CEER-0-57

RESULTS OF OCEANIC MEASUREMENTS RELATABLE TO AN OTEC INSTALLATION AT PUNTA TUNA, PUERTO RICO

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CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

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EXECUTIVE STATEMENT

As Puerto Rico is considered among the prime world locations for a land-connected, operating Ocean Thermal Energy Conversion (OTEC) electrical generating power plant, the U.S. Department of Energy is looking at the oceanographic conditions around the island. The main emphasis is being directed toward Punta Tuna, on the southeast coast of the main island, but other locations have been discussed as well.

This document is in response to a portion of a 4-phase project design to secure and evaluate oceanic data specifically at the Punta Tuna site. The phases provide for:

1. The compilation of a yearly set of periodically sampled oceanic data at the Benchmark site of Punta Tuna.
2. An interpretation of the relevant literature, recently procured data, and long-term current meter data taken concomitant to this program.
3. A thorough historical literature and data search of oceanic data and an interpretation thereof.
4. Recommendations for future studies of the OTEC oceanographic program.

This document addresses the first and second phases, and includes a revision on the fourth phase of the project.

During the contract period, the Punta Tuna site was visited for hydrographic measurements six times:

early August, 1978
mid October, 1978
early December, 1978
mid February, 1979
late April, 1979
early June, 1979

The purpose of each of the cruises was to measure the physical, chemical, and biological variables at many depths and finally look at the temporal changes of those variables throughout the year. This program was supplemented by the U.S. Navy Underwater System Laboratory, New London, Conn. which placed two subsurface current meter moorings near Punta Tuna. The recorded data from two of the recovered current meters is also discussed herein.

As the Punta Tuna site was the primary focus, this location is emphasized, in both the measurements and in the results. However, a nearby site, off Vieques island is compared to Punta Tuna, as are two west coast locations and numerous sites along the south coast. Punta Tuna was determined to offer the best overall potential operating efficiency with the closest offshore distance.

The temperature measurement results show there is virtually no change in the deep water (1000 m) temperature throughout the year at Punta Tuna. The surface water temperature changes by as much as 3 C°, from a low in late winter to a high in early autumn. The Thermal Resource for a full-size OTEC plant could be expected to vary from 20-23 C° annually, if the condenser water intake were at the 1000 m depth and the evaporator water intake were at about 20 m depth. These results would change at other Puerto Rico sites. At the Vieques location, the surface temperature is consistantly about 1/4-1/2 C° cooler than at Punta Tuna. At Punta Borinquen, on the northwest coast, the deep water (1000 m) is about 2 C° warmer than at Punta Tuna, thereby reducing the northwest coast site's operating efficiency considerably.

The Mixed Layer Depth at Punta Tuna was found to vary seasonally from a depth of as much as 90 m during the winter, when the weather is more rough, to virtually zero in the summer, when the weather is calm. The Mixed Layer Depth at Vieques was not much different than that at Punta Tuna. Since the evaporator intake for a full size OTEC plant may be at a depth of 20-25 m, a plant in Puerto Rico waters might draw water from below the Mixed Layer during part of the summer.

The basic water column structure did not change from one location to another, although the temperature structure was slightly different, as mentioned previously. With a similar vertical density structure, the effluent from either a mixed (cold and warm water together) or separated discharge at any of the investigated locations would probably have similar vertical dynamics. The horizontal water motion, however, will influence the fate of the discharge more than the relative density.

Very little is known about the subsurface water currents around Punta Tuna, or even Puerto Rico in general. As a result of the water current profile measurements taken during each cruise, and the moored current meter returns, (about one month of data), diurnal and semi-diurnal tidal components were identified moving east and west along the south coast past Punta Tuna. Eastward and westward motion appeared dominant at Punta Tuna down to about 500 m during the profiling, with considerable motion in all other directions as well. Between 650-750 m the water direction turns primarily to the northeast and northwest. This scattered information is still insufficient to predict the dynamics of a plant discharge.

Dissolved oxygen results at Punta Tuna compared well with the historical values, showing high surface and near surface values, and a relative minimum at mid-depth, and generally increasing values below 800 m. Likewise, chlorophyll results showed typical patchiness, but within the normally expected ranges for tropical oceanic waters.

The comparison between the air temperature from meteorological records in the Caribbean basin, compares well with the sea surface temperature fluctions. Furthermore, periods of sustained higher winds produced the expected increase in the Mixed Layer Depth. Zooplankton results were statistically non-definative due to the lack of replication of sampling. Little new information was learned.

As indicated in the recommendation section of the report, much of the long-term temperature information is available, at least enough to design and build a power plant. The water currents, however, are poorly understood, therefore intake, discharge, and cold-water pipe dynamics are still uncertain. Continuation of studies of nutrient chemistry must also be carried out. Finally, the biological knowledge is the weakest, with virtually no predictive capability for any of the ecosystem components relative to the many interactions that the OTEC plant will have with the biota in the sea.

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Acknowledgements

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1.0 INTRODUCTION

An Ocean Thermal Energy Conversion (OTEC) power plant uses sun-heated tropical or subtropical oceanic waters to produce usable energy. The OTEC plant uses large quantities of warm oceanic surface water and cold deep water to run a thermal engine. The usual estimate is that at least 20 C° difference between the surface and the deep water is desired to run the engine with sufficient efficiency to justify this type of energy production. The thermal engine is then used to drive an electricity producing generator. If the power plant is on, or near, shore, the electrical power can be fed into the local electrical system. If the plant is far offshore, it may be used as the energy source for a floating energy-intensive industrial operation.

Puerto Rico is considered by most scientists and technologists as one of the prime U.S. locations for an OTEC power plant. Furthermore, Puerto Rico seems to qualify as a prime example of a location for a nearshore floating OTEC power plant. More than half of the island's 600 km shoreline has water of a depth of 1000 m or greater less than 13 km from shore. At some places this offshore distance is only about 3 km. In Puerto Rico, it appears that the 1000 m depth will assure at least 20 C° temperature differences from surface to deep water throughout the year (Wolff, 1978). Another advantage of Puerto Rico's location is that it is truly representative of an open ocean island, with little terrestrial runoff and only a small shelf for shallow water coastal organisms to inhabit. Although Puerto Rico is located in the Caribbean, (Fig. 1), and therefore experiences occasional hurricanes, there are several "safe" harbors around the island for personnel and vessels. Finally, Puerto Rico is a technically modern island, with adequate road, seaport and airport facilities, a total inter-island electrical power grid, and a vastly expanding electrical need.

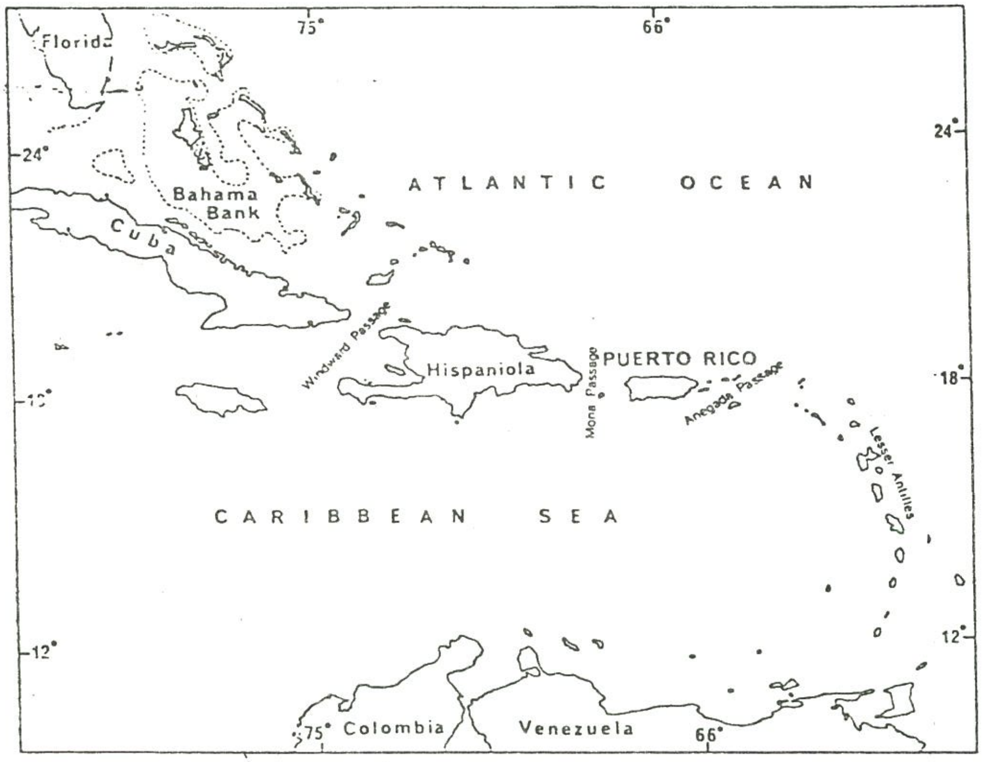


Fig. 1 - Puerto Rico and its location in the Caribbean.

Due to these reasons, the U.S. Department of Energy has contracted the Center for Energy and Environment Research (CEER), of the University of Puerto Rico, to conduct a series of bimonthly cruises to an oceanic site (Fig. 2), about 4 km southeast of Punta Tuna, Puerto Rico (Fig. 3). The purpose of these cruises was to measure and evaluate the variability of many OTEC-related oceanic variables. Punta Tuna and its environment has been determined as one of the optimum Puerto Rico sites (please see Atwood et al., 1976 for a more complete general description of the area).

The purpose of this report is to describe the activities and measurements involved with these bimonthly cruises as well as analyze and interpret the resulting data. Finally, recommendations are made applicable to subsequent oceanic OTEC measurement programs for this geographical area.

1.1 Introduction to the Measurement Program

During the measurement period, the Punta Tuna station was occupied for hydrographic measurement purposes six times:

early August, 1978
mid October, 1978
early December, 1978
mid February, 1979
late April, 1979
early June, 1979

During the first cruise (August, above), the mooring buoy was not yet implanted, and the vessel was allowed to drift while on station. All subsequent hydrographic cruises used a mooring buoy to maintain location while at the Punta Tuna benchmark station (Station "B"). This mooring buoy was available to use with this program because the U.S. Department of Energy also plans to conduct an at-sea experiment for biofouling and corrosion of OTEC heat-exchanger components at the same site, and a deep sea mooring buoy was implanted at 17° 57.6'N, 65° 51.9'W (about 4 km southeast of Punta Tuna) in September of 1978 (Sasscer et al., 1979).

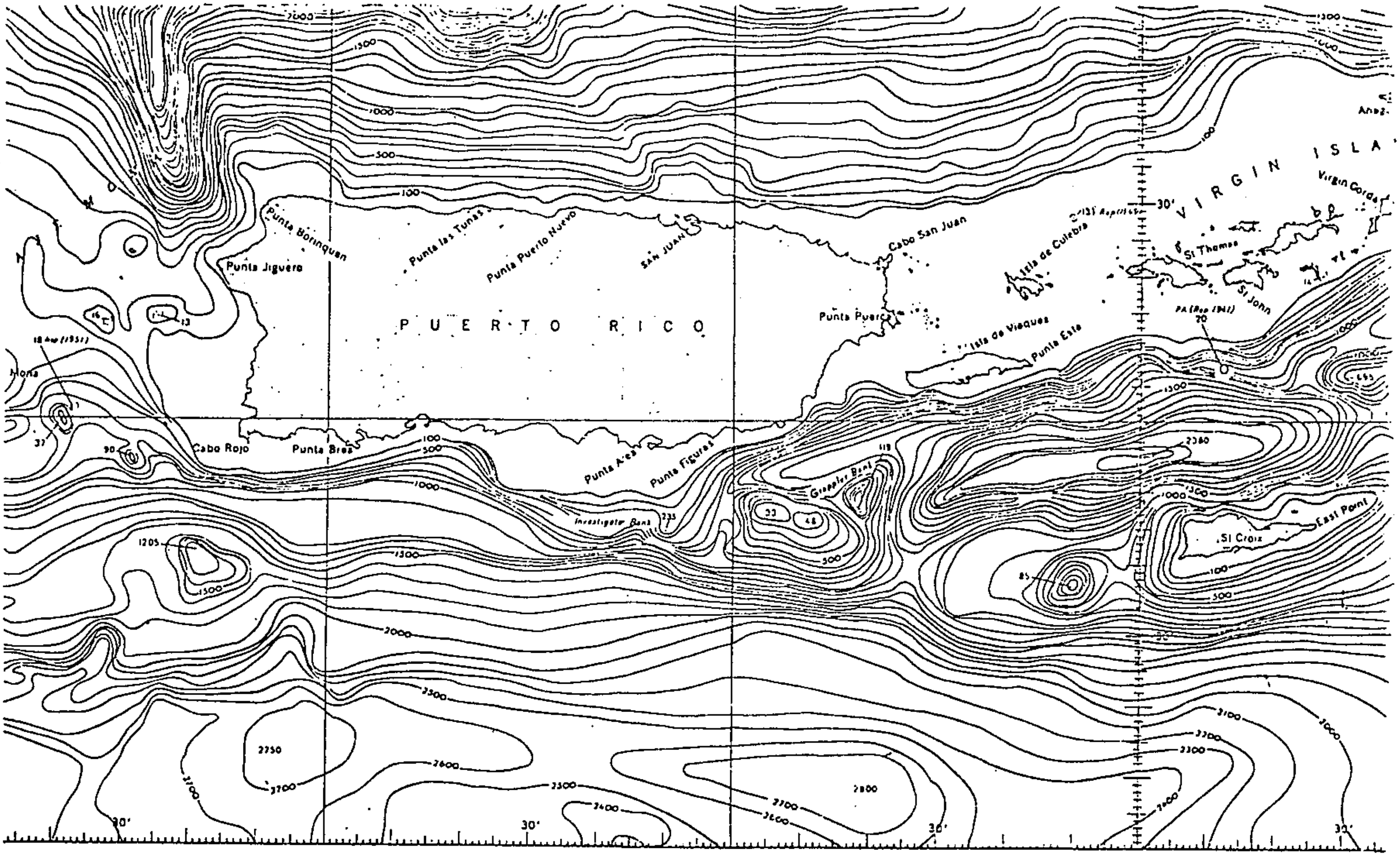


Fig. 2 - Bathymetry of Puerto Rico and vicinity.

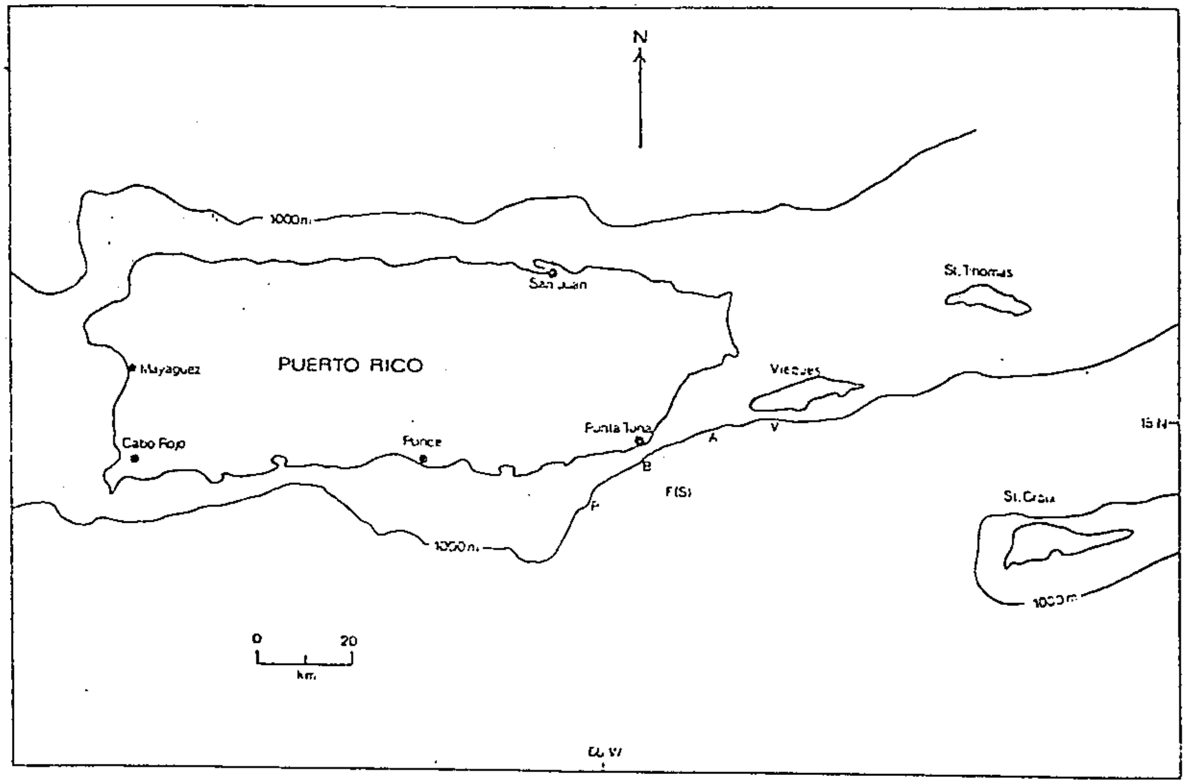


Fig. 3 - Map showing Puerto Rico, Vieques and surroundings. (The occupied stations near southeast Puerto Rico and Vieques are also shown).

The general plan (please see Appendix G for a typical cruise plan) for each hydrographic cruise was to board, load, and disembark from the western part of the island, either from La Parguera (home port for the vessel, Fig. 3) or Mayaguez, and arrive at Punta Tuna about one-half day later. Usually the Benchmark station was visited first, and the vessel remained at the mooring about 36 hours. During this time 2 Hydrocasts, 2 Biocasts, 4 Current profiles, 5 Zooplankton hauls, and numerous XBT's were taken. After leaving the mooring (referred to hereafter as Station "B") various other nearby stations were visited, taking only an XBT with a drifting current meter profile in the beginning of the program. Finally, a station was visited south of Punta Vaca, Vieques (Fig. 3). This station is located about 40 km from Punta Tuna, and was used to determine spatial variations (funded by the Puerto Rico Water Resources Authroity). At Vieques (referred to as Station "V"), 1 Hydro/Biocast, 3 Zooplankton hauls, and 1 or 2 XBT's were taken.

In addition to these hydrographic measurements, the U.S. Navy Underwater System Laboratory of New London, Conn. was contracted by the U.S. Department of Energy to work in cooperation with CEER on the implant action of two strings of current meters in the Punta Tuna area. The schedule called for 2 to 4 months between servicing of the meters, with a possible total yearlong submersion as the goal. One mooring was set in early January of 1979 at near our Station "A" (Fig. 3). The recovery operation for this mooring occurred during our February cruise, along with the re-implanting of the mooring at Station "F" (Fig. 3) location. This second mooring had not yet been recovered as of August 1979, although an unsuccessful attempt was made in early May 1979.

2.0 MEASUREMENT DESCRIPTION

During the bimonthly cruises, samples and/or data were taken to determine values of oceanic chemical, physical, and biological parameters at, or near, Punta Tuna, Puerto Rico (Fig. 3). These data and/or samples were taken according to a fixed temporal schedule (if possible) as well as procedure. (Please see Appendix G for a typical cruise plan).

The data/sampling operation may be grouped into nine categories:

1. Hydrocast
2. Biocast
3. Current Profile
4. Underwater Horizontal Light Transmission
5. Zooplankton Haul
6. Expendable Bathythermograph (XBT)
7. Weather
8. Current Meter Mooring

2.0.1 Hydrocasts

The Hydrocasts were standard oceanographic water casts that reached down to about 1000 m depth. The usual procedure was to lower the hydrowire down to the maximum depth, with an open 5 liter Niskin sampling bottle set at each of the desired depths. Each Niskin bottle contained a set of 2 or 3 oceanographic reversing thermometers (discussed later). The desired sampling depths for the Hydrocasts were 0, 50, 100, 200, 250, 300, 400, 500, 600, 800, and 1000 m. During each cruise there were at least 2 Hydrocasts. One scheduled Hydrocast was at Station "B" about noon (1000-1400 hours) and the other was scheduled about midnight on the same day (2200-0200 hours). The water collected during the Hydrocasts was apportioned for on board analysis of dissolved oxygen, and on shore laboratory analysis of salinity and nutrients.

2.0.2 Biocasts

Biocasts were standard oceanographic water casts that reached down to about 400 m. They were designed to measure parameters primarily in and just below the photic zone. Again, the procedure was to lower the hydrowire down to the maximum depth, with an open 5 liter Niskin sampling bottle set at each of the desired depths. As with the Hydrocasts, each of the Niskin bottles contained a set of 2 or 3 oceanographic reversing thermometers. The desired sampling depths of the Biocasts were 0, 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, and 400 m. During each cruise there were at least two Biocasts. One was scheduled for about noon of the second day at Station "B" (1000-1400 hr), and the other was scheduled for about midnight (2200-0200 hr). The water collected during the Biocasts was apportioned for on shore analysis of salinity and chlorophyll.

2.1 Water Temperature

Three methods were used to determine the in situ water temperature. For discrete values, reversing thermometers were used, in conjunction with the water sampling bottles mentioned above. For a continuous profile, an expendable bathythermograph (XBT) was used, and on one occasion, a Salinity-Temperature-Depth (STD) system was available.

2.1.1 Reversing Thermometers

There were four types of reversing thermometers used during this program. About one-third of the thermometers are of Watanabe Keiki manufacture. These include both protected and unprotected units. The other two-thirds are distributed by Kahl Scientific Instrument Corp., Calif., and also include both protected and unprotected types. All these thermometers have been calibrated to within ± 0.01 C°. The thermometers were all used as per U.S. Navy manual (U.S. Navy, 1968) procedures. Two protected units were used at each depth to determine the actual temperature. After all the appropriate corrections were made the results of these two units were averaged. A single unprotected thermometer was used at depths of 300 m and greater to determine the accepted measurement depth, again as per the USN Manual (U.S. Navy, 1968). During shipboard operations, the thermometers were allowed to equilibrate at the measurement depth for 15 minutes and "wait" on shipboard for at least one-half hour to stabilize before reading.

2.1.2 XBT

To collect a continuous graphical profile of temperature vs. depth data, an XBT probe and recorder was used. The instrument and recorder, both manufactured by Sippocon, Corp., Mass., were used as per the manufacturer's instructions. A surface "bucket" water sample was taken for the initial temperature calibration. Although the stated accuracies of the XBT probe and recorder are ± 0.2 C°, and ± 2% for depth, lack of a smooth descent can increase the error. The initial analysis of these data included offsetting the surface reading, and subsequent readings, as per the bucket temperature indication. Then, the depth for each integer centigrade degree was noted, down to the maximum readable depth of slightly more than 760 m.

2.2 <u>Salinity</u>

The salinity of the water at discrete depths was determined by collecting the water samples in the 5 liter Niskin sampling bottles and subsampling into an aged, twice rinsed, 250 ml plastic bottle. The estimated depth of the sample was recorded. The actual salinity determination was made using a Plessy Environmental Systems (Now Grundy Environmental Systems) Model 6220 Laboratory Salinometer. The salinometer was adjusted at the beginning of the measurement period, using standard (Copenhagen) sea water, and then was monitored and corrected using a filtered, seawater secondary standard. The manufacturer's estimated accuracy after making all appropriate corrections is ± 0.003 °/₀₀ (Plessy, 1976).

2.3 Water Current

2.3.1 Water Current Profiles

An Interocean, Model 135, Savonious rotor-type current meter was used to measure the water current profile. The strip-chart recording instrument was suspended off the vessel at discrete depths from 25 m down to 750 m, the limits of the meter. The depths sampled during the program varied, but an attempt was made to include representative values from each of the water masses in the water column. On the first cruise, the current profiles were taken at each station, including the Benchmark station and three auxiliary stations. Due to the inaccuracy of the vessel's location fixes, the normal error in the meters and possible induced drag errors the total error in the speed measurement amounted to as much as ± 25%. On subsequent cruises, current profiles were performed only while moored at the Benchmark station.

Originally, the timing of the profiles, which took about 2 1/2 hours to perform, was at 0000, 1200, and 1800 hours. During the program it became evident that a tidal component may be entering into the measurement, but was possibly being aliased. Therefore, during the last two cruises, the measurement period was planned to occur at times of suspected peak tidal current in the area, both ebb and flood. The instrument originally was designed for full scale of 150 cm/sec with a resolution of about 1.25 cm/sec, and a manufacturer's estimated accuracy of 1.5 cm/sec (Interocean, 1975). The instrument was modified for the last two cruises to improve the resolution. The full scale values were decreased to 50 cm/sec, with the resolution of about 0.4 cm/sec. The accuracy was not altered, but by spreading the usable scale, the processed data should be more reliable.

The direction of the water current is sensed by a large external vane, which rotates the entire meter housing. This rotation is sensed relative to a north seeking compass internal to the housing. The manufacturer's stated accuracy is ± 4° of direction.

2.3.2 Moored Water Current Meters

On 6-8 January 1979 an expedition was conducted by Mr. Richard Noble (U.S. Navy Underwater Systems Laboratory, New Haven, Conn.) to implant 2 current meter moorings. One mooring was to be implanted at about location "A" (Fig. 3), which is at 18° 02.2'N, 65° 39.7'W, and the second was to be at location "B". Prior to each implantation the desired location was to be surveyed bathymetrically. Upon determining a suitable location, the mooring was to be released, using an "anchor last" deployment.

During 6 January, the area around Station "A" was surveyed (Fig. 4) using an onboard Gifft precision depth recorder for depth measurements and the U.S. Navy Tracking Team of Roosevelt Roads Naval Base for location. Upon choice of a suitable location, the vessel returned to the site and the anchor (attached to the floating, deployed mooring string) was released. It came to rest at the site labeled "A" on Figure 4. This actual resting site was somewhat deeper than originally planned, due to the presence of the rough, uneven terrain.

On 8 January 1979 the second mooring, "B" was cancelled due to navigational problems and malfunction of the precision depth recorder.

A schematic of the mooring "A" is shown in Figure 5. The mooring was to have a subsurface buoyancy module about 20 m below the surface. Aanderaa current meters, Model RCM-5 were to be located at depths of 100, 200, 400, and 800 m. Also, stretched between 200 and 400 m were two thermister strings, with temperature sensors every 10 m. The final configuration was different in that the thermister string was not used and each element of the entire array was 115 m deeper because the actual depth of 1215 m was 115 m deeper than design. The current meters were set to record every 10 minutes. Of this entire array, only the subsurface float and the upper two meters were recovered on 11 February 1979, and the results of the recovered data is presented in Section 3.4.2.

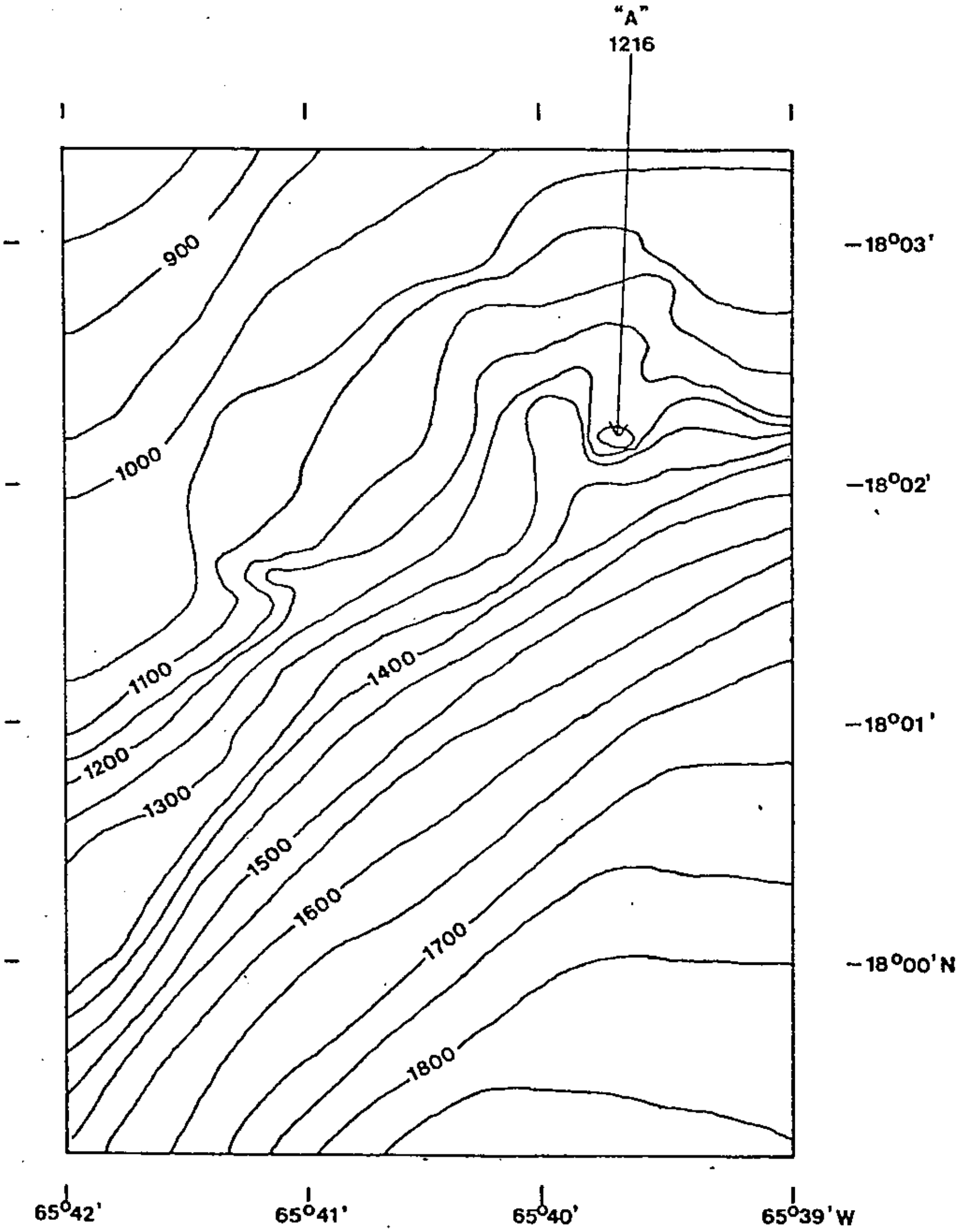


Fig. 4 - Bathymetry of the area surrounding the location of the first current meter mooring, "A" (sounding in meters).

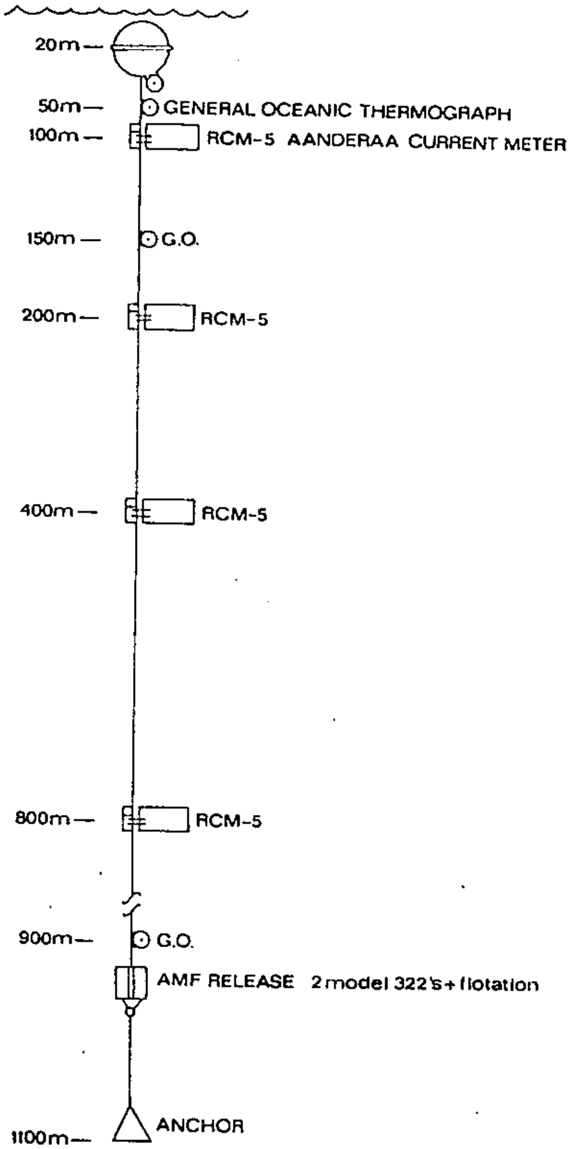


Fig. 5 - Schematic representation of current meter mooring "A".

On 14 February 1979 a second mooring was implanted at Station "F". This station was favored over "B" as it is very flat (± 1 m over about 1 km radius circle). This flatness was confirmed by a bathymetric survey of "F" prior to mooring deployment. As the area is so flat immediately surrounding "F", no purpose would be served to include the bathymetric chart of this small area, therefore, an isometric drawing is included to show the bathymetric comparison between "F" and the Benchmark area, Station "B" (Fig. 6). Again, the "anchor last" depolyment method was used, and the mooring schematic for mooring "F" is shown in Figure 7. The major difference was the depth and inter-meter spacing. The depth at "F" was 1970 m, while that at "A" it was only 1215 m. Mooring "F-1" was to be recovered in April 1979, but the attempt proved unsuccessful. As of November 1979, the mooring had still not been recovered.

2.4 Water Density

The values of density of the sea water were calculated using the above measured temperatures, from the reversing thermometers, and the Niskin bottle-sampled salinity determinations (Knudsen, 1901). These values were substituted into the following equations:

$$\sigma_t = \Sigma_t + (\sigma_\circ + 0.1324)\ (1 - A_t + B_t\ \{\sigma_\circ - 0.1324\})$$

$$\Sigma_t = \quad - \left(\frac{(t-3.98)^2}{503.57}\right)\left(\frac{t+283}{t+67.26}\right)$$

$$\sigma_\circ = \quad -0.069 + 1.4708C\ell - 0.00157C\ell^2 + 0.0000398C\ell^3$$

$$A_t = \quad t(4.7867 - 0.09815t + 0.0010843t^2)\ \ 10^{-3}$$

$$B_t = \quad t(18.03 - 0.8164t + 0.0167t^2)\ \ 10^{-6}$$

$$C\ell = \quad \frac{S - 0.03}{1.805}$$

S = Salinity of the sample (°/∘∘)

t = Temperature of the sample (°C)

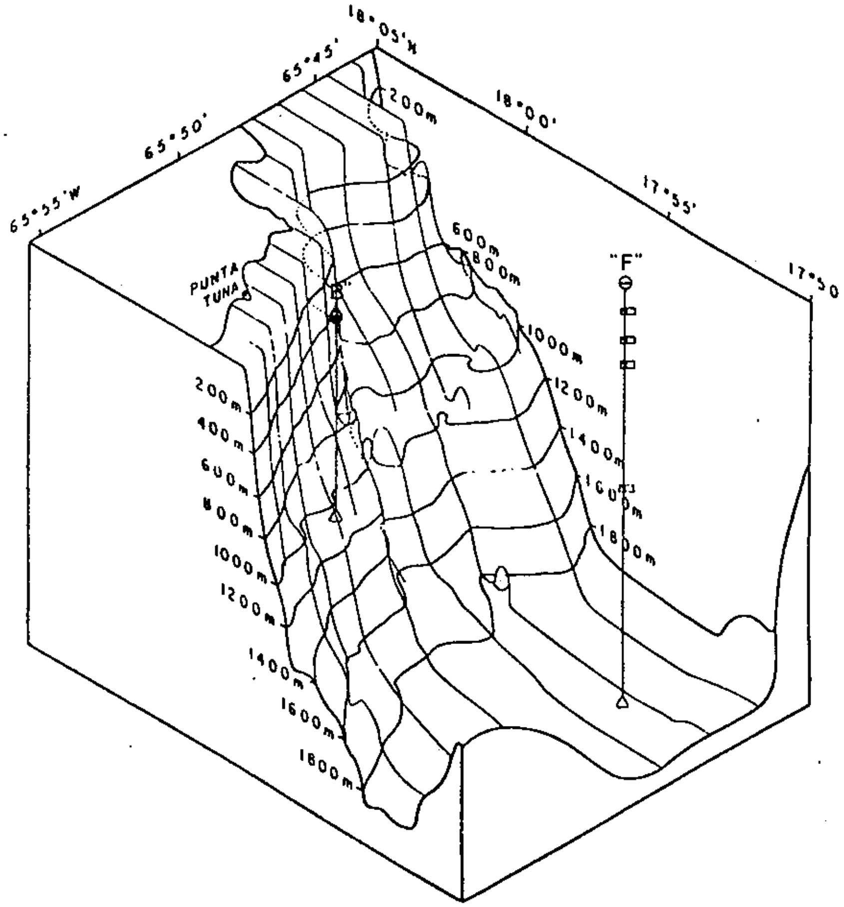


Fig. 6 - Bathymetry of the Punta Tuna area, including the location of the mooring buoy and the second current meter mooring "F".

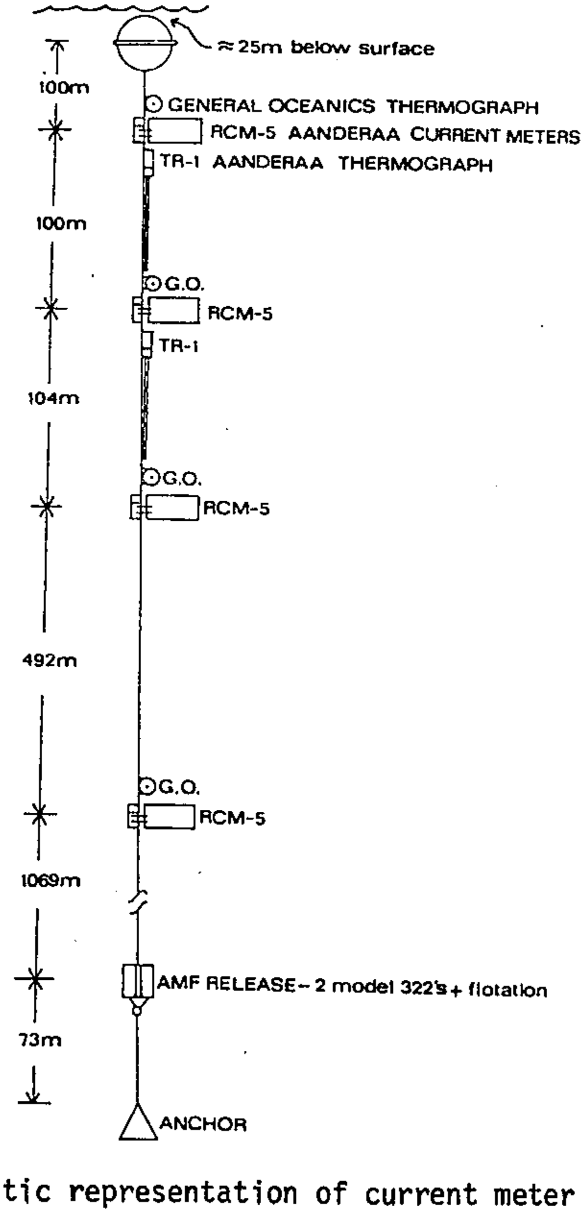


Fig. 7 - Schematic representation of current meter mooring "F".

2.5 Dissolved Oxygen

Dissolved oxygen samples were taken from the Niskin water-sampling bottles during the Hydrocast stations. The subsamples were collected using a 300 ml glass bottle, after suitable rinsing, and carefully drawing the sample to avoid air entrapment. The analytical procedure used is that described for use during the International Indian Ocean Expedition (Menzel, 1962). The procedure, shown in Appendix H, is a modification of the standard Winkler techniques, and is followed as soon as possible after the subsampels are collected.

Repetitive laboratory sampling and analysis of standards using this method yielded a repeatability of ± 0.13 mℓ/ℓ.

2.6 Chlorophyll Analysis

Analysis for concentration of chlorophyll a, the main photosynthetic pigment and for phaeophytin a, its immediate degradation product were carried out fluorometrically following the guidelines established by Strickland and Parsons (1972). Samples of marine plankton on Millipore or glass fiber filters were stored at -5°C in air tight containers with silica gel dessicator. Samples were routinely protected from exposure to strong light. For extraction of pigments, the filters were placed in screw-cap test tubes with 90% spectrophotometric grade acetone (20 ml), shaken vigorously and stored for 24 to 48 hours at 5°C in the dark. Prior to fluorometric analysis, the samples were centrifuged at 5000 rpm for 5 min, decanted and allowed to come to room temperature. The extracts were quantified using a Turner 110 filter fluorometer equipped with filters, door and photomultiplier recommended by the above authors. For phaeophytin a analysis, the above extracts were treated with two drops of .1 N HCl, allowed to react for 5 min and then read again on the fluorometer.

Calibration of the fluorometer was achieved comparing the response to pigments to that of a Beckman DU spectrophotometer equipped with the Gilford up-dating electronic array. Twenty-one liters of sea water obtained from waters offshore of La Parguera (Fig. 3), were filtered onto Whatman No. 3 filters and extracted in 90% acetone. Absorbance at 665 nm was measured using 10 cm path length cuvettes and pigment concentrations were calculated using the formulae provided by Strickland and Parsons (1972). Door factors for the fluorometer were then computed from data on fluorometer response to known dilutions of the primary standard.

2.7 Zooplankton

Zooplankton sampling was carried out either by vertical, horizontal or oblique hauls. For vertical or oblique hauls, the 202 micron (silk size #8), 3/4 m diameter opening net is secured to a double trip mechanism and lowered to the desired depth. The closed net is then raised, and a messenger is sent down the cable, activating the first portion of the double trip mechanism to open the net at the desired depth. As the open net ascends and approaches the upper limit of the fishing depth, a second messenger is lowered again activating the double trip mechanism, this time to close the net. When the vessel was at the mooring, the haul was almost vertical. If the vessel was drifting, the path of the net became oblique due to the ship's motion. The dpeths sampled were: 1000 m-0 m, 1000 - 800 m, 800 m - 200 m, 200 m - 0 m. Finally, to achieve a 25 m deep horizontal haul, or tow, the net was lowered in the closed position while the vessel was steaming at or less than 1.5 m/sec. The actual net depth for these horizontal tows was computed, based on the wire angle from the vertical. At the desired depth, messengers are lowered to open and close the net at the appropriate time interval. In all cases a flow meter was mounted at the net entrance and was read to indicate the water volume passing through the net.

The collected samples were hosed with sea water into a container, where they were preserved in a 4% buffered formaldehyde solution for future laboratory analysis.

In the laboratory, after sorting and cleaning to remove foreign particles, a subsample is drawn using a 1 mℓ stempel pipette. (If the number of copepods did not reach 300-400, subsequent subsamples were drawn and added to the first). Under a stereo-zoom binocular dissecting microscope, the animals were keyed to species (copepod) when possible or family (others). All the animals were measured for length.

2.8 Nutrients

Water samples were analyzed for nitrite, nitrate, phosphate, and silicate. Originally, the samples were filtered through a Nuclepore filter then treated with hydrochloric acid. Subsequently, chloroform replaced the hydrochloric acid and the filters were changed to Millipore membrane filter (45 μm mesh). The plastic bottles in which the subsamples were stored were acid washed.

During the first four cruises, the subsample of water to be drawn and filtered on board was drawn with an acid washed, twice sample-rinsed poly-bottle. After filtering, the sample was returned to the plastic bottle and treated with preservative. As a precaution against unfiltered contamination, a twice-rinsed transfer bottle was used on the last two cruises to carry the water to the filtering apparatus. Only after filtering, was the sample placed into a clean, acid-washed storage bottle and preservative added. On all occasions, after preservation samples were stored at 4-5 °C until the analysis was completed. Analysis procedures were virtually identical to those provided by manufacturer of the Technicon Autoanalyser (Technicon, 1972; Technicon, 1973; Technicon, 1973a).

2.9 Horizontal Light Transmission

The horizontal light transmission was measured using a Hydro Products, model 912-S transmissometer system. The unit reads both percent of light transmitted over a 1 meter path length and the instrument depth (Hydro Products, 1974). The instrument was read at convenient intervals, usually about 15 m, both while descending and ascending through the water column. The two readings from each depth were averaged.

The instrument never functioned properly throughout the field measurement period, even after factory recommended repairs and a trip back to the manufacturer.

2.10 Meteorological Data

The meteorological data, taken during the cruise, consisted of air temperature, wet and dry bulb thermometer, barometric pressure, sea state, wind speed and direction, and cloud cover. As the methods for these data are adequately reported, (U.S. Navy, 1968), they will not be reported here. Also included in this report are some analysis of data taken at the Coast Guard Station at Punta Tuna Light and the NOAA Climatological Data from San Juan. The Punta Tuna Light data are taken every 3 hours (on week days) from 0800-1700 hr. The San Juan data are from hourly observations, as well as monthly averages, dating back to 1941.

3.0 RESULTS AND INTERPRETATION

The following sections describe the results of the data acquisition program during the period from August, 1978 through June, 1979. Preceeding the discussion of these results, a summary of historical information is included that will help to describe some of the physical, biological and chemical characterisitics of the area.

3.0.1 Summary of Historical Results

3.0.1.1 Climate. The Commonwealth of Puerto Rico, associated with the United States by bilateral agreement, consists of a main island and several smaller islands. These islands are all located along the Antilles Chain of islands, extending almost from Florida, USA to Venezuela, South America (see Fig. 1). Puerto Rico is approximately half way along the Chain, about 1700 km from Miami, Florida. The nearest large land mass to Puerto Rico is the island of Hispañola, about 130 km to the west. The Chain separates the Atlantic Ocean and the Caribbean Sea. As Puerto Rico is situated along an east-west axis, the Atlantic washes its north coast, and the Caribbean, its south coast. At the latitude of about 18°N, Puerto Rico is in the trade wind belt, with both the winds and oceanic currents generally moving east to west past the island.

The main island of Puerto Rico is roughly rectangular in shape, about 180 km east to west, and about 60 km north to south. The island is a mixture of mountains, rolling hills, and broad flat plains. In general, where the plains meet the sea, the climate is typically tropical marine (except along the semi-arid southwestern coast). That is, during the day as the land mass heats up, a convection cell is devoloped, causing the winds to move landward from the sea, bringing moist sea air inland. In the evening as the land cools, the convection cell reverses and the winds blow offshore. Due to the numerous hills and mountains on the island of Puerto Rico, the moist sea air is frequently cooled to saturation while still over the land mass. This causes considerable rainfall, almost daily over some parts of the island.

3.0.1.2 Wind Regime. The sixth edition of the U.S. Coastal Pilot, Area 5 (U.S. Dept. of Commerce, 1967), summarizes the wind regime on the coast of the island as follows:

> "The prevailing winds over Puerto Rico are the easterly trades, which generally blow fresh during the day. The center of the Bermuda High shifts a little north in summer and south in winter changing the direction of the winds over that island from north-northeast in winter to east in summer.
>
> Factors which interrupt the trade wind flow are frontal and easterly wave passages. As the cold front approaches, the wind shifts to a more southerly direction, and then as the front passes there is a gradual shift through the southwest and northwest quadrants back to northeast. The easterly wave passage normally does not bring a westerly wind but is usually characterized by an east-northeast wind ahead of the wave and a change to east-southeast following the passage.
>
> Over most of the ocean near Puerto Rico the strength of the winds increases in midsummer, with lighter winds in the spring and autumn seasons. There are also somewhat higher average winds in the northwest part of the area in the late autumn and winter. Mean winds speeds over the Atlantic in this area range from 9 to 10 knots (4.5 to 5 m/sec) during the autumn to a high of 12 to 15 knots (6 m/sec) in midsummer".

3.0.1.3 Water Masses and Circulation. The water masses in the Caribbean have been discussed by many authors (Wust, 1963; Atwood et al., 1976; Craig et al., 1978; Lee et al., 1978), but for completeness they shall be mentioned again in this report as the source, depth location, movement, and characteristics of the water masses are important to the understanding of the data described in the following sections.

The cold water intake pipe of an OTEC plant in Puerto Rico waters would probably extend from near the surface to about 1000 m deep. With the intake opening at 1000 m depth, the intake water would come from approximately 50-100 m above and below that depth. Therefore, for the purposes of this report, the water masses in the upper 1100 m of water in the northern Caribbean will be considered.

The upper water mass is called the Tropical Surface Water (TSW). The origin of this water is under the equatorial atmospheric trough (low), which is a tropical rain belt located to the northeast of South America. The TSW is influenced both by heavy precipitation in that area and by runoff from the Amazon and Orinoco Rivers. This water mass is driven by wind and the earth's rotation into the eastern Caribbean Sea through passages in the Lesser Antilles island chain. As the water mass continues to move under the wind stress of the predominent easterly winds, the water moves northwest toward the Yucatan. By the time it reaches Puerto Rico, the temperature and salinity of this upper water mass has been further affected by the general and local climate of the area through which it has passed. Additional precipitation and runoff, (although slight), or evaporation from wind and insolation could further influence both the temperature and salinity. In the TSW, salinity generally ranges from 33-36 °/₀₀, and temperature generally ranges from 25°C to 29°C. This water mass appears to be wedge-shaped, attaining its maximum depth along the northern Caribbean, due to geostrophic subsidence as the water moves westward. The local depth of the water mass, may be influenced more by atmospheric pressure and its variation. Normally, atmospheric pressure changes little, with changes of 3-6 mm of mercury in a month being considered large. However, as a tropical pressure trough moves through the Caribbean, the pressure is severely reduced, causing the water level to be raised, pushing the upper water mass to the side, and upwelling the cooler, more saline water mass below. This upwelling would occur during a hurricane and, to a lesser degree, during a tropical wave or a tropical storm. This atmospheric effect on an operating OTEC plant would be to severely reduce its thermal efficiency.

The water mass directly beneath the Tropical Surface Water is called the Subtropical Underwater (SUW). This lower water mass originates directly beneath the Bermuda atmospheric high pressure zone. The Bermuda High is the atmospheric downwelling component of the Hadley cell which gives rise to the Equatorial Atmospheric Trough, which in turn is related to the origin of the Tropical Surface Water discussed above. The air under the Bermuda High is generally warm and dry. Due to the lower relative humidity, evaporation is great and salinity is increased, making this water mass the most saline in all the Caribbean. The SUW descends to form the upper portion of the thermocline in the Caribbean. The salinity within the SUW does not vary much (36.8-37.2°/₀₀) because the water rarely comes into contact with any diluting agent. During conditions of low atmospheric pressure, this water is drawn upward, as evidenced by the very high salinity seen at or near the surface.

The temperature range within the SUW is 20°C-24°C. Due to thermal conduction, the temperature does not remain as invariant as the salinity. The density difference between the Tropical Surface Water and the Subtropical Underwater is large enough that they remain two distinct water masses. The SUW moves southward from the higher latitudes near Bermuda and enters the Caribbean through passages along both the north and east. From these passages, the water moves generally southward or westward, or both to spread throughout the entire Caribbean beneath the TSW.

As the SUW moves westerly into the Caribbean, it is seen to dilute somewhat to about 36.5°/₀₀-36.6°/₀₀ in the Yucatan Strait. Near Puerto Rico, the water enters the Caribbean southward through both the Anegada and Mona Passages. The core of this water mass generally lies at about 125-150 m depth in the Puerto Rico area.

Below the SUW lies a transition zone of indistinct characteristics. The transition zone contains the lower portion of the thermocline, and extends into the definite area of the cold water zone. This transition water is a mixture of North Atlantic Central Water and diffused and diluted Mediterranean Water. The salinity ranges about 36.8°/₀₀, from the water mass above it, down to about 35°/₀₀. The temperature ranges from 20°C to about 7°C. This transition zone reaches from about 200 m to 600 m depth. Just below this zone lies the oxygen minimum, which many people define as the boundary of the cold water zone in the oceans. This transition water enters the Caribbean from the north and from the east and probably moves both southward and westward.

The Antarctic Intermediate Water (AIW) is found just below the transition zone (600 m-800 m). This water is formed at the Antarctic Convergence Zone, about 45°-55° south latitude. The water tends to be low in salinity, as it is formed in an area where precipitation far exceeds evaporation. The AIW is seen moving northward from its area of formation, and makes its way into the Caribbean over the moderately deep sills of the Lesser Antilles, the Anegada Passage, and the Windward Passage, between Cuba and Hispañola. These latter deep sills may also form a path of departure from the Caribbean for the AIW that has entered through the Lesser Antilles passages. This water mass spreads to cover much of the Caribbean Basin. The movement of the AIW near Puerto Rico could be either south and west (having entered either through the Lesser Antilles or the Anegada Passage) or east (entering through the Windward Passage) or even north and east or west (departing through the Anegada or Windward Passages). As the water has moved northward through the Atlantic, it has been in contact with higher salinity water. Therefore, the salinity of the AIW as it passes Puerto Rico is no longer the 34°/₀₀ of its origin, but rather about 34.8°/₀₀. The temperature is 6-7°C.

From 800 m down to 1000 m, between the Antarctic Intermediate Water and the North Atlantic Deep Water, (NADW) lies another thin transition zone. From about 1000 m depth and deeper the water mass found in the Caribbean Sea has most of the characteristics of the North Atlantic Deep water. This water is formed in the high northern latitudes, and while descending both in depth and latitude, entrains some of the Mediterranean water, thereby increasing its salinity, density, and depth. This water enters the Caribbean only through the Windward and Anegada Passages. The water moves mainly westward from the Windward Passage, but south and west from the Anegada Passage to fill all the deep basins in the Caribbean. This water is characterized by 4-5°C temperatures, and a salinity of 35°/₀₀. After this water mass moves into the Caribbean, it is virtually trapped, with only a small passage out through the Yucatan Strait. The water remains in the Basin and is slightly different in silicate content from its origin, the NADW, found outside the Caribbean Basin. For this reason, some people choose to call this deep, cold water the Venezuela Bottom Water. In some portions of the Caribbean Basin, this water mass is over 3000 m thick.

3.0.1.4 Tides

The tides on the Caribbean coasts of Puerto Rico are generally of the mixed diurnal type, with a small semidiurnal component. An amphidromic (nodal) point of the principal lunar semidiurnal (M_2) tidal constituent lies near Punta Tuna (Atwood et al., 1976; Dietrich, 1963; Defant, 1961). The nearness to the node implies minimal tidal motion. In addition, as Punta Tuna is on the somewhat exposed eastern side of the island, the tidal system affecting the North Atlantic (with its amphidromic east of Newfoundland) may also affect our site. The result could be a moderately confused tidal current over our area of interest.

The tidal currents in the Punta Tuna area are expected to move generally east and west, west during the flood tide and east during the ebb tide. The actual result of this tidal motion on the prevailing water motion at Punta Tuna is still unknown.

3.0.1.5 Productivity. Productivity, which can be defined as the rate at which biological organisms store energy, usually decreases from the coastal margins to the open ocean (Davis, 1973). In general, tropical ocean waters have low productivity and show little variation with changing seasons of the year. Raymont (1963) states that two compounds, phosphate and nitrate (together with nitrite and ammonia to a lesser extent) are clearly of extreme importance to marine plant growth. In general, values of both these essential nutrients in the upper photosynthetic zone, which is the only zone directly concerned with primary productivity, are low and fairly constant in sub-tropical and tropical waters. It would appear, therefore, that the tropics and subtropics would have low productivity. However, the overall productivity in tropical regions, considered on a yearly basis, may be much greater than would first appear, since the nutrients are recycled rapidly in the warm tropical water and thus pass through several cycles during the course of a year. In tropical seas around the world, the standing phytoplankton crop tends to be low at any one time, but the thickness of the photosynthetic zone is considerably greater in tropical seas due to the lower turbidity, than in other waters (Riley, 1939).

The portion of the water column with sufficient sunlight to photosynthesize is called the euphotic zone (Duxbury, 1971).

It reaches down to about 100 m in depth. At the OTEC plant site the euphotic zone corresponds closely with the Tropical Surface Water (TSW). This water mass may have a thickness of up to 100 m and its characteristics have been discussed previously in Section 3.0.1.3 in this report. Almost all phytoplankton activity takes place in the first 100 m of depth off Punta Tuna.

3.0.1.6 Zooplankton. In the Caribbean, the most common groups of zooplankton are, in order of numerical importance, copepods, chaetognaths, and pteropods. Approximately 450 species of oceanic calanoid, harpacticoid and cyclopoid copepods have been reported from the Caribbean. Although the number of calanoid species is far greater than that of cyclopoids, the latter nearly equal calanoids in total number of individuals. The most numerous cyclopoids, Farranula carinata and Oithona plumifera are more than twice as abundant as the top ranking calanoids, Clausocalanus furcatus and Mormonilla minor. Harpacticoida, the smallest group of planktonic copepods, includes the third most numerous form Microsetella rosea (Michel, Foyo and Haagensen, 1976).

There are 15 species of chaetognaths prevalent in tropical oceans, five rare bathypelagic forms, Bathybelos typhlops, Eukronia hamata, E. proboscidea, Sagitta megalopthalma and S. planktonis, and two neritic species which are sometimes swept into oceanic waters, S. helenae and S. hispida. The most common pteropods encountered around Puerto Rico are: Limacina inflata, L. trochiformis, Creseis acicula, Styliola subula, Diacria trispina, Cavolina inflexa and Desmopterus papilio.

3.0.1.7 Dissolved Oxygen. The dissolved oxygen concentration throughout the Caribbean water column varies little throughout the year. Dissolved oxygen in surface waters generally ranges from 4 to 5 ml/l. This is a highly saturated condition. From this high, mixed layer value, there is a steady decrease, caused by both the length of time since the lower waters have been oxygenated at the surface and the depletion of the available of oxygen by decomposition of descending dead and detrital matter. This oxygen minimum occurs at about 500-700 m depth, and has an oxygen concentration of around 2.5-3.2 ml/l. Below the oxygen minimum, the concentration increases, due to the high oxygen carrying capacity of the cold, less saline North Atlantic Deep Water. The values at about 1000 m may rise to about 3.5-4 ml/l, and at 2000 m, the dissolved oxygen concentration may rise to as much as 5.5-6 ml/l (Atwood et al., 1976; Wust, 1964).

3.0.1.8 Nutrients. Tropical surface waters, such as the Caribbean, are usually deficient in many of the nutrients necessary for phytoplankton growth. The photosynthetic processes remove the nutrients from the upper, photic zone. As there is little land mass to produce organic runoff, the replenishment is very poor. Furthermore, nutrients are lost to the upper water column as detritus and dead organisms sink below the photic zone and continue to the bottom. Therefore, generally, the Upper Mixed Layer nutrient concentrations are quite low in (these) tropical and subtropical seas and remain low to at least about 200 m depth. Below this depth, the concentrations are seen to rise to maximums at depths of 600 m and below. Typically, the ratio of maximum values to minimum values may be about 15:1 for phosphate, 10:1 for silicate, and about 25:1 for nitrate. Although these ratios are by no means fixed, they are typical of what is measured in Caribbean waters (Atwood, et al., 1976).

3.1 Temperature Results

During each cruise, an attempt was made to collect at least four sets of discrete temperature data at the Punta Tuna benchmark site, Station "B". Usually the four sets consisted of two Hydrocasts (to about 1000 m) and two Biocasts (to about 400 m). On all the cruises, except the first, several XBT's were taken at the Benchmark station, as well as other stations in the nearby area. Figures 8-13 show temperature versus depth profiles for each of the six hydrographic cruises. The profile shown in each figure is the average temperature, as measured with the reversing thermometers, from the four casts at the Benchmark station during that particular cruise. There is a moderately strong seasonal thermocline seen during all but the June 1979 cruise. The April data shows some reduction in the thermocline strength over that seen during the rest of the year, but during June, no thermocline was observable at all. Thermal variations with depth are also present throughout the year, but the next set of figures are used to show this variation more clearly.

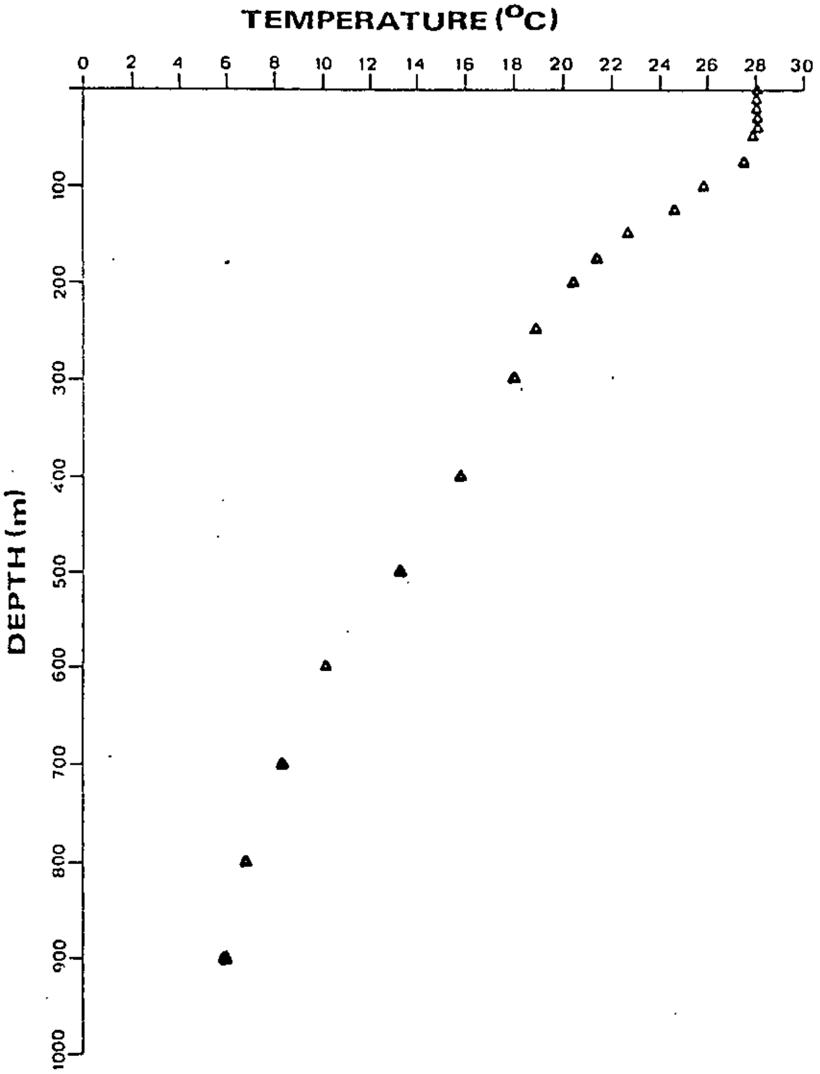


Fig. 8 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of August, 1978.

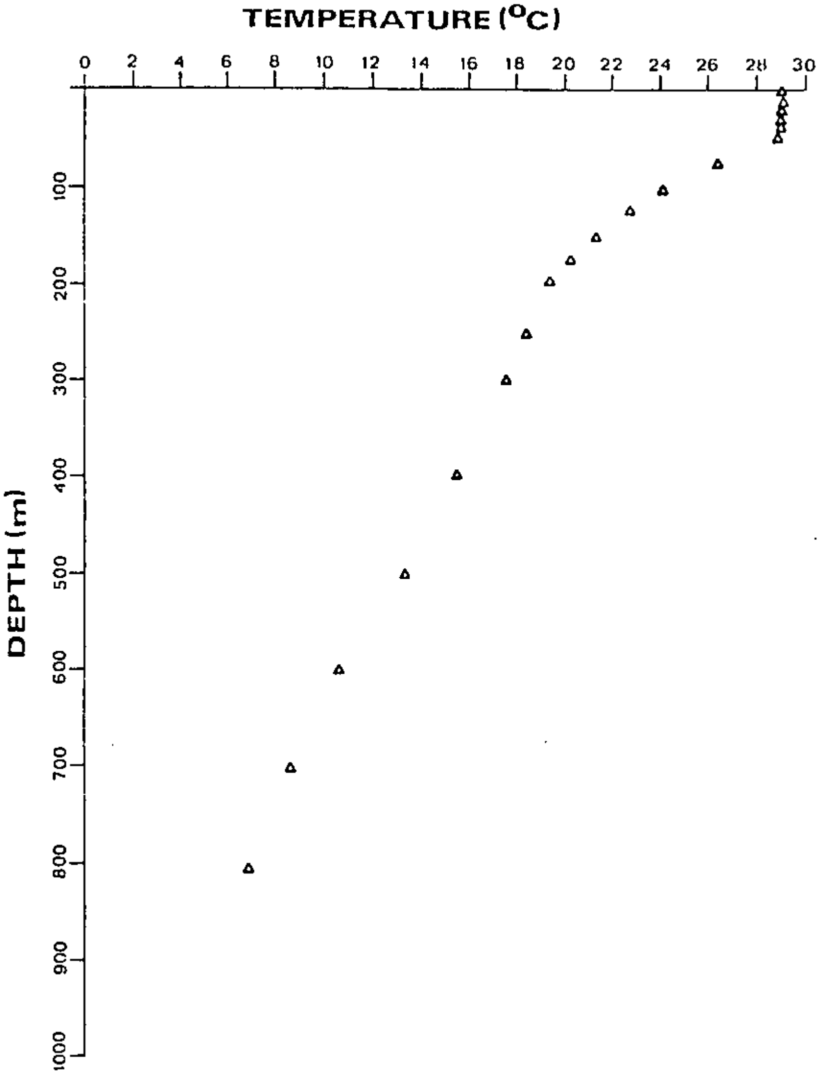


Fig. 9 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of October, 1978.

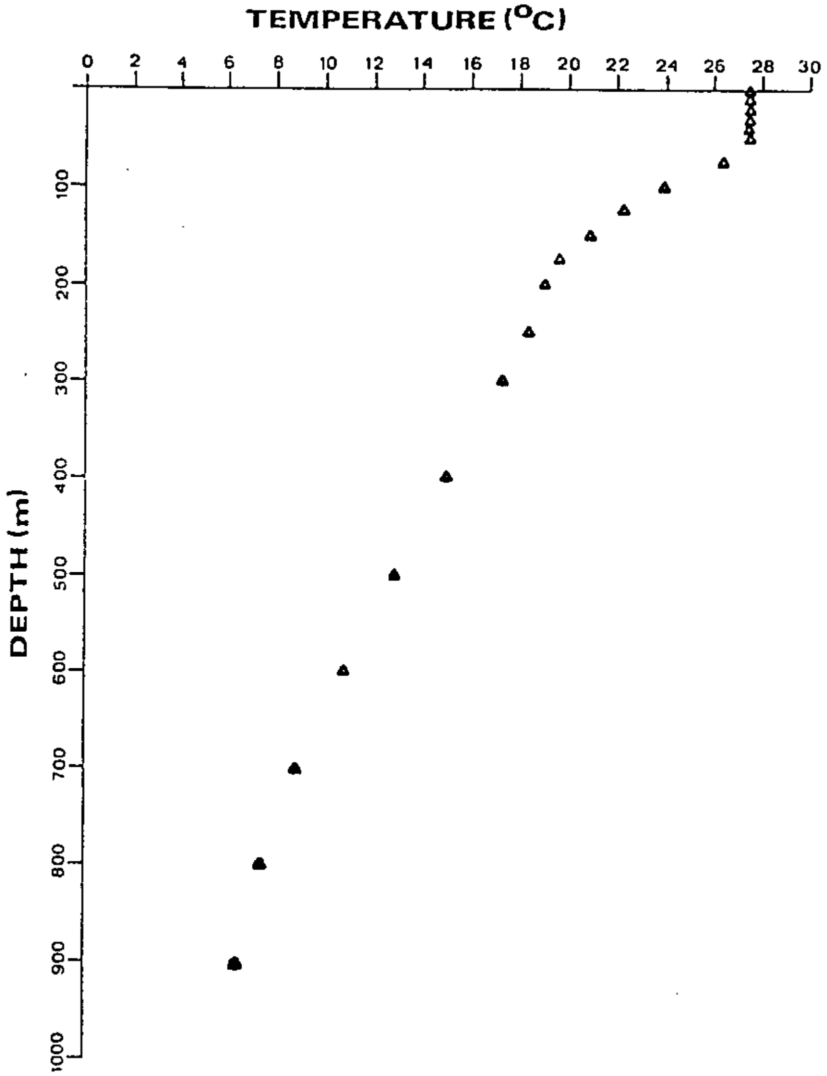


Fig. 10 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of December, 1978.

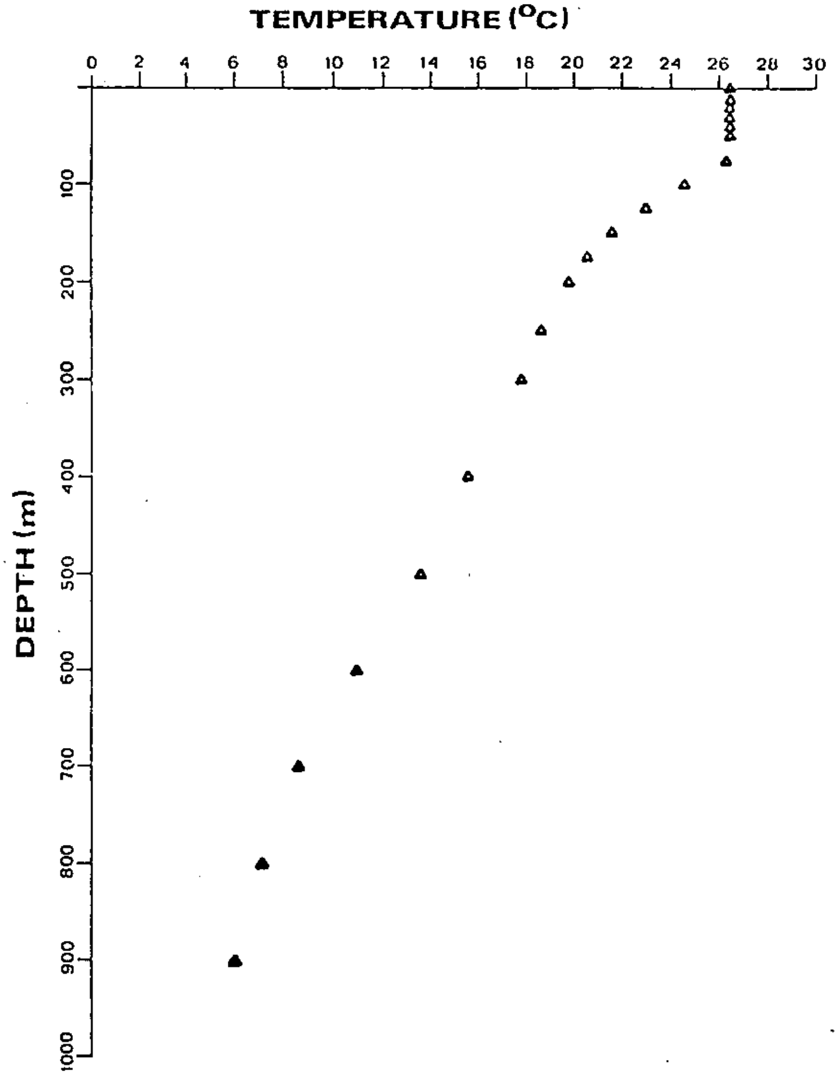


Fig. 11 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of February, 1979.

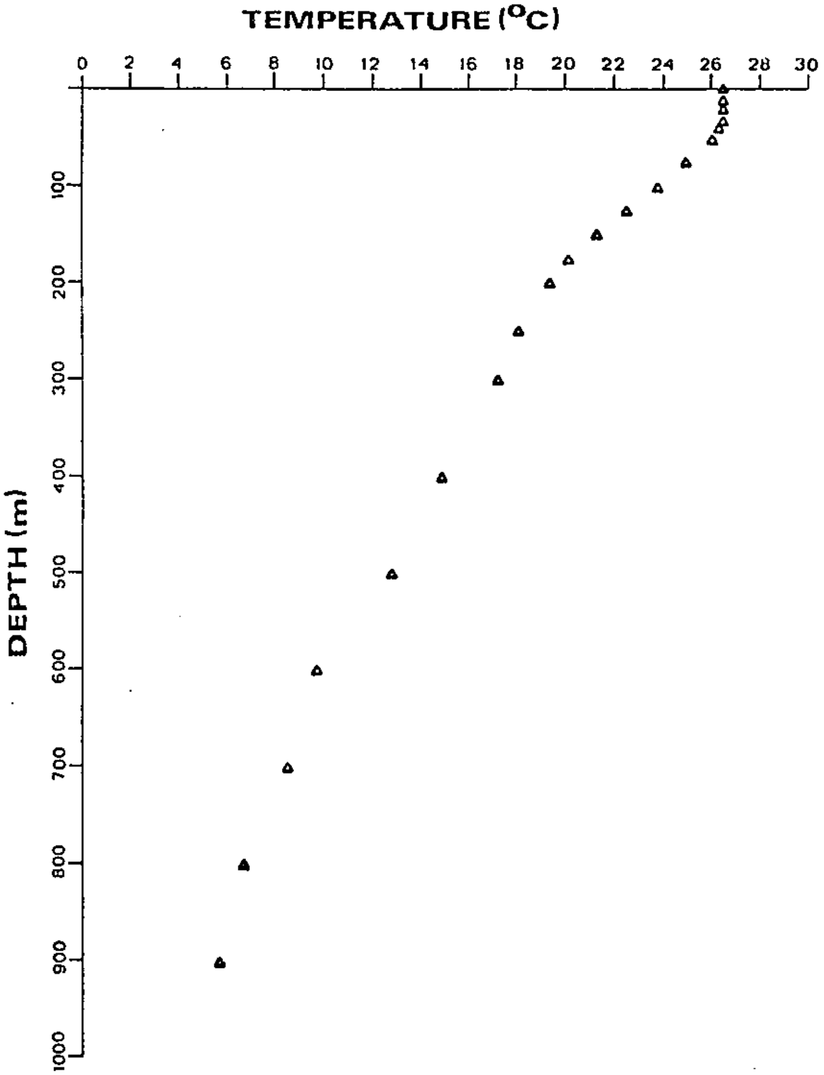


Fig. 12 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of April, 1979.

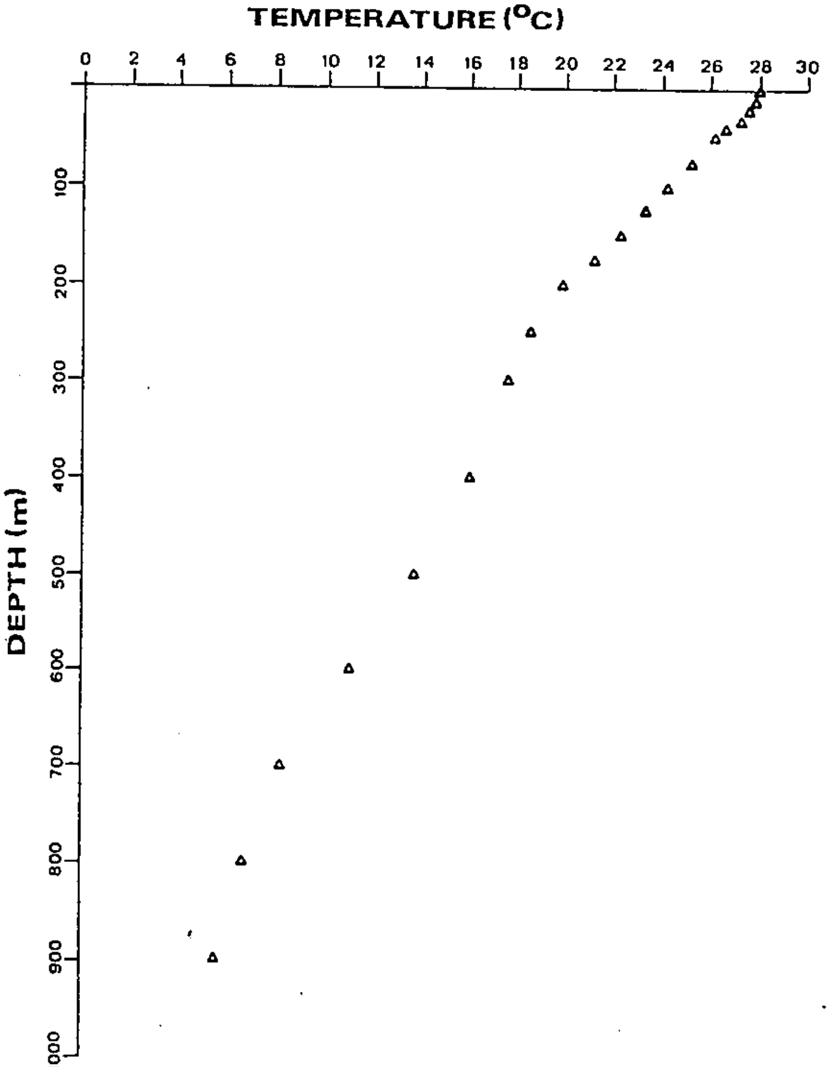


Fig. 13 - Temperature profile at Punta Tuna using average reversing thermometer values for the cruise of June, 1979.

Figure 14 shows a time series of the temperature at the Benchmark site (as taken from the reversing thermometer averages) throughout the year. The temperature of the upper waters was about 29°C during October 1978, over 27°C from August to December 1978, and again in June of 1979. During February and April 1978, the upper water temperature was about 26.4°C. Although there is some experimental error in both the depth determination and the temperature determination, there still appears to be a slight rise of the 26°C isotherm during April and June. Also, there appears to be a vertical migration of the 6°C isotherm throughout the year, however, an error in the December value alone could account for much of this cold water variation.

Finally, Figures 15-20 show the time series of temperature during each cruise. Each of these figures are made by using all the XBT and all the reversing thermometer data made during each respective cruise. Usually there are at least four thermometer sets per cruise and at least eleven XBT casts. The reversing thermometer data correspond to the four aforementioned casts at the Benchmark site and one additional cast at the Vieques station. The XBT casts were taken at the Benchmark station, Vieques, and a few nearby locations, seen in Figure 3. Exceptions to this general trend are the first cruise, which was terminated early due to the equipment problems, and had a nonfunctioning XBT recorder, the fourth cruise, which was terminated early due to a collision at sea, and the last cruise, which has many other stations shown. A further description of the last (June 1979) cruise will be shown in Section 6.0. In these thermal time series displays (Figs. 15-20) the thermometer data are shown as dashed lines and the XBT data are shown as solid lines. The intention in showing these figures are to give the reader our actual temporal variation of the water temperature during the cruise. Also, an easy comparison is possible between the XBT values and the much more accurate thermometer values. As to be expected, the XBT values show a much greater variation than the thermometers, pointing out a potential hazard in

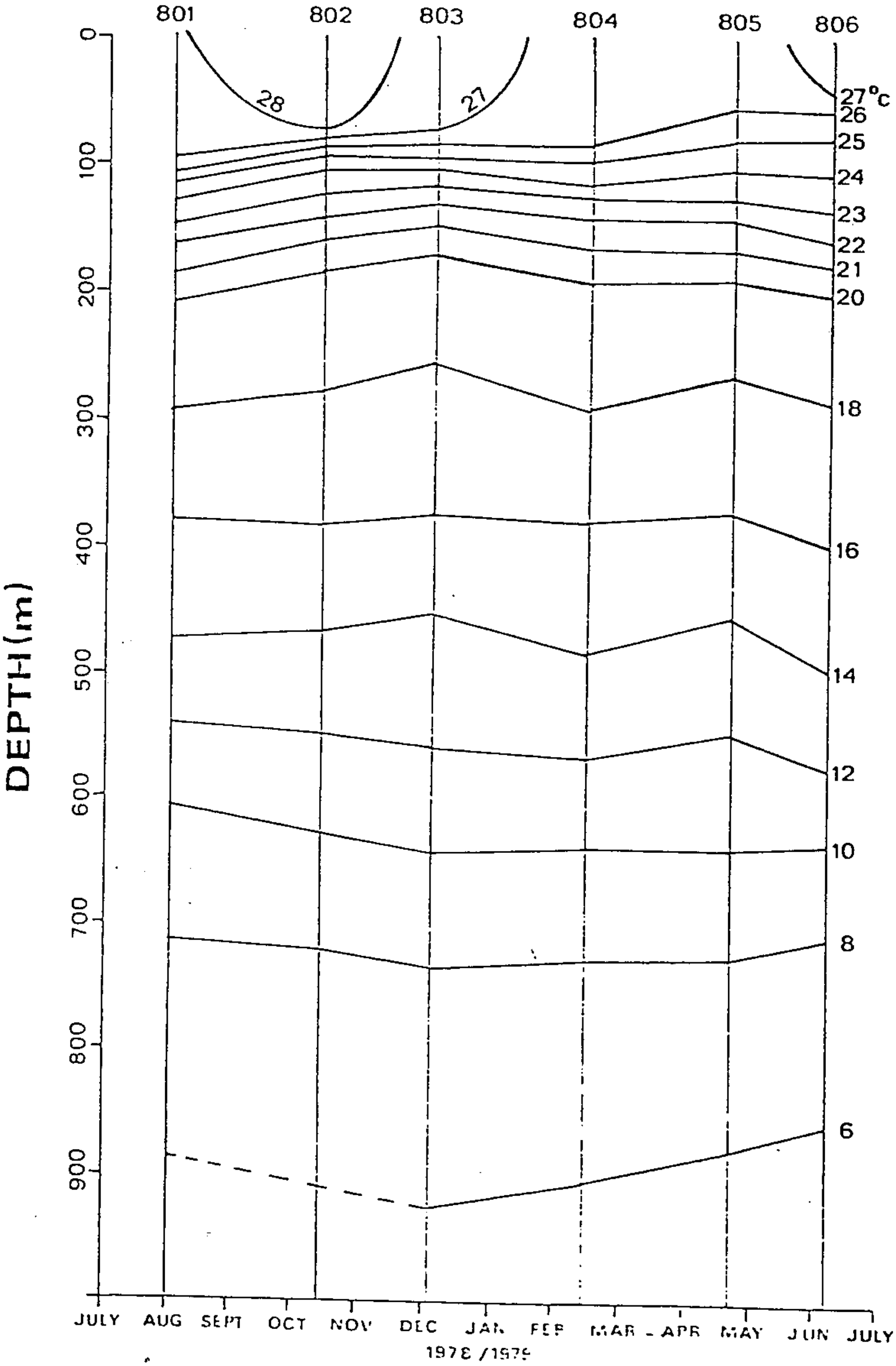


Fig. 14 - Time series of average reversing thermometer results at Punta Tuna from August, 1978 to June, 1979.

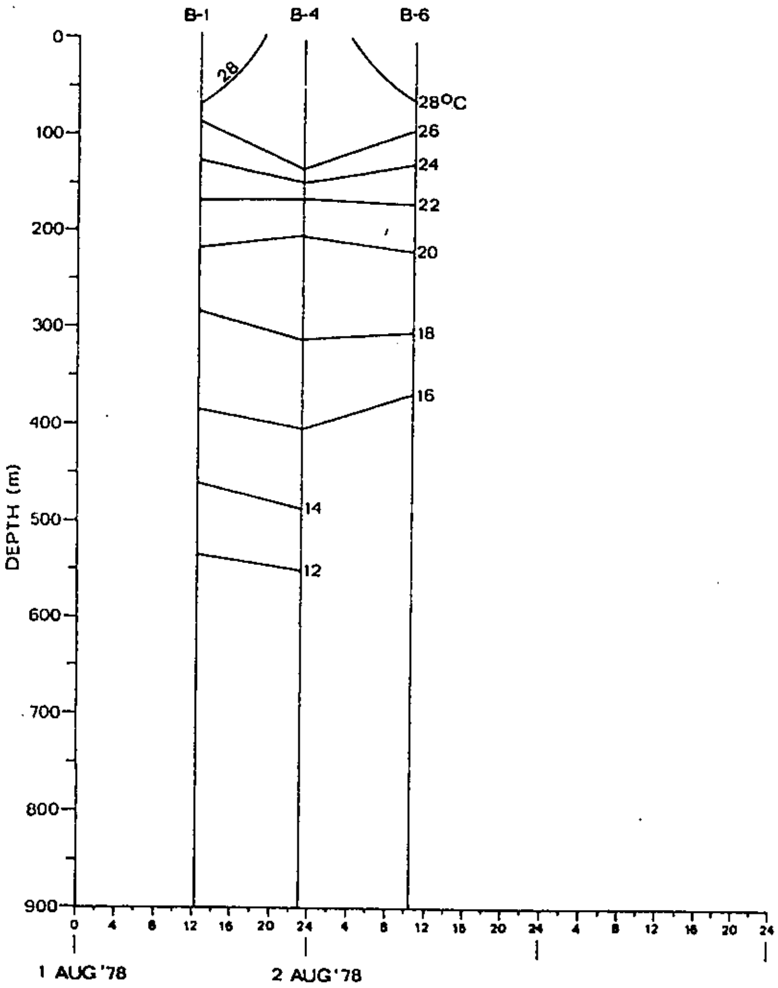


Fig. 15 - Time series of reversing thermometer results at Punta Tuna during the cruise of August, 1978.

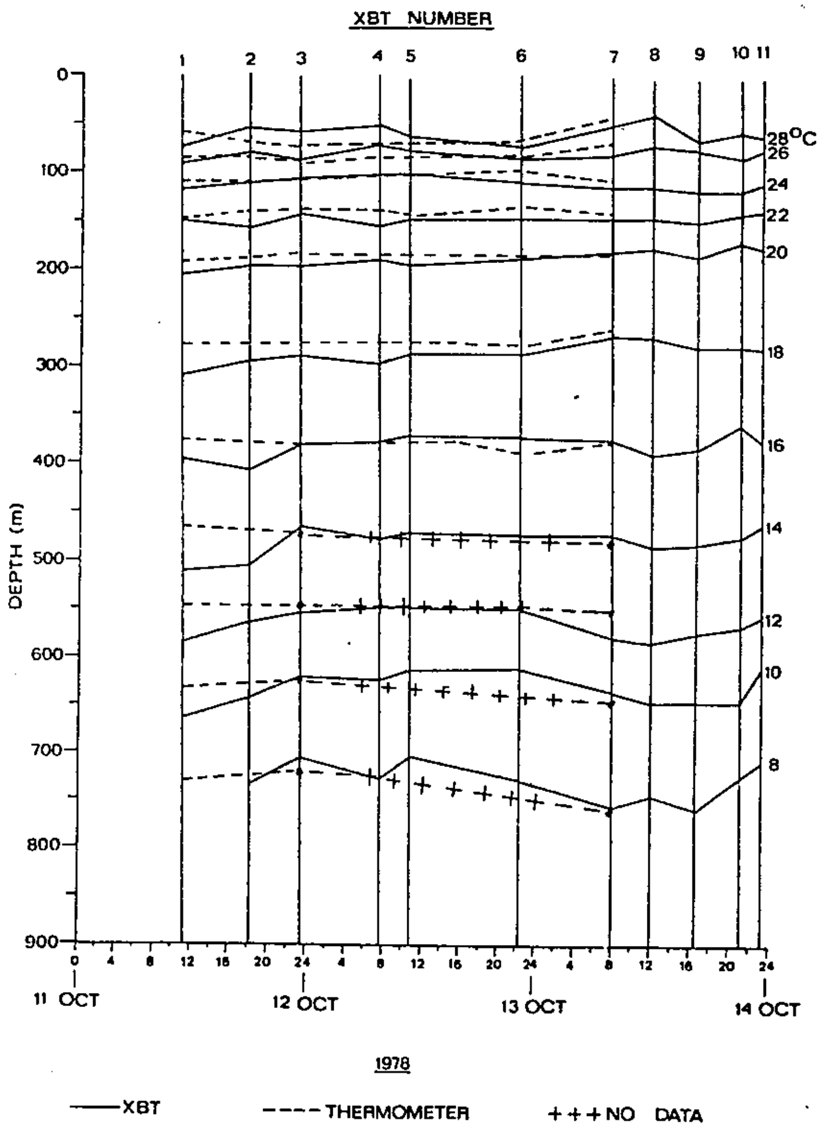


Fig. 16 - Time series of reversing thermometer and XBT results during the cruise of October, 1978.

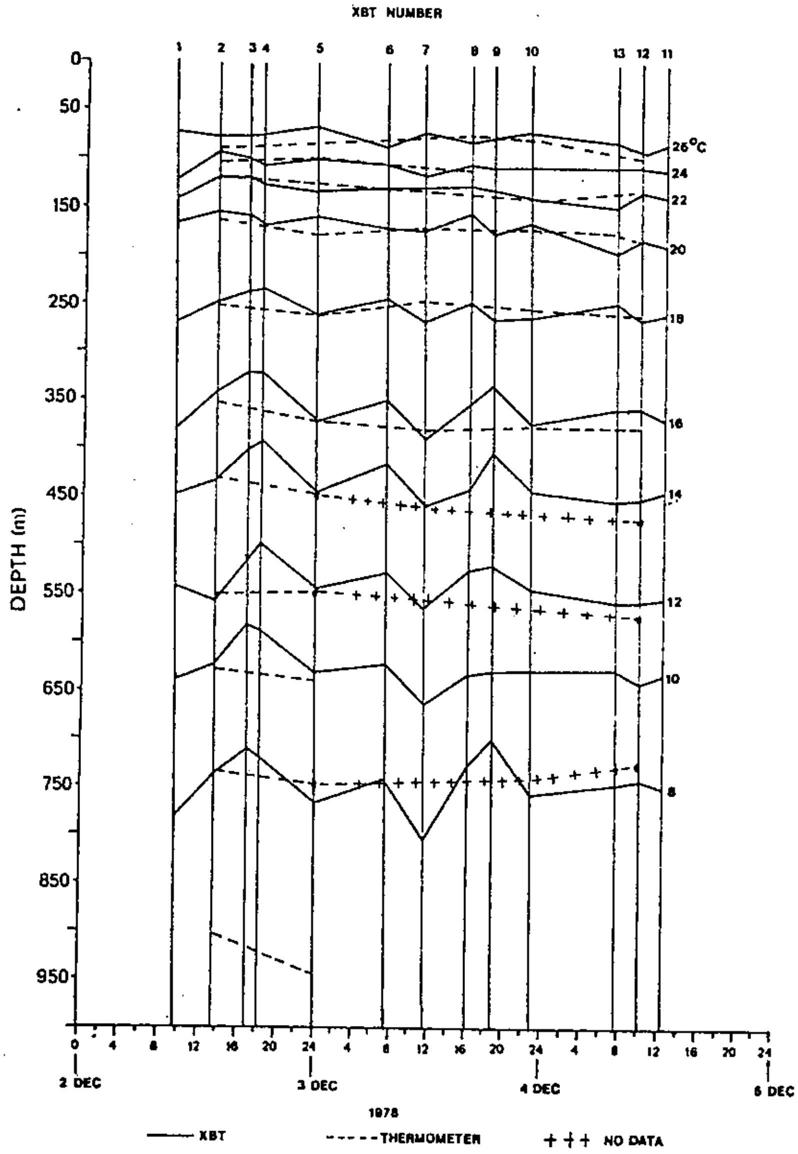


Fig. 17 - Time series of reversing thermometer and XBT results during the cruise of December, 1978.

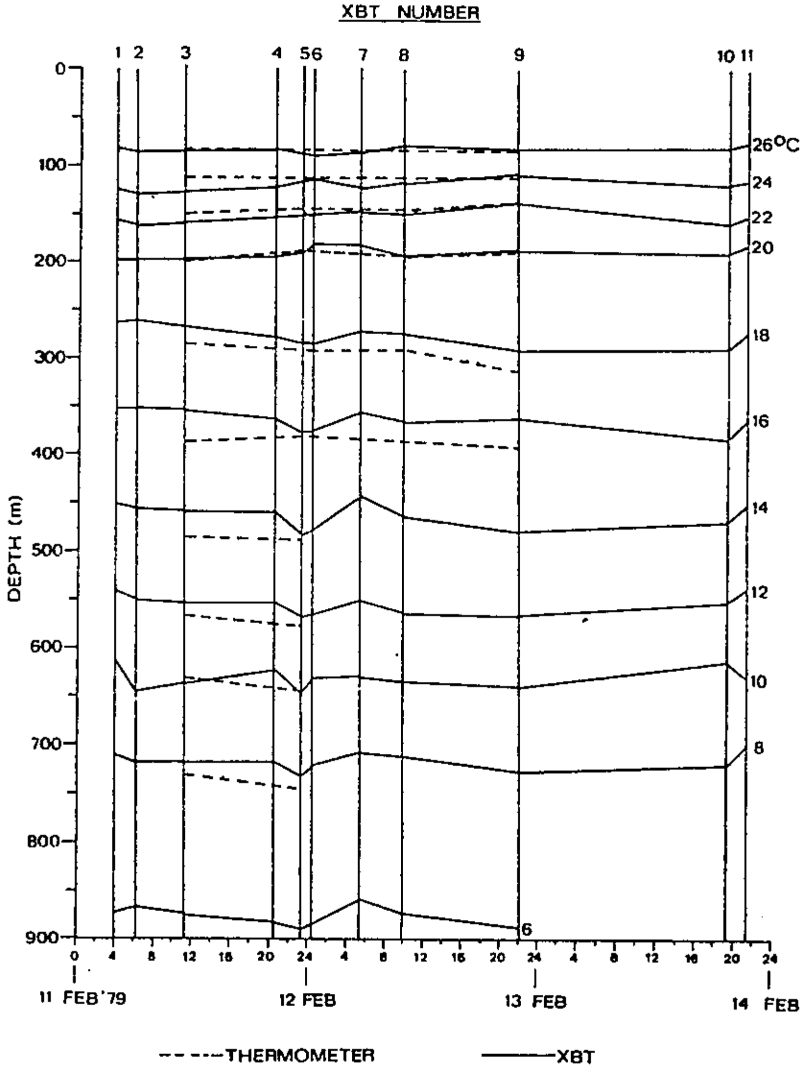


Fig. 18 - Time series of reversing thermometer and XBT results during the cruise of February, 1979.

