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PROGRESS REPORT

1 March 1973 through 31 December 1973

The Development of Methods for Studying Physical and Biological Processes in the Nearshore Zone on the Pacific Coast of the United States

Robert L. Holton
Principal Investigator

William P. Elliott
Co-Principal Investigator

Submitted to

Eugene Water and Electrical Board
Portland General Electric
Pacific Power and Light

Reference 74-3 February 1974

OREGON STATE UNIVERSITY

THE DEVELOPMENT OF METHODS FOR STUDYING PHYSICAL AND BIOLOGICAL PROCESSES IN THE NEARSHORE ZONE ON THE PACIFIC COAST OF THE UNITED STATES

Principal Investigator: Robert L. Holton
Co-Principal Investigator: William P. Elliott

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John V. Byrne
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ACKNOWLEDGEMENTS

A major expense in this type of research is the obtaining of adequate boat time. We gratefully acknowledge the School of Oceanography for making the R/V PAIUTE available to us on a regular basis to support this program.

We also wish to express our thanks to the numerous students and staff members who have contributed in many ways to the success of this project.

NOTICE

The progress report that follows includes research results ranging from unproven ideas to the adaptation of proven methods for use on smaller boats. The end of the year finds several facets of our work in various stages of preparation, therefore the reader is cautioned that all results are subject to revision as a result of additional information obtained in the future.

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INTRODUCTION

The following report presents a summary of the work conducted between 1 March 1973 and 31 December 1973 as proposed in our research contract "The Development of Methods for Studying Physical and Biological Processes in the Nearshore Zone on the Pacific Coast of the United States," supported by the Eugene Water and Electric Board, Pacific Power and Light Company and the Portland General Electric Company.

The experience gained on this project during 1972 provided the necessary basis for the fulfillment of many of the objectives of this project during 1973. This progress is demonstrated in more detail in later sections of this report. Some highlights of the year's work are summarized below.

We feel that the additional year's experience, using a larger and better equipped Pacific City dory, fully justifies our earlier confidence that this type of a vessel could provide an adequate platform for data collection in the nearshore zone. Since we also did a great deal of work off the PAIUTE which has a 33 foot, V bottom, fiberglass hull, typical of many sportfishing vessels, we can compare the utility of both hulls. Our field people describe the dory as a more stable and pleasant vessel to work on. The shallow draft of the dory also allows it to work into the beach area itself, while the PAIUTE never crosses the surf zone to come onto the beach.

The hydraulic system for the dory has proven an efficient and safe method of providing power to operate a variety of work-saving devices. The variety of small, modern hydraulic motors now available encourages us to state that this system could be adapted to any power requirement that might occur in the future.

The radar selected has proven to be compact and rugged. It functions very well on a 24 foot dory and provides a considerable margin of saftey for operation during inclement weather. The ability to relocate research stations using the radar to fix positions is less precise than we desire; nevertheless, it certainly is useful.

The majority of effort on the phytoplankton during 1973 was centered on developing methods to perform the necessary field work for chlorophyll measurements and C-14 productivity studies on board the dory. These objectives have been achieved and both types of measurements can now be made on a routine basis. However it must be added that this work is the most weather-sensitive portion of the data gathering operation.

Two objectives were achieved in our zooplankton program during 1973. The problem of sampling at the surface in the turbulent nearshore zone has been approached by the construction of a surface sampler of largely new design. The sampler seems to work well and will be used in an intensive sampling program in the future to evaluate the organisms present in the surface water of the nearshore zone.

The ability to collect a zooplankton sample from a specific point in space, as opposed to a space-integrated sample obtained with a towed net, was a serious requirement that became evident during 1972. The zooplankton pumping system that we have developed successfully fulfills this need. The system is both inexpensive and compact enough to be easily used on the dory. This is in contrast to several larger, bulky systems which have been reported in the literature. An extensive set of samples produced by this system are now being analyzed.

The program in the development of fish sampling techniques has become a vigorous effort and several innovative techniques are currently being evaluated. The problems associated with surveys of a relatively small and specific area that would be associated with any industrial siting in the nearshore zone are leading us to look increasingly at stationary sampling devices, traps, fyke nets, etc., which will allow us to capture fish, tag them for identification, return them to the ocean and, hopefully, to study their abundance and movements by recapturing them at a later time. Considerable effort will be devoted to this technique in the future in order to evaluate its effectiveness on the edge of the ocean.

The benthic sampling program is making progress in the development of sampling methods. Again it appears that methods of trapping, marking, and recapture will produce the most valuable information. The feasibility of such a program will be examined by field studies during the next phase of the program.

With the development of techniques for collecting the appropriate biological samples, we will further evaluate the sampling gear with an intensive field program to characterize the biotic community of a specific area. A second area of methodology development will be carefully considered during this same field program. We will consider the logistic requirements necessary to obtain a maximum amount of data with a minimum expense. We are particularly interested in the various conditions which will let us obtain several kinds of data on a quasi-synoptic basis with a minimum expenditure for the data.

The thermal effects laboratory is set up and in operation. The laboratory will provide excellent conditions for conducting the basic thermal studies planned for the immediate future. Thermal studies on Dungeness crab larval stages are currently underway. We are able to capitalize on the expertise of a person who already has the ability to handle the larval stages of crabs and to proceed with work on this important species as the initial project in our thermal laboratory studies program. We will initiate studies on the thermal tolerance of various zooplankton species as the second phase of our laboratory program. An extensive bibliography on zooplankton has been completed as a background for these studies.

During the summer of 1973, the current studies program was highlighted by two very large drift bottle drops made in August. Data from this effort is currently under analysis. A comprehensive review of literature on nearshore current measurement techniques has been completed; the review and a bibliography of materials covered is included in this report.

Greater details on the progress made is presented in the following pages.

WORKING VESSEL AND EQUIPMENT

Hull

The Pacific City Dory, long known for its seaworthiness, was selected as a boat well suited for our field work. The hull, constructed at Pacific City Boat Works in Pacific City, Oregon, has a 6 foot bottom, an 8 foot beam and is 24 feet in length.

Other characteristics include a forward deck of 5 feet, a transom depth of 32 inches, an amidships depth of 35 inches, and a forward depth of 47 inches.

The exterior hull consists of marine Douglas fir plywood, grade AA. The bottom is a double layer of 3/8 inch plywood and the sides are a single layer of 3/8 inch plywood. The frames are 13/16 inch mahogany, strengthened with plywood gussets.

Motor

The power unit is a Ford, 6-cylinder Maverick (Model TP250-2). It has a displacement of 250 cubic inches and a gross automotive rating of 155 horsepower @ 4000 rpm. This is coupled by a 12 inch splicer to a Hamilton two-stage jet pump (Model 2C). The pump is fitted with standard impellers and a 4 3/8 inch diameter nozzle.

The actual horsepower of the combined unit is rated to be around 125 horsepower with 1000 pounds of thrust @ 4000 rpm. The combined weight of the boat, motor and jet is approximately 2500 pounds.

The engine is cooled through the use of a heat-exchanger cooling system. The coolant (water or antifreeze) circulates in a closed system. It passes through the heat exchanger where it is cooled by sea water which is delivered to the exchanger by the jet unit. The sea water then passes to the oil cooler, the manifold, and water jacketed exhaust for exhaust cooling and discharge.

The speed of the dory is, of course, dependent upon such factors as ocean conditions and load size. Presently, at 3600 rpm the speed is approximately 15 mph. It was observed that running at 4000 rpm merely increases gasoline consumption, and not speed; while running at lower rpm's sacrifices speed. Therefore, it was determined that 3600 rpm is the most economical cruising speed.

Other features of this outfit include a tachometer (rpm), voltmeter, oil pressure (lb/in^2), fuel gauge, temperature gauge (F), light switch and a 35 amp alternator. The steering is Teleflex® and the controls are Morse M.J.

Two 20-gallon gasoline tanks, located in the aft portion, with one on the port and the other on the starboard side, provide 40 gallons of gasoline, an adequate supply for a day's work. Gasoline consumption varies with speed, but appears to average 3-5 gallons per hour.

This combination of a dory hull and jet power provides several advantages over conventional craft for nearshore research. It is possible to work in much closer to the shore, crossing the surf zone and working inside this zone with safety and ease. The jet power unit has proved to be excellent in working with various kinds of unusual sampling gear. The jet offers the advantage of being very maneuverable and very effective in protecting the equipment since there is no propeller to foul sampling gear. This hull design also provides the necessary space to carry out a wide range of sampling operations.

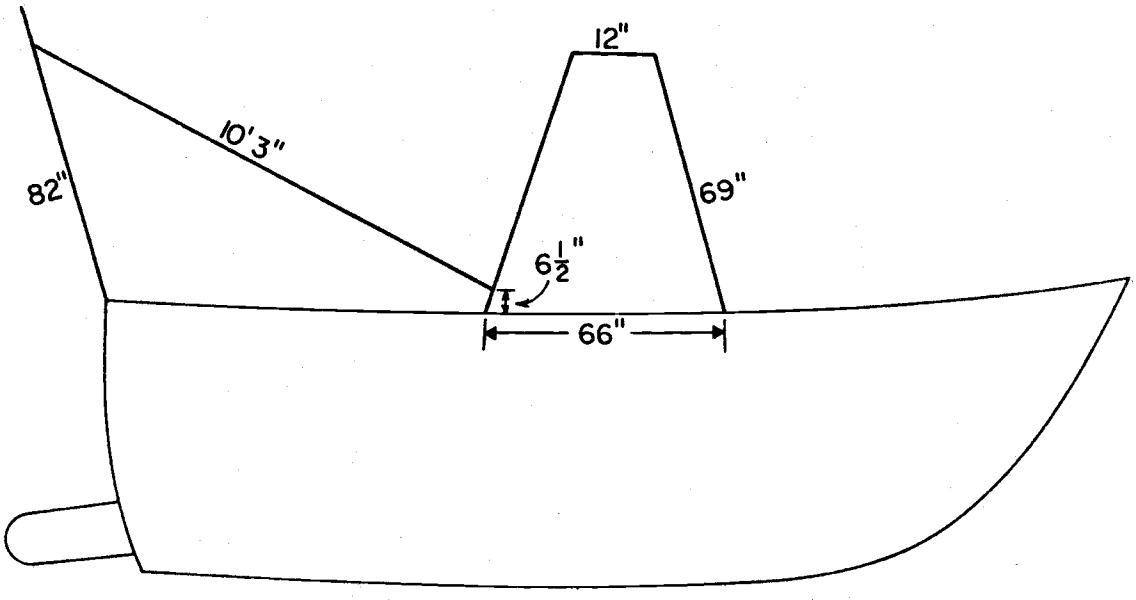
Although the dory, as presently equipped, has proven to be effective, we must note that we are still not getting the expected performance from it. The hull design and mounting of the jet require modification to increase efficiency. With the completion of these modifications we expect to at least double the speed obtained at 3600 rpm, as well as to attain increased responsiveness in handling. These modifications are currently underway and will be completed well before an intensive summer working season.

Equipment

The equipment added to the dory consists of the necessary gear required to make it a safe and efficient working vessel. The standard Coast Guard requirements were the first items to be considered. This included life jackets, the proper fire-estinguisher, a horn and lights.

Superstructure. An A-frame, a stern davit and a side boom, constructed from an aluminum alloy, were designed specifically for the dory (Fig. 1). The A-frame itself serves as a mount for the radio antenna and the scanner unit of the radar. The port side of the A-frame is modified to allow an extendable boom to be incorporated into the system. Together the A-frame and the stern davit serve as a means for pulling trawls of various types.

Hydraulic System. In order to work more efficiently we have developed a hydraulic system specifically for the dory (see Fig. 2). The hydraulic pump, a Vickers VTM-42-60-75, is driven by power from the engine. It has a maximum flow rate of 7.5 gallons per minute at 1500 lb/in^2. The fluid power developed by the Vickers pump is utilized in the system as the driving force required to operate several hydraulic motors. The first is a small motor that drives a water pump. A second motor (Char-Lynn RS25291) runs a modified commercial fishing gurdy. This is used in combination with the extendable boom on the port side for lowering and raising equipment to desired depths. The third motor (Char-Lynn RS25291) runs a large winch which will be used in pulling trawls.



Boat Length 24'

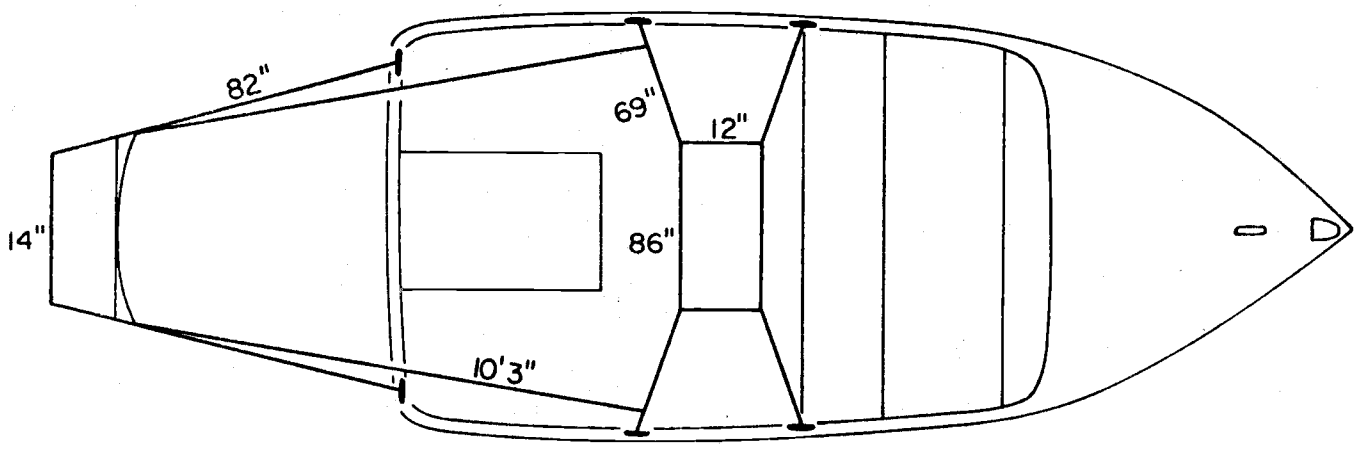


Fig. 1. A-Frame, Stern Davit and Side Boom on Dory.

(Not drawn to scale)

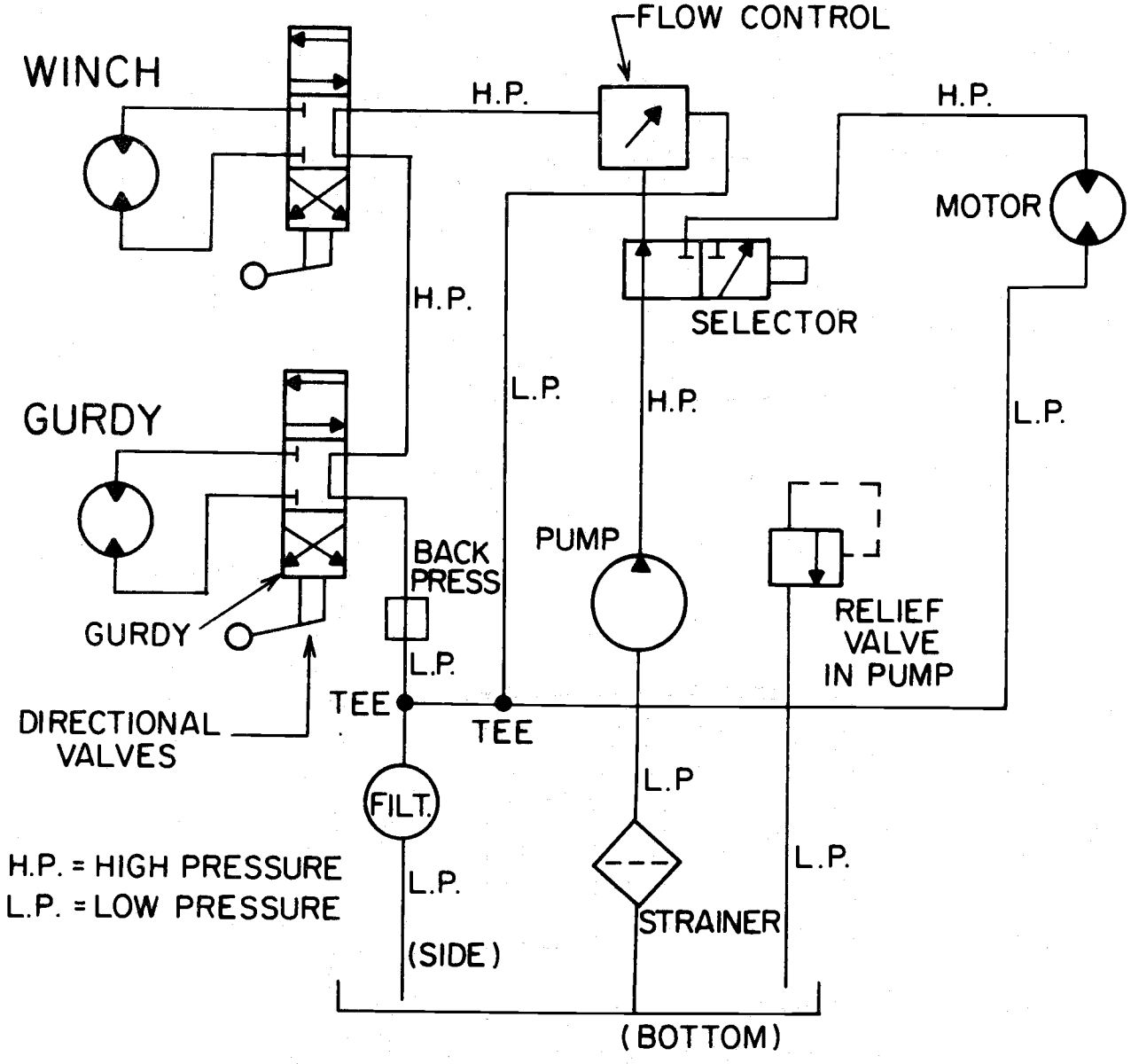


Fig. 2. Schematic of Hydraulic System.

Two systems of driving the pump with the engine have been used. The first system provided a mechanical clutch for engaging and disengaging the pump as desired. The clutch and operating levers were poorly engineered and difficult to mount; they operated poorly and did not provide adequate power to pump with the single belt pulleys being used. The second system provided a double pulley drive with no clutch on the engine. With this system the hydraulic pump was in continuous operation and the hydraulic system operated at a higher temperature than is acceptable. We are rejecting both of these systems and will be installing an electric clutch which provides a double belt drive to the hydraulic pump. We feel that this will solve the problems encountered with each of the other systems.

Radar. The radar selected for the dory is a Decca 050 Model MK2. It has a maximum range of 12 nautical miles (n.m.) and a minimum range of better than 23 meters on 10^2 m targets. Range scales are, 0.5 n.m., 1.5 n.m., 3.0 n.m., 6.0 n. m. and 12 n.m., with ring intervals of 0.5 n.m., 0.5 n.m., 0.5 n.m., 2 n.m. and 2 n.m., respectively. It requires a 12 volt power supply and consumes 75 watts.

The scanner unit, type 65198, contains the aerial, the radar transceiver, aerial turning motor and gearbox, and the power supply circuits for both the scanner and display units. It is 3 feet in diameter, 18 inches in height and weighs 55 pounds.

The display unit, type 65198, contains a six inch cathode ray tube and the necessary controls for the radar system. The specifications of this unit indicate a bearing measurement accuracy of better than three degrees and a range ring accuracy of better than two percent.

Communication System. The communication system consists of two Citizens Band radios. One is installed on the boat and the other in a mobile unit on shore. They are Johnson Messenger 120's, having five channels and requiring a 12 Vdc power supply.

Other navigational and research aids include a compass (Aqua Meter Model 70) and a fathometer (Furuno Model FG-11 Mark-3). The fathometer can be read as a flasher or a recorder with depth ranges from 0 to 160 fathoms. It requires 12 Vdc as its power supply, but consumes only two watts.

Trailer. For increased mobility and occasional boat maintenance a trailer was required to get the dory in and out of the water. The Calkins, (Model No. DT-22-7080) tandem wheel trailer was chosen because of its quality and rugged construction.

PHYTOPLANKTON STUDIES

Equipment Development

Filtering Manifold

Ecological studies dealing with primary productivity or the standing crop of phytoplankton require the collection of numerous water samples. The most accurate estimations of chlorophyll levels or concentrations are obtained when the samples are immediately filtered through Millipore membrane filters which are then stored in a cold, dry, dark container for later laboratory analysis. Unfortunately, it is usually not possible to filter water samples in situ when the ecological research is being carried out in a small vessel such as the research dory. Under such conditions the samples must be returned to a shore station for processing.

In order to circumvent the time lag problem, a system has been devised for filtering water samples in situ on the research dory by using the vacuum created by the natural operation of the water jet. A water filtering manifold was built with polyvinyl chloride (PVC) tubing and consists of four parallel filtering heads (1 1/4 inch diameter) four inches apart. A one-half inch PVC valve was connected to each filtering head by means of adaptors and 90 degree elbows. The four valves allow individual control at each site. In turn, the valves were connected by 90 degree elbows, or tees, to a 1 inch (diameter) by 24 inch (length) tube which actually consisted of a connecting series of tees, nipples and unions. A master PVC valve and vacuum gage were installed immediately before the first branch to filtering head number one. These two devices allow regulation of total vacuum, should excessive vacuum be created. The entire manifold was then mounted in the bottom of a paint-blackened portable box and can be installed in the foreport of the dory when required. A one-half inch vacuum line connects the manifold to the water aspirator in the stern of the dory. (See Fig. 4, p. 15.)

A given water sample is processed by removing the cap from either the 250 ml or 1000 ml bottle and placing it on a rack built into the box directly above the manifold. A long three-sixteenth inch flexible tube is inserted into the water sample. The tube is connected to a filter holder containing a fresh Millipore filter. Water passes through the device and exits on the opposite side into the manifold via another flexible tube which penetrates a one and one-fourth inch rubber stopper capping the filtering head of one of the four filtering units. At the termination of filtration, the vacuum is turned off with the connecting valve and a new membrane filter is installed for a successive sample.

An assessment of the system reveals that it is only adequate, at best, for filtering a maximum of two samples simultaneously because vacuum decreases sharply with each additional sample. Filtering times were longer (on the order of minutes) as compared to land station filtering techniques. This is partly attributed to the fact that the water jet does not produce adequate vacuum. In addition, the engine has to be maintained at high rpm's in neutral gear to provide the necessary vacuum. Esthetically, the PVC tubing is not pleasing, being too large and awkward to use and is not recommended. In concept, however, the idea of constructing an in situ filtering device is good and can certainly be improved upon.

Chlorophyll Studies

As noted in the 1972 Progress Report (Holton and Elliott 1973) our greatest problem in developing a method for taking chlorophyll measurements in the nearshore zone was our total inability to reduce the variability of replicate samples by the methods being used at that time. Our program in 1973 was directed toward solving this problem first and we were rewarded with rather rapid results.

After literature reviews and discussions with other people making chlorophyll measurements, we adopted a twofold approach to reduce the variability. We attempted to reduce all exposures to light to an absolute minimum, after the time of sample collection, and we reduced the temperature of the collected sample to a value as low as possible (about 1 to 3°C) in order to reduce the possibility of pigment changes.

These objectives were accomplished by keeping collected samples in a light-tight freezer chest with an abundant supply of ice. To reduce the light during the filtering process, it was necessary to move the shore-based operations out of the tent used in 1972. A Navy surplus van was acquired to replace the tent as a shore-based filtering station. It was possible to darken the van almost completely and hence to eliminate the problem of excess light during sample filtering. As a result of the use of the revised procedures, we were able to reduce the coefficient of variation between replicate samples to about 10% as shown in Appendix I. This is the same level of precision that is attained on board the YAQUINA and the CAYUSE.

The tent had proven to be unsatisfactory on several counts as working quarters in a windy coastal area. Not only was light a problem, but sand frequently was blown into the tent and onto the "O" rings of the filtering apparatus, interfering with the seal, and greatly lengthening filtering time. On several occasions the wind actually blew the tent over and made further operations impossible. All of these problems were eliminated by working in the van.

Methodology development continued with an attempt to complete the entire filtering process on board the dory. The filtering column and mounting desk was readily adapted to the dory. The light problem was resolved by working under a hood. This worked well and again we were able to produce replicate samples with a coefficient of variation of about 10%. However, two problems remain partly unresolved. Working under the hood requires a person who is extremely resistant to motion sickness and the placement of filters on the filter holder can become an exercise in frustration if any wind is present. We will strive to reduce these problems by further modifications in the future.

The availability of an improved computer program has reduced the time required to evaluate data and has resulted in an easier to read computer output.

Sampling Procedure

Water samples are collected at depth with a Van Dorn bottle. Surface samples are collected by placing the Van Dorn just beneath the surface. The Van Dorn is drained and water samples are placed in one liter polyethylene bottles. The bottles are filled quickly, put in a sturdy covered ice chest filled with sea water and ice to keep the samples as cold as possible until they are filtered. As the water samples are taken, the station and its location, the time of day, depth of sample and water temperature are recorded.

The filtering apparatus is a one meter long, cylindrical, stainless steel column which we fabricated. This column is attached to a stainless 47 mm Millipore Pressure Filter Holder (Model XX40 047 00). The completed system has a capacity of one liter. The sample is forced through the filter with pressure from compressed nitrogen. A filtering pressure of 20 pounds per square inch is used.

The phytoplankton from the water sample are filtered onto a 0.8 µm MF-Millipore® Filter. The liter sample is poured into the column and 1 3/4 cc of saturated solution of $MgCO_3$ is added as a precautionary measure against the development of acidity and hence pigment degradation.

After filtering 20-30 seccnds should elapse before reducing the pressure and removing the filter. The filter is then removed with forceps and placed on a 5.5 cm Whatman filter paper which has recorded on it the date, station number and sample number. The filters are then folded in half with the plankton innermost, folded again, secured with a paper clip, and stored in a desicator which is in an ice chest and surrounded by dry ice. The column is rinsed with filtered sea water after each sample is filtered. The frozen filters are transported to the laboratory in Corvallis where they are extracted as soon as possible.

Extraction procedure

The reagent, distilled, reagent-grade acetone, is distilled by boiling it over one percent of its weight of anhydrous sodium carbonate and anhydrous sodium sulphite. The first few milliliters that boil off are discarded and then the acetone is collected and stored in tightly sealed dark glass jars. The 90 percent acetone is then prepared by pouring 100 ml of distilled water into a liter volumetric flask and adding the acetone to bring the volume to 1000 ml.

The filter is ground in approximately 8 ml of 90 percent acetone for 3 minutes in a Serval Omni-Mixer® . Under reduced light the contents of the grinder are transferred into a 15 ml centrifuge tube. The blades of the grinder and the cup are rinsed with acetone to rinse off any chlorophyll and bring the extracted volume to 10 ml. Each sample is treated in this way. After all samples have been extracted, they are centrifuged at 10,000 rpm for 20 minutes.

Spectrophotometric Determination The supernatant liquid is pipetted into a 10 cm path length spectrophotometer cell which is designed to hold 10 ml or less. Cell blanks are taken for each spectrophotometer cell used to make a correction for optical inequalities. This is done by filling each cell with 90 percent acetone solution and finding the cell to cell variation of the sample cell against the reference cell at all wavelengths used. The wavelengths used in this procedure are 480, 510, 630, 645, 665, 750.

Each sample is measured at each of the wavelengths and a drop of 3M HCl is added to each cell, mixed and allowed to set for at least five minutes. Then readings are retaken at 750 and 665 and transmittance is read. An example of this output is presented in Appendix I. The data is then reduced by means of a computer program to determine the amount of the various pigments that are present. Examples of this output are also presented in Appendix I.

Production Measurements

Principles

Primary production estimates may be made using the radio-isotope carbon-14 (C-14). Phytoplankton incorporate carbon (C) into their cellular matter at a particular rate under given conditions. This rate may be a function of many things including tmeperature, light, nutrients and past history of the population. By adding C-14 as a tracer, this rate of carbon incorporation, or production as it is usually termed, may be estimated; the usual units are milligrams of carbon per unit volume per unit time (MgC/volume/time). The estimate is made by knowing the total natural carbonate content of the sample, the total radioactivity added as C-14 bicarbonate and by measuring the amount of C-14 taken up by the phytoplankton over some length of time.

The above procedures give the rate of primary production at a given depth over a given length of time: mgC/m^3/time. By making consecutive C-14 measurements over the daylight day at a given depth, the total daily production can be obtained by integrating over time, mgC/m^3/day. This measurement can also be calculated by assuming that the production rate for that fraction of the day measured is representative of the entire day, and multiplying by the number of hours in the daylight day. If the photic zone has been sampled with depth, the production of the water column can be calculated by integrating the production rates over depth. This latter form of a production term, mgC/m^2/time is often used for comparing the productivity of different areas.

Carbon-14 data can yield useful information about the population and ecology of an area when used in conjunction with chlorophyll a, physical and chemical data. Physical and chemical data are often particularly helpful in explaining spatial distributions. The ratio of C-14 assimilated at light saturation to chl a at that depth yields a number referred to as the assimilation number (Table 4). This has been used as a relative index of nutrient sufficiency.

Laboratory and Field Procedures

Uptake of radioactive carbon was measured following Strickland and Parsons (1968:267ff). Choice of dilution and ampule strength is at the discretion of the investigator. Generally a stock solution is of such an activity that dilutions to a variety of innoculation strengths can be easily effected. The microcurie strength of the ampules chosen by the investigator is subject to two main factors: a) the efficiency of counting equipment available, and b) knowledge of the area under study. In the present case, liquid scintillation counting (efficiency $\geq$ 90%) was used and production was expected to be relatively high; an innoculation activity of 2 µCi/ampule proved entirely adequate. The samples were counted using a Packard Liquid Scintillation Counter.

Salinity, temperature, alkalinity and pH were determined from water samples taken at each site and time. These values can be used in a series of equations given by Strickland and Parsons (1968) to calculate total weight of carbon, W (mgC/m^3), in the waters. This value can be used to calculate production from raw count rates (cpm). For the latter calculation, the following equation is used:

$$\text{Production} = \frac{[(L-B)-(D-B)]\ [Q]\ [W]\ [1.05]}{[C-B]\ [Q]\ [H]}\ , \qquad \text{(Eq. 1)}$$

where L is cpm light bottle; D is cpm dark bottle; C is cpm ampule; B is instrument background (= 50 cpm); Q is quench correction; W is weight C in mg/m^3; 1.05 is a correction for differential uptake of C-14 vs. C-12; and H is hours incubated.

In this study, Eq. 1 was modified to

$$\text{Production} = \frac{(L-B)\ (W)\ (1.05)}{(C-B)\ (H)}\ . \qquad \text{(Eq. 2)}$$

The quench term, Q, cancels from Eq. 1, because variations in quenching due to varying amounts of water are eliminated by the Aquasol® used as fluor material. The elimination of black bottle correction will be discussed in a later section.

This project required development of special apparatus and techniques for sampling, filtering and mooring described below.

Black Incubation Bottles and Storage Box. Approximately one-third of the incubation bottles were wrapped with several layers of black electricians' tape, including the neck, and then dipped into black paint, dried and checked for leaks, and re-wrapped with tape when necessary. The bottles are equipped with black caps. During innoculation periods the bottles are stored in a black wooden box with a segmented, double top. This allows a separate compartment for each bottle and only half the box is open at a time, thus minimizing light exposure.

Bottle Holders. For in situ incubation cylindrical, clear, plexiglass bottle holders designed by the OSU Phytoplankton Ecology group are used. They are fitted with swivel eyes on lines attached to top and bottom, thus allowing attachment to mooring line. The bottom has a non-corrosive wire web; the top has a length of latex tubing long enough to wrap around the neck of the top bottle. The length should accomodate three bottles: one dark bottle on the bottom and two light bottles above. Thirty-seven centimeters is sufficient length for three bottles; if less than three bottles are used, wood spacers may be wired into the bottle holder (Fig. 3).

Liquid Scintillation Vial Holder A protective box was constructed to hold the liquid scintillation counting (LSC) vials. A piece of styrofoam (25 cm x 17 cm x 4 cm) with holes carved to fit the vials was cut to fit the bottom of a styrofoam ice chest. This is adequate, but the styrofoam tends to shred, making it somewhat messy.

Filtering System

Filtering on board the dory was possible because the bilge pump acts as an aspirator. A length of vacuum tubing is attached to a valve in the bilge system and to the vacuum apparatus. The vacuum apparatus is made of polyvinyl chloride (PVC) and consists of positions for four filtering holders and funnels (although only two were used), a vacuum gauge, and a valve to turn off the vacuum to the system (Fig. 4). The vacuum apparatus was housed in a wooden box (Fig. 5) 80 cm x 62 cm x 32 cm, made of 1/2 inch plywood, the interior of which was painted black to reduce light. The front is open, with a small ledge at the bottom. The interior is designed to clamp the vacuum apparatus to the bottom and to clamp two different sized bottles to the back. The two pieces of wood nailed to the back are fitted with screw clamps to hold inverted bottles, either 500 ml or 1000 ml, over the filter holders. The inverted bottles, taped black to reduce light, act as funnels, i.e., their bottoms are cut out allowing the sample to be poured into the bottle-funnel. Both Chl a and C-14 samples are filtered on this apparatus, thus the need to have clamps for two different sized bottles.

The filter holders are 25 mm Swinney adapters from Millipore. These filters are fitted with 1/4 inch Tygon® tubing on the top; this passes through a stopper fitting the mouth of the 500 ml funnel. The bottom of the Swinney has a 1/4 inch needle adapter fitting into 1/4 inch Tygon® tubing; the latter passes through a stopper which fits the mouth of the vacuum apparatus (Fig. 6).

The present system is adequate to do the job, but it does have some problems. There are too many connections where leaks can occur if the tubing, fittings, or stoppers are loose. The Swinney adapter had an inherent problem with air bubble locks. The cavity over the filter is just large enough to allow an air bubble to form; if the air covers the entire filter, it is impossible to draw the sample through. When this happens, slightly opening the filter holder with the vacuum turned on allows the air to escape out of the holder and water can be drawn to the filter; filtering then proceeds normally. Complete stoppage of the filtering does not usually occur; rather, a partial air bubble remains on the filter even after the opening of the holder. This will not harm the sample, but the reduced area for filtering increases filtering time considerably (from two minutes to eight minutes per sample for C-14 and from six minutes to 18 minutes for Chl samples). As that portion of the filter becomes clogged, filtering will become even slower and it is possible in a dense phytoplankton bloom to completely stop the filtering process. In the latter instance, the sample is normally lost. Swinney adapters are also difficult to operate in the dory because they consist of four separate pieces: screw bottom and top, gasket and filter. With the dory's motion and exposure to the elements it is easy to lose gaskets, place a filter on crooked, cross thread it when screwing it together or lose the filter after filtering. To alleviate some of the problems and to speed up the process, several sets of filter holders

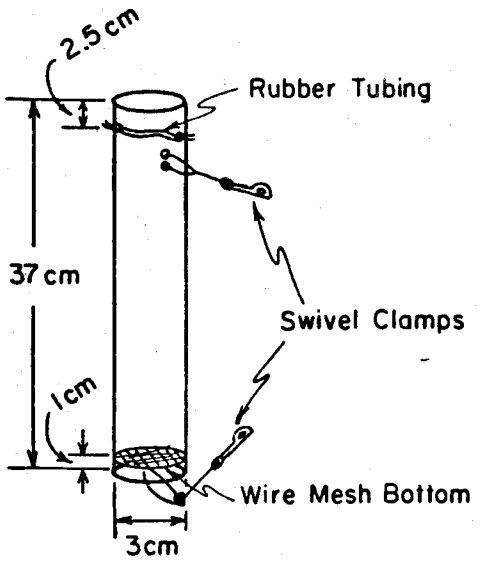


Fig. 3. In Situ Bottle Holder.

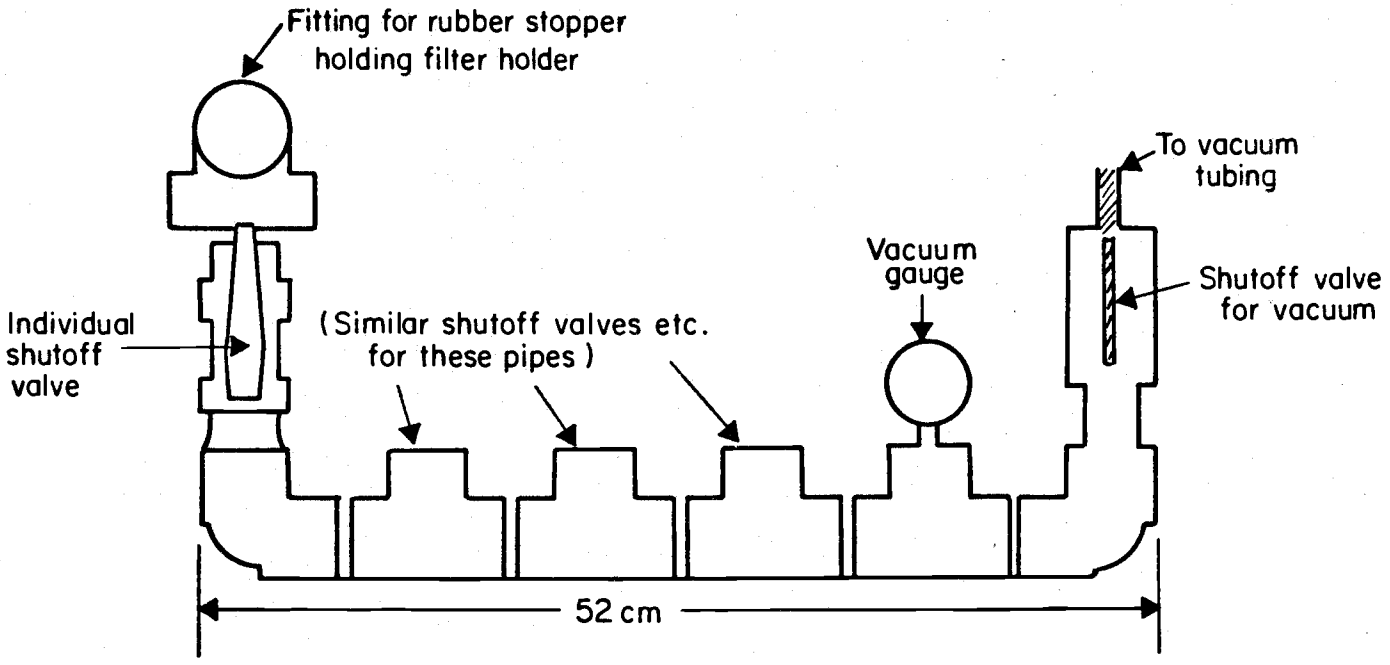


Fig. 4. Top View of Filtering Manifold (Vacuum Apparatus): Detail of One Set of Fittings for Filter Holders. (drawn to scale)

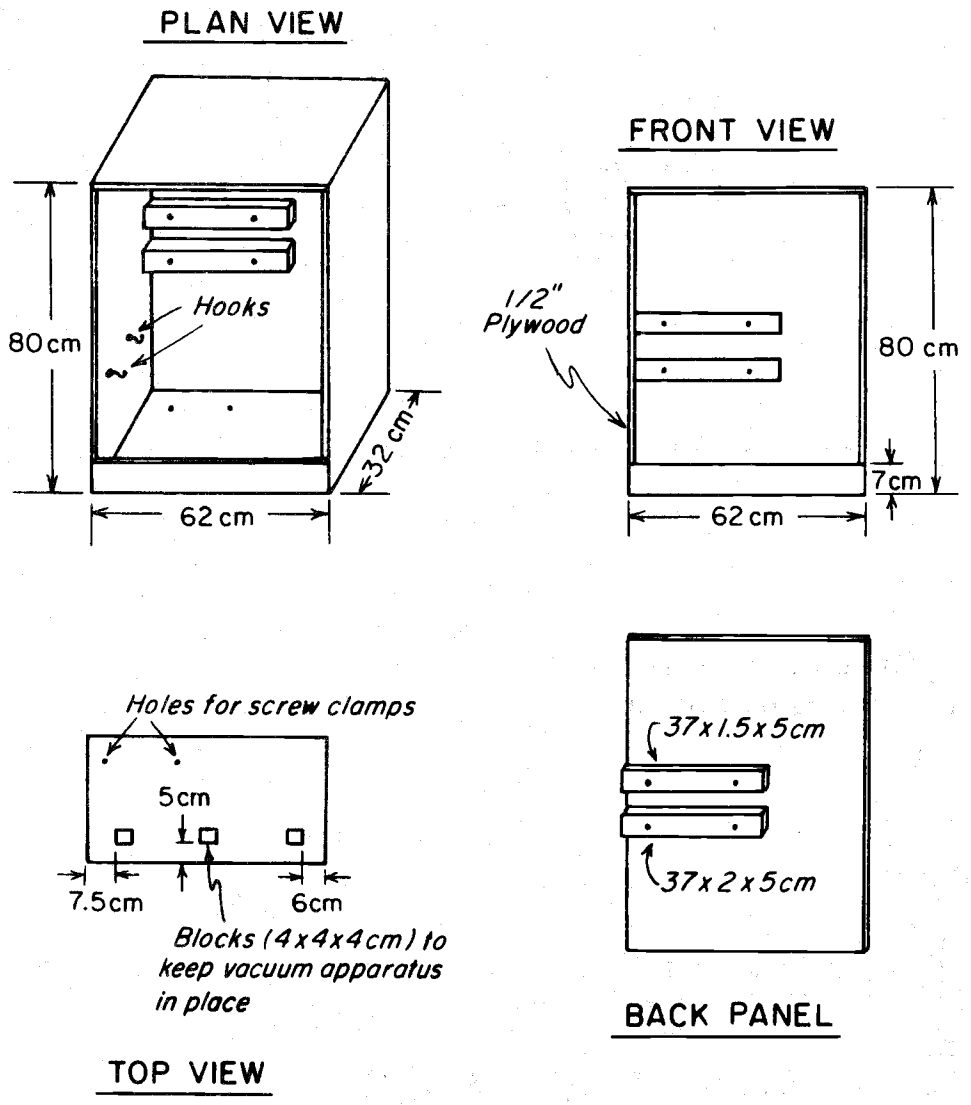


Fig. 5. Filtering Box Plan.

