12-52

RELATION BETWEEN NATURAL RADIOACTIVITY IN SEDIMENT AND POTENTIAL
HEAVY MINERAL ENRICHMENT ON THE WASHINGTON CONTINENTAL SHELF

M.S. Thesis by Ronald Carl Scheidt*

Natural radionuclides may be indicators for dense mineral placers along marine shorelines. Relict beach and river deposits occur in continental shelf sediments. These deposits result from the reworking of beach sands by wave action during the Holocene Transgression. Some dense, resistant minerals associated with placer deposits are known to contain ^{238}U and ^{232}Th activities. Shelf sediments, enriched in heavy minerals, might be expected to be high in these natural radioactivities. The usefulness of natural radioactivity to locate and to map dense mineral deposits was therefore explored and relations between natural radioactivity in marine sediments and dense mineral content were established.

High ^{40}K activity in sediments was positively correlated significantly with high mud content. High ^{230}Th and ^{232}Th activities were associated with fine, well-sorted sands and correlated very highly with the weight percent total heavy mineral sands in the sediment. These relations distinguish depositional environments as high in ^{40}K content and erosional environments as high in ^{230}Th and ^{232}Th content.

Two areas of enrichment were found by radiometric mapping and by mineral analyses. Off Destruction Island, Washington, maximum ^{230}Th and ^{232}Th activities were found in 30 m water depth. Activity distribution and mineral enrichment were consistent with general northward transport of nearshore sediment. In 33 m water depth off Clatsop Spit, Oregon, the second enrichment area was found. The $^{232}\text{Th}/^{230}\text{Th}$ activity ratios are different for these two areas. Probably the heavy minerals in these two areas are from different sources.

* Major Professor: Norman H. Cutshall, Ph.D.

MEETINGS ATTENDED

Norman H. Cutshall

Ocean Dumping Workshop
National Academy of Science-National Research Council
Woods Hole, Massachusetts
September 10-13, 1974

Robert L. Holton

Biological Effect of Pollutants on Marine Organisms
National Science Foundation, International Decade of Oceanographic
Exploration
Nanaimo, British Columbia
August 11-14, 1974

William G. Pearcy

American Society of Limnology and Oceanography
University of Washington, Seattle
June 23-28, 1974

*Paper presented: "Food Habits of Deep-Sea Macrourid Fishes off the
Oregon Coast" (with J. Ambler).

Ocean Dumping Workshop
National Academy of Science-National Research Council
Woods Hole, Massachusetts
September 10-13, 1974

National Fisheries Plan Meeting
National Oceanic Atmospheric Administration and Sea Grant
Everett, Washington
December 2-4, 1974

Workshop on Problems of Assessing Populations of Nekton
National Science Foundation and Office of Naval Research
Santa Barbara, California
February 24-28, 1975

* The published text of this paper is reprinted in the "Research Completed" section of this report.

RESEARCH IN PROGRESS

POST-SHUTDOWN RADIONUCLIDE TRANSPORT STUDY

Vernon G. Johnson and Norman H. Cutshall

Sample analysis and data reduction for this study have been completed and final data analysis and interpretation are proceeding as time permits. Some of the results will be presented at the Fourth National Symposium on Radioecology in May, 1975.

Decline of Radioactivity in Sediment

McNary Dam surface sediment samples for the period 1971-1974 and recent cores show a general radionuclide decline since closure of KE reactor in 1971. However, some deviations from this general pattern of decline were observed for ^{54}Mn , ^{60}Co and ^{137}Cs . These deviations seem to correlate well with the 1972 radioactive discharge data for N reactor (U.S. Atomic Energy Commission, 1974). Zinc-65 and the europium isotopes do not appear to have been affected by these new inputs and may thus still be useful for estimating sediment dilution rates. The surface sediment and core ^{152}Eu data suggest a half-time of dilution or decline of 1-2 years for the upper 3 cm layer. Whether this rather slow rate of decline is due to "environmental mixing" or to continuous upstream release from old sources is a point yet to be resolved.

Isotope Age Dating

The new high resolution counting system has greatly increased our ability to use the long-lived component of the residual Hanford radioactivity for age dating. Thus far, two recent McNary cores and selected sections of Youngs Bay cores have been analyzed with this new system. At the present time $^{60}\text{Co}/^{152}\text{Eu}$ ratios show the most promise for at least assigning relative ages to certain sediment levels, if not actual sedimentation rates. This "time tag" has been especially useful in the Youngs Bay sedimentation study (described below) where it has been possible to superimpose an historical "event" marker on a $^{60}\text{Co}/^{152}\text{Eu}$ depth profile. This allows us to assign the same age to sediment layers in other cores having the same $^{60}\text{Co}/^{152}\text{Eu}$ ratio. Furthermore, it is hoped that by comparing the historical record of sediment accumulation with the isotope ratio determined rate, that some estimate of the influence of environmental mixing (bioturbation, etc.) of sediment can be made. Benthic biological data from the Youngs Bay Study should be very helpful in these interpretations.

LOSS OF ZINC-65 AND MANGANESE-54 FROM THE FRESHWATER CLAM *ANODONTA*P.J. Harney¹, N.H. Cutshall and R.L. Holton

Loss of ^{65}Zn and ^{54}Mn from the freshwater clam *Anodonta* was examined to determine whether uptake of these nuclides occurred from sediments, the only significant radionuclide source remaining after production reactor shutdown at Hanford, Washington, in January of 1971.

A comparative field loss study was performed to determine if uptake of ^{65}Zn and ^{54}Mn by *Anodonta* occurred after shutdown. Loss rates of these two nuclides were measured in organisms transferred to the non-radioactive Willamette River and compared to loss rates found in organisms remaining *in situ* in the Columbia River. Resulting ^{65}Zn half-lives of 103 ± 5 days and 136 ± 15 days for transfer and *in situ* groups respectively, these half-lives being the time-averaged result of four months of study, indicated that significant uptake took place after shutdown. Time-averaged results of periodic sacrifice collections of *Anodonta* from McNary Reservoir and the estuary further confirmed this finding. Large variation in the *in situ* ^{54}Mn data precluded a meaningful comparison of time-averaged loss rates, although sacrifice collections yielded ecological half-lives that were not significantly different from the pooled effective half-life.

Examination of *in situ* loss rates calculated on a monthly basis compared to time-averaged transfer loss rates indicated that uptake of both nuclides took place during restricted periods and that uptake and loss was relatively rapid, suggesting the limited importance of radionuclide uptake from sediments for this organism. Further, the low specific activity ($5.8 \text{ nCi } ^{65}\text{Zn/g}$; $0.5 \text{ nCi } ^{54}\text{Mn/g}$) of an organism transferred from the Willamette River to McNary Reservoir indicated that uptake from higher specific activity sediment remained minor more than a year after transfer.

The results of this research will be presented at the Fourth National Symposium on Radioecology in May 1975.

¹ Environmental Section, Oregon State Highway Department, Salem, Oregon.

ACCUMULATION AND CYCLING OF HANFORD PRODUCED ^{32}P BY THE
JUVENILE STARRY FLOUNDER *PLATICHTHYS STELLATUS* (PALLAS)
IN THE COLUMBIA RIVER ESTUARY

John J. Bolen¹ and William C. Renfro²

Seasonal variations in concentration, turnover and mode of accumulation of ^{32}P by the juvenile starry flounder was investigated during 1969-70 in Alder Slough, a small segment of the Columbia River Estuary. Concentrations of ^{32}P and specific activity in flounder followed a similar annual cycle. Radioactivity was maximum in the spring and summer and minimum in fall and winter. Concentration factors for flounder ranged from about 600 in winter to near 200,000 in summer. Retention studies using caged fish, and turnover estimates from free-living flounder showed effective half-lives of ^{32}P on the order of 10-14 days. These results suggest that ^{32}P elimination from flounder occurred at about the same rate as physical decay of the radionuclide. The amounts of ^{32}P accumulated by flounder from food, water or labeled sediment was determined. Flounder fed labeled food or labeled food and sediment mixtures accumulated respectively 3.3 and 3.7 times the activity of flounder receiving ^{32}P from water alone. Radioactive sediment did not appear to make a direct contribution to the ^{32}P body burden of the fish.

The results of this research will be presented at the Fourth National Symposium on Radioecology in May 1975.

¹ Division of Technical Review, U.S. Regulatory Commission, Washington, D.C.

² Environmental Programs, Northeast Utilities Co., Hartford, Connecticut

EFFECTS OF SEAWATER ON TRANSITION METAL CHEMISTRY

D.W. Evans¹, F.A. Cross², D.A. Wolfe², N.H. Cutshall

Research is underway to develop a predictive model of dissolved concentrations of the trace metals Zn, Cd, Mn, Fe and Cu in estuaries of the southeastern United States. It is hoped these studies, based at the National Marine Fisheries Service, Atlantic Estuarine Fisheries Center, Beaufort, North Carolina, can be compared with related efforts in estuaries of the northwestern United States.

¹ Off Campus 1974 school year

² National Marine Fisheries Service, Beaufort, NC

The model uses the physico-chemical distribution of trace metals in adjacent ocean water and in river water flowing into the estuary as input variables. Deviations from the distribution predicted by a simple linear dilution model can then be related to *in situ* measurements of salinity, Eh and pH.

Dissolved and particulate metal concentrations of transition metals have been measured across a broad salinity range at different levels of river discharge in the Newport River estuary. Mr. Evans will return to OSU in Spring 1975 to begin thesis writing.

⁶⁵Zn IN MUSSELS AND ITS RELATIONSHIP TO THE SPECIFIC ACTIVITY APPROACH

Ingvar L. Larsen and Jerome J. Wagner

⁶⁵Zn specific activity in mussels (*Mytilus californianus*) along the Oregon coast has been investigated continuously since termination of the last single-pass plutonium production reactor at Hanford, Washington. Monthly samples, beginning with 21 January 1971 to present (24 January 75) have been collected and analyzed for ⁶⁵Zn specific activity. A conceptual model for specific activity has been developed to describe the uptake, turnover, and loss occurring in mussels during steady-state conditions and decline. A steady-state level of ⁶⁵Zn specific activity existed in the mussels for approximately six months following reactor shutdown, exemplifying the extent of ⁶⁵Zn within the marine coastal environment. The ⁶⁵Zn biological half-life is approximately an order of magnitude greater than reported for this species remote from this region, emphasizing the importance of local environmental influences upon metabolic activity. Estimates of transport rates along the Oregon coast following the decline have been made. Zinc-65 specific activity during steady-state conditions is approximately 20% greater in younger mussels than older ones. Differences in specific activity between male and female specimens were not observed indicating that discrimination based upon gender for ⁶⁵Zn is slight or nonexistent.

An idealistic representation illustrating the distribution of ⁶⁵Zn specific activity in mussels with time and distance along the Oregon coast before and following reactor termination has been developed.

A manuscript is now under preparation.

Similar studies are being done using (*Pollicipes (Mitella) polymerus*) gooseneck barnacles collected over the same time period and location as the mussels.

GROWTH RATE STUDIES OF MUSSELS, *MYTILUS CALIFORNIANUS*

Ingvar L. Larsen

Growth rates of mussels at our long term sampling locations are being determined. Mussels from Yaquina Head have been measured monthly for several months. To date, growth rates (change in length with time) have been much lower than reported growth rates of similar species from Southern California. Attempts to determine ages of various sizes of mussels as well as correlations of interior shell volumes and lengths is also underway.

COBALT-60 IN ALBACORE TUNA OFF THE WEST COAST OF NORTH AMERICA

E.E. Krygier

Radioactive cobalt-60 (^{60}Co), found in livers of albacore tuna collected in 1963-1969 from the west coast of North America (Washington to Baja California), exhibit geographical, annual and within season variations. Highest concentration of ^{60}Co in tuna was found to occur at latitudes from 42° to 43°N during the first part of summer; thereafter a steady decline in radioactivity is observed through the remaining summer months. There are two possible sources of this radionuclide in the tuna populations off Oregon. Cobalt-60 has been one of the radionuclides emitted from the Hanford Plant via the Columbia River and it is also a known product of atmospheric fallout. The results of this project are to be presented at the Fourth National Symposium on Radioecology in May 1975.

DEPTH VS. ZINC-65 RADIOACTIVITY AND SPECIFIC ACTIVITY OF OCEANIC ANIMALS

William G. Percy

Data on ^{65}Zn activity of oceanic animals captured from the surface (neuston) to 2800 m (abyssobenthics) have been tabulated for winter and summer seasons, for three time periods (1962-1970) and for four taxa (fishes, crustacea, cephalopods and medusae), punched on computer cards and regressed against depth of capture or depth of maximum nighttime abundance for each species. The slope of the lines fitted to the $\log ^{65}\text{Zn}$ data therefore estimates the rate of change of radioactivity with depth.

This can be interpreted as a transport rate from surface waters into the deep-sea. Although the variability of the data is large, the slopes of the regressions are often similar.

The results of this research will be presented at the Fourth National Symposium on Radioecology in May 1975.

VERTICAL DISTRIBUTION OF MESOPELAGIC AND BATHYPELAGIC ANIMALS

William G. Pearcy

Our intensive research with opening-closing midwater trawls has characterized the pelagic fauna of micronekton in the mesopelagic (200-1000 m) and epipelagic (0-200 m) zones of the open ocean off Oregon. Many of the common species of fishes and shrimps are known to migrate vertically on a daily basis. Seasonal migrations are indicated for some species of crustacea, perhaps extending into the bathypelagic realm (1000-4000 m). Because so little research has been conducted on the deep pelagic fauna in general and because many researchers theorize that migrations within the bathypelagic realm may accelerate transport of materials and energy to the deep-sea benthos, we are interested in conducting quantitative midwater sampling below 1000 m.

Results of several tows to 2000 m off Oregon to date indicate that crustaceans, notably shrimps and mysids, are the dominant micronekton. Fishes, abundant at shallower depths, have been conspicuously rare in our bathypelagic samples.

DEEP OCEAN FALLOUT STUDY

Norman H. Cutshall

The presence of long-lived fallout radionuclides in Atlantic deep-sea sediments has been noted by Noshkin and Bowen (1973). When our low-level counting system is operated with large samples in a Marinelli beaker, the sensitivity is ample for direct measurement of ^{137}Cs at the reported levels. We are planning to count sediments from the Pacific for comparison to Atlantic sediments. One surface sediment from 3000 meters off Oregon appears to be much lower than Noshkin and Bowen found at 5000 meters in the Atlantic. More samples will be analyzed.

CARBON-14 AND DEEP-SEA FOOD WEBS

William G. Pearcy and M. Stuiver

This cooperative research with Dr. M. Stuiver, University of Washington, consists of ^{14}C analysis of oceanic and deep-sea animals. Like the research on ^{65}Zn , it provides unique data on the flux and pathways of materials in the ocean. Results show that ^{14}C specific activities of various pelagic animals decrease significantly with depth. Some fishes, and especially one deep-sea medusa, had anomalously low ^{14}C activity, however, suggesting different carbon pathways. Benthic animals from 2800-2900 include species with surprisingly large ^{14}C values, indicating rapid transport of carbon to these depths, as well as species with low ^{14}C specific activities.

BIOLOGY AND SYSTEMATICS OF DEEP-SEA ANIMALS

William G. Pearcy and D. Stein

Abyssal Octopods. W. Pearcy spent three months in the spring of 1974 working in Dr. G.L. Voss's laboratory on the systematics of deep-sea octopods. These animals have received very little attention in the past and none of the specimens from the extensive O.S.U. material could be confidently identified to species.

Based on the research with Dr. Voss, our material probably includes one new species of *Graneledone*, two new species of *Benthoctopus*, two new species of *Grimpotteuthis* and *Cirroteuthis mulleri*. Dr. Voss is in the process of comparing our material with holotypes in Europe and U.S.A.

Liparid Fishes. David Stein is presently studying the taxonomy of the liparid fishes occurring below 200 m from Oregon and adjacent waters for his Master's degree in Fisheries. These fishes are common in deep-water benthic collections. His research shows that they compose a remarkably large number of species. Twenty-five species have been identified, including two new genera, nine new species, four second records, and 7 first Oregon records.

UPTAKE OF TRACE METAL RADIOISOTOPES BY MARINE PHYTOPLANKTON

G.F. Riedel, N.H. Cutshall, I.L. Larsen, R.L. Holton and L.F. Small

Cross et al. (1971) and Bernhard and Zattera (1969) noted that phytoplankton have remained at lower ^{65}Zn specific activities than the culture medium in which they were grown for many generations.

It is suggested that this phenomenon is related to selective uptake or adsorption of particular physico-chemical states of the element, which, due to the methods of ^{65}Zn addition to the culture medium, might result in different specific activities among the physico-chemical states in the medium. It is also suggested that various taxonomic groups of phytoplankton might show different preferences among the physico-chemical states of zinc.

The uptake of ^{65}Zn , ^{54}Mn , ^{59}Fe , and ^{60}Co , are being studied in six 1200 liter tanks with varying methods of trace metal additions in order to determine if trace metal isotopes are selected for or against by phytoplankton as a result of compartmentalization of the total trace metal composition of the medium into various forms.

ANODIC STRIPPING VOLTAMETRY

A. Russel Flegal, G.F. Riedel and N.H. Cutshall

Preliminary tests have been started in anodic stripping voltametry. Various electrode plating techniques are being evaluated, and the sensitivity and precision of the existing equipment is being determined. An inverting amplifier will be built to increase the sensitivity of the system.

If the results of these tests are satisfactory, then anodic stripping voltametry will be applied to the study of the equilibrium and kinetics of trace metal complexes in seawater.

ROLE OF DEPOSIT-FEEDING ESTUARINE CRUSTACEANS IN THE CYCLING OF ^{65}Zn

Katsuo Nishikawa K. and Norman H. Cutshall

I. INTRODUCTION

The biodeposition of suspended matter by filter feeding organisms has been suggested as an important accelerating mechanism of sedimentation in estuaries (Duke et al., 1966). By this process many trace elements and radionuclides can be removed from the water column and deposited with the fecal material (Haven and Morales-Alamo, 1966). However, before the trace elements and radionuclides become permanently trapped and buried by the sediments, they are exposed to the deposit-feeding organisms of the estuarine benthos. In this community, the detrital food web is the most important mechanism of energy transference. Coprophagy plays a significant role in trophic relationships among the benthic communities (Frankenberg and Smith, 1967). Therefore, fecal material, which may contain trace metals and radionuclides, will be ingested and excreted several times, depending upon its nutritional value and the particular needs of the organisms that comprise a specific bottom-level community.

II. OBJECTIVES

This experiment intends to evaluate the transference, loss and short time accumulation of ^{65}Zn in the detrital food web using the coprophagy capacity of two crustaceans, the epibenthic crab (*Hemigrapsus nudus*) and the bottom dwelling ghost shrimp (*Callinassa californiensis*).

The departure point of this experiment will be the fecal material (feces and pseudofeces) contaminated with ^{65}Zn from the Pacific oyster (*Crassostrea gigas*) which according to Bernard (1974) furnishes an important nutritional substrate.

III. EXPERIMENTAL WORK

The feces and pseudofeces will be collected from Pacific oysters feeding on the natural food available in the Yaquina Bay. The fecal material will be isolated and contaminated with ^{65}Zn at the Radiation Center in Corvallis. Before this contaminated material can be used as food, it has to be aged during different time periods. At the end of each aging period, the fecal material will be washed in order to remove all the non-adsorbed ^{65}Zn . At this point, the material will be offered as food to the crab and/or to the ghost shrimp.

The fecal pellets produced by these organisms, after being aged for different periods, will continue to be offered as food either to the same organisms or to others, until the nutritional value declines or rejection by the organisms occurs.

In each step described previously, the partition of the ^{65}Zn in: (1) the fecal pellets, (2) the water as liquid excretion, (3) the surface of the organisms and container vessels, and (4) its retention, will be measured. In order to control the nutritional quality of the fecal pellets, the content of organic carbon and total nitrogen will be measured in the freshly excreted and aged fecal material.

In this experiment, different levels of concentration of ^{65}Zn will be used and the partition of this radionuclide among different parts of the experimental system will be measured and correlated with the nutritional values of the food. The quantification of ^{65}Zn will be performed by gamma-ray spectrometry using an NaI (Tl) detector. In order to calculate the specific activity of ^{65}Zn , the total zinc will be measured by atomic absorption spectrometry. The organic carbon and the total nitrogen analysis will be made by gas chromatography.

YOUNGS BAY SEDIMENTATION STUDY (based on data collected for AMAX Baseline Project)

Vernon G. Johnson, Norman H. Cutshall and Robert L. Holton

Jennings (1966) found a maximum in $^{51}\text{Cr}/^{65}\text{Zn}$ ratios in Youngs Bay, an appendix to the Columbia River estuary. He postulated that the maximum indicated a zone where reduction and sorption of ^{51}Cr caused high ^{51}Cr deposition. We are using data collected for the AMAX Baseline Study (see Introduction) to examine this possibility further. Eighty-five surface and 131 subsurface sediment samples have been analyzed for radionuclides, fluoride and Fe, Mn, Zn, Cd, Cu, Pb, Ni, Cr and Co. A few samples were run for total sulfide. Preliminary examination of the data confirms that a chemically reducing sediment underlies the zone of high $^{51}\text{Cr}/^{65}\text{Zn}$ ratios. Surface sediment in the zone appears to be oxidizing, however, suggesting that the "reducing trap" probably operates intermittently. More elaborate treatment of the data is under way.

THE FEEDING BEHAVIOR OF THE STARRY FLOUNDER, *PLATICHTHYS STELLATUS*

John N. McCall and Robert L. Holton

Youngs Bay serves as a nursery area for several species of larval and juvenile fish, providing them with a protected environment and abundant food during their period of rapid growth. We are presently examining food-web relationships within the Bay, placing special emphasis on the feeding

ecology of these fish. The starry flounder, *Platichthys stellatus*, is far the most abundant of the juvenile fish in the estuary, and is found in large numbers at all times of the year. Therefore, this study focuses primarily upon it, although other species of fish are also being examined when practical.

The availability of numerous trawl samples dating back to January 1974 will enable us to examine feeding habits beginning with that period. Research to date indicates significant seasonal changes in feeding behavior, as well as age-group and species-specific differences. These observations point the way for further field work, and also for laboratory experiments to examine specific aspects of the feeding ecology. Possible experiments include the determination of the affect of prey type and size, as well as the affect of prey abundance and distribution. The influence of factors within the physical environment will also be examined.

ADAPTIVE FEEDING AND SWIMMING STRATEGIES OF AN INTERTIDAL GAMMARID AMPHIPOD, *COROPHIUM SALMONIS* STIMPSON

John Steven Davis and Robert L. Holton

Preliminary investigation in Youngs Bay has revealed that *Corophium salmonis*, a tube-dwelling gammarid amphipod, is the numerically dominant intertidal and subtidal infaunal resident. This dominance is reflected in the prevalence with which *Corophium* is found in fish stomachs.

An investigation will be carried out, utilizing field sampling and laboratory experiments, to examine when and why the organisms leave the substrate and enter the water column, how this behavior is modified by its food density and how hydrographic dynamics might redistribute local populations. The purpose is to develop an understanding of how localized these Bay residents may be, whether there is free migration to other parts of the estuary, and how they become available to fish predators.

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RESEARCH COMPLETED*

Crustaceana 27 (2), 1974. E. J. Brill, Leiden

RLO-2227-T12-19

A DESCRIPTION OF *PETALIDIUM SUSPIRIOSUM* BURKENROAD, 1937
(DECAPODA, NATANTIA)

BY

ROBERT A. WASMER

Bass Memorial Academy, Lumberton, Mississippi, U.S.A.

Prior to 1937, the genus *Petalidium*, a poorly known genus in the penaeid shrimp family Sergestidae, was considered to differ from the genus *Sergestes* in the smaller number of gills above the fourth pereopods, in the lesser degree of ramification of its gills, and in the bifurcation of the processus ventralis of its petasma (Hansen, 1922; Burkenroad, 1937). In 1937, Burkenroad described *Petalidium suspiriosum* from two female specimens taken in the eastern Pacific off Mexico. These specimens differed from other species of *Petalidium* in having the same number of gills above the fourth pereopods as does *Sergestes*, and in having considerably more branched gills.

Over 1000 specimens of *Petalidium suspiriosum* Burkenroad are among the mesopelagic decapod crustaceans collected since 1961 by the Department of Oceanography of Oregon State University in the northeastern Pacific Ocean. Since this species is only known from Burkenroad's two type specimens, and since the male is completely unknown, it seems desirable to redescribe the species from the material now available.

The collection of the specimens by vessels of the OSU Department of Oceanography was supported by U.S. Atomic Energy Commission Contracts AT(45-1) 1726 and AT(45-1) 1750, RLO-2227-T12-19. I wish to thank Dr. William G. Percy of the Department of Oceanography and Dr. Ivan Pratt of the Department of Zoology for their suggestions and helpful criticisms made in reviewing the manuscript.

Petalidium Bate, 1881

The following diagnosis of the genus *Petalidium* is based largely on Hansen (1922), with additions made to indicate the increase in the number of gills and their increased ramification in *Petalidium suspiriosum*:

Sergestidae with first 3 pairs of pereopods elongate; 1st pereopod without proper chela; 2nd and 3rd pereopods with very small chelae, 4th and 5th pereopods with 6 segments, the dactyli being absent, 5th much shorter than 4th, both natatory. First maxilla with palp; 2nd maxilla with 2 lobes; 1st maxilliped with segmented palp. Branchial lamellae as well as arthrobranchs present; arthrobranchs of up to 13 rami, with as many as 12 lamellae per ramus; lamellae relatively large

* Arranged by RLO number.

and independent. Number of arthrobranchs above 4th pereopods variable: none, a single rudimentary, or two may be present; none above 5th. Petasma with processus ventralis forked.

***Petalidium suspiriosum* Burkenroad, 1937 (figs. 1-8)**

Petalidium suspiriosum Burkenroad, 1937: 325, figs. 8-12.

P. suspiriosum — Percy & Forss, 1966: 1136, 1137, 1140.

Type. — Burkenroad's (1937) type specimens of *P. suspiriosum* were collected in the eastern Pacific off Mexico, 20°36'N 115°07'W, and are deposited in the collections of the Department of Tropical Research of the New York Zoological Society, Catalogue number 361,043.

Diagnosis. — A well-developed anterior arthrobranch of nine rami, with up to six lamellae per ramus, and a small posterior arthrobranch of three rami bearing several lamellae each above fourth pereopod. An anterior arthrobranch, which may have up to thirteen rami, with up to twelve lamellae per ramus, and a posterior arthrobranchial lamella above third maxilliped and first three pereopods. Posterior, secondary branch of lobus armatus of petasma reaching beyond middle of primary branch, armed with up to six crochets; external branch of processus ventralis reaching beyond external branch, and almost as far as internal branch, of lobus terminalis; internal branch of lobus terminalis armed with one or two terminal crochets. Small hepatic spine present. Ocular peduncle with two tubercles.

Description. — The following is based on new material of *P. suspiriosum* from the northeastern Pacific Ocean, deposited in the U.S. National Museum, Washington, D.C., Catalog Nos. 139318-139323.

Integument thin and membranous; most specimens seen are damaged, with distal articles of antennular peduncles, tips of antennal scales, third maxillipeds, pereopods, and distal portion of uropods missing.

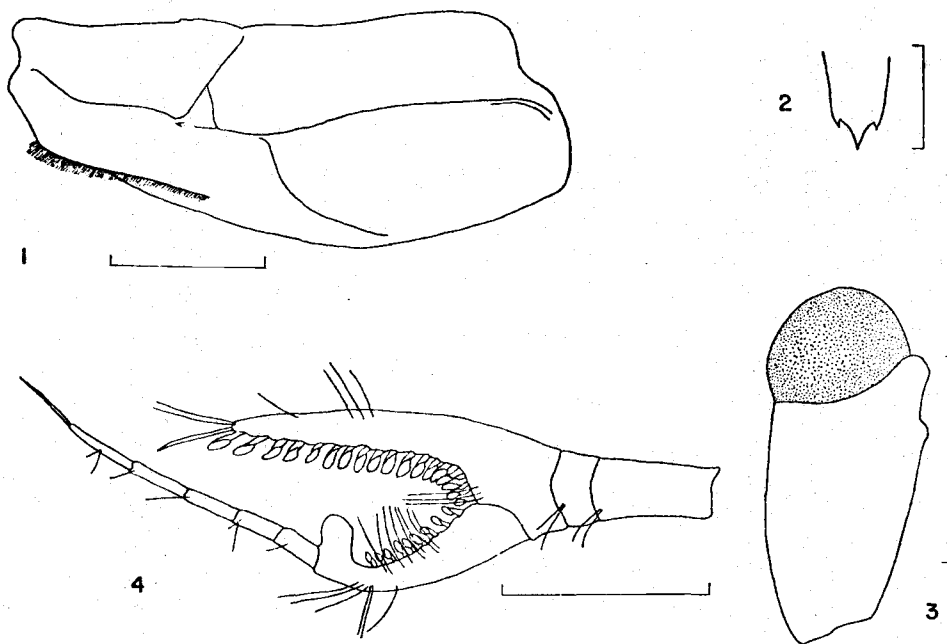
Male. Rostrum (fig. 1) very short and moderately high, superior margin convex; tip rounded, without dorsal spines. Carapace without dorsal carina. At about the level of hepatic spine, dorsal midline of carapace is elevated into a variously shaped hump, quite low in some specimens, but in others in form of a conspicuous, anteriorly directed sub-conical projection. Cervical sulcus very distinct, continued across dorsum, accompanied on carapace sides by cervical carina. Branchiocardiac carina and antennal carina well-developed. Weakly developed inferior carina and sulcus extending obliquely downward and backward across anterior portion of branchial region. Supraorbital spine absent. Minute hepatic spine present; may occasionally be missing on one or both sides, in which case a distinct hepatic prominence remains.

Abdominal somites not dorsally carinate. Sixth somite as long as fourth and fifth combined, terminating in a minute tooth.

Telson slightly more than half as long as the external margin of uropodal

PETALIDIUM SUSPIRIOSUM BURKENROAD

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Figs. 1-4. *Petalidium suspiriosum* Burkenroad. 1, carapace, lateral view, male (carapace length 9.4 mm); 2, telson, distal portion, male (c.l. 9 mm); 3, left eye in dorsal view, male (c.l. 9 mm); 4, right inferior antennal flagellum, medial view, male (c.l. 9.5 mm). Scale for fig. 1 = 3 mm; for fig. 2 = 0.5 mm; figs. 3, 4 = 1 mm.

exopodite, narrowing abruptly to a small terminal spine, often flanked by a pair of fixed lateral teeth (fig. 2). Uropodal exopodite slender, a little less than five times as long as wide; less than distal one-seventh of external border setose, with a well-developed tooth between setose and non-setose portions. Subcuticular tissue of telson and uropods reticulate in appearance.

Cornea of eyes (fig. 3) wider than long, about same width as peduncle, dark brown in color. Well-developed tubercle at base of cornea on inner side of peduncle, and a smaller projection more proximally on peduncle.

First article of antennular peduncle less than twice as long as wide, with stylocerite in form of a very small acute tooth near middle of outer margin; slightly longer than outer margin of second and third together. Outer margin of third article slightly less than 1.5 times as long as wide, about same length as outer margin of second.

Inferior antennular flagellum (fig. 4) as long as two distal articles of antennular peduncle, divided into peduncle of four articles and a flagellum. Upper prolongation of third article very long, reaching to the third article of flagellum; distal portion with a strong spine. Inferior margin of prolongation somewhat concave, armed with 16 large, distally blunt and spatulate spines. Superior margin of fourth article deeply concave, terminating in a high, rounded protuberance; concave portion armed with nine spines similar to those on prolongation of third

article, but somewhat smaller. Flagellum of five articles; last article with single large spine.

Antennal scale three times longer than greatest width, narrowing distally with both margins convex; extending to distal half of third article of antennular peduncle. Apex of lamella extending beyond vestige of small distal tooth on external margin. Subcuticular tissue of scale reticulate in appearance.

Antennal flagellum extremely long. In only specimen seen with attached flagellum, the flagellum is about ten times carapace length, extending approximately 97 mm compared with a carapace length of about 9.5 mm, but is obviously longer in life as a distal portion is missing. Flagellum divided into a proximal non-setose and a distal setose portion by region in which the annuli form a double bend; annuli of distal portion bear paired plumed setae which arch upwards toward each other, between which, at various intervals of annuli, single straight plumed setae project upward.

Mandible with palp of three articles; second article one and one-half times as long as third, which is slender.

First maxilla has two strong brown spines distally on palp.

Second maxilla has endite of two lobes; proximal lobe relatively narrow and setose, distal lobe distinctly divided by an incision into two parts, proximal part narrow; endopodite armed distally with spines.

Endopodite of first maxilliped consists of three articles, reaching beyond exopodite; the distal lobe of endite two and one-half times longer than wide, proximal lobe subdivided by a suture into two parts; epipodite large and well-developed.

Second maxilliped thickly covered with golden-brown setae. Dactylus slightly more than half as long as propodus, narrow proximally, widening towards middle.

Third maxilliped reaching to distal end of antennular peduncle. Neither propodus nor dactylus divided into subsegments.

First pereopod non-chelate, reaching to distal end of first article of antennular peduncle. Carpus has four long setae in middle of inner margin; a comb-like arrangement of setae distally on carpus and proximally on propodus, in opposition across the articulation between the segments.

Fourth pereopod reaching just beyond distal end of first article of antennular peduncle. Carpus and propodus setose on only one margin.

Fifth pereopod short, reaching to proximal fifth of merus of fourth pereopod. Carpus and propodus setose on only one margin.

First maxilliped with exopodite and epipodite, no branchiae; podobranch and arthrobranchial lamella (= rudimentary arthrobranch) above second maxilliped; an anterior arthrobranch, which may have up to thirteen rami, with up to twelve lamellae per ramus, and a posterior arthrobranchial lamella above third maxilliped and first three pereopods; a well-developed anterior arthrobranch of nine rami, with up to six lamellae per ramus, and a small posterior arthrobranch of three rami bearing several lamellae each above fourth pereopod; no branchiae above fifth pereopod.

The nomenclature for describing the petasma is that used by Hansen (1919, 1922). Petasma of adult (figs. 5, 6) with pars externa an oblong plate about four times as long as wide, not divided into lamina externa and processus uncifer; distal border obliquely truncate, with sharp oblique tooth. Processus basalis moderately long, posteriorly directed, distally blunt. Pars astringens a flat, folded, rectangular plate attached to proximal part of inner margin of pars media; inner margin straight, with row of small cincinnuli. Pars media long, wide at base, narrowing gradually.

Processus ventralis long, somewhat curved, directed anteriorly and a little externally; proximally slender, thickening towards middle, where it is divided into two branches; internal branch less than half as long as external branch, terminating in one small crochet (retractable hook); external branch curved medially, narrowing distally, extending almost as far as internal branch of lobus terminalis, with 12 or 13 oblique, triangular crochets on its internal surface.

Lobus armatus divided into two branches; primary branch very thick proximally, almost conical, directed externally and to posterior, with a series of up to 11 large triangular crochets on distal part of its anterior margin; smaller secondary branch originates on posterior surface of primary branch, reaching to beyond middle of primary branch, armed with up to six crochets, including two distally.

Lobus connectens in the form of a low rounded protuberance, visible on anterior side of petasma, between lobus armatus and lobus inermis, without hooks.

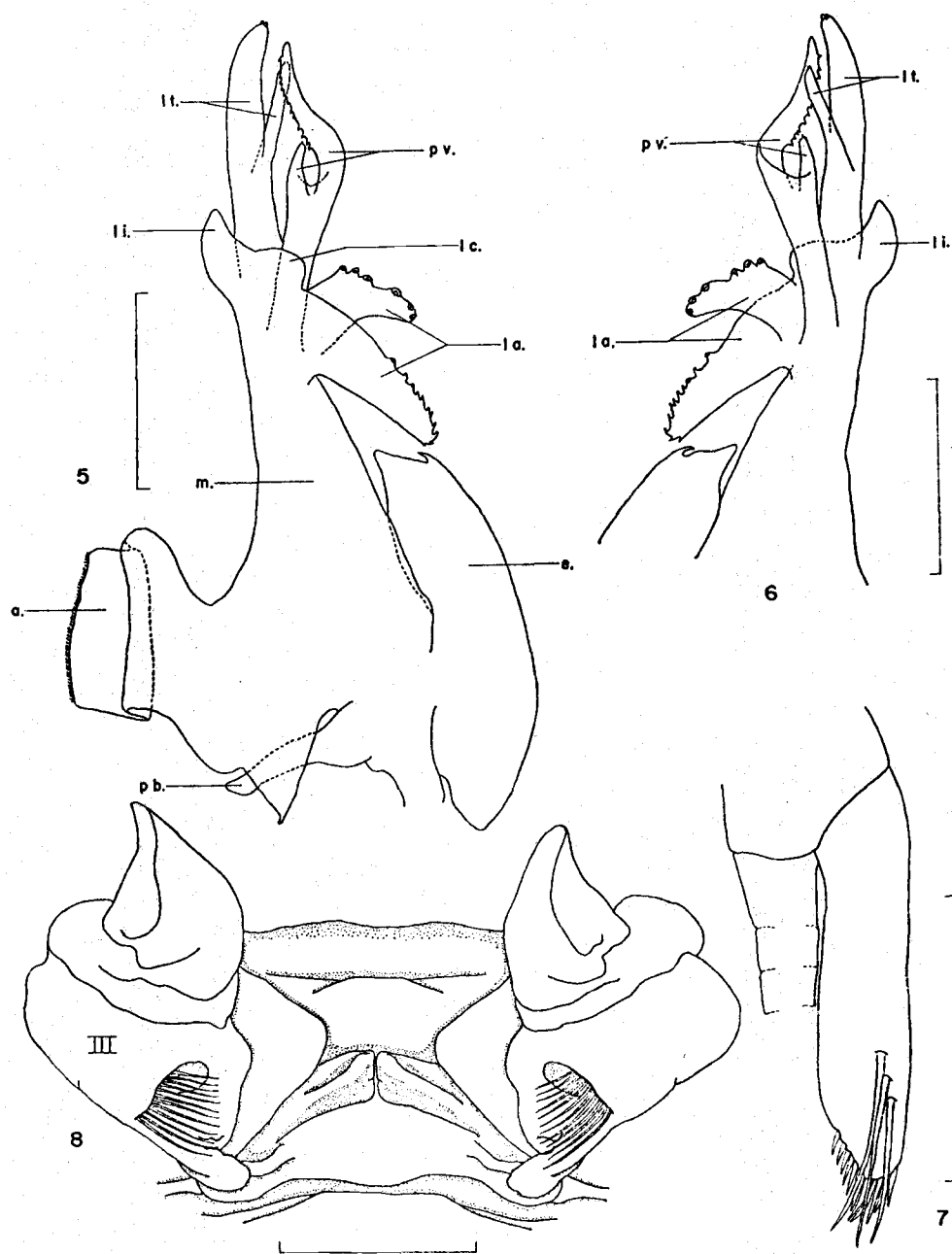
Lobus inermis conical, without hooks.

Lobus terminalis originates behind lobus connectens and lobus inermis, long, extending past processus ventralis; divided into two branches a little before its middle; external branch slim, as long as undivided portion of lobe; internal branch longer than external branch, wide, with one or two terminal crochets.

Appendix masculina (fig. 7) on second pleopod terminates in 11 spines, with three long spines on distal portion of internal surface.

Female. Females usually larger than males taken in same haul. Rostrum differs from that of males by having a pointed tip and usually a rudimentary dorsal tooth. Genital area of female (fig. 8) lacks an operculum; posterior lip of receptacular atrium incised medially, overlying anterior lip. Large triangular lamella arising from articulation of coxa of third pereopod extends about half way to incised region of posterior lip. Postero-median margin of coxa of third pereopod well-developed, in form of elongate, blunt projection, which fits into a hollow on oblique ridge at posterior edge of plate between bases of third pereopods.

Size. — Due to the fragile nature of the integument of *P. suspiriosum* and the resulting damage to many of the specimens during capture, it is often difficult to measure carapace lengths accurately. Therefore, in many cases, no attempt was made to measure carapace lengths. In those specimens which were measured, carapace lengths of males ranged from 7 mm to 11 mm; specimens with a carapace



Figs. 5-8. *Petalidium suspiriosum* Burkenroad. 5, right petasma, anterior view (carapace length 9.5 mm); 6, distal portion of right petasma, posterior view (c.l. 9.5 mm); 7, appendix masculina, medial view (c.l. 9.5 mm); 8, genital area, female, showing coxae of third pereopods (c.l. 12.5 mm). Scale = 1 mm. a. = pars astringens, e. = pars externa, la. = lobus armatus, lc. = lobus connectens, li. = lobus inermis, lt. = lobus terminalis, m. = pars media, pb. = processus basalis, pv. = processus ventralis.

length of less than 8 mm invariably had a petasma with incompletely developed lobes and crochets. Carapace lengths of females ranged from 8 mm to 14 mm.

Color in formalin. — Fresh material carmine, abdominal somites lighter; stomach and esophagus deep carmine. Older material faded to white except for stomach, esophagus, and mouthparts, which tend to retain their carmine color.

Distribution. — Northeastern Pacific Ocean. Specimens in the OSU Department of Oceanography collections have been taken as far north as $51^{\circ}40.9'N$ $138^{\circ}30.3'W$ and as far south as $34^{\circ}23'N$ $140^{\circ}46'W$. The most southerly capture record is that of the type locality, $20^{\circ}36'N$ $115^{\circ}07'W$ (Burkenroad, 1937). Although specimens have been taken by midwater trawls within the upper 200 m, *Petalidium suspiriosum* appears to be mainly mesopelagic in distribution. The results of collections made over a period of three years from the upper 1500 m of water off the central Oregon coast ($44^{\circ}39'N$ $125^{\circ}15'W$) show *P. suspiriosum* to be most abundant in the depth range of 200-1000 m (Pearcy & Forss, 1966).

Remarks. — As was pointed out by Burkenroad (1937), *Petalidium suspiriosum* differs from other members of the genus as follows in the structure of the gills: rami of the anterior arthrobranchs above the third maxilliped and first three pereopods may have as many as twelve lamellae, instead of generally five or six (Hansen, 1922); and two arthrobranchs are present above the fourth pereopod (the anterior one large and well-developed), instead of a single rudimentary one as in *P. obesum* Krøyer, 1859 (Hansen, 1922) or none as in *P. foliaceum* Bate, 1888 (Hansen, 1903; Illig, 1914).

Otherwise, *Petalidium suspiriosum* differs from *P. obesum* (as described and illustrated by Hansen, 1922) as follows: integument not reticulate except in telson, uropods, and antennal scales; cervical sulcus distinct; hepatic spines present; a second tubercle present proximal to well-developed one distally on ocular peduncle; and genital area of female without operculum over lips of receptacular atrium.

The petasma of *Petalidium suspiriosum* differs from that of *P. obesum* chiefly in the size and armature of the posterior, secondary branch of the lobus armatus, reaching beyond the middle of primary branch and armed with up to six crochets in *P. suspiriosum*, instead of being much smaller than the primary branch and armed with two crochets as in *P. obesum*; external branch of processus ventralis reaching beyond external branch, and almost as far as internal branch, of lobus terminalis; and internal branch of lobus terminalis armed with one or two terminal crochets, instead of three on its distal external face as in *P. obesum*.

Illig (1927: 283) published a rather poor figure of the petasma of a specimen of *Petalidium*, identified by him as *P. foliaceum*, taken in the South Atlantic not far north of the previous records for the species; according to Burkenroad (1937), this figure agrees with Hansen's (1922) figures of the petasma of *P. obesum* (it also bears some resemblance to the petasma of *P. suspiriosum*

as herein described). *Petalidium obesum* otherwise has been taken only in the North Atlantic, having been recorded as far north as 40°15'N 56°25'W (Hansen, 1922).

Petalidium suspiriosum differs from *P. foliaceum* Bate most clearly in the number of gills above the fourth pereopod, as pointed out above. The information concerning the nature of the cervical sulcus, the presence or absence of supraorbital and hepatic spines and of a second tubercle on the ocular peduncle in *P. foliaceum* is incomplete and sometimes contradictory. Burkenroad (1937) draws together information on these features of *P. foliaceum* from descriptions of the species by Bate (1888), Hansen (1903), Illig (1914, 1927), and Stebbing (1914). According to Hale (1941), the five specimens of *P. foliaceum* taken by the British Australian and New Zealand Antarctic Research Expedition agree closely with the "Challenger" specimens (Bate, 1888; Hansen, 1903). The cervical sulcus is well-marked; there are no supraorbital spines, but minute and easily overlooked hepatic spines are present; and the ocular peduncle has two tubercles in all the specimens. The genital area of the female appears to be much like that of *P. suspiriosum*.

Figures of the petasma of *P. foliaceum* (cf. Illig, 1914; Stebbing, 1914; and Hale, 1941) are in close agreement, and differ from that of *P. suspiriosum* as follows: the posterior, secondary branch of lobus armatus is larger and more heavily armed than the primary branch; external branch of processus ventralis reaches about as far as external branch of lobus terminalis; and internal branch of lobus terminalis has a series of large crochets on its external face.

Petalidium foliaceum appears to be subantarctic in distribution (Hansen, 1920), having been reported from the Pacific and Atlantic sectors of the Antarctic Ocean.

Petalidium is closely allied to *Sergestes* (Hansen, 1922: 189; Burkenroad, 1945: 577). Prior to the description of *P. suspiriosum*, *Petalidium* was considered to differ from *Sergestes* in the lesser degree of ramification of its gills, in the smaller number of gills above the fourth pereopods, and in the bifurcation of the processus ventralis of its petasma (Hansen, 1922; Burkenroad, 1937). The differences in gills amounted to the following: the arthrobranches in *Petalidium* had a much lower number of rami, a much lower number of lamellae per rami, with the lamellae much larger, curved upward, and looking much more independent than those in *Sergestes*; and in *Petalidium* there were no arthrobranches above the fourth pereopods (*P. foliaceum*) or a single rudimentary one (*P. obesum*), while in *Sergestes* there are always two arthrobranches above the fourth pereopods.