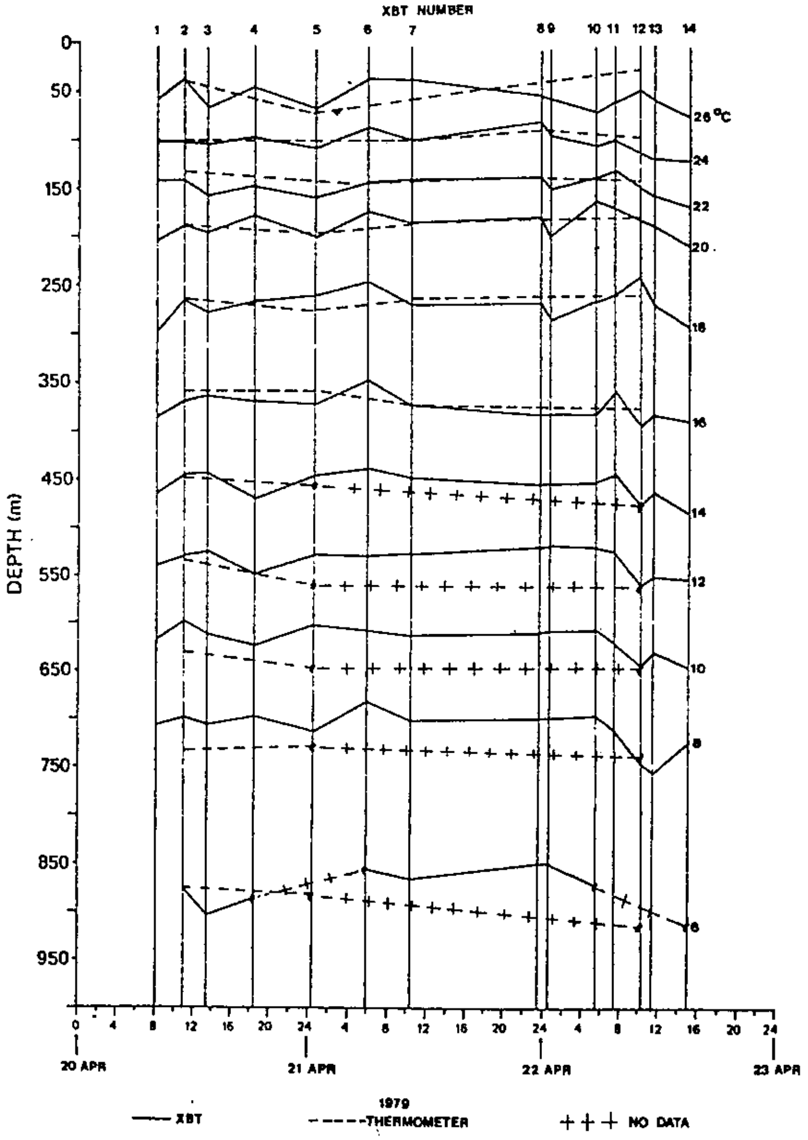


Fig. 19 - Time series of reversing thermometer and XBT results during the cruise of April, 1979.

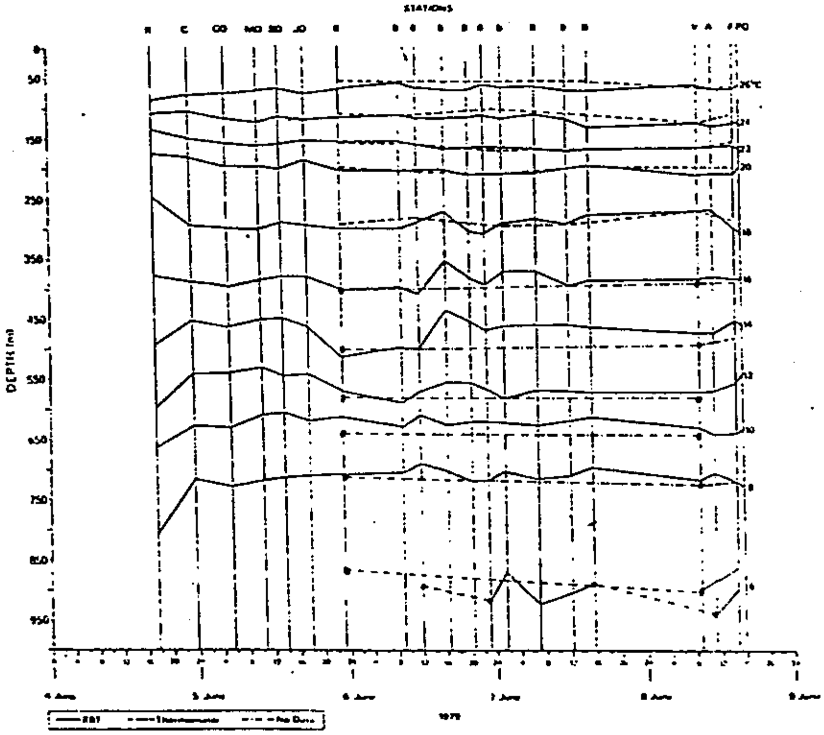


Fig. 20 - Time series of reversing thermometer and XBT results during the cruise of June, 1979.

relying on the XBT results alone. Although the average results of both series are similar, the variation of the individual XBT values should be viewed in the proper perspective.

3.1.1 Thermal Resource

Figure 21 shows a temperature vs. depth profile based on all the thermometer data during our measurement program. In this figure, the ranges of all thermometer values are also shown at each depth as well as the standard deviation from the mean for depths down to 100 m. The average profile exhibits a thermally mixed layer, with an observable thermocline. The range of observed values were about $27.5^{+2\ C^\circ}_{-1\ C^\circ}$ at the surface but the spread increases considerably at about 125 m depth to $23^{+3.5\ C^\circ}_{-1.5\ C^\circ}$. From this depth, the spread of values generally decrease to less than 0.2 C°. The standard deviation from the mean in the upper water is about ± 1 C°.

Also shown in Figure 21 is a conversion from actual temperature to usable temperature-difference (Thermal Resource). From the bottom auxiliary axis, the Thermal Resource can be easily seen to exceed 20 C° from 50 m to 1000 m.

Figure 22 is a time series of the Thermal Resource at the Punta Tuna Benchmark site, as it affects the OTEC plant. The Thermal Resource is that temperature difference that can be used by a plant to actually run the thermal engine and produce power. Usually the Thermal Resource is considered as the temperature difference (in Centigrade or Kelvin degrees) between the surface water and the water at 1000 m depth. As these results may be used to formulate design criteria, Figure 22 contians not only this information, but also the difference from the surface to 900 m depth. As can be seen in the figure, the difference in using 900 m over 1000 m reduces the Thermal Resource about 0.5 C°. Realistically, some depth other than the surface should be used for the warm water intake value. In the case of this Puerto Rico data, the only change that would result would be a decrease in the available Thermal Resource with depth below the surface in

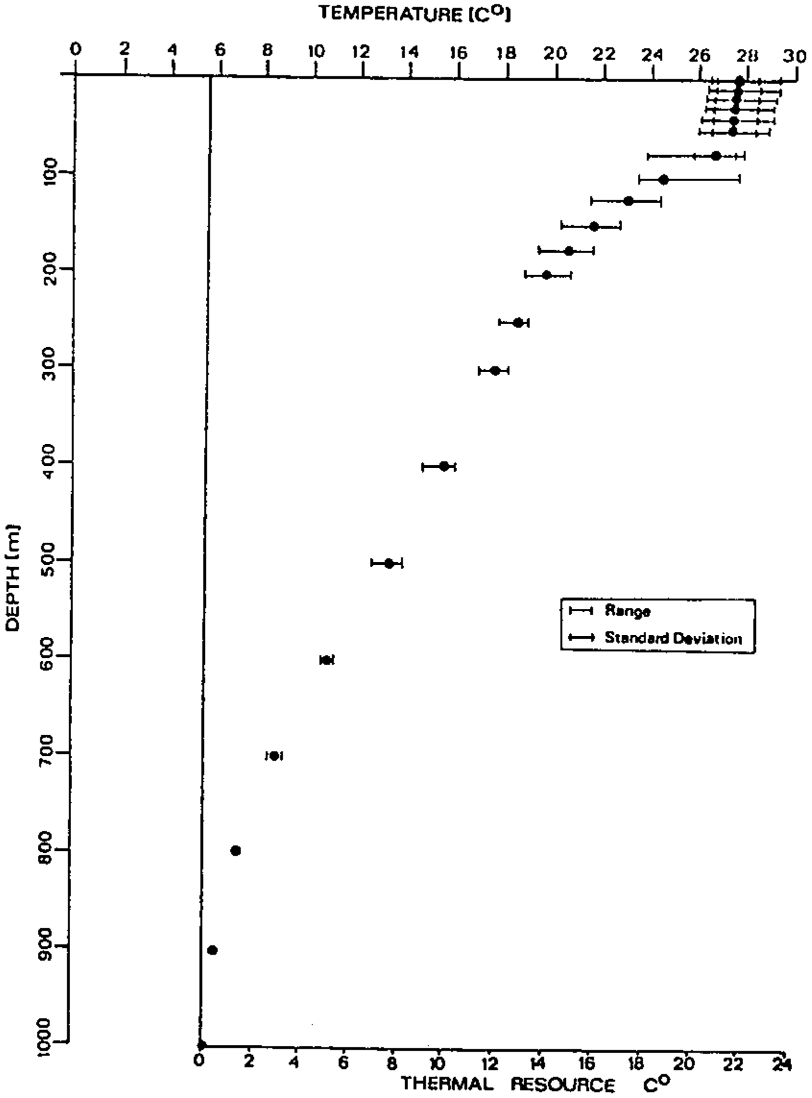


Fig. 21 - Temperature profile of the average thermometer data taken at Punta Tuna for all cruises, from August, 1978 to June, 1979. (The maximum and minimum temperatures at each depth are also shown).

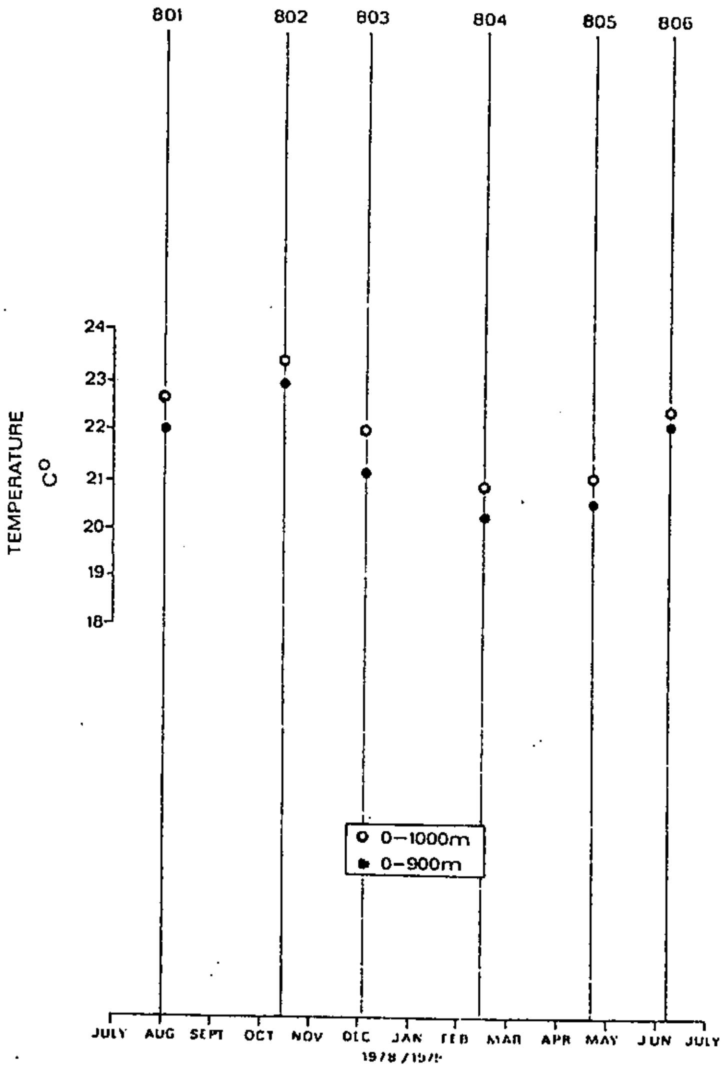


Fig. 22 - Time series of Thermal Resource potential at Punta Tuna from August, 1978 to June, 1979.

June (due to the aforementioned lack of thermally mixed layer at that time), and a somewhat reduced effect in April. The loss of Thermal Resource in June could be as much as 0.4 C° in 20 m depth.

With regard to the actual variation of the Thermal Resource, the figure clearly shows a minimum in late winter (our February cruise), and a maximum in early Autumn (or late summer). These results are similar to those seen in the literature, and our values serve to help confirm the historical data (Wolff, 1978). The Thermal Resource varied from 20.8-23.4 C° (1000-0 m case), with a mean of 22.1±1.0 C°, and 20.3-23.0 C° (900-0 m case), with a mean of 21.5±1.0 C°.

3.2 Salinity Results

During each cruise an attempt was made to collect at least four sets of water samples for subsequent salinity determination as a function of depth. As with the temperature data, the four sets consisted of two Hydrocasts (to about 1000 m) and two Biocasts (to about 400 m). Also, when possible, extra casts were taken either at the Vieques station, or Station "F" or both. Figures 23-28 show vertical profiles of salinity for each of the six hydrographic cruises. In each figure, the salinity displayed in the profile is the average of the four casts, when possible. All the profiles show the same general shape, with a variable upper water salinity, a salinity maximum of about 37°/₀₀ at 125-150 m, and a gentle salinity decrease to about 34.9-35.0°/₀₀ at about 700 m and below. In cases where the spread in the salinity determination during a particular cruise exceeded ±0.02°/₀₀ at a given depth, the data spread is also shown in the figure.

Figure 29 is a time series description of the salinity profiles throughout the year. These values were made using the salinity averages for each cruise, as were the previous figures. The noteworthy points in this figure are the large salinity variations in the upper water throughout the year, and the lack of variation elsewhere in the water column.

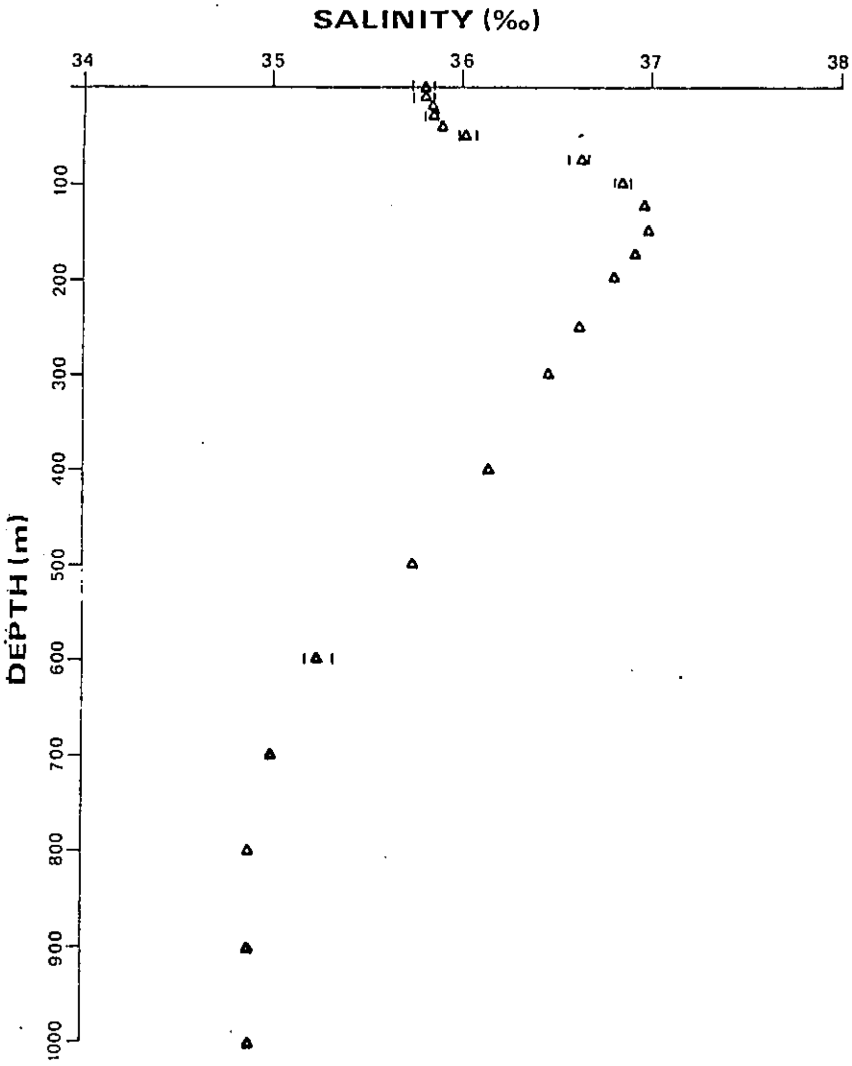


Fig. 23 - Average salinity profile at Punta Tuna for the cruise of August, 1978. (Maximum and minimum observed salinity values are shown at each depth).

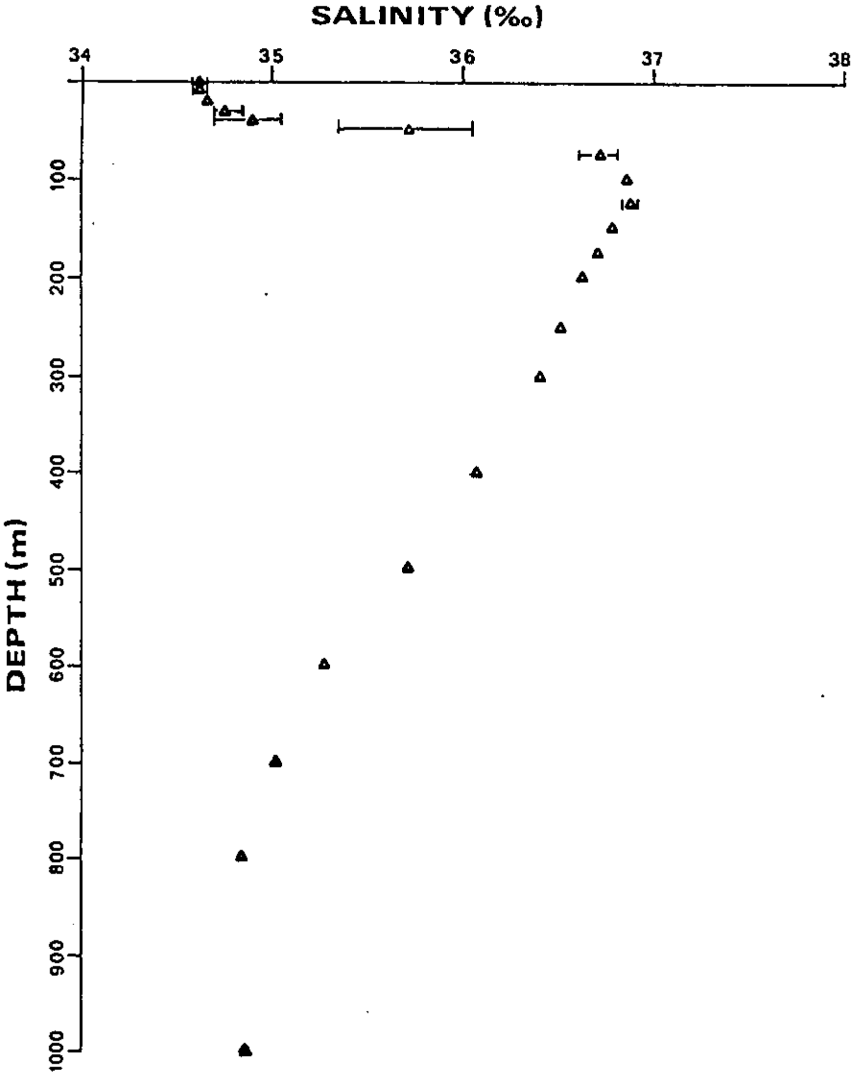


Fig. 24 - Average salinity profile at Punta Tuna for the cruise of October, 1978. (Maximum and minimum observed salinity values are shown at each depth).

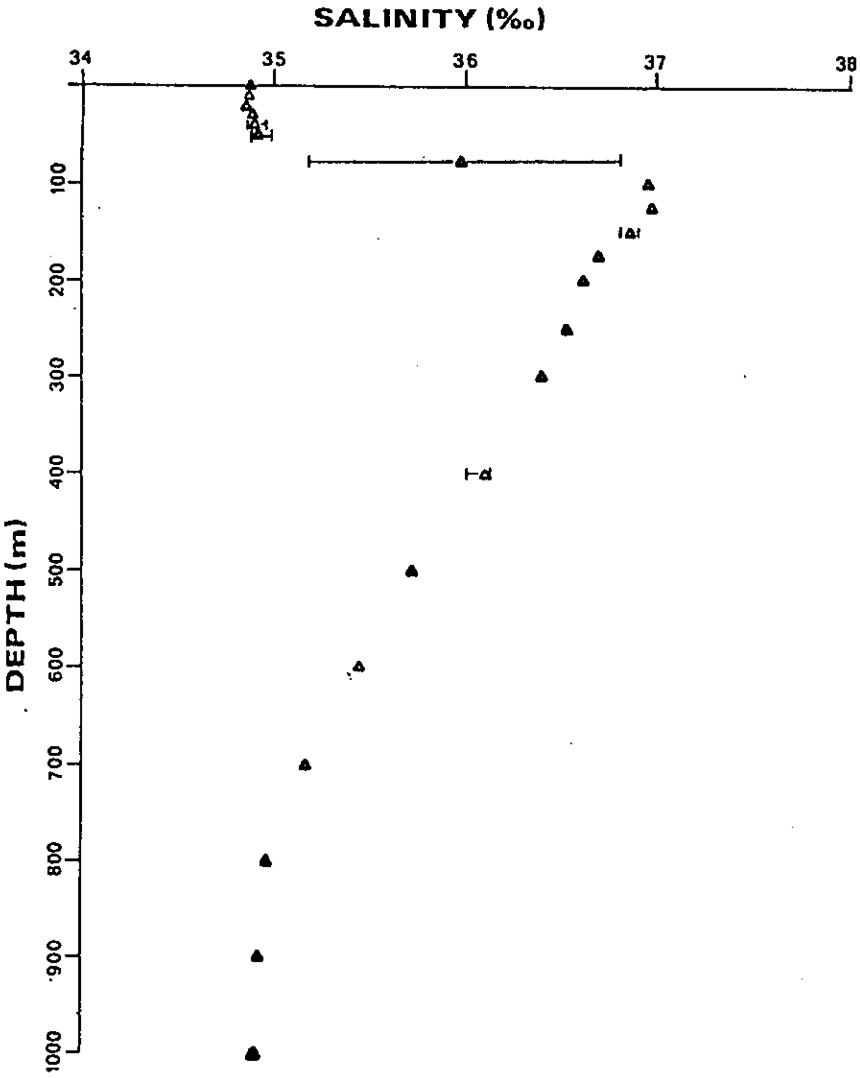


Fig. 25 - Average salinity profile at Punta Tuna for the cruise of December, 1978. (Maximum and minimum observed salinity values are shown at each depth).

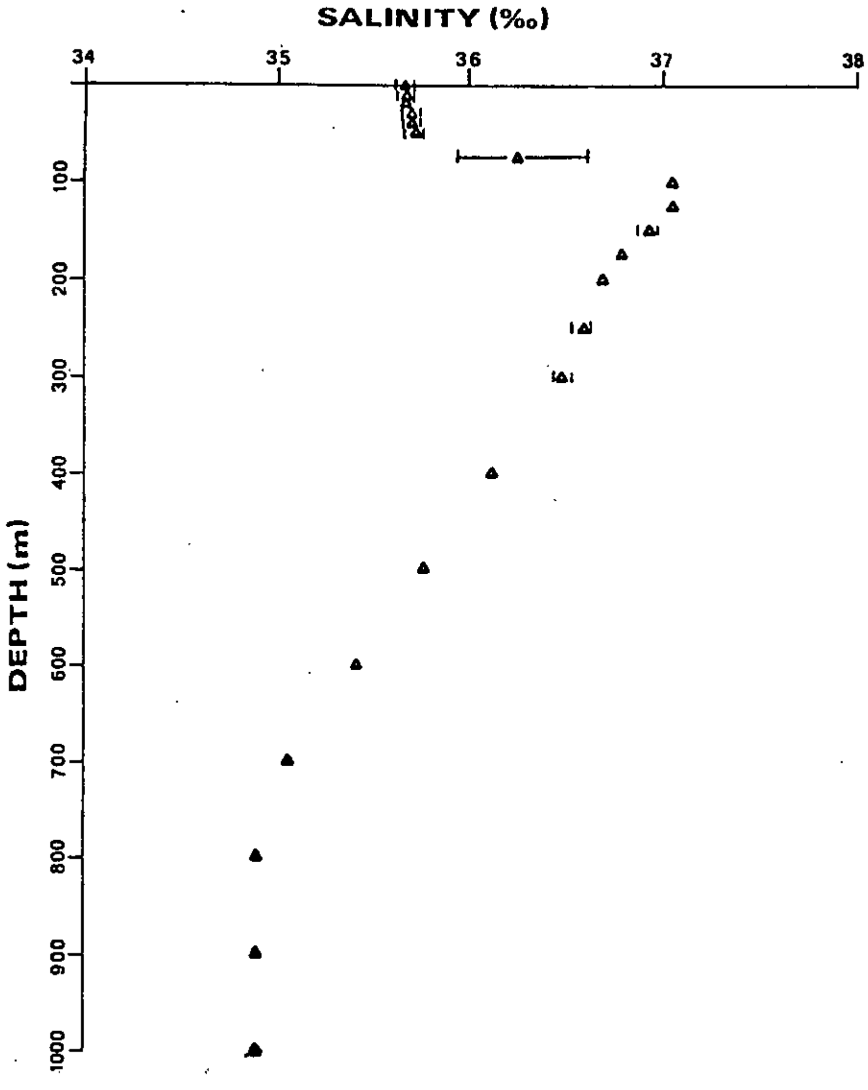


Fig. 26 - Average salinity profile at Punta Tuna for the cruise of February, 1979. (Maximum and minimum observed salinity values are shown at each depth).

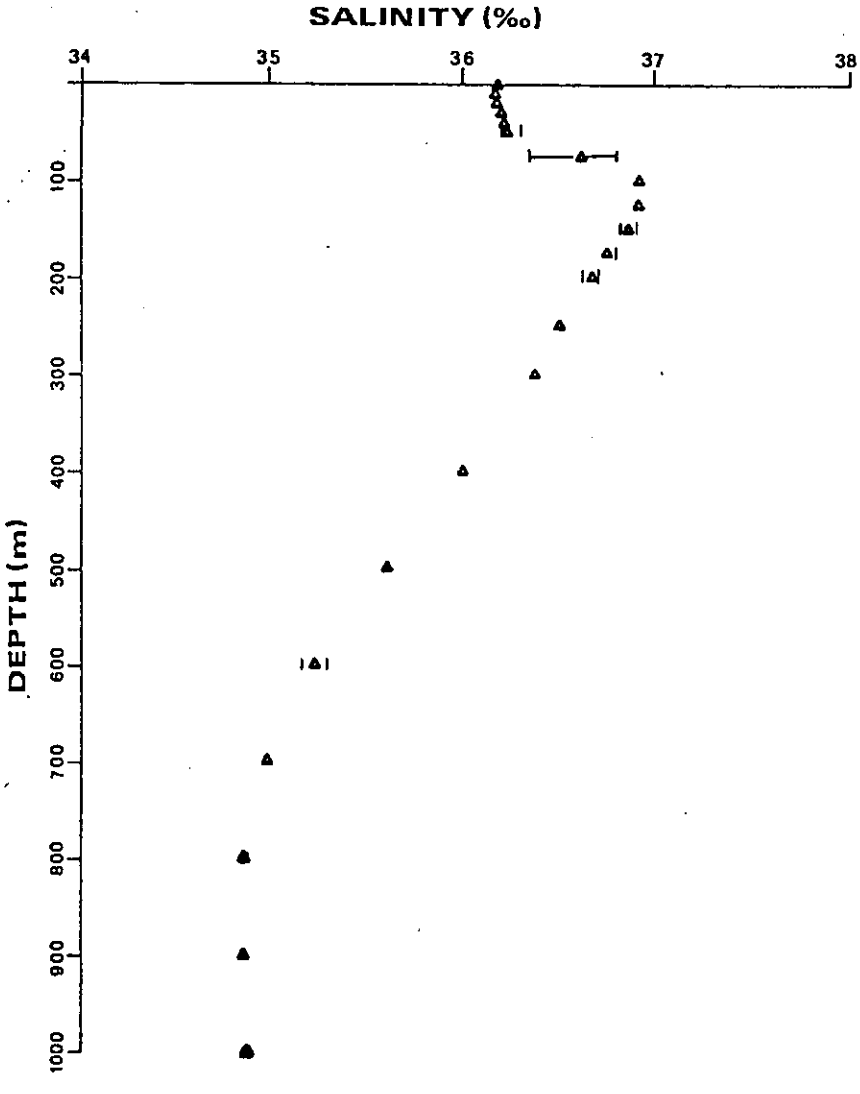


Fig. 27 - Average salinity profile at Punta Tuna for the cruise of April, 1979. (Maximum and minimum observed salinity values are shown at each depth).

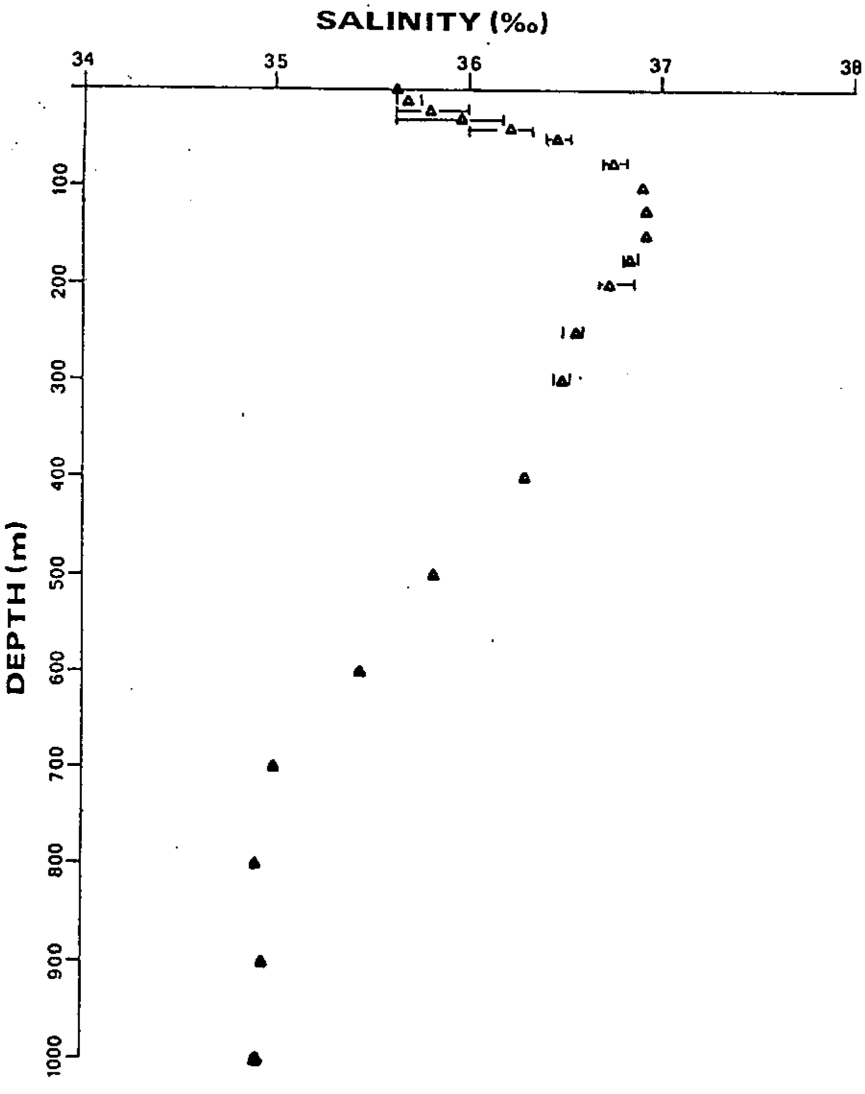


Fig. 28 - Average salinity profile at Punta Tuna for the cruise of June, 1979. (Maximum and minimum observed salinity values are shown at each depth).

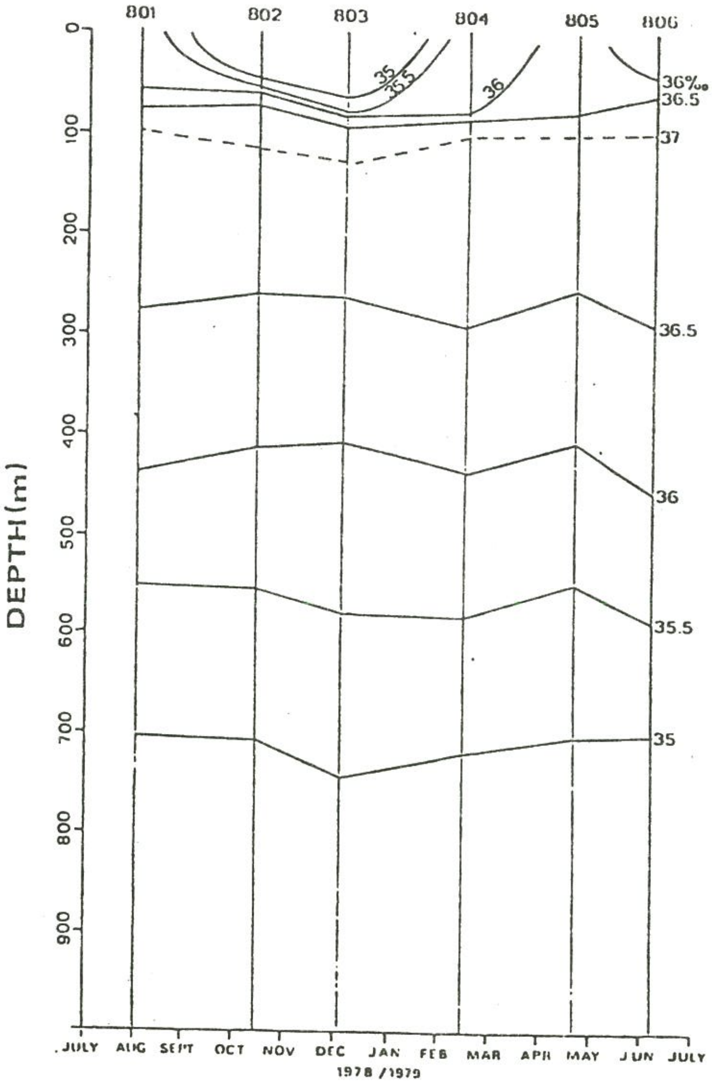


Fig. 29 - Time series of the average salinity values observed at Punta Tuna from August, 1978 to June, 1979.

The salinity of the upper water is seen to vary from about 34.7°/oo in October to 36.2°/oo in April. As the depth of the salinity maximum varied little, the salinity/depth gradient was quite high during the autumn and early winter, the period of lowest surface salinity. The remainder of the water column seems to be experiencing only small changes in salinity throughout the year, and these changes may be a result of error in depth determination, rather than salinity. These results compare well with the temporal salinity variations discussed by Froelich et al., (1978), in which they point out the strong functional relationship between the fluctuations in the Caribbean surface water salinity and the fresh water discharge from the Amazon and Orinoco Rivers.

Figure 30 shows the average vertical salinity profile for all the data taken at the Benchmark Station during our 6 cruises from August, 1978 to June, 1979. Although the average salinity itself is not important, the observed spread of values shows the entire range seen throughout the program. As expected, the spread is greatest in the upper water waters, covering $35.5^{+0.7}_{-0.9}$ °/oo. In the vicinity of the maximum halocline, the annual salinity variation even exceeded the surface values, but again this may be a result of our inability to accurately determine the exact depth of the water sampling bottle in this rapidly changing environment. In the vicinity of a large vertical gradient of salinity, a small error in depth of only a few meters may appear to be large salinity excursion. With increasing depth, the observed data spread decreased considerably from about ±0.15°/oo at the salinity maximum to less than ±0.02°/oo at depths greater than 800 m.

3.3 Density Results

The density of any water particle in the water column is primarily a function of the temperature and the salinity of that particle. The relative density of that particle, compared to all others, will determine the vertical location of that particle within the column.

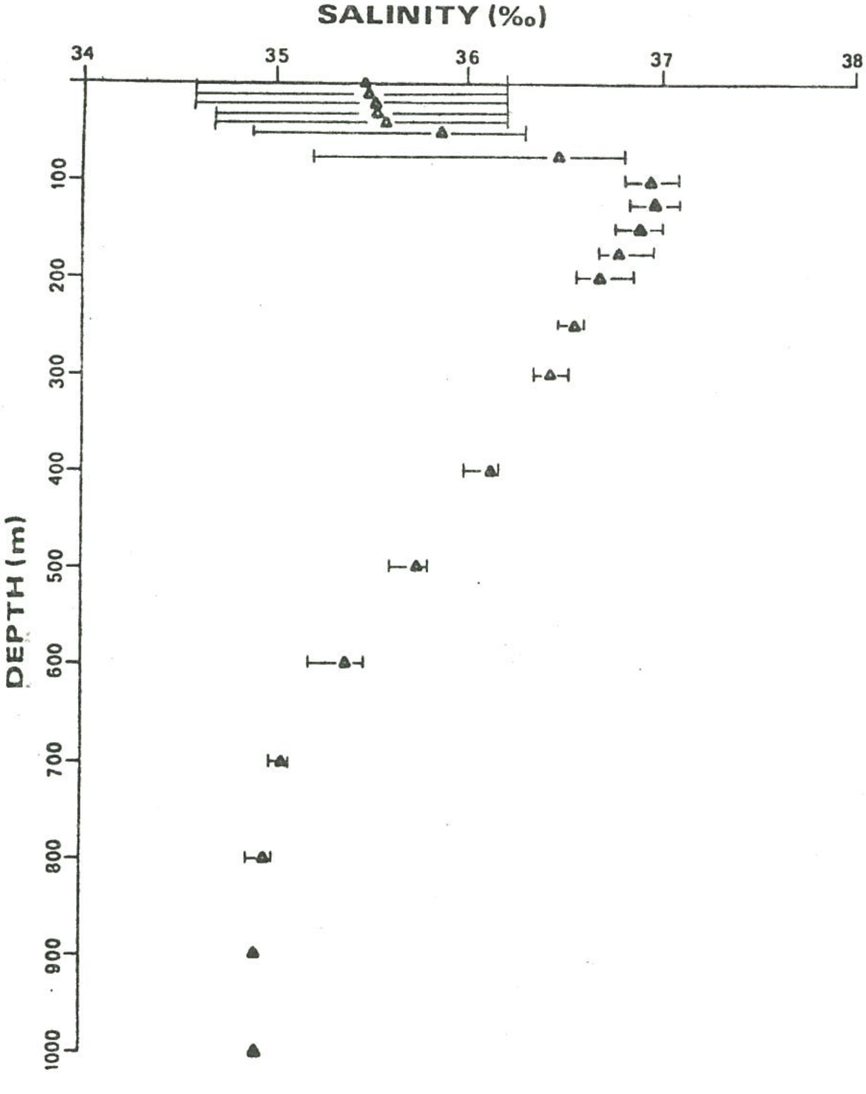


Fig. 30 - Average salinity profile observed at Punta Tuna for all cruises from August, 1978 to June, 1979. (Maximum and minimum observed salinity values are shown at each depth).

Figures 31-36 show the average vertical density profiles for each of the six hydrographic cruises. In all, but the last cruise (June 1979), a thick isopycnic layer is clearly defined at the surface. Just below this uniform layer lies a relatively sharp pycnocline of about 2 sigma-t units within less than 100 vertical meters. As the normal wind field develops over the Caribbean, the mixing intensifies, enhancing the presence of a strong pycnocline. In the absence of mixing, the isopycnic layer may decrease to almost nothing.

Figure 37 is a vertical profile of the average density including all the data from this program. The average profile also shows an isopycnic layer at the surface, and a sharp pycnocline directly beneath it. Also shown in this figure are the ranges of the density values determined for each depth during the sampling period. As usual, the maximum variations are found in the upper, near-surface waters, with generally decreasing variations down to about 300 m. Below this depth there is less than ±0.1 sigma-t units change at each depth throughout the year. This figure, and the preceding density profiles, combined with the temperature and salinity profiles can be used to make estimates of the density change due to heating and cooling of the water pumped through an OTEC power plant. Subsequent predictive models can be developed for ultimate depth determination of the effluent waters, relative to the existing ambient water column.

3.3.1 Mixed Layer Depth

The water intake for the evaporation of an OTEC plant would draw the heat from the upper water layers of the ocean. As mentioned previously, the uppermost layer is usually in a state of vertically stable equilibrium, and is isothermal, isohaline, and therefore, isopycnic (constant density) for many meters down from the surface. It is important for the uniformity of the intake water to know the depth of this uniform layer.

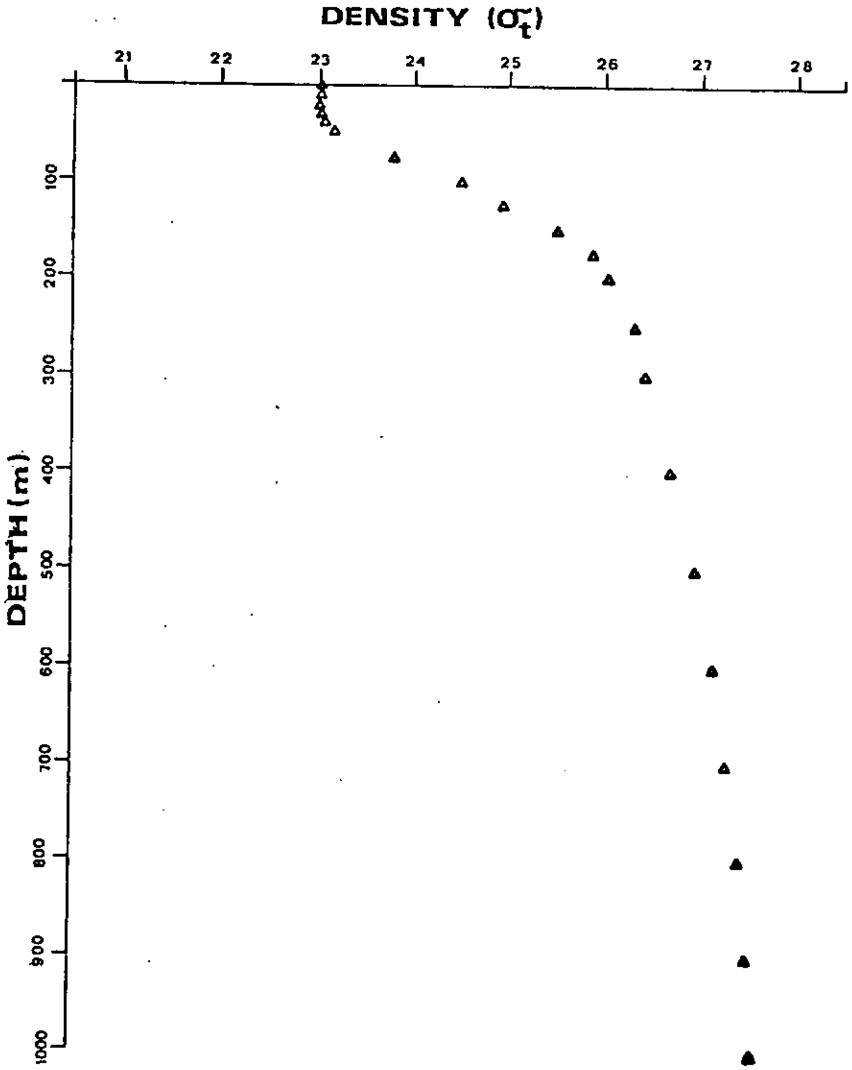


Fig. 31 - Average density profile observed at Punta Tuna during the cruise of August, 1978.

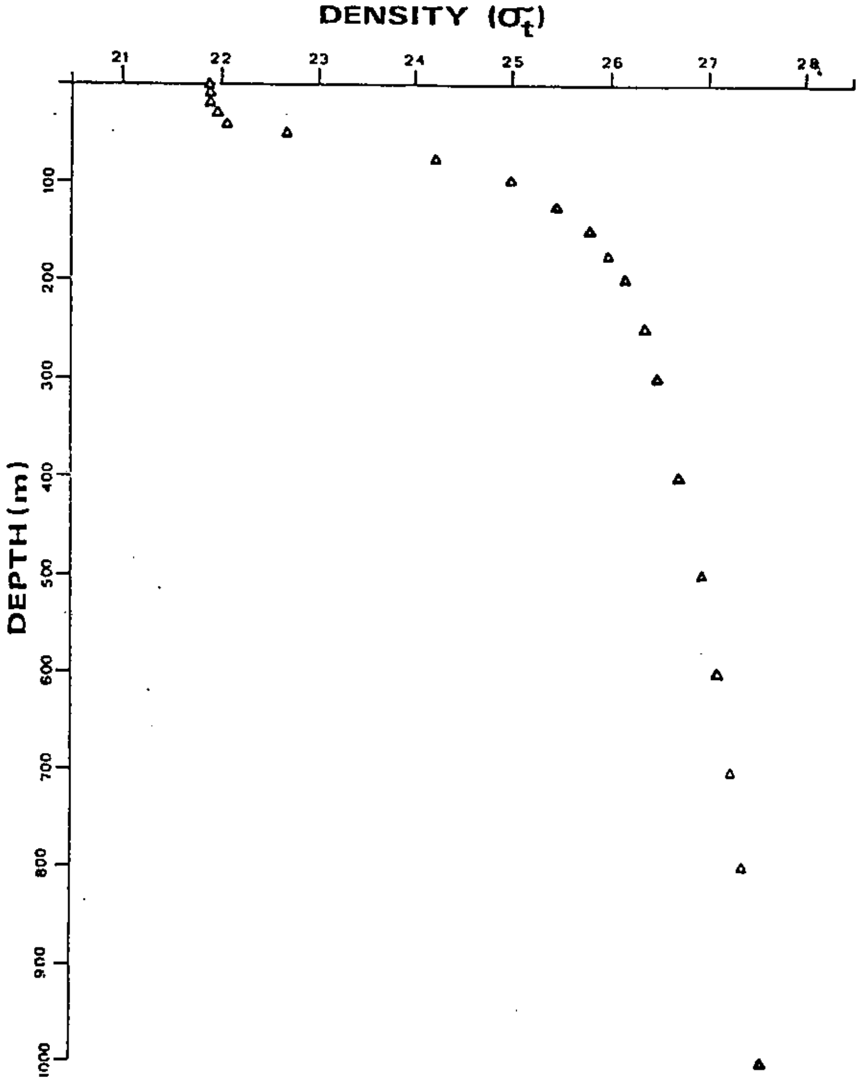


Fig. 32 - Average density profile observed at Punta Tuna during the cruise of October, 1978.

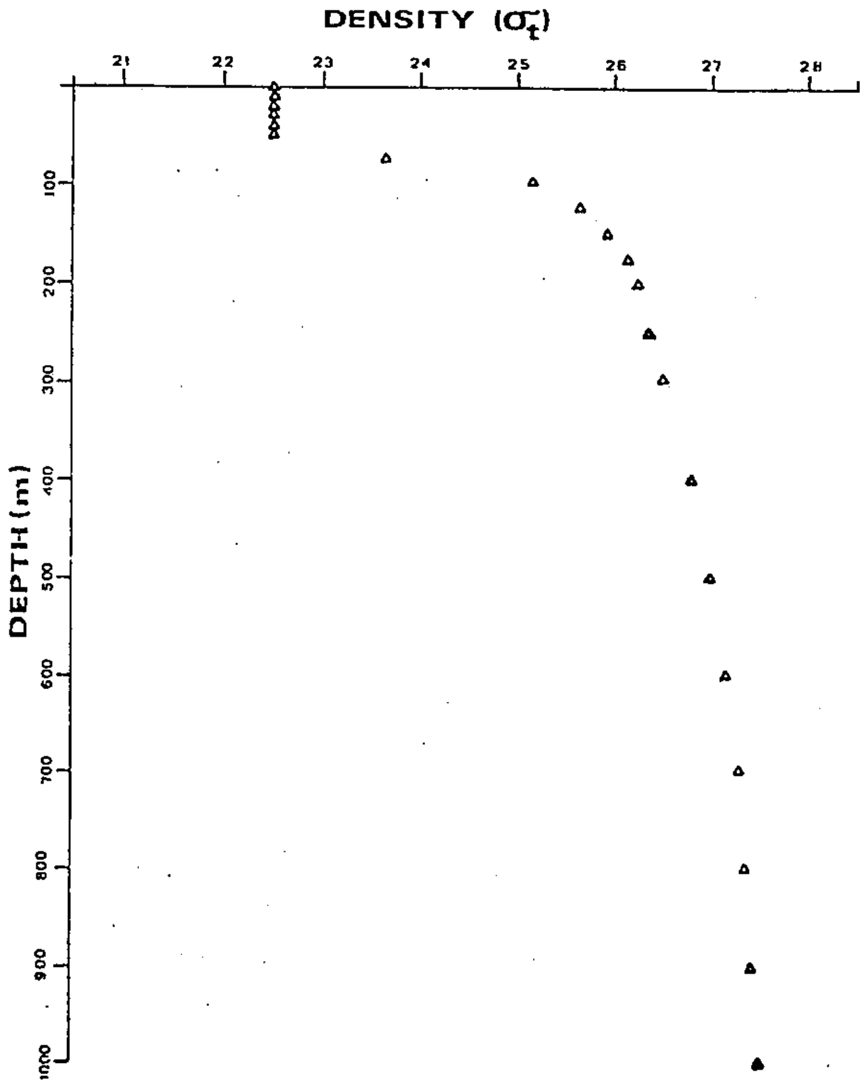


Fig. 33 - Average density profile observed at Punta Tuna during the cruise of December, 1978.

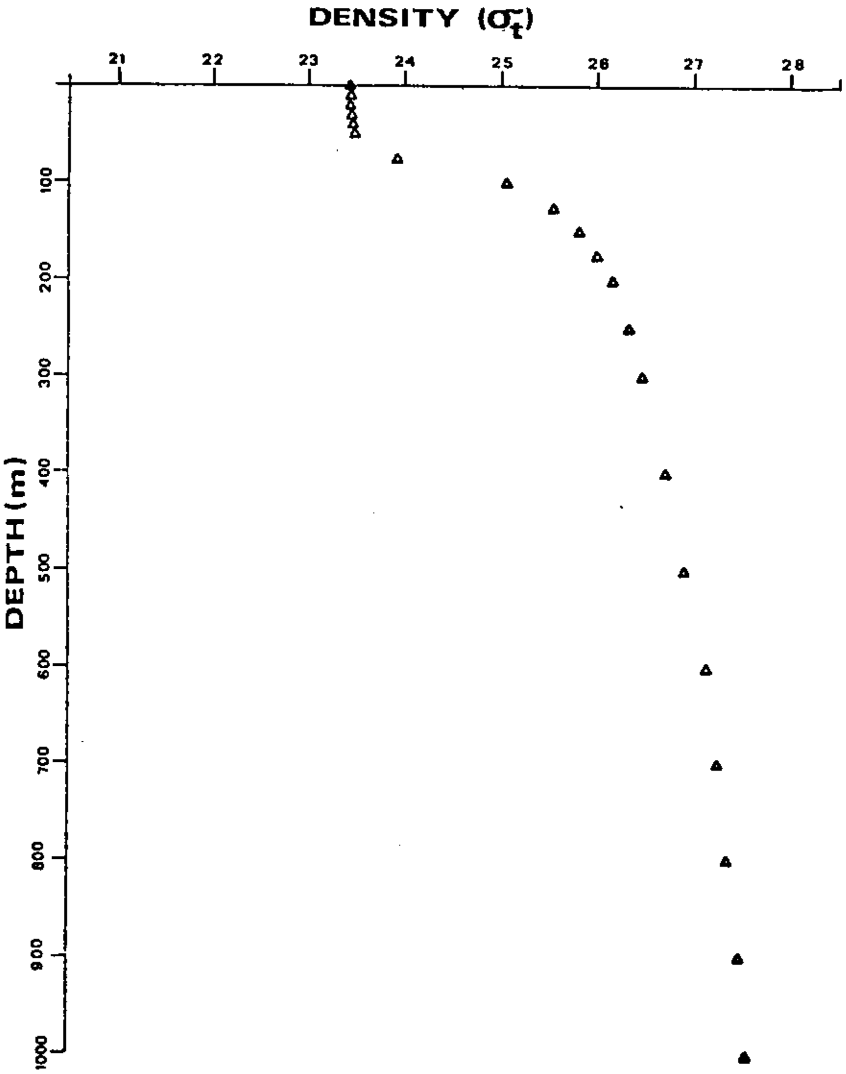


Fig. 34 - Average density profile observed at Punta Tuna during the cruise of February, 1979.

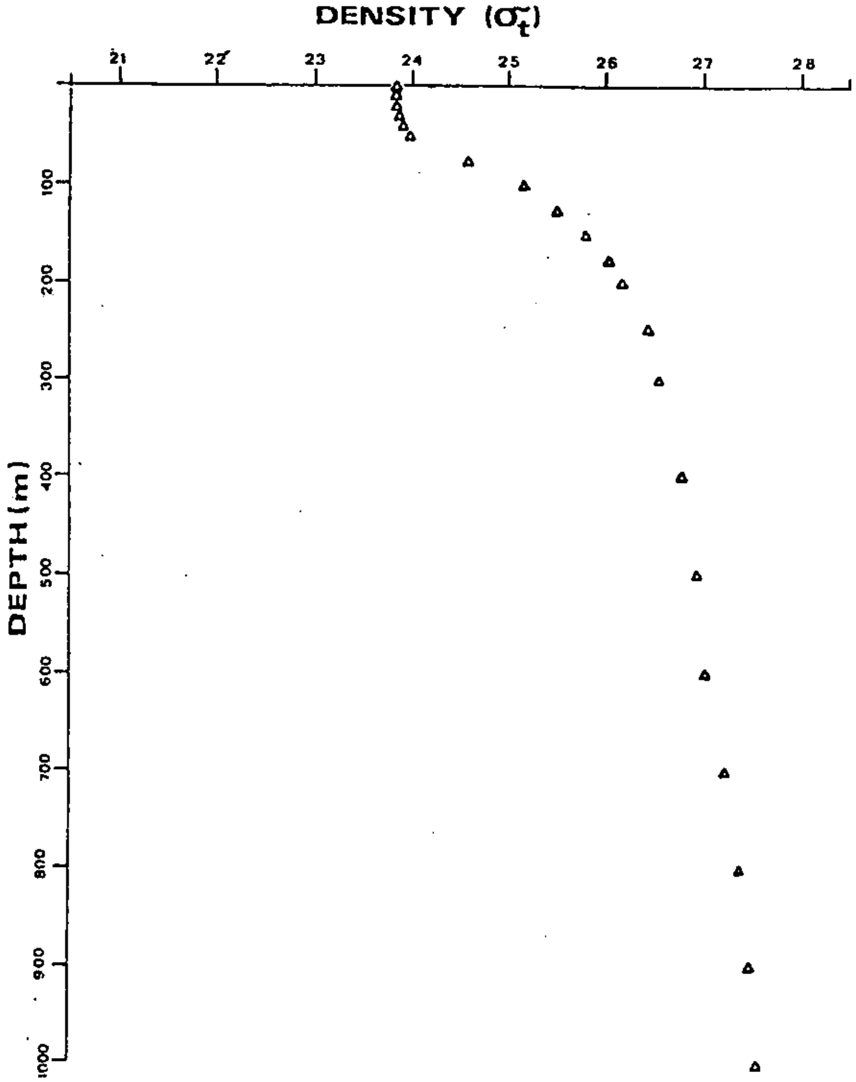


Fig. 35 - Average density profile observed at Punta Tuna during the cruise of April, 1979.

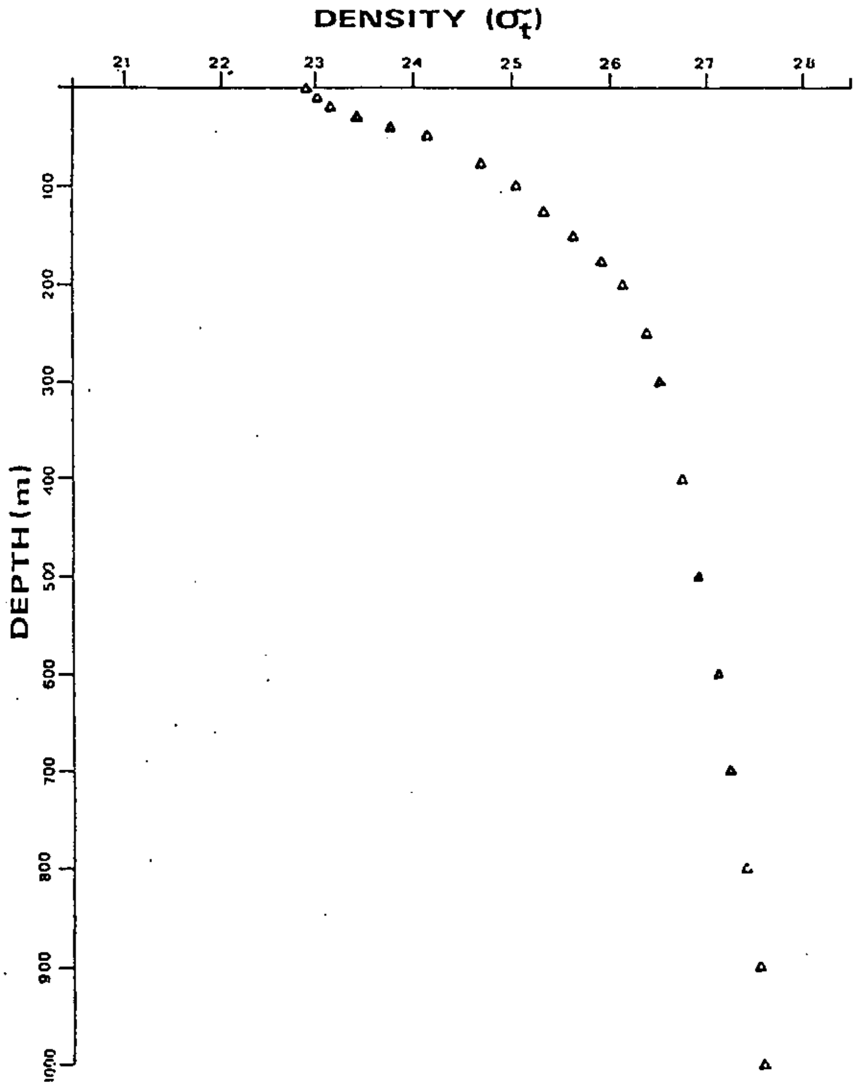


Fig. 36 - Average density profile observed at Punta Tuna during the cruise of June, 1979.

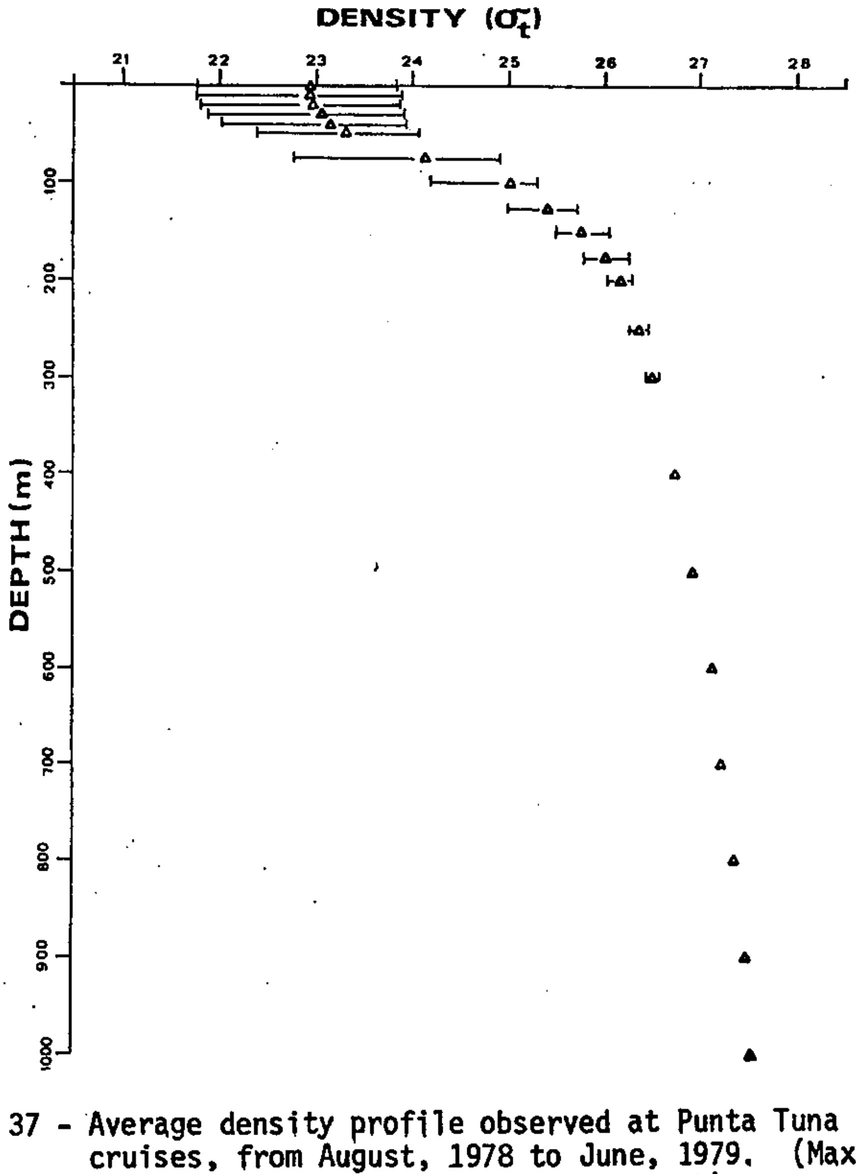


Fig. 37 - Average density profile observed at Punta Tuna for all cruises, from August, 1978 to June, 1979. (Maximum and minimum values are shown at each depth).

A variety of definitions for the Mixed Layer Depth (MLD), have been put forward, but usually they all determine about the same depth value. The reason being that the upper layer is usually well mixed, and immediately below this uniform upper layer, the temperature, salinity, and therefore, the density all experience such a large vertical gradient, that almost any reasonable definition will yield about the same depth for the bottom of the mixed layer as it would mark the depth beginning of the gradient. An example of this uniformity of definition is seen in Table 1. For the Table, the MLD is determined supposedly, for each of our cruises, using a temperature criteria, a salinity criteria and a density criteria, all independent of each other. The temperature criteria is--that depth when the change from the surface temperature equals 1 C°; this is shown for both the thermometer data as well as the average XBT data. The salinity criteria requires--a change of 1°/₀₀ from the surface value. The density criteria uses--a 1 sigma-t unit change from that of the surface. As seen in the Table, when the criteria can be applied, as in most of these cases, the results are quite similar for all the criteria. With only a few exceptions, the difference in values for all the criteria was less than 10 m depth. The non-complying cases occur when the salinity was quite high already (April) and was less than 1°/₀₀ different from that value at the salinity maximum, and in June, when there was no uniform upper layer. Another interesting point to note from the Table is the MLD difference that would be calculated by using the XBT averages, as opposed to the thermal values, the salinity values, or the density values, all of which are much harder to compute and collect than are the XBT values. Generally, the average XBT results are close.

Using the results of Table 1, Figure 38 shows a time series display of the MLD throughout our measurement period. In general, the MLD remains greater than 50 m throughout the year, except during the early summer, where it moves quite close to the surface. The comparison between our results and

TABLE 1

Calculated Mixed Layer Depth (MLD) seen at
Punta Tuna, Puerto Rico from August, 1978 to June, 1979.

CRUISE/DATE	TEMPERATURE		SALINITY	DENSITY	VALUE USED
	Therm	XBT			
August,. 1978	85m	---	90m	80m	85m
October, 1978	60	(65)	50	60	60
December, 1978	70	(70)	70	70	70
February, 1979	90	(90)	90	85	90
April, 1979	65	(55)	--	60	60
June, 1979	35	(35)	60	45	35
CRITERIA	$\Delta T = 1C°$		$\Delta S = 1°/_{\circ\circ}$	$\Delta\sigma_t = 1$	

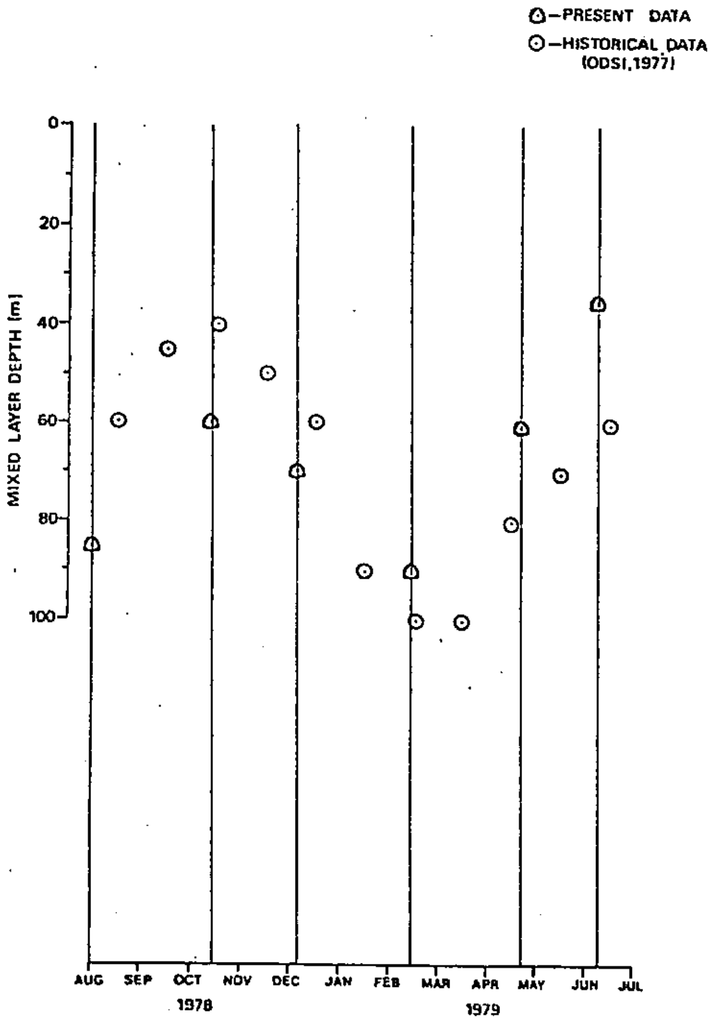


Fig. 38 - Time series of the Mixed Layer Depth at Punta Tuna from August, 1978 to June, 1979. (Average historical values are also shown).

the most probable historical values are also seen not to differ considerably.

3.3.2. Temperature/Salinity Relationships

Although temperature and salinity are not necessarily controlled by the same mechanisms in the ocean, there do exist rather reliable interrelationships between the two. Figure 39 shows the temperature/salinity, or T/S diagram for the six cruise averages. Although the cruises were taken during separate times of the year, many T/S characteristics remain quite constant during this time. The Tropical Surface Water (TSW) is the most variable, as seen by the scatter in the upper portion of the Figure. The Subtropical Underwater (SUW) is relatively constant in its characteristics, and the vertical range of this water mass, not easily seen in this Figure, is usually only affected by severe weather conditions. The two deeper water masses, the Atlantic Intermediate Water (AIW) and the North Atlantic Deep Water (NADW) have little seasonal variation.

Another T/S relationship can be seen in Figure 40. This is a time series of the upper 40 m for temperature, salinity, and density during the time of our measurement program. From this type of display, one can easily note the inverse variation between the temperature and the salinity throughout the year. Another easily discernible relationship is the matching of the density with the salinity, not the temperature, as might be expected. In the density determination, the salinity is seen to be a much stronger functional force than is the temperature. The results of a figure such as this must be used to determine effluent mixing and dispersal depth.

3.4 Water Current Results

During each cruise a set of water current profiles were taken at least 4 times while at the Benchmark station. Also, during the program year, 2 current meter moorings were implanted near the Benchmark.

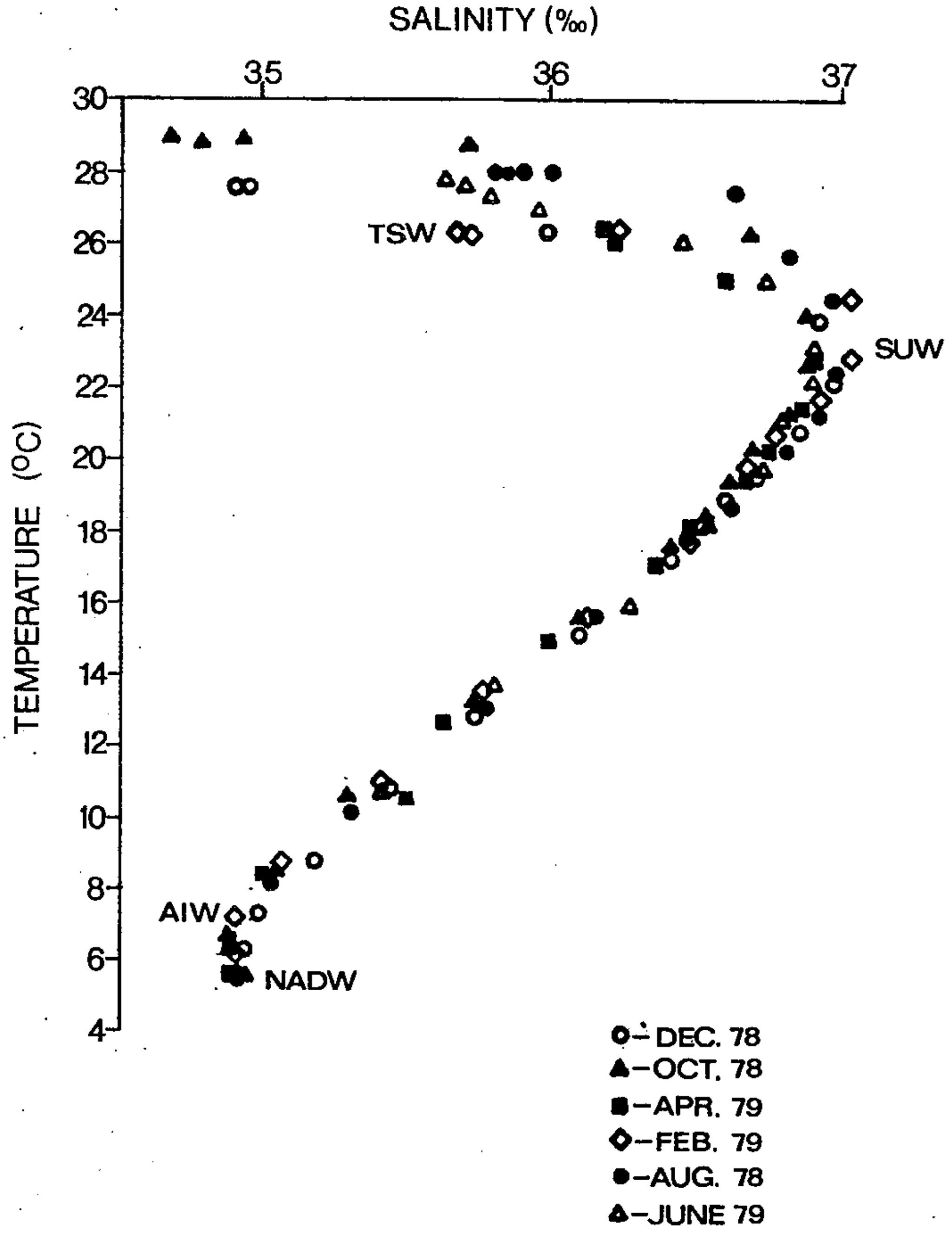


Fig. 39 - Temperature/Salinity diagram of all data observed at Punta Tuna from August, 1978 to June, 1979.

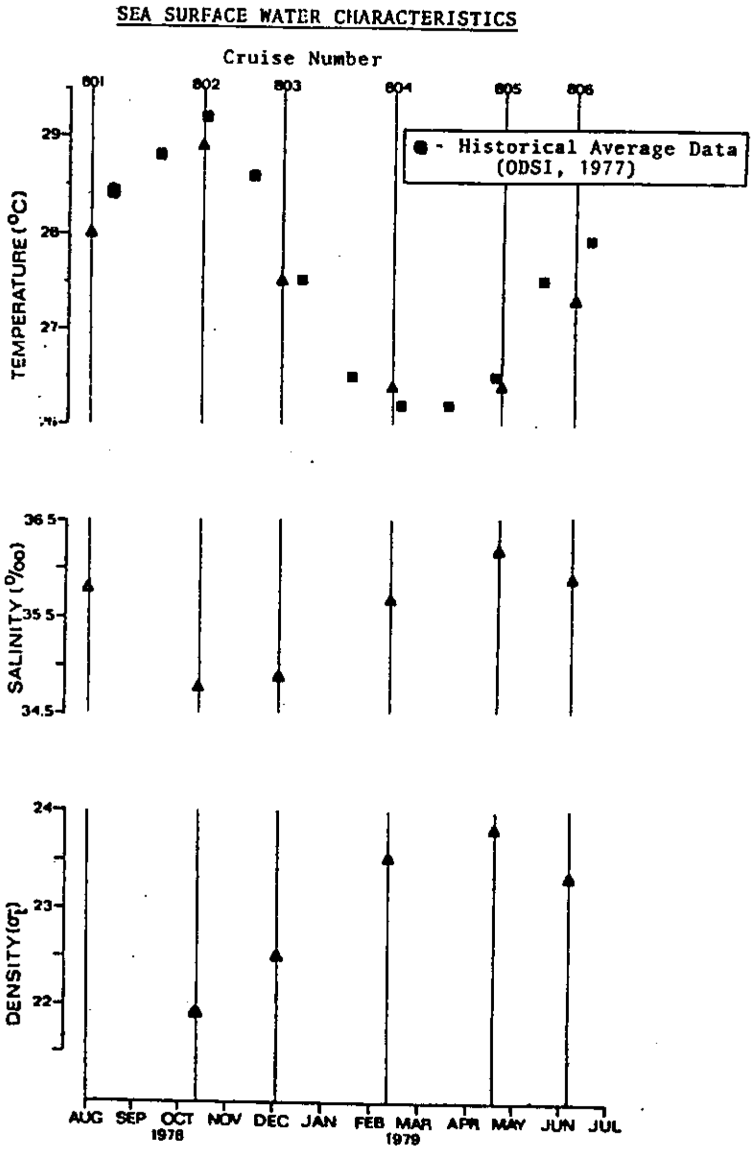


Fig. 40 - Time series of sea surface-water characteristics at Punta Tuna observed from August, 1978 to June, 1979.

3.4.1 Current Meter Profiles

On the first cruise, current profiles were taken while the vessel was drifting. Starting with the October 1978 cruise, the measurements were made with the vessel secured to the mooring. The results of the initial measurements were strongly influenced by the drift of the vessel. An error analysis using the best available estimates for the instrument accuracy, the instrument readability, and the vessel position finding capability (the largest error of the three) produced possible errors in excess of ±10-15 cm/sec and entire quadrants of direction. Also, it is possible that our meter might be adversely affected by being pulled through the water by the drifting vessel, and having the plane of the Savonius rotor of the meter not necessarily in the same plane as the water flow. During the program, the current meter was upgraded to increase the readability by expanding the scale 3-fold. This did not necessarily change the precision of the meter, but increased our ability to read the speed values in the 0-10 cm/sec range considerably.

To compliment the current profiles, the north-south components of the geostrophic current have been calculated using the data taken at both Punta Tuna (Station "B"), and Vieques (Station "V"). These calculations have been made for October and December, 1978, and April and June, 1979. Geostrophic current calculations are most accurate outside the influence of surface meteorological forcing, away from boundaries (such as land), and at mid latitudes. In spite of these shortcomings, the results of the calculations, shown in Table 2, compare well with the north-south component of the current profiles. In the calculations, the level of no motion is assumed to be 800 m deep. This assumption is based soley on the maximum measured depth, not on any physical observation.

Figures 41-52 show modified stick-type diagrams of the current profiles for each cruise, as well as time series current patterns in N-S and E-W component form for each cruise.

TABLE 2

North-South Components of Calculated Geostrophic Currents Between Punta Tuna and Vieques ("+" signifies North, Speed in cm/sec)

DEPTH	Cruise Oct. 1979	Cruise Dec. 1978	Cruise Apr. 1979	Cruise June 1979
30	-19	-22	-8	22
50	-13	-14	-3	12
75	- 5	- 7	+2	10
100	- 1	- 6	+5	12
125	- 3	- 5	+4	12
150	- 4	- 4	+1	10
175	- 3	- 3	-1	9
200	- 3	- 3	-1	9
250	- 2	- 3	+1	10
300	0	- 3	+2	12
400	0	- 3	+2	10
500	+ 1	- 3	+1	10
600	+ 2	- 3	+1	10
700	0	- 2	0	7
800	"0"	"0"	"0"	"0"
900			0	-11
1000			-1	-24

Assumed Level of No Motion
is 800 m

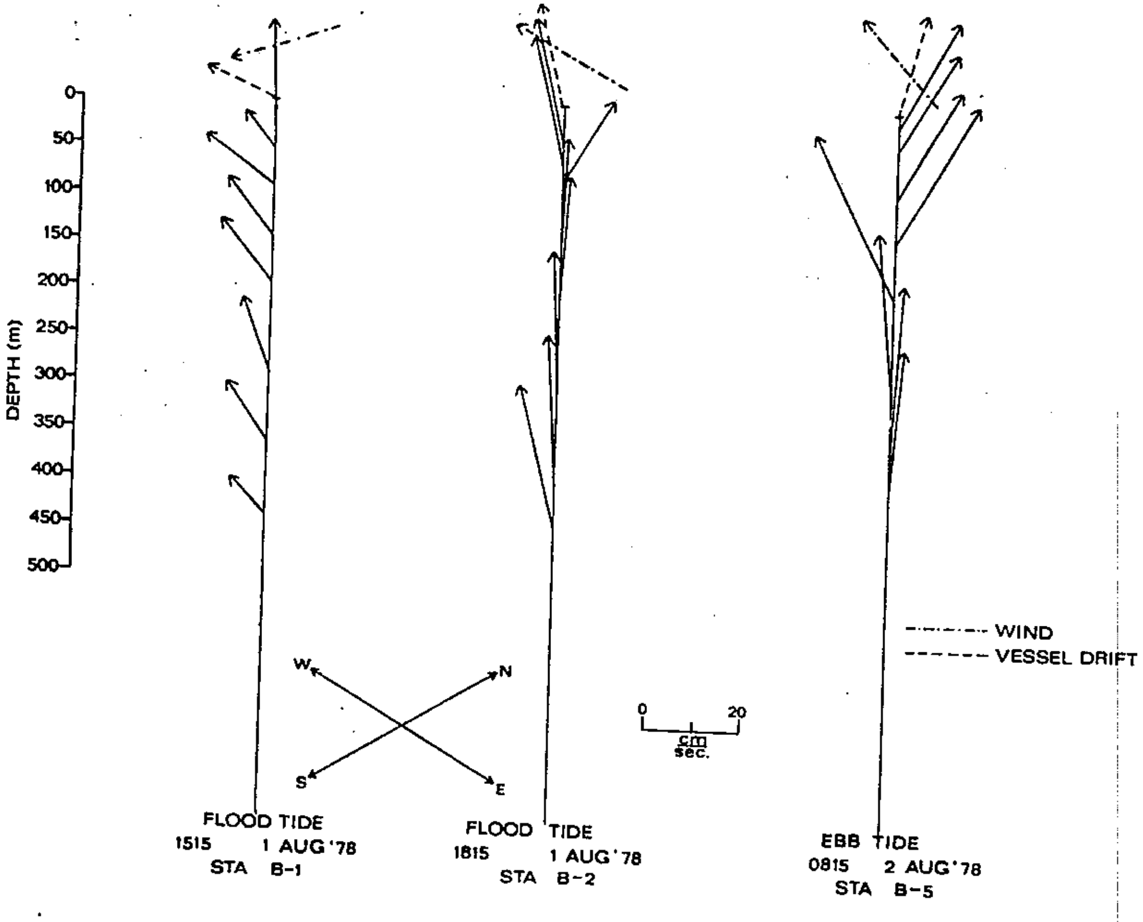


Fig. 41 - Stick plot of water current profiles taken at Punta Tuna during the cruise of August, 1978. (Note-vessel drifting during the measurements).

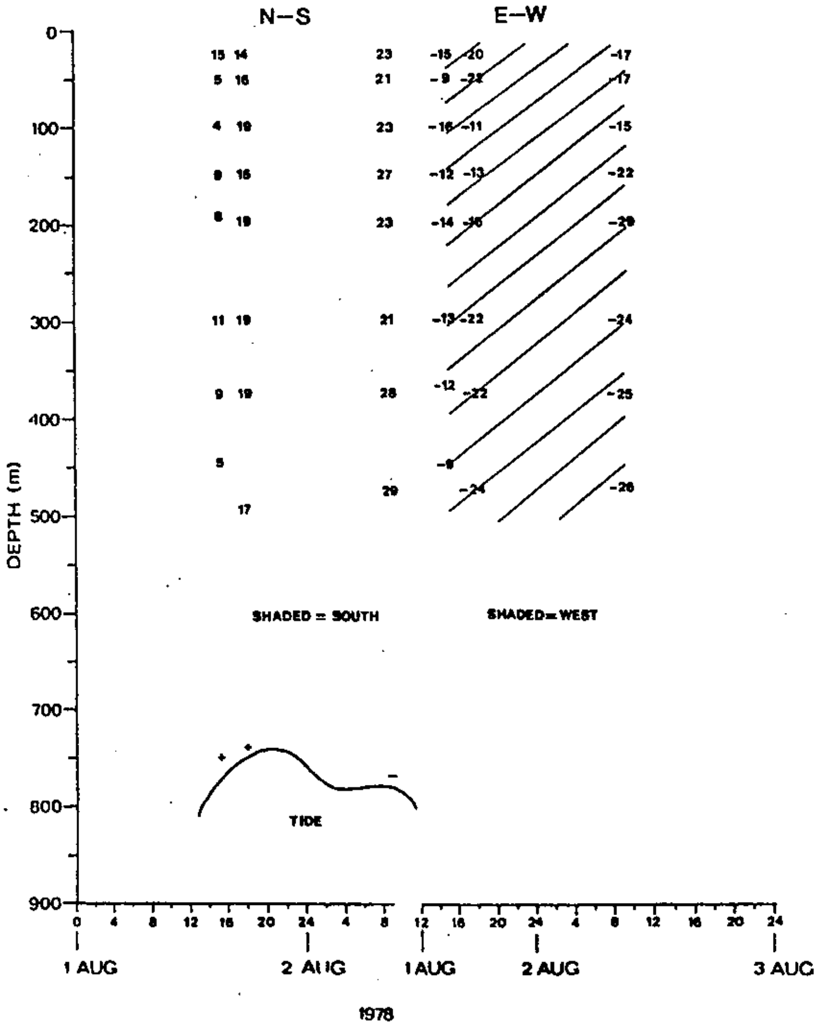


Fig. 42 - Time series of the water current profiles taken at Punta Tuna during the cruise of August, 1978. (Estimated tidal condition and current is also shown).

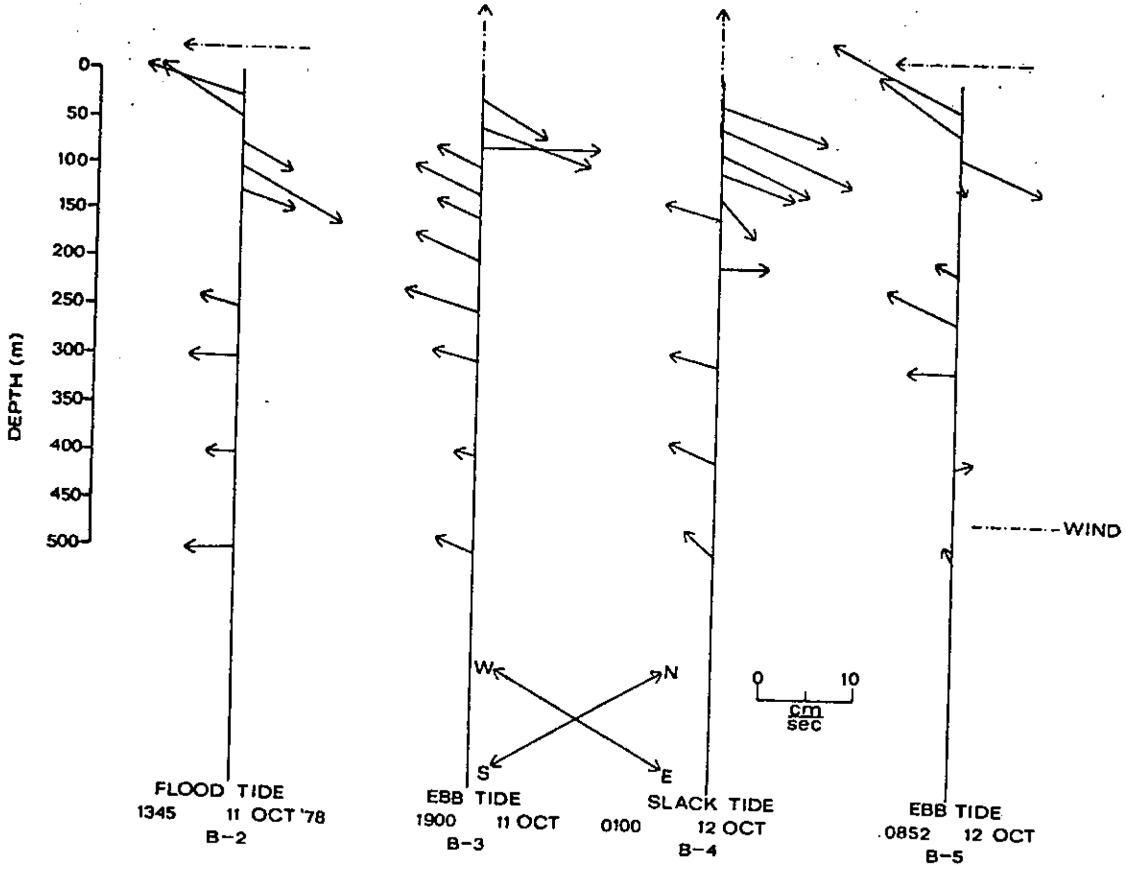


Fig. 43 - Stick plot of water current profiles taken at Punta Tuna during the cruise of October, 1978. (Note-vessel moored during the measurements).

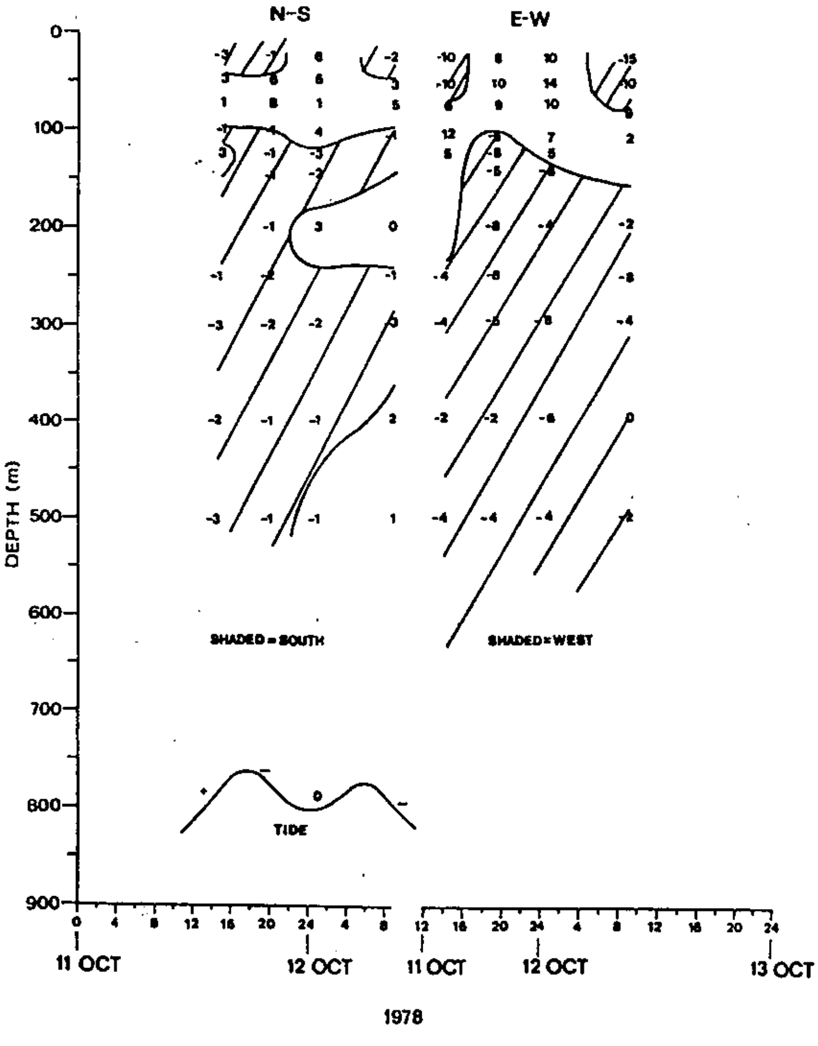


Fig. 44 - Time series of the water current profile taken at Punta Tuna during the cruise of October, 1978. (Estimated tidal condition and current is also shown).

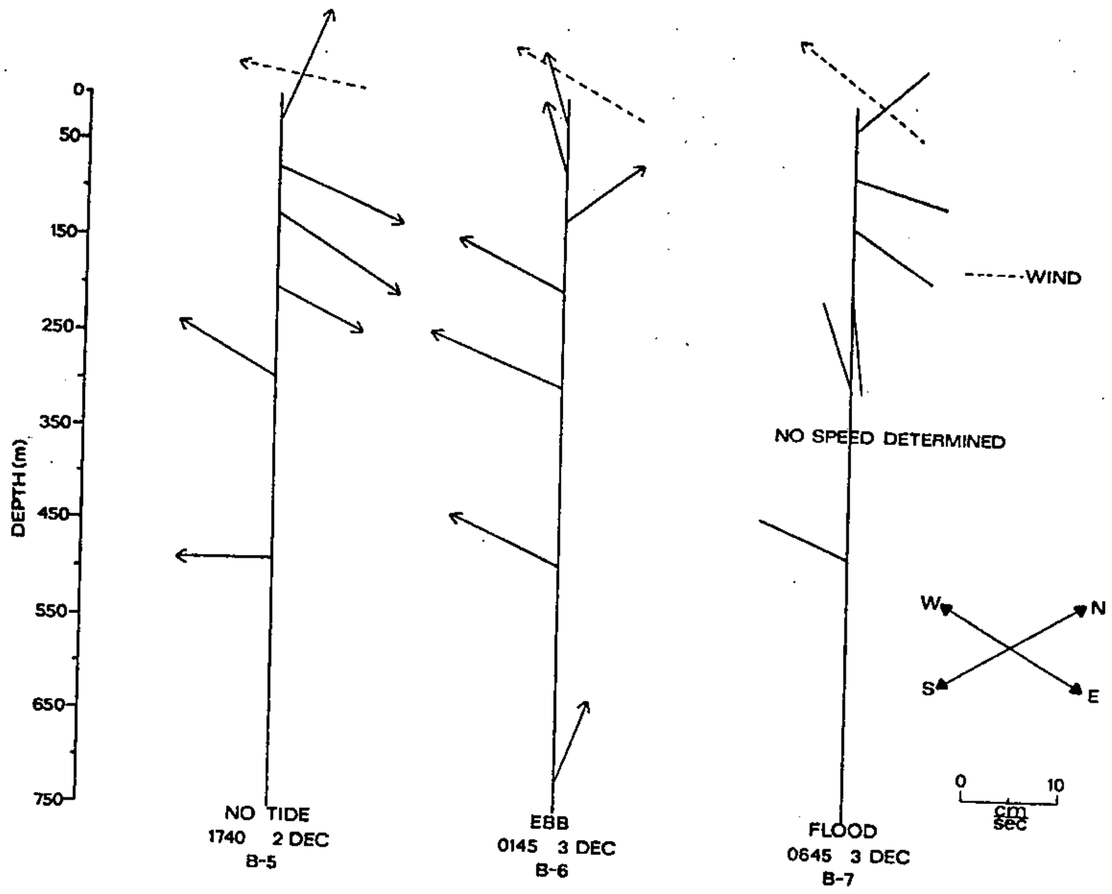


Fig. 45 - Stick plots of water current profiles taken at Punta Tuna during the cruise of December, 1978. (Note-vessel moored during the measurements).