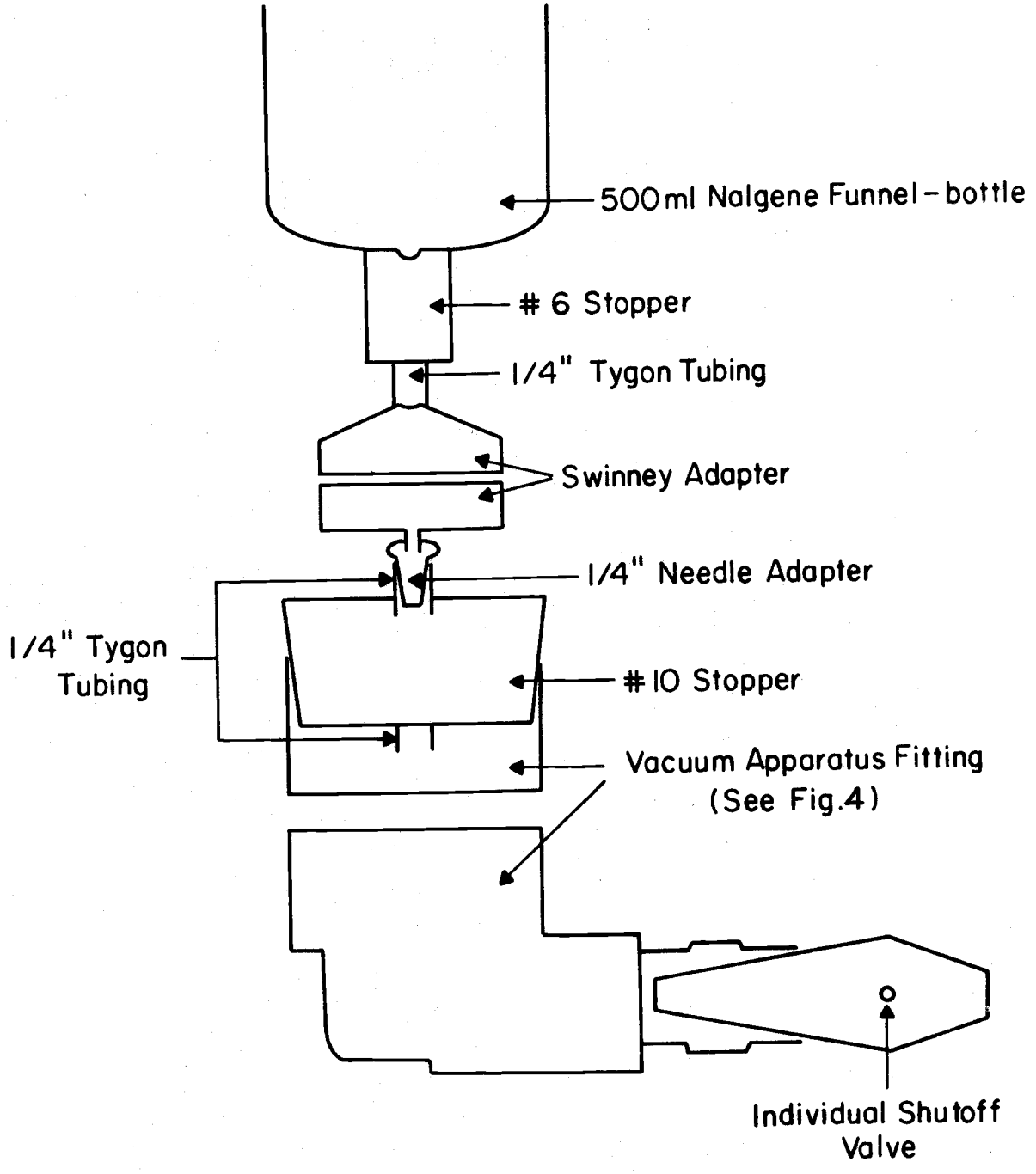


Fig. 6. Cutaway Side View of Filtering System.

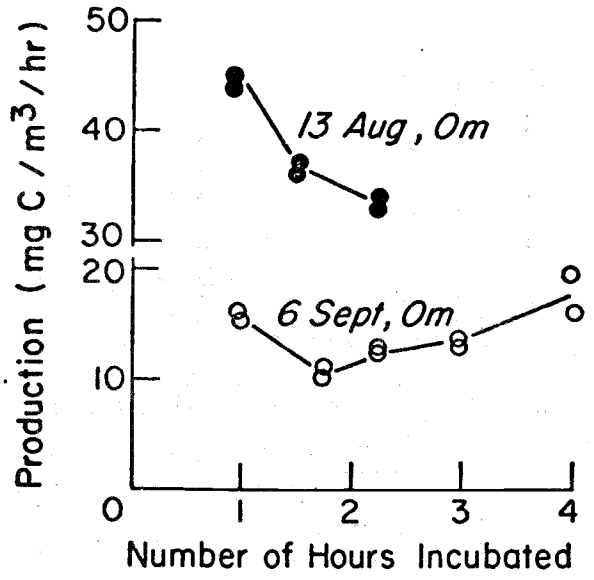


Figure 7: Graph showing numbers of hours incubated vs. production in light bottles, innoculated at t = 0, incubated for different lengths of time.

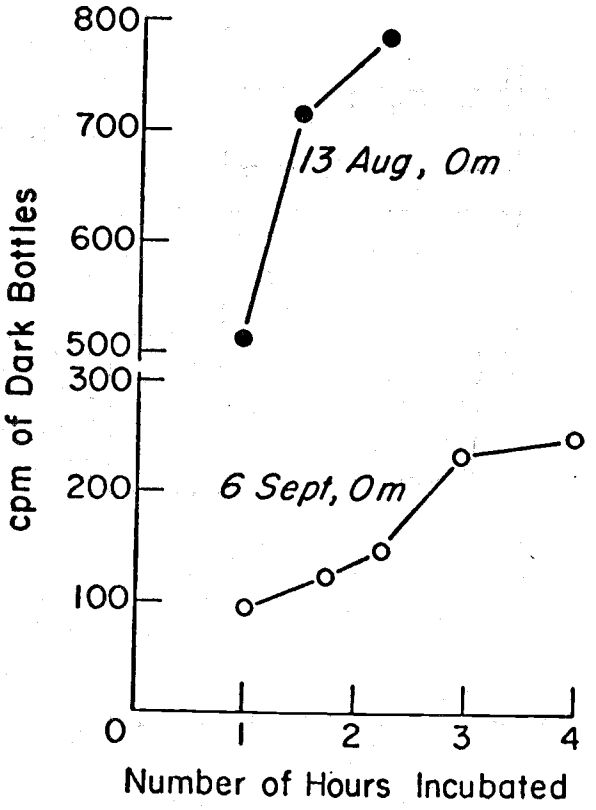


Figure 8: Graph showing number of hours incubated vs. cpm of dark bottles, innoculated at t = 0, incubated for different lengths of time.

and corks are taken out already rigged. In this way filtering could continue non-stop, while somewhat more time and care could be devoted to retrieving the sample filter and placing a new filter in the holder. Part of the difficulties involved lie with the degree to which one is exposed to the elements. Since the dory has no shelter, wind can come from any direction at any time, spray tends to get things wet and any sea or swell causes considerable rolling which makes changing filters difficult, but possible. Most of the above comments also apply to the Chl analysis. In fact, filtering for Chl is more difficult than C-14, since the samples must not be exposed to light.

Sampling Technique Water samples are obtained in non-toxic samplers capable of being closed from the surface. The sample bottle is rinsed at depth taken several times before filling. Two light bottles and one dark bottle are filled for each depth and then stored in a black box to reduce exposure to light.

Each sample bottle is than innoculated with C-14, using 1 ampule/bottle; it is then capped tightly and stored in a black box until ready to incubate. Samples were taken at a single depth at a time; the procedures for sampling, innoculating and incubating were repeated for as many depths as were sampled.

The samples are incubated for a minimum of two hours and a maximum of six hours. From each water sample, samples for salinity, pH, alkalinity and chlorophyll, and initial temperature were taken, along with a secchi disk reading. Appropriate procedures to follow can be found in Strickland and Parsons (1968).

Mooring Techniques Simplified portable mooring lines were used to hang bottles. The line was cut to various lengths with eyes spliced into their ends. Before sampling on a given day, the area, the total depth and the depths to be sampled were decided. Appropriate lengths of line were shackled together, with an anchor shackled to one end and an orange flotation buoy shackled to the opposite end. Overhand knots for holding tubes were tied every five meters. A weight was hung several meters below the last knot in order to keep the upper meters and sample bottles vertical, while still allowing adequate slope in the anchor line. These buoys were moored on a daily basis.

Filtering Procedures After incubation, the samples were filtered through 25 mm .8 µm MF - Millipore® filters. Using forceps, these filters are immediately placed into labelled LSC vials. Care is taken to protect the LSC vials from possible damage at this time. Once the filters are in the vial, they can be exposed to light without danger.

Discussion

Field testing of these procedures was undertaken in August and September, 1973, due to a delay in the receipt of C-14, technical difficulties with the dory, and inclement weather. For initial testing, calm weather was desired so that errors introduced by inclement weather would not occur, and so some of the testing was carried out in Yaquina Bay.

Table 1 gives a summary of the pertinent data for the experiments undertaken this summer. The experiments were designed a) to evaluate the necessity of using black bottles; b) to determine the strength of ampules and the length of time and time of day for incubation; c) to evaluate the accuracy of the system by taking replicate samples; d) to determine whether the chlorophyll-light method of calculating production could be used.

Evaluation of Black Bottle Experiments The use of black bottles in the C-14 technique involves several problems of interpretation and analysis. In these experiments the black bottle count rates (cpm) represent a small, although variable, fraction of the light bottle cpm. In most cases, the black bottle cpm represented less than 10 percent of the light bottle cpm (Table 2). For a few of the samples production was calculated using light bottle cpm corrected for dark uptake (Column IX of Table 2). As expected, the production calculated in this manner varies less than 10 percent from the production calculated without dark bottle correction (Column VII of Table 2).

Part of dark uptake represents the amount of isotopic exchange occurring in the experiment. The exchange could be represented as cpm and subtracted from the light bottle cpm. In an effort to determine the isotopic exchange, a series of surface samples were innoculated at the same time and incubated for different lengths of time. The data for this experiment was taken 13 August 1973 at 0 m and 6 September 1973 at 0 m. Plots of the light bottle production (Fig. 7; uncorrected for dark uptake) indicate that isotopic exchange occurred. The higher production rate during the first hour is the erroneous effect of isotopic exchange, making it appear that the phytoplankton took up more carbon than they actually did. Sample 11, August 13, is excluded from these plots. It is considered invalid since it was cloudy when incubated and had half the cpm of sample 10. The plots of the black bottle counts (Fig. 8) show the expected C-14 dark uptake curve, from which an isotopic exchange value might possibly be extracted, if the data were more extensive. It is also evident that, if it could be determined from the dark bottle rate, the value would have to be determined each time sampling occurred. Obtaining this information is too complicated and time consuming for routine sampling procedures. Since the total dark bottle cpm is a small percentage of the light bottle cpm (Table 2), no serious error should be introduced by not subtracting isotopic exchange.

Another difficulty with dark bottle counts arises from the fact that some part of the count rates actually represents dark uptake. When the productive capacity of an area is under consideration, dark uptake should not be subtracted; in fact, there would be justification for adding it to light bottle cpm. In that case the problem of separating isotopic exchange from dark uptake would reoccur. If interest were strictly in the photosynthetic production of an area, it would be possible to subtract dark bottle cpm. Because of the confusion over interpretation and because this project is concerned with total productivity, it seems desirable to drop dark bottle experiments from the procedure.

Table 1. Pertinent Data For Experiments Undertaken in 1973:
Light Bottle Results

Date	Depth	Sample No.	LB CPM* uncorrected	LB CPM* corrected	Weight mgC/m^3	Time of Incubation	Period of Incubation (hrs)	Production mgC/m^3 per hr.
13 Aug.								
Yaquina Bay								
A Series	0 m	10	7,408	7,358	19.8×10^3	1400-1500	1.0	45.0
		11(cloudy)	3,631	3,581			1.0	22.0
		6	9,170	9,120		1400-1530	1.5	36.5
		7	8,416	8,376			1.5	33.6
		8	12,284	12,234		1400-1615	2.25	32.7
		9	12,988	12,938			2.25	34.5
	5 m	2	10,294	10,244	26.2×10^3	1330-1600	2.5	32.6
		3	9,307	9,257				28.1
		4	9,765	9,715				29.5
		5	9,488	9,438				28.6
20 Aug.								
S. Beach								
Newport								
B Series	0 m	2	4,833	4,783		1100-1445	3.75	9.31
	5 m	3	4,120	4,070		1115-1500	3.75	7.86
		4	4,171	4,121				8.0
	0 m	5	1,679	1,629		1345-1630	2.75	4.19
		6	3,245	3,195				8.21
	5 m	7	1,955	1,905		1400-1630	2.5	5.4
		8	2,318	2,268				6.14
30 Aug.								
S. Beach								
(incubated in Bay)								
C Series	0 m	6	6,261	6,211	23.2×10^3	1230-1500	2.5	17.8
		7	7,237	7,187				20.6
		8	7,057	7,007				20.3
		10	6,096	6,046				17.3
		11	6,982	6,932				19.9

*Light Bottle Counts Per Minute

Table 1. (Continued)

Date	Depth	Sample No.	LB CPM* uncorrected	LB CPM* corrected	Weight mgC/m^3	Time of Incubation	Period of Incubation (hrs)	Production mgC/m^3 per hr.
Series C (cont.)	5 m	1	5,357	5,307	31.7×10^3	1220-1550	3.5	14.2
		2	4,428	4,378				11.9
		3	5,273	5,223				14.0
		4 (cloudy)	3,364	3,314				8.95
		5	4,909	4,859				13.1
5 Sept. Yaquina Bay D Series	0 m	2	1,524	1,474	22.0×10^3	0900-1100	2.0	5.0
		3	1,784	1,734	21.5×10^3	1100-1330	2.5	4.58
		4	1,757	1,707				4.54
		5	2,094	2,044				5.54
		6	1,720	1,670				4.45
		7	2,391	2,341	24.2×10^3	1310-1520	2.0	8.8
		8	2,102	2,052				7.73
		9	2,291	2,241				8.31
		11	1,303	1,253	21.4×10^3	1510-1700	2.0	4.15
		12	1,149	1,099				3.63
		13	1,234	1,184				3.91
		14	1,237	1,187				3.92
6 Sept. Yaquina Bay E Series		1	2,503	2,453	20.8×10^3	1245-1355	1.0	15.7
		2	2,759	2,709				17.1
		3	3,103	3,053		1245-1425	1.75	11.2
		4	3,441	3,391				12.4
		5	4,574	4,524		1245-1500	2.15	13.5
		6	4,604	4,554				13.6
		7	6,981	6,931		1245-1550	3.0	14.8

* Light Bottle Counts Per Minute

Table 1. (Continued)

Date	Depth	Sample No.	LB CPM* uncorrected	LB CPM* corrected	Weight mgC/m^3	Time of Incubation	Period of Incubation (hrs)	Production mgC/m^3 per hr.
Series E (cont.)	0 m	8	6,518	6,468				13.8
		9	12,211	12,161		1245-1640	4.0	19.5
		10	10,863	10,813				17.4
7 Sept. Yaquina Bay F Series	0 m	2	9,315	9,265	23.2×10^3	0800-1000	2.0	33.2

* Light Bottle Counts Per Minute

Table 2. Pertinent Data For Experiments Undertaken in 1973: Dark Bottle Results

Date	I. Depth	II. DB* Sample No.	III. Corresponding LB† Sample No.	IV. DB CPM** uncorrected	V. DB CPM** corrected	VI. Period of incubation	VII. DB/LB CPM (%)	VIII. Calculated production in mgC/m^3·hr: w/o DB cor.*†	IX. w DB cor.*
13 Aug.	0 m	A	10,11	512	462	1.00 hr.	6.2	45.00	42.00
		B	6,7	718	668	1.50 hr.	7.8		
		E	8,9	785	735	2.25 hr.	5.8		
	5 m	D	2,3,4,5	435	385	2.50 hr.	4.2		
20 Aug.	0 m	A	2	850	800	3.75 hr.	16.0		
		C	5,6	596	546	2.75 hr.	16.0		
	5 m	B	3,4	945	895	3.75 hr.	21.0		
		D	7,8	195	145	2.50 hr.	7.6		
30 Aug.	0 m	D,E,F	6,7,8,10,11	187	137	2.50 hr.	1.9-2.2		
	5 m	A,B,C	1,2,3,4,5	160	110	3.50 hr.	2.0-2.5		
5 Sept.	0 m	A	2	330	280	2.00 hr.	18.7	5.00	3.90
		B	3,4	219	170	2.50 hr.	9.6,10		
		C	5,6	238	188	2.50 hr.	11,9	5.54	4.94
		D	7,8	274	224	2.00 hr.	10,9.4		
		E	9	147	97	2.00 hr.	6.5		
		F	11,12	150	100	2.00 hr.	9.1,8		
		G	13,14	108	58	2.00 hr.	4.7,4.7		
6 Sept.	0 m	A	1,2	94	44		1.7,1.6		
		B	3,4	121	71		2.0,2.2		
		C	5,6	142	92		2.0,2.0	13.50	13.20
		D	7,8	237	187		2.88,2.68		
		E	9,10	245	195		1.6,1.79		

* Dark Bottle
† Light Bottle
** Dark Bottle Counts Per Minute
*† Without Dark Bottle Correction
*††With Dark Bottle Correction

Ampule Strength and Incubation Time The ampules were originally prepared at a strength of 1.5 μCi/ampule with the anticipation that it might be necessary to alter the strength. A qualitative count of the first experiment soon after it was completed indicated that 1.5 μCi/ampule was sufficient to give 10,000 cpm with 2-3 min; in other words, the initial choice of incubation activity was a good one.

There are two alternatives as far as when to sample and how long to incubate. One can either run short term 2-3 hour incubations all day, or incubate the samples for half the daylight day. If short term experiments are run all day, it is evident from Fig. 8 that they should incubate a minimum of two hours to prevent isotopic exchange from influencing the calculation. Half day incubations require the incubation to be either the first half, sunrise to midday, or last half, midday to sunset, of the daylight day. Other combinations are unacceptable, due to diel variation on carbon production.

Consecutive two hour incubations on August 20 at 0 and 5 meters and September 5 at 0 meters shows this diel variation (Fig. 9). The most accurate procedure is, of course, to run short term experiments all day; however, this is rarely possible due to the ship time involved. In some cases, such as for calibrating the chlorophyll-light technique, it is essential to run short term experiments all day, but they do not need to be run very often for this purpose. A longer half day incubation is judged most suitable for the present work, since this will average the difference in diel periodicity much more accurately than a short incubation taken some time during the day. If at all possible, the experiemnts, no matter what type, should be run at the same time of day in order to be comparable (due to diel periodicity) and should be run for a least three depths so that a curve of production with depth can be drawn.

Replicate Samples Replicate samples were taken six times: four times at the surface and twice at 5 m. The results are given in Table 3. The standard deviation is the variation about a mean for a particular experiment. However, different experiments can be compared by using the coefficient of variation. The coefficient of variation is less than 10 percent in all cases but one. The sample taken 30 August 1973 at five meters consisted of five replicates; the cpm of one of them (no. 4) were low. The coefficient of variation calculated without including that sample was 10 percent, 8 percent lower than when that sample is included. The sample is suspect because the sky was very cloudy during incubation and this may have caused a decrease in counting efficiency. A statistical evaluation of this sample indicated it was significantly different from the other four samples at the 1 percent level, and so the sample was dropped. In this instance, there were enough samples to justify this decision; however, had this been a routine sample of two light bottles with one of them significantly lower, it would have been very difficult to justify dropping the sample. For one thing, there may be insufficient evidence to determine which of the two values should be used. Since dark bottle cpm are of uncertain interpretation anyway, this is the primary reason for using three light bottles per depth.

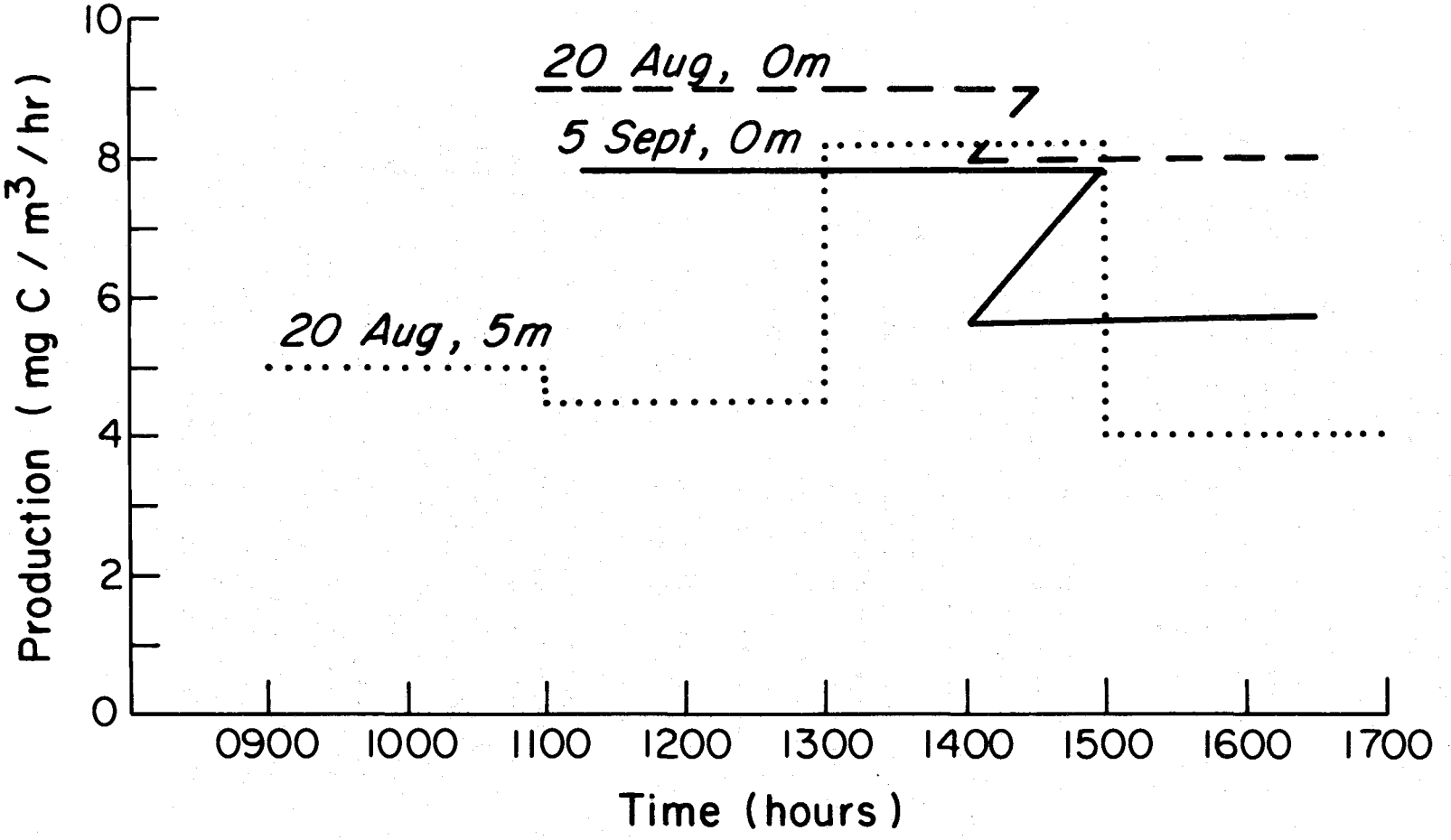


Fig. 9. Graph Showing Time vs. Production for Consecutive Short Term Experiments.

Table 3. Replicate Samples

Date	Depth	Sample No.	CPM*	Standard Deviation	Coefficient of Variation (%)
13 Aug.	5 m	2	10,294		
		3	9,307		
		4	9,765	445	4.5
		5	9,488		
30 Aug.	0 m	6	6,261		
		7	7,237		
		8	7,057	447	6.6
		10	6,096		
		11	6,982		
	5 m	1	5,357	895†	18.0†
		2	4,428	or	or
		3	5,273		
	cloudy	4	3,364	548††	10.0††
		5	4,909		
5 Sept.	0 m	3	1,784		
		4	1,757	173	8.0
		5	2,094		
		6	1,720		
		7	2,391		
		8	2,102	141	6.0
		9	2,291		
		11	1,303		
		12	1,149		
		13	1,234	63	5.0
		14	1,237		

* counts per minute
† includes Sample No. 4
†† excludes Sample No. 4

Another instance of this type of data resulted from experiments carried out 20 August 1973. The experiment was run by inexperienced personnel who had been instructed only the previous week. The five meter samples were good, however the data from the surface samples were unusable. This experiment involved consecutive short term experiments. One of the samples from the first surface set was lost during filtering; the difference between cpm of the second set were twofold. There is no way of knowing what happened; however, the data cannot be used for chlorophyll-light calibration because of the uncertainties in the surface data. The data was plotted in Fig. 9 using the single first set value and the higher of the second set values to demonstrate diel variation. There is some justification in this instance for arbitrarily choosing the higher of the two values. It was a sunny day; the five meter values were fairly high; the first of the surface set values was high and the experiments were carried out in the afternoon before surface values might have dropped. There is also some justification for using an average value (i.e., the data exists, use it) or the lower value (one could involve surface light depression, although that would have been more apt to occur in the first set). A third light bottle in any case would probably have simplified the analysis.

Chlorophyll-light Method

The chlorophyll-light method of calculating productivity could not be evaluated due to insufficient data. The procedure requires chlorophyll data coincident with C-14 data, but due to technical difficulties with the chlorophyll analysis, this could only be attempted twice. The short term experiments with chlorophyll a analysis on 20 August and 5 September, were designed to evaluate the method, but the uncertainties of the surface data in the 20 August samples precluded use of that data and the 5 September samples were unfortunately light limited. One of the other requirements for this method is that light saturation occur at some depth below the surface. September 5 was rainy and overcast; the C-14/Chl ratios even at the surface are so low that light limitation must have occurred (Table 4). Without this data, and incident light data which was not available at the time of this writing, it is impossible to attempt this analysis.

Table 4. Carbon Per Chlorophyll Ratios

Date	Depth	Time	Production mgC/m^3 per hour	chl *a* mgChl a/m^3	Assimilation Number: MgC/mgChl *a* per hour
20 Aug	0 m	1100-1445	9.31	2.83	3.2
		1345-1630	4.19	1.85	2.5
			8.21		4.9
	5 m	1115-1500	7.86	2.96	2.6
			8.0		3.0
		1400-1630	5.4	1.96	2.7
			6.14		3.1
5 Sept	0 m	0900-1105	5.0	5.047	1.0
		1105-1330	4.58	4.823	.96
			4.54		.93
			5.54		1.15
			4.2		.88
		1310-1520	8.8	4.91	1.8
			7.73		1.6
			8.31		1.7
		1510-1700	4.15	5.26	.79
			3.63		.69
			3.91		.74
			3.92		.74

ZOOPLANKTON RESEARCH

Surface Sampler

The surface sampler was designed and built for sampling zooplankton at the air-sea interface. Adaptability was the major guideline in its design to allow modification during development and flexibility in its use. It also had to be small enough to handle aboard a 24-foot Pacific City dory. The only other sampler of this type described in the literature was one built by Kahl Scientific Instrument Corporation of San Diego, California. However, it was too large for use on a small boat. This Kahlsico sampler served as the initial guide in the surface sampler development, but the end result was a distinctly different sampler.

The surface sampler consists of a frame which floats at the surface, a box which may be lowered to a depth of one meter, and a plankton net. Fig. 10 is a photograph and Fig. 11 is a drawing of the sampler. The overall measurements of the sampler are: length 306 cm, width 95.25 cm, height 131 cm and weight 13.5 kg. It is constructed of aluminum sheets and tubing and crab ring floats. The sampler may be disassembled for transport and storage. Hairpins (obtained from tractor equipment stores) hold the sections together as indicated in Fig. 10 and 11.

The frame for the box is made of 3/8 inch aluminum, 4 inches wide. Fig. 12 shows the details of the box and its frame. Individual pieces of the box and frame are welded together by metal inert gas (MIG) welding. The box is held to the upright portions of the frame by four bolts (5/16 inch-N.F.). The nine pairs of threaded holes (5/8 inch) along the sides of the frame make it possible to position the box to sample the top six inches of ocean surface or any depth down to one meter (Fig. 13 and 14.). The box itself is made of 3/16 inch aluminum and measures 45.7 x 30.5 x 15.25 cm. Extensions at the bottom and sides form positions for attaching a bridle. The six 9/16 inch holes on each side extension allow for adjustment in the bridle towing position. The top extension and back of the bottom extension are used to attach 1/8 inch nylon ropes extending to the tail section for additional support of the frame. The net frame attaches to the box by a spring-bar as indicated in Fig.12 and 15. Four screws in the box bottom fit into four holes in the net frame. The top then slides into a spring-held bar that locks the net frame onto the box. The handle on the net frame makes net attachment and removal much easier when the sample is overboard.

The floats slide over the one-inch aluminum tubing that fits into the frame side extensions. These floats hold the frame at the surface, even when the box is sampling at one-meter depth. They also make it possible to sample a more constant depth than with standard samplers, since the floats remain at the surface and the box at a fixed distance below. (See Fig. 16.)

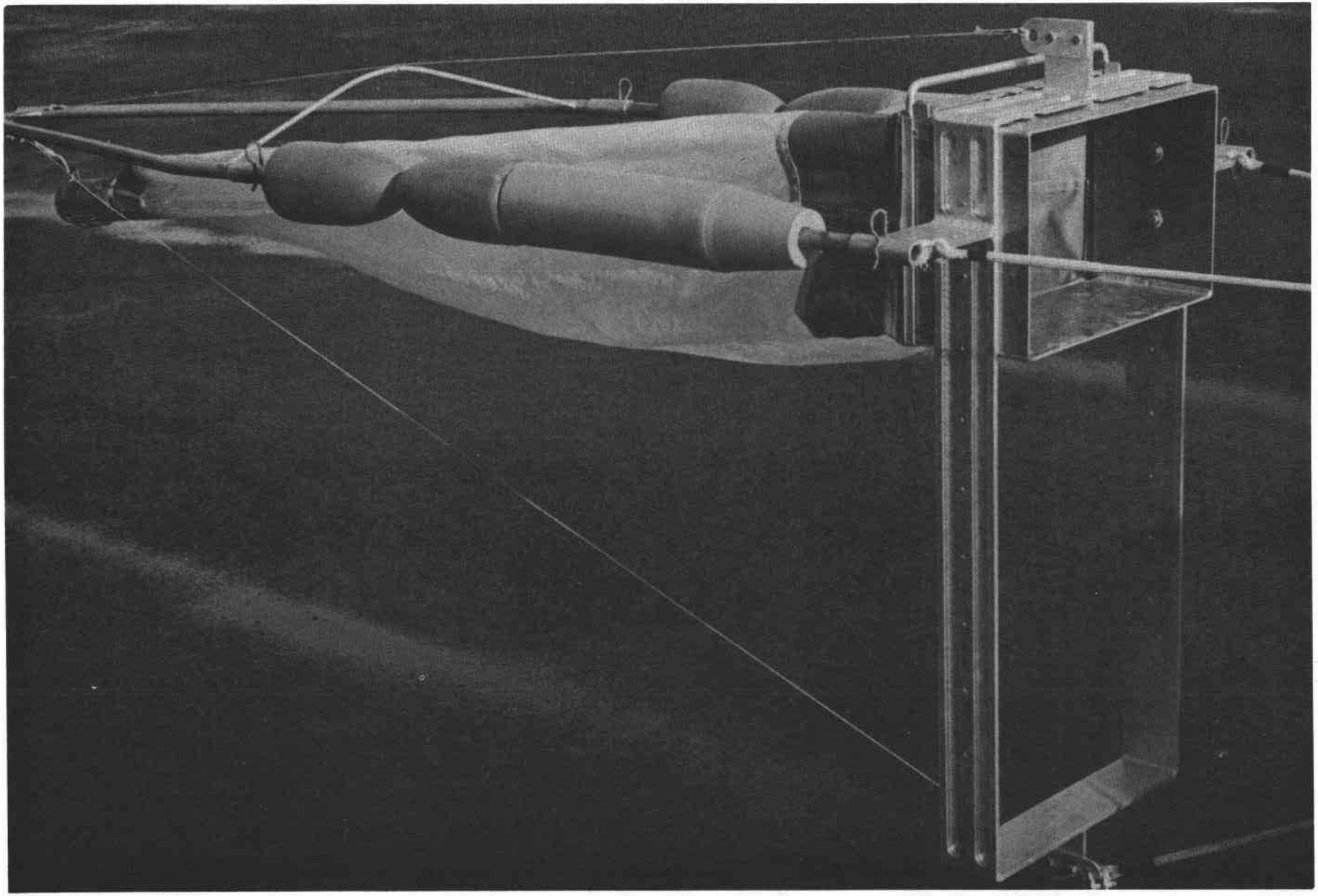


Fig. 10. Photograph of the Surface Sampler.

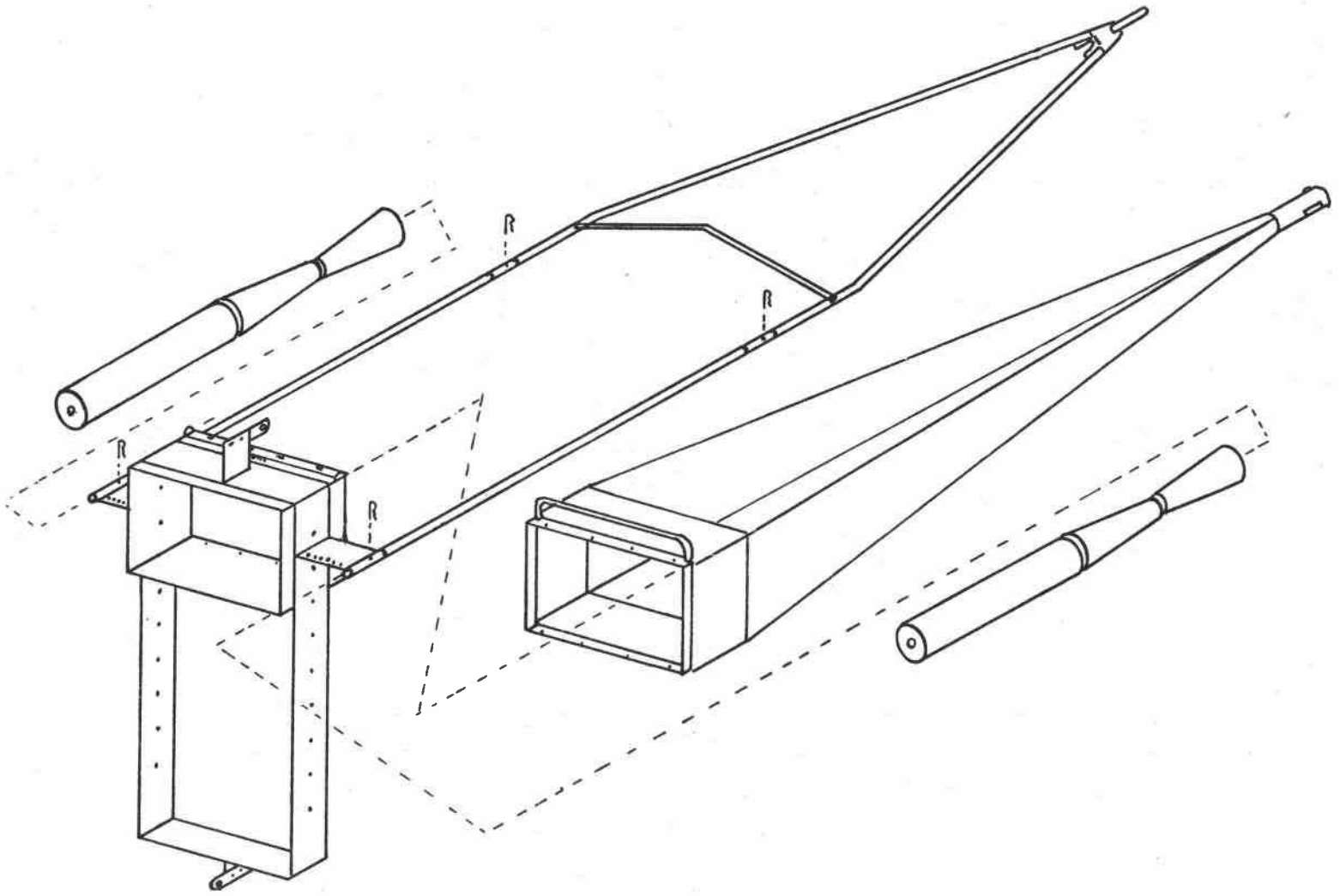


Figure 11: Surface Sampler Drawing

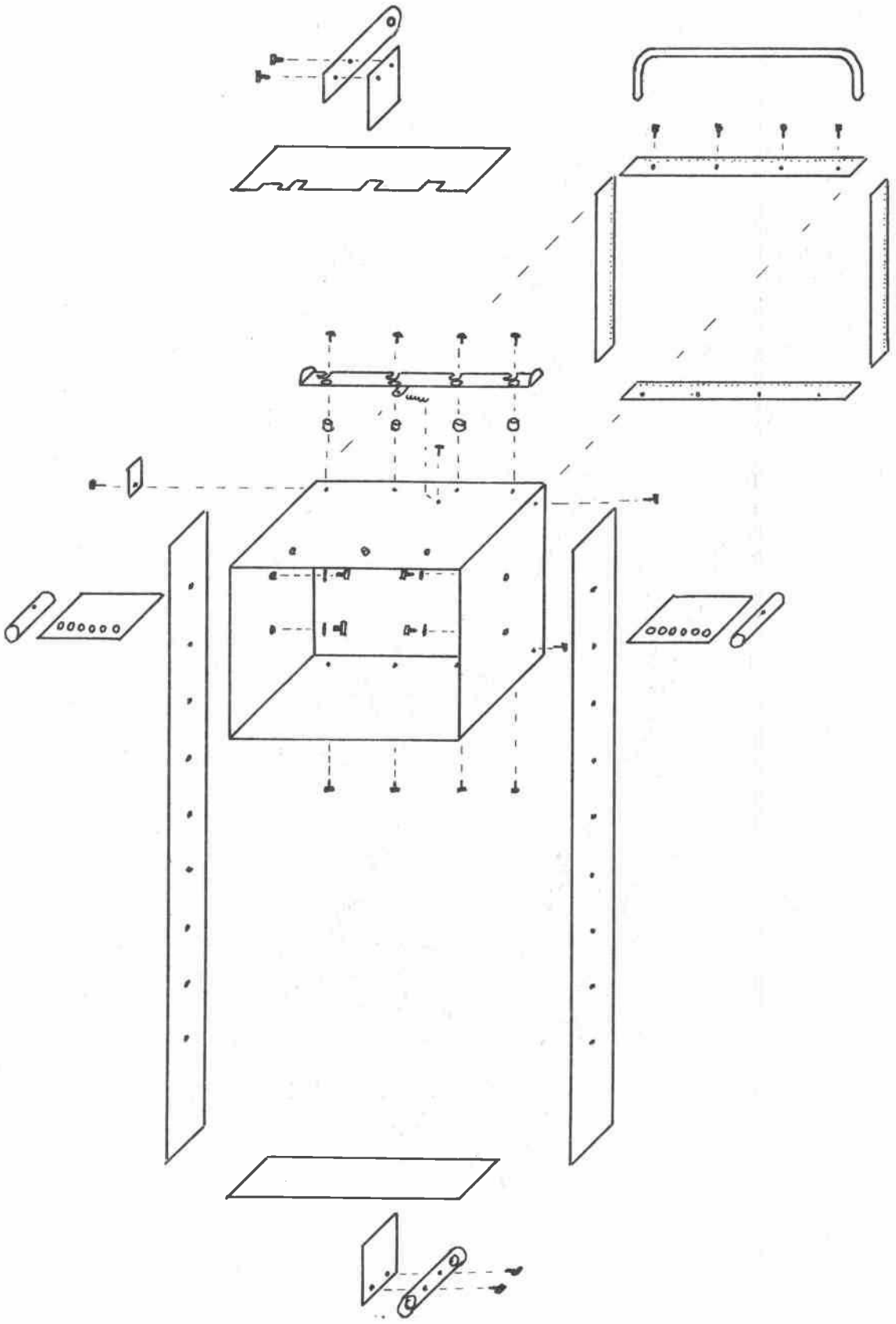


Fig. 12. Detail Showing Box and Frame of Surface Sampler.

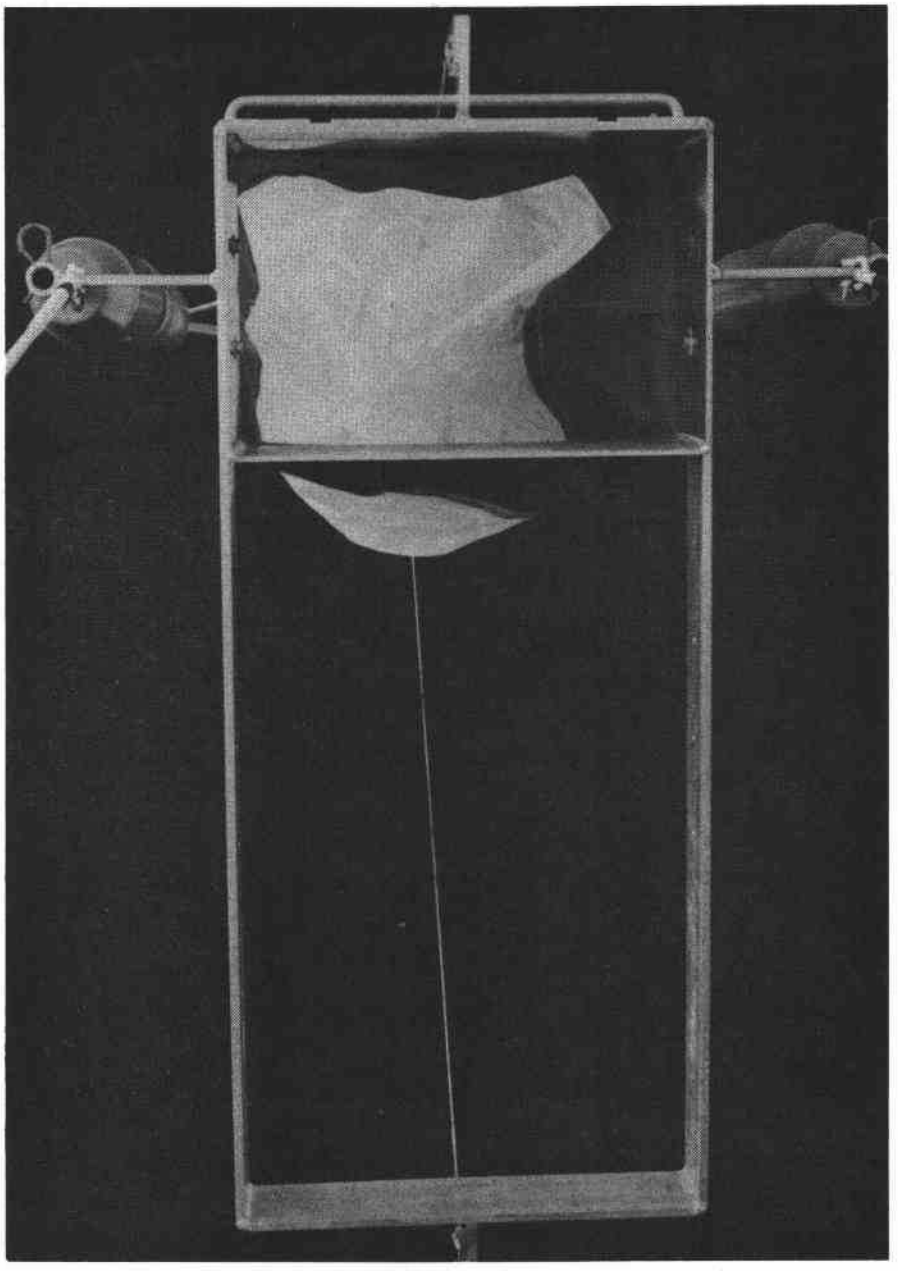


Fig. 13. Front View of Surface Sampler with Box at Top Sampling Position.