As has been pointed out by Burkenroad (1937), the condition of the gills in *P. suspiriosum* differs from that previously described for the genus, in that the gills are considerably more ramified (though still less so than in *Sergestes*), and that there are the same number above the fourth pereopod as in *Sergestes*.

Besides the biramous condition of the processus ventralis of the petasma of

Petalidium, Hansen (1922: 190) mentions that the petasma differs from that in *Sergestes* in that the pars externa is not divided into a lamina externa and processus uncifer, and that the pars astringens is reduced in regards to size. The petasma of *P. suspiriosum*, as herein described, agrees in these characters with the other petasmata described for the genus.

Other characters given by Hansen (1922) by which *Petalidium* differs from *Sergestes* are that the fringed portion of the outer margin of the uropodal exopodite is much shorter in *Petalidium* than in any *Sergestes*, that the telson is quite short and wide, without dorsal spines, and that the inferior antennal flagellum of the male, which is modified into a clasping organ, is very much different in *Petalidium* than in *Sergestes*. However, due to the often damaged condition of specimens of *Petalidium*, these last differences are of limited usefulness in distinguishing between the two genera.

Petalidium apparently differs further from the majority of species of *Sergestes* in lacking luminous organs of the types known to be found in *Sergestes*. Three different types of luminous organs occur in *Sergestes*, although no species has more than one type and some have none at all (Yaldwyn, 1957). Yaldwyn (1957) divided the genus *Sergestes* into the subgenera *Sergestes* and *Sergia* by the presence or absence of organs of Pesta (luminescent modifications of the gastrohepatic gland). Within the subgenus *Sergia* is a group of species lacking dermal photophores and having membranous integuments (the "*S. japonicus*" group of Yaldwyn). According to Burkenroad (1937), *P. suspiriosum* shows "considerable superficial resemblance" to *Sergestes mollis* (= *Sergestes* (*Sergia*) *japonicus*) and *Sergestes* (*Sergia*) *inons*, both members of the "*S. japonicus*" group; *P. suspiriosum* can be distinguished from these species (Burkenroad, 1937) by differences such as the appearance of its gills, by the presence of an hepatic spine, by the absence of more than one pair of lateral spines on its telson, and by its shorter but larger eyes with distomedially tuberculate peduncle.

The development of *Petalidium* is known with certainty only as far back as the early mastigopus (post-larval) stages, and in view of the general near-identity of the mastigopus and adults of *Sergestes* and *Petalidium* (Burkenroad, 1945: 566-567), it is unlikely that earlier larvae will differ greatly from those of *Sergestes*. A series of sergestid larval stages were attributed to *Petalidium* by Gurney (1924), but later were regarded as belonging to *Sicyonella* Borradaile (Gurney & Lebour, 1940). These same larvae (referred to now as "Gurney's larvae") were predicted by Burkenroad (1945) to belong to an as yet undiscovered seventh genus of Sergestidae, probably closely related to *Peisos*.

The presence in *Petalidium suspiriosum* of an antennal flagellum which is divided into a proximal and a distal portion by a section of annuli forming a double bend, with the distal section being heavily and characteristically setose, makes it possible to add *Petalidium suspiriosum* to the list of species (Foxton, 1969) which have such antennae. Foxton records such antennae from species of three genera, including the penaeids *Punchalia* and *Gennadas*, and the sergestid

Sergestes; to these he adds the sergestid *Acetes* on the basis of evidence presented by Burkenroad (1934). Of these, only the species of *Funchalia* lack the kink or double bend in the flagellum, although a point of flexure is present between the proximal non-setose and the distal setose sections (Foxton, 1969).

The hump or projection in the anterior dorsal midline of *Petalidium suspiriosum* agrees very well with Hansen's (1921) description (quoted in Hansen, 1922: 20) of the so-called "dorsal organ" found in many *Sergestes* larvae and adults. Although its function is disputed, the "dorsal organ" can be traced in the embryos, larvae, or adults of most groups of Crustacea (Gurney, 1942). This is apparently the first record of its occurrence in *Petalidium*.

ZUSAMMENFASSUNG

Petalidium suspiriosum Burkenroad, 1937, wird wiederbeschrieben an Hand von Material, das im nordöstlichen Pazifik westlich von Oregon gesammelt wurde. Die Unterschiede zwischen *Petalidium suspiriosum* und den anderen Arten dieser Gattung, und zwischen den Gattungen *Petalidium* und *Sergestes* werden diskutiert. Die Antennengeißel von *P. suspiriosum* gleicht der Geißel wie sie bei einigen Arten der Gattungen *Funchalia*, *Gennadas*, *Sergestes* und *Acetes* vorkommt. Ein „Rückenorgan“, wie in der Gattung *Sergestes*, ist ebenfalls vorhanden.

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OCCASIONAL PAPERS

OF THE

California Academy of Sciences

No. 111, 79 pages, 25 figures, 1 table.

A SYSTEMATIC REVIEW OF THE
RATTAIL FISHES (MACROURIDAE:GADIFORMES)
FROM OREGON AND ADJACENT WATERS

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INTRODUCTION

During the past decade, Oregon State University research vessels have conducted a number of cruises to sample the deep-water fauna off the coast of Oregon. Fishes of the family Macrouridae comprised the bulk of benthic catches below approximately 600 meters. Macrourids collected revealed few species, but allocating correct names to the different forms proved extremely perplexing because of inadequate published descriptions, the lack of keys, and the profusion and confusion of names previously given to the various species.

It was the intent of this study to resolve some of these problems and particularly to: (1) give adequate descriptions

and illustrations of the species found off Oregon and adjacent waters; (2) establish proper scientific names; (3) provide lists of synonyms for each species; and, finally, (4) provide a key to the species. We have also discussed the generic problems involving *Coryphaenoides* and related genera and offered our views for handling them.

The macrourid fauna in the boreal western Pacific has been recently reviewed by Rass (1963) for the Okhotsk Sea, and Okamura (1970; 1971) for the rich fauna off the coast of Japan, but no recent review is available for eastern North Pacific macrourid fishes. Earlier works on this region with important descriptive information include those by Gilbert (1891; 1892; 1895; 1915), Gilbert and Burke (1912), Jordan and Evermann (1898), Gill and Townsend (1897), Jordan and Gilbert (1899), Townsend and Nichols (1925), and Clemens and Wilby (1946). Macrourid fishes from the Pacific off Central and South America are very poorly known. Garman (1899) worked on the extensive *Albatross* collections and gave descriptions of 22 species, 20 of which he described as new. The status of many of his species (most treated as species of *Macrurus*) is presently uncertain, although Marshall (1973) allocated them to different genera. Günther (1878; 1887) and Gilbert and Thompson (1916) described a number of species from off the west coast of South America. Chirichigno F. (1968; 1969) recently treated the species off Peru, and Pequeño (1971) treated the species from off Chile, three of which he described as new.

We limited the scope of this study to the macrourid fishes found in eastern Pacific waters from northern California to the Bering Sea. Two species, *Nesumia liolepis* (Gilbert) and *Coelorinchus scaphopsis* Gilbert, have been recorded from central California and may occasionally stray into waters north of San Francisco Bay. These are included in the key, but are not described in detail. Macrourid fishes south of San Francisco are poorly known, and a comprehensive study of all eastern Pacific species is needed.

MATERIAL AND METHODS

Collections by the Oregon State University research vessels *Yaquina* and *Cayuse*, comprised the principal source of materials for this study. Depths from 637-4100 meters were sampled in four major areas off the Washington-Oregon coast: (1) the continental slope 44-833 km. off Oregon; (2) Cascadia Abyssal Plain; (3) Tufts Abyssal Plain; and (4) 185 km. west of the Strait of Juan de Fuca. Gear used was a 3-meter beam trawl (see Carey and Heyamoto, 1972) and a 22-foot Gulf semi-balloon shrimp trawl (see Day and Pearcy, 1968), both towed at 2-3 knots. Duration of drags varied from two hours on the abyssal plain to 15 minutes on the continental slope. Specimens deposited at Oregon State University are housed either in the Department of Oceanography

(OSUO), or in the Department of Fisheries and Wildlife (OSUFW). Representative specimens now listed as OSUO uncataloged will be deposited at the California Academy of Sciences after other studies have been completed on them. Other collections used to supplement Oregon State University material are those of the College of Fisheries, University of Washington (UW); University of British Columbia (UBC); California Academy of Sciences (CAS); Ichthyological Collections, Stanford University (SU) (now housed at CAS); Scripps Institution of Oceanography (SIO); U. S. National Museum of Natural History (USNM); Museum of Comparative Zoology, Harvard University (MCZ); and Humboldt State College.

Methods for taking meristic and morphometric data follow general procedures described by Gilbert and Hubbs (1916), Hubbs and Lagler (1958), and modified by Iwamoto (1970). The measurement 'internasal width' refers to the least distance between the supranarial ridges. In the descriptions, the information given pertains only to specimens we examined, unless otherwise stated. In the 'Specimens Examined' sections, the depository is listed first, followed by the catalog number (if available), the number of specimens and the ranges of head and total lengths (in parentheses), and pertinent capture data.

ACKNOWLEDGMENTS

We are indebted to many persons for their help in the preparation of this paper. The following curators and staff members assisted us in the examination of specimens under their care: Dr. Miles Alton, National Marine Fisheries Service, Seattle; Mr. Robert Behrstock, Humboldt State University; Dr. William N. Eschmeyer, Mrs. Lillian J. Dempster, and Miss Pearl Sonoda, California Academy of Sciences; Mr. Thomas McClain, Department of Fisheries and Wildlife, Oregon State University; Dr. Richard H. Rosenblatt and Mr. Joseph Copp, Scripps Institution of Oceanography; Dr. Victor G. Springer, United States National Museum of Natural History; Dr. Norman J. Wilimovsky, Mr. Tony Kluge, and Mr. Don E. Wilson, University of British Columbia.

Mr. Richard A. Grinols, Peninsula Junior College, Port Angeles, Washington, kindly furnished us with data, photographs, and radiographs of specimens he had studied while employed by the U. S. Fish and Wildlife Service, Seattle, Washington. Dr. Daniel M. Cohen, National Center for Systematics, Washington, D.C., advised and assisted us in numerous ways. Dr. Carl L. Hubbs, Scripps Institution of Oceanography, gave advice and kindly allowed us to examine and describe the new species of *Coryphaenoides* he had previously planned to study. Mr. S. Jurgen Westheim, Fisheries Research Board of Canada, made possible the collection of a specimen of *Nezumia stelgidolepis* off British Columbia. Larry Hanna, Julie Ambler, and Martha Casteel, Oregon State

University, assisted in the examination of specimens. Dr. Lo-Chai Chen, California State University, San Diego, helped in the loan of specimens.

We gratefully acknowledge the aid of Dr. William G. Pearcy, School of Oceanography, Oregon State University, who initiated and encouraged this study. Financial support was provided through a grant to Dr. Pearcy from the U. S. Atomic Energy Commission (RLO 227-T12-35, "Ecological and radioecological studies of the Columbia River estuary and adjacent Pacific Ocean").

Drs. D. M. Cohen, W. N. Eschmeyer, and W. G. Pearcy critically reviewed and gave useful advice on improving the manuscript.

Key to adult macrourids of the eastern North Pacific north of San Francisco, California

- 1a. A stout spinous ridge midlaterally on head, passing continuously from tip of snout to preopercle angle (fig. 1A). A large, black, naked fossa midventrally on chest; anus at origin of anal fin (fig. 2A). Second dorsal spine smooth at all sizes (fig. 3A). Pelvic fin rays invariably 7.....*Coelorrhinus scaphopsis* (p.50)
- 1b. Not as above combination of characters..... 2
- 2a. Anus far removed from origin of anal fin; usually a small black naked fossa (sometimes obscure) located anterior to anus (fig. 2B). Branchiostegal rays 7..... 3
- 2b. Anus immediately anterior to anal fin; no black naked fossa on abdomen (fig. 2C). Branchiostegal rays 6..... 4
- 3a. Second dorsal spine strongly serrate (fig. 3C). Scales along suborbital shelf very stout, coarse, strongly adherent. Black naked fossa of light organ, when present, between bases of pelvic fins (fig. 2B). Pelvic fin rays 9-10 (usually 10).....*Nezumia stelgidolepis* (p.47)
- 3b. Second dorsal spine weakly serrate (fig. 3B). Scales along suborbital shelf, if present, weak and deciduous. Naked fossa on abdomen very small, situated notably posterior to a line connecting bases of pelvic fins. Pelvic fin rays 10-11 (usually 11).....*Nezumia liolepis* (p.46)
- 4a. Pelvic fin rays 7, rarely 6 or 8 (if 8, upper jaw long, extending past vertical through posterior margin of orbits and with no stout spinous

- scutes on snout tip).....
*Coryphaenoides pectoralis* (p.37)
- 4b. Pelvic fin rays 8 or more (if 8, upper jaw shorter, not extending past vertical through posterior margin of orbits and with stout scute-like scales on snout tip)..... 5
- 5a. Teeth in upper jaws in one or two (widely separated) distinct rows, the teeth in the outer row much larger than those of inner row..... 6
- 5b. Teeth in upper jaws in two irregular rows (rows not distinct and not widely separated), or more than two rows, or teeth in bands..... 8
- 6a¹. Pores on ventral surfaces of lower jaws and sub-orbital region large and prominent (figs. 12, 15B)..... 7
- 6b¹. Pores on ventral surfaces of lower jaws and sub-orbital region small, inconspicuous (fig. 15A) 8
- 7a. Outer ray of pelvic fin extremely long, 136-192 percent of H.L. First dorsal fin rays II, 12-14.....*Coryphaenoides longifilis* (p.24)
- 7b. Outer ray of pelvic fin not notably long, less than 90 percent of H.L. First dorsal fin rays II,8-10.....*Coryphaenoides armatus* (p.27)
- 8a. Orbits small, horizontal diameter 15-21 percent of H.L. Ventral surfaces of snout, suborbital area, preopercle, and lower jaws naked. Interopercle slender (fig. 24)..... 9
- 8b. Orbits moderate to large, 23-34 percent of H.L. Naked areas on head usually confined to ventral surfaces of snout; suborbital area, preopercle, and lower jaws usually completely covered with scales. Interopercle broad, not shaped as in figure 24..... 10
- 9a. Snout pointed, protruding well beyond mouth. Scales stout, coarse, strongly spinulated; spinules aligned in 3-6 sharp, ridge-like rows. Length outer gill-slit 18-20 percent H.L.*Coryphaenoides yaquinae* (p.34)

¹Couplet 6 comprises a second set of characters that will serve in the event of questionable interpretation of teeth patterns (from couplet 5) in specimens of *C. acrolepis*, *C. filifer*, and *C. yaquinae*. Teeth in upper jaws in *C. leptolepis* are always in a broad band.

- 9b. Snout bluntly rounded, scarcely protruding beyond mouth. Scales thin, deciduous; spinulation on scales reduced, present as greatly reclined points along low divergent ridges. Length outer gill-slit 23-28 percent H.L. ...
*Coryphaenoides leptolepis* (p.42)
- 10a. Pelvic fin rays 8, rarely 9. First dorsal fin rays II,9-11. Entire orbital circumference black. Outer pelvic ray relatively short, 50-70 percent H.L. Entire leading edge of snout with series of enlarged tubercular scales.....*Coryphaenoides acrolepis* (p.12)
- 10b. Pelvic fin rays usually 9-10, rarely 8. First dorsal fin rays II,10-14. Orbital rim black anteroventrally only. Outer pelvic fin ray usually greater than 70 percent H.L. Leading edge of snout with enlarged tubercular scales only at tip and at lateral angles.. 11
- 11a. First dorsal fin rays usually II,10-12 (one with II,14). Internasal width broad, 20-25 percent H.L. Suborbital shelf very narrow anteriorly with small thorn-like branch on anteroventral margin (fig. 5B).....
*Coryphaenoides cinereus* (p.20)
- 11b. First dorsal fin rays usually II,12-14, rarely II,11. Internasal width narrower, 16-20 percent H.L. Suborbital shelf not especially narrow anteriorly, no thorn-like branch on ventral edge of shelf (fig. 5A)....
*Coryphaenoides filifer* (p.17)

Genus *Coryphaenoides* Gunner, 1765

- Coryphaenoides* Gunner, 1765 (type-species *Coryphaenoides rupestris* Gunner, 1765, by monotypy).
Chalinura Goode and Bean, 1883, p. 198 (type-species *Chalinura simula* Goode and Bean, 1883, by monotypy).
Nematonurus Günther, 1887, p. 150 (as subgenus, type-species *Macrurus armatus* Hector, 1875, by subsequent designation).
Lionurus Günther, 1887, p. 141 (as subgenus, type-species *Coryphaenoides filicauda* Günther, 1878, by subsequent designation).
Moseleya Goode and Bean, 1896, p. 417 (type-species *Coryphaenoides longifilis* Günther, 1877, by original designation).
Albatrossia Jordan and Evermann, 1898, p. 2573 (type-species *Macrurus pectoralis* Gilbert, 1892, by original designation).
Bogoslovius Jordan and Evermann, 1898, p. 2574 (type-species

- Bogostolius clarki* Jordan and Gilbert, in Jordan and Evermann, 1898, by original designation).
Dollos Jordan, 1900, p. 897 (replacement for *Moseleya* Goode and Bean, preoccupied).
Hyomacrurus Gilbert and Hubbs, 1920, p. 422 (as subgenus, type-species *Macrourus hyostomus* Smith and Radcliffe, in Radcliffe, 1912, by original designation).
Hemimacrurus Fraser-Brunner, 1935, p. 322 (type-species *Macrurus acrolepis* Bean, 1884, by original designation).
Cariburus Parr, 1946, p. 57 (type-species *Macrurus santophorus* Vaillant, 1888, by original designation).

DIAGNOSIS. Branchiostegal rays 6. Anus situated immediately in advance of anal fin or slightly anterior to it, but never associated with a light organ. No light organs present. Dentition highly variable in size and arrangement between species, in broad bands to one or two distinct rows on premaxilla; in broad bands to a single row on mandible; teeth never very few and fanglike. Snout shape variable, from sharply pointed to bluntly rounded. Scaling on snout from completely and uniformly scaled to entirely naked; snout frequently armed with stout, tubercle-like buttons at tip and lateral angles. Suborbital ridge variable, from prominent, sharp, and stout, to faint and smoothly rounded; suborbital ridge never extends continuously to preopercle ridge. Pelvic fin highly variable in length and in ray count (which varies from 6-14). Second spinous ray of dorsal fin usually slightly prolonged and serrated along leading edge; rarely completely smooth. Anterior rays of second dorsal fin never well developed. Precaudal vertebrae 12-16 (judging from the few species we examined for this character). Pyloric caeca relatively few, simple, unbranched, usually slender and relatively long, usually fewer than 20. Retia and gas glands 2-6 each. Exposed fields of scales invariably covered with spinules or radial ridges at some stage of life; spinulation usually reduced in number and size in very young and in very deep dwelling, soft-bodied species (particularly in subgenus *Lionurus*); spinulation sometimes reduced in large specimens of some species.

REMARKS. We follow the Gilbert and Hubbs' (1916) concept of the genus, further clarified by the detailed works of Okamura (1970; 1971). We do not follow Parr's (1946) recognition of *Nematonurus*, *Cariburus*, *Coryphaenoides*, and *Chalinura*. Although Parr's structuring of this complex suits the western Atlantic species reasonably well, species from other parts of the world break down his generic framework. We do agree with Parr, however, that *Macrourus berglax* Lacépède, 1802, and *Coryphaenoides rupestris* represent opposite extremes. We have not examined in detail members of the genus *Macrourus* and, therefore, cannot comment fur-

ther on the genus. Marshall (1973) recognized only three species of *Macrourus*: *M. berglax*, *M. holotrachys* Günther, 1878, and *M. whitsoni* Regan, 1913.

Parr appreciated the distinctness of *C. rupestris* and Marshall and Iwamoto (1973) further added that "in its combination of a relatively high snout, scaling on the anterior gular membrane, a high number of gill rakers on the second arch, reduced mandibular dentition and short abdominal region, *C. rupestris* is not closely related to any known species of the genus." In fact, in its head and body shape, *C. rupestris* is remarkably similar to members of *Cetonus*, a macrourine genus with seven branchiostegal rays. If we followed Parr's definition of *Coryphaenoides*, the only species included would be *C. rupestris*.

Parr's diagnosis for *Nematonurus* is untenable. He used proportional measurements to differentiate *Nematonurus* from *Cariburus*, *Chalinura*, and *Coryphaenoides*. His diagnostic characters, however, show considerable individual as well as size-related variation. For example, he used the length of the trunk, as reflected in the measurement snout to anal origin, as a key character distinguishing *Nematonurus* from the other three genera. *Nematonurus* supposedly has a snout-to-anal-origin length nearly twice that of the head compared with less than two-thirds longer than head in *Cariburus*, *Chalinura*, and *Coryphaenoides*. A brief survey of that measurement in other species shows how unacceptable it is as a generic character. *Coryphaenoides armatus*² has an exceptionally long trunk and its great snout-to-anal measurement (160-210 percent of head length) reflects this. But some specimens of *C. macrocephalus* Maul, 1951, have trunks almost as long (150-190 percent) but with the lower part of the range well below the "less than 2/3 longer than head" figure. Other species that fall on either side of the supposed dividing line include: '*pectoralis*' (144-182), '*yaquinae*' (163-178), '*guentheri*' (Vaillant, 1888) (159-179), '*colon*' Marshall and Iwamoto, 1973, (158-178), '*filifer*' (129-174), and '*acrolepis*' (142-167). Thus, based on that character, different individuals of one species may fall in either key category.

The same sort of situation applies with Parr's other character for *Nematonurus*, "ventrals well behind pectorals, but distance from base of outer ventral rays to anal fin more than 2/3 length of head." Small individuals of '*arma-*

²It should be noted that Parr (1946, p. 18) used *Nematonurus goodii* in his discussion of the subfamily, yet he later placed that name in the synonymy of *N. armatus*. Furthermore, he failed to realize that Gilbert and Hubbs (1916, p. 162) did not retain *Nematonurus* as a genus but rather relegated it to subgeneric status.

tus' (see fig. 13) and 'macrocephalus' and most specimens of 'pectoralis', 'longifilis', and 'yaquinae' have their ventrals directly under the pectorals, but their outer ventral to anal measurements fall at or beyond the supposed "2/3 length of head" limit. A few examples of this measurement (expressed as percent of head length) serve to illustrate its variability within a species and its wide overlap between distantly related species: 'cinereus' 43-57; 'filifer' 41-77; 'acrolepis' 49-67; 'pectoralis' 51-76; 'yaquinae' 61-77.

Parr's *Cariburus* and *Chalinura* represent two relatively distinct but closely related groups. However, using his definitions would necessitate including in *Cariburus* most species that we consider as belonging in subgenus *Coryphaenoides*. If we accept Parr's concepts of both *Coryphaenoides* and *Cariburus*, then *Cariburus* must be relegated to the status of a junior synonym of *Hemimacrus* Fraser-Brunner with *Macrus* *acrolepis* Bean as type-species.

Marshall (1973) used other characters to redefine the several natural groups within the *Coryphaenoides* complex. However, his key to the genera breaks down, in places, when dealing with this complex. For example, in one couplet he used the extent of scaling on the head and snout to differentiate *Coryphaenoides* from *Macrourus*, *Nematonurus*, *Chalinura*, and *Lionurus*, but our experience has been that this character is too variable between and within species of *Coryphaenoides* to be consistently useful at the generic level. One of Marshall's key characters for distinguishing *Coryphaenoides* is "Head fully scaled except for the gular and branchiostegal membranes." Marshall and Iwamoto (1973) on the other hand reported scales on the anterior part of the gular membrane in *C. rupestris*, and we have found small loose scales on some specimens of *C. acrolepis* and *C. filifer*. Marshall's use of retia mirabilia numbers appear good for distinguishing *Coryphaenoides* (4) and *Macrourus* (4) from *Nematonurus* (5?), *Chalinura* (6), *Lionurus* (6), and *Hyomacrus* (2). This character lends support for recognizing a subgenus *Albatrossia* to include 'pectoralis', a species Marshall and Iwamoto (1973) included in *Coryphaenoides*, but which has only two retia. The high retia counts in *Nematonurus* (5 fide Marshall, but we counted 6 in 'yaquinae' and 'armatus' and only 4 in 'longifilis'), *Chalinura* and *Lionurus* probably indicates a close relationship of the three. (See also comments under 'Remarks', p. 80, in description of subgenus *Chalinura*.) Marshall's figures for abdominal vertebrae numbers is inconsistent with our limited findings. He gives 11 or 12 as the number in *Coryphaenoides*, but our data show 'acrolepis' with 14-16, 'filifer' with 13-14, 'cinereus' with 13-14, and an undescribed species from the Eastern Pacific with 12. *Nematonurus*, according to Marshall, has 15, but we found 13-15 in 'armatus', 13-14 in 'pectoralis', and 14-15 in 'longifilis'.

Although we agree that Marshall's genera do generally represent natural groups, we feel that they are best considered as subgenera. It is apparent that *Chalinura*, *Coryphaenoides*, *Lionurus*, *Nematonurus*, and *Hyomacrus* are more closely related to each other than to any genus outside this group. Treating *Coryphaenoides* as a broadly encompassing genus and using subgeneric designations for the groups within *Coryphaenoides* conveys our ideas of relationships best. Bolin (1947) and Rosen and Bailey (1963, pp. 5-7) gave useful discussions of the pragmatic and philosophic needs of taxonomy in the delimitation of genera. We have given their comments much consideration in our treatment of the *Coryphaenoides* complex.

The diagnoses given below for the three subgenera of *Coryphaenoides* from the eastern North Pacific are preliminary and subject to alteration when examination of other specimens adds additional information. It is apparent that much work remains before a good understanding of the phylogeny of this diverse genus is realized.

VARIATION OF DENTITION PATTERNS IN GENUS *CORYPHAENOIDES*

Patterns of dentition have long been used to support generic recognition of groups of species related to *Coryphaenoides*. Dentition patterns were initially used by Günther (1887, p. 124) to distinguish the genera *Coryphaenoides*, *Nematonurus*, and *Chalinura*. Goode and Bean (1896) and Jordan and Evermann (1898) used them in distinguishing even more genera. Gilbert and Hubbs (1916), however, after examining most of the known species of macrourids, found species with intermediate dentition. They consequently placed *Albatrossia* and *Bogoslovia* in the synonymy of *Nematonurus*, relegated *Nematonurus* to subgeneric status under *Coryphaenoides*, and placed *Chalinura* in the synonymy of subgenus *Coryphaenoides*. Okamura (1970; 1971) concluded after detailed study of many different characters, including dentition patterns, that *Nematonurus* is best treated as a subgenus of *Coryphaenoides*. Marshall (1973) used dentition patterns in his key to the macrourine genera to separate *Nematonurus*, *Chalinura*, and *Lionurus*. Our examination of large series of specimens of some of the species treated here revealed much variation in dentition patterns within and between species, such that they cannot generally be used as primary characters to distinguish genera. Nevertheless, enough differences do exist between certain groups in the *Coryphaenoides* complex that the character may be of some use at the subgeneric level. The dentition patterns of species belonging to three subgenera of *Coryphaenoides* are, therefore, here described in detail.

1. Subgenus *Coryphaenoides*. Members of subgenus *Coryphaenoides* characteristically have teeth in bands on both

jaws. Unlike *Chalinura*, with no variation in premaxillary dentition, in *Coryphaenoides* the teeth vary considerably making it difficult to utilize dentitional characters to differentiate between this subgenus, *Nematonurus*, and the three members of subgenus *Coryphaenoides* considered here. In *C. (C.) acrolepis*, the pattern of premaxillary teeth is variable at all sizes; variation does not appear to be associated with age or growth. Teeth are arranged in either two irregular rows or in a narrow band; in the latter case, the outer series of teeth is often much enlarged. Mandibular teeth are smaller than those on the premaxilla, although similarly arranged. *Coryphaenoides (C.) cinereus* is unlike either *C. acrolepis* or *C. filifer* in having both jaws with narrow bands of uniformly small teeth which do not seem to vary extensively. The dentition of *C. filifer* resembles that of *C. acrolepis* in type of variation but shows a lesser degree. Most individuals of *C. filifer* have premaxillary teeth in bands with enlarged outer series. The pattern of the mandibular teeth is usually irregularly biserial but is occasionally narrowly banded.

2. Subgenus *Nematonurus*. Members of subgenus *Nematonurus* usually have premaxillary teeth in two distinct rows, the inner row well separated from the outer one and much reduced. Mandibular teeth are usually uniserial but sometimes irregularly biserial in arrangement. Three out of four northeast Pacific species of *Nematonurus* (*C. yaquinae* the exception) exhibit these dentition characteristics in specimens smaller than about 700 mm. total length, but not in larger ones. Premaxillary teeth of large specimens of *C. pectoralis* are in bands that consist of very large, strong, slightly recurved teeth that decrease in size inwardly. Mandibular teeth are in two irregular rows or very narrow bands in larger individuals. The premaxillary dentition pattern of *C. longifilis* does not change with size of the fish, but remains in essentially two rows. Mandibular teeth in *C. longifilis* are in one or two rows; when in two rows, teeth in the outer row are much reduced while those in the inner are enlarged. In *C. armatus*, the inner series of the premaxilla regresses with increase in size, with the result that, in large specimens, the premaxillary dentition consists of only a single row. Mandibular dentition is uniserial at all sizes. In *C. yaquinae*, teeth in the upper jaws are arranged in three irregular rows or in a widely scattered band. Teeth in the lower jaws are in about two irregular series near the symphysis and in a single row posteriorly.

3. Subgenus *Chalinura*. The dentition pattern of *Coryphaenoides (Chalinura) leptolepis* is generally consistent with that of other members of the subgenus. The premaxillary dentition invariably consists of a wide band of uniformly small teeth, the band narrowing posteriorly, with an

outer series of much enlarged wide-spaced teeth. The arrangement of mandibular teeth varies, however, both with size and between individuals. Small (shorter than 200 mm. total length) individuals have teeth of uniform size, biserial or in bands, but irregularly arranged. Larger specimens tend to have a uniserial (although often irregular) arrangement of teeth. Most large (longer than 400 mm. total length) members of *C. leptolepis* have spaced, uniform, uniserially arranged mandibular teeth, as characteristic for the subgenus.

Subgenus *Coryphaenoides* Gunner

DIAGNOSIS. Arrangement of teeth variable but usually in a narrow to broad band on both jaws and never in (1) two distinct rows above and one row below, or (2) a broad cardinal band of minute teeth with distinctly enlarged, spaced outer series above and a distinct single row of slightly enlarged teeth below. Anus immediately in front of anal fin. Scales usually adherent and coarse with well developed spinules; scales at tip and lateral angles of snout and along suborbital ridge often stoutly enlarged and deeply embedded. Opercular openings usually somewhat restricted ventrally and broadly connected to isthmus, with rather narrow free fold or none over isthmus. Outer (first) gill-slit moderately to greatly restricted. Precaudal vertebrae 12-16. Retia and gas glands 2-4 each.

Coryphaenoides (Coryphaenoides) acrolepis (Bean).
(Figures 6, 7.)

Macrurus acrolepis Bean, 1884, pp. 362-363 (original description; holotype, USNM 32496, from stomach of a fur seal, Juan de Fuca Strait off Neah Bay, Washington); Gilbert, 1895, p. 457 (*Albatross* collections records off Washington and Oregon, 345-786 fathoms (631-1437 meters)); Jordan and Gilbert, 1899, p. 487, pl. 82 (1 juvenile specimen; illustration; Bering Sea off Bogoslof Island, *Albatross* station 3634 in 664 fathoms (1214 meters)); Evermann and Goldsborough, 1907, p. 350, fig. 131 (records; illustration of juvenile after Jordan and Gilbert, 1899); Gilbert and Burke, 1912, p. 91 (8 *Albatross* collections off Aleutian Islands and east of Kamchatka, in 344-1217 fathoms (629-2226 meters)); Gilbert, 1915, p. 376 (records off California between San Diego and Monterey Bay, in 331-1350 fathoms (605-2469 meters)); Townsend and Nichols, 1925, p. 16, pl. 4 (numerous specimens between 29°N. and 36°N., in 534-1090 fathoms (976-1993 meters)); Johnsen, 1927, p. 241 (considered *Ateleobranchium pterotum* Gilbert and Burke to be a larva of "*Macrurus* sp., possibly *acrolepis*"); Schultz and DeLacy, 1936, p. 15 (range, records).

- Macrurus firmisquamis* Gill and Townsend, 1897, p. 234 (original description; holotype, USNM no. 48779, 31 inches long, Bering Sea, SW. of Pribilof Island, Albatross collections).
- Bogoslavius firmisquamis*, Jordan and Evermann, 1898, pp. 2575-2576 (description); Evermann and Goldsborough, 1907, p. 349 (1 specimen; Bering Sea).
- Coryphaenoides bona-nox* Jordan and Thompson, 1914, p. 305, pl. 38, figs. 1, 1a (original description; illustrations; Japan); Gilbert and Hubbs, 1916, pp. 162-163 (2 specimens, Enoshima, Japan; species synonymized with *Macrurus acrolepis* Bean).
- Hemimacrurus acrolepis*, Fraser-Brunner, 1935, p. 322 (*Macrurus acrolepis* Bean designated type species for new genus *Hemimacrurus*); Grey, 1956, pp. 181-182 (distribution; records; extensive synonymy); Rass, 1963, p. 219, fig. 4, table 7 (description; illustration; 28 specimens, 51-87 cm.; Okhotsk Sea SW. of Bussol Strait and Kurile-Kamchatka Trench, over waters 3420-8100 meters in depth using midwater nets).
- Coryphaenoides acrolepis*, Gilbert and Hubbs, 1916, p. 162 (name in footnote; placed in subgenus *Nematonurus*); Makushok, 1967, pp. 201, 203 (comments on bathypelagic life habits, mass concentrations, feeding; compiled); Okamura, 1970, pp. 125-129, pl. 27, text fig. 51 (good description; illustration; 11 specimens, 380-748 mm. total length, off Japan, in 620-2200 meters).
- Nematonurus acrolepis*, Okada and Matsubara, 1938, p. 448 (not seen); Okada, 1955, pp. 424-425, text fig. (description; illustration).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers: outer series of first arch 5-7; inner series first arch 11-13 total (usually 2 + 10-11); inner series second arch 12-14 total (usually 2 + 10). Scales below origin of first dorsal fin 9-13; below origin of second dorsal fin 7-9.

MORPHOMETRY. Measurements based on 20 specimens ranging from 26-159 mm. in head length, 140-783 mm. in total length. The following in percent of head length: snout length 25-30; preoral length 13-19; horizontal diameter of orbits 24-31; interorbital width 18-24; orbit to angle of preopercle 38-43; suborbital width 11-13; length upper jaw 36-44; length barbel 11-19; (usually 15-19); length outer gill-slit 14-22 (usually 15-16); preanal length 142-167; distance isthmus to anal origin 82-100; greatest body depth 57-82 (usually about 65-75); height first dorsal fin 72-93; length pectoral fin about 50-55; length pelvic fin about 50-70; interspace between first and second dorsal fins 8-15.

DESCRIPTION. Figures 6 and 7 show general features of

the fish at both small and large sizes. The head is relatively shallow, broad, and the surface contours are generally rounded. Relatively stout ridged scutes cover the tip and lateral angles of the snout. Ridges on the snout and suborbital are rounded and not particularly conspicuous in larger specimens. The ridges, however, appear somewhat more angular in smaller specimens (smaller than about 100 mm. head length). The interopercle is broadly exposed and scaled posteriorly beyond the preopercle. Gill openings are moderately wide; they extend forward to a point slightly behind a vertical through the posterior edge of the orbits. The gill membranes are restricted over the isthmus with only a narrow free fold, if any.

Some distinct size-related changes were noted in the morphometry of certain head characters. The snout appears more slender and less bluntly pointed in specimens larger than about 70 mm. head length. The head also seems much more robust in comparison to the body in the small specimens. The orbits are relatively smaller in the larger specimens. In specimens under 25 mm. head length, the orbits go approximately 0.7-0.9 times into the snout and about 1.1-1.3 into the postorbital length. In specimens 40-50 mm. head length, the orbits go about 0.9-1.1 times into the snout and 1.2-1.6 into the postorbital length. In the largest specimens, 100 mm. head length or larger, the orbits go about 1.2-1.3 times into the snout and about 1.8-2.0 into the postorbital length.

Scales are adherent and uniformly cover all surfaces of the head and body with the exception of the fins and a ventromedian area on the snout. This scaleless area on the snout continues posteriad as a narrow margin along the ventral edge of the snout and suborbital. In some specimens, the naked area extends dorsally over the leading edges of the snout on both sides of the midline. Patches of small scales are sometimes present on the branchiostegal and gular membranes of large specimens. Mucous pores, sometimes fairly prominent, liberally pocket the naked areas on the snout and suborbital. Scales along the suborbital are comparatively small, but resemble most scales on the head in being strongly adherent. Small, strong, close-set spinules form three sharp, divergent, ridge-like rows on most scales of the suborbital region. Scales on other parts of the head and body usually have spinules arranged in more than three rows, and the spinules are finer. In the largest specimens examined, five divergent rows of spinules were present on large scales of the trunk. The number of spinule rows varied from 3-5 in smaller specimens, but the rows were nevertheless well developed at all body sizes.

The paired, first dorsal, and anal fins are well developed, but no rays are particularly long. The first spinous ray of the dorsal fin protrudes as a sharp stout spike at the base of the long serrated second spine. Serrations on

the spine are large and strongly developed in all specimens, regardless of size. They are, however, more numerous and more closely spaced in individuals up to about 130 mm. head length; in larger specimens, serrations tend to be less prominent and reduced in size near the base. The outer ray of the pelvic fin is slender and slightly prolonged. The filamentous tip of that ray barely extends posteriad beyond the anal-fin origin in all specimens.

Four slender retia were each connected to four small gas glands in two specimens examined. Pyloric caeca were long and slender, 12, 12, and 14 in three specimens. Okamura (1970, p. 126) counted 13 in three specimens.

Coloration is generally grayish brown to dark chocolate brown overall, the darker color most common in the largest specimens. Specimens smaller than about 70 mm. in head length frequently tend to be tawny overall, with a silvery gray sheen about the abdomen and gill cover. Fins are pale to dusky in smaller specimens, but blackish in larger specimens. The orbital rim is conspicuously black in all fresh and most preserved specimens; this feature serves as a useful diagnostic character, particularly under field conditions.

COMPARISONS AND RELATIONSHIPS. *Coryphaenoides acrolepis* seems closest to *C. filamentosus* Okamura from Japan. It bears many superficial resemblances to that species, especially in squamation and head configuration. *Coryphaenoides filamentosus*, however, has a blunter, higher, and shorter snout, a deeper body, broader interorbital space, longer pectoral fins, higher first dorsal fin, and the gill membranes forming a broad, free fold over the isthmus.

Coryphaenoides acrolepis is not likely to be confused with any boreal eastern Pacific species of Macrouridae. The species is readily distinguished from *C. armatus* by its fewer pelvic finrays, its dentition, the absence of large naked areas below the suborbital, preopercle, and mandible (that are so conspicuous in *C. armatus*), the shorter interspace between the dorsal fins (8-15 percent head length compared with 39-77 percent), the larger orbits (24-28 percent head length vs. 18-24), and numerous other features.

Coryphaenoides acrolepis can be distinguished from *C. filifer* by its fewer dorsal rays (II, 8-11 versus usually II, 12-13), fewer pelvic rays (usually 8 versus usually 10-11), its shorter paired and first dorsal fins, more adherent scales armed with stouter spinules arranged in sharper more divergent rows, black orbital rims, and numerous other characters.

REMARKS. This well known, widely distributed fish has been reported many times. It was the first known macrourid fish from the eastern Pacific, and it is now probably the best known rattail in the entire North Pacific. Although the holotype (the only type specimen), is in poor condition (having come from the stomach of a seal), there is little doubt that specimens reported subsequent to the original

description under the name *C. acrolepis* all refer to the same species.

We have examined the holotype (USNM no. 48779) of *Macrurus firmisquamis* Gill and Townsend and found no difference between that specimen and others identified by various workers as *C. acrolepis*.

SIZE. The holotype of *M. firmisquamis*, at 159 mm. head length and 783 mm. total length, is the largest specimen we have examined. Rass (1963, p. 220) reported specimens as large as +87 cm. in length taken over the Kurile-Kamchatka Trench.

DISTRIBUTION. The species is broadly distributed and abundant in boreal slope waters of the North Pacific basin. It ranges from southern California to Alaska in the eastern Pacific and from Japan to the Okhotsk and Bering Seas in the western Pacific. Its primary depth range appears to be about 600 to 2500 meters, but the species is recorded from drags made at even greater depths. Rass (1963, table 7) reported 25 specimens captured over the Kurile-Kamchatka Trench with a conical net fished from 8000 meters to the surface over a bottom depth of 8100 meters. It is doubtful, however, that the fish were actually captured at the 8000-meter level. They were more likely taken in the mid-waters where they apparently lead a partially bathypelagic life. Rass (1963, p. 221) gave an example of a large specimen of *C. acrolepis* taken in a fish-plankton net in waters more than 1250 meters above the bottom (which was 3250 meters below the surface). Makushok (1967, p. 201) stated that the species is not infrequently taken several thousand meters above bottom, and that based on stomach contents, Birshteyn and Vinogradov (1955, as cited by Makushok) considered the species bathypelagic. The R/V *Yaquina* captured a 610-mm. specimen of *C. acrolepis* (OSUO no. 1718) in a 6-foot midwater trawl fishing at a depth of 0-1000 meters over a bottom depth of 2800 meters (44°42.2'N., 125°44.8'W.).

SPECIMENS EXAMINED. USNM no. 48779 (holotype of *Macrurus firmisquamis* Gill and Townsend, 159 mm. H.L., 783 mm. T.L.) Bering Sea, SW. of Pribilof Island, *Albatross* collections; USNM no. 188140 (1, 67 mm. H.L.), off Oregon, 45°49' N., 124°52'W., R/V *Cobb*, in 415-427 fathoms (759-780 meters); UW no. 19293 (1, 153 mm. H.L., 655 mm. T.L.), SW. of Columbia River, 46°N., 125°W., 750 fathoms (1372 meters); UW no. 19308 (4, 80-141 mm. H.L., 400-630 mm. T.L.), SW. of Columbia River, 46° N., 125° W., 750 fathoms (1372 meters); USNM uncataloged (1, 99 mm. H.L.), off Washington, 47°22'N., 125°48'30"W., *Albatross* station 3074, 877 fathoms (1604 meters); OSUO uncataloged (6, 74-144 mm. H.L., +340-700 mm. T.L.), 48°38.0'N., 127°00.0'W., *Yaquina* trawl no. BMT 9 DWD, in 2189 meters; OSUO no. 377 (1, 121 mm. H.L., 540 mm. T.L.),

48°38.5'N., 126°58.0'W., *Yaquina* trawl no. BMT 10 DWD, in 1998 meters; OSUO no. 393 (1, 74 mm. H.L., 345 mm. T.L.), 44°34.4'N., 124°58.4'W., *Yaquina* trawl no. OTB 22, in 800 meters; OSUO no. 402 (1, 113 mm. H.L., 500 mm. T.L.), 44°21.7'N., 125°07.9'W., *Yaquina* trawl no. OT 27, in 1000 meters; OSUO no. 401 (1, 132 mm. H.L., 610 mm. T.L.), 44°27.6'N., 125°14.2'W., *Yaquina* trawl no. OT 28, in 1150 meters; OSUO no. 394 (1, 77 mm. H.L., 326 mm. T.L.), 44°20.7'N., 125°05.9'W., *Yaquina* trawl no. OT 42, in 823-914 meters; OSUO no. 395-397 (3, 26-77 mm. H.L., 140-352 mm. T.L.), 44°20.8'N., 124°59.9'W., *Yaquina* trawl no. OT 43, in 640-732 meters; OSUO no. 398-399 (2, 139-121 mm. H.L., 630-564 mm. T.L.), 44°27.2'N., 125°13.3'W., *Yaquina* trawl no. OT 52, in 1372-1394 meters; OSUO uncataloged (1, 137 mm. H.L., about 578 mm. T.L.), 44°36.0'N., 125°17.0'W., *Yaquina* trawl no. OTB 63, in 1600 meters.

Coryphaenoides (Coryphaenoides) filifer (Gilbert).
(Figures 4B, 5A, 8, 10, 11.)

Chalinura filifera Gilbert, 1895, pp. 458-459 (original description; types, 3 specimens, 520-550 mm. long; British Columbia off Queen Charlotte Island, *Albatross* station 3342, in 1588 fathoms (2904 meters)); Clemens and Wilby, 1946, pp. 135-136, fig. 77 (description; illustration).

Macrurus lepturus Gill and Townsend, 1897, p. 233 (original description; holotype USNM no. 48767, 22 inches long, Bering Sea, SW. of Pribilof Island, *Albatross* station 3604, in 1401 fathoms (2562 meters)); Jordan and Evermann, 1898, pp. 2584-2585 (description; *Macrurus dorsalis* Gill and Townsend synonymized with *M. lepturus*); Gilbert and Burke, 1912, pp. 91-92, fig. 35 (description; illustration of holotype; 2 specimens, 375-550 mm., off Yunaska Island, Aleutian chain, *Albatross* stations 4764, 4765, in 1130 fathoms (2065 meters) and in 1217 fathoms (2226 meters), respectively).

Macrurus dorsalis Gill and Townsend, 1897, p. 233 (original description; holotype USNM no. 48768, 22 inches long, Bering Sea, SW. of Pribilof Island, *Albatross* station 3604, in 1401 fathoms (2562 meters)); Jordan and Evermann, 1898, p. 2585, footnote, (description from Gill and Townsend; species synonymized with *Macrurus lepturus* Gill and Townsend).