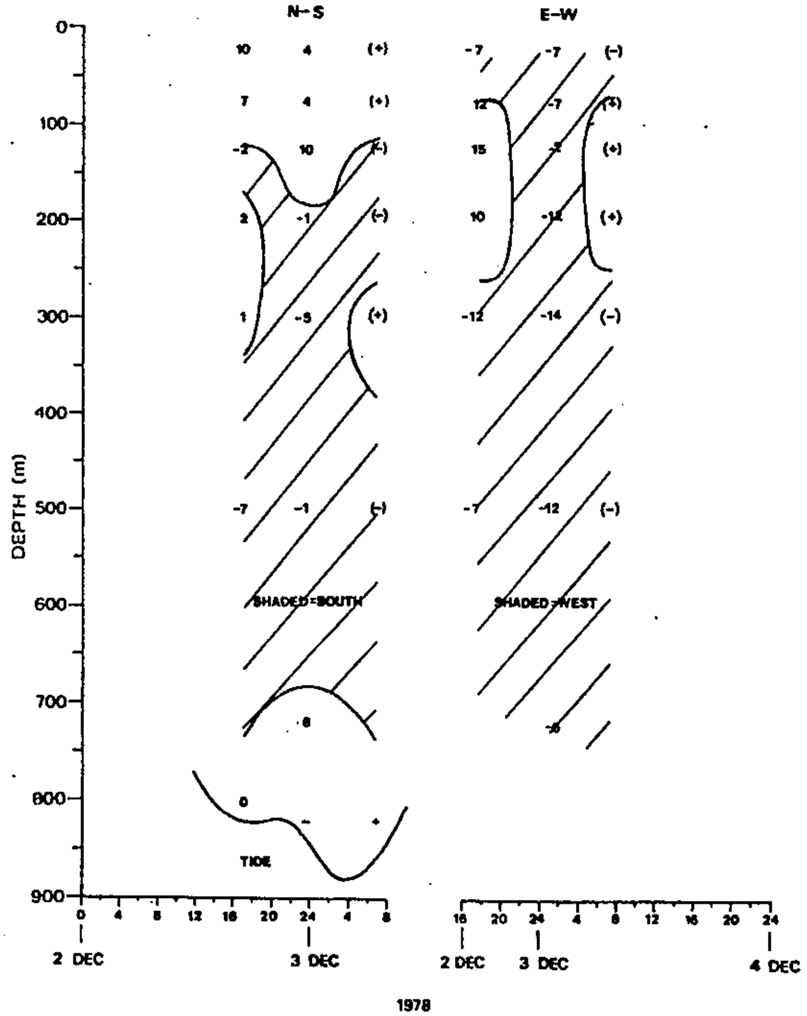


Fig. 46 - Time series of the water current profile taken at Punta Tuna during the cruise of December, 1978. (Estimated tidal condition and current is also shown).

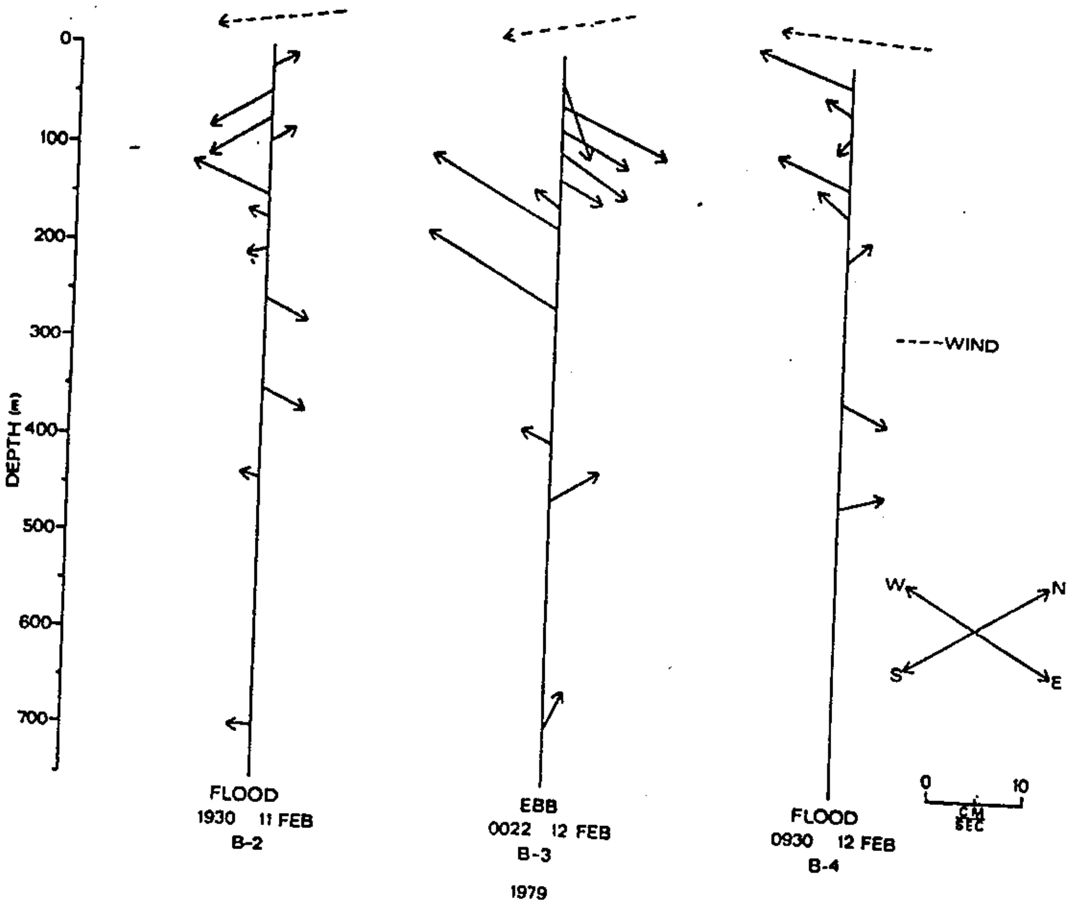


Fig. 47 - Stick plots of water current profiles taken at Punta Tuna during the cruise of Feburary, 1979. (Note-vessel moored during the measurements).

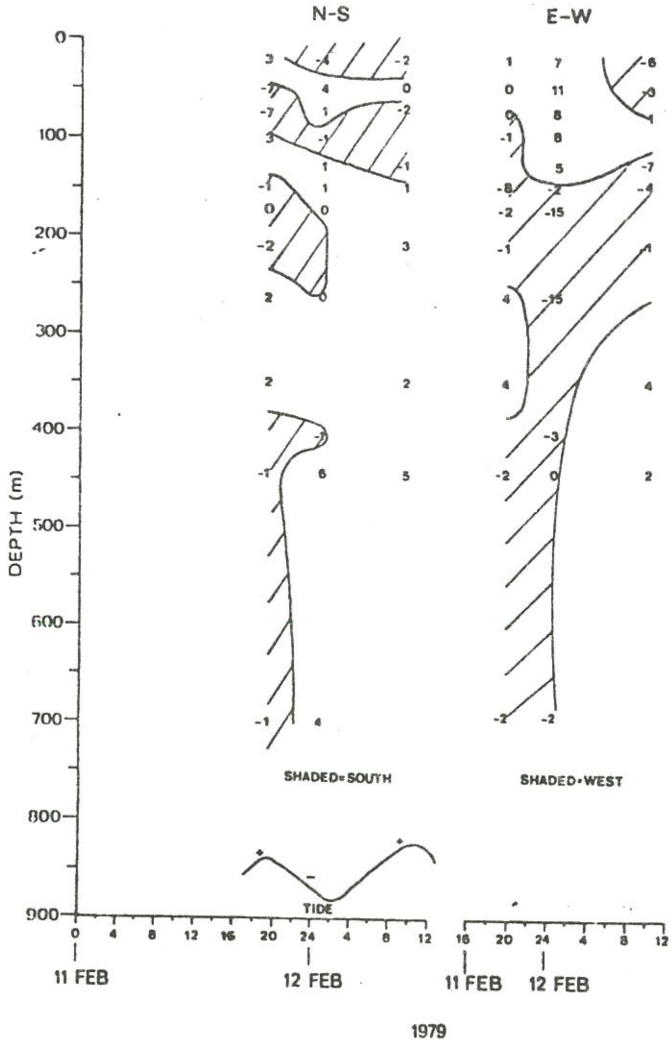


Fig. 48 - Time series of the water current profile taken at Punta Tuna during the cruise of February, 1979. (Estimated tidal condition and current is also shown).

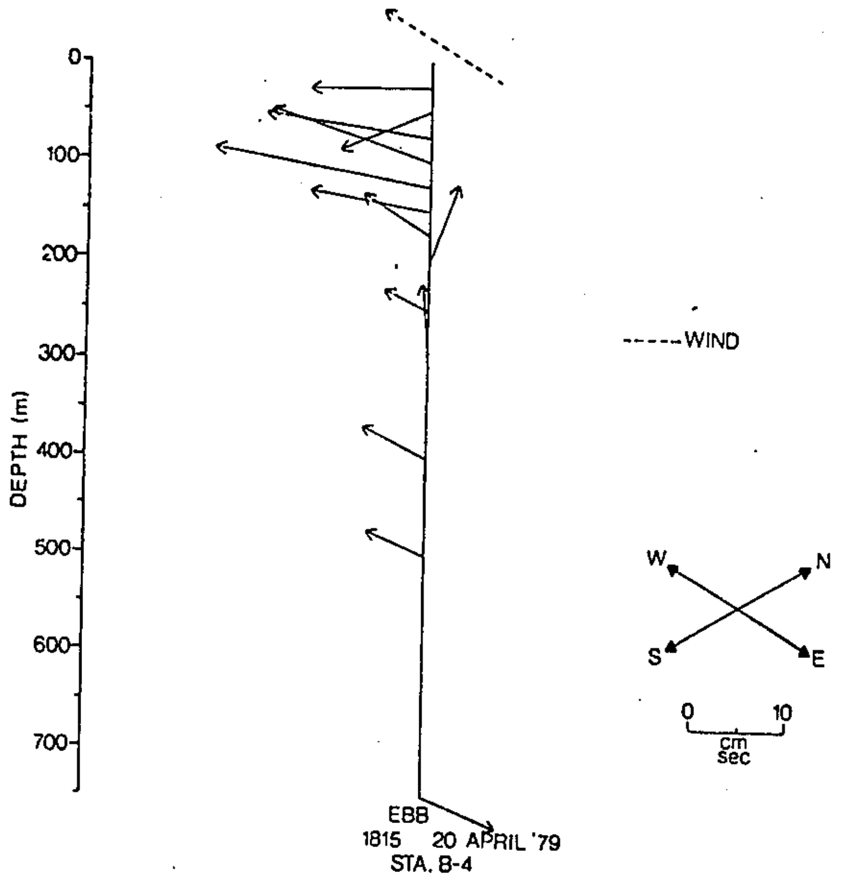


Fig. 49 - Stick plots of water current profiles taken at Punta Tuna during the cruise of April, 1979. (Note-vessel moored during the measurements).

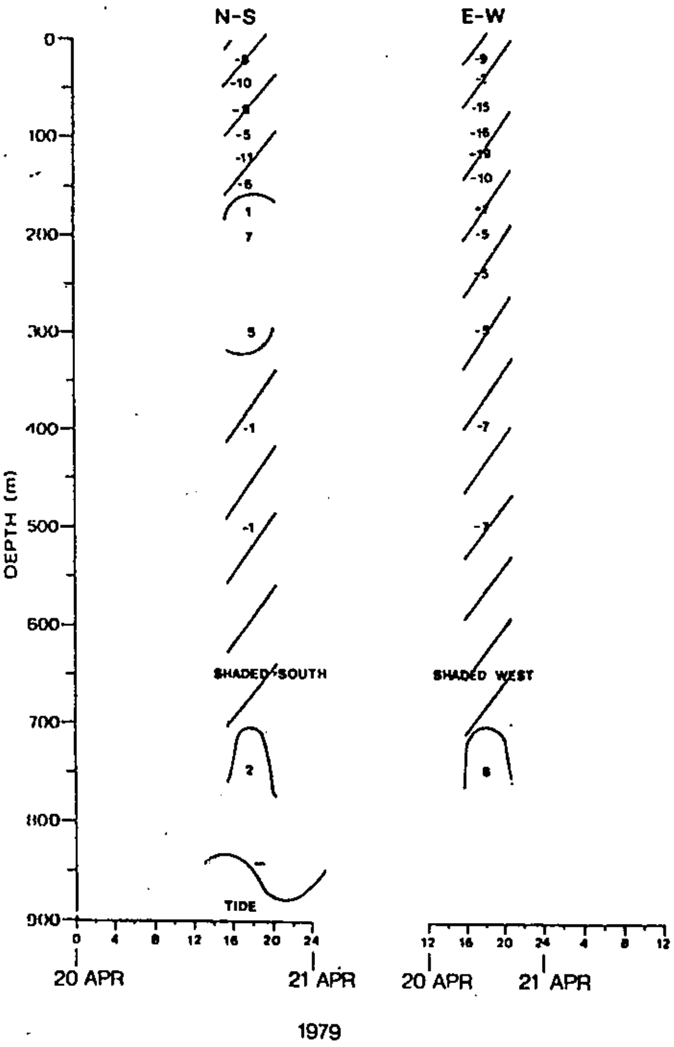


Fig. 50 - Time series of the water current profile taken at Punta Tuna during the cruise of April, 1979. (Estimated tidal condition and current is also shown).

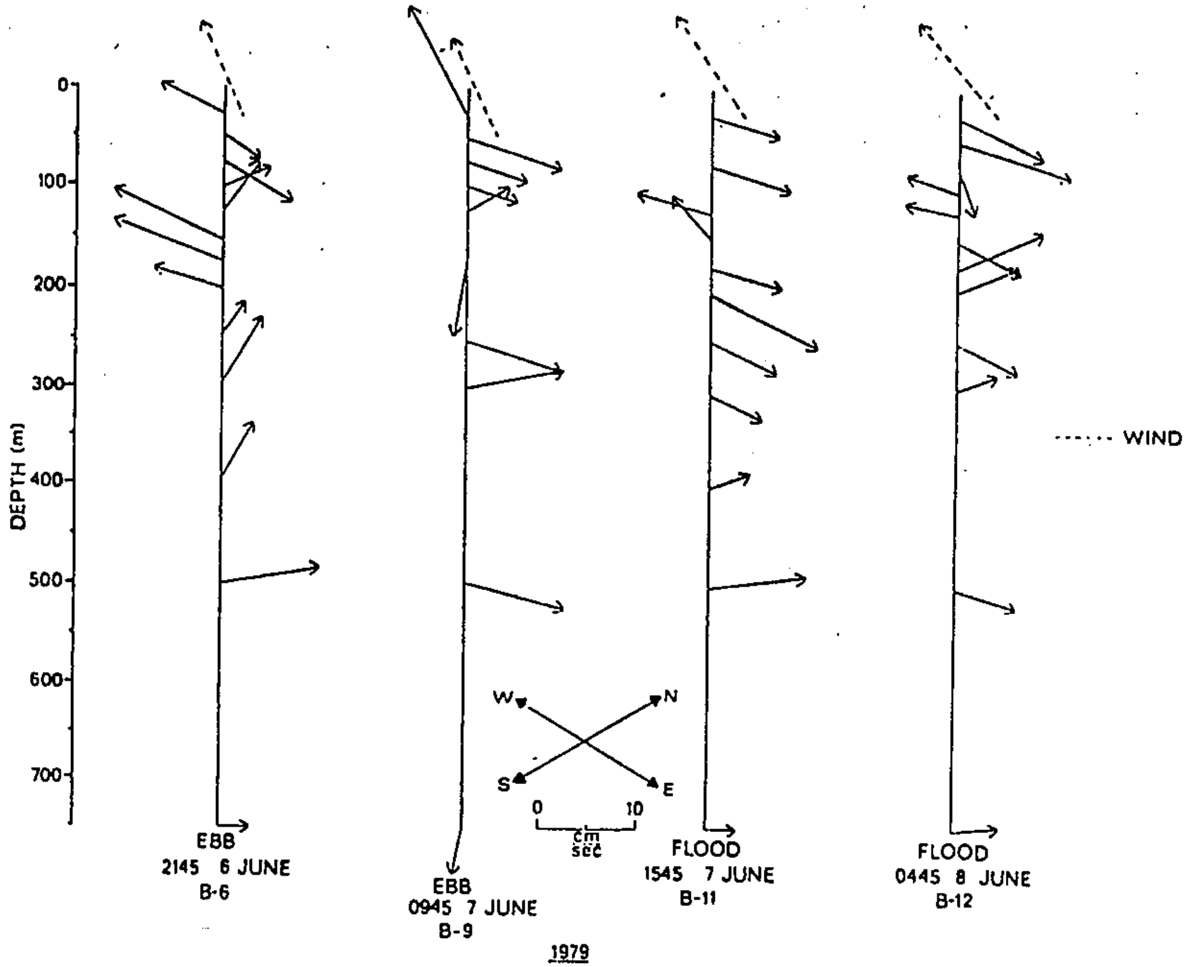


Fig. 51 - Stick plots of water current profiles taken at Punta Tuna during the cruise of June, 1979. (Note-vessel moored during the measurements).

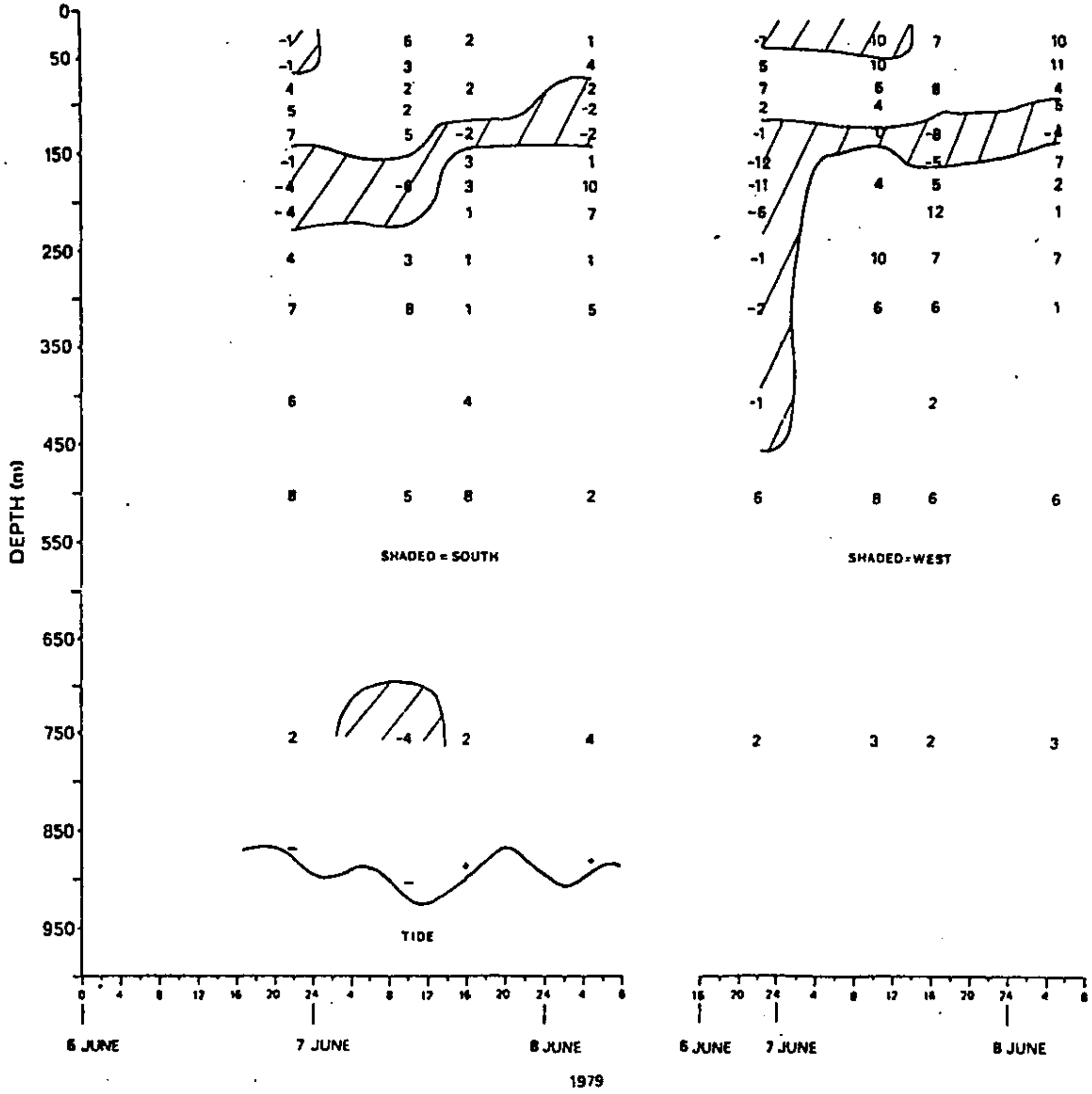


Fig. 52 - Time series of the water current profile taken at Punta Tuna during the cruise of June, 1979. (Estimated tidal condition and current is also shown).

Each of the stick-type diagrams has both the speed and direction of the measured water flow at each sampled depth for the profiles measured during that respective cruise.

The speed scale of the first cruise, August 1978, is 1/2 that of the other cruises. The scale difference is due to the high speed indicated during the measurements. These higher speeds were probably due to the aforementioned errors induced by vessel drift. The results of these measurements are seen in Figure 41. In this figure, alone, the vessel drift vector is also shown for comparison. As seen in Figures 41 and 42, most of the water current results from this cruise were probably influenced quite a bit by the drifting vessel. However, from the lower portion of Figure 41, the effects of flood or ebb tide may still be seen in these results. The first two profiles were measured during periods of flooding tidal current (to the west), the third was measured during the ebbing tide. This tidal shift may explain the westerly to northerly shift in the upper water.

Figures 43 and 44 display the current profile results of the 2nd cruise, in August 1978. During this cruise, as in all subsequent operations, the vessel was moored during the current profile operations. The stick-type diagram (Fig. 43) shows the surface water mass (TSW) shifting from westerly to easterly, both at 10-15 cm/sec. The westerly movement is seen during both the flood (first) and ebb (last) periods. The next lower water mass, identifiable as the Subtropical Underwater (SUW), is also seen to change from easterly to westerly and back, with speeds of about 10 cm/sec. Unfortunately, the timing of the profile measurements was not necessarily optimum for determining the tidal effects. The water in the transition zone between the SUW and the Antarctic Intermediate Water (AIW), between 250-500 m, moves generally westerly at about 5 cm/sec (Fig. 43). The results of Table 2 confirm the predominantly southerly flow.

Figures 45 and 46 show the results of the current profile measurements for the December 1978 cruise. Again, considerable current reversal is seen, but either the time (first profile) was not ideal, as it corresponded to a projected slack tidal current period, or the speed indicator did not function, as in the third profile. In any case, there is a definite westerly motion down to depth of about 300 m in the second profile, which should correspond to an ebbing tidal flow (easterly). The directions shown for the third profile are nearly all easterly for the upper 300 m. This is estimated to correspond to a flood tidal flow. All the speeds were about 10 cm/sec, even for the deeper waters. In all cases, during this cruise, the 500 m water was seen to move westerly, with a strong northerly flow seen at 750 m. The time series displays show E-W oscillations in the upper 200 m. The southerly component is also seen in Table 2 as in Figure 46.

The February 1979 cruise results can be seen in Figures 47 and 48. There are reversals at virtually all depths, but the upper water seem to move westerly during the flood tide and easterly during the ebb. The transition zone between the Subtropical Underwater and the Antarctic Intermediate Water (200-700 m) has speeds of 5 cm/sec and also has direction reversals, but opposite to those of the upper waters. Water at the 700 m depth varied from southwest to northwest with speeds of about 5 cm/sec.

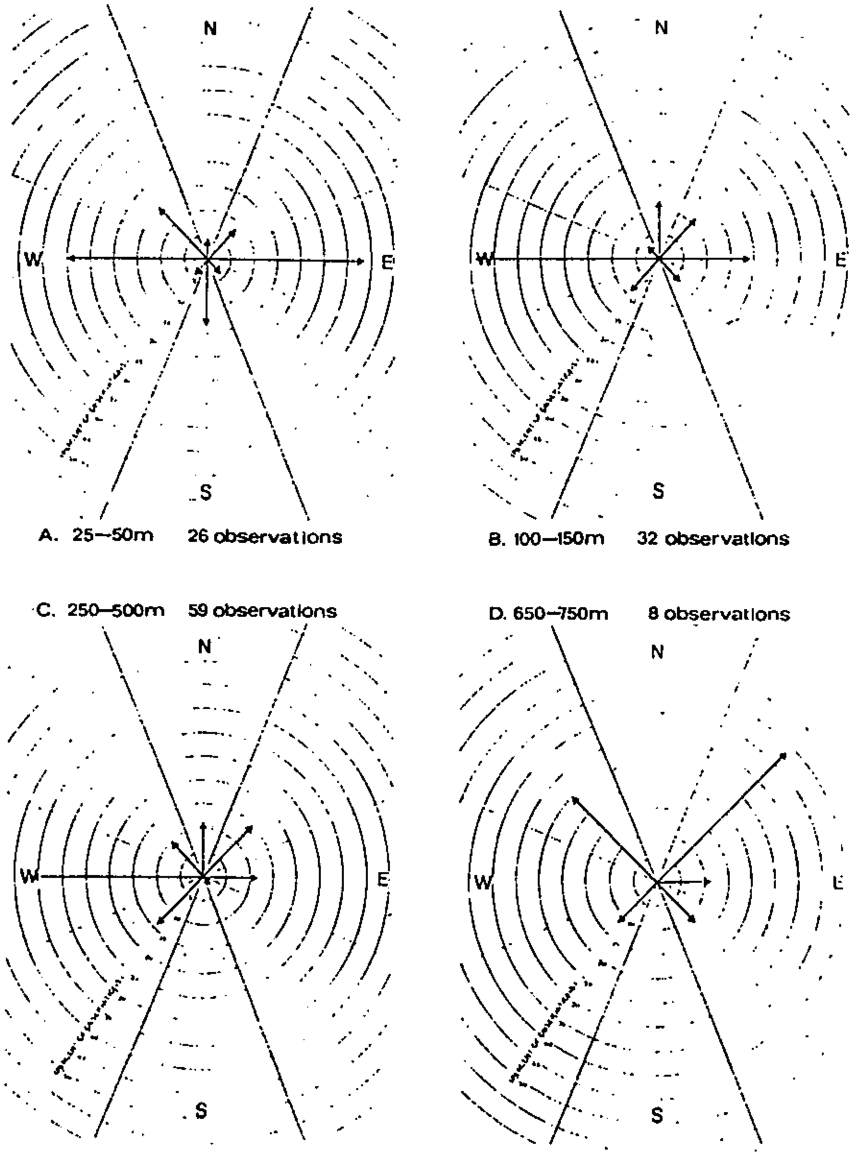
The April cruise resulted in only 1 current profile, seen in Figures 49 and 50. Throughout most of the water column the flow was westerly except at 700 m, were the direction was almost due east. The upper waters, the TSW and the SUW, down to about 150 m, showed speeds of 10-20 cm/sec, while the lower water moved at 5-10 cm/sec. The time of the measurement should have corresponded to a strong ebb current flow. The geostrophic calculations seen in Table 2 show similar north-south component distribution as seen in Figure 50.

The final, or June 1979 cruise, had a full complement of 4 current profiles, and they were all timed specifically correspond to ebb or flood tidal current periods. The ebb period (first two profiles) of Figures 51 and 52 show much of the upper water moving generally easterly. This easterly flow is also seen during the flood tide periods. Almost all the water below 200 m is moving easterly or northerly, except the first profile, which shows a northwest component. The northerly components are also seen in Table 2.

Figure 53 shows the frequency of occurence of the water current within compass octants (current rose) for 4 depth ranges at Punta Tuna. The depth ranges that are considered are: 25-50 m (Tropical Surface Water), 100-150 m (Subtropical Underwater), 250-500 m (Transition Zone), and 650-750 m (Antarctic Intermediate Water).

The TSW appears to have a definate bimodal distribution of water current directions. About one-half of the observations had westerly or northerly flow. This is to be expected with the predominant easterly winds. However, about one-third of the observations showed an easterly flow, directly opposing the winds. Although these reversals have been seen by others (Lee et al., 1978) it was not expected, as the vessel never moved east of the mooring, only west. The tidal motion in this area is expected to be E-W in character, and this also could help to explain the large number of easterly observations.

The observations taken from within the SUW showed a dominant westerly flow more than one-third of the time, with a weaker easterly component and a mixed distribution between these two. This bimodal distribution may also be a reduced tidal oscillation, as above. However, as this water mass is thought to come from the Bermuda area, North of Puerto Rico, and move into the Caribbean through the various passages (i.e., Mona to the West, Anegada to the East of Puerto Rico), the water could be expected to have components of W, SW, S, SE, and E. Unexpected directions would be N and NE. Both of these directions were seen. Also, there were no southerly directions observed. As this water mass, and below, may contain an OTEC plant discharge (mixed cold and warm together), this confusion must be cleared up.



A. 25—50m 26 observations

B. 100—150m 32 observations

C. 250—500m 59 observations

D. 650—750m 8 observations

Fig. 53 - Current roses of water current direction using all the current profile data taken at Punta Tuna from August, 1978 to June, 1979. (Four vertical depth bands are considered).

The water in the Transition Zone is seen to be moving with a very strong predominance toward the West, as this water is a mixture of the SUW above, and the AIW below, it may be entering the area from either the North as mentioned above, or from the East through the passages of the Lesser Antilles. Therefore, almost any water direction might be possible, and that is what is seen.

Finally, the AIW direction appears to be generally northerly (NE, NW). As this water is thought to enter the Caribbean through the Lesser Antilles and move generally westerly and northerly, the dominant directions are explainable, with the water moving past Punta Tuna towards either the Yucatan to the West or the Jungfern Sill to the northeast. The other directions almost appear as slight "noise" in the measurements.

In general, the results also indicate that at least the north-south component of the water moving past Punta Tuna may be somewhat characterized by geostrophic flow in the mid-to-deep water.

Figure 54 shows the frequency distribution for the observed speeds in the same four depth ranges seen in Figure 53; 25-50 m, 100-150 m, 250-500 m, and 650-750 m. The TSW (upper depth range) has a distribution tending toward the higher speeds, with an average speed of about 10 cm/sec. The SUW (100-150 m) shows a slight shift toward the lower speeds, averaging about 8 cm/sec. As expected, the two lower depth bands show decreasing speed with increasing depth. At the 250-500 m depth, the average speed is about 7 cm/sec, and at the 650-750 m depth, the speed averaged only about 5 cm/sec.

3.4.2 Water Current Mooring

The description of deep water circulation is based on the velocity data retrieved from in-situ meters recovered from depths of 215 and 332 meters at Station A. Bottom depth at this station was approximately 1216 meters. The sampling

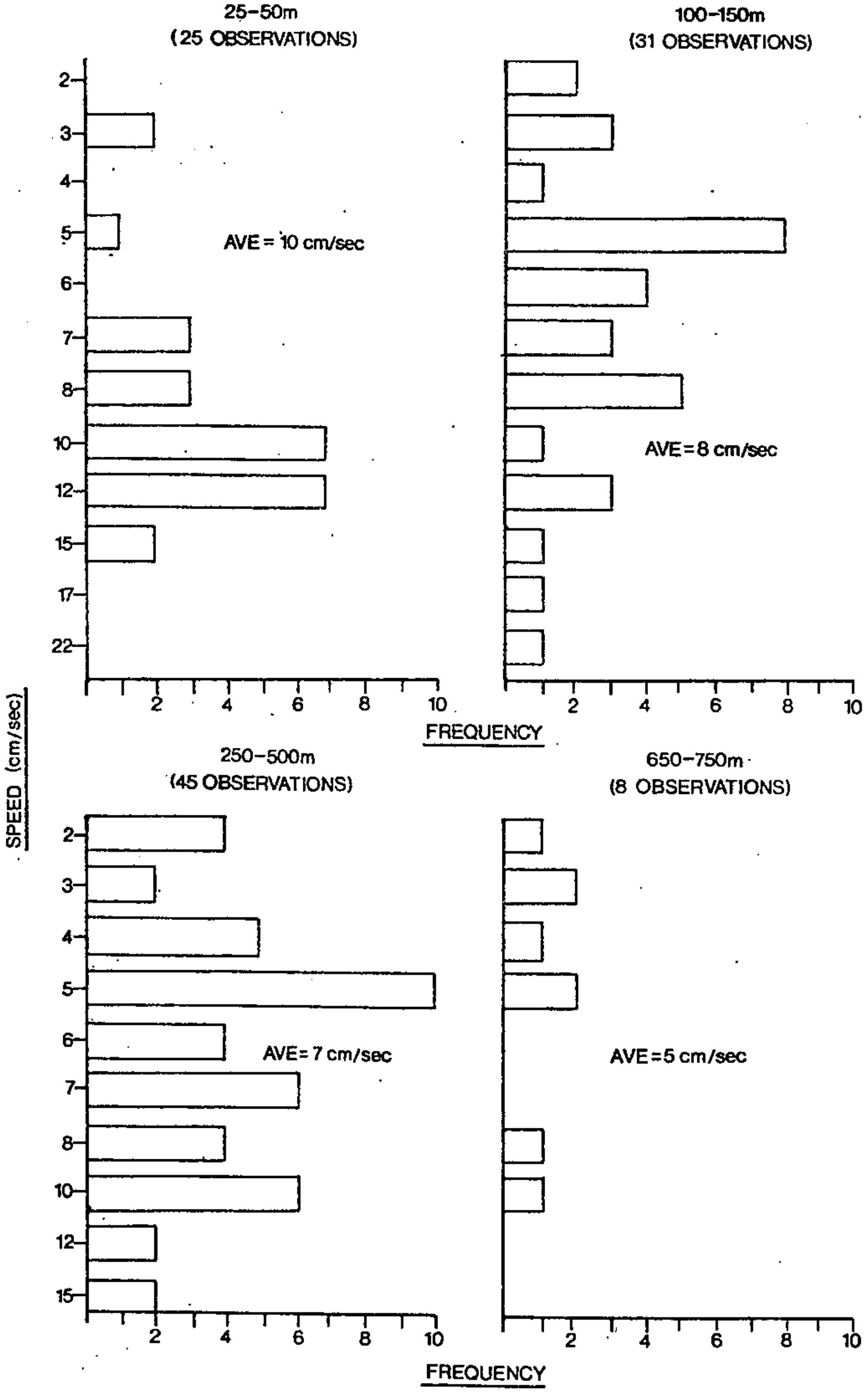


Fig. 54 - Frequency of observed speeds using the current profile data taken at Punta Tuna from October, 1978 to June, 1979. (Four vertical depth bands are considered).

rate of both meters was at 10 minutes intervals; the records recovered extend from 6 January to 10 February, 1979. Data points from the first and last days in the records were discarded in order to prevent the inclusion of spurious effects caused by deployment and retrieval operations of the meters.

Conventional methods of current flow analysis were employed to describe and determine circulation patterns and their variability. These included resultant velocity vectors statistics, histograms, stick plots, progressive vectors diagrams, and vectorial components graphs in order to smooth out superimposed water flow oscillations, Energy spectral analyses could not be performed as programmed owing to persistent malfunction of the computer at the last stages of the analysis.

The analyses revealed the following general statistical results:

1. Currents flow, direction and speed, are highly variable at both monitored depths. Direction statistics indicate that the flow is almost equally distributed around the compass rose.
2. Average current speed at a depth of 215 meters is about 7 cm/sec. Resultant direction angle is 8.2 degrees azimuth (NNE). Average resultant current stability is 93.9%, with speeds ranging from 1 to 60 cm/sec (Fig. 55).
3. Average current speed at a depth of 332 meters is approximately 5.3 cm/sec flowing in a NNE (12 degrees azimuth) direction. Average resultant current stability is 94%, with speeds ranging from 1 to 30 cm/sec (Fig. 55).
4. Tidal, inertial and longer period oscillations (days and weeks) are superimposed in the current structure.

The discussion of the graphs, diagrams and statistical tables that follows demonstrate these general results.

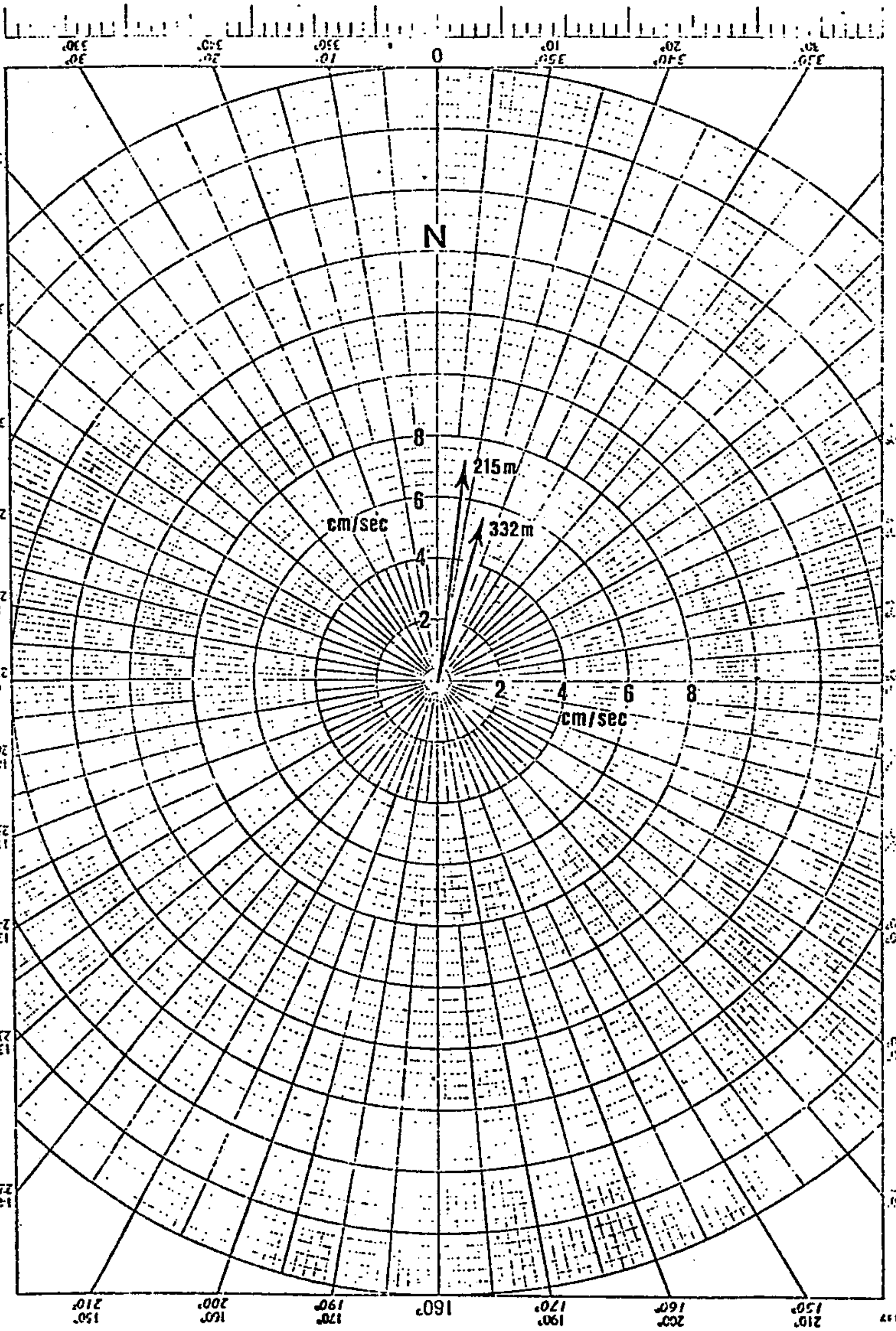


Fig. 55 - Currents resultant-vectors rose.

Table 3 tabulates the data points velocity statistics for the 215 meters-depth current meter. Record length is for 784 hours or a total number of 4704 observations. The speed range at this depth extends from 1 to approximately 70 cm/sec (one data point) with a direction distribution covering the whole compass rose. Statistics indicate that the highest percentage, 41.3%, of current speeds lie within the 1 to 5 cm/sec range; the average speed for the whole record length was 7.13 cm/sec as shown in Table 4. Current direction statistics indicate that flow is almost equally distributed among each quadrant; the highest cumulative percentage occurs from 45 to 135 degrees azimuths (N to ESE) with another peak at the 270 to 300 degrees (NW quadrant) interval. The highest direction relative frequency percentage was 5.8% at the 75-90 degrees (E) interval. Average current flow direction (Table 4) is at an angle of 8.24 degrees T (NNE) with an average speed of 7.13 cm/sec. The histograms for the data in Table 3 are shown in Figure 56; the cumulative frequency curve shows that 80% of the current speed values are below 10 cm/sec.

Current velocity statistics for 1 hour averaged data points at a depth of 215 meters are shown in Tables 5 and 6. The total number of observations was reduced to 784 through the averaging and velocity resultants calculations. The average stability of current flow for an average speed of 7.13 cm/sec and an average resultant velocity of 6.90 cm/sec flowing in a 8.24 degree azimuth (NNE) is of about 93.9%, the values ranged from 99.99 to 8.47%. Direction relative distribution percentage is 6.3% in the 270-285 degrees range interval (WNW); the dominant azimuths are still between 60 and 120 degrees (E quadrant). Figure 57, the histograms for 12 hours averaged data points, illustrate that the two directions peaks become more apparent in the averaging process.

The statistics for the data points recorded at a depth of 332 meters are shown in tables 7, 8, 9 and 10; and the

DIRECTION(Degrees)															SUM	PERCENT
000-015	48	60	7	3	1	1									120	2.6
015-030	64	69	9	5	1										148	3.1
030-045	86	64	21	4	1	2									178	3.8
045-060	92	88	42	11	1	1	1								236	5.0
060-075	89	106	47	8	8	3	1	1							261	5.5
075-090	108	113	34	5	9	3	1		1						274	5.8
090-105	109	111	35	8	3										266	5.7
105-120	95	110	33	4	1	1	1	1							246	5.2
120-135	90	111	34	4	7	2		1			1				250	5.3
135-150	80	76	53	6	9	4	1								229	4.9
150-165	71	64	26	9	4	3									177	3.8
165-180	71	44	20	7	2	1	2								147	3.1
180-195	73	63	16	3	4										159	3.4
195-210	99	53	9	1	3										165	3.5
210-225	88	50	11	1	2	2									154	3.3
225-240	81	51	8	2	1										143	3.0
240-255	95	61	13	4	1		1								175	3.7
255-270	79	84	24	8	2	4								1	202	4.1
270-285	79	104	40	17	12	3	4	4				1			264	5.6
285-300	76	103	42	26	6	1	1	1		1		1			258	5.5
300-315	70	71	41	14	5	4	1			1		1			208	4.4
315-330	62	64	16	6	2		1					1	1		153	3.3
330-345	70	50	26	5	2										153	3.3
345-360	69	55	10	2	1				1						138	2.9
SPEED(cm/s) 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70		
Sum	1944	1825	617	163	86	35	15	8	2	2	1	4	1	1	4704	
Per Cent	41.3	38.8	13.1	3.5	1.8	0.7	0.3	0.2	0.0	0.0	0.0	0.1	0.0			

Frequency of 0 cm/sec = 0

Table 3 - Measured current direction and speed relative frequencies (%) for the 215 meters depth level.

TABLE 4

Current's data-based statistics for the 215 meters depth level.

Number of Observations	4,704
Average Speed (cm/sec)	7.13
Average Direction (deg).	008.24

PUNTA TUNA OTEC SITE A, STATION #1, METER #RCM-5 #1 DATE: 07-JAN-79
BOTTOM DEPTH = 1216 METERS METER DEPTH = 215 METERS
INPUT DATA

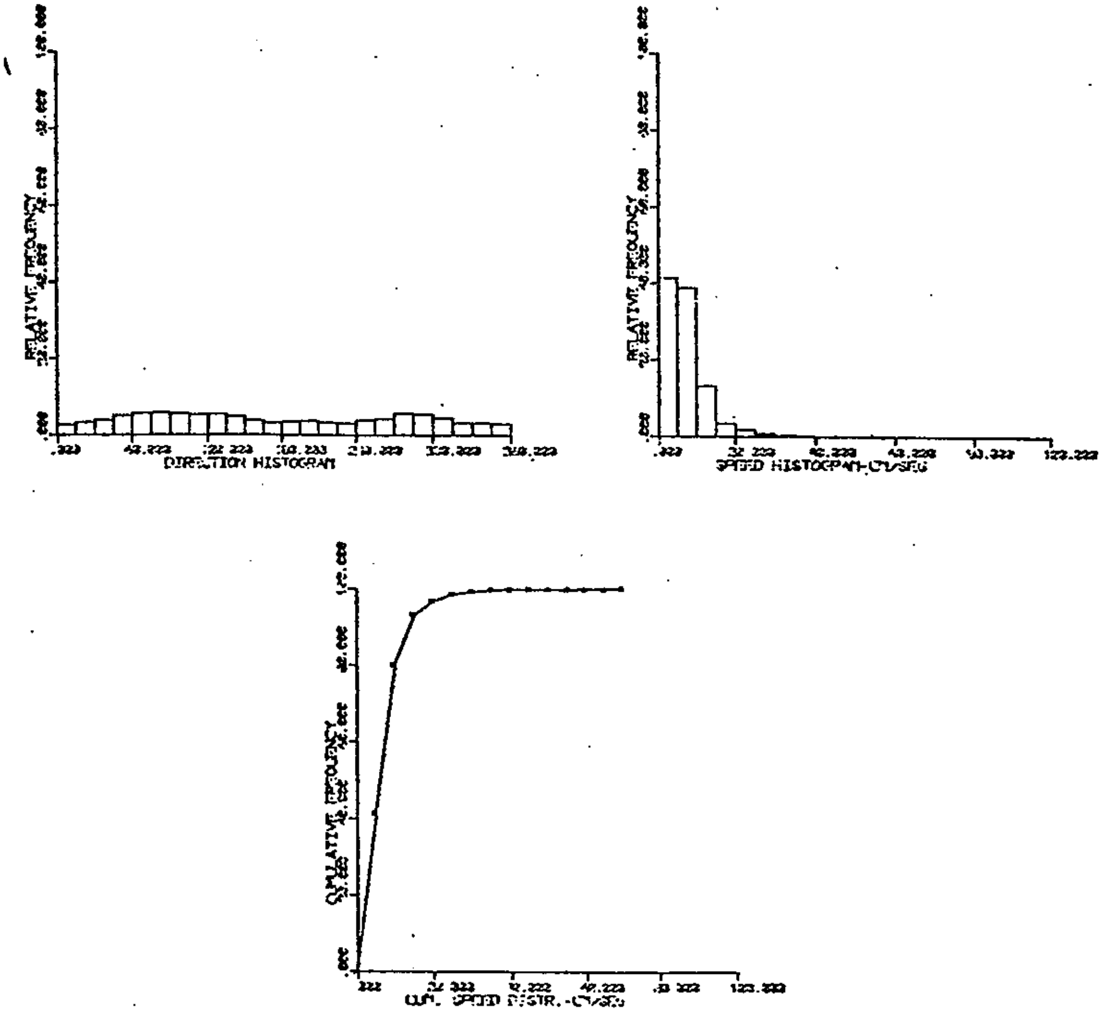


Fig. 56 - The 215 meters depth level direction, speed, and cumulative speed distribution histograms.

DIRECTION(Degrees)																SUM	PERCENT
000-015	6	11	2													19	2.8
015-030	8	16	1	1												26	3.3
030-045	13	9	5													27	3.4
045-060	22	15	6	1	1											45	5.7
060-075	15	18	9	3	1											46	5.9
075-090	8	23	4	4												39	5.0
090-105	18	20	6	1												45	5.7
105-120	20	15	6		1											42	5.4
120-135	16	19	7	3												45	5.7
135-150	17	15	7	4												43	5.6
150-165	7	5	6	3	1											22	2.8
165-180	19	7	5													31	4.0
180-195	13	12	3	1												29	3.7
195-210	13	3	3													19	2.4
210-225	10	11	3													24	3.1
225-240	18	10														28	3.6
240-255	13	9	2													24	3.1
255-270	14	12	8	2												36	4.8
270-285	15	16	10	5	2	1										49	6.3
285-300	19	12	7	4	2											44	5.6
300-315	13	11	10	3			1									38	4.8
315-330	8	12	2	1	1											24	3.1
330-345	8	10	3													21	2.7
345-360	8	8	1	1												18	2.3
SPEED(cm/s)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70		
Sum	321	299	116	37	9	1	1	0	0	0	0	0	0	0			
Per Cent	40.9	38.1	14.8	4.7	1.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		784	

Frequency of 0 cm/sec = 0

Table 5 - One hour current's resultant vector: Direction and speed relative frequencies (%) for the 215 meters depth level.

TABLE 6

One hour current's resultant vectors: Data-based statistics for the 215 meters depth level

Average Velocity (cm/sec)	7.13
Average Resultant Velocity (cm/sec)	6.90
Resultant Direction (deg)	008.24
Average Stability (%)	93.91
Stability Range (%):	
Maximum	99.99
Minimum	8.47

PUNTA TUNA OTEC SITE A, STATION #1, METER #RCM-5 #1 DATE: 07-JAN-79
BOTTOM DEPTH - 1216 METERS METER DEPTH = 215 METERS
12 HOUR INTERVALS

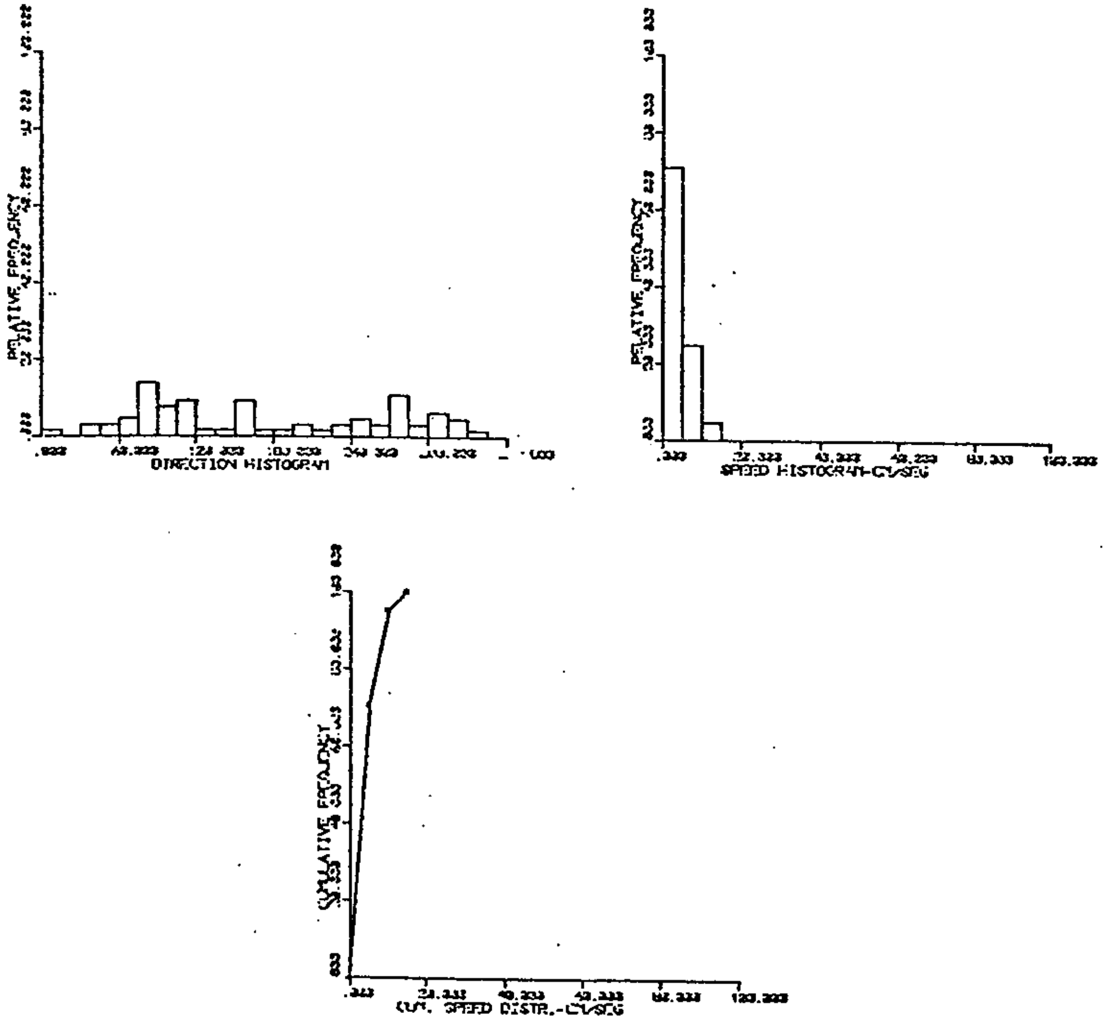


Fig. 57 - Direction, speed, and cumulative speed distribution histograms for 12 hours averaged data points from the 215 meters depth level.

DIRECTION(Degrees)																SUM	PERCENT
000-015	80	78	8													166	3.5
015-030	83	70	4													157	3.3
030-045	80	75	2													157	3.3
045-060	82	91	7													180	3.8
060-075	85	132	26													243	5.2
075-090	132	182	18													332	7.1
090-105	106	189	23													298	6.3
105-120	118	161	7			1										287	6.1
120-135	97	102	2													201	4.3
135-150	83	90	1													174	3.7
150-165	87	88														175	3.7
165-180	99	79														178	3.8
180-195	82	89	1													172	3.7
195-210	91	74														165	3.5
210-225	80	75														155	3.3
225-240	102	47														149	3.2
240-255	96	72														168	3.6
255-270	75	94	4													173	3.2
270-285	85	91	22													198	4.2
285-300	96	72	21	2												191	4.1
300-315	111	121	19			1										252	5.4
315-330	105	71	10													187	4.0
330-345	97	62	2													161	3.4
345-360	96	80														176	3.7
SPEED(cm/s)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70		
Sum	2249	2265	177	2	0	2	0	0	0	0	0	0	0	0		4695	
Per Cent	47.9	48.2	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

Frequency of 0 cm/sec = 0

Table 7 - Measured currents direction and speed raltive frequencies (%) for the 332 meters depth level.

TABLE 8

Current's data-based statistics for the 332 meters depth level.

Number of Observations	4,695
Average Speed (cm/sec)	5.28
Average Direction (deg)	012.13

DIRECTION (Degrees)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	SUM	PERCENT
000-015	11	12														23	2.9
015-030	14	10														24	3.1
030-045	18	11														29	3.2
045-060	15	15	2													32	4.1
060-075	18	23	4													45	3.8
075-090	16	28	1													45	3.8
090-105	18	32	4													54	6.9
105-120	22	28														50	6.4
120-135	19	15														34	4.3
135-150	15	11														26	3.3
150-165	17	16														33	4.2
165-180	15	12														27	3.5
180-195	11	16														27	3.5
195-210	17	7														24	3.1
210-225	18	12														30	3.8
225-240	23	6														29	3.7
240-255	13	10														23	2.9
255-270	10	21														31	4.0
270-285	15	15	2													32	4.1
285-300	19	13	3													35	4.5
300-315	22	19	2													43	3.5
315-330	15	13														28	3.6
330-345	18	12														30	3.8
345-360	14	13	1													28	3.6
SPEED (cm/s)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70		
Sum	393	370	19	0	0	0	0	0	0	0	0	0	0	0		782	
Per Cent	50.3	47.3	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

Frequency of 0 cm/sec = 0

Table 9 - One hour current's resultant vectors: Direction and speed relative frequencies (%) for the 332 meters depth level.

TABLE 10

One hour current's resultant vectors;
Data-based statistics for the
332 meters depth level.

Average Velocity (cm/sec)	5,29
Average Resultant Velocity (cm/sec)	5,09
Resultant Direction (deg)	012,13
Average Stability (%)	94,03
Stability Range (%):	
Maximum	100,00
Minimum	8,91

PUNTA TUNA OTEC SITE A, STATION #1, METER #RCM-5 DATE: 07-JAN-79
BOTTOM DEPTH = 1216 METERS METER DEPTH = 332 METERS
INPUT DATA

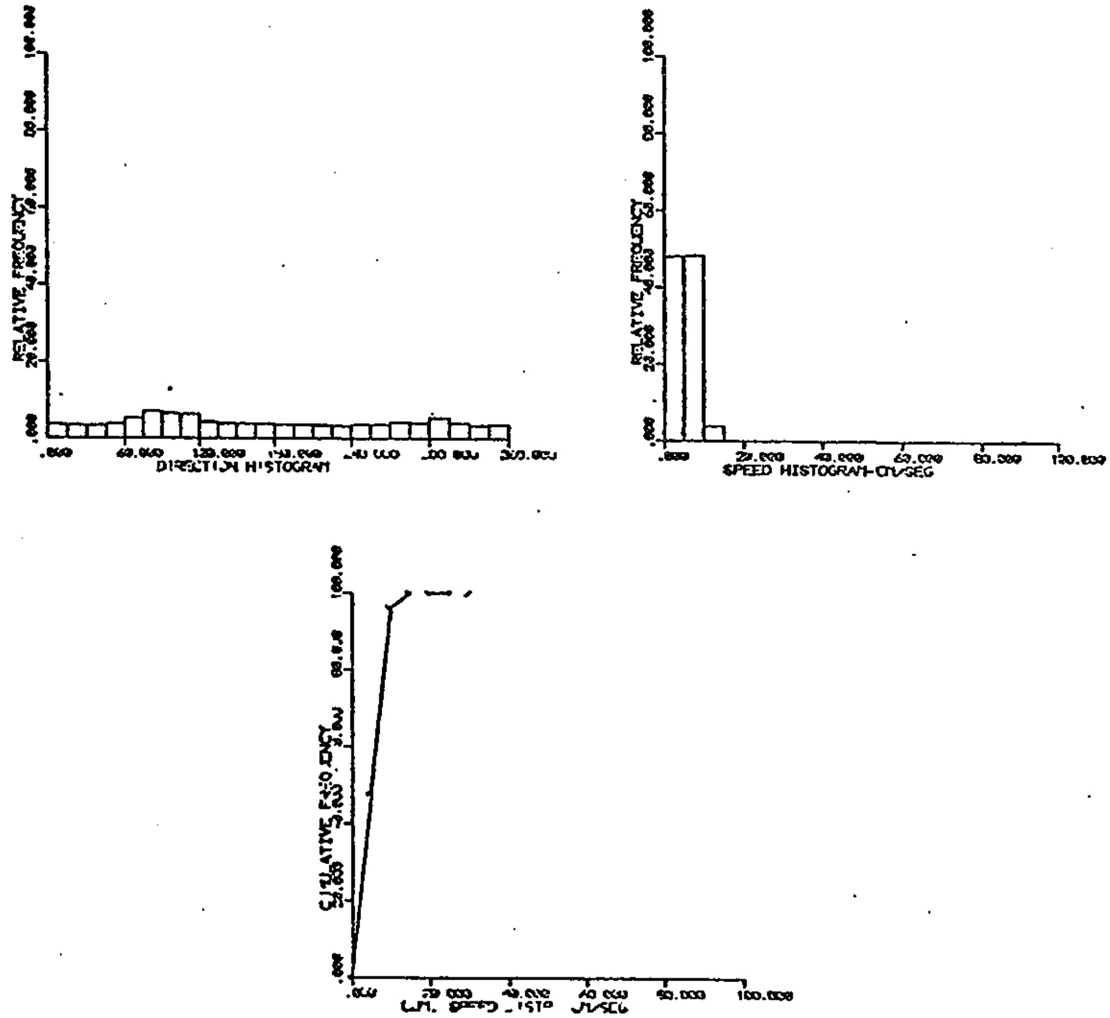


Fig. 58 - The 332 meters depth level direction, speed, and cumulative speed distribution histograms.

histograms of Figure 58. Table 7 indicates that a higher percentage (48.2%) of current speeds lie at the 5 to 10 cm/sec interval. The histogram in figure 58 shows the slight differences that were found between the results of the 215 m and 332 m depths; 96.1% of all speeds at the 332 m are below 10 cm/sec against 80% at a depth of 215 meters. Current directions at the 332 m level are scattered over the compass rose with a dominant relative frequency percentage of 19.5 between the 75 to 120 degrees azimuths (E quadrant); the highest percentage, 7.1%, is found in the 75-90 degrees interval (ENE to E). The average speed (Table 8) is of about 5.3 cm/sec in a NNE (12.13 degrees) direction; current stability ranged from 8.9 to 100 percent, with an average stability of 94.0%, when calculated for 1 hour current velocity resultants at an average speed of 5.29 cm/sec and an averaged resultant velocity of 5.09 cm/sec as shown in Table 10. Table 9 indicates that 97.6% of the 1 hour intervals speed averages are bleow the 10 cm/sec speed range.

Circulation patterns and variability at the monitored depths are evident in the velocity time series graphs (Figs. 59 to 63), the stick plots (Figs 64 to 68) and the progressive resultant velocity vectors diagrams of Figures 70 to 81. All diagrams reveal a pattern of flow mostly dominated by tidal variations when compared with the predicted tidal curves for Puerto Maunabo (Punta Tuna) as shown in Figure 69.

In Figures 59 and 60, velocity variation curve at the 215 and 332 meters level respectively, two relatively constant variations tendencies can be observed: (1) with few exceptions minimum speeds usually occur at the time of low tide; (2) when compared with the tidal fluctuations of Figure 69 the highest speeds are encountered during the monthly spring tides periods. Higher speeds coincide with flood tidal stages; low-low tides consistently occur around midnight hours. These observations become more evident in the 6 and 12 hours averaged speeds graphs of Figure 61 and 62.

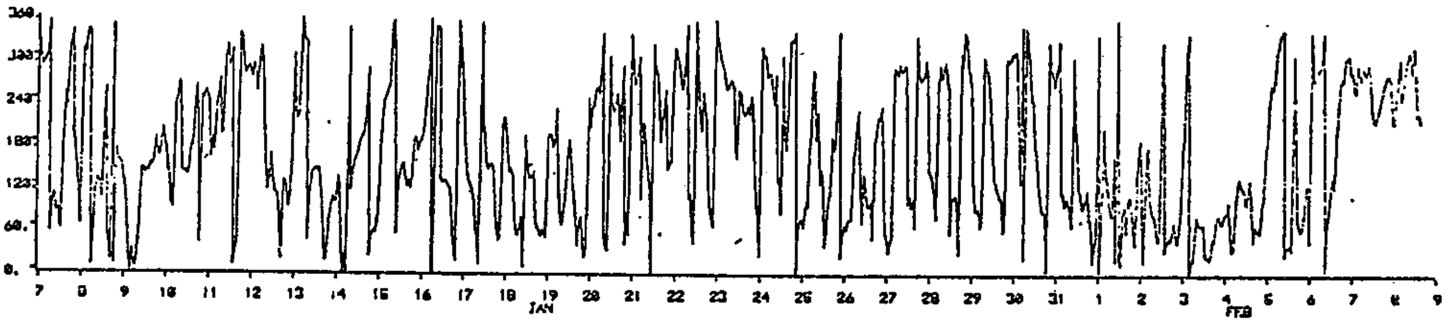


Fig. 59 - Multyplot diagram: velocity variations-time series graph at a depth of 215 meters.

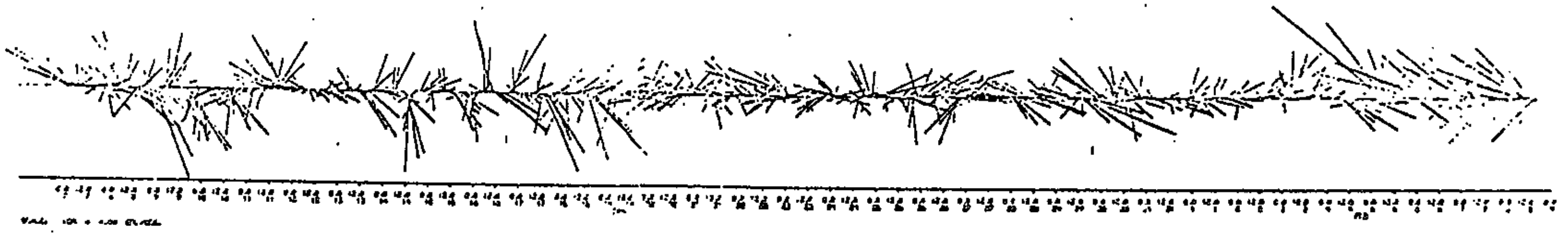


Fig. 60 - Multyplot diagram: velocity variations-time series graph at a depth of 332 meters.

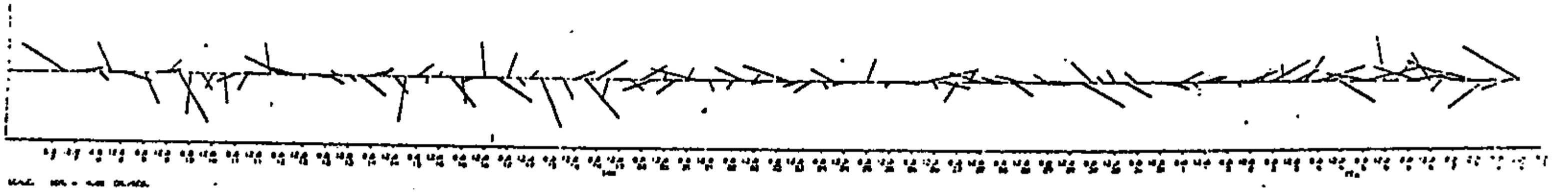


Fig. 61 - Multyplot diagram: 6 hours averaged velocity variations-time series graph at a depth of 215 meters.

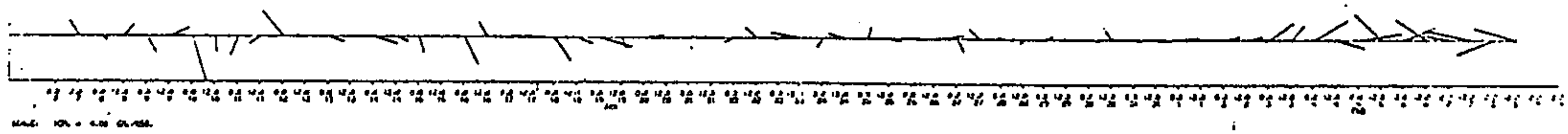


Fig. 62 - Multyplot diagram: 12 hours averaged velocity variations-time series graph at a depth of 215 meters.

Fig. 63 - Multyplot diagram: Direction variations-time series graph at a depth of 215 meters.

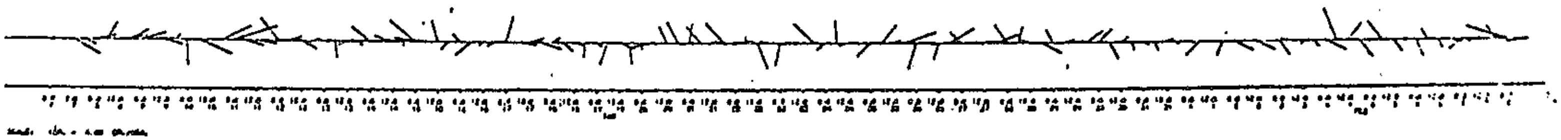


Fig. 64 - Stick plot diagram: 1 hour averaged resultant vectors for the 215 meters depth level.

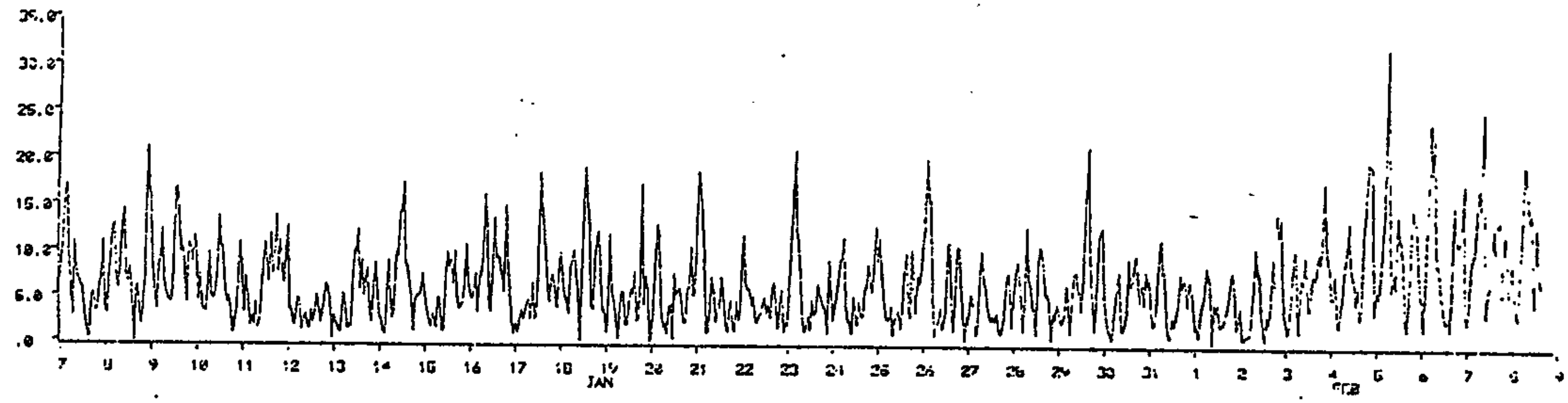


Fig. 65 - Stick plot diagram: 6 hours averaged resultant vector for the 215 meters depth level.

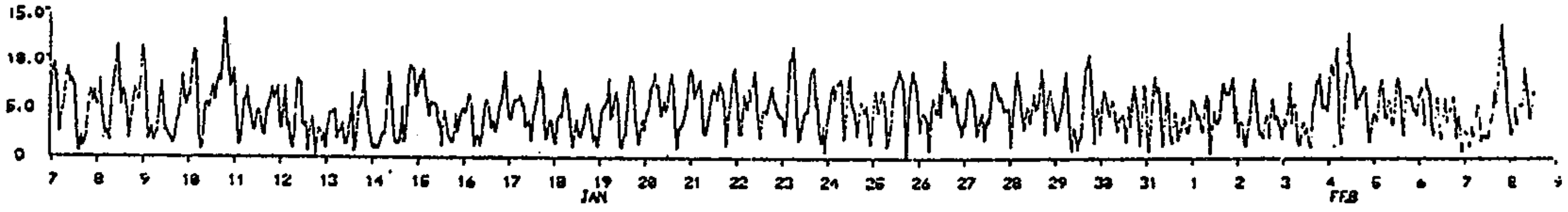


Fig. 66 - Stick plot diagram: 12 hours averaged resultant vector for the 215 meters depth level.

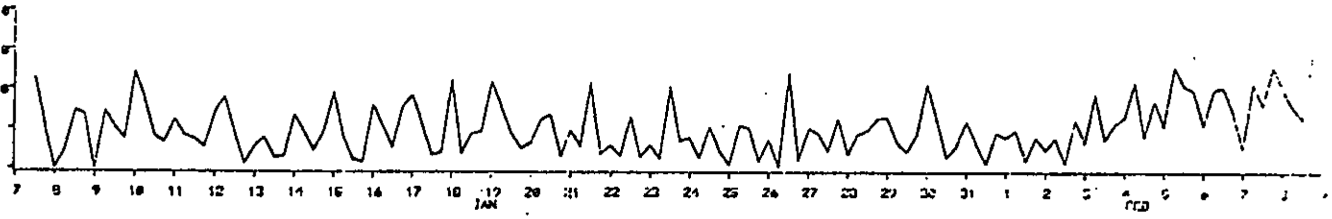


Fig. 67 - Stick plot diagram: 1 hour averaged resultant vectors for the 332 meters depth level.

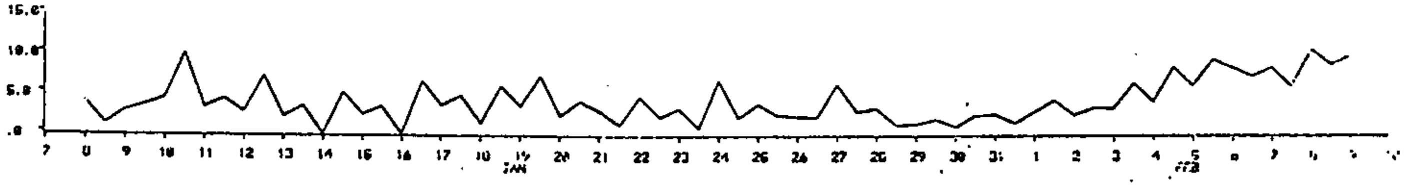


Fig. 68 - Stick plot diagram: 6 hours averaged resultant vectors for the 332 meters depth level.

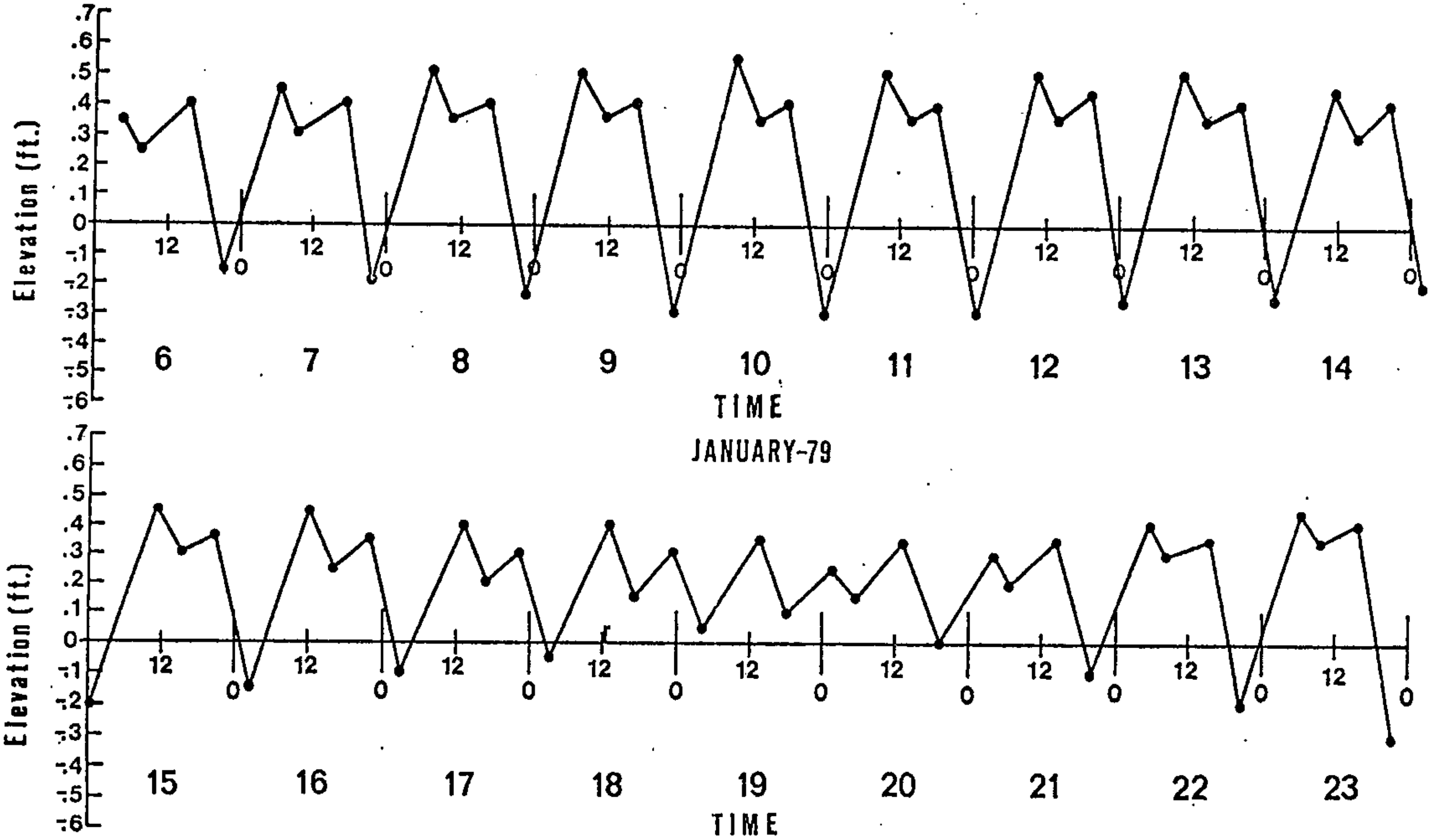


FIG. 69 PREDICTED LOW & HIGH TIDES AT PUERTO MAUNABO (PUNTA TUNA), PUERTO RICO. Reference Sta.: Galveston, Texas (U.S. Dept. of Commerce, 1979)

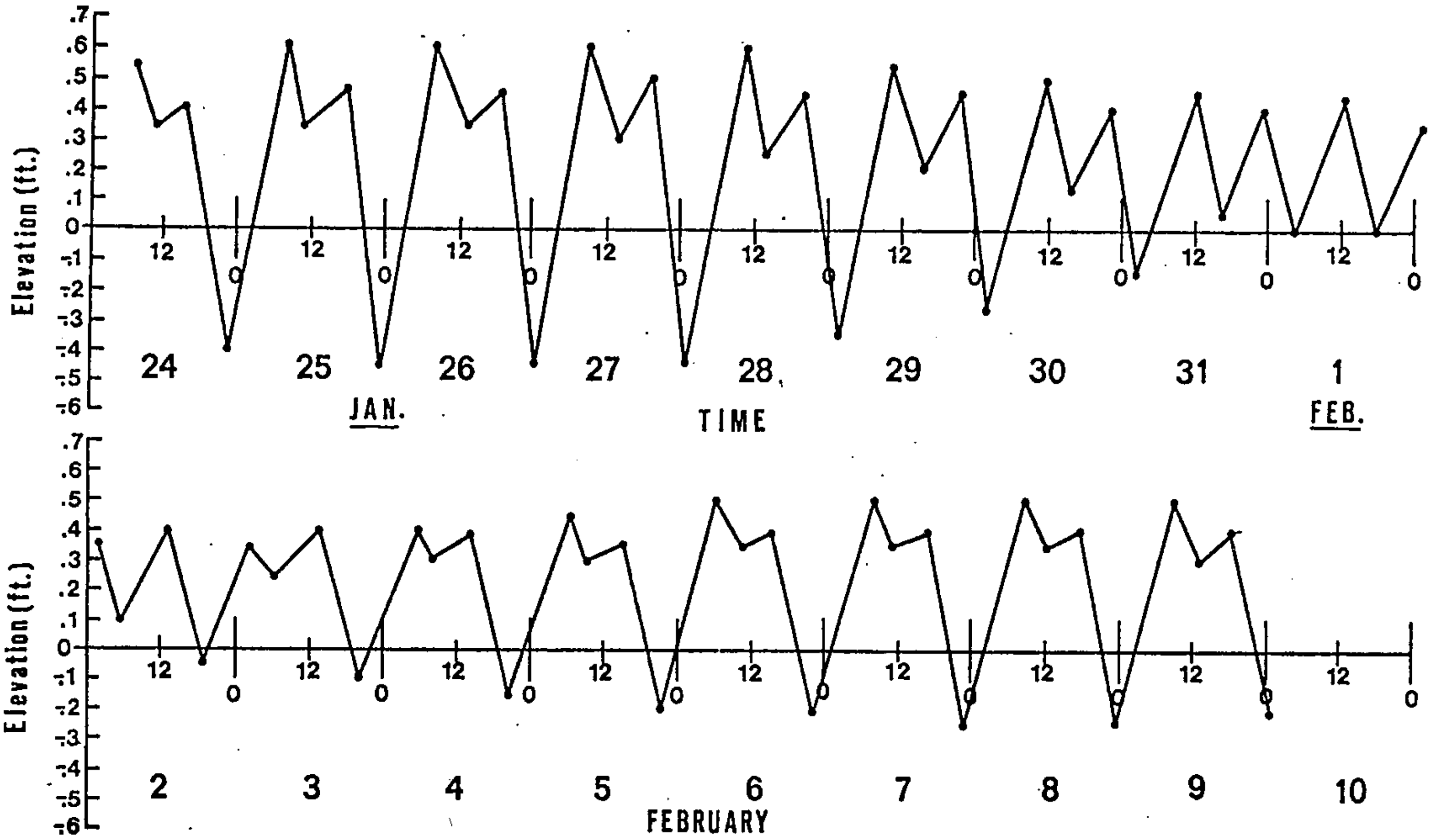

Elevation (ft.)
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
12
0
24
25
26
27
28
29
30
31
1
JAN.
TIME
FEB.
Elevation (ft.)
2
3
4
5
6
7
8
9
10
FEBRUARY

FIG. 69 (cont.)

Other periodic fluctuations that are superimposed on the record prevent exact tidal correlations.

The current velocity-tidal fluctuations correlations is more apparent in the stick plots of Figures 64-68. Observe that greater speeds (vector length) occur in three distinctive periods of the record length: the first from the 8 to 12 of January; the second from the 25 to the 30 of January; and the third from February 5 to 9. Figure 69 indicates that these periods coincide with monthly spring tides. In general, the changes in direction closely correlate with the ebb and flood stages of the tides. Ebb flow direction is toward the southern quadrants (SE, S, SW), while flood directions are mainly toward northern azimuths (NW, N, NE). Figures 65 and 66 show this ebb and flood flows directions through the 6 and 12 hours resultant vectors diagrams at the 215 meters level. Similar current velocity-tide general correlations can be observed in the stick diagrams of Figures 67 and 68, the resultant vectors plots for the 332 meters level. Tidal forcing seems to be the dominant process affecting the speed and direction of water flows at the monitored depths. Tides along the south coast of Puerto Rico are mainly diurnal with a semi-diurnal component superimposed (mixed tides) as shwon in Figure 69.

Progressive resultant vectors diagrams (Figs. 70 to 81) illustrate much better the effects of tidal forcing in the circulation at the 225 and 332 meters depth levels. Superimposed periodic fluctuations-other than tidal- can also be surmised from these diagrams. For example: in Figure 70, the progressive resultant vectors diagram at a depth of 215 meters, there is a trend of variation in speed and direction every 6 to 7 hours (semi-diurnal tide component) and a larger one from 12 to 13 hours (diurnal tide). Larger loops are also apparent at intervals of approximately 37 to 40 hours. The calculated inertial currents periods for latitutde 18°N, the location of the Punta Tuna Site, is of about 36.9 hours. Thus, it seems that inertial currents

```
PROGRESSIVE CURRENT VECTOR DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER SCM-5 #1  07-JAN-79  0:30
BOTTOM DEPTH = 1216 METERS   . METER DEPTH = 215 METERS
DATE:  7-JAN-79  TO  11-JAN-79                    DIAGRAM # : 1
SCALE:      1 MM. = 1.00  CM/SEC
```

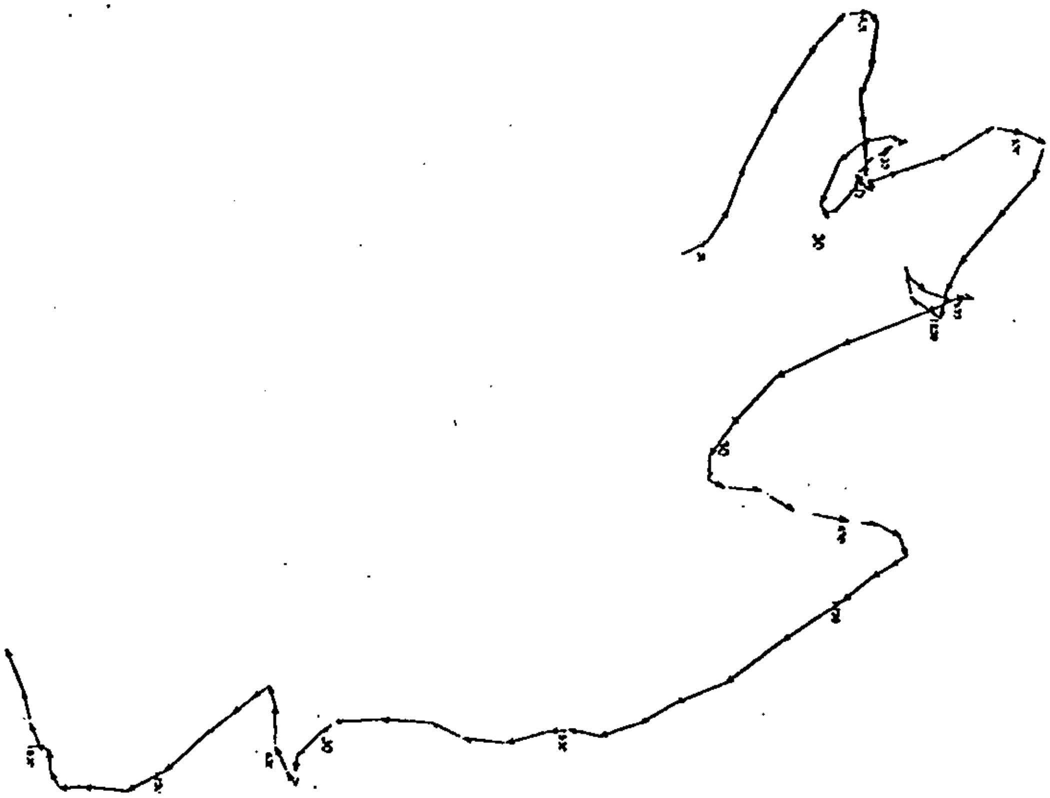


Fig. 70 - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level.

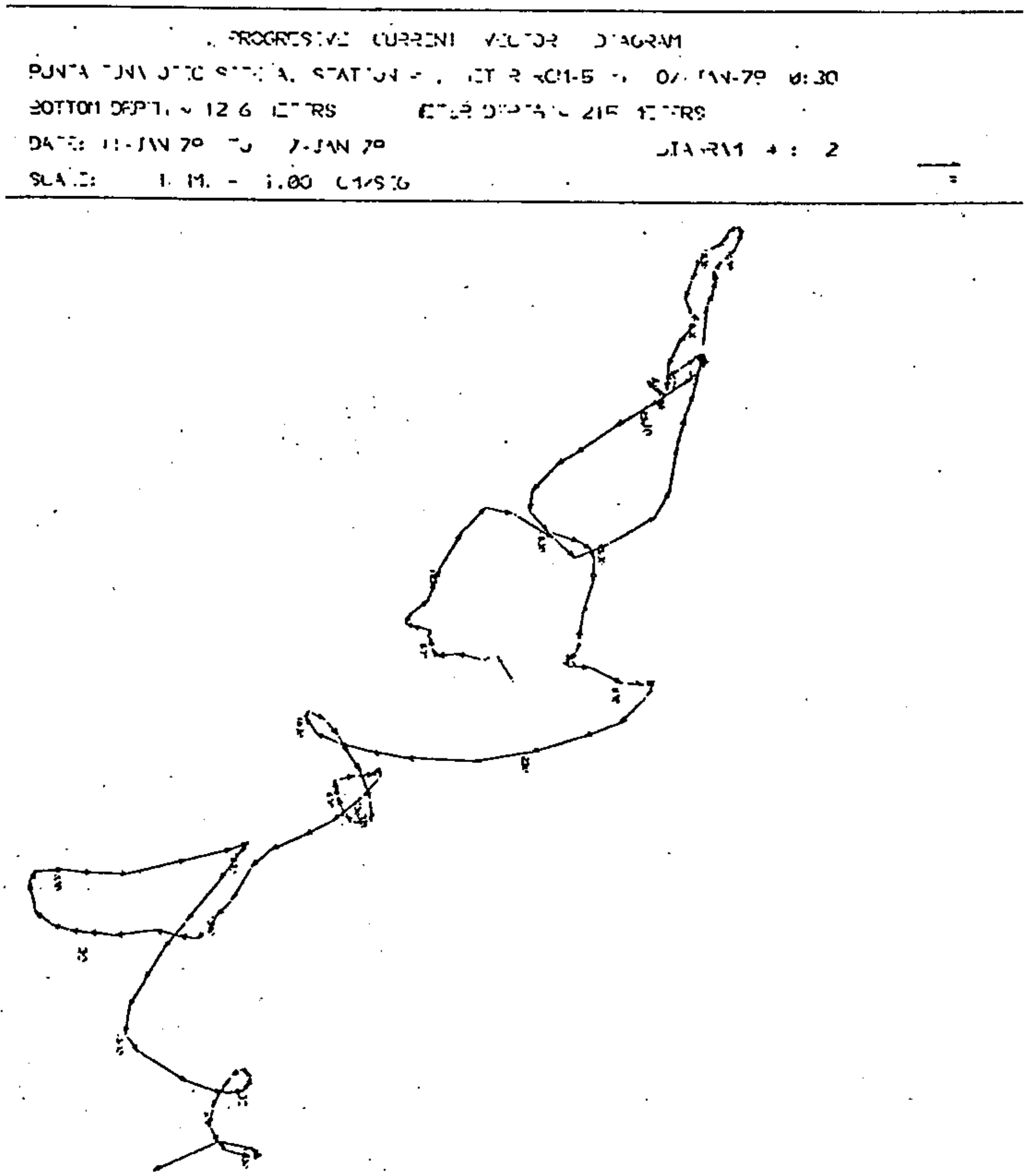
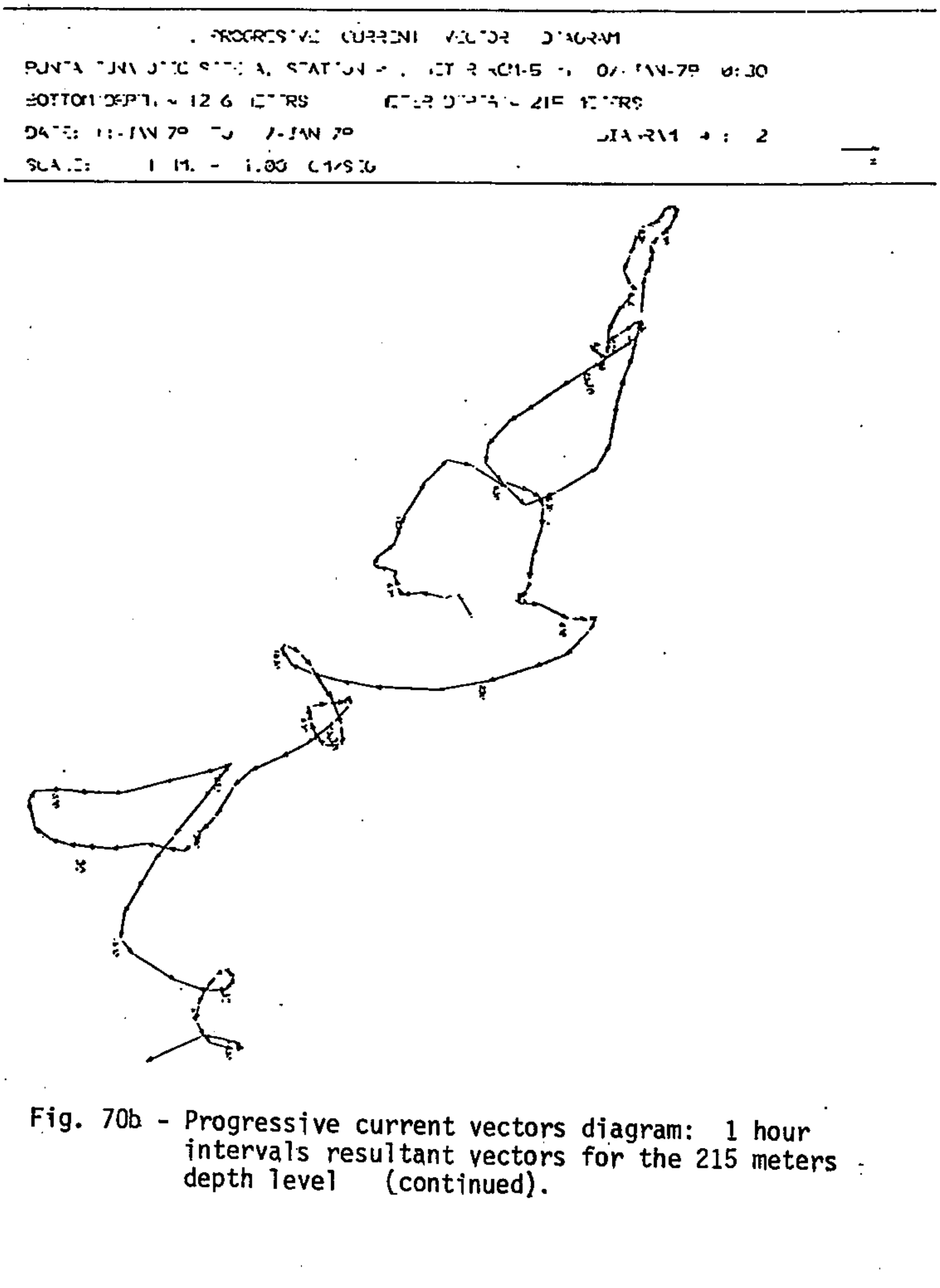


Fig. 70a - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level (continued).



```
PROGRESSIVE CURRENT VECTOR DIAGRAM
PUNTA TUNA OTEC STUDY A, STATION # , METER RCM-5 , 07-JAN-79 0:30
BOTTOM DEPTH = 12 6 METERS        METER DEPTH = 215 METERS
DATE: 11-JAN 79 TO 7-JAN 79                        DIAGRAM # : 2
SCALE:     1 MM. = 1.00 CM/SEC
```

Fig. 70b - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level (continued).

```
                PROGRESSIVE  CURRENT  VECTOR   DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #1  07-JAN-79  0:30
BOTTOM DEPTH = 1215 METERS       METER DEPTH = 215 METERS
DATE: 17-JAN-79  TO  23-JAN-79                         DIAGRAM #:  3
SCALE:      1 MM. = 1.00  CM/SEG
```

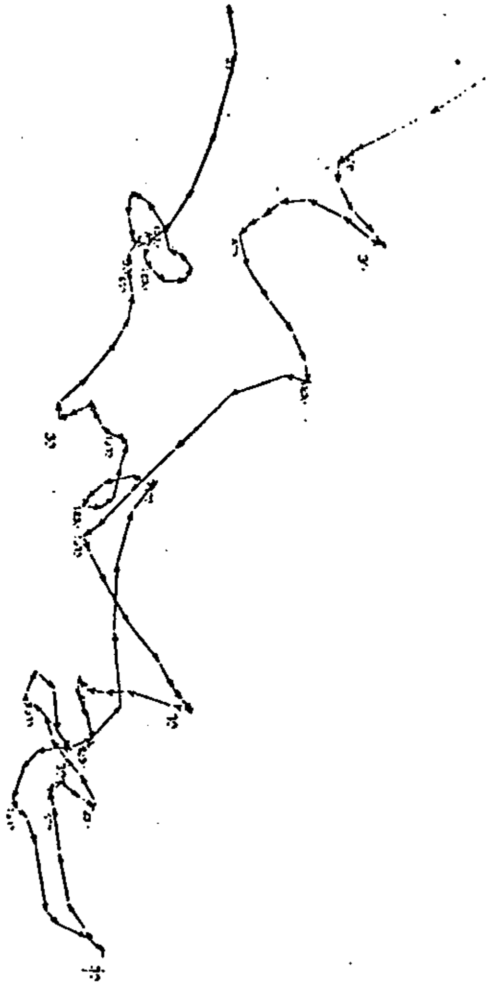


Fig. 70c - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level.(continued).