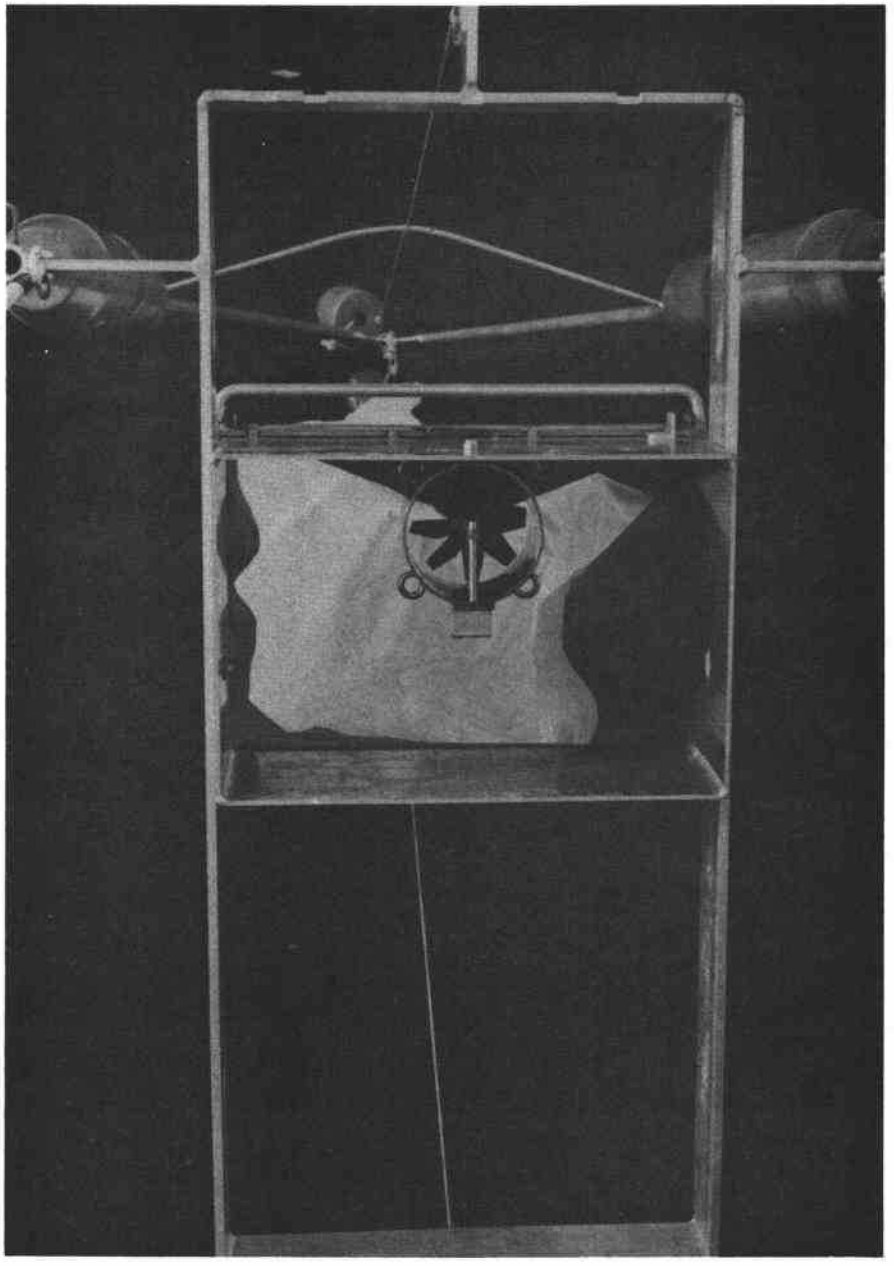


Fig. 14. Front View of Surface Sampler with Box at Middle Sampling Position.

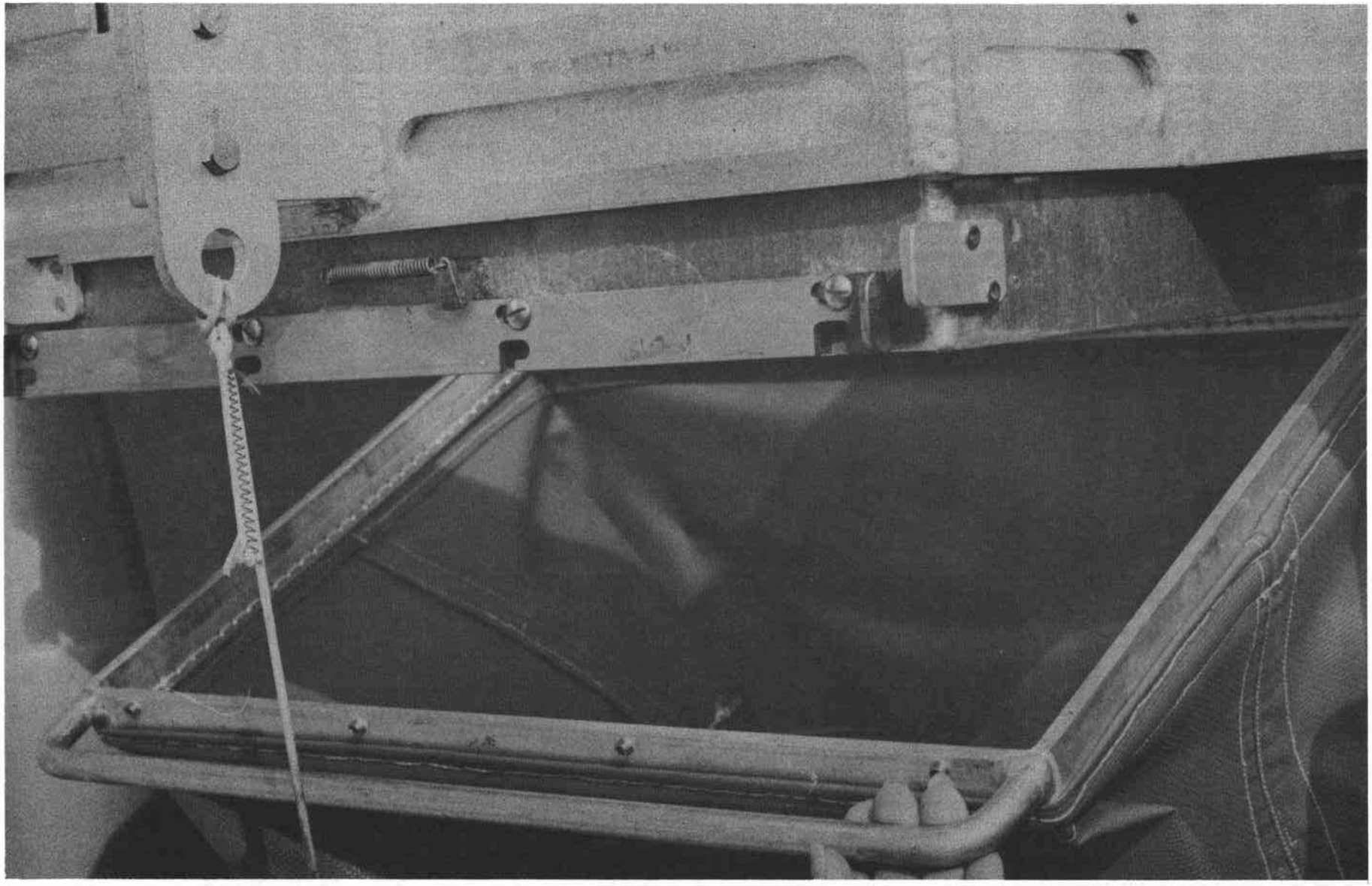


Fig. 15. Spring-held Bar Mechanism for Net Attachment to Surface Sampler.

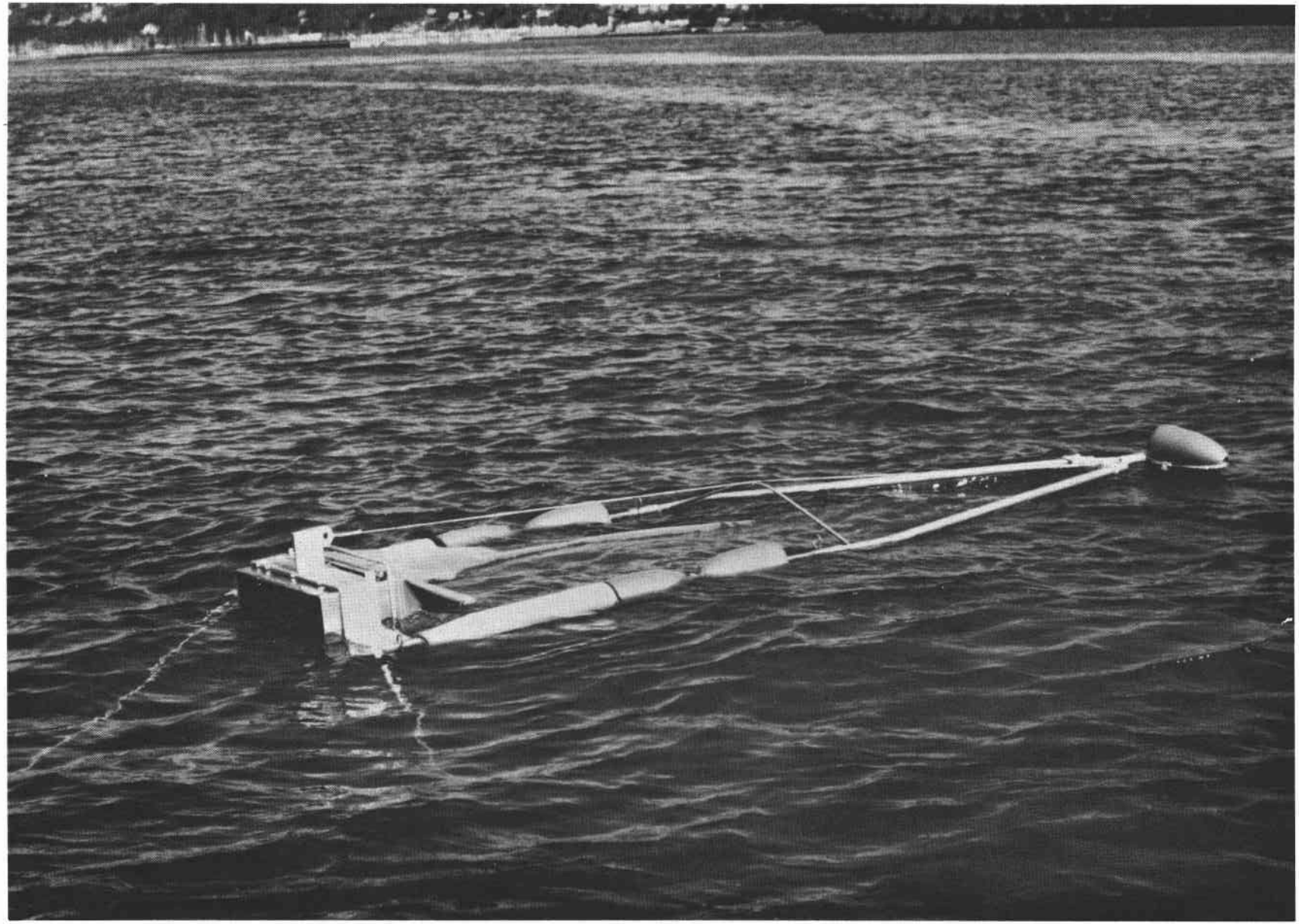


Fig. 16. Surface Sampler in the Water.

The tapered tail section forms a point where the cod end may be attached. The cod end is a brass bucket for a half-meter net with an eye welded to the top rear surface. It has a #6 mesh metal screen insert on one side to allow water to drain out. A snap attached to a rope connects the bucket to the tail section. A piece of 3/8 inch aluminum tubing forms a brace for the tapered tail section to minimize bowing of the frame.

The net is made of #6 (.233 mm) Nitex® mesh and is 245 cm long. The Nitex® was obtained from Tobler, Ernst & Traber, Inc. (P.O. Box 112, Elmsford, New York 10523). A 15 cm collar of Herculite® is attached at both the mouth and cod ends. The net has only two French seams running its length to minimize possible entrapment areas for the animals. The collar is hand sewn to the outside of the metal frame. A flexible steel band (hose clamp) securely holds the cod end of the net to the bucket.

A six meter long bridle of 3/8 inch Sampson® rope is used to tow the sampler. Shackles attach the bridle's spliced ends to the frame at the side and bottom extensions. The three ropes shackle to an aluminum plate with six holes along its length to permit fine adjustments in bridle length. The plate connects to the winch line by a swivel shackle.

This sampler is designed to collect zooplankton in the upper meter of the ocean. When positioned to sample the upper 15 cm of the air-sea interface, only qualitative samples may be obtained. However, when the box is completely below the surface, a flow meter may be attached to any of three different positions in the top of the box to give quantitative sampling. By towing off the side of the boat, samples are unaffected by the boat's passage through the water. In this way it is possible to obtain organisms, such as crustacean eggs, which are trapped in the surface scum, and harpacticoids, which live on floating plants and debris.

The towing angle of the sampler and the bridle length are critical in positioning the sampler. Best towing position is attained if the winch line is let out over a block set at least two meters above the ocean surface. This keeps the floats riding at the surface. Minor adjustments in the length of the bottom bridle rope will also greatly affect the towing attitude. If it is too long, the sampler will dive and if it is too short, the sampler will tow above the water. Also, when sampling at the surface, a float attached to the end of the tapered tail section helps maintain the sampler at a level towing position. When sampling at increasing depths, weights attached to the tapered tail section are needed to maintain the sampler's level position.

To obtain a sample, the sampler needs only to be brought up along the side of the boat and raised so the mouth of the net is out of the water to prevent back flushing. The net can then be removed by use of

the frame's handle, washed down, and the bucket removed and emptied. The entire sampler does not need to be brought aboard unless changing stations.

The sampler obtains the same organisms that would be obtained in a half-meter net. However, it also obtains an increased number of crustacean eggs and harpacticoids found in the scum and debris at the surface. It is easily handled by three people and is adaptable for sampling both in estuarine and nearshore regions. The surface sampler rides the top of the swells (does not cut through) permitting sampling at a constant depth - a feature not present in most plankton samplers.

Plankton Pumping System

The pump system to be described is designed for use aboard a small vessel while studying small-scale distribution of zooplankton or phytoplankton. However, due to its simplicity and adaptability, it may also be used in general plankton sampling. It incorporates a pump which is belt-driven off a hydraulic motor, a thermistor and a rapid filtering system. The pumping system in other forms and sizes has been used repeatedly in plankton sampling by Aron (1958), Barnes (1949), Cassie (1958,1964), Beers, Stewart and Strickland (1967) and Lenz (1972).

The pump is a Jabsco pump model 10490. It is a self-priming centrifugal-type pump with neoprene impeller which permits the animals to be pumped with little or no damage. The pump is run at 1000 rpm, producing a pumping rate of 281 liters per minute. This rate can be readily calibrated by pumping into a plastic garbage can of known volume. This rate varies insignificantly with pumping depth down to 20 meters, with a one-meter suction head. There is no apparent significant variation in flow rate during a pumping period.

The intake and outlet hose are two inch inside diameter plastic suction hose. This hose is Radial Flex Light Duty suction hose made by B.F. Goodrich, a combination of flexible PVC reinforced with a rigid PVC spiral. The hose attaches to the pump with standard quick connect brass fittings. The intake hose is lowered to the sampling depth with the winch line. A 45 kg weight is attached to the bottom of the winch line to maintain it in a vertical position. The hose itself attaches to the line.

The intake hose is marked off every meter with black electrical tape to determine sampling depth. A thermistor and the wire connecting it to the meter on board ship are taped to the intake hose. This makes it possible to record the temperature changes of the water at the intake. (See Fig. 17.)

The discharge hose empties into a filtering system which reduces the water flow rate. It uses two funnels to let out excess water held in a rack over the side of the boat. Two funnels set up side-by-side permit continuous filtering. While setting up one funnel, water may be filtered through the other. The filtering system is constructed as illustrated in Fig. 18.

The Nitex® used to make the inserts and later the net itself was ordered from Tobler, Ernst & Traber, Inc. (P.O. Box 112, Elmsford, N.Y. 10523). Openings were cut in the funnel and the mesh inserts glued onto the inside with Scotch super strength adhesive. Another

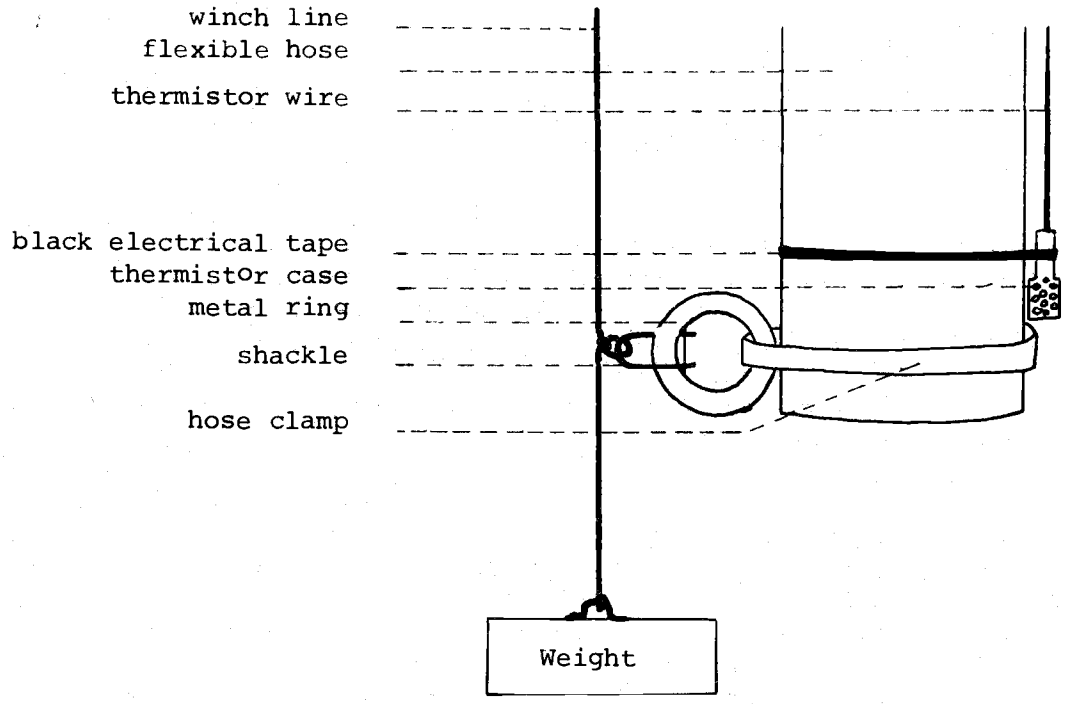


Fig. 17: Hose and Thermistor Attachment to the Hydrographic Wire.

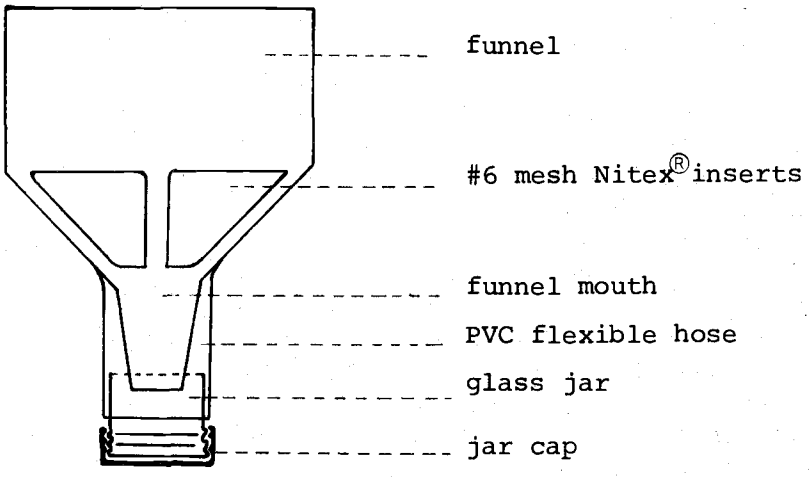


Fig. 18: Filtering Funnel in Plankton Pumping System.

layer of glue was applied to smooth out any irregularities formed by the Nitex® which would allow the animals to become caught.

The PVC flexible hose may be shaped to fit over the funnel and the jar by heating it in ethylene glycol for five minutes at 130°C. While warm, it is pushed onto the funnel (or jar) and allowed to cool into shape. It can then be glued into place with a strong, water resistant glue.

The sample jar cap with a 1 1/2 inch diameter hole in the center holds a two inch diameter disc of #6 mesh Nitex® onto which the zooplankton are trapped. A rubber gasket between the cap and the mesh disc supplies enough pressure to hold the mesh tight when the cap is screwed onto the jar. See Fig. 19.

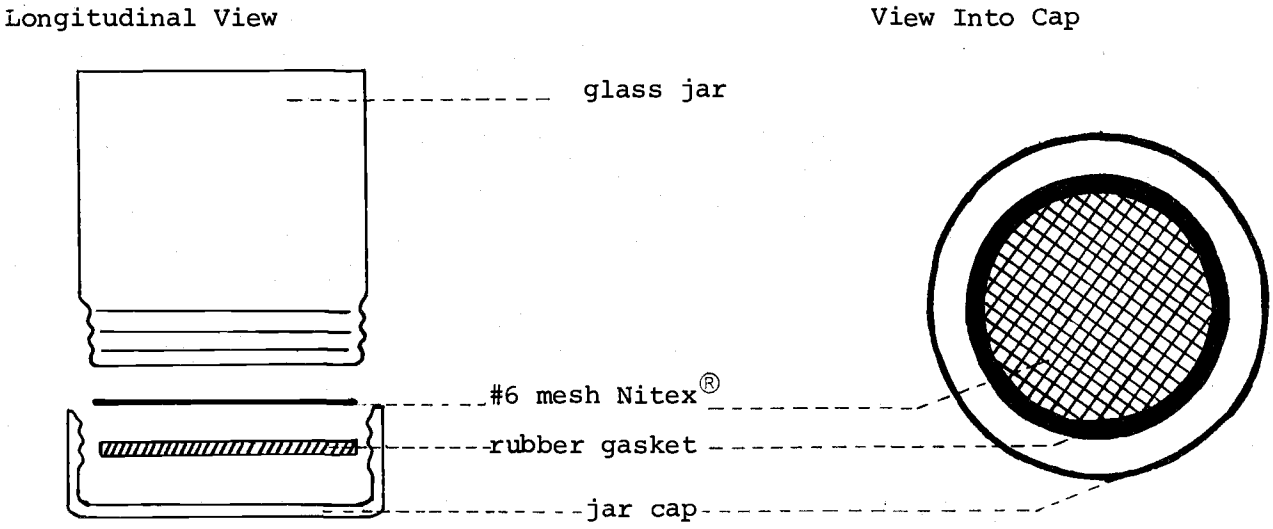


Fig. 19. Sample Jar and Cap for Plankton Pumping System

Samples are obtained by unscrewing the cap, removing the mesh disc and placing the disc in a sample jar with 10 percent formalin. Due to the fast flow of water and the tilt of the funnels on the side of the dory, the water is swirled around the funnel, thus continually flushing it. It is not washed down between samples. Animals do not appear to get caught on the funnel mesh.

Through its simplicity the entire system results in a rapid sampling (may sample every two minutes, depending on the size of the sample needed). The animals come through alive and in good condition for identification.

Patchiness Study

In 1972 the zooplankton studies centered around the use of a Clarke-Bumpus plankton sampler. Throughout the summer sampling was conducted repeatedly using the same stations, equipment, and standard methods (Holton and Elliott 1973). An expected change in numbers and species of zooplankton was observed which could be accounted for due to weekly and seasonal changes in the plankton populations. However, when replicate samples were taken, we found a greater variability than expected. Table III-1 of Appendix III shows the variability observed in the replicate samples of 1972. Improved navigation and more extensive standardization of methods failed to reduce this variability to any significant extent. This impressed upon us the need to study patchiness to determine whether it could be an explanation for the variability found in the zooplankton samples.

Literature Review

Throughout the century it has been recognized that density variations are a persistent characteristic of zooplankton sampling. This variability may be a result of the sampling method or a density variation in the population itself. Winsor (1936) noted that Hensen studied variability of towed net samples as early as 1887. Then little work was done on the subject until the 1930's.

Winsor and Walford (1936) were the first to study extensively density variations in copepod populations. As an assumption of their work, they described the zooplankton population as randomly distributed. The observed changes in density were ascribed to changes in the volume of water filtered in successive hauls. Because there was little variability between the widely different species , the idea of a nonrandom distribution was rejected. However, Winsor and Walford did indicate that a nonrandom distribution was an alternative explanation.

Later studies disagreed with the explanations postulated by Winsor and Walford. Ricker looked at the distribution of zooplankton in a freshwater lake. He found the density to be greater than the mean which implies the population is aggregated. (Referred to in Barnes 1951).

In 1938 Langford compared the mean and variance of a number of hauls at one station as well as over an area. He also found aggregation in populations. However, he indicated that although some organisms were aggregated, other animals maintained a random distribution.

Barnes 1949, used a pump instead of a towed net to look at the density variation of copepods. He found that if the volume of water filtered was maintained constant with a plankton pump, the variation was still observed. This indicated that the variation was not due to the volume of water filtered as Winsor and Walford indicated, but rather due to a nonrandom distribution of organisms.

Barnes continued his work with Marshall in 1951. They used a submersible pump in the channel between the Islands of Cumbrae and Bute (4° 55'W.,

55° 47'N.) to obtain samples and at the same time made salinity and temperature measurements. The data was analysed by fitting suitable mathematical models to the frequency distributions of sample counts. When temperature, salinity, and distribution of organisms were plotted on maps of the sampling area, it was found that, although they did not coincide, most population boundaries did lie within salinity boundaries. Very seldom did a population extend over a wide range of salinities. Therefore, Barnes and Marshall concluded that small changes in the physical properties making up the "microclimate" could explain the variations or nonrandomness found in the zooplankton populations. These boundaries may be sharply defined for some species, especially copepod nauplii. They also noted that at low population densities, a random distribution was closely approximated. However, this is a statistical artifact. Large densities show nonrandomness, but small densities statistically do not.

Cushing and Tungate, 1963, followed a Calanus patch for 5-8 days during 19 March to 4 June 1954. They were observing a patch of 30-50 km radius in the North Sea. The patches were plotted and their change with time illustrated by contouring the abundances of each life stage over a grid of stations. They found that the Calanus patch would retain its identity for 5-8 days at a time regardless of diffusion.

Cassie has done extensive work with nonrandom zooplankton populations. In the late 1950's and early 1960's he attempted to describe the zooplankton distribution and analyze it statistically. His data was taken by means of a plankton pump from Port Nicholson, an enclosed inland waterway in New Zealand. Cassie, 1958, indicated that aggregation is evident on three levels - megadistribution, 100's of meters; mesodistribution, 10's of meters; and microdistribution, less than 10 meters. He found temperature and salinity to be correlated with inhomogeneity for four reasons: First, both are biologically significant to the zooplankton population. Secondly, they are virtually independent of the organisms themselves because they are not changed by the population as are oxygen, carbon dioxide, and nutrient content. Thirdly, although temperature and salinity are variable in space, they are conservative properties of the ocean with respect to time. Finally temperature and salinity may serve as an index of the origin and past history of the water they describe (Cassie, 1959a).

Cassie (1959c) concluded that, especially as applied to microdistributions, two or more species may depend upon the temperature and salinity in the area. The temperature and salinity may also influence the distribution of a third species in an adjacent region. Temperature and salinity are not characteristic of a particular species or environment, because the same species may exhibit different relationships at different times. His data does indicate that the small physical changes in an enclosed island waterway may be on a scale large enough to affect the small-scale distribution of zooplankton.

Wiebe (1970) tried to obtain information on the size, shape, distribution, and density of patches on a scale of one to 100's of meters. He used a Longhurst-Hardy plankton recorder in the open ocean. The patches were observed to be essentially circular with a radius of approximately 13-16 meters during the day and 38-73 meters at night and were randomly distributed. The density

of the organisms within the patch was 2.6 to 5 times the background densities. He also found that organisms with a lower density more nearly approximated a random distribution as did Barnes.

Miller (1969) used a vertically migrating parachute drogue to study both patchiness and vertical migration of zooplankton. The drogue was an attempt to follow a zooplankton patch and thus reduce the variability of sampling. Net tows made near the drogue throughout its course were variable, however, making it appear that the drogue did not follow a patch. He also found only slow, steady changes in species composition of a patch from day to night instead of rapid, abrupt changes as were predicted.

Each study conducted previously has either been beset with problems or was conducted in a physical environment which in itself could cause patches. These problems leave doubt as to the basis for the conclusions drawn. Therefore, further study must be conducted to determine whether indeed patches occur and, if so, their dimensions. Cassie (1958) suggested that one way to look at the patchy structure of zooplankton was to use a stationary pump and allow the water to flow past the intake. This suggestion forms the basis for the patchiness study conducted during 1973.

Sampling Method

The plankton pumping system described above afforded the opportunity to look at patches with the method suggested by Cassie. Nets obtain integrated samples because they must be towed over a relatively long distance. When stationary, a pump can obtain samples from a discrete position, thus avoiding the integration which would mask the patches. It also permits sampling for short time periods -- a requirement necessary for obtaining a large number of samples in a few hours. By using the combination of a stationary pump, a large number of serial samples, and allowing the current and thus the patch to move instead of the boat, it was hoped that the problems underlying previous studies could be overcome.

After the hydraulic system had been installed on the dory and the pumps and motors were functional, we waited for the right day to sample. Weather was critical because the seas had to be fairly calm to avoid possible mixing of the zooplankton population and to reduce variations in sampling depth due to swell heights. October 5, 1973, was a good day and the sampling was conducted.

The samples were taken at a permanent buoy approximately 1.5 km offshore from Moolack Beach, north of Newport, Oregon. Sampling began at 1000 hours and ended at 1500 hours. This time period was chosen to minimize the effects of vertical migration of the zooplankters.

The PAIUTE tied up to the permanent buoy and immediately conducted a depth series to determine the depth of maximum abundance of zooplankton. A current meter was then set at the depth of greatest abundance to determine current direction. The dory then anchored parallel to the PAIUTE and the current, at a distance of 40 meters offshore of the PAIUTE.

A sextant reading from the dory determined the distance between the two boats. The pumping rate was correlated on both boats by pumping into plastic garbage cans to determine the rate. Both boats pumped 337 liters per minute throughout the sampling period.

Sampling began with a five second countdown to permit sampling at precisely the same instant on both boats. Water was pumped continuously into the funnel and the funnels were changed every two minutes. Countdowns were made throughout the sampling period to make certain sampling times were precisely the same on both boats. During the sampling a break was made to conduct a depth series checking for changes in the depth of maximum abundance. Another depth series was taken at the end of the sampling period. At the beginning of each two minute sampling interval, current meter and temperature readings were taken on the PAIUTE and temperature readings were taken on the dory.

The result of this one day of sampling was 235 samples with corresponding temperature and current meter readings. Two periods of sequential samples were obtained with an initial, an intermediate and a final depth series. The tide changed after the first sequence of sampling causing a gap in data and a 180 degree reversal in current direction. The first 50 pairs of samples have been analyzed and are the basis of the patchiness study.

Counting

In the lab, three samples taken at random throughout the series were counted totally to determine densities and species composition. Altogether, 22 species of zooplankton were observed in these samples. Subsampling was decided against because it would induce more variability within a sample than we expected to find between samples. Instead, only nine categories were counted; however they were completely counted in each sample. These categories were:

Acartia clausi female
Acartia clausi male
Acartia longiremis female
Acartia longiremis male
Oithona similis female
Oithona similis male
Pseudocalanus sp. female
Pseudocalanus sp. male
Pseudocalanus sp. copepodite.

These groups were chosen because of their high densities in each sample relative to the other categories. Sample #35 taken from the dory was one of the samples originally counted to determine densities. The data from this total count is shown on Table 2 of Appendix III. It also illustrates which other organisms were present in the samples. These categories also permit analysis of patches relative to life stage and sex as well as to species. It is normally found that more information can be derived if observations are

made at a species or near-species level, rather than at a more inclusive level of classification. These copepods could be more readily and specifically identified than the other groups observed in the samples. Therefore they were chosen in an attempt to obtain as much information on patches as possible.

Analysis

The counting of the samples was completed in January. Graphs of the numbers of organisms per sample vs sample number are presented in Appendix IV. The graphs in Appendix IV do seem to show that patchiness exists. There appear to be three patches in the sampling sequence. This is observed not only in the total numbers, but also in the density graphs of the individual categories. Because the densities of Pseudocalanus male were low and show little resolution, its graph is not included.

At this point we can only conclude that the graphs appear to show three patches. However, this must be verified by the statistical analysis which has just begun. A time series analysis has been suggested as a means of analytical study, but this decision will not be made until the raw data has been more closely examined. The current meter readings should make it possible to estimate one dimension of the patch and the interval of low density between patches.

For several reasons the results from this patchiness study would be of great use to power companies planning to build a plant on the coast. First, ecological monitoring required by law must be conducted by a method which minimizes sampling variability and thus reflects the true effects of a power plant. By knowing patch structure and indeed its existence, an attempt may be made more successfully to minimize patch effects on sampling. Secondly, the method of pumping samples as done in this study could be used in a power plant. Plankton samples could be collected quite simply and instantaneously by putting pumps in both the inlet and the outlet. By knowing patch structure, very precise timing of sampling could be attained. Thirdly, the pumping system itself can also make it possible to find the best depth for the intake. The key to all of this is to know whether patches occur and, if they do, to be able to detect them and to use the knowledge of their structure for planning sampling techniques, preventing misinterpretation of sample data, and also for determining the best depth for placement of the intake.

LARGE ANIMAL SAMPLING PROGRAM

The large animal sampling program was begun during the summer of 1973. The thrust of this portion of the project was twofold. The first was to evaluate the usefulness of various types of standard and modified gear to nearshore sampling from small boats. The second was to formulate and carry out sampling programs designed to evaluate particular aspects of the ichthyofauna of the study area.

Equipment Development

Initial attention was directed primarily toward bottom sampling. Bottom trawls can be successfully scaled down to dimensions which are manageable from small boats and remain efficient sampling devices for small adult and juvenile bottom fishes. The use of bottom trawls is limited primarily by the character of the bottom in a given area. Their use in this program is described in the section on distribution studies.

Set Gear for Bottom Sampling. A second effort was to develop gear which can effectively sample areas where the bottom is unsuitable for the employment of trawls. A system for efficiently setting and retrieving longline gear was developed which qualitatively samples adult bottom and near bottom fishes over rocky substrates and reef areas. Longlining was carried out through the summer in the rocky area offshore from Yaquina Head.

Initial evaluation of the use of bottom set gill nets was begun and methods for setting and retrieving them were worked out. We have recently obtained two experimental gill nets made of panels of graded mesh sizes which will allow us to evaluate the relationship of mesh size to species and size classes sampled.

Consultations with the National Marine Fisheries Service Gear Development Base in Seattle resulted in the loan of two of their deep water bottomfish traps to us for developmental work. We are presently in the process of evaluating their usefulness in our sampling program and considering modifications to improve their efficiency for the species which we wish to sample.

A fyke net (a hoop net trap with mesh wings to serve as leads) has been constructed and we are in the process of evaluating its usefulness to studying along shore and on and offshore movements of bottom fishes with currents, tides, and changes in environmental parameters.

Mid-water and Surface Sampling. Initial work has begun on developing gear to sample actively swimming fishes which are not captured by bottom trawls and other bottom oriented sampling methods. A modification of the British Columbia mid-water herring trawl was chosen and is currently being constructed. This net utilizes a set of four doors as hydrofoils and depressors to hold the net open when towed from a single boat. Work with this type of net by the California Department of Fish and Game indicates that it can readily be handled by boats of the size and power which we are using. This gear will be evaluated this winter and will be ready for use in a standardized sampling program by the spring of 1974.

A one meter net with mesh size of 0.5 mm is also under construction for the sampling of larval fishes and other micronekton. This net is designed to provide information on the early history of fishes whose later juvenile and adult stages are sampled with other types of gear. A modified net for the surface sampler developed in the zooplankton program is also being considered to adapt it for sampling ichthyoplankton.

Distribution Studies

Bottom Sampling. The bottom trawl sampling program was carried out during the summer of 1973 with weekly samples taken along tracks parallel to shore at 3/4 mile, two miles, and three miles offshore centered on the reference buoy positioned in the study area off Moolack Beach. Three types of trawls were used to evaluate their usefulness and relative sampling bias. The standard piece of sampling gear was a Marinovich 16-foot semi-balloon trawl (Model by Marinovich Trawl Company, 1317 E 1st Street, Biloxi, Mississippi). A 16-foot box trawl design and a 25-foot semi-balloon trawl were also utilized. One half inch stretch mesh cod end liners were utilized so that juveniles were retained. This sampling program very effectively sampled populations of juvenile flatfishes in the study area and provided quantitative data on flatfish and near bottom living round fishes present. Evaluation of the samples obtained in this program is presently underway. Appendix V. is a representative breakdown of one day's samples. This data is proving effective in evaluating the presence and strength of year classes of juvenile flatfishes present in the study area. Average growth rates within populations can be obtained from this data as can the role of this nearshore area in the life history of particular species. Of particular interest is the role of the nearshore region as a rearing area for economically valuable flatfish species such as the English sole (Parophrys vetulus) and the butter sole (Isopsetta isolepis).

Longlining was found to be a moderately effective method of sampling adult specimens of some species over both sandy and rocky bottoms. Some difficulty was experienced over rocky bottoms with the dropper lines snagging on outcroppings. On sandy bottoms longlining was found to sample large adult flatfishes and was also effective in catching large rays. In reef areas lingcod, rockfishes, and cabezons were taken in small numbers.

Evaluation of Bottom Samples. A major problem in evaluating data gathered by these and most other sampling methods is that of obtaining information on absolute abundance. Actively swimming animals are often able to avoid trawls and it is very difficult to obtain any kind of estimate of the magnitude or bias of that avoidance. Passive sampling gear, such as traps and set nets, rely on the animal catching himself which he may or may not do. Again it is difficult to evaluate what proportion of the population is sampled by the gear and the bias involved.

In the end result virtually all data must be considered relative and bias of particular methods inferred from comparison with other data. The approach we have taken is to employ a wide range of gear to sample various segments of the population and then determine those pieces of gear which are particularly effective in sampling certain portions of the local species complex. We are then in a position to make inferences about those elements not sampled by particular gear to avoid the mistake of estimating what is not present from its absence in particular samples. A tagging program is planned to provide further input in evaluating sampling gear bias.

While the examination of material taken by bottom sampling methods during the summer is not yet complete, some initial observations may be drawn. A complete list of species taken, with an indication of their relative abundance, is presented in Appendix VI.

Juvenile tomcod (Microgadus proximus) are abundant in the nearshore region of the study area. Individuals of average size, five to seven centimeters, were commonly taken by bottom trawls and are assumed to be year-class one individuals.

Sanddabs (Citharichthys sordidus and C. stigmaeus) are very numerous in the study area. C. stigmaeus is concentrated close to shore with C. sordidus occurring in greatest numbers two to three miles offshore. Adults and juveniles of all sizes are common and it can be inferred that both species undergo their complete life cycle in this area.

Butter sole (Isopsetta isolepis) juveniles are also very numerous in the area. Adults move inshore to spawn in the winter and the young fish move offshore again as they mature. Year-class one (average length about 10 cm.) and year-class two (average about 20 cm.) are numerous in bottom trawl samples.

English sole (Parophrys vetulus) juveniles are also common in the study area with year-class one and two individuals being frequently taken.

Multimodal size distributions within the size distribution of year classes was observed for both English and butter sole. This suggests that several populations of adults move into the area to spawn during different times in the winter and possibly early spring.

Year-class one dover sole (Microstomus pacificus) larvae were frequently taken in the offshore portion of the study area. A few juvenile and adult rex sole (Glyptocephalus zachirus) were taken in the same area.

Sand sole (Psettichthys melanostictus) adults and juveniles are common in the study area with the principle rearing areas for juveniles occurring close to shore.

Evaluation of Sampling Techniques. For the most part it is proving effective to use modified gear to fish from small boats in sampling the nearshore environment. One problem is the difficulty of sampling active adults. Small boats and scaled down gear effectively sample juveniles and smaller species and trapping programs can be handled, but the pursuit and capture of large, rapidly swimming animals may necessitate the use of larger vessels and gear.

The open jet-powered dory used during the last summer has proved its usefulness in the large animal sampling program. It is responsive and highly maneuverable. Coordination in the delicate process of setting and retrieving gear is more easily achieved than with larger decked boats. Final evaluation of the dory's full capabilities and usefulness awaits the installation of the main winch which will be complete by late winter.

BENTHIC SAMPLING PROGRAM

Equipment Development

Smith-McIntyre. The benthic sampling program began this summer with most of the preliminary work being conducted with the Smith-McIntyre grab sampler (Smith and McIntyre 1954). This particular grab samples an area of 0.1 m^2, with penetration depending upon the type of substrata being sampled. The areas we sampled were sandy with penetration remaining fairly constant at approximately 12 cm. Although the Smith-McIntyre is used successfully from the PAIUTE, it would not be useful from the dory because of its bulky form and weight. However, we do have a great deal of experience in using this sampler and therefore we feel confident in the quality of the samples we obtain with it. The sampling with it off the PAIUTE will provide a baseline for samples taken with other sampling devices being developed for use off the dory.

Dredge. Early in the summer of 1973 a dredge designed after the clam dredges used on the East Coast was constructed for our purpose. Initial testing of the dredge showed that it will work with a few modifications. We are presently fabricating a bag for the cod end which will enable us to further test its effectiveness.

Suction Dredge. Through the cooperation of the Oregon State Fish Commission we were able to test the effectiveness of a Venturi Suction Dredge (see Figs.20-21). A similar sampler based on the same principle as the Venturi has already been used successfully for collecting benthic organisms in Florida. (Allen et al. 1970). The Venturi requires the assistance of two divers and at least one man on the dory to operate the pump. The dredge we used sampled an area of one square foot by two feet deep. We feel the dredge will be a valuable sampling tool that can easily be handled from the dory. However, because we worked with the dredge for only a limited period of time, it is impractical to make any definite statements about our sampling results. (See Appendix VII for a summary of dredge samples).

Crab Pots. The use of crab pots as a means of sampling the epifauna was another area developed by the Benthic program. We modified the commercial crab pot, making it lighter and reducing the mesh size to 2 inches. The success of this gear as an effective quantitative sampling tool cannot be determined at this particular time. More pots and more work with the pots must be completed before any judgments can be made. In order to better understand the movements of crabs, we will attempt a tagging procedure and also will require some observations by divers.

Sampling Results

Immediately following a grab, the sample is washed with seawater through a .495 mm sieve. The organisms retained on the sieve are preserved and stored for future identification. We had experimented with sieves as large as 2 mm but found that with these larger sizes there was a substantial loss of organisms.