Coryphaenoides filifer, Gilbert and Hubbs, 1916, p. 143 (name only).

Coryphaenoides lepturus, Gilbert and Hubbs, 1916, p. 144 (name only).

Coryphaenoides (Nematonurus) lepturus, Gilbert and Hubbs, 1916, p. 162, footnote (name only).

Nematonurus lepturus, Grey, 1956, p. 167 (distribution).

Coryphaenoides filifera, Clemens and Wilby, 1961, pp. 169-170, fig. 87 (description; illustration).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers: outer series of first arch 8-10 total; inner series first arch 12-14 total; inner series second arch 11-14 total (usually 1-2 + 10-12). Scale rows below origin of first dorsal fin 10-11; below origin of second dorsal fin 7-10.

MORPHOMETRY. Measurements from 45 specimens ranging 54-125 mm. in head length, 264-662 mm. in total length. The following in percent of head length; snout length 24-29; preoral length 5-18 (usually 10-15); internasal width 17-20; horizontal diameter of orbits 22-30 (usually 24-28); interorbital width 22-27; orbit to angle of preopercle 41-48; suborbital width 9-13; length upper jaw 36-42; length barbel 6-13 (usually 9-12); length outer gill-slit 18-26 (usually 20-22); preanal length 129-174; distance isthmus to anus 68-108; greatest body depth 68-92 (usually about 70-80); height first dorsal fin 79-118; length pectoral fin 56-69; length pelvic fin 74-135; interspace between first and second dorsal fins 9-29.

DESCRIPTION. General features of the fish are best seen in the illustration (fig. 8). *Coryphaenoides filifer* has a moderately broad head with large orbits that are round to oval. Small specimens tend to have proportionately larger orbits than larger specimens (fig. 10). Head contours are gently rounded in well preserved specimens. The interopercle is broad and slightly exposed along its posteriormost end where it has small, loose scales. The chin barbel is short, stout at the base but tapering into a thin tip. Gill openings are broad and extend forward to a vertical about a pupil's length behind the orbits. The gill membranes are closely joined to the isthmus with no free fold present. Pores of the sensory lateralis system are small and scarcely developed.

The tip of the snout is armed with a stout, conical scute, which is generally stouter and proportionately larger in *C. filifer* than in any other species treated in this paper. It normally has between four and seven usually serrated ridges that radiate out from the apex; the horizontal (mid-lateral) ridges are usually markedly larger than the others, resulting in the scute being broader than high.

Scales are moderate in size with about three to seven parallel to slightly divergent ridge-like rows of very small, greatly reclined spinules. Scales uniformly cover almost all of the head and body. A small area along the anteroventral snout surface is naked. The medioventral surface of the gular membrane has small, loose scales in a few specimens, but they are apparently rubbed off in most others. Ventral surfaces of the lower jaws are broadly covered with scales. The lateral angles of the snout have a few deeply embedded, stout, but small scute-like scales. These

are not prominent in well preserved specimens. The broad suborbital shelf has a double row of stout, deeply embedded scales (except in an occasional specimen with one row of embedded scales, see figs. 4B and 8). Again, these stout scales are not prominent in well preserved specimens, but they stand out in specimens having most other scales removed. No other ridges on the head have similar deeply embedded scale rows.

Paired fins and the first dorsal fin are large and long. The first spinous ray of the dorsal fin is short and closely appressed to the long, serrated second spinous ray. The outer pelvic ray is elongate with a broad membranous mesial border.

Coloration is dark brown to swarthy, especially over the head. Membranes of the upper and lower jaws and the gular region are whitish with a bluish to blackish tinge. A thin black margin of the upper lip overlies the teeth. Fins and gill membranes are black. The peritoneum is brownish black; the buccal membrane is grayish to blackish.

Ten long, slender pyloric caeca were found in a *Yaquina* specimen from station BMT 190. Four retia and four small gas glands were found in the swimbladder of a specimen from British Columbia (UBC64-444).

COMPARISONS AND RELATIONSHIPS. *Coryphaenoides filifer* appears most closely related to *C. cinereus* with which it shares many general features such as head, body, and fin configurations, squamation, dentition, barbel shape and size, and many meristic and morphometric features. *Coryphaenoides filifer* is distinguishable from *C. cinereus* chiefly by: (1) its broader suborbital shelf (fig. 5A) with no anteroventral process; (2) its more adherent, stouter scales on the suborbital shelf (fig. 4B); (3) its generally more segmented first dorsal rays (usually 12-13 compared with usually 10-11 in *C. cinereus*); and (4) its narrower internasal space (17-20 percent of head length compared with 21-25 percent in *C. cinereus*).

Coryphaenoides filifer also appears fairly close to *C. acrolepis* but is easily distinguished from that species in having more first dorsal (usually 11, 12-13 versus 11, 9-11) and pelvic (9-10 versus usually 8) fin rays, longer pelvic fins (74-135 percent head length versus 50-70), and a somewhat shorter barbel (6-12 percent head length versus 11-19).

REMARKS. A search through the type collection at the U. S. National Museum of Natural History in April, 1971, failed to reveal any of the three syntypes of *C. filifer*. Böhlke (1953) did not list any paratype for the species in the Stanford University collections, and our visit to that collection in March 1972 revealed no specimen of *C. filifer*. The distinctive features of the species, as noted above, and the excellent original description leave little doubt that the name '*filifer*' truly applies to the specimens herein considered.

Although we have not examined the type specimens of *Maorurus lepturus* Gill and Townsend and *M. dorsalis* Gill and Townsend, the descriptions of these two species and the illustration of the holotype of the first (given by Gilbert and Burke, 1912, fig. 35) suggest that the names '*filifer*', '*dorsalis*', and '*lepturus*' all refer to a single species. The high first dorsal fin ray counts, the head physiognomy, the fin sizes, the strong terminal snout scute, the suborbital shelf, the barbel size, and scale features support our view that they are one and the same. The descriptions of '*lepturus*' and '*dorsalis*' also leave open the possibility that the species are synonyms of *C. cinereus*. The absence of prior records of '*filifer*' from the Bering Sea, where '*cinereus*' is apparently abundant, lends credence to this idea. But the high first dorsal fin ray counts and the shape of the suborbital shelf (illustrated for '*lepturus*' by Gilbert and Burke, 1912) weigh heavier towards '*filifer*' as the correct identification.

DISTRIBUTION. Eastern North Pacific from the Bering Sea to southern California. Depth range 2065-2904 meters.

SPECIMENS EXAMINED. OSUO uncataloged (1, 64 mm. H.L., 321 mm. T.L.), 47°51.1'N., 127°02.3'W., *Yaquina* trawl no. DWD 5, in 2519 meters; OSUO uncataloged (2, about 90-93 mm. H.L., 465-575 mm. T.L.), 48°39.6'N., 126°55.3'W., *Yaquina* trawl no. DWD 9, in 2189 meters; OSUO uncataloged (2, 45-83 mm. H.L., 235-585 mm. T.L.), 44°40.5'N., 125°46.0'W., *Yaquina* trawl no. OTB 49, in 2800 meters; OSUO uncataloged (2, 72-119 mm. H.L., 357-638 mm. T.L.), 44°34.0'N., 125°32.0'W., *Yaquina* trawl no. BMT 186, in 2816 meters; OSUO no. 406 (1, 114.5 mm. H.L.), 44°58.8'N., 125°40.4'W., *Yaquina* trawl no. BMT 188, in 2792 meters; OSUO uncataloged (5, 108-114 mm. H.L., 570-630 mm. T.L.), 45°19.8'N., 125°44.3'W., *Yaquina* trawl no. BMT 190, in 2597 meters; OSUO uncataloged (1, 67.6 mm. H.L., +263 mm. T.L.), 45°39.2'N., 125°44.6'W., *Yaquina* trawl no. BMT 192, in 2450 meters; OSUO no. 333 through 339, 354 (8, 92-125 mm. H.L., 467-662 mm. T.L.), 46°00.7'N., 126°42.4'W., *Yaquina* trawl no. BMT 256, in 2743 meters; OSUO no. 313 through 317 (5, 80-119 mm. H.L., 364-630 mm. T.L.), 45°55.5'N., 126°39.4'W., *Yaquina* trawl no. BMT 258, in 2670 meters; OSUO uncataloged (1, 54 mm. H.L., 264 mm. T.L.), 45°57.2'N., 127°40.7'W., *Yaquina* trawl no. BMT 276, in 2761 meters; SIO 66-53-62 (1, 100 mm. H.L., +520 mm. T.L.), off California, 38°01.8'N., 124°10.8'W., UBC64-444 (12, 30-116 mm. H.L., +150-610 mm. T.L.), off Triangle Island, British Columbia; UBC64-446 (1, 109 mm. H.L., 570 mm. T.L.), off Triangle Island, British Columbia.

Coryphaenoides (Coryphaenoides) cinereus (Gilbert).
(Figures 4A, 5B, 9, 10, 11.)

Maorourus cinereus Gilbert, 1895, p. 457 (original descrip-

tion; numerous specimens, N. of Unalaska Island and North Pacific, S. of Oukamok Island, *Albatross* stations 3307, 3329, 3340, in 399-1033 fathoms (730-1889 meters); Jordan and Evermann, 1896, p. 497 (records; distribution); 1898, pp. 2586-2587 (description after Gilbert; "Bering Sea; excessively abundant," many specimens near Bogoslof Island, 664 fathoms (1214 meters)); Jordan and Gilbert, 1899, p. 487 (record off Bogoslof Island, *Albatross* station 3634); Evermann and Goldsborough, 1907, p. 350 (records, Bering Sea and Cape Edgecumbe, *Albatross* station 3634, 4267, in 660-922 fathoms (1207-2048 meters)); Gilbert and Burke, 1912, p. 92 (7 Bering Sea localities, 344-771 fathoms (629-1410 meters)).

Coryphaenoides cinereus, Gilbert and Hubbs, 1916, p. 167 (characters; 2 specimens from off Sakhalin Island, *Albatross* station 5015, in 510 fathoms (933 meters)); 1920, p. 371 (sexual dimorphism); Schmidt, 1950, pp. 61-62, table 6 (description; 1 specimen, 245 mm. T.L., Sakhalin, in 1643 meters); Okamura, 1970, pp. 129-133, pl. 28, text-fig. 52 (description; illustration; geographic variation).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers: outer side of first arch 0-1 + 9-10; inner side of second arch 1-2 + 10-13 (total 12-14). Scales below origin of second dorsal fin 7-10 in 16 Bering Sea and Okhotsk Sea specimens, 9-10 1/2 in 4 eastern Pacific specimens.

MORPHOMETRY. Measurements based on 20 specimens ranging 39-94 mm. in head length, 217-560 mm. in total length. Measurements for 16 specimens from the Bering Sea and Okhotsk Sea are given first followed in parentheses by measurements for 4 specimens from off Oregon and British Columbia. Where a measurement of one specimen deviated considerably from the range of the others, that measurement is enclosed in brackets. The following in percent of head length: snout length 25-29, (28-29); preoral length [8]11-18, (16-19); internasal width 21-24, (23-25); horizontal diameter of orbit 27-34, (23-28); interorbital width 24-30, (27-30); orbit to angle of preopercle 42-48, (46-49); suborbital width 11-16, (13-14); length upper jaw 35-38[41], (38-39); length barbel 2-8, (6-7); length outer gill-slit [16]18-20, (20-23); preanal length 130-150, (135-156); greatest body depth 65-81, (79-87); height first dorsal fin 85-105; length pectoral fin 62-84; length pelvic fin 67-116, (83-141); interspace between first and second dorsal fins [9.5]15-22[24], (13-20).

DESCRIPTION. The head is broad, the orbits are large and slightly longer than the interorbital width in immature specimens, but becomes smaller relative to the interorbital width in mature individuals (fig.10). The snout is moderately acute and tipped with a broad spinous scute which has 4-10 finely

serrated radiating ridges. This spinous terminal snout scute is similar to that of *C. filifer* although normally smaller. The suborbital region has a prominent shelf that becomes very constricted anteriorly (figs. 4A, 5B). A small spike or prong juts ventrally from the lower anterior edge of the shelf (fig. 5B). The ascending limb of the preopercular ridge is slightly inclined from the vertical and usually extends dorsad to meet, at a tangent, the postorbital ridge. The interopercle is partially exposed beyond the preopercle; its posterior end is naked and broadly rounded. Upper jaws are moderate in size but fail to reach a vertical through the posterior margin of the orbits; the gill openings, however, are wide and extend forward to slightly behind that vertical. The mental barbel is very short and small; its length is less than the length of the posterior nostril.

Scales are moderate in size and relatively deciduous. Exposed fields of body and most head scales have numerous (5-9) rows of low, fine, parallel to slightly divergent, ridge-like rows of spinules. The number of spinule rows increases with size. The smallest specimens (39-40 mm. H.L.) examined had only 3 rows on large body scales while a larger (60 mm. H.L.) specimen had 6-7 rows and those larger than about 70 mm. in head length had 7-10 rows. Scales are apparently lacking in this species over the leading edge and most of the ventral surfaces of the snout. The head and body are uniformly scaled everywhere else, however, except for the gular and branchiostegal membranes and the interopercle. Scales along the suborbital shelf are thin and deciduous except for a few stout scales at the anteriormost end. In no specimen were stout, deeply embedded scales present along the entire course of the suborbital region (as in *C. filifer*). Grooved scales of the lateral line series are discontinuously arranged. The path of the lateral line appears as long broken dashes. Grooving of the lateral line scales is shallow and faint.

Dentition in both jaws is composed of very small and fine teeth in narrow bands. There is no distinct enlargement of the outer series of teeth in either jaw.

Pyloric caeca are short, much shorter than the orbit diameter and number 5-7 (Gilbert and Hubbs, 1916, p. 167). The gas bladder is large and filled with spongy white material. Four long, slender retia were connected to four small, globular gas glands in two large male specimens from the eastern Pacific. Gonads in these specimens were slightly developed; those in a large female specimen (UBC64-444) were moderately developed. Precaudal vertebrae based on X-ray photographs 13 (2 specimens) and 14 (1 specimen).

Coloration of denuded specimens is a dirty white with margins of scale pockets brownish. Paired and first dorsal fins are black in adult specimens, but dusky or pale in the young; the second dorsal fin and anal fin are dusky or grayish. Gill membranes are blackish. The oral cavity is dark

gray to black; branchial cavity walls and the peritoneum are black. The ventral edge of the orbits are black, but the remainder is grayish. The barbel is blackish. The species name '*cinereus*' is derived from its generally grayish color.

COMPARISONS AND RELATIONSHIPS. *Coryphaenoides cinereus* is closest to *C. filifer* and the two are often difficult to tell apart. Chief distinguishing characters are given under the comparisons section for *C. filifer*. In addition to those characters, other more variable, but often useful, ones were found. Thus *C. cinereus* tends to have a paler color, a slightly wider interorbital region (fig. 11), broader naked areas on the snout, and its lateral line grooves are fainter and more interrupted than in *C. filifer*.

Coryphaenoides cinereus is apparently also closely related to *C. filamentosus* Okamura from Japan, but it can be distinguished from that species in having softer head bones, scale spinules arranged in parallel, rather than divergent ridges, a larger orbit, and a shorter barbel (Okamura, 1970).

REMARKS. Gilbert and Hubbs (1916, p. 167) and Okamura (1970, p. 132) noted variations in meristic and morphometric characters exhibited by this species. Some of these variations are seen in the above section on morphometry where populations from different regions are compared. Overlap is seen in all compared characters, however, and there is no reason to suspect specific divergence.

Gilbert and Hubbs (1916) noted a particularly large variation in the length of the filamentous outer pelvic ray. A later reinvestigation (Gilbert and Hubbs, 1920, p. 371) showed this variation to be attributable to sexual dimorphism. The outer pelvic ray is notably larger in the male than in the female. Our specimens from Oregon and British Columbia confirm their observations. Three of our four large specimens were males with pelvic fin lengths of between 125-141 percent head length. The fourth specimen from British Columbia was a female with a pelvic fin length of only 83 percent head length.

DISTRIBUTION. The range of this species seems to be centered in the northwestern Pacific around the Bering Sea, Kamchatka, and the Okhotsk Sea where it is most abundant. The specimens reported here represent not only the first record of the species from the eastern Pacific outside the Bering Sea, but the Oregon specimen is also the largest and from the greatest depth (2832 meters compared with the previous depth record of 1890 meters). The paucity of material from this area, despite relatively extensive coverage by research vessels of the Scripps Institution of Oceanography, Oregon State University, and National Marine Fisheries Service (Seattle), indicates that the eastern Pacific is marginal to the normal range of the species.

Depth range approximately 630-2832 meters.

SPECIMENS EXAMINED. USNM no. 48577 (1 syntype, 75 mm. H.L., 408 mm. T.L.), *Albatross* collection; USNM no. 70849 (2, 61-63 mm. H.L., 345-333 mm. T.L.), Bering Sea, *Albatross* collection, 426 fathoms (779 meters); USNM no. 70908 (1, 39 mm. H.L., 217 mm. T.L.), *Albatross* collection, 682 fathoms (1247 meters); USNM no. 77249 (1, 62.5 mm. H.L., 381 mm. T.L.), S. of Sakhalin, *Albatross* collection, 426 fathoms (779 meters); MCZ no. 28211 (1, 81 mm. H.L., 430 mm. T.L.), *Albatross* collection; SU no. 22976 (1, 61 mm. H.L., 364 mm. T.L.), Okhotsk Sea off Sakhalin, 46°44'N., 144°02'E., 510 fathoms (932 meters), *Albatross* station 5015; SU no. 5742 (3, 59-73 mm. H.L.), Bering Sea, 54°51'N., 167°27'W., *Albatross* station 3634, 664 fathoms (1214 meters); SU no. 14229 (1, 87.5 mm. H.L., 494 mm. T.L.), *Albatross* collection, ?1904-05?; SU no. 11191 (1, 75 mm. H.L., 444 mm. T.L.), Bering Sea, *Albatross* collection, 1890; SU no. 5493 (4, 40-75 mm. H.L., +195-438 mm. T.L.) off Alaska Peninsula near Shumagin Island, 54°19'N., 159°40'W., 625 fathoms (1143 meters), *Albatross* station 3338; UBC64-444 (3, 84-97 mm. H.L., 488-520 mm. T.L.), British Columbia off Triangle Island area, 11 Sept. 1964; OSUO uncataloged (1, 94 mm. H.L., 560 mm. T.L.), 44°39.1'N., 126°40.1'W., *Yaquina* trawl no. CP-2-6, haul 271, 2832 meters.

Subgenus *Nematonurus* Günther

DIAGNOSIS. Teeth in upper jaws in two distinct series with outer series enlarged; mandibular teeth usually in a single series, when in two series, the outer much reduced. Retia 2-6, gas glands 2-6. Precaudal vertebrae 13-16.

REMARKS. Dentition appears to be the only useable character that will diagnose the subgenus as we have defined it. Based on this character, *Nematonurus* must include *C. armatus* (Hector), *C. pectoralis* (Gilbert), and *C. longifilis* (Günther) in addition to one or more other species not here considered. But, as indicated in our descriptions, *C. pectoralis* is widely divergent from *C. armatus* and *C. longifilis* by what seem to be several fundamental characters, such as swimbladder size and ossification of the skeleton. *Coryphaenoides* (*Nematonurus*) *longifilis* also appears superficially very different from *C. armatus*, but our material does not allow critical examination of important characters of *C. longifilis*. The only other species of macrourine rattail whose status in *Nematonurus* we are reasonably sure of is *C. leccointei* Dollo, 1900.

Coryphaenoides (*Nematonurus*) *longifilis* Günther.
(Figure 12.)

Coryphaenoides longifilis Günther, 1877, p. 439 (original

description; S. of Yeddo (Tokyo), Japan).

Macrurus (Nematonurus) longifilis, Günther, 1887, p. 151, pl. 35 (description, illustration; one specimen (holotype), 28 inches long, S. of Yeddo (Tokyo), Japan, Challenger station 235, in 565 fathoms (1033 meters)). *Moseleya longifilis*, Goode and Bean, 1896, p. 417, pl. 100, fig. 349a (illustration after Günther; *Macrurus longifilis* Günther designated type species of new genus *Moseleya*).

Bogoslavius clarki Jordan and Gilbert, in Jordan and Evermann, 1898, p. 2575 (original description; 4 specimens, 24-41 cm. long, Bering Sea off Bogoslof Island, Albatross station 3634, in 664 fathoms (1216 meters)) (this description predates that of Jordan and Gilbert, 1899); Jordan and Gilbert, 1899, pp. 487-488, pl. 83 (description, illustration; supposedly original description but described in an earlier publication by Jordan and Evermann, 1898).

Dolloa longifilis, Jordan, 1900, p. 897 (*Macrurus longifilis* designated type species of new genus *Dolloa*, erected to replace *Moseleya* Goode and Bean, preoccupied).

Coryphaenoides (Nematonurus) longifilis, Gilbert and Hubbs, 1916, pp. 159-161 (description; 3 specimens, off Japan, Albatross station 4956, in 720 fathoms (1317 meters) and station 4980, 507 fathoms (927 meters); Okamura, 1970, pp. 121-124, pl. 26, text fig. 50 (good description; illustration; southern Japan, in 850-1700 meters); 1971, figs. 5B, 63B (scale, alimentary canal).

Nematonurus longifilis, Kamohara, 1952, p. 96 (listed).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers on first arch 2-3 + 12-13 (total 14-16); on second arch 2-3 + 11-13 (total 13-15). Scales below origin of first dorsal fin 16; below origin of second dorsal fin 14 (one specimen). Precaudal vertebrae 14-15. Retia 4; gas glands 4.

MORPHOMETRY. Measurements from 7 specimens ranging +240-360 mm. in total length, 44-68.5 mm. in head length. The following in percent of head length: snout length 25-31; horizontal orbit diameter 20-25; interorbital width 23-24; orbit to angle of preopercle 38-45; suborbital width 10-13; length upper jaws 43-47; length barbel 2-3.5; length outer gill-slit 21-23; preanal length 130-147; distance isthmus to anal origin 74-87; greatest body depth about 64-72; height first dorsal fin 72-87; length pectoral fin 77-114; length pelvic fin 136-192; interspace between first and second dorsal fins 11-15.

DESCRIPTION. The head is large and compressed with the snout profile low and smoothly rounded; the scarcely developed rostrum results in the mouth being essentially terminal. The suborbital region is almost flat, but a low, smooth ridge traverses the region midlaterally. The inter-

opercle is broadly exposed posteriorly beyond the preopercle. The barbel is rudimentary. Sensory pores on the head are well developed.

The first dorsal, pectoral, and pelvic fins are all long and well developed. The second spinous dorsal ray is finely serrated and slightly prolonged into a filamentous tip. The dorsalmost pectoral ray is to the long second ray. The third ray of the pectoral fin is longest. The fourth, fifth, and sixth rays of that fin are about as long as the second ray, all of these being about equal in length to the postrostral length of the head. The outermost pelvic ray is thick and greatly prolonged; the length is normally more than 1.5 of length of the head.

Scales are thin, small, and appear to cover almost all of the head and body. Gill membranes are entirely naked. The lower jaw is finely scaled. No apparent naked areas are present on the snout or suborbital area of specimens we have examined, but fresh specimens may indicate otherwise.

Teeth in the upper jaws are in two distinct and widely separated series, between which very small teeth are sometimes scattered. Teeth on the outer series of the premaxillae are enlarged and slightly recurved; the spacing between each tooth is comparatively wide and even. The inner series of premaxillary teeth is very small and arranged in a dense, single row; the teeth are directed almost horizontally. Mandibular teeth occur either in a single row or in two somewhat irregular rows. Teeth of the inner row are moderately enlarged but smaller and more closely spaced than the outer premaxillary series. The outer mandibular teeth, when present, are much smaller than those on the inner row. Very small teeth are occasionally interspersed between the larger mandibular teeth.

Coloration in 70 percent ethanol is tawny overall to almost whitish over surfaces of the head. Lips, branchiostegal membranes, and oral and branchial cavities are dark brown. Fins are probably dusky in life.

REMARKS. This species was ably described and illustrated by Okamura (1970, p. 121, pl. 26), and Günther's illustration (1887, pl. 38) is excellent, showing the trenchant features of this distinctive fish. Makushok (1964, p. 138), in a lengthy discussion comparing descriptive information from the literature of *C. longifilis* and *C. clarki*, gave abundant evidence for considering the two nominal species as conspecific.

No specimens of this species were found in the collections made by Oregon State University vessels. *Coryphaenoides longifilis* is known only from the western North Pacific off southern Japan and in the Bering Sea. Rass (1965) did not report it from the Okhotsk Sea, and there are no records of its having been captured in the eastern Pacific south of the Aleutian Islands. Its depth distribution ranges from 850 to 1700 meters (Okamura, 1970, p. 124).

SPECIMENS EXAMINED. USNM no. 70987, (7,44-69 mm. H.L., +240-360 mm. T.L.), Bering Sea on Bowers Bank, 54°33'30"N., 178°44'E., Albatross station, 4775, 585 fathoms (1070 meters); USNM no. 149479 (1, 130 mm. H.L.), Japan, off Yokohama, Albatross collection.

Coryphaenoides (Nematonurus) armatus (Hector).
(Figures 13, 14, 15B.)

Macrurus armatus Hector, 1875, p. 81 (original description; off Cape Farewell, New Zealand, *Challenger* collection, in 400 fathoms (731 meters)).

Coryphaenoides variabilis Günther, 1878, p. 27 (original description; between Cape of Good Hope and Kerguelen Island, S. of Australia, mid-Pacific, and SW. of Juan Fernandez, *Challenger* collection, in 135-2425 fathoms (247-4435 meters)).

Macrurus asper Goode and Bean, 1883 (*nec Coryphaenoides asper* Günther, 1877), pp. 196-197 (original description; holotype 322 mm. T.L.; Blake stations 308 and 309, in 1242 and 304 fathoms (2271 and 556 meters)).

Macrurus goodii Günther, 1887, p. 136 (substitute for *Macrurus asper* Goode and Bean, preoccupied).

Macrurus (Nematonurus) armatus, Günther, 1887, p. 150, pl. 40, fig. A (description; illustration; synonymized *Coryphaenoides variabilis* Günther with *Macrurus armatus* Hector; corrects Hector's count of pelvic fin rays in holotype).

Coryphaenoides gigas Vaillant, 1888, pp. 232-233, pl. 20, figs. 2, 2a-c. (original description; holotype MNHN no. 86-117, 116 mm. H.L., 730 mm. T.L., *Talisman* station 136, in 4255 meters).

Macrurus cyclolepis Gilbert, 1895, p. 458 (original description; 2 specimens, off Queen Charlotte Island, British Columbia, Albatross station 3342, in 1588 fathoms (2904 meters)).

Hymenocephalus goodei, Goode and Bean, 1896, p. 407, fig. 340 (description; illustration; many western North Atlantic localities).

Nematonurus armatus, Goode and Bean, 1896, p. 416 (name; distribution).

Nematonurus gigas, Goode and Bean, 1896, p. 416 (description after Vaillant).

Macrurus (Nematonurus) suborbitalis Gill and Townsend, 1897, p. 234 (original description; holotype 20 inches long; Bering Sea, SW. of Pribilof Island, Albatross station 3603, in 1771 fathoms (3239 meters)).

Macrurus (Hymenocephalus) goodei, Lütken, 1898, p. 26 (specimens from Denmark and Davis Straits, in 1300-1715 fathoms (2378-3137 meters)).

Moseleya cyclolepis, Jordan and Evermann, 1898, pp. 2570-2571 (description after Gilbert).

Nematonurus goodei, Jordan and Evermann, 1898, pp. 2571-2572 (description after Goode and Bean).

Nematonurus suborbitalis, Jordan and Evermann, 1898, pp. 2572-2573 (description after Gill and Townsend).

Nematonurus abyssorum Gilbert, 1915, p. 374, pl. 21, fig. 23 (holotype, USNM no. 75827, off Santa Catalina Island, 33°02'15"N., 120°42'W., Albatross station, 4390, in 1350-2182 fathoms (2469-3991 meters)).

Coryphaenoides abyssorum, Barnhart, 1936, p. 24, fig. 81 (brief description; illustration from Gilbert, 1915).

Dollosa cyclolepis, Jordan, Evermann, and Clark, 1930, p. 203 (listed).

Nematonurus cyclolepis, Böhlke, 1953, p. 59 (listed).

Coryphaenoides cyclolepis, Clemens and Wilby, 1961, pp. 168-169, fig. 86 (description; illustration).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers on outer series of first arch 0-1 + 6-9 (usually 0 + 8) (total 7-9); inner series of first arch 1-3 + 10-12 (11-14 total); inner series of second arch 1-3 + 9-12 (11-13 total). Scales below origin of second dorsal fin 8-10.

MORPHOMETRY. Measurements from 40 specimens ranging 23.5-165 mm. in head lengths. The following in percent of head length: snout length 20-31; preoral length 6-17; horizontal diameter of orbits 18-27; interorbital width [18.5] 21-26; orbit to angle of preopercle 35-49; suborbital width 9-13; length upper jaw 34-40 (usually 36-38); length barbel 11-19; length outer gill-slit 12-18; length snout to anus 156-202; distance isthmus to anus 89-135; greatest body depth 66-113; height first dorsal fin 53-75; length pectoral fin 31-74 (usually 50-60); length pelvic fin 39-88; interspace between first and second dorsal fins 39-77.

DESCRIPTION. General features of this species are best seen in figs. 13 and 14. The snout protrudes prominently beyond the mouth in small specimens, but tends to become lower, blunter, and less prominent in specimens larger than about 100 mm. in head length (note leveling of growth curve at larger sizes in fig. 16). Proportional measurements of the snout varied accordingly over a wide range. The orbits are small; the horizontal diameter is less than the interorbital width in most specimens (fig. 17) and usually much shorter than the snout length (fig. 18). The abdomen is very long, the distance from the isthmus to the anus being greater than the head length in specimens larger than 40 mm. in head length (fig. 19). The gill openings are wide and extend far forward to beneath the orbits. The gill membranes form, at most, a narrow free fold across the isthmus. The barbel is stout at the base but tapers sharply into a thin filamentous tip; its length is less than the suborbital width. The lips are thick and bear many papillae. Ventral

aspects of the snout and suborbital are covered with fleshy, naked skin and liberally pocketed with enlarged pores of the sensory lateralis system. In large specimens (larger than about 150 mm. in head length) the leading edge and ventral aspects of the snout have an especially dense covering of papillae giving an almost fur-like texture to the surface. Lower jaw rami on the largest specimens are usually entirely naked, but small scales are present posteriorly along the midline of each ramus in the smaller specimens. Mucous pores along the lower jaw are especially prominent. In small specimens (under about 80 mm. head length), a prominent naked area is present on each side, just behind the leading edge of the snout. The condition is similar to that found in specimens of subgenus *Chalinura*. The outer (posterior and ventral) margins of the gill covers are naked in the largest specimen examined, but generally covered with scales in all other specimens. The ventral surface of the preopercle is naked below the preopercular ridge, and the interopercle is exposed posteriorly as a narrow, fleshy, naked tab. There are no scales on the gular or branchiostegal membranes.

Scales uniformly cover most surfaces of the head and body, other than for the areas noted above. The trunk and tail are completely covered with large, thin scales. Scale spinules are thin and sharp and arranged in discrete parallel rows with the median row in each scale slightly larger than the lateral rows. The spinule rows on large trunk scales numbered as few as three in the smallest specimen examined, to as many as 8-10 in the largest specimen. Spinules are relatively coarser on scales of small specimens, where they overlap the hind margin of the scales. Spinules in large specimens are arranged in low, narrow, horizontal rows on the exposed fields of trunk scales; they do not overlap the hind margin of the scales. In very large specimens (larger than 100 mm. head length), the scales tend to become deeply embedded and the spinules greatly reduced. Exposed fields become relatively much smaller, in these large specimens, and the fields widely separated from each other by broad naked margins. Head scales are generally smaller, coarser, and more adherent than body scales. Scales over the suborbital shelf in the largest specimen (165 mm. head length) are small and appear no different from other head scales. There are approximately four scale rows over the narrowest part of the shelf in this specimen. There are no enlarged or stoutly modified scales on the snout.

Pores of the sensory lateralis system are particularly well developed in specimens of *C. armatus* larger than about 80 mm. in head length. In addition to the usual complement of enlarged pores on the head found in many other species of macrourid fishes, additional smaller pores are found in *C. armatus* on the dorsal surfaces of the head and trunk. These dorsally situated pores are black rimmed and prominently contrasted in large specimens against the brown

ground color of the fish. They originate just behind the first dorsal fin and follow a line forward on each side of the first dorsal fin to an area over the supraoccipital area. A less well defined row of pores is present one scale row above the anterior portion of the lateral line. A transverse series over the hind end of the frontal bones meets an ill defined postorbital series on each side of the head. The two postorbital series run anteromedially over the interorbital space and onto the snout.

Fins have no ray prolonged except the outer pelvic ray which extends posteriorly to slightly beyond the vent in small specimens, but falls well short of the vent in larger ones. The second dorsal spine is strongly triangular in cross section near the base, but becomes laterally compressed distally; serrations along its leading edge are sharp and prominent in small specimens but become progressively reduced in larger specimens where they remain evident only near the distal end.

There are six long, slender retia and six small, peltate gas glands in a 93 mm. head length specimen from off Oregon (Yaquina station no. BMT 253). Radiographs (kindly made available to us by Richard A. Grinols) of 22 specimens revealed 13 (3 specimens), 14 (16 specimens), and 15 (3 specimens) precaudal vertebrae.

Overall coloration is dark brown to blackish. All fins are blackish in large specimens but tend to be dusky to pale in the smallest specimens. Ventral surfaces of the head, including the gill membranes, barbel, lips, suborbital region, and lower snout surfaces, are black. The oral, branchial, and peritoneal linings are black.

COMPARISONS. *Coryphaenoides armatus* is most closely related to *C. yaquinae* but differs primarily in teeth characters, in the presence of large pores of the sensory lateralis system on the head, and in a number of scale features including relatively finer scale spinulation; and small, irregularly arranged scales about 4-5 rows wide on the suborbital (see description of *C. yaquinae* for a more detailed comparison).

C. armatus is not likely to be confused with any other species found in the North Pacific except *C. leptolepis* in the smaller sizes. The broad band of very small and fine teeth on the premaxillae of *C. leptolepis*, however, immediately distinguishes that species from *C. armatus* (which has its premaxillary teeth in one or two distinct rows).

SIZE. *Coryphaenoides armatus* is one of the largest known members of the family. The maximum size of specimens we examined was 165 mm. in head length and over 870 mm. in total length.

DISTRIBUTION. The species apparently occurs in all oceans except the Arctic. Its depth range is extremely great

(according to published records) ranging 282-4700 meters (Grey, 1956, p. 169), but most specimens have been captured in depths of approximately 2500-3500 meters. Eastern North Pacific specimens were taken in abundance at depths of between 2000 and 4000 meters. Large collections are presently housed at Scripps Institution of Oceanography, Oregon State University, and the University of Washington.

The presence of *C. armatus* in the eastern North Pacific is not surprising, when the localities of past captures of the species are considered. *Coryphaenoides armatus* was originally described by Hector (1875) from a specimen taken by the *Challenger* off New Zealand. Günther (1878 and 1887) later reported several other specimens (reported in 1878 under the name *Coryphaenoides variabilis*) taken in the southern Indian Ocean, the South Pacific, the mid-equatorial Pacific, and in the central North Pacific. Many subsequent workers, summarized by Parr (1946), reported the species from the North Atlantic. The cosmopolitan distribution of *C. armatus* was discussed by Nybelin (1957) who plotted the world-wide distribution of the species.

REMARKS. We feel that the statuses of many species closely related to *Coryphaenoides armatus* still remain undetermined. The problem cannot, however, be adequately resolved without a thorough examination of all type specimens concerned, and examination of additional material from representative areas throughout the supposed range of *C. armatus*.

Our cursory study indicates that there are some differences between Atlantic and Pacific populations of what is now recognized as *C. armatus*. These differences, as enumerated below, are slight, but probably meaningful. If the populations are indeed conspecific, as we believe they are, the cause of geographical variation may be some degree of isolation in the North Atlantic and Pacific cul-de-sacs. Perhaps, as Günther (1887, p. 150) stated, the species is widely variable, even within a given area. However, we encountered little variability in specimens from either the North Atlantic or the North Pacific.

Günther (1887, p. 150) described a pallid, albino-like form that is not present in our study material. The great variability he speaks of may have resulted from his having two closely related species. The very similar looking *Coryphaenoides yaquinae*, for example, could very easily be mistaken for a *C. armatus*. The closely related *C. lecointei* (Dollo) ranges in the southern hemisphere where most of Günther's specimens were taken. His study material may have contained members of that species.

Most notable differences in meristic features of Atlantic and Pacific specimens of *C. armatus* were the counts for pelvic fin rays and scales below the origin of the second dorsal fin (tabl 1). Nybelin (1957, p. 261) summarized, in a table, all previous records of pelvic fin ray counts for

C. armatus; they were 9 or 10. Scale row counts below the origin of the second dorsal fin were slightly lower in Pacific specimens, ranging 8-10, with a mode at 8. Our Atlantic specimens had a range of 9-10 with a strong mode at 10. Koefoed (1927, p. 111) tabulated the scale row counts of 17 Atlantic specimens; these showed a range of 8-11 with a mode at 10.

Marshall (1973) used the ratio of snout length to orbit diameter to distinguish *C. armatus* from '*abyssorum*', but a plot of these measurements (fig. 18) showed complete overlap in this character between specimens from the Atlantic and the Pacific. The distance from the isthmus to the anus (fig. 19) was slightly longer in North Atlantic material of moderate to large sizes, but the difference appeared negligible.

DISCUSSION OF SYNONYMY. We follow Makushok (1967) in placing *Nematonurus abyssorum* Gilbert, *N. cyclolepis* Gilbert, and *Macrurus (Nematonurus) suborbitalis* Gill and Townsend into the synonymy of *C. armatus* (Hector). We have examined and compared the holotypes of '*abyssorum*' and '*suborbitalis*' and the two syntypes of '*cyclolepis*', in addition to many specimens previously referred to '*abyssorum*' taken in the eastern Pacific off Oregon, Washington, and off southern California (type locality for '*abyssorum*' off Santa Catalina Island). We found no significant differences between any of these specimens.

There is some confusion regarding the type specimens of *N. cyclolepis*. Gilbert (1895) described the species from two small specimens, the largest of which was only 150 mm. long. Two specimens catalogued under USNM no. 48585 are designated as types in the United States National Museum of Natural History, but one of these is a large specimen of *Coryphaenoides ariommus* Gilbert and Thompson, 1916, measuring 230 mm. in total length. (That species is only known from off Chile.) The other specimen in the 'type' lot is a small specimen too badly decomposed to properly examine. A specimen deposited in the Stanford University collections (now housed at the California Academy of Sciences) was listed by Böhlke (1953) as a paratype of '*cyclolepis*'. We examined that specimen and found it to closely fit Gilbert's description of '*cyclolepis*'. The specimen measured slightly over 115 mm. in total length and is not likely to have been longer. Because the Stanford syntype is in good condition and the USNM specimens are of questionable status, we have designated the former (SU no. 3090) as the lectotype. We have examined many small Pacific specimens of what we have called *C. armatus* and found them no different from the lectotype of '*cyclolepis*'.

We do not agree with Makushok (1967) in his placing of *Macrurus albatrossus* Townsend and Nichols, 1925, into the synonymy of *C. armatus*. We have not examined the holotype and only specimen of '*albatrossus*', and the description for

that species is inadequate. The original illustration, however, indicates a species with a much blunter and higher snout than that found in *C. armatus*; the orbits also appear much larger and the abdomen appears shorter. The general physiognomy, in fact, appears much closer to that of *C. cinereus* and quite unlike that of *C. armatus*.

SPECIMENS EXAMINED. Western Atlantic: MCZ no. 25815A (2, 34-55 mm. H.L., 176-+300 mm. T.L.) (cotypes of *Macrurus asper* Goode and Bean, non *M. asper* Günther); USNM no. 38161 (1, 133 mm. H.L., 660 mm. T.L.); USNM no. 38169 (1, 68 mm. H.L., +310 mm. T.L.), 36°35'N., 74°03'30"W., Albatross station 2727, in 1289 fathoms (2357 meters), 24 Oct. 1886; USNM no. 38104 (1, 78 mm. H.L., 455 mm. T.L.), 38°59'N., 70°07'W., Albatross station 2711, in 1544 fathoms (2824 meters), 16 Sept. 1886; USNM no. 33392 (3, 58-64 mm. H.L., +240-340 mm. T.L.), 41°43'N., 65°21'50"W., Albatross station 2074, in 1309 fathoms (2394 meters), 3 Sept. 1883; USNM 132234 (1, 76 mm. H.L., 410 mm. T.L.); USNM no. 143199 (3, 52-65 mm. H.L.), off Cape Sable, Nova Scotia, Albatross collection; USNM 38102 (1, 50 mm. H.L., 260 mm. T.L.), 38°20'N., 70°68'30"W., Albatross station 2713, in 1859 fathoms (3400 meters), 17 Sept. 1886; USNM no. 92829 (1, 85 mm. H.L., +400 mm. T.L.), 39°15'N., 68°08'W., Albatross station 2568, in 1781 fathoms (3257 meters), 31 Aug. 1885.

Eastern Pacific: USNM no. 75827 (1, 152 mm. H.L., +803 mm. T.L.), California, off Santa Catalina Island, 1350-2182 fathoms (2470-4500 meters) (holotype of *Nematonurus abyssorum* Gilbert); USNM no. 48773 (1, 96 mm. H.L., 468 mm. T.L.) (holotype of *Nematonurus suborbitalis* Gill and Townsend); USNM no. 48585 (one small specimen, badly decomposed, possibly one of two syntypes of *Nematonurus cyclolepis* Gilbert); SU no. 3090 (1, 26.7 mm. H.L., +115.5 mm. T.L.), off British Columbia, in 1588 fathoms (2920 meters) (we designate this specimen as lectotype of *Nematonurus cyclolepis* Gilbert); OSUO uncataloged (3, 45-105 mm. H.L.), 44°39.8'N., 125°33.3'W., Yaquina trawl no. OTB 50, in 2800 meters; OSUO no. 405 (1, 155 mm. H.L., 843 mm. T.L.), Yaquina trawl no. OTB 331; OSUO uncataloged (1, 110 mm. H.L., 555 mm. T.L.), 44°58.8'N., 125°40.4'W., Yaquina trawl no. BMT 188, in 2792 meters; OSUO uncataloged (2, 93-165 mm. H.L.), 44°39.0'N., 126°44.8'W., Yaquina trawl no. BMT 253, in 2816 meters; OSUO uncataloged (1, 78 mm. H.L.), 45°55.5'N., 126°39.4'W., Yaquina trawl no. BMT 258, in 2670 meters; OSUO uncataloged (1, 60 mm. H.L., 330 mm. T.L.), 45°38.4'N., 126°43.7'W., Yaquina trawl no. BMT 262, in 2721 meters; OSUO uncataloged (1, 116 mm. H.L., 670 mm. T.L.), 45°36.5'N., 126°46.1'W., Yaquina trawl no. BMT 263, in 2730 meters; OSUO uncataloged (1, 31 mm. H.L., 161 mm. T.L.), 45°24.7'N., 127°41.1'W., Yaquina trawl no. BMT 278, in 2811 meters; SIO no. 66-54-62 (2, ca. 486-586 mm. T.L.), off California, 38°23.0'N., 124°06.5'W., 24-25 May 1966; SIO no. H53-338 (1, 176 mm. T.L.), off Kamchatka and Aleutian Islands, 46°16.5'N., 168°52.0'E.,

6-7 Sept. 1953; UBC no. 64-444 (3 small specimens) off British Columbia, Triangle Island area, 11 September 1964.

Coryphaenoides (Nematonurus) yaquinae, Iwamoto and Stein, new species.
(Figures 15A, 20.)

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers on inner series of first arch 11-12 total; inner series of second arch 11. Scales below origin of first dorsal fin 8; below origin of second dorsal fin 8.

MORPHOMETRY. Measurements from the type specimens which ranged 53-79 mm. in head length, and +255-400 mm. in total length. The following in percent of head length: snout length 26-30; preoral length 12-16.5; horizontal orbit diameter 19-21; interorbital width 25-26; distance orbit to angle of preopercle 47; suborbital width 10-11; length upper jaw 39-40; length barbel 16-18; length outer gill-slit 18-20; length snout to anal origin 163-178; outer pelvic ray to anal origin 61-77; distance isthmus to anus 100-122; greatest body depth 77-92; height over anal origin 61-68; length first dorsal fin 65-74; length pectoral fin 55-57; length pelvic fin 72; interspace between first and second dorsal fins 44-51.

DESCRIPTION. The head is broad and somewhat depressed; the dorsal profile takes a notable dip above the orbits before rising over the strongly arched nape. The interorbital region is broad and relatively level, there being no distinct troughs or ridges across most of its breadth. The suborbital region has a low but distinct ridge traversing its entire length. Small scales are present on the shelf above the crest of the ridge. Gill openings are wide and extend forward ventrally to a vertical approximately a pupil's length behind the orbits. The gill membranes connect over the isthmus and form a moderately broad free fold in the holotype but a rather narrow free fold in the paratypes. The interopercle is narrow and barely exposed posterior to the preopercle angle. Lips are rather fleshy and papillose. The barbel has a relatively short base but tapers rapidly into a thin filament. Mucous pores are outlined in black and fairly prominently cover large areas of the head, especially in the interorbital region back to the base of the nape and ventrally on the snout and suborbital surfaces. The blackish pores do not extend onto the body as they do in large specimens of *C. armatus*. Pores of the sensory lateralis system that are so large and prominent in *C. armatus* and *C. leptolepis* are not well developed in *C. yaquinae*.