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                  PROGRESIVE  CURRENT  VECTOR   DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #1  07-JAN-79  0:30
BOTTOM DEPTH = 1216 METERS        METER DEPTH = 215 METERS
DATE: 23 JAN-79  TO   1-FEB-79                        DIAGRAM # : 4
SCALE:       1 MM. = 1.00  CM/SEG
```

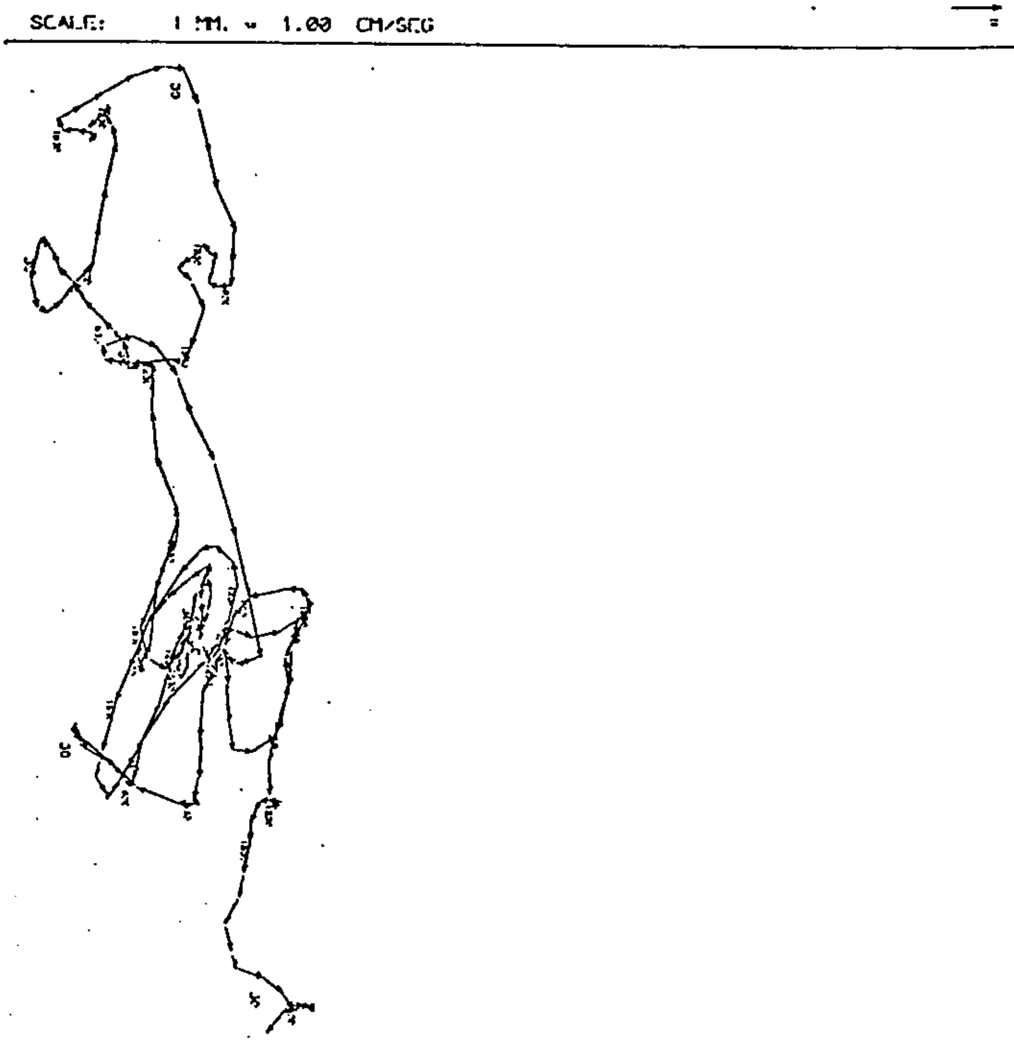


Fig. 70d - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level.(continued).

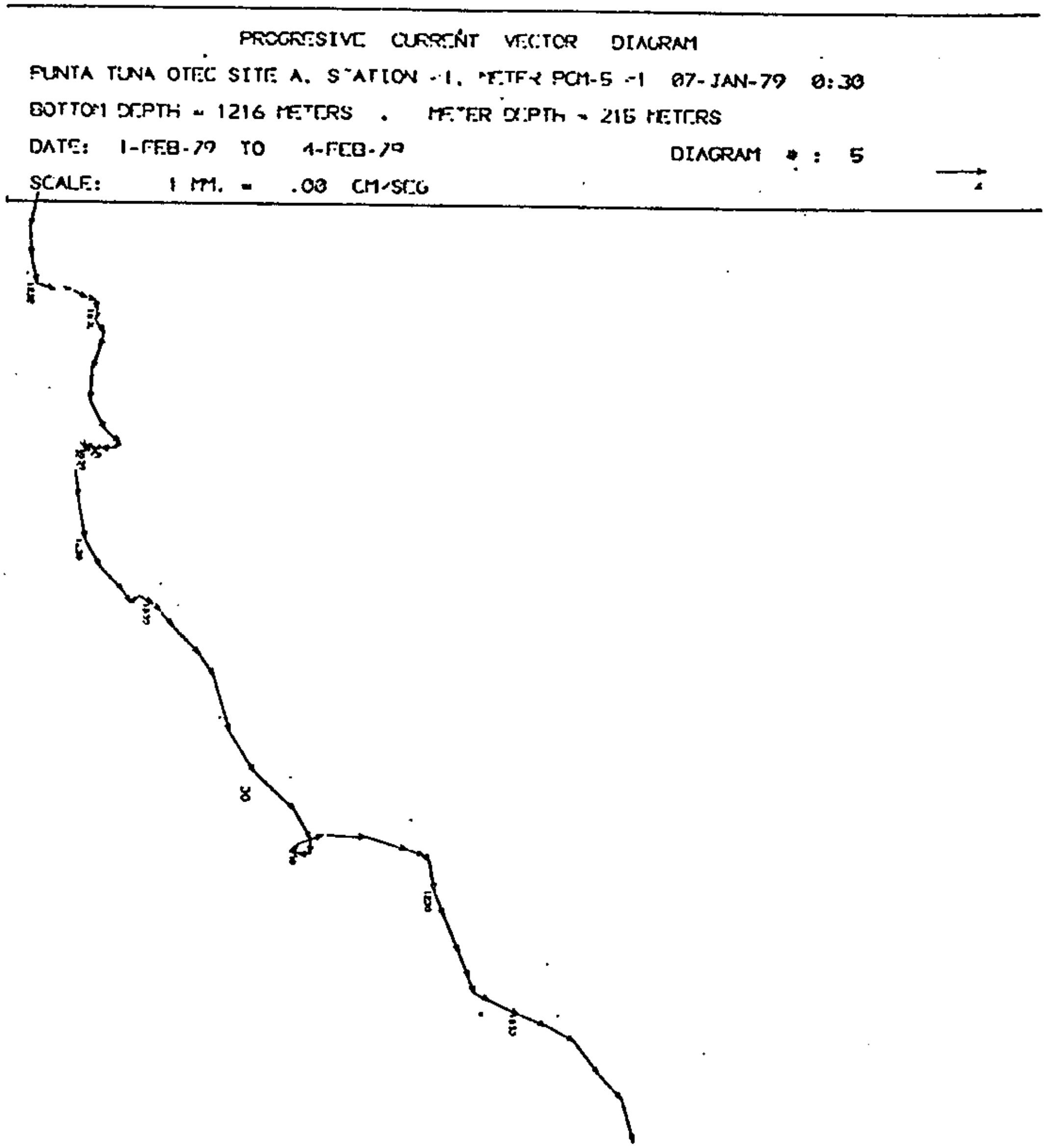


Fig. 70e - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level. (continued).

PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1, METER R M-5 . 07-JAN-79 0:30

BOTTOM DEPTH = 216 METERS METER DEPTH = 215 METERS

DATE: 4-FEB-79 TO 7-FEB-79 DIAGRAM # : 6

SCALE: 1 MM. = 1.00 M/SEC

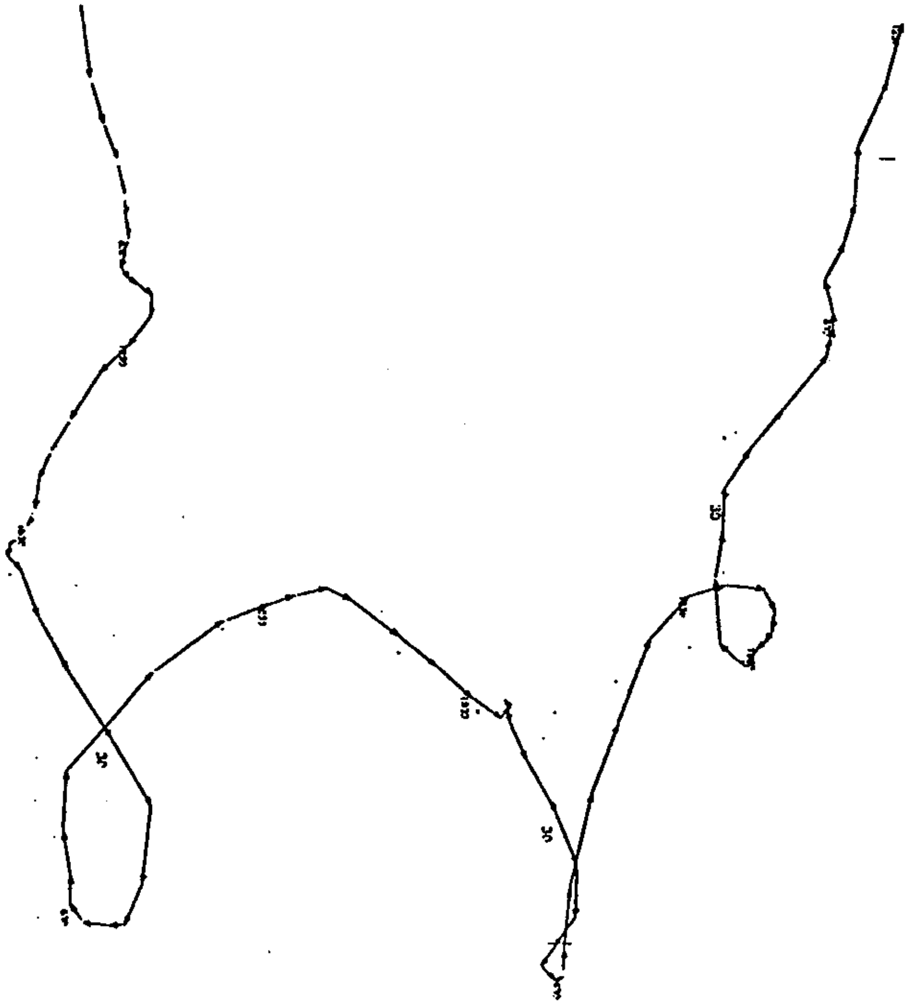
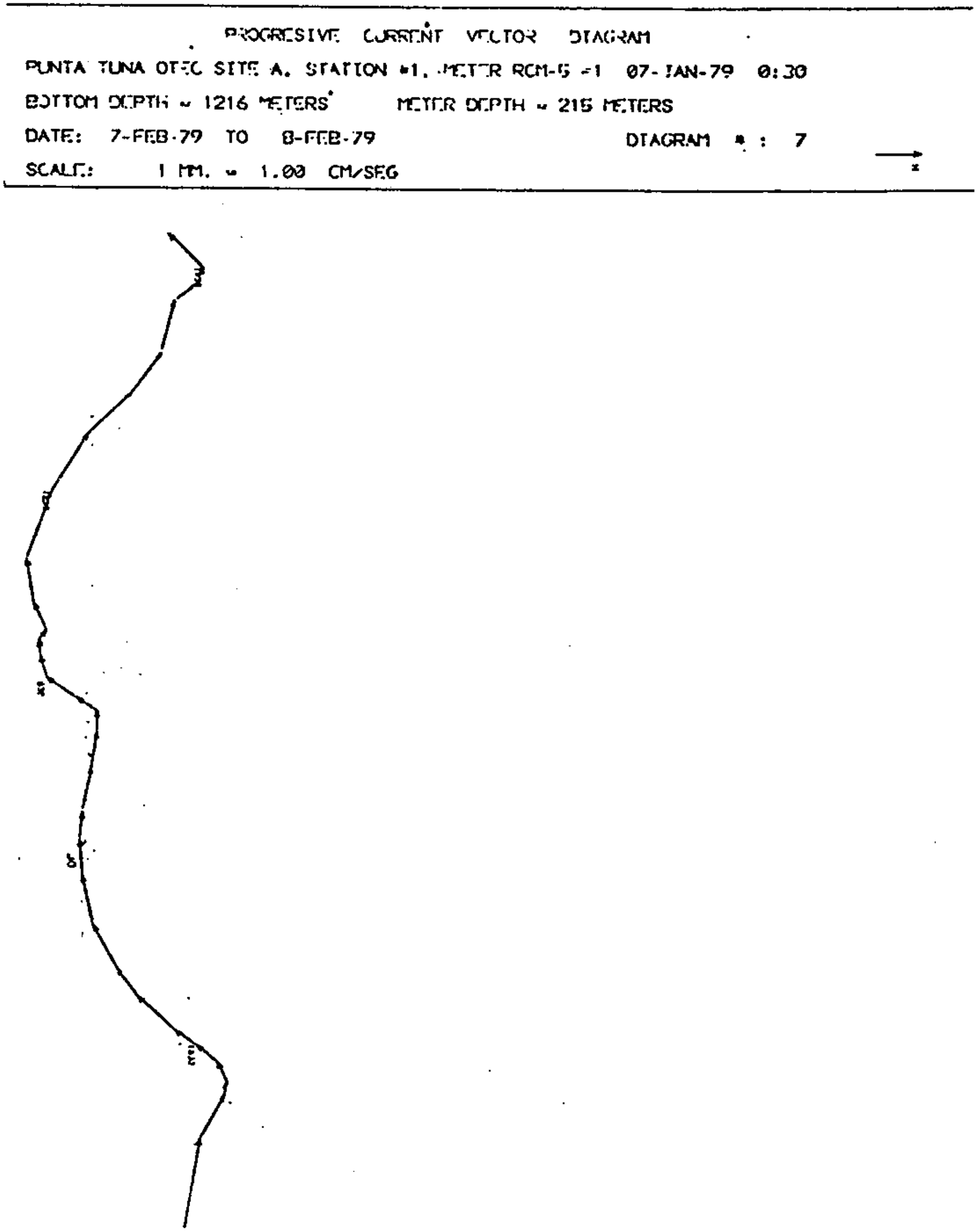


Fig. 70f - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level (continued).



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                PROGRESIVE  CURRENT  VECTOR  DIAGRAM
PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #1  07-JAN-79  0:30
BOTTOM DEPTH = 1216 METERS      METER DEPTH = 215 METERS
DATE:  7-FEB-79  TO  8-FEB-79                     DIAGRAM # :  7
SCALE:     1 MM. = 1.00  CM/SEG
```

Fig. 70g - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 215 meters depth level (continued).

PROGRESIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #1 07-JAN-79 0:30

BOTTOM DEPTH = 1216 METERS METER DEPTH = 215 METERS

DATE: 7-JAN-79 TO 4-FEB-79 DIAGRAM # : 1

SCALE: 1 CM. = 5.00 CM/SEG 6 HOUR INTERVALS.

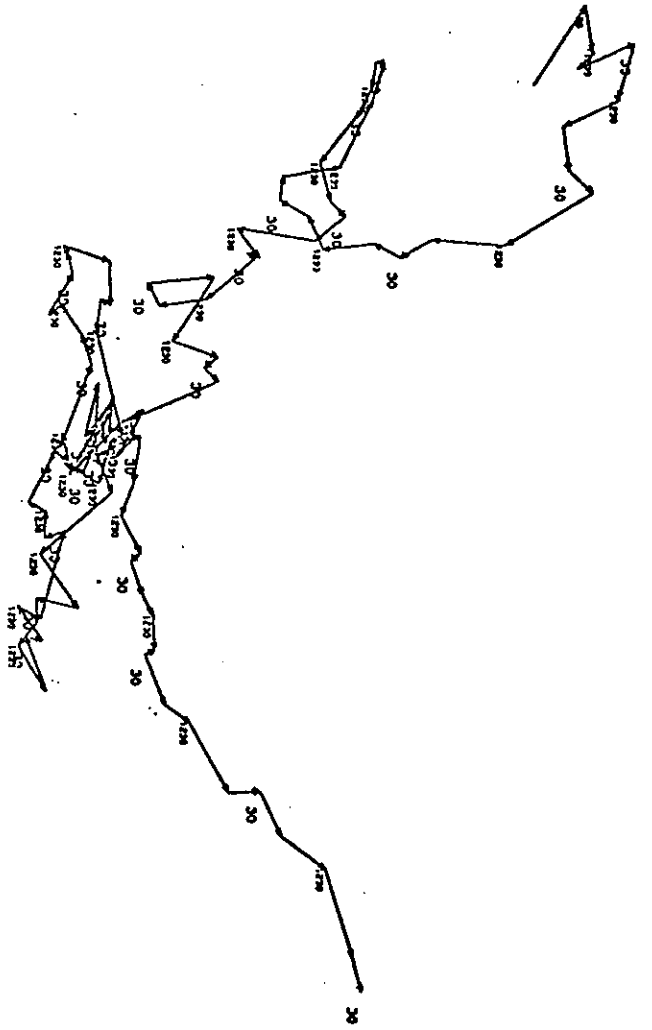


Fig. 71 - Progressive current vectors diagram: 6 hours intervals resultant vectors for the 215 meters depth level.

PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #1 07-JAN-79 0:30

BOTTOM DEPTH = 1216 METERS METER DEPTH = 215 METERS

DATE: 4-FEB-79 TO 9-FEB-79 DIAGRAM # : 2

SCALE: 1 CM. = 5.00 CM/SEG 6 HOUR INTERVALS.

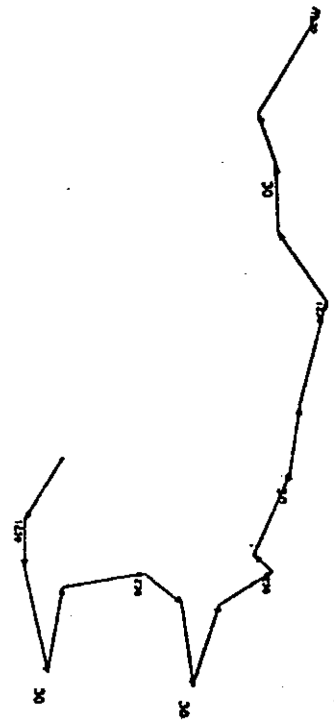


Fig. 71a - Progressive current vectors diagram: 6 hours intervals resultant vectors for the 215 meters depth level. (continued).

PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #1 07-JAN-79 0:30

BOTTOM DEPTH - 1216 METERS METER DEPTH - 215 METERS

DATE: 7-JAN-79 TO 9-FEB-79 DIAGRAM # : 1

SCALE: 1 CM. = 3.00 CM/SEG 12 HOUR INTERVALS.

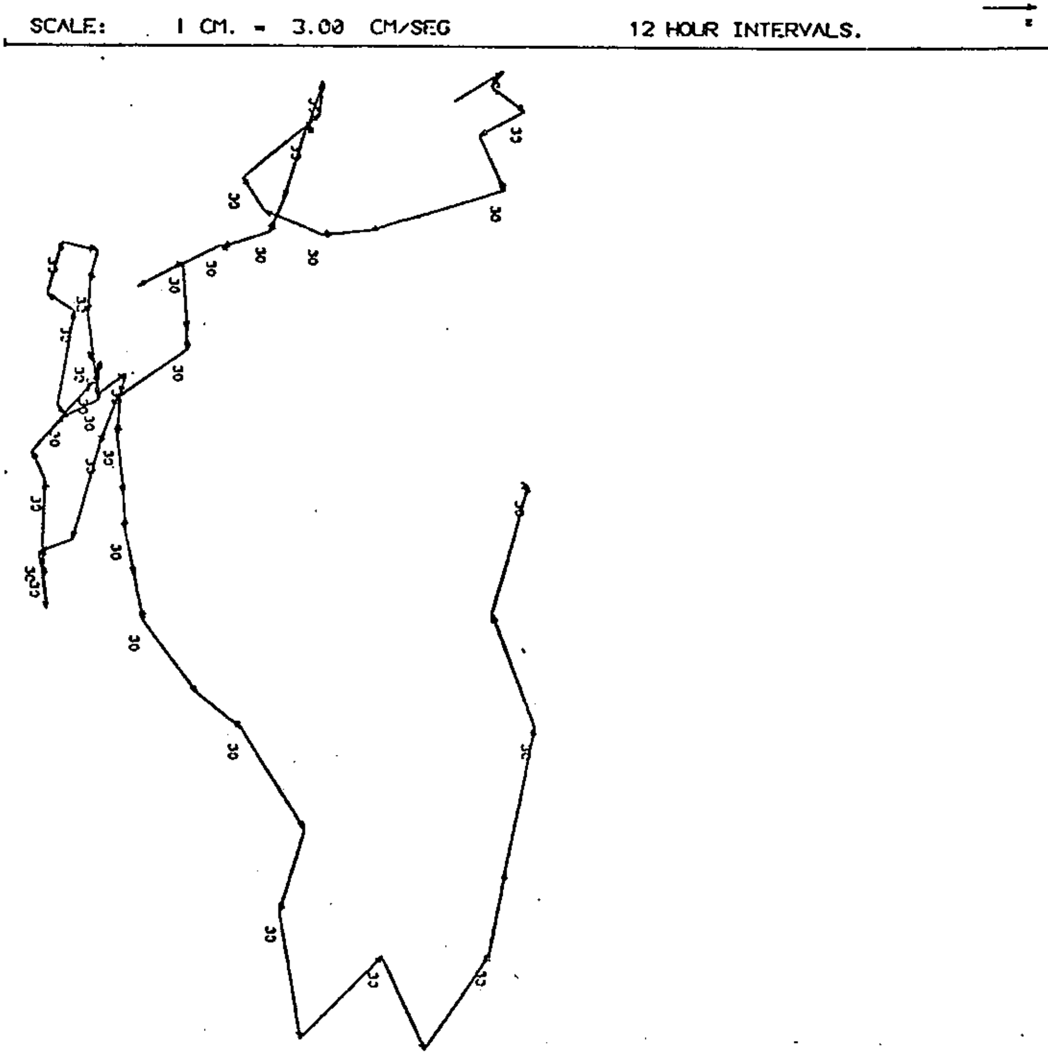
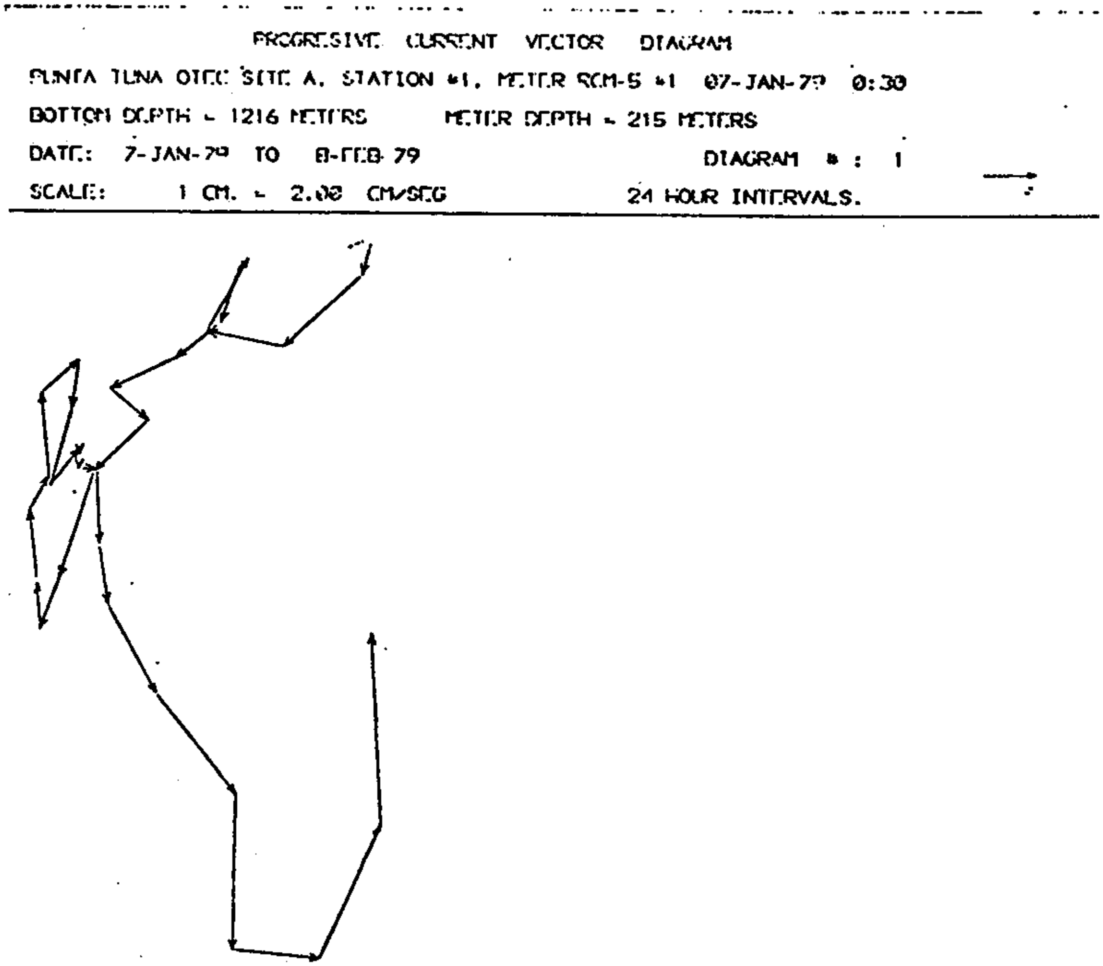


Fig. 72 - Progressive current vectors diagram: 12 hours intervals resultant vectors for the 215 meters depth level.



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PROGRESSIVE  CURRENT  VECTOR  DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #1  07-JAN-79  0:30
BOTTOM DEPTH = 1216 METERS        METER DEPTH = 215 METERS
DATE:  7-JAN-79  TO  8-FEB 79                    DIAGRAM  # :  1
SCALE:     1 CM. = 2.00  CM/SEG              24 HOUR INTERVALS.
```

Fig. 73 - Progressive current vectors diagram: 24 hours intervals resultant vectors for the 215 meters depth level.

PROGRESSIVE CURRENT VECTOR DIAGRAM
PUNTA TUNA OTEC-SITE A, STATION #1, METER RCM-5 #1 07-JAN-79 0:30
BOTTOM DEPTH = 1216 METERS METER DEPTH = 215 METERS
DATE: 7-JAN-79 TO 7-FEB-79 DIAGRAM # : . 1
SCALE: 1 CM. = 1.00 CM/SEG 36 HOUR INTERVALS.

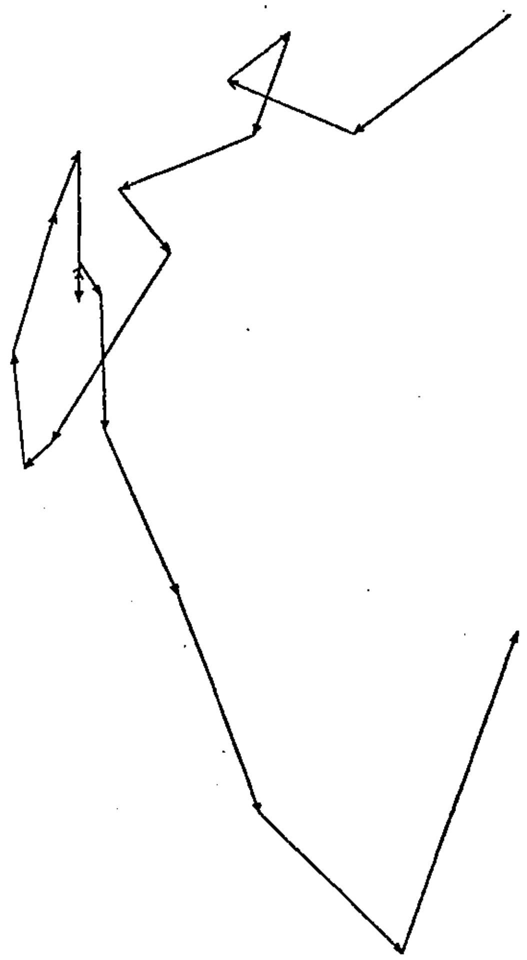


Fig. 74 - Progressive current vectors diagram: 36 hours intervals resultant vectors for the 215 meters depth level.

PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #1 07-JAN-79 0:30

BOTTOM DEPTH = 1216 METERS METER DEPTH = 215 METERS

DATE: 7-JAN-79 TO 8-FEB 79 DIAGRAM # : 1

SCALE: 1 CM. = 1.00 CM/SEG 48 HOUR INTERVALS.

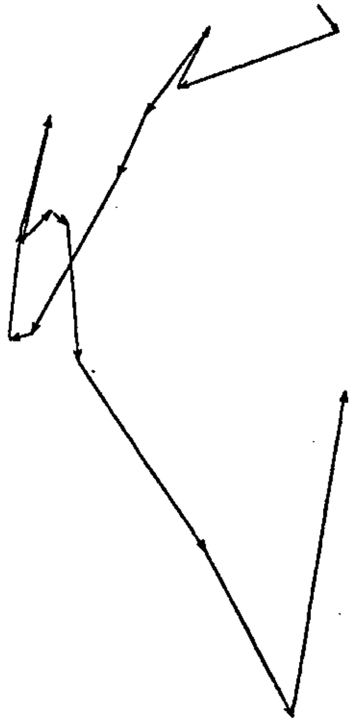
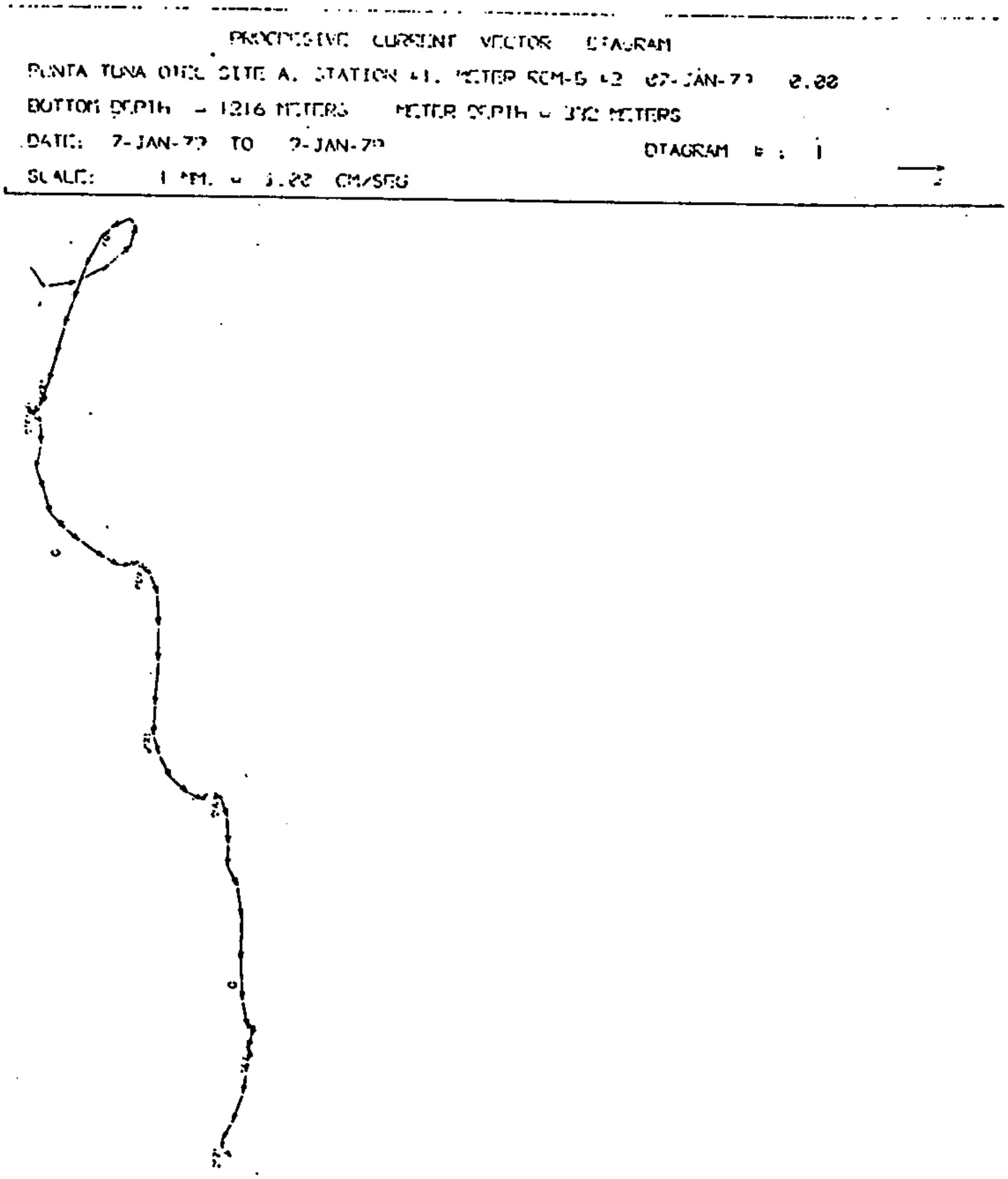


Fig. 75 - Progressive current vectors diagram: 48 hours intervals resultant vectors for the 215 meters depth level.



PROGRESSIVE CURRENT VECTOR DIAGRAM

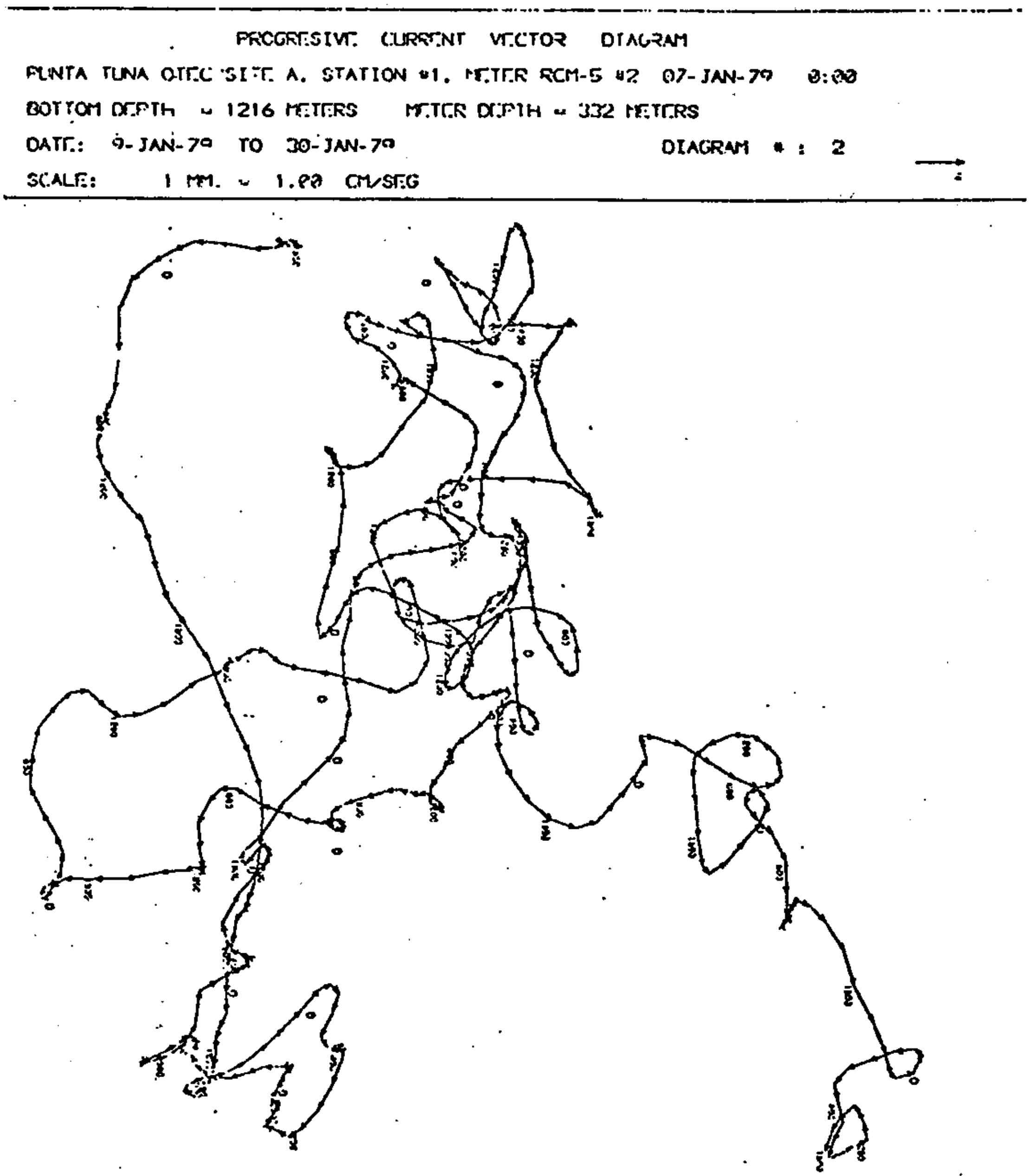
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #2 07-JAN-79 0.00

BOTTOM DEPTH = 1216 METERS METER DEPTH = 332 METERS

DATE: 7-JAN-79 TO 9-JAN-79 DIAGRAM # : 1

SCALE: 1 MM. = 3.22 CM/SEC

Fig. 76 - Progressive current vectors diagram: 1 hour intervals resultant vectors for the 332 meters depth level.



```
PROGRESSIVE CURRENT VECTOR DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #2  07-JAN-79  0:00
BOTTOM DEPTH = 1216 METERS      METER DEPTH = 332 METERS
DATE:  9-JAN-79  TO  30-JAN-79                    DIAGRAM # : 2
SCALE:     1 MM. = 1.00 CM/SEG
```

Fig. 76a- Progressive current vectors diagram: 1 hours intervals resultant vectors for the 332 meters depth level.(continued).

```
                    PROGRESSIVE  CURRENT  VECTOR  DIAGRAM
PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #2  07-JAN-79   0.00
BOTTOM DEPTH  = 1216 METERS     METER DEPTH = 332 METERS
DATE: 30-JAN-79  TO   8-FEB-79                        DIAGRAM  # :  3
SCALE:      1 MM. =  1.00  CM/SEG
```

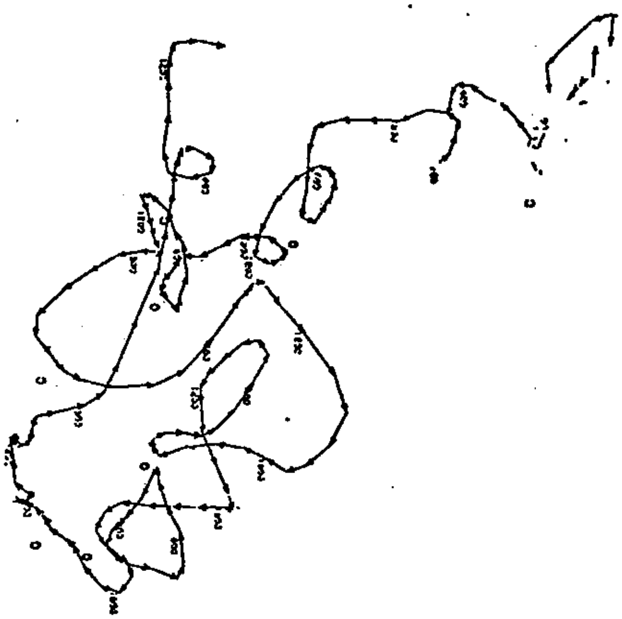
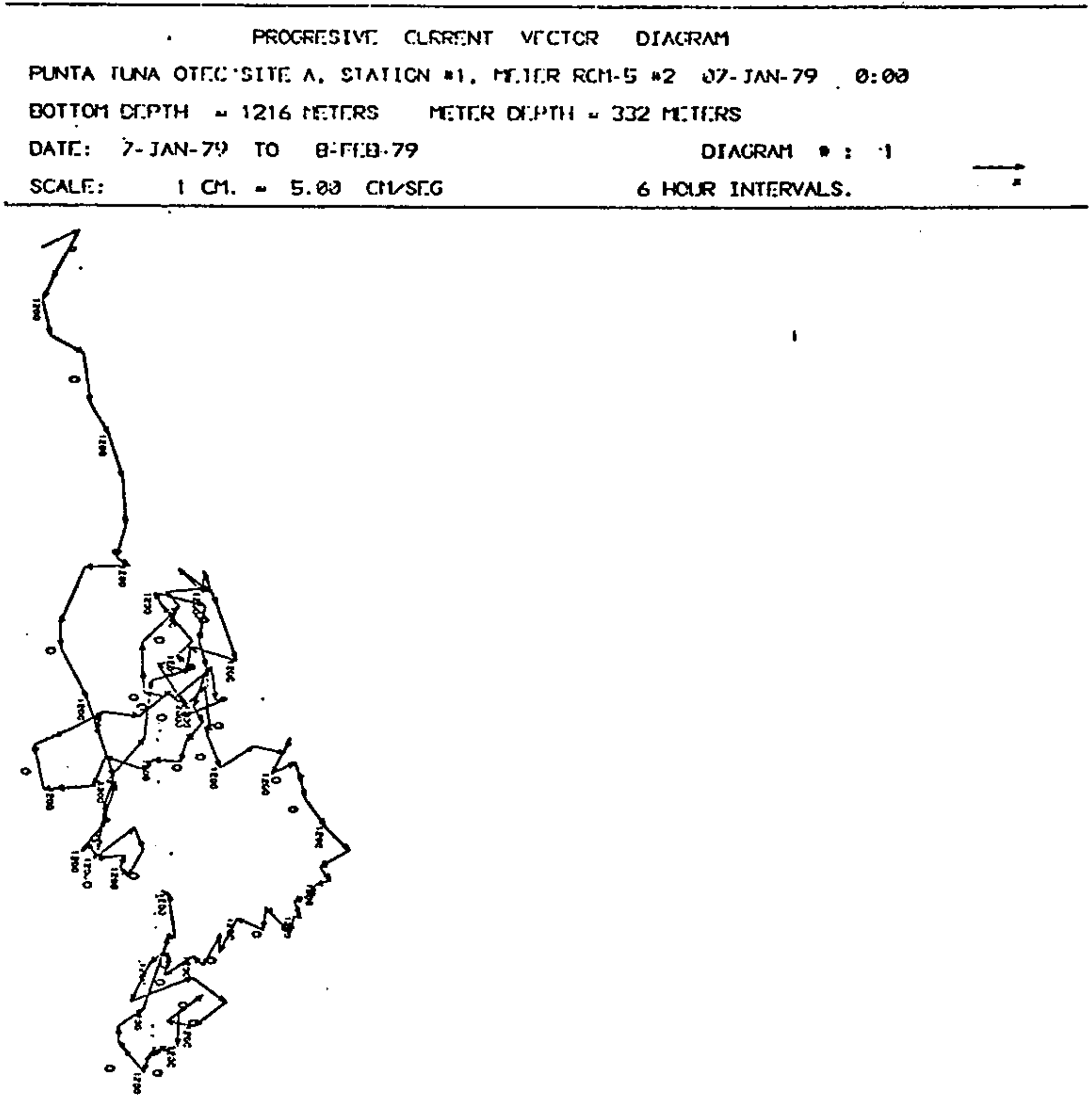


Fig. 76b- Progressive current vectors diagram: 1 hours intervals resultant vectors for the 332 meters depth level (continued).



PROGRESIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A, STATION #1, METER RCM-5 #2 07-JAN-79 0:00

BOTTOM DEPTH = 1216 METERS METER DEPTH = 332 METERS

DATE: 7-JAN-79 TO 8-FEB-79 DIAGRAM # : 1

SCALE: 1 CM. = 5.00 CM/SEG 6 HOUR INTERVALS.

Fig. 77 - Progressive current vectors diagram: 6 hours intervals resultant vectors for the 332 meters depth level.

```
                    PROGRESSIVE  CURRENT  VECTOR  DIAGRAM
PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #2  07-JAN-79   0:00
BOTTOM DEPTH  = 1216 METERS    METER DEPTH = 332 METERS
DATE:  7-JAN-79  TO   9-FEB-79                    DIAGRAM  # :  1
SCALE:     1 CM. =  4.00  CM/SEG            12 HOUR INTERVALS.
```

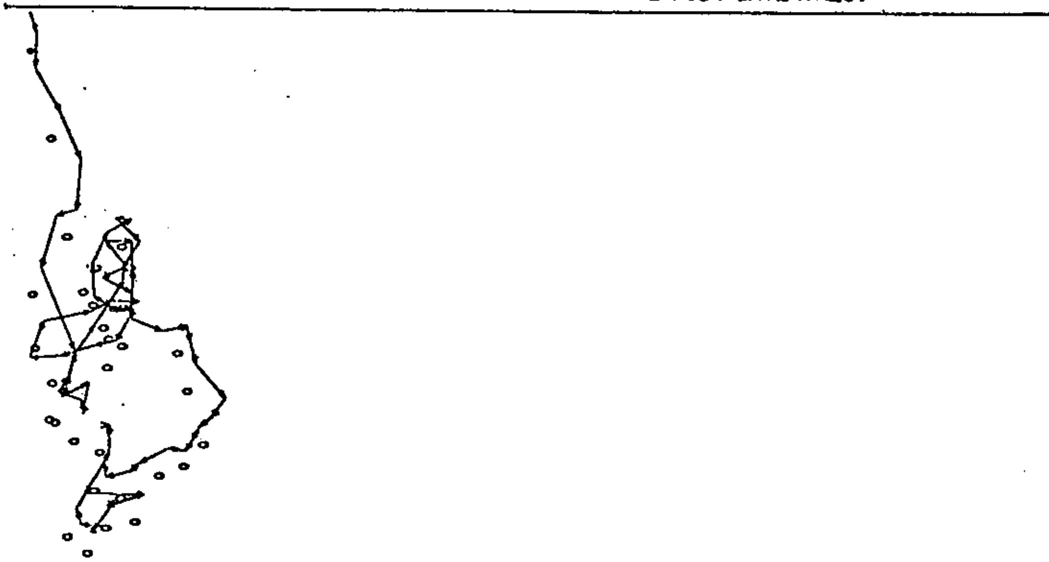
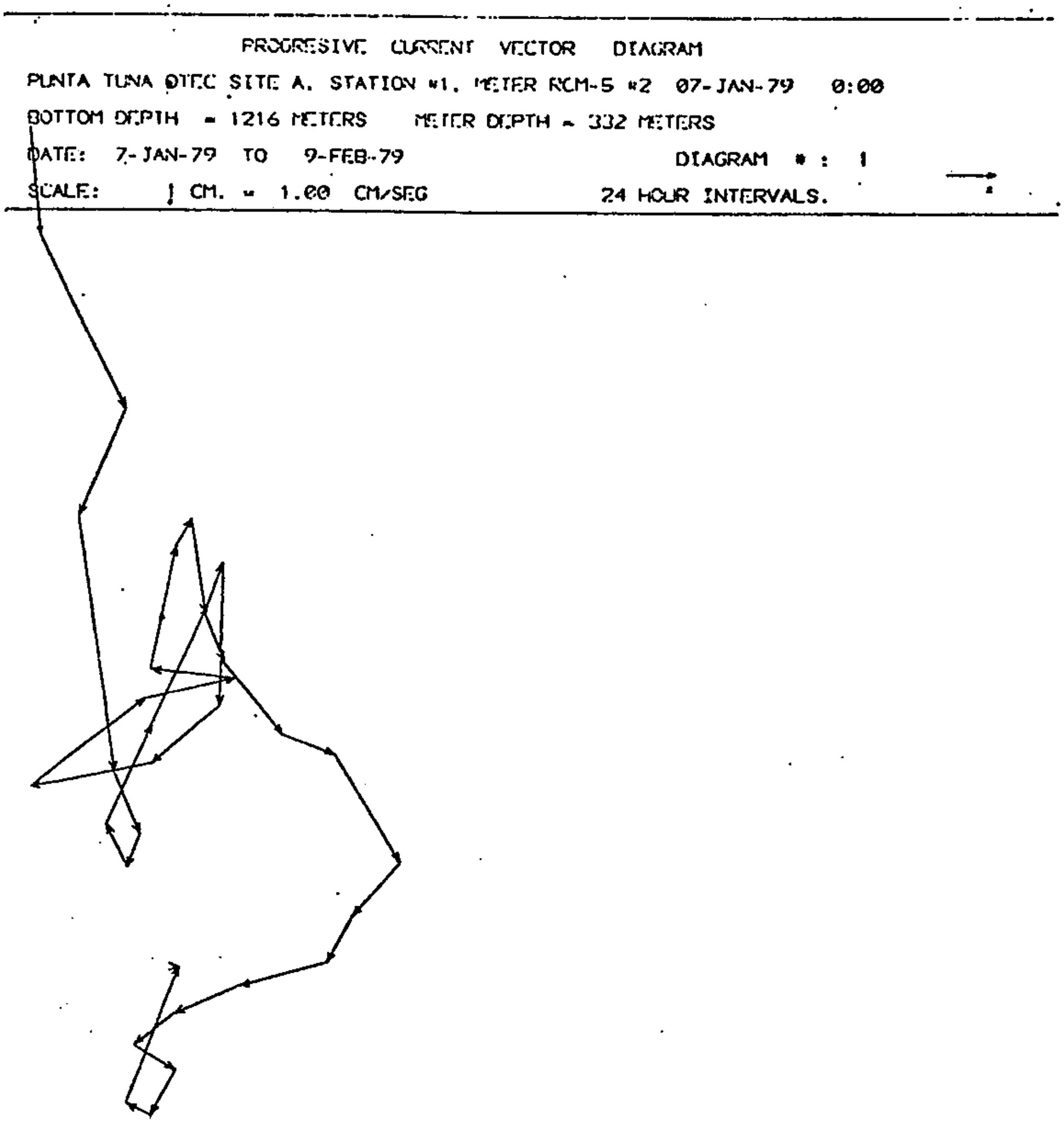


Fig. 7.8 - Progressive current vectors diagram: 12 hours intervals resultant vectors for the 332 meters depth level.



PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #2 07-JAN-79 0:00

BOTTOM DEPTH = 1216 METERS METER DEPTH = 332 METERS

DATE: 7-JAN-79 TO 9-FEB-79 DIAGRAM # : 1

SCALE: 1 CM. = 1.00 CM/SEG 24 HOUR INTERVALS.

Fig. 79 - Progressive current vectors diagram: 24 hours intervals resultant vectors for the 332 meters depth level.

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                  PROGRESIVE  CURRENT  VECTOR   DIAGRAM
PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #2  07-JAN-79   0:00
BOTTOM-DEPTH  =-1216 METERS    METER DEPTH = 332 METERS
DATE:  7-JAN-79  TO   9-FEB-79                      DIAGRAM  # :  1
SCALE:      1 CM. =  1.00  CM/SEG               36 HOUR INTERVALS.
```

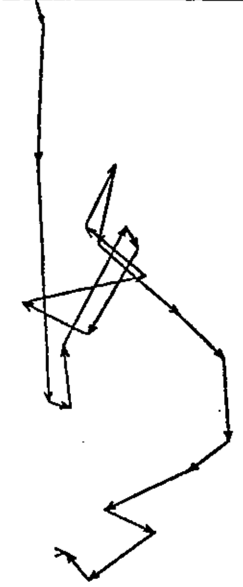
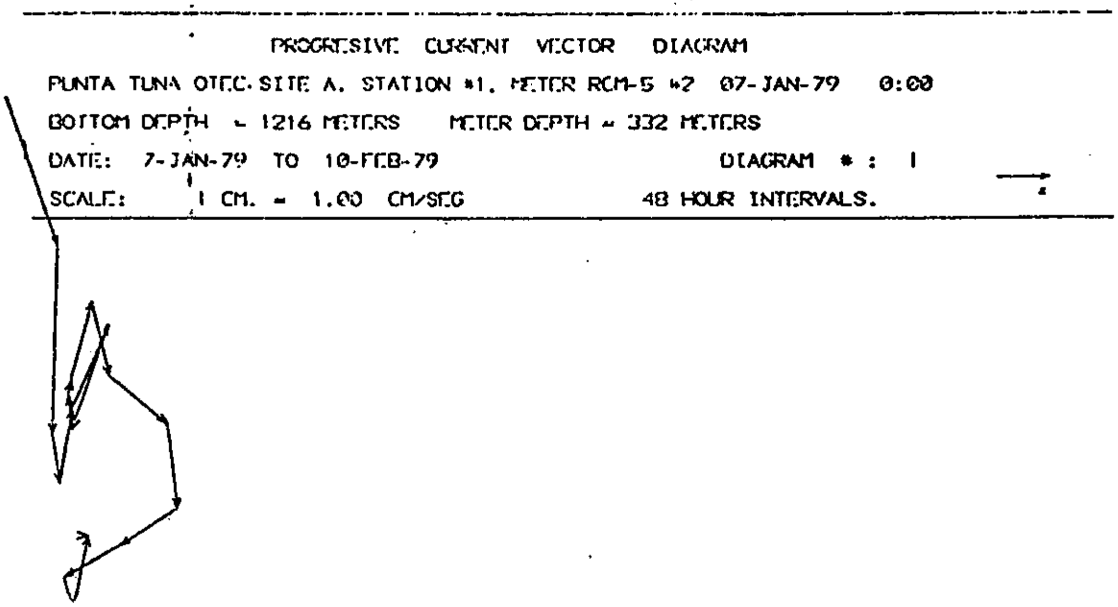


Fig. 80 - Progressive current vectors diagram: 36 hours intervals resultant vectors for the 332 meters depth level.



PROGRESSIVE CURRENT VECTOR DIAGRAM

PUNTA TUNA OTEC SITE A. STATION #1. METER RCM-5 #2 07-JAN-79 0:00

BOTTOM DEPTH = 1216 METERS METER DEPTH = 332 METERS

DATE: 7-JAN-79 TO 10-FEB-79 DIAGRAM # : 1

SCALE: 1 CM. = 1.00 CM/SEG 48 HOUR INTERVALS.

Fig. 81 - Progressive current vectors diagram: 48 hours intervals resultant vectors for the 332 meters depth level.

are also affecting the circulation pattern at the monitored depths. Smoothing out the velocity data by averaging demonstrate that after the tidal cycle have been "averaged out" higher period oscillations are still present; see Figures 71 to 75, which illustrate the resultant circulation at the 215 meter level after averaging the 6, 12, 24, 36, and 48 hours resultant vectors, respectively. Observe that even after 48 hours there are higher periodic variations ranging from about 4 to 12 days.

The above discussion of the 215 meters level progressive resultant vectors diagrams apply to Figures 76 to 81, the circulation diagrams at a depth of 332 meters.

To determine the higher periodic, superimposed variations on the general circulation, which they might not be immediately apparent in the smoothed-out progressive vectors diagrams, the vectorial components of the resultant vectors were plotted as in Figures 82 to 87. The north and east vectorial components of the smoothed-out resultant vectors for 24, 36, and 48 hours were plotted against time at both depths. Figures 82 and 83 illustrate the vectorial components after the 24 hours oscillations (tides) have been smoothed-out. The inertial component is still present: there are periodic fluctuations of approximately 36 to 40 hours (2 1/2 days intervals) with some longer oscillations of several days periods. After the 36 hours components have been averaged out (Figs. 84 and 85) oscillations with periods ranging from 4 to 12 days, which also appeared in the 24 hours curves, remain in the record. It is not known why the east-west component smoothed-out more readily than the north-south component which, even after 48 hours, still contians large periodic variations (Fig. 87). It can only be surmised that eddy movements with periods ranging from days to weeks are also present superimposed in the general circualtion. Much more data than what is now available is needed to determine the source of the longer period oscillations; only the small scale flow and fluctuations can be interpreted at the moment.

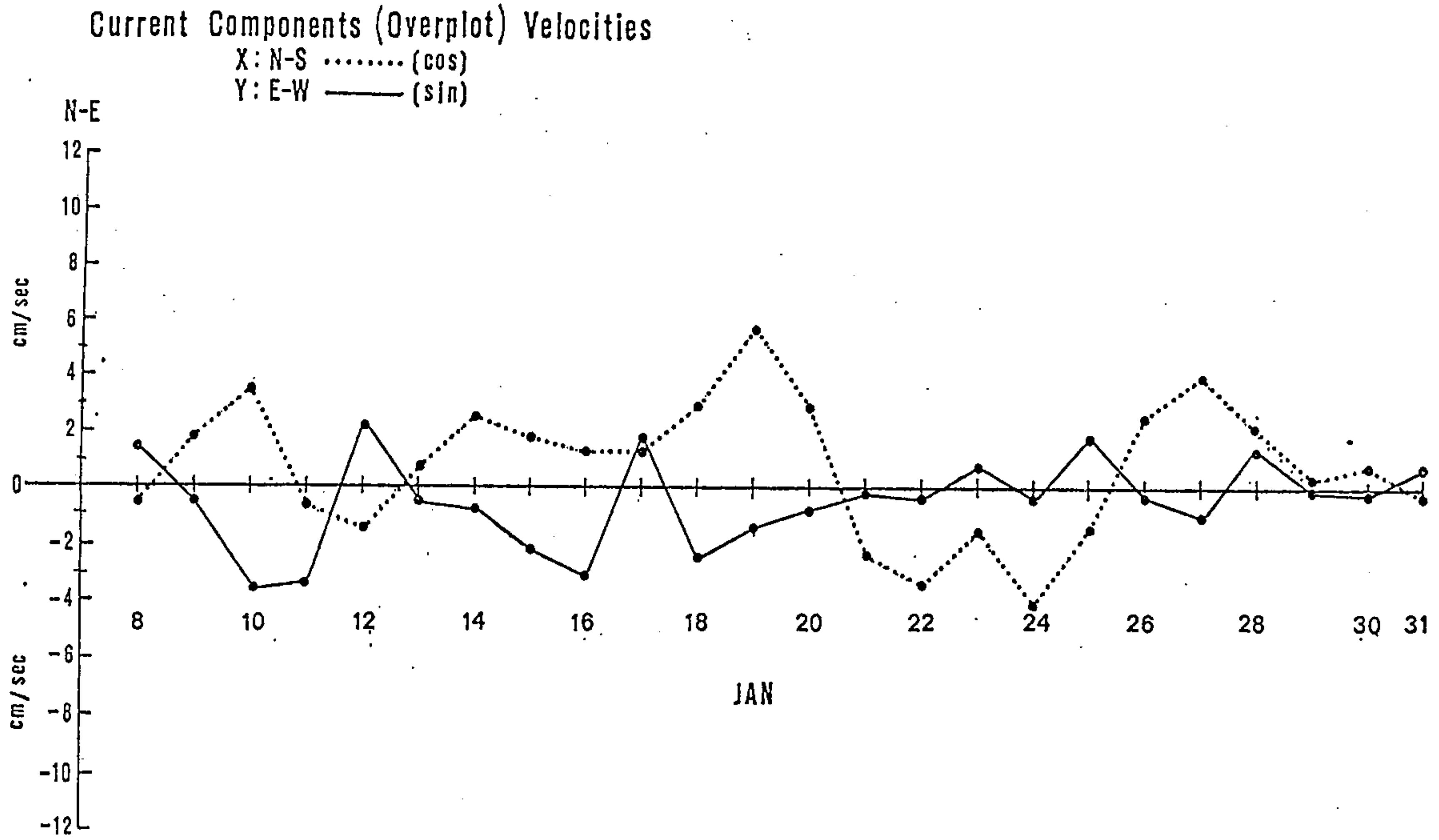
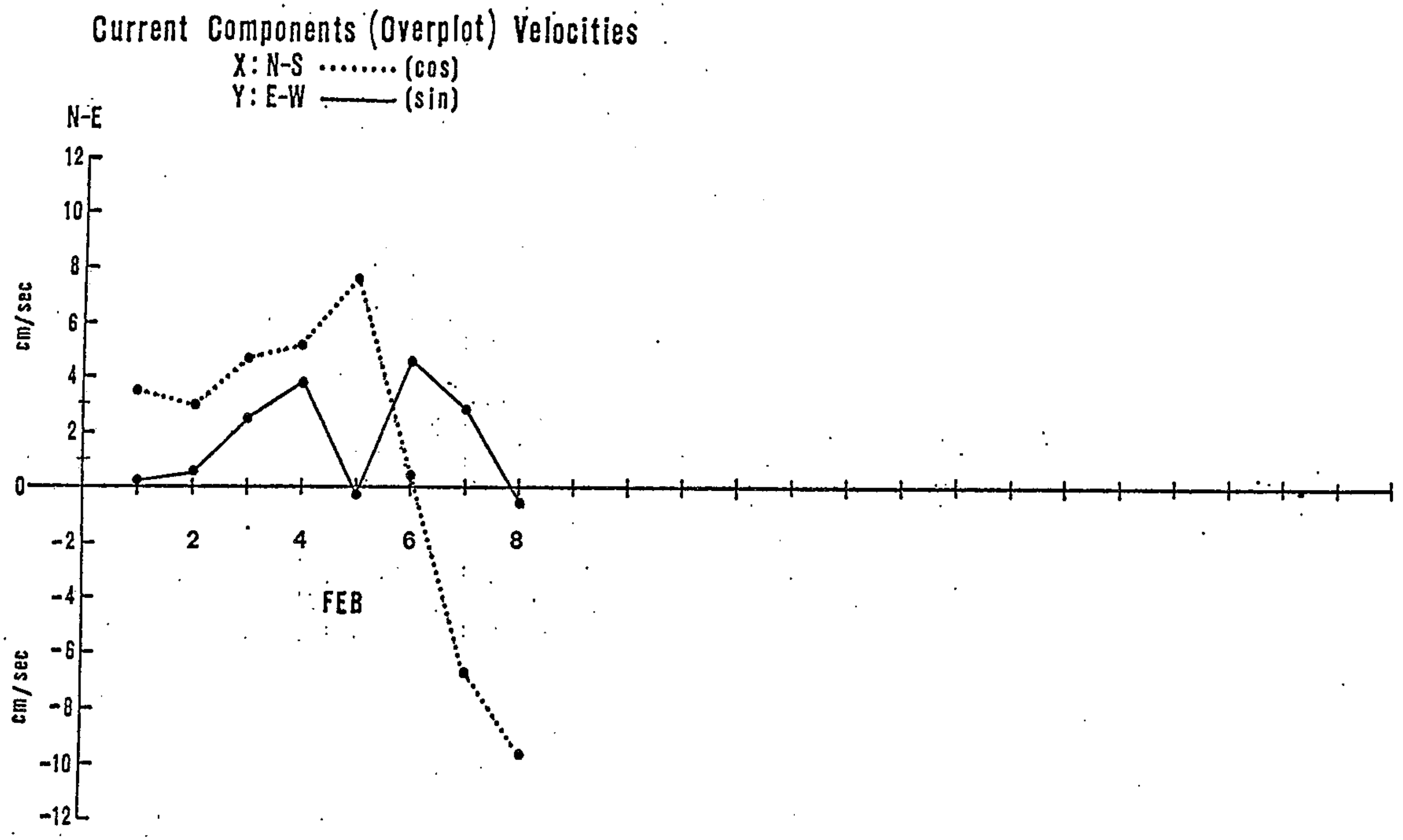


Fig. 82 - 215 m depth level 24 hours intervals vectorial components graph.



. Fig. 82 - 215 m depth level 24 hours intervals vectorial components graph (cont.)

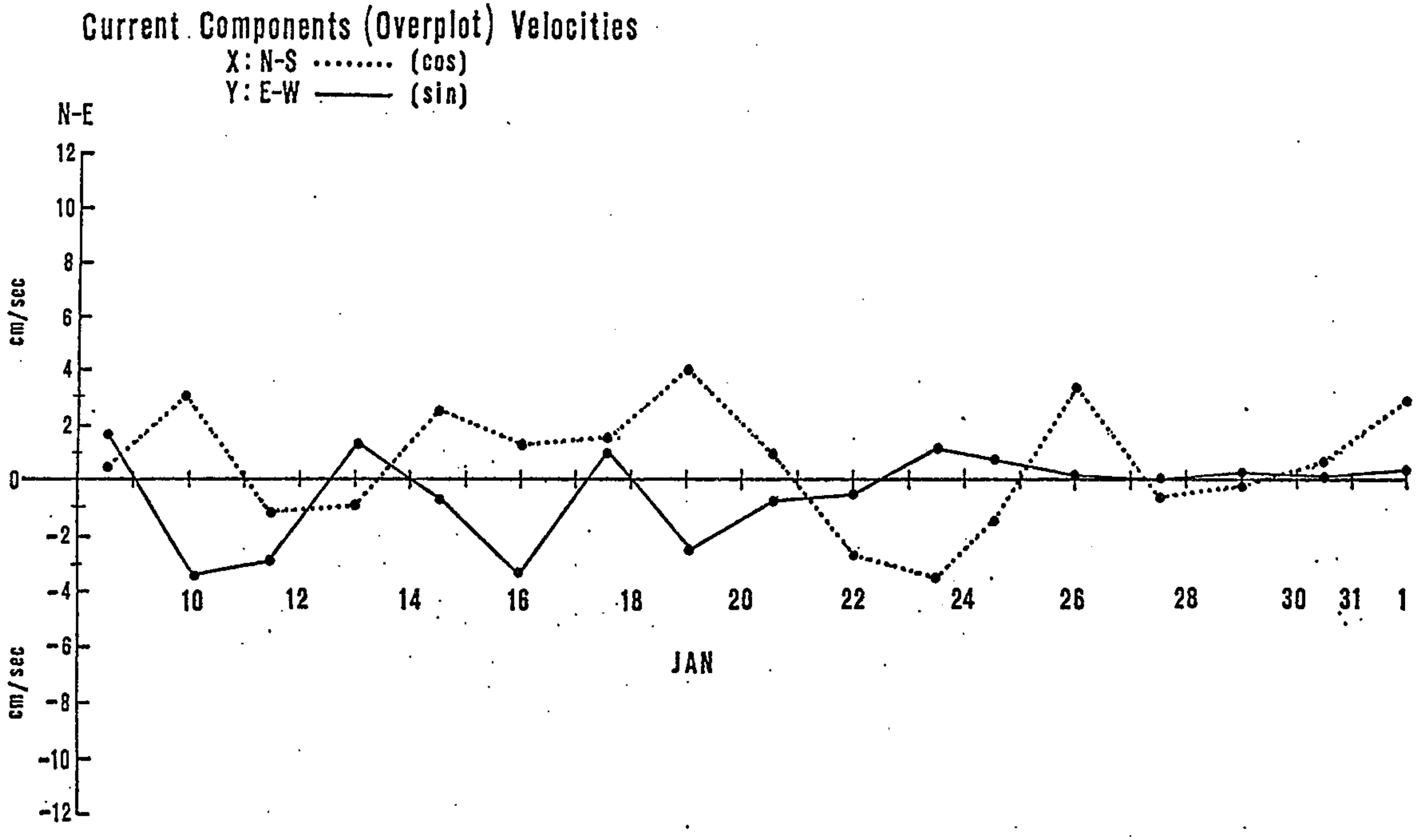


Fig. 83 - 332 m depth level 24 hours intervals vectorial components graph.

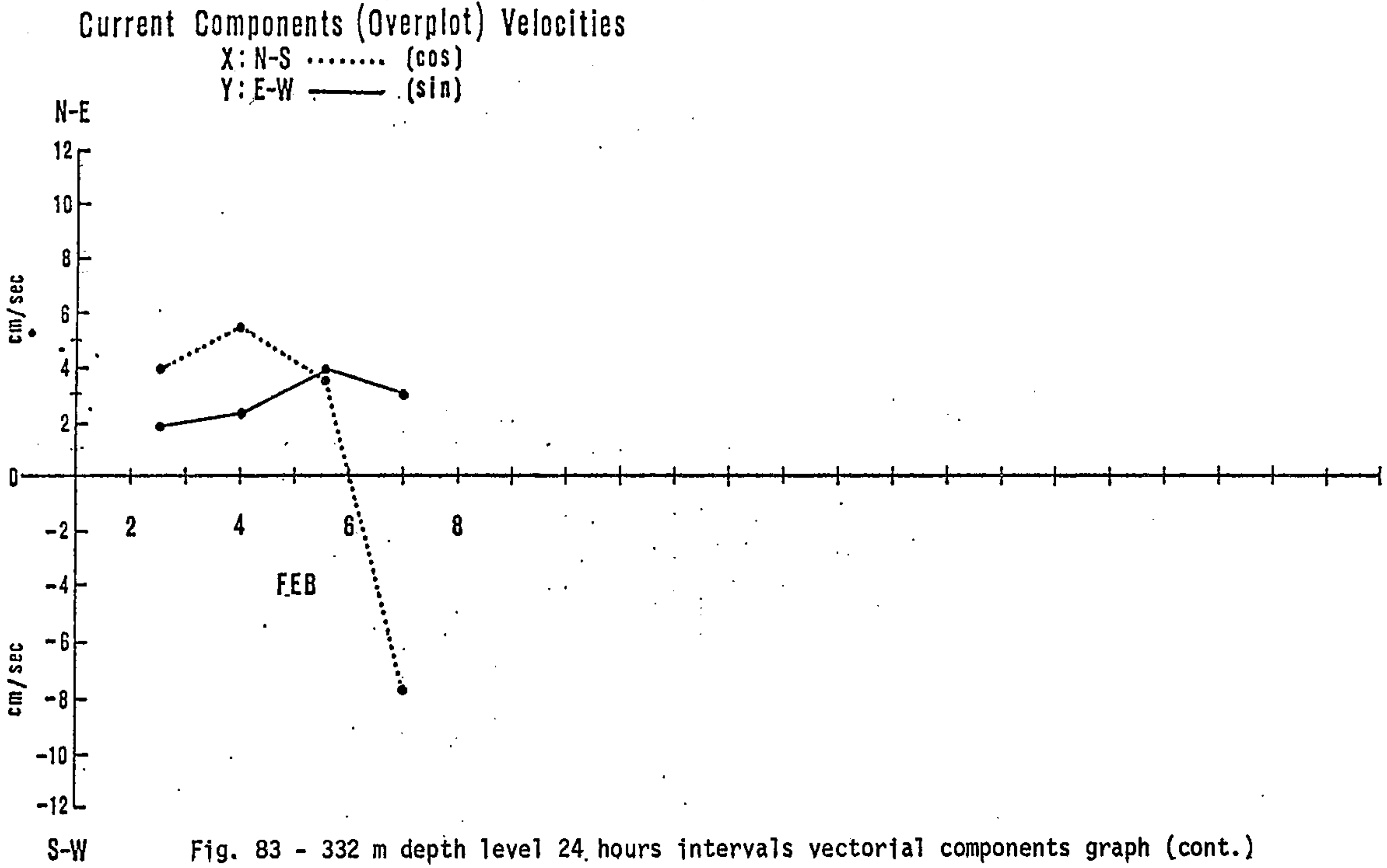


Fig. 83 - 332 m depth level 24 hours intervals vectorial components graph (cont.)

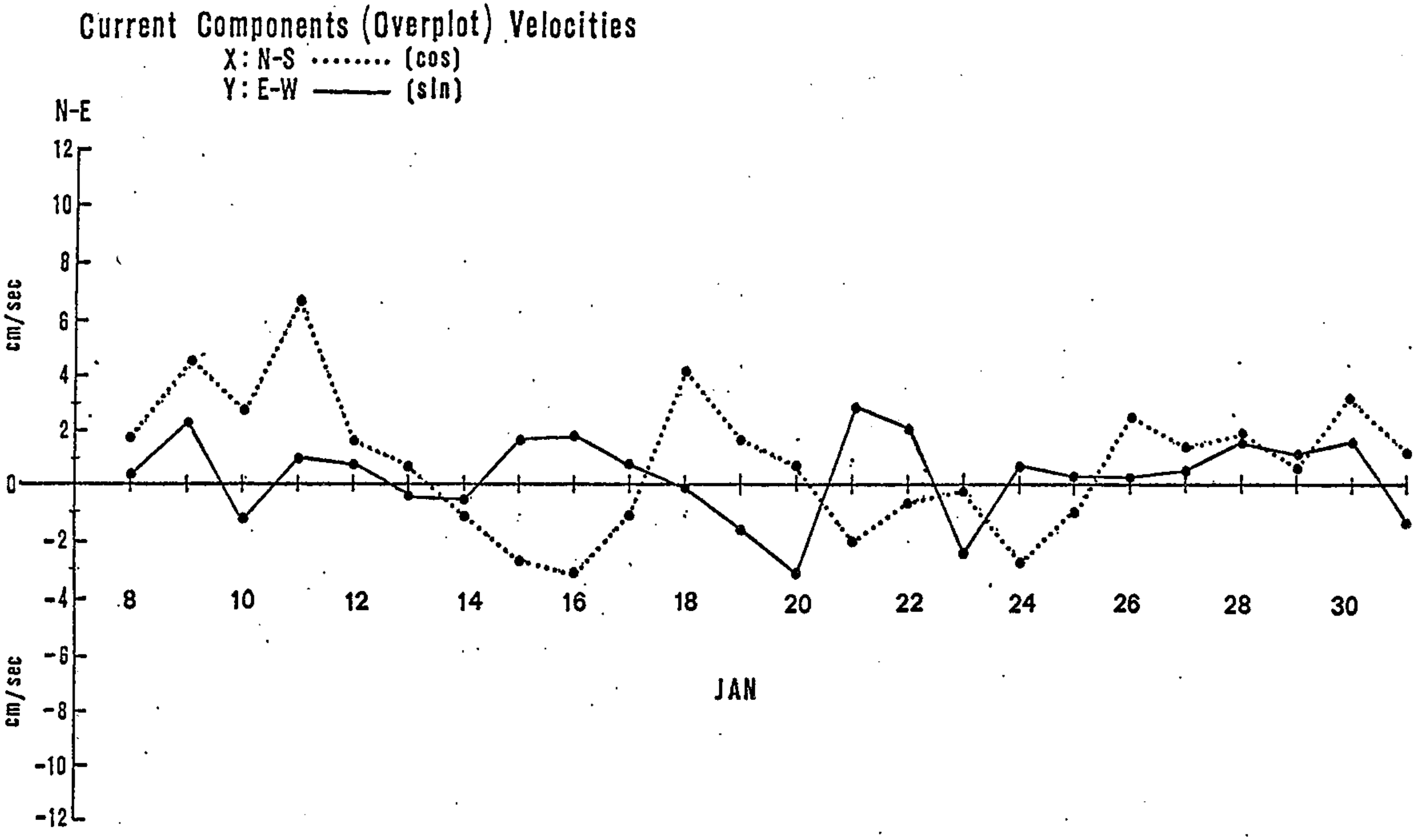


Fig. 84 - 215 m depth level 36 hours intervals vectorial components graph.

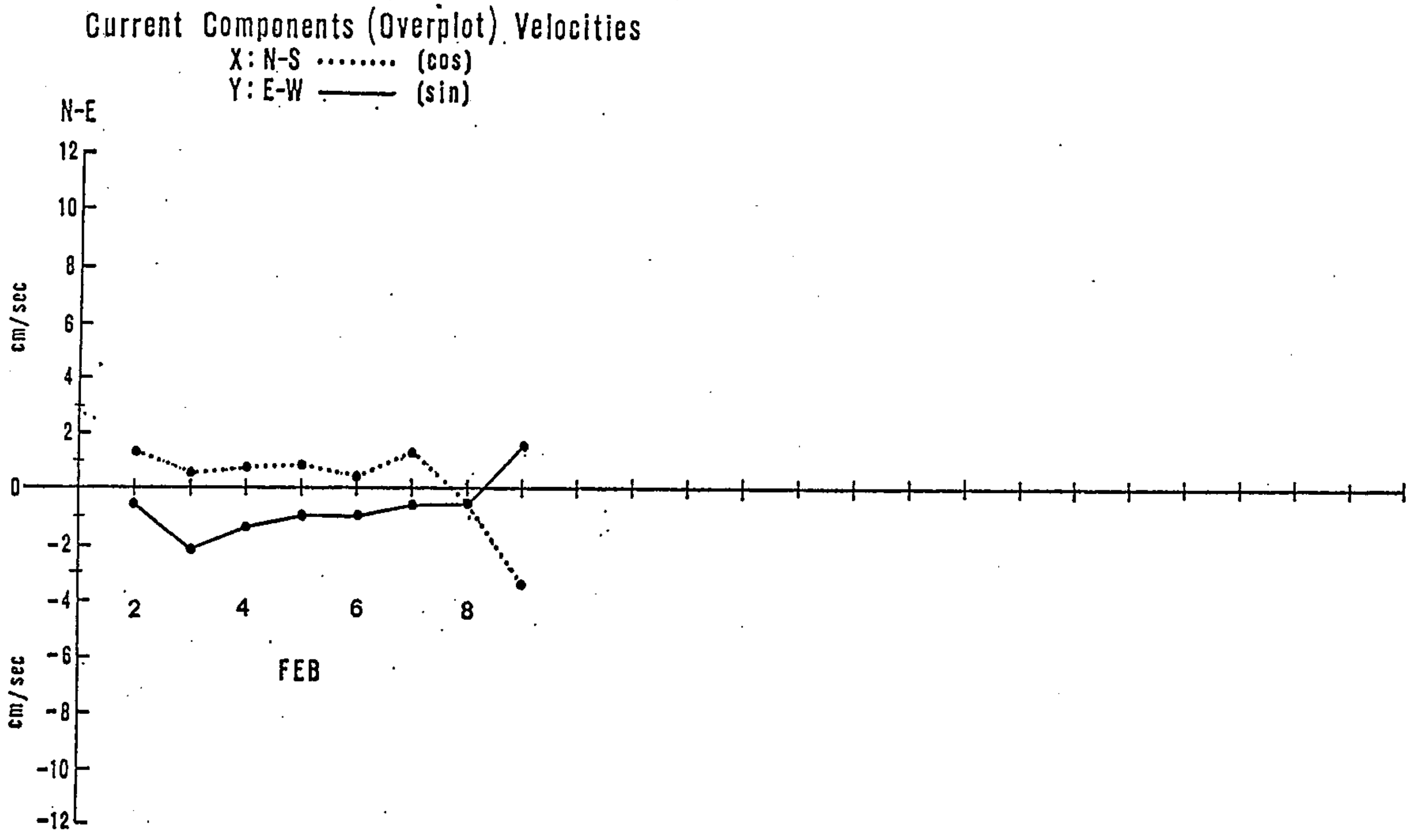


Fig. 84 - 215 m depth level 36 hours intervals vectorial components graph (cont.)

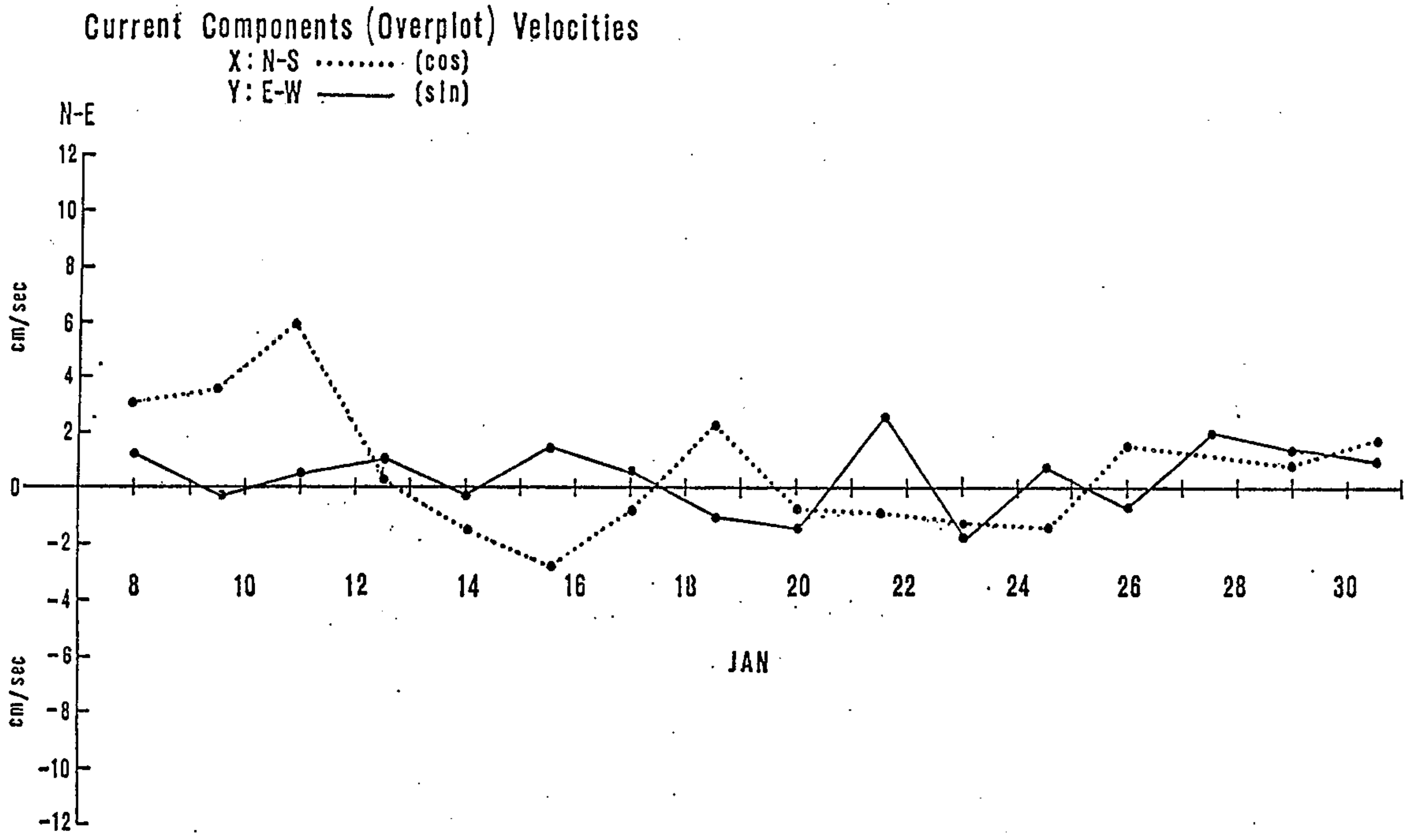


Fig. 85 - 332 m depth level 36 hours intervals vectorial components graph.

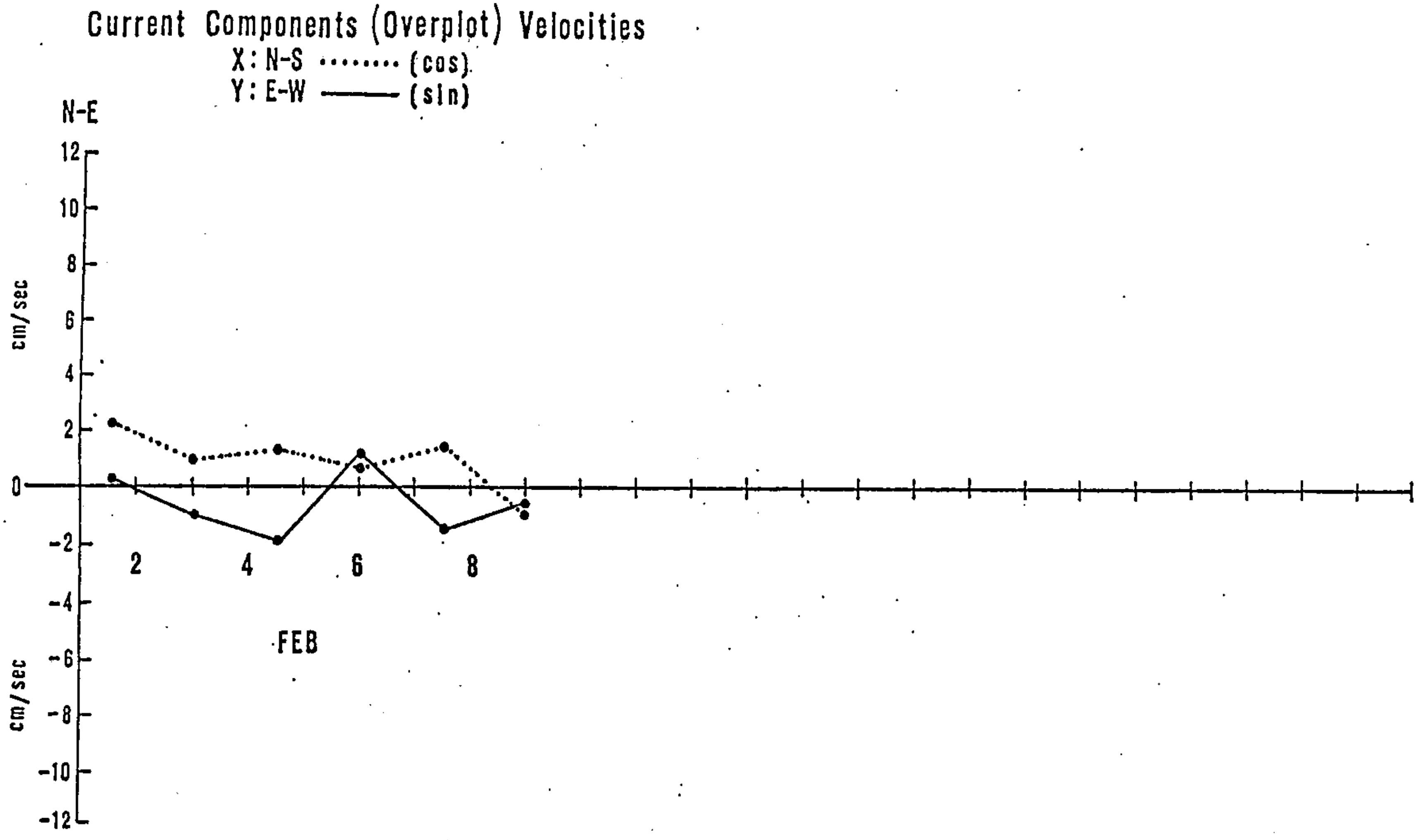


Fig. 85 - 332 m depth level 36 hours intervals vectorial components graph (cont.)

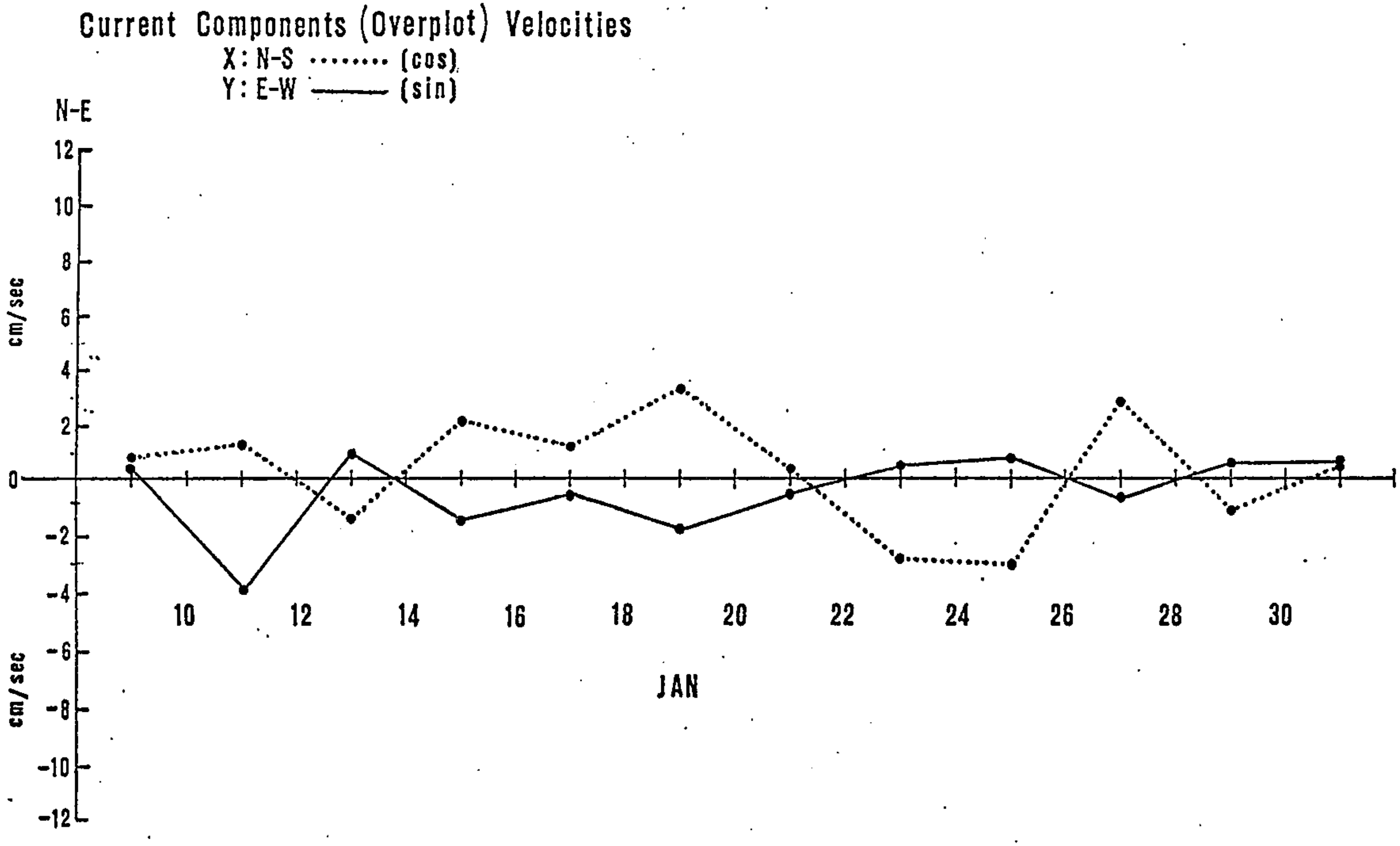


Fig. 86 - 215 m depth level 48 hours intervals vectorial components graph.