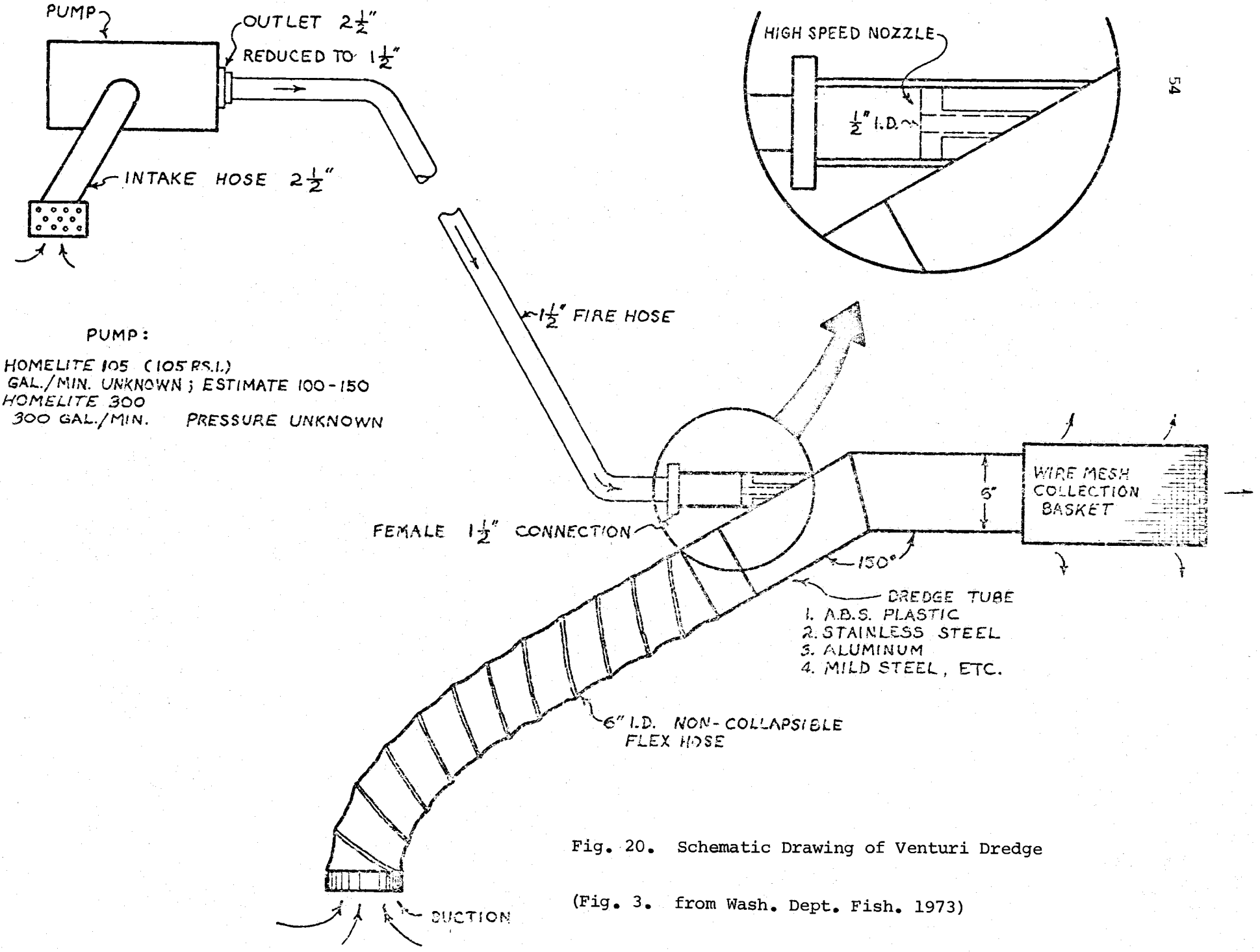


Fig. 20. Schematic Drawing of Venturi Dredge

(Fig. 3. from Wash. Dept. Fish. 1973)

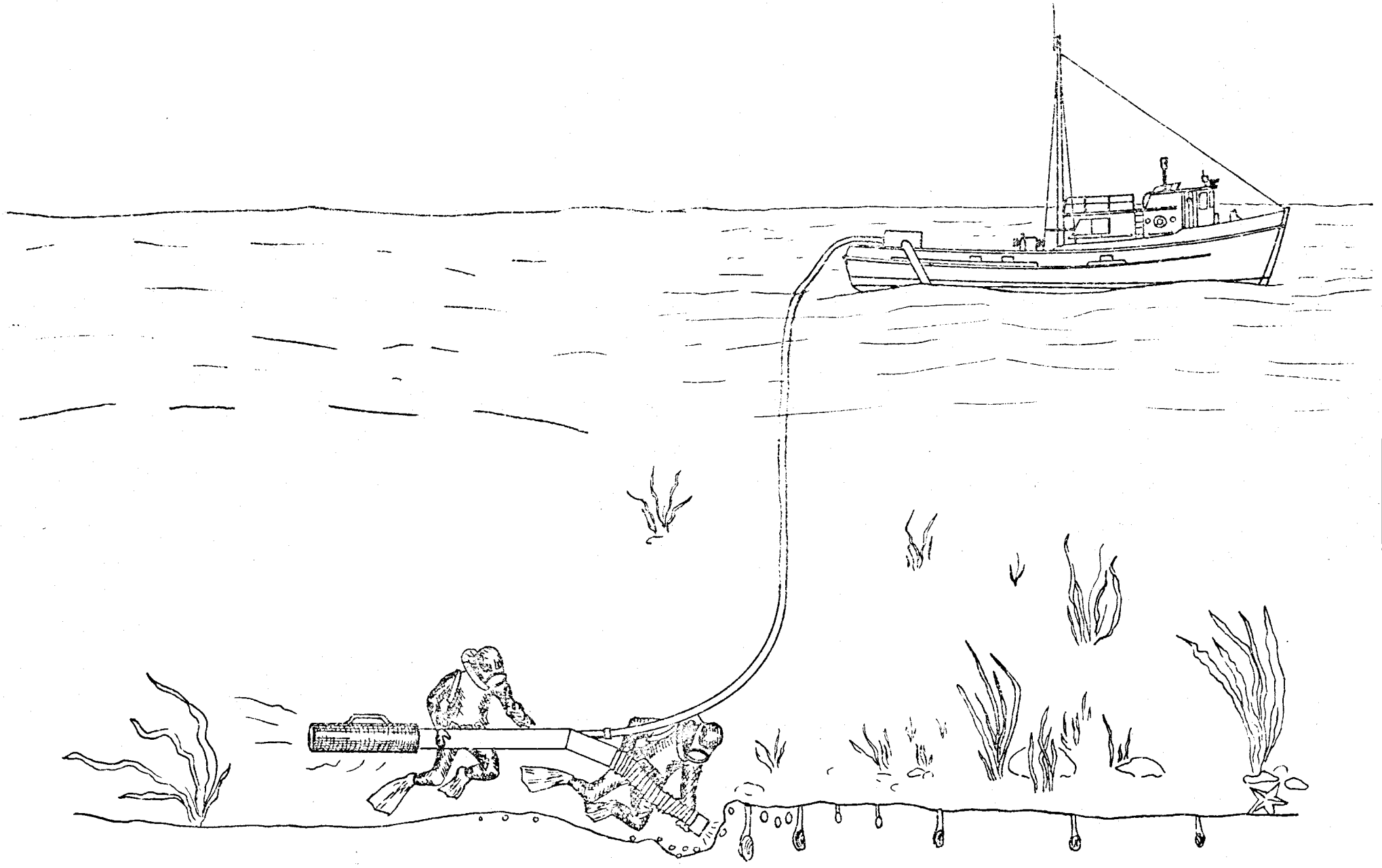


Fig. 21. Divers With Venturi Dredge Sampler.

(Fig. 2. from Wash. Dept. Fish. 1973)

A total of 11 stations were sampled during the summer of 1973 with the majority of them coming from the nearshore area between Yaquina Head and Otter Rock. (See Fig. 22). Other stations included those taken in waters off Yaquina Head and Cape Foulweather. In order to decrease the amount of error that might be encountered through the movement of the boat and the handling of the Smith-McIntyre, a minimum of at least five samples per station was essential. Although examination of all samples has not yet been completed, there are noticeable differences from station to station in the types of organisms found. For example, stations 2, 3 and 9 produced many more gastropods than did stations 6, 7, 8 and 10. Station 11 had very few organisms as compared with other stations. (See Appendix VII for a summary of organisms).

We feel that a more intensive sampling schedule with the Smith-McIntyre is required in order to arrive at any definite conclusions.

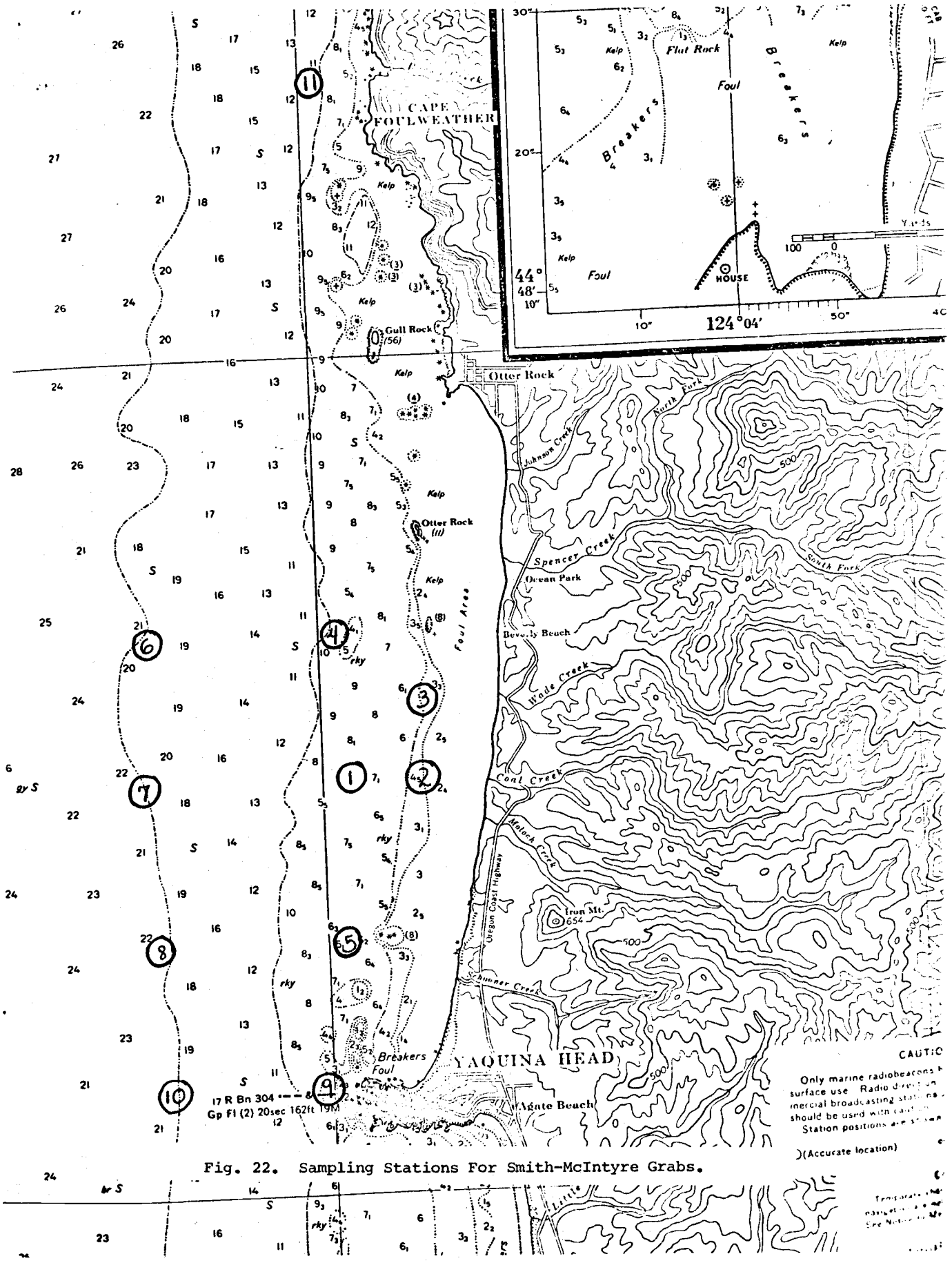


Fig. 22. Sampling Stations For Smith-McIntyre Grabs.

THERMAL EFFECTS STUDIES

Development of Thermal Effects Laboratory

Physical Characteristics:

A space approximately 20 feet x 20 feet x 15 feet high was made available to the project for development into a thermal effects laboratory. Walls bounding the space were lined with 2 1/2 inches of fiberglass insulation and covered with masonite pressed wood. The ceiling was spanned by 2 x 6-inch beams at a height of 9 feet and similarly lined with insulation and covered with pressed wood. Insulation was used to help maintain a controlled atmosphere within the space; pressed wood has superior water-resistant characteristics. The walls and ceiling were then painted with two coats of epoxy "Ro-Pon" paint to reduce the effects of humidity and to provide a light background color to the room to increase light reflectivity. It is important to maintain even lighting in a laboratory where larval forms are being studied because most larvae are sensitive to light and dark patterns within their environment. Six double-tubed, 48-inch long flourescent light fixtures were suspended from the ceiling to provide even illumination to all water tables.

Six water table stands were constructed out of 2 x 4's and 4 x 4's. Each stand is 2 feet wide, 8 feet long and 7 feet high. Each stand has a lower storage shelf and two upper shelves for holding water tables. The water tables were constructed of 3/4-inch exterior A/C grade plywood and flat-headed brass wood screws; each table is 2 feet wide, 8 feet long and 6 inches high. The tables were coated on the outside with epoxy paint and given four coats of polyester resin on the inside. All inside edges were covered with fiberglass prior to the application of the last two coats of resin. Each of the 12 tables holds approximately 65 gallons of water.

A seawater distribution system consisting of grade 1, type 1 Schedule 80 PVC plastic piping was installed in the laboratory. Running seawater is supplied to each water table at a capacity of approximately 5-10 gallons per minute. A drainage system which permits great flexibility in the placement of drains, and thus optimum use of the space within each table, was also installed. The drain system consists of Schedule 40 PVC piping.

A work shelf and a sink with hot and cold running freshwater were constructed along one wall of the room.

The accompanying overhead diagram (Fig. 23) of the room shows the distribution of the water table stands within the room and the location of the work shelf and sink. Included in the diagram are lines indicating the position of the running sea water system (drainage system not included) and the distribution of electrical power within the room.

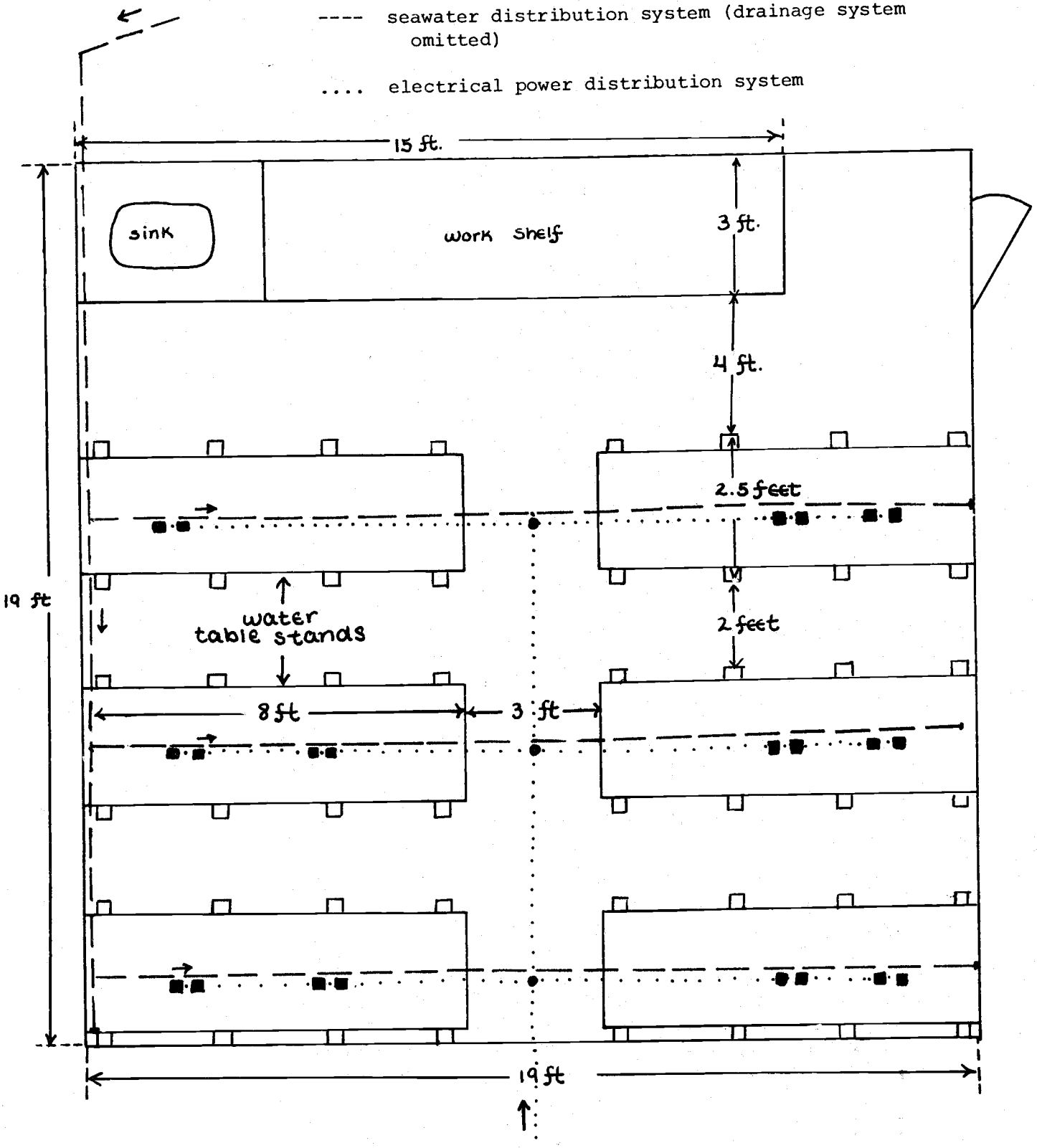


Fig. 23: Overhead Diagram of Thermal Effects Laboratory

Capabilities:

The water tables provide almost 200 square feet of research space serviced by the seawater system and electrical power. It will be possible to run concurrently a number of studies in the laboratory. It is estimated that the Cancer magister larvae studies will use about 20-25 square feet of seawater and power-supplied space; it may be assumed that perhaps as many as 5 or 6 similar projects could be in progress at the same time within the lab. Both the seawater system and the power distribution system have been designed to provide adequate service for this situation.

Invertebrate Larvae Studies

It is generally recognized that potentially the most profound effect of thermal addition may be that inflicted upon larval forms (Costlow and Bookhout, 1969; de Sylva, 1969), although detrimental effects on adults are known to occur (Pearce, 1969). The larvae of marine animals are typically more sensitive to temperature changes in their environment than are adult forms; they cannot move from an area of increasing temperatures as readily as the adults, and adult organisms usually can survive wider temperature fluctuations than their larvae (de Sylva, 1969). Thus, it is quite possible that the effects of thermal addition would not be seen in terms of an immediate reduction in the number of adults of a species, either by direct mortality or due to migration from the area, but, rather, due to a reduction in the number of larvae of that species leading, after a number of years, to a reduction in the adult population as fewer larvae reach adulthood.

A search of the available literature through September, 1973, concerning the effects of thermal additives on the growth and development of marine vertebrate and invertebrate larval forms revealed a general lack of information. Several papers were found dealing with the effects of thermal additives on adult freshwater and marine fishes, but few were found dealing with the larval development of important marine species from the northwest coast of the U.S. Several important books and articles dealing with the general topic of biological effects of thermal pollution are listed in Appendix VIII.

Because effects are more likely to be seen with larvae rather than with mature animals, it is apparent that research directed towards the biological effects of thermal addition should begin with an examination of such effects on the larval forms of marine organisms from the general area under consideration. The marine animals selected should meet several criteria: a) they should be fairly abundant in the area under study, thus having an important role in the ecosystem; b) their larval forms should be well known and capable of being cultured under laboratory conditions; and c) the organisms should be of some economic importance. Several marine animals meeting the above criteria are under consideration, including northern anchovy, Dover sole, razor clams, oysters and Dungeness crab. The Dungeness crab, Cancer magister, will be examined first as it meets all of the above criteria, and it is an animal of current concern along the Pacific coast of the U.S. Research studies involving two or three of the other animals listed above will be developed and initiated during the next 12 months.

Current plans for research include studying thermal tolerance ranges, mortality rates, growth rate and activity rates of C. magister larvae under controlled laboratory conditions. Such a program will probably take about two years from the start of the laboratory research to completion. Dungeness crab larvae, like all marine vertebrate and invertebrate larvae, are available only seasonally. It is anticipated that two periods of availability will be necessary to complete the proposed research.

Successful conclusion of this research program will provide data on the effects of various temperature regimes on the development, growth and activity of a variety of marine larval forms. Such data would prove valuable in determining temperature changes that may or may not be tolerated by the larval forms examined, and in providing a general picture of the overall impact a heated water outfall may have on the faunal assemblage of the affected area.

Zooplankton Thermal Studies

From a biological point of view, one potentially important physical parameter of the nearshore zone is water temperature. The influence of above normal temperature and temperature changes on zooplankton are of particular interest. Zooplankton occupy an important position in the food web. Because of this, any external influence which manifests itself as a change in the composition of the zooplankton of an area could be felt throughout the system. It has been shown by McLaren (1965) and several others that such factors as body size, egg size, rate of development, fecundity and mobility are affected by temperature. Despite this"general" knowledge, very little is known about the "particulars" for more than a handful of species. In addition, what studies have been conducted on this type of problem may or may not contribute directly to an understanding of the situation on the Oregon coast. By far the majority of these studies have been conducted on Atlantic or even fresh-water species, which could differ considerably from their nearest Oregon relatives, which have evolved in an environment with a very different temperature regime.

In a review Jensen et al. (1969) state that the sudden changes in temperature which an organism experiences may have as great an effect on it as do the extremes of temperature. However, this review of the literature did not cite any study as having been done on this problem in the last fifteen years. Such a study could easily be undertaken and its results could be helpful in gaining an understanding of the nature of thermal stress. Toward this end, work on culturing methods for various species of copepods was begun late in the summer of 1973. The work centered around the culturing of harpacticoid copepods. These require a minimum of space and equipment. The equipment consists of four glass aquaria with volumes of two-to-four gallons each. It was found that it was not necessary to pump air into the tanks so long as the water surface was permitted free access to the atmosphere. The copepods are fed a combination of dried algae from the ocean and cracked wheat. At present, the cultures have survived for over five months and (although generations are not discrete) have produced at least three generations.

As increased laboratory space becomes available, it is anticipated that calanoid copepods will also be cultured. Much of the work on methods of

culturing these organisms has been reported in the literature and several references are included in the bibliography on marine zooplankton presented in Appendix IX. However, the specifics of culturing each species must be mastered as work is begun on it.

Some work on the effects of sudden temperature changes on estuarine copepods has recently been done in Chesapeake Bay by Dr. D.R. Heinle. Several of his works have been cited in the appended bibliography. Dr. Heinle has perfected several experimental methods and laboratory techniques during his studies, and it may be very instructive to duplicate some of his procedures. Because one of the copepods with which he worked (Acartia tonsa) is found in Oregon's estuaries as well, some basis for comparison between East Coast and Oregon species might be determined in this way. Also on the practical side, recent advances in the art of "vital staining" (Dressel, Heinle and Grote 1972) may provide the means by which far greater numbers of zooplankton can be effectively handled in thermal stress experiments. The dyes used in this technique stain only those organisms which are living at the time the dye is added. Consequently, the sample may be separated at some later time into its "living" and "dead" components.

CURRENT STUDIES

Horizontal Variation of Surface Currents

As discussed in the last Progress Report (Holton and Elliott 1973), we made a series of drogue measurements in January off Yaquina Head. The data shows clearly that, in this case, there is a sharp separation in flow regime between the very nearshore area and the offshore area. We were able to calculate the divergence of the surface waters by calculating the change in the area enclosed by the drogue positions as a function of time. By making some plausible assumptions concerning the depth of this effect, we can estimate an upwelling speed of between 0.05 and 0.1 cm/sec. This figure is fairly large when compared with estimates of upwelling speed based on long-term measurements, but may well be in the correct range for this time scale.

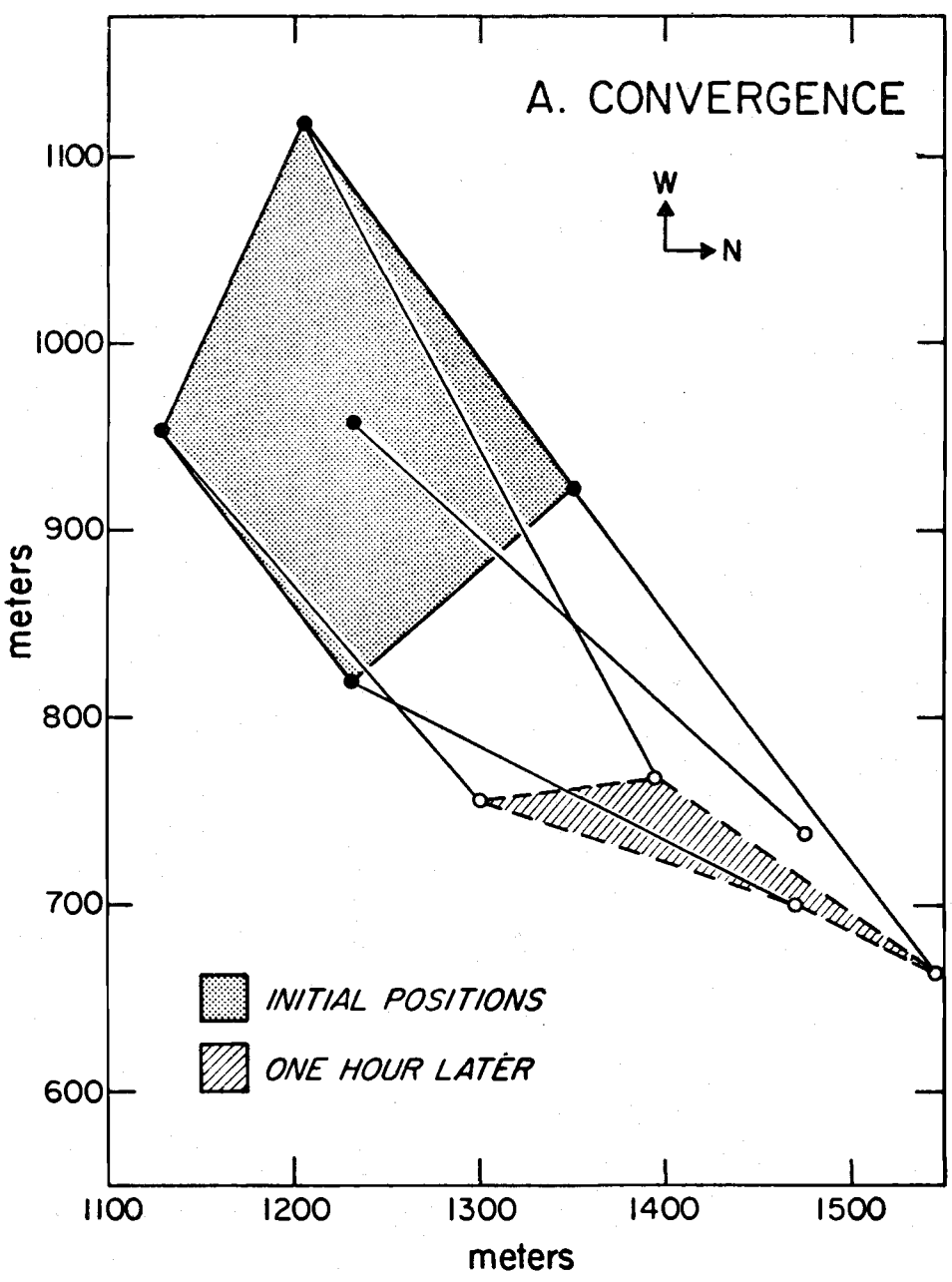
On 31 August 1973 we set out two separate diamond-shaped patterns of five drogues each, 950 meters off Moolack Beach, as shown in Fig. 24 , and monitored the change in shape of these. The two sets were laid out from a dory approximately 800 meters apart, as nearly at the same time as possible. The results are surprising and somewhat disturbing. One set of drogues showed clearly a convergence, while the other diverged. This shows that regions of small scale convergence and divergence exist in the surface water. They are transient features, not likely to be found at the same location at different times (although underwater topography may well produce preferred locations).

To investigate this problem further and to define better the whole flow in the nearshore zone, two massive drift-bottle experiments were conducted. On two separate days in August we dropped 720 bottles, one half on each set of the tide.

It is these data that are still being analyzed, along with some simultaneous current meter data taken on the second day. Computer programs have been developed for handling the massive amounts of data and they are being processed. Some tentative conclusions may be drawn at this point. As was suspected, the mean surface currents within a mile or so of the beach seem largely dominated by the local wind conditions. The fact that nearshore the surface current was toward the beach implies not only wind dominance, but also that there must be a return current toward the ocean to preserve continuity. We hope our analysis will be able to find these regions; however, it may well be that the dominant return flow occurs as an undercurrent, rather than as a surface current. A rip current system could well account for the necessary continuity, and probably does in the surf zone. Further seaward a slow undercurrent may well exist.

Discussion

The implications of these possible patterns of surface current flow for the distribution of organisms are many. Local areas of convergence



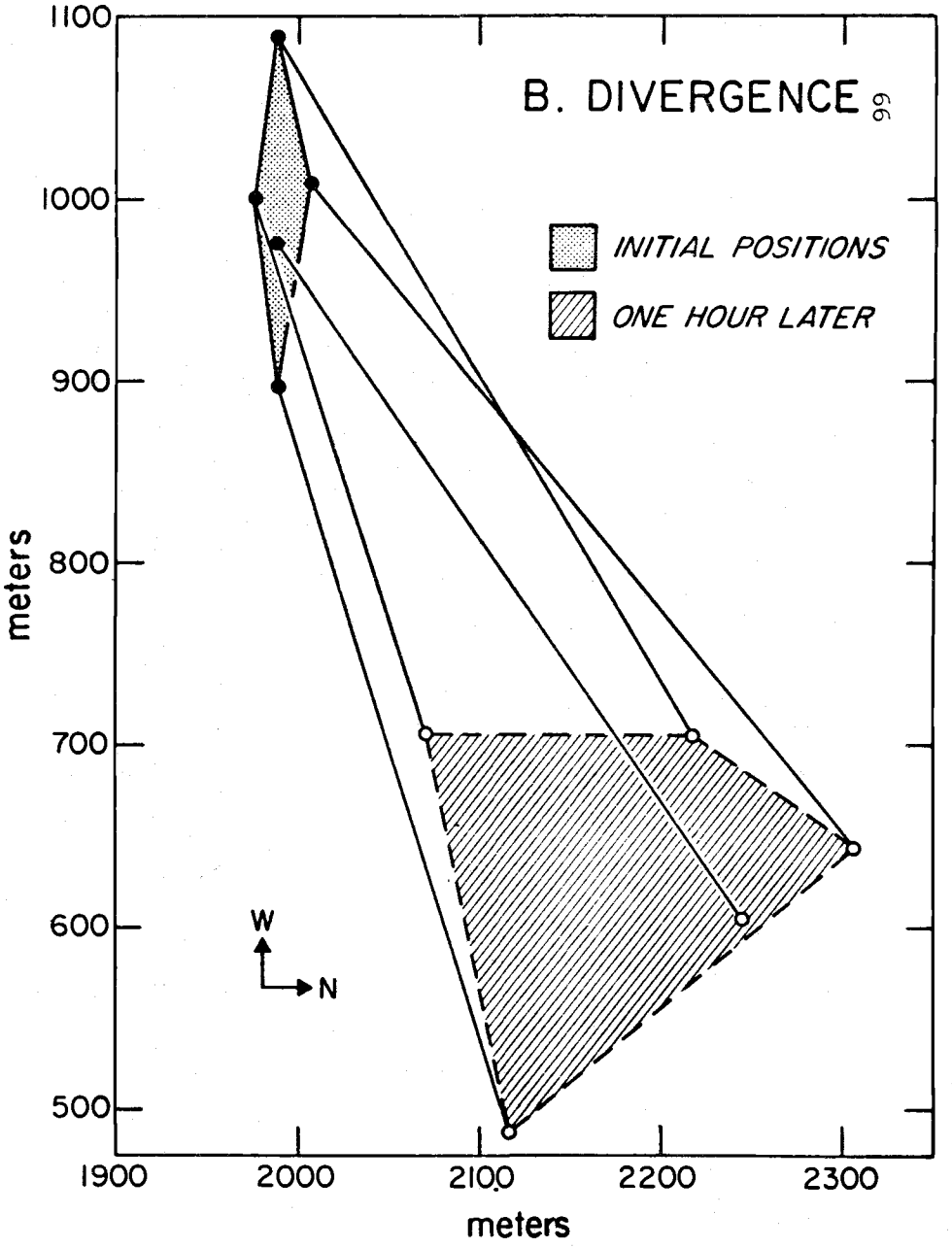


Fig. 24: Drogue Patterns.

and divergence could account for some of the patchiness found in the distribution of the biota. Whether the local upwelling and downwelling patterns implied by these can influence local nutrient supplies, or whether they occur too rapidly to influence productivity, remains to be seen. The effects of a seaward flow at mid-depth may also influence the distribution of organisms and may possibly indicate preferred locations for introducing an effluent so as to be most readily carried seaward.

Bibliography and Literature Review

We have surveyed the literature for various techniques applied by others for current measurements in the nearshore region. We paid particular attention to those methods that could be used from aircraft in order to avoid the problems of operating with small boats in this difficult region, particularly in winter. The following paragraphs discuss some of the more relevant papers and a select Bibliography is provided in Appendix X.

Drift bottles, dye markers, and drogues of assorted sizes, shapes, and materials have been the most popular Lagrangian methods of current measurement because they provide consistently informative data. Waldichuk (1970) compiled the most comprehensive report of surface tracers available with an excellent summary of their behavior in the water, appearance in black-and-white film, advantages and disadvantages to their use, and additional references for each material. Included in the collection are drogues of plywood panels and polyethylene sheets, paper strips, water-filled balloons, foam (both natural and artificial), dye (in solution or package form), oil film, wood chips, aluminum powder, river silt, and industrial effluent.

The use of dye is becoming more frequent, due to the many ways of successfully introducing it into the water, its utility as an easily-visible current and diffusion tracer, and its low cost. It is, however, easily dispersed by turbulence, making the time scale of the study the most critical consideration.

Ship-borne fluorometers have been used with reasonable success to continuously sample dye concentrations (Noble and Ayers 1961; Fisher 1966). The method does give an estimate of dispersion of the dye and has the advantage of making depth sampling possible, but inaccuracies are introduced by the ship's motion through the patch.

One of the most interesting approaches to the problem of dye tracing was made by Ichiye and Plutchak (1966) by testing a new method for determining dye concentrations. Black and white aerial photographs were taken of floating dye patches, measured with a densitometer, and calibrated with measurements taken simultaneously by a shipborne fluorometer. This method has the special advantage of providing a rapid succession of synoptic pictures of the entire dye field, but is necessarily limited to surface measurements.

The use of aircraft is now being recognized as the fastest and most versatile means of data gathering in coastal areas. As mentioned above, when used for aerial photography, it is capable of giving a truly synoptic picture of the area included in each photograph, and its speed makes possible the recording of short time scale phenomena--a distinct advantage in the study of coastal processes. Horikawa and Sasaki (1973) have extended the method by the use of a tethered balloon and a helicopter as stable air-borne platforms for stereo photography.

Aircraft are also being used for more than aerial photography (Burke 1972). Richardson, White, and Nemeth (1972) have developed an expendable dye probe to be launched from fixed-wing aircraft. The probe consists of a surface marker and two weighted, buoyant markers which are pre-timed to release their weights and float to the surface to dispense dye. If depth and the rates of descent and ascent of the markers are known, the transport unit width may be calculated from a measurement of their surface separation. Kielhorn, Richardson, and Burke (1971) have also experimented with the use of an expendable bathythermograph modified to be used from fixed-wind aircraft. The modification is simply the use of three-conductor wire with one of sufficient length to remain in the plane to be attached to a recorder. It was concluded that both of these techniques are especially applicable for use in areas difficult for a research vessel to reach.

Another interesting method of current measurement from aircraft was used by Sharikov (1969). Stereophotographs of dye traces released by weighted probes were used to determine the depth changes with time of characteristic and easily identified points on the trace. However, this method is time-limited by the dispersive characteristics of the dye and also requires relatively clear water in order for the dye trace to be seen at depth. The latter especially limits its value in Pacific Northwest coastal studies.

Stafford (1972) reviewed the current use of aircraft in coastal studies and offers a very thorough coverage of the most informative techniques: black and white and color aerial photographs, black and white and color infrared aerial photographs, multispectral aerial photographs, satellite photographs, infrared imagery, multispectral imagery, and radar imagery. It is an excellent and complete summary, giving a brief description of each technique, its particular use in coastal surveys, advantages, limitations, and many additional references. Also mentioned as a new development with excellent potential in aircraft hydrodynamic surveying is an airborne fluorometer, currently undergoing improvements. To these Nelson (1969) adds satellite interrogation of moored data buoys and includes photographic illustrations of the use of an infrared line scanner and color aerial photography in eddy detection.

A similar, but less comprehensive, report on recent developments in aerial remote sensing by Magoon and Pirie (1973) does, however, provide more specific information on the use of multiband photography, an infrared scanner, and side-looking airborne radar. In addition, methods of processing to make such data more available and useful are discussed (multiband camera film viewer, additive color viewer-printer and data color system).

Aside from aerial remote sensing, a system specifically for use in nearshore areas has been developed and described in detail by Lowe, Inman, and Brush (1973) using moored sensor transmitting to a portable shore recording station. The Shelf and Shore (SAS) system is composed of up to six offshore stations, each containing as many as 15 sensors (digital wave staffs, absolute pressure sensors, and electronic current meters are reported to be frequently used) which send simultaneous digital transmissions to the portable data processing center on shore. This system has been tested and found to endure adverse conditions in shallow water very successfully.

At the present time current meters are still of limited use for surface current measurement in very nearshore areas. Olson (1967) reviewed the types of current meters available at that time: acoustic, impellor, electromagnetic, drag force, savonius rotor, and thermo-anemometer, and evaluated their usefulness in shallow water. Of these, he found the electromagnetic to be most promising.

Appell and Woodward (1973) have summarized the most recent advances in current meter technology: vortex-shedding, electromagnetic, acoustic - doppler, and vector-averaging meters. The first three are extremely sensitive and, at their present stage of development, much too responsive for use under the turbulent conditions of the nearshore zone. The vector-averaging meter is an improvement on the well known Savonius rotor current meter and does eliminate some of the errors of this instrument. This device samples the current every one-eighth turn of the rotor and averages these over a predetermined time. This system, while given a much better indication of the prevailing current direction, still obtains the current magnitude from a rotor and is thus still susceptible to the inaccuracies of that mechanical device.

The problem with using current meters in the nearshore zone lies as much with the mooring design as with the sensitivity of the instruments, particularly in surface current measurement in relatively shallow water. The mooring systems described by Filimov (1965) for use in measuring nearshore currents are reported to withstand even storm conditions and are constructed out of easily obtained and inexpensive materials. There are two methods: 1) an anchored frame resting on the bottom with the current meter suspended inside, and 2) a float held in position by three anchors with the meter vaned and suspended below the float. However, they can be of only limited use in detecting surface currents in the shallow ocean margins due to the sometimes dramatic changes in sea level in a very short time (one-half tidal cycle). They are excellent for use in areas of minimal tidal range to measure subsurface currents.

The Secchi disk, one of the earliest means of measuring turbidity and estimating extinction coefficients, has been tested against a relative irradiance meter and a one-meter-path-length beam transmittance meter (Holmes 1970) with good results in each case. The extreme simplicity of this device is its most attractive asset, but also the cause of the mistrust surrounding it. In his tests with it in the Central and Eastern

Pacific, Graham found that, if taken together with the Forel-Ule ranking of water color, he could consistently obtain a reasonable estimate of the extinction coefficient (Graham 1966).

Radioactive isotopes, both artificial and naturally occurring, have been used in longshore current studies, including water-mass and offshore current tracing, as well as for littoral sand transport. The research of Kamel (1962) is of interest for the use of the natural radioactivity introduced at discrete points along the California coast by thorium-rich granite outcrops. In addition to his own research efforts, he includes an extensive summary of prior littoral drift studies using radioactive tracer techniques.

The research by Neal, Keene, and Detweiler (1969) represents a first effort in comprehensive nearshore surveys of the Pacific Northwest. Many methods of current measurements were successfully adapted for use in this environment, with most emphasis on those methods which were both inexpensive and provided useful information and taken together with salinity, temperature, dissolved oxygen, tidal, wave, meteorological measurements. Drift bottles injected from shore and an aircraft launched dye marker system were used together with aerial photographs for current tracing with the most success.

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APPENDICES

APPENDIX I: Chlorophyll Data

PART A: Day Series

The data presented in this section of the appendix shows precisely how the data is developed from the field to the final computer print-out. The sampling was done in the van and consisted of a time series study. Replicate samples in groups of six were obtained and represent the following:

1 - 6 - from bucket #1 - filtered immediately
7 - 12 - from bucket #1 - filtered after 1 hour
13 - 18 - from bucket #1 - filtered after 2 hours
19 - 24 - from bucket #2 - filtered immediately
25 - 30 - from bucket #2 - filtered after 2 hours

The first form presented is the field data form showing the information written down during filtering in the van. The second form shows the spectrophotometer readouts obtained in the laboratory. The third sheet shows the readings of chlorophyll content obtained from the computer. Scor-Unesco chlorophylls A, B, and C. and Total A are the categories analyzed in studying the data. The last page is a table of the statistics on each set of replicates. The mean, variance, standard deviation, standard error of the means, and coefficient of variation are calculated for each set of samples.