Almost all surfaces of the body and the dorsal surfaces of the head are coarsely scaled. A prominent, broad,

swarthy, naked area lies dorsally behind the leading edges of the snout on either side of the median nasal ridge. The ventral surfaces of the snout, suborbital, preopercle, and lower jaws are naked. The interopercle and the branchiostegal and gular membranes are also naked. Almost all scales on the head and body have strong sharp ridges comprised of close-set sharp spinules. Spinules on body scales tend to be more reclined and larger than those on head scales. Spinules on body scales are arranged in about 3-5 more-or-less parallel rows with the middle spinule row longer and slightly higher. The posteriormost spinules extend beyond the margin of the scale. Compared with the body scales, those on the head have much smaller, more erect and more closely appressed spinules. The spinule rows on these scales are widely divergent and number 1-3 on small scales and as many as 5-7 on the large scales of the operculum.

Dentition of the upper jaw of the holotype consists of a band of very small, widely scattered teeth with a distinctly enlarged outer series of sharp conical teeth. In the paratypes, the inner teeth are better described as in two irregular series. Lower jaw teeth in all type specimens were moderate-sized, conical teeth arranged in two irregular rows near the symphysis but narrowing to a single series posteriorly. The lower jaw teeth are smaller than the enlarged outer premaxillary series but larger than the inner premaxillary teeth.

The spinous second ray of the first dorsal fin is distinctly serrated along its leading edge; it tapers to a fine, thin, but scarcely produced tip. The outer pelvic ray is produced well beyond the other rays of the fin and extends a short distance posterior to the anal-fin origin.

The swimbladder of the 53 mm. head length paratype measures about 32 mm. in greatest length and is covered with a thin, translucent external tunica. There is little fatty tissue within the lumen. Six slender retia, each about 30 mm. long, form coiled loops terminating in six small peltate gas glands each approximately 3-4 mm. in diameter and about 1 mm. thick. The alimentary canal is similar in its coiling pattern to that illustrated for *C. (N.) pectoralis* by Okamura (1971, fig. 63A). There are ten simple, slender pyloric caeca, each about 15 mm. long.

Coloration overall is a grayish brown with the snout, lips, orbits, barbel, opercle, and posterior margins of the gill membranes swarthy to blackish. Fin membranes are all dusky except for those bordering the outer pelvic rays and the distal half of the serrated spinous dorsal ray; these last membranes are black. The oral cavity is dark gray; the linings of the gill and abdominal cavities are black.

COMPARISONS AND RELATIONSHIPS. *Coryphaenoides yaquinae* appears most closely related to *C. armatus*; the two differ mainly in dentition and squamation. The inner premaxillary series of teeth in *C. yaquinae* are either in two irregular

series or in a widely scattered band, whereas those in *C. armatus*, if present, are always in a distinct single row (the inner premaxillary series is essentially lost in very large specimens of *C. armatus*). Mandibular teeth in *C. yaquinae* are arranged in two irregular series near the symphysis but in a single row posteriorly. *Coryphaenoides armatus*, in contrast, has mandibular teeth in a continuous, single row, both at the symphysis and posteriorly. Scales in *C. yaquinae* are notably coarser than in *C. armatus*. Scale spinules in *C. yaquinae* are more erect and the spinule ridges are higher and fewer than those found in comparable-sized *C. armatus*. Scales on the suborbital shelf (fig. 15) are in fewer rows (usually only two rows along the narrowest portion) in *C. yaquinae* compared with *C. armatus*, which has suborbital scales in more than two rows. Coloration shows slight differences between the two species, but the differences are not readily apparent unless specimens of both are compared directly. Generally, *C. yaquinae* is more pallid with a grayish cast while *C. armatus* tends to be darker with a brownish black coloration. Pores of the sensory lateralis system are comparatively much larger and more prominent on the head of *C. armatus* than in *C. yaquinae* (fig. 15).

Chalinura ferrieri Regan (1903, p. 236) from the Antarctic Ocean appears to be close to *C. yaquinae*. We had no specimens of *Chalinura ferrieri* for comparison, and the description for that species is inadequate; however, the two species appear to differ mainly in that *C. ferrieri* has a more pointed snout, more extensive naked areas on the preopercle, larger pores on the suborbital region, a longer barbel, fewer spinule rows on body scales, and more pelvic fin rays (11 versus 10). When more adequate comparative material becomes available, the species may be shown to be conspecific. Until such comparisons are made, however, it seems best to treat the specimens reported here as representing a distinct species.

REMARKS. We are indebted to Dr. Carl L. Hubbs who first recognized this fish as representing an undescribed species. Dr. Hubbs had a manuscript name for the species and intended to describe the two Scripps specimens, but, learning of our study, he graciously relinquished his specimens and allowed us to use them in our description.

The presence of an undescribed species in our collections was surprising in view of the many nominal, but few valid species we found from the eastern North Pacific. It is remotely possible that the species was reported previously under one of the synonyms of *C. armatus*. As indicated in our comparisons, the two species are very close and could easily be confused. The possibility of *C. yaquinae* being conspecific with an Antarctic species, *C. ferrieri*, has already been suggested. If this proves true, *C. ferrieri* should be expected throughout most of the Pacific.

The few known specimens and the great depths at which they were taken may indicate that *C. yaquinae* is either very rare in the eastern North Pacific or that it is normally an inhabitant of greater depths than have been adequately sampled.

SPECIMENS EXAMINED. Holotype: USNM uncataloged, (75 mm. H.L., 376 mm. T.L.) Tufts Abyssal Plain, 44°39.9'N., 133°37.2'W., Yaquina station TP-3, haul 232, in 3724 meters, 3 June 1970. Paratypes: SIO no. 67-115-62, (2, 53-79 mm. H.L., 255-400 mm. T.L.) California, SW. of Farallon Islands, 37°22'16"N., 123°54'53"W., collected by C. L. Hubbs, et al., 31 July 1967.

Coryphaenoides (Nematonurus) pectoralis (Gilbert).
(Figures 21, 22.)

Macrurus (Malacocephalus) pectoralis Gilbert, 1892, pp. 563-564 (original description; off Oregon, Albatross stations 3071, 3074, and 3075, in 685-877 fathoms (1253-1604 meters)).

Macrurus (Nematonurus) magnus Gill and Townsend, 1897, p. 234 (original description; holotype 43 inches long, Bering Sea, SW. of Pribilof Islands, Albatross collection).

Albatrossia pectoralis, Jordan and Evermann, 1898, pp. 2573-2574 (description after Gilbert; synonymized *Macrurus magnus* Gill and Townsend with this species; designated type-species of new genus *Albatrossia* Jordan and Evermann); Jordan and Gilbert, 1899, p. 487 (2 specimens; Bering Sea off Bogoslof Island, Albatross station 3634; in 1214 meters); Taranetz, 1933, p. 77 (Bering Sea, Olyutorskiy Gulf).

Coryphaenoides (Nematonurus) pectoralis, Gilbert and Hubbs, 1916, pp. 161-162 (description; specimens from off E. and SE. coasts of Sagkalin and S. coast Hokkaido, in 309-510 fathoms (565-933 meters)); Okamura, 1970, pp. 118-121, text fig. 49, pl. 25 (description; illustration; 14 specimens, 620-1050 mm. total length; off Japan, in 550-1200 meters); 1971, figs. 5A, 14H, 17D, 22A, 27B, 31B, 34G, 42A, 45A, 47B, 55F, 63A, tables 1, 11 (osteological and internal characters).

Coryphaenoides pectoralis, Taranetz, 1937, p. 169 (listed); Schmidt, 1950, p. 62 (Bering Sea near Bering Island).

Nematonurus pectoralis, Andriashev, 1937, p. 346, fig. (description; illustration; 2 specimens, Bering Sea off Bering Island, in 200 meters); Matsubara, 1955, p. 1308 (in key).

Chalinura pectoralis, Rass, 1963, pp. 217-219, fig. 3, table 5 (description; illustration; 5 specimens, 552-965 mm. total length, Okhotsk Sea, Vityaz station 103, 116, 132, in 1500, 1030, and 890 meters); Novikov, 1970, pp. 304-331 (extensive life history information).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers on inner series of first arch 12-14 total (usually 2 + 10-11); inner series of second arch 11-14 (usually 2 + 10-11). Scale rows below origin of first dorsal fin 13-15, below origin of second dorsal fin 9-13 (usually 10-12).

MORPHOMETRY. Measurements from 15 specimens ranging 94-228 mm. in head length, +350-+970 mm. in total length. The following in percent of head length: snout length 24-28; preoral length 8-12, horizontal diameter of orbit 19-23; interorbital width 23-28; orbit to angle of preopercle 40-45; suborbital width 9-12; length upper jaw 35-47 (usually 42-44); length barbel 6-13; length outer gill-slit 18-20; preanal length 144-182; distance isthmus to anal origin 88-123; greatest body depth 65-86; depth over anal origin 63-72; height first dorsal fin about 35-50; length pectoral fin 43-56; length pelvic fin 36-52; interspace between first and second dorsal fins 10-21.

DESCRIPTION. General features of the fish are best shown in figure 21. (See also Okamura, 1970, pp. 118-121, pl. 25, for a detailed description and good illustration.) Body musculature is soft and the neurocranium appears poorly ossified. The head is broad with the greatest width more than 50 percent of the length. Ridges of the head are rounded; they are neither sharp nor strongly set off by rows of deeply embedded scales. The terminal and lateral angles of the snout are prominent but lack enlarged, deeply embedded, scute-like scales. In fact, most specimens are partially naked at these points. The suborbital region is gently convex in cross-section and completely covered with small, unmodified scales. The interorbital region is broad, its width about equaling the snout length and considerably longer than the orbit diameter. The interopercle is broadly exposed along its posteroventral border and along its anterior articulation with the lower jaw. The barbel is very fine and small. Gill openings are wide and extend forward to a point just behind a plane through the posterior end of the upper jaw. Gill membranes adhere closely to the isthmus and lack a free fold. Head pores of the sensory lateralis system are small and inconspicuous. The lateral line, however, is very large and strongly marked.

All fins are relatively small and weakly developed. The first dorsal and pelvic fins are notably small and the rays relatively slender and weak. The first spinous ray of the dorsal fin is very small, closely adhered to the second ray,

and completely embedded within the integument. The second spinous ray is weak, slender, and either entirely smooth or with minute denticles distally. Smaller specimens tend to have the prickles best developed. The narrow and short pelvic fins have a single outer ray slightly prolonged. This prolonged ray falls short of, or barely reaches, the anus.

Scales are comparatively small, thin, and deciduous. Some size-related variation is seen in both the number of longitudinal ridges on the exposed fields and the amount of spinulation on these ridges. The smallest specimens we have examined have 3-5 divergent ridge-like rows of small, sharp spinules. Larger specimens have correspondingly fewer ridge-rows and spinules on the ridges are less developed. The largest specimens have a single non-spinulated ridge running longitudinally across the middle of the exposed field. Scales uniformly cover most of the head and body. Naked areas include most of the anterior portion of the snout, a thin margin along the ventral edge of the suborbital region, lips, gill membranes, small areas behind the bases of the paired fins, and all fins. The exposed portions of the interopercle and the lower jaws are finely scaled. The suborbital region is uniformly covered with small, unmodified scales, except along the extreme dorsal and ventral margins where the skin is naked.

Variation in the dentition of this species is discussed under the description of the genus. Dentition in the upper jaw consists of moderately large teeth, usually in two irregular series with the outer series slightly enlarged. Teeth laterally on the premaxilla are sometimes in a single row. Mandibular teeth are usually in a single row and moderately enlarged; the teeth are not crowded together but are usually evenly and well spaced. All teeth have distinctly arrowhead-shaped tips.

Coloration of specimens with scales completely intact (we had no perfect specimens) is probably uniformly medium brown with the fins, gill membranes, lips, and lower surface of the snout somewhat blackish. Specimens denuded of scales (most of our study material) were pale with a slight pinkish to violet tinge.

The swimbladder is much reduced in size. A female specimen (UW no. 19304) 188 mm. in head length has a swimbladder about 22 mm. in length. Two very slender retia, each measuring about 15 mm. in length, terminates in two small, flat gas glands. The reduced condition of the swimbladder gives further indication of the wide separation of *C. pectoralis* from other members of the genus. Pyloric caeca in two specimens are long, slender, and number 13 and 15. Okamura (1970, p. 121) gave a count of 12-15 for the species, while Andriashev (1937) counted 12 and Gilbert and Hubbs (1916, p. 161) counted 16. Radiographs of 16 specimens showed 13 (4 specimens) or 14 (12 specimens) precaudal vertebrae.

DISTRIBUTION. This large boreal North Pacific species ranges along the North American coast from off Northern California to the Bering Sea. It is abundant in the Bering and Okhotsk Seas (Rass, 1963, p. 219) and extends southward along the western side of the Pacific to southern Hokkaido. Capture depths range from about 200 meters (Andriyashev, 1937, p. 346) to 2170 meters (Novikov, 1970).

REMARKS. Although Jordan and Evermann (1898, p. 2574) stated that this is a firm-fleshed species, the consistency of the flesh is quite soft when compared with all other species considered here. The reduced condition of the gas bladder, the relatively soft flesh, and the scarcely ossified bones of the head are features not found in any other species of *Coryphaenoides* of which we know. The comparatively reduced fins and the peculiar dentition are additional features that set this species apart. A more detailed examination of the internal structure may reveal other characters that could justify a subgeneric or generic separation of this species. *Albatrossia* Jordan and Evermann is available.

Mr. Robert N. Lea of the California Department of Fish and Game informs us that commercial fishermen operating out of Trinidad and San Francisco, California, occasionally capture and market large specimens of *C. pectoralis*. Novikov (1970) states that the species is "especially common" in the North Pacific, often "being more abundant than ... halibuts and rockfishes" with catches amounting "to 4-6 tons per trawling" "in several cases." He considers the fish as "a valuable food" and "promising commercial species."

Novikov (1970) has reported on aspects of the life history of *C. pectoralis*. From catch data, he speculates that the young are pelagic, descending to demersal layers after reaching a length of 50-60 cm. Females are usually larger than males and normally maintain a shallower depth regime (300-700 m. compared with deeper than 700 m. for males). The largest specimen Novikov examined measured 116 cm. and weighed 758 g. (or about 16.5 lbs.). From his data, the fish at this size would be over 17 years old.

SIZE. This species attains the largest size of any macrourid fish known. The largest specimen we have examined weighed 17.5 lbs. and measured 1031 mm. in total length with a large section of the tail missing. A specimen which may have been even larger was captured by the R/V *Cobb* of the National Marine Fisheries Service off the Columbia River. The specimen shown in the photograph (fig. 22) was brought to our attention by Mr. Richard B. Grinols, formerly a fishery biologist with the National Marine Fisheries Service. A rough estimate of the size of the specimen based on the photograph would be approximately 5 feet or about 150 cm.

SPECIMENS EXAMINED. UW no. 19279 (1, 181 mm. H.L., about

920 mm. T.L.), off mouth of Columbia River, AEC station 39A, 1000 fathoms (1829 meters), 28 May 1964; UW no. 19289 (5, 105-181 mm. H.L., 604-708 mm. T.L.), approximately 46°N., 125°W., AEC station 35A, 900 fathoms (1646 meters), 29 May 1964; UW no. 19290 (1, 206 mm. H.L., + 970 mm. T.L.), approximately 46°N., 125°W., AEC station, 10A, 275 fathoms (503 meters), 10 April 1967; OSUFW uncat. (1, 115 mm. H.L., + 520 mm. T.L.), off Coos Bay, Oregon, 310-320 fathoms (567-585 meters), 26-27 Dec. 1970; OSUO no. 376 (1, 228 mm. H.L., 48°38.4'N., 126°58.0'W., Yaquina station DWD 5, 1998 meters).

Other specimens examined but from which no data were taken: OSUO uncataloged (1, 1031 mm. T.L.), off Trinidad, Calif.; SIO no. H51-367 (1, 710 mm. T.L.), 56°20'N., 145°20'W., 330 fathoms (603 meters), 25 Aug. 1951; UBC no. 64-443 (3 specimens), British Columbia, SW. of Baja Reef, 9 Sept. 1964; UBC no. 62-465 (1 specimen), 54°26'30"N., 159°13'20"W., Morning Star haul 212, station 24P, 10 July 1961; UBC no. 62-478 (1 specimen), 54°18'40"N., 160°01'40"W., haul 183, station 21-N., 250 fathoms (457 meters), 30 June 1961; UBC no. 62-464 (1 specimen), 53°39'N., 165°00'W., haul 6, station 1-E, 14 May 1961; CAS 20521 (2, 110-123 mm. H.L., about 450-530 mm. T.L.), Calif., off Ft. Bragg; CAS 20598 (1, 129 mm. H.L., 700 mm. T.L.), Calif., off Crescent City, 19 May 1952; CAS 25908 (3, 115-128 mm. H.L., 640-650 mm. T.L.), Calif., off Point St. George, 25 May 1952; CAS 26333 (1, 121 mm. H.L., 500 mm. T.L.), Calif., off Humboldt Co.; CAS 26337 (1, 117 mm. H.L., 610 mm. T.L.), Calif., off Trinidad Head, 4 May 1958; CAS 26343 (1, 136 mm. H.L., 680 mm. T.L.), Calif., off Trinidad Head, 14 May 1958; CAS uncat., acc. 1965-II:23 (1, 133 mm. H.L., 715 mm. T.L.), Calif., off Sonoma Co., 24 miles W. by S. of Bodega, S. side of Bodega Canyon, between 270-320 fathoms, 23 Feb. 1965; CAS uncat., acc. 1965-IX:9 (1, 121 mm. H.L., 600 mm. T.L.), Calif., probably off Eureka.

Subgenus *Chalinura* Goode and Bean

DIAGNOSIS. Dentition in upper jaws a broad cardiform band of minute teeth with a distinctly enlarged, spaced outer series; dentition in lower jaw usually a distinct single row of slightly enlarged teeth (occasionally in narrow bands in young individuals). Precaudal vertebrae 12. Retia and gas glands 6 each. Scales usually relatively small and loose; spinules on exposed fields short, but sharp, arranged in discrete, usually parallel, ridge-like rows; a characteristic single row of small scales along leading edge of snout, passing over supranarial ridges, and usually over median nasal ridge. Broad naked areas behind scale row along leading snout edge; also broad naked areas over ventral aspects of snout, suborbital, and preopercle. Opercular opening wide with a broad free fold over isthmus. Outer gill-slit moderately wide. Interopercle slender, naked. Orbits small, usually about 20 percent of head length;

interorbital broad, width greater than orbit length. Head pores of sensory lateralis system large.

REMARKS. Subgenus *Chalinura* appears to comprise a well marked group of species containing *C. leptolepis* Günther, 1877, *C. brevis* Goode and Bean, 1896, *C. profundicola* Nybelin, 1957, *C. murrayi* (Günther, 1878), *C. mediterraneus* Giglioli, 1893, *C. liocephalus* (Günther, 1887), *C. affinis* (Günther, 1878), and *C. fernandezianus* (Günther, 1887). The dentition appears to be the only character that definitely distinguishes it from other subgenera as here defined. That character breaks down to some degree, however, when the mandibular dentition of *C. leptolepis* is compared with that of members of subgenus *Lionurus*. Our examination of many specimens of *C. leptolepis* indicates considerable variability in this character, with many specimens (particularly the smaller ones) having teeth arranged in a narrow band (the condition in subgenus *Lionurus*) rather than in a distinct single row (as is characteristic of subgenus *Chalinura*). The premaxillary dentition in *Chalinura* characteristically has a broad band of very small cardiform or villiform teeth with a distinct enlarged outer series. The teeth on the premaxilla of *Lionurus* are identical except that the outer enlarged series is generally less well developed.

The broad naked areas on the ventral surfaces of the head are features shared in common with the subgenus *Lionurus*. A number of species belonging to subgenera *Coryphaenoides* and *Nematonurus* also have similar naked areas. *Coryphaenoides* (*Nematonurus*) *armatus* has broad naked areas on the ventral surfaces of the snout, suborbital region, preopercle, and lower jaws and, in the smaller specimens, even on the anterior dorsal surfaces of the snout, behind the leading edge. The squamation along the leading edge of the snout in small specimens of *C. armatus* very closely resembles that found in all members of subgenus *Chalinura*.

Coryphaenoides (*Chalinura*) *leptolepis* Günther.
(Figures 23, 24.)

Coryphaenoides leptolepis Günther, 1877, p. 441 (original description; "off the coasts of Brazil and Japan, Mid-Pacific").

Chalinura simula Goode and Bean, 1883, pp. 199-200 (original description; holotype MCZ no. 25824, 458 mm. total length, 41°24'45"N., 65°35'30"W., Blake station 308, in 1242 fathoms (2271 meters); 3 other specimens, "probably belonging to [this] species"); Goode and Bean, 1896, pp. 412-413, fig. 345 (description; illustration; Blake and Albatross records from western North Atlantic); Roule, 1919, p. 86 (2 specimens; Azores, 1919-2102 meters); Parr, 1946, pp. 65-68, fig. 20 (description; illustration).

Macrurus (Chalinurus) leptolepis, Günther, 1887, p. 144, pl. 31 (description; illustration; one specimen, the holotype, 18 inches long, off Pernambuco, Brazil, *Challenger* station 122, 350 fathoms (640 meters); other specimens of original type series from Japan and mid-Pacific re-described and designated types for new species, *Macrurus liocephalus*).

Macrurus (Chalinurus) simulus, Günther, 1887, p. 145 (description; compiled).

Chalinura serrula Bean, 1891, p. 37 (original description; off Prince of Wales Island, about 55°N., 136°W., in 1569 fathoms (2870 meters)).

Chalinura leptolepis, Goode and Bean, 1896, p. 414 (description after Günther); Nybelin, 1957, p. 264 (in key), pp. 267-268 (characters; comparison with '*simula*').

Macrurus (Chalinura) simulus, Lütken, 1898, pp. 28-29 (description; 4 specimens Denmark Strait, in 912-1236 fathoms (1668-2260 meters)); Koefoed, 1927, pp. 100-103 (description; 7 specimens, eastern North Atlantic, in 2615-3120 meters).

Coryphaenoides serrulus, Gilbert and Hubbs, 1916, p. 144 (listed).

Macrurus (Chalinura) leptolepis, Koefoed, 1927, p. 102 (comparison with '*simula*').

Coryphaenoides simulus, Fowler, 1936, p. 457 (description after Goode and Bean).

COUNTS. Frequency distributions of selected counts are given in table 1. Gillrakers on outer series of first arch 8-11 total (0-1 + 8-10); inner series of second arch 10-14 total (1-2 + 8-19).

MORPHOMETRY. Measurements based on 21 specimens ranging 31-103 mm. in head length, and 160 to over 460 mm. in total length. The following in percent of head length: snout length 24-31 (usually 25-28); preoral length 4-16 (usually 4-10); horizontal orbit diameter 15-20; interorbital width 23-27 (usually 23-25); orbit to angle of preopercle 48-51; suborbital width 10-16; length upper jaw 41-47; length barbel 16-23; length outer gill-slit 23-28; length snout to anus 134-154; predorsal length 107-122; distance isthmus to anus 65-88; greatest body depth 65-78; length pectoral fin 52-62; length pelvic fin 70-102; interspace between first and second dorsal fins 27-50 (usually about 35-45).

DESCRIPTION. General features of *C. leptolepis* are shown in figure 23. Gill openings are wide and the gill membranes form a broad free fold across the isthmus. The preopercle forms a prominent, broad, posteriorly projecting lobe at its lower angle. The posterior end of the interopercle is exposed as a slender naked sliver. Pores of the sensory lateralis system are extremely large and prominent on the head. Their locations are best seen in the illus-

tration (fig. 24).

Scales of *C. leptolepis* are very thin and deciduous. Spinulation is poorly developed on all scales, but, when present, they occur as small, greatly reclined points along low divergent ridges. A single row of small, adherent scales is present along the dorsal leading edge of the snout. This row of scales connects laterally, on each side, with a similar row of adherent scales that passes over the supranarial ridge onto the dorsal edge of the orbits. A row of scales is also sometimes present on the dorsomedian snout ridge. A broad area behind the leading edge of the snout, on either side of the dorsomedian ridge, is naked. The ventral surfaces of the snout, suborbital, preopercle, and lower jaws are naked. Serrations along the leading edge of the second dorsal spine are low and generally reclined, and well developed in individuals of all sizes. The spine tapers to a thin filamentous tip but is little prolonged. The outer pelvic ray is relatively much thicker than other rays of the fin and is much prolonged, extending well past the anal-fin origin.

Coloration in denuded specimens is whitish overall with a pinkish tinge. The gill cover has a violet tinge resulting from the black lining of the branchial chamber showing through the opercular bones. The lips, gular and branchiostegal membranes, the barbel, most of the orbit margin, and the edge of the urogenital orifice are blackish. The oral, branchial, and peritoneal linings are black. All fins are dusky to pale.

Six long thin retia were connected to six small peltate gas glands in a 95-mm. head length female specimen. Radiographs of nine specimens showed a consistent count of 12 precaudal vertebrae.

REMARKS. *C. leptolepis* was originally described by Günther (1877) from a single specimen taken off the coast of Brazil. Goode and Bean (1883) later described *Chalinura simula* from specimens taken by the *Blake* off the east coast of the United States. The two nominal species were compared by Koefoed (1927, p. 102) who found differences between the two "extremely small and uncertain." He noted that his seven specimens, which he identified as *C. simula*, had longer barbels, longer outer pelvic fin rays, and a slightly shorter distance between the isthmus and anus compared with what was given in the description of *C. leptolepis*. Nybelin (1957, p. 268) re-examined the type of *C. leptolepis* and compared it with two specimens of '*simula*.' He found differences only in proportional values of the distance isthmus to anus, distance pelvic base to anal, predorsal length, and barbel length. These very slight differences, between only the three specimens, in characters that normally exhibit considerable variability, scarcely seem valid as specific differences. Our findings using many more specimens from the eastern North Pacific and the western North Atlantic

show even greater variability for these characters.

Chalinura serrula Bean was originally described from three individuals taken in the Pacific off the coast of southeastern Alaska. Koefoed (1927, p. 103) recognized its closeness to *C. simula* but noted that the eye diameter was slightly smaller in *C. serrula*. Our data show complete overlap in that character for specimens from the eastern North Pacific and the western North Atlantic. Comparisons of other features showed no significant differences.

The only differences of possible significance that we were able to detect between Atlantic and Pacific specimens of *C. leptolepis* were the fin ray counts of the first dorsal fin and pelvic fins. Table 1 shows the slight differences in modes of the two characters between populations.

DISTRIBUTION. *Coryphaenoides (Chalinura) leptolepis* thus appears to be a widely distributed species inhabiting relatively deep waters of the Pacific and Atlantic Oceans. The distribution of *C. leptolepis* in the southern hemisphere is unknown. It is plausible to assume that its distribution is continuous around the southern tip of South America, but we know of no records that would verify this.

COMPARISONS. The only other species of *Chalinura* (*fernandezianus* Günther) from the eastern Pacific seems quite distinct; it is only known from the holotype taken by the *Challenger* south of Juan Fernandez Island in 1375 fathoms (2515 meters). *Coryphaenoides liocephalus* (Günther) appears extremely close to, and may be conspecific with, *C. leptolepis*. Günther gave no good characters that would distinguish the two species except that *C. liocephalus* was blackish and *C. leptolepis* a dirty whitish. *C. liocephalus* is known only from the type series, one taken near Yokohama, Japan in 1875 fathoms (3429 meters) and two taken in the mid-Pacific (about 36°N., 178°W.) in 2050 fathoms (3749 meters). A fourth Pacific species of the subgenus *Chalinura* is *C. murrayi* (Günther) described from five specimens taken off New Zealand. That species, which was once thought to have occurred also in the Atlantic, differs from *C. leptolepis* in having slightly more pelvic fin rays (11-12 compared with 9-11 in *leptolepis*), broader interorbital space, longer interspace between the dorsal fins, and a distinctly darker coloration.

SPECIMENS EXAMINED. Pacific: OSUO no. 404 (1, 103 mm. H.L.), 45°59.6'N., 125°44'W., cruise 6507, trawl no. 78 in 2500 meters; OSUO no. 384 (1, 61 mm. H.L., +295 mm. T.L.), 48°18.4'N., 127°42.4'W., trawl no. DWD 1, in 2560 meters; OSUO uncataloged (2, 81-89 mm. H.L., 410-457 mm. T.L.), 44°58.8'N., 125°40.4'W., Yaquina trawl no. BMT 188, in 2792 meters; OSUO uncataloged (2, 35-58 mm. H.L., 187-268 mm. T.L.), 45°19.8'N., 125°44.3'W., Yaquina trawl no. BMT 190, in 2597 meters; OSUO uncataloged (1, 58 mm. H.L., 283 mm.

T.L.), 45°39.2'N., 125°44.6'W., Yaquina trawl no. BMT 192, in 2450 meters; OSUO uncataloged (3, 42-83 mm. H.L., 207-404 mm. T.L.), 45°55.3'N., 125°53.7'W., Yaquina trawl no. BMT 251, in 2377 meters; OSUO no. 2089-2090 and uncataloged (4, 37-78 mm. H.L., 200-406 mm. T.L.), 45°45.7'N., 126°33.1'W., Yaquina trawl no. BMT 259, in 2665 meters; OSUO no. 2073 (1, 35 mm. H.L., 168 mm. T.L.), 45°38.9'N., 126°46.1'W., Yaquina trawl no. CP2-B, in 2669 meters; OSUO no. 2100 (1, 31 mm. H.L., 160 mm. T.L.), 45°38.4'N., 126°43.7'W., Yaquina trawl no. BMT 262, in 2721 meters.

Atlantic: USNM no. 38081 (1, +460 mm. T.L.), 38°29'30"N., 70°54'30"W., Albatross station 2715, in 1753 fathoms (3408 meters); USNM no. 38103 (1, 74 mm. H.L., +320 mm. T.L.), 38°20'N., 70°68'30"W., Albatross station 2713, in 1859 fathoms (3400 meters); USNM no. 38138 (1, 83 mm. H.L., 435 mm. T.L.), 36°47'N., 73°09'W., Albatross station 2723, in 1685 fathoms (3082 meters); USNM no. 39152 (1, 71 mm. H.L.), 39°29'N., 70°58'40"W., Albatross station 2095, in 1342 fathoms (2454 meters); USNM no. 143225 (1, 64 mm. H.L., 332 mm. T.L.), 40°34'18"N., 66°09'W., Albatross station 2573.

Specimens examined but from which no data were taken: SIO 67-115-62 (12, 282-368 mm. T.L.), 37°22'N., 123°54'W., 14 June 1967; UBC 64-444 (8 specimens), Canada, British Columbia, off Triangle Island area, 11 Sept. 1964.

Genus *Nezumia* Jordan, 1904

Nezumia Jordan, in Jordan and Gilbert, 1904, p. 620 (type-species *Nezumia condylura* Jordan and Gilbert, by original designation).

Nezumia liolepis (Gilbert).
(Figure 1B.)

Macrurus (Lionurus) liolepis Gilbert, 1891, p. 117 (original description; off southern California, Albatross station 2980, in 603 fathoms (1103 meters)).

Lionurus liolepis, Goode and Bean, 1896, p. 409 (listed); Gilbert, 1915, p. 376 (characters; numerous records from off California between San Diego and Monterey Bay, in 161-110 fathoms (294-201 meters)); Townsend and Nichols, 1925, p. 17 (numerous specimens, N. of Pt. Conception to Cape San Lucas, Lower California, in 284-645 fathoms (519-1180 meters)).

Macrurus liolepis, Garman, 1899, pp. 199-200 (description; records from off Baja California, Albatross stations, in 660-905 fathoms (1207-1655 meters)); Gilbert, 1896, p. 473 (record from off Monterey Bay, Calif., Albatross station 3126, in 456 fathoms (834 meters)).

Lionurus (Lionurus) liolepis, Gilbert and Hubbs, 1916, p. 146 (listed).

Nezumia liolepis, Fitch and Lavenberg, 1968, p. 142 (listed).

REMARKS. *Nezumia liolepis* is a divergent member of its genus, marked by few spinules on the scales, few serrations on the second dorsal ray, and small ventral light organ. The only other species of the genus with comparable reductions in these features is *N. barbiger* (Garman), an eastern Pacific species found in waters off Central America.

DISTRIBUTION. The species is known from Cape San Lucas, Baja California to off Monterey Bay, California. Capture depths range 201-1655 m.

SPECIMENS EXAMINED. CAS no. 26638 (4, 41-56 mm. H.L., 185-272 mm. T.L.), Calif., off San Mateo Pt., 23 June 1953; SU no. 21402 (5, 51-64 mm. H.L., 242-295 mm. T.L.), Calif., off Santa Cruz Island, Albatross station 4428, in 764-891 fathoms (1397-1629 meters).

Nezumia stelgidolepis (Gilbert).
(Figures 2B, 3C, 25.)

Macrurus stelgidolepis Gilbert, 1891, p. 116 (original description; off Pt. Conception, California, 34°10'45"N., 120°16'45"W., Albatross station 2960, in 267 fathoms (488 meters)); Goode and Bean, 1896, p. 391 (listed); Gilbert, 1915, p. 376 (recorded from off San Diego, Albatross station 4306, in 207-497 fathoms (378-910 meters)).

Macrurus gracillicauda Garman, 1899, pp. 206-207, pl. H., fig. 1 (original description; illustration; specimens from off Pacific Panama, Albatross stations 3384 and 3385, in 458 and 286 fathoms (837 and 523 meters)).

Lionurus (Nezumia) stelgidolepis, Gilbert and Hubbs, 1916, p. 145 (listed).

Lionurus stelgidolepis, Barnhart, 1936, p. 24 (brief description).

Nezumia stelgidolepis, Roedel, 1951, p. 509, fig. 183 (16 records from off California); Fitch and Lavenberg, 1968, pp. 73-74, fig. 37 (illustration; characters; otoliths and life history notes).

COUNTS. First dorsal fin rays II, 8-10; pectoral fin rays 23-24; pelvic fin rays 10 (rarely 9). Outer gillrakers on first arch 2 + 9-10 (10-12 total); on second arch usually 2 + 9 (9-11 total). Scales below origin of first dorsal fin 9-10; below origin of second dorsal fin 7-8.

MORPHOMETRY. Measurements from 7 specimens ranging 49-96 mm. in head length, +200-+380 mm. in total length. The following in percent of head length: snout length 24-26; preoral length 12-15; horizontal orbit diameter 26-28;

interorbital width 24-26; orbit to angle of preopercle 40-45; suborbital width 12-14; length upper jaws 34-37; length barbel 15-23; length outer gill-slit 16-18; distance snout to anal origin 126-157; greatest body depth 75-89; body depth over anal origin 62-83; height first dorsal fin 59-68; length pectoral fin 52-55; length pelvic fin 43-50; interspace between first and second dorsal fins 27-44.

The head is moderately compressed and contours are generally rounded; head ridges are not strongly angular. The interopercle is broadly exposed and scaled. Gill openings are wide, the branchiostegal membranes unite over the isthmus at a point below the hind margin of the orbits or slightly posteriorly, and a moderately broad free fold is formed. Pores of the sensory lateralis system on the head are large and prominent. The vent is located below the middle of the first dorsal fin, behind the bases of the pelvic fins, but well ahead of the anal fin. The distance between the vent and the anal-fin origin is greater than the orbit diameter. A small black fossa lies between the medial margins of the pelvic-fin bases (fig. 2B). A relatively much larger area of scaleless black skin lies anterior to the vent -- these black areas represent parts of the light organ.

Fins lack enlarged or greatly prolonged rays. The outer pelvic ray is thin, the tip filamentous and extending slightly beyond other rays but falling well short of the anal-fin origin. Serrations on the second spinous dorsal ray are stout, well developed at all sizes, and sharp.

Scales are densely covered with slender, lanceolate to conical spinules arranged in an irregularly quincuncial pattern. Scales over the dorsal portion of the suborbital region are large, stout, and in two discrete longitudinal rows along the narrowest portion. Spinules on these scales are erect and arranged in 3-5 sharp, divergent, ridge-like rows. The tip and lateral angles of the snout are armed with stout, heavily spined, tubercle-like scales. Ventral surfaces of the snout and almost all of the suborbital region are naked. The anterior half to two-thirds of the lower jaw rami are naked; sensory pores are very large and prominent here. The third to fifth branchiostegal rays are usually heavily scaled along their bases.

Premaxillary dentition consists of a broad band of villiform teeth with a series of somewhat enlarged, spaced, outer teeth. Broad bands of irregular-sized teeth are present on the mandible; the inner teeth are generally larger. The mandibular band tapers to one to two rows posteriorly.

Coloration is dark brown to swarthy overall and bluish over the abdomen. Gill membranes, lips, gular membranes, lower surfaces of the snout and suborbital, and fins are blackish. The oral cavity is rather pale or dusky, except for blackish oral valves. Gill chambers are black along the outer margins but pale along the anteroventral outer walls and ventralmost and dorsalmost portions of the inner wall.

Peritoneal linings are pale. Gillrakers are darkish, but gill arches and filaments are pale.

SIZE. A 445-mm. specimen reported by Roedel (1951, p. 509) as taken off Point Vicente, California, is the largest known.

COMPARISONS. *Nezumia stelgidolepis* appears most closely related to *N. atlantica* (Parr, 1946) from the western Atlantic. It is readily distinguished from that species by the presence of heavy scales on the branchiostegal rays, the posteriorly produced upper opercular angle and the extensive naked areas on the lower jaw. The relationships of these two species with *N. burragei* (Gilbert, 1905) and *N. tomiyamai* (Okamura, 1963) are briefly discussed by Iwamoto (1970). *Nezumia liolepis* is the only other member of the genus normally found in eastern Pacific waters north of southern California. That species differs markedly from *N. stelgidolepis*, particularly in its thinner, less spinulated, more deciduous scales, its lower first dorsal fin, its more numerous pelvic fin rays (usually 11), its weaker serrations on the second dorsal spine, and its more posteriorly located vent.

DISTRIBUTION. The species is known from off Vancouver Island, British Columbia, south to Panama where it has been reported as *Macrurus gracillicauda* Garman (a synonym *vide* Gilbert and Hubbs, 1916, p. 145). We found no specimens from off Oregon or Washington and suspect that the species is rare north of California.

SPECIMENS EXAMINED. SU no. 102 (1, 49 mm. H.L., +200 mm. T.L.), off Lower California, 26°24'N., 113°49'W., Albatross station 3045, in 184 fathoms (336 meters), 10 April 1889; SU no. 17168, (1, 68.5 mm. H.L., + 330 mm. T.L.), off Trinidad Head, Calif., 235 fathoms (430 meters), 14 Aug. 1950; SU no. 22931, off Pt. Loma, Calif. (1, 50 mm. H.L., + 215 mm. T.L.), Albatross station 4306, 207-497 fathoms (379-909 meters), 2 March 1904; CAS no. 25992, (2, 85-96 mm. H.L., +380-+405 mm. T.L.), off Pescadero Pt., Calif., 15 April 1954; CAS no. 26072, (1, 81 mm. H.L., 400 mm. T.L.), off Ft. Bragg, Calif., April 1954; CAS no. 15384, (1, 48 mm. H.L., 240 mm. T.L.), G. B. Reed cruise 72-3, station 17, off Vancouver Island, British Columbia, 48°45.4'N., 126°21.5'W., in 257 fathoms (470 meters).

Additional specimens from which no meristic or morphometric data were taken: CAS no. 14276, (10, 54-71 mm. H.L.), off Santa Cruz Island, Calif., 19 Feb. 1951; CAS no. 17166, (1, 67 mm. H.L.), off Eureka, Calif., 0-200 fathoms (0-366 meters), Jan.-April, 1950; CAS no. 20558, (1, 69 mm. H.L.), SW. of St. George Light, Calif., Clara G, 200 fathoms (366 meters), 3 Sept. 1951; CAS no. 26347, (1, 90 mm. H.L.), off Ft. Bragg, Calif., 10 June 1958; CAS uncataloged, (1, 63 mm.

H.L.), off Pigeon Pt., Calif., 200 fathoms (366 meters), 22 Dec. 1963.

Genus *Coelorinchus*³ Giorna, 1805

Coelorinchus Giorna, 1809, p. 179 (type-species *Lepidoleprus coelorhincus* Risso, 1810, by tautonymy).

Coelorinchus scaphopsis (Gilbert).
(Figures 1A, 2A, 3A.)

Macrurus (*Coelorhynchus*) *scaphopsis* Gilbert, 1890, p. 115 (original description; many specimens, Gulf of California, 29°19'N., 112°50'W., Albatross station 3015, in 145 fathoms (265 meters)); Böhlke, 1953, p. 58 (12 syntypes, SU no. 179, listed).

Coelorhynchus scaphopsis, Goode and Bean, 1896, p. 397 (listed).

Coelorhynchus (*Coelorhynchus*) *scaphopsis*, Gilbert and Hubbs, 1916, p. 144 (listed).

DISTINGUISHING FEATURES. This species is readily distinguished from all other macrourid fishes treated here by the following combination of characters: a large, black, naked fossa on midventral line just anterior to pelvic fins; snout pointed, produced, and stoutly supported by sharp lateral ridges that pass continuously from tip of snout to the preopercle angles; pelvic fin rays 7; second spinous dorsal ray smooth at all sizes.

REMARKS. *Coelorinchus scaphopsis* is the only member of the genus *Coelorinchus* known to inhabit eastern Pacific waters north of Baja California.

Mr. Joseph Copp of Scripps Institution of Oceanography informs us that this species is rather commonly taken by commercial trawlers fishing out of Santa Barbara. Three specimens we examined come from that general area, but we know of none from north of Point Conception.

³Lillian J. Dempster and William I. Follett of the California Academy of Sciences point out that Giorna's original spelling of the generic name, *Coelorinchus*, was improperly emended to *Coelorhynchus* by most later authors. There is no justification for this according to Article 32(a)(ii) of the International Code of Zoological Nomenclature. The spelling should remain *Coelorinchus*. The different spellings of *Coelorinchus* (*Coelorhincus*, *Coelorhynchus*, *Coelorrhynchus*, etc.) are homonyms according to Article 58 (1 and 4) of the Code.

SPECIMENS EXAMINED. SU no. 179 (5 paratypes, 41-59 mm. H.L., 261-240 mm. T.L., Gulf of California, 29°19'N., 112° 50'W., Albatross station 3015, in 145 fathoms (265 meters), 24 March 1889; CAS no. 14555, (1, 54 mm. H.L., 245 mm. T.L.), Calif., Santa Cruz Island, Pelican Bay, in 110-150 fathoms (201-274 meters); SIO no. 61-194-62A (1, 80 mm. H.L., 340 mm. T.L., Calif., off Pt. Conception, in 145-150 fathoms (265-274 meters); SIO no. 67-267-62 (1, 58 mm. H.L., 230 mm. T.L.), Calif., Santa Cruz Island, Pelican Bay, in 135 fathoms (247 meters); SIO no. 68-93-62, (32, 83-206 mm. T.L.), Mexico, Gulf of California, SE. of San Felipe, 19 June 1968.

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TABLE 1. Frequency distribution of selected meristic characters of eight species of Coryphaenoides.

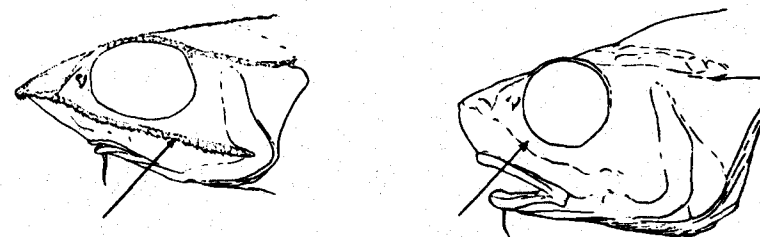
	Segmented rays of first dorsal fin								Pectoral finrays*							
	7	8	9	10	11	12	13	14	16	17	18	19	20	21	22	23
<i>C. pectoralis</i>	1	7	--	--	--	--	--	--	1	2	3	12	3	3	--	--
<i>C. longifilis</i>	--	--	--	--	--	1	4	1	--	1	--	7	4	--	--	--
<i>C. armatus</i> (Atlantic)	--	6	8	--	--	--	--	--	--	--	--	2	14	6	1	--
<i>C. pacificus</i> (Pacific)	--	3	5	6	--	--	--	--	--	--	--	2	4	5	4	--
<i>C. yaquinae</i>	--	1	1	1	--	--	--	--	--	--	--	--	--	4	--	--
<i>C. leptolepis</i> (Atlantic)	--	2	3	--	--	--	--	--	--	--	--	--	3	5	1	--
<i>C. pacificus</i> (Pacific)	--	5	10	3	--	--	--	--	--	--	3	11	5	2	2	--
<i>C. filifer</i>	--	--	--	--	3	25	15	4	--	--	1	8	10	15	17	1
<i>C. cinereus</i>	--	--	--	8	8	3	--	1	--	--	--	3	10	6	6	2
<i>C. acrolepis</i>	--	--	8	8	3	--	--	--	--	--	--	4	4	5	3	--

* Includes counts from both right and left fins.

TABLE 1. (Continued).

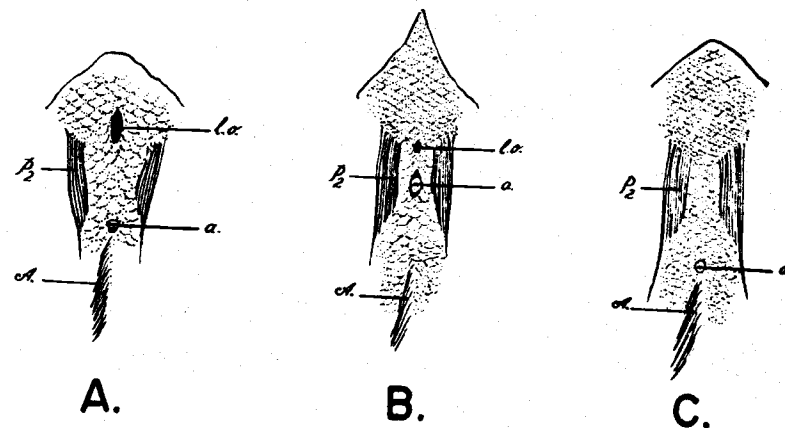
	Pelvic finrays*												Scales below middle of first dorsal fin					
	6	7	8	9	10	11	12	6	7	8	9	10	11	10	9	8	7	6
<i>C. pectoralis</i>	2	20	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>C. longifilis</i>	--	--	--	7	5	--	--	--	--	--	--	1	1	--	--	--	--	--
<i>C. armatus</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(Atlantic)	--	--	--	1	21	1	--	--	--	--	--	--	--	--	--	--	--	--
(Pacific)	--	--	--	--	1	15	5	--	--	--	--	--	--	--	--	--	--	--
<i>C. yaquinae</i>	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>C. leptolepis</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(Atlantic)	--	--	--	7	3	--	--	--	--	--	--	--	--	--	--	--	--	--
(Pacific)	--	--	--	6	10	7	--	--	--	--	--	--	--	--	--	--	--	--
<i>C. filifer</i>	--	--	--	47	17	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>C. cinereus</i>	--	--	2	30	2	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>C. acrolepis</i>	--	--	18	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Includes counts from both right and left fins.