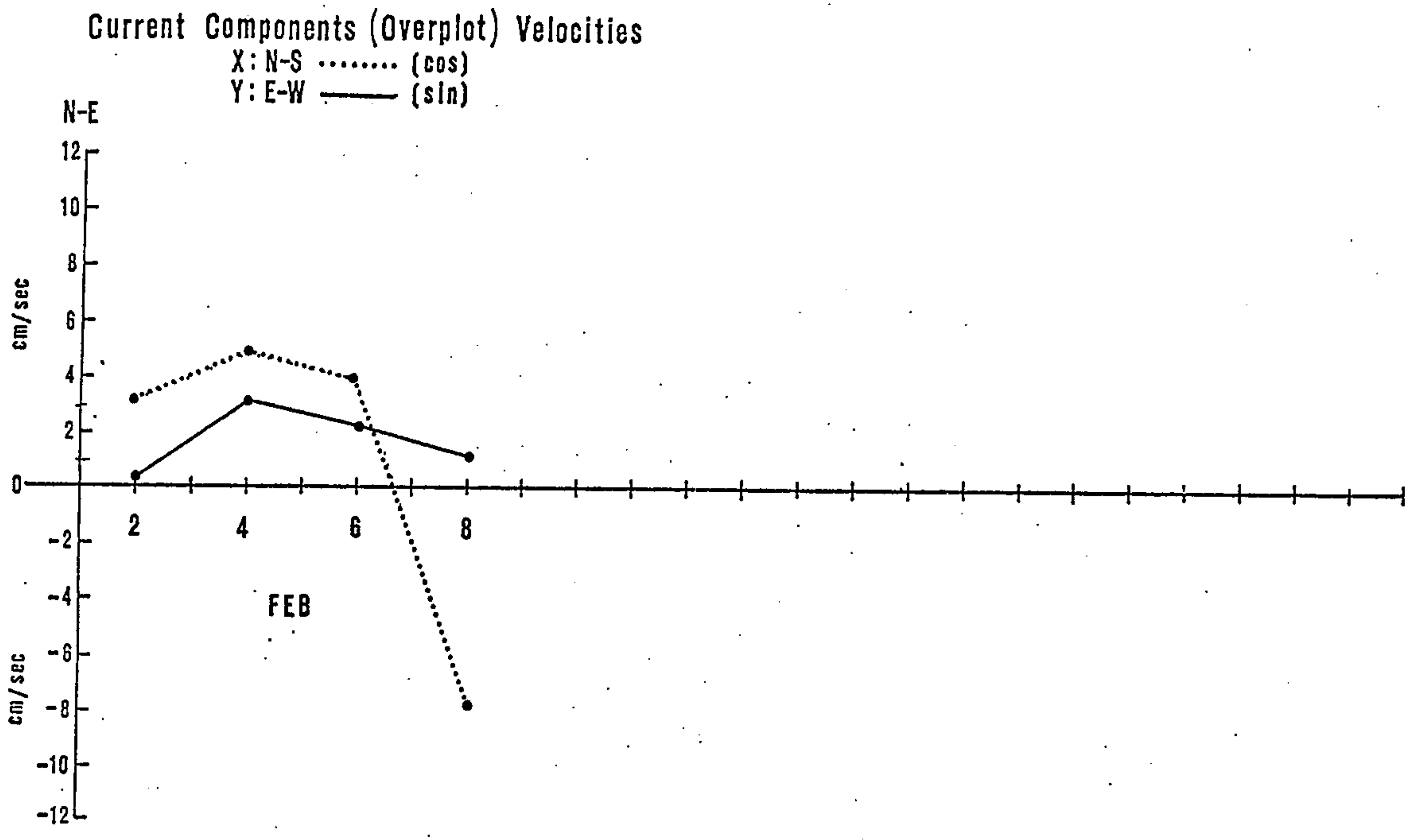


Fig. 86 - 215 m depth level 48 hours intervals vectorial components (cont.)

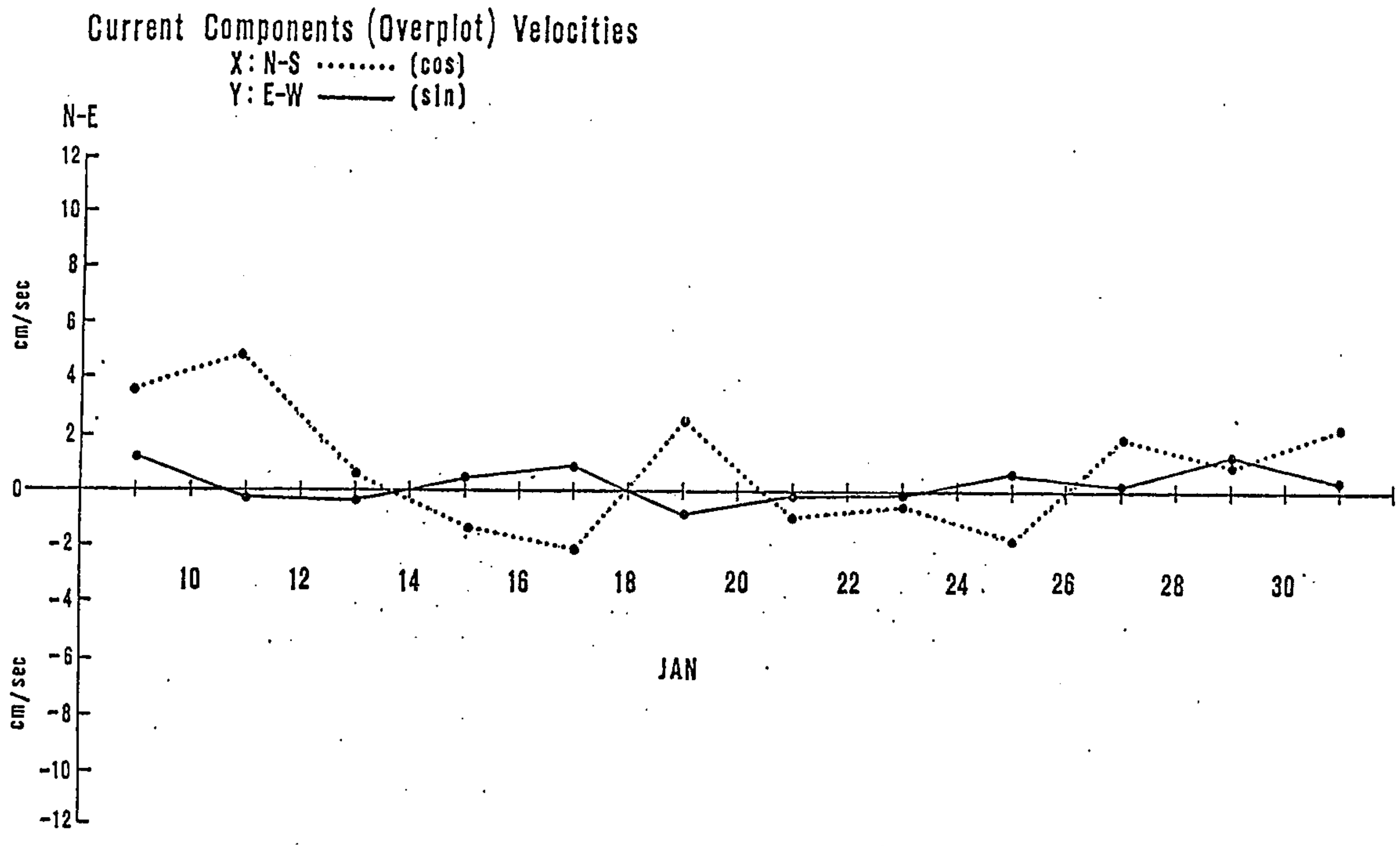


Fig. 87 - 332 depth level 48 hours intervals vectorial components graph.

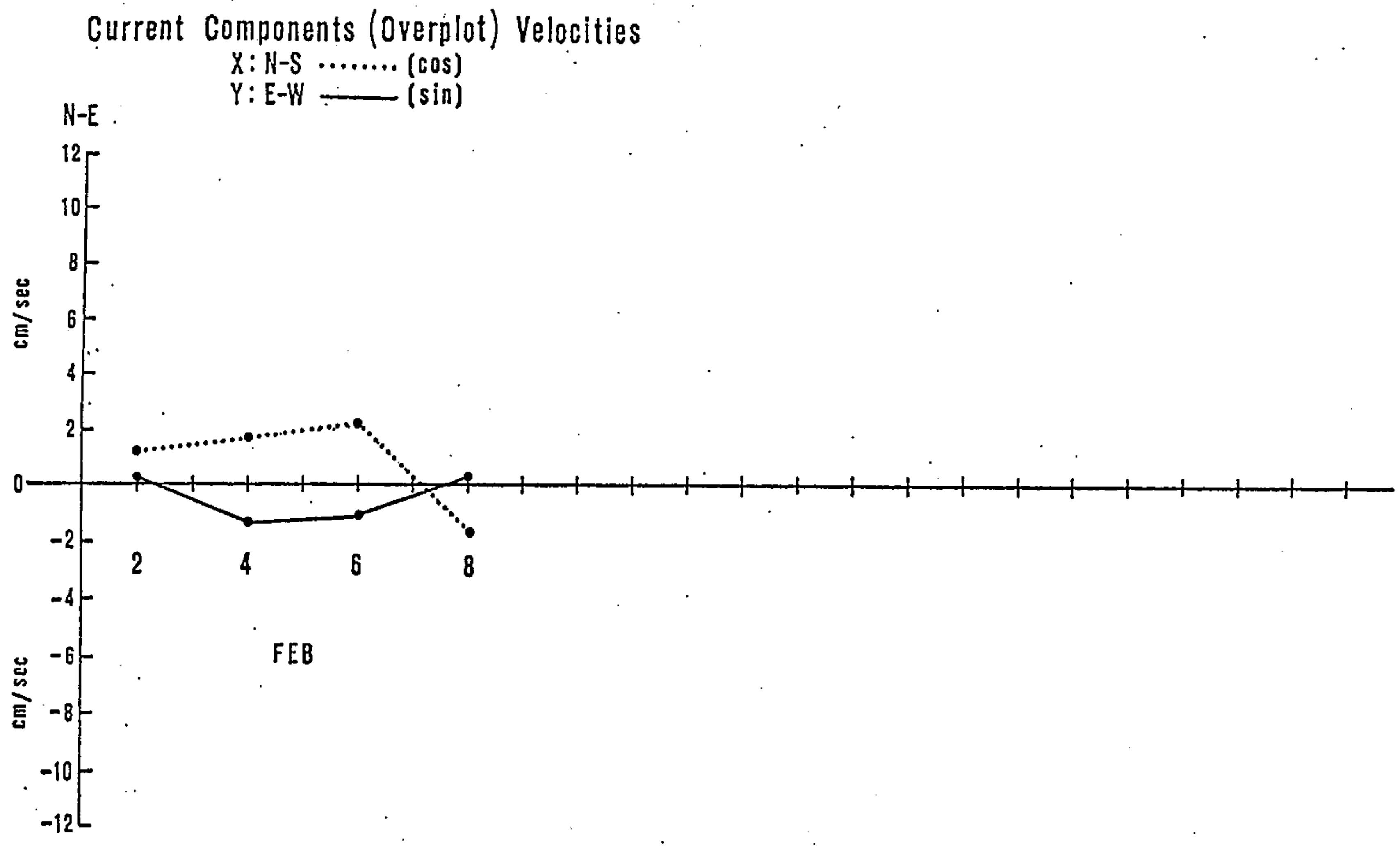


Fig. 87 - 332 m depth level 48 hours intervals vectorial components graph (cont.)

It should be noted that resulting drift from 33-days current meters record is not necessarily representative of all currents measured during that time. Not only are currents of tidal and inertial periods present, but longer-period oscillations that are variable, steady, strong and/or weak at irregular intervals on the record can be present. These types of oscillations make interpretation of a current meter record questionable in terms of resulting flow.

Various investigators have reported east flowing currents at the Punta Tuna Site area (Atwood et al., 1976; Metcalf, 1976; Stalcup et al., 1975). Circulation patterns description at depths below the surface levels have been determined by geostrophic flow calculations. Sturges (1970) and Stalcup et al., (1975) reported that marked variations in both speed and direction at frequencies including seiche periods, semidiurnal and diurnal tidal periods, and longer periods of the order of days or weeks have been measured on the southern part of the Jungfern Passage, which encompasses the Punta Tuna Site area.

Metcalf (1976) describes the 200 to 400 meters water layer at the southern end of the Jungfern Passage as the 18 °C water where there is an oxygen maximum. It can be considered, according to Sverdrup (cited by Metcalf, 1976), as Tropical Atlantic Central Water having Θ-S characteristics intermediate between the more saline North Atlantic Central Water and the less saline South Atlantic Central Water. Circualtion at this layer supposedly is toward the Caribbean Sea, coming from the Atlantic through the Anegada Passage (Metcalf, 1976).

The present data suggest that the effect of several dynamic and submarine morphological forcing factors should be investigated in order to determine the long-term circulation variablility. These are as follows:

1. The action of tidal funnelling effects through the Vieques and Jungern Passages,

2. Presence of long-term Ekman's circulation effects at deeper layers,
3. Effect of the submarine morphology in the area,
4. The presence of seiches periods fluctuations and
5. The presence of long-period eddies.

To determine these forcing factors comprehensive, long-term currents measurements at deeper water levels and several locations in the area are necessary. Resultant water flow might possibly be in an opposite direction in deeper waters (east) to what is generally thought of at present (westerly).

3.5 Dissolved Oxygen

During each cruise, samples for dissolved oxygen (D.O.) determination were taken at both day and night periods except for the first cruise (August 1978), which was terminated early with only the day-time samples being taken. The samples were usually taken around noon and midnight. The depths sampled extended from the surface to about 1000 m deep. Figure 88 shows the result of all the collected data, combining both the day and night results for all six data sets. This figure is included to show the general trend and scatter of the D.O. data the the Benchmark station throughout the year. Generally the D.O. level remained above 4 ml/l from the surface downward below the pycnocline, and below the Subtropical Underwater. At, or near the core of the Antarctic Intermediate Water, 600-800 m deep, lies the D.O. minimum of 2.7-3.2 ml/l. The D.O. values then rise to almost the surface values (3.5-4 ml/l) at 950-1000 m. This general curve is well documented for the Caribbean (Wust, 1964).

These D.O. values indicate a high degree of saturation of oxygen at the surface (about 70%). The percent of saturation at the oxygen minimum depth is only about 30%.

Figures 89-94 represent the D.O. profiles for each of the six cruises, consecutively. For each cruise (except August, 1978) both the day and the night values are shown. Generally, the night values average slightly higher than the day averages, but by only 0.1-0.2 ml/l, as seen in Figure 95. This difference is not important biologically or chemically, when compared to the typical values of 3-4 ml/l. At two depths, nearly all the night values were higher than the day values. At the 50 m depth, 100% of the night values exceeded the values measured during the daylight hours. At about 250 m depth, 80% of the measurements showed night values higher than day values. Both of these depths may be important to an OTEC plant, and the reason for the day/night difference should be investigated. The 50 m depth frequently lies near the upper portion of the pycnocline, or the boundary between

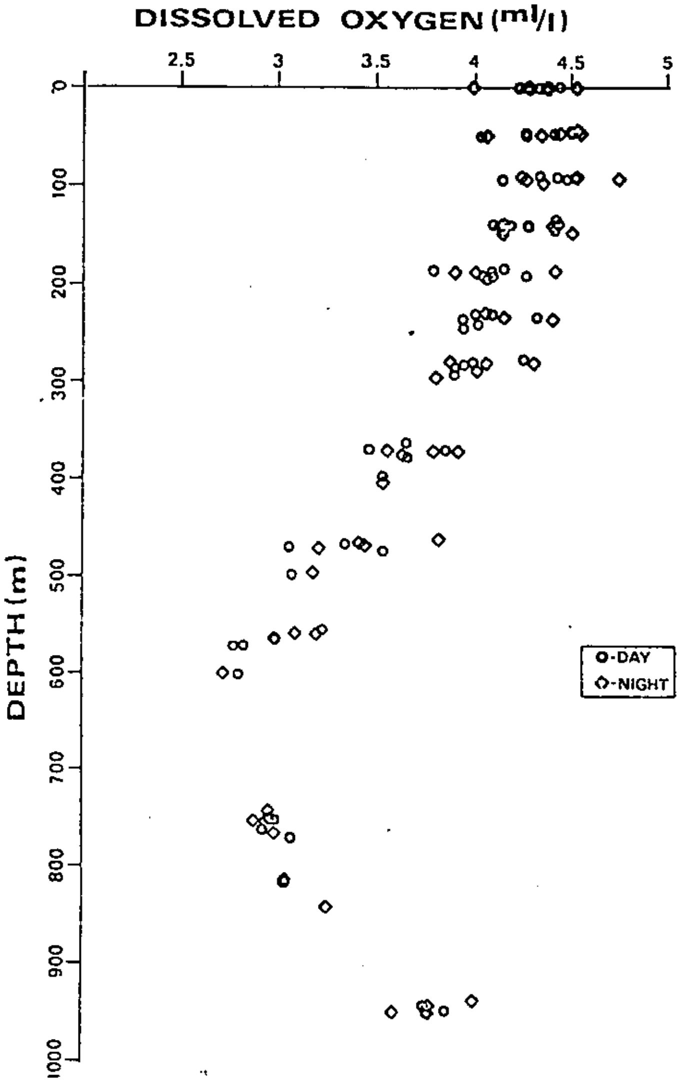


Fig. 88 - Dissolved oxygen profile for all data collected at Punta Tuna from August, 1978 to June, 1979.

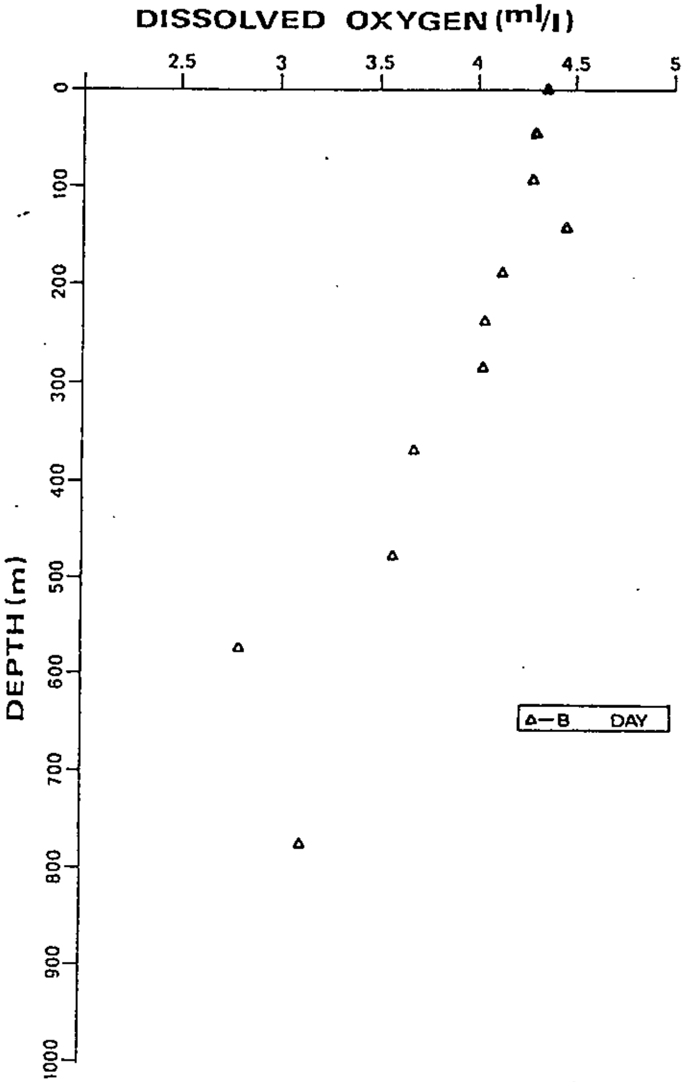


Fig. 89 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of August, 1978.

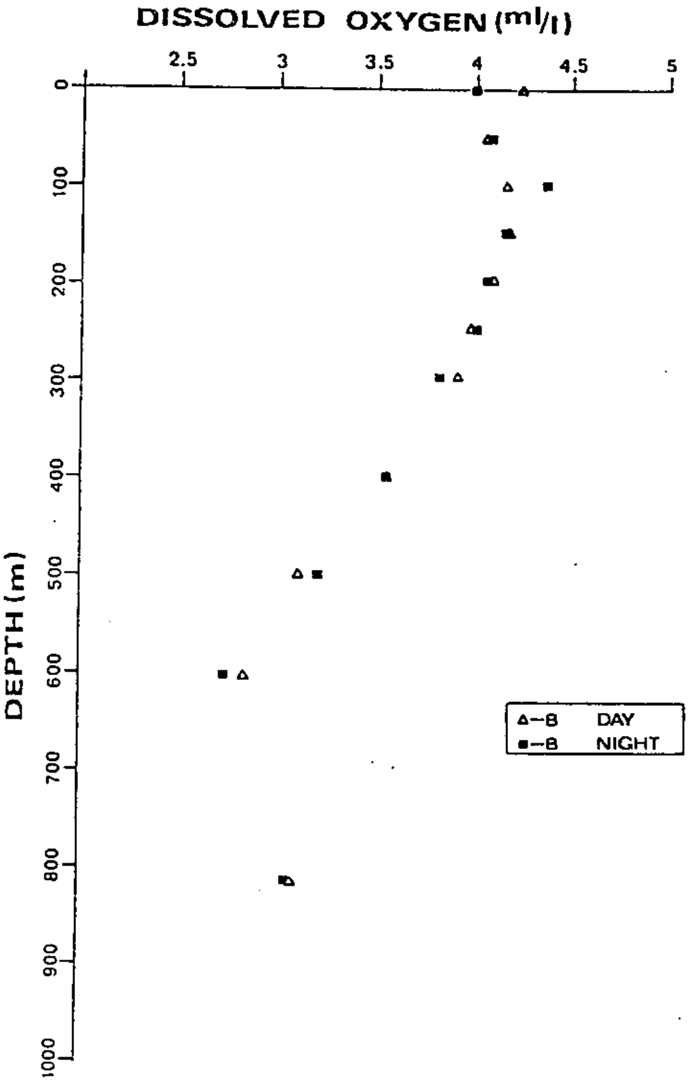


Fig. 90 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of October, 1978.

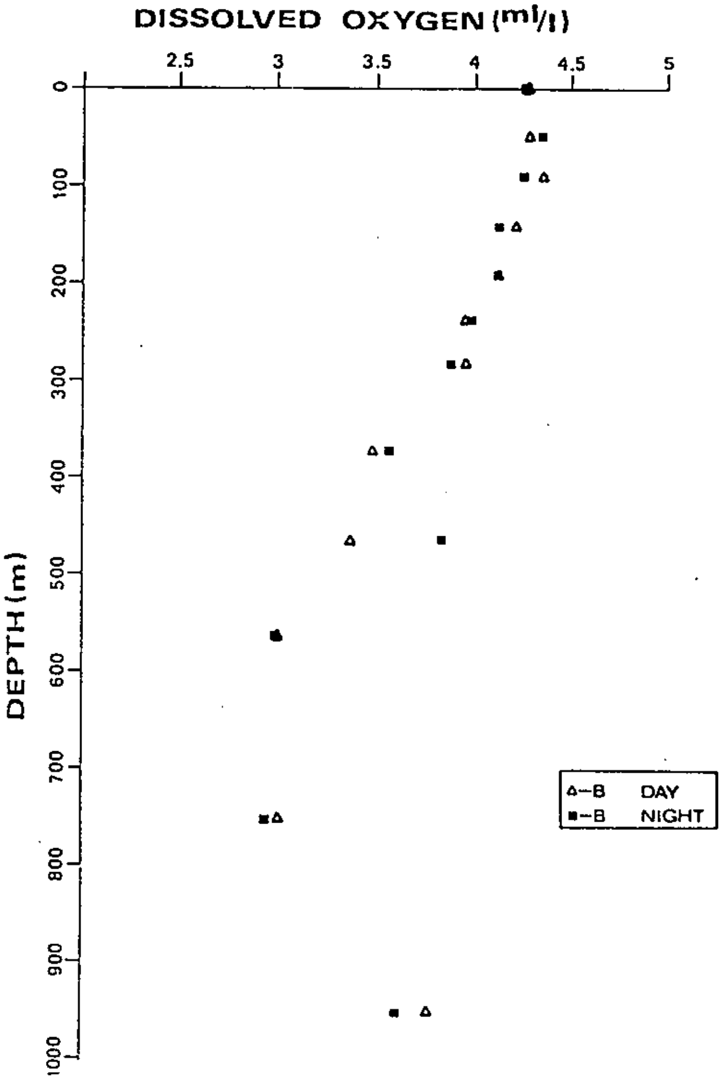


Fig. 91 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of December, 1978.

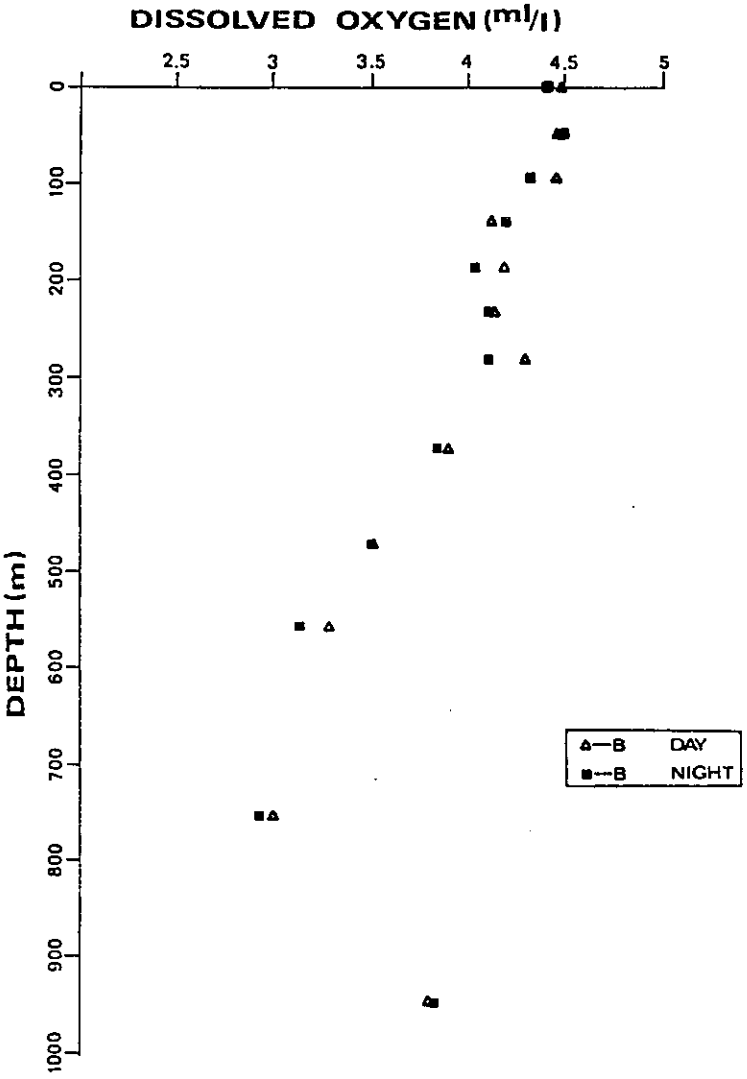


Fig. 92 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of February, 1979.

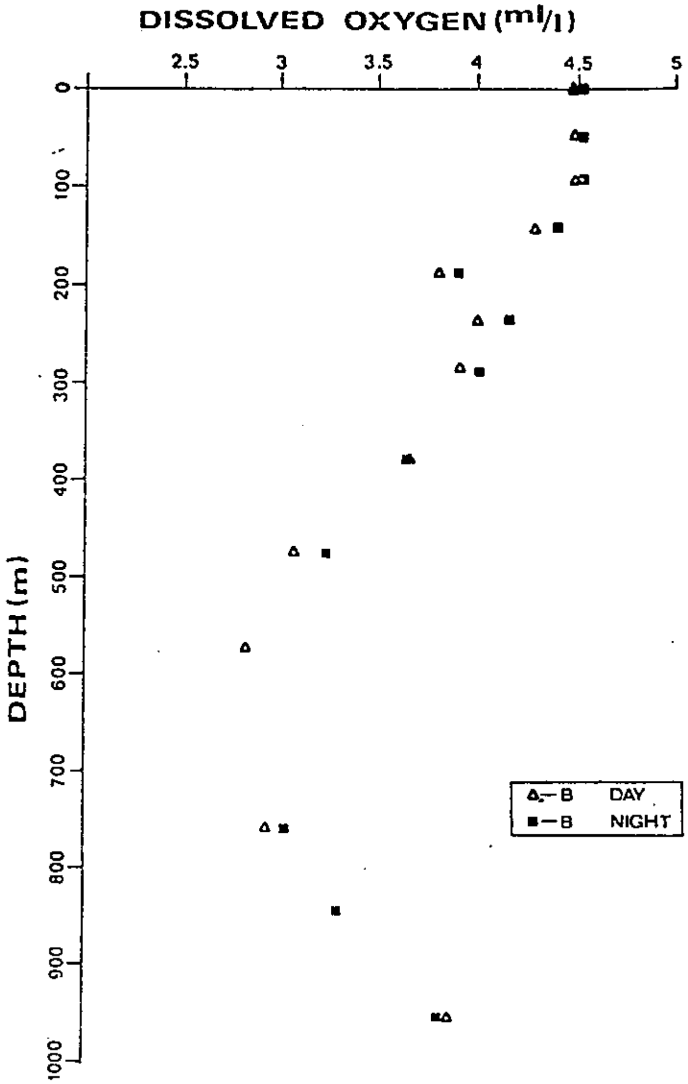


Fig. 93 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of April, 1979.

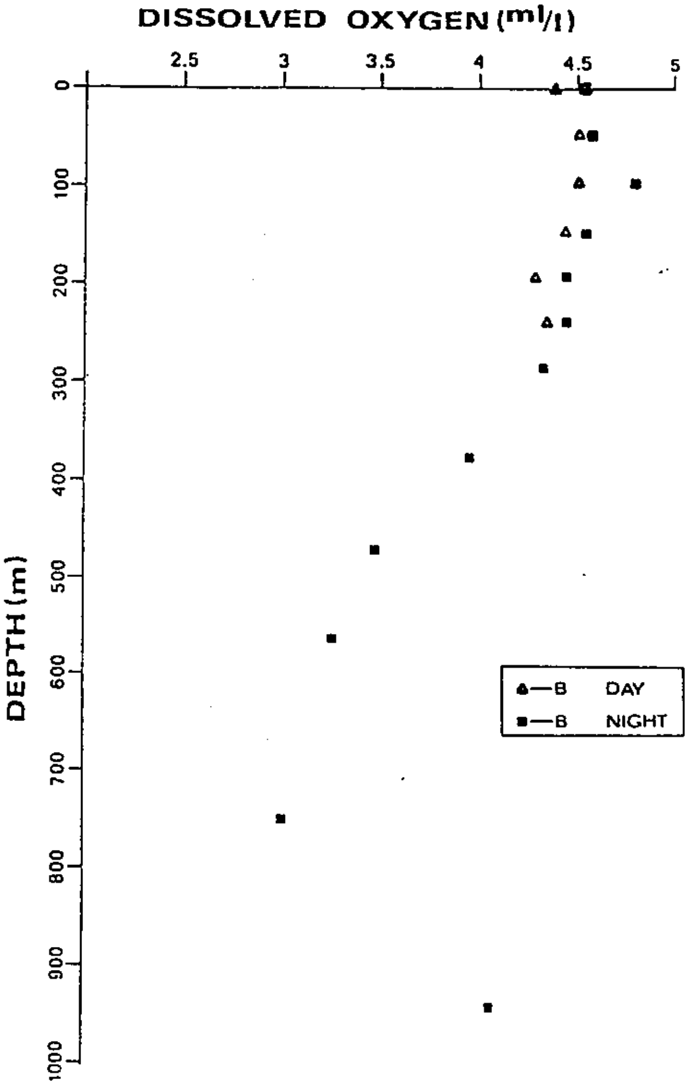


Fig. 94 - Dissolved oxygen profile for data collected at Punta Tuna during the cruise of June, 1979.

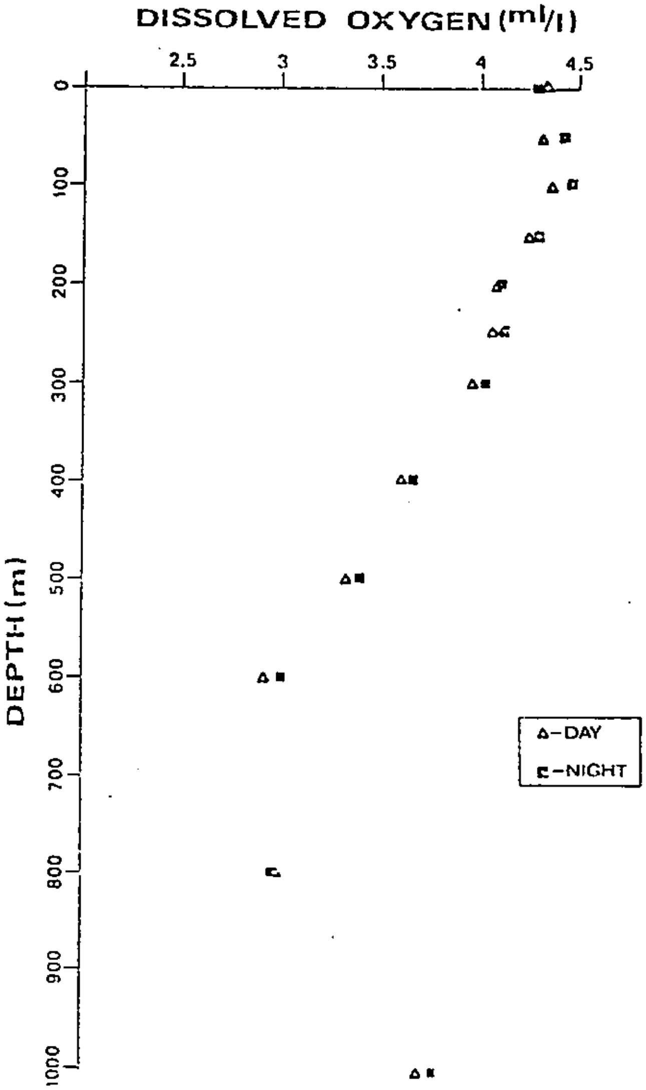


Fig. 95 - Average dissolved oxygen profile for all data collected at Punta Tuna from August, 1978 to June, 1979.

the Upper Mixed Layer and the Subtropic Underwater. The 250 m depth is near the depth that a mixed discharge may rest, at least temporarily during some temperature/salinity conditions during the year.

Figure 89 shows a nearly constant D.O. value throughout the Upper Mixed Layer. At the depth of the salinity maximum (about 150 m from Fig. 23), an oxygen maximum is also observed during the August 1978 cruise. From here downward, the D.O. is seen to slowly decrease to 3.5 ml/l between 450-550 m depth. Below this depth a sharp D.O. discontinuity occurs, with a very low value of 2.7 ml/l occurring at about 575 m. By 800 m the value has risen again to over 3.0 ml/l. During the October 1978 cruise (Fig. 90), again an unusually high D.O. value is seen at the salinity maximum depth. At this time, both the salinity maximum (Fig. 24), and the D.O. maximum were closer to 100 m deep. During this cruise, the D.O. values seem to have a more smooth and continuous decrease to the oxygen minimum of about 2.7 ml/l near 600 m deep.

Figure 91 shows the high (4.1-4.3 ml/l) values of D.O. throughout the upper 200 m. This occurred in spite of only a 70 m deep MLD. From these high values, the D.O. decreased smoothly (except for the night value at 470 m possibly a measurement error) to about 575 m. During this cruise the sampling missed the oxygen minimum depth, but it was probably between 575-750 m. The D.O. during February 1979 (Fig. 92) was 4.0 ml/l or higher from the surface to about 300 m. Again, from this depth downward to about 575 m the D.O. decreased smoothly. The oxygen minimum was located about 750 m deep at this time.

During the April 1979 cruise (Fig. 93), the upper 100 m had virtually constant D.O. values throughout, with only a small decrease at about 150 m (4.5-4.3 ml/l). However, at 190 m, a sudden decrease is seen to almost 3.8 ml/l during both the day and night sampling. Below this depth the values rise to more typical values of about 4 ml/l and slowly decrease downward as seen on the previous cruises. Neither temperature (Fig. 12) nor salinity (Fig. 27) show any abnormalities at or near this depth that could be related to the high oxygen consumption. However, Figure 102 (which will be discussed in Section 3.6) shows abnormally high chlorophyll values, about 5-10 times normal, at slightly more shallow depths of 100-125 m. As the chlorophyll were seen in greater quantities at night only, apparently the large numbers of phytoplankton were able to reduce the available oxygen by a measureable amount.

The June 1979 cruise (Fig. 94) had very high and very uniform D.O. values (4.6-4.3 ml/l) down to about 300 m. The only exception was a slightly high value again seen at 100 m. This was very close to the depth of the salinity maximum (Fig. 28). During this cruise there was almost no Upper Mixed Layer, except as seen using the D.O. values. The remainder of the water column appeared typical at this time.

Figure 96 and 97 represent the time series of the day and night dissolved oxygen values respectively during the measurement program. Both figures show a general trend toward increasing values of D.O. throughout the measurement period in the upper 200 m. The upper water temperature was warmest in October (Fig. 14), corresponding to the low upper-water D.O. as saturation of oxygen decreases with increasing temperature. The low October D.O. may be explained as maintaining the same percent of saturation (70%), but able to hold less gas. As the temperature decreases through February and April, D.O. increases in the upper waters. The D.O. values deeper than 500 m do not appear to change much throughout the year. Between 200 and 450 m, a change in the D.O. is seen. However, it is in this depth range that the day-night values are differing, and most of time series differences at these depths may correspond to specific bioactivity during the measurements, as opposed to overall annual trends.

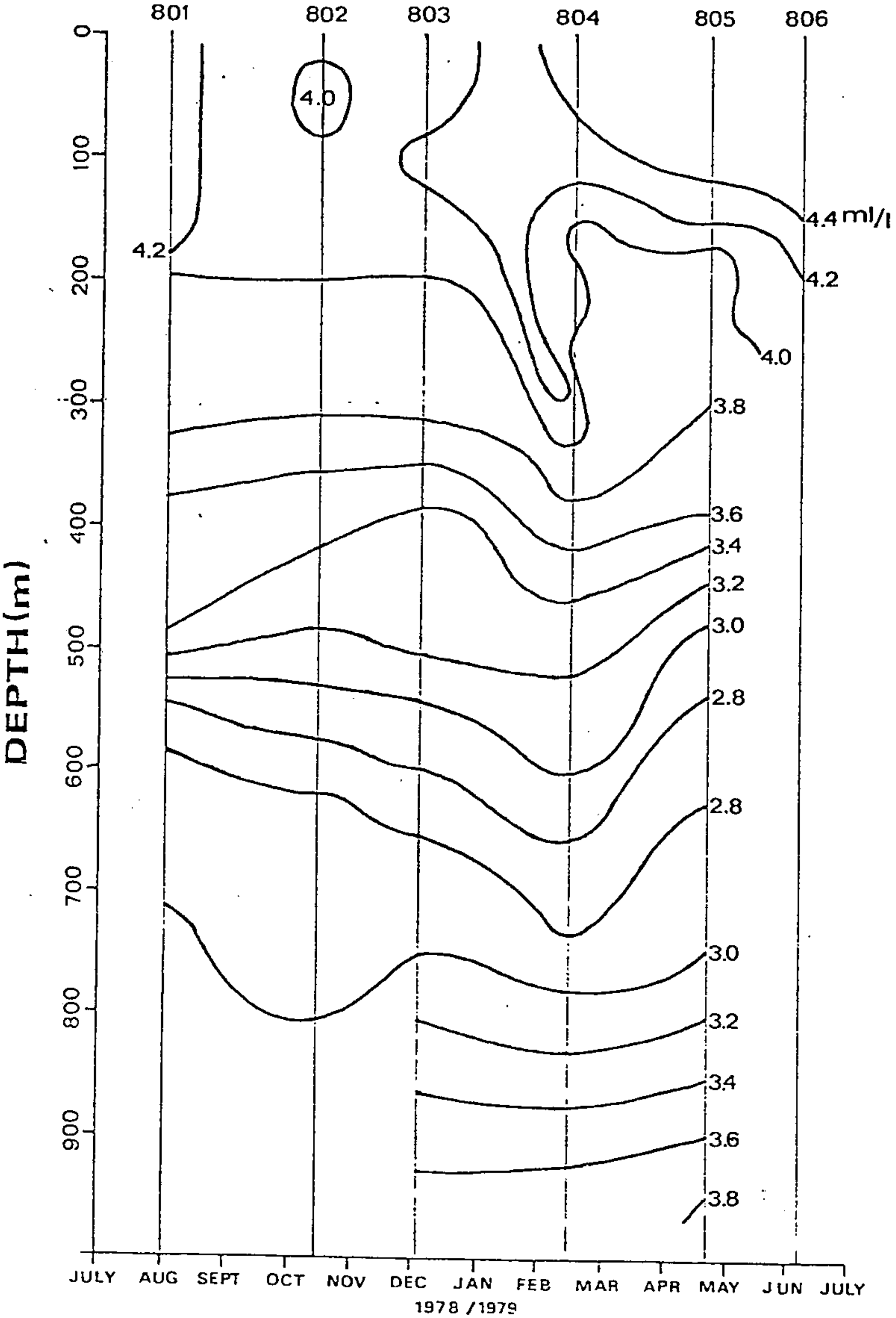


Fig. 96 - Time series for dissolved oxygen data collected during daylight at Punta Tuna from August, 1978 to June, 1979.

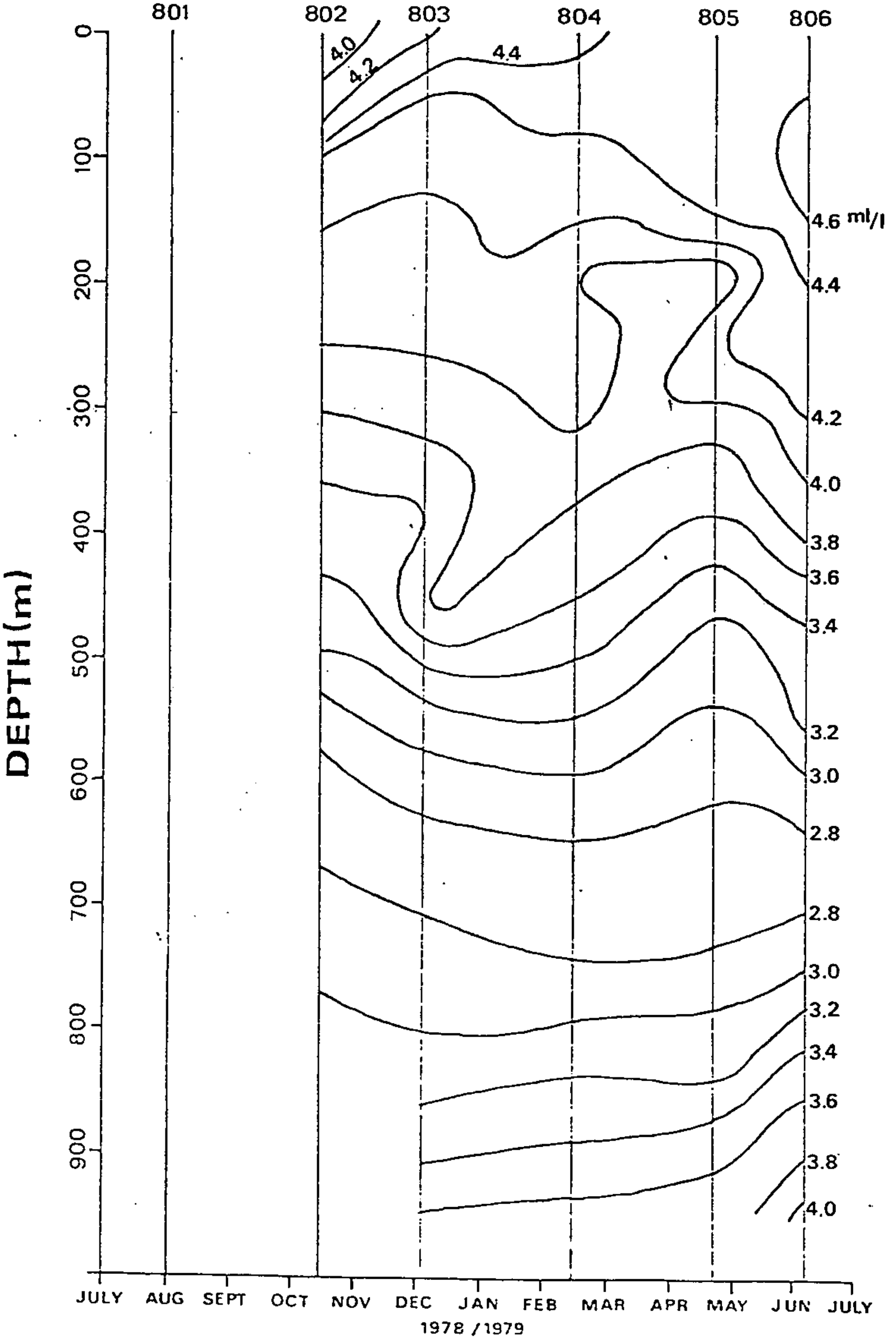


Fig. 97 - Time series for dissolved oxygen data collected during nighttime at Punta Tuna from August, 1978 to June, 1979.

3.6 Chlorophyll a Results

During each cruise, samples were taken to determine the concentration of live flora (chlorophyll a) at discrete depths down to about 400 m. These samples were taken both during a noon Biocast and a midnight Biocast, except during the first cruise, which was terminated before the night Biocast could be made.

Figures 98-103 show the chlorophyll a profiles vs. depth for both the day and night casts for each of the 6 cruises. Also, shown on each figure is the water density profile for comparison.

By studying the figures of the six cruises, the following points can be seen. First, during the August 1978 cruise, (Fig. 98), improper filter paper was used for chlorophyll analysis, and the results were poor. Many of the values were not reproducible, and this data should probably be discounted.

Starting from the second cruise, a pattern may be visible. From figures 99-103, it appears that the day and night chlorophyll values seem surpressed somewhat by the pycnocline. The number of viable cells seen in each sample were generally higher below the pycnocline than above. This implies difficulty in passing through this strong density gradiant. This same depth gradiant was seen by Beers, et al., (1968).

During the April 1979 cruise (Fig. 102) the chlorophyll a values were 5-10 times higher at the 100-125 m depths than the values seen at any depth during the other cruises. Typical values at this depth were 0.1-0.3 µg/l, but during April the values were 0.9-1.5 µg/l during the night sampling. This type of anomalously high value might normally be attributed "normal patchiness", however, it also corresponded to an easily measurable dissolved oxygen decrease at about the same depth throughout the day. (Please see Fig. 93). This high concentration of phytoplankton may possibly have been present during the other cruises and may have been missed by our discrete sampling procedure, however, the dissolved oxygen

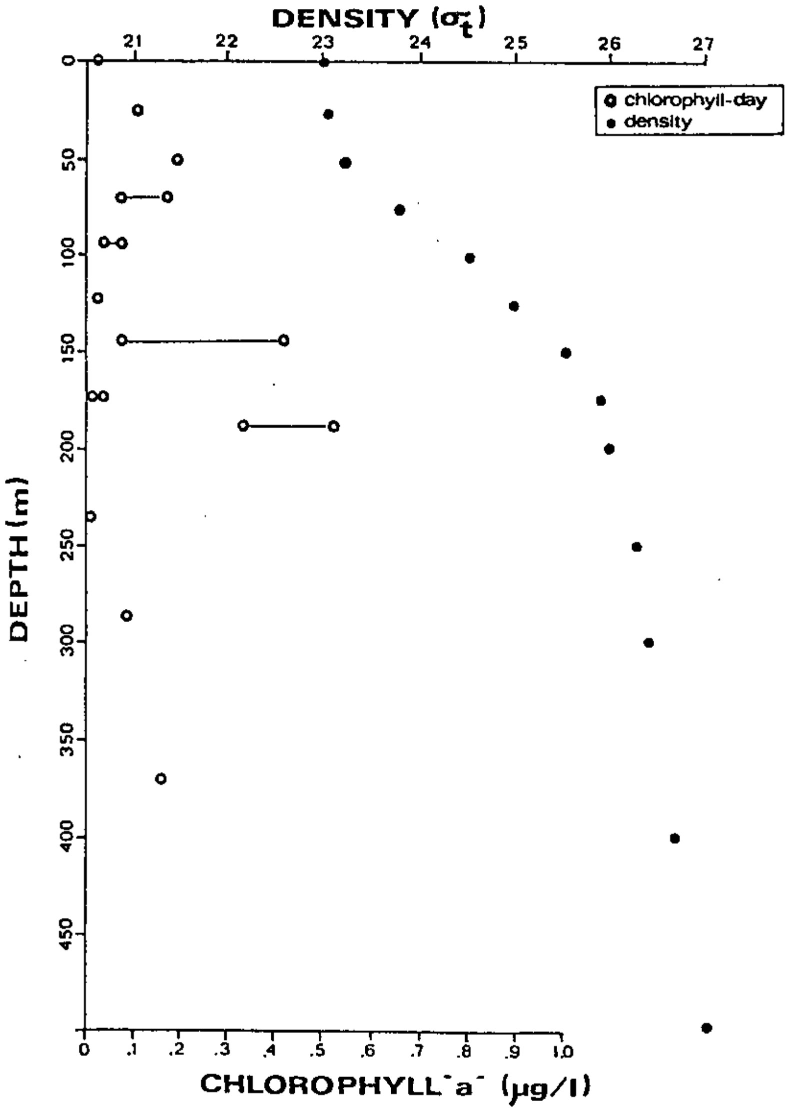


Fig. 98 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of August, 1978.

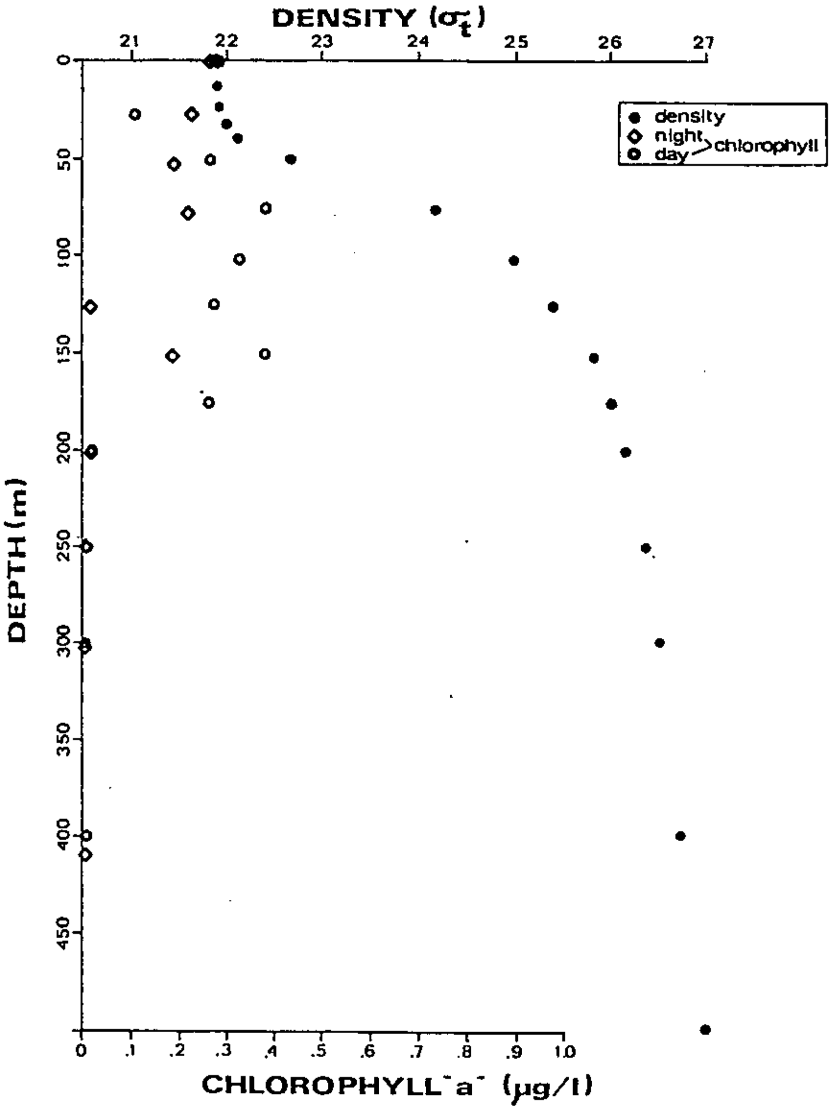


Fig. 99 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of October, 1978.

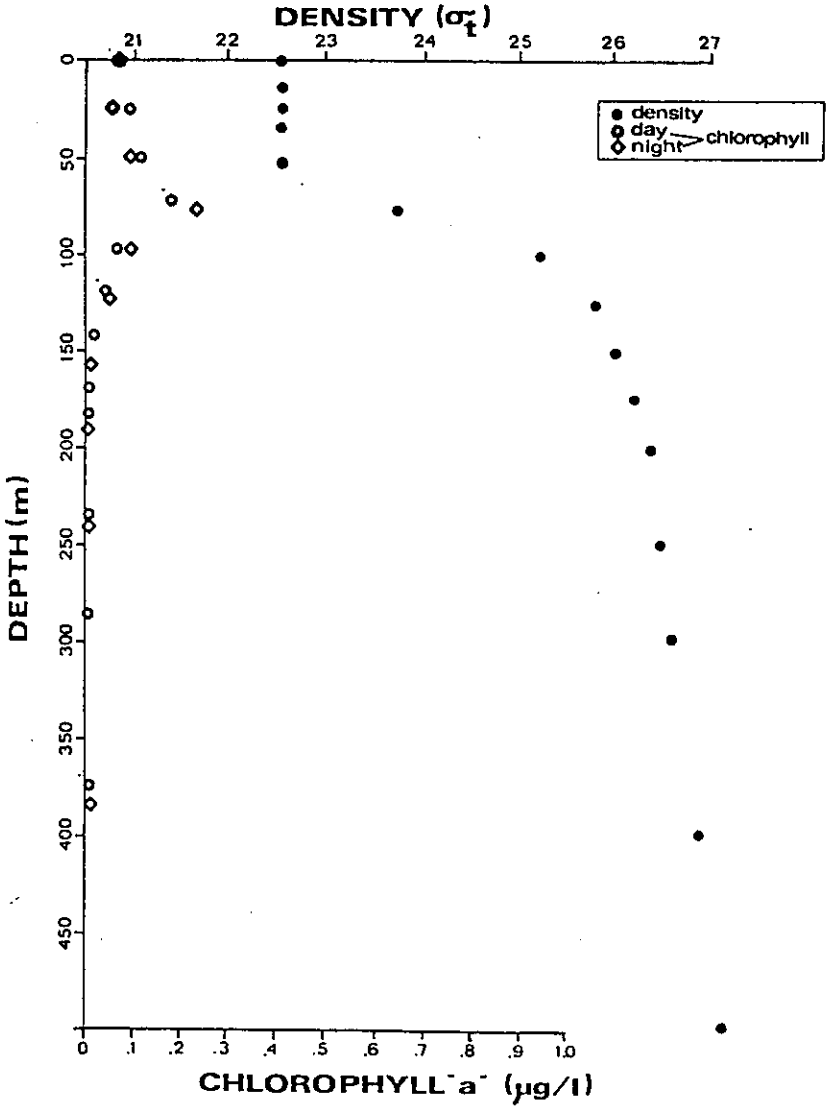


Fig. 100 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of December, 1978.

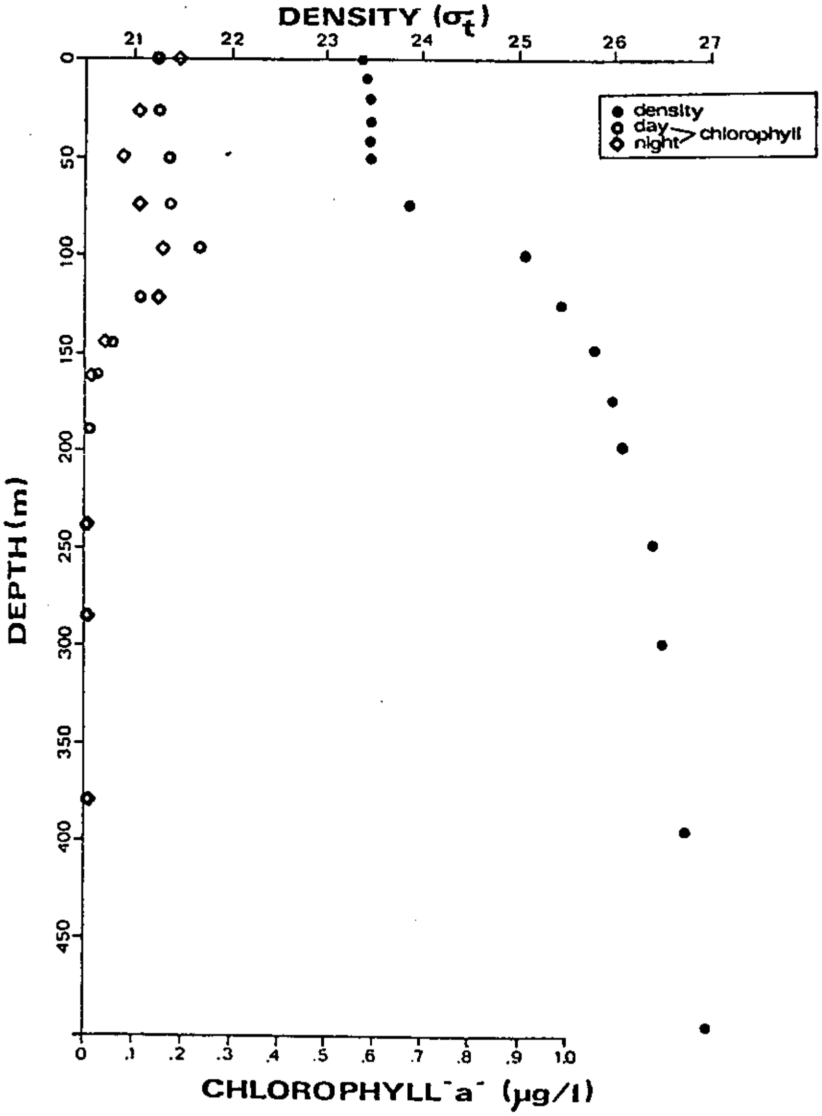


Fig. 101 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of February, 1979.

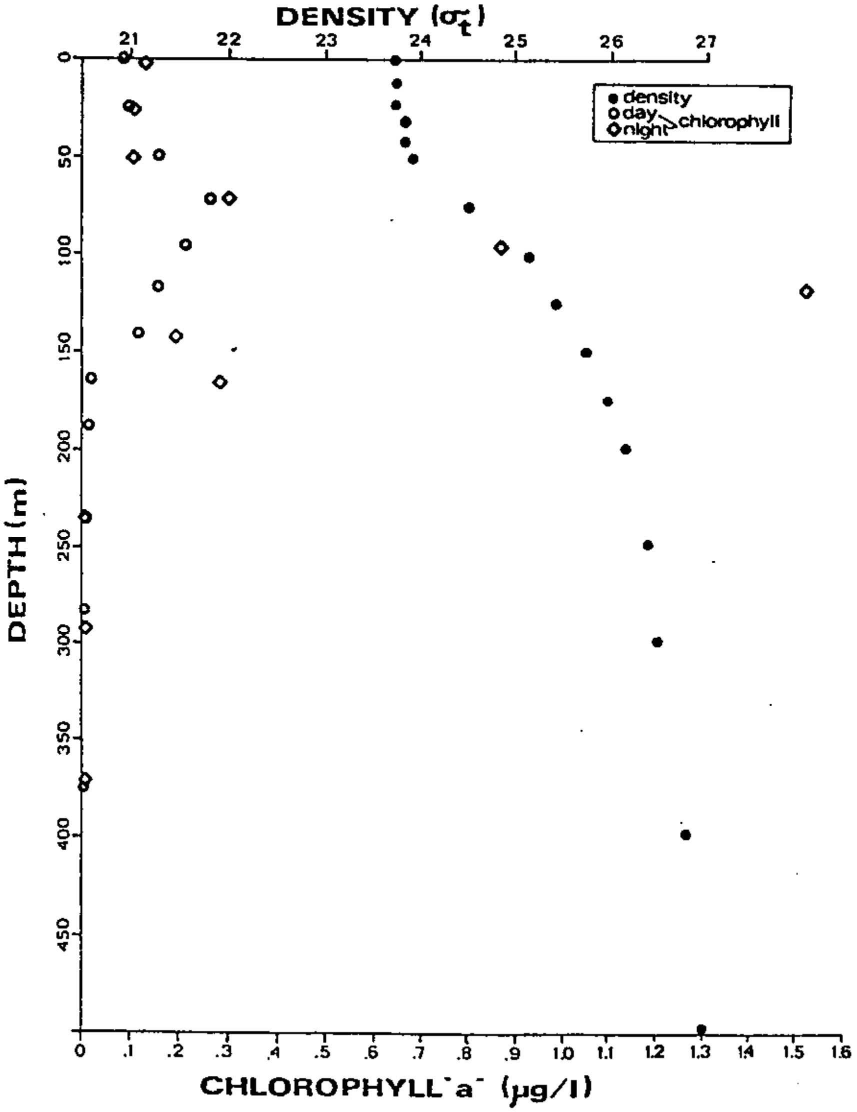


Fig. 102 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of April, 1979.

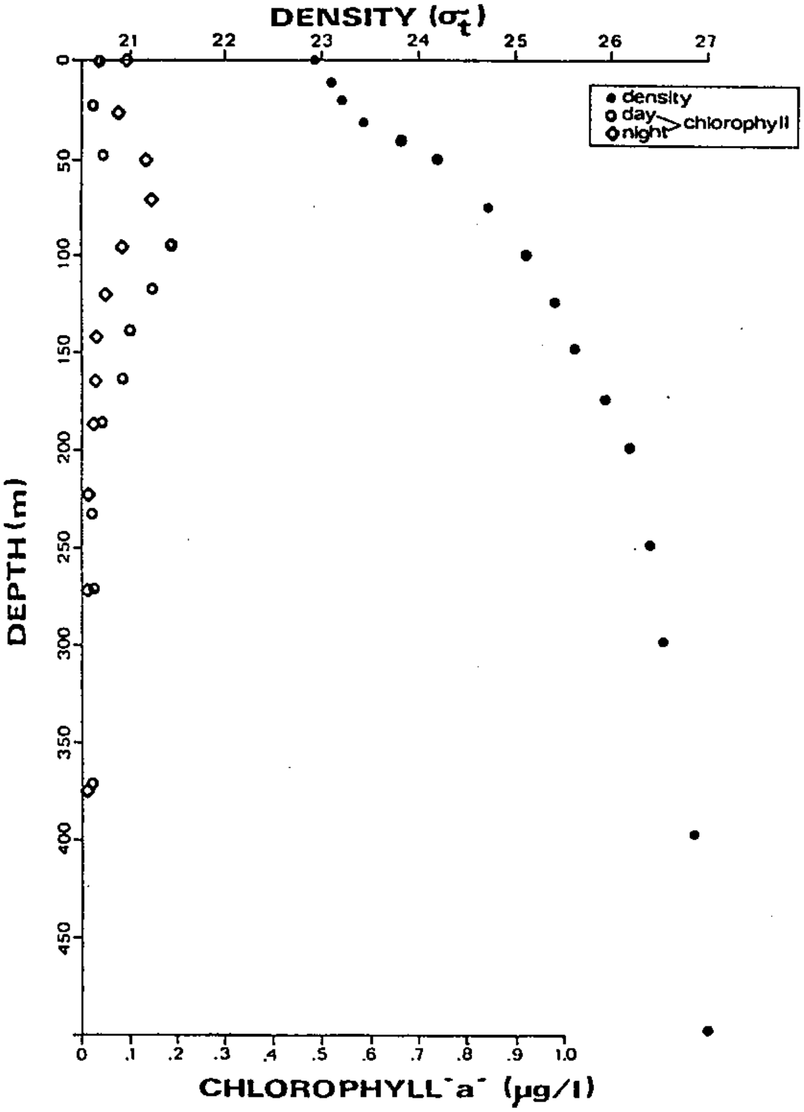


Fig. 103 - Chlorophyll "a" profile observed at Punta Tuna during the cruise of June, 1979.

concentration would probably have been surpressed if that were the case. Unfortunately, the nutrient data taken during this program was not refined enough to help explain the exceptionally high chlorophyll a values for April 1979. In fact, this chlorophyll a maximum corresponded temporarily with the highest surface salinity values (Fig. 40). According to Froelich, et al., (1978), the salinity of the Caribbean surface water is strongly influenced by the fresh water run-off from the Amazon and Orinoco Rivers. Therefore, when the salinity is lowest, the river's influence is highest, and the available nutrients might be expected to be above normal. During April the surface salinity was highest of all our cruises (Fig. 29), and therefore the rivers' influence would be expected to be minimal. With less river runoff as might be the terrestrially derived nutrients, which control the chlorophyll production in the sunlight-rich Caribbean Sea, would also be at a minimum. Therefore, this bloom may have been a temporal and spatial anomaly.

Figures 104 and 105 show the time series of the chlorophyll a values for the day and night periods, respectively. The upper waters had minimum in December 1978 and June 1979 and maximums in October 1978 and February 1979 during both the daylight and the night periods. The higher values throughout the water column are easily seen as occurring in October 1978 and April 1979. The highest overall values were seen in April, at 125 m as mentioned before. Beers, et al. (1968) also found his highest surface values during the late autumn and winter at Jamaica (specifically October), and during late autumn and winter (specifically February) at Barbados. At neither location were the peak values found as deep as 125 m.

Figure 106 shows the normalized day/night-average integrated chlorophyll a resulting from all samples taken down to 200 meters for each cruise. Relative peaks occur in August, October, and April. Also, in the figure are the values of surface salinity during each of the cruises. According to Froelich et al., (1978), the lower salinity values are due to periods influenced by the Amazon and Orinoco Rivers. These

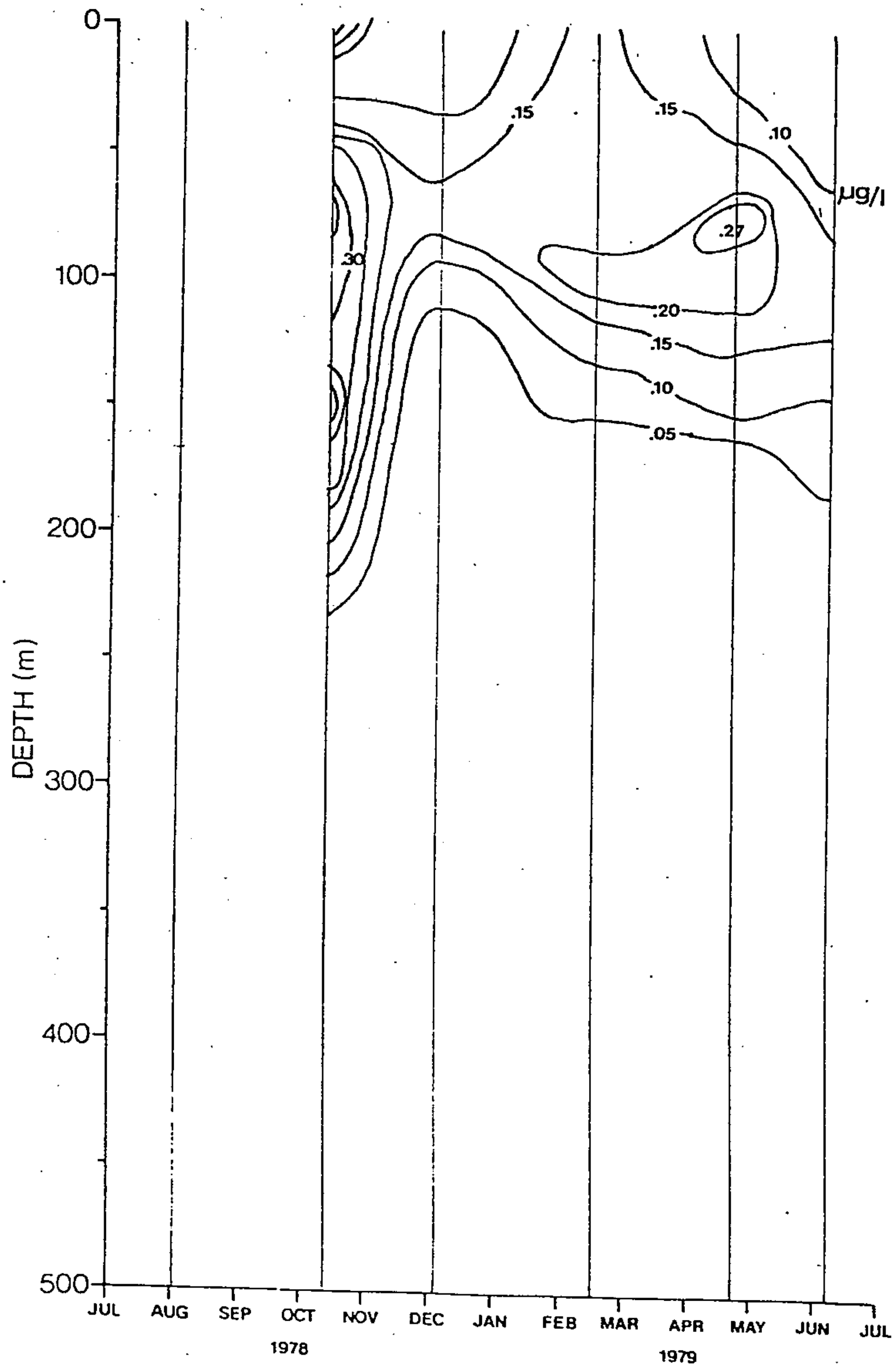


Fig. 104 - Time series of chlorophyll "a" values measured during daylight at Punta Tuna from August, 1978 to June, 1979.

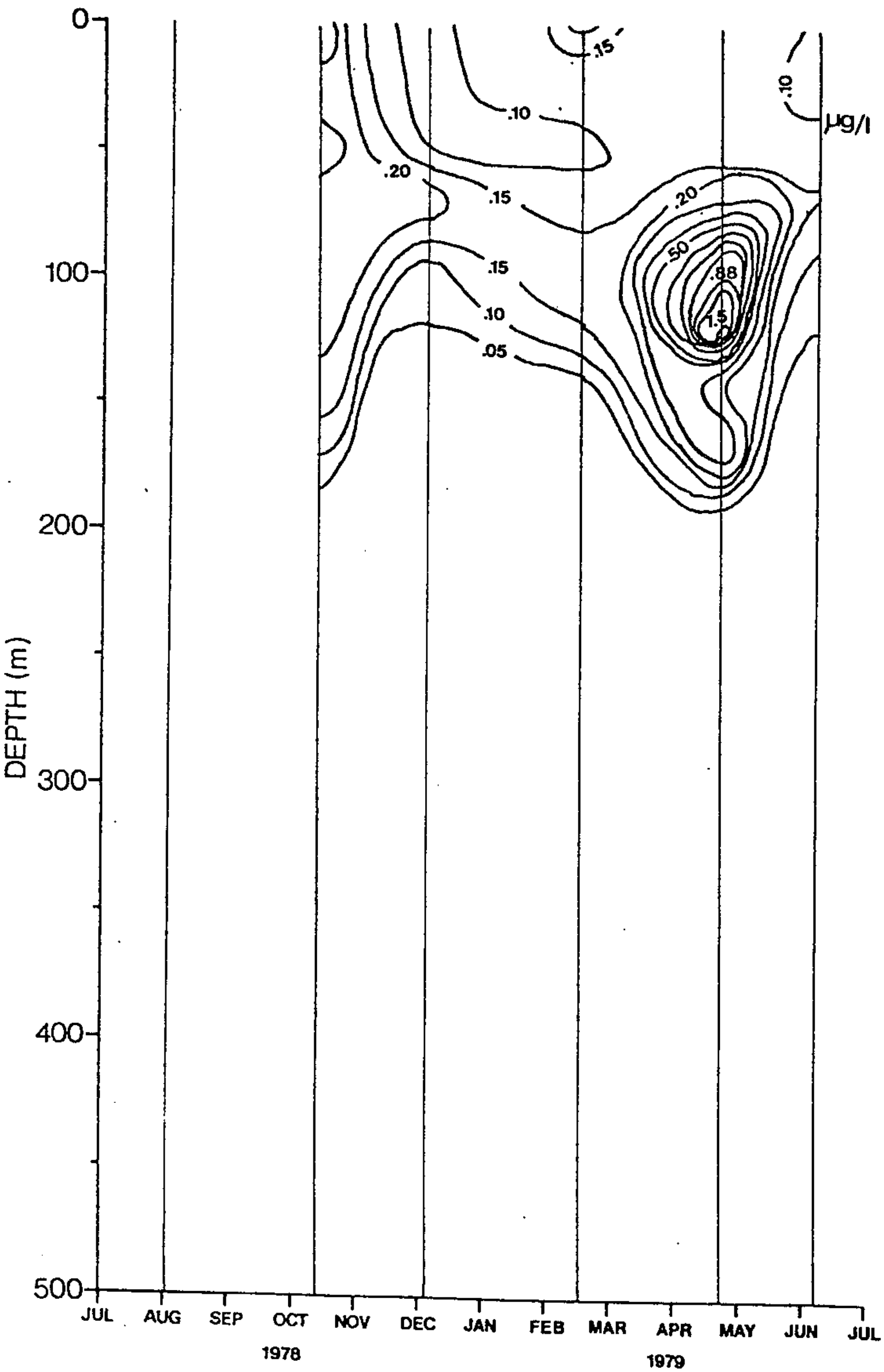


Fig. 105 - Time series of chlorophyll "a" values measured during nighttime at Punta Tuna from August, 1978 to June, 1979.

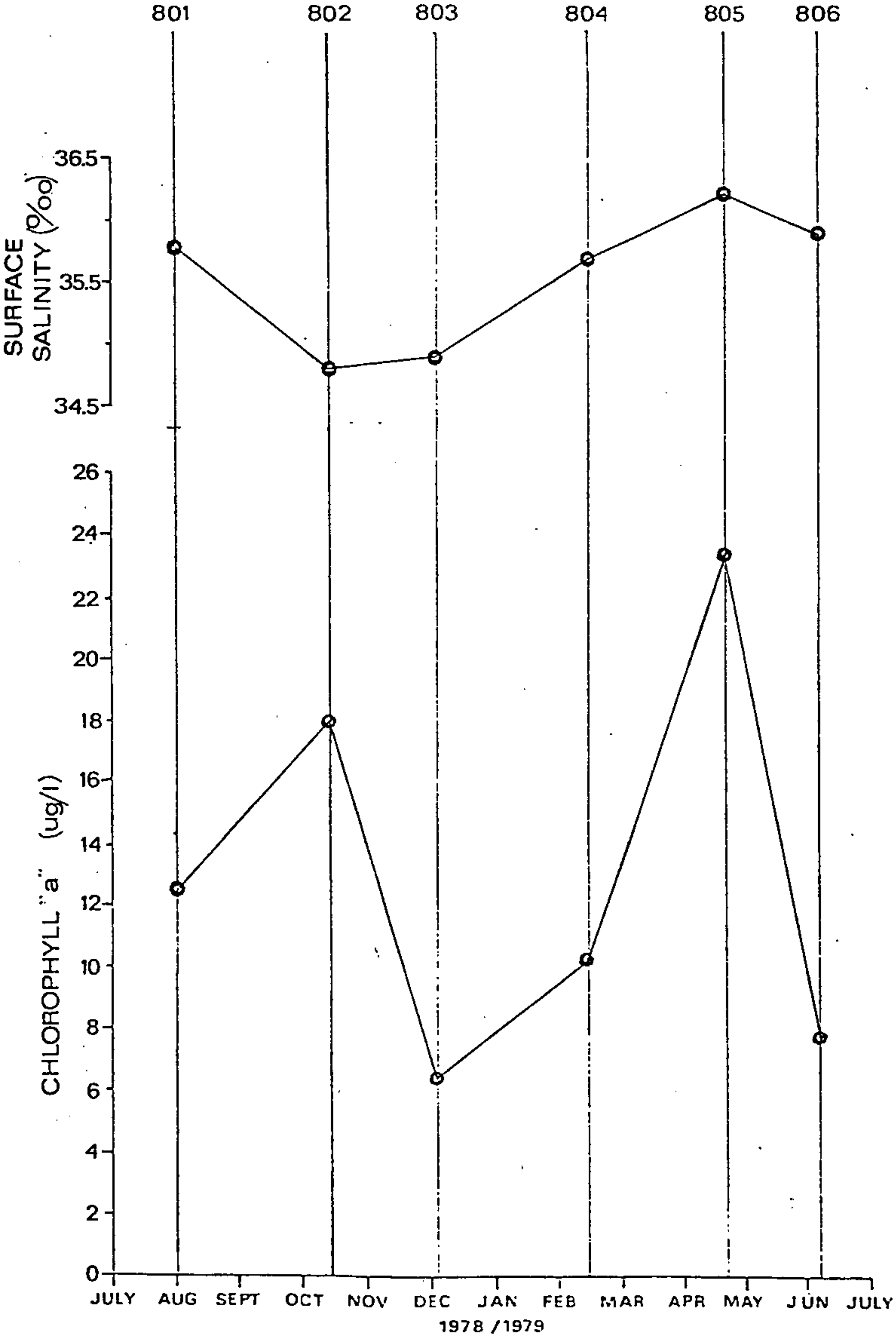


Fig. 106 - Time series of surface salinity and integrated chlorophyll "a" from the surface-to 200 m measured at Punta Tuna from August, 1978 to June, 1979.

waters of lower salinity should carry with them the more rich river waters, with possibly more available nutrients than other times of the year. Therefore, an inverse correlation might be expected between the two curves shown in Figure 106. Except for the extremely strong peak in April, this appears to be the case, however more information is needed before this relationship is actually confirmed. As mentioned earlier, the nutrient information collected during this program is inadequate to support the chlorophyll data. Beers et al.,(1968), found peaks in gross primary productivity in June, September and October in Jamaica and July, February and May in Barbados. Their peaks in productivity appeared to match their peaks in nutrients, as expected.

Finally, it might be pointed out that these chlorophyll values were taken from discrete samplings at about every 25 m depth. There may be much more vertical structure to the chlorophyll profiles that have eluded this study due to to the few chosen sampling depths. The phytoplankton tend to be patchy in both the horizontal and the vertical directions as well as with time. These factors may influence any distortion of the chlorophyll seen in this report.

3.7 Zooplankton Results

On each cruise, zooplankton samples were taken. When possible, one sample was taken at each of the following depths:

25 m Horizontal tow (day)
25 m Horizontal tow (night)
200-0 m Vertical tow
800-200 m Vertical tow
1000-800 m Vertical tow
1000-0 m Vertical tow

The tow covering the entire water column (1000-0 m) was not sorted as part of this work, but was sent to the Lawrence Berkeley Laboratory of the University of California, for analysis. The following portion of this section describes the results of the laboratory and statistical analysis of the remainder of the samples, and the interpretation thereof.

3.7.1 Size Frequency Analysis

The data summarized in Figure 107 present the percent of total copepoda analyzed throughout the year (frequency) versus their size class expressed in mm (magnitude). Plankters were collected towing a 202 μ net, which explains why so few individuals represented in the <0.5 mm size class interval. A finer mesh net captures those members that would seep through a 202 μ net and will increase the number of individuals represented in the <0.5 mm size class interval.

Of the copepoda represented in this histogram those included in the 0.5-0.9 mm size class interval are the most abundant. If we assume there is no clogging problem and that the size of copepoda is normally distributed, a 202 μ net is useful to collect those plankters bigger than 0.5 mm.

3.7.2 25 Meters Day vs. Night Tows

All data for all tests were log transformed from $\#/m^3$. A series of t-distribution tests were applied to the following data groups to test for any significant difference between the day and night surface tows:

- Total Copepoda
- Dominant Species
    - Clausocalanus furcatus
    - Oithona plumifera
    - Calocalanus pavo

Results for each of the t-distribution tests conducted are presented in Table 11. All of the values calculated are not significant (N.S.) at the 0.05 level.

It is a well-known fact that during the night some zooplankton vertically migrate to the surface waters (the reasons for such events are not part of this exposition). Therefore, we could expect much or at least higher concentrations of plankters on the surface waters at night. This might be the case, but variability is so ample that the differences are not statistically significant.

Fig. 107 - Copepoda size-frequency distribution for all zooplankton samples collected at Punta Tuna from August, 1978 to June, 1979.

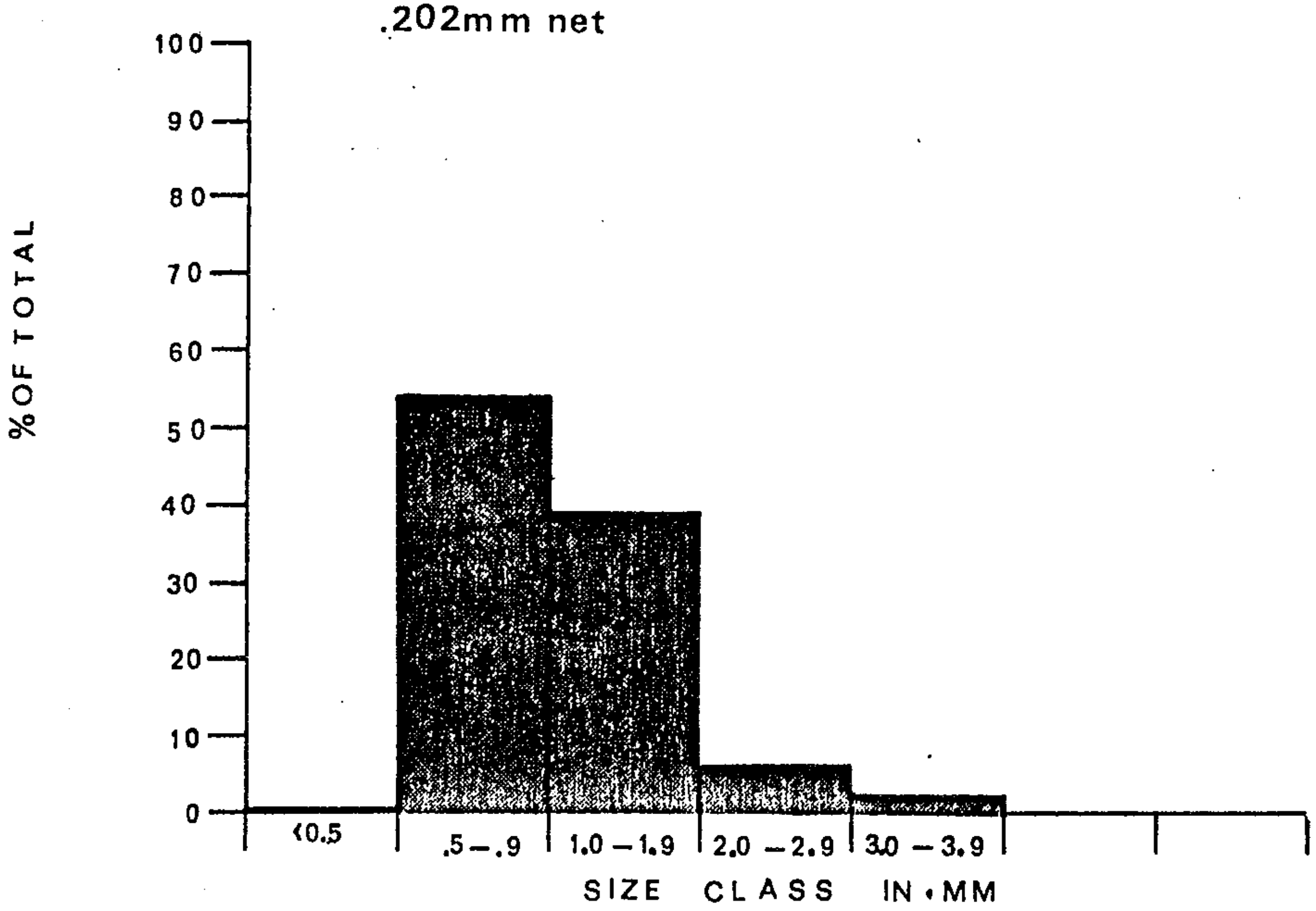


TABLE 11

Results of t-distribution tests on three zooplankton species collected at Punta Tuna to determine the day/night significance for 25 m deep horizontal tows.

	Total Copepoda	Clausocalanus furcatus	Oithona plumifera	Calocalanus pavo
t_{10}	0.311	0.952	0.285	0.541
$p>0.05$	>.05 N.S.	>.05 N.S.	>.05 N.S.	>.05 N.S.

Dominant species were selected after construction of a rank order species list. The three most abundant species were chosen for the test.

Of the three species of copepoda subjected to the test, none were significant at the 0.05 level. But this could very well be that they are non-migratory species, or that there is not enough data (replicates) to reject the null hypothesis.

Season Depth Distribution

Two way analysis of variance tests were applied to the following data groups to test for any significant difference between season and depth:

- Total Copepoda
- Dominant Species
    - *Oncaea venusta*
    - *Oithona plumifera*
    - *Clausocalanus furcatus*

For total copepoda (Table 12) there is slight evidence that their abundance varies with month, i.e. seasonal variations. If water masses of different temperature, salinity, and/or nutrients would go by the Punta Tuna site, variations in the planktonic population could or should be detected. Therefore, seasonal variations are expected.

Dominant species were selected after construction of a rank order species list. The three species most common for all months were chosen for the test.

Of the three species compared in the test, only O. venusta shows any significance at the 0.05 level. If we compare all copepoda and the three species chosen for this test none of the data group show any relation with depth at all.

Throughout the year a species list was constructed for the copepoda found in the waters of the Punta Tuna site. All identified species are listed in Table 13.

TABLE 12

Results of tests for significance of depth and seasonality for total copepoda and three zooplankton species collected at Punta Tuna from August, 1978 to June, 1979.

	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Mean Square (M.S.)	Variance Ratio (F)	Probability (P)
TOTAL COPEPODA					
MONTH	5.861	5	1.172	5.586	0.05
DEPTH	4.534	2	2.268	2.887	N.S.
ERROR	65.467	10	6.547		
TOTAL	75.862	17			
ONCAEA VENUSTA					
MONTH	0.262	5	0.0524	6.471	0.05
DEPTH	0.831	2	0.4155	0.8161	N.S.
ERROR	3.391	10	0.3391		
TOTAL	4.484	17			
OITHONA PLUMIFERA					
MONTH	1.822	5	0.3644	3.957	N.S.
DEPTH	1.369	2	0.6845	2.107	N.S.
ERROR	14.419	10	1.442		
TOTAL	17.610	17			
CLAUSOCALANUS FURCATUS					
MONTH	2.726	5	0.542	2.465	N.S.
DEPTH	5.048	2	2.524	0.532	N.S.
ERROR	13.444	10	1.344		
TOTAL	21.218	17			

TABLE 13. List of Species - Copepoda

Acartia spinata
A. lonsa
A. lilljeborgii
A. danae
A. negligens
Acrocalanus longicornis
Aetideus armatus
Calanus tenuicornis
Candacia bispinosa
C. pachydacilla
C. paelongimana
Calocalanus pavo
C. pavonicus
Clausocalanus arcuicornis
C. furcatus
Clytemnestra scutellata
Conaea gracilis
Copilia quadrata
C. mirabilis
Corycaeus amazonicus
C. speciosus
C. subulatus
C. typicus
C. limbatus
C. latus
Eucalanus attenuatus
E. elongatus
Euchiriella rostrata
Euchaeta marina
Euaetideus giesbrechti
Farranula gracilis
Haloptilus Longicornis
Heterorhabdus abysalis
H. papilliger
H. spinifer
Labidocera aestiva
Lubbockia aculeuta
L. squillimana
Lucicutia flavicornis
Macrosetella gracilis
Mecynocera clausi
Metridia brevicaudata
Microsetella norvegica
Miracia efferata
Miracia minor
Mormonilla minor
Nannocalanus minor
Oncaea conifera
O. ornata
O. mediterranea
O. venusta
Oithona plumifera
Paracandacia simplex
Paracalanus aculeatus
P. parvus
Phaena spinifera
Pleuromama abdominalis
P. piseki
P. xiphias
Pontella atlantica
Pontellina plumata
Pontellopsis regalis
Rhincalanus cornutus
R. nasutus
Sapphirina nigromaculata
Scaphocalanus magnus
Scolethricella vittata
Scolethrix danae
Temora styllifera
T. turbinata
Temoropia mayumbaensis
Undinula vulgaris
Undeuchaeta mayors
U. plumosa
Valdiviella insignis

3.7.3 A Comparative Study of Copepod Data Reported from Around the Puerto Rico Area.

The Copepoda make up the largest group (ca 70-85%) of the planktonic organisms sampled in our waters. Consequently, quantitative studies of their occurrence constitute an excellent tool for the understanding of distributional patterns of our zooplankton. Further, when inshore and offshore (pelagic) systems are compared, major differences are evident; some species being restricted to some areas and others to others.

In addition to these observations we find some species which are always present, others are commonly present, and still others exist but are extremely rare. Similar observations in the past led Preston (1948) to write the classic ecological paper "The commonness and rarity of species." This is clearly indicative of the concern of traditional ecologists for this type of observation and their relevance for the establishment of basic concepts in ecology.

Anonymous (1978) made an analysis of copepod populations from off the south coast of Puerto Rico based on data generated by Wood, et al. (1975, 1975c) and presented a scheme that fits the overall pattern observed in our marine waters. An examination of copepod lists provided from other deep water areas around Puerto Rico, (Youngbluth, 1974, 1975; Nutt, 1975, and Nutt and Yeaman, 1975), reveal that the species present are indeed in common with those from similar areas discussed above. Anonymous (1978) and Michel et al. (1976) found similar results off the southeast of Puerto Rico and Vieques, respectively. Coker and González (1960) reported on species restricted to inshore waters. Examination of their list on Table 2, p. 18 reveals how some species such as Acartia tonsa, Paracalanus crassirostris, and Oithona simplex are found in larger numbers in embayments like Phosphorescent Bays; then become less abundant in open bays (Montalva) and offshore, while others increase in abundance. See for instance the distribution of Corycaeus americanus, Centropages furcatus, and Temora turbinata. See also Tables 14-18 for reference in this discussion.

TABLE 14. A list of the copepod species identified from the Punta Higuero collections (after Nutt and Yeaman, 1975).

COPEPODA SPECIES

Acartia spinata
Acartia lilljeborgii
Paracalanus crassirostris
Paracalanus parvus
Paracalanus aculeatus
Oithona oculata
Oithona plumifera
Oithona sp. A
Clausocalanus furcatus
Temora turbinata
Temora stylifera
Oncaea venusta
Oncaea mediterranea
Corycaeus subulatus
Corycaeus giesbrechti
Corycaeus pacificus
Corycaeus agilis
Corycaeus speciosus
Corycaeus anglicus
Corycaeus clausi
Corycaeus lautus
Farranula gracilis
Farranula sp. A
Undinula vulgaris
Nannocalanus minor
Centropages furcatus
Calocalanus pavo
Lucicutia flavicornis
Calanopia americana
Macrosetella gracilis
Microsetella norvegica
Acrocalanus longicornis
Candacia pachydactyla
Euchaeta marina
Eucalanus cf. attenuatus
Labidocera spp.
Miracia efferata
Euterpina acutifrons

TABLE 15. Species of copepods found at sampling stations in the vicinity of Vieques Island (after Michel et al., 1976).

COPEPODA SPECIES

Acrocalanus longicornis
Euchaeta marina
Lucicutia flavicornis
Haloptilus longicornis
Mormonilla minor
Mormonilla phasma
Paracalanus aculeatus
Rhincalanus cornutus
Scolecithrix danae
Undinula vulgaris
Other calanoids
Aegisthus aculeatus
Macrosetella gracilis
Microsetella rosea
Other harpacticoids
Conaea gracilis
Farranula carinata
F. gracilis
Oithona plumifera
Oncaea mediterranea
O. venusta
Other cyclopoids

TABLE 16. Analysis of the copepod populations from Punta Verraco and Cabo Mala Pascua Sites. (After Anonymous 1978).

Table 16-A Copepod population observed at Punta Verraco.

Species usually most numerous
(>5 individuals/m^3)

Clausocalanus furcatus
Paracalanus spp. (P. aculeatus, P. crassirostris, P. parvus)
Farranula gracilis
Oithona spp. (O. plumifera, O. spp.)
Acartia spinata
A. lilljeborgii
Temora turbinata

Species commonly present
(observed on 5 or more sampling periods)

Corycaeus spp. (C. giesbrechti, C. pacificus, C. speciousus)
Euterpina acutifrons
Calanopia americana
Undinula vulgaris

Species occasionally present

Euchaeta marina
Corycaeus spp. (C. pavo, C. pavoninus)
Pseudodiamptomis cokeri
Nannocalanus minor
Calocalanus spp. (C. pavo, C. pavoninus)
Centropages spp. (C. furcatus, C. caribbeanensis)
Scolecithrix danae
Labidocera spp. (L. scotti, L. spp.)
Candacia pachydactyla
Mecynocera clausi
Acrocalansu lingicornis
Eucalanus spp.
Lucicutia flavicornia
Temora stylifera

Source: Wood, E. D., M. J. Youngbluth, P. Yoshioka, and M. J. Canoy. 1975. Punta Verraco Environmental Studies. Puerto Rico Nuclear Center, Mayaguez.

(cont.)

TABLE 16. Analysis of the copepod populations from Punta Verraco (IX-A) and Cabo Mala Pascua Site, Puerto Rico (IX-B). (After Anonymous 1978).

Table 16-B Copepod populations observed at the Cabo Mala Pascua Site.