CRUISE IDENTIFICATION Moolack Beach OBSERVER C. Mullikin DATE July 26

station no. or coordinates	time of day	depth	bottle no.	fluorometer reading	pigments: filter no.	pigments: vol. filt.	pigments: time filt.	remarks
	11:15	0	1		1	1 l.	11:32 11:34	broken filter
			2	#1	2		11:35 11:37	
			3	run	3		11:38 11:40	
			4	immedi-	4		11:42 11:44	
			5	ately	5		11:46 11:50	
			6		6		11:52 11:54	
	12:00		1		19		12:07 12:0	
			2		20		12:12 12:14	
			3	#2 run	21		12 12:19	
			4	immedi-	22		12:20 12:22	
			5	ately after	23		12:55	
			6	bucket	24		12:31	
			7		7		12:32 12:34	
			8		8		12:35 12:37	
			9	#1	9		12:40	
			10	1 hour	10			
			11	after	11			
			12	collection	12		1:55	
			13		13			
			14	#1	14		1:37	
			15	2 hours	15			
			16	after	16		1:45	
			17		17			
			18		18		1:54	

CRUISE IDENTIFICATION Moolack Beach OBSERVER C. Mullikin DATE July 26

station no. or coordinates	time of day	depth	bottle no.	fluoro-meter reading	pigments			remarks
					filter no.	vol. filt.	time filt.	
	2:00	0	12		25	1	2:10	
			13		26			zooplankton on filter
			14	#2	27	1		
			15	2 hours	28			
			16	later	29			
			17		30		2:30	

Pigment Content of a Phytoplankton Crop, Moolack Beach, July 26

OSU 1450

	750	665	645	630	510	480	750 after acid	665 after acid
1	96.8	14.1	61.0	62.0	48.8	13.9	87.1	19.0
2	94.0	8.0	51.9	52.8	35.1	5.0	79.1	11.0
3	95.9	10.1	56.2	57.9	41.9	9.0	86.0	14.5
4	96.0	10.8	57.0	58.0	43.0	9.0	86.0	16.0
5	94.5	7.0	51.1	52.2	35.9	4.9	79.1	10.1
6	95.1	7.0	52.0	53.0	36.0	5.5	84.6	11.1
7	96.0	7.9	53.0	54.0	37.9	6.1	85.0	11.5
8	92.0	7.0	50.2	51.2	36.0	6.0	82.0	11.0
9	92.8	8.1	51.9	52.2	37.0	6.6	79.1	11.9
10	95.9	8.1	54.0	55.0	38.1	7.0	83.9	12.0
11	95.0	7.5	52.5	53.1	37.0	6.5	82.0	10.9
12	95.1	9.0	54.9	55.0	38.0	6.1	82.1	12.1
13	96.2	8.2	54.0	55.5	39.2	7.2	83.8	12.5
14	95.1	8.0	53.0	54.1	38.8	7.2	83.1	12.0
15	96.0	8.0	52.9	53.5	36.8	5.8	82.0	11.2
16	96.0	12.0	58.1	59.0	42.5	8.2	83.2	16.0
17	95.5	10.9	57.1	58.0	43.2	9.5	86.0	15.0
18	95.5	7.9	53.0	54.0	38.0	6.9	86.1	12.0
19	96.0	15.2	62.3	63.2	49.6	13.9	87.7	21.1
20	95.0	17.0	63.1	64.0	50.2	15.1	84.9	21.8
21	95.0	13.0	59.0	59.9	44.0	11.0	85.9	17.9
22	95.1	23.0	66.8	67.0	52.8	16.0	88.1	29.0
23	95.9	17.0	64.0	64.9	49.9	13.9	86.9	21.9
24	95.9	13.0	60.0	60.0	44.0	10.0	84.5	17.0
25	96.1	34.9	75.1	76.0	65.0	30.9	89.9	41.1
26	94.0	32.8	73.2	73.5	64.0	29.0	89.0	40.8
27	95.2	35.0	75.0	75.1	65.0	31.1	90.9	43.2
28	94.8	28.1	69.2	70.1	60.0	24.5	88.0	35.8
29	94.9	33.3	73.1	74.0	64.0	27.2	90.0	41.0
30	95.0	30.1	70.8	71.1	61.0	26.0	88.0	37.0

CRUISE DATA 6
OBSERVER C. MULLIKIN

STATION ON MOOLACK BEACH
DATE /7 2/6 7
TIME 3 11 1 HRS

SAMP. NO.	Z	PARSONS-STRICKLAND CHL. A	CHL. B	CHL. C	SCOR-UNESCO CHL. A	CHL. B	CHL. C	PHAEO CHL. A	TOTAL A	CAROT.	PHAEO A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
1	0	9. 409	-0. 194	3. 828	9. 271	0. 351	3. 237	4. 683	12. 367	2. 984	7. 684	0. 379	3. 153
2	0	12. 023	-0. 232	5. 033	11. 848	0. 467	4. 277	5. 694	16. 013	4. 736	10. 319	0. 356	2. 538
3	0	10. 992	-0. 264	4. 074	10. 835	0. 365	3. 385	5. 457	14. 450	3. 668	8. 993	0. 378	2. 996
4	0	10. 672	-0. 258	4. 281	10. 519	0. 358	3. 609	5. 833	13. 659	3. 796	7. 826	0. 427	2. 811
5	0	12. 710	-0. 339	5. 005	12. 530	0. 393	4. 204	6. 314	16. 706	4. 914	10. 392	0. 378	2. 586
6	0	12. 752	-0. 470	4. 773	12. 578	0. 256	3. 964	6. 703	16. 485	4. 547	9. 783	0. 407	2. 805
7	0	12. 201	-0. 330	4. 843	12. 028	0. 372	4. 073	5. 765	16. 245	4. 459	10. 480	0. 355	2. 737
8	0	12. 581	-0. 355	4. 945	12. 403	0. 368	4. 151	6. 575	16. 306	4. 258	9. 730	0. 403	2. 955
9	0	11. 907	-0. 334	5. 055	11. 738	0. 357	4. 300	6. 313	15. 375	4. 078	9. 062	0. 411	2. 920
10	0	12. 083	-0. 421	4. 572	11. 916	0. 268	3. 806	6. 108	15. 793	4. 080	9. 686	0. 387	2. 998
11	0	12. 402	-0. 392	5. 008	12. 229	0. 322	4. 219	6. 042	16. 380	4. 130	10. 338	0. 369	3. 003
12	0	11. 519	-0. 413	4. 779	11. 360	0. 251	4. 044	5. 137	15. 542	4. 471	10. 405	0. 330	2. 576
13	0	12. 035	-0. 365	4. 426	11. 867	0. 321	3. 668	6. 489	15. 452	4. 077	8. 964	0. 420	2. 952
14	0	12. 088	-0. 314	4. 773	11. 916	0. 382	4. 011	6. 266	15. 707	4. 027	9. 442	0. 399	3. 002
15	0	12. 131	-0. 306	5. 079	11. 957	0. 398	4. 312	5. 729	16. 159	4. 480	10. 480	0. 355	2. 708
16	0	10. 153	-0. 198	4. 220	10. 005	0. 392	3. 582	4. 995	13. 390	4. 046	8. 395	0. 373	2. 510
17	0	10. 595	-0. 245	4. 323	10. 443	0. 368	3. 656	4. 917	14. 175	3. 640	9. 257	0. 347	2. 911
18	0	12. 173	-0. 356	4. 767	12. 002	0. 344	3. 998	6. 049	15. 995	4. 065	9. 946	0. 378	2. 995
19	0	9. 006	-0. 248	3. 548	8. 879	0. 270	2. 980	4. 852	11. 572	3. 063	6. 720	0. 419	2. 940
20	0	8. 396	-0. 144	3. 497	8. 272	0. 344	2. 970	4. 187	11. 036	2. 849	6. 848	0. 379	2. 947
21	0	9. 708	-0. 209	3. 976	9. 568	0. 354	3. 365	4. 876	12. 731	3. 246	7. 854	0. 383	2. 991
22	0	6. 921	-0. 031	3. 342	6. 814	0. 381	2. 910	3. 574	9. 028	2. 906	5. 453	0. 396	2. 382
23	0	8. 446	-0. 196	3. 403	8. 325	0. 292	2. 871	4. 080	11. 187	3. 093	7. 108	0. 365	2. 730
24	0	9. 759	-0. 308	4. 195	9. 622	0. 258	3. 573	4. 578	13. 016	3. 561	8. 438	0. 352	2. 741
25	0	4. 941	-0. 002	2. 156	4. 864	0. 289	1. 850	2. 669	6. 361	1. 756	3. 692	0. 420	2. 813
26	0	5. 131	-0. 029	2. 410	5. 052	0. 275	2. 089	3. 165	6. 331	1. 889	3. 166	0. 500	2. 717
27	0	4. 878	-0 054	2. 300	4. 805	0. 235	1. 993	2. 977	6. 038	1. 735	3. 062	0. 493	2. 812
28	0	5 921	0 099	2. 869	5. 824	0. 456	2. 506	3. 671	7. 309	2. 128	3. 637	0. 502	2. 782
29	0	5. 096	0. 074	2. 409	5. 014	0. 380	2. 097	3. 027	6. 382	2. 101	3. 355	0. 474	2. 426
30	0	5. 593	0. 063	2. 864	5. 502	0. 402	2. 518	3. 281	7. 033	2. 013	3. 752	0. 467	2. 778

Chlorophyll Statistics

26 July 1973

Sample nos.	mean	variance	standard deviation	standard error of mean	coefficient of variation
Scor-Unesco					
2 - 6	11.662	.904	.951	.425	8.2%
7 - 12	11.946	.137	.370	.165	3.1%
13 - 18	11.365	.802	.896	.399	7.9%
2 - 18	11.657	.583	.763	.185	6.5%
19 - 24	8.580	1.086	1.042	.464	12.1%
25 - 30	5.177	.161	.401	.178	7.8%
Total A					
2 - 6	15.463	1.793	1.339	.599	8.7%
7 - 12	15.940	.184	.429	.191	2.7%
13 - 18	15.146	1.236	1.112	.495	7.3%
19 - 24	11.428	2.042	1.429	.637	12.0%
25 - 30	6.576	.236	.486	.216	7.4%

APPENDIX I: Chlorophyll Data

PART B: Filtration in the Van

The data presented in this section of the appendix was obtained by filtration in the van as described previously. The following is a general description of the sampling conducted each day and an explanation of the meanings of the samples:

10 July 1973 - replicates of eight samples to test variations in place of addition of $MgCO_3$.
samples 1 - 8 - $MgCO_3$ added to top of bottle
samples 9 - 16 - $MgCO_3$ added to bottom of bottle

12 July 1973 - time series study to determine maximum length of time a sample may be kept before filtering
Samples were taken from two separate buckets of water and each bucket constitutes a time series.
Time series #1
1 - 3 - filtered immediately
4 - 6 - filtered after 1 hour
7 - 9 - filtered after 2 hours
10 - 12 - filtered after 3 hours
Time series #2
13 - 15 - filtered immediately
16 - 18 - filtered after 1 hour
19 - 21 - filtered after 2 hours
22 - 24 - filtered after 3 hours

19 July 1973 - time series study - $MgCO_3$ added at top
Samples:
1 - 6 - from first bucket, filtered immediately
7 - 12 - from second bucket, filtered immediately
13 - 18 - from first bucket, filtered after 2 hours
19 - 24 - from second bucket, filtered after 2 hours

5 September 1973 - replicates of 9 samples
Samples: 1 - 9, 11 - 18, 19 - 27, 28 - 36

The statistical data is also presented for each day. Mean, variance, standard deviation, standard error of the mean, and coefficient of variation is supplied for each sampling group.

Reduced Chlorophyll Data

10 July 1973

Sample No.	SCOR-UNESCO Chl.A	Chl.B	Chl.C	Total A
1	13.275	0.827	6.571	18.772
2	10.733	0.491	3.965	14.166
3	16.215	0.292	6.010	21.210
4	16.330	0.495	6.265	19.999
5	18.236	0.610	6.471	22.847
6	13.433	0.433	4.761	17.101
7	10.581	0.241	3.879	13.283
8	13.331	0.472	5.104	17.471
9	10.798	0.220	6.500	13.453
10	9.847	0.441	4.264	13.376
11	9.579	0.511	4.100	12.018
12	11.762	0.448	4.676	15.737
13	10.334	0.873	5.166	13.145
14	8.320	0.568	3.842	10.768
15	9.305	0.465	3.635	12.036
16	10.415	0.463	4.096	16.667

Chlorophyll Statistics

10 July 1973

Sample No.	Mean	Variance	Standard Deviation	Standard Error of Mean	Coefficient of Variation
1-8	14.017	7.419	2.724	.963	19.4%
9-16	9.837	.818	.904	.369	9.2%
Total A.					
1-8	18.106	10.905	3.302	1.168	18.2%
9-16	13.241	3.876	1.969	.877	14.9%

Reduced Chlorophyll Data

12 July 1973

Sample No.	SCOR -UNESCO Chl.A	Chl.B	Chl.C	Total A.
1	4.474	0.547	1.917	6.840
2	4.578	0.592	1.699	6.954
3	4.023	0.431	1.499	6.250
4	4.272	0.447	1.641	6.480
5	4.141	0.399	1.525	6.452
6	3.627	0.470	1.818	5.653
7	4.467	0.319	1.681	6.672
8	4.536	0.609	2.248	6.848
9	4.686	0.528	1.634	7.063
10	4.452	0.433	1.311	6.816
11	4.652	0.534	2.002	7.291
12	4.536	0.492	1.916	6.872
13	4.647	0.465	1.460	6.557
14	4.304	0.409	1.607	6.435
15	3.992	0.539	1.695	6.272
16	4.094	0.388	1.465	6.190
17	4.514	0.538	1.718	6.916
18	4.543	0.473	1.754	6.827
19	4.084	0.500	1.892	6.126
20	3.605	0.345	1.533	5.438
21	4.862	0.563	2.013	7.536
22	4.375	0.628	2.390	6.540
23	5.302	0.568	2.371	7.773
24	4.651	0.463	1.765	6.977

Chlorophyll Statistics

12 July 1973

Sample Nos.	Mean	Variance	Standard Deviation	Standard Error of Mean	Coefficient of Variation
Scor-Unesco:					
1-3	4.358	.087	.295	.170	6.8%
4-6	4.013	.116	.341	.197	8.5%
7-9	4.563	.013	.112	.065	2.45%
10-12	4.547	.010	.100	.058	2.2%
13-15	4.314	.107	.328	.189	7.6%
16-18	4.384	.063	.251	.145	5.7%
19-21	4.184	.402	.634	.366	15.1%
22-24	4.776	.227	.456	.275	9.96%
Total A:					
1-3	6.681	.143	.378	.218	5.7%
4-6	6.195	.221	.470	.271	7.6%
7-9	6.861	.083	.196	.113	2.9%
10-12	6.993	.067	.260	.150	3.7%
13-15	6.421	.020	.143	.083	2.2%
16-18	6.644	.157	.400	.229	5.96%
19-21	6.367	1.144	1.070	.617	16.8%
22-24	7.097	.391	.625	.361	8.8%

CRUISE DATA A
OBSERVER C. MULLIKIN

STATION ON MOOLACK BEACH
DATE /7 1/9 7
TIME 3 10 HRS

SAMP. NO.	Z	PARSONS-STRICKLAND CHL. A	PARSONS-STRICKLAND CHL. B	PARSONS-STRICKLAND CHL. C	SCOR-UNESCO CHL. A	SCOR-UNESCO CHL. B	SCOR-UNESCO CHL. C	PHAEO. CHL. A	TOTAL A	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
1	0	3.857	0.059	3.137	3.790	0.313	2.888	2.604	4.628	1.374	2.025	0.563	2.806
2	0	3.667	0.115	2.594	3.602	0.351	2.365	2.684	4.257	1.277	1.572	0.631	2.872
3	0	3.724	-0.072	2.264	3.668	0.156	2.024	2.441	4.495	1.454	2.053	0.543	2.562
4	0	3.219	0.049	2.423	3.164	0.257	2.217	2.401	3.701	0.948	1.300	0.649	3.395
5	0	3.469	0.098	2.366	3.409	0.319	2.150	2.438	4.095	1.189	1.657	0.595	2.917
6	0	3.513	0.281	3.382	3.441	0.527	3.164	2.840	3.922	0.643	1.082	0.724	5.466
7	0	3.449	0.064	2.634	3.390	0.268	2.414	2.353	4.121	1.075	1.768	0.571	3.208
8	0	3.422	0.066	2.323	3.364	0.283	2.108	2.567	3.923	1.192	1.356	0.654	2.871
9	0	3.505	-0.100	1.781	3.454	0.109	1.556	2.412	4.142	1.350	1.730	0.582	2.596
10	0	3.168	0.349	3.463	3.098	0.580	3.269	2.685	3.501	0.376	0.866	0.753	8.416
11	0	3.391	-0.050	2.096	3.339	0.159	1.878	2.326	4.023	1.269	1.697	0.578	2.672
12	0	3.640	-0.088	2.273	3.586	0.135	2.036	2.577	4.259	1.314	1.681	0.605	2.770
13	0	3.778	-0.009	2.669	3.717	0.230	2.425	2.484	4.568	1.420	2.084	0.544	2.661
14	0	4.051	0.156	2.880	3.979	0.417	2.629	2.861	4.779	1.349	1.919	0.599	3.004
15	0	4.073	0.192	3.879	3.995	0.473	3.619	3.034	4.712	0.915	1.678	0.644	4.454
16	0	3.245	0.123	2.757	3.185	0.340	2.551	2.566	3.642	0.930	1.076	0.705	3.488
17	0	3.761	0.387	4.112	3.678	0.661	3.880	2.953	4.276	0.695	1.323	0.691	5.413
18	0	4.251	0.104	2.775	4.178	0.373	2.509	3.065	4.960	1.428	1.894	0.618	2.977
19	0	2.752	0.400	3.300	2.685	0.608	3.134	2.367	3.001	0.331	0.634	0.789	8.319
20	0	3.595	0.029	2.596	3.535	0.259	2.366	2.546	4.223	1.118	1.677	0.603	3.216
21	0	3.616	0.222	3.248	3.546	0.469	3.023	2.823	4.096	0.827	1.273	0.689	4.371
22	0	3.095	0.132	2.729	3.037	0.341	2.533	2.352	3.543	0.857	1.190	0.664	3.611
23	0	2.674	0.268	2.746	2.616	0.459	2.582	2.296	2.900	0.510	0.603	0.792	5.240
24	0	3.315	0.621	4.772	3.226	0.889	4.574	3.318	3.316	-0.020	-0.003	1.001	163.878

Chlorophyll Statistics

19 July 1973

Sample No.	Mean	Variance	Standard Deviation	St dard Errc of Mean	Coefficient of Variation
Scor-Unesco:					
1-6	3.512	.049	.222	.091	6.3%
7-12	3.372	.258	.161	.066	4.7%
13-18	3.789	.122	.350	.143	9.2%
19-24	3.108	.163	.404	.165	13.0%
1-6 & 13-18	3.651	.099	.314	.091	8.6%
7-12 & 19-24	3.240	.105	.324	.094	10.0%
Total A:					
1-6	4.183	.122	.349	.143	8.3%
7-12	3.995	.071	.267	.109	6.7%
13-18	4.490	.225	.474	.194	10.6%
19-24	3.513	.304	.552	.225	15.7%
1-6 & 13-18	4.336	.183	.428	.124	9.9%
7-12 & 19-24	3.754	.234	.484	.140	12.9%

CRUISE DATA 11
OBSERVER C. MULLIKIN

STATION IN BAY
DATE 9/ 5/ 73
TIME 09 00 HRS

SAMP. NO.	Z	PARSONS-STRICKLAND CHL. A	PARSONS-STRICKLAND CHL. B	PARSONS-STRICKLAND CHL. C	SCOR-UNESCO CHL. A	SCOR-UNESCO CHL. B	SCOR-UNESCO CHL. C	PHAEO. CHL. A	TOTAL A	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
revised → 2 1	5	6. 075	−0. 230	2. 091	5. 992	0. 113	1. 706	2. 419	8. 392	1. 622	5. 973	0. 288	3. 746
7 2	5	4. 875	0. 032	2. 319	4. 798	0. 324	2. 017	2. 465	6. 402	0. 920	3. 937	0. 385	5. 301
9 3	5	5. 692	−0. 174	1. 689	5. 614	0. 144	1. 334	2. 909	7. 415	1. 596	4. 506	0. 392	3. 567
15 4	5	3. 658	−0. 086	1. 297	3. 606	0. 123	1. 069	1. 634	4. 935	0. 954	3. 302	0. 331	3. 835
16 5	5	3. 961	−0. 085	1. 414	3. 904	0. 141	1. 167	1. 733	5. 371	1. 045	3. 638	0. 323	3. 791
33 6	5	5. 696	−0. 006	2. 048	5. 610	0. 323	1. 700	4. 318	6. 460	1. 849	2. 142	0. 668	3. 081
1 7	5	4. 430	0. 053	1. 779	4. 359	0. 313	1. 510	1. 897	6. 055	0. 726	4. 158	0. 313	6. 099
3 8	5	5. 836	−0. 142	1. 800	5. 754	0. 186	1. 437	2. 795	7. 738	1. 493	4. 942	0. 361	3. 908
4 9	5	4. 496	0. 051	1. 848	4. 425	0. 316	1. 574	2. 194	5. 959	1. 118	3. 765	0. 368	4. 023
5 10	5	4. 954	0. 299	0. 956	4. 868	0. 581	0. 679	3. 315	5. 951	1. 317	2. 635	0. 557	3. 762
6 11	5	5. 100	0. 061	1. 366	5. 020	0. 350	1. 062	3. 974	5. 709	1. 384	1. 735	0. 696	3. 684
8 12	5	4. 663	−0. 012	1. 856	4. 592	0. 260	1. 569	2. 126	6. 275	1. 213	4. 149	0. 339	3. 845
11 13	5	5. 276	−0. 263	1. 848	5. 207	0. 033	1. 510	2. 587	6. 941	1. 008	4. 354	0. 373	5. 233
12 14	5	5. 550	−0. 104	1. 787	5. 470	0. 211	1. 443	2. 569	7. 426	1. 473	4. 857	0. 346	3. 768
13 15	5	5. 993	−0. 128	1. 652	5. 909	0. 206	1. 282	2. 297	8. 347	1. 606	6. 050	0. 275	3. 732
14 16	5	5. 301	−0. 059	1. 940	5. 223	0. 246	1. 612	2. 403	7. 136	1. 384	4. 733	0. 337	3. 829
17 17	5	3. 994	−0. 108	1. 370	3. 938	0. 118	1. 120	1. 640	5. 488	1. 093	3. 848	0. 299	3. 655
18 18	5	5. 407	−0. 043	1. 534	5. 327	0. 262	1. 205	3. 458	6. 570	1. 539	3. 112	0. 526	3. 513
19 19	5	5. 297	−0. 276	1. 791	5. 229	0. 020	1. 451	3. 041	6. 656	1. 667	3. 615	0. 457	3. 178
20 20	5	5. 176	−0. 289	1. 921	5. 109	0. 003	1. 586	3. 135	6. 389	1. 761	3. 255	0. 491	2. 940
21 21	5	5. 174	−0. 128	1. 862	5. 101	0. 167	1. 538	2. 919	6. 556	1. 667	3. 638	0. 445	3. 104
22 22	5	5. 862	−0. 287	2. 119	5. 785	0. 043	1. 743	3. 781	7. 079	2. 173	3. 298	0. 534	2. 698
23 23	5	3. 999	−0. 152	1. 130	3. 946	0. 070	0. 879	2. 239	5. 069	1. 405	2. 830	0. 442	2. 846
24 24	5	4. 180	−0. 071	1. 554	4. 119	0. 169	1. 294	2. 359	5. 300	1. 423	2. 940	0. 445	2. 937
25 25	5	5. 442	0. 467	3. 083	5. 335	0. 813	2. 768	2. 784	7. 180	2. 004	4. 396	0. 388	2. 715
26 26	5	5. 180	−0. 204	1. 755	5. 110	0. 088	1. 427	3. 049	6. 464	1. 804	3. 415	0. 472	2. 872
27 27	5	4. 545	−0. 102	1. 799	4. 480	0. 160	1. 513	2. 376	5. 894	1. 498	3. 518	0. 403	3. 034
28 28	5	6. 330	−0. 000	1. 986	6. 235	0. 360	1. 602	4. 787	7. 184	1. 957	2. 397	0. 666	3. 235
29 29	5	4. 452	−0. 038	1. 684	4. 385	0. 219	1. 408	1. 357	6. 458	1. 238	5. 100	0. 210	3. 595
30 30	5	5. 889	0. 079	2. 218	5. 796	0. 423	1. 862	3. 947	7. 052	1. 826	3. 105	0. 560	3. 226
31 31	5	5. 368	0. 044	2. 050	5. 283	0. 357	1. 724	3. 791	6. 289	1. 816	2. 498	0. 603	2. 956
32 32	5	4. 348	−0. 073	1. 696	4. 284	0. 178	1. 425	2. 590	5. 418	1. 343	2. 828	0. 478	3. 238
34 33	5	5. 040	−0. 185	2. 028	4. 97[illegible]	0. 104	1. 707	2. 775	6. 430	1. 754	3. 655	0. 432	2. 874
35 34	5	5. 141	−0. 309	1. 427	5. 078	−0. 028	1. 098	2. 722	6. 612	1. 791	3. 891	0. 412	2. 871
36 35	5	5. 829	−0. 219	2. 000	5. 750	0. 110	1. 631	3. 443	7. 268	1. 936	3. 825	0. 474	3. 010

Chlorophyll Statistics

5 September 1973

Sample No.	Mean	Variance	Standard Deviation	Standard Error of Mean	Coefficient of Variation
Scor-Unesco:					
1-9	5.047	.359	.599	.199	11.8%
11-18	4.823	.753	.868	.307	17.9%
19-27	4.913	.362	.602	.201	12.3%
28-36	5.266	.429	.655	.218	12.4%
Total A:					
1-9	6.655	.901	.949	.316	14.2%
11-18	6.527	1.374	1.172	.414	17.9%
19-27	6.287	.536	.732	.244	11.6%
28-36	6.575	.318	.564	.188	8.6%

APPENDIX I: CHLOROPHYLL DATA

PART C: Filtration aboard Dory

The data presented in this section of the appendix was obtained by vacuum filtration aboard the dory. The following is a general description of the sampling conducted each day and an explanation of the meaning of the samples:

24 August 1973 - replicates of six were taken to test the accuracy of the vacuum system. Groupings were:
Samples 1 - 6, 7 - 12, 13 - 18, 19 - 24

30 August 1973 - replicates of six were taken. Groupings were:
Samples 1 - 6, 7 - 12, 13 - 18, 19 - 24
samples 1 - 6 had no $MgCO_3$ added

6 September 1973 - replicates of six were taken. Groupings were:
Samples 1 - 6, 7 - 12, 13 - 18, 19 - 24

Also presented is the statistical analysis of the data collected each day. Only the Scor-Unesco chlorophylls A, B, and C and Total A were analysed. In each group of replicates, the mean, variance, standard deviation, standard error of the mean, and coefficient of variation were calculated.

CRUISE DATA 7
OBSERVER C. MULLIKIN

STATION IN BAY
DATE 8/ 24/ 73
TIME 12 00 HRS

SAMP. NO.	Z	PARSONS-STRICKLAND CHL. A	CHL. B	CHL. C	SCOR-UNESCO CHL. A	CHL. B	CHL. C	PHAEO. CHL. A	TOTAL A.	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
1	0	14. 220	-0. 522	5. 392	14. 025	0. 289	4. 489	10. 309	16. 399	7. 289	6. 090	0. 629	1. 951
2	0	13. 064	-0. 321	4. 893	12. 878	0. 428	4. 073	10. 724	14. 207	6. 468	3. 482	0. 755	2. 020
3	0	13. 023	-0. 387	5. 030	12. 840	0. 359	4. 207	9. 571	14. 941	6. 573	5. 370	0. 641	1. 981
4	0	14. 466	-0. 296	5. 368	14. 258	0. 533	4. 464	11. 370	16. 092	7. 120	4. 722	0. 707	2. 032
5	0	12. 078	-0. 172	4. 782	11. 900	0. 528	4. 029	9. 710	13. 296	5. 821	3. 586	0. 730	2. 075
6	0	14. 436	-0. 035	4. 125	14. 220	0. 781	3. 251	16. 294	12. 608	7. 371	-3. 686	1. 292	1. 959
7	5	16. 454	-0. 572	6. 285	16. 227	0. 368	5. 241	13. 084	18. 172	8. 141	5. 088	0. 720	2. 021
8	5	13. 386	-0. 062	5. 130	13. 183	0. 715	4. 306	15. 013	11. 772	7. 081	-3. 241	1. 275	1. 890
9	5	14. 820	-0. 090	7. 083	14. 592	0. 792	6. 156	10. 793	17. 129	6. 853	6. 336	0. 630	2. 163
10	5	14. 596	-0. 533	5. 060	14. 397	0. 291	4. 138	11. 281	16. 338	6. 913	5. 057	0. 690	2. 111
11	5	16. 558	-1. 191	6. 761	16. 355	-0. 256	5. 669	12. 342	18. 798	8. 452	6. 456	0. 657	1 959
12	5	15. 757	0. 042	7. 924	15. 508	0. 990	6. 942	11. 048	18. 534	7. 541	7. 486	0. 596	2. 089
13	5	9. 168	-0. 173	3. 570	9. 030	0. 356	2. 997	9. 242	8. 768	4. 865	-0. 473	1. 054	1. 883
14	0	8. 736	-0. 125	4. 224	8. 605	0. 394	3. 672	7. 429	9. 343	4. 096	1. 914	0. 795	2. 133
15	0	11. 646	-0. 460	4. 425	11. 488	0. 203	3. 683	8. 073	13. 687	6. 083	5. 615	0. 590	1 915
16	0	15. 401	-0. 352	3. 630	15. 187	0. 496	2. 686	16. 786	13. 822	8. 270	-2. 964	1. 214	1. 862
17	5	15. 581	-0. 554	5. 861	15. 367	0. 334	4. 873	10. 944	18. 218	8. 317	7. 274	0. 601	1. 873
18	0	14. 910	-0. 455	5. 593	14. 702	0. 397	4. 652	9. 886	17. 851	7. 843	7. 965	0. 554	1 901
19	5	8. 592	-0. 304	3. 522	8. 474	0. 190	2. 974	6. 411	9. 788	4. 275	3. 377	0. 655	2. 010
20	5	12. 848	-0. 372	4. 815	12. 668	0. 363	4. 006	9. 795	14. 492	6. 176	4 697	0. 676	2. 080
21	5	6. 121	-0. 275	2. 313	6. 039	0. 072	1. 921	4. 469	7. 031	3. 020	2. 561	0. 636	2. 027
22	5	10. 379	-0. 299	3. 645	10. 234	0. 290	2. 994	6. 897	12. 414	5. 077	5. 517	0. 556	2. 044
23	5	10. 767	-0. 243	4. 130	10. 613	0. 376	3. 455	5. 691	13. 917	5. 220	8. 225	0. 409	2. 063
24	5	10. 995	-0. 141	3. 807	10. 834	0. 488	3. 128	9. 373	11. 724	5. 378	2. 351	0. 799	2. 044

Chlorophyll Statistics

24 August 1973

Sample No.	Mean	variance	standard deviation	standard error of mean	coefficient of variation
Scor-Unesco					
1 - 6	11.687	14.907	3.861	1.576	33.0%
7 - 12	15.044	1.484	1.218	.497	8.1%
13 - 18	12.397	9.691	3.113	1.271	25.0%
19 - 24	9.810	5.208	2.282	.932	23.0%
Total A					
1 - 6	14.591	2.280	1.510	.616	10.3%
7 - 12	16.721	8.585	2.930	1.310	17.5%
13 - 18	15.028	14.160	3.763	1.346	25.0%

CRUISE DATA 8
OBSERVER C. MULLIKIN

STATION IN BAY
DATE 8/ 30/ 73
TIME 16 30 HRS

SAMP. NO.	Z	HARSONS-STRICKLAND CHL. A	CHL. B	CHL. C	SCOR-UNESCO CHL. A	CHL. B	CHL. C	PHAEO. CHL. A	TOTAL A	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
1	5	2. 508	0. 042	0. 903	2. 468	0. 189	0. 752	0. 847	3. 588	0. 567	2. 741	0. 236	4. 426
2	5	5. 980	-0. 036	1. 923	5. 890	0. 305	1. 558	1. 935	8. 593	1. 419	6. 658	0. 225	4. 213
3	5	6. 225	0. 158	2. 952	6. 121	0. 534	2. 574	1. 051	9. 655	1. 950	8. 604	0. 109	3. 192
4	5	8. 124	-0. 242	2. 529	8. 012	0. 214	2. 022	3. 433	11. 089	2. 132	7. 655	0. 310	3. 810
5	5	8. 420	0. 022	3. 529	8. 289	0 517	3. 011	3. 839	11. 338	2. 330	7. 499	0. 339	3. 614
6	5	8. 586	-0. 201	2. 931	8. 465	0. 287	2. 396	3. 715	11. 669	2. 271	7. 954	0. 318	3. 781
7	0	7. 965	-0 263	2. 660	7. 856	0. 186	2. 159	3. 341	10. 889	2. 133	7. 547	0. 307	3. 735
8	0	7. 750	-0. 270	2. 634	7. 644	0. 167	2. 145	2. 766	10. 933	2. 036	8. 166	0. 253	3. 806
9	0	5. 723	-0. 157	2. 168	5. 643	0. 171	1. 808	2. 284	7. 912	1. 494	5. 628	0. 289	3. 831
10	0	6. 891	0. 115	3. 162	6. 779	0. 528	2. 742	1. 250	10. 620	2. 048	9. 370	0. 118	3. 365
11	0	7. 002	-0. 156	2. 551	6. 902	0. 244	2. 113	2. 554	9. 851	1. 850	7. 297	0. 259	3. 785
12	0	7. 564	-0. 124	2. 967	7. 454	0. 313	2. 495	3. 596	10. 065	2. 027	6. 469	0. 357	3. 732
13	0	7. 491	-0. 202	2. 292	7. 387	0. 218	1. 826	2. 298	10. 833	1. 978	8. 536	0. 212	3. 787
14	0	7. 084	0. 154	2. 258	6. 970	0. 563	1. 837	1. 812	10. 889	1. 817	9. 577	0. 120	3. 898
15	0	6. 611	-0. 067	2. 444	6. 513	0. 314	2. 035	2. 827	9. 021	1. 839	6. 193	0. 313	3. 594
16	0	6. 974	-0. 194	2. 272	6. 877	0. 199	1. 836	2. 266	9. 998	1. 878	7. 733	0. 227	3. 714
17	0	7. 292	-0. 074	2. 828	7. 184	0. 349	2. 376	2. 329	10. 504	2. 088	8. 174	0. 222	3. 493
18	0	5. 785	-0. 119	2. 023	5. 702	0. 210	1. 663	1. 985	8. 227	1. 448	6. 243	0. 241	3. 996
19	0	4. 990	0 258	2. 974	4. 899	0. 568	2. 673	-0. 356	8. 602	1. 727	8. 957	-0. 041	2. 890
20	0	6. 170	-0. 073	2. 312	6. 079	0. 282	1. 930	2. 180	8. 739	1. 697	6. 558	0. 250	3. 637
21	0	6. 559	-0. 125	2. 371	6. 464	0. 251	1. 963	2. 245	9. 333	1. 785	7. 088	0. 241	3. 675
22	0	6. 277	-0. 172	2. 122	6. 189	0. 184	1. 729	1. 782	9. 181	1. 750	7. 398	0. 194	3. 587
23	0	7. 069	0. 060	2. 825	6. 958	0. 475	2. 394	2. 468	10. 051	2. 026	7. 584	0. 246	3. 490
24	0	6. 665	0. 006	2. 599	6. 562	0. 395	2. 190	2. 341	9. 461	1. 842	7. 120	0. 247	3. 619

Chlorophyll Statistics

30 August 1973

Sample No.	mean	variance	standard deviation	standard error of mean	coefficient of variation
Scor-Unesco					
1 - 6	6.540	5.221	2.285	.931	34.9%
7 - 12	7.046	.420	.805	.329	11.4%
13 - 18	6.772	.362	.602	.246	8.9%
19 - 24	6.192	.497	.705	.288	11.4%
Total A					
1 - 6	9.322	9.242	3.040	1.241	32.6%
7 - 12	10.045	1.777	1.333	.463	11.3%
13 - 18	9.912	1.158	1.076	.439	10.9%
19 - 24	9.230	.276	.525	.214	5.7%

CRUISE DATA 0
OBSERVER C. MULLIKIN

STATION IN BAY
DATE 9/ 6/ 73
TIME 08 00 HRS

SAMP. NO.	Z	PARSONS-STRICKLAND CHL. A	CHL. B	CHL. C	SCOR-UNESCO CHL. A	CHL. B	CHL. C	PHAEO. CHL. A	TOTAL A	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A/ CAROT. RATIO
1	5	9. 291	-0. 539	3. 869	9. 172	-0. 009	3. 264	6. 452	10. 896	3. 040	4. 444	0. 592	3. 056
2	5	11. 587	-0. 610	4. 743	11. 435	0. 051	3. 992	7. 040	14. 299	3. 929	7. 258	0. 492	2. 949
3	5	11. 704	-0. 814	4. 051	11. 562	-0. 165	3. 287	6. 455	14. 870	4. 022	8. 415	0. 434	2. 910
4	5	11. 833	0. 021	5. 637	11. 648	0. 728	4. 903	2. 780	17. 775	3. 409	14. 995	0. 156	3. 471
5	5	8. 592	-0. 841	2. 647	8. 500	-0. 376	2. 074	4. 587	10. 990	3. 063	6. 403	0. 417	2. 805
6	5	10. 659	-0. 452	4. 546	10. 514	0. 162	3. 861	6. 647	13. 049	3. 748	6. 402	0. 509	2. 844
7	5	11. 400	-0. 607	4. 452	11. 252	0. 039	3. 715	7. 545	13. 632	3. 689	6. 087	0. 553	3. 090
8	5	8. 892	-0. 566	3. 618	8. 780	-0. 062	3. 036	5. 366	10. 988	3. 051	5. 621	0. 488	2. 914
9	5	7. 353	-0. 453	2. 830	7. 260	-0. 038	2. 351	4. 729	8. 882	2. 394	4. 153	0. 532	3. 072
10	5	10. 572	-0. 689	3. 731	10. 442	-0. 100	3. 043	2. 710	15. 623	3. 538	12. 913	0. 173	2. 988
11	5	9. 190	-0. 619	3. 461	9. 077	-0. 104	2. 860	5. 779	11. 184	3. 061	5. 405	0. 517	3. 002
12	5	9. 491	-0. 550	3. 975	9. 369	-0. 009	3. 356	5. 558	11. 854	3. 223	6. 295	0. 469	2. 945
13	5	5. 005	-0. 181	1. 436	4. 937	0. 097	1. 123	2. 352	6. 659	1. 778	4. 307	0. 353	2. 815
14	5	7. 598	-0. 159	2. 566	7. 490	0. 272	2. 093	5. 049	9. 094	2. 537	4. 044	0. 555	2. 995
15	5	7. 080	-0. 260	2. 548	6. 983	0. 141	2. 100	3. 856	9. 057	2. 494	5. 202	0. 426	2. 838
16	5	5. 188	0. 064	2. 471	5. 104	0. 376	2. 152	3. 517	6. 191	1. 285	2. 674	0. 568	4. 039
17	5	6. 010	-0. 152	2. 247	5. 925	0. 192	1. 870	3. 071	7. 839	2. 071	4. 767	0. 392	2. 902
18	5	6. 727	-0. 170	2. 230	6. 632	0. 211	1. 810	3. 447	8. 764	2. 335	5. 318	0. 393	2. 881
19	5	18. 100	-0. 734	8. 167	17. 851	0. 317	7. 000	12. 071	21. 620	5. 953	9. 550	0. 558	3. 041
20	5	15. 239	-0. 639	6. 297	15. 032	0. 236	5. 319	11. 947	16. 944	5. 300	4. 997	0. 705	2. 875
21	5	15. 613	-0. 576	7. 198	15. 395	0. 335	6. 194	10. 514	18. 587	5. 267	8. 073	0. 566	2. 964
22	5	18. 050	-0. 923	7. 751	17. 812	0. 114	6. 580	13. 115	20. 780	5. 927	7. 665	0. 631	3. 046
23	5	16. 841	-0. 942	6. 967	16. 622	0. 018	5. 872	12. 975	18. 856	5. 812	5. 881	0. 688	2. 897
24	5	16. 736	-1. 153	6. 947	16. 529	-0. 205	5. 845	11. 377	19. 777	6. 046	8. 399	0. 575	2. 768

Chlorophyll Statistics

6 September 1973

Sample No.	mean	variance	standard deviation	standard error of mean	coefficient of variation
Scor-Unesco					
1 - 6	10.472	1.817	1.348	.550	12.9%
7 - 12	9.363	1.915	1.384	.565	14.8%
13 - 18	6.179	1.067	1.033	.422	16.7%
19 - 24	16.540	1.385	1.177	.481	7.1%
Total A					
1 - 6	13.646	6.791	2.606	1.064	19.1%
7 - 12	12.027	5.443	2.333	.953	19.4%
13 - 18	7.934	1.593	1.262	.515	15.9%
19 - 24	19.427	2.792	1.671	.682	8.6%

APPENDIX I: Chlorophyll Data

PART D: Comparison of Methods

The data presented in this section of the appendix was obtained to compare the reliability and replicability of the three methods of obtaining chlorophyll data; filtering in the dory with a vacuum, filtering in the van, and C-14 tracer studies. The following is an explanation of the samples taken on 20 August 1973:

Samples*:
- 1 - 5 - Samples collected at 1100 hours and 0 m depth in van - used to compare with C-14.
- 6 - 10 - Samples collected at 1115 hours, 5 m depth, and run in the van - used to compare with C-14.
- 11 - 16 - Samples collected at 1400 hours, 1 m depth and run in van - used to compare with C-14.
- 17 - 22 - Samples collected at 1415 hours,5 m depth and run in van - used to compare with C-14.
- 23 - 25 - Samples filtered on dory, 1230 hours, 0 m depth
- 26 - 28 - Samples filtered on dory, 1515 hours, 1 m depth
- 29 - 31 - Samples filtered in van - 0 m depth
- 32 - 34 - Samples filtered in van - 1 m depth

* Revised Sample Numbers

CRUISE DATA 9
OBSERVER C. MULLIKIN

STATION OFFSOUTHBEACH
DATE 8/ 20/ 73
TIME 11 00 HRS

Revised

SAMP. NO.		Z	PARSONS-STRICKLAND CHL. A	CHL. B	CHL. C	SCOR-UNESCO CHL. A	CHL. B	CHL. C	PHAEO. CHL. A	TOTAL A	CAROT.	PHAEO. A	PER CENT PHAEO. CHL. A	CHL. A. CAROT. RATIO
1	6	5	2. 899	-0. 085	0. 960	2. 859	0. 079	0. 779	1. 534	3. 741	0. 757	2. 208	0. 410	3. 831
2	7	5	3. 162	-0. 155	1. 090	3. 121	0. 022	0. 888	1. 552	4. 159	0. 826	2. 606	0. 373	3. 830
3	1	5	2. 972	0. 009	1. 155	2. 926	0. 183	0. 973	1. 972	3. 570	0. 757	1. 598	0. 552	3. 926
4	2	5	2. 718	-0. 089	0. 900	2. 681	0. 064	0. 729	2. 082	3. 056	0. 847	0. 974	0. 681	3. 207
5	8	0	2. 746	-0. 136	1. 061	2. 710	0. 020	0. 884	1. 846	3. 265	0. 854	1. 419	0. 565	3. 214
6	3	0	2. 904	-0. 110	0. 817	2. 866	0. 051	0. 635	5. 384	1. 050	1. 010	-4. 334	5. 127	2. 874
7	9	0	3. 037	-0. 106	1. 179	2. 995	0. 067	0. 986	1. 692	3. 861	0. 743	2. 169	0. 438	4. 087
8	10	0	3. 155	-0. 144	0. 982	3. 114	0. 032	0. 782	1. 667	4. 067	0. 872	2. 400	0. 410	3. 618
9	4	0	2. 863	-0. 078	1. 192	2. 822	0. 087	1. 011	2. 020	3. 345	0. 841	1. 326	0. 604	3. 405
10	29	0	2. 474	-0. 003	1. 146	2. 436	0. 144	0. 992	1. 820	2. 848	0. 774	1. 027	0. 639	3. 195
11	30	0	2. 546	-0. 027	0. 995	2. 508	0. 121	0. 838	1. 712	3. 037	0. 886	1. 325	0. 564	2. 873
12	31	0	6. 504	-1. 501	-0. 640	6. 479	-1. 218	-1. 101	10. 807	3. 048	0. 870	-7. 758	3. 545	7. 471
13	17	0	2. 269	-0. 077	0. 930	2. 237	0. 054	0. 786	1. 176	2. 947	0. 709	1. 771	0. 399	3. 199
14	18	0	2. 556	-0. 044	0. 927	2. 519	0. 103	0. 768	1. 192	3. 415	0. 980	2. 223	0. 349	2. 608
15	19	0	1. 676	0. 051	0. 482	1. 648	0. 147	0. 384	2. 345	1. 153	0. 545	-1. 192	2. 034	3. 074
16	11	0	2. 094	-0. 051	0. 672	2. 064	0. 067	0. 542	3. 080	1. 322	0. 807	-1. 758	2. 330	2. 596
17	12	0	2. 031	0. 087	0. 970	1. 995	0. 211	0. 849	2. 316	1. 773	0. 851	-0. 543	1. 306	2. 387
18	13	0	2. 160	-0. 113	0. 787	2. 132	0. 008	0. 648	1. 378	2. 619	0. 746	1. 241	0. 526	2. 896
19	32	0	2. 843	-0. 127	1. 132	2. 805	0. 035	0. 949	1. 983	3. 332	1. 142	1. 348	0. 595	2. 490
20	33	0	2. 155	-0. 158	0. 741	2. 129	-0. 038	0. 600	1. 413	2. 580	0. 940	1. 167	0. 548	2. 293
21	23	0	2. 211	-0. 159	0. 766	2. 185	-0. 037	0. 621	1. 548	2. 579	0. 648	1. 031	0. 600	3. 415
22	24	0	2. 929	0. 015	1. 589	2. 882	0. 193	1. 406	2. 823	2. 909	1. 221	0. 086	0. 970	2. 399
23	26	0	2. 472	-0. 113	0. 850	2. 440	0. 026	0. 692	1. 748	2. 878	0. 937	1. 130	0. 607	2. 637
24	27	0	2. 302	0. 007	1. 017	2. 266	0. 143	0. 874	1. 908	2. 500	1. 059	0. 593	0. 763	2. 174
25	5	0	2. 938	-0. 074	0. 969	2. 897	0. 092	0. 786	3. 135	2. 687	1. 584	-0. 447	1. 166	1. 854
26	20	0	2. 169	-0. 021	0. 853	2. 136	0. 105	0. 718	1. 162	2. 795	0. 810	1. 633	0. 416	2. 678
27	21	0	2. 096	-0. 179	0. 275	2. 073	-0. 071	0. 141	0. 127	3. 372	0. 697	3. 245	0. 038	3. 007
28	22	0	1. 196	0. 046	0. 717	1. 175	0. 121	0. 644	0. 707	1. 506	0. 356	0. 799	0. 469	3. 365
29	14	0	1. 729	-0. 154	0. 564	1. 709	-0. 060	0. 449	1. 036	2. 134	0. 622	1. 099	0. 485	2. 779
30	15	0	1. 415	-0. 054	0. 555	1. 396	0. 027	0. 465	0. 991	1. 657	0. 510	0. 665	0. 598	2. 774
31	16	0	1. 743	-0. 008	0. 862	1. 716	0. 096	0. 753	1. 608	1. 779	0. 767	0. 171	0. 904	2. 271
32	34	0	2. 137	-0. 165	0. 936	2. 111	-0. 044	0. 794	1. 548	2. 456	0. 893	0. 908	0. 630	2. 393
33	25	0	1. 999	-0. 190	0. 712	1. 977	-0. 080	0. 578	1. 536	2. 230	-0. 442	0. 694	0. 689	-4. 526
34	28	0	2. 158	-0. 075	0. 944	2. 127	0. 051	0. 806	1. 656	2. 426	0. 720	0. 770	0. 682	2. 998

Chlorophyll Statistics

20 August 1973

Sample No.	mean	variance	standard deviation	standard error of mean	coefficient of variation
Scor-Unesco					
1 - 5	2.838	.009	.096	.043	3.3%
6 - 10	2.960	.031	.176	.079	5.9%
11 - 16	1.835	.078	.279	.114	15.2%
17 - 22	1.964	.228	.478	.195	24.4%
23 - 25	2.348	.225	.474	.274	20.9%
29 - 31	2.472	.003	.051	.036	2.0%
23-25+29-31	2.398	.118	.343	.153	14.3%
26 - 28	2.277	.025	.157	.091	15.6%
32 - 34	2.348	.156	.395	.228	16.8%
26-28+32-34	2.313	.074	.272	.111	11.7%
Total A					
1 - 5	2.742	1.000	1.000	.448	36.5%
6 - 10	3.820	.123	.351	.157	9.1%
11 - 16	1.881	.199	.446	.182	23.7%
17 - 22	2.531	.992	.996	.395	38.2%
23 - 25	2.573	.116	.340	.196	13.2%
29 - 31	2.978	.016	.112	.065	3.8%
23-25+29-31	2.775	.100	.317	.129	11.4%
26 - 28	2.600	.059	.242	.139	9.3%
32 - 34	2.789	.225	.474	.274	17.0%
26-28+32-34	2.695	.124	.352	.144	13.1%

APPENDIX II

Data for production measurements collected during 1973 from the liquid scintillation count of the samples. Each sample was counted twice. The sample identification code is as follows:

Code	Date taken
A: 2 - 11 A - E	13 Aug.
B: 1 - 8 A - D	20 Aug.
C: 1 - 11 A - F	30 Aug.
D: 1 - 14 A - G	5 Sept.
E: 1 - 10 A - E	6 Sept.
F: 2, A	7 Sept.