A.

B.

FIGURE 1. Diagrammatic illustrations of heads of (A) *Coelorinchus scaphopsis* and (B) *Nezumia liolepis*. Arrows point to suborbital ridge.

A.

B.

C.

FIGURE 2. Diagrammatic illustrations showing ventral views of abdominal region of (A) *Coelorinchus scaphopsis*, (B) *Nezumia stelgidolepis* and (C) *Coryphaenoides acrolepis*. Abbreviations: A. -- anal fin; a. -- anus; l.o. -- naked fossa (dermal window of light organ); P₂'-- pelvic fin.

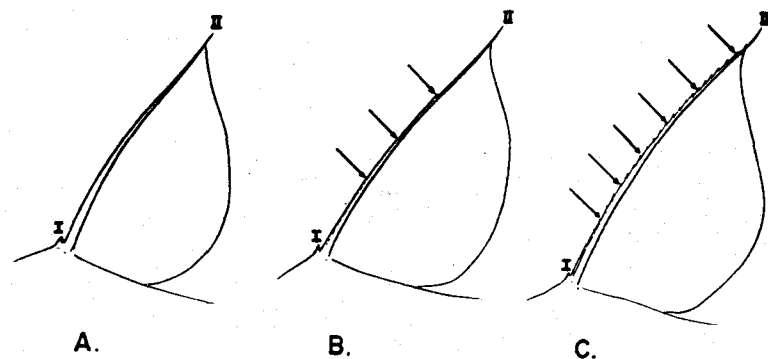


FIGURE 3. First dorsal fins of (A) *Coelorinchus*, (B) *Nezumia liolepis*, and (C) *Nezumia stelgidolepis*, showing different degrees of serration on leading edges of spinous second ray (II), and position and size of first spinous ray (I).

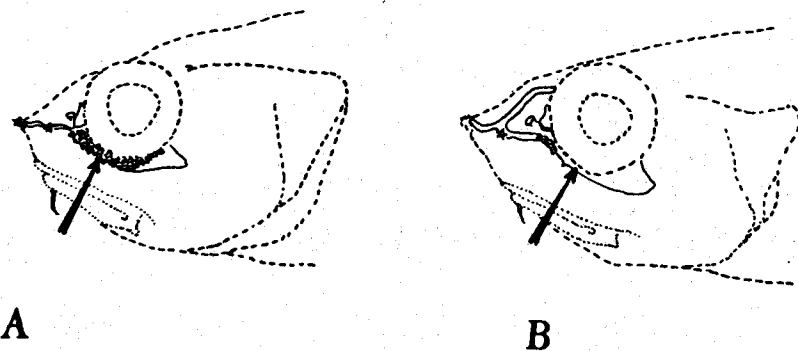


FIGURE 4. Diagrammatic illustrations of heads of (A) *Coryphaenoides filifer* and (B) *C. cinereus* comparing widths and scaling of suborbital shelf (arrows). Drawn by Katherine P. Smith.

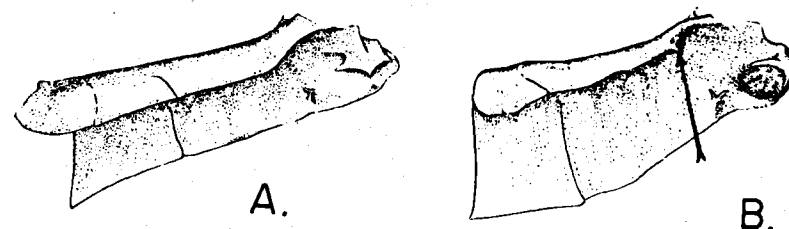


FIGURE 5. Right suborbital bones of (A) *Coryphaenoides filifer* and (B) *C. cinereus* comparing shape of suborbital shelf and presence of anteroventral branch (arrow) in *C. cinereus*.

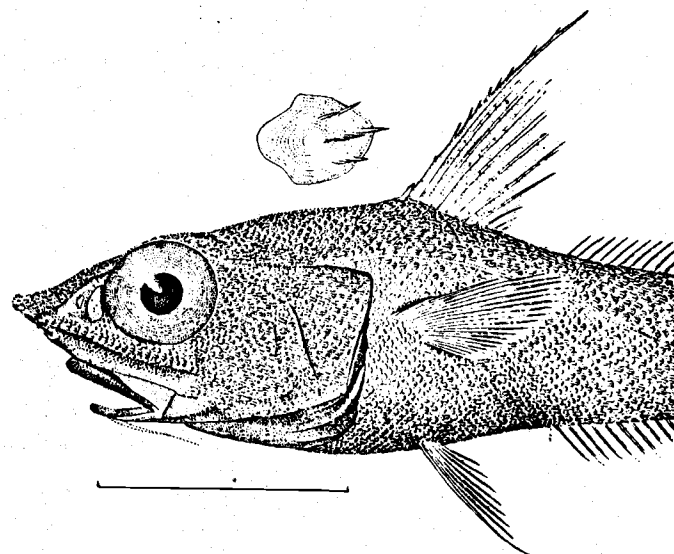


FIGURE 6. Juvenile of *Coryphaenoides* (*Coryphaenoides*) *acrolepis* from off Bogoslof Island, Bering Sea, Albatross station 3634. From Jordan and Gilbert (1899, pl. 82). Drawn by Anna L. Brown.

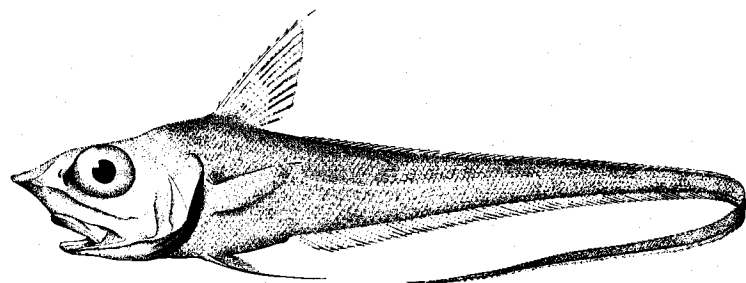


FIGURE 7. Adult of *Coryphaenoides acrolepis* from off Washington (51°23'N., 130°34'W.), Albatross station 2860 in 876 fathoms (1602 meters), 31 August 1888. Drawn by S. F. Denton.

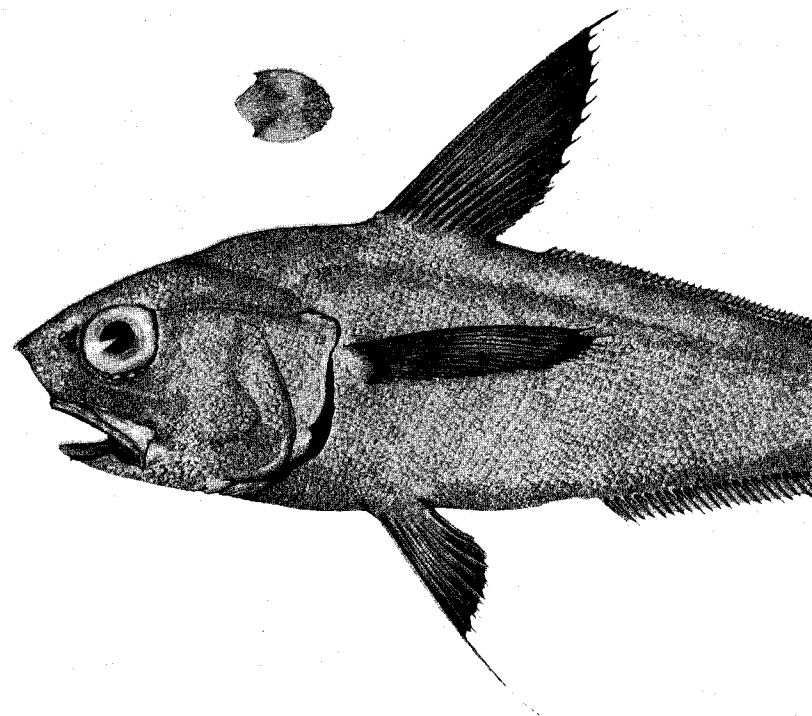


FIGURE 8. *Coryphaenoides (Coryphaenoides) filifer*. A specimen 108 mm. head length, 610 mm. total length (UBC64-444) from off Triangle Island, British Columbia. Drawn by Katherine P. Smith.

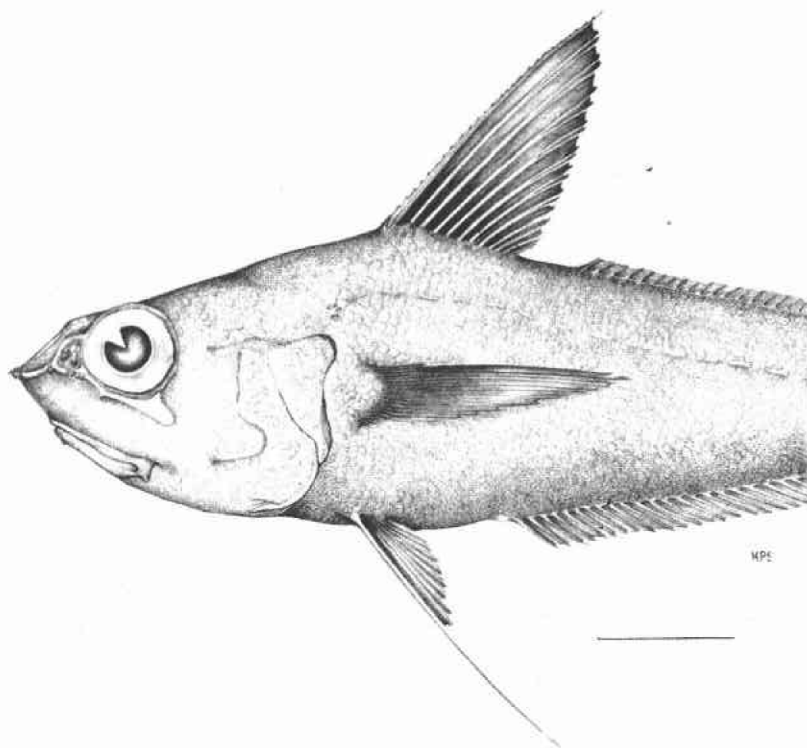


FIGURE 9. *Coryphaenoides (Coryphaenoides) cinereus*. A specimen 61 mm. head length, + 360 mm. total length (SU 22976) from the Okhotsk Sea. Drawn by Katherine P. Smith.

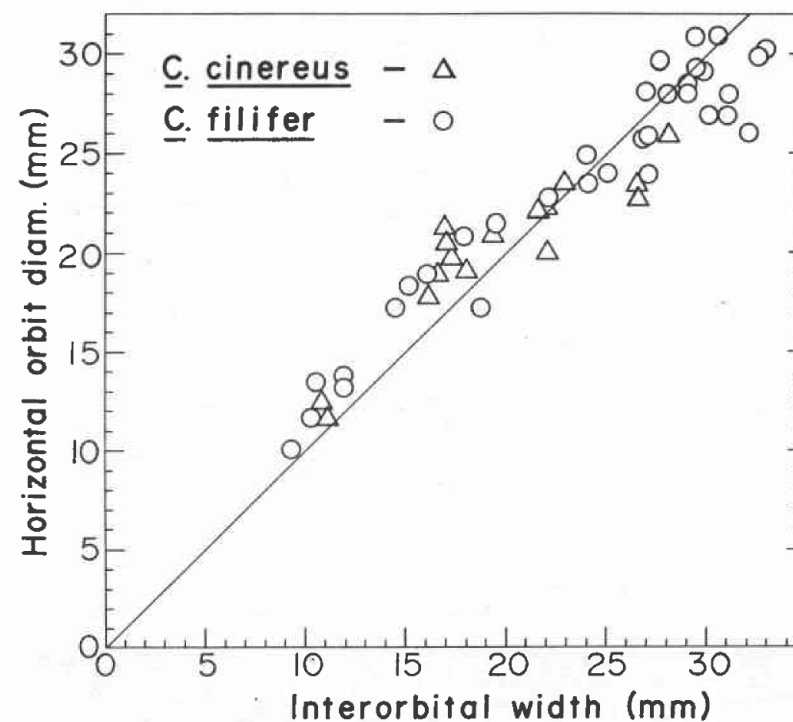


FIGURE 10. Scatter diagram showing relationship of orbit diameter to interorbital width in two species of *Coryphaenoides* (*C. cinereus* and *C. filifer*). Note that the orbit diameter becomes proportionately smaller with increase in interorbital width. Diagonal line represents 1:1 ratio.

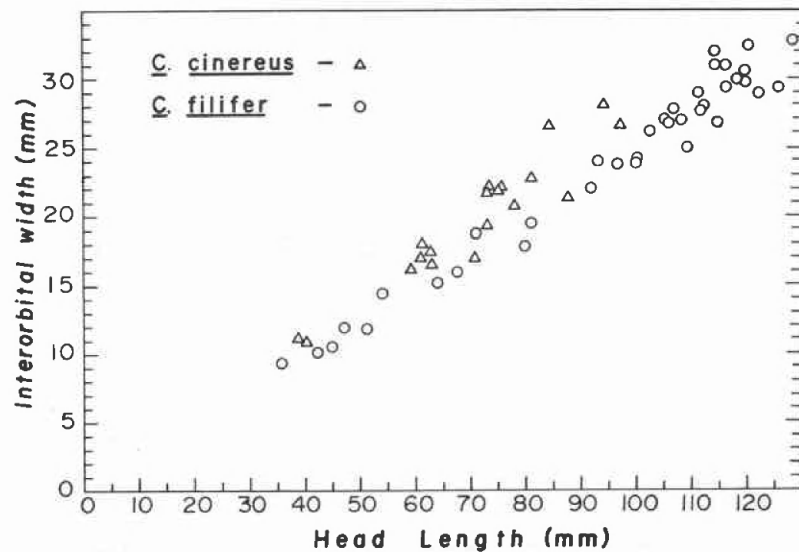


FIGURE 11. Scatter diagram comparing interorbital widths of *Coryphaenoides cinereus* and *C. filifer*.

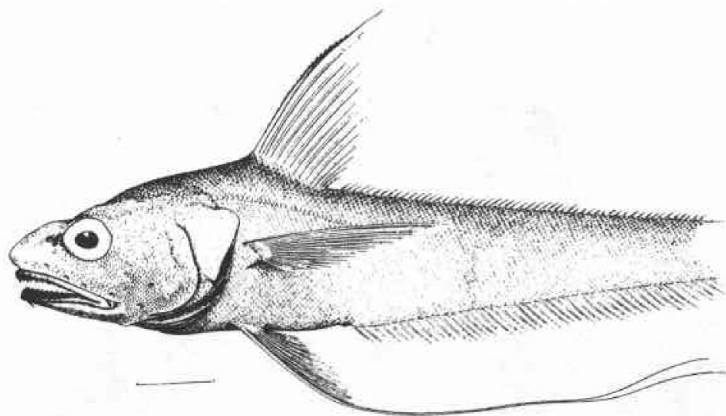


FIGURE 12. *Coryphaenoides (Nematonurus) longifilis* from off Bogoslof Island, Bering Sea. From Jordan and Gilbert (1899, pl. 83). Drawn by Chloe L. Starks.



FIGURE 13. *Coryphaenoides (Nematonurus) armatus* (Hector). Photograph of young specimen approximately 200 mm. long from off Oregon.

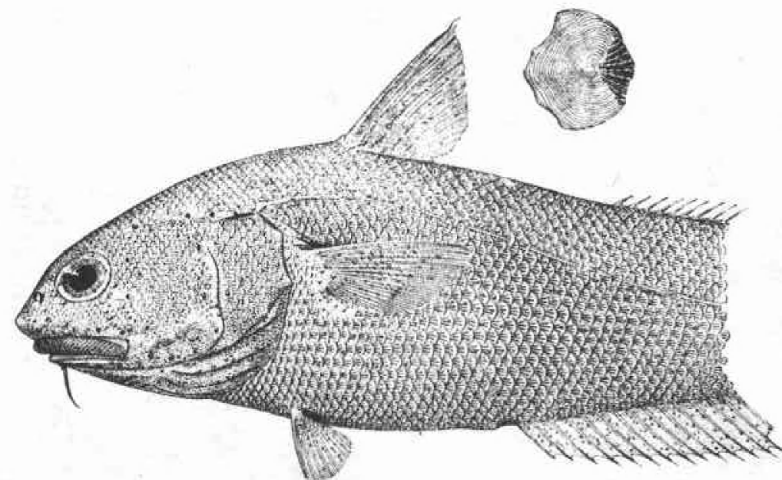


FIGURE 14. *Coryphaenoides (Nematonurus) armatus*. Illustration of specimen 803 mm. long, from Albatross station 4390, off Santa Catalina Island, California. From Gilbert (1915, pl. 21)

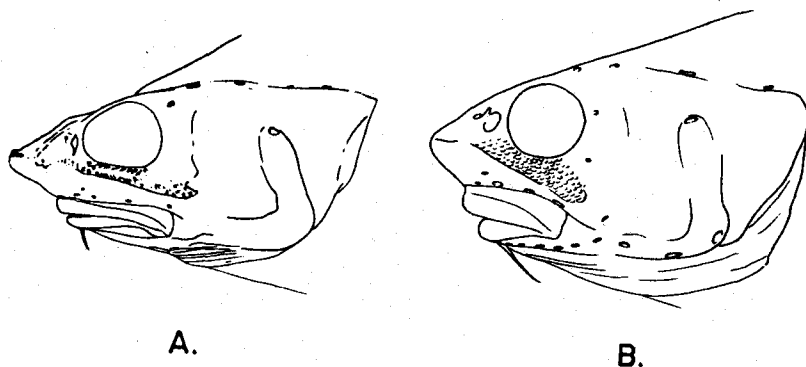


FIGURE 15. Diagrammatic illustrations of heads of (A) *Coryphaenoides yaquinae* and (B) *C. armatus* comparing size of sensory pores on head and scaling on suborbital shelves.

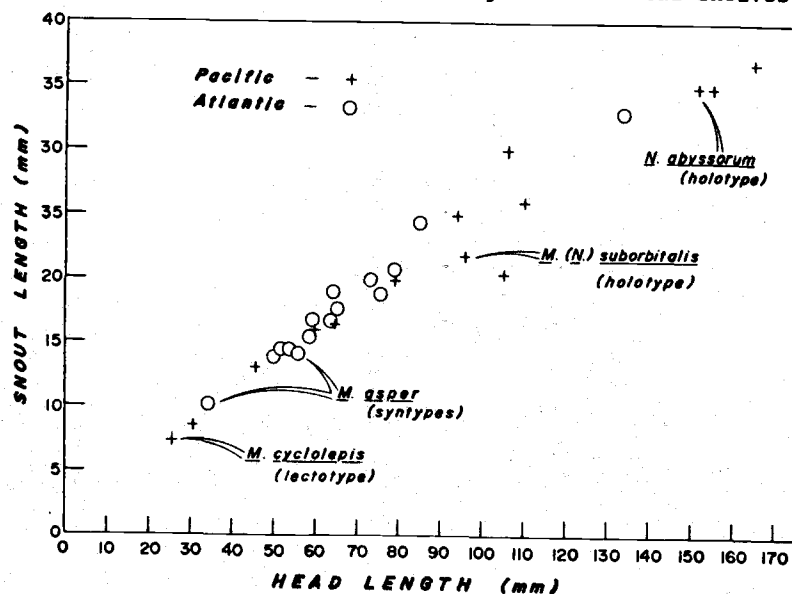


FIGURE 16. Scatter diagram comparing snout lengths of *Coryphaenoides armatus* specimens from the Pacific and Atlantic Oceans. Arrows point to plotted measurements of holotype of *Nematonurus abyssorum* Gilbert, holotype of *Macrurus* (*Nematonurus*) *suborbitalis* Gill and Townsend, two syntypes of *Macrurus asper* Goode and Bean, and lectotype of *Macrurus cyclolepis* Gilbert.

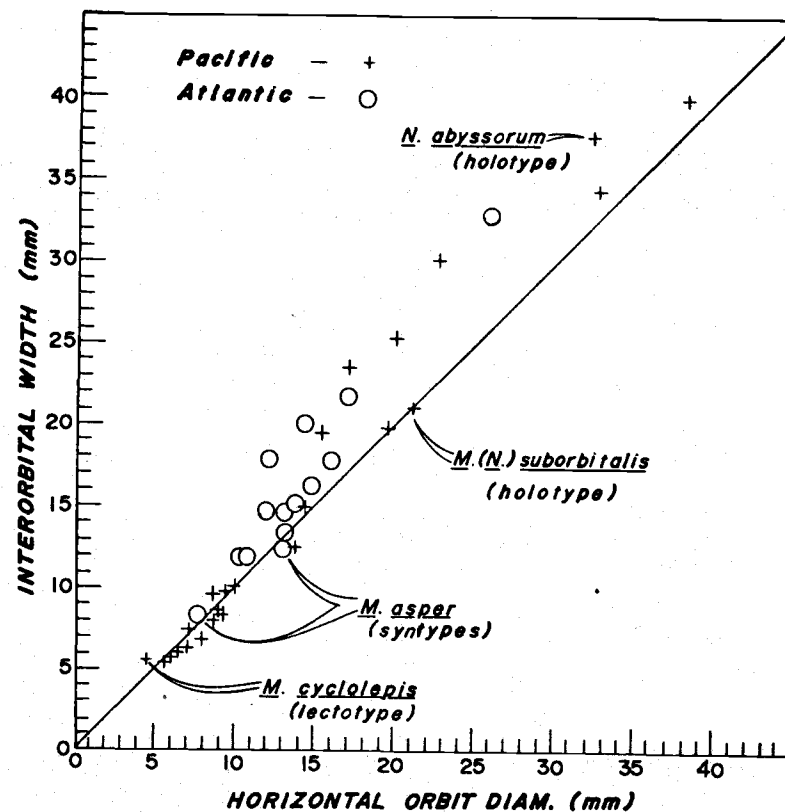


FIGURE 17. Scatter diagram plotting relationship of interorbital width to horizontal orbit diameter in specimens of *Coryphaenoides armatus* from the Pacific and the Atlantic Oceans. Arrows point to plotted measurements of holotype of *Nematonurus abyssorum* Gilbert, holotype of *Macrurus* (*Nematonurus*) *suborbitalis* Gill and Townsend, two syntypes of *Macrurus asper* Goode and Bean, and lectotype of *Macrurus cyclolepis* Gilbert. Diagonal line represents 1:1 ratio.

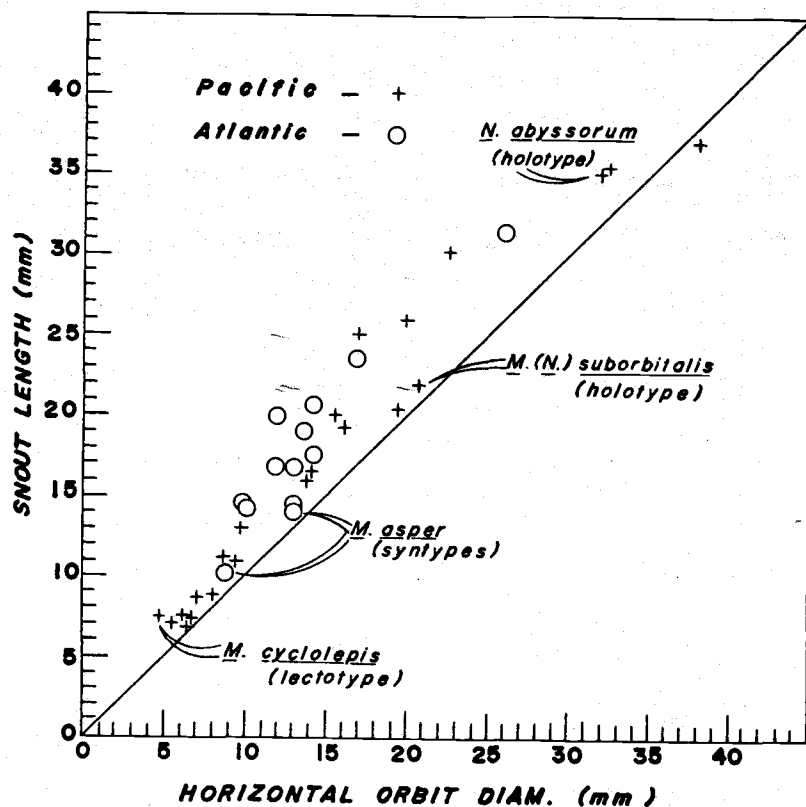


FIGURE 18. Scatter diagram showing relationship of snout length to horizontal orbit diameter in specimens of *Coryphaenoides armatus* from the Pacific and Atlantic Oceans. Arrows point to plotted measurements of holotype of *Nematonurus abyssorum* Gilbert, holotype of *Maorurus* (*Nematonurus*) *suborbitalis* Gill and Townsend, two syntypes of *Maorurus asper* Goode and Bean, and lectotype of *Maorurus cyclolepis* Gilbert. Diagonal line represents 1:1 ratio.

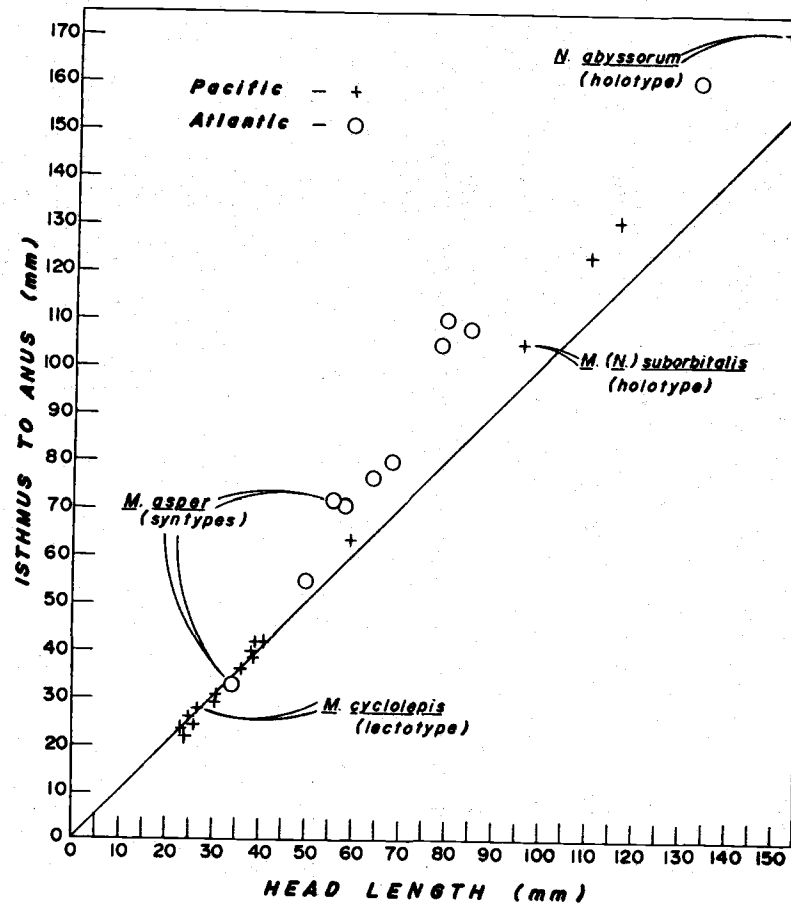


FIGURE 19. Scatter diagram comparing measurements of the distance from isthmus to anus in Pacific and Atlantic specimens of *Coryphaenoides armatus*. Arrows point to plotted measurements of holotype of *Nematonurus abyssorum* Gilbert, holotype of *Maorurus* (*Nematonurus*) *suborbitalis* Gill and Townsend, two syntypes of *Maorurus asper* Goode and Bean, and lectotype of *Maorurus cyclolepis* Gilbert. Diagonal line represents 1:1 ratio.

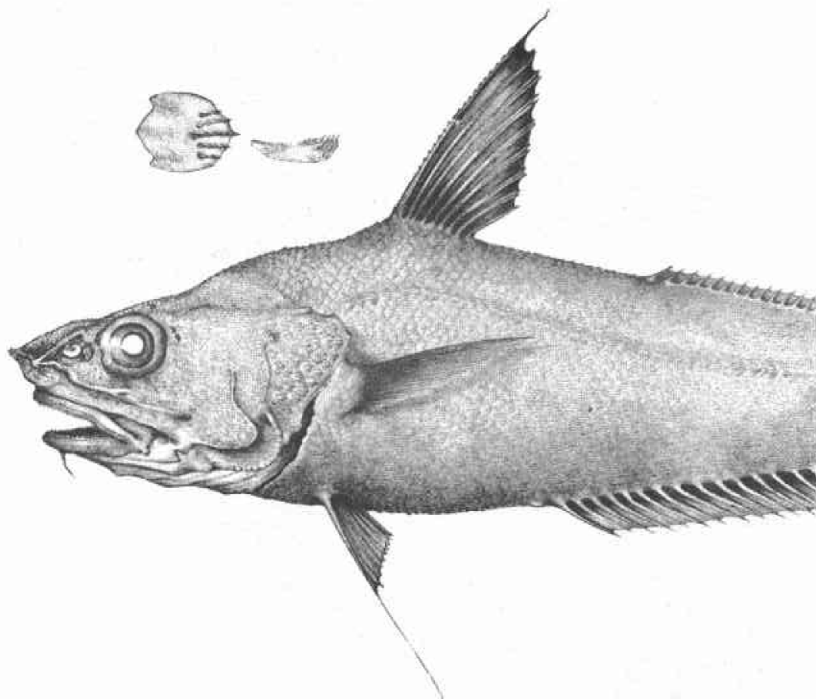


FIGURE 20. *Coryphaenoides (Nematonurus) yaquinae* new species. Holotype, (USNM uncat., 75 mm. H.L., 376 mm. T.L., Tufts Abyssal Plain, Yaquina station TP-3, haul 232, in 3724 meters. Drawn by Katherine P. Smith.

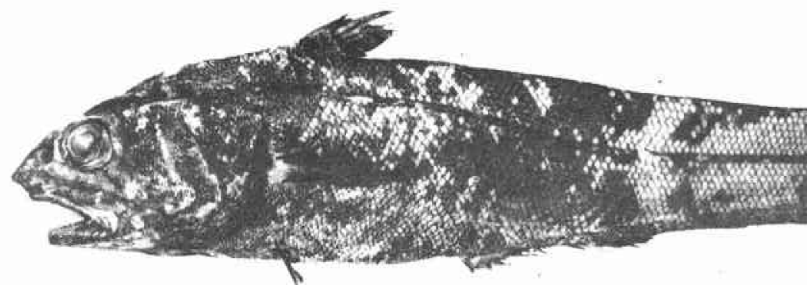


FIGURE 21. *Coryphaenoides (Nematonurus) pectoralis*. A specimen (CAS 20521) 110 mm. in head length, 450 mm. in total length from off Fort Bragg, California.

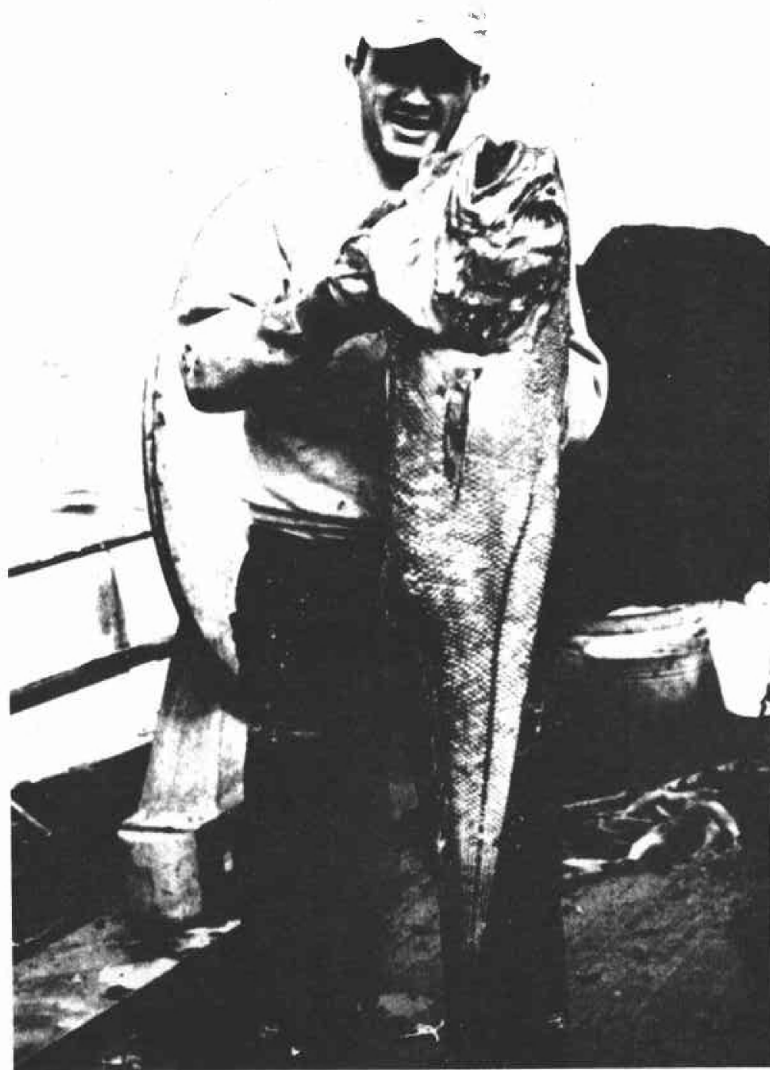


FIGURE 22. Photograph of a large specimen of *Coryphaenoides pectoralis* captured off the Columbia River by the National Marine Fisheries Service research vessel *Cobb*. Photograph provided by Richard B. Grinols.

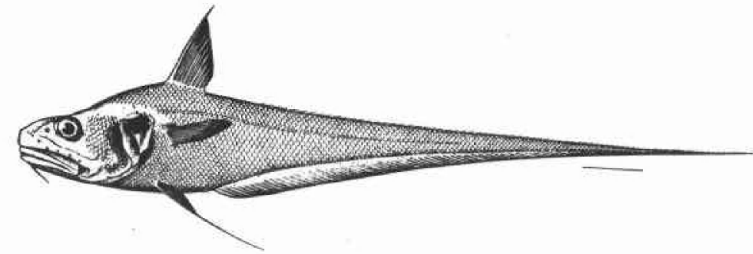


FIGURE 23. *Coryphaenoides (Chalinura) leptolepis*. From off Prince of Wales Island, Alaska, 55°20'N., 136°20'W., Albatross station 2859, in 1569 fathoms (2869 meters), 22 August 1888.

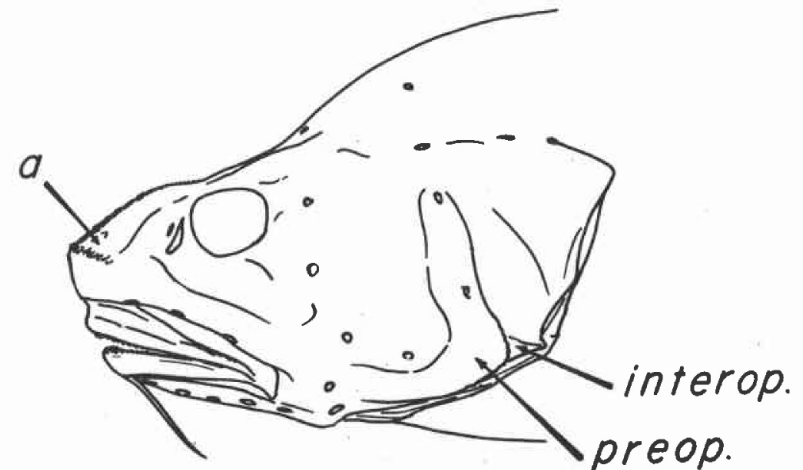


FIGURE 24. *Coryphaenoides (Chalinura) leptolepis*. Diagrammatic illustration showing size and locations of sensory pores on head. Arrow (a) indicates naked region on leading dorsal edge of snout. Note crenulated margin of preopercle (preop.) and narrow interopercle (interop.).

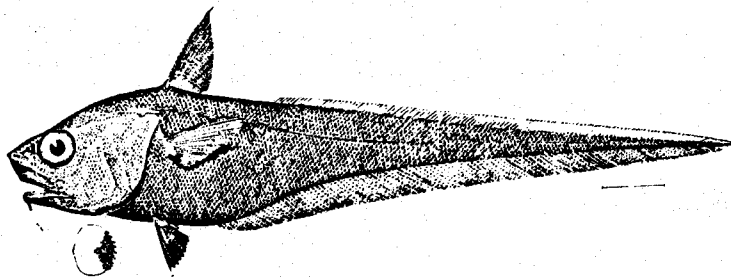


FIGURE 25. *Nezumia stelgidolepis*. From Pt. Conception, California. 34°10'45"N., 120°16'45"W., Albatross station 2960 in 267 fathoms (488 meters), 9 February 1889. Drawn by A. H. Baldwin.

Health Physics Pergamon Press 1974. Vol. 26 (April), pp. 327-331. Printed in Northern Ireland

TURNOVER OF ZINC-65 IN OYSTERS

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(Received 16 April 1973; in revised form 2 July 1973)

Abstract—The uptake and loss of ^{65}Zn by Pacific oysters are fitted by solutions to a first-order, linear differential equation that describes "single-compartment" isotope substitution kinetics. The rate constants for loss are related to the rate constants for uptake and to steady-state concentration factors for stable zinc and ^{65}Zn .

The single-compartment solutions adequately fit uptake and loss data from field experiments extended as long as several hundred days. The rate constant estimated from loss data is $5.49 \times 10^{-3} \text{ d}^{-1}$ and that from uptake data is $4.93 \times 10^{-3} \text{ d}^{-1}$. The apparent importance of multiple compartments can be affected in experiments where uptake times are short.

WOLFE⁽¹⁾ remarked upon the notoriety of oysters as accumulators of zinc and showed that the metal is predominantly bound to soluble, high molecular weight proteins. Because of their role as concentrators of zinc and their commercial importance, oysters have drawn attention in studies of radioactive ^{65}Zn ($T_{1/2} = 245$ days). Rapid accumulation of ^{65}Zn by oysters immersed in seawater containing the isotope was noted in early radioecological literature.^(2,3) In the 1950's ^{65}Zn was reported in Pacific oysters (*Crassostrea gigas*) and other organisms collected along the coast of Oregon and Washington.^(4,5) Zinc-65 was introduced into this region by the Columbia River, whose waters had been used to cool reactors at Hanford, Washington.

Several studies have been devoted to the kinetics of accumulation and loss of ^{65}Zn by oysters. CHIPMAN⁽³⁾ noted rapid accumulation rates. SEYMOUR⁽⁶⁾ reported on accumulation and loss of this nuclide by oysters in a natural environment. SALO and LEET⁽⁷⁾ related rates of accumulation of ^{65}Zn by oysters in a reactor effluent canal to reactor discharge rates. ROMERIL⁽⁸⁾ determined rates of uptake of ^{65}Zn for various organs of oysters in the laboratory, and WOLFE⁽¹⁾ reported changes in ^{65}Zn content of oysters during times when the ^{65}Zn supply (worldwide fallout was the source in his case) was diminishing. Each of these authors used some form of exponential equation to fit his data. The adequacy of exponential models to describe kinetics in complex ecological situations has been questioned.^(9,10) The latter

authors suggest that power functions more adequately describe radionuclide kinetics in marine organisms. The exponential and power function models were contrasted by FELDT⁽¹¹⁾ in keynoting a recent marine radioecology conference. REICHLER *et al.*⁽¹²⁾ noted that solutions based on power functions provided better estimates of biological turnover for bone-seeking radionuclides than did exponentials. Many experiments designed to measure biological turnover rates of radionuclides emphasize only loss data; whereas, uptake data are, in principle, equally useful. Indeed, comparison of rate parameters determined both by uptake and loss experiments provides a test of the adequacy of a single-compartment kinetic model and its exponential solution. Consequently, we have re-examined data reported by SEYMOUR⁽⁶⁾ in order to determine the adequacy of single-compartment kinetics in describing ^{65}Zn turnover in oysters and to show the relationship between uptake, loss and steady-state.

Briefly, Seymour's experiment consisted of cross-transplants of oysters (*Crassostrea gigas*) from Willapa Bay, near the Columbia River mouth, to essentially ^{65}Zn -free waters in Puget Sound of Hood Canal, and vice versa. The loss of ^{65}Zn from oysters taken from Willapa Bay was followed in time, as was the accumulation of radionuclide by oysters planted in Willapa Bay. Both loss and accumulation were followed for as long as 2 yr following transplant. Although the season of transplant varied and the initial ^{65}Zn concentrations in oysters taken from

Willapa Bay varied, the pooled data from eight such groups followed an exponential decline rather well (SEYMOUR,⁽⁶⁾ Fig. 5). The effective half-life found was 135 days, and the corresponding biological half-life was 300 days. No analysis of the accumulation data was presented, although it was noted that uptake rates were most rapid during early times and that initial uptake rates varied with season of transplant.

Single-compartment equations

The equations used below have been often reported. They are reviewed here simply to indicate my procedures and to demonstrate the common source of equations for accumulation, loss, and steady-state conditions. The physical model is one of isotope substitution. With the assumption that an organism's uptake and loss of the total element are equal, its radionuclide dynamics are described by:

$$\frac{dA}{dt} = RS_s - RS_b - \lambda A, \quad (1)$$

where

- R = the rate of uptake (equal to loss) of all isotopes of the element in question per unit body weight;
- S_s = the specific activity of the radionuclide in the source;
- S_b = the specific activity of the radionuclide in the organism;
- λ = the radionuclide decay constant; and
- A = the concentration of radionuclide in the organism.

We have implicitly assumed that the radioisotope makes no significant contribution to the total concentration of the element in the system. This is almost always the case for ⁶⁵Zn. Still further simplifying assumptions are made before obtaining solutions to equation (1):

1. The source specific activity and elemental uptake rates are constant in time.
2. All atoms of the element in question, contained in the organism, are equally likely to be lost by excretion.
3. No allowance is made for growth of the organism.

The mean residence time, or turnover time, of the element in the organism can be defined:

$$\tau = \frac{P}{R},$$

where P = total element concentration. The turnover time is related to the more commonly used "biological half-life" ($T_{1/2}$) and to the "biological rate constant" (β):

$$\tau = \frac{T_{1/2b}}{\ln(2)} = \frac{1}{\beta}.$$

Thus, after substitution, equation (1) can be written as

$$\frac{dA}{dt} = RS_s - (\lambda + \beta)A. \quad (2)$$

Solutions may now be readily obtained:

Loss Situation ($S_s = 0$, boundary condition $A = A_0$ at $t = 0$),

$$A = A_0 \cdot e^{-(\lambda+\beta)t} \quad (3)$$

Uptake Situation (boundary condition $A = 0$ at $t = 0$),

$$A = \frac{RS_s}{\lambda + \beta} (1 - e^{-(\lambda+\beta)t}). \quad (4)$$

The equation for the steady-state condition, $dA/dt = 0$, may be obtained either by setting equation (2) equal to zero, or by allowing time to become infinite in equation (4)

$$A \text{ (steady-state)} = \frac{RS_s}{\lambda + \beta}. \quad (5)$$

At steady-state the specific activity of radionuclide in the organism (S_b) is less than the specific activity of the source:

$$S_b = \frac{\beta}{\lambda + \beta} \cdot S_s. \quad (6)$$

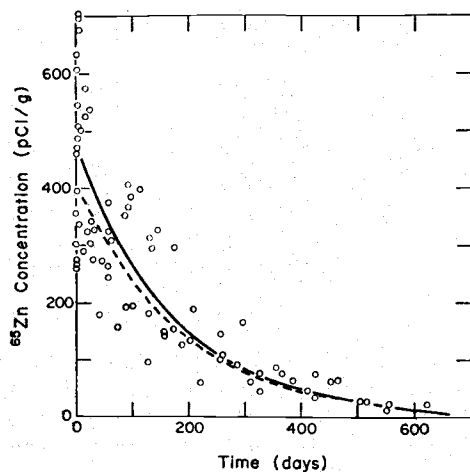
This observation has been qualitatively made before,⁽¹³⁾ as has the equivalent statement for concentration factors.⁽¹⁴⁾ If the radionuclide source is water, then equation (6) can be rearranged to yield:

$$CF^* = \frac{\beta}{\lambda + \beta} CF, \quad (7)$$

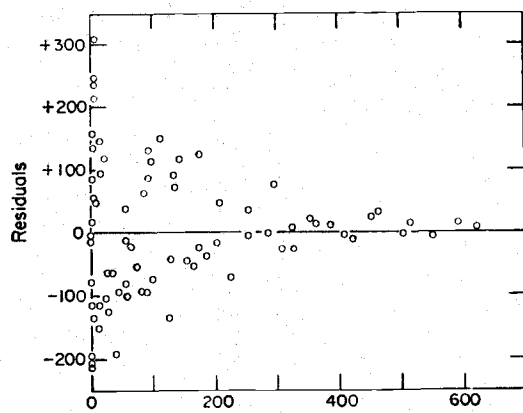
where CF^* is the radioisotope concentration factor, and CF is the elemental concentration factor. Equations (6) and (7) afford a third means for calculating turnover rate constants, if the appropriate specific activities or concentration factors are known.