Species usually most numerous
(>5 individuals/m^3)

Clausocalanus furcatus
Paracalanus spp. (P. aculeatus, P. crassirostris, P. parvus)
Farranula gracilis
Oithona spp. (P. aculeatus, P. crassirostris, P. parvus)
Acartia spinata
Temora turbinata
Calanopia americana

Species commonly present
(observed on 5 or more sampling periods)

Corycaeus spp. (C. giesbrechti, C. pacificus, C. speciosus)
Undinula vulgaris
Calocalanus pavo
Euchaeta marina
Nannocalanus minor
Labidocera spp.
Candacia pachydactyla
Mecynocera clausi
Acrocalanus longicornis
Temora stylifera

Species ocassionally present

Oncaea spp. (O. mediterranea, O. venusta, O. spp.)
Corycaeus spp. (C. subulatus, C. spp.)
Pseudodiaptomis cokeri
Calocalanus pavoninus
Scolecithrix danae
Centropages furcatus
Eucalanus spp.
Lucicutia flavicornis
Miracia efferata
Copilia spp.
Sapphirina spp.
Macrosetella gracilis
Phaenna spinifera

Source: Wood, E. D., M. J. Youngbluth, P. Yoshioka, M. J. Canoy. 1975. Cabo Mala Pascua Environmental Studies. Puerto Rico Nuclear Center, Mayaguez.

TABLE 17. Zooplankton species distribution, abundance, and diversity in the vicinity.

COPEPODA SPECIES

Acartia lilljeborgii
Acartia spinata
Acartia tonsa
Calanopia americana
Calocalanus pavo
C. pavoninus
Candacia curta
C. pachydactyla
Clausocalanus furcatus
Copepod nauplii
Corycaeus amazonicus
C. subulatus
Corycaeus sp.
Euaetideus giesbrechti
Eucalanus sp.
Eucalanus elongatus
Euchaeta marina
Euterpina acutifrons
Euchirella curticauda
Eucalanus attenuatus
Euchirella bitumida
Farranula gracilis
Haloptilus longicornis
H. mucronatus
Lucicutia flavicornis
L. clausii
Macrosetella gracilis
Mecynocera clausii
Microsetella norvegica
Nannocalanus minor
Oithona plumifera
O. simplex
O. hebes
O. sp.
O. nana
Oncaea sp.
Oncaea venusta
O. mediterranea
Paracalanus aculeatus
P. crassirostris
P. parvus
P. sp.
Phaenna spinifera
Pleuromama gracilis
Rhinecalanus cornutus
Temora stylifera
T. turbinata
Undinula vulgaris
Unidentified Copepodies
Unidentified Calanoid Copepods

TABLE 18. Zooplankton from Tortuguero Bay (after Nutt 1975).

COPEPODS

Calanoids:

Nannocalanus minor
Undinula vulgaris
Eucalanus attenuatus
Acrocalanus longicornis
Acrocalanus andersoni
Paracalanus aculeatus
Paracalanus parvus
Calocalanus pavo
Mecynocera clausii
Clausocalanus furcatus
Euchaeta marina

Scolecithriz danae
Temora stylifera
Temora turbinata
Pleuronamma gracilis
Centropagues furcatus
Lucicutia flavicornis
Candacia pachydactyla
Paracandacia bispinosa
Calanopia americana
Labidocera sp.
Acartia spinata

Harpacticoids:

Miracia efferata
Macrosetella gracilis

Oculosetella gracilis
Euterpina acutifrons

Cyclopoids:

Oithona plumifera
Oithona setigera
Oithona oculata
Saphirella tropica
Copilia mirabilis
Copilia quadrata
Corycaeus (*Corycaeus*) *speciosus*
Corycaeus (*Corycaeus*) *clausi*
Corycaeus (Agetus) *flaccus*

Corycaeus (Agetus) *typicus*
Corycaeus (*Urocorycaeus*) *lautus*
Corycaeus (*onychocorycaeus*) *giesbrechti*
Corycaeus (*onychocorycaeus*) *agilis*
Oncaea mediterranea
Oncaea venusta
Saphirina sp.
Farranula gracilis

Upon studying carefully the Punta Tuna data, it is found that the diversity of the species is much higher than in all other sites mentioned above. This is apparently due to the fact that net tows were made down to a depth of 1000 meters (a large number of species reported here are deep water species), and were spaced out throughout the year. This offered a greater opportunity to catch organisms that undergo seasonal fluctuations in addition to stragglers from other regions.

The information obtained confirms previous observation of the distributional patterns of copepod species, but correlations with other parameters are not evident or can not be carried out because the data can not be tested statistically for that purpose.

Because the diversity of species found in the Punta Tuna site is considerably larger than in any other site explored before, it was believed proper to make a more extensive survey devoted exclusively to the study of pattern of the pelagic plankton populations. This will ensure that a dissection of vertical stratification of species and the overall plankton structure of the pelagic environment could be understood.

The presence of _Acartia tonsa_, an inshore species, in the pelagic environment off Punta Tuna is of no significant consequence. However, the ongoing study may be able to add further insight on this observation.

3.8 Nutrient Results

During each cruise an attempt was made to collect samples from throughout the water column down to 1000 m for subsequent nutrient analysis. Shipboard handling and laboratory problems resulted in acceptable results not being available until the 5th cruise. Although the results of the last two cruises are much more meaningful than those preceeding, the results of all the cruises shall be represented, but special emphasis should be given to the April and June 1979 cruises.

In Caribbean surface waters, the low nutrient concentrations in the photic zone is the primary cause for the generally low primary production. In areas of upwelling, where traditionally nutrient rich deeper waters are moved upward into the photic zone, the primary production, and the entire food web is enhanced, both in species and in numbers.

3.8.1 Nitrate/Nitrite Results

Figures 108-112 show the average values of the nitrites and nitrates for each of the last 5 cruises respectively. The values seen for the October 1978 (Fig. 108), December 1978 (Fig. 109), and February 1979 (Fig. 110) cruises for the concentration of nitrate and nitrite in the water are inconsistant, both among themselves and relative to literature values. The nitrate values seen during October (Fig. 108) were quite high at the surface, decreased with depth to about 200 m, then showed fairly constant values downward. The nitrite values for this same cruise showed irratic high and low values. The values of nitrate concentration seen during the December cruise (Fig. 109) is very low until the 200 m depth is reached. From that depth downward, the values generally increase. The nitrite concentration for this same cruise is shown to be virtually zero throughout the water column. The nitrate values for the February cruise (Fig. 110) are quite low near the surface, but then increase to extremely

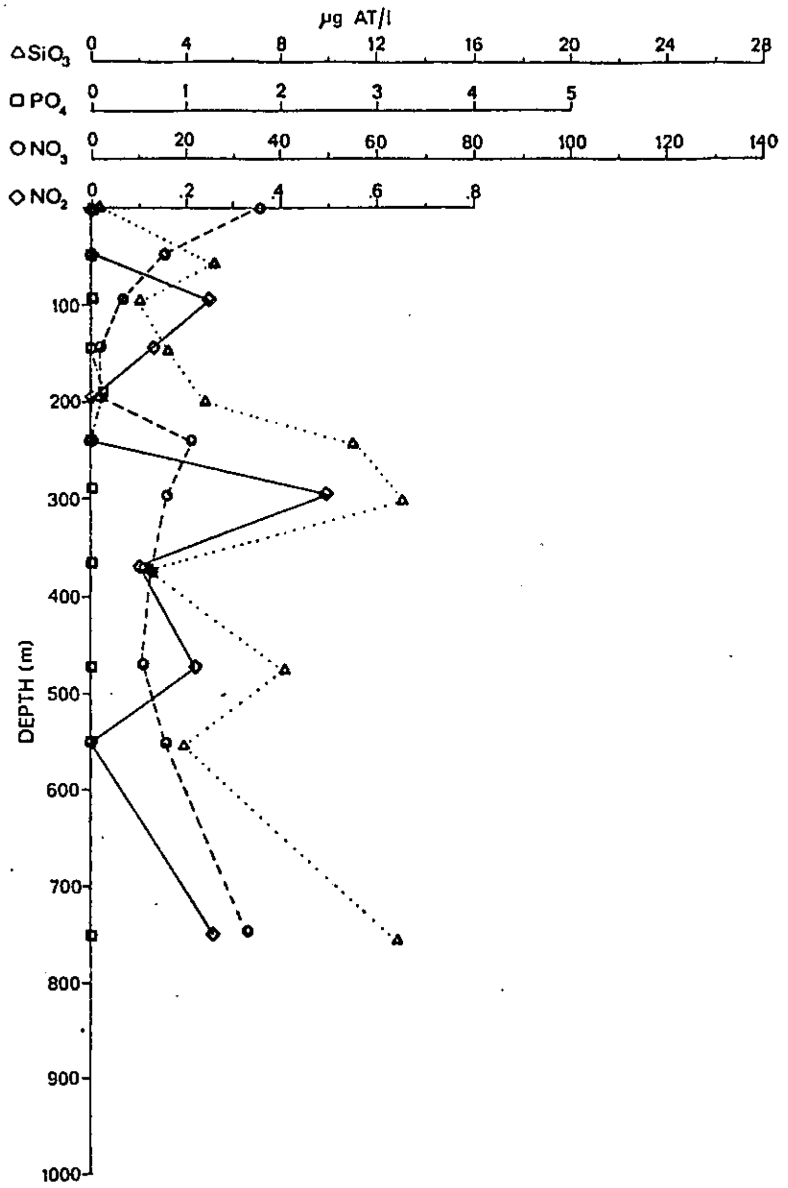


Fig. 108 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during the cruise of October, 1978.

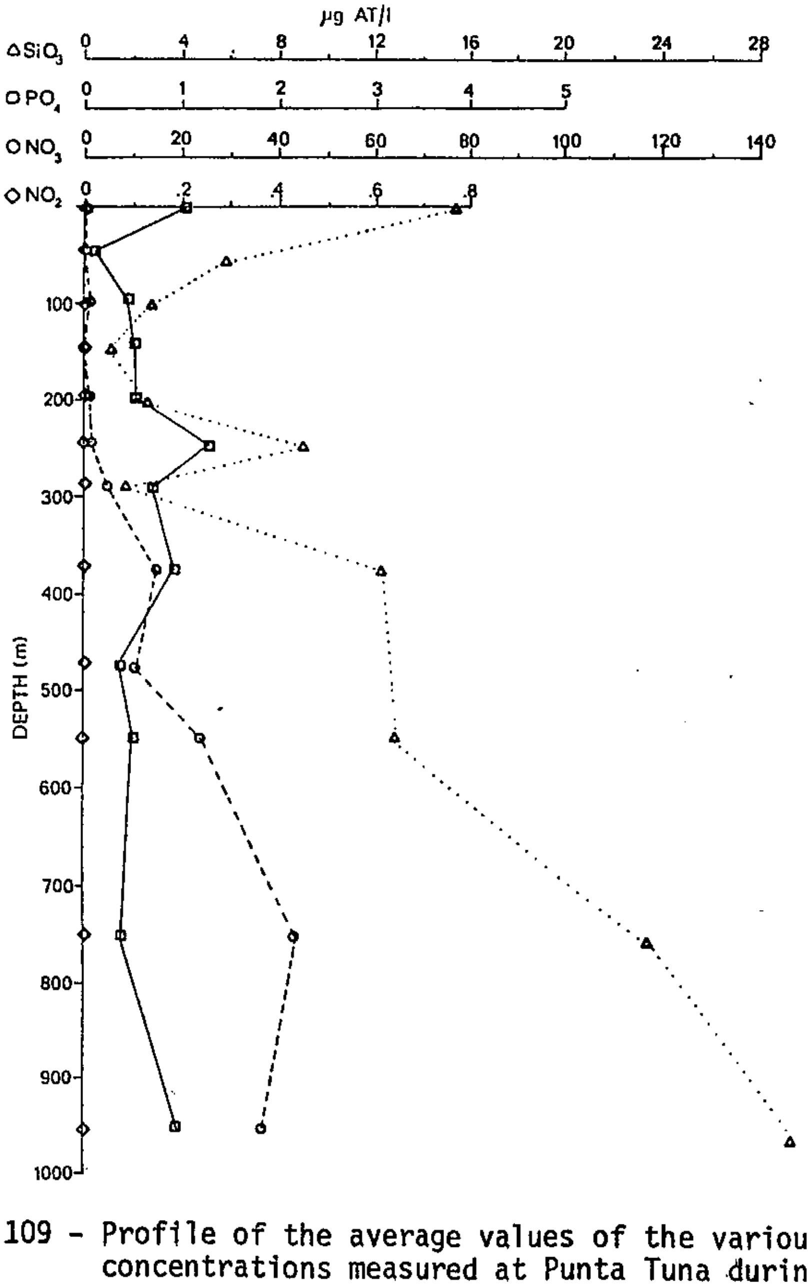


Fig. 109 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during the cruise of December, 1978.

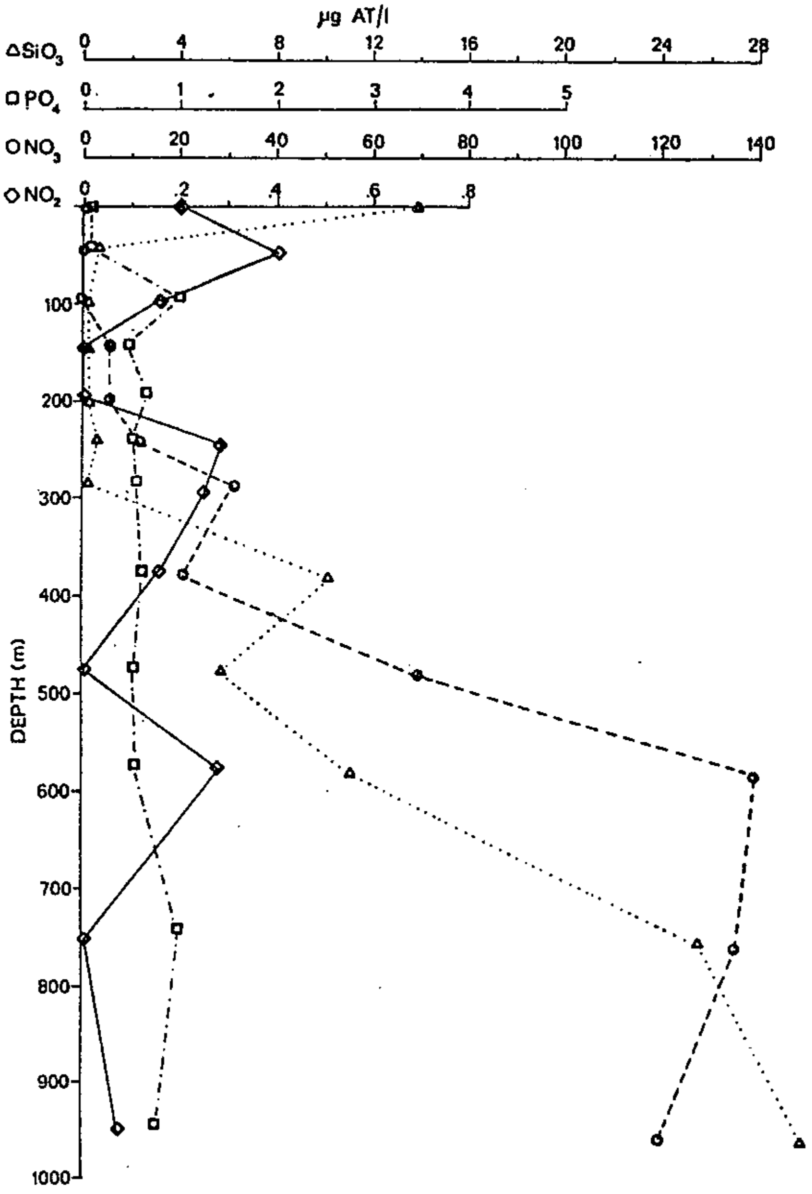


Fig. 110 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during the cruise of February, 1979.

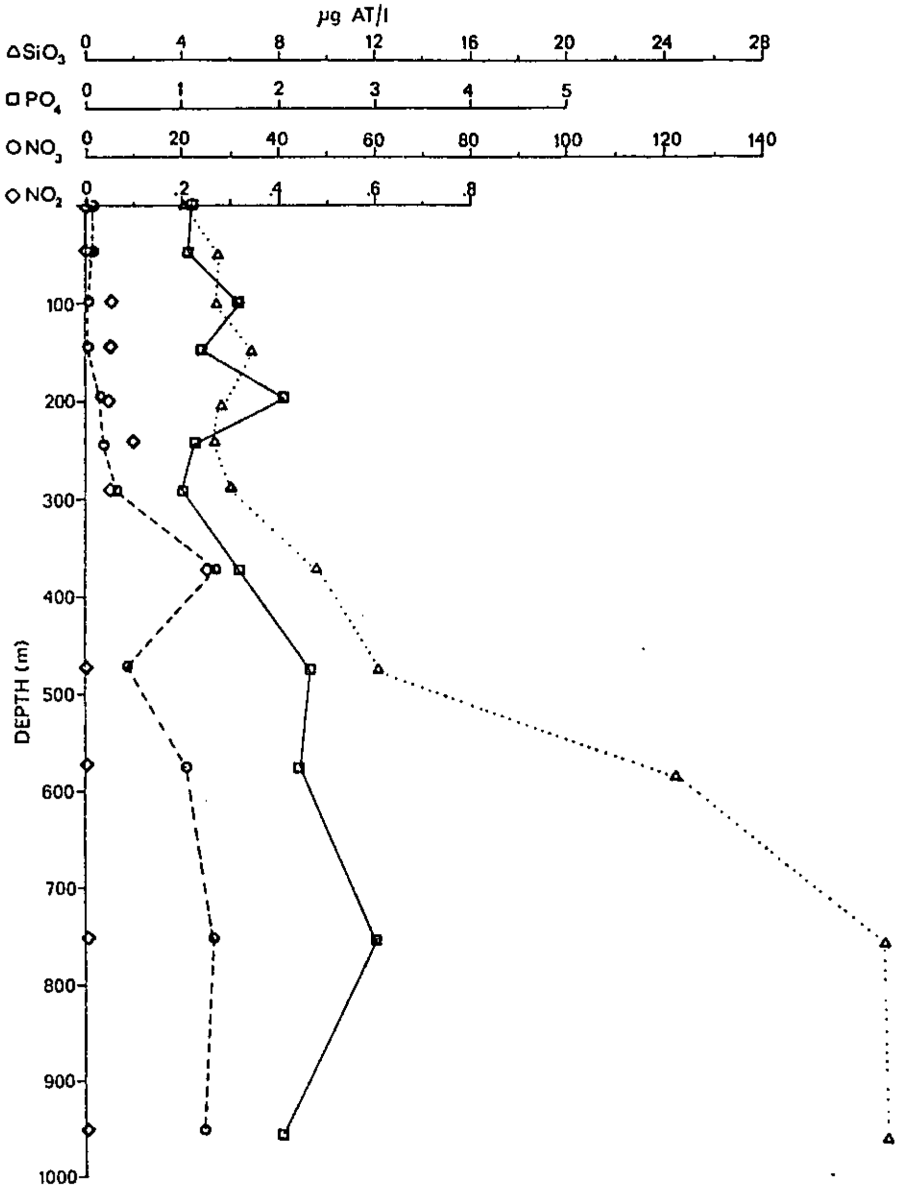


Fig. 111 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during the cruise of April, 1979.

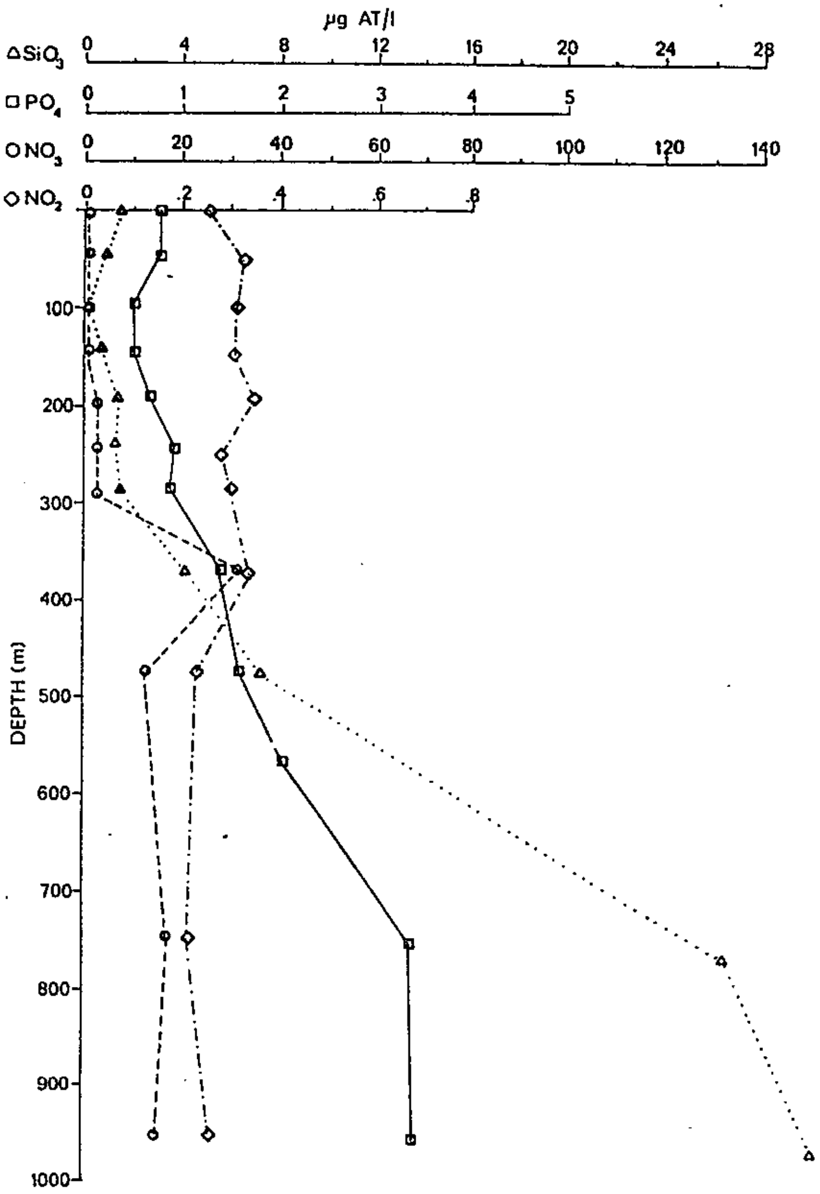


Fig. 112 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during the cruise of June, 1979.

high values (about 140 μg-At/l) at about 500-900 m. It is quite possible that the samples were contaminated during the water collection period. The nitrite concentrations during this cruise were quite irratic.

April 1979 (Fig. 111), and June 1979 (Fig. 112) had similar nitrate profiles. Generally, during these cruises the concentration is very low at the surface and throughout the photic zone. Below this level, there is a trend toward increasing nitrate concentration as depth increases. The nitrite concentration is virtually unchanged throughout the water column in both of these cruises, except for a peak near 400 m in April 1979. The typical values of nitrite concentration is almost undetectable in April, but almost 0.2 μg-At/l in June, showing a possible systematic offset during the handling and/or analysis during the last cruise.

Normally, the upper waters of the Caribbean are quite low in nitrites and nitrates (Atwood et al., 1976; Beers et al., 1968). Typically, nitrate values of less than a few μg-At/l are seen in the literature throughout the photic zone. Only below this level do the values usually rise to significant levels. Putting our emphasis and confidence on the nitrate values of the April and June cruises of 1979, the typical values would be low throughout the upper 100 m, and start to rise gradually as the bottom is approached. Significant changes in the surface and upper water nutrient concentration levels could occur if an OTEC plant would be permitted to produce an artificial upwelling of these nitrates and nitrites. The increase could be as much as 10-50 times the present values.

3.8.2 Phosphate Results

The profiles of phosphate concentrations vs. depth for each of the last 5 cruises are also shown in Figures 108-112. The above mentioned problems encountered with the samples before the April cruise also apply to the phosphate concentrations.

April (Fig. 111) concentrations showed not much vertical structure, and simply varied from 1-3 µg-At/l throughout the entire water column. These values do not appear reliable. During the June cruise (Fig. 112), the phosphate concentrate remained between .5-1 µg-At/l down to about 300 m. Below 300 m, the concentration steadily increased to almost 3.5 µg-AT/l.

In summary, the concentration of phosphate generally showed low values near the surface, increasing with depth below the photic zone. However, many of the data seem to display systematic errors which at times either inhibit higher values or overshadow the lower values.

3.8.3 Silicate Results

The concentration of reactive silicate for the Punta Tuna waters is shown in Figures 108-112, covering the period from October, 1978 until June, 1979. The samples from the cruises of October and December, 1978 (Figs. 108-109), and February and April, 1979 (Figs. 110-111) all suffered from extended time delays between collection and chemical analysis. The October, December, and February samples also suffered from possible contamination of the samples due to improper handling at sea. These factors may account for the unclear results.

The October, 1978 results (Fig. 108) shows a surprising peak at mid-depth and a considerable decrease at 400 m. The December, 1978 (Fig. 109) values are surprisingly high in the upper 250 m, but appear to increase smoothly with depth below 4-0 m. The February, 1979 (Fig. 110) concentrations of silicate display either a peak at 400 m or a dip at 500 m, depending on the interpretation, but the values appear usable otherwise. The upper water values (0-300 m) show a relatively uniform, but moderate concentration in April, 1979 (Fig. 111). Below this depth, the values appear consistant with the other months. The values for June, 1979 (Fig. 112) are quite low in the upper 300 m, and steadily increasing with depth below this. The values for June, 1979 appear to most closely follow those concentration envelopes seen in the literature (Cummings et al., 1979).

The average concentrations are shown in Figure 113. Although the early data appears unrealiable, the general curve form is not a typical.

3.8.4 Nutrient Summary

In summarizing the nutrient results, the following items can be addressed: relative nutrient concentrations, present data quality, and expected OTEC impacts.

In general, normal Caribbean offshore nutrient concentration levels are very low at the surface, and rise to relative maximum near the core of the Antarctic Intermediate Water, about 700 m depth (Atwood et al., 1976). This typical profile applies to those specific nutrient species measured during this program, namely silicate, phosphate, nitrate and nitrite. At times there are slight increases seen near or at the surface, but the shape of the profile does not seem to vary much.

The "average" profiles for nutrient concentration are seen in Figure 113. These "average" values, together with their standard deviations are also shown in Table 19.

The nitrate values all show standard deviations greater than the mean, implying lack of reliability of the data or much greater variation than normally seen. Also, the concentration profiles vs. depth for nitrite is seen to have many relative maximums and minimums.

The phosphate concentrations are not consistant near the surface waters, but seem to improve with increasing depth. Although the standard deviations are not quite as large, (relative to the mean) as with the nitrites, the spread of data is still quite large compared to expected sampling variations for this species, as seen in the literature (Cummings et al., 1979; Lee et al., 1978; Wood et al., 1975; and Wood and Asencio, 1975). As seen in the figure,

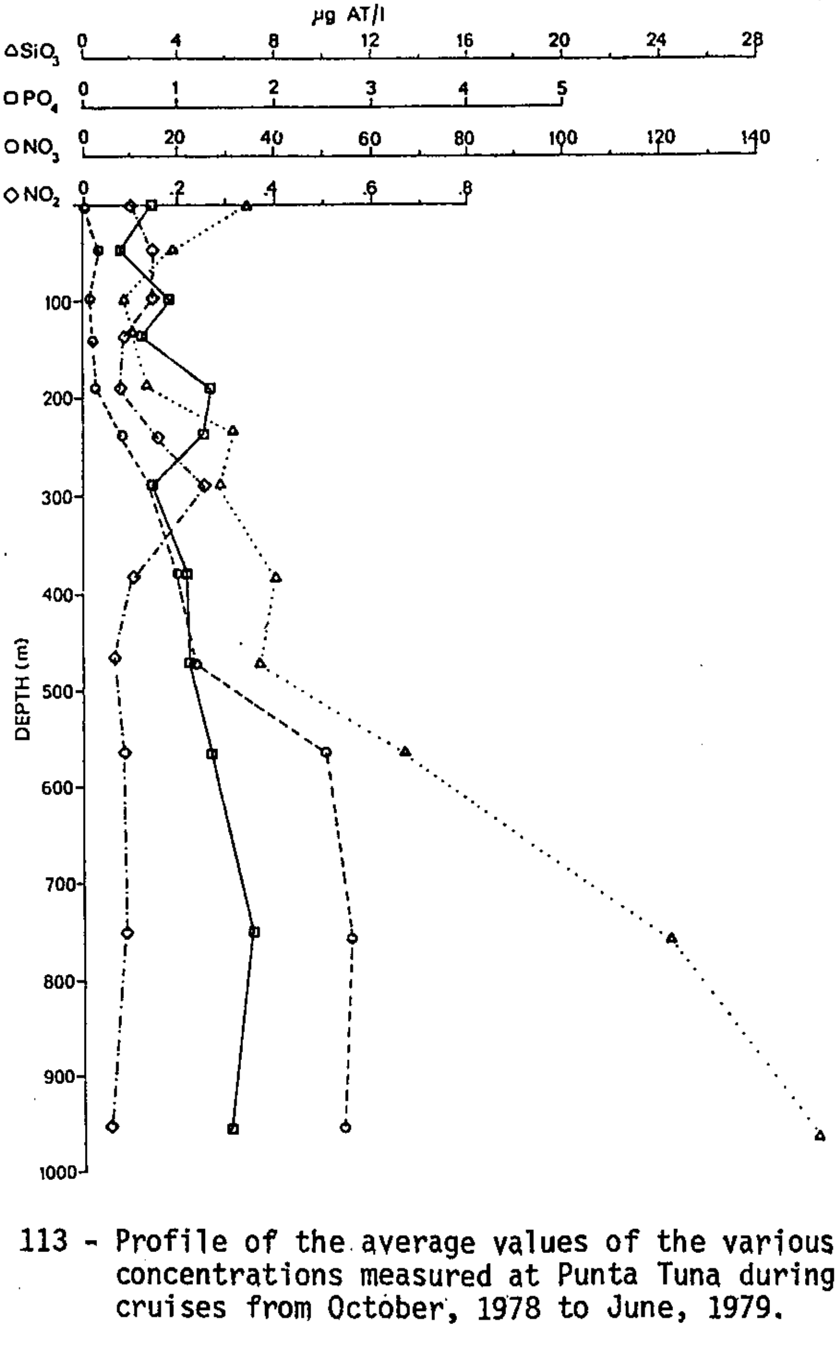


Fig. 113 - Profile of the average values of the various nutrient concentrations measured at Punta Tuna during all cruises from October, 1978 to June, 1979.

TABLE 19

Average values of nutrient concentrations in the water at Punta Tuna from October, 1978 to June, 1979 (and standard deviation of measurements).

NOMINAL DEPTH (M)	PO_4 (μgm-AT/ℓ)	NO_2 (μgm-AT/ℓ)	NO_3 (μgm-AT/ℓ)	SiO_3 (μgm-AT/ℓ)
0	0.78 ± .49	0.10 ± .17	1.0 ± 1.6	5.4 ± 6.3
50	0.55 ± .44	0.15 ± .28	3.8 ± 9.1	4.6 ± 3.0
100	0.94 ± .54	0.15 ± .18	2.1 ± 4.7	2.6 ± 2.3
150	0.79 ± .34	0.10 ± .13	2.3 ± 4.4	3.1 ± 3.4
200	1.36 ± 1.01	0.08 ± .14	3.9 ± 3.0	3.6 ± 3.1
250	1.43 ± 1.38	0.13 ± .14	8.5 ± 11.3	6.3 ± 7.5
300	0.79 ± .30	0.23 ± .28	13.2 ± 19.0	5.4 ± 7.7
400	1.10 ± .41	0.15 ± .20	20.7 ± 13.4	7.5 ± 5.8
500	1.12 ± .91	0.08 ± .13	24.3 ± 44.8	7.5 ± 5.8
600	1.33 ± 1.05	0.08 ± .13	50.2 ± 55.8	13.1 ± 9.5
800	1.74 ± 1.34	0.08 ± .13	55.1 ± 78.9	22.6 ± 9.8
1000	1.49 ± 1.01	0.05 ± .10	22.3 ± 13.3	30.1 ± 2.3

the average values oscillate between relative maximum and relative minimums down to about 300 m. Below this depth, there appears to be a single maximum value at about 750 m depth, in agreement with historical observations (Atwood et al., 1976).

The average nitrate profiles show very low surface and near surface values, increasing steadily from about 200 m to the deep waters. These values also show very high (mean vs. standard deviation) ratios, indicating considerable variation in the results.

On the figure, the average silicate concentrations show moderate levels near the surface, a decrease below the mixed layer, and a fairly steady increase with depth below that. The reliability of most of the values is in question, however, as the standard deviation exceeded the mean value in almost all cases.

Table 20 is included as a comparison in Table 19. Table 20 shows the average nutrient concentrations and their deviations from the mean for only the last two cruises, April and June, 1979. These cruises employed optimum shipboard handling procedures, and probably any significant variations in these results are due to either our preservative, any delays between the collection and the measurements, or the laboratory handling and analysis. The values in Table 20 are not necessarily similar to those in Table 19. The phosphate values range from about 1-3 μgm-AT/ℓ, with the higher values seen below 500 m. The deviations from the means are a smaller fraction of the mean than seen for the phosphates in Table 19. The nitrite values are irratic, with high standard deviations from the means. Nitrate concentrations are generally lower near the surface and high in the deep water. However, the progression from one realm to another is not necessarily smooth, with frequent high deviations. The silicate values show quite constant, moderate levels, from the surface to 300 m. However, the deviations from the mean quite often almost equal, or exceed the mean.

TABLE 20

Average values of nutrient concentrations in the water at Punta Tuna during April and June, 1979 (and standard deviation of the measurements).

NOMINAL DEPTH (M)	PO_4 (μgm-AT/ℓ)	NO_2 (μgm-AT/ℓ)	NO_3 (μgm-AT/ℓ)	SiO_3 (μgm-AT/ℓ)
0	1.00 ± .30	0.15 ± .18	0.49 ± .30	2.93 ± 1.32
50	0.94 ± .17	0.17 ± .20	0.92 ± .67	3.26 ± 2.67
100	1.11 ± .67	0.18 ± .16	1.04 ± .45	2.85 ± 3.08
150	0.86 ± .40	0.17 ± .15	0.66 ± .52	4.00 ± 4.11
200	1.44 ± 1.04	0.20 ± .17	3.56 ± .60	3.51 ± 2.71
250	1.05 ± .20	0.18 ± .13	3.31 ± 1.60	3.13 ± 2.32
300	0.91 ± .28	0.18 ± .16	4.13 ± 2.77	3.48 ± 2.54
400	1.50 ± .15	0.28 ± .25	28.2 ± 18.7	7.77 ± 4.34
500	2.02 ± .42	0.08 ± .14	9.83 ± 7.65	10.2 ± 4.69
600	2.41 ± .43	0.00 ± .00	20.1 ± 12.8	18.4 ± 9.36
800	3.12 ± .17	0.07 ± .13	22.4 ± 5.7	28.0 ± 7.79
1000	2.40 ± .90	0.08 ± .14	19.6 ± 9.2	29.7 ± 4.86

The concentration at depth is generally high. In most cases in the table, the deviations from the mean are high relative to the mean, again indicating low reliability of the results.

In general, the nutrient concentrations tend to be higher in the deep waters than in the near surface waters. This trend suggests confirmation of the potential situation that may be common to an operating OTEC plant in any tropical waters. If the plant were to draw into its cold water intake these nutrient rich deep waters, and exhaust them into the nutrient poor photic zone, a totally unnatural situation could be created in the open Caribbean waters.

However, this scenario seems highly unlikely. Should the cold water system remain separated from the warm water system, the exhausted cold water would quickly descend to its deep final resting place. If the plant were to use a mixed effluent, the resultant mixture would also probably descend below the photic zone within a matter of a few hours after leaving the plant. This nutrient rich effluent could only be expected to impact on nearby (or downstream) submerged structures which may diverst some of the flow upward into the photic zone. It is these nearby shallow or shelf structures that could be subjected to an artificial "upwelling" of this newly created water mass.

3.9 Meteorological Results

The meteorological and climatological observations were made for two purposes during this program. The first purpose is to note how the weather varied during our measurement period as opposed to the normal, long-term climatological averages. This may account for any observed abnormal physical characteristics. The second purpose was to compare the meteorological data taken while on board the research vessels during their occupations of the Benchmark station, with the recorded meteorological data observed at the Punta Tuna Coast Guard Light Station, about 3 km northwest of our mooring.

3.9.1 Comparison with Historical Data

Figure 114 shows comparison of the long-term meteorological averages of temperature and wind speed with those measured during the year of our measurement program. As the island is only about 60 km (N-S) by 180 km, and San Juan is located on the coast (although the north coast, as opposed to the south coast for the Benchmark station), and because there is historical data for San Juan weather, the comparison of the historical data versus that seen during 1978-1979 will be done using the San Juan data files.

The upper portion of Figure 114 shows the temperature comparisons. The circles represent the historical average monthly temperature data from all the reporting stations in the San Juan area during the period from 1941-1970 (NOAA, 1979). These monthly averages are compared with the monthly average temperature measured from June, 1978 to June, 1979 at the San Juan National Weather Service Forcast Office (NOAA, 1978-1979).

In general, the present values are higher than the historical averages, and this is probably due to the specific weather reporting location within the city. Throughout the year (1978-1979), the data averaged about 1.3 C° higher than the historical data, with the standard deviation being about ±0.3 C°. The exceptions to this trend occured in January, February, and June, 1979, when the difference was almost 1.5 times as great, and March, 1979, when the difference was about 0.7 times. This probably indicates that the air temperature was slightly warmer during the first half of 1979 than can be normally expected. Another interpretation might be that 1979 may be the more typical year, and the later half of 1978 may actually be slightly cooler than the average. In either case, the sea surface may react to this difference from the mean, by either producing slightly cooler than normal surface temperature values during August, October, and December, 1978, or slightly warmer than average values during February and June, 1979. The actual comparison of the

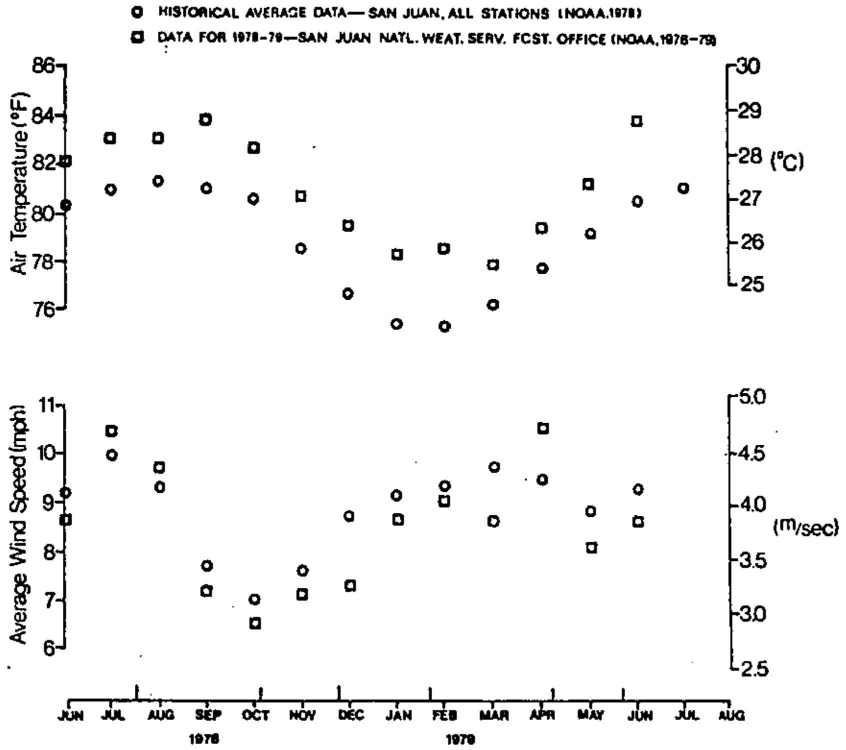


Fig. 114 - Time series of air temperature and wind speed at San Juan, Puerto Rico from June, 1978 to June, 1979. (Historical averages are also shown).

historical sea surface temperature (ODSI, 1977) with measurements taken during 1978-1979 are shown in Figure 40. The results indicate that most of the recent data seems cooler than normal with only the February cruise data showing above normal sea surface temperatures. This would correspond to the interpretation of the historical/present meteorological data, that says that January and February of 1979 had above average air temperatures.

Another type of comparison of the historical versus the recent meteorological data is to evaluate any difference in the observed wind speed. The lower portion of Figure 114 shows the historical San Juan monthly average wind data compared to the monthly averages during 1978-1979. Although there is considerable variation between the two sets, the average difference is only about 0.2 m/sec, with the recent data showing the slightly lower wind speed. Again, this difference may be due to the actual sensor location within the city. If this small negative difference is taken into account, the periods of major differences occured during our August cruise, when the average wind speed was greater than the historical average, and during our December and April cruises, when the average wind speed was lower than the historical values. This suggests better wind mixing during the August cruise, and poorer mixing during the December and April cruises. Figure 38 shows the comparison between our measured data for the MLD (Mixed Layer Depth) and the historical averages (ODSI, 1977). Our August cruise saw a somewhat more developed mixed surface layer, so the depth was slightly greater than the average. The MLD during December was not much different than the historical value. Finally, our April cruise data indicates a somewhat shallower MLD than the historical average, for that time period.

This all indicates that the local meteorological conditions can, and do influence the hydrographic parameters relatable to an OTEC plant.

3.9.2 Comparison with Shipboard Data

Table 21 shows the comparisons between two typical sets of shipboard meteorological data and those data observed at the Punta Tuna Coast Guard Light Station which takes observations at 800, 1100, 1400, and 1700 hours, week-days only. These two shipboard data sets were chosen as they represent considerably different measurement capabilities aboard the research vessels. The set from the BA-804 cruise (February, 1979) was observed and recorded by the crew of the USNS BARTLETT (T-AGOR-13). These data, with the exception of the wave height values, are measured using remotely located instruments, some set on the superstructure, and the anemometer and wind vane on the ship's mast. The second data set was observed and recorded by the crew of the R/V CRAWFORD, using hand-held instruments in all cases. These latter observations were made usually against the superstructure and as such are also closer to the sea level and in a more restricted air passage.

The table reflects the locations of the instruments and the observers. In general, if we assume that all the instruments are within calibration (which is probably a poor assumption), the wind speed sensor aboard the BARTLETT, by being higher above sea level (wind speed generally increases with height above the sea surface), and less obstructed should give a higher reading than the value seen on the CRAWFORD. This higher elevation seems to be the case, with the wind speed values observed from the BARTLETT even higher than those from the Light Station, as well as higher than the CRAWFORD. The speeds observed from the CRAWFORD were usually lower than at the Light Station. This could also be an artifact of the above mentioned calibration.

In all cases, the wind direction was more southerly from the shipboard observation than seen at the Light Station. The most probable cause of the difference is that the Light Station is sitting at the base and to the south

TABLE 21

Comparison between the shipboard meteorological observations and those from the Punta Tuna, Coast Guard Light Station.
(Research Vessel value minus Light Station value)

CRUISE/STATION	WIND SPEED (KT)	WIND DIRECTION (DEG)	AIR TEMP. (F°)	WAVE HT. (M)
BA-804/B-1	+2	+080	+5	+1/2
BA-804/B-4	+5	+025	-3	+1/2
BA-804/B-5	+7	+015	-4	+2 1/2
BA-804/B-6	+2	+015	-6	+1/2
BA-804/B-10	-4	+150	-3	+1/2
CR-806/B-2	+2	+050	+4	0
CR-806/B-3	-1	+050	+6	0
CR-806/B-4	-3	+050	+8	0
CR-806/B-9	-6	+070	+3	0
CR-806/B-10	-6	+045	+5	0
CR-806/B-11	-4	+025	+1	-1/2

of a 400-500 m high hill, which would deflect any southern component of wind.

The difference in air temperature is as yet unexplained and is probably due to poor instrument calibration or solar exposure to the thermometers.

Finally, as the wave height observations are taking place from a lower deck aboard the CRAWFORD than from the BARTLETT, it is expected that the wave height observations from the CRAWFORD may be more direct, and less remote, with less of a vertical error involved in the observation. However, it is truly impossible to estimate the wave height in open sea from the Light Station, located about 20 m above sea level, and about 1/2 km inside an energy breaking reef.

Overall, it appears that the infrequent meteorological observations at the Punta Tuna Light Station may be reasonably suitable for short-term observations, but for long-term trends, and averages, the meteorological data taken from the San Juan station (hourly over many years) may be more practical. On board measurements are still necessary, but care must be taken to insure quality measurements.

4.0 COMPARISON BETWEEN PUNTA TUNA AND PUNTA VACA, VIEQUES AS POTENTIAL OTEC SITES

4.1 Introduction

Throughout the measurement program, from August 1978 until June 1979, a series of measurements were made to test the hypothesis that "there is no significant difference between Punta Tuna, Puerto Rico and Punta Vaca, Vieques from an OTEC siting standpoint, as far as environmental and thermal resource variables are concerned." This investigation was not designed to consider socio-economic condition, cable costs, or land-based support. The criteria that were evaluated were available thermal resource, temperature/salinity /density structure in the water column, Mixed Layer Depth, chlorophyll and dissolved oxygen.

Punta Vaca, Vieques is a small point of land on the southwest part of Vieques jutting into the Caribbean Sea. Much as Punta Tuna sticks out from the main island of Puerto Rico, Punta Vaca is about 40 km ENE from Punta Tuna (Fig. 115, Station "V"). Both points face southward, and are in areas of significant terrestrial mountains. Also, both are located only 3-3.5 km from the 1000 m depth contour. The bottom topography off both points is quite similar, with very rough and uneven bottom during the descent. With these similarities described, the evaluation must be made as to what, if any, are the basic differences. Punta Tuna lies in the windward path of the southeast winds and seas moving to the northwest. Punta Tuna is also exposed to northeast winds and their associated seas, as this point is virtually exposed on the southeast corner of Puerto Rico. Punta Tuna is also located about 1/2 km east of the mouth of the Maunabo River, which brings silt, nutrients, and fresh water into the oceanic area, although in small amounts.

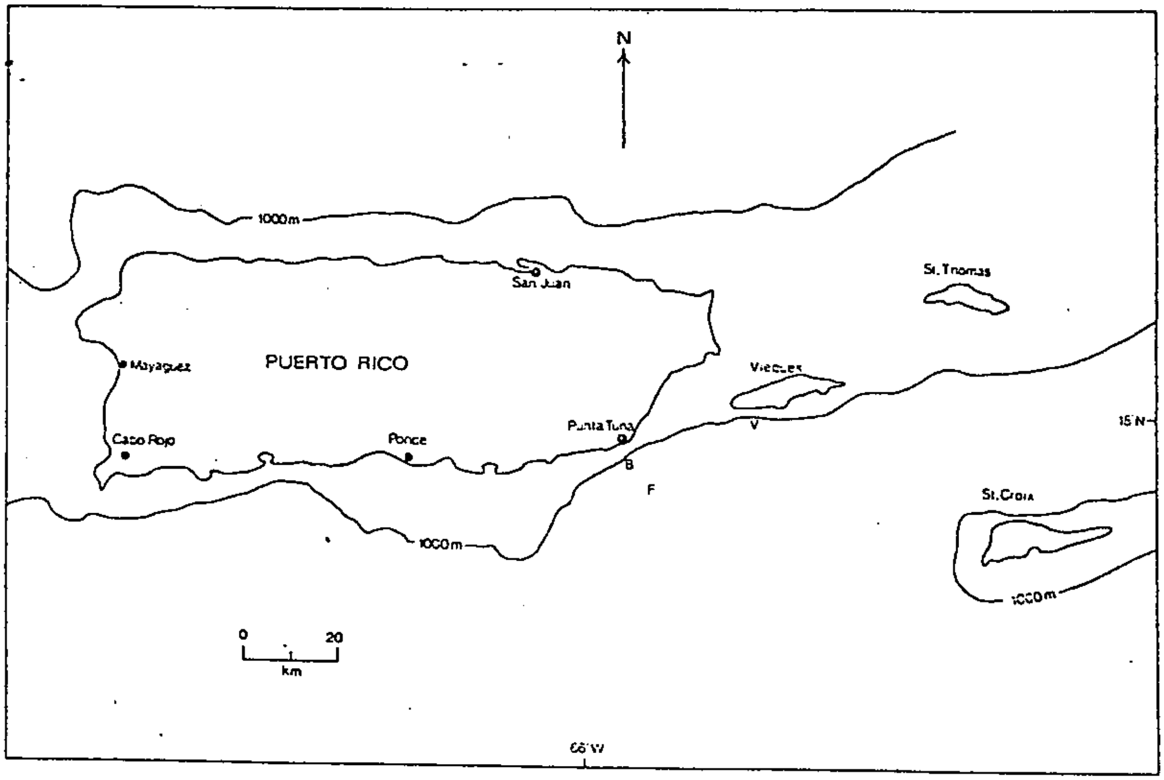


Fig. 115 - Map showing Vieques in relation to Puerto Rico.

Punta Vaca, however, is relatively protected. This point lies directly northwest of the island of St. Croix. This location tends to protect Punta Vaca from some of the strong southeast winds and their effects. Also, as Punta Vaca lies in the southwest side of the island of Vieques, it is protected quite well from activities to the north, such as North Atlantic Storms. There are no major rivers or streams flowing into the ocean near Punta Vaca, and furthermore, as Vieques is a small island, any runoff would be even less significant than at Punta Tuna.

The measurements made and samples taken at Punta Vaca were similar to those taken at Punta Tuna. The major difference was that the ship was allowed to drift while on station, as there is no fixed mooring buoy at the Vieques location. This results in unusually less deep hydrocasts, due to the considerable wire angle.

During the measurement period, six cruises were conducted to the area of interest. However, on two occasions, the cruises had to be terminated before reaching the Vieques Station. Comparative data is available only for the cruises of October and December 1978, and April and June 1979.

4.2 Results

4.2.1 Temperature Results

Reversing thermometer data of Vieques was compared with the average reversing thermometer temperature results determined at Punta Tuna. These profiles, both the Vieques values and the Punta Tuna values are seen in Figures 116-119, representing each of the 4 usable cruise results. The October 1978 results (Fig. 116), show a surprising departure from the Punta Tuna data near the surface. Apparently, near the Vieques Station there was a very shallow mixed surface layer at that time. This may have been due to the protection from the southeast winds, as Punta Vaca lies in the lee of St. Croix. This would have reduced the wind mixing, thus reducing the MLD.

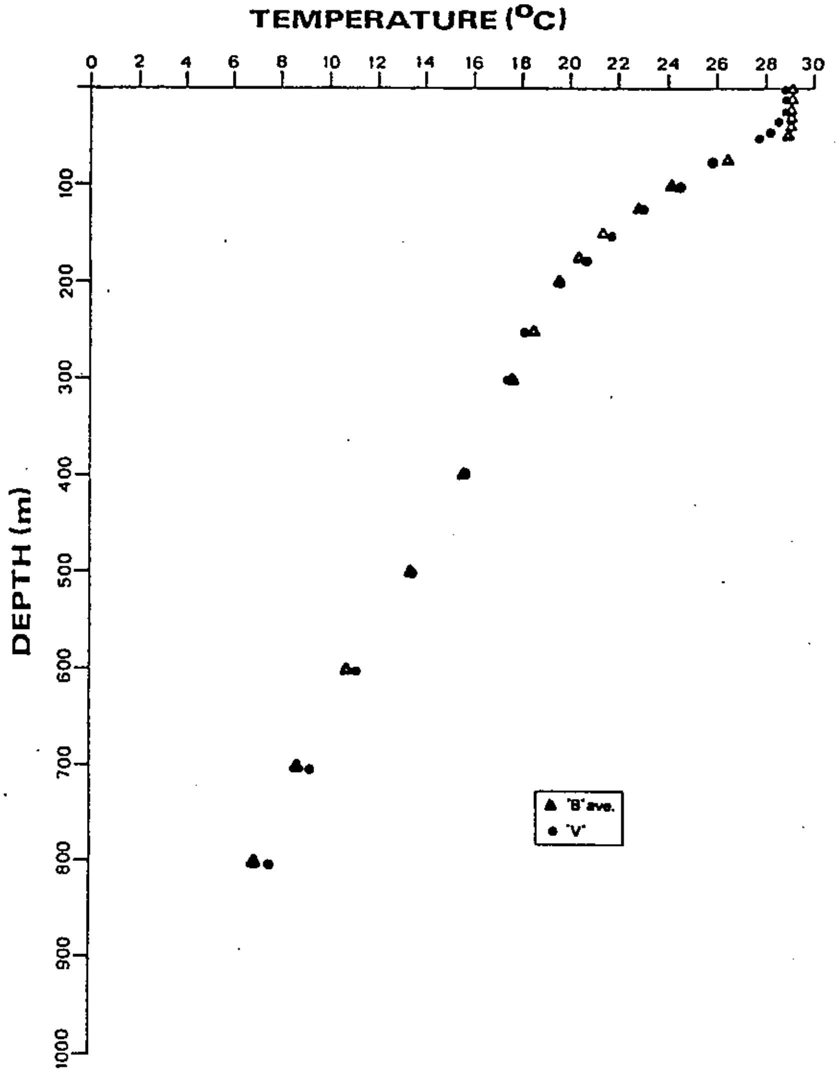


Fig. 116 - Temperature profile of average reversing thermometer values at Punta Tuna (Station "B") vs. reversing thermometer values taken at Vieques (Station "V") for the cruise of October, 1978.

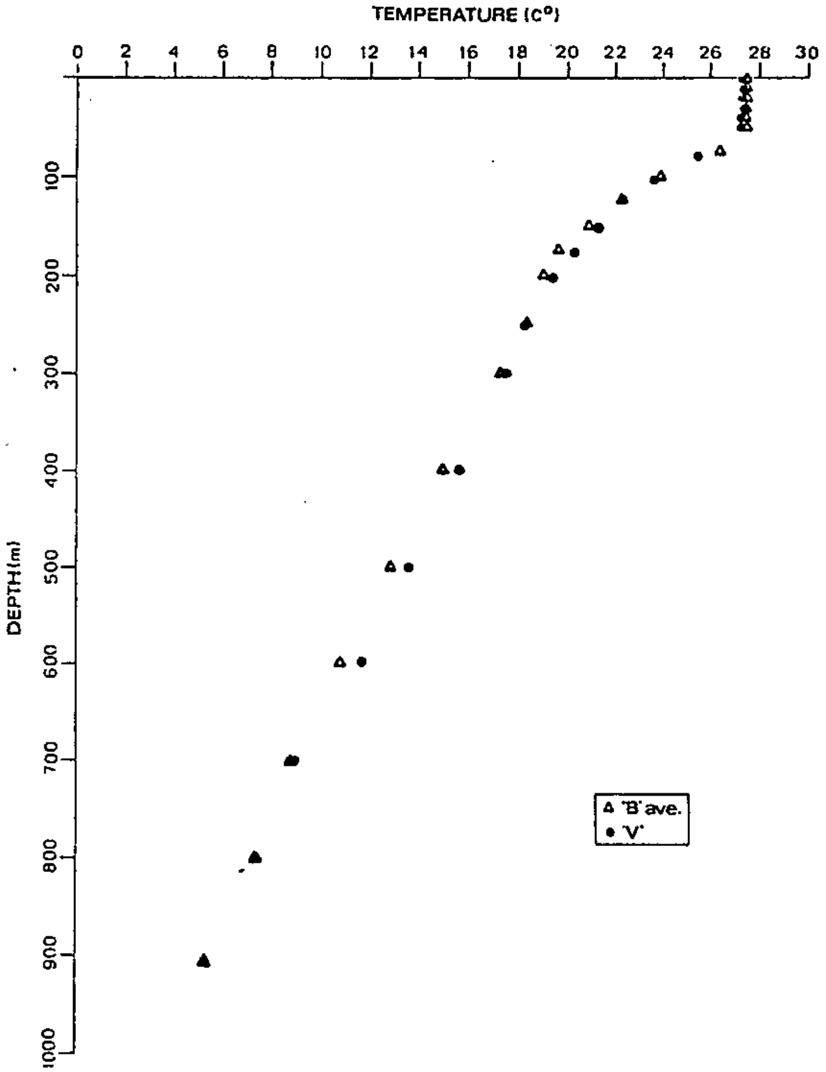


Fig. 117 - Temperature profile of average reversing thermometer values at Punta Tuna (Station "B") vs. reversing thermometer values taken at Vieques (Station "V") for the cruise of December, 1978.

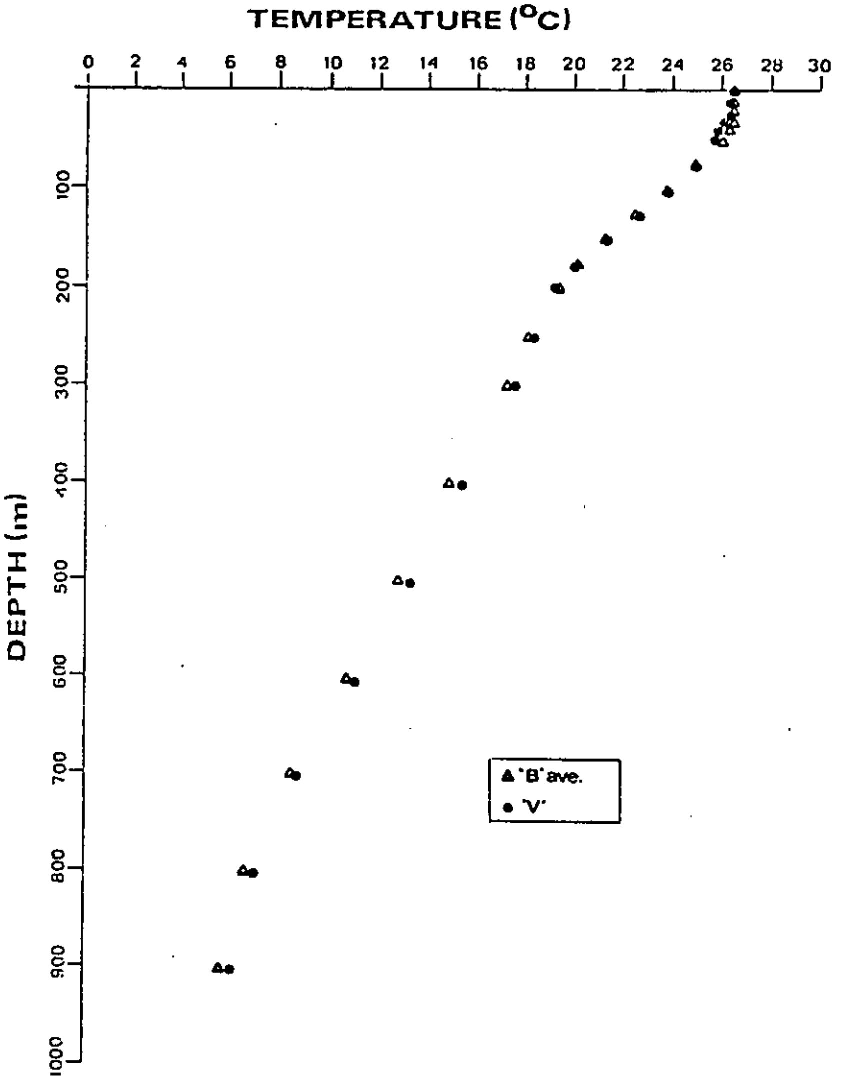


Fig. 118 - Temperature profile of average reversing thermometer values at Punta Tuna (Station "B") vs. reversing thermometer values taken at Vieques (Station "V") for the cruise of April, 1979.

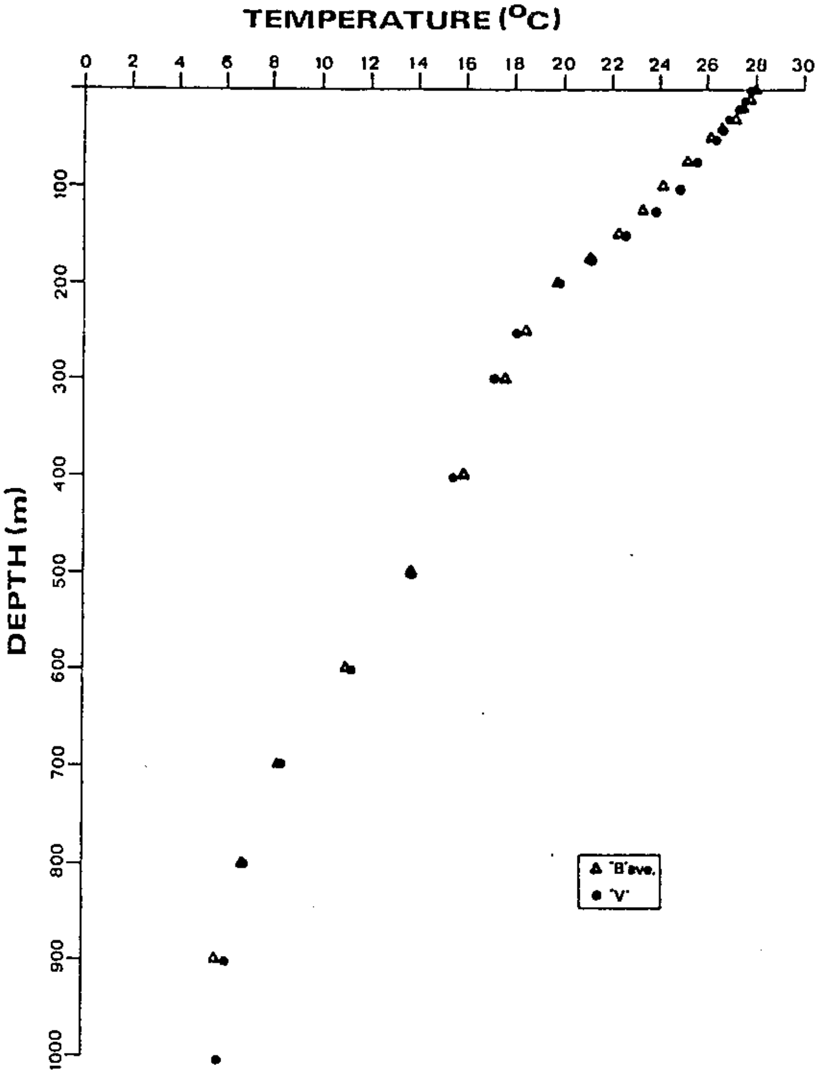


Fig. 119 - Temperature profile of average reversing thermometer values at Punta Tuna (Station "B") vs. reversing thermometer values taken at Vieques (Station "V") for the cruise of June, 1979).

Also, the water at depths greater than 600 m appeared slightly warmer at Vieques than at Punta Tuna. The direct temperature difference between Punta Tuna and Vieques can be seen in Figures 120-123. Figure 120 shows this difference observed during the October 1978 cruise. Punta Tuna water was warmer, by up to 1.2 C°, in the upper 80 m and cooler than Vieques below 500 m. During the December 1978 cruise (Fig. 117 and 121), less temperature difference was seen between the two stations in the upper waters. In general, the surface waters were about 0.1 C° warmer at Punta Tuna, and the mixed layer structure was similar between the two locations (Fig. 121). The deeper water (400-600 m) was warmer at Vieques by about 0.6 C°, but at 800 m, the Vieques water was cooler by about 0.8 C°. This latter value may be in error, as no other case exhibits such a strong difference reversal at these depths. The error is probably in the depth values, rather than temperature. During the April 1979 cruise, (Fig. 118), again the upper mixed layer was less pronounced at Vieques than at Punta Tuna. Also, the upper waters were warmer at Punta Tuna (Fig. 122) by as much as 0.5 C° at 50 m. The deeper waters differed by less than 0.25 C°, with the Vieques waters being warmer. The last cruise, June 1979, (Fig. 119 and 123) showed almost no upper mixed layer structure at either of the two stations. In the near surface waters (0-30 m), the water at Punta Tuna was slightly warmer, but directly below this, the Vieques water was more than 0.5 C° warmer (at 100 m). In the deep waters, from 600-1000 m, the water at Vieques was as much as 0.3 C° warmer.

Table 22 shows a summary of the average temperature differences between Punta Tuna and Punta Vaca, Vieques. Near the surface, the water at Punta Tuna tends to be slightly warmer, but as deep as 30 m, the difference was only 0.3 C°. In the deep water, the average difference is even less, as expected, but occasionally a large difference is seen, resulting in the standard deviation at 800 m being ±0.22 C°.

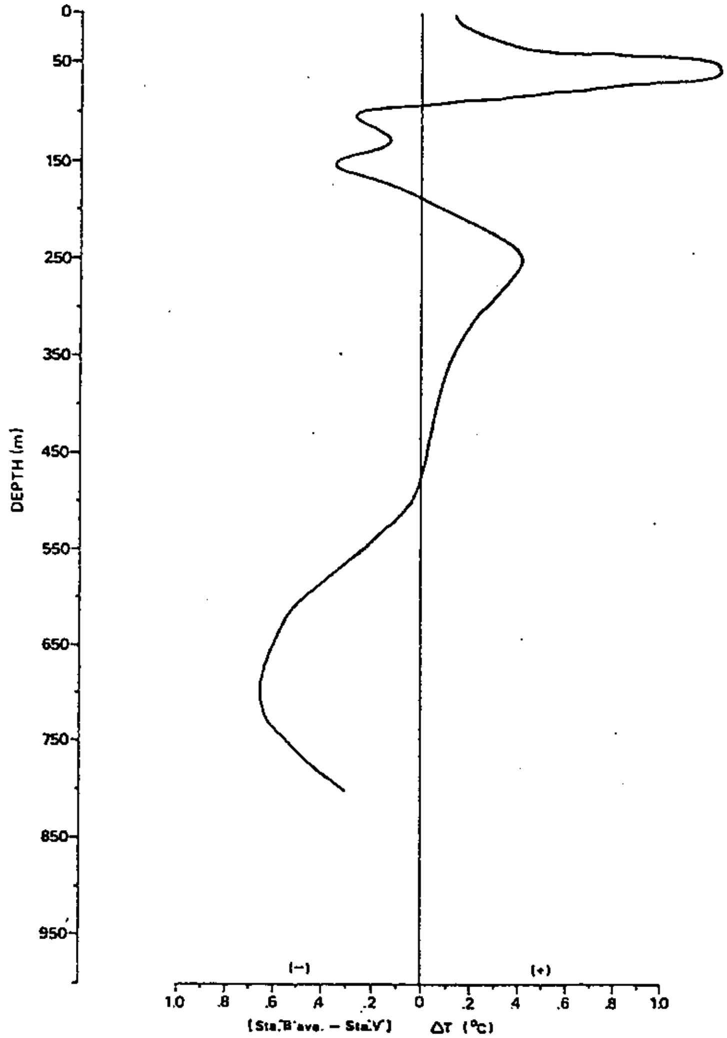


Fig. 120 - Temperature difference between average temperature values at Punta Tuna (Station "B") and values at Vieques (Station "V") for the cruise of October, 1978.

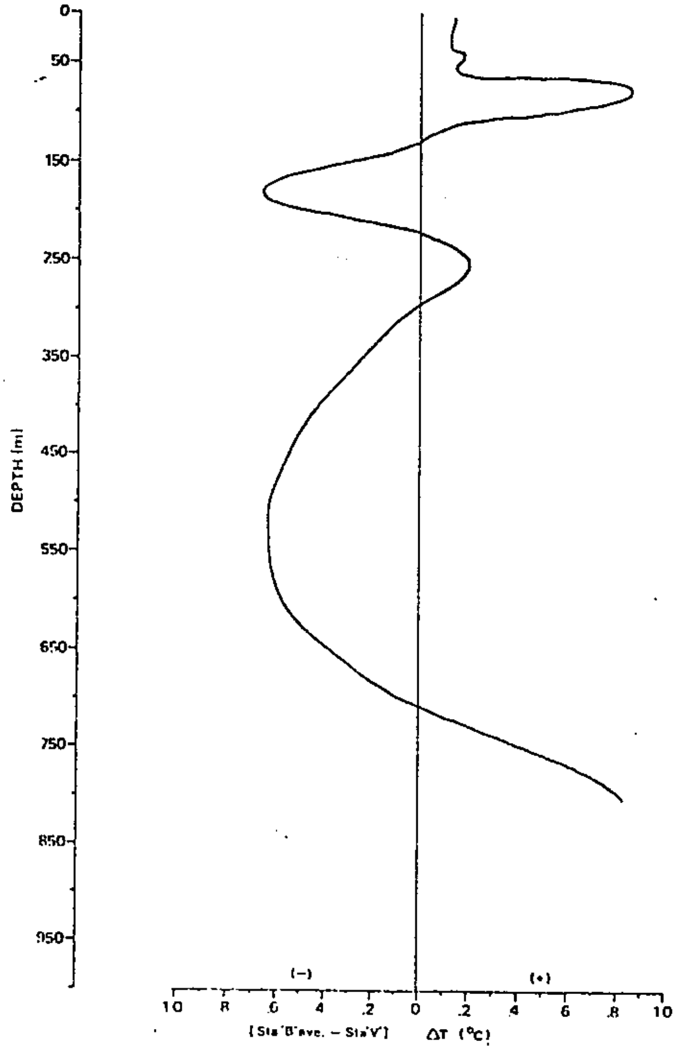


Fig. 121 - Temperature difference between average temperature values at Punta Tuna (Station "B") and values at Vieques (Station "V") for the cruise of December, 1978.

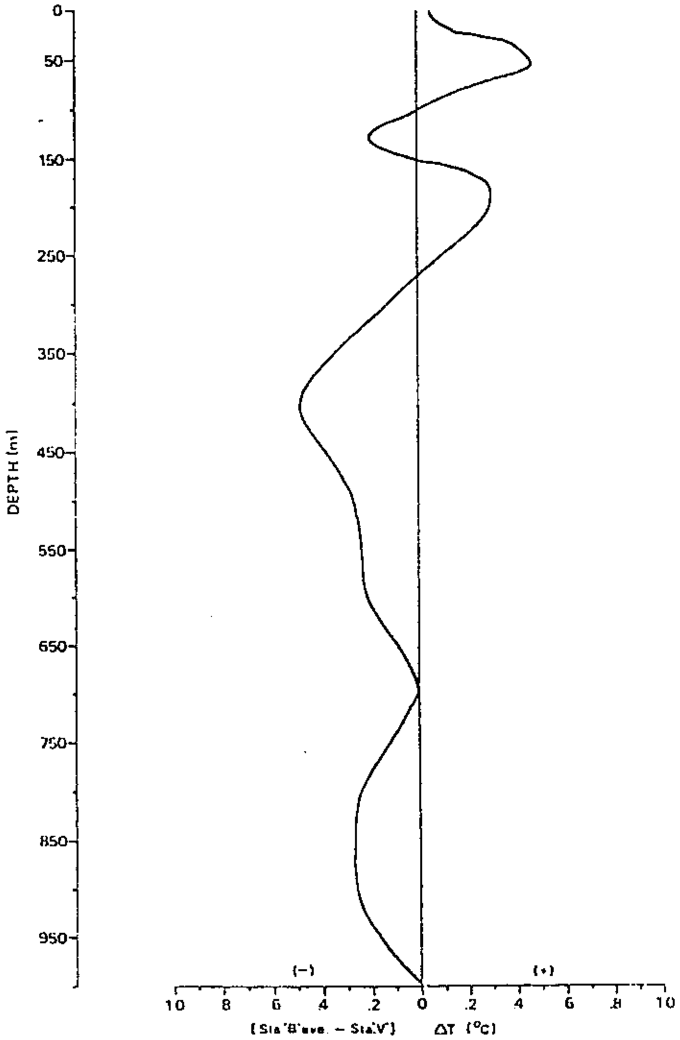


Fig. 122 - Temperature difference between average temperature values at Punta Tuna (Station "B") and values at Vieques (Station "V") for the cruise of April, 1979.

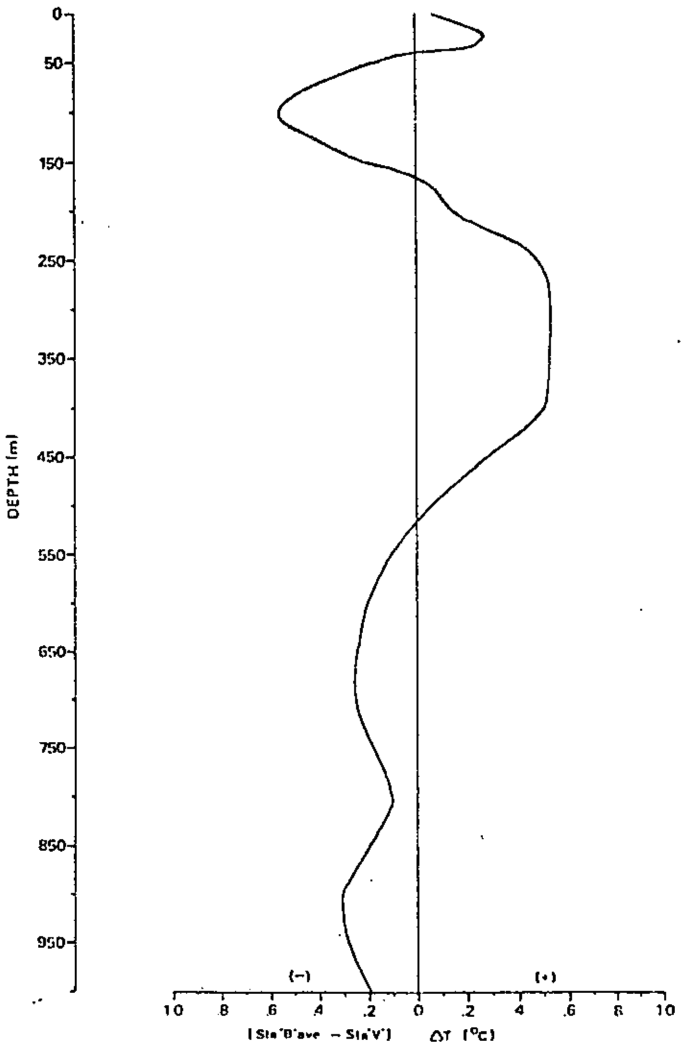


Fig. 123 - Temperature difference between average temperature values at Punta Tuna (Station "B") and values at Vieques (Station "V") for the cruise of June, 1979.

TABLE 22

Average Temperature Difference Between Punta Tuna and Punta Vaca, Vieques

Depth (M)	Temperature Difference (C°)	Standard Deviation (C°)
0	+ 0.1	0
20	+ 0.2	± .05
30	+ 0.3	± .07
50	+ 0.4	± .28
75	+ 0.3	± .26
100	- 0.2	± .15
125	- 0.2	± .08
150	- 0.2	± .09
175	- 0.1	± .19
200	0	± .11
250	+ 0.3	± .08
300	+ 0.2	± .12
400	- 0.1	± .20
500	- 0.2	± .13
600	- 0.4	± .09
700	- 0.2	± .14
800	0	± .22
900	- 0.2	± .05
1000	- 0.1	± .07

(+ Signifies that Punta Tuna is warmer than Vieques).

4.2.2 Thermal Resource Results

More important than the occasional variations in the temperature of portions of the water column is the actual difference in the available Thermal Resource that would be usable for an OTEC power plant. Unfortunately, during two of the four comparable cruises, no thermal data is available below 800 m depth. Therefore two types of presentation will be discussed regarding the Thermal Resource. In the first case, the discussion will involve looking at the temperature difference between the 20 m depth and the 800 m depth, the deepest temperature common to the four cruises. The second discussion will consider only the warm water resource, and assume the deep waters are virtually equal.

The first discussion assumes that the warm water intake will be located 20 m below the surface and that the cold water intake will be at a depth of 800 m. As far as thermal efficiency is concerned for an OTEC plant in Puerto Rico waters, 1000 m depth is probably required, but the 20 m to 800 m difference must be used to allow use of all the available cruise data. The lower portion of Figure 124 shows this Thermal Resource for both Punta Tuna and Vieques. In October 1978, and April and June of 1979, there is a greater Thermal Resource at Punta Tuna than there is at Vieques (by about 1/2 C°), while in December 1978 there was an exception to this trend, and the Vieques station had the greater Thermal Resource by more than 1 C°. As mentioned above, the December deep water temperature for Vieques is suspect. Therefore, it appears that the Thermal Resource at Punta Tuna is higher than at Vieques, by almost 1/2 C°.

The second part of the discussion comparing the Thermal Resources between surface and 1000 m, assumes that cold water intake temperatures equal. This assumption also may not be valid, but it allows a second comparison, which may help validate the first. The upper portion of Figure 124 shows the change in surface water temperature for the two stations throughout the year. In every case where surface temperature

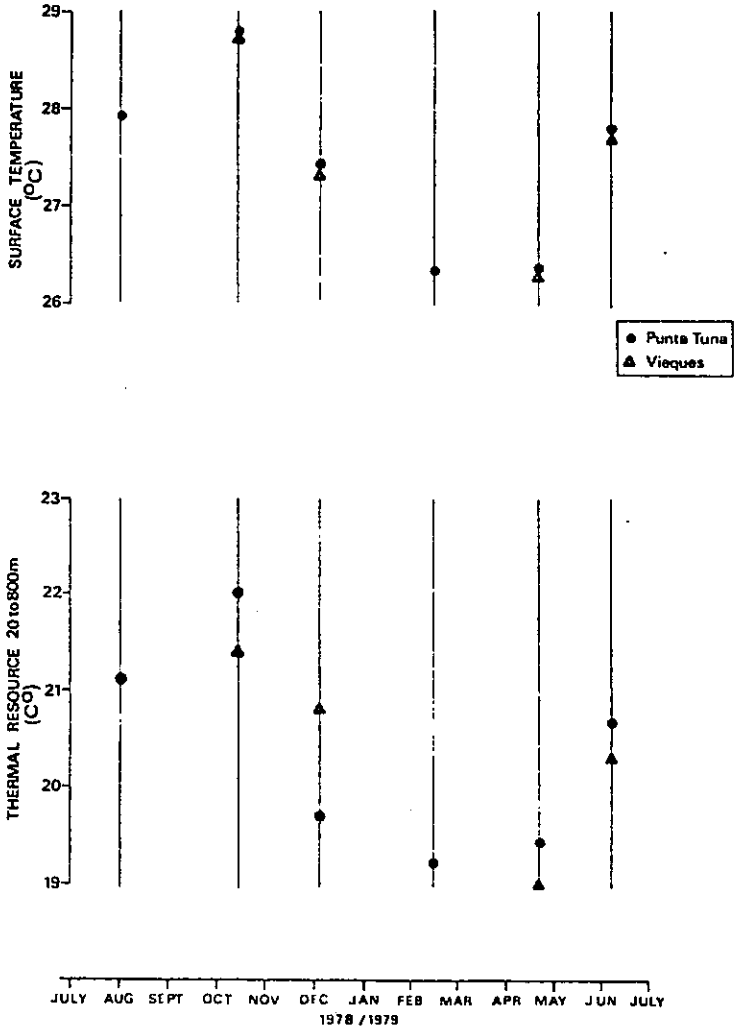


Fig. 124 - Comparison of surface waters and thermal resource (20 m-800 m) between Punta Tuna and Vieques from August, 1978 to June, 1979.

was measured at both stations, the Punta Tuna station always showed a higher temperature, by about 1/4 C°. If the deep water intake temperature were the same, again the thermal resource at Punta Tuna would be greater than at Vieques.

4.2.3 Salinity Results

The salinity/depth relationship at the Punta Tuna and Vieques locations is compared to try to interpret differences in water movement that may affect either the operation of an OTEC Plant or the path of a plant's effluent (Figs. 125-128). During the October cruise (Fig. 125), the salinity of the upper water was higher at the Vieques station down to about 200 m. Below that depth the salinities were fairly similar. As mentioned in the previous section discussing the temperature results, there was less evidence of good mixing in the surface layers at Vieques than at Punta Tuna. With less mixing, the local precipitation may not be carried down as far into the mixed layer, causing higher subsurface salinities. But this can not explain the salinity difference at and below the salinity maximum depths.

To explain this difference one must assume the Subtropical Underwater (SUW) is entering into the Caribbean from the North, it may mix and diffuse slightly with time. Vieques is closer to the source of this water mass (closer to the Anegada Pass), therefore the Vieques location would be more inclined to experience original higher salinity.

During the cruise of December 1978, (Fig. 126), the vertical salinity structure at Vieques was more nearly the same as at Punta Tuna than during October. The major differences seen during December were in the lower water column. These small, but noticeable differences could be explained by a small error in depth determination.

During the April 1979, cruise (Fig. 127), the mixed layer at Vieques was not as well defined as at Punta Tuna. This is consistent with the temperature results for this cruise. Otherwise, the salinities are similar. During June

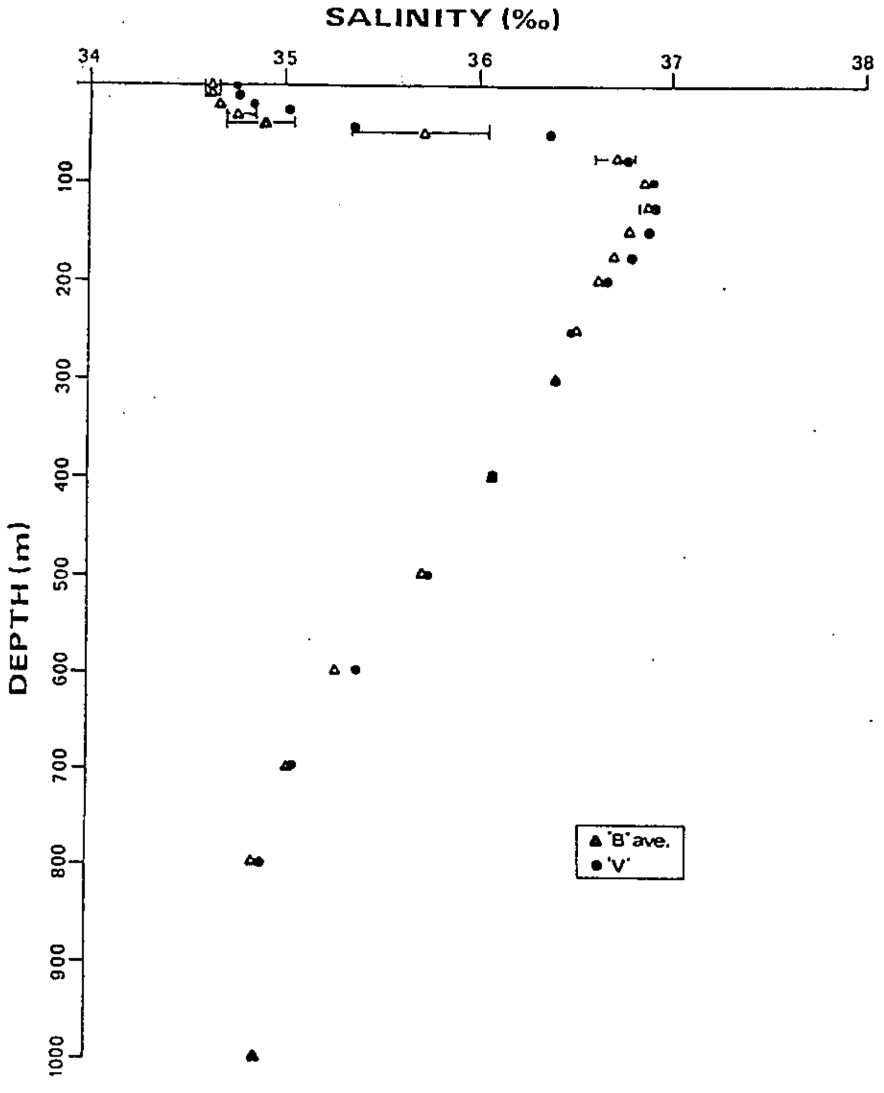


Fig. 125 - Salinity profile of average values measured at Punta Tuna (Station "B") and values measured at Vieques (Station "V") during the cruise of October, 1978.

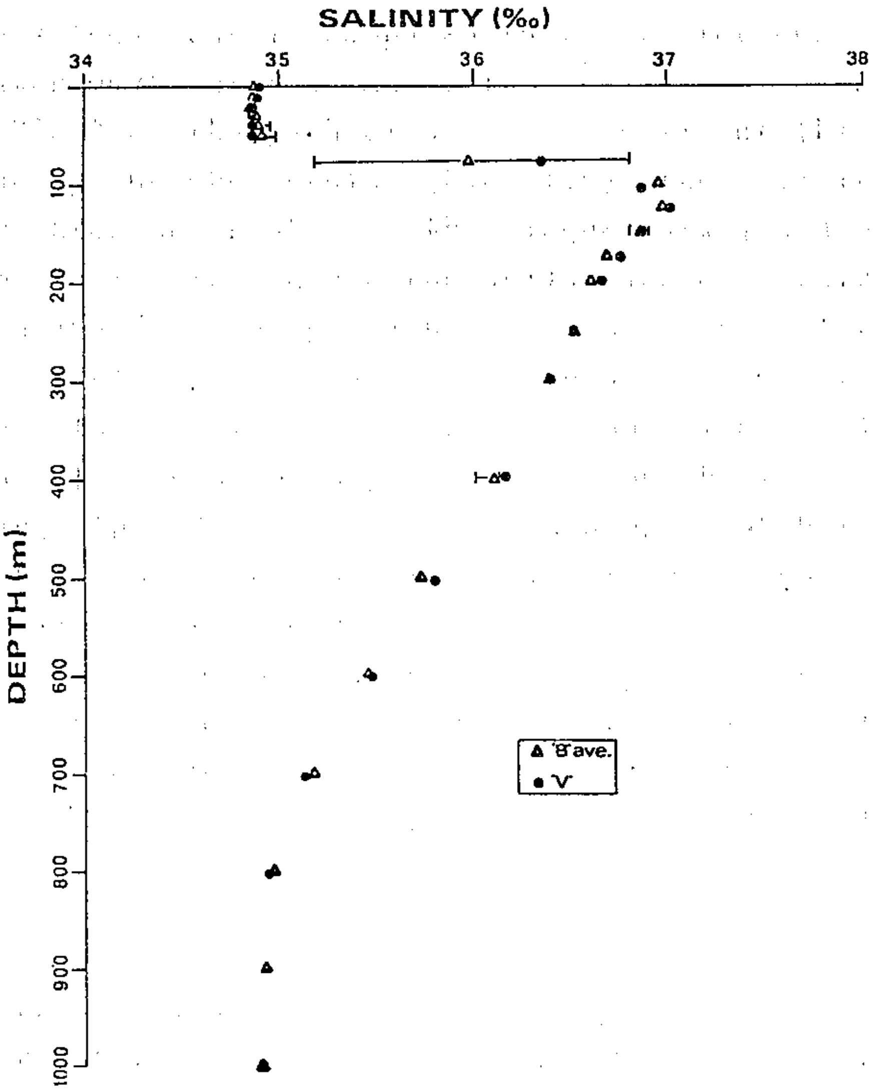


Fig. 126 - Salinity profile of average values measured at Punta Tuna (Station "B") and values measured at Vieques (Station "V") during the cruise of December, 1978.

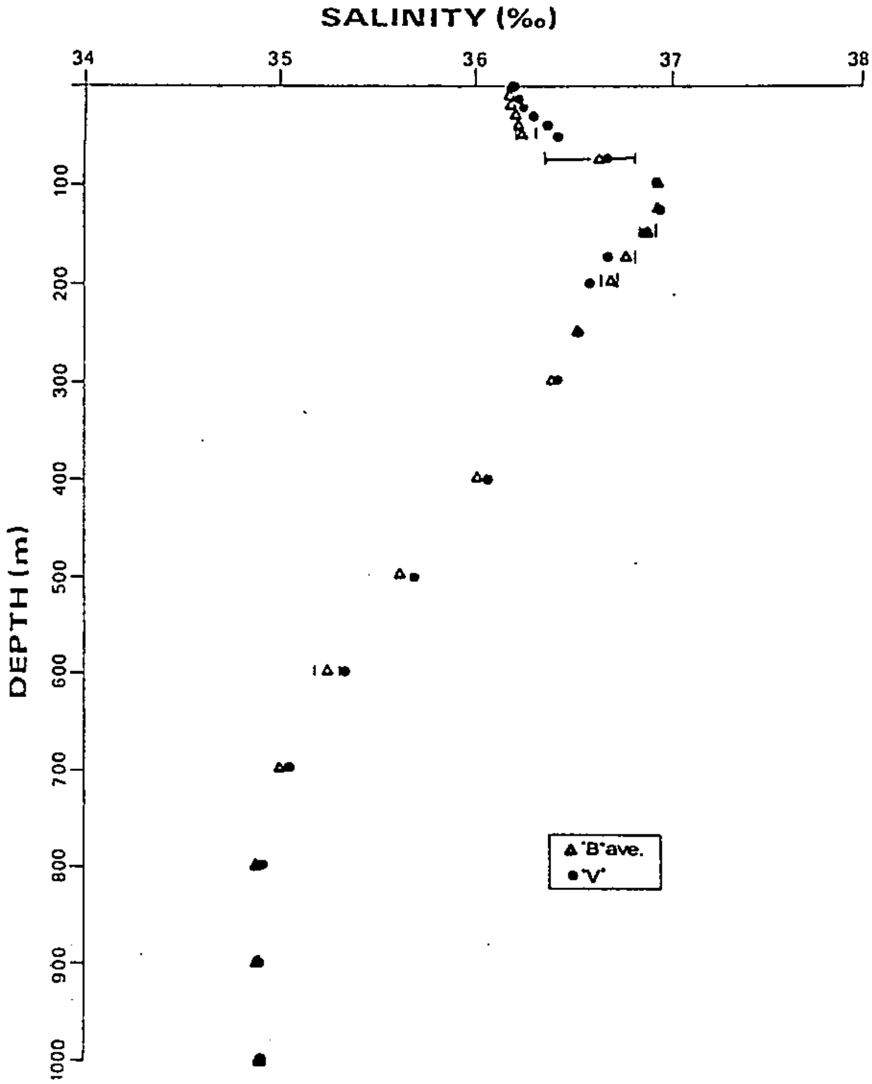


Fig. 127 - Salinity profile of average values measured at Punta Tuna (Station "B") and values measured at Vieques (Station "V") during the cruise of April, 1979.

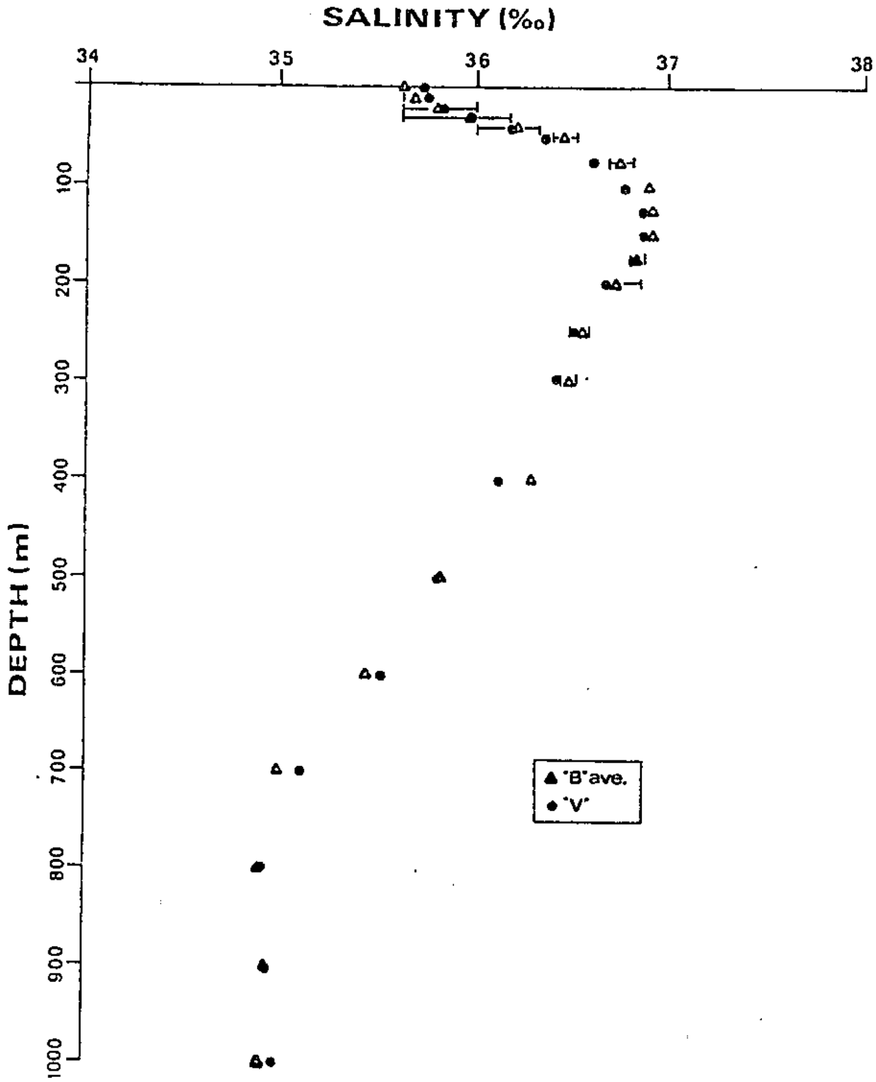


Fig. 128 - Salinity profile of average values measured at Punta Tuna (Station "B") and values measured at Vieques (Station "V") during the cruise of June, 1979.