Further identification of the samples can be obtained by reference to Table 1 in the text. The output for each sample is in the following format:

.6130 [a]	1 [b]	.963 [c]	2644 [d]	10000 [e]	6033 [f]
(2745.5 2.5) [g]	(10384.2	1.0) [h]	(6264.7	1.5) [i]	.438 [j]

a) External Standard Ratio
b) Machine sample number
c) time counted in minutes
d) gross counts, red channel
e) gross counts, green channel
f) gross counts, blue channel
g) 2745.5 = cpm, red channel
   2.5 = % standard deviation of counts in red channel
h) 10384.2 = cpm in green channel (C-14 counting channel)
   2.5 = % standard deviation of count in green channel
i) 6264.7 = cpm in blue channel
   1.5 = % standard deviation in blue channel
j) channels ratio: red/blue channel

DATA FOR PRODUCTION MEASUREMENTS

.6130		1	.963	2644	10000	6033	A1	.6210		1	.980	2530	10000	6079
2745.5	2.5	10384.2	1.0	6264.7	1.5	.438		2581.6	2.5	10204.0	1.0	6203.0	1.5	.416
.5719		2	1.067	2571	10000	5493	3	.5817		2	1.082	2577	10000	5446
2409.5	2.5	9372.0	1.0	5148.0	1.5	.468		2381.7	2.5	9242.1	1.0	5033.2	1.5	.473
.6224		3	1.027	2537	10000	6142	4	.6276		3	1.021	2629	10000	6167
2470.3	2.5	9737.0	1.0	5980.5	1.5	.413		2574.9	2.5	9794.3	1.0	6040.1	1.5	.426
.6285		4	1.063	2615	10000	6239	5	.6381		4	1.045	2557	10000	6241
2460.0	2.5	9407.3	1.0	5869.2	1.5	.419		2446.8	2.5	9569.3	1.0	5972.2	1.5	.409
.6064		5	1.097	2583	10000	5911	6	.6177		5	1.084	2594	10000	5933
2354.6	2.5	9115.7	1.0	5388.3	1.5	.436		2392.9	2.5	9225.0	1.0	5473.2	1.5	.437
.5726		6	1.208	2586	10000	5313	7	.5814		6	1.169	2569	10000	5344
2140.7	2.5	8278.1	1.0	4398.1	1.5	.486		2197.6	2.5	8554.3	1.0	4485.8	1.5	.489
.6242		7	.818	2466	10000	6076	8	.6304		7	.810	2475	10000	6128
3014.6	2.5	12224.9	1.0	7427.8	1.5	.405		3055.5	2.5	12345.6	1.0	7565.4	1.5	.403
.6227		8	.772	2467	10000	6211	9	.6317		8	.768	2524	10000	6305
3195.5	2.5	12953.3	1.0	8045.3	1.5	.397		3286.4	2.5	13020.8	1.0	8209.6	1.5	.400
.6434		9	1.361	2376	10000	6265	10	.6499		9	1.339	2421	10000	6311
1745.7	2.5	7347.5	1.0	4603.2	1.5	.379		1808.0	2.5	7468.2	1.0	4713.2	1.5	.383
.5983		10	2.000	1748	7218	4463	11	.6052		10	2.000	1859	7309	4576
874.0	2.5	3609.0	1.5	2231.5	1.5	.391		929.5	2.5	3654.5	1.5	2288.0	1.5	.406
.5992		52	2.000	230	1042	645	AA	.6008		52	2.000	205	1009	597
115.0	7.5	521.0	2.5	322.5	4.5	.356		102.5	7.5	504.5	2.5	298.5	4.5	.343
.6302		53	2.000	302	1440	906	B	.6330		53	2.000	311	1435	910
151.0	7.5	720.0	2.5	453.0	3.5	.333		155.5	7.5	717.5	2.5	455.0	3.5	.341
.5962		54	2.000	173	889	547	D	.5958		54	2.000	193	850	477
86.5	9.5	444.5	3.5	273.5	4.5	.316		96.5	9.5	425.0	3.5	238.5	4.5	.404
.6113		55	2.000	339	1561	1004	E	.6143		55	2.000	355	1582	989
169.5	7.5	780.5	2.5	502.0	2.5	.337		177.5	7.5	791.0	2.5	494.5	3.5	.358

.6409	11	2.000	437	2225	1599	B1	.6497	11	2.000	433	2179	1516
218.5 4.5	1112.5 2.5		799.5 2.5		.273		216.5 4.5	1089.5 2.5		758.0 2.5		.285
.6176	12	2.000	2491	9862	5952	2	.6234	12	2.000	2339	9473	5717
1245.5 2.5	4931.0 1.5		2976.0 1.5		.418		1169.5 2.5	4736.5 1.5		2858.5 1.5		.409
.6136	13	2.000	2046	8283	5084	3	.6150	13	2.000	1911	8008	4842
1023.0 2.5	4141.5 1.5		2542.0 1.5		.402		955.5 2.5	4004.0 1.5		2421.0 1.5		.394
.6173	14	2.000	2016	8360	5153	4	.6217	14	2.000	1974	8317	5104
1008.0 2.5	4180.0 1.5		2576.5 1.5		.391		987.0 2.5	4158.5 1.5		2552.0 1.5		.386
.6150	15	2.000	807	3469	2110	5	.6186	15	2.000	824	3250	1941
403.5 3.5	1734.5 2.5		1055.0 2.5		.382		412.0 3.5	1625.0 2.5		970.5 2.5		.424
.6225	16	2.000	1487	6529	4137	6	.6264	16	2.000	1507	6452	3969
743.5 2.5	3264.5 1.5		2068.5 1.5		.359		753.5 2.5	3226.0 1.5		1984.5 2.5		.379
.6507	17	2.000	872	3918	2608	7	.6561	17	2.000	846	3898	2603
436.0 3.5	1959.0 2.5		1304.0 2.5		.334		423.0 3.5	1949.0 2.5		1301.5 2.5		.325
.5469	18	2.000	1185	4651	2690	8	.5501	18	2.000	1176	4625	2645
592.5 2.5	2325.5 1.5		1345.0 2.5		.440		588.0 2.5	2312.5 1.5		1322.5 2.5		.444

.6127	56	2.000	397	1702	1049	BA	.6131	56	2.000	373	1697	1040
198.5 7.5	851.0 2.5		524.5 2.5		.378		186.5 7.5	848.5 2.5		520.0 2.5		.358
.6174	57	2.000	434	1880	1210	B	.6162	57	2.000	451	1902	1186
217.0 4.5	940.0 2.5		605.0 2.5		.358		225.5 4.5	951.0 2.5		593.0 2.5		.380
.6138	58	2.000	251	1202	818	C	.6184	58	2.000	247	1189	781
125.5 7.5	601.0 2.5		409.0 3.5		.306		123.5 7.5	594.5 2.5		390.5 4.5		.316
.6069	59	2.000	80	378	227	D	.6064	59	2.000	86	409	244
40.0 .0	189.0 7.5		113.5 7.5		.352		43.0 .0	204.5 4.5		122.0 7.5		.352

	.6053		19	1.876	2474	10000	6232	C1	.6101		19	1.857	2476	10000	6185
	1318.7	2.5	5330.4	1.0	3321.9	1.5	.396		1333.3	2.5	5385.0	1.0	3330.6	1.5	.400
	.6173		20	2.000	2247	8737	5599	2	.6215		20	2.000	2186	8975	5813
	1123.5	2.5	4368.5	1.5	2799.5	1.5	.401		1093.0	2.5	4487.5	1.5	2906.5	1.5	.376
	.6141		21	1.885	2436	10000	6369	3	.6208		21	1.908	2424	10000	6515
	1292.3	2.5	5305.0	1.0	3378.7	1.5	.382		1270.4	2.5	5241.0	1.0	3414.5	1.5	.372
	.6172		22	2.000	1769	7408	4858	4	.6225		22	2.000	1738	7243	4869
	884.5	2.5	3704.0	1.5	2429.0	1.5	.364		869.0	2.5	3621.5	1.5	2434.5	1.5	.356
	.6189		23	2.000	2417	9842	6611	5	.6212		23	2.000	2269	9794	6567
	1208.5	2.5	4921.0	1.5	3305.5	1.5	.365		1134.5	2.5	4897.0	1.5	3283.5	1.5	.345
	.6262		24	1.608	2369	10000	6684	6	.6286		24	1.586	2377	10000	6721
	1473.2	2.5	6218.9	1.0	4156.7	1.5	.354		1498.7	2.5	6305.1	1.0	4237.7	1.5	.353
	.6313		25	1.385	2500	10000	6445	7	.6320		25	1.378	2432	10000	6411
	1805.0	2.5	7220.2	1.0	4653.4	1.5	.387		1764.8	2.5	7256.8	1.0	4652.3	1.5	.379
	.6315		26	1.402	2491	10000	6548	9	.6320		26	1.432	2472	10000	6504
	1776.7	2.5	7132.6	1.0	4670.4	1.5	.380		1726.2	2.5	6983.2	1.0	4541.8	1.5	.380
	.6223		27	1.659	2434	10000	6384	10	.6271		27	1.622	2537	10000	6487
	1467.1	2.5	6027.7	1.0	3848.1	1.5	.381		1564.1	2.5	6165.2	1.0	3999.3	1.5	.391
	.6398		28	1.427	2441	10000	6598	11	.6410		28	1.437	2398	10000	6619
	1710.5	2.5	7007.7	1.0	4623.6	1.5	.369		1668.7	2.5	6958.9	1.0	4606.1	1.5	.362

	.6164		60	2.000	48	298	169	(M)A	.6176		60	2.000	66	329	194
	24.0	.0	149.0	7.5	84.5	9.5	.284		33.0	.0	164.5	7.5	97.0	9.5	.340
	.6210		61	2.000	67	358	189	C	.6168		61	2.000	61	297	165
	33.5	.0	179.0	7.5	94.5	9.5	.354		30.5	.0	148.5	7.5	82.5	9.5	.369
	.6350		62	2.000	97	416	258	D	.6355		62	2.000	84	430	269
	48.5	.0	208.0	4.5	129.0	7.5	.375		42.0	.0	215.0	4.5	134.5	7.5	.312
	.6323		63	2.000	76	391	241	E	.6339		63	2.000	86	395	239
	38.0	.0	195.5	7.5	120.5	7.5	.315		43.0	.0	197.5	7.5	119.5	7.5	.359
	.6336		64	2.000	64	325	197	F	.6336		64	2.000	61	293	184
	32.0	.0	162.5	7.5	98.5	9.5	.324		30.5	.0	146.5	7.5	92.0	9.5	.331

D2	.6201		29	2.000	712	3010	1802	
	356.0	4.5	1505.0	2.5	901.0	2.5	.395	
3	.6056		30	2.000	931	3604	2199	
	465.5	3.5	1802.0	2.5	1099.5	2.5	.423	
4	.6132		31	2.000	859	3633	2152	
	429.5	3.5	1816.5	2.5	1076.0	2.5	.399	
5	.5979		32	2.000	1027	4206	2539	
	513.5	2.5	2103.0	1.5	1269.5	2.5	.404	
6	.6076		33	2.000	795	3471	2086	
	397.5	4.5	1735.5	2.5	1043.0	2.5	.381	
7	.5952		34	2.000	1208	4897	2913	
	604.0	2.5	2448.5	1.5	1456.5	2.5	.414	
8	.6195		35	2.000	960	4171	2552	
	480.0	3.5	2085.5	1.5	1276.0	2.5	.376	
9	.6396		36	2.000	1078	4621	2905	
	539.0	2.5	2310.5	1.5	1452.5	2.5	.371	
11	.6236		37	2.000	639	2571	1582	
	319.5	4.5	1285.5	2.5	791.0	2.5	.403	
12	.6169		38	2.000	555	2316	1397	
	277.5	4.5	1158.0	2.5	698.5	2.5	.397	
13	.6146		39	2.000	591	2489	1519	
	295.5	4.5	1244.5	2.5	759.5	2.5	.389	
14	.6197		40	2.000	568	2460	1515	
	284.0	4.5	1230.0	2.5	757.5	2.5	.374	
DA	.5889		65	2.000	154	654	371	
	77.0	9.5	327.0	4.5	185.5	7.5	.415	
B	.6204		66	2.000	99	445	248	
	49.5	.0	222.5	4.5	124.0	7.5	.399	
C	.6189		67	2.000	112	473	275	
	56.0	9.5	236.5	4.5	137.5	7.5	.407	
D	.6186		68	2.000	104	541	311	
	52.0	9.5	270.5	4.5	155.5	7.5	.334	
E	.6061		69	2.000	70	306	169	
	35.0	.0	153.0	7.5	84.5	9.5	.414	
F	.6065		70	2.000	48	299	150	
	24.0	.0	149.5	7.5	75.0	9.5	.320	
G	.6302		71	2.000	41	218	122	
	20.5	.0	109.0	7.5	61.0	9.5	.336	

D 2	.6172	29	2.000	784	3104	1847
	392.0	4.5	1552.0	2.5	923.5	2.5	.424
3	.6014	30	2.000	910	3531	2113
	455.0	3.5	1765.5	2.5	1056.5	2.5	.430
4	.6093	31	2.000	905	3596	2182
	452.5	3.5	1798.0	2.5	1091.0	2.5	.414
5	.5981	32	2.000	1018	4171	2496
	509.0	2.5	2085.5	1.5	1248.0	2.5	.407
6	.6081	33	2.000	839	341:	2113
	419.5	3.5	1705.5	2.5	1056.5	2.5	.397
7	.5943	34	2.000	1148	4669	2817
	574.0	2.5	2334.5	1.5	1408.5	2.5	.407
8	.6161	35	2.000	987	4240	2604
	493.5	3.5	2120.0	1.5	1302.0	2.5	.379
9	.6379	36	2.000	1101	4547	2811
	550.5	2.5	2273.5	1.5	1405.5	2.5	.391
11	.6204	37	2.000	664	2645	1637
	332.0	4.5	1322.5	2.5	818.5	2.5	.405
12	.6163	38	2.000	549	2283	1392
	274.5	4.5	1141.5	2.5	696.0	2.5	.394
13	.6138	39	2.000	552	2448	1485
	276.0	4.5	1224.0	2.5	742.5	2.5	.371
14	.6166	40	2.000	592	2488	1484
	296.0	4.5	1244.0	2.5	742.0	2.5	.398
O A	.5895	65	2.000	149	668	391
	74.5	9.5	334.0	4.5	195.5	7.5	.381
B	.6186	66	2.000	86	430	238
	43.0	.0	215.0	4.5	119.0	7.5	.361
C	.6153	67	2.000	114	481	300
	57.0	9.5	240.5	4.5	150.0	7.5	.380
D	.6187	68	2.000	123	557	328
	61.5	9.5	278.5	4.5	164.0	7.5	.375
E	.6090	69	2.000	59	291	169
	29.5	.0	145.5	7.5	84.5	9.5	.349
F	.6081	70	2.000	59	301	179
	29.5	.0	150.5	7.5	89.5	9.5	.329
G	.6299	71	2.000	20	217	102
	10.0	.0	108.5	7.5	51.0	9.5	.196

	.6020	41	2.000	1235	5011	3014	
	617.5 2.5	2505.5 1.5		1507.0 2.5		.409	
	.6187	42	2.000	1315	5536	3421	
	657.5 2.5	2768.0 1.5		1710.5 2.5		.384	
	.5995	43	2.000	1555	6222	3777	
	777.5 2.5	3111.0 1.5		1888.5 2.5		.411	
	.5902	44	2.000	1609	6868	4041	
	804.5 2.5	3434.0 1.5		2020.5 1.5		.398	
	.6157	45	2.000	2274	9230	5679	
	1137.0 2.5	4615.0 1.5		2839.5 1.5		.400	
	.5969	46	2.000	2338	9194	5593	
	1169.0 2.5	4597.0 1.5		2796.5 1.5		.418	
	.5966	47	1.422	2473	10000	5996	
	1739.0 2.5	7032.3 1.0		4216.5 1.5		.412	
	.6066	48	1.530	2463	10000	6061	
	1609.8 2.5	6535.9 1.0		3961.4 1.5		.406	
	.6441	49	.829	2464	10000	6345	
	2972.2 2.5	12062.7 1.0		7653.7 1.5		.388	
	.6571	50	.927	2345	10000	6474	
	2529.6 2.5	10787.4 1.0		6983.8 1.5		.362	

E1	.6028	41	2.000	1165	5000	2983	
	582.5 2.5	2500.0 1.5		1491.5 2.5		.390	
2	.6166	42	2.000	1267	5503	3379	
	633.5 2.5	2751.5 1.5		1689.5 2.5		.374	
3	.6034	43	2.000	1550	6190	3773	
	775.0 2.5	3095.0 1.5		1886.5 2.5		.410	
4	.5937	44	2.000	1675	6898	4132	
	837.5 2.5	3449.0 1.5		2066.0 1.5		.405	
5	.6164	45	2.000	2199	9069	5573	
	1099.5 2.5	4534.5 1.5		2786.5 1.5		.394	
6	.5968	46	2.000	2264	9222	5555	
	1132.0 2.5	4611.0 1.5		2777.5 1.5		.407	
7	.6002	47	1.443	2439	10000	6034	
	1690.2 2.5	6930.0 1.0		4181.5 1.5		.404	
8	.6083	48	1.538	2403	10000	6010	
	1562.4 2.5	6501.9 1.0		3907.6 1.5		.399	
9	.6459	49	.809	2399	10000	6358	
	2965.3 2.5	12360.9 1.0		7859.0 1.5		.377	
10	.6583	50	.914	2451	10000	6552	
	2681.6 2.5	10940.9 1.0		7168.4 1.5		.374	

	.6050	72	2.000	29	191	112	
	14.5 .0	95.5 9.5		56.0 9.5		.258	
	.6013	73	2.000	39	247	138	
	19.5 .0	123.5 7.5		69.0 9.5		.282	
	.5897	74	2.000	57	307	170	
	28.5 .0	153.5 7.5		85.0 9.5		.335	
	.6369	75	2.000	111	477	286	
	55.5 9.5	238.5 4.5		143.0 7.5		.388	
	.6347	76	2.000	106	492	299	
	53.0 9.5	246.0 4.5		149.5 7.5		.354	

A	.6013	72	2.000	34	186	106	
	17.0 .0	93.0 9.5		53.0 9.5		.320	
B	.6007	73	2.000	29	239	133	
	14.5 .0	119.5 7.5		66.5 9.5		.218	
C	.5923	74	2.000	52	265	138	
	26.0 .0	132.5 7.5		69.0 9.5		.376	
D	.6359	75	2.000	104	474	282	
	52.0 9.5	237.0 4.5		141.0 7.5		.368	
E	.6388	76	2.000	111	486	304	
	55.5 9.5	243.0 4.5		152.0 7.5		.385	

FA	.5692	77	2.000	292	1226	762
	146.0 7.5	613.0 2.5		381.0 4.5		.383
	.5695	77	2.000	326	1324	836
	163.0 7.5	662.0 2.5		418.0 3.5		.389
F2	.5503	51	1.080	2600	10000	6344
	2407.4 2.5	9259.2 1.0		5874.0 1.5		.409
	.5479	51	1.067	2572	10000	6298
	2410.4 2.5	9372.0 1.0		5902.5 1.5		.408

APPENDIX III

Zooplankton Data

Table III-I. Zooplankton Data - July 26, 1972

Replicate Clarke - Bumpus Net Tows

The following table presents the data obtained from replicate tows with a Clarke - Bumpus sampler. All tows originated from the same station which was one kilometer offshore of Moolack Beach. Two complete replicate sets were taken; two tows to the North (.4N1, .4N2) and two tows to the South (.4S3, .4S4). The table lists the number of females, males and immatures per cubic meter of water filtered. All tows were made at a depth of three meters in water with a salinity of 33.566 ‰.

Station/Time	.4N1/0812			.4N2/0820			.4S3/0836			.4S4/0852		
ORGANISMS	FEMALES	MALES	IMMS	FEMALES	MALES	IMMS	FEMALES	MALES	IMMS	FEMALES	MALES	IMMS
ACARTIA CLAUSI	50.8	36.6	73.2	74.2	31.7	91.7	99.5	31.8	95.5	124.5	59.7	107.9
ACARTIA LONGIREMIS	48.3	34.1	23.3	74.2	29.2	28.4	97.5	39.8	77.6	110.5	53.3	68.6
CALANUS SP	0	0	2.5	1.7	0	2.5	6.0	0	0	1.3	1.3	3.8
CENTROPAGES MCMURRICHI	0	.8	0	0	0	0	2.0	2.0	0	0	0	1.3
EUCALANUS SP	0	0	0	0	0	.8	0	0	0	0	0	1.3
OITHONA SIMILIS	60.7	0	7.5	118.4	0	3.3	240.8	0	4.0	174.0	0	2.5
OITHONA SPINIROSTRIS	0	0	0	0	0	0	0	0	0	3.8	0	0
PSEUDOCALANUS	6.7	7.5	36.6	31.7	10.0	46.7	29.9	8.0	49.8	27.9	26.7	49.5
COPEPOD NAUPLIUS	0	0	0	0	0	0	2.0	0	0	1.3	0	0
GAMMARID AMPHIPOD	0	0	0	1.7	0	0	0	0	0	0	0	0
BARNACLE CYPRIS	1.7	0	0	0	0	0	0	0	0	0	0	0
BARNACLE NAUPLIUS	0	0	0	0	0	0	0	0	0	7.6	0	0
CHAETOGNATHA	0	0	0	1.7	0	0	0	0	0	1.3	0	0
CRAB ZOEA	.8	0	0	0	0	0	0	0	0	0	0	0
HERMIT CRAB LARVAE	0	0	0	.8	0	0	0	0	0	0	0	0
PORCELAIN CRAB ZOEA	0	0	0	1.7	0	0	2.0	0	0	0	0	0
CRUSTACEAN EGGS	1.7	0	0	0	0	0	0	0	0	0	0	0
DECAPOD LARVAE	3.3	0	0	7.5	0	0	6.0	0	0	14.0	0	0
MEDUSAE	2.5	0	0	.8	0	0	2.0	0	0	1.3	0	0
MYSID LARVAE	3.3	0	0	12.5	0	0	6.0	0	0	2.5	0	0

Table III-2

PLANKTON COUNT

Date 10/5/73 Station 1mi Sampler pump MSH 6 Depth 7m Sample No. 35d

Start _____ Finish _____ Total _____ Rev. _____ Cal. F. _____

Cor. F. _____ Water strained (m^3) _____ S.V. .3ml D.V. — Ex. V. —

BTMT _____ °C BTMS _____ ‰ ST _____ °C SS _____ ‰ F _____ S _____

#Sp 20 Counted by Linda Smith Date Counted 10/12/73

Comments total sample counted

Organism	Code	Tab. Count	Organism	Code	Tab. Count
Acartia clausi f.	001	104	Annelid larvae	056	27
Acartia clausi m.	001	137	Aquatic mite	057	
Acartia clausi cop.	001	265	Barnacle cypris	058	31
Acartia longiremis f.	002	13	Barnacle nauplius	059	89
Acartia longiremis m.	002	5	Callianassa larvae	060	
Acartia longiremis cop.	002	41	Chaetognath	061	2
Acartia sp.	003		Cladocera-Evadne	062	15
Calanus sp. f.	004		Podon leuckarti	063	175
Calanus sp. m.	004		Crab megalops	064	
Calanus sp. cop.	004	2	Crab Zoea	065	
Centropages mcmurrichi f.	005		Hermit Crab Larvae	066	
Centropages mcmurrichi m.	005		Porcelain Crab Zoea	067	4
Centropages mcmurrichi cop.	005		Crustacean eggs	068	7
Epilabidocera amphitrites f.	006		Ctenophora	069	
Epilabidocera amphitrites m.	006		Cumacean	070	
Epilabidocera amphitrites cop.	006		Decapod Larvae	071	
Eucalanus sp. f.	007		Echinoderm Larvae	072	
Eucalanus sp. m.	007		Euphausiid nauplius	073	9
Eucalanus sp. cop.	007		Euphausiid calytopsis	074	
Eurytemora sp. f.	008		Euphausiid furcilia	075	
Eurytemora sp. m.	008		Fish Eggs	076	
Eurytemora sp. cop.	008		Fish Larvae	077	
Oithona similis f.	009	537	Foraminifera	078	
Oithona similis m.	009	7	Gastropod Eggs	079	
Oithona similis cop.	009	34	Gastropod Larvae	080	141
Oithona spinirostris f.	010		Isopoda	081	
Oithona spinirostris m.	010		Medusae	082	
Oithona spinirostris cop.	010		Mysid Larvae	083	
Pseudocalanus sp. f.	011	13	Oikopleura	084	
Pseudocalanus sp. m.	011	1	Pelecypod Larvae	085	508
Pseudocalanus sp. cop.	011	86	Misc. Unidentified	099	1 eggmass
Tortanus discaudatus f.	012				
Tortanus discaudatus m.	012				
Tortanus discaudatus cop.	012	4			
Copepod nauplius	049	17			
Unidentified Calanoid	050				
Harpacticoid	051				
Amphipod-Gammarid	054	1			
Amphipod-Hyperiid	055				
Amphipod-Caprellid	052				
Amphipod-Corophid	053				

total # animals = 2276

APPENDIX IV

The raw data from the patchiness sampling is presented in Tables IV-1 (from the dory) and IV-2 (from the PAIUTE). They present the number of copepods of each category counted in each sample. The total count is also given for each sample. The samples represent two minutes of pumping at 337 liters/minute. The pumping was continuous from first to last sample.

The graphs (Fig. III-1 through III-9) illustrate the data from the table plotted as number of organisms vs. sample number. Throughout the graphs, from total counts to individual categories, three similar peaks are observed. These peaks of high density may represent patches.

Table IV-1 : Dory Patchiness Data - October 5, 1973

Sample Number	Number of Copepods									
	Acartia clausi f.	Acartia clausi m.	Acartia longiremis f.	Acartia longiremis m.	Oithona similis f.	Oithona similis m.	Pseudo-calanus f.	Pseudo-calanus m.	Pseudo-calanus cop.	Total
1	236	276	61	38	80	1	50	7	378	1127
2	177	170	44	45	119	3	50	3	338	949
3	337	226	90	129	287	7	64	17	1044	2201
4	482	814	150	195	605	39	23	11	876	3195
5	650	828	95	152	426	21	26	11	677	2886
6	909	1296	126	245	635	21	28	7	785	4092
7	441	1025	116	233	794	37	210	19	1132	4007
8	256	413	57	98	462	51	80	18	889	2324
9	251	392	50	91	570	34	46	9	822	2265
10	344	668	104	199	741	58	49	10	1623	3796
11	374	823	82	156	554	43	53	11	1236	3332
12	326	719	98	158	553	42	49	10	1492	3447
13	288	471	152	161	555	31	73	13	1359	3103
14	347	575	124	255	441	43	73	16	1546	3420
15	126	249	26	40	481	35	37	4	252	1250
16	65	230	41	40	152	17	16	1	141	703
17	100	279	42	39	279	17	27	4	92	875
18	95	302	72	42	156	14	19	2	68	770
19	78	222	62	57	246	15	8	1	77	776
20	74	178	51	30	180	6	8	1	57	585
21	70	219	23	28	147	11	16	0	59	573
22	74	238	15	21	139	10	10	2	32	541
23	53	157	15	16	86	2	5	0	25	359
24	114	283	6	17	195	5	12	3	78	713
25	321	844	105	132	337	14	45	6	1097	2901
26	528	1144	120	195	247	15	59	8	1305	3621

Table IV-1 (Continued).

Number of Copepods

Sample Number	Acartia clausi f.	Acartia clausi m.	Acartia longiremis f.	Acartia longiremis m.	Oithona similis f.	Oithona similis m.	Pseudo-calanus f.	Pseudo-calanus m.	Pseudo-calanus cop.	Total
27	466	1151	103	171	917	72	49	13	2029	4971
28	565	1244	146	195	440	26	60	7	1884	4567
29	296	889	39	44	541	37	24	6	285	2161
30	87	159	6	15	313	12	13	0	67	672
31	69	223	9	5	609	39	9	0	46	1009
32	188	551	13	17	466	24	16	2	94	1371
33	562	1276	54	62	858	52	28	0	443	3335
34	226	600	18	26	478	35	21	1	121	1526
35	104	137	13	5	537	7	13	1	86	2276
36	135	185	10	12	341	15	7	0	106	811
37	159	290	7	8	462	27	24	4	103	1084
38	223	428	8	19	342	33	8	1	112	1174
39	392	937	26	29	620	33	11	3	108	2159
40	324	564	45	65	195	5	17	2	278	1495
41	492	788	146	171	129	12	45	9	742	2534
42	492	909	94	144	183	22	35	10	753	2642
43	576	860	69	64	332	23	26	4	348	2302
44	387	713	19	34	238	14	11	10	123	1539
45	632	1538	52	44	464	24	13	0	123	3398
46	515	875	40	52	165	8	24	6	326	2011
47	548	1043	79	121	363	17	33	16	964	3184
48	538	799	53	82	194	6	24	3	560	2259
49	585	823	76	106	356	19	30	9	768	2772
50	576	723	46	73	185	5	33	3	459	2103

Table IV-2: PAIUTE Patchiness Data - October 5, 1973

Sample Number	Number of Copepods									
	Acartia clausi f.	Acartia clausi m.	Acartia longiremis f.	Acartia longiremis m.	Oithona similis f.	Oithona similis m.	Pseudo-calanus f.	Pseudo-calanus m.	Pseudo-calanus cop.	Total
1	200	450	84	138	314	28	31	6	487	1738
2	106	380	45	52	118	16	30	5	312	1064
3	76	534	52	53	162	12	38	7	385	784
4	167	544	49	47	81	9	32	4	257	1190
5	70	253	22	29	57	3	15	2	158	609
6	203	492	99	134	200	11	49	5	716	1909
7	234	542	48	85	436	18	34	11	622	2030
8	227	348	88	149	76	11	42	5	662	1608
9	309	696	49	127	379	22	45	1	687	2315
10	434	710	74	113	225	7	18	8	312	1901
11	245	580	81	122	279	13	34	10	625	1989
12	214	414	67	157	79	7	41	12	736	1727
13	156	411	40	82	219	11	50	12	681	1662
14	152	520	42	93	337	21	37	19	862	2083
15	295	846	75	111	708	32	40	4	760	2871
16	286	794	56	104	222	11	32	10	745	2260
17	289	820	85	187	119	24	39	7	853	2423
18	213	526	46	136	145	12	34	9	763	1884
19	294	547	68	101	261	13	49	7	542	1882
20	370	1170	112	209	204	12	57	8	989	3131
21	138	257	30	29	222	10	31	1	299	1017
22	42	144	24	18	96	8	9	0	64	405
23	14	29	2	7	74	9	3	0	26	164
24	33	101	13	10	159	10	2	2	37	367
25	32	72	14	21	136	5	5	0	29	314
26	35	118	10	8	221	6	2	2	34	436
27	36	150	5	15	216	11	7	1	39	480

Table IV-2 (Continued).

Number of Copepods

Sample Number	Acartia clausi f.	Acartia clausi m.	Acartia longiremis f.	Acartia longiremis m.	Oithona similis f.	Oithona similis m.	Pseudo-calanus f.	Pseudo-calanus m.	Pseudo-calanus cop.	Total
28	52	181	6	8	190	13	9	0	43	502
29	189	457	21	39	315	7	23	1	108	1160
30	219	444	32	62	139	7	26	3	451	1383
31	275	626	35	57	238	10	36	15	543	1835
32	254	656	33	50	207	17	18	12	614	1861
33	336	847	55	108	365	12	17	13	640	2393
34	309	737	34	80	149	11	18	6	589	1933
35	232	419	41	60	227	8	28	1	361	1377
36	122	294	7	14	291	15	17	3	58	821
37	204	402	12	32	329	10	9	2	50	1050
38	152	335	4	5	235	9	9	0	60	809
39	159	366	17	19	229	4	12	2	108	916
40	244	404	33	46	155	9	8	0	192	1091
41	310	356	75	103	129	5	31	7	327	1343
42	323	617	16	20	218	3	11	2	119	1329
43	344	883	20	22	291	8	12	0	118	1698
44	381	439	27	59	141	6	23	4	243	1323
45	380	589	38	62	95	4	15	0	193	1376
46	498	926	38	85	54	3	21	3	218	1846
47	411	838	47	97	69	4	19	6	332	1823
48	303	492	47	80	61	10	18	4	329	1344
49	179	307	32	52	66	9	16	1	272	934
50	193	305	23	38	57	3	13	4	316	952