Evaluation of rate constants

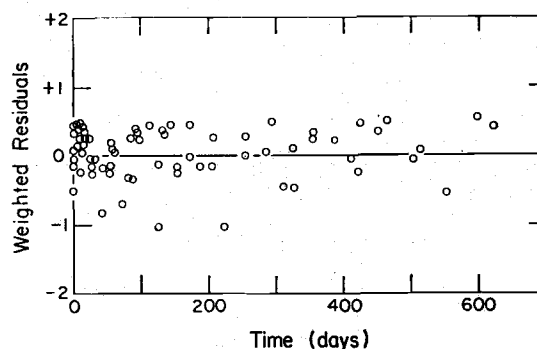
SEYMOURS⁽⁶⁾ loss data were fitted with an equation of the form of (3) using the method of least squares (Fig. 1a). The value of $(\lambda + \beta)$ thus obtained was $5.71 \times 10^{-3} \text{ d}^{-1}$. Differences between the fitted line and the data (residuals) are plotted versus time in Fig. 1b. Convergence of the residuals implies that a better fit would result if the data were weighted.⁽¹⁵⁾ Conse-



(a)



(b)



(c)

FIG. 1. Analysis of loss data. (a) Zinc-65 concentration vs time. Solid line is fitted by least-squares using unweighted data; dashed line is fitted using weighting. (b) Residuals from unweighted fit vs time, showing convergence. (c) Weighted residuals from weighted fit.

quently, I fitted the data using the weighting factor $1/A$ (Fig. 1a). The value of $(\lambda + \beta)$ was changed to $5.49 \times 10^{-3} \text{ d}^{-1}$. No pattern is apparent in the plot of the weighted residuals (Fig. 1c). Therefore, the latter value for $(\lambda + \beta)$ is taken as the best estimate from the loss data.

Treatment of the accumulation data is slightly more complicated in that two parameters must be determined: the effective rate constant $(\lambda + \beta)$ and the asymptotic value of ^{65}Zn concentration, $RS_s/(\lambda + \beta)$ (equation (4)). Data from oysters planted in Willapa Bay, fitted by least squares, yielded values of the effective rate constant and the asymptote of $4.93 \times 10^{-3} \text{ d}^{-1}$ and 215 pCi/g, respectively. The curve for these parameter values and the accumulation data are plotted in Fig. 2a. Deviations from the fitted points (residuals) are plotted versus time in Fig. 2b. No weighting of data was required for a better fit of the line in Fig. 2a.

SEYMOUR⁽⁶⁾ reported concentration factors for ^{65}Zn and zinc in Willapa Bay oysters as 9900 ± 2700 and 14000 ± 9700 , respectively. Solving equation (7) for $(\lambda + \beta)$ using these data yields $9.73 \pm 7.24 \times 10^{-3} \text{ d}^{-1}$.

Discussion

The rate constants determined from uptake data do not differ appreciably from those

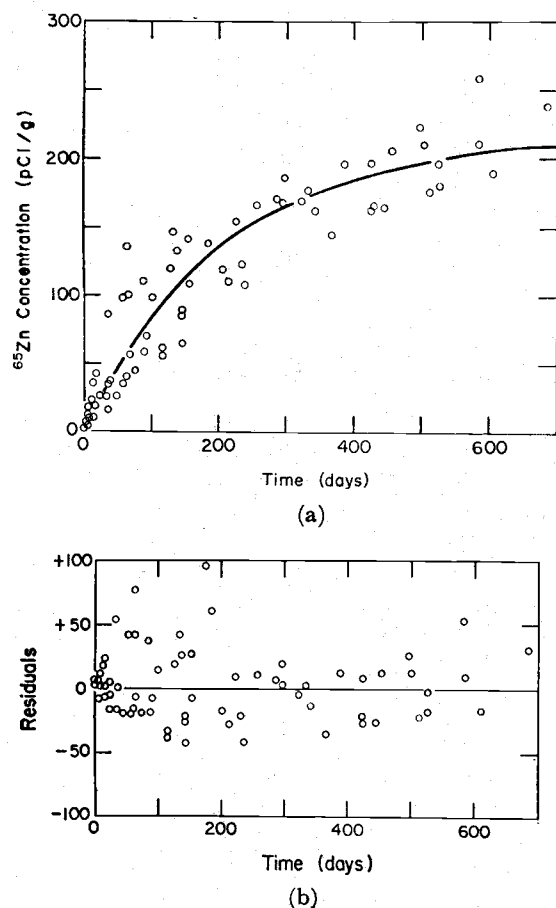


FIG. 2. Analysis of uptake data. (a) Zinc-65 concentration vs. time. (b) Residuals vs. time.

determined from loss data. These values do not differ appreciably from the values estimated using concentration factors, although the large error term associated with the latter makes the comparison relatively insensitive. Residuals from the fitting of uptake and loss data with exponential equations do not reveal any failure of the single-compartment model; that is, no systematic pattern is evident when the residuals are plotted against time.

I conclude that simple exponential equations quite adequately fit the uptake data, the loss data, and the steady-state concentration factors observed by SEYMOUR.⁽⁶⁾ Because the single-compartment model fits the data so well, I also conclude that either the individual organs of the oysters have closely similar turnover-rate

constants for zinc or at least that the dominant organs in whole-body zinc content turn over at similar rates. These results are especially significant because few turnover studies combine the quantity of data and duration in time as that above.

THE PROBLEM OF MULTIPLE STEPS

Where radionuclide uptake proceeds through multiple steps which have roughly similar first-order rate constants, uptake data, particularly during early times, will not follow the simple relationship used above. ATEN⁽¹⁶⁾ showed that a two-trophic-level system produced radionuclide concentration at the second level which initially increased in proportion to the second power of time. Such possibilities may have been obviated in Seymour's experiment because the oysters were planted in Willapa Bay after the rest of the Bay ecosystem had ample time to approach its own steady-state level.

THE PROBLEM OF MULTIPLE COMPARTMENTS

Where an element is present in an organism in several compartments (organs, types of binding sites, etc.), the whole-organism kinetics may be more complicated than the above equations would indicate. To demonstrate this possible source of difficulty, I shall assume that the protein-bound zinc which WOLFE⁽¹⁷⁾ found in *Crassostrea virginica* (96% of total body zinc turns over with an effective half-life of 135 days ($\lambda + \beta = 5.13 \times 10^{-3} \text{ d}^{-1}$) and the remaining 4% will be assumed to turn over with a 1-day effective half-life ($\lambda + \beta = 0.693 \text{ d}^{-1}$). Calculated loss curves for different periods of uptake are shown in Fig. 3. It can readily be seen that the loss of ^{65}Zn following 0.1 or 1 day of uptake (lower two curves) is dominated by the smaller, rapid-turnover compartment; whereas, were uptake carried out for 135 or 1000 d (upper two curves), the larger, slow-turnover compartment would dominate. Experimental loss of ^{65}Zn by mussels follows curves which are strikingly similar to Fig. 3.⁽¹⁸⁾

It should be noted that radionuclide loss studies following short uptake periods are most relevant to simulation of accidental spill

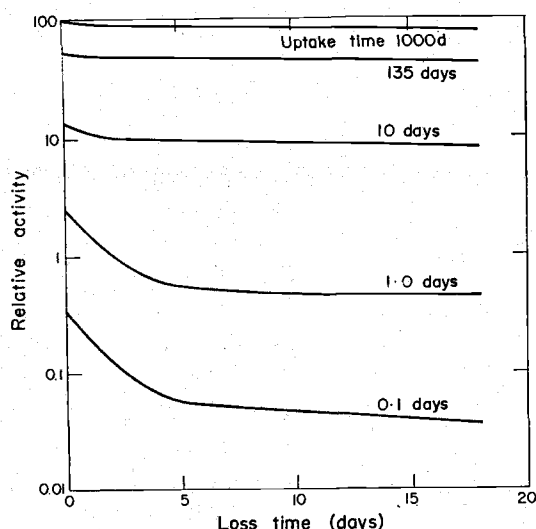


FIG. 3. Calculated loss curves for a two-compartment model after various uptake periods.

conditions, that is, impulse sources. On the other hand, long uptake periods may be required in order to simulate chronic contamination situations. The latter is, of course, more relevant for determination of the role of organisms in trace element cycling.

Acknowledgement—This work was supported by the U.S. Atomic Energy Commission Contract AT (45-1) 2227, Task Agreement 12, (RLO-2227-T12-36). I thank Drs. R. HOLTON, W. RENFRO, L. SMALL and H. VANDERPLOEG for many helpful discussions and suggestions.

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RLO-2227-T12-40

Food habits of deep-sea macrourid fishes off the Oregon coast

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(Received 30 November 1973; in revised form 6 February 1974; accepted 8 February 1974)

Abstract—The abyssal macrourid fishes off Oregon are generalized feeders, as theory predicts for large searchers in an unproductive environment. Analysis of stomach contents revealed that fish feed on a wide variety of foods, but the proportions of different taxa of food vary among and within species, indicating some food selectivity. Broad feeding overlaps occurred between large *Coryphaenoides armatus* and *C. filifer*, which fed mainly on squid and fish, and between small *C. armatus* and *C. leptolepis*, which fed largely on epifaunal crustaceans. Pelagic crustaceans were numerous in the stomachs of large *C. leptolepis*. Overlap among the food of these macrourids was more than the overlap among shallow-water, demersal fishes.

Most food consisted of epifauna or pelagic animals. It is not known if the squid, shrimp, and fish prey, known to inhabit mesopelagic depths, have vertical distributions extending to 2800 m where they were consumed, or whether macrourids forage far above the bottom. The fact that some squid beaks were from squids larger than the fish which ate them suggests that macrourids are sometimes scavengers and feed on sinking carcasses. The importance of pelagic animals in the diet of large macrourids implies a direct trophic link between abyssobenthic and pelagic animals that may be important in the transport of energy and elements into the deep ocean.

INTRODUCTION

THE IMPORTANCE of the cod-like fishes of the family Macrouridae (grenadiers or rat-tails) in the deep sea has been recognized since the *Challenger* Expedition (GÜNTHER, 1887). They are widespread geographically and there are numerous, approximately 300, species, most of which are benthic or benthopelagic, although a few are bathypelagic. Macrouridae are the dominant fishes, both in biomass and numbers, on the continental slopes and adjoining abyssal plains of many regions of the world (MURRAY and HJORT, 1912; GREY, 1956; MARSHALL, 1964, 1965; KORT, 1967; IWAMOTO, 1970). The recent commercial exploitation of macrourids in the North Atlantic and North Pacific oceans attests to their abundance (PECHENIK and TROYANOVSKII, 1970; NOVIKOV, 1970).

Studies using underwater cameras provide new evidence that macrourids are abundant near the bottom in slope and abyssal waters. Sequential photographs over bait reveal that large numbers of grenadiers are attracted 'almost immediately', suggesting that these fishes are motile and able to locate food rapidly in the deep ocean (ISAACS, 1969; DAYTON and HESSLER, 1972). These photographs, as well as those by MARSHALL and BOURNE (1964), show that macrourids, because of their capacious gas-filled swimbladders, are neutrally buoyant and swim or hover over the bottom (MARSHALL, 1965).

Macrourids are the dominant family of fishes by weight and numbers in deep-water bottom trawl catches off Oregon and Washington. They are present on the

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upper continental slope and dominate the benthic fish catches on the lower slope from 1400 to 2800 m as well as on the abyssal plains from 2800 to at least 3990 m and 834 km offshore (DAY and PEARCY, 1968; ALTON, 1972).

Despite the recognized importance of macrourids in deep-sea benthic communities, little is known about their food habits, particularly of abyssal species. Knowledge of their food habits would be especially interesting because whether predators are specialists or generalists is relevant to the structure of the deep-sea benthic community and because their food habits may provide insight into the relative amounts of different types of food transported from upper waters into the deep-sea food web.

SANDERS' (1968, 1969) time-stability hypothesis predicts that large numbers of stenotopic species evolve to form 'biologically-accommodated communities' where physical conditions have remained constant and uniform for long time periods, such as in the deep sea. If food is limited, abyssal animals such as macrourids may be expected to have specialized, stenophagous feeding habits. DAYTON and HESSLER (1972), on the other hand, contend that the maintenance of the high species diversity among deep-sea benthic invertebrates is a result of biological disturbance produced by the cropping of predators, reducing the possibility of resource competition and competitive exclusion. They emphasize the lack of food-niche specialization of deposit feeding invertebrates and the generalized feeding habits of predators in the deep sea. For arguments against the Dayton-Hessler theory, see GRASSLE and SANDERS (1973).

The rapid appearance of macrourids at bait suggests two rather independent food sources for the deep sea: (1) a 'rain' of fine detritus that supports the deposit and filter feeding animals, and (2) widely separated falls of large food items that support active animals like the grenadiers (ISAACS, 1969).

If small particles are the predominant source of energy for the deep-sea benthic community, macrourids would be expected to feed mainly on small deposit feeders. If large, fast-falling particles (such as carcasses of fishes, squids, shrimps, whales, etc.) are important (ISAACS, 1969; DAYTON and HESSLER, 1972), large, motile animals like macrourids would be expected to utilize this food. In the latter situation, large fishes may not have an important role as predators of benthic invertebrates and thus may not be an important 'cropping disturbance'. Actually by feeding on corpses they may act to even out patchiness and unpredictability of scattered high organic inputs by distributing feces over a large area (see DAYTON and HESSLER, 1972, and for a contrary view, GRASSLE and SANDERS, 1973).

Whether macrourids feed mostly on pelagic or benthic food, infauna or epifauna, is still in question. MARSHALL and BOURNE (1964) observed that most grenadiers have longer anal than dorsal fin rays, which maintain the head close to the bottom. Further, the triangular snout and subterminal mouth is adaptive for 'rooting in the ooze' for benthic food. However, the presence, or even predominance, of pelagic animals reported in the stomachs of some species (PODRAZHANSKAYA, 1967; PECHENICK and TROYANOSKII, 1970; OKAMURA, 1970; NOVIKOV, 1970; HAEDRICK and HENDERSON, 1974) raises doubts about the importance of benthic animals in the food habits of some Macrouridae.

METHODS

Otter trawl (6.7-m foot rope) and beam trawl (2.7 m wide) collections of macrourids

were made on the continental slope and abyssal plain off Oregon from 1961 to 1972. Mesh sizes of the trawl liners were 1.3 or 3.2 cm (stretch). Most of the trawl collections were from the Cascadia Abyssal Plain 120 to 270 km off central Oregon. Some are from Tufts Plain 565 to 834 km offshore and some were from below 1000 m on the continental slope and abyssal plain off northern Oregon and off Washington. Fishes were preserved in formalin at sea after the body cavity was incised. In the laboratory, fishes were specifically identified. Identifications and nomenclature are based on IWAMOTO and STEIN (1974), who include *Nematonurus*, *Chalinura*, and other previously recognized genera as subgenera within the genus *Coryphaenoides*. The fullness of all non-everted stomachs was noted for most specimens. Animals in each stomach were identified to species or genus, when possible, and then sorted into taxonomic groups or unidentifiable remains, which were weighed (drained wet weight) to the nearest 0.1 g. Results are expressed in frequency of occurrence and wet weight. A total of 2295 fishes (including those with everted stomachs) from over 100 collections were examined. Observations on whether stomachs were everted, empty, or contained food were made on 2279 fishes.

Squid beaks were identified using dissections of identified specimens, CLARKE (1962) and AKIMUSHKIN (1965).

RESULTS

Five species of macrourids, all in the genus *Coryphaenoides*, were collected off the Oregon and Washington coasts. *Coryphaenoides (Nematonurus) armatus* (Hector 1875), *C. (Chalinura) leptolepsis* (Günther 1878), and *C. (Coryphaenoides) filifer* (Gilbert 1895) were caught on abyssal plains (2700 to 3990 m depth); they co-occur and are all commonly captured in the same collection, i.e. they are syntopic (see RIVAS, 1964). *Coryphaenoides (Nematonurus) pectoralis* (Gilbert 1892) and *C. (Coryphaenoides) acrolepis* (Bean 1884) were captured from 1000 to 2200 m on the continental slope. The number of individuals of each species of *Coryphaenoides* examined and the number with food in their stomachs are summarized in Table 1. A large percentage of all species had everted stomachs. This necessitated examination of many individuals in an attempt to obtain an adequate sample of stomach contents.

Table 1. The number of macrourids examined and percentage with everted stomachs, not everted but empty stomachs, and stomachs with contents for 2279 specimens of the five species collected off Oregon.

	Total no.	% everted	% empty	% with contents
<i>C. armatus</i>	1044	73	0.2	27
<i>C. filifer</i>	837	92	1	7
<i>C. leptolepsis</i>	160	49	0.6	50
<i>C. acrolepis</i>	216	95	2	3
<i>C. pectoralis</i>	22	55	27	18

Table 2. Taxa identified from the stomach contents of macrourids.*

	<i>C. armatus</i>	<i>C. leptolepis</i>	<i>C. filifer</i>	<i>C. pectoralis</i>	<i>C. acrolepis</i>
POLYCHAETES					
Maldanidae	x				
<i>Maldane</i> sp.	x				
Lumbrineridae	x				
<i>Lumbrineris</i>	x				
Onuphididae	x	x	x		
<i>Onuphus</i> sp.	x				
<i>Nothria</i> sp.	x	x			
Phyllodocidae	x				
Glyceridae	x				
<i>Travesia</i> sp.	x		x		
BIVALVIA					
<i>Solemya agassizi</i>	x		x		
Other bivalves	x	x	x		
CEPHALOPODA					
<i>Gonatopsis borealis</i>	x		x		
<i>Gonatus magister</i>	x		x		
<i>Gonatus fabricii</i>	x		x		x
Cranchiidae	x		x	x	x
Onychoteuthidae	x		x		
<i>Onychoteuthis banksi</i>	x				
<i>Octopoteuthis sicula</i>	x		x		
Unidentified squid beaks	x				x
<i>Japetella</i> sp.	x		x	x	
<i>Vampyroteuthis infernalis</i>	x				x
PYCNOGONIDA					
Colossendeidae		x			
CRUSTACEA					
Copepoda					
Phaennidae	x	x	x		
<i>Xanthocalanus</i> sp.	x	x	x		
Aetideidae	x	x	x		
Scolecithricidae	x	x	x		
Euchaetidae	x	x	x		
Mysidacea					
Small mysids	x	x	x		
<i>Gnathophausia gigas</i>	x		x		
Cumacea					
Tanaidacea	x	x			
Isopoda					
<i>Storhyngura</i> sp.	x	x			
Fish-louse type	x				
Amphipoda					
Gammaridea—Benthic†	x	x	x		x
<i>Aceroides edax</i>	x				
<i>Bathymedon candidus</i>		x			
<i>Bruzelia inlex</i>	x				
<i>Epimeria</i> sp.		x			

Table 2. (continued)

	<i>C. armatus</i>	<i>C. leptolepis</i>	<i>C. filifer</i>	<i>C. pectoralis</i>	<i>C. acrolepis</i>
<i>Halice</i> sp.					
<i>Harpiniopsis triplex</i>	x				
<i>Harpiniopsis excavata</i>	x	x			
<i>Harpiniopsis</i> sp.		x	x		
<i>Hippomedon tracatrix</i>	x				
<i>Hippomedon</i> sp.		x			
<i>Lepidepcreum</i> sp.	x				
<i>Liljeborgia cota</i>	x	x			
<i>Monoculodes necopinus</i>		x			
<i>Monoculodes recandescio</i>	x				
<i>Oediceroides abyssorum</i>	x	x			
<i>Orchomene tabasco</i>	x	x			
<i>Schisturella totorani</i>	x				
<i>Syrrhoë</i> sp.	x	x			
<i>Tryphosella metacaecula</i>	x				
<i>Uristes</i> sp.					
<i>Uristes perspinis</i>		x			
<i>Valettioopsis dentatus</i>	x				
Gammaridea—Pelagic†					
Lysianassidae	x				
<i>Eusirus</i> sp.	x				
<i>Hyperioopsis</i> sp.		x			
<i>Koroga megalops</i> ‡	x	x			
<i>Paracallisoma coecum</i>	x	x			
<i>Paralicella</i> sp.	x		x		
<i>Paragissa</i> sp.	x		x		
<i>Pseudotiron</i> sp.‡		x	x		
<i>Rhachotropis distincta</i>		x			
<i>Rhachotropis</i> sp.	x				
<i>Stegocephaloides</i> sp.	x	x			
<i>Synopiidae</i> ‡	x				
Hyperiidea	x				
Euphausiacea					
<i>Thysanopoda</i> sp.	x	x	x		
Other euphausiids	x				
Decapoda					
<i>Sergestes similis</i>	x		x		
<i>Bentheogennema</i> n. sp.		x	x		
Pasiphaeidae	x		x		
<i>Hymenodora acauthitelsonis</i>		x			
<i>Hymenodora glacialis</i>	x	x	x		
<i>Systellapsis braueri</i>	x				
<i>Crangon abyssorum</i>	x	x	x		x
<i>Munidiopsis</i> sp.	x				
<i>Chionecetes tanneri</i>					x
Megalops	x				
Unknown crab					x
HOLOTHURIOIDEA	x		x		
<i>Protankyra pacificum</i>	x		x		
OPHIUROIDEA					
<i>Ophiocten pacificum</i>		x		x	
<i>Ophiocten</i> sp.			x		
<i>Ophiacantha</i> sp.		x	x	x	
<i>Amphiura</i> sp.			x		
<i>Scotoplanes</i> sp.				x	

Table 2. (continued)

	<i>C. armatus</i>	<i>C. leptolepis</i>	<i>C. filifer</i>	<i>C. pectoralis</i>	<i>C. acrolepis</i>
OSTEICHTHYES					
<i>Tactostoma macropus</i>	×		×		
<i>Chauliodus macouni</i>	×				
Stomioid	×				
Myctophidae	×				
Searsiidae	×				
Macrouridae			×		
Vertebrae, bones, flesh	×		×	×	×
Fish scales (cycloid and ctenoid)	×		×	×	×
MISCELLANEOUS					
Plant					
<i>Zostera</i>	×				
<i>Fucus</i>	×				
Potato peel	×				
Nematoda	×	×	×		×
Medusae	×	×			
Formaninifera	×				
Echiurida	×				
Hooks—from unknown animals	×	×	×		×
No. fish with stomach contents	290	80	60	5	11

* × indicates the lowest tax on to which a food item could be assigned. Hence genera listed do not necessarily belong in the family given immediately above.

†Distinction between benthic and pelagic amphipods was based on morphology (BARNARD, 1962, 1969) and J. Dickinson (personal communication).

‡Not known if pelagic or benthic.

Many different food items were found in the stomachs (Table 2), especially in the abyssal species: 84 in *C. armatus*, 41 in *C. leptolepis*, and 40 in *C. filifer*. The number of food taxa listed is related to the number of fish examined with recognizable prey in their stomachs and to our skill in identification, but even so, some qualitative differences in food habits are obvious. Many taxa of amphipods, cephalopods, polychaetes, and fishes were found in *C. armatus* stomachs, but of these only amphipod taxa were well represented in *C. leptolepis* and only cephalopods in *C. filifer* stomachs.

Individual fish usually had a variety of food types in their guts, rather than many individuals of the same food taxa. This was especially true for small fishes that fed more on small invertebrates. On the average, only 1.9 individuals of each amphipod taxon were found in individual macrourid stomachs. Of the 63 fishes that had amphipods in their stomachs, most (60%) contained only a single amphipod. Both the diversity of food found in the species of macrourids and the variety of food in individuals suggest that the three abyssal species are feeding generalists.

The average frequency and fraction of different food items by weight is given for each abyssal species in Table 3. Crustaceans, molluscs, polychaetes, and echinoderms were common to the diet of all three species. Benthic crustaceans, copepods, poly-

Table 3. Average frequency of occurrence and per cent by weight of major food items in the stomachs of the three abyssal macrourids. Feeding overlap, C_λ of HORN (1966), is given at the bottom of the table. C_λ for frequency of occurrence was calculated omitting the values for crustacean remains (in parentheses) which were generally for fragments of crustaceans whose occurrence was already represented. Trace amounts are indicated by a 'T'.

	Frequency of occurrence			Per cent by weight		
	<i>C. armatus</i>	<i>C. filifer</i>	<i>C. leptolepis</i>	<i>C. armatus</i>	<i>C. filifer</i>	<i>C. leptolepis</i>
<i>Crangon abyssorum</i>	32	9	54	1.1	T	41.7
<i>Storhyngura</i> sp.	25	0	39	0.3	0	3.2
Amphipods	21	9	30	0.1	0.1	0.9
Copepods	43	3	48	0.1	0.03	T
Shrimp	2	11	1	3.0	4.4	2.6
Mysids	3	11	10	0.6	8.8	2.8
Euphausiids	1	1	1	1.0	2.4	10.0
Unidentified decapods	5	11	9	1.5	1.1	4.4
Other crustaceans	6	0	1	0.4	6.7	0
Crustacean remains	(35)	(43)	(57)	3.8	1.6	27.1
Cephalopods	19	74	3	67.3	54.0	T
Pelecypods-gastropods	3	2	1	0.1	0.05	0.4
Polychaetes	22	15	25	0.2	1.9	3.0
Ophiuroid	0	6	12	0	0.05	3.9
Holothuroid	16	20	0	7.6	3.8	0
Echiuroid	1	0	0			
Fish	8	13	0	11.3	12.5	0
Fish scales	15	30	0	0.5	1.8	0
Fish or squid lenses	14	22	1	1.1	1.4	
Σ	236	237	235	100.0	100.0	100.0
Overlap— C_λ	<div> <div>0.54</div> <div>0.22</div> <div>0.85</div> </div>			<div> <div>0.96</div> <div>0.04</div> <div>0.04</div> </div>		

chaetes, and holothurians were frequent in *C. armatus* stomachs. *Coryphaenoides filifer* had the lowest occurrence of benthic crustaceans and the highest of cephalopods and fishes, whereas *C. leptolepis* appears to be a more benthic predator, feeding largely on crustaceans like the shrimp *Crangon abyssorum* and the isopod *Storthyngura*. The larger fraction of benthic food in the stomachs of *C. leptolepis* and the lower percentage of everted stomachs (Table 1) suggest that this species may have a smaller swimbladder and a higher specific gravity and thus it may have more demersal habits than the other macrourids.

Food overlap

HORN'S (1966) formula for overlap, C_λ (with a possible range from 0.0 to 1.0), was used to estimate similarity among the food of the three abyssal species. Feeding overlap based on frequency of occurrence of different taxa indicates a high degree of similarity, 0.86, between the diets of *C. armatus* and *C. leptolepis*. Both species had similar occurrences of many groups, especially crustaceans and polychaetes. The overlap among the other species is less, 0.54 between *C. armatus* and *C. filifer* and 0.22 between *C. filifer* and *C. leptolepis*, indicating less similar diets.

On the basis of weight, cephalopods, mainly gonatid squids, dominated the diet of both *C. armatus* and *C. filifer*. For both of these species, fishes were next in importance, followed by holothurians or crustaceans. Broad overlap of feeding, $C_\lambda = 0.96$, is evident between these species, indicating highly similar food habits. Crustaceans, on the other hand, were most important in the diet of *C. leptolepis*; *Crangon abyssorum* was the major food; it comprised 41.7% by weight of the stomach contents. The overlap among *C. leptolepis* and either *C. armatus* or *C. filifer* is small (0.04) on a weight basis. The large difference between feeding overlap of *C. armatus* and *C. leptolepis* on a frequency of occurrence and weight basis (0.86 versus 0.04) is explained by the fact that although *C. armatus* frequently ingests small invertebrates, such as crustaceans and polychaetes, these are relatively less important on a total weight basis than squids and fishes. In general, these comparisons indicate that these three grenadiers often feed on the same types of prey, although the proportions of specific items sometimes vary significantly among species.

Food habits versus size of fish

The most apparent trend in the food habits of *C. armatus* (Table 4) is the decrease in the fraction of benthic crustacea (largely *Crangon abyssorum* and *Storthyngura* sp.) with increasing size of fish and an increase in the weight fraction of cephalopods and fishes. A similar trend in the diet of *C. armatus* from Hudson Canyon in the Atlantic Ocean was found by HAEDRICH and HENDERSON (1974). Food overlap (C_λ) on a weight basis is only 0.33 between 100 to 299- and 300 to 399-mm length classes based on the food categories of Table 3. Large fish eat large, pelagic prey and apparently compete little with the small fish that prey on benthic crustaceans.

Of the few small *C. filifer* (200 to 500 mm) that had non-everted stomachs, holothurians (largely *Protankgra pacificum*) and pelagic crustaceans comprised the most important portion of their stomach contents, whereas gonatid squids and fishes increased in importance in large individuals, as they did with *C. armatus*.

Coryphaenoides leptolepis clearly depends on crustaceans for its food. Benthic crustacea are most important for all sizes, 100 to 500 mm in length, but a trend toward

Table 4. Per cent by weight that major identifiable food categories comprised of the diet for different sizes of three species of macrourids.

<i>C. armatus</i>					
Total length (mm) (No. fish)	100-299 (44)	300-399 (44)	400-499 (19)	500-599 (4)	> 600 (4)
Benthic Crustacea	38	2	1	0	0
Pelagic Crustacea*	8	12	3	1	5
Crustacean remains	32	9	5	0	0
Cephalopods	1	45	60	94	1
Polychaetes	5	0	0	0	0
Holothurians	2	15	8	1	0
Ophuroids	0	0	0	0	0
Fishes	0	4	20	3	94
Miscellaneous	14	2	3	1	0
Per cent pelagic†	9	61	83	97	100
Per cent unidentifiable‡	66	35	17	5	8
<i>C. filifer</i>					
Total length (mm) (No. fish)	200-399 (3)	400-499 (6)	500-599 (17)	600-699 (20)	
Benthic Crustacea	0	0	0	1	
Pelagic Crustacea*	0	7	20	12	
Crustacean remains	0	47	3	11	
Cephalopods	33	1	64	47	
Polychaetes	0	7	0	3	
Holothurians	67	38	4	2	
Ophuroids	0	0	0	0	
Fishes	0	0	5	19	
Miscellaneous	0	0	3	4	
Per cent pelagic†	33	8	89	78	
Per cent unidentifiable‡	95	72	33	39	
<i>C. leptolepis</i>					
Total length (mm) (No. fish)	100-299 (17)	300-399 (18)	400-499 (8)	500-599 (2)	
Benthic Crustacea	59	56	44	28	
Pelagic Crustacea*	0	5	4	45	
Crustacean remains	41	34	36	20	
Cephalopods	0	0	0	0	
Polychaetes	0	0	10	0	
Holothurians	0	0	0	0	
Ophiuroids	0	3	3	7	
Fishes	0	0	0	0	
Miscellaneous	0	1	2	0	
Per cent pelagic†	0	5	4	45	
Per cent unidentifiable‡	51	47	54	21	

*Includes identified mysids, euphausiids, and pelagic shrimps as well as red and orange shrimp remains.

†Includes identifiable pelagic shrimps, cephalopods, and fishes.

‡Per cent of total weight of stomach contents, identifiable and unidentifiable.

increasing proportions of pelagic crustacea (euphausiids and shrimps) and decreasing fractions of benthic crustacea is evident as fish size increases. Fishes and cephalopods were not important in the diet of any of the *C. leptolepis* examined. Although the average food overlap based on weight between *C. armatus* and *C. leptolepis* is low ($C_\lambda = 0.04$, Table 3), the overlap among small individuals (100 to 299 mm) of these two species is high ($C_\lambda = 0.85$) because of the predominance of small benthic crustaceans in their stomachs.

DISCUSSION

According to theories on feeding strategies, predators that spend much of their time in search rather than pursuit of prey should be feeding generalists, especially if the predator is large and inhabits an unproductive, non-patchy environment (EMLEN, 1966; MACARTHUR and PIANKA, 1966; SCHOENER, 1971; MACARTHUR, 1972). This conclusion accords with IVLEV (1961) and HALL, COOPER and WERNER (1970), who observed that diets of fishes were more diversified when food density was low. Deep-sea predators, therefore, should be generalists and consume a broad variety of foods.

The actual categorization of the diet of an animal as 'generalized' or 'specialized' may not be easy. Quantitative criteria are seldom applied, and intuitive judgments may emphasize that the problem is largely one of semantics. For example, different authors considering the same data reached opposite conclusions on whether some species of carnivorous deep-sea benthic invertebrates are food generalists or specialists (SOKOLOVA, 1959; DAYTON and HESSLER, 1972; GRASSLE and SANDERS, 1973). Similarly, the macrourids in our study could be called generalists or specialists depending on what data are selected on total number of prey taxa consumed, frequency of occurrence, weights of prey taxa, or overlap of food among the different species or sizes of fishes.

In an attempt to answer the question of whether deep-sea fishes have more generalized diets than shallow-water fishes, we compared the amount of food overlap of the abyssal macrourids with that reported for northern, marine, demersal fishes by TYLER (1972). Reoccurrences or overlap of prey types were calculated from our data using his methods (Table 3). Principal prey—food taxa that occurred in 10% or more of the individuals of a species or comprised 5% or more of the food weight—were listed in a predator-prey matrix table and the number of reoccurrences was computed as a percentage of the possible number of reoccurrences. The overlap among the three macrourids based on frequently occurring prey was 50%, compared to values of 15 to 24% given by Tyler for fishes of Passamaquoddy Bay, Nova Scotia, and the Irish Sea. Overlap based on prey comprising 5% or more of the weight was 12% for macrourids and 10% for fishes from the Sea of Okhotsk. Although estimates of food overlap and specialization are influenced by the number and similarity of fishes and by the number and taxonomic breadth of food categories, the Oregon rattails do not appear to be any more specialized or have any less food overlap than shallow-water fishes. Considering these comparisons, the high food overlap among some species, and the diversified diets of all the abyssal macrourids (Tables 2 and 3), we conclude that they have relatively generalized food habits, but this does not preclude some trophic specialization or prey selection. Some selection is evidenced by absence in the rattail diets of common benthic invertebrates, such as species of holothurians and other echinoderms, and by differences in the feeding habits of different species and sizes of a species.

As generalists, small macrourids, which were primarily benthic feeders (Table 4), could be important in maintaining the high species diversity of the deep-sea benthos in accordance with the hypothesis of DAYTON and HESSLER (1972). Large macrourids, on the other hand, fed mainly on pelagic animals and thus have a different trophic niche in the deep-sea food web.

Other investigators have also found that macrourids are euryphagus and feed on a variety of both benthic and pelagic animals. PECHENICK and TROYANOVSKII (1970)

found that *Macrurus rupestris* in slope waters of the northwest Atlantic feed intensively on zooplankton (shrimps, euphausiids, *Calanus*, and amphipods), and they found seasonal bathymetric migrations of *M. rupestris* to be related to changes in the vertical distributions of these pelagic animals. The food habits of *M. rupestris* from Icelandic waters were studied by PODRAZHANSKAYA (1967), who found that the pelagic shrimp *Pasiphaea* comprised 74.4% of the diet; euphausiids and *Themisto*, a pelagic amphipod, were also common. NOVIKOV (1970) reported 34 taxa of food in stomachs of *Coryphaenoides pectoralis* caught in slope waters of the North Pacific. Squids and shrimps were important prey, although ctenophores, bryozoans, echinoderms, amphipods, lanternfishes, and liparids sometimes were common (frequency of occurrence of 10% or more). The food habits of 25 species of macrourids caught on the continental slope off Japan revealed that the most important prey were euphausiids (OKAMURA, 1970). Euphausiids were found in the stomachs of all but one species of grenadier and often constituted 50 to 100% of the diet of individual species. Polychaetes, shrimps, fishes, squids, and isopods were next in overall importance, sometimes exceeding the percentage of euphausiids for individual species of macrourids. Okamura concluded that some genera of macrourids are true benthic feeders, intimately associated with the sea floor, while others, like the subgenus *Nematonurus*, are primarily bathypelagic.

These papers indicate that pelagic animals may be more important than benthic animals as the food of some species. We found that this was especially true for large *Coryphaenoides*; over 50% of the fishes represented in Table 4 had diets consisting mostly of pelagic organisms. The occurrence of vertically migrating or mesopelagic animals such as euphausiids, shrimps, squids, and lanternfishes in the diet of slope-dwelling macrourids is not unexpected because these animals may migrate close to the bottom during the day (PECHENIK and TROYANOVSKII, 1970). However, their presence in the stomachs of grenadiers taken on the abyssal plain off Oregon is surprising. The squids *Gonatus fabricii*, *G. magister*, and *Onychoteuthis banksii*, the shrimps *Hymenodora*, *Bentheogennema*, *Sergestes similis*, and *Systellaspis braueri*, euphausiids, and the fish *Tactostoma macropus* are all found within the upper 1000 m off Oregon, sometimes with peaks in abundance above 1000 m (PEARCY and FORSS, 1966; PEARCY and LAURS, 1966). These animals are not known to be distributed to 2800 m, the depth of the bottom where most macrourids were collected, although few opening-closing net tows have been made below 1000 m. There are several possible explanations of the problem of how these deep-sea fishes obtain their pelagic food:

1. After being caught in the trawl, macrourids fed on pelagic animals collected in the net from shallower depths.
2. The vertical distributions of pelagic prey may actually extend into bathypelagic waters close to the bottom.
3. Macrourids may undertake extensive feeding migrations into overlying waters.
4. The pelagic food items were actually consumed on or near the bottom after sinking as corpses through much of the water column.

A few pelagic animals from macrourid stomachs such as an *Onychoteuthis banksii*, a squid found at the surface at night (CLARKE, 1966; PEARCY, 1965), and a *Tactostoma macropus*, which was caught in largest numbers above 500 m (PEARCY and LAURS, 1966), were in excellent condition and therefore recently ingested. Possibly this resulted from feeding in the trawls, as suspected for a pelagic shrimp by JUDKINS and FLEMINGER (1972). However, many of the other prey, like the gonatid squids, were

often partially digested or only identifiable from beaks and had obviously not been recently ingested. Moreover, squids of the size eaten by macrourids are good avoiders and are rarely if ever captured in our trawl nets. In fact, pelagic animals, in general, are rare in bottom trawl catches compared to benthic fauna; therefore, if indiscriminate net feeding occurred, benthic animals and sediment (which was rare) would be expected in the stomachs of macrourids.

Little is known about the vertical distribution of animals in deep water, and possibly the ranges of some of the pelagic prey of macrourids in fact extend to near-bottom depths off Oregon. Small gonatid squids and *Octopoteuthis sicula* are common within the upper 500 m (PEARCY, 1965; DEGNER, 1925), and *G. fabricii* and *G. magister* are considered to be usually mesopelagic (CLARKE, 1966). However, AKIMUSHKIN (1965) believed that *Gonatus fabricii* and *Gonatus magister*, both important prey for *C. armatus* and *C. filifer*, are eurybathic, ranging to depths of over 4000 m. CLARKE and MERRETT (1972) found cephalopod remains in the stomachs of the demersal shark *Centroscymnus coelolepis* caught on long lines in the North Atlantic at depths of 998 to 1975 m and believe that some species of squid live on or near the bottom at least some of the time. The ommastrephid squid *Illex* has been commonly observed near the bottom at 1800 m on *Alvin* dives in the North Atlantic (R. R. Hessler, personal communication). Macrourids may therefore feed on eurybathic squids near the abyssal ocean floor.

Pelagic shrimps found in the stomachs have also been caught in mesopelagic waters, but little is known about their distributions below 1000 m. *Sergestes similis* is a diel migrator with a center of abundance usually above 500 m off Oregon. The centers of abundance of *Hymenodora* spp., *Bentheogennema* n. sp., and *Systellaspis braueri*, also found in grenadier stomachs, are deeper than those of *S. similis* (PEARCY and FORSS, 1966). Their distributions extend into bathypelagic waters below 1000 m. Both *S. braueri* and *H. glacialis* have been collected in closing midwater trawls at depths of 2000 to 2400 m off Oregon. According to VINOGRADOV (1970), *Hymenodora glacialis* is distributed from 1000 to 6000 m in the Kurile-Kamchatka Trench. He postulates a scheme of overlapping ontogenetic and diel vertical migrations of pelagic animals to provide for active transport of organic matter from surface waters into the deep sea.

The best evidence for macrourids migrating vertically far above the bottom where they forage on pelagic animals pertains to some of the slope species. A few *C. acrolepis* have been collected in midwater trawls off Oregon at least 1000 m above the bottom (IWAMOTO and STEIN, 1974). KORT (1967) reported a similar finding for this species on the basis of stomach contents. He cites BIRSHTEN and VINOGRADOV (1955), who consider *C. acrolepis* to be a bathypelagic form, though they found that stomach contents also contained benthic isopods. Sometimes *M. rupestris* rise 100 to 200 m above the bottom as indicated in echograms and low catches on the bottom (PECHENIK and TROYANOVSKII, 1970). OKAMURA (1970) noted that *C. pectoralis* and *C. longifilis* (subgenus *Nematonurus*) rely on squids and fishes for a great part of their food and he believes this subgenus may swim well away from the sea floor and possess bathy- or mesopelagic habits. No evidence exists to our knowledge, however, for extensive migrations of abyssal species into upper waters that could explain the occurrence of mesopelagic prey, although HAEDRICH and HENDERSON (1974) invoke extensive vertical migrations of *C. armatus* to explain animals like *Chauliodus* in the diet of this rattail.

Finally, animals may die and sink to the bottom where they are devoured by fishes. Photography has revealed rapid localization and consumption of bait by macrourids and other deep-sea fishes, suggesting that they are efficient searchers and scavengers (ISAACS, 1969; CURTIS, 1971; DAYTON and HESSLER, 1972). Though we found no evidence for ingestion of pieces of large fishes or marine mammals, as did CLARKE and MERRETT (1972), the relative size of squid beaks ingested suggests the possibility that sometimes portions of dead cephalopods were eaten by grenadiers off Oregon.

The length of the lower rostrum of beaks from gonatid squids was regressed on body weight using intact specimens and data from CLARKE (1962). The estimated median size of gonatid squids in *C. armatus* stomachs was 100 g (range 1.4 to 1100 g) and in *C. filifer* was 205 g (range 8.2 to 3000 g). Most of the squids were probably eaten whole. However, the estimated weights of three squid were actually larger than the fish that ate the beaks, and the weights estimated from 6 of 26 beaks were over one-half the weight of the fish from which the beaks were found. Since large squids are good swimmers and, if healthy, are probably too fast to be caught by macrourids, dead or dying squids may sink to the bottom where they are eaten whole or in pieces by macrourids. The possibility exists that other pelagic organisms found in grenadier stomachs may also have been eaten after they died and settled to the bottom. Because of the slow microbial decomposition of organic matter in the deep sea (JANNASCH, EIMHJELLEN, WIRSEN and FARMANFARMIAN, 1971), such corpses may constitute a fairly stable food supply for motile abyssobenthic scavengers.

We believe that these macrourids are both predators and scavengers, and that this is another indication of their generalized foraging habits in the deep sea. Our data do not support the idea that they depend on large organic falls, however, because small pelagic and benthic animals comprise much of the diet. Pelagic animals are especially important food for large macrourids, but we are unable to say where in the water column they are devoured.

Acknowledgements—We are grateful to ANDREW CAREY for providing many of the fishes from his collections, to DAVID STEIN, JOHN DICKINSON, DANIL HANCOCK, and ROBERT WASMER for identification, respectively, of macrourids, amphipods, polychaetes, and shrimps, and to C. B. MILLER for criticism of the manuscript. This research was supported by the U.S. Atomic Energy Commission (Contract No. AT(45-1)-2227, Task Agreement 12; R20-2227-T12-40).

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a shallow water "mini-dredge"

An inexpensive shallow water "mini-dredge" has been designed, fabricated, and used to obtain surface sediment grab samples. The total cost of materials involved was less than \$10.00. The dredge is a 3.8 liter (1 U.S. gallon), rectangular gasoline can with the top end removed. A bridle, fabricated from the steel strips of a hanging file folder support (0.3 cm x 1.3 cm), was attached to the narrow sides of the can such that, when towed, the largest surface area of the can is parallel

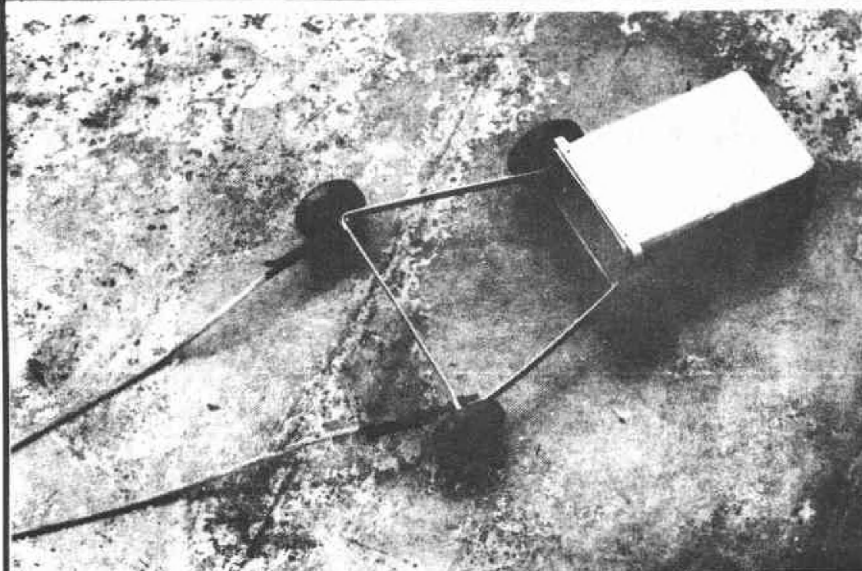


Figure 1. Overall view of the "mini-dredge"

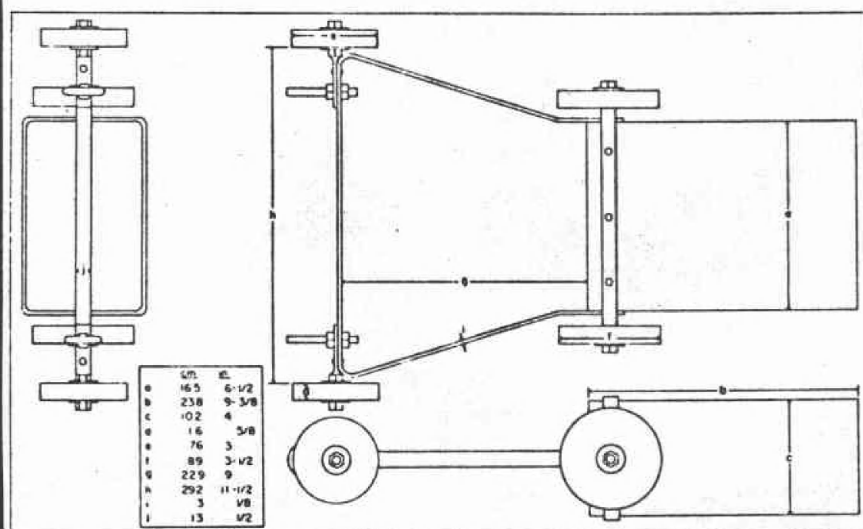


Figure 2. "Mini-dredge" dimensions.

to the sediment. The bridle can be articulated slightly in order to alter the angle of penetration of the orifice into the sediment. Lead weights, wheel shaped for convenience, were attached as ballast (3.8 kg) to the bridle by stove bolts. These weights were made by pouring molten lead into jar lids, allowing them to cool, and drilling holes for mounting.