1979, (Fig. 128), the upper waters appeared similar at both stations, but the core of the SUW was thicker at Punta Tuna than at Vieques, resulting in lower salinities in the 50-150 m depth range at Vieques. Other differences occur in the lower water column, but these appear to be artifacts of measurement errors.

4.2.4 Density Results

The density profile of the water column is compared for the two locations, Punta Tuna and Vieques, only as it relates to a potential effluent depth. Figures 129-132 show density vs. depth profiles for each of the four comparable cruises, respectively, for both Punta Tuna and Vieques. There is almost no difference in the density/depth profiles between the two stations on the October and December cruises (Figs. 129 and 130). This indicates the effluent dynamics would be virtually the same at the two locations. The upper water during April 1979, was more dense at Vieques than at Punta Tuna, and this difference did not disappear until a depth of about 100 m. This indicates that a mixed (warm and cold water) effluent would seek a greater depth after discharge from an operating OTEC power plant at Vieques during these conditions. As a greater equilibrium depth for the effluent may be an advantage, this could be considered a positive indicator. During June, however, although the density of the upper 30 m was higher at Vieques, from about 40 m to almost 200 m, the water at Punta Tuna was more dense than at Vieques. As this is the depth range where a mixed effluent would probably be found, the structure at Vieques during this period was less desirable.

4.2.5 Mixed Layer Depth

The warm water intake for an OTEC plant will be pumped into the evaporators from the upper mixed layer of the ocean. The depth of this layer, the variation of that depth, and its physical characteristics are then important to plant operation.

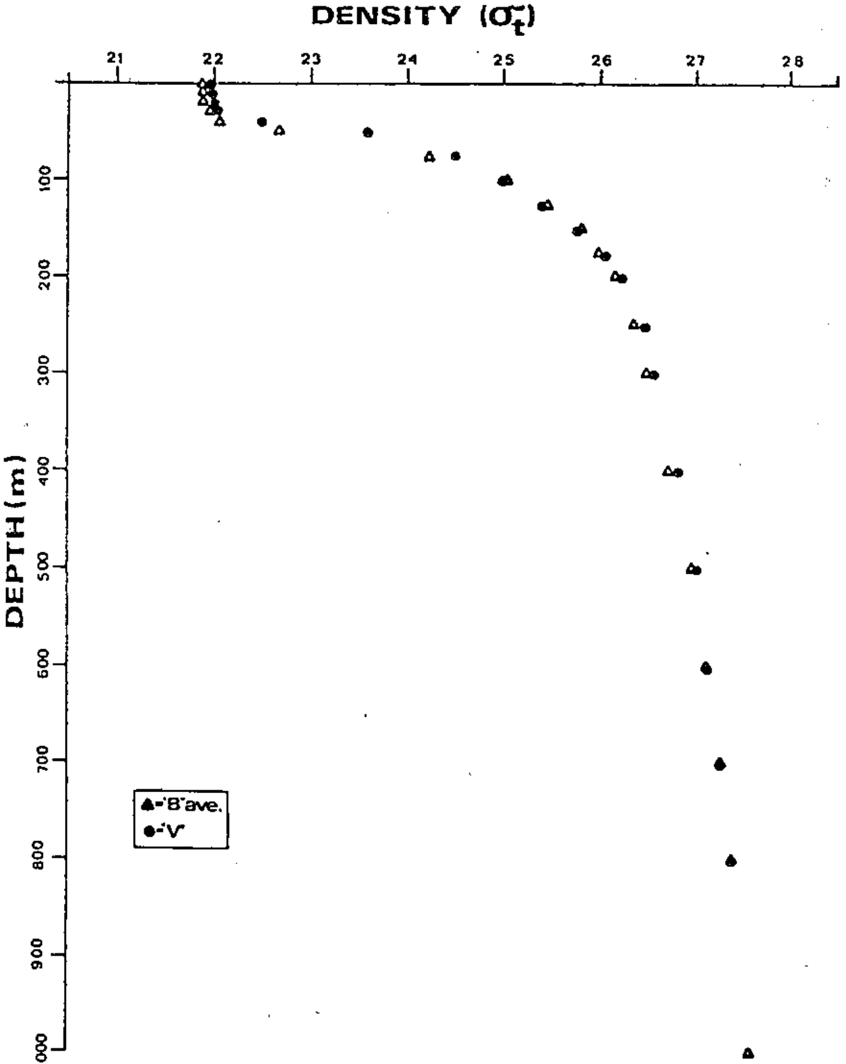


Fig. 129 - Density profile of the average values observed at Punta Tuna (Station "B") and the values observed at Vieques (Station "V") during the cruise of October, 1978.

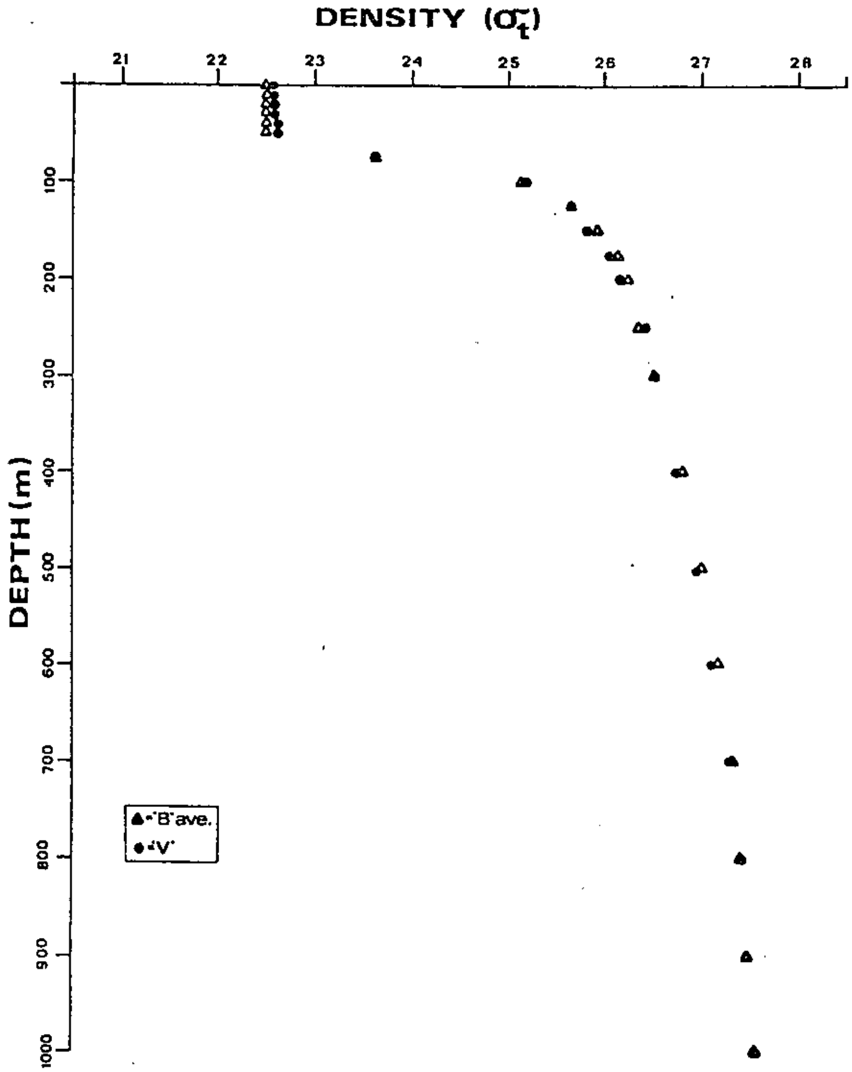


Fig. 130 - Density profile of the average values observed at Punta Tuna (Station "B") and the values observed at Vieques (Station "V") during the cruise of December, 1978.

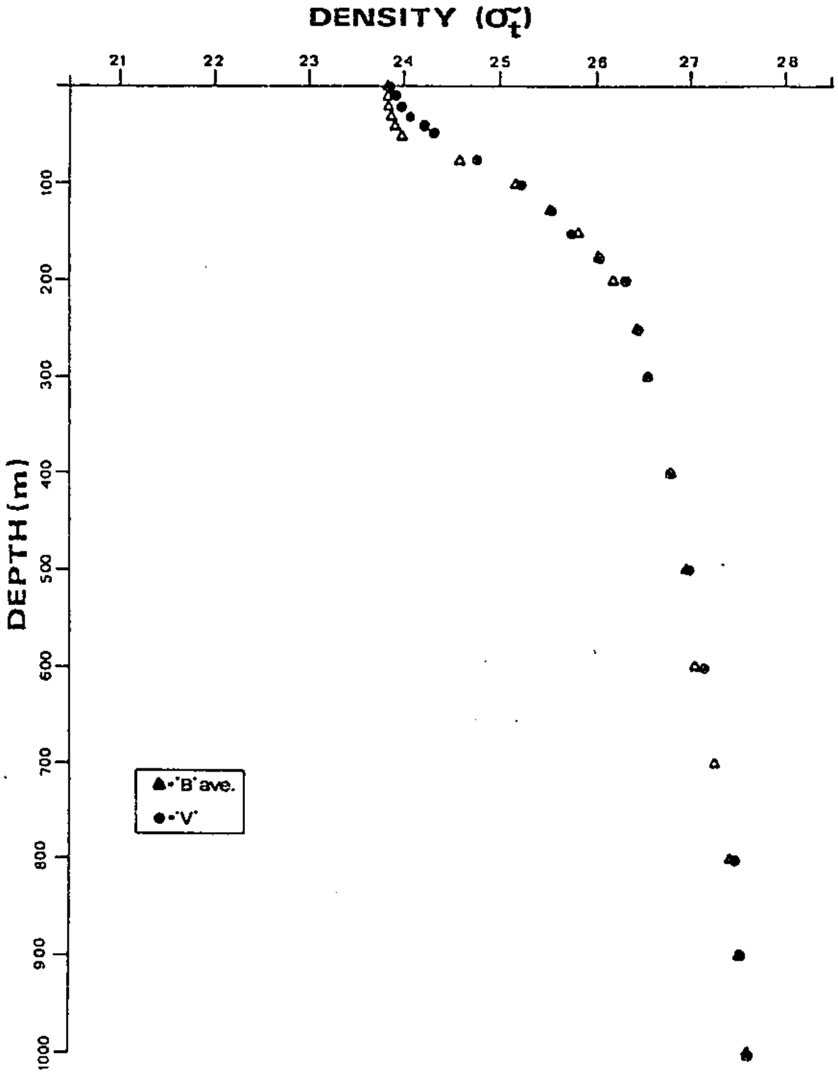


Fig. 131 - Density profile of the average values observed at Punta Tuna (Station "B") and the values observed at Vieques (Station "V") during the cruise of April, 1979.

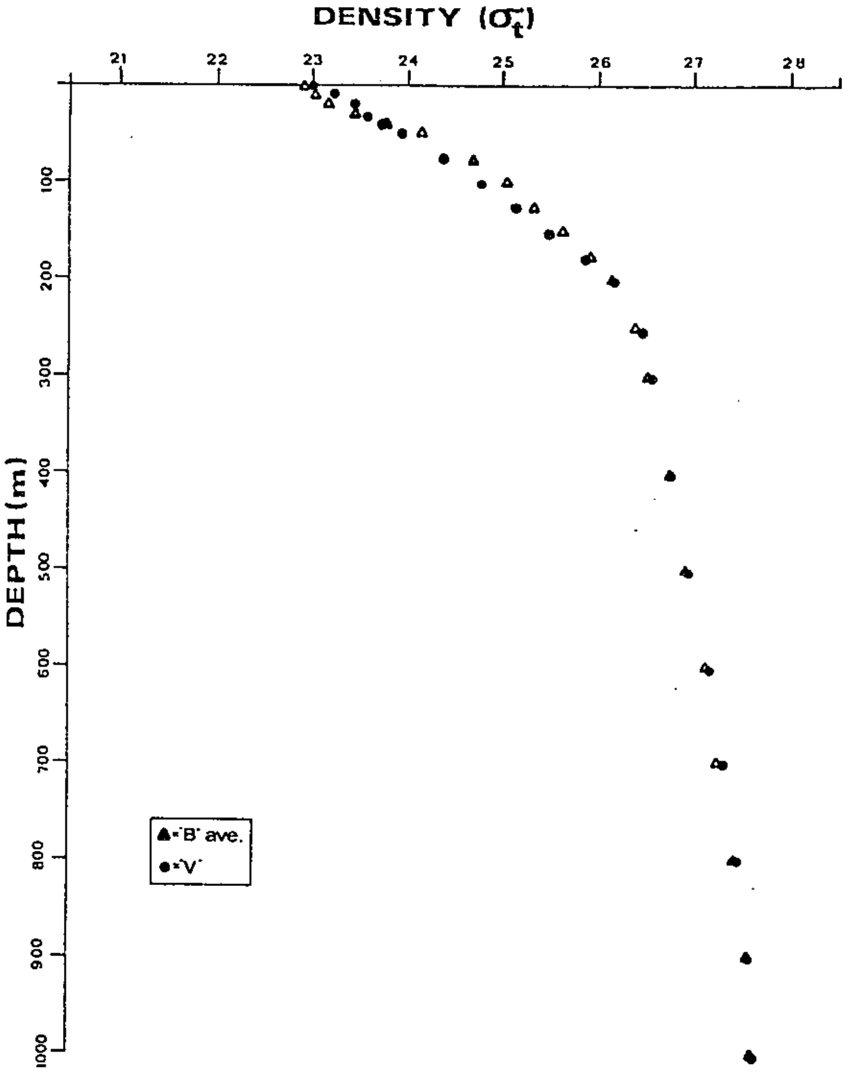


Fig. 132 - Density profile of the average values observed at Punta Tuna (Station "B") and the values observed at Vieques (Station "V") during the the cruise of June, 1979.

Also, the dynamics of the mixed layer will determine some of the plant discharge design characteristics and effluent flow patterns. The time series description of the Mixed Layer Depth (MLD) for Punta Tuna (both from this program and from the historical averages) and Vieques is seen in Figure 133 Other than the wind and open sea sheltering effects at Vieques (by St. Croix), there are no apparent explanations for the differences in the MLD between Punta Tuna and Vieques. During October the MLD at Vieques was much more shallow than at Punta Tuna, however, during December, the opposite was true. During April and June the two locations had about the same MLD (Table 23). Therefore, MLD can not be used as a criteria to chose between the two, although there may be differences.

4.2.6 Chlorophyll Results

Figures 134-137 give the chlorophyll "a" profile for both Punta Tuna and Vieques during each cruise. There were no significant differences between the two locations. Figure 138 shows the time series description of the integrated chlorophyll "a" values in the upper 200 m at both Punta Tuna and at Vieques. Also shown in this figure is the time series of the surface salinity throughout the year. If the theory of the Amazon and Orinoco Rivers being the major factor influencing the surface salinity (Atwood et al. 1976) is corrected, the periods of lowest salinity have the greatest amount of river runoff and its associated nutrients. If that were the case, the chlorophyll "a" might be expected to reflect a negative correlation to the salinity. The waters at Punta Tuna reflect this inverse relationship during much of the year, but the large peak, in April, is directly opposed to the theory. The values at Vieques do seem to reflect the inverse relationship, even during April. This might be explained by having the aforementioned Maunabo River influence the productivity at Punta Tuna more than might be thought. If that were the case, Vieques could be seen as a more representative "open ocean"

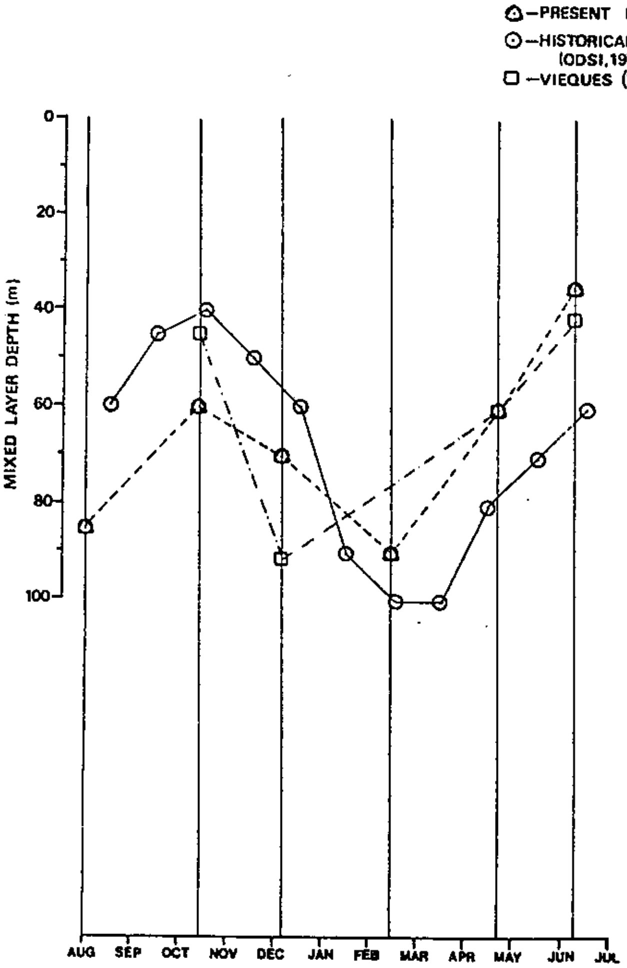


Fig. 133 - Values of Mixed Layer Depth seen in the historical data (ODSI, 1977) and those seen at Punta Tuna and at Vieques during the period from August, 1978 to June, 1979.

TABLE 23

Calculated Mixed Layer Depth (MLD) seen at
Punta Vaca, Vieques from October, 1978 to June, 1979.

Cruise		Temperature		Salinity	Density	Value Used
		Thermometer	XBT			
October	'78	45m	53m	45m	45m	45m
December	'78	115	85		70	90
April	'79	55	60	--	85	60
June	'79	30	35	95	50	40

CRITERIA ΔT = 1C° $\Delta S = 1^{\circ}/_{\circ\circ}$ $\Delta\sigma_t = 1$

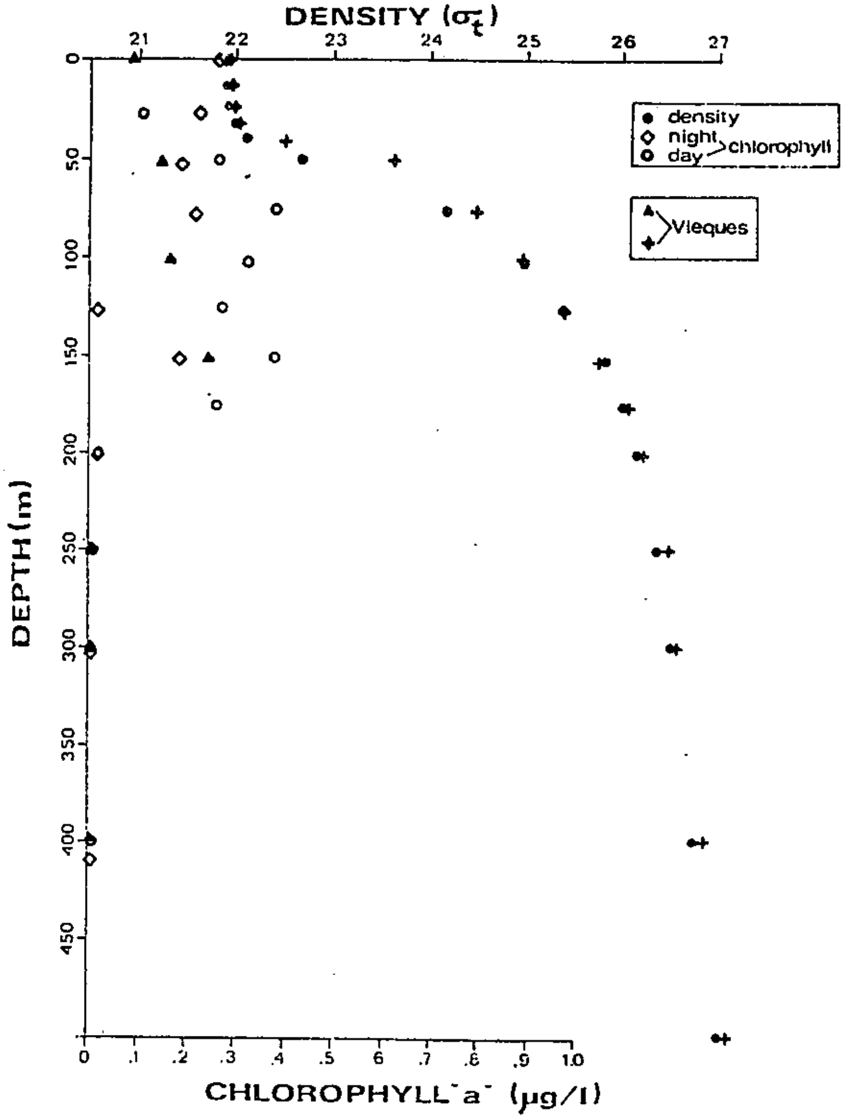


Fig. 134 - Chlorophyll "a" profiles observed at both Punta Tuna and at Vieques during the cruise of October, 1978.

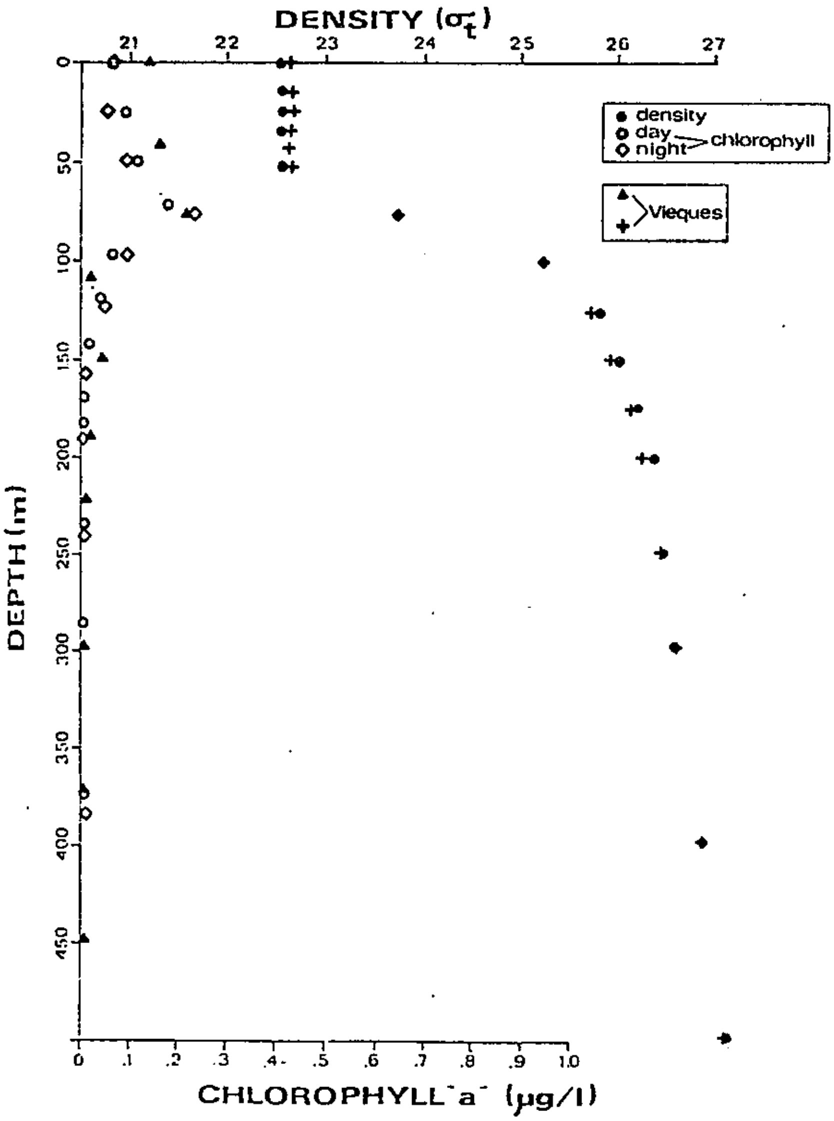


Fig. 135 - Chlorophyll "a" profiles observed at both Punta Tuna and at Vieques during the cruise of December, 1978.

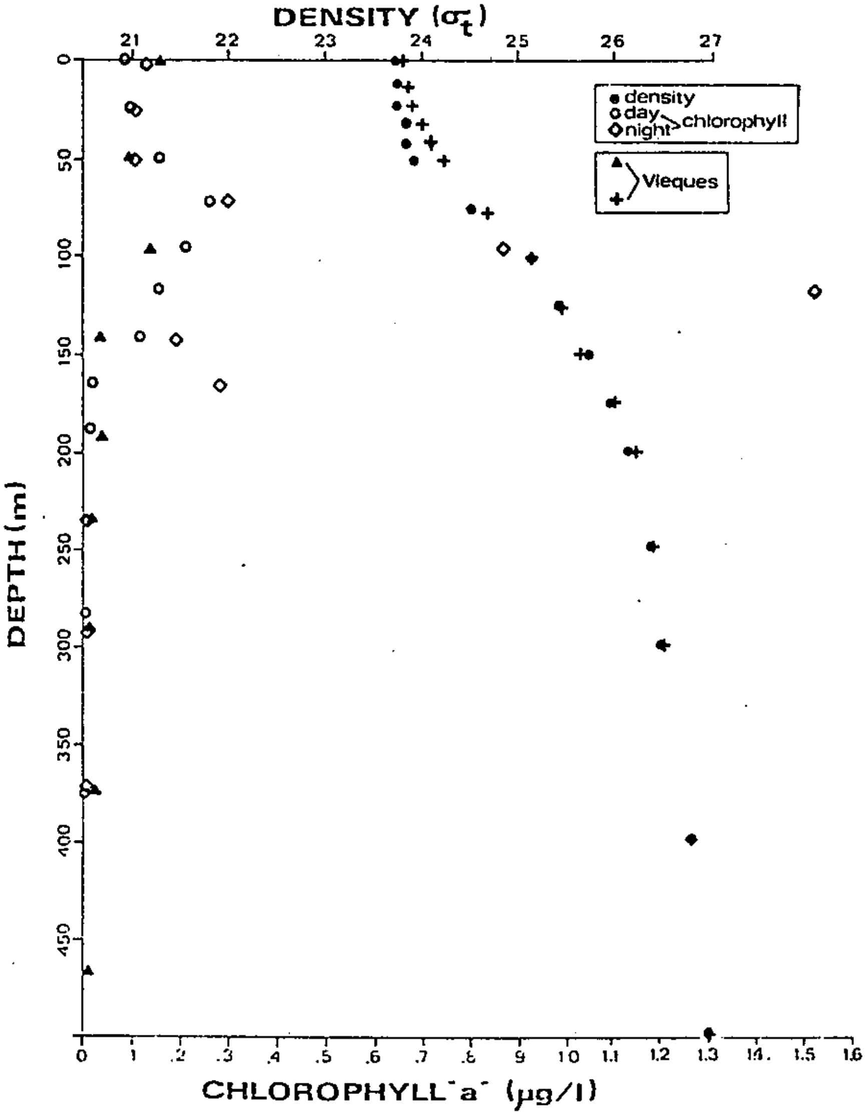


Fig. 136 - Chlorophyll "a" profiles observed at both Punta Tuna and at Vieques during the cruise of April, 1979.

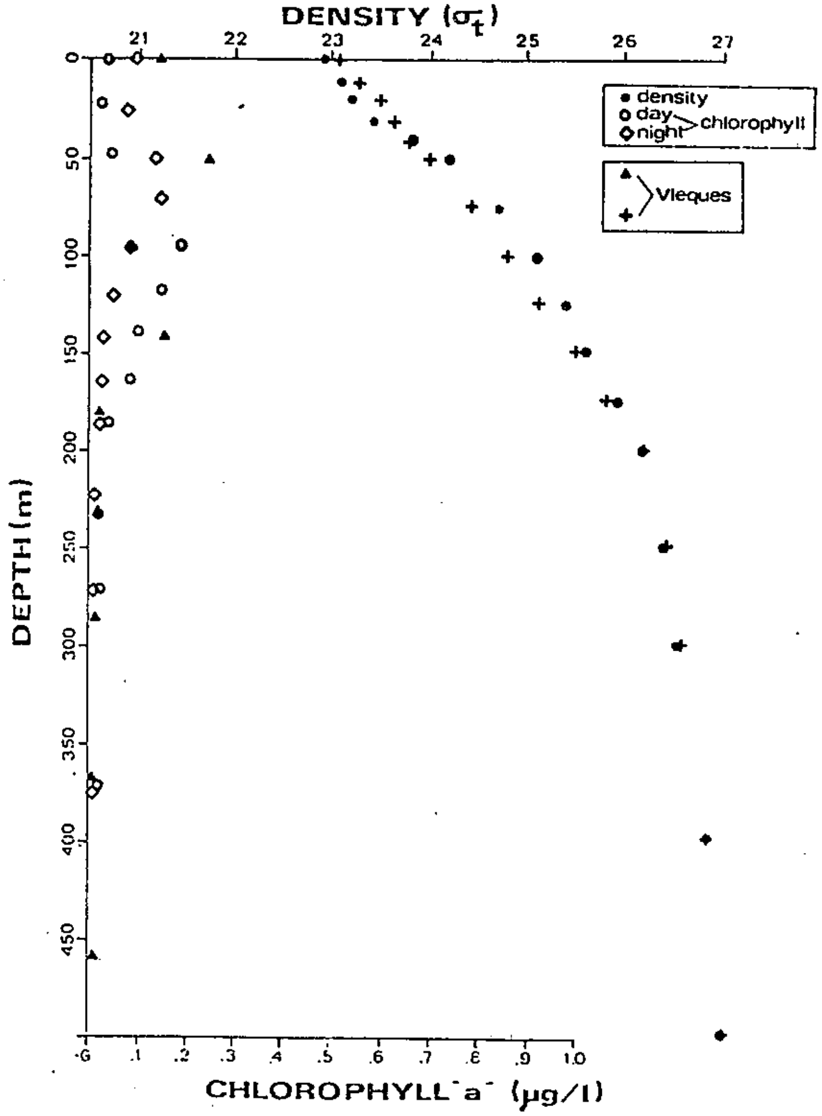


Fig. 137 - Chlorophyll "a" profiles observed at both Punta Tuna and at Vieques during the cruise of June, 1979.

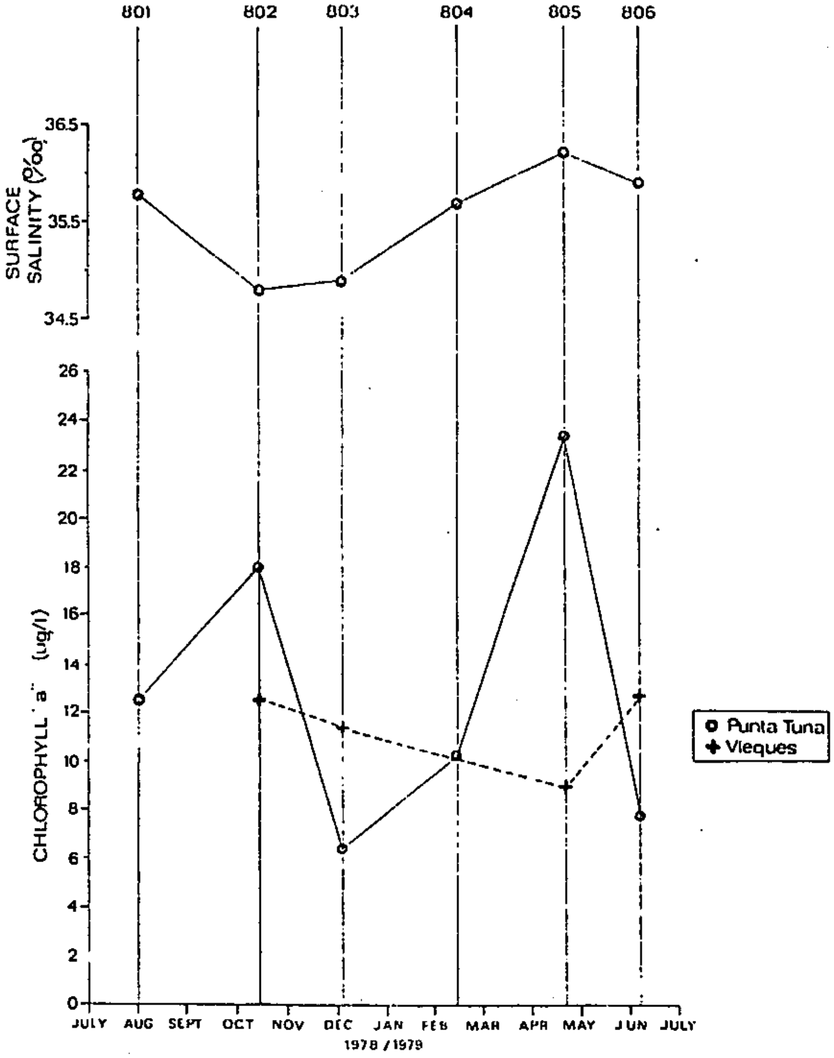


Fig. 138 - Time series of integrated chlorophyll "a" in the upper 200 m measured at both Punta Tuna and at Vieques during the period from August, 1978 to June, 1979.

site, with less terrestrial influence. Another explanation to the April peak could be the natural patchiness of the phytoplankton producing the measured values of chlorophyll "a".

4.2.7 Dissolved Oxygen

Dissolved oxygen may be a limiting factor to the natural recovery of an ecosystem after it experiences a serious perturbation. It is thought that a large OTEC plant bringing the deep water up to near the surface may have an adverse effect. Figure 139 has the average dissolved oxygen profiles for both all the Punta Tuna cruises and all the Vieques stations. The two locations have dissolved oxygen concentrates that differ by less than 0.1 ml/l anywhere in the water column. As this represents a very small difference, which is probably at about the limit of the measurement error, it must be assumed that the area near Punta Tuna would act similarly, with regard to oxygen availability, as that near Vieques.

4.3 Conclusions

Both the influence of the environment on an OTEC plant and the effect of an OTEC plant on its environment were evaluated to determine if there is a significant siting difference between Punta Tuna, Puerto Rico and Punta Vaca, Vieques. From the results of this comparative work, it appears that an OTEC plant operating at Punta Tuna would have a slightly greater Thermal Resource available throughout the year. This advantage would result in slightly greater thermal efficiency. The primary reason for the greater Thermal Resource is the slightly higher surface temperature at Punta Tuna. Vieques surface water may be more influenced by the cooler North Atlantic water than can occur at Punta Tuna.

Terrestrial runoff may influence the Punta Tuna site whereas it is not nearly as important at Punta Vaca. Runoff is high in nutrients. Usually more nutrients in the surface

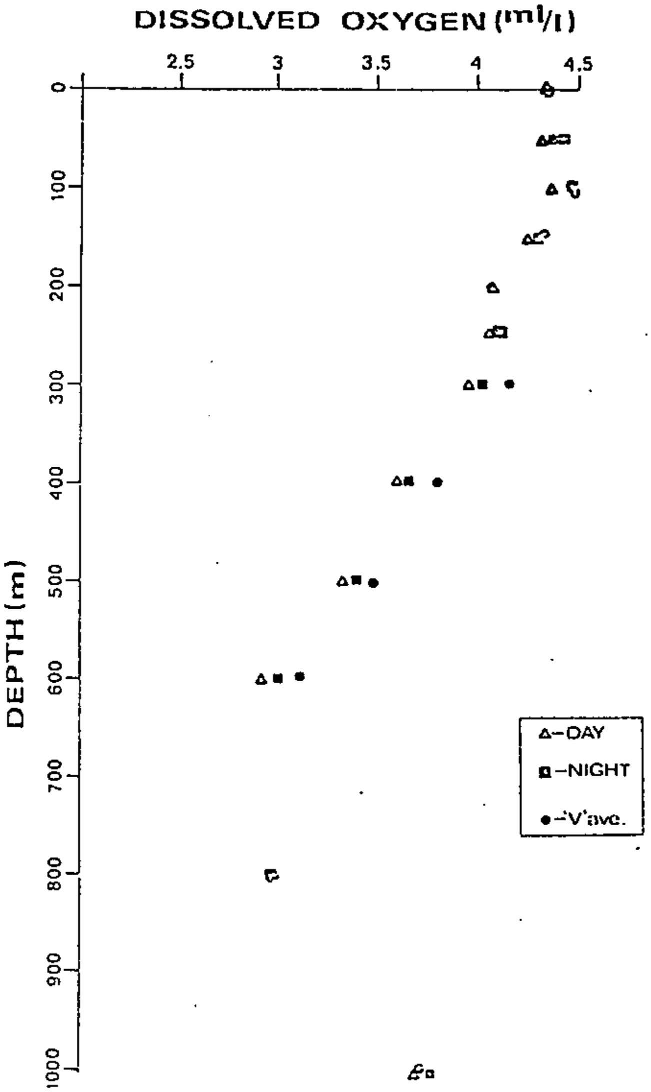


Fig. 139 - Dissolved oxygen profile for the average of all values measured at Punta Tuna and the average values measured at Vieques, (Station "V").

waters will produce more phytoplankton. These phytoplankton may either damage the evaporator plumbing of an OTEC plant, or attract more predators, which in turn may cause problems to the plant.

The density structure in the water column will ultimately determine the vertical fate of the effluent water. There seemed to be no systematic difference in water column structure between the two sites that would favor one over the other. Chlorophyll concentrations as well as the dissolved oxygen levels are the same between the sites.

In conclusion, the only significant difference between Punta Tuna and Punta Vaca, Vieques is the available Thermal Resource. Measurements made during this period from August 1978 to June 1979 indicate that the Thermal Resource at Punta Tuna is consistantly 1/4-1/2 C° greater than the Thermal Resource at Punta Vaca, Vieques. This amounts to a potential difference of 2-3% of the net output power from a large operating OTEC power plant.

5.0 COMPARISON OF PUNTA TUNA WITH CABO ROJO AND PUNTA BORINQUEN

5.1 Introduction

Serious thought is being given to the advantages and disadvantages of changing the "Benchmark", or "most suitable site" in Puerto Rico to a location other than Punta Tuna. The three prime choices (Fig. 140) are a site off Cabo Rojo (Station "C"), on the southwest corner of the island, a site off Punta Borínquen (Station "R"), on the northwest of the island, and a location designated Station "F" about 17.8 km southeast of Punta Tuna, and 14 km southeast of our current "Benchmark" mooring.

Although all three alternate sites are further offshore than the Punta Tuna mooring, one or more of these sites may have advantages that could outweigh the financial and logistical problems that are related to the greater offshore distance. Because the literature indicated the prevailing water currents are to the westward, the discharge from an OTEC plant off Cabo Rojo or Punta Borínquen would have little effect on the island of Puerto Rico. If the water did indeed move westward, then both the Cabo Rojo and Punta Borínquen sites could possibly be located 140-160 km from the next nearest influencable shoreline. That would be the eastern shore of the Dominican Republic, located in the island of Hispañola, and separated from Puerto Rico by the Mona Passage, which is about 160 km wide.

The third alternate being considered is Station "F". There are two advantages to this site over the present Punta Tuna site. First, as Station "F" lies 14 km further south of the island than the present mooring, it is hoped that the discharged effluent would have less chance to impact on the coastal ecosystem due to the greater distance offshore. Secondly, as can be seen in Figure 6 (previously shown), the

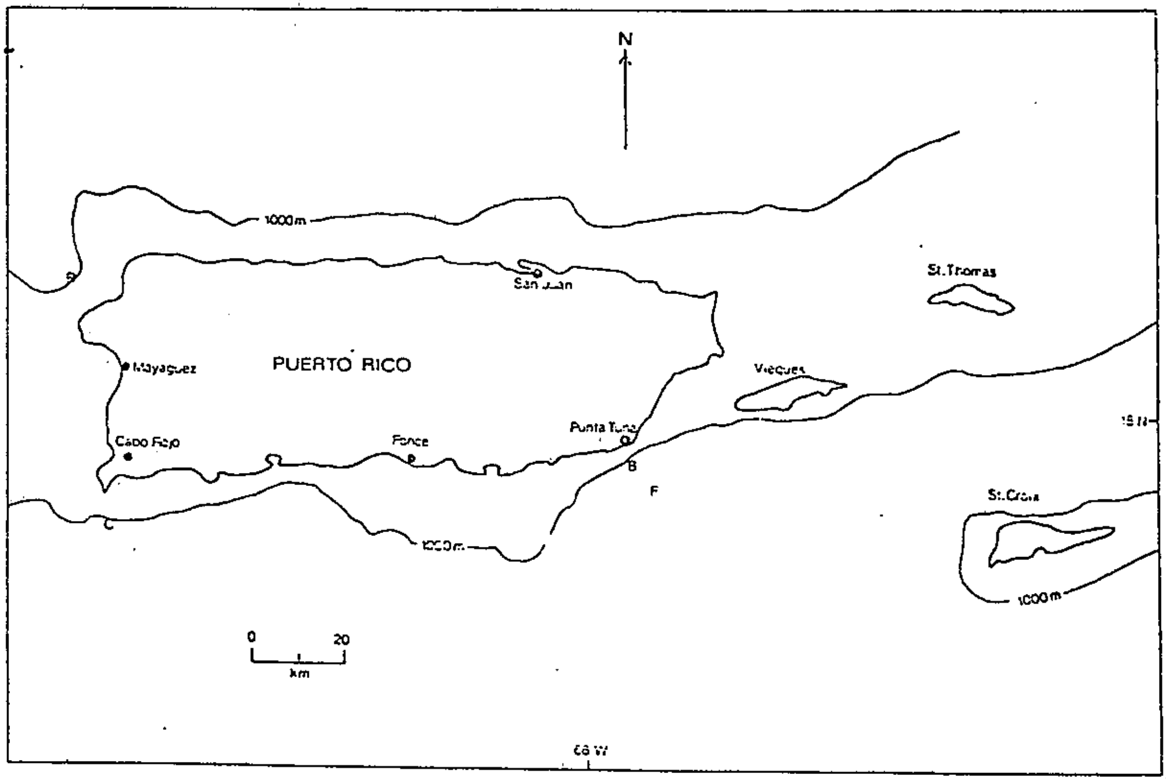


Fig. 140 - Location of Stations "C", "R", and "F" relative to the island of Puerto Rico and its surroundings.

bottom at the present mooring site is steep and uneven. The area around Station "F", although almost twice as deep (1950m), is flat to within ±2m over a circle of radius of about 1 km. Mooring an OTEC plant on this flat plane may be considerably easier than using the uneven underwater hillside at the present mooring site.

This section is devoted to a comparison of the 4 sites from an OTEC/Oceanographic point of view, without any regard for financial or logistic difficulties. The sites will be compared with respect to temperature, salinity, density, dissolved oxygen, chlorophyll, and any oceanographic insights learned during this measurement program. The data described and compared in this section was collected during the cruise of June, 1979.

Throughout this section the four alternate sites will be compared, and in both the text and in the figures the stations will be referred to as:

"B" - Punta Tuna Benchmark site
"C" - Cabo Rojo site
"R" - Punta Borínquen site (Rincõn)
"F" - Station southeast of "B" (Flat area).

5.2 Results

Figure 141 shows the temperature vs. depth profiles for all four locations. The data for Station "B" is the average of all thermometer values. Data for the other stations is the result of a single hydrocast at each station. No thermocline is evident at any of the stations, and all have nearly the same temperature, about 28°C, at the surface. The variation in surface temperature for all the stations ranged from a low of 27.84°C for Station "B" to a high of 28.14°C at "F". The temperature at 50 m had more variation, from 25.98°C at "B" to 27.00°C at "C", giving "C" the smallest thermal gradiant in the surface layer.

The deep water comparison must be made at 900 m because 1000 m depths were not achieved during the hydrocasts to give

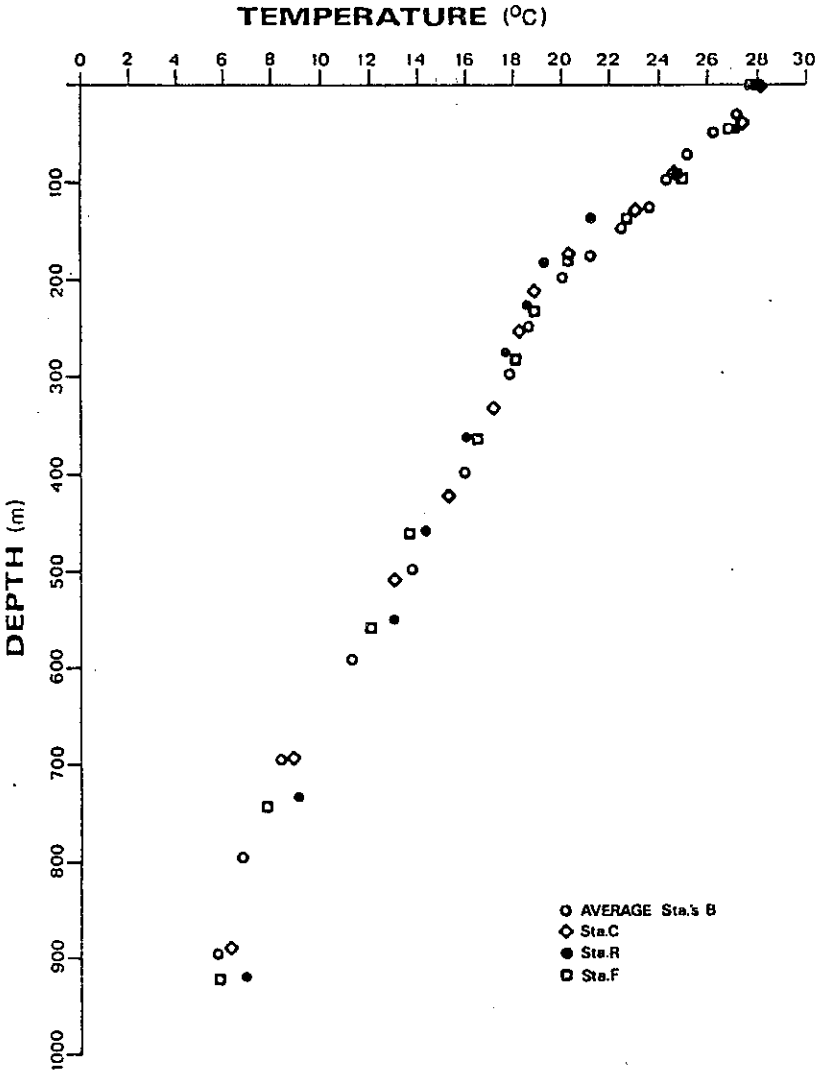


Fig. 141 - Temperature profiles comparing thermometer data measured at Stations "C", "R", and "F" with the average data measured at Punta Tuna ("B") during the cruise of June, 1979.

a full depth range. The 900 m depth value shall be used as a comparative for the Thermal Resource. The temperature at 900 m ranged from 5.7°C at "B" to 7.15°C at "R". Using the surface and 900 m values the Thermal Resource values are as listed below:

Station "F" - 22.3 C°
Station "B" - 22.1 C°
Station "C" - 21.8 C°
Station "R" - 20.7 C°

This clearly shows that the Stations "B" and "F" are not only similar, thermally, but superior to the other two relative to thermal resource. There is no reason to suspect that the 1000 m temperature would reveal any significant difference. Site "R", and to a lesser degree, Site "C" are effected by Atlantic water, in which the Antarctic Intermediate Water is not quite as shallow as in the Caribbean, and therefore not as cold at 900 m.

Figure 142 has the salinity profile with respect to depth for the 4 sites. Again, Stations "B" and "F" are very similar. Station "R" is most dissimilar (although it has the same shape profile), and "C" is intermediate.

Figure 143 contains the density vs. depth profiles for the 4 locations. There is little difference in the density between any of the stations.

Dissolved oxygen profiles for the 4 stations are shown in Figure 144. Stations "B" and "F" are again very similar throughout most of the water column. Stations "C" and "R" are similar to each other, but different from the other two to a depth of about 450 m. Below this depth the values for "C" and "R" diverge considerably, with "C" remaining less than the "B" - "F" values. All the curves have a similar shape, with an oxygen maximum near the surface, (another relative maximum at about 300 m), and a minimum at about 700 m, and a characteristic increase as depth increases beyond 700 m.

An estimate of the standing crop of an area can be made by evaluating the concentration of chlorophyll "a" in the

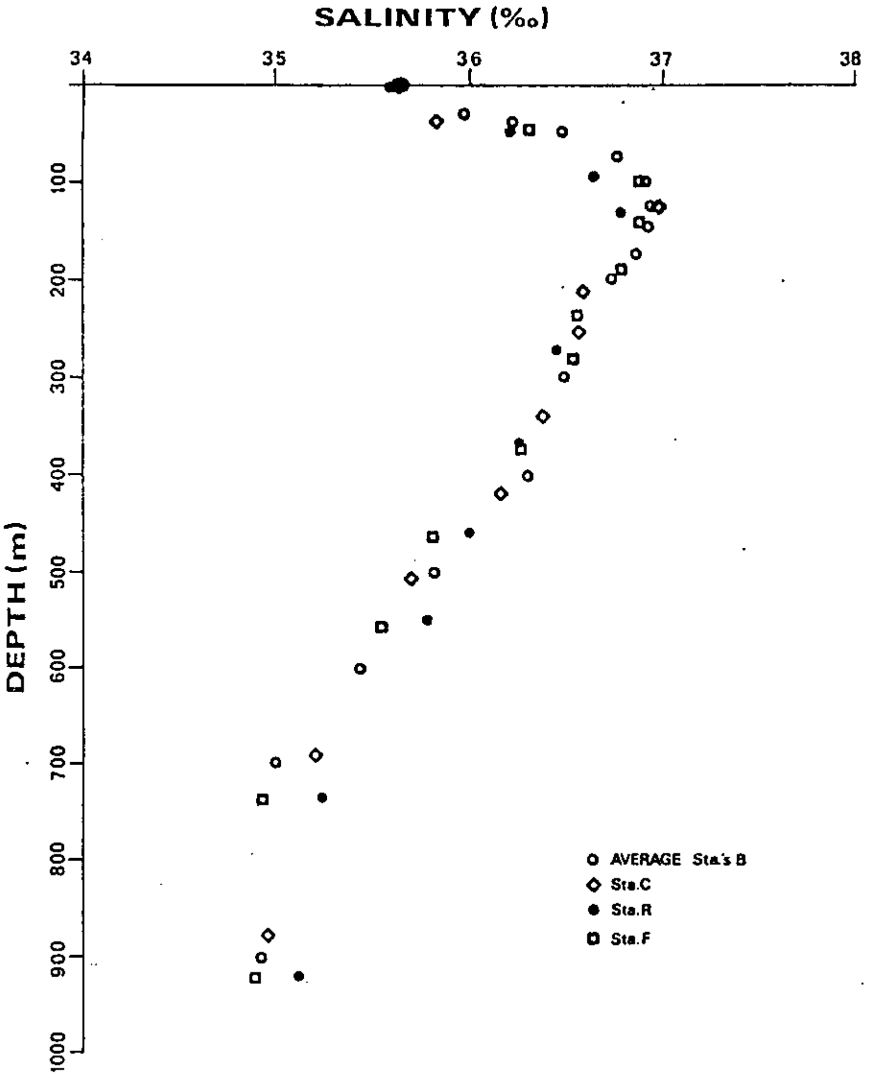


Fig. 142 - Salinity profiles comparing values measured at Stations "C", "R", and "F" with the average data measured at Punta Tuna ("B") during the cruise of June, 1979.

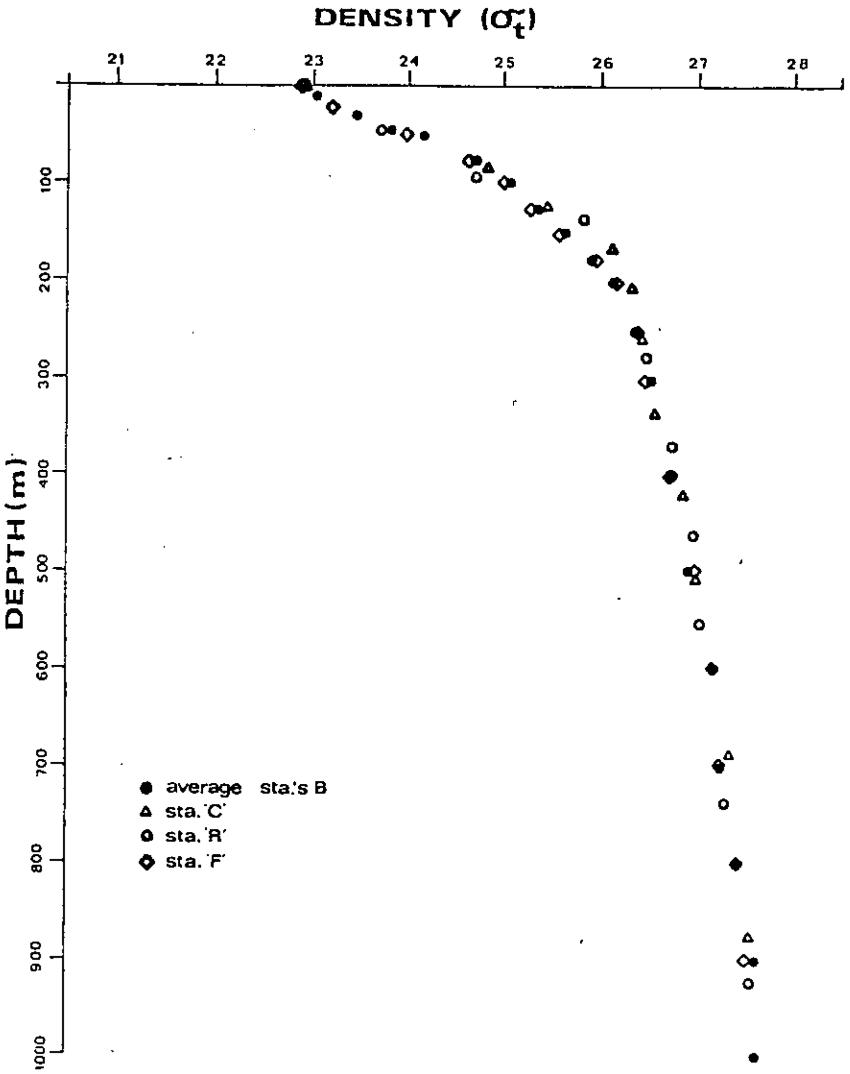


Fig. 143 - Density profiles comparing values observed at Stations "C", "R", and "F" at Punta Tuna ("B") during the cruise of June, 1979.

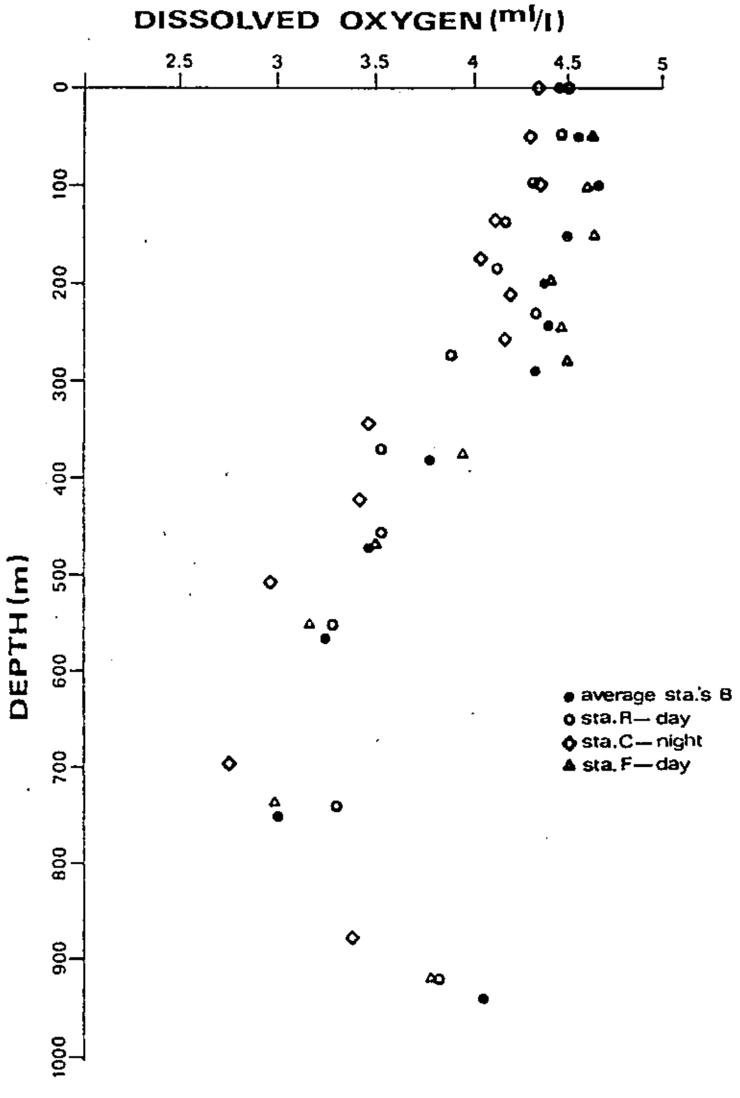


Fig. 144 - Dissolved oxygen profiles comparing values observed at Stations "C", "R", and "F" with the average data measured at Punta Tuna ("B") during the cruise of June, 1979.

water column. The profile of chlorophyll "a" is shown in Figure 145 for the four stations. Not only does Station "C" have a strong peak at about 50 m depth, but by integrating the values from the surface to 200 m depth, the amount of chlorophyll measured at Station "C" is about twice that at either Station "B" or Station "F". Station "R" is half that at Station "B". As the sampling time varied from day to night, and the sampling was done at descrete depths, rather than over the continuous profile, the reasons for these differences are not entirely clear. The most probable reason is the land runoff supplying more nutrients from along the entire south coast. This nutrient rich water would be carried by the westward drifting surface water intensifying the nutrient concentration near the west coast of the island, in the vicinity of Station "C". The wide, shallow shelf at "C" would also help trap these materials in the photic zone. Along the north coast they would be carried out to sea, past Station "R". With respect to the variables measured, the only difference between stations is the smaller Thermal Resource at Station "R". The other comparative evaluations offer no preference of one location over another. One important factor missing is information on water currents at the sites.

Generally, surface water has been seen to move westerly from both Station "C" and Station "R" (Metcalf et al., 1977; Duncan et al., 1977; Bane, 1965). There are strong tidal currents in the Mona Passage (Goldman et al., 1977; U.S. Dept. of Commerce, 1977), that move the surface water north-south at speeds often exceeding 50 cm/sec. There are many large, living reefs in the Mona Passage, especially along the southwestern coast of Puerto Rico, extending 5-10 km from shore (Goldman et al., 1977). This reef area, as well as the other shallow shelf communities would certainly be affected by an OTEC plant sited at "C" or possibly even at "R", because of these tidal currents. Another consideration is the strong bimodal east-west water flow at Station "B" (Fig. 53). Any

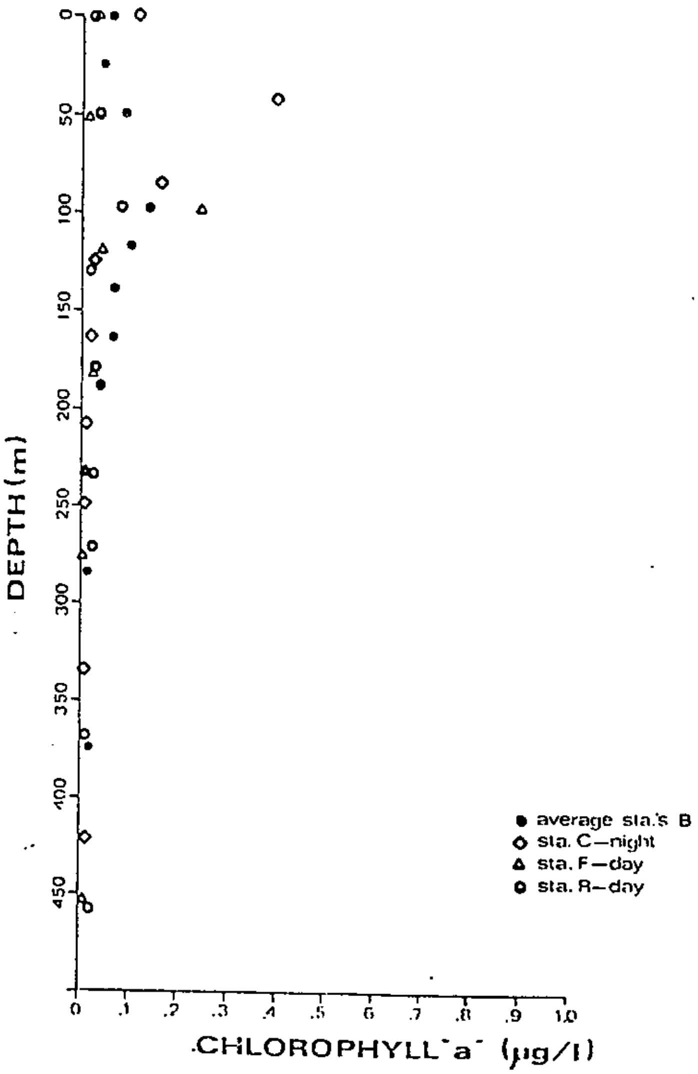


Fig. 145 - Chlorophyll "a" profiles comparing values observed at Stations "C", "R", and "F" at Punta Tuna ("B") during the cruise of June, 1979.

advantage of siting a plant at either Station "C" or "R" may be eliminated if this bimodal flow is also seen to occur along the West Coast. Also, such factors as the high sediment load (so prevalent on the west coast), and the "island wake" effect during winter at Station "R" (waves and water moving westerly along the storm driven North Atlantic wrap around Punta Borînquen and strike the West Coast from the west) must be taken into account (Wood et al., 1975a; Wood et al., 1975B).

5.3 Conclusions

In conclusion, based on this one cruise and the interpretation of the data collected during that time, the only alternative location that might be considered as good, or better than Station "B" from an OTEC siting point-of-view is Station "F". This is not due to any potential improvement in the plant operating efficiency, but rather due to its greater distance from land, and the possible associated advantages, as well as the flat submarine terrain.

At present, there is not sufficient information available to suggest any other conclusions related to this siting matter.

6.0 COMPARISON OF SOUTH COAST STATIONS

6.1 Introduction

During the June 1979 cruise, hydrocasts were made at seven stations along the South Coast from Cabo Rojo Light (west) to southeast of the Benchmark Station (Fig. 146). The purpose of this study was to determine what spatial variability, if any, might be encountered in either the placement of or the effluent from an OTEC plant along the south coast. Measurements of temperature, salinity and dissolved oxygen were made of each station. Samples were also taken for subsequent laboratory analyses of nutrient concentration and zooplankton, but results of these analyses are not available at this time.

Figure 146 shows the location of the stations. The cruise design was to visit stations of approximately equal depth, and therefore, of equal interest with regard to OTEC plant siting. Some stations are located much further offshore than others. This is because the shelf is wider south of the middle of the island.

6.2 Results

Figures 147-152 show the temperatue, salinity, density and dissolved oxygen profiles for all the south coast stations visited. The depth at Station "F" was about 2000 m, and Station "60" had a depth of 1300 m.

The spatial temperature distribution along the south coast is shown in Figure 147. Along western half, there was no apparent temperature variations. The 27°C isotherm was about 25 m shallower on the western half. The actual surface temperature varied from 28.1°C at Stations "F" to 27.6°C at Stations "GO" and "MO". Although the difference 0.5 C° is important thermodynamically, the 27°C isotherm of these 3 stations varied by less than 15 m in depth, indicating the

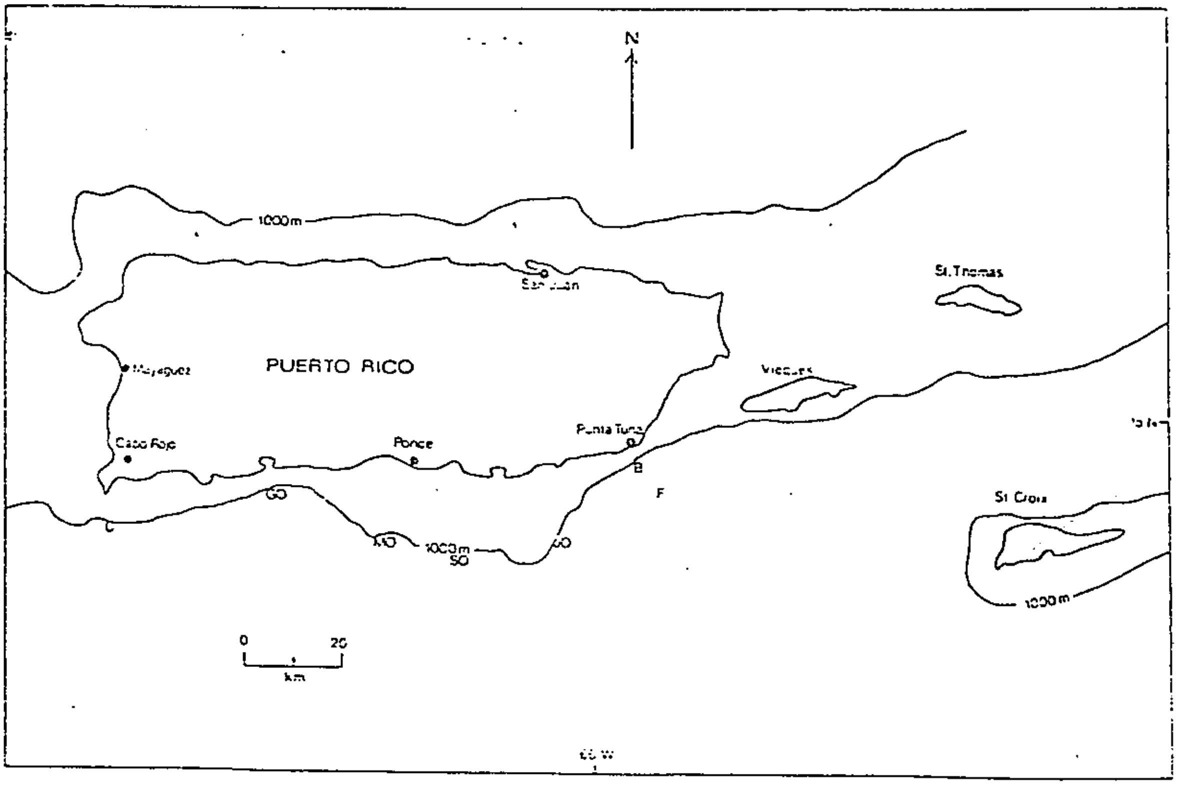


Fig. 146 - Location of stations along the south coast of Puerto Rico during the cruise of June, 1979.

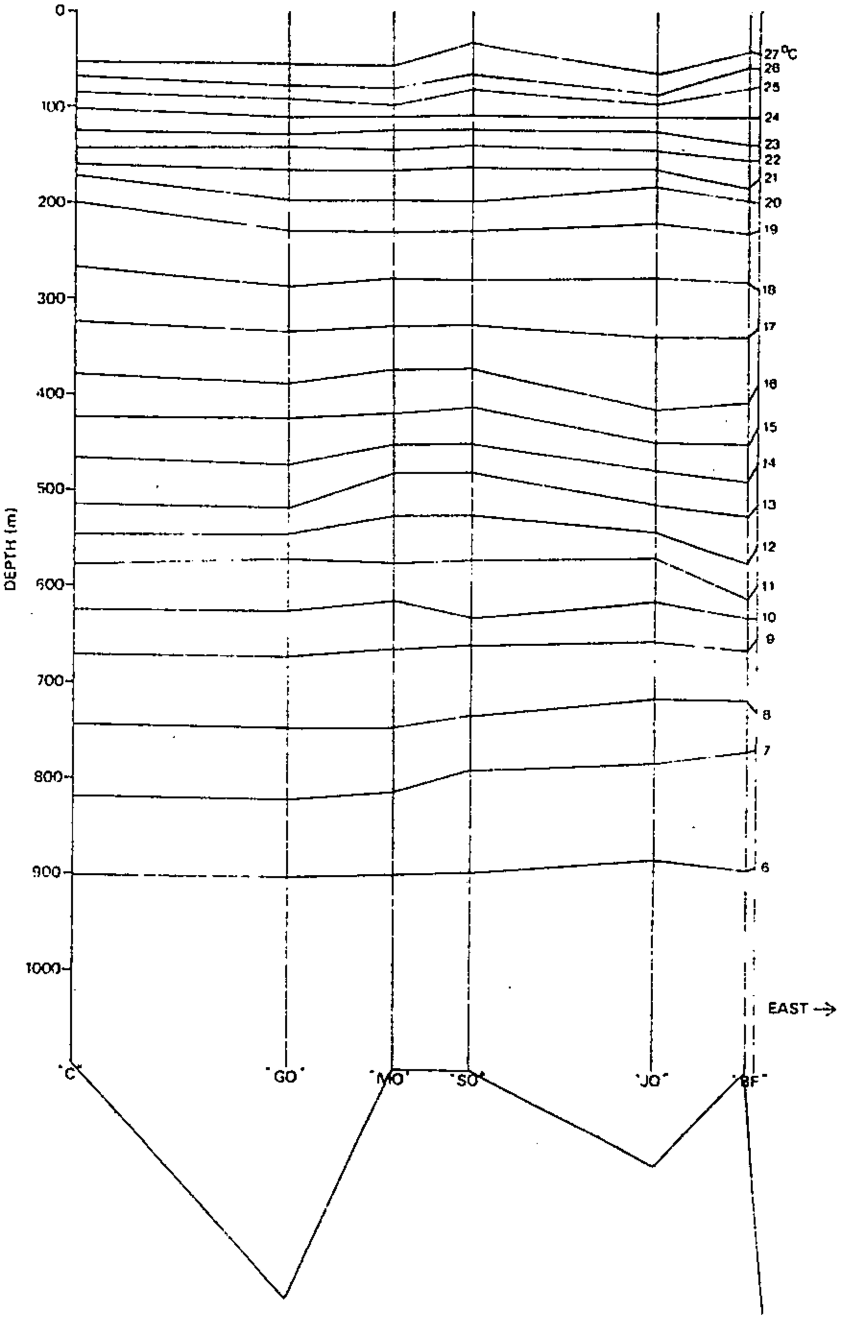


Fig. 147 - Temperature cross section along the south coast of Puerto Rico, measured during the cruise of June, 1979.

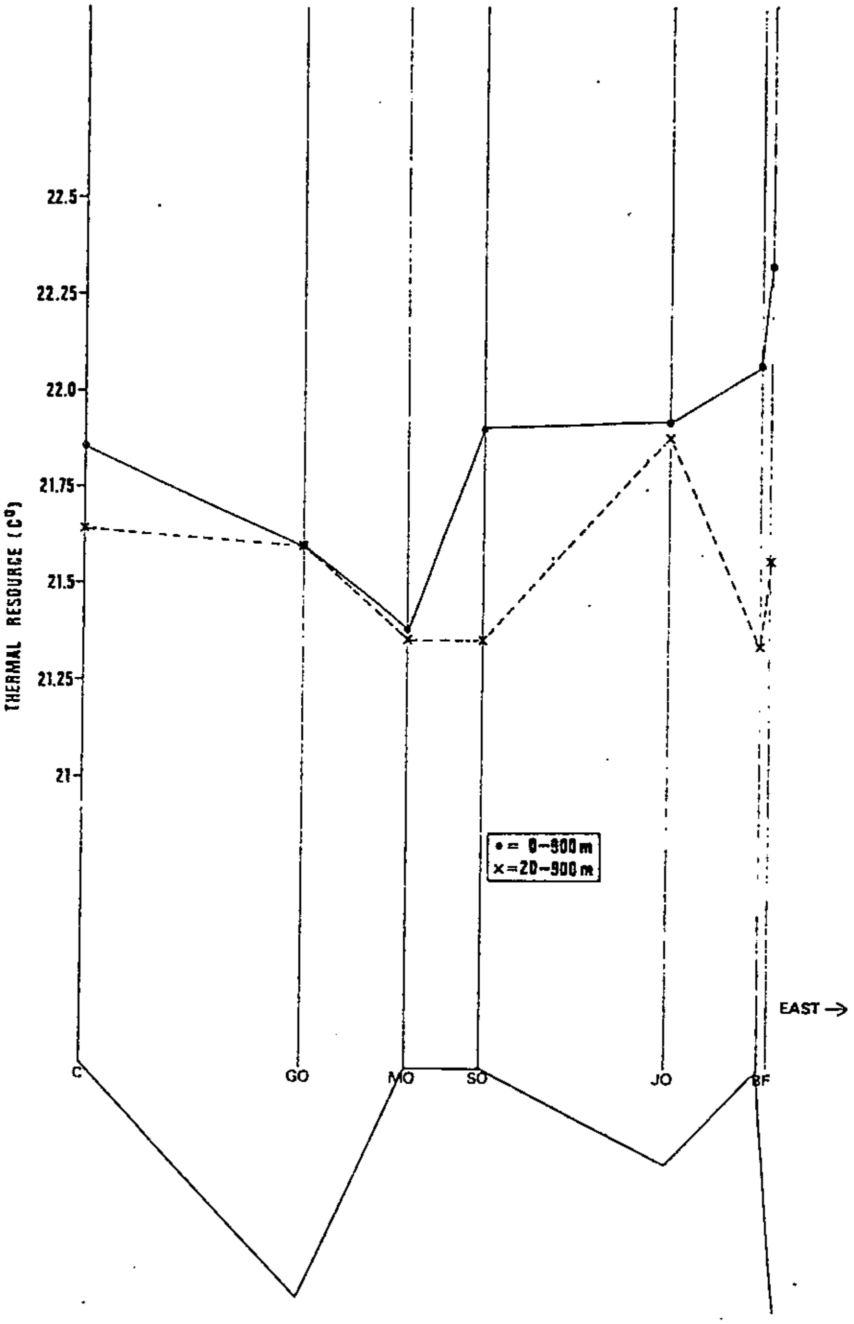


Fig. 148 - Thermal Resource for seven stations along the south coast of Puerto Rico for June, 1979.

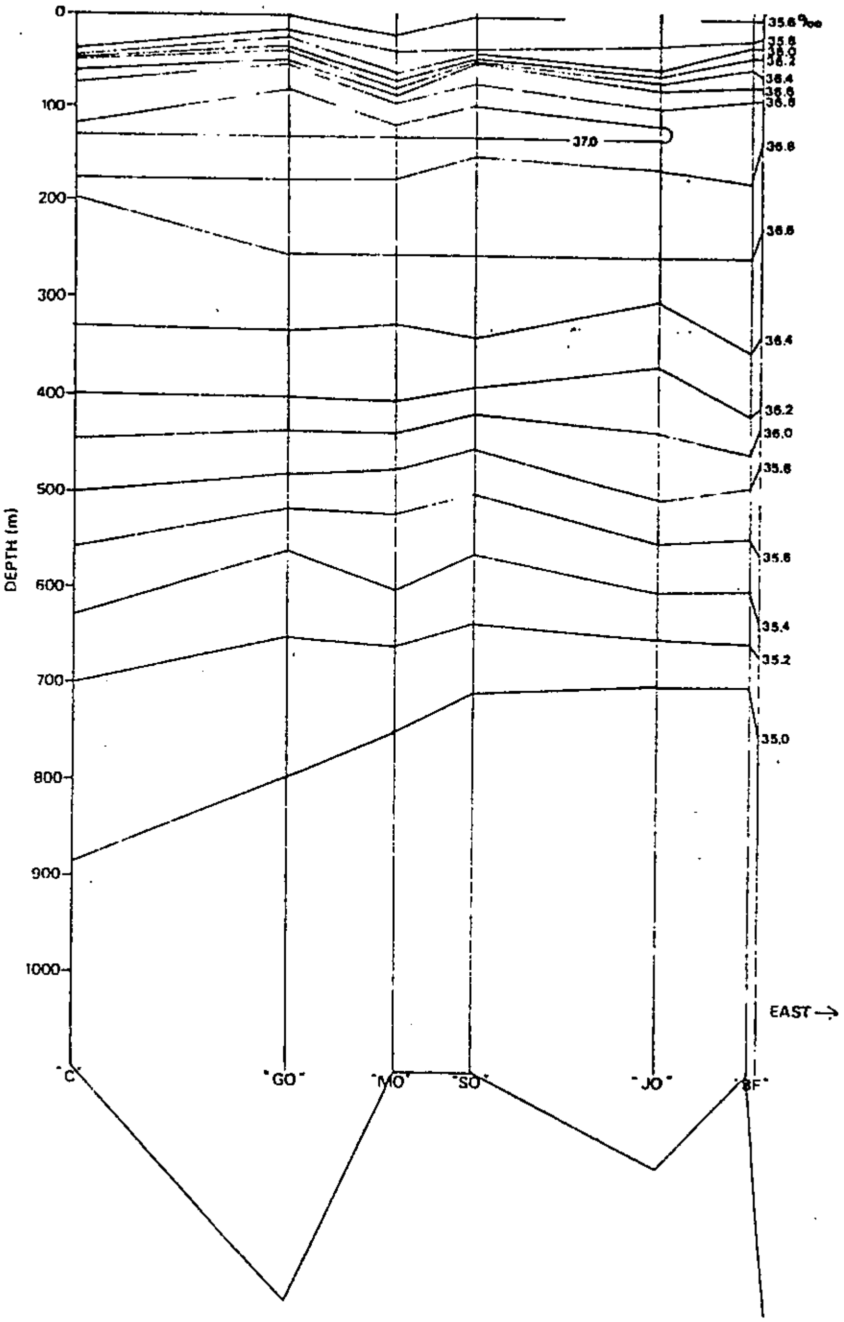


Fig. 149 - Salinity cross section along the south coast of Puerto Rico, measured during the cruise of June, 1979.

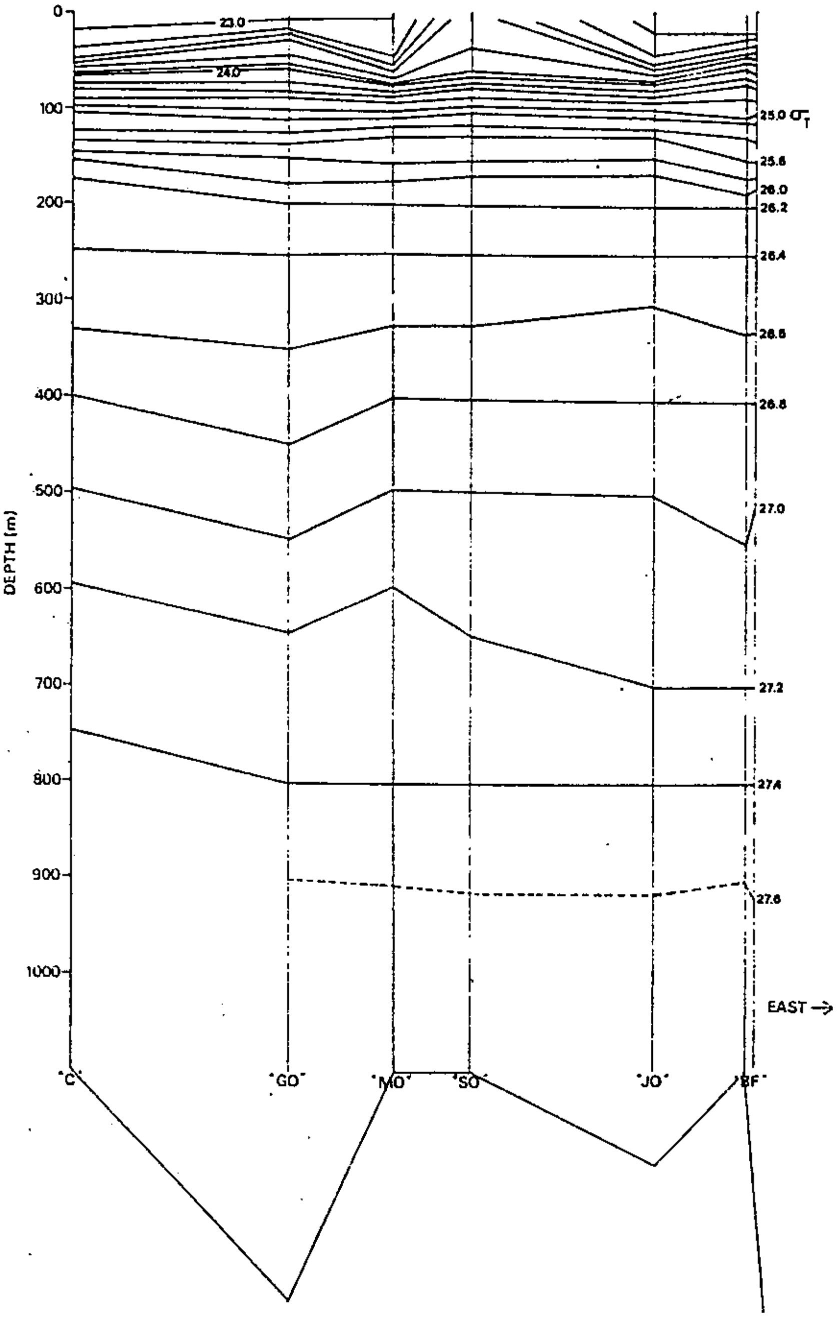
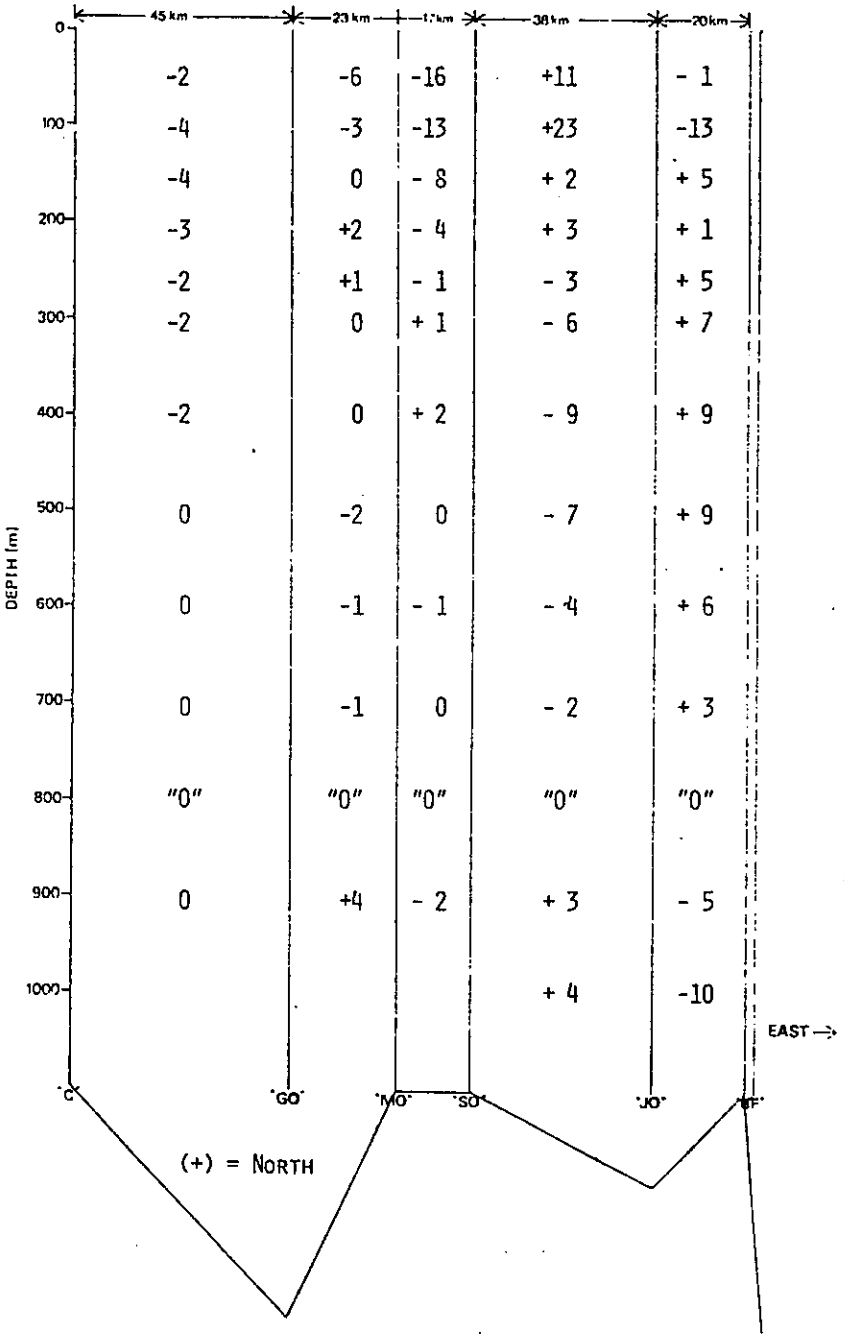


Fig. 150 - Density cross section along the south coast of Puerto Rico, measured during the cruise of June, 1979.



DEPTH (m)	45 km	23 km	17 km	38 km	20 km
0					
	-2	-6	-16	+11	- 1
100	-4	-3	-13	+23	-13
	-4	0	- 8	+ 2	+ 5
200	-3	+2	- 4	+ 3	+ 1
	-2	+1	- 1	- 3	+ 5
300	-2	0	+ 1	- 6	+ 7
400	-2	0	+ 2	- 9	+ 9
500	0	-2	0	- 7	+ 9
600	0	-1	- 1	- 4	+ 6
700	0	-1	0	- 2	+ 3
800	"0"	"0"	"0"	"0"	"0"
900	0	+4	- 2	+ 3	- 5
1000				+ 4	-10

Fig. 151 - Geostrophic currents calculated along the south coast of Puerto Rico. (The level of no motion is taken to be 800 m, (+) signifies north).

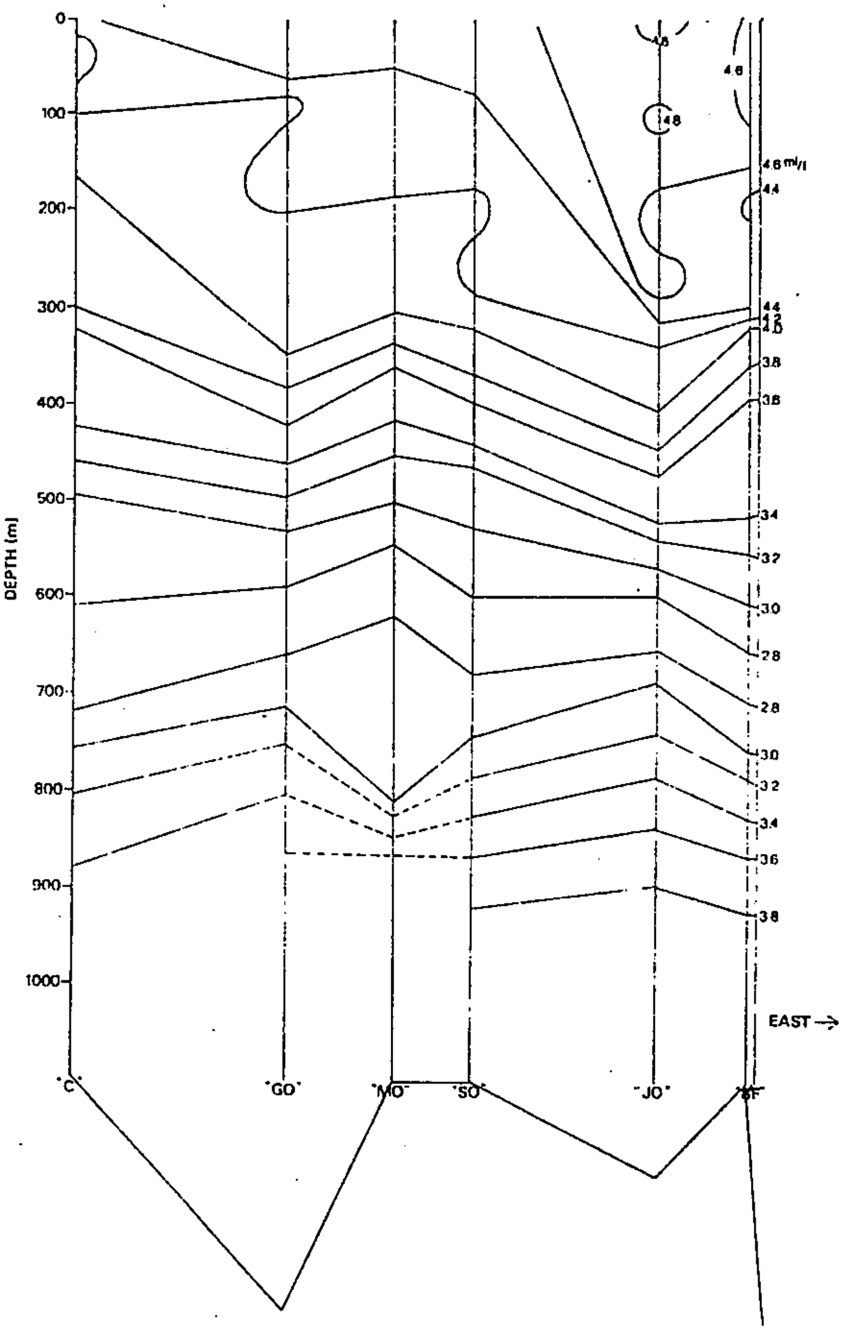


Fig. 152 - Dissolved oxygen cross section along the south coast of Puerto Rico, measured during the cruise of June, 1979.

difference is possibly only a surface "skin effect". Since the stations were not sampled simultaneously, this difference may or may not be real.

Except for a few anomalous values, the isotherms show little variation, especially the deepest isotherm, 6°C. There is a slight temperature rise from west to east at the 900 m depth. If this rise is real it supports the theory of the source of this deep water as coming over the Jungfern Sill (Wust, 1964) and moving westward, cooling as it goes.

The Thermal Resource was calculated for seven south coast stations. The temperature at 900 m was used as the cold water resource temperature, because 900 m is the maximum depth at which all the station had determinable temperatures from our measurements. (Note- An operating OTEC plant at any of these locations would probably use water from at least 1000 m in condensers but unfortunately the temperature at this depth was not measured at all of the stations, and uniformity of comparison is being stressed here, not the actual usable Thermal Resource). The Thermal Resource was calculated using both the actual surface temperature and the temperature at 20 m depth for the warm water resource. These results are seen in Figure 148.

For the 0-900 m case, the Thermal Resource is fairly constant, except for the low value at Station "MO" and the high value at Station "F". There appears to be a general trend toward an increase in Thermal Resource while moving eastward. The values ranged from 21.39 C° at Station "MO" to 22.34 C° at Station "F". The average 0-900 m Thermal Resource is 21.88 C°, with a standard deviation of ±0.31 C°.

If a more realistic warm water resource is used, the temperature at the results change somewhat. In general, the average Thermal Resource for the 7 stations is now 21.54 C°, about 0.36 C° less than the surface to 900 m value. However, these 20 m depth values are more uniform, with a standard deviation of only ±0.21 C°, and no east-west dependency. As this 20-900 m value is probably more representative of the subsurface warm water intake of a full size OTEC plant, it seems that there is little if any, indication of preferential location along Puerto Rico's south coast to maximize the Thermal Resource.

Another feature that can be seen in Figure 148 is the amount of thermal mixing in the upper 20 m at these 7 locations. As the cold water resource is the same for both the 0-900 m depth, and 20-900 m Thermal Resource for a station, The only difference in the Thermal Resource is due to the temperature difference from 0-20 m. From this figure, the 0-20 m temperature difference appears large at Stations "C", "SO", "B", and "F". At Stations "GO", "MO", and "JO" the water is well mixed at least to the 20 m depth, Apparently these stations far from shore, more exposed to the southeast winds are well mixed. Station "SO" might be thought to fall into this same category, but it is actually protected from the winds and seas, by a small sub-shelf to the south and east, thereby minimizing the oceanic mixing.

Figure 149 shows the results of salinity measurements at stations along the south coast. In this case, salinity is no better an indicator of water movement than temperature.

Section 3.4.1 described that the SUW was moving eastward at Station "B". The eastward motion is not denied by the temperature or salinity structure.

The transition water mass between the SUW and the Antarctic Intermediate Water (AIW), appears to be moving northward past both Stations "C" and "B", this is shown by the virtually level isotherms in Figure 147 and the upward tilt of the isohaline below 500 m from Station "C" to Station "SO". The expected isopycnal tilting also can be seen in Figure 150 below 300 m depth. If this water, and the AIW below it are moving northward, they must be coming into the Caribbean through the deep passages of the Lesser Antilles, and then departing over the deep northern passages (Anegada, Windward) and through the Yucatan Straits.

The deeper North Atlantic Deep Water (NADW), identifiable by a salinity of 34.9 °/₀₀ is coming over the Jungfern Sill (in the Anegada Pass near Station "B") and spreading in all directions to cover the Caribbean Basin. This might explain the slight rise in salinity moving westward from station "B".

Figure 151 shows the calculated geostrophic currents using the data from this cruise. There are many shortcomings with these results, a few of which are: a) the stations are not much more than 20 km apart, which is a reasonable lower scale limit for geostrophic calculations, b) at the latitute of only 18° the geostrophic calculations are still weak, and c) these calculations assume no boundary effects, either bottom, side, or top. Furthermore, in the final result, a "level of no motion" was assumed to exist at 800 m. This is not based on any measurements only a need to normalize the results.