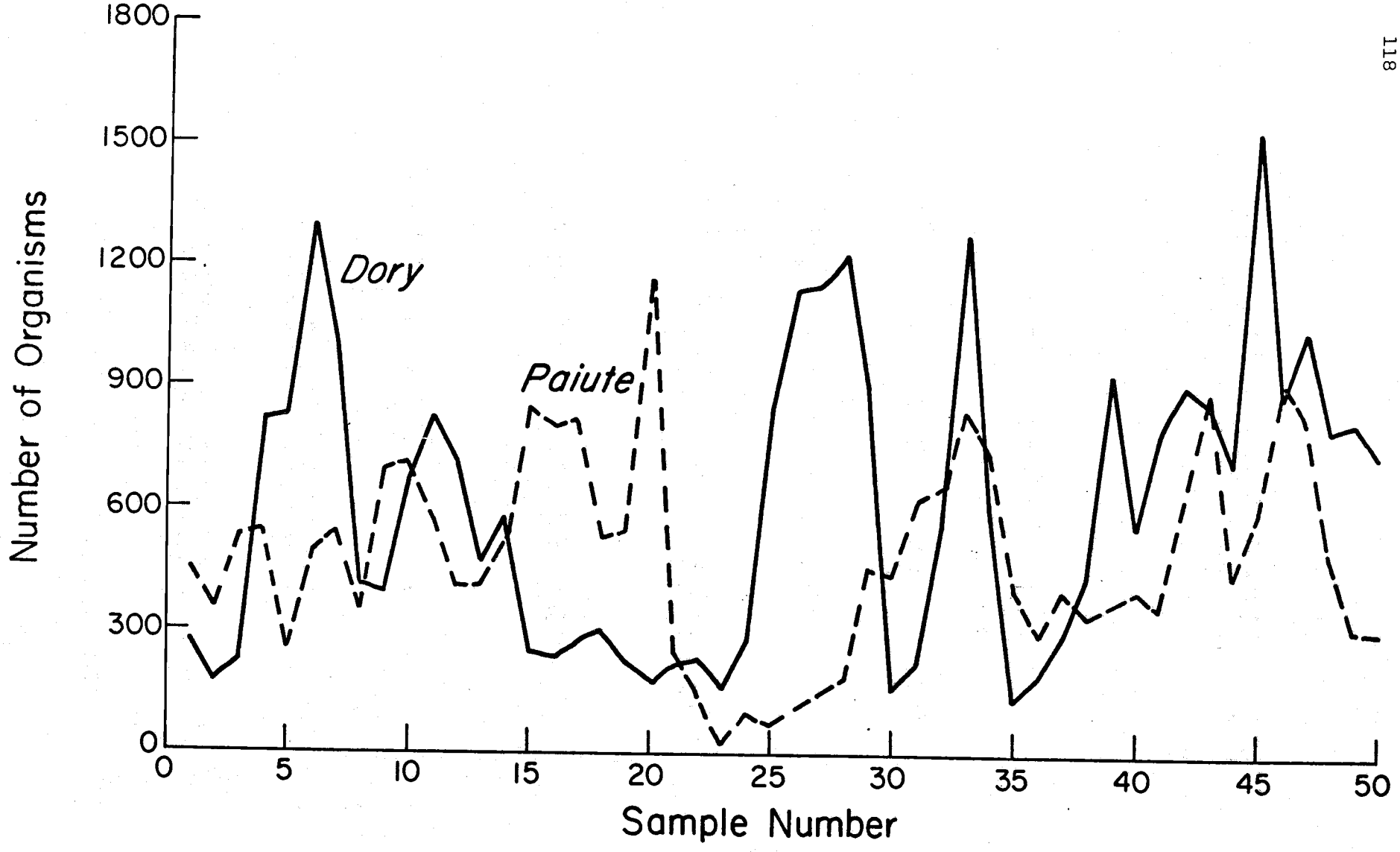

Fig. IV-1. Acartia clausi male

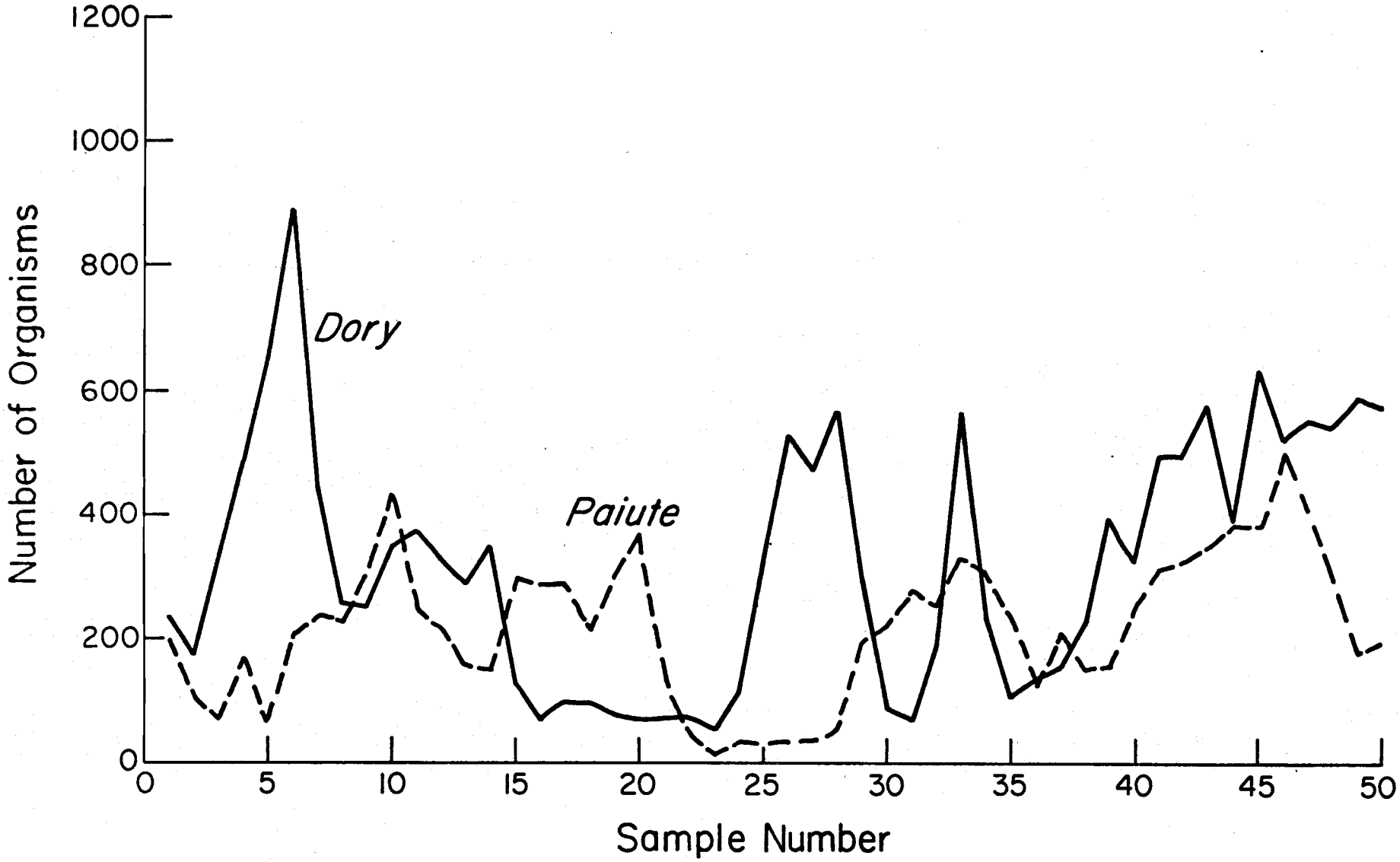

Fig. IV-2. Acartia clausi female

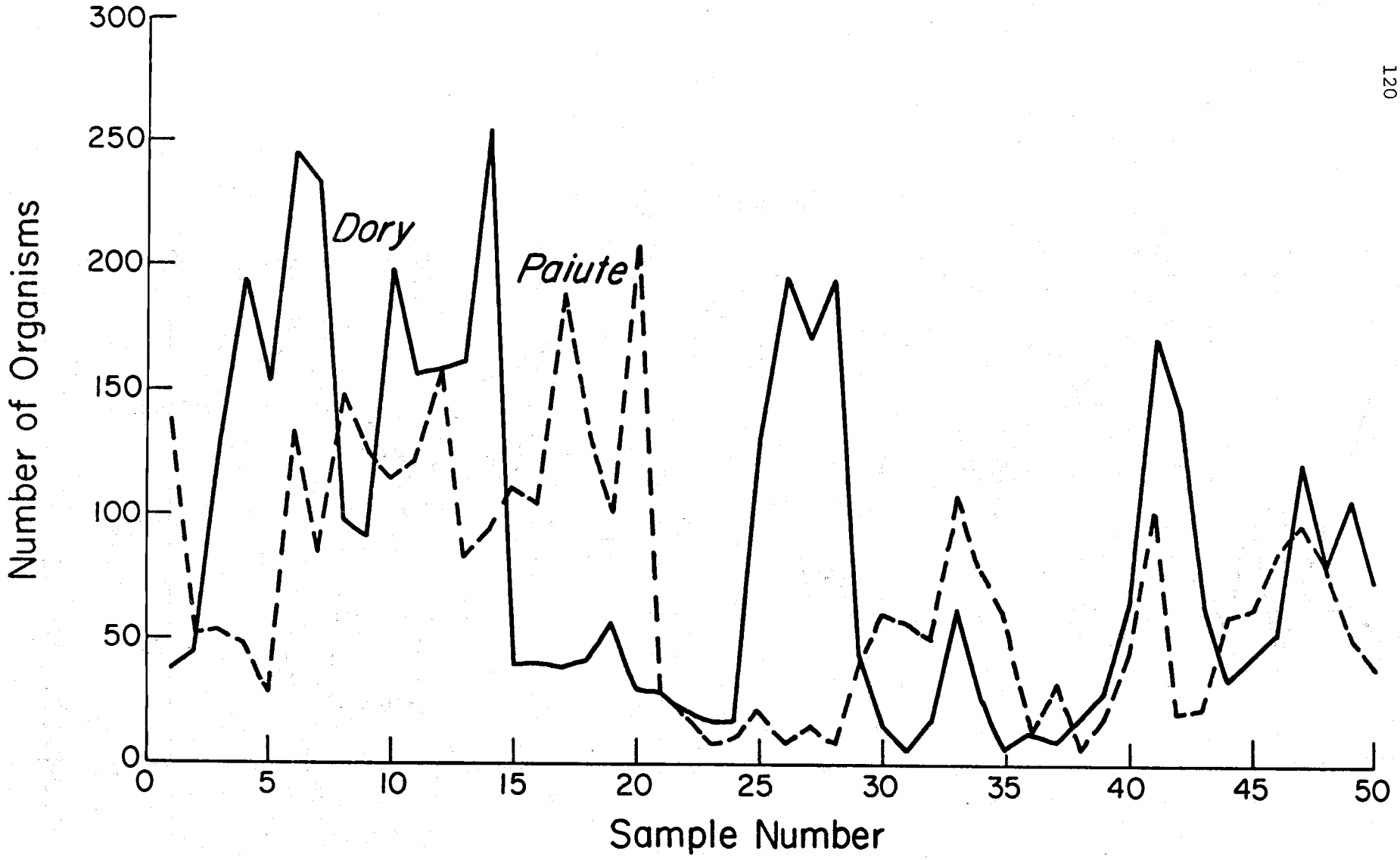

Fig. IV-3. Acartia longiremis male

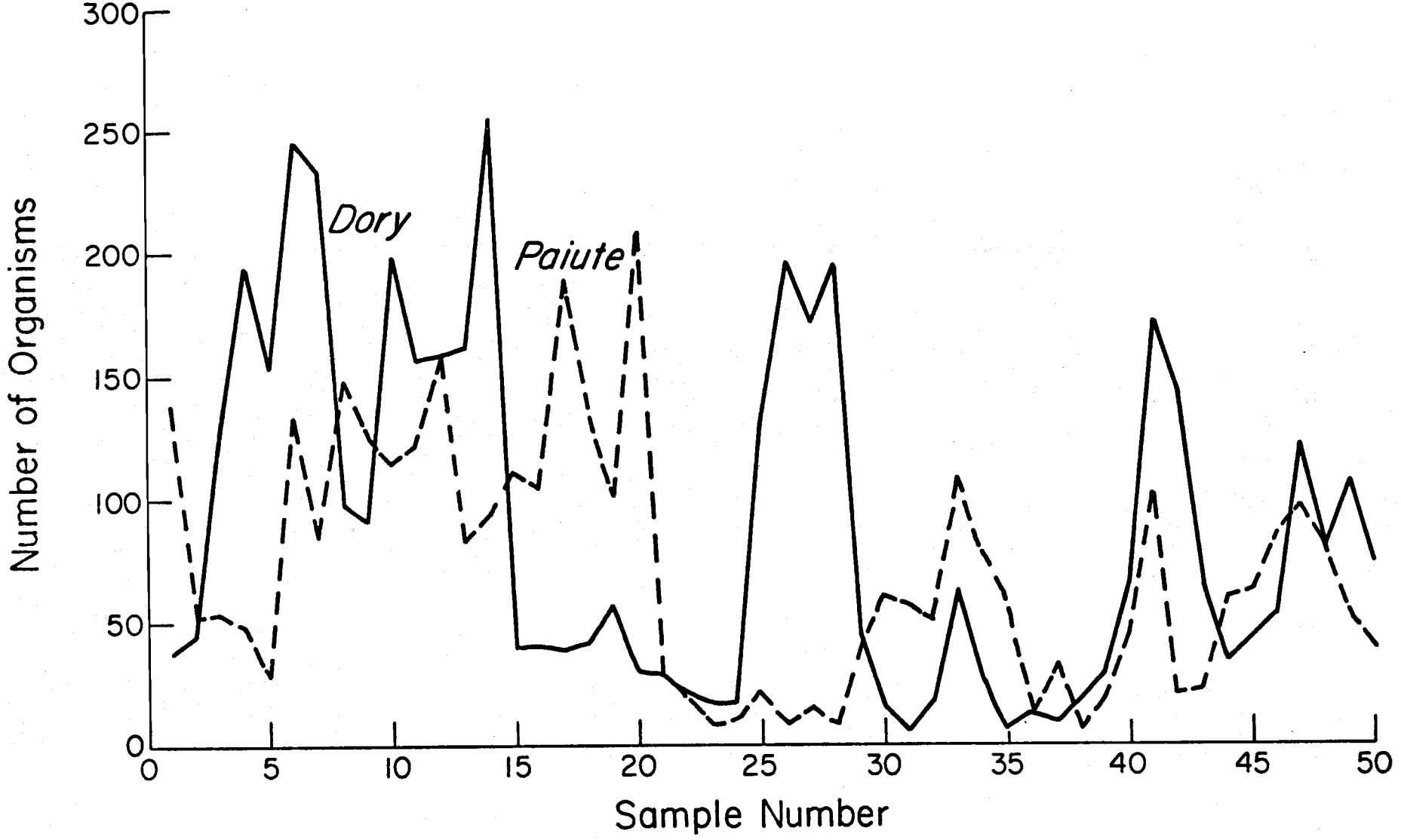

Fig. IV-4. Acartia longiremis female

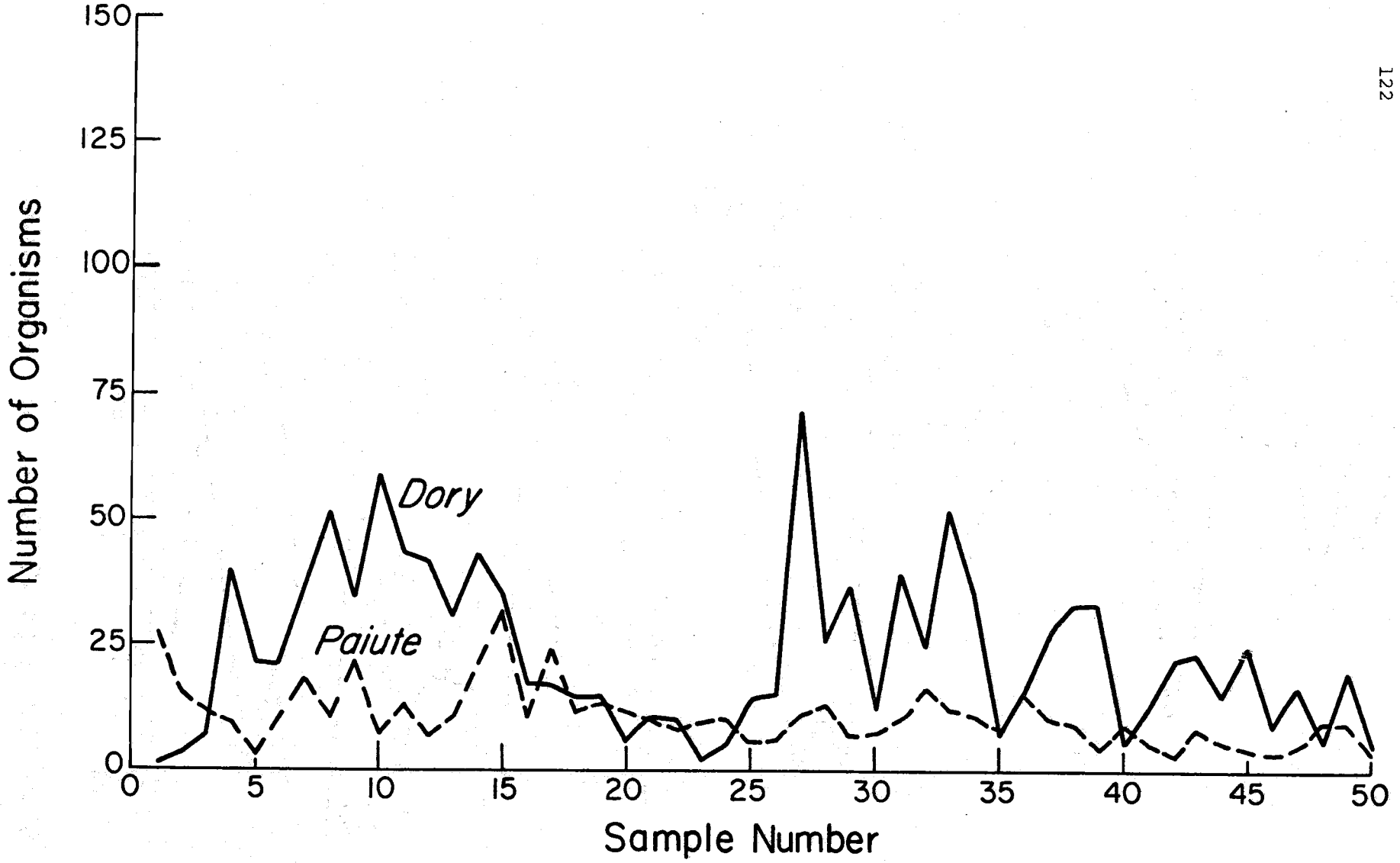

Fig. IV-5. Oithona similis male

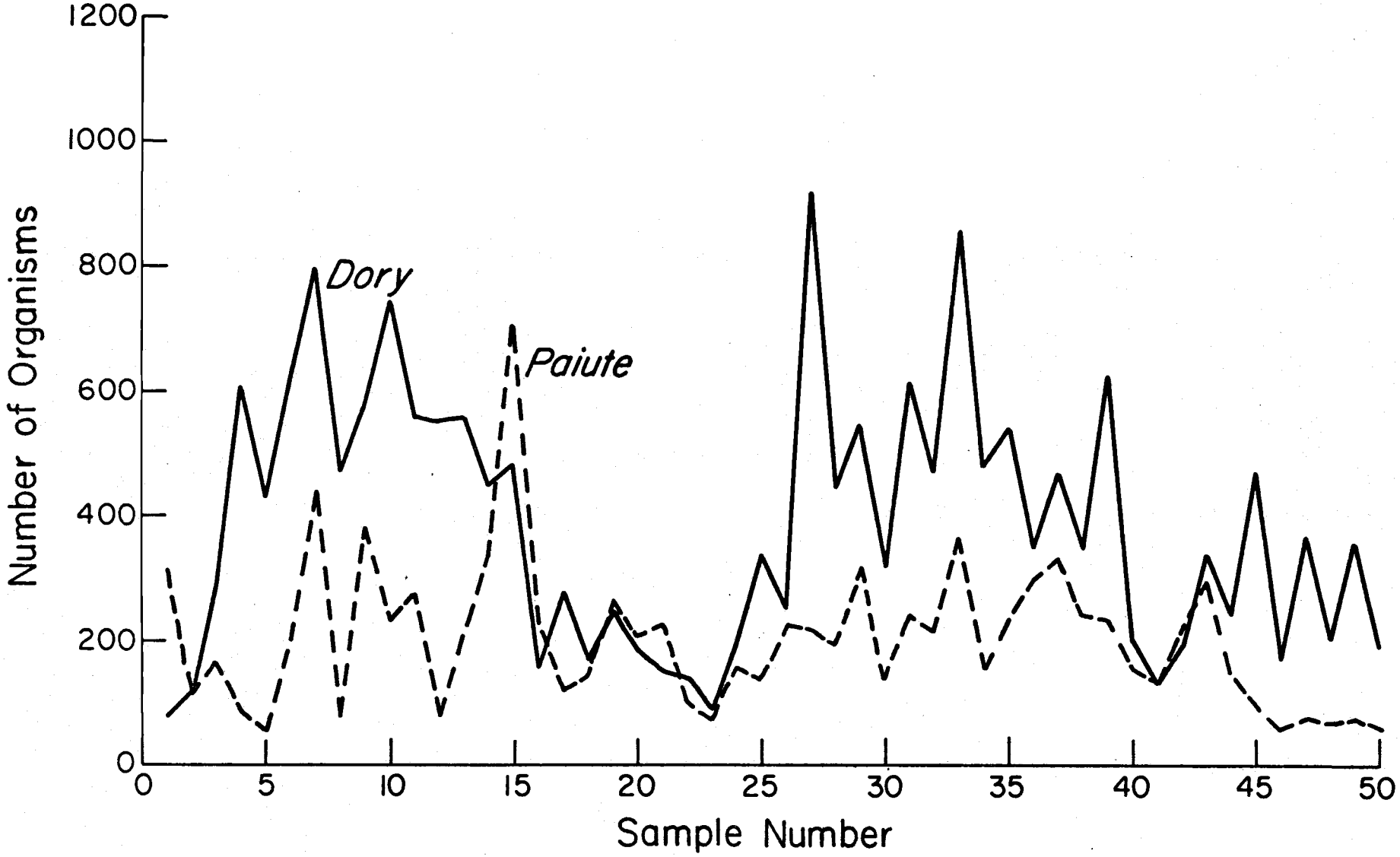

Fig. IV-6. Oithona similis female

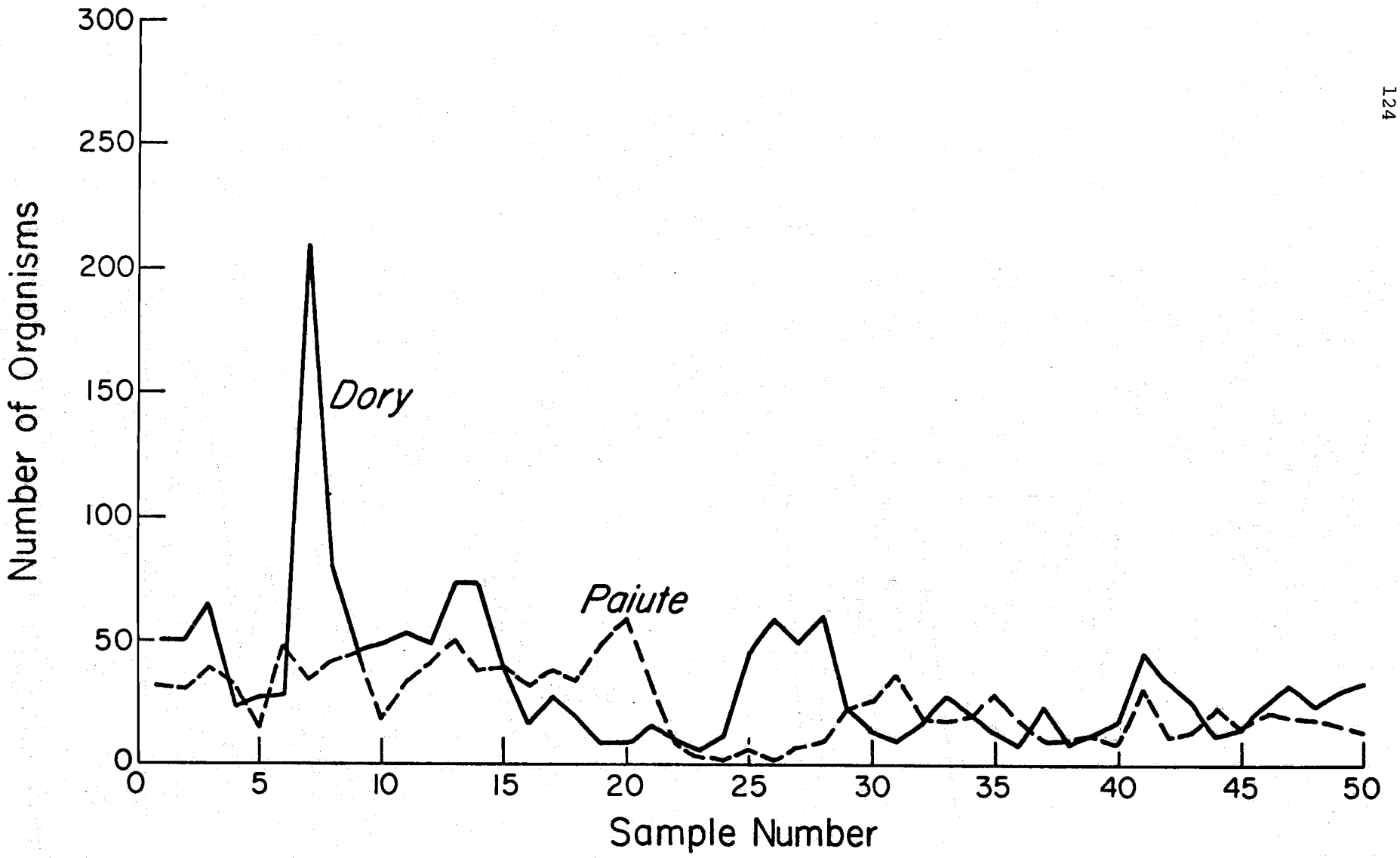

Fig. IV-7. Pseudocalanus female

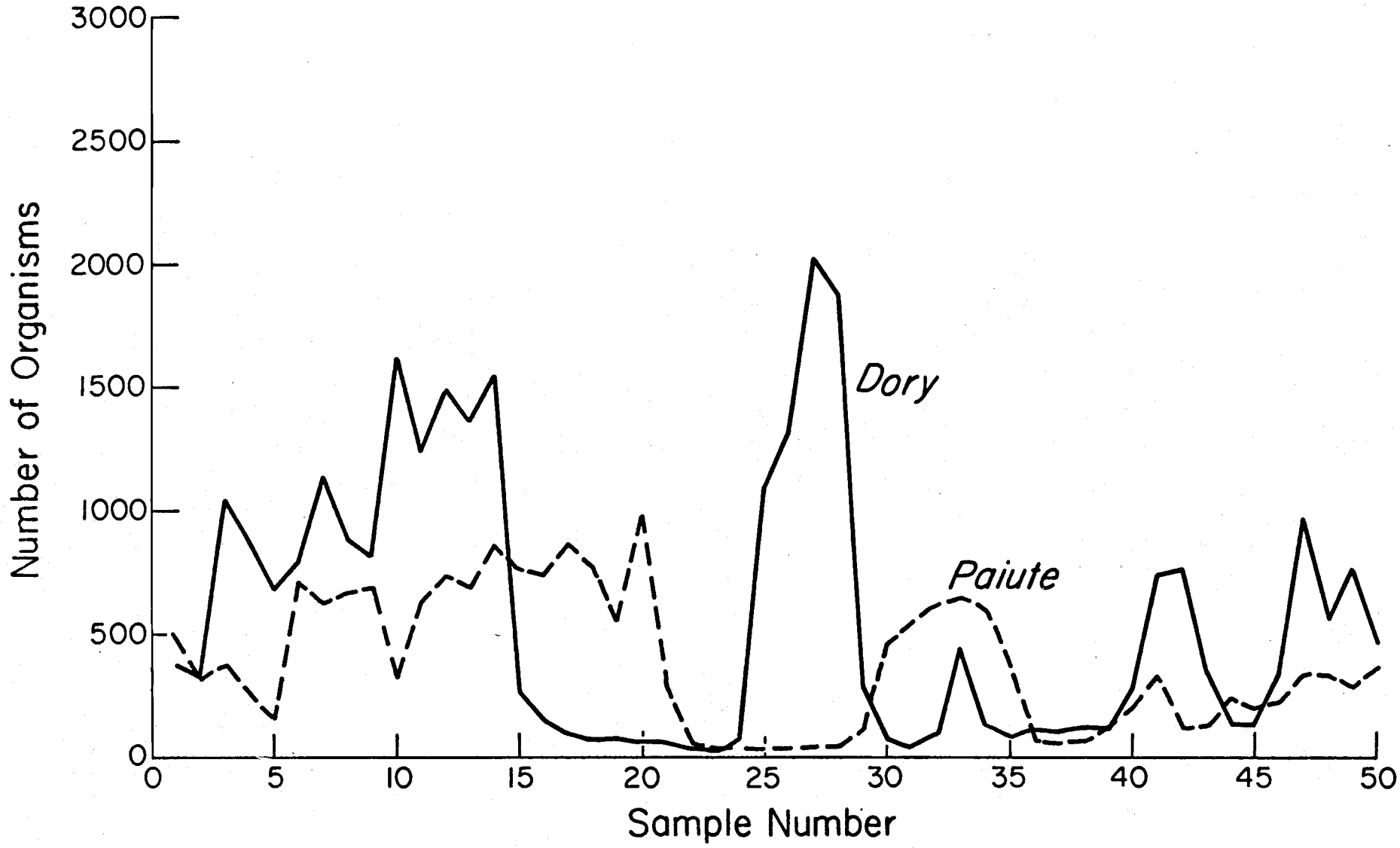

Fig. IV-8. Pseudocalanus copepodites

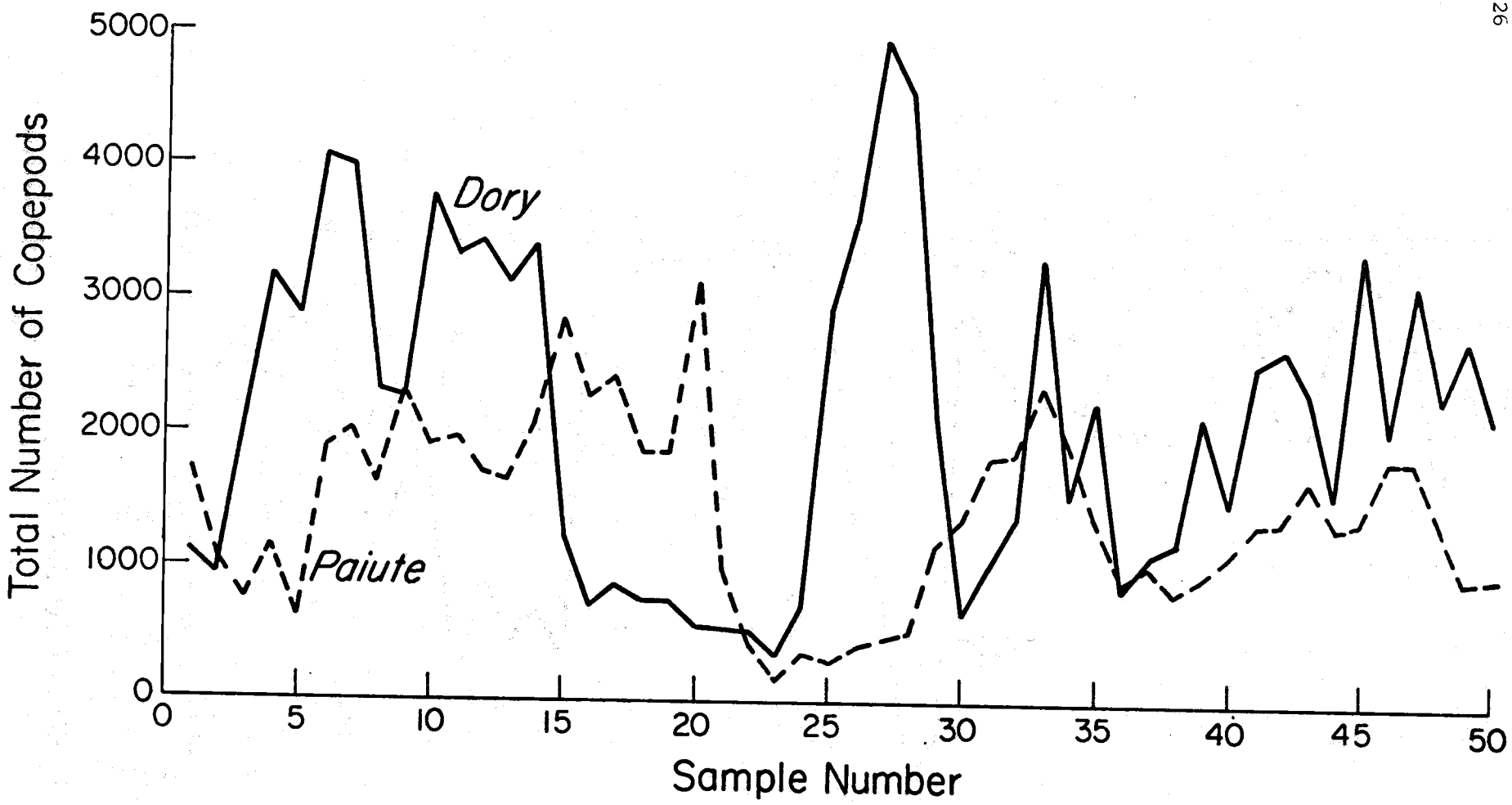

Fig. IV-9. Total Number of Copepods Counted.

APPENDIX V

A representative breakdown of one series of bottomfish sample taken in a 16 foot otter trawl off Moolack Beach, north of Newport, Oregon, on 24 July 1973. Three trawls were made: the first, one mile offshore at a depth of 27 m; the second, two miles offshore at a depth of 42 m; the third, three miles offshore at a depth of 54 m. Boat speed was 2½ - 3 knots and all trawls were towed on bottom for 15 minutes. Tables 1, 2, and 3 list species, numbers, and size distribution of fish taken on the three trawls. Figures 1 through 9 are length frequency histograms of the most abundant species in each trawl.

TABLE V-1. Numbers and size distribution of bottomfish species taken on 24 July 1973 one mile offshore.

LENGTH (CM)	Lingcod	Eulachon	Warty Poacher	Todcod	Butter Sole	Sand Sole	English Sole	Speckled Sanddabs
3						1	1	
4			1	1		2	7	
5			5	3		1	31	7
6			2	2			37	8
7		2	1	8			1	11
8		12		2		3		1
9		5				12		1
10		1				21		
11	1					6		
12	1					2		
13						6		
14						1		
15						2		
16					1	1		
17								
18								
19								
20								
21								
22						1		
23						1		
24								

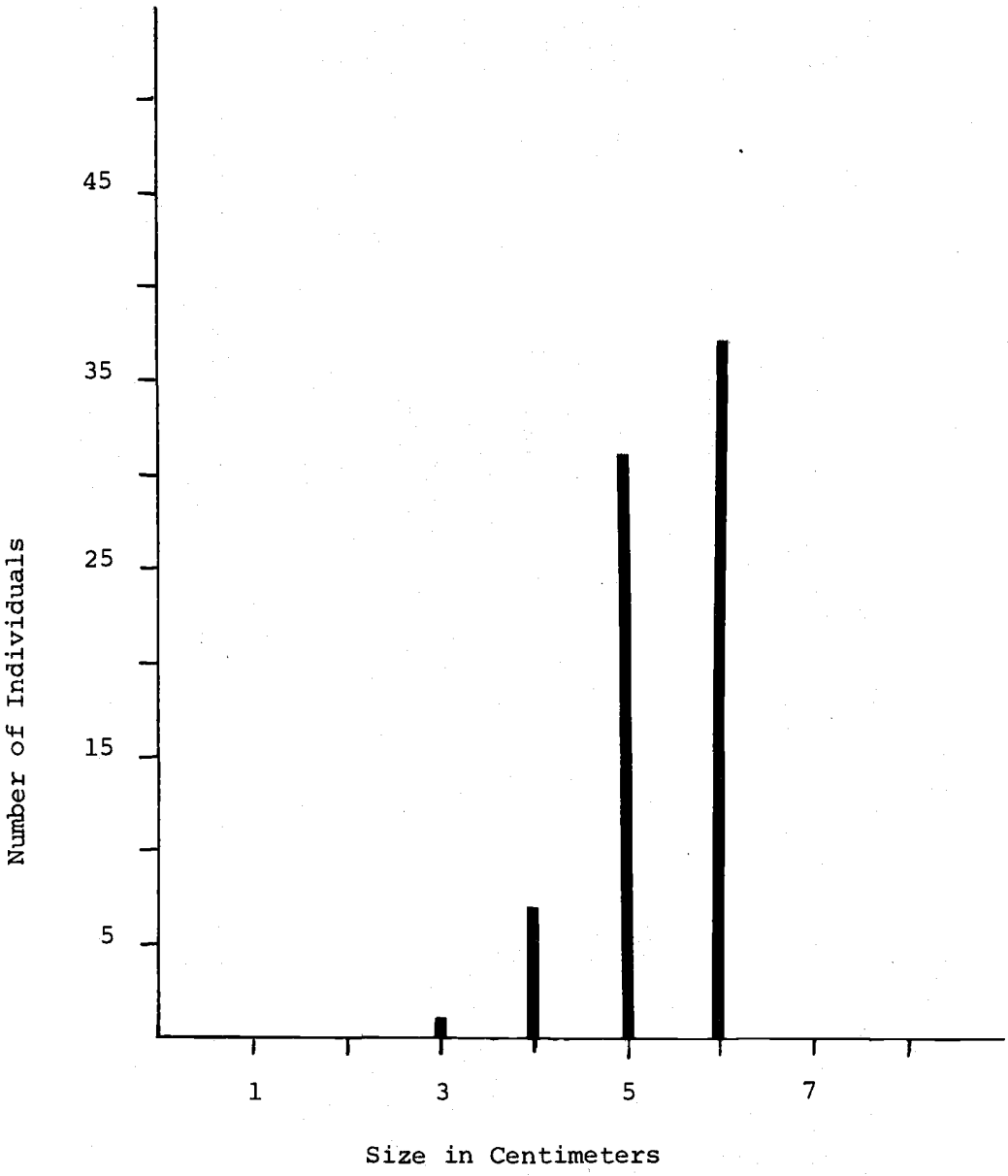

Fig. V-1 English Sole (Parophrys vetulus)
Taken 7-24-73, 1 mile offshore

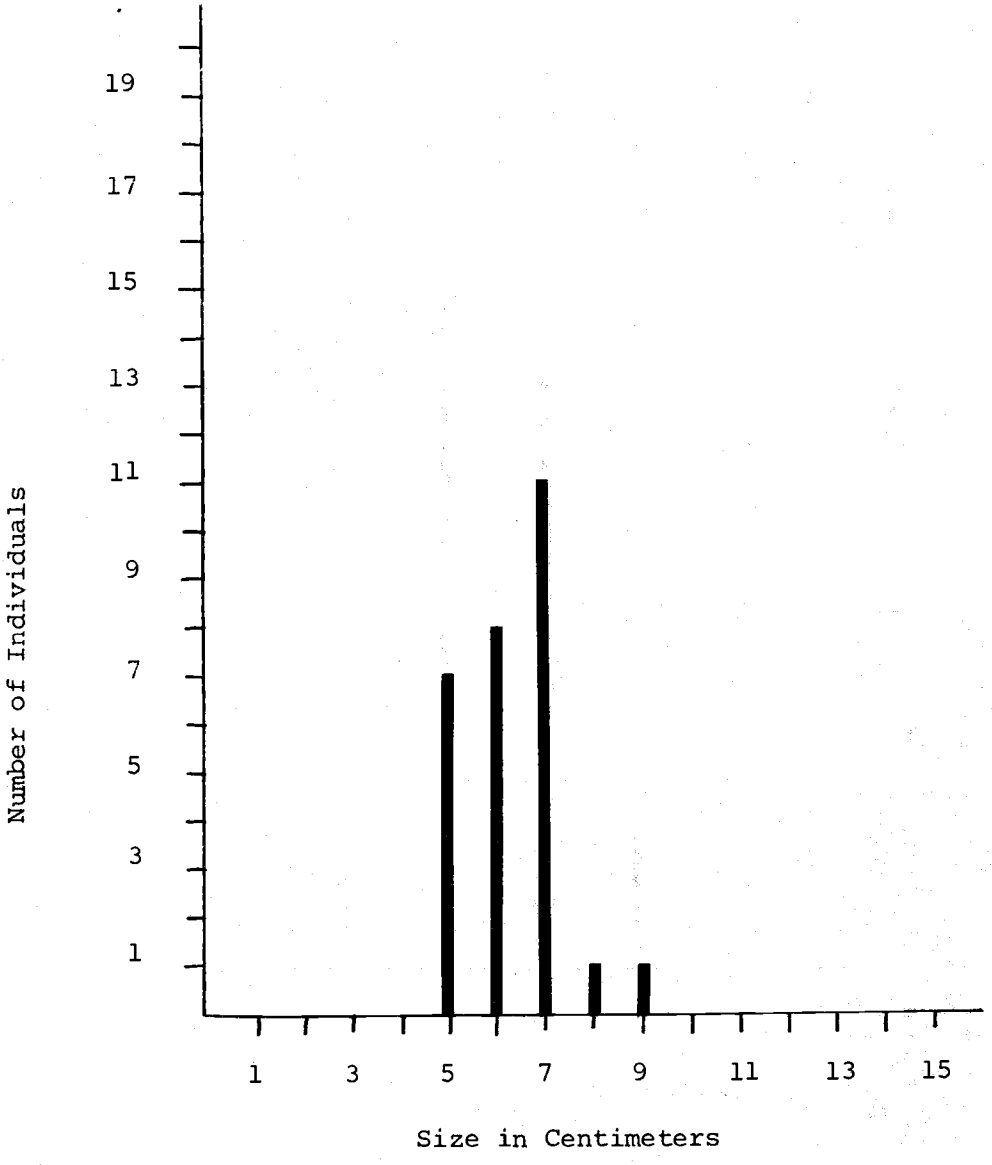

Fig.V-2 Speckled Sanddab (Citharichthys stigmaeus)
Taken 7-24-73, 1 mile offshore

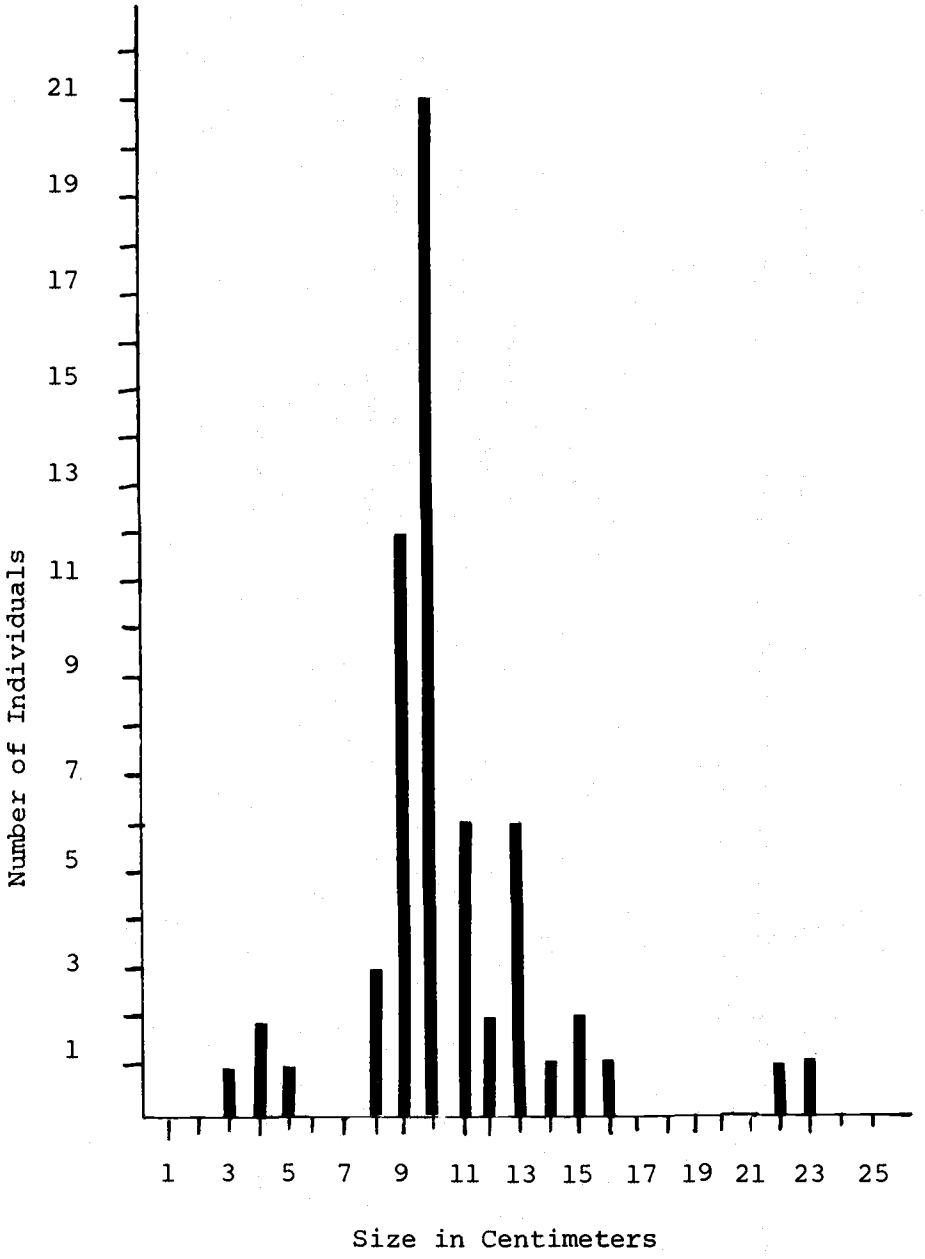

Fig. V-3 Sand Sole (Psettichthys melanostictus)
Taken 7-24-73, 1 mile offshore

TABLE V-2. Numbers and size distribution of bottomfish species taken on 24 July 1973 two miles offshore.