Modifications can readily be made to adapt the dredge to particular needs. For example, penetration depth could be controlled by adding adjustable skids. The removal of the posterior end and replacement with a bag-shaped net may allow for collection of benthic organisms such as mollusks.

The dredge has been used successfully to water depths of approximately 20 meters in estuaries and reservoirs, towed from a small boat at 1 to 2 knots. The volume of sediment collected ranged from approximately 1/2 to 3 liters, depending upon the sediment characteristics and towing time.

A depth penetration of approximately 6 cm was estimated for a grab sample composed of 30 percent sand and 70 percent silt-clay. This estimate was determined by comparison with a sediment core collected concurrently with the grab sample. In coarse sand, a penetration of about 1 cm was observed visually.

We wish to acknowledge the assistance given by Dr. Norman Cutshall and Mr. Vernon Johnson in sampling and sediment analysis. This project is supported by AEC contract No. AT (45-1)-2227, Task Agreement 12, Document RLO-2227-T12-45.

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From: Naidu and Cutshall. 1974. Oceanography Reference 74-9. Oregon State University, Corvallis, Oregon

RADIOACTIVE ZINC (^{65}Zn), ZINC, CADMIUM AND MERCURY IN THE PACIFIC HAKE, *MERLUCCIUS PRODUCTUS* (AYRES), OFF THE WEST COAST OF THE UNITED STATES:
A DATA REPORT

By J.R. Naidu and N.H. Cutshall

INTRODUCTION

This report presents the results of analyses of several hundred Pacific Hake, *Merluccius productus*, for zinc (Zn), zinc-65 (^{65}Zn), cadmium (Cd), and mercury (Hg). The fish were collected off the coast of the western United States in 1969-1972. In addition, some data from mercury analyses of fresh and seawater samples collected in 1970-1973 are presented. The contents of this report were used in Mr. Naidu's doctoral thesis (Naidu, 1974). A majority (80%) of the hake samples were collected during July and August, 1969, from 32°N to 48°N along the western coast of the United States.

This study was accomplished under United States Atomic Energy Commission Contract No. AT(45-1)-2227, Task Agreement 12, and is assigned No. RLO-2227-T12-48. Karla McMechan provided great assistance in the preparation of this report.

COLLECTION AND STORAGE

Fish. Most of the samples of Pacific Hake, *Merluccius productus*, were collected by Russian scientists on board PROFESSOR DERYUGIN, in collaboration with the U.S. Bureau of Commercial Fisheries [now, National Marine Fisheries Service (NMFS)] in July and August 1969. Additional samples were collected by NMFS vessels, JOHN N. COBB, BARON and COMMANDO, and by the OSU School of Oceanography CAYUSE and YAQUINA in 1969-1972. Location of sampling stations and a summary of data collected are presented in Section I of the data.

Standard procedures for preserving the fishes were followed on all cruises: fishes were packaged in plastic bags, labelled and immediately frozen at about -10°C. In the laboratory the

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fishes were kept frozen at about -25°C until time of analysis.

Water. Marine, estuarine and freshwater samples were collected for mercury analysis in 1971-73 from the OSU vessels YAQUINA and SACAJAWEA. A map of sampling sites and a summary of the data collected are presented in Section II of the data. Surface water samples were collected in a plastic bucket which was cleaned with nitric acid between sampling. Samples at depth were collected with a Van Dorn sampler. Each sample was immediately transferred into a two-liter polyethylene bottle (which had been cleaned with nitric acid), acidified with 15 ml (70%) nitric acid and kept frozen until time of analysis.

PREPARATION OF SAMPLES

Standard length measurements were taken and the fish were prepared for Zn, ^{65}Zn and Cd analyses of entire fish samples and Zn, ^{65}Zn , Cd and Hg analyses of flesh only samples.

Entire Fish: Stomach contents were removed and discarded. The entire fish, skeleton included, was cut into small pieces and put into PyrexTM beakers, previously cleaned with nitric acid and tared.

Fish Flesh: Each fish was skinned while still frozen; the muscle portion (flesh) from both sides was removed, cut into pieces and stored in PyrexTM beakers, previously cleaned with nitric acid and tared. Approximately 30 g of the flesh of each fish was put into cold storage ($\sim -25^{\circ}$) for mercury analysis.

Samples were then dried in a hot-air-circulating oven at $90 \pm 5^{\circ}\text{C}$ for approximately three days. Dried samples were removed

from the oven and immediately sealed with Saran WrapTM to prevent moisture absorption. The dry weight was measured and corrected for the weight of the Saran WrapTM and beaker.

After cooling, the Saran WrapTM was removed and samples were ashed in a muffle furnace at 400°C. The temperature of the furnace was monitored with a separate thermometer and generally ranged within $\pm 20^\circ\text{C}$ of 400°C. Samples were kept in the oven for 48 hours, by which time a grey-white ash was produced. Air was constantly circulated through the muffle furnace to accelerate the ashing process, since the temperature must be kept well below 600°C (Gorsuch, 1959) to prevent loss of cadmium and zinc. After ashing, samples were removed from the furnace and again sealed with Saran WrapTM as in the drying stage. Ashed weights were measured and corrected for Saran WrapTM and beaker.

The ashed samples were ground to a fine powder using a mortar and pestle (cleaned with nitric acid between samples) and packed into 12 ml plastic vials. The vials were then counted for gamma-emitting radionuclides. A sub-sample of ash from each vial was subsequently taken for determination of Zn and Cd.

For mercury determinations the fish-flesh and water samples were digested using oxidizing agents prior to the analysis, as outlined in the following section.

ANALYTICAL METHODS

Zinc-65. The ashed samples were analyzed for ^{65}Zn by gamma-ray spectrometry. The twelve cm^3 plastic vials containing this ash were placed in a 5" x 5" NaI(Tl) well-type detector coupled to a 512-Channel analyzer. Counting times were from 100 to 800 minutes, depending on the level of radioactivity. After subtraction of background, the resultant data were reduced for ^{65}Zn

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and ^{40}K by spectrum stripping. No other gamma-emitting radionuclides were detected in the samples. Calibration standards for ^{65}Zn and ^{40}K are certified by the supplier to within $\pm 2\%$.

Zinc and Cadmium. Following radionuclide analysis, subsamples of the ash were analyzed for Zn and Cd by atomic absorption spectrometry. The subsamples were weighed into 25 ml volumetric flasks, dissolved using 70% nitric acid, evaporated to dryness and then dissolved using 0.36N hydrochloric acid. Conventional flame methods were used for Zn analysis of the resultant solution with a Perkin-Elmer Model 303 A.A. Spectrophotometer. For the Cd analysis a Varian Techtron Model 63 Carbon Rod Atomizer coupled to a Varian Techtron Model AA-5R was used. Corrections for non-atomic absorbance were required for Cd determinations.

Details pertaining to the calibration line, absolute sensitivity, detection limit, precision and accuracy for Zn determination have been described by Larsen (1971).

The calibration line for Cd, using Fisher Standards at concentrations of 0.025 ng, 0.05 ng and 0.125 ng Cd, had a correlation coefficient (the Pearson r) of 0.99804. Using this line the absolute sensitivity (weight of an element which produces an absorbance of 0.0044 or 1% absorption) was 1.0×10^{-12} g. The relative standard deviation (RSD) of 10 replicate determinations ranges from 0.7 to 2.2% for standards and from 2 to 3% for samples.

Mercury. Fish-flesh samples were prepared for mercury analysis by digestion with 70% nitric acid and hydrogen peroxide in a reflux system. The water samples were digested in a hot water bath (-90°C) with 70% nitric acid, sulfuric acid, potassium permanganate and potassium persulfate. These are modifications

of the methods used by Buhler et al. (1973) for biological samples, and by the U.S. Environmental Protection Agency (1971) for water samples.

The oxidized samples were reduced in a system as outlined by Buhler et al. (1973) for biological samples and the U.S. EPA (1971) for water samples. Typically the reductant was stannous chloride and sulfate, or hydroxylamine hydrochloride, and the elemental mercury thus formed was volatilized into a 20 cm absorption cell. The sample absorption at 2357 Å was compared to that of standards and the concentration of mercury in the sample was calculated accordingly.

The calibration line for fish-flesh samples had a correlation coefficient of 0.997537, and the RSD ranged from 0.24 to 0.47% for the standards and 1.32% for the samples. Sample homogeneity in the hake flesh had an RSD of 2.35 to 3.69%.

For water samples the calibration line had a correlation coefficient of 0.997208, and the RSD ranged from 2.36 to 3.17% for the standards and from 3.5 to 4.2% for samples. Detection limit in this study was 3.4 ng/l.

REFERENCE STANDARDS AND INTERCALIBRATIONS

The results of intercalibration exercises and standard analyses are presented in Section III. Standard reference materials were analyzed using the same procedures used for samples and, in some cases, also by neutron activation analysis. In all cases good agreement was obtained among analytical methods. Results conform to standard reference data.

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EDITOR'S NOTE: The data section (pp. 7-53) has been omitted. Limited copies are available from Dr. N.H. Cutshall, School of Oceanography, Oregon State University, Corvallis, Oregon 97331.

RLO-2227-T12-50

METALS IN ESTUARIES*

Norman H. Cutshall

Two questions consistently recur when metal pollution in estuarine systems is discussed. First, "What is the biological significance of a metal?" Second, "What is the rate of transport of the metal through some particular system?"

Each of these questions has several manifestations. In the former case, the primary concern may be for the health of persons eating contaminated food, for the health of the food organisms themselves, for some other species of economic importance, or even for the overall stress upon a system. In the latter case the concern may involve steady-state levels associated with constant inputs; it may involve transient, accidental spill problems, or it may involve clearance times for a system once a chronic contamination has been eliminated.

The chemist addressed with such questions instinctively responds, "What is the chemical form of the metal?" After a period of silence, the chemist begins to consider alternative means for learning the answer to his question. In a number of cases, research projects have been created to approach the question of chemical form and its corollary, "What chemical reactions are changing the form?"

My purpose here is to compare the results of several studies aimed towards answering this corollary question. I will focus primarily upon differentiation between particulate and dissolved chemical forms. Distinction between these is normally made by filtration with the portion appearing in the filtrate being called "dissolved" and that retained on the filter being called "particulate." Colloidal matter passing through the filter and ionic matter ~~being~~ adsorbed to the filter make the analytical distinction questionable; but, because of its simplicity, filtration continues to be an important procedure.

Each of these classes consists of many chemical forms. "Particulate" matter includes detrital and weathered mineral fragments, both living and dead organic matter, coatings of organic matter of hydrous iron and manganese oxides, and matter sorbed to one or another of these. "Dissolved" includes ions (perhaps complex) and soluble, but electrically neutral species, as well as colloidal forms. While there have been efforts to discern each of these forms separately, relatively few such experiments have been repeated from place to place or by different analysts. Therefore, I shall focus upon only the two broader groups.

*To be published in *Proceedings of the 4th Annual Technical Conference on Estuaries of the Pacific Northwest, 14-15 March 1974*. [In Press] OSU Sea Grant College Program, Corvallis, Oregon.

The introduction of radioactive nuclides into the environment via nuclear detonations in the 1940's and 1950's provided awareness that local, regional and global transport systems were "operative". It was clear that matter was not only transferred from one place to another, but also that it could be passed from one component of the ecosystem to another in the normal operation of that system. Not that such knowledge is particularly obscure or difficult to comprehend, but rather that few, if any, people had consciously realized the implications until radioisotopes so clearly showed them.

Because of the hazard and the mystical, invisible nature of radiations from radioactive material, great efforts were focused upon consideration of the aforesaid implications. A particularly lucid and succinct exposition of the chemists' involvement in "radioecology" was made by Waldichuk (1961). Because of such clear recognition of important questions for radioisotopes rather earlier than for elements in general, much of the knowledge available today regarding partitioning of metals comes from studies of artificial radionuclides.

In the present report three types of experiments are discussed: those involving the analysis of sediments, those in which water is analyzed and those involving direct reaction of water and sediment in an experimental configuration.

An early "process" study was reported by Johnson (1966), and Johnson et al. (1967). Johnson recognized that although the radionuclides ^{60}Co , ^{65}Zn , and ^{54}Mn were in ionic form when released in the effluent from the Hanford, Washington, reactors, they were in particulate form by the time they reached the Columbia River estuary. He reasoned that the process of mixing with seawater in the estuary exposed the particles to a changing ionic medium and that ion exchange reactions were likely.

He sought to determine directly the "ion exchangeable" portion of radionuclides by direct leaching of Columbia River sediment with seawater. Seawater removed some 40% of the ^{54}Mn , five to fifteen percent of ^{60}Co and only one percent or less of ^{65}Zn . No ^{46}Sc or ^{51}Cr was removed. He suggested that the exchangeable portion of ^{54}Mn was displaced from particles by the abundant Na^+ and Mg^{++} ions in seawater, but that ^{60}Co and ^{65}Zn were bound to the sediment by some more specific adsorption reaction than simple cation exchange. This experiment was later repeated by Robertson et al. (1973) with the same results and conclusions.

Because these leaching experiments allowed only one to two hours of contact, Cutshall et al. (1973) and Evans and Cutshall (1973) sought to provide a longer time period for desorption. They transferred Columbia River sediment to the non-radioactive Yaquina Bay. This time up to eleven weeks of contact with seawater was provided. Again, however, about half of the ^{54}Mn was removed by seawater and very little, if any ^{65}Zn or ^{60}Co .

In the Rhine River and its estuary de Groot et al. (1971) measured metal contents of sediments. They found that metallic contamination of

sediments is greatest for fine-grained material. When the effect of particle size is removed from their data, an interesting pattern of metal contents of bed sediments of the estuary is found. For several metals the concentration is lower nearer the sea. Mercury, for example, is markedly lower. The difference in metal content is interpreted as desorption or "mobilization" of the metal from sediment during transport through the estuary. Copper and zinc appear to undergo up to 80% removal from sediments during transport downstream through the estuary. For some metals, however, no change is found. Manganese content of sediment throughout the estuary is unchanging and this metal was even used to trace Rhine River sediment along the North Sea coast. The inferences from sediment analyses agree with those from the seawater leaching experiments (Johnson 1966) in that some metals are solubilized in the estuary. The order among the various metals, however, was markedly different.

A different approach was taken by Lowman et al. (1966). They carried filtered water from the metal-rich Añasco River out to sea and artificially mixed it with offshore seawater. The metal remaining in filtered samples of the mixture was followed over the course of several hours. "Soluble" concentrations of most metals declined markedly during this time. Scandium was most rapidly lost from solution, followed by cobalt, zinc and manganese. This result contrasts with that of the sediment study because the direction of the reaction is from soluble to particulate. The relative order of solubility is similar to that of the seawater leaching experiments.

Yet another approach was taken by Evans and Cutshall (1973), again in the Columbia River. If no reaction occurs during estuarine mixing, a linear relationship between metal (or radioisotope) concentration and salinity should be found. Deviations from linearity indicate that either some reaction occurs, or there is an alternative input (output) for the substance being considered. Using this approach, Evans and Cutshall (1973) found no reaction of ^{46}Sc or ^{51}Cr in the Columbia River estuary. Zinc-65 and ^{54}Mn appear to be desorbed to the extent of 30% and 50% respectively. The authors suggested that their results for ^{65}Zn differ from those of Johnson et al. (1967) because suspended particulates and bed sediments differ in sorption-desorption properties.

Let us now recapitulate the experiments reported and summarize their results. Table 1 lists essential observations from each experiment.

There are points of contrast and points of similarity in all of the reports. Each experiment indicates that some reaction occurs. Each experiment shows that scandium, the only trivalent element common to all, is least soluble among the elements studied. Among the divalent metals Hg, Cu, Zn, Co and Mn, ~~(Mn⁺⁺ can fairly readily be oxidized to MnO₂)~~ an order of solubility roughly parallel to the Irving-Williams (1953) order for the strength of coordination complexes is seen. That order is $\text{Mn} < \text{Co} < \text{Zn} < \text{Cu} < \text{Hg}$. The correspondence to coordination complex formation, plus the observation that the more tightly bound metals can be desorbed by other transition metals (Johnson et al. 1967), suggests that coordinate covalent bonding is involved in transition metal adsorption.

TABLE 1: RESULTS OF DESORPTION STUDIES

<u>EXPERIMENT</u>	<u>% DESORBED</u>						<u>ORDER OF "SOLUBILITY"</u>	<u>REFERENCE</u>
	<u>Sc</u>	<u>Hg</u>	<u>Cu</u>	<u>Zn</u>	<u>Co</u>	<u>Mn</u>		
Leach Columbia River Bed Sediment in Sea Water (Radioisotopes)	0	-	-	1	10	40	Sc < Zn < Co < Mn	Johnson et al. (1967) Robertson et al. (1973)
Analyze Rhine River Bed Sediments	0	95	85	80	-	0	Sc,Mn < Zn < Co < Hg	de Groot et al. (1971)
Analyze Filtered Columbia River Water (Radioisotopes)	0	-	-	30	-	50	Sc < Zn < Mn	Evans & Cutshall (1973)
% PRECIPITATED AFTER 2 HRS.								
Mix Añasco River Water with Sea Water	100	-	8	65	100	25	Sc < Co < Zn < Mn	Lowman et al. (1966)

The "degree of solubility" varies from one experiment to another and there are minor changes in the order of solubility. Conclusions based on the Rhine River bed sediment data, however, are markedly different. While there is preservation of the Irving-Williams order, it is reversed with respect to that found in the other experiments. Manganese, with the lowest tendency to form complexes, is most securely retained, while metals high in the Irving-Williams order are substantially released or "mobilized". The contrast to other results is sufficiently striking to warrant careful examination of the unique features of the Rhine River study. The Rhine study relies upon interpretation of bed sediment data, whereas the others cited are results of water or water and sediment analyses.

De Groot et al. (1971) were not unaware of the similarity of the order of mobilization to the Irving-Williams order and they suggested that organic chelating ligands were responsible for selectively leaching metals from particles. They note that an abundance of marsh vegetation roughly corresponds in space to the apparent reaction location in the Rhine. On the other hand, almost no marsh vegetation surrounds the Columbia River estuary. Thus the Columbia would lack the source of chelating substances present in the Rhine. This conclusion would suggest that other rivers with abundant vegetation, such as those passing through salt marsh estuaries, should display the "inverse order" of solubility as compared with relatively barren systems like the Columbia.

The considerable mobilization of manganese observed in the Columbia, the Mississippi (Murata, 1939), and the Hudson (Lentsch et al., 1973) could not be explained. Manganese is low in the Irving-Williams series and therefore should not be mobilized by chelating substances. In the Rhine it apparently is not mobilized. On the other hand, perhaps manganese is also mobilized in the Rhine and subsequently re-precipitated, so that the sediment concentration does not vary appreciably. "Mobilization" or desorption of metals during estuarine mixing may be a universal, inorganic chemical process roughly following the Irving-Williams series for transition metals because binding of transition metals to sediments is dominated by coordinate bonding. Subsequent re-precipitation might occur if, for example, divalent manganese is oxidized to MnO_2 . During precipitation of MnO_2 , other metals would be scavenged from solution as well, unless they were sequestered as complexes by soluble ligands in the water. Such sequestering would also follow the Irving-Williams series. Thus the inverted Rhine order would be compatible with that seen in the other studies cited.

The above rationalization is highly speculative. It is, however, subject to experimental verification. First, the premise that desorbed metals re-precipitate can be checked. Were this to happen, there should be a negative deviation from linear mixing at salinities higher than those where a desorption apparently occurs. There must also be a correspondence between the apparent order of solubility in an estuary and the organic matter chemistry of that estuary. It should be fairly easy to devise experiments to uncover such correspondence. Estuaries with little organic matter like the Columbia would have Mn apparently more soluble than Zn, whereas estuaries with an abundance of organic matter like the Rhine would

have Zn more soluble than Mn. Quite possibly the order would be seasonal, owing to fluctuations in the production and abundance of organic matter.

Metals appear to undergo reactions in estuaries. Whether these reactions are toward increased or lessened solubility may depend upon the specific metal and estuary. Seasonal variations are possible. Changes in physical form can be expected to affect the transport routes and rates of metals in the coastal zone and their persistence in estuaries. Changes in both physical and chemical form influence the biological significance of metals because toxicity and assimilation efficiency both depend heavily upon chemical form.

Acknowledgments

This work was supported by the U.S. Atomic Energy Commission under Contract No. AT(45-1)-2227, Task Agreement 12 and is assigned number RLO-2227-T12-50. I thank Dr. Robert Holton and Ms. Karla McMechan for helpful reading of the manuscript.

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RLO-2227-T12-51

Accepted by *Fishery Bulletin*

DESCRIPTION AND BIOLOGY OF A NEW SPECIES OF PELAGIC PENAEID SHRIMP,
[REDACTED], FROM THE NORTHEASTERN PACIFIC¹

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ABSTRACT

The new species of pelagic penaeid shrimp lacks the richly plumose arthrobranch described for the genus and has a single pair of terminal spines on the telson. It is found mainly in transitional water of the north Pacific between 500-1000 m by day and 150-1000 m at night. Examination of testes and ovaries, and the structures of the petasma and thelycum, indicates a 4-5 month spawning season and an equal male to female sex ratio. Generation time was estimated to be two years.

¹Research was supported by the Office of Naval Research (Contract N000-14-67-A-0369-007 under project NR 083-102) and the Atomic Energy Commission (Contract AT[45-1]-2227, Task Agreement 12), publication number RLO-2227-T12-51. [Because of possible nomenclature problems, the new species name has been deleted.]

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INTRODUCTION

This paper describes the systematics and biology of a new species of pelagic penaeid shrimp of the genus *Bentheogennema*. Since 1961 studies of the fauna and ecology of the mesopelagic waters off the coast of Oregon have been conducted by members of the School of Oceanography, Oregon State University. Several unusual species of macrurous decapod Crustacea have been obtained. The discovery and identification of this new species of *Bentheogennema* was by Dr. Carl Forss, who entrusted his material to the authors. Subsequent sampling with midwater trawls has provided detailed information on the distribution and biology of this shrimp, as well as abundant material for taxonomic description.

METHODS AND MATERIALS

Material for the zoogeographic distribution was collected in Isaacs-Kidd Midwater Trawls (IKMT's) from the research vessels YAQUINA, ENDEAVOR, JOHN R. MANNING and HUGH M. SMITH in the northeastern Pacific, normally within 320 m of the surface (Wasmer, 1972). Information on vertical distribution, reproductive biology, and growth of this species was obtained from samples taken on five cruises aboard R/V YAQUINA at a single sampling station 65 nautical miles (120 km) off the central Oregon coast (NH 65-44°35'N; 125°25'W) in 1972-73. Samples at this station were taken both day and night, using an 8' IKMT with a five net opening-closing codend section similar to the one described by Percy and Mesecar (1970).

All samples were preserved at sea in 10% buffered formalin. The samples were later sorted, identified, sexed when possible, and measured. Carapace length (measured from the postorbital margin to the median posterior edge of

the carapace) was used as an indication of size. All figures were drawn with the aid of a camera lucida.

In males, sexual maturity was based on three characteristics: (1) petasmata joined, (2) well-developed accessory lobe on anterior surface of the petasma, (3) and dilated vas deferens with large terminal ampoule (indicative of developed spermatophore) at the base of the fifth pereopod. The combined characteristics of fully developed thelycum and the posterior lateral lobe of the ovary swollen with eggs at the base of the fifth pereopod were used as signs of sexual maturity in females. Estimates of growth are presented from analysis of length-frequency data.

Section Penaeidea

Family Penaeidae Bate

Subfamily Aristaeinae Alcock

Series Benthescicymae Bouvier

[REDACTED] n. sp.

Types: Holotype (USNM 150835), male, carapace length (c.l.) 18 mm, from Station 51°-26'N Lat. and 138°-28'W Long., Midwater Trawl No. 857 (Mt-857); Allotype (USNM 150836), female, 14.5 mm c.l., station Newport Hydrographic Line 65 n. mi. (120 km) offshore (NH 65), MT-2130; Paratypes: 1 male (USNM 150837), 15 mm c.l., from NH 265, MT 604; 2 males (USNM 150838), 8 and 6.5 mm c.l., NH 65, MT 2088; 1 male (USNM 150839), 14 mm c.l., NH 65, MT 2131; 1 male (USNM 150840), 13.5 mm c.l., NH 65, MT 2130, 4 females (USNM 150841), 14.5, 14, 10, 18 mm c.l., NH 65, MT 2130, 4 males (USNM 150842), 12.5, 13.0, 13.2, 17.5 mm c.l., NH 65, MT 2130; 1 male (USNM 150843), 9.0 mm c.l., NH 50, MT 570; 1 male (USNM 150844), 9.5 mm c.l., 40°28' lat, 133°46' long, MT 613;

3 females (USNM 150845), 13.3, 14.0, 15 mm c.l., NH 65, MT 2121 Net #5; 1 female (USNM 150846), 20.0 mm c.l., NH 65, MT 2133 Net #1; 2 females (USNM 150847), 7 and 10 mm c.l., NH 65, MT 2070 Net #5; 2 males, 1 female (BMNH 1975:10), 14.2, 16.4, 13.2 mm c.l., NH 65, MT 2175 Net #5; 1 female (BMNH 1975:10), 15.7 mm c.l., NH 65, MT 2178 Net #4; 1 female (BMNH 1975:10), 12.6 mm c.l., NH 65, MT 2302 #4; 1 male (BMNH 1975:10), 11.5 mm c.l., NH 65, MT 2301 #1. Other, non-paratype, material deposited at L.A. County Museum; F.R.B.C. Biological Station, Nanaimo, B.C.; and Dept. Oceanography, Oregon State University, Corvallis, Oregon.

DIAGNOSIS:

Benthescymae with podobranch on second maxilliped to third pereopod inclusive; first maxilliped with single rudimentary arthrobranch; only sixth abdominal somite with middorsal carina; telson distally truncate, usually with single pair of mobile terminal lateral spinules. Accessory lobe of petasma characterized by large upturned terminal hook. Plate of thelycum on sixth thoracic sternite triangular and elevated, projecting ventrally in strong ridge; plate on eighth thoracic sternite pentagonal with anteriormost angle concave and antero-lateral margins bearing spines.

DESCRIPTION:

Rostrum extending to level of eye tubercle, well elevated above mid-dorsal carina of carapace (Fig. 1). Margin between rostral tip (apex) and dorsal spine with usual setal fringe (though broken in type). Middorsal carina of carapace bearing minute tubercle posterior to dorsal spine; carina absent between well defined cervical and postcervical sulci and on posterior-most portion of the carapace. Mid-lateral longitudinal carina consisting of

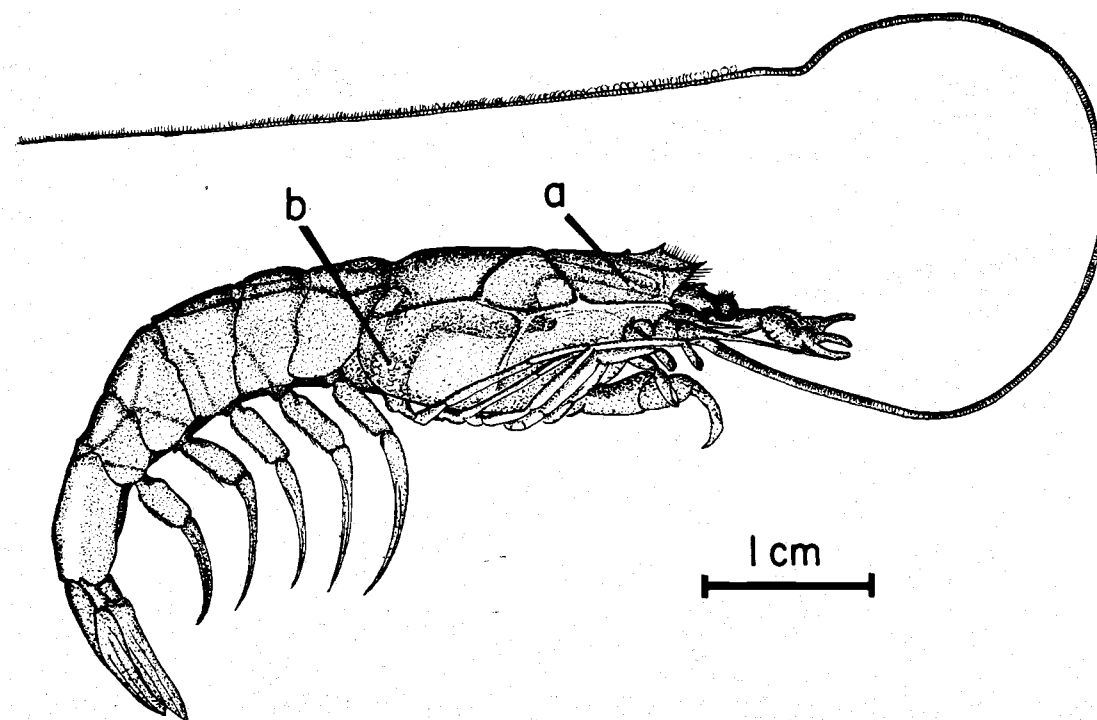


Figure 1. Mature female [redacted] n. sp. illustrating the (a) anterior and (b) posterolateral lobes of the ovary.

strong antennal carina continuous with hepatic and branchial carinae. Branchiostegal spine small and branchiostegal carina distinct; hepatic sulci continuous from branchiostegal spine towards lower margin of carapace; post-hepatic carina orientated dorsal-ventrally from longitudinal hepatic carina toward inferior margin of carapace. Antennal angle obtuse and infra-antennal angle acute (Fig. 2a).

Only sixth abdominal somite with middorsal carina; second through fifth abdominal somites with weak lateral ridges in approximately dorsal-ventral position extending from mid-lateral to ventral lateral edge of the pleuron. Fourth, fifth, and sixth abdominal somites with prominent, roughly transversal, lateral ridges which together form "half moon" area (Fig. 1). Fourth and fifth abdominal somites bearing small mid-lateral tooth on posterior margins.

Antennal flagellum (Fig. 1) similar to *Gennadas* (Foxton, 1969), having proximal and distal sections divided by short series of annuli forming kink in flagellum; proximal section rigid, bearing scattered short non-plumose setae; distal section bearing paired arched plumose setae with small plumose setae perpendicular to flagellum at irregular intervals between bases of some arched pairs. Second element of antennular peduncle, along dorsal midline, 0.7 ultimate element (Fig. 2b). Antennal scale (Fig. 2c) little less than three times as long as greatest width; distinct spine (outer margin of scale), slightly convex, terminal end free, not extending beyond narrow apex of blade.

Mandible (Fig. 2d) with two segmented palp; palp thickly covered with setae on medial and lateral margins, distal element not quite as long as widest portion of basal element. Endopod of first maxilla (Fig. 2e) distally narrow, with tip rounded; proximal gnathobasic lacinia (endite of coxa) subequal in width to distal lacinia (endite of basis), both terminating in strong spines among setae fringe. Anterior lobe of proximal lacinia (endite

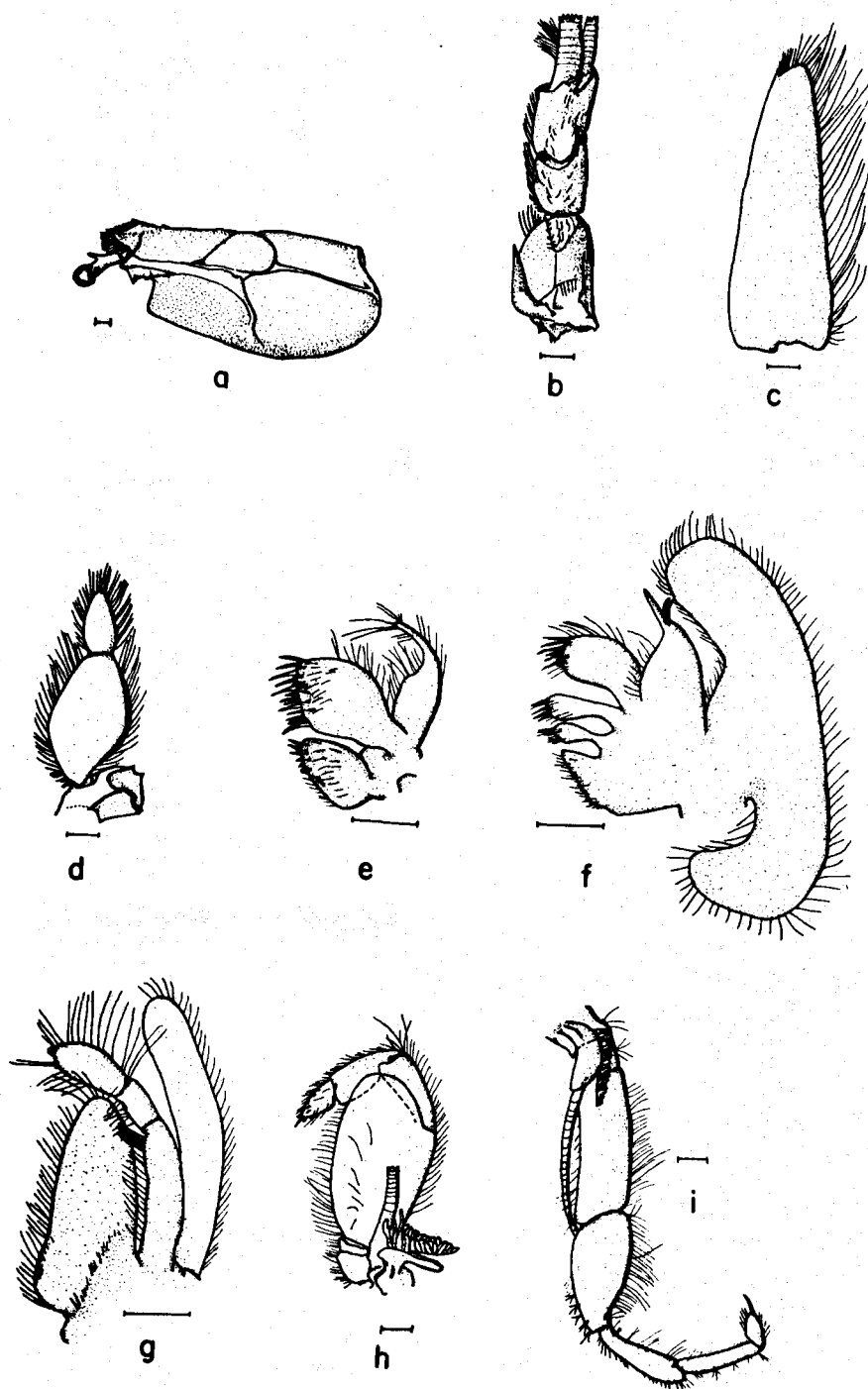


Figure 2. [REDACTED] n. sp. (Holotype male 18 mm c.l.) #a, carapace; b, antennular peduncle; c, antennal scale; d, mandible; e, first maxilla; f, second maxilla; g, first maxilliped; h, second maxilliped; i, third maxilliped. Scale equals 1 mm.

of coxa) of second maxilla (Fig. 2f) strongly constricted behind apex, not broader than posterior lobe of distal lacinia (endite of basis); anterior lobe of distal lacinia very broad; endopod distally long and narrow, with two (sometimes three) curved spines at base of apical portion.

Endopod of first maxilliped (Fig. 2g) reaching beyond endite of basis but falling short of exopod; endopod of four elements, third less than twice second; fourth extremely minute; first element bearing usual complement of three curved spines on distomesial margin. Exopod blade-like, without constricted, segmented distal portion. Merus of second maxilliped (Fig. 2h), including anterior prolongation, 1.9 times as long as wide; dactylus with single strong apical spine surrounded by medium and small spines back to proximal end of propodus; merus and carpus with numerous spines and setae; podobranch present. Third maxilliped (Fig. 2i) reaching to, or beyond, middle of ultimate joint of antennal peduncle; ischium nearly three times as long as greatest width; merus usually twice as long as greatest width; carpus slightly longer than propodus; dactylus with long slender terminal spine; podobranch present.

Merus of first pereopod (Fig. 3a) 1.4 times length of carpus and 1.7 ischium; fingers slightly setose. In second pereopod (Fig. 3b), carpus 1.2 times length of propodus; merus 1.2 carpus and 1.5 propodus; chela with heavy tufts of bristles. Merus and carpus of third pereopod (Fig. 3c) of equal length, each twice ischium; fingers of chela similar to those of second pereopod. Carpus and propodus of fourth pereopod nearly equal, each approximating two-thirds merus which is 2.4 times ischium. Propodus of fifth pereopod subequal to carpus which is subequal to merus; ischium slightly more than one third of merus.

Outer scale of appendix masculina (Fig. 3d) longer than inner; proximal half of lateral margin expanding slightly then tapering toward base. Inner

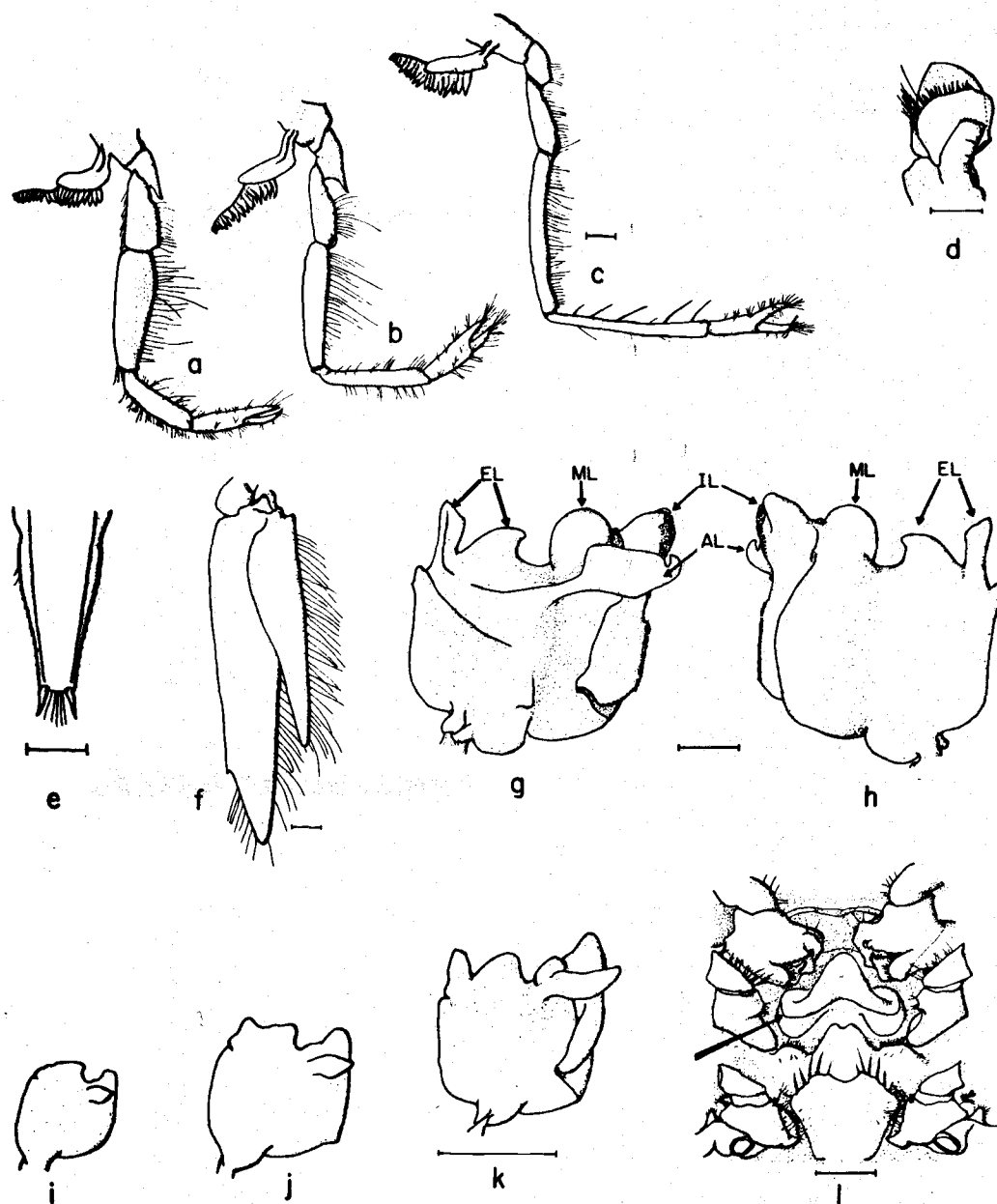


Figure 3. [redacted] n. sp. (Holotype) #a, first pereopod; b, second pereopod; c, third pereopod; d, appendix masculina; e, distal half of telson; f, uropod; g, anterior view of petasma (EL = external lobe, ML = median lobe, IL = internal lobe, AL = accessory lobe); h, posterior view of petasma; i, anterior view of petasma from young male (8.0 mm c.l.); j, anterior view of petasma from young male (9.0 mm c.l.); k, anterior view of petasma from young male (9.5 mm c.l.); l, thelycum of female (17 mm c.l.); arrow pointing to right sperm receptacle. Scale equals 1 mm.

scale broadly rounded distally; spines on distomesial margin (few to many) long and thin, spines on distal margin smaller, stronger, and of uniform length.

Telson with single pair of mobile terminal-lateral spines (Fig. 3e) fringed with setae on terminal and distal two-thirds of lateral margins (of the large number of specimens inspected, only two mature males had any indication of more than one pair of mobile spines [USNM 150839, 150840], each with two pair of mobile spines on terminal edge of telson). No mobile nonterminal-lateral spines present on telson. Lateral margins of lateral rami of uropods (Fig. 3f) bearing spine at 0.78 total length. Mesial rami about .73 lateral rami.

Each half of petasma (Fig. 3g, h), distally divided into three lobes (external, median, and internal [Balss, 1927] which are equivalent to Burkenroad's [1936] distoventral, distolateral and distomedian lobes). External lobe bipartite; lateral part elongate projection with minute terminal teeth-like protuberances distally; mesial part curving inward with apex directed toward median lobe. Median lobe broadly rounded; subdistally, accessory lobe on anterior face of petasma, characterized by large upturned terminal hook (Fig. 3g) with free margin attaching to base of median lobe, attachment area distinguishable to level of elongate projection of external lobe. Internal lobe undivided bearing rigid hooks continuous with row of cincinnuli, holding two halves of petasma together. The accessory lobe develops early in the juvenile stage (Fig. 3i, j, k) and together with characteristic spination of telson and presence of podobranchs behind second maxilliped, young of this species were discernable to a size of 6 mm c.l. (the smallest size captured).

Thelycum (Fig. 3 1) with plate on eighth thoracic sternite pentagonal, with anteriormost angle concave, antero-lateral margin bearing long spines (this plate exhibits greatest variation during growth, being more rectangular in young females, changing to the pentagonal shape at maturity but becoming almost bilobed in very large females). Plate of seventh thoracic sternite bearing three anterior directed projections; lateral pair, shortest, bearing short spines; center projection exhibits varying amount of concavity after maturity such that disto-lateral margins may appear as raised wings. Elevated plate on sixth thoracic sternite triangular and inverted "V" shaped, with apex pointing anteriorly; apex not reaching anterior limit of sternite. Sperm receptacles located toward lateral edges near bases of inverted "V".

Coloration at time of capture varying from deep red over entire body to medium red on cephalothorax and lighter on abdomen. Black pigment fleck on distolateral edge of ocular peduncle just below corneal region (Fig. 2a). Other small flecks of purple pigmentation often observed on carpus and propodus of third maxilliped and first and second pereopods, on carpus of third pereopod, and on ventral surface of abdominal somites just anterior to lateral edge of base of each pleopod.

REMARKS:

Burkenroad (1936) proposed the genus *Bentheogennema* for those species of *Gennadas* Bate which possess podobranchs on the second maxilliped to third pereopods inclusive. Other generic characters he included were: arthrobranch of first maxilliped large and richly plumose; exopod of first maxilliped without a constricted, segmented distal portion; dorsal carina on sixth abdominal somite only; telson with truncated apex and more than a single pair of mobile lateral spinules.

As is often the case, the addition of a new species changes the generic formula for that group. The new species is similar to *Gennadas* in the armature of the telson but more closely resembles *Bentheogennema* with podobranchs on the second maxilliped through third pereopod. We agree with Kemp (1909) and Burkenroad (1936) that the presence of podobranchs, a primitive characteristic, is a more important generic trait than the number of pairs of spines on the telson.