LENGTH (CM)	Pacific Sanddab	Speckled Sanddab	Butter Sole	English Sole	Tomcod	Staghorn Sculpin	Tubesnout Poacher	Sand Sole	Eulachon
3			1						
4	1	8	9		2				
5		29	2		20				
6	3	85			1				1
7		69			2				
8		17							
9	1	1							
10		3	4						
11		10	8						
12		23	8						
13	1	4	6						
14	1	1	5				1		
15	2		2	1					
16	7	1	1					1	
17	5								
18	2								
19	6		2						
20	3		2						
21			2			1			
22	1		3					1	
23									
24								1	

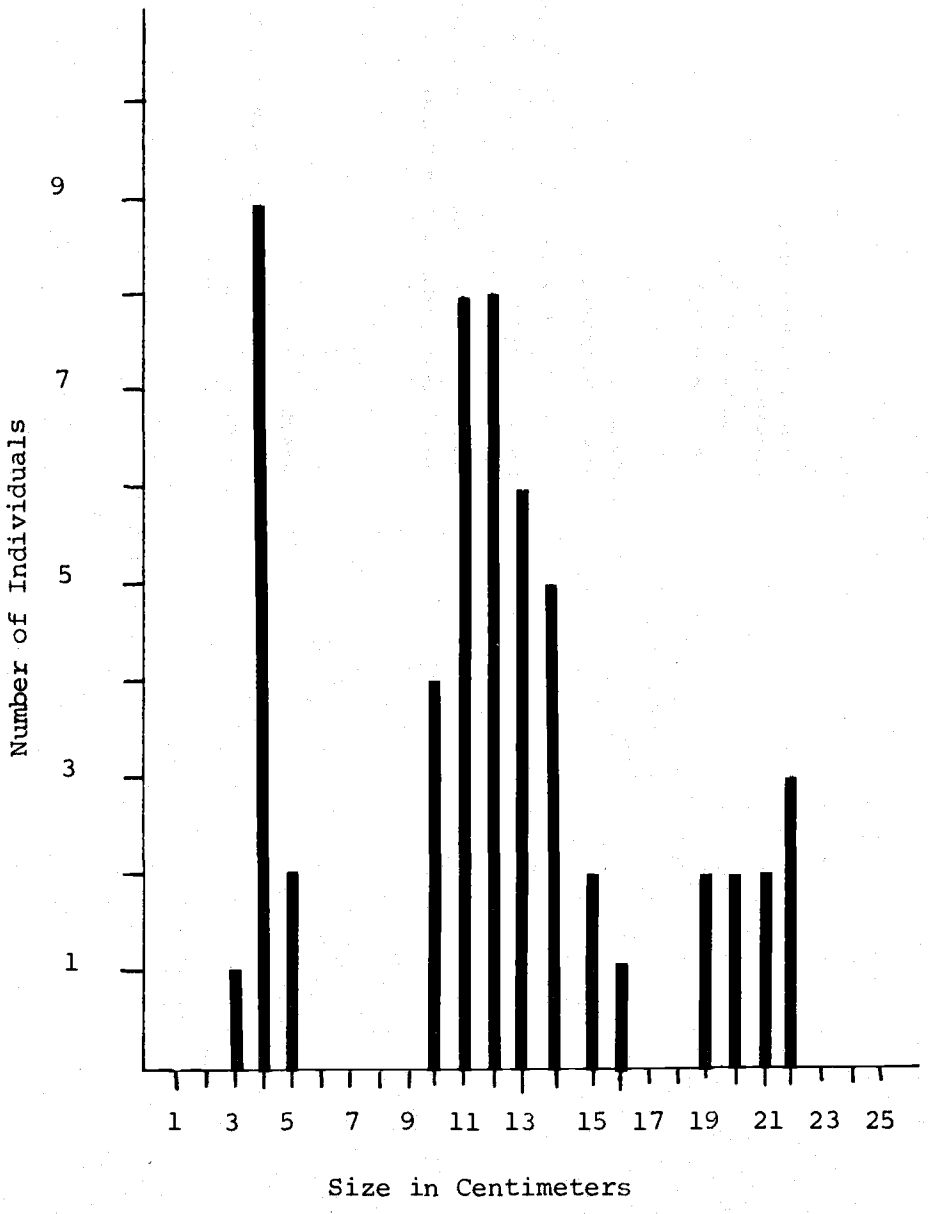

Fig.V-4 Butter Sole (Isopsetta isolepsis)
Taken 7-24-73, 2 miles offshore

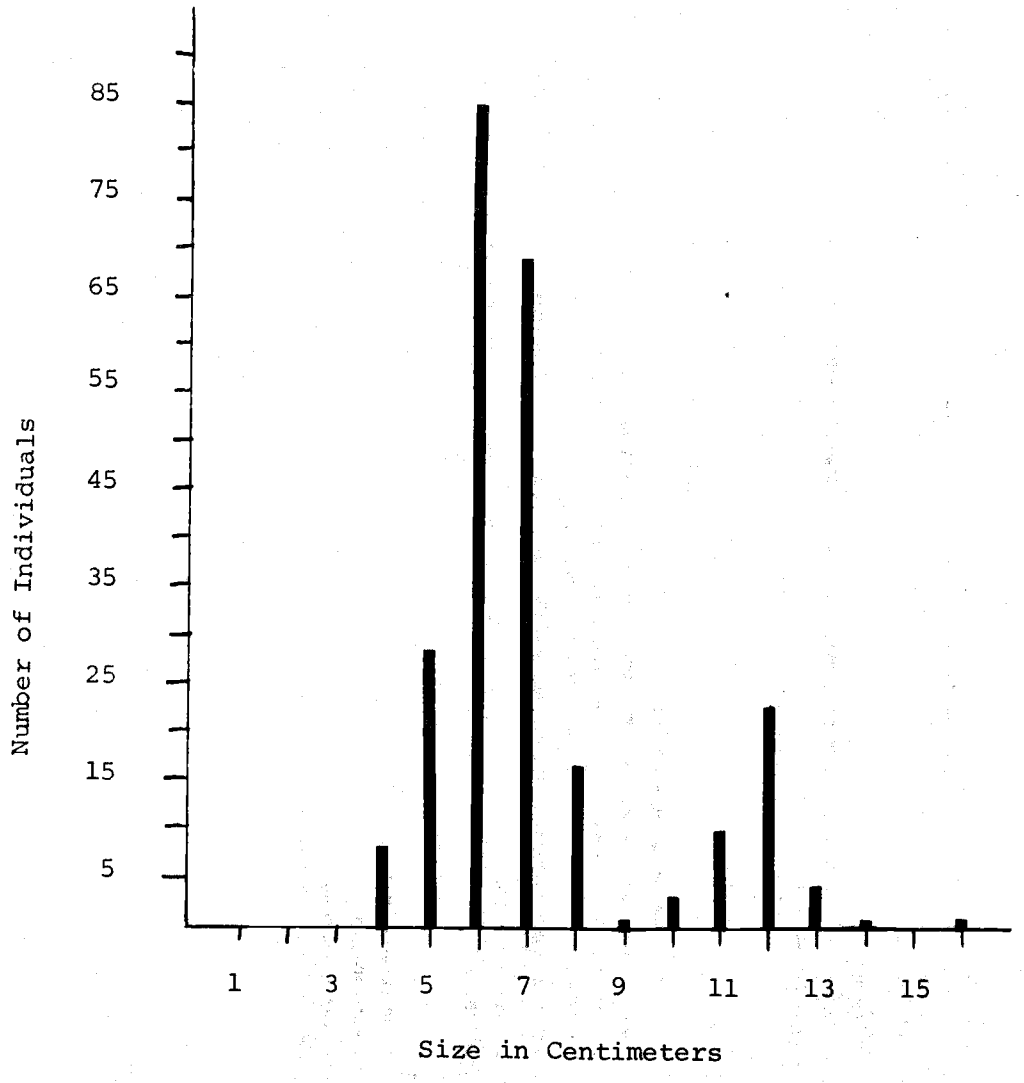

Fig. V-5 Speckled Sanddab (Citharichthys stigmaeus)
Taken 7-24-73, 2 miles offshore

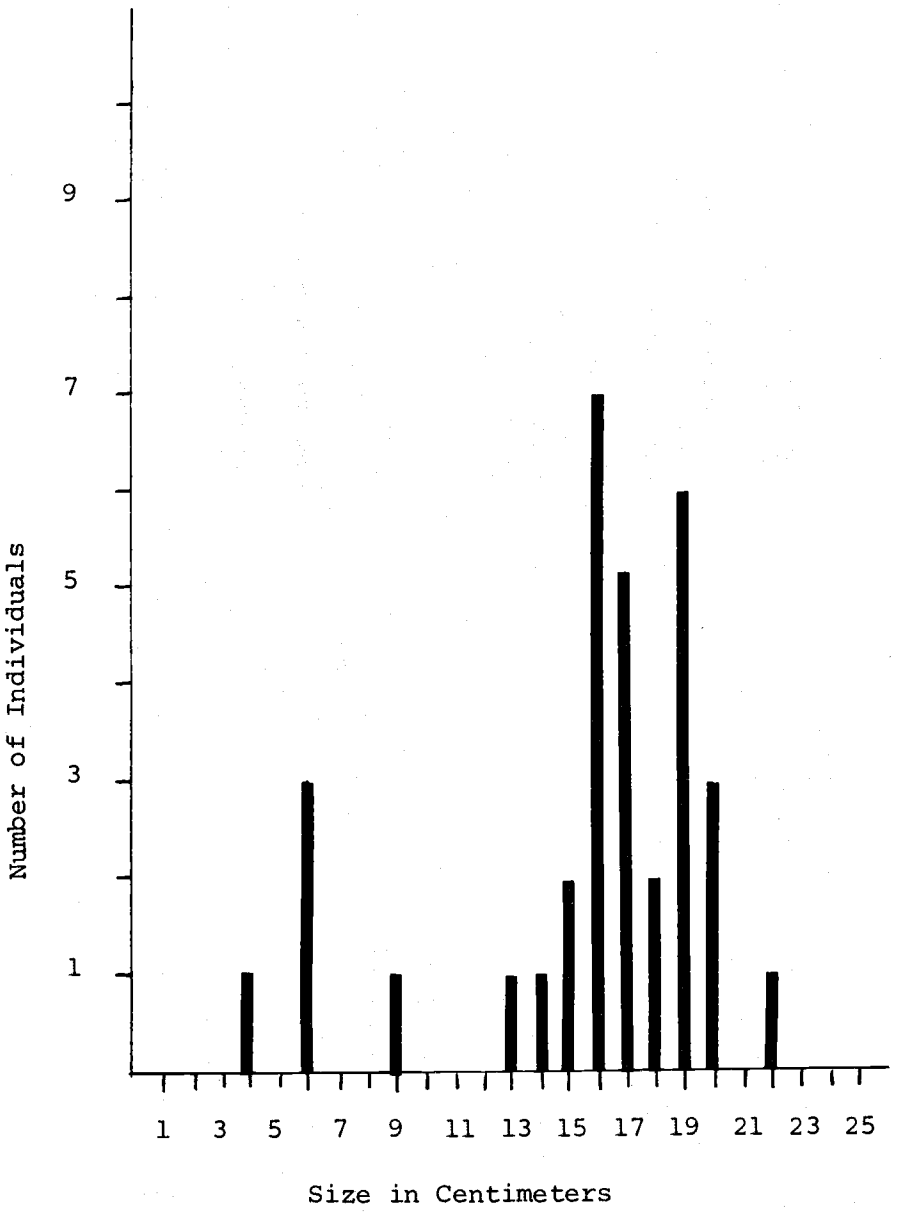

Fig. V-6 Pacific Sanddab (Citharichthys sordidus)
Taken 7-24-73, 2 miles offshore

TABLE V-3. Numbers and size distribution of bottomfish species taken on 24 July 1973 three miles offshore.

LENGTH (CM)	Rex Sole	Sand Sole	Dover Sole	Butter Sole	English Sole	Pacific Sanddab	Speckled Sanddab	Warty Poacher
4						2	1	
5						43	15	1
6				1		131	63	4
7						220	79	1
8			8			75	22	1
9			4			21	6	
10			1	1	1	6	10	
11				14	1	23	48	
12				15	1	26	30	
13				6	1	9	16	3
14				2	3	4		2
15				1	1	7		
16					4	10		
17				2	2	2		
18				2	3	3		
19				4		2		
20				2		1		
21		2			1	1		
22	1							
	1-25 cm			1-24 cm				
	1-28 cm							

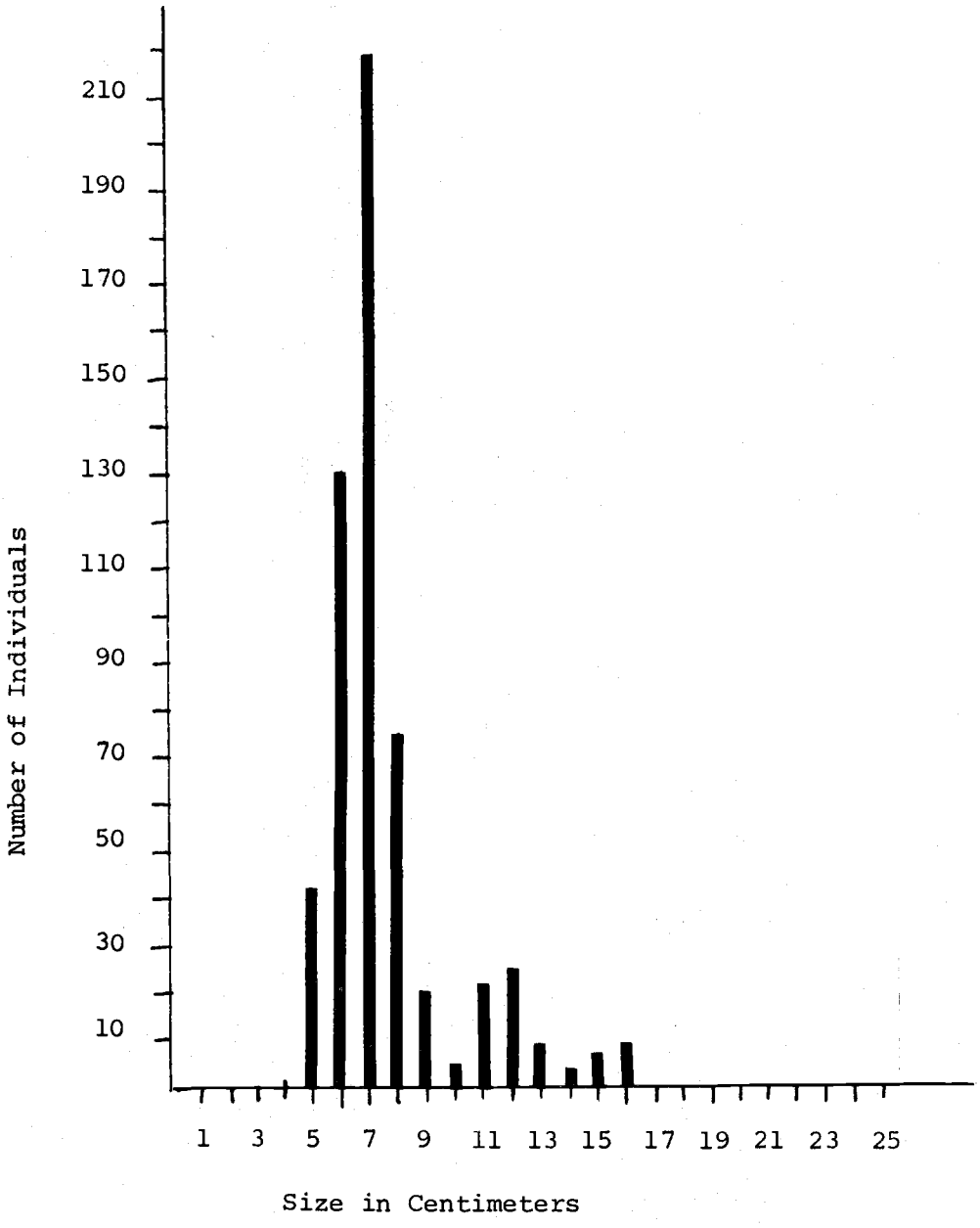

Fig.V-7 Mottled Sanddab (Citharichthys sordidus)
Taken 7-24-73, 3 miles offshore

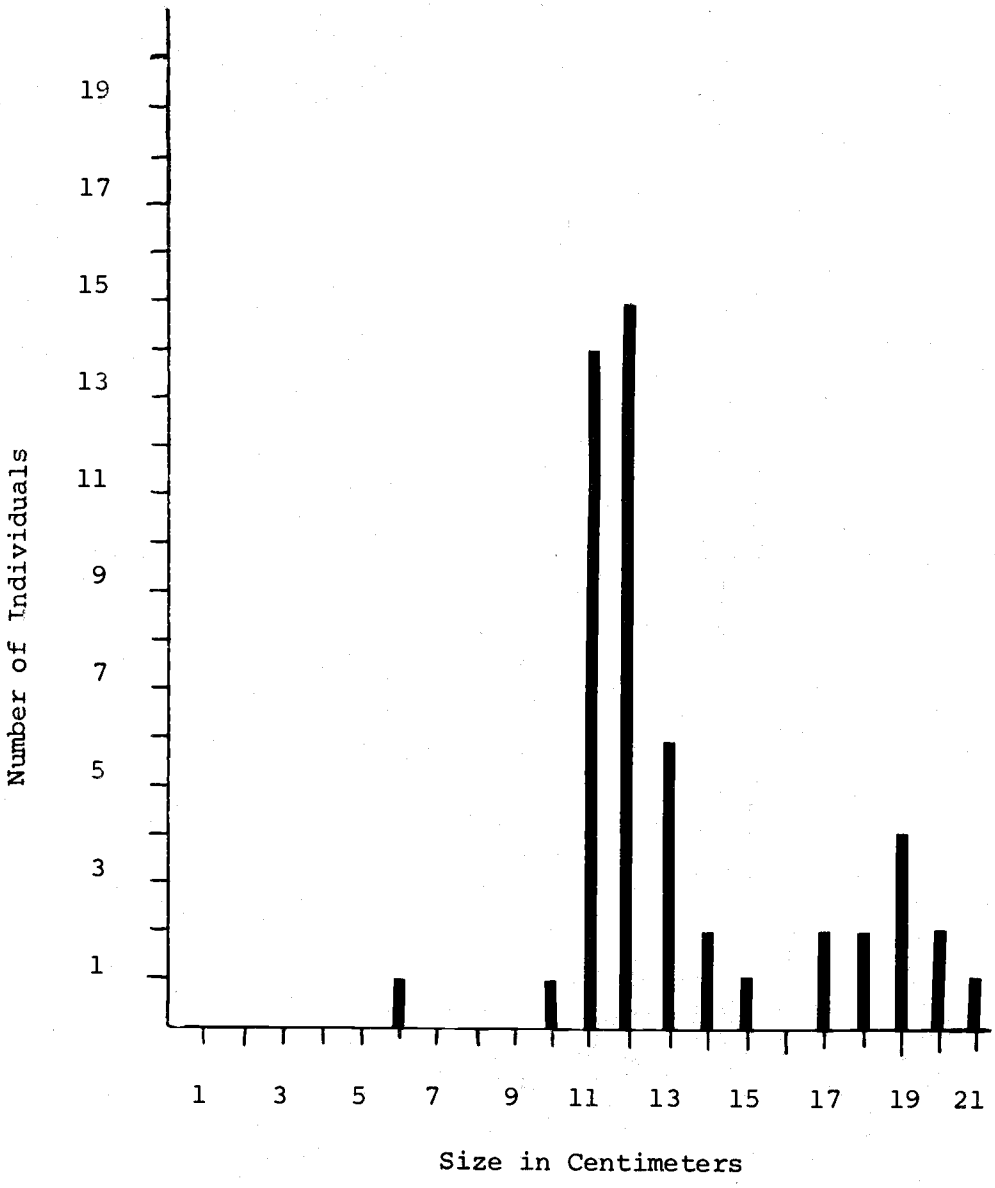

Fig. V-8 Butter Sole (Isopsetta isolepsis)
Taken 7-24-73, 3 miles offshore

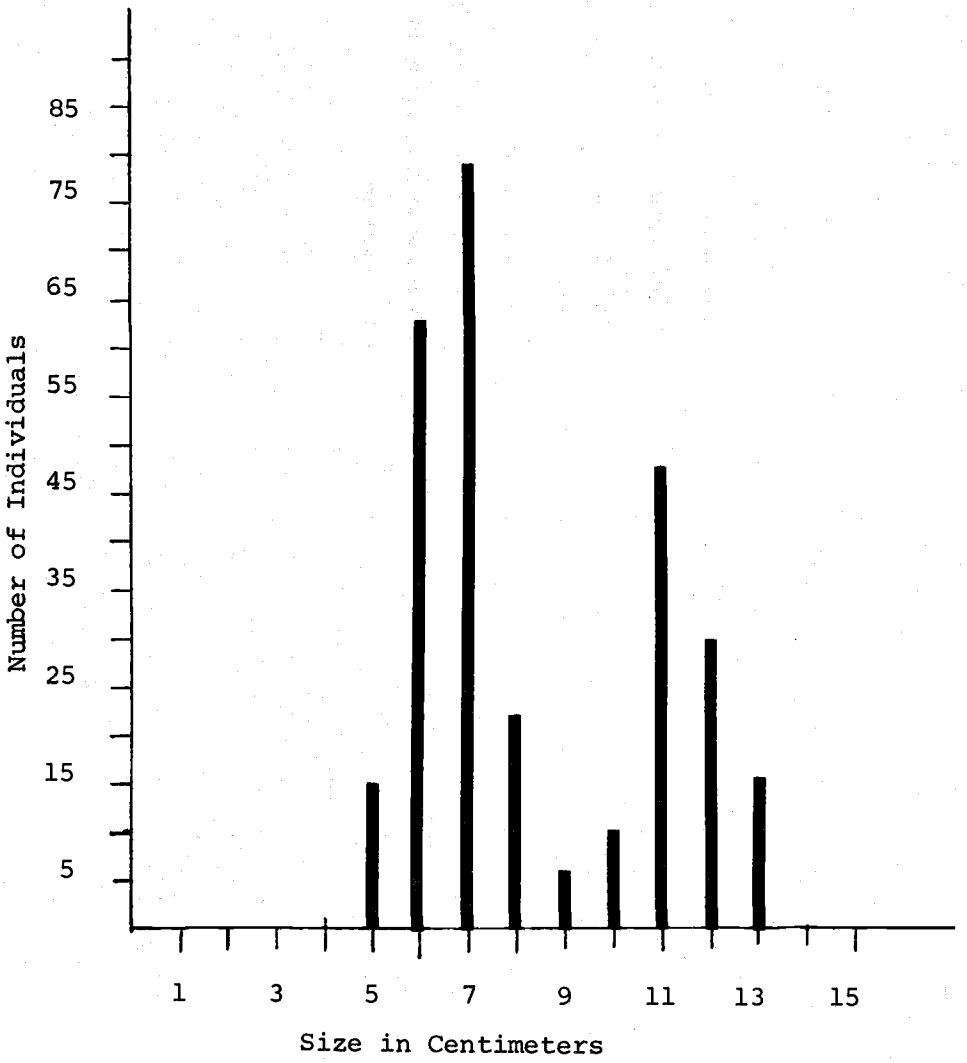

Fig. V-9 Speckled Sanddab (Citharichthys stigmaeus)
Taken 7-24-73, 3 miles offshore

APPENDIX VI

A list of species taken in the bottomfish sampling program off Moolack Beach, north of Newport, Oregon, during the summer of 1973.

List of Species Taken in Bottomfish Samples, Summer, 1973

Agonus acipenserinus	sturgeon poacher
Ammodytes hexapterus	Pacific sand lance
Anarrhichthys ocellatus	wolfeel (2)
Chitonotus pugetensis	roughback sculpin
Citharichthys sordidus	Pacific sanddab (1)
Citharichthys stigmaeus	speckled sanddab (1)
Clupea harengus pallasi	Pacific herring (2)
Engraulis mordax	northern anchovy (2)
Eopsetta jordani	petrale sole
Glyptocephalus zachirus	rex sole (2)
Hydrolagus colliei	ratfish (2)
Isopsetta isolepis	butter sole (1)
Lepidopsetta bilineata	rock sole
Microgadus proximus	tomcod (1)
Microstomus pacificus	dover sole (2)
Occa verrucosa	warty poacher (2)
Odontopyxis trispinosa	pygmy poacher
Ophiodon elongatus	lingcod (2)
Pallasina barbata	tubesnout poacher (2)
Parophrys vetulus	English sole (1)
Platichthys stellatus	starry flounder (2)
Pleuronichthys accurrens	curlfin sole
Psettichthys melanostictus	sand sole (1)

Ptilichthys goodei quillfish

Radulinus aspellus slim sculpin

Raja binoculata big skate (2)

Raja rhina longnose skate

Scorpaenichthys marmoratus cabezon

Sebastes melanops black rockfish

Thalichthys pacificus eulachon (2)

(1) abundant in samples

(2) common in samples

Appendix VII

Analyses of benthic sampling results using a Smith-McIntyre Grab Sampler and a Venturi Suction Dredge at the stations shown on Figs. 17-18 in the text.

Table VII-1. Number of Organisms in Venturi Sampling Dredge Samples taken from Tillamook Bay, Oregon on 21 November, 1973

Organism	Stations 1	2	3	4	5
Cockles	5	12	1	9	7
Littlenecks	1	2		5	
Butter	1			1	
Gaper	1				
Polychaeta			1	1	
Mud Shrimp				2	
Macoma Irus	10		1		

Table VII-2. Organisms Present in Smith-McIntyre Samples Taken in 1973 at Stations from Yaquina Head to Cape Foulweather, Oregon.

Phylum	Stations										
	1	2	3	4	5	6	7	8	9	10	11
Annelida	X	X	X	X	X	X	X	X	X	X	X
Mollusca	X	X	X		X			X	X		
Arthropoda		X	X						X	X	
Echinodermata		X	X						X		

Table VII-3. Number of Benthic Organisms Taken With McIntyre Grab Sampler in 1973.
(5 grabs per station)

Organism	Stations 1	2	3	Total
Phylum Annelida				
Class Polychaeta				
Family Polynoidae				
Arctonoe	17			17
Lepidonotus	7	30	26	63
Family Spionidae				
Nerine	13	19	20	52
Family Gonoiadidae				
Glycinde		4		4
Family Sabellidae				
Chone		6	8	14
Sabella	11	19	26	56
Family Glyceridae				
Glycera	21			21
Phylum Mollusca				
Class Gastropoda				
Olivella	10	26	20	56
Phylum Arthropoda				
Class Crustacea				
Subclass Malacastraca				
Superorder Peracarida				
Order Amphipoda		9	15	24
Phylum Echinodermata				
Class Echinoidea				
Superorder Gnathostomata		3	7	10
Totals	79	116	122	317

APPENDIX VIII

A Partial Bibliography of Thermal Pollution Articles.

A PARTIAL BIBLIOGRAPHY OF THERMAL POLLUTION ARTICLES

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APPENDIX IX

A Select Bibliography on Marine Zooplankton.

A SELECT BIBLIOGRAPHY ON MARINE ZOOPLANKTON

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APPENDIX X.

A select bibliography on nearshore current measuring techniques. Particular attention was paid to those methods that could be used from aircraft.

A SELECT BIBLIOGRAPHY

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Appendix XI.

"Chlorination: A Fouling Control Method for Seawater Cooling System ," by Linda Smith and Robert Holton. A paper presented at the 1973 Western Regional Conference held at Oregon State Univeristy, Corvallis, Oregon, April 12, 13, 14, 1973.

Abstract

A literature survey of the use of chlorination as an antifouling method is presented. The chemical reactions involved in chlorination are discussed in relation to their role in controlling fouling and their possible environmental consequences. HOCl and OCl^- are distinguished as the major "killing" compounds, but the importance of chloramines is also indicated. The relative concentrations of the breakdown products of chlorine may be determined from a table related to freshwater. The chlorination procedures and effect of chlorine on the byssus threads are discussed. Various procedures of conducting the chlorination are differentiated.

CHLORINATION: A FOULING CONTROL METHOD FOR SEAWATER COOLING SYSTEMS

INTRODUCTION

With the advent of using seawater as a coolant in the condenser systems of nuclear and steam-generated power plants, a problem has arisen. Algae, bacteria, molluscs, and other organisms readily grow in the intake tunnels and condensers and the outflow through which the seawater flows. The growth build-up can eventually block the system and reduce the efficiency by reducing flow and reducing heat transfer. There is also a possibility of perforations appearing in the tubes which would allow seawater to enter the boilers causing serious corrosion (Beauchamp,1969). This accumulated growth of unwanted organisms within the cooling system is termed fouling. Fouling occurs in freshwater, but is much less severe than in seawater.

Water is carried from the sea to steam condensers through intake tunnels lined either with metal or concrete. The seawater tunnels at the modern power plants are sprayed with a very smooth sheet of concrete. These tunnels may be three meters or more in diameter. In the first few months after operation is begun, there is very little fouling. Holmes, 1970, attributed this to the normal leaching of chemicals out of the still-curing concrete. Apparently, these chemicals are enough to prevent the growth of marine organisms. Fairly rapidly, a succession of organisms does develop which signifies the beginning of a nonending battle to maintain a clear cooling system. The community grows and develops, eventually reaching a stage when the organisms die or become dislodged and due to their size, block the condenser tubes as they flow through. The fouling process also occurs in the discharge tunnel, but not in as great a proportion.

FOULING ORGANISMS

Work is continuing in the study of community development of fouling organisms. It is known that the first life to appear is a bacterial slime developing on the concrete surface. This is followed by a community con-

sisting of: algae, hydroids, barnacles, tube worms, mussels, crabs, dog whelks, amphipods, and worms. Mussels, Mytilus, are one of the largest organisms in the fouling community. Because they are also the most difficult to control, they are the logical organisms to use in studying the fouling process and antifouling methods. Mussels attach to the concrete wall while a small spat (up to 1.5 mm long). They may grow 30 mm in one year under favorable conditions. Attachment to the wall is by a strong elastic thread system called the byssus which is laid down by the mussel's foot throughout its life. These threads are formed from quinone tanned protein which is similar to keratin. When the mussel dies, the byssus production is ended, the attachment is weakened, and with enough pressure, the mussel is dislodged from its position (Holmes, 1970). In a cooling system the dislodging can cause serious problems, for if the mussel is large enough, it may become wedged within a condenser tube preventing water flow.

METHODS OF CONTROL

The most effective control has been the use of biocides. Biocide simply refers to any compound which either kills or limits growth of an organism. Although sulpher dioxide, bromine, and chlorinated phenols in combination with copper and zinc have been used, chlorine is the biocide most often used due to its effectiveness on living organisms and its reactiveness with organic materials usually results in a low residual in the effluent (Jensen, 1969).

CHLORINE CHEMISTRY

Before analysing the chlorination process and its effects on the marine organisms, it is advantageous to study the chemistry of chlorine. Draley, 1972, Laubusch, 1969, and Betz, 1957, give good descriptions of the chemistry related to chlorination. When chlorine is added to the water in the form of chlorine gas, the follosing reaction takes place:

$$Cl_2 + H_2O = HOCl + H^+ + Cl^- \qquad K_1 = 3.94 \times 10^{-4} \qquad (1)$$

This reaction runs to equilibrium within a few seconds. Note that chlorine available for use in chlorination is immediately reduced by half: Cl_2 to HOCl. Under coastal or estuarine power plant conditions - dilute solution, pH 8.0 - the equilibrium is to the right. Therefore, little chlorine gas is actually found in solution. The hypochlorous acid (HOCl) almost totally dissociates at this pH.

$$HOCl = H^+ + OCl^- \qquad K_2 = 3.2 \times 10^{-8} \qquad (2)$$

Therefore, in solution the dominant forms present are OCl^- (hypochlorite ion) and a much smaller amount of HOCl which did not dissociate. The relative proportions of the end products are dependent upon both pH and temperature of the intake water. For example, table 1, gives the percentages of HOCl and OCL^- at the normal bottom and surface pH's and temperatures off the Oregon coast. The values are actually for freshwater systems and will be different for seawater since ions are involved, but the general relationships should be representative of those in seawater.

Table 1. Percentages of HOCl and OCl^- at two temperatures and pH's in freshwater.

Temperature °C	pH	% HOCl	% OCl^-
0	8.2	22	78
0	7.9	36	64
20	8.2	16	84
20	7.9	25	75

This shows that HOCl concentration decreases with increasing temperature. Therefore, as intake water is warmed, more of the HOCl should dissociate. The OCl^- concentration increases with increasing pH (Laubusch, 1962).

Chlorine reacts readily with ammonia present in the seawater. The result of their reaction produces chloramines.

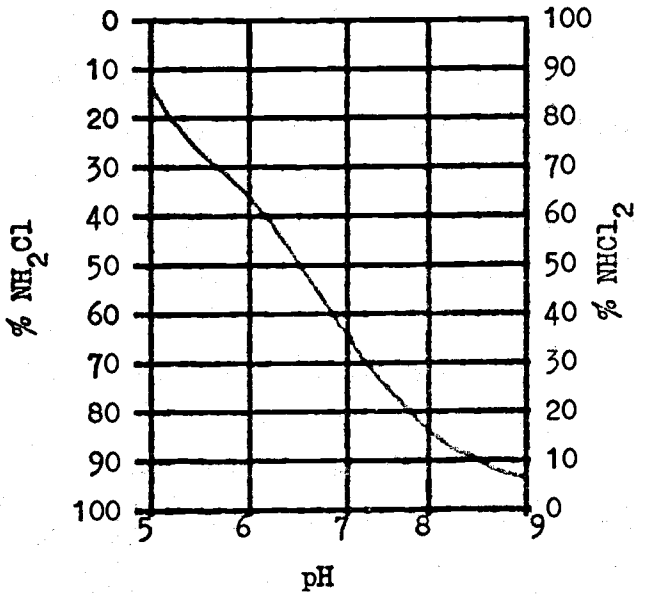
$$NH_3 + HOCl = \underset{\text{monochloramine}}{NH_2Cl} + H_2O \qquad K_3 = 3.6 \times 10^9 \qquad (3)$$

$$NH_2Cl + HOCl = \underset{\text{dichloramine}}{NHCl_2} + H_2O \qquad K_4 = 1.33 \times 10^6 \qquad (4)$$

$NHCl_2 + HOCl = NCl_3 + H_2O$ (5)
trichloramine — very little reactivity at normal pH

The actual chloramine formed depends upon the Cl_2:NH_3 ratio and on the pH of the solution. The following graph form Laubusch, 1962, illustrates this for freshwater. The same relative proportions would be expected to exist in seawater.

Table 2. Relative amounts of chloramines formed at various pH levels (Laubusch, 1962)



Generally, low pH levels and high Cl_2:NH_3 ratios favor dichloramine formation. At the pH of seawater, monochloramine and dichloramine would both be present. Chlorine's reactivity is a function of its ability to combine with or oxidize organic material. Monochloramine reaches its maximum reactivity rate at pH 8.3. Chlorine's reaction rate generally increases with increasing temperature and decreasing pH.

It is possible to predict the concentrations of the chlorine and ammonia-containing species. Using table 3, these equilibrium concentrations may be determined at a common chloride ion concentration by knowing the residual chlorine concentration, pH, and total ammonia. Again, this data is available only for freshwater. Since neutral species are involved and they would have a constant activity coefficient, the relative relationships would hold (powers of the magnitude would remain unchanged) in seawater. An example may be illustrative of using a table of this type. Assuming residual chlorine concentration of

TABLE III

EQUILIBRIUM CONCENTRATIONS OF IMPORTANT CONSTITUENTS IN CHLORINATED NATURAL WATERS

UNITS FOR CHLORINE-CONTAINING SPECIES ARE MG/L CL, FOR NON-CL, NITROGEN-CONTAINING SPECIES, MG/L N

RESIDUAL CHLORINE	CHLORIDE ION	PH	TOTAL AMMONIA	NH4+	NH3	NH2CL	NHCL2	OCL-	HOCL	CL2
1.0000	10.0	6.5	1.000	0.6398	0.0011	0.8209	0.1760	0.0003	0.0029	0.0000
1.0000	10.0	6.5	0.100	0.0001	0.0000	0.0138	0.4783	0.0467	0.4613	0.0000
1.0000	10.0	6.5	0.010	0.0000	0.0000	0.0008	0.0491	0.0873	0.8628	0.0000
1.0000	10.0	7.0	1.000	0.6166	0.0034	0.9252	0.0734	0.0003	0.0011	0.0000
1.0000	10.0	7.0	0.100	0.0000	0.0000	0.0163	0.4734	0.1237	0.3866	0.0000
1.0000	10.0	7.0	0.010	0.0000	0.0000	0.0009	0.0488	0.2304	0.7199	0.0000
1.0000	10.0	7.5	1.000	0.5999	0.0105	0.9729	0.0264	0.0004	0.0004	0.0000
1.0000	10.0	7.5	0.100	0.0000	0.0000	0.0238	0.4586	0.2604	0.2573	0.0000
1.0000	10.0	7.5	0.010	0.0000	0.0000	0.0014	0.0479	0.4782	0.4725	0.0000
1.0000	10.0	8.0	1.000	0.5751	0.0318	0.9905	0.0090	0.0004	0.0001	0.0000
1.0000	10.0	8.0	0.100	0.0000	0.0000	0.0436	0.4189	0.4095	0.1280	0.0000
1.0000	10.0	8.0	0.010	0.0000	0.0000	0.0027	0.0453	0.7254	0.2267	0.0000
1.0000	10.0	8.5	1.000	0.5157	0.0901	0.9963	0.0032	0.0004	0.0000	0.0000
1.0000	10.0	8.5	0.100	0.0000	0.0000	0.0856	0.3348	0.5275	0.0521	0.0000
1.0000	10.0	8.5	0.010	0.0000	0.0000	0.0060	0.0386	0.8695	0.0859	0.0000
0.1000	10.0	6.5	1.000	0.9592	0.0017	0.0981	0.0017	0.0000	0.0002	0.0000
0.1000	10.0	6.5	0.100	0.0649	0.0001	0.0803	0.0166	0.0003	0.0028	0.0000
0.1000	10.0	6.5	0.010	0.0003	0.0000	0.0081	0.0327	0.0054	0.0538	0.0000
0.1000	10.0	7.0	1.000	0.9554	0.0053	0.0994	0.0005	0.0000	0.0001	0.0000
0.1000	10.0	7.0	0.100	0.0621	0.0003	0.0915	0.0071	0.0003	0.0010	0.0000
0.1000	10.0	7.0	0.010	0.0001	0.0000	0.0093	0.0313	0.0144	0.0450	0.0000
0.1000	10.0	7.5	1.000	0.9441	0.0165	0.0998	0.0002	0.0000	0.0000	0.0000
0.1000	10.0	7.5	0.100	0.0602	0.0011	0.0967	0.0026	0.0004	0.0004	0.0000
0.1000	10.0	7.5	0.010	0.0001	0.0000	0.0117	0.0268	0.0309	0.0306	0.0000
0.1000	10.0	8.0	1.000	0.9102	0.0503	0.0999	0.0001	0.0000	0.0000	0.0000
0.1000	10.0	8.0	0.100	0.0577	0.0032	0.0986	0.0009	0.0004	0.0001	0.0000
0.1000	10.0	8.0	0.010	0.0001	0.0000	0.0158	0.0186	0.0500	0.0156	0.0000
0.1000	10.0	8.5	1.000	0.8177	0.1429	0.0999	0.0000	0.0000	0.0000	0.0000
0.1000	10.0	8.5	0.100	0.0517	0.0090	0.0992	0.0003	0.0004	0.0000	0.0000
0.1000	10.0	8.5	0.010	0.0001	0.0000	0.0203	0.0096	0.0638	0.0063	0.0000
0.0100	10.0	6.5	1.000	0.9943	0.0017	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	6.5	0.100	0.0960	0.0002	0.0096	0.0002	0.0000	0.0002	0.0000
0.0100	10.0	6.5	0.010	0.0071	0.0000	0.0067	0.0010	0.0002	0.0021	0.0000
0.0100	10.0	7.0	1.000	0.9906	0.0055	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	7.0	0.100	0.0956	0.0005	0.0099	0.0001	0.0000	0.0001	0.0000
0.0100	10.0	7.0	0.010	0.0066	0.0000	0.0083	0.0006	0.0003	0.0009	0.0000
0.0100	10.0	7.5	1.000	0.9789	0.0171	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	7.5	0.100	0.0944	0.0016	0.0099	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	7.5	0.010	0.0062	0.0001	0.0091	0.0002	0.0003	0.0003	0.0000
0.0100	10.0	8.0	1.000	0.9439	0.0521	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	8.0	0.100	0.0910	0.0050	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	8.0	0.010	0.0059	0.0003	0.0094	0.0001	0.0004	0.0001	0.0000
0.0100	10.0	8.5	1.000	0.8479	0.1481	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	8.5	0.100	0.0818	0.0143	0.0100	0.0000	0.0000	0.0000	0.0000
0.0100	10.0	8.5	0.010	0.0053	0.0009	0.0095	0.0000	0.0004	0.0000	0.0000

KA=3.20-08, KB=1.81D-05, KCHLORAMINE=3.60+09, K2=1.33D+06, KCHLORINE=2.54D+03

From Draley, 1972

1.0 mg/l, pH 8.0, and total ammonia of 0.1 mg/l, the following constituent concentrations are observed:

NH_4^+	0.0000 mg/l N
NH_3	0.0000 mg/l N
NH_2Cl	0.0436 mg/l Cl
$NHCl_2$	0.4189 mg/l Cl
OCl^-	0.4095 mg/l Cl
HOCl	0.1280 mg/l Cl
Cl_2	0.0000 mg/l Cl

The component in the smaller concentration (either ammonia or chlorine) will be almost totally converted to chloramines (Draley, 1972). The molecular chlorine concentrations are too small to be indicated in the table. The HOCl and OCl^- concentrations are important for they largely control the rate of kill of plants and animals (Draley, 1972). As seen from the table, for a given residual chlorine concentration, as ammonia concentration increases, the HOCl concentration decreases which in turn means a decreased kill rate. Monochloramine and to a lesser extent the other chloramines are normally present in the seawater for longer periods than HOCl. The problem arises in determining the relative differences in harmful effects to the biota among HOCl and the chloramines.

The rates of formation of the species and processes interfering with their production are vital to obtaining realistic estimates of the actual quantities of species obtained in the natural environment. The table assumed nothing was lost due to other chemical processes which is not the realistic case. To obtain more realistic values, it is essential to look at reaction rates in natural waters.

Because equations 1 and 2 are nearly instantaneous, the ratios such as $HOCl/Cl_2$ and $HOCl/OCl^-$ can be considered constant for a given pH. At pH 8.3 equation 4 reaction rate is maximum and the concentration of molecular ammonia and hypochlorous acid are maximum.

Free chlorine is lost as hypochlorous acid when it decomposes to form oxygen.

$$HOCl = \tfrac{1}{2} O_2 + H^+ + Cl^- \qquad K_6 \quad 10^{18} \qquad (6)$$

This reaction is catalysed by ultraviolet light. Hypochlorous acid and hypochlorite ion concentrations directly influence the light absorption and thus the reaction rate. From experiments it can be shown that it would take 31

seconds to reduce free chlorine from 0.5 ppm to a "safe" 0.01 ppm (Draley, 1972). The times increase from 50 to 200 times when in the dark which would be the case in a cooling system.

Chlorine and its compounds also react with other substances present in the seawater due to their oxidizing potential. Chlorine decreases pH which reduces the alkalinity and therefore has a potential of eventually overcoming the buffer capacity of seawater. Iron, manganese, hydrogen sulfide, and nitrite all react with chlorine. The general reaction using H_2S as an example is:

$$H_2S + 4\ Cl_2 + 4\ H_2O = H_2SO_4 + 8\ HCl \qquad (7)$$

The chlorine oxidizes the metals to insoluble precipitates and nitrite to nitrate. However, chloramines do not greatly enter into these reactions (Laubusch, 1962).

Chlorine addition or substitution products may form when chlorine or its compounds react with the organic materials in seawater. It is also possible for the chlorine to oxidize the organic materials completely.

Chlorine is also capable of reacting with bacteria and other organisms in such a way which may eventually kill them. But this is a special topic of upmost importance to antifouling and will be discussed further later in the paper.

LOSS OF CHLORINE AND CHLORAMINES

Chlorine and chloramines are lost in power plants by methods which are great enough to normally keep the concentration of chloramines near zero. Evaporation in natural waters and cooling towers causes loss of chloramines, especially dichloramine. Free chlorine may be lost by evaporation of molecular HOCl. Molecular chlorine evaporation is negligible due to its low concentrations.

The rate of loss is also dependent upon a factor termed chlorine demand. This is the difference between the amount of chlorine added to water and the amount of free and/or combined available chlorine remaining at the end of a specified contact period. The free available residual chlorine is an ion such as OCl^- or HOCl. It is dependent on the constituents available with which it may react. (Draley, 1972).

CHLORINATION PROCEDURE

There is no set procedure to follow when using chlorination as an anti-fouling method. At the present time, there is a wide range of ideas about exactly how the procedure should be carried out. Most of the disagreement centers around whether the chlorination should be continuous or intermittent and at what concentration the chlorine should be added. Betz, 1957, gives a summary of the possible methods. (Table 4)

Table 4. Comparison of Chlorination Programs

Program	Remarks
Continuous chlorination Free residual	Most effective - Most costly Not always technically or economically feasible due to high chlorine demand
Continuous chlorination Combined residual	Less effective - Less costly Inadequate for severe cases
Intermittent chlorination Free residual	Usually effective Less costly than continuous chlorination
Intermittent chlorination Combined residual	Least effective Least costly

This table breaks down the procedures into different residual types. He explains that not all forms of chlorine have the same biocide effect. Free available chlorine residual is the part of the total residual chlorine which will react chemically and biologically as HOCl or OCl^-. These forms produce the strongest bacteriocidal effect. Combined available chlorine residual (chloramines and organic chloramines) are relatively mild bactericidal and oxidizing agents. The free residual concentration is very important in determining the method of chlorination. Because of the increased Cl_2 and/or increased contact time, Betz supports using free residual on an intermittent basis.

Koolen and Draley support a continuous chlorination program. In this method, as in the others, there must be an excess of free chlorine, chlorine not tied up with reducing agents. This excess is generally designated at

0.5-1.0 ppm and is termed the residual chlorine. To get this as an excess level, it may be necessary to chlorinate at rates up to 5 mg/l to allow for oxidation-reduction reactions which will occur before reaching the condenser due to chlorine demand. Chlorine is added to the water just upstream of the intake as a gas. This helps insure that some chlorine reactions will not have taken place by the time the chlorine passes through the condenser. This decreases the amount of chlorine needed in the antifouling process and also allows the slower chlorine demand reactions to occur before releasing the water. In this way, a minimal amount of chlorine is released. The water is flowed through the cooling system at a low rate (1.5-2.0 m/sec or greater) - a rate just great enough to force the mussel attachment to break when the organism dies so it may be swept out of the system. By continuing this procedure without interruption, mussels cannot avoid contact with the chlorine and may be eliminated before they are large enough to block the condenser tubes. By the time the seawater reaches the outfall culverts, the chlorine concentration should be reduced to 0.1 mg/l. Upon mixing with ambient seawater, the increased chlorine demand should virtually reduce chlorine concentration to zero (Holmes, 1970).

EFFECT ON ORGANISMS

Now that a little understanding has been gained about the complexity of chlorine chemistry and the variety of compounds which form in water each capable of acting as biocides, it is time to approach the topic of how chlorine may be used to defoul an intake tunnel. Chlorine basically acts on the mussel by weakening the mussel's byssus attachment system. This is accomplished by depressing the foot activity causing decreased production of threads. It may interfere with the quinone tanning process of thread formation so threads are formed weaker than normal. The water flow speed is important for it must be high enough to break the attachment after it is weakened by the chlorine (Holmes, 1970). The dosage concentration becomes important when thinking about how to get it inside the mussel shell. Mussels apparently find chlorine and its combined forms very distasteful. When chlorine is added to water, they close their shells. They open their shells intermittently to start to feed, but close them again if chlorine is present. By keeping a constant flow of chlorine, the mussels are defeated in two ways. First, by continually opening and closing

their shells, they rapidly use up energy resources which are not replaced by feeding. Eventually, they detach and are carried out of the system (Beauchamp, 1969). Secondly, continual addition of chlorine will constantly break down the thread formation process making it difficult to attach. Therefore, continuous chlorination prevents mussels from attaching in the very beginning so fouling does not occur.

CONCLUSION

Antifouling control presents an intriguing theoretical and environmental problem. Work has been done on the problem, but there has not been enough, especially as related to marine cooling systems. Chlorination was first used in freshwater systems. Now an increasing number of nuclear power plants are being constructed along estuaries and coastlines. It is essential that we know what effects are actually occurring in the marine environment by chlorination. The fouling problem is much greater in marine systems which means it may become more and more necessary to use increased concentrations of chlorine. Before this can be done safely, intensive studies must be made in the natural environment to determine specific chemical reactions. Theorizing from freshwater to seawater is a great beginning, but it is only a beginning. It is reassuring to know chlorine undergoes many oxidization reactions rapidly and that it probably dissipates rapidly upon entering open water again, but what about the residuals? Just what happens to them when they leave the system? They are toxic, just as in chlorine and its dissociation products. It will be vital to understand their chemistry before environmental statements may be made in any certainty at all.