We found that the two species of *Bentheogennema*, *B. borealis* [Rathbun] and [REDACTED] n. sp., from the Oregon coast lack the large, richly plumose arthrobranch on the first maxilliped that Burkenroad (1936) included as a generic characteristic. Both have small rudimentary arthrobranches similar to *Gennadas*. We assume that Burkenroad (1936) did not have samples of *B. borealis* but included this arthrobranch structure as a generic characteristic from samples of *B. intermedium* (Bate) and *B. pasithea* (Man).

Although Tirmizi (1959) stated that the endopod of the first maxilliped is five-segmented in *Gennadas* and apparently only four-segmented in *Bentheogennema*, we have found that *Gennadas propinquus* Rathbun off the Oregon coast has a four-segmented endopod. Hence these characters are not reliable to distinguish these two genera.

[REDACTED] can be separated from *B. borealis*, *B. intermedium*, *B. pasithea*, and *B. stephenseni* by the armature of the telson, and the structures of the petasma and thelycum. The telson of [REDACTED] typically possesses only a single pair of terminal-lateral spines, whereas the other members of this genus possess two or more pairs of lateral spines. *B. borealis* and *B. stephenseni* have two pairs [Rathbun, 1902; Burkenroad, 1940]; *B. pasithea* has three pairs [Man, 1911]; and *B. intermedium*, as

described in Tirmizi (1959), has four pairs. The number of spines present on the telson should not be held as an invariable characteristic; there is undoubtedly a small percentage of variation as exemplified by the two males of [REDACTED] (USNM 150839, 150840) which possess 2 pairs of terminal spines. It is possible that one of the two specimens of *Gennadas calmani* (Kemp, 1909) (Synonymy: *B. borealis*), which Kemp illustrated with 2 pairs of terminal spines is also an example of such variation.

The petasma of this new species is unique and easily distinguishable from that of other members of the genus. The combined structures of the accessory lobe with its mode of attachment, its large size, and its terminal hook (present in mature individuals) and the shape of the bipartite external lobes make identification, even of the juvenile stages (Fig. 3g, k), possible.

The thelycum differs from that seen in other species by the pentagonal shape of the plate on the eighth thoracic sternite and the elevated triangular plate on the sixth sternite (Fig. 3 l).

We have named [REDACTED] after [REDACTED], whose work on Crustacea, especially the Penaeidae, is well known.

Geographical and Vertical Distribution

Shrimps were examined from midwater trawl collections taken over much of the North Pacific (Fig. 4). [REDACTED] was found only in collections from the northeastern sectors (52-34°N and east of 142°W) (Wasmer, 1972). Percy and Forss (1966, 1969) observed [REDACTED] off the coast of Oregon, as close as 28 km to the northern end of the coast and occurring >92 km off the central and south coast. Wasmer (1972) found the greatest concentration in the Transitional Water Mass (Fig. 5), with a few individuals occurring in the Pacific Subarctic and eastern North Pacific Central Water

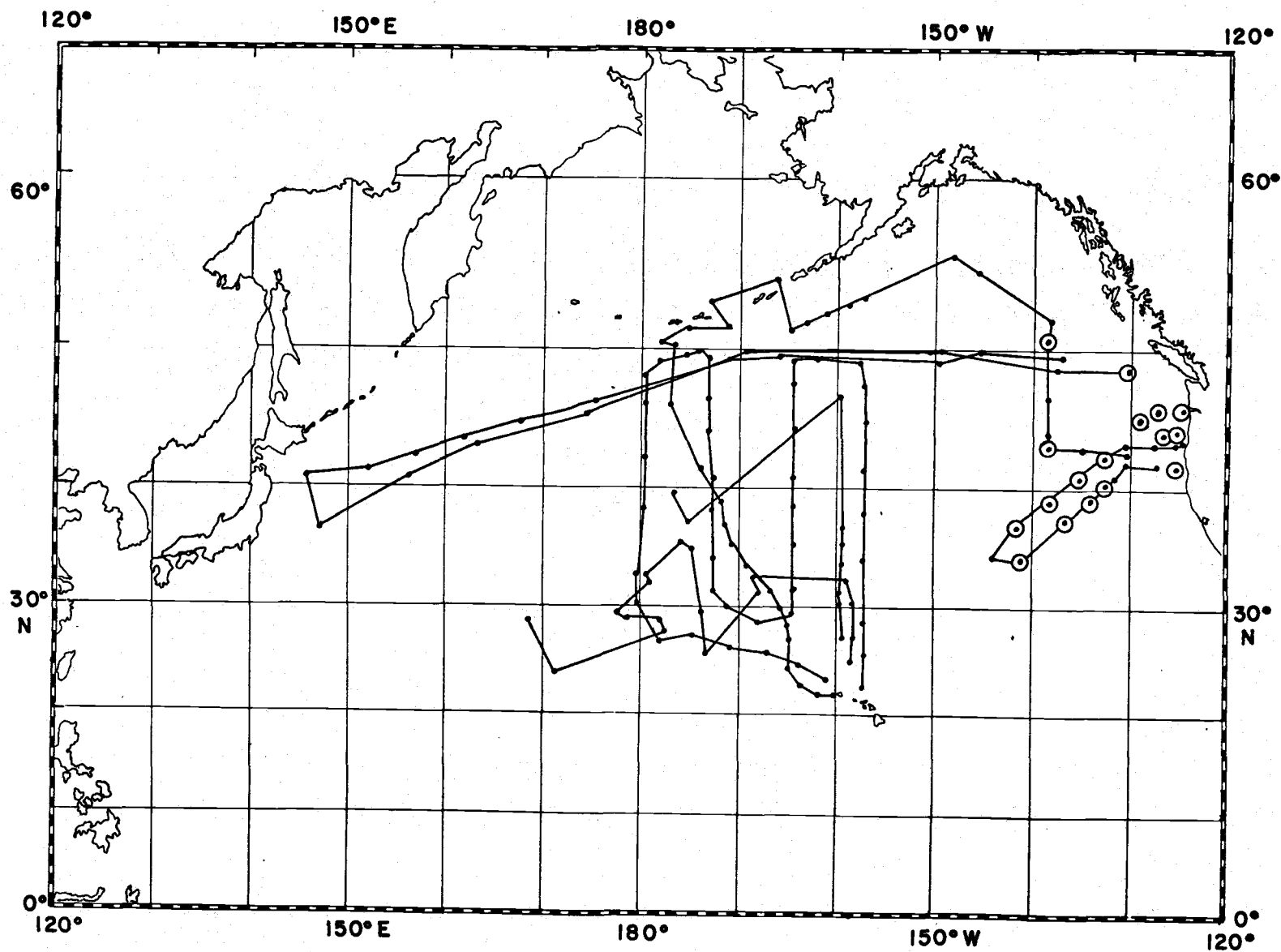


Figure 4. Cruise tracks of the North Pacific from which shrimp were enumerated, indicating midwater trawl stations (solid dots). n. sp. was collected at stations where dot is encircled.

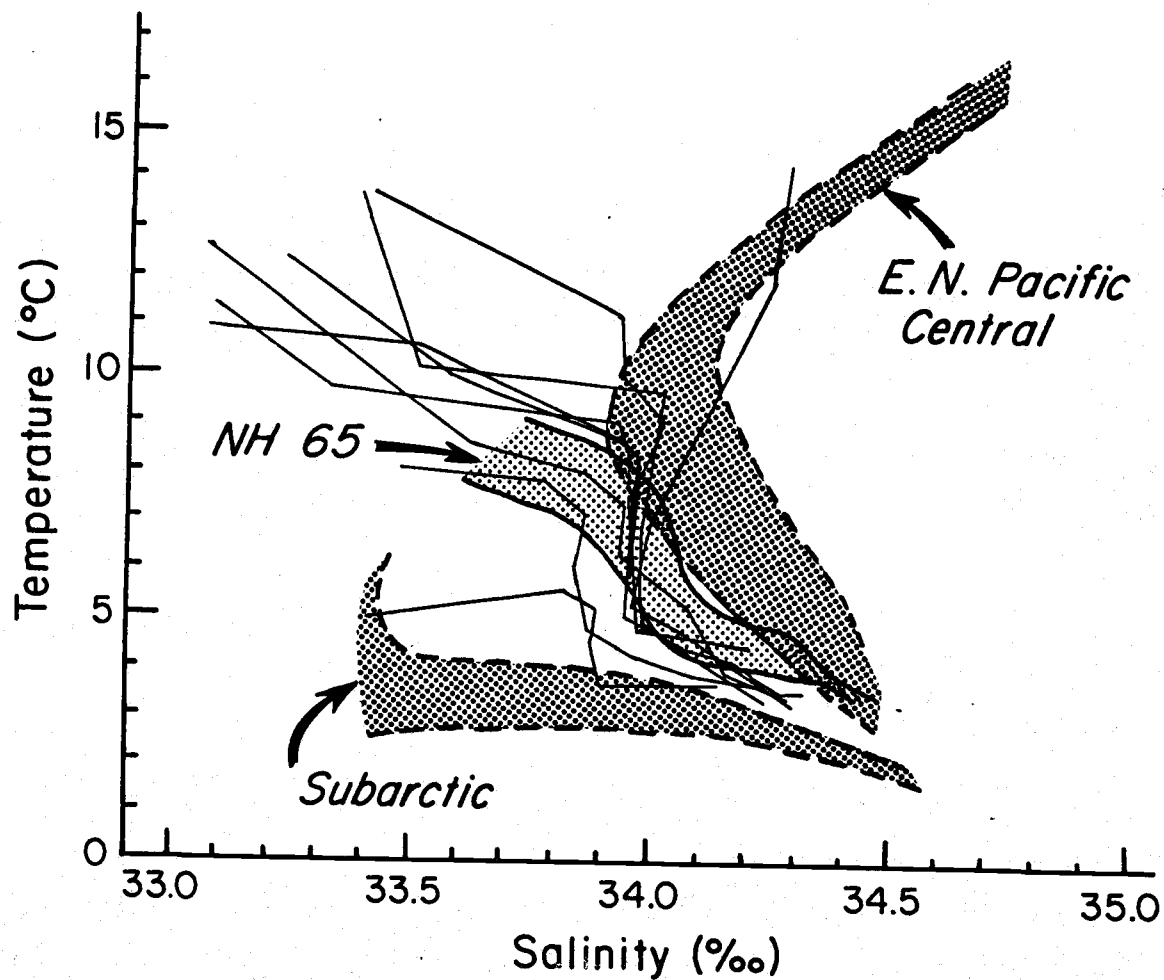


Figure 5. Zoogeographical temperature-salinity capture diagram for [redacted] n. sp. Relevant water masses in darkest bands; medium band is T-S envelope for the station 65 miles off Newport, Oregon (NH 65); single lines indicate T-S diagram for sampling stations other than NH 65 where this shrimp was captured.

Masses. It is assumed to be a transitional species, though as is the case for many shrimp, it is not totally confined to a single physico-chemically defined water mass (Wasmer, 1972). Since [REDACTED] is a deep mesopelagic species and most of the available geographical collections were from shallow depths, the known geographic range will undoubtedly be increased by more systematic deep trawls in the eastern Pacific.

This species was captured in opening-closing nets from the surface to 1000 m depth. It apparently demonstrates a diel vertical migration. The depth distribution is, with few exceptions, below 500 m during the day and below 100 m at night (Table 1). Neither day nor night distributions are confined to a narrow depth stratum but are diffused in concentration over a broad range. The nocturnal migration into the upper waters appears to entail only a small segment of the population with the main concentration remaining at depth. Those migrating above 500 m included both sexes, though the immature shrimp (<11 mm males and <12 mm females) were not observed to migrate as high in the water column as adults. Vinogradov (1968) earlier stated that the intensity of diurnal migration of zooplankters increases with age, and migration may be absent in early stages of development, and our observations concur with this.

More shrimp were caught in nighttime than daytime tows. This may be explained by enhanced visual avoidance of the net during the day (Pearcy and Laurs, 1966). However, the lack of obvious differences in size structure between day and night-caught shrimp (Fig. 6) argues against increased daytime avoidance, as larger more mobile animals should be preferentially sampled at night. Another explanation for the increased nighttime catch, as suggested for *Acanthephyra purpurea* Milne-Edwards and *Gennadas valens*

Table 1. Seasonal diel vertical distribution to a depth of 1000 m of mature males (>11 mm c.l.), mature females (>12 mm c.l.), and sexually immature male and female [redacted] at a sampling location 65 miles off Newport, Oregon ($44^{\circ}35'$ N Lat. - $125^{\circ}30'$ W Long.).

Time of Year	Size Group	Depth (m)											
		0-50	50-100	100-150	150-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-1000
<u>DAY</u>													
June 1972	mature males									3	4	2	2
	" females									3	2	3	2
	immature								1	5	6	2	2
Sept. 1972	mature males								1	2	6	4	1
	" females								2		8	2	4
	immature										2	1	1
Nov. 1972	mature males			1				1	2	2	4	5	
	" females				1				2	3	3		1
	immature									1	1		1
March 1973	mature males										3**		
	" females										1**		
	immature						1		1		1**		
Total Number				1	1		1	1	9	19	41	19	14
Total Volume in 1000 m ³		103.5	149.9	103.2	94.7	474.7	497.9	310.9	259.6	132.6	182.3	183.3	162.4
Number/1000 m ³ (DAY)		0	0	.0097	.0106	0	.0020	.0032	.0347	.1433	.2249	.1037	.0862
<u>NIGHT</u>													
June 1972	mature males	1				1	3				1		
	" females						1	3		1			
	immature						2	2					
Sept. 1972	mature males	2*			1	1	1	4	5	1*	2	1	1
	" females			1	2		5	2	2		3	1	4
	immature						3	1	1	1	5		
Nov. 1972	mature males					1	5	2		7	3		5
	" females				1*	4	7	2	1	5	1	1	4
	immature					1		1		1	3		1
March 1973	mature males				3	3	1	1	1	1	1		
	" females			1	1	4	2	1	1	2			
	immature					2			1	1			
Total Number		3		2	8	17	30	19	12	20	19	3	15
Total Volume in 1000 m ³		111.8	530.6	184.8	292.8	251.0	435.9	288.6	261.6	147.2	170.7	132.3	129.3
Number/1000 m ³ (NIGHT)		.0268	0	.0108	.0273	.0677	.0688	.0658	.0459	.1359	.1113	.0227	.1160

Twilight * 1-hr. before sunrise ** 1-hr. after sunset

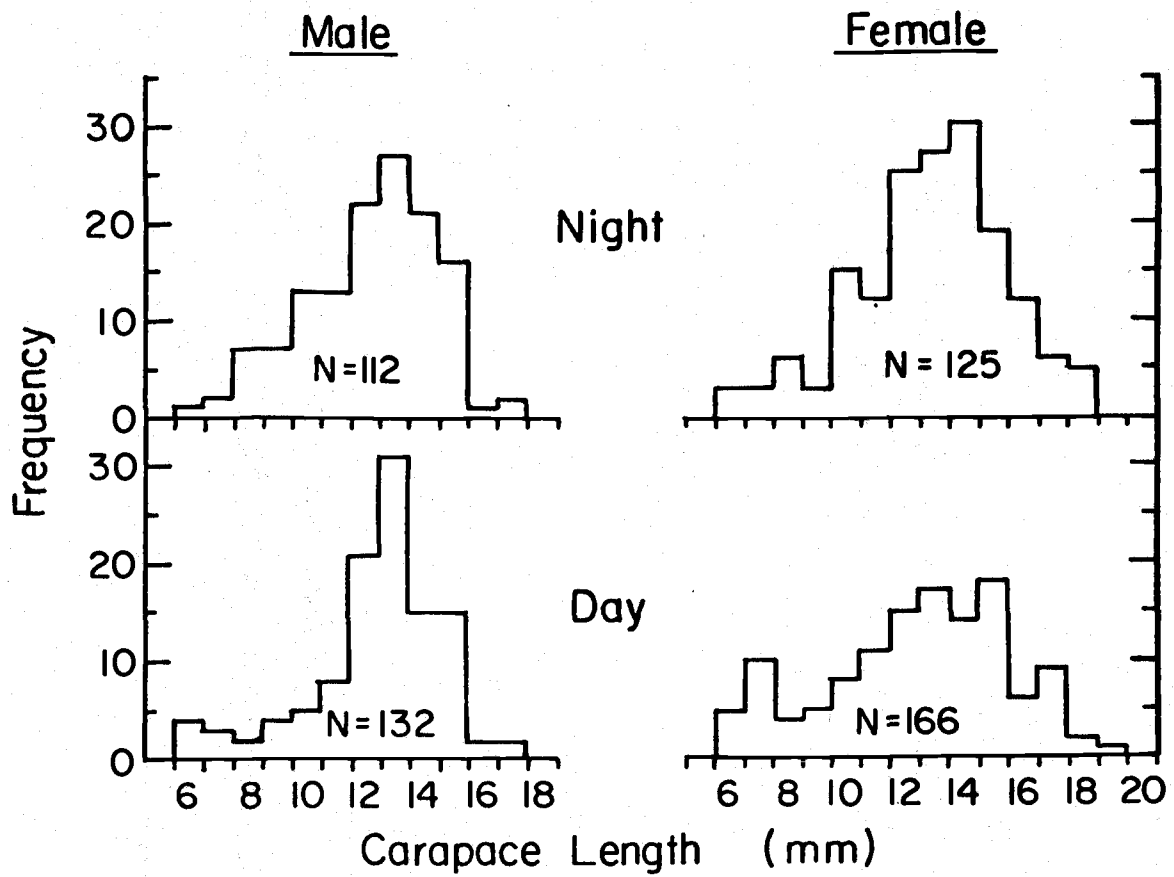


Figure 6. Day and night length-frequency distributions of male and female [REDACTED] n. sp.

(Smith) by Foxton (1970a and b), is migration up from below our maximum sampling depth of 1000 m. Such a migration is indicated by the high concentrations between 600-1000 m both day and night with no progressive drop in concentration with increased depth to 1000 m (Table 1).

The slight upward movement of this species may be related to its morphology. Vinogradov (1968) considers reduced musculature and a thin integument, which we observed in [REDACTED] to be a means of achieving buoyancy. Because of weak swimming musculature, they may swim too slowly to keep pace with the upward movement of the stimulating isolume, resulting in broad day and night distributions (Donaldson, 1973).

Reproduction

Since penaeid shrimp do not brood their eggs, a description of the breeding cycle must rely on anatomical changes, especially in the development of the ovary and ova. The female reproductive system consists of a bilaterally symmetrical ovary and paired oviducts internally, and externally of a thelycum. Each half of the mature ovary has an anterior lobe angling from the cervical sulcus and almost reaching the base of the eye, and then folding back along itself (Fig. 1a). The anterolateral lobe lies over the hepatopancreas extending approximately one-half the way down the body wall. The posterolateral lobe, of such a mature ovary, will have visible distinct ova, measuring up to 240-288 μ crosssectional diameter, and extend ventrally making a pouchlike structure at the base of each of the fifth pereopods (Fig. 1b). The posterior lobes extend beneath the dorsal abdominal muscle bands, becoming swollen in the first abdominal segment and then extending on toward the end of the third segment. Females were considered to have

reached maturity after attaining a size of 12 mm and males at a size of 11 mm c.l.

The reproductive cycle, as judged from the sexual condition of the testis and ovary, appears to consist of a four to six month spawning season and a six to eight month resting phase. Based on samples collected in 1972 and 1973 the carapace of females in June is fairly rigid, though the ovaries are not ripe. Some males, from external observation, appear to be ready to release sperm, though most display only partial swelling of the terminal ampoule and vas deferens or lack swelling at all. By fall females exhibit developing ovaries, (two females were in spawning condition) and the carapace is correspondingly rigid. Most males have full, ripe looking testes and dilated terminal ampoules. By the end of November, spawning is in evidence. Most all females are mature with readily distinct ova; some mature females have evidently spawned as the thoracic cavity appears empty, the carapace is correspondingly non-rigid, due to the spent ovary which had crowded much of the other organs; others have developing ovaries distended by small diameter ova. All males at this time have ripe testes and dilated terminal ampoules. By February, 50% of all females exhibit signs of spawning activity, the rest have probably spawned for their thoracic cavities appear empty and the carapace non-rigid due to the flaccid ovary. Most males still exhibit ripe testes and enlarged terminal ampoules.

The sex ratio for adult males to females ($N = 440$), when all tows are included, was: 1:1, 1:1.08, 1:1.02, and 1.03:1 for the respective cruises. This approximate 1:1 sex ratio, if it applies to all ages, indicates that there is no selective mortality by sex for this species (Geise, 1959).

Growth

If spawning occurs from November through February and young (6-7 mm c.l.) enter the population April through June (Fig. 7), the intervening egg and larval stages must take 3-5 months. Based on size frequency diagnosis, about 12 additional months are required to reach maturity (11-12 mm c.l.) and another 5-6 months are required before spawning commences. Thus the generation time is estimated to be about 2 years. The largest shrimps captured were a 17 mm c.l. male, and 20 mm c.l. female.

Since the mesh size of the net liner was small enough to retain the young (6-7 mm c.l.) and we assume equal chance of capture of young and adults, then adults apparently live more than a year or two after first spawning since the number of adults captured is greater than the number of immature. In fact the 12-15 mm mode must consist of greater than one age class since by itself it exceeds the juveniles in number. This overlap of age classes at >12 mm c.l. indicates that growth slows after maturity is reached.

Acknowledgements

We thank Mr. R.J. LeBrasseur (Fisheries Research Board of Canada, Nanaimo, B.C. [POG]) and Mr. E.C. Jones (Hawaii Area Fishery Research Center in Honolulu [POFI]) for providing us with shrimp specimens collected during their oceanographic exploration. We thank Robert Carney for his aid and instruction in the illustrations, and Dr. W.G. Pearcy for his critical review and financial support.

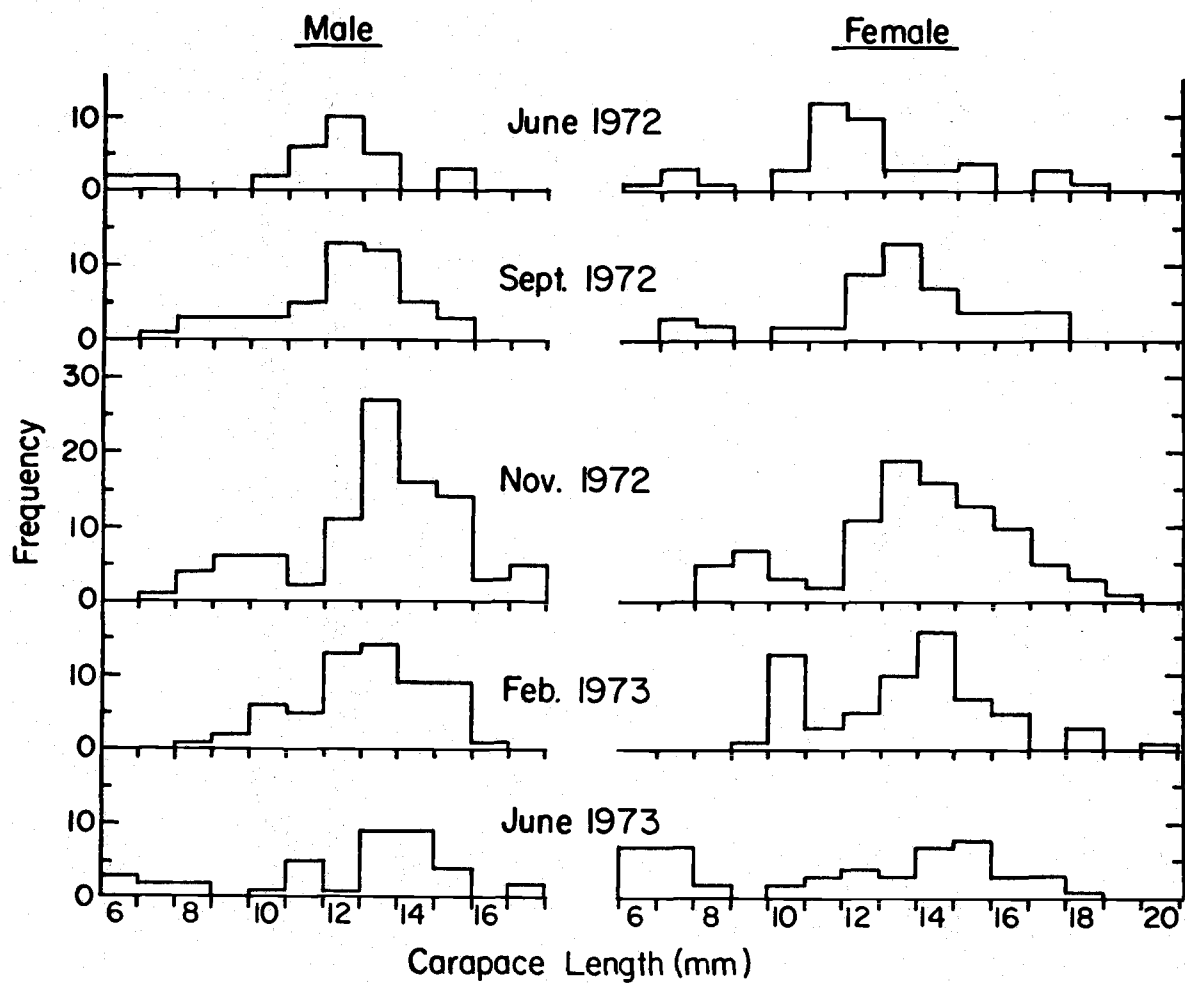


Figure 7. Length frequency histograms of [redacted] n. sp., from the five cruises (1972-73) off the Oregon coast.

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RLO-2227-T12-53

ESTUDIOS BASICOS DE CONTAMINACION MARINA

Radioactividad en organismos marinos de la costa
noroccidental de Baja California¹

Katsuo Nishikawa K.²

and

Ingvar L. Larsen³

ABSTRACT

As a contribution to the establishment of baseline values for marine pollution along the coast of México, studies have been made regarding the radionuclide content in mussels (*Mytilus californianus*) and barnacles (*Pollicipes polymerus*) of the Northwestern coast of Baja California.

These organisms have been selected as biological monitors because they are widely distributed, abundant, sessile, easily collected, and are known concentrators of radionuclides.

Results of recently analyzed samples are compared with previously reported values. Levels of radioactivity have decreased considerably over the past decade. Comparisons with other geographical areas are presented.

RESUMEN

Como contribución al establecimiento de valores de la contaminación marina en la costa de México, se han realizado estudios sobre el contenido de radionúclidos en mejillones (*Mytilus californianus*) y percebes (*Pollicipes polymerus*) de la costa noroccidental de Baja California.

Estos organismos han sido seleccionados como indicadores biológicos por tener una amplia distribución, ser abundantes, sesiles, facilmente colectables y además ser concentradores conocidos de radionúclidos.

Los resultados de las muestras recientemente analizadas son comparados con valores previamente publicados; durante la última década los niveles de radioactividad han decrecido considerablemente. Se presentan comparaciones con otras áreas geográficas.

¹ To be published in Memorias del V Congreso nacional de Oceanografía, Guaymas, Sonora, Mexico, October 22-25, 1974.

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INTRODUCCION

La introducción activa a nuestro medio ambiente de energía y sustancias ajenas al mismo, ha tenido como consecuencia el paulatino deterioro de nuestra biosfera. La magnitud y el alcance de la contaminación, son por desgracia poco conocidos, ya que sus efectos combinados y asociados a los cambios cíclicos y no cíclicos a nivel de ecósfera, son en su mayoría detectables unicamente a largo plazo. Es por esto que las observaciones realizadas ahora sobre nuestro medio, serán de utilidad en los futuros estudios ambientales.

El presente artículo es una contribución al establecimiento de valores básicos de la contaminación en las costas mexicanas. El contaminante en cuestión, es la radioactividad asociada a organismos marinos de la franja litoral, en la costa noroccidental de México.

Las fuentes de los radioisótopos artificialmente creados, están generalmente coligados al uso de los diferentes tipos de reactores y a las detonaciones de artefactos nucleares. Su presencia en organismos de la costa refleja algunas características de la lluvia radioactiva regional, la cual a su vez deriva de las explosiones en la atmósfera, de armas atómicas en los campos de prueba existentes en diferentes regiones del planeta.

En este informe, se consideran dos organismos sedentarios: un molusco, el mejillon (*Mytilus californianus*) y un crustaceo, el percebe (*Pollicipes polymerus*) como indicadores biológicos de las variaciones en los niveles de radioactividad ambiental. La selección de dichos organismos se debe a que estos poseen ciertas características deseables para este tipo de estudios, tales como: tener amplia distribución, ser organismos sedentarios facilmente colectables y finalmente ser concentradores conocidos de radionúclidos.

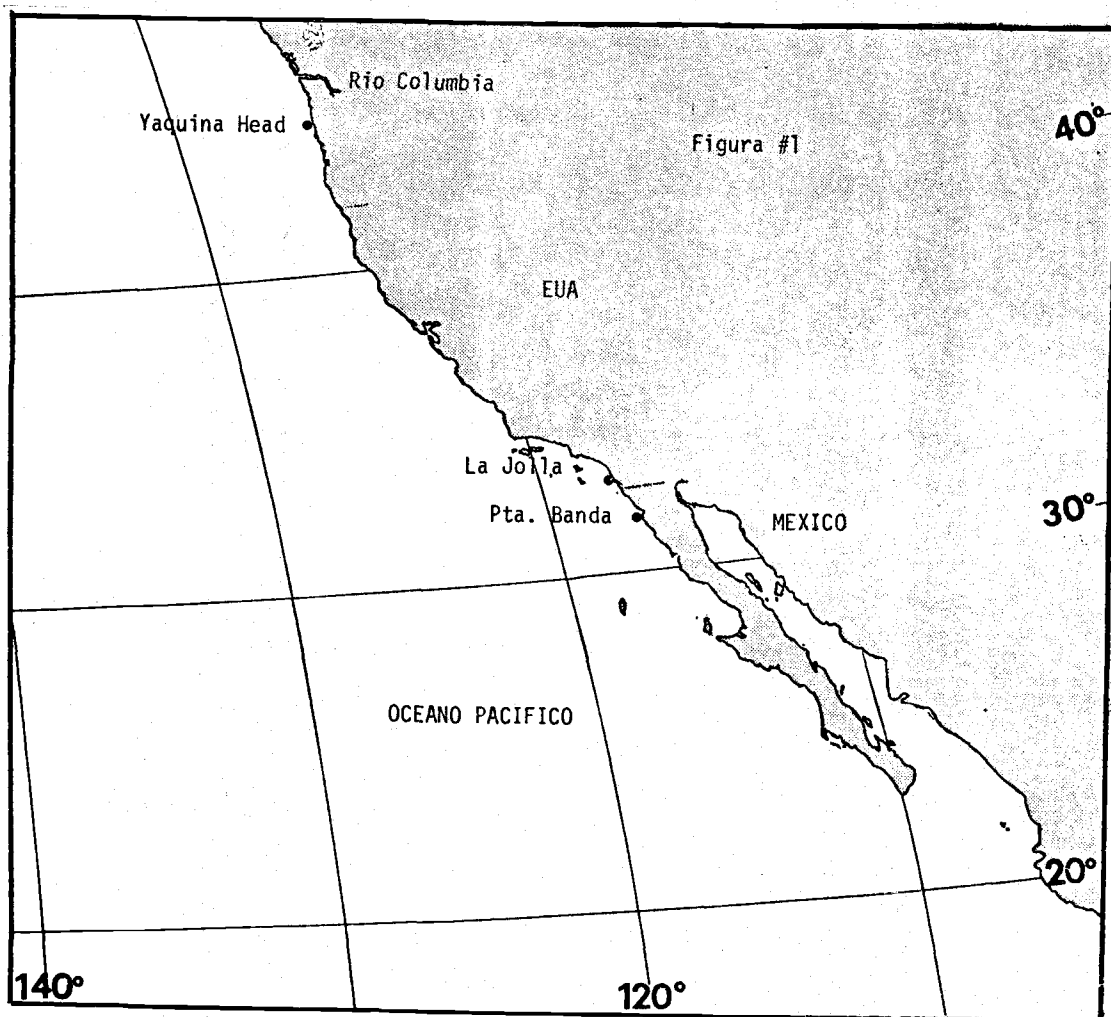
La presencia de radionúclidos fué investigada en cuatro muestras integradas de tejido blando. Cada una de ellas compuesta de varios organismos de la misma especie y características, como se muestra en el Cuadro No. 1.

Los valores obtenidos en Punta Banda, Baja California, se comparan con los de otras regiones en los Estados Unidos.

II - MATERIALES Y METODOS

Las muestras de mejillones y percebes, fueron colectadas el 13 de Junio de 1974, en la zona intermareal de Punta Banda, Baja California (Fig. 1). Se congelaron en hielo seco para su transporte al laboratorio. Previo a la preparación de las muestras para su análisis, estas fueron seleccionadas ya sea por tamanos (mejillones) ó por órganos (percebes) como se muestra en el Cuadro No. 1.

Una vez realizada la selección, los mejillones fueron abiertos y se separó las partes blandas con espátula de plástico. Los percebes se disectaron y se obtuvieron sus diferentes partes en formas separadas, de



CUADRO No. 1

CARACTERISTICAS DE LAS MUESTRAS

Muestra No.	Organismo	No. de Ejemplares	Talla Promedio	Talla Rango	Peso Promedio (g)	Tamaño de la muestra (g)	Materia seca (%)	Ceniza (%)
35	Mejillon ¹	16	11.96 cm	13.75- 9.50	35.6275	570.04	16.688	2.244
36	Mejillon ²	19	7.64 cm	8.80- 6.00	13.8663	263.46	18.204	2.359
37	Percebe-M ³	124	25.83 mm	32.00-20.00	2.6238	325.35	21.408	2.294
38	Percebe-V ⁴				1.9061	236.36	19.733	2.483

Nota: ¹Mytilus californianus, grupo de ejemplares grandes.

²Mytilus californianus, grupo de ejemplares chicos.

³Pollicipes polymerus, muestra de tejido musculoso peduncular.

⁴Pollicipes polymerus, muestra de la masa visceral localizada dentro de las placas calcareas.

las cuales unicamente se analizaron el músculo peduncular y la masa visceral. Con excepción de la concha del mejillón, el resto fué secado a 110° C durante 72 hs. Se usaron vasos de precipitados descontaminados. Posteriormente las muestras fueron calcinadas en al mufla a 450° C durante 72 hs.

Una vez reducidas a cenizas, las muestras fueron transferidas a tubos de conteo, a los cuales se obtuvo el peso y volúmen de la muestra. El análisis fué llevado a cabo por medio del espectrómetro de rayos gama con detector de poso de NaI(Tl) de 12.7 cm x 12.7 cm. El tiempo de conteo fué de 800 minutos.

Después de terminar el conteo de cada muestra, la contribución de la radioactividad ambiental natural y del equipo durante el conteo, fué electrónicamente substraído. Los resultados del análisis se obtuvieron simultáneamente en un graficador X-Y, en un impresor digital y en cinta de papel perforado.

Los datos obtenidos se transfirieron a una computador CDC-3300 de la Universidad Estatal de Oregon, EUA. La reducción de los datos se llevó a cabo con un programa de mínimos cuadrados no lineal.

Con el propósito de comparar el espectro de energía de la muestra, el programa de la computadora fué alimentado con un estandard de valores conocidos de radioactividad. Finalmente los valores de radioactividad fueron corregidos a la fecha de muestreo y expresados en pCi/g de ceniza.

La conversión de los valores a peso seco y húmedo se llevó a cabo con los siguientes factores:

Muestra No.	factor cenizas a seco	factor seco a húmedo
35	7.436	5.992
36	7.716	5.493
37	9.332	4.671
38	7.948	5.608

III - RESULTADOS

El examen de las muestras, dió como resultados espectros de energía en los cuales el único fotopico bien definido, fué el correspondiente al canal potasio-40. Los resultados se muestran en los Cuadros 2 y 3.

CUADRO No. 2

Nivel de K-40 encontradas en las muestras

Muestra No.	pCi K-40/kg Materia Humeda
35	1643
36	2074
37	1819
38	1786

CUADRO No. 3

Punta Banda, B.C., México, 31° N

<u>Referencia</u>	<u>Fecha de Muestreo</u>	<u>Organismo</u>	<u>Radionúclidos (pCi/kg-Tejido Humedo)*</u>				
			<u>Zn-65</u>	<u>Mn-54</u>	<u>K-40</u>	<u>Cs-137</u>	<u>Co-60</u>
Nagaya y Folsom, 1964	5/63	Mejillón	111±6.0	28.5±1.6	-	0±1.4	-
Young y Folsom, 1972	2/64	Mejillón	95±13.0	46±6.6	-	-	15±1.2
Hodge V., 1973	10/70	Mejillón	9.0±1.7	-	1280±30	52±0.6	12.7±0.4
Young y Folsom, 1972	11/71	Mejillón	6.9	3.1	-	-	3.3
Young y Folsom, 1972	11/71	Percebe	6.9	5.4	-	-	5.0
Nishikawa y Larsen, 1974	6/74	Mejillón	< 5	< 3	1643	< 3	< 5
Nishikawa y Larsen, 1974	6/74	Percebe	< 5	< 3	1786	< 3	< 5

* ± indica una desviación estandar

Este isótopo se encuentra ampliamente distribuido en forma natural en la Ecósfera, tiene una vida media de 1.3×10^9 años. Decae por emisión beta a calcio-40, y por captura K a argon-40. Este último por emisión gama, forma el Ar-40 estable (Eisenbud, 1963).

Ningún otro radioelemento se logro detectar, ya sea por su ausencia, ó porque su concentración fué menor ó igual al límite de detección del instrumento, con respecto a las condiciones de la muestra usada.

IV - DISCUSION

A partir de 1963, varios autores han publicado artículos sobre el contenido de radionúclidos en mejillones (*M. californianus*) de Punta Banda, Baja California. El Cuadro No. 3 resume dichos informes. Con respecto al percebe (*P. polymerus*) únicamente existe una publicación previa a la presente por Young y Folsom (1972), ambos valores se encuentran citados en el Cuadro No. 3.

Los Cuadros No. 4 y 5, corresponden a valores obtenidos en la Jolla, California, EUA, y Yaquina Head, Oregon, EUA. Ambos se citan con fines comparativos.

En la discusión se consideran 5 radioisótopos: zinc-65, manganeso-54, potasio-40, cesio-137 y cobalto-60. Esto es debido a que ellos son los más importantes ya que poseén una vida media larga, y/ó se encuentran en la lluvia radioactiva atmosférica ó bien son productos de activación.

Como puede apreciarse en los Cuadros 3, 4 y 5, la máxima actividad fué registrada a principios de la década del 60. Con excepción del radionúclido natural K-40, los demás isótopos muestran una marcada disminución hasta obtenerse, como en el caso de Punta Banda, registros en los que no se han detectado.

Para Punta Banda y la Jolla, estos valores altos son posiblemente el reflejo de la lluvia radioactiva ocasionada por las pruebas de armas nucleares previo a su limitación. Cabe señalar que en esa época se llegó al maximo de detonaciones por año de dichos artefactos, declinando abruptamente su uso, sobre todo las detonaciones atmosféricas.

Sin embargo, en los últimos años, países como la República Popular de China y Francia, que no firmaron el acuerdo de la limitación de armas atómicas, han continuado sus experimentos atmosféricos

A pesar de lo anteriormente señalado, según los últimos análisis, no ha existido incremento alguno en el contenido de radionúclidos en los organismos que se han analizado de esta zona.

Los valores altos de Zn-65 que se muestran en el Cuadro No. 5, correspondiente a Yaquina Head, Oregon, EUA, fueron ocasionados por los reactores de la planta de Plutonio en Hanford, Washington. Dicha planta se encuentra

CUADRO No. 4

La Jolla, California, EUA, 33° N

<u>Referencia</u>	<u>Fecha de Muestreo</u>	<u>Organismo</u>	<u>Radionuclidos (pCi/kg-Tejido Humedo)*</u>			
			<u>Zn-65</u>	<u>Mn-54</u>	<u>K-40</u>	<u>Cs-137</u>
Young y Folsom, 1963	8/63	Mejillón	50	50	-	-
Young y Folsom, 1963	8/63	Percebe	100	100	-	-
Alexander y Rowland, 1966	8/64	Mejillón	8.08	-	-	-
Alexander y Rowland, 1966	8/64	Percebe	27.8	73.4	-	-
Hodge V., 1973	1/73	Mejillón	2.0	-	1490±30	3.7±0.4
Hodge V., 1974	6/74	Mejillón	1.5	-	-	-

* ± indica una desviacion estandar

CUADRO No. 5

Yaquina Head, Oregon, EUA, 40° N

<u>Referencia</u>	<u>Fecha de Muestreo</u>	<u>Organismo</u>	<u>pCi/kg-Tejido Humedo</u>	
			<u>Zn-65</u>	<u>K-40</u>
Seymour y Lewis, 1964	7/61	Mejillón	9.4×10^3	2.5×10^3
Seymour y Lewis, 1964	6/62	Mejillón	1.1×10^4	2.6×10^3
Seymour y Lewis, 1964	10/63	Mejillón	6.9×10^3	1.9×10^3
Larsen, 1971	3/64	Mejillón	2.6×10^3	-
Larsen, 1971	10/65	Mejillón	8.3×10^3	-
Mellinger, 1966	6/66	Mejillón	3.7×10^3	-
Larsen, 1971	7/67	Mejillón	2.4×10^3	-
Toombs, 1969	8/69	Mejillón	2.2×10^3	-
Toombs, 1972	7/70	Mejillón	1.0×10^3	-
Larsen, 1974	6/71	Mejillón	3.9×10^2	1.4×10^3
Larsen, 1974	6/72	Mejillón	1.2×10^2	1.8×10^3
Larsen, 1974	6/73	Mejillón	3.1×10^1	1.4×10^3
Larsen, 1974	6/74	Mejillón	1.9×10^1	1.3×10^3

sobre el río Columbia que desemboca en el Océano Pacífico (Fig. No. 1). Estos reactores estuvieron trabajando desde mediados de la década del cuarenta hasta Enero de 1971. Su contribución a la radioactividad de los organismos de Yaquina Head a 173 km al sur de la desembocadura; como puede apreciarse, ha sido considerable. Esta localidad es un ejemplo típico de la evolución de una zona que estuvo expuesta a la contaminación radioactiva.

El contenido de Zn-65 en mejillones de Punta Banda a principios de la década del 60, fué más alta que las encontradas en la Jolla, California. Sin embargo, en el caso del Mn-54, los valores altos correspondieron a la Jolla.

El Cs-137 en Punta Banda, B.C., subió de ± 1.4 en 1963 a 52 pCi/kg-Tejido Húmedo (TH) en 1970, sin embargo en 1974 no se logró detectarlo. En el caso del Co-60 este disminuyó de 15 pCi/kg-TH en 1964 a valores no detectables diez años después.

En los Cuadros No. 3 y 4 puede apreciarse que los percebes por lo general contienen más radionúclidos que los mejillones por kg de tejido húmedo.

V - CONCLUSIONES

El análisis de espectrometría de rayos gama de radionúclidos en las muestras de mejillón, *M. californianus* y percebe, *P. polymerus*, colectados en Punta Banda, Baja California, el 13 de Junio de 1974, revelaron únicamente la presencia del radionúclido natural K-40. Los valores obtenidos en pCi/kg-TH fueron los siguientes:

- 1.- Mejillón (7.64 cm de longitud total) : 2074
- 2.- Mejillón (11.96 cm de longitud total): 1643
- 3.- Tejido muscular peduncular de percebes: 1819
- 4.- Masa visceral de los percebes : 1786

AGRADECIMIENTOS

Este trabajo fué subvencionado por la Comisión de Energía Atómica de los EUA. USAEC Contract AT(45-1)-2227, Task Agreement 12 (RLO-2227-T12-53).

El autor agradece al Consejo Nacional de Ciencia y Tecnología de México, por la oportunidad que le ha brindado a través de la beca para estudios de postgrado que disfruta; gracias a lo cual se ha logrado desarrollar este trabajo.

Agradecemos al Sr. Marcos Geffroy por su valiosa ayuda en la colección de los ejemplares y la preparación de las muestras.

Nuestra gratitud al Dr. Norman Cutshall por la revisión y discusión del presente artículo.

El manuscrito fué realizado por la Ocean. Amelia Ch. de Nishikawa a quién agradecemos sus observaciones y diligente trabajo.

Finalmente hacemos patente nuestra gratitud a la Sra. Karla McMechan por su valiosa critica de esté artículo.

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RLO-2227-T12-55

A SYSTEMATIC REVIEW OF THE DEEP WATER LIPARIDAE FROM
THE COAST OF OREGON AND ADJACENT WATERS

By David Stein

Submitted to *Occ. Pap. Calif. Acad. Sci.*

PRECIS

Since 1961, over 470 liparids have been collected in 22' Gulf semi-balloon trawls and 3 m beam trawls between 200 and 4200 meters depth off Oregon and Washington. Until the present, few have been identifiable.

Examination of this material, and comparison with type and other reference specimens of known species, has resulted in the identification of 23 species in nine genera. There are nine new species*: [REDACTED]

[REDACTED] and [REDACTED]
[REDACTED] two new genera: [REDACTED] and [REDACTED] four second records: [REDACTED] and [REDACTED]

and three new Oregon records: [REDACTED] and [REDACTED]
[REDACTED] The literature indicates there is reason to believe another eight species occur off Oregon, although they are not included in the collection, totaling 31 species found below 200 meters in the study area.

The high diversity of this family is unlike that of any other deepwater family from the same area. A definite depth-dependent stratification does exist among species, especially between slope and abyssal plain species. At least two, and possibly four or more species are pelagic. A preliminary examination of stomach contents indicates that diversity may be correlated with highly selective feeding habits.

* To prevent nomenclature problems, new names, and new name combinations have been deleted. New records have also been deleted.

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- Stander, J.M. 1970. Diversity and similarity of benthic fauna off Oregon. M.S. Thesis, Oceanography, Oregon State University. 72 numbered leaves.
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