Along the eastern portion of the island, the geostrophic results indicate the SUW and the AIW water moving northward, probably through the Anegada Passage. The NADW is seen to be moving southward, over the Jungfern Sill, as expected. However, along the western sector, the results are more confusing, showing the SUW and transition water moving southward into the Caribbean, as opposed to that seen along the eastern profile. Because of the low values seen, and the above mentioned sources of errors, any further attempts at analysis of these geostrophic resutls are probably futile.

Figure 152 shows the dissolved oxygen distribution along the south coast. In the upper waters the dissolved oxygen concentration is somewhat higher along the eastern portion of the south coast. These waters may be more exposed to wind mixing from the southeast and the northeast. In the deeper waters, the dissolved oxygen concentration changes little from east to west, but when it does, it seems to follow the isopycnal slope.

6.3 Conclusions

In conclusion, it appears that any south coast location could be said to have virtually the same Thermal Resource. Furthermore, if the warm water discharge will be mixed with the cold, deep water, the resulting effluent will probably be found in the boundaries of the Subtropical Underwater. If the results of this cruise are universal, it seems that such an effluent may have a high probability of moving eastward. If this were the case, an eastern location may be more preferable. However, the other water movement results of this study indicate that this water mass may change direction frequently, giving no advantages to either east or west.

Therefore, the conclusions of this work is that the criteria that will probably influence the particular choice of a south coast location will be logistics distance to shore, and mooring considerations, rather than thermodynamic or biological considerations.

7.0 SUMMARY OF RESULTS

Temperature measurements made throughout the year show that there is almost no seasonal change in the deep-water (1000 m) temperature at Punta Tuna. The surface water temperature does vary seasonally, yielding a Thermal Resource of about 20-23 C° and a mean value of 22.1 ± 1.0 C°. During June this Thermal Resource did not vary along the entire south coast of Puerto Rico. The Thermal Resource off the norhtwest coast, near Punta Borĩnquen is smaller because of a 2 C° warmer deep-water temperature. The Thermal Resource off Punta Vaca, Vieques is about 1/2 C° less than that at Punta Tuna.

The Mixed Layer Depth was found to vary seasonally from a depth of as much as 90 m during the winter, when the weather is more rough, to virtually zero in the summer, when the weather is calm. Since the warm-water intake for a full size OTEC power plant will probably be at a depth of 20-25 m, it is possible that a plant off Punta Tuna might draw water from below the MLD during part of the summer.

Very little is known about the water currents around Punta Tuna. During this program both diurnal and semi-diurnal tidal components were seen moving east and west along the south coast. Also seen were a predominance of east-west movement at various depths down to about 500 m, however, other compass directions are not insignificant. Water motion at depths of 650-750 m usually is towards the northeast or northwest. This little knowledge is insufficient to predict dynamics of the intake and discharge from an OTEC plant.

Much of the temporal and spatial dynamics of the chemical and biological interactions are still poorly understood for the Punta Tuna area. The results of this program simply emphasizes the lack of depth of understanding of these systems and their interactions as they would affect and be effected by an OTEC power plant.

8.0 RECOMMENDATIONS

As a result of both the field program, discussed in this report, and the physical and biological oceanographic literature search conducted for the Punta Tuna area, under this same contract, the following recommendations are given. The purpose of these recommendations are to minimize the field work where there is now adequate information, and maximize the field efforts to emphasize the serious deficits in the present knowledge of the area. Those recommendations with two asterisks (**) should be given the highest priority. The recommendations with a single asterisk (*) should receive a moderate priority. The other recommended activities are important, but of a lower priority with respect to the future measurement programs at the Punta Tuna area.

1. Temperature

**a) of the mixed layer, using thermometers, STD, or XBT (<u>daily</u>), when possible, for short-term variations.

*b) to 200 m, using recorded monitoring equipment for upper water thermal structure during severe weather events.

*c) in the water column to 1000 m, using thermometers STD, or XBT (<u>monthly</u>) for ecological structuring and plant design purposes.

d) of the actual sea surface and the mixed layer, using thermometers, STD, XBT, and satellite (<u>whenever the satellite data will be available</u>) to correlate the satellite sea surface temperature monitoring with the mixed layer temperature.

e) of the mixed layer, using thermometers, STD, and XBT (<u>weekly</u>), for ecological structuring.

2. Thermocline depth

*a) using XBT (<u>daily, when possible, otherwise weekly</u>), to anticipate discharge dynamics.

3. Salinity

*a) to 200 m depth downstream, at discrete depths or with STD (<u>biweekly</u>), to assess the density structure for water discharge.

*b) in the water column, at descrete depths (monthly or bimonthly), for ecological structuring.

*c) to 200 m, using recording equipment, to determine vertical movement of water masses and salinity structure (during severe weather events).

d) in the mixed layer, at the benchmark site, at descrete depths, (weekly), to correlate with the rainfall in the surface water mass at its source area (the Amazon and Orinoco Rivers), for predictive purposes.

4. Mixed Layer Depth

*a) using STD or XBT (daily, if possible), for engineering design requirements.

*b) using recording equipment with thermister strings, to monitor thermal resource variation during severe weather events.

5. Internal waves

*a) at one site in the Caribbean and one in the Atlantic, measuring both amplitude and period, by monitoring the temperature profile with recording thermister strings, to determine the effect of the variation of the horizontal thermal structure (due to large amplitude long waves) on intake and outlet.

6. Wave spectra-surface

a) at one Caribbean and one Atlantic site, using a recording wave rider, to determine the long-term wave spectra for plant and personnel safety.

7. Water currents

*a) using current profilers, (4 per day on a weekly basis), to supplement the moored data, with emphasis during the tidal periods.

**b) using moored, recording current meters at descrete depths, to determine the stress to the plant mooring and deep water pipe, and to estimate the long and short-term eulerian movement of water past the site for intake and discharge.

8. Water trajectory

*a) using drogues above and below the thermocline, (bimonthly for 2-5 days), to determine the trajectory diffusion and plume dynamics of the plant discharge.

9. Zooplankton

**a) at the site and downstream, using a suitable mesh net, at descrete depth intervals, (hourly for 48 hours, bimonthly) to determine the patchiness of the zooplankton population.

*b) at the site and downstream, using a suitable mesh net, at descrete depth intervals (daily for a week, bimonthly) to determine the short-term variations in the zooplankton population.

c) at the site and downstream, using a suitable mesh net, at descrete depth intervals, (weekly), to determine the mid-term seasonality of the zooplankton population.

*d) at the site and downstream, using a suitable mesh net, at descrete depth intervals, (monthly or bimonthly), to determine the seasonal patterns of the zooplankton population.

**e) in all of the above zooplankton sampling cases, it is necessary to replicate each tow at least once (more often, if possible), replicate subsamples from each tow, and repeat the analysis on each final aliquot to determine the statistical nature of the zooplankton population.

10. Chlorophyll

**a) either at descrete depths or by pumping throughout the upper 200 m (bihourly for 48 hours, quarterly), to determine the normal short-term temporal variability.

*b) at the sites and downstream, at either descrete depths or by pumping throughout the upper 200 m (bimonthly), to determine the chlorophyll distribution for ecological structuring.

11. Phytoplankton

*a) at the sites and downstream, at descrete depths in the upper 200 m by net or bottle, (bimonthly), for counting and identification to determine the spatial distribution and species present for ecological structuring.

**b) at descrete depths in the upper 200 m (bihourly, quarterly), for counting and identification to determine statistics related to patchiness.

12. Primary productivity

*a) at the site and downstream (weekly), to determine the productivity rates for ecological structuring.

13. Deep Scattering Layer

*a) at the site monitor the depth and thickness, and the components of the Deep Scattering Layer, (hourly for 48 hours bimonthly), to determine the vertical dynamics of the DSL.

14. Nutrients

*a) downstream along the 200 m isobath, at descrete depths, (bimonthly), to determine if normal upwelling exists, for ecological structuring.

*b) downstream in the plume from the sites, at discrete depths throughout the water column, (monthly), for ecological structuring.

*c) at the benchmark site, at discrete depths (bihourly for 48 hours, quarterly) to determine temporal variation.

15. Trace metals

*a) at the site near the surface and bottom and mid-depths (monthly) to determine the background trace metal levels in the area.

*b) at the site and downstream, in organisms near the surface and mid-depths to determine the background trace metals and the fate through the food chain in the area.

16. Particulate matter

*a) at the site, at 10-25 m depth (bihourly for 48 hours bimonthly) to determine the extent, size distribution, and components of potential intake matter.

17. Bottom sampling

*a) at and around the site (once) to determine the small scale bottom materials and topography for anchoring and turbulence effects.

18. Fish attraction

*a) in upper waters from a moored structure, to determine attraction effects of a floating pelagic structure.

9.0 REFERENCES

Anonymous 1978. A baseline environmental assessment for ocean disposal of dredged materials near Roosevelt Roads Naval Station, Puerto Rico EG & G Environmental Consultants, Waltham, Mass.

Atwood, D. K., P. Duncan, M. C. Stancup, and M. J. Barcelona. 1976. Ocean Thermal Energy Conversion: Resource Assessment and Environmental Impact for Proposed Puerto Rico Site. Final Report-NSF Grant #AER-75-00145, University of Puerto Rico, Dept. Mar. Sci.

Atwood, D. K., C. P. Duncan, M. C. Stalcup, and M. J. Barcelona. 1977. Resource assessment of a high potential OTEC site near Puerto Rico. Proc. 4th Ann. OTEC Conf. New Orleans. pp. 1-1 to 1x-24.

Bane, G. W. 1965. Results of Drift Bottle Studies Near Puerto Rico. Caribbean Journal of Science, Vol. 5 (3/4), pp. 173-174.

Beers Jr., D. M., Steven and J. B. Lewis. 1968. Primary Productivity in the Caribbean Sea of Jamaica and the Tropical North Atlantic.

Coker, R. E. and J. G. González. 1960. Limnetic copepod populations of Bahía Fosforecente and adjacent waters, Puerto Rico. J. of Elisha Mitchell Scient. Soc., 76(1): 8-28.

Craig Jr., H. L., T. Lee, H. B. Michel, S. C. Hess, R. Munir, M. Perlmutter. 1978. A Source Book of Oceanographic Properties Affecting Biofouling and Corrosion of OTEC Plants at Selected Sites. Univ. of Miami, RSMAS, TR78-1, 369 pp.

Cummings, S. R., D. Atwood, J. M. Parker. 1979. Inorganic Nutrients and Dissolved Oxygen Variation Determined from Historical Data at Three Proposed Ocean Thermal Energy Conversion (OTEC) sites: Puerto Rico, St. Croix and Norhtern Gulf of Mexico. NOAA Tech. Memorandum, ERL AOML-36. 67 pp.

Davis, R. A. 1973. Principal of Oceanography. Addison-Wesley Publishing Co., Mass., 434 pp.

Defant, A. 1961. Physical Oceanography, Vol. II. Pergamon Press, N.Y. 598 pp.

Dietrich, G. 1963. General Oceanography, an Introduction. Wiley and Sons, N. Y. 588 pp.

Duncan, C. P., D. Atwood, J. R. Duncan and P. N, Froelich. 1977. Drift Bottle Returns from the Caribbean. Bull. Mar. Scie., Vol. 27, #3, 580-586 pp.

Duxbury, A. C. 1971. The Earth and its Oceans. Addison-Wesley Publishing Co., 381 p.

Froelich, P. N., D. K. Atwood, G. S. Giese. 1978. Influence of Amazon River Discharge on Surface Salinity and Dissolved silicate concentration in the Caribbean Sea. Deep-Sea Research, Vol. 25. pp. 735-744.

Goldman, G. C., J. M. López, and R. Castro. 1977. Prediction of the Effects of Resuspension of Sediment During the Construction Phase of a Hypothetical Offshore Power Plant, West of Mayaguez, Puerto Rico. CEER/UPR, Mayaguez, Puerto Rico. CEER-M-37.

Hydroproducts. 1974. Operation and Maintenance Instructions for Model 912 Transmissometer and 906 Module Container. Pub. #M802319. Hydroproducts, San Diego, Calif.

Interocean Systems, Inc. 1975. Model 135 Current Meter, Operation and Maintenance Manual. Interocean Systems, Inc., San Diego, Calif.

Knudsen, M. 1901. Hydrographic Tables. Copenhagen, G.E.C. GAD. 63 pp.

Lee, T. N., R. S. C. Munier, S. Chiu. 1978. Water Mass Structure and Variability North of St. Croix, U.S. Virgin Islands, as Observed During the Summer of 1977 for OTEC Assessment. U. of Miami. RSMAS #78004.

Menzel, D. 1962. Instruction Manual for Routine Measurements for the U.S. Program in Biology, International Indian Ocean Expedition. Woods Hole Oceanographic Institution.

Metcalf, W. G. 1976. Caribbean-Atlantic Water Exchange through the Anegada-Jungfern Passage. Jour. Geophysical Research, Vol. 81, No. 36 pp. 6,401.

Metcalf, W. G., M. C. Stalcup and D. K. Atwood. 1977. Mona Passage Drift Bottle Study. Bull. of Mar. Sci., Vol. 27, #3, pp. 586-591.

Michel, H. B., M. Foyo, and D. A. Haagensen. 1976. Caribbean Zooplankton, Part I - Siphonophora, Heteropoda, Copepoda, Euphausiacea, Chaetognatha, and Salpidae. Part II - Thecosomata. Office of Naval Research, Dept. of Navy, i-iv, 549 pp.

NOAA. 1978-79. Local Climatological Data, Monthly Summary. NOAA, National Climatic Center, Asheville, N.C.

NOAA. 1979. Local Climatological Data, 1978, San Juan, Puerto Rico. NOAA, National Climatic Center, Asheville, N.C. 4 pp.

Nutt, M. E. 1975. Zooplankton Studies 1974. In Tortuguero Bay Environmental Studies. PRNC-181. pp. 48-57.

Nutt, M. E. and M. N. Yeaman. 1975. Zooplankton Studies 1974. In Punta Higuero Environmental Studies. PRNC-183. pp. 50-61.

ODSI. 1977. OTEC Thermal Resource Report for Puerto Rico. Ocean Data Systems, Inc. Cont. EG-77-C-01-4028 with U.S. Dept. of Energy, Monterey, Calif.

Plessy Environmental Systems. 1976. Operation and Maintenance Manual, Laboratory Salinometer, Model 6220. Plessy Environmental Systems (now Grundy Environmental Systems), San Diego, Calif.

Preston, F. W. 1948. The Commonness and Rarity of Species. Ecol. 29, 254-283 pp.

Raymont, J. E. G. 1963. Plankton and Productivity in the Oceans. Pergamon Press, N.Y. 660 pp.

Riley, G. A. 1939. Plankton Studies II, the Western North Atlantic, May-June, 1939. J. Marine Research, Vol. 2, 145-162 pp.

Sasscer, D. S., T. R. Tosteson, K. B. Pederson, F. Rosa, F. L. Benítez. 1979. Design and Construction Phase of a Biofouling, Corrosion, and Materials Study from a Moored Platform at Punta Tuna, Puerto Rico. In Proc. of 6th OTEC Conf., 19-22 June, 1979, Wash. D.C., U.S. DOE Conf.-790631/1, Vol. I.

Stalcup, M. C., W. G. Metcalf, and R. G. Johnson. 1975. Deep Caribbean Inflow Through the Anegada-Jungfern Passage. J. Mar. Res., 33, Suppl. 15-35.

Strickland, J. D. H. and T. R. Parsons. 1968. A Practical Handbook of Seawater Analysis. Bulletin 167, Fisheries Research Board of Canada, Ottawa.

Sturges, W. 1965. Observations of Deepwater Renewal in the Caribbean Sea. J. Geophys. Res. 75, 7602-7610 pp.

Technicon. 1972. Nitrate and Nitrite in Water and Seawater. Technicon Industrial Systems, Tarrytown, N.Y.

Technicon. 1973. Orthophosphate in Water and Seawater. Technicon Industrial Systems, Tarrytown, N.Y.

Technicon. 1973a. Silicates in Water and Seawater. Technicon Industrial Systems, Tarrytown, N.Y.

U.S. Dept. of Commerce. 1967. U.S. Coastal Pilot, #5, Atlantic Coast, Gulf of Mexico, Puerto Rico, and Virgin Islands, 9th edition, NOAA/NOS, Chapt. 13, p. 212.

U.S. Navy. 1968. Instruction Manual for Obtaining Oceanographic Data. Pub. No. 60M, U.S. Naval Ocean Office.

U.S. Dept. of Commerce. 1978. Tidal Current Tables, Atlantic Coast of North America. NOAA/NOS, 214 p.

Wolff, P. M. 1978. Temperature Difference Resource. Proc. of 5th Ocean Thermal Energy Conf. 20-22 Feb. 1978, Miami Beach, III-11 to 37. N.S. DOE Conf. 780236.

Wood, E. D. and R. Asencio. 1975. Hydrographic Data Report South Coast of Puerto Rico. Puerto Rico Nuclear Center/ Univ. of Puerto Rico. PRNC-185, 187 pp.

Wood, E., M. J. Youngbluth, P. Yoshioka, M. Canoy. 1975. Cabo Mala Pasqua Environmental Studies. Puerto Rico Nuclear Center UPR/Mayaguez, PRNC-188, 95 pp.

Wood, E. D., M. J. Youngbluth, P. Yoshioka. 1975a. Cabo Rojo Environmental Studies. Puerto Rico Nuclear Center, UPR/Mayaguez, PRNC-187, 76 p.

Wood, E. D., M. J. Youngbluth, M. E. Nutt, M. N. Yeaman, P. Yoshioka, M. J. Canoy. 1975b. Punta Higuero Environmental Stuides. PRNC-183, Puerto Rico Nuclear Center UPR/Mayaguez, 181 pp.

Wood, E. D., M. J. Youngbluth, P. Yoshioka, and M. J. Canoy. 1975c. Punta Verraco Environmental Studies, Puerto Rico Nuclear Center, Mayaguez, PRNC-189, 109 pp.

Wust, G. 1963. On the Stratification and the Circulation in the Cold Water Sphere of the Antillean-Caribbean Basin. Deep Sea Res. Vol. 10, 165-187 pp.

Wust, G. 1964. Stratification and Circulation in the Antillean-Caribbean Basin, Part 1. Spreading and Mixing of Water Types of Ocean. Columbia Univ. Press, 201 pp.

Youngbluth, M. J. 1974. Punta Higuero Power Plant Environmental Studies, 1973-74. 32-56.

Youngbluth, M. J. 1975. Diversity and Abundance of Copepod Species. In Punta Higuero Environmental Studies, PRNC-183. 42-49 pp.

APPENDIX A

CRUISE REPORT AND DATA FROM OTEC CRUISE #1 (CR-801)

31 JULY - 3 AUGUST 1978

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #1 (CR-801)

31 July - 3 August 1978

by

Gary C. Goldman, Chief Scientist

CRUISE REPORT

OTEC Cruise #1 (CR-801) 31 July - 3 August 1978

I. Objectives:

A. Measure oceanic parameters relatable to "OTEC" at Punta Tuna, P. R.
B. Measure the variability of the above parameters.
C. Evaluate and develop techniques for measuring these parameters.

II. Research Vessel:

R/V CRAWFORD (University of Puerto Rico).

III. Supporting Agency (ies):

A. U.S. Department of Energy (LBL).
B. P.R. Water Resources Authority.
C. UPR/CEER.

IV. Dates of Cruise:

31 July - 3 August 1978.

V. Cruise Plan:

See Appendix II. (Not included)

VI. Scientific and Technical Personnel:

C. Bonafe -- Technician
D. Corales -- Technician
G. Goldman -- Shief Scientist
A. Horn -- Visiting Scientist (LBL)
A. Nazario -- Technician
D. Pesante -- Biological Coordinator
J. Rivera -- Scientific Assistant
J. Sandusky -- Visiting Scientist (LBL)
M. Shafnacker -- Technician

VII. Station Locations:

See attached Cruise Plan, Appendix II, (Not included)

VIII. Types of Sampling:

See attached Cruise Plan, Appendix II. (Not included)

IX. Land Travel:

---31 July 1978. All personnel and equipment were transported to Magueyes. CEER vehicles (truck and Ramcharger) took most of the equipment from CEEE/ Mayaguez. Rental station wagon (LBL) brought Sandusky, Horn and Bullock (capt. of CRAWFORD) plus LBL equipment to Magueyes. CEER vehicles (Ramcharger and station wagon) transported remainder of personnel. All CEER vehicles were returned to Mayaguez and drivers (members of scientific/technician staff) returned to Magueyes in LBL station wagon.

---3 August 1978. LBL station wagon used to transport some personnel to Mayaguez, then returned with CEER Ramcharger for remainder of personnel. LBL station wagon remained at Magueyes for use by LBL personnel and equipment.

---4 August 1978. CEER Ramcharger and truck used to bring CEER equipment from Magueyes to Mayaguez.

X. Reasons for termination of cruise:

A. Hydrographic separated, leaving apparently weakened cable.
B. Starboard screw not getting power.
C. Potential tropical depression in next 12 hours.
D. Lack of ship's crew supplying winch operator, thereby overtaxing the scientific/technical personnel.

XI. Accomplishments:

A. Collected much of data from stations B-1 to B-6.
B. Evaluated data collection techniques of staff and equipment.

XII. Changes to be effected:

A. Not take unnecessary equipment.
B. Correct transmissometer reading problem.
C. Correct XBT problem.
D. Install mooring at Station "B".
E. Use "Bucket" method for chlorophyl sampling from Niskin bottles.
F. Minimize current meter underwater time.
G. Request UPR change cable, repair BT winch and stern capstan, and supply 24-hour winch operator.
H. Improve transmissometer cable deployment.

XIII. Stations Visited:

See Cruise Plan (Appendix I) for planned activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not accomplished
B-1	1 Aug '78	1000-1600	65°50.9'W	17°57.7'N	HYDRO-1 (Note 1) Plankton-1 Current-1 (Note 0)	XBT-1 (Note 2) STD-1 (Note 2)
B-2	1 Aug '78	1730-1900	65°51.9°W	17°58.8 N	Current-2	XBT-2 (Note 2) STD-2 (Note 2)
B-3	1 Aug '78	2025-2035	65°50.6'-51.2'W	17°57.3'N	Plankton-2	XBT (Note 2)
B-4	1-2 Aug'78	2200-0430	65°50-52'W	17°57.8'N	HYDRO-2 (Note 1) Plankton-3	XBT-3 (Note 2) STD-3 (Note 2) Current-3 (Note 3)
B-5A					See Dr. James Sandusky...	
B-5B	2 Aug '78	0730-0900	65°51W	17°58N	Current-3	XBT-4 (Note 2) STD-4 (Note 2)
B-6	2 Aug '78	1000-1800	65°46.1'W	17°58.7'N	BIOCAST-1(Note 4) Trans-1 (Note 5) Plankton-4	XBT-5 (Note 2) STD-5 (Note 2) Current-4(Note 0) Plankton-5(Note 6)

Notes--

--0 Actually started the Stationary Current-Profiles at B-1 instead of B-2, as planned. Therefore, did not need Current-4 at B-6. Also, changed the depths to 25, 50, 75, 100, 150, 200, 300, 400, and 500m.

--1 Hydrocast depths changed to 0, 50, 100, 150, 200, 250, 300, 400, 500, 600, 800 and 1000m. HYDRO-1 had extra bottles (2) at 25m for Sandusky, had no temperature reading at 800 and 1000m, had nutrients (unfiltered) and dissolved oxygen. HYDRO-2 had filtered nutrients and no DO.

--2 STD supplied by CEER was Martek, Mark IV, and was not acceptable. XBT recorder did not work.

--3 Stationary Current Profiles were begun at B-1, rather than B-2. Therefore, the noon B-6 Current was not necessary. B-4 Current was delayed due to extended time of plankton tow, and was to be made up at B-7.

--4 BIOCAST depths changed to 0, 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, and 400m. BIOCAST-1 had no nutrients, no DO, and did have chlorophyl.

August 7, 1978
Biological Report
Daniel Pesante

According to the plan of work, eight zooplankton samples were to be obtained from the proposed site.

1) 25 m day)
2) 25 m night)
3) 1200 m to SFC)
4) 1200 m to 800 m) Punta Tuna
5) 800 m to 200 m)
6) 200 m to SFC)

7) 25 m)
8) 800 m to 200 m) Vieques

Of the eight samples only four were gathered as, while making the fifth tow, the hydrographic cable broke and the net and complementary equipment were lost (included in Dr. Goldman's report). Further use of the cable was cancelled as it proved to be a big risk.

Getting acquainted with the zooplankton sampling gear was no problem, although extreme care had to be taken in rolling the net tightly to the D.T.M.

My main concern at this point is that of knowing the exact depth at which the sampling gear is located. Due to high wire angles (60°) and to unknown subsurface currents, the position of net at sampling time could not be estimated accurately. For this reason a pinger should be purchased and coupled to the CRAWFORD ecosounder system. This will prove very useful, not only for the zooplankton sampling but also for all other sampling procedures where the exact depth of sampling has to be observed.

Included is a report on the biological organisms observed during this first cruise.

8-7-78

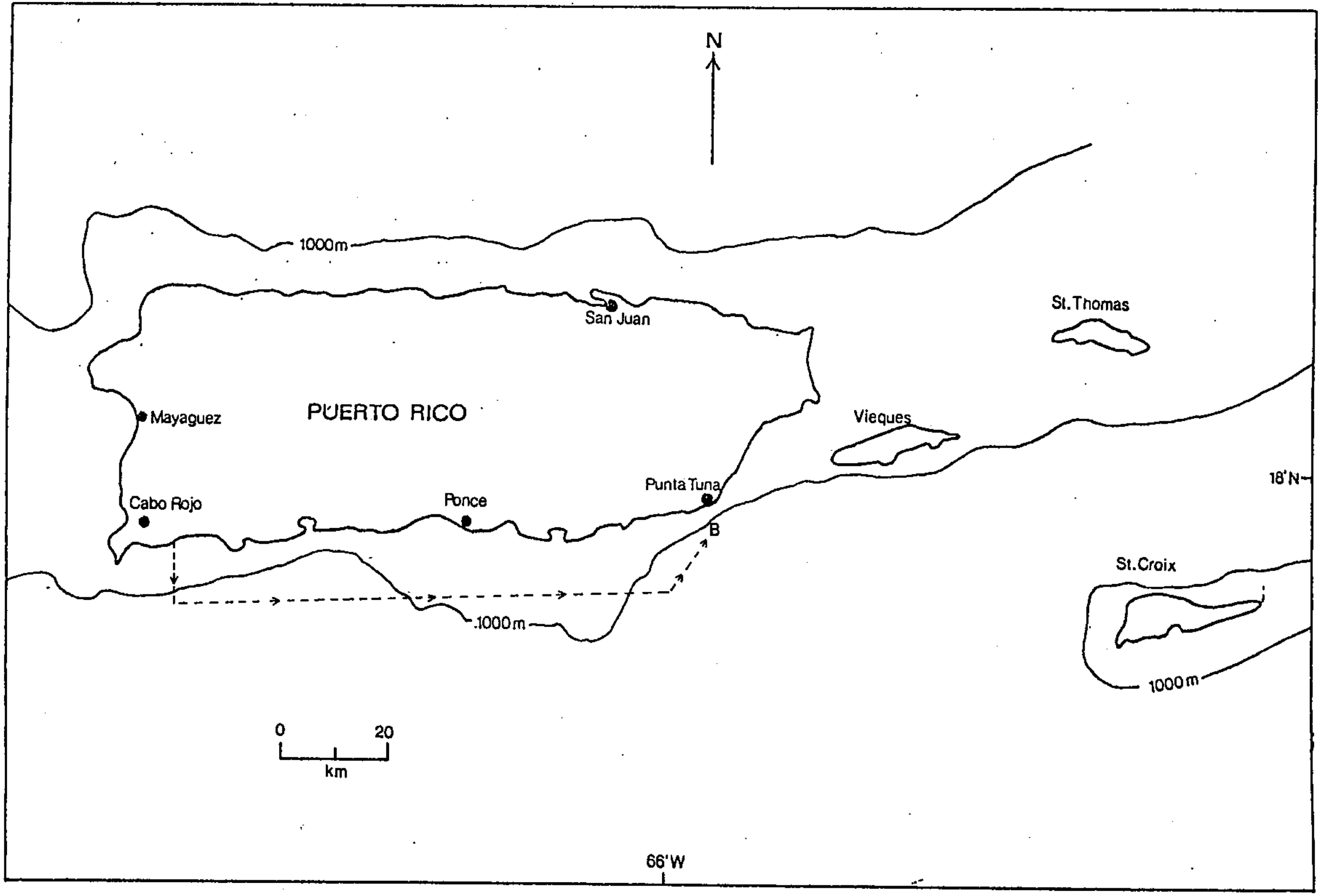
Observations concerning biological specimens observed during OTEC Cruise #1.

The following organisms were observed during day or night hours. Although the number of individuals could not be estimated, the family and/or scientific name is included.

Tursiops truncatus	Porpoise
	Blue Marlin
	Terns - white
Fregata magnificens	- Tigerillas
Caranx	Jacks - Cojínua
	- Boba
	- Flying fish
	- Trigger fish
	- Barracuda

\- Thalassia leaves -
\- Sargassum natans -
fluitans -

Trackline for OTEC cruise #1 (CR-801), 31 July-3 August 1978.



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE CE-801 STATION E-1 Rev. DATE 1 August 1979 WEATHER 10-12KT/020°, 83°, 78°, 1/2, 090°
DATES 31 July - 3 August 1978 LOCATION 17° 57.7'N, 65° 50.9'W WIRE ANGLE 10° 15°
GENERAL AREA Punta Tuna, P.R. TIME 1045-1600 AST; HYDROCAST (1225), CURRENT (1430-1600)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1445 DEPTH TO BOTTOM 1100 MAX SAMPLE 970 SAF 1017

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DIS.O2 (ML/L)	CHLOR"a" (µG/L)	PHAEO"a" (µG/L)	ATP (µG/L)	PO4 (µG AT/L)	SiO2 (µG AT/L)	NO2 (µG AT/L)	NO3	XBT DEPTH (M)	XBT TEMP (°C)	TRANSMISSIVITY DEPTH (M)	TRANSMISSIVITY TRAN. (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σT)
000	28.20	35.855	22.99	4.34	N.A.	N.A.	N.A.	0.50		0.50	•	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
047	28.20	35.963	23.07	4.30				0.20		•	•								
095	24.99	36.812	24.73	4.28				0.60		•	0.80								
143	23.04	37.001	25.46	4.45				0.30		•	1.4								
191	20.84	36.847	25.96	4.10				0.60		0.10	2.4								
239	19.04	36.851	26.44	4.02				0.59		0.10	2.8								
287	17.99	36.490	26.43	3.99				0.35		•	0.90								
383	15.96	36.172	26.68	3.65				0.65		•	58.65								
480	13.84	35.821	26.87	3.54				0.55		•	151.90								
577	10.70	35.275	27.06	2.75				2.3		•	•								
774	---	34.920	---	3.06				1.7		•	86.4								
971	---	--	---	--				-		-	--								

WATER CURRENTS DEPTH (M)	DIR (DEG)	SPEED (CM/S)
025	315	21
046	302	20
088	285	17
138	307	15
188	300	16
288	311	17
362	307	15
438	300	10

Vessel Drifting

• = Less than 0.1

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)
000	28.20	35.855	22.99
010	28.20	35.855	22.99
020	28.20	35.855	22.99
030	28.20	35.870	22.99
040	28.20	35.900	23.05
050	28.15	36.000	23.25
075	27.10	36.560	24.30
100	24.80	36.830	24.85
125	23.80	36.955	25.25
150	22.55	36.980	25.53
175	21.45	36.930	25.80
200	20.45	36.825	26.02
250	16.70	36.625	26.27
300	17.70	36.450	26.45
400	15.50	36.125	26.70
500	13.0	35.737	26.90
600	--	35.190	---
700	--	34.925	---
800	--	--	---
900	--	—	—
1000	--	--	---

CRUISE: CR-801 STATION: B-2 REV DATE: 1 AUGUST 1978 WEATHER: 13-15KT/090°, 82°, 81%, 1/2, 090°
DATES: 31 JULY - 3 AUGUST 1978 LOCATION: 17° 58.8'N, 65° 51.9'W WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 1730-1900 AST; CURRENT
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2130 DEPTH TO BOTTOM 1100 MAX SAMPLE 475 BAR 1014

	WATER CURRENT	
DEPTH (M)	DIRECTION (DEG)	SPEED (CM/S)
25	305	24
50	305	27
96	331	22
144	319	20
194	319	25
288	312	29
388	312	29
475	305	29

VESSEL
DRIFTING

STATION CR-031 [illegible] B-4 Bay [illegible] 1 August 1976 [illegible] 12/1/1171, 82°, 795, --, --

DATES 31 July - 3 August 1976 [illegible] 17° 57.8'N, 65° 50'-52'W WIRE ANGLE 10°

GENERAL AREA [illegible] TIME 2200-2215 T: HYDROCAST

SHIP CRAWFORD CAS. NO. 3 TIME ON [illegible] DEPTH TO BOTTOM 1200 MAX SAMPLE 1000 BAP 1016

											[illegible]		[illegible]		S T D				[illegible]		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O$_2$ (ML/L)	CHLOR A (µG/L)	PHAEOPHY (µG/L)	ATP (µG/L)	PO$_4$ SiO$_2$ (µG AT/L)	NO$_3$ (µG AT/L)	N$_3$	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.52	35.843	23.19	N.A.	N.A.	N.A.	N.A.	*	*	*	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
048	27.56	36.017	23.32					*	*	*											
096	27.57	35.793	23.90					2.52	0.25												
144	22.97	36.994	25.47					0.35	0.40	*											
193	20.16	36.763	26.08					0.45	*	*											
241	19.13	36.644	26.26					0.10	2.5	0.95											
289	18.29	36.522	26.38					*	*	3.45											
385	16.21	36.214	26.65					0.6	*	1.3											
482	14.18	35.882	26.85					0.65	*	16.50											
530	10.71	35.403	27.16					2.3	*	*											
771	7.16	34.905	27.34					1.45	*	27.95											
967	5.44	34.916	27.58					0.45	0.15	0											
- - - -	- - - -	- - - -	- - - -																		
000	27.58	35.843	23.19																		
010	27.58	35.843	23.20																		
020	27.58	35.845	23.20																		
030	27.57	35.860	23.25																		
040	27.57	35.900	23.29																		
050	27.57	36.075	23.35																		
075	27.57	36.560	23.58																		
100	27.56	35.899	24.20																		
125	26.40	36.935	25.00																		
150	22.70	36.950	25.54																		
175	20.90	35.850	25.88																		
200	19.95	36.740	26.10																		
250	18.95	36.628	26.30																		
300	18.10	36.505	26.44																		
400	15.95	36.163	26.69																		
500	13.55	35.775	26.90																		
600	10.20	35.330	27.11																		
700	8.25	35.050	27.30																		
800	6.85	34.930	27.43																		
900	5.90	34.930	27.55																		
1000	--	--	---																		

* LESS THAN 0.1

CRUISE: CR-801 STATION: B-5B-REV DATE: 2 AUGUST 1978 WEATHER: 8-10KT/120°, 80°, 87%, 1/2, 090°

DATES: 31 JULY - 3 AUGUST 1978 LOCATION: 17° 58'N, 65° 51'W WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0730 - 0900 AST; CURRENT

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1130 DEPTH TO BOTTOM 1100 MAX SAMPLE 470 BAR 1015

WATER CURRENT

DEPTH (M)	DIRECTION (DEG)	SPEED (CM/S)
25	327	28
44	322	27
88	327	28
138	322	35
188	308	37
288	312	32
388	318	37
468	319	39

VESSEL
DRIFTING

CRUISE __CR-101__ STATION __B-6 Press2__ DATE __2 August 1978__ WEATHER __[illegible]/1101, [illegible], [illegible], 1/4, 090°__

DATES __31 July - 2 August 1978__ POSITION __12° 58.7'N, 65° [illegible]__ WIRE ANGLE __20°__

GENERAL AREA __Punta [illegible], P.R.__ TIME __[illegible]-1330 AST; [illegible] CAST ([illegible]), TRANSMISSION (1330)__

SHIP __[illegible]__ REP. NO. __[illegible]__ TIME OUT __[illegible]__ DEPTH TO BOTTOM __[illegible]__ MAX SAMPLE __[illegible]__ BAR __1014__

												B.T.		TRANSPARENCY		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR "A" (µG/L)	PHAEO "A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_3 (µG AT/L)	NH_3	DEPTH (M)	TEMP (°C)	SECCHI (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	28.14	35.741	22.93	N.A.	.02	0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	FAULTY ELECTRONICS		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
023	23.02	35.759	22.96		.11	0																
047	28.20	35.936	23.05		.19	0																
071	---	36.587	---		.07-.17	0																
095	24.87	36.256	24.80		.04-.07	0																
119	24.06	36.968	25.13		.02	0																
143	23.06	37.004	25.46		.07-.42	0																
167	21.82	36.922	25.75		.01-.03	0																
191	20.89	36.851	25.95		.33-.52	0																
239	19.10	36.632	26.26		0	0																
287	18.32	36.527	26.38		.08	0																
383	15.32	36.154	26.69		.15	0																
- - -	- - -	- - -	- - -																			
000	28.14	35.741	22.93																			
010	28.14	35.741	22.94																			
020	28.10	35.750	22.95																			
030	28.10	35.810	23.00																			
040	28.10	35.875	23.03																			
050	28.10	35.980	23.10																			
075	27.70	36.650	23.75																			
100	24.99	35.830	24.25																			
125	23.70	36.975	25.23																			
150	22.65	36.980	25.54																			
175	21.60	36.912	25.83																			
200	20.65	36.805	26.03																			
250	18.90	36.620	26.26																			
300	17.95	36.440	26.45																			
400	---	--	---																			
500	---	--	---																			
600	---	--	---																			
700	---	--	---																			
800	---	--	---																			
900	---	--	---																			
1000	---	--	---																			

SIZE CLASS	SIZE IN MILLIMETERS
1	< 0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 19.9
13	20.0 - 29.9
14	30.0 - 39.9
15	40.0 - 49.9
16	> 50.0

DATE: 1 August 1978

STATION NUMBER: BENCHMARK

SHIP: CRAWFORD

TIME: 1325

SAMPLE NUMBER: 801-1

TYPE OF NET: CONICAL 5:1

MESH SIZE: 202μ

RING SIZE: 0.75 m

TYPE OF HAUL: HORIZONTAL

SAMPLING DEPTH: 25 m

METERS OF WIRE: 60 m

ANGLE: 60°-65°

FLOWMETER START: 0

FLOWMETER FINISH: 26082

LENGTH OF TOW: 20 min

LATITUDE: 17° 57.8'N

LONGITUDE: 65° 51.0'W

SEA STATE AND WEATHER: SS#1-2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata		2	3												2.2	16	5
Acartia tonsa	2	14	2												7.8	58	18
Calocalanus pavo		42													18.1	135	42
Clausocalanus furcatus		21	22				1								19.0	142	44
Copilia quadrata			4												1.7	13	4
Corycaeus sp		9													3.9	29	9
Farranula gracilis		10													4.3	32	10
Lophothrix sp				1											0.4	3	1
Oithona plumifera		21	11												14.7	109	32+2
Oncaea mediterranea		3													1.3	10	3
Oncaea venusta		2													0.9	6	2
Paracalanus parvus		19													8.2	61	19
Temora styllifera		1													0.4	3	1
Scollecithrix danae		1													0.4	3	1
Undinula vulgaris		12	18	9											16.8	126	39
																	232

SIZE CLASSES

Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods																	
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae			1	7	1	1											10
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans	3																3
Coelenterates																	
Siphonophores		1	3														4
Hydromedusae																	
Polychaetes		3															3
Mollusks																	
Gastropods																	
Heteropods																	

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Echinoderm larvae																	
Urochordates																	
Salpa/Doliolids			1														2
Larvaceans		1	54	22													77+4=81
Chordates																	
Fish			2														2
TOTAL PLANKTON COUNTED																	336+6=342
TOTAL PLANKTON/m^3																	1103 m^3
VOLUME OF WATER FILTERED BY NET																	310 m^3
ALIQUOT																	1000
SUB SAMPLE																	1

DATE:	1 August 1978
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	2015
SAMPLE NUMBER:	#2
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	0.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	55°-60°
FLOWMETER START:	026793
FLOWMETER FINISH:	046057
LENGTH OF TOW:	10 min
LATITUDE:	17° 58.3'N
LONGITUDE:	65° 51.2'W
SEA STATE AND WEATHER:	SS#2

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata		56	78												41.5	144	134
Calocalanus pavo		24													7.4	26	24
Candacia pachydactila				1											0.3	1	1
Clausocalanus furcatus		35	19												16.7	59	54
Corycaeus		4													1.2	4	4
Corycaeus speciosus			1												0.3	1	1
Farranula gracilis		4	6												3.1	11	10
Lucicutia flavicornis			4												1.2	4	4
Macrosetella gracilis			1												0.3	1	1
Oncaea mediterranea		2													0.6	2	2
Oncaea venusta		3	1												1.2	4	4
Oithona plumifera		10	7												5.3	19	17
Paracalanus parvus		39													12.1	43	39
Parasitic copepoda		1													0.3	1	1
Pleuromamma piseki			10												3.1	11	10
Temora stylifera			1												0.3	1	1
Undinula vulgaris		1	8	7											5.0	17	16
																	323

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods		1	1														2
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae			5	4	3	1				1							14
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			1														1
Hydromedusae																	
Polychaetes		1			1												2
Mollusks																	
Gastropods																	
Heteropods																	
																	19

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans			3	1													4
Chordates																	
Fish			1	2													3
TOTAL PLANKTON COUNTED																	353-6=347
TOTAL PLANKTON/m^3																	379.9=380
VOLUME OF WATER FILTERED BY NET																	228.7-229
ALIQUOT VOLUME																	500 ml
SUB SAMPLE																	2 ml

DATE:	2 August 1978
STATION NUMBER:	BENCHMARK #3
SHIP:	CRAWFORD
TIME:	1:30
SAMPLE NUMBER:	#3
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	.75 m
TYPE OF HAUL:	OBLIGUE
SAMPLING DEPTH:	1,200 m SFC
METERS OF WIRE:	1,300
ANGLE:	50
FLOWMETER START:	106724
FLOWMETER FINISH:	201189
LENGTH OF TOW:	47 min
LATITUDE:	17° 57.8'N
LONGITUDE:	65° 50.2'W
SEA STATE AND WEATHER:	SS#2

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia lillgeborgii			1														1
Acartia spinata		5	5														10+
Acartia tonsa		45	7														52+
Acrocalanus longicornis		1	1														2
Calocalanus pavo		16	1														17+
Candacia sp (cop)		1															1
Clausocalanus arcuicornis		3															3
Clausocalanus furcatus		18	15														33
Conaea gracilis		6	1														7
Corycaeus sp		9	4														13
Corycaeus (c) speciosus			3														3
Eucalanus elongatus			1														1
Eucalanus sp		2															2
Euchaeta sp				1													1
Farranula gracilis		7															7
Haloptilus longicornis		2	8														10+1
Lubochia squillimana			1														1
Lucicutia flavicornis			8														8
Macrosetella gracilis			1														1
Mecynocera clausi		1															1

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Miracia efferata		1															1
Monstrillidae																	
Oncaea mediterranea		21	4														25
Oncaea venusta		0															0
Oithona plumifera		14	21														35+
Paracalanus aculeatus		1															1
Paracalanus parvus		52															52
Pleuromamma abdominalis				2													2
Pleuromamma piseki			7														7
Rhincalanus cornutus					1												1
Scolocithrix danae			1														1
Temora stylifera		1	3														4
Undinula vulgaris		9	17	8													34
																	346+14

								SIZE CLASSES									
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods	4	11	2														17
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids						1											1
Decapods																	
Caridean larvae			1	3	1	1											6
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans	12	1															13
Coelenterates																	
Siphonophores				1													1
Hydromedusae																	
Polychaetes		2	1														3
Mollusks																	
Gastropods																	
Heteropods																	

SIZE CLASSES

Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids			1		2												3
Larvaceans			18	25	1												44+32
Chordates Fish																	
TOTAL PLANKTON COUNTED																	448
TOTAL PLANKTON/m^3																	100
VOLUME OF WATER FILTERED BY NET																	1121.5 m^3
ALIQUOT VOLUME																	500
SUB SAMPLE																	2 ml

APPENDIX B

CRUISE REPORT AND DATA FROM OTEC CRUISE #2 (JE-802)

10-14 OCTOBER 1978

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #2 (JE-802)

10-14 October 1978

by

Gary C. Goldman, Chief Scientist

MAILING ADDRESS: CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, COLLEGE STATION, MAYAGUEZ, PUERTO RICO 00708

CRUISE REPORT

OTEC Cruise #3 (JE 802) 10-14 October 1978

I. Objectives:

A. Measure oceanic parameters relatable to "OTEC" at Punta Tuna, P. R.
B. Measure the variability of the above parameters.
C. Evaluate and develop techniques for measuring these parameters.
D. Measure variability of the parameters at Punta Vaca.
E. Measure water currents at two other sites.

II. Research Vessel:

R/V Jean A (P.R. Department of Natural Resources)

III. Supporting Agencies:

A. U.S. Department of Energy (LBL)
B. P.R. Water Resources Authority
C. UPR/CEER

IV. Dates of Cruise:

10-14 October 1978

V. Cruise Plan:

See Appendix II (Not included)

VI. Scientific and Technical Personnel:

C. Bonafe -- Technician
D. Corales -- Technician
G. Goldman -- Chief Scientist
A. Nazario -- Technician
D. Pesante -- Biological Coordinator
J. Rivera -- Scientific Assistant
M. Shafnacker -- Technician

VII. Station Locations:

See attached Cruise Plan, Appendix II (Not included)

VIII. Types of Sampling:

See attached Cruise Plan, Appendix II (Not included)

IX. Land Travel:

---26 September 1978. All personnel and equipment were transported to Magueyes. CEER vehicles took the equipment from CEER/Mayaguez. After aborted attempt to depart on R/V CRAWFORD, all personnel remained on board CRAWFORD until the following morning.

---27 September 1978. All personnel were transported to Mayaguez using CEER vehicles. Equipment remained aboard CRAWFORD.

--- 9 October 1978. R/V JEAN A departed from San Juan to rendezvous with scientific personnel in Mayaguez.

---10 October 1978. All personnel were transported from CEER/ Mayaguez to Malecon port in Mayaguez using CEER vehicles.

---14 October 1978. All personnel were transported from Malecon port in Mayaguez to CEER using CEER vehicles.

X. Reasons for termination of cruise:

Completed virtually all planned operations.

XI. Accomplishments:

A. Collected most of data from Station "B" - only missed transmission.
B. Evaluated data collection techniques and sample preservation and processing.
C. Collected all data from Station "P".
D. Collected all data from Station "A".
E. Collected all data from Station "V".
F. Did not get Bathymetric data for Station "B" and "A".
G. Seemed to take only necessary equipment (see last Report).
H. Corrected XBT problem (See last Report).
I. Used mooring at Station "B" (see last Report).
J. Tried and successfully used "Bucket Method" for chlorophyll sampling (see last Report).

XII. Changes to be effected:

A. Try transmissometer cable deployment.
B. Minimize current meter underwater time.
C. Find reliable, useable, available vessel of sufficient size.
D. Try to charge battery at "B" mooring.

XIII. Stations Visited:

See Cruise Plan (Appendix II) for planned activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-1	11 Oct '78	0930-1000	65°51.9'W	17°57.6'N	PLANKTON I (note 0)	
B-2	11 Oct '78	1030-1630	65°51.9'W	17°57.6'N	HYDRO-1 (Note 1) XBT-1 CURRENT-1 PLANKTON-2 (Note 2)	
B-3	11 Oct '78	1730-2030	65°51.9'W	17°57.6'N	CURRENT-2 XBT-2	
B-4	11-12 Oct '78	2200-0200	65°51.9'W	17°57.6'N	HYDRO-2 (Note 1) CURRENT-3 PLANKTON-3 (Note 3) XBT-3	
B-5	12 Oct	0745-1000	65°51.9'W	17°57.6'N	CURRENT-4 XBT-4	
B-6	12 Oct '78	1000-1600	65°51.9'W	17°57.6'N	BIOCAST-1 (Note 1) XBT-5	PLANKTON-4 (Note 4) PLANKTON-5 (Note 5)
B-7	12 Oct	2200-2330	65°51.9'W	17°57.6'N	BIOCAST-2 (Note 1) XBT-6	
V-1	13 Oct '78	0810-1630	65°32'W	18°02'N	HYDRO/BIOCAST (Note 1) XBT-7 XBT-8 CURRENT-5 PLANKTON-6 (Note 6) PLANKTON-7 (Note 7)	
A-1	13 Oct '78	1600-1800	65°40-41'W	18°02-02.7'N	CURRENT-6 XBT-9	
P-1	13 Oct '78	2035-2238	66°00.0'-.9'W	17°54.9-55'N	CURRENT-7 XBT-10	
B-8	14 Oct '78	0000-0030	65°51.9'W	17°57.6'N	PLANKTON-8 (Note 8) XBT-11	

Notes--

--0 20-minute horizontal tow at 25 m depth.

--1 Only 900 m of hydrocable, therefore, only sampled to 800 m.

--2 Vertical tow 800 m to 200 m.

--3 Vertical tow 200 m to surface.

--4 Only 900 m of cable, so no 1100 m plankton tow was possible.

--5 Tried 800 m to surface, but double trip mechanism on net malfunctioned repeatedly, and finally lost the net.

--6 Verticle (oblique) tow 800 m - 200 m.

--7 Verticle (oblique) tow 200 m to surface.

--8 20-minute tow at 25 m depth during night.

CRUISE REPORT FOR BIOLOGY DIVISION OTEC, P. R.

During the dates of October 10-14, 1978, the second field trip to Punta Tuna and the first field trip to Vieques took place. Of the eight samples taken by using the Double Trip Mechanism with the 200 plankton nets, only three samples are representative of the stratums sampled. These are the 25 m at Punta Tuna - day, 25 m at Punta Tuna - night, 200 m - SFC at Punta Tuna.

Due to malfunction of the DTM and the fact that the R/V JEAN A had only 900 m of hydrocable, no other samples could be obtained. On arrival from the cruise, and through personal communication with personnel from General Oceanics, different alternatives were delineated in order to increase the percent of success of the zooplankton sampling.

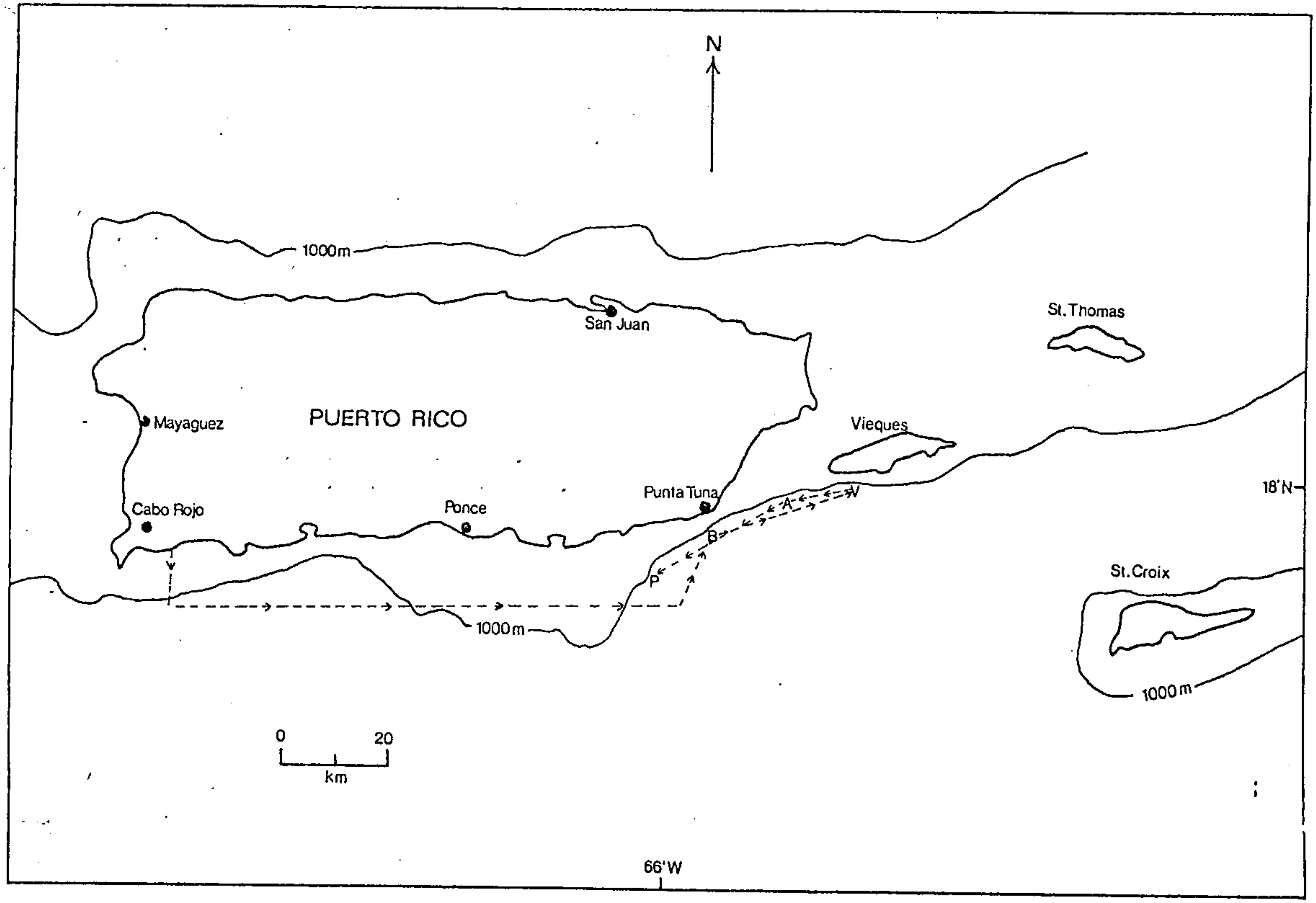
Mechanical malfunction at the level of the second phase of release of the net was the main problem as the first messenger would actuate both first and second phases of the sampling procedure, making it impossible to obtain the samples.

The fact that a buoy was installed at the benchmark site at Punta Tuna has somewhat changed the environment in the sense that fish are congregating around and under the buoy.

Dolphin fish and sharks up to 100 in number were seen at the buoy during different times of the day. As of this date the list of species of those animals found around the buoy is being worked out.

Sea States of SS # 2-3 were observed during this cruise.

Trackline for OTEC cruise #2 (JE-802), 10-14 October 1978



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE JE-802 STATION B-2 Rev. DATE 11 October 1978 WEATHER 15KT/045°, 80°, --, 1, --
DATES 10-14 October 1978 LOCATION 17° 52.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 1100-1500 AST; HYDROCAST (1100-1300), XBT (1055), CURRENT (1230-1500)
SHIP JEAN A MAR. SQ. 43 TIME GMT 1500 DEPTH TO BOTTOM 1120 MAX SAMPLE 900 BAR 1016

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O$_2$ (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_2$ (µG AT/L)	NO$_3$ (µG AT/L)	NH$_3$
000	29.18	34.689	21.79	4.24	N.A.	N.A.	N.A.	*		*	4.68
050	23.76	35.527	22.56	4.04				*		*	4.13
100	24.45	36.839	24.92	4.16				*		*	15.30
150	21.52	36.788	25.73	4.17				*		*	2.30
200	19.60	--	---	4.08				0.30		*	4.45
250	18.46	36.522	26.34	3.97				*		*	5.80
300	17.31	36.376	26.51	3.89				*		0.20	27.25
402	15.39	36.073	26.73	3.52				*		*	13.65
503	13.29	35.731	26.92	3.17				*		0.1	1.88
607	10.49	35.297	27.11	2.78				*		*	28.33
820	6.51	34.875	27.41	3.01				*		0.20	33.63

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)
000	29.18	34.689	21.79
010	29.18	34.695	21.80
020	29.10	34.780	21.85
030	29.00	34.885	22.00
040	29.00	35.075	22.25
050	28.76	35.527	22.56
075	26.70	36.625	23.85
100	24.45	36.839	24.92
125	22.90	36.835	25.42
150	21.52	36.788	25.73
175	20.50	36.725	25.90
200	19.60	36.663	26.06
250	18.46	36.522	26.34
300	17.31	36.376	26.51
400	15.48	36.090	26.72
500	13.20	35.750	26.92
600	10.65	35.325	27.10
700	8.55	35.070	27.26
800	6.82	34.900	27.39
900	--	--	---
1000	--	--	---

XBT DEPTH (M)	XBT TEMP (°C)
000	28.9
071	28
077	27
085	26
095	25
113	24
131	23
142	22
172	21
206	20
242	19
305	18
350	17
383	16
465	15
519	14
547	13
594	12
610	11
665	10
700	9

TRANSMISSOMETER DEPTH (M)	TRANSMISSOMETER TRAN (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σ_t)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

WATER CURRENTS DEPTH (M)	DIR (DEG)	SPEED (CM/S)
025	252	10
050	283	10
075	084	6
100	096	12
125	060	6
150	-	-
200	-	-
250	252	4
300	228	5
400	228	3
500	228	5

* = Less than 0.1

CRUISE: JE-802 STATION: B-3 REV DATE: 11 OCTOBER 1978 WEATHER: 8-10KT/135°, 83°, 80%, 1, 135°
DATES: 10-14 OCTOBER 1978 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 1730-2030 AST; CURRENT (1730-2030), XBT (1815)
SHIP JEAN A MAR. SQ. 43 TIME GMT 2130 DEPTH TO BOTTOM 1120 MAX SAMPLE 500 BAR ---

XBT

DEPTH (M)	TEMP (°C)
000	28.8
052	28
066	27
080	26
093	25
107	24
140	23
154	22
171	21
197	20
250	19
292	18
358	17
405	16
468	15
502	14
530	13
562	12
607	11
646	10
686	9
730	8

WATER CURRENT

DEPTH (M)	DIRECTION (DEG)	SPEED (CM/S)
025	096	8
050	060	12
075	048	12
100	264	5
125	264	8
150	264	5
200	264	8
250	252	8
300	252	5
400	252	2
500	264	4

CRUISE JC-202 STATION B-8 Rev-2 DATE 11-12 October 1978 WEATHER 10KT/135°, 82°, 80%, 1, 135°
DATES 10-14 October 1978 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2200-0200 AST; HYDROCAST (2200-2400), XBT (2334), CURRENTS (0000-0200)
SHIP JEAN A MAR. SQ. 43 TIME GMT 0200 DEPTH TO BOTTOM 1120 MAX SAMPLE 800 BAR ---

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3
000	28.77	34.646	21.90	4.00	N.A.	N.A.	N.A.	*		*	2.96
050	28.83	36.041	22.92	4.08				*		*	29.49
100	24.29	36.868	24.99	4.36				*		0.47	1.52
150	20.98	36.754	25.85	4.16				*		0.26	2.92
200	19.54	36.618	26.13	4.08				*		*	3.56
250	18.41	35.518	26.35	4.00				*		*	38.87
300	17.51	36.389	26.47	3.81				*		0.83	11.77
402	15.61	36.301	26.70	3.52				*		0.22	13.63
503	13.22	35.701	26.91	3.17				*		0.36	20.11
607	10.54	35.285	27.10	2.70				*		*	4.45
820	6.49	34.843	27.38	3.01				*		0.33	35.76

* = Less than 0.1

XBT DEPTH (M)	XBT TEMP (°C)
000	28.8
067	28
076	27
087	26
097	25
107	24
127	23
142	22
153	21
195	20
237	19
285	18
330	17
377	16
428	15
463	14
513	13
552	12
586	11
625	10
660	9
703	8
760	7

TRANSMISSION DEPTH (M)	TRANSMISSION TRAN (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σ_T)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

WATER CURRENTS DEPTH (M)	DIR (DEG)	SPEED (CM/S)
025	060	12
050	072	15
075	084	10
100	060	8
125	120	6
150	252	6
200	048	5
250	-	-
300	252	8
400	264	6
500	283	4

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000	28.77	34.646	21.90
010	28.77	34.650	21.90
020	28.77	34.675	21.92
030	28.80	34.750	22.05
040	28.81	34.975	22.35
050	28.83	36.041	22.92
075	27.80	36.750	24.10
100	24.29	36.868	24.99
125	22.50	36.825	25.55
150	20.98	36.754	25.85
175	20.10	36.675	26.00
200	19.54	36.618	26.13
250	18.41	36.518	26.35
300	17.51	36.389	26.47
400	15.62	36.100	26.70
500	13.33	35.708	26.90
600	10.60	35.285	27.10
700	8.35	35.025	27.25
800	6.85	34.855	27.35
900	--	--	---
1000	--	--	---

CRUISE JE-802 STATION B-5 Rev DATE 12 October 1978 WEATHER 20KT/045°, 82°, --, 1, --

DATES 10-14 October 1978 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE N.A.

GENERAL AREA Punta Tuna, P.R. TIME 0745-1000 AST ; CURRENTS (0745-1000), XBT (0750)

SHIP JEAN A MAR. SQ. 43 TIME GMT 1145 DEPTH TO BOTTOM 1120 MAX SAMPLE 500 BAR 1014

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	28.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	264	15
												053	28							050	288	10
												061	27							075	060	10
												070	26							100	120	2
												084	25							125	-	-
												101	24							150	-	-
												142	23							200	264	2
												153	22							250	264	8
												166	21							300	228	5
												190	20							400	012	2
												240	19							500	300	2
												293	18									
												328	17									
												373	16									
												443	15									
												476	14									
												525	13									
												550	12									
												598	11									
												626	10									
												678	9									
												725	8									

CRUISE JE-302 STATION B-6 Rev DATE 12 October 1978 WEATHER 20-25KT/045°, 82°F, 1M/040°
DATES 10-14 October 1978 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 1000-1600 AST; Biocast (1000-1200), XBT (1100), Plankton

SHIP Jean A MAR. SQ. 43 TIME GMT 1400 DEPTH TO BOTTOM 1120 MAX SAMPLE 200 BAR 1014

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O$_2$ (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_3$ (µG AT/L)	NO$_2$ (µG AT/L)	N$_3$
000	26.76	34.655	21.91		.270	0					
025	26.78	34.674	21.91		.102	0					
050	28.78	35.977	22.89		.263	0					
075	24.93	36.797	24.73		.378	0					
100	23.67	36.880	25.18		.324	0					
125	23.07	36.907	25.33		.270	0					
150	21.40	36.731	25.74		.378	0					
175	20.26	36.635	26.00		.263	0					
200	19.45	36.590	26.14		.016	0					
250	18.35	36.504	26.35		.002	0					
300	17.52	36.404	26.43		.001	.002					
400	15.39	36.064	26.72		.002	0*					
- - -	- - -	- - -	- - -								
000	28.76	34.655	21.91								
010	22.76	34.660	21.91								
020	28.77	34.670	21.91								
030	23.78	34.780	21.95								
040	28.78	34.900	22.06								
050	28.78	35.977	22.89								
075	24.98	36.797	24.73								
100	23.67	36.820	25.18								
125	23.07	36.907	25.33								
150	21.48	36.781	25.74								
175	20.26	36.685	26.00								
200	19.45	36.590	26.14								
250	18.35	36.504	26.35								
300	17.52	36.404	26.40								
400	15.39	35.064	26.72								
500											
600											
700											
800											
900											
1000											

* Less than .001

XBT DEPTH (M)	XBT TEMP (°C)	TRANSMISSION DEPTH (M)	TRANSMISSION TRANS (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σ_t)	WATER CURRENTS DEPTH (M)	WATER CURRENTS DIR (DEG)	WATER CURRENTS SPEED (CM/S)
000	28.7									
064	28									
070	27									
076	26									
081	25									
101	24									
136	23									
147	22									
164	21									
196	20									
230	19									
280	18									
336	17									
373	16									
423	15									
471	14									
515	13									
550	12									
585	11									
610	10									
650	9									
704	8									

CRUISE JC-802 STATION B-7 Rev DATE 12 October 1978 WEATHER ---
DATES 10-14 October 1978 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2200-2330 AST; Biocast (2200-2300), XBT (2255)

SHIP JEAN A MAR. SQ. 43 TIME GMT 0200 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 BAR --

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O_2 (ML/L)	CHLOR"A"* (µG/L)	PHEO"A"* (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_2 (µG AT/L)	NO_3
000	28.82	34.663	21.89		.270	0					
025	28.78	34.673	21.91		.216	0					
050	28.85	35.350	22.40		.185	0					
075	26.02	36.653	24.29		.218	0					
100	24.08	36.866	25.05		--	-					
125	22.61	36.911	25.51		.021	.021					
150	21.16	36.799	25.83		.185	0					
175	19.93	36.677	26.08		--	-					
200	19.34	36.612	26.18		.001	.002					
250	13.44	36.536	26.36		.002	0*					
302	17.66	36.421	26.46		0*	.002					
406	15.46	36.091	26.73		.004	0					

* Less than .001

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)
000	28.82	34.663	21.89
010	28.80	34.668	
020	28.80	34.670	
030	28.80	34.678	
040	28.82	34.725	
050	28.85	35.350	22.40
075	26.02	36.653	24.29
100	24.08	36.866	25.05
125	22.61	36.911	25.51
150	21.18	36.799	25.83
175	19.93	36.677	26.08
200	19.34	36.612	26.18
250	18.44	36.536	26.36
300	17.67	36.422	
400	15.50	36.092	
500			
600			
700			
800			
900			
1000			

XBT DEPTH (M)	XBT TEMP (°C)	TRANSMISSION DEPTH (M)	TRANSMISSION TRANS (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σ_t)	WATER CURRENTS DEPTH (M)	WATER CURRENTS DIR (DEG)	WATER CURRENTS SPEED (CM/S)
000	28.9									
063	28									
075	27									
097	26									
093	25									
110	24									
130	23									
145	22									
164	21									
186	20									
230	19									
285	18									
335	17									
375	16									
422	15									
473	14									
512	13									
550	12									
580	11									
613	10									
658	9									
728	8									

CRUISE: JE-802 STATION: B-8 REV DATE: 14 OCTOBER 1978 WEATHER: ---/---, --, --, --, --

DATES: 10-14 OCTOBER 1978 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0000-0030 AST; XBT (0000), PLANKTON

SHIP JEAN A MAR. SQ. 43 TIME GMT 0400 DEPTH TO BOTTOM 1120 MAX SAMPLE 25 BAR ---

XBT	
DEPTH (M)	TEMP (°C)
000	28.8
062	28
065	27
075	26
090	25
110	24
128	23
135	22
157	21
175	20
216	19
280	18
320	17
375	16
420	15
455	14
497	13
552	12
590	11
606	10
646	9
700	8
760	7

CRUISE JE-602 STATION V-1 Rev-3 DATE 13 October 1978 WEATHER 10KT/045°, 79°F, 1K/040°
DATES 10-14 October 1978 LOCATION 18° 02'N, 65° W (Drifting) WIRE ANGLE 10°
GENERAL AREA Punta Vaca, Vieques TIME 0800-1630 AST; HYDROCAST (0810-0910), XBT (0900), XBT (1240), CURRENT (0913-1116)
SHIP JEA. A MAN. SQ. 43 TIME GMT 1200 DEPTH TO BOTTOM 1200 MAX SAMPLE 200 BAR ---

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" µG/L	PHEO"A" µG/L	ATP µG/L	PO_4 µG AT/L	SiO_2 µG AT/L	NO_3 µG AT/L	NO_3
000	28.75	34.741	21.97	4.04	.079	.011	N.A.	*		0.19	2.29
049	27.56	36.356	23.58	4.20	.133	.094		*		*	2.21
098	24.43	36.073	24.95	4.32	.162	.000		*		0.24	2.53
148	21.66	36.871	25.75	4.04	.242	.000				0.40	2.00
198	19.21	36.643	26.24	3.83	--	--		*		0.20	3.67
248	17.89	36.466	26.44	3.76	.001	.007		*		*	2.08
297	17.24	36.371	26.52	3.81	.009	.000		*		*	4.53
397	15.44	36.085	26.73	3.65	.004	.000		-		-	--
496	13.33	35.753	26.93	3.52	--	--		0.25		0.20	21.75
596	11.24	35.393	27.06	2.81	--	--		*		*	25.53
799	7.19	34.881	27.32	2.86	--	--		*		0.11	31.91

* = Less than 0.10

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)
000	28.75	34.741	21.97
010	28.75	34.750	21.97
020	28.60	34.825	21.98
030	28.40	35.025	22.05
040	28.10	35.350	22.50
050	27.55	36.356	23.60
075	25.80	36.745	24.50
100	24.40	36.875	44.98
125	22.30	36.880	25.40
150	21.65	36.860	25.75
175	20.45	36.775	26.04
200	19.40	36.640	26.20
250	18.00	36.460	26.45
300	17.25	36.370	26.55
400	15.44	36.085	28.80
500	13.30	35.750	26.95
600	11.10	35.393	27.10
700	9.10	35.050	27.23
800	---	---	---
900	---	---	---
1000	---	---	---

XBT		TRANSMISSIVITY	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)
000	28.8	000	28.8
053	28	032	28
062	27	050	27
080	26	070	26
093	25	087	25
114	24	111	24
124	23	137	23
143	22	140	22
166	21	154	21
180	20	175	20
214	19	213	19
262	18	268	18
333	17	336	17
374	16	392	16
406	15	427	15
471	14	489	14
514	13	522	13
583	12	593	12
607	11	620	11
638	10	650	10
690	9	693	9
757	8	745	8

S T D			
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)
N.A.	N.A.	N.A.	N.A.

WATER CURRENTS		
DEPTH (M)	DIR (DEG)	SPEED (CM/S)
025	132	15
050	048	8
075	---	--
100	012	10
125	024	10
150	346	10
200	---	--
250	192	10
300	156	--
400	252	14.5
500	264	17

VESSEL DRIFTING

CRUISE JE-802 STATION A-1 REV DATE 13 OCTOBER 1978 WEATHER ---/---, --, --, --, --

DATES 10-14 OCTOBER 1978 LOCATION 18° 0.20'-02.7'N, 65° 40'-41'W WIRE ANGLE N.A.

GENERAL AREA BETWEEN P.R. AND VIEQUES TIME 1600-1800 AST; CURRENT (1600-1800), XBT (1715)

SHIP JEAN A MAR. SQ. 43 TIME GMT 2000 DEPTH TO BOTTOM 1200 MAX SAMPLE 500 BAR ---

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.. .	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	28.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	012	9
												065	28							050	021	9
												070	27							075	278	19
												075	26							100	275	32
												095	25							125	278	19
												116	24							150	281	15
												134	23							200	282	20
												150	22							250	294	20
												160	21							300	289	24
												187	20							400	311	23
												207	19							500	301	21
												277	18									
												328	17									
												380	16									
												430	15									
												477	14									
												522	13									
												570	12									
												604	11									
												645	10									
												697	9									
												760	8									

VESSEL
DRIFTING

CRUISE JE-802 STATION P-1 Rev DATE 13 October 1978 WEATHER 10KT/135°, 79°, 95%, 1, 135°

DATES 10-14 October 1978 LOCATION 17° 54.9'-55.0'N, 66° 00.0'-00.9'W WIRE ANGLE N.A.

GENERAL AREA Patillas, P.R. TIME 2035-2238 AST; CURRENT (2035-2238), XBT (2155)

SHIP JEAN A MAR. SQ. 43 TIME GMT ________ DEPTH TO BOTTOM ________ MAX. SAMPLE ________ BAR ________

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHAEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	29.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	270	11
												048	29							050	238	3
												059	28							075	010	7
												066	27							100	292	9
												085	26							125	278	13
												100	25							150	271	18
												119	24							200	274	18
												133	23							250	270	22
												139	22							300	274	21
												153	21							400	279	28
												172	20							500	274	28
												210	19									
												275	18							VESSEL DRIFTING		
												316	17									
												354	16									
												428	15									
												470	14									
												526	13									
												567	12									
												608	11									
												647	10									
												672	9									

SIZE CLASS	SIZE IN MILLIMETERS
1	< 0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 19.9
13	20.0 - 29.9
14	30.0 - 39.9
15	40.0 - 49.9
16	> 50.0

DATE:	11 October 1978
STATION NUMBER:	BENCHMARK #1
SHIP:	JEAN A
TIME:	0935
SAMPLE NUMBER:	5
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	3/4
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	63 m
ANGLE:	55°-60°
FLOWMETER START:	004459
FLOWMETER FINISH:	0036174
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	#2

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia negligens			0.68						0.29								0.68
Acrocalanus longicornis			4.08						1.72								4.08
Calocalanus pavo		36.74							15.52								36.74
Calocalanus pavoninus		6.12							2.59								6.12
Clausocalanus sp.		28.57	29.93						24.09	12.37							58.51
Corycaeus speciosus			6.8						2.87								6.8
Farranula gracilis		27.21							11.49								27.21
Oithona plumifera		6.12	8.16						6.03								14.28
Oncaea mediterranea		8.84	0.68						4.02								9.52
Oncaea venusta		4.76															4.76
Paracalanus sp.		9.52	4.08						5.75								13.61
Pontellina plumata			0.68														0.68
Sapphirina nigromaculata			0.68						0.29								0.68
Scolecithrix sp.			0.68						.29								0.68
Temora stylifera			5.44						2.30								5.44
Undinula vulgaris		6.8	4.76	4.76					6.89								16.32
Unidentified calanoids		17.0	8.16						10.63								25.16

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Amphipods																	
hyperiid																	
Cephalopod larvae						0.68											0.68
Chaetognatha						4.08						0.68					4.76
Decapoda																	
protozoea																	
zoea					2.04												2.04
Echinoderm larvae																	
bipinnaria																	
pluteus				0.68													0.68
Euphausiacea (juveniles)										0.68							0.68
Fish (juveniles)																	
Foraminifera	4.08																4.08
Larvacea				7.48													7.48
Nauplius																	
Noctiluca sp.		3.40															3.40
Ostracoda			2.04														2.04
Pelecypods	0.68																0.68

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Polychaeta		1.36															1.36
Radiolarians																	
Siphonophores			1.36	0.68		0.68		0.68									3.40
Thaliacea																	
Doliolidae		0.68															0.68
Salpidae																	
Thecostomata																	
Carolina sp.					0.68												0.68
Creseis sp.																	
Halocyclix sp.																	
Limacinia sp.	0.68				2.72												3.4
Peraclis sp.		0.68															0.68

DATE:	11 October 1978
STATION NUMBER:	BENCHMARK
SHIP:	JEAN A
TIME:	1543
SAMPLE NUMBER:	6
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	3/4
RING SIZE:	202µ
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	800-200 m
METERS OF WIRE:	810
ANGLE:	0
FLOWMETER START:	0036827
FLOWMETER FINISH:	077330
LENGTH OF TOW:	17 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	#2

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia danae			0.07							0.39							0.07
Acartia negligens			0.07							0.39							0.07
Aegisthus mucroratus				0.07						0.39							0.07
Calocalanus pavo		0.2								1.12							0.2
Calocalanus pavoninus		0.13								0.73							0.13
Conaea gracilis		0.87	1.2							11.59							2.06
Copilia mirabilis				0.07	0.07					0.79							0.14
Corycaeus limbatus			0.2														0.2
Euaetideus giesbrechti			0.13							0.73							0.13
Euchaeta marina			0.47		0.07					3.0							0.54
Farranula gracilis		0.2	0.13							1.86							0.33
Haloptilus sp.			0.53	0.67						6.76							1.2
Heterorhabdus papilliger			0.13							.73							0.13
Lubbockia aculeata				0.07						0.39							0.07
Lubbockia squillimana			0.46							2.59							0.46
Lucicutia flavicornis			0.87							4.90							0.87
Mecynocera clausii		0.2															0.2
Miracia minor		0.07								0.39							0.07
Mormonilla minor			0.53							2.98							0.53
Nannocalanus minor		0.07								.39							0.07

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oithona plumifera			2.53							14.25							2.53
Oncaea conifera			0.07							0.39							0.07
Oncaea venusta		0.2															0.2
Paracandacia bispinosa		0.14	0.13							1.52							0.27
Pleuromamma gracilis			0.6							3.38							0.6
Sapphirina metallina				0.07						0.39							0.07
Temora turbinata		0.8	0.53							7.5							1.33
Temoropia mayumbaensis			0.2							1.13							0.2
Undinula vulgaris				0.27						1.5							0.27
Unidentified Calanoids			2.4	0.73		0.07				18.07							3.21

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Amphipods																	
hyperiid		0.07															0.07
Cephalopod larvae																	
Chaetognatha						2.13			0.07	0.07	0.07	0.47					2.8
Decapoda																	
protozoea																	
zoea																	
Echinoderm larvae																	
bipinnaria																	
pluteus																	
Euphausiacea (juveniles)				1.3					0.07			0.07					0.27
Fish (juveniles)							0.07	0.07									0.14
Foraminifera	0.53																0.53
Larvacea					0.2												0.2
Nauplius																	
Noctiluca sp.	1.07																1.07
Ostracoda		1.4	0.47														1.87
Pelecypods																	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Polychaeta		0.07	0.13	0.07													0.27
Radiolarians	0.27																0.27
Siphonophores			0.13	0.13	0.13	0.07	0.07	0.13									0.66
Thaliacea																	
Doliolidae			0.07	0.13													0.2
Salpidae			0.07	0.07													0.14
Thecostomata																	
Carolina sp.																	
Creseis sp.			0.07														0.07
Halocyclix sp.																	
Limacinia sp.	0.13	0.07															0.2
Peraclis sp.	0.33																0.33

DATE: 11 October 1978

STATION NUMBER: BENCHMARK

SHIP: JEAN A

TIME: 2205

SAMPLE NUMBER: 7

TYPE OF NET: CONICAL 5:1

MESH SIZE: 3/4 m

RING SIZE: 202µ

TYPE OF HAUL: VERTICAL

SAMPLING DEPTH: 200 SFC

METERS OF WIRE: 230

ANGLE: 0

FLOWMETER START: 077332

FLOWMETER FINISH: 089374

LENGTH OF TOW: 17° 57.6'N

LATITUDE: 65° 51.9'W

LONGITUDE:

SEA STATE AND WEATHER:

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia danae		1.79	0.9							1.50							2.69
Acrocalanus longicornis		0.9	0.9							1.00							1.79
Calanus tenuicornis		0.9								0.5							0.9
Calocalanus pavo		7.16								3.99							7.16
Calocalanus pavoninus		3.58								2.00							3.58
Clausocalanus sp.		8.96	8.96							10.00							17.92
Corycaeus latus			0.9							0.5							0.9
Corycaeus lautus			0.9							0.5							0.9
Corycaeus typicus			0.9							0.5							0.9
Euchaeta marina		0.9	0.9		1.79					2.00							3.59
Farranula gracilis		11.65								6.5							11.65
Haloptilus sp.		1.79	1.79	0.9						2.5							4.48
Heterorhabdus spinifer			0.9							0.5							0.9
Lubbockia aculeata		1.79								1.00							1.79
Lucicutia flavicornis			4.48							2.5							4.49
Macrosetella gracilis			0.9							0.5							0.9
Mecynocera clausii		1.79	0.9							1.50							2.69
Miracia minor		0.9								0.5							0.9
Oithona plumifera		8.96	28.66							20.9							37.62
Oncaea mediterranea		5.37	1.79							4.00							7.17

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oncaea venusta		5.37															5.37
Paracalanus sp.		3.58	0.9							2.5							4.48
Paracandacia simplex			0.9							0.5							0.9
Pleuromamma abdominalis		2.69	0.9	0.9						2.50							4.49
Rhincalanus cornutus					0.9					0.5							0.9
Saphirella sp.		0.9								0.5							0.9
Scolecithrix sp.			0.9							0.5							0.9
Temora stylifera		1.79	1.79							2.00							3.58
Temora turbinata		9.85	5.38							8.5							15.23
Temoropia mayumbaensis		0.9								0.5							0.9
Undinula vulgaris			8.96							5.0							8.96
Unidentified Calanoids		16.12								9.00							16.12

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Amphipods																	
hyperiid																	
Cephalopod larvae																	
Chaetognatha							1.79			0.9							2.69
Decapoda																	
protozoea		0.9															0.9
zoea		0.9		1.79		0.9											3.58
Echinoderm larvae																	
bipinnaria			0.9														0.9
pluteus																	
Euphausiacea (juveniles)						0.9	0.9			0.9							2.69
Fish (juveniles)			0.9	0.9								0.9					2.69
Foraminifera		8.96															8.96
Larvacea				6.27													6.27
Nauplius		1.79															1.79
Noctiluca sp.	40.31																40.31
Ostracoda			10.75														10.75
Pelecypods	0.9																0.9

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Polychaeta			0.9	0.9													1.79
Radiolarians	2.69																2.69
Siphonophores				0.9	1.79			0.9	0.9								4.48
Thaliacea																	
Doliolidae				0.9													0.9
Salpidae			0.9														0.9
Thecostomata																	
Carolina sp.																	
Creseis sp.		0.9	0.9														1.79
Halocyclix sp.																	
Limacinia sp.		3.58															3.58
Peraclis sp.	2.69																2.69

DATE:	13 October 1978
STATION NUMBER:	BENCHMARK
SHIP:	JEAN A
TIME:	0030
SAMPLE NUMBER:	11
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	65
ANGLE:	70
FLOWMETER START:	102682
FLOWMETER FINISH:	142790
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	#2

The quantities in the following data sheets are $\#/m^3$.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo		55.94	68.85							13.22							124.8
Calocalanus pavoninus		12.91								1.37							12.91
Candacia sp.			8.61							0.912							8.61
Centropages caribbeanesis		4.3	4.3	4.3						91.4							12.91
Clausocalanus sp.		163.53								12.03							163.53
Corycaeus typicus			8.61							0.91							8.61
Euchaeta marina			4.3		4.3					0.91							8.61
Farranula gracilis		64.55	51.64							12.31							116.19
Lucicutia flavicornis			25.82							2.73							25.82
Miracia minor			4.3							0.45							4.3
Oithona plumifera		12.91	55.94							7.29							68.85
Oncaea mediterranea		55.94								5.92							55.94
Oncaea venusta		34.43	30.12							6.84							64.55
Paracalanus sp.		4.3	4.3							0.91							8.61
Pontellina plumata			4.3							0.45							4.3
Scolecithrix danae				8.61						0.91							8.61
Temora stylifera			8.61							0.91							8.61
Temora turbinata		47.34	68.85							12.31							116.19
Undinula vulgaris			12.91	17.22						3.19							30.13
Unidentified Calanoids		86.07	55.94							15.04							142.01

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Amphipods																	
hyperiid			4.3														4.3
Cephalopod larvae																	
Chaetognatha							4.3	4.3			4.3						12.91
Decapoda																	
protozoea				4.3													4.3
zoea				4.3													4.3
Echinoderm larvae																	
bipinnaria																	
pluteus																	
Euphausiacea (juveniles)							4.3	4.3		4.3							12.91
Fish (juveniles)																	
Foraminifera	17.21																17.21
Larvacea			47.34	21.52													68.85
Nauplius																	
Noctiluca sp.	296.94	12.91															309.85
Ostracoda		4.3															4.3
Pelecypods																	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Polychaeta		8.61	4.3														12.91
Radiolarians																	
Siphonophores				4.3	4.3	12.91											25.82
Thaliacea																	
Doliolidae																	
Salpidae																	
Thecostomata																	
Carolina sp.				4.3													4.3
Creseis sp.				4.3													4.3
Halocyclix sp.					4.3												4.3
Limacinia sp.	8.61	4.3															12.91
Peraclis sp.																	

APPENDIX C

CRUISE REPORT AND DATA FROM OTEC CRUISE #3 (CR-803)

1-5 DECEMBER 1978

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #3 (CR-803)

1-5 December 1978

by

Gary C. Goldman, Chief Scientist

CRUISE REPORT

OTEC Cruise #3 (CR 803) 1-5 December 1978

I. Objectives:

A. Measure oceanic parameters relatable to "OTEC" at Punta Tuna, P. R.
B. Measure the variability of the above parameters.
C. Evaluate and develop techniques for measuring these parameters.
D. Measure variability of the parameters at Punta Vaca.
E. Measure water currents at two other sites.

II. Research Vessel:

R/V CRAWFORD (University of Puerto Rico)

III. Supporting Agencies:

A. U. S. Department of Energy (LBL)
B. P. R. Water Resources Authority
C. UPR/CEER

IV. Dates of Cruise:

1-5 December 1978

V. Cruise Plan:

See Appendix II (Not included)

VI. Scientific and Technical Personnel:

C. Bonafé -- Technician
D. Corales -- Technician
G. Goldman -- Chief Scientist
E. González -- Technician
A. Nazario -- Technician
R. Noble -- Visiting Contractor
D. Pesante -- Biological Coordinator
J. Rivera -- Scientific Assistant
M. Shafnacker -- Technician

VII. Station Locations:

See attached Cruise Plan, Appendix II (Not included)

VIII. Types of Sampling:

See attached Cruise Plan, Appendix II (Not included)

IX. Travel:

--- 1 December 1978. R/V CRAWFORD departed from Magueyes to rendevous with scientific personnel in Mayaguez at Malecon Port.

--- 1 December 1978. All personnel were transported from CEER/ Mayaguez to Malecon Port in Mayaguez using CEER vehicles.

--- 5 December 1978. All personnel were transported from Malecon Port in Mayaguez to CEER using CEER vehicles. R/V CRAWFORD returned to Magueyes.

X. Reasons for termination of cruise:

Completed virtually all planned operations.

XI. Accomplishments:

A. Collected all of data from Station "B".
B. Evaluated data collection techniques and sample preservation and processing.
C. Collected all data from Station "P".
D. Collected all data from Station "A".
E. Collected all data from Station "V".
F. Did not get Bathymetric data for Station "B" and "A".
G. Tried unsuccessfully to repair burned out light on buoy.

XII. Changes to be effected:

A. Combine our operations with those of recovering and re-mooring current meters.

XIII. Stations Visited:

See Cruise Plan (Appendix II) for planned activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-1	2 Dec '78	--	65°51.9'W	17°57.6'N	Nothing (Note 1)	Watercast
B-2	2 Dec '78	0600-1300	65°51.9'W	17°57.6'N	PLANKTON (1000m - surface) XBT-1	
B-3	2 Dec '78	1300-1415	65°51.9'W	17°57.6'N	HYDROCAST-1 XBT-2	
B-4	2 Dec '78	1430-1700	65°51.9'W	17°57.6'N	PLANKTON (1000m-800m) PLANKTON (800m-200m) PLANKTON (200m-0m) XBT-3	
B-5	2 Dec '78	1709-1820	65°51.9'W	17°57.6'N	CURRENT PROFILE-1 XBT-4	
B-6	2-3 Dec '78	2300-0230	65°51.9'W	17°57.6'N	HYDROCAST-2 CURRENT PROFILE-2 XBT-5	
B-7	3 Dec '78	0600-0730	65°51.9'W	17°57.6'N	CURRENT PROFILE-3 (Note 2) XBT-6	
B-8	3 Dec '78	1030-1400	65°51.9'W	17°57.6'N	BIOCAST-1 TRANSMISSION-1 XBT-7, 7a CURRENT PROFILE-4 (Note 3)	

XIII. Stations Visited:

See Cruise Plan (Appendix II) for planned activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-8a	3 Dec '78	1445-1515	65°52.0'W	17°57.3'N	PLANKTON (25m deep tow)	
P-1	3 Dec '78	1540-1657	65°56.5'-57.5'W	17°54.5'-55.0'N	CURRENT PROFILE-5 XBT-8 (Note 2)	
S-1	3 Dec '78	1835-2000	65°45.0'-45.7'W	17°55.1'-55.2'N	CURRENT PROFILE-6 (Note 3) XBT-9	
B-9	3 Dec '78	2200-2350	65°51.9'W	17°57.6'N	BIOCAST-2 TRANSMISSION-2 XBT-10, 10a	
B-9a	4 Dec '78	0000-0400	65°51.9'W	17°57.6'N	PLANKTON (1000m-0m)	
A-1	4 Dec '78	0500-0630	65°40.0'W	18°02.0'N	PLANKTON	CURRENT PROFILE-7
V-1	4 Dec '78	0700-1150	65°33.0'-33.7'W	18°02.7'-03.3'N	HYDRO/BIOCAST-1 CURRENT PROFILE-8 PLANKTON (1000m-0m) PLANKTON (800m-200m) (200m-0m) XBT-13, 13a, 12	
A-2	4 Def '78	1217-1337	6539.2'-39.7'W	18°02.3'-02.4'N	CURRENT PROFILE-7 XBT-11	

Notes--

--1 This cast would have been made for Dr. Sandusky, if he were on the cruise.

--2 Rotor bearing malfunction -- no speed record.

--3 Bearing repaired, recorder malfunction -- no record.

CRUISE REPORT FROM ZOOPLANKTON SUB-DIVISION

On this last cruise (CR-803), all zooplankton samples were collected.

Through previous trial of the nets and mechanism at the Mona Channel, it was possible to find out what was wrong with the mechanism. Correction for the weight of the first messenger resulted in 100% rate of success at all sampling depths, even in relatively rough seas.

The biota reported for the last cruise (CR-802) is the same for this cruise. A steady population of sharks is still present at the buoy.

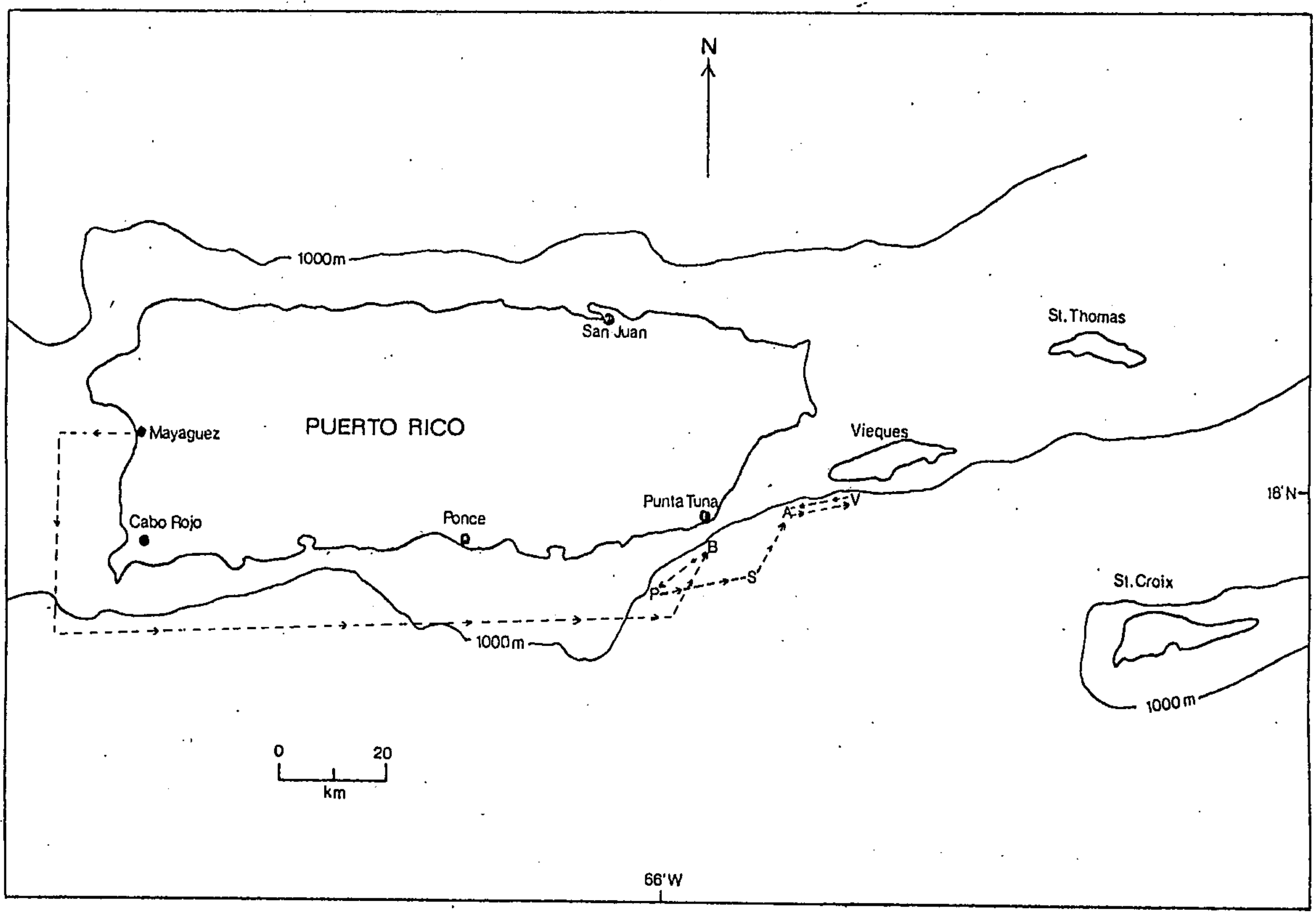
Samples collected were practically devoid of particulate matter, a factor which will speed the processing of the data.

A prima facie observation of the samples revealed the presence of medusae and a leptocephallus which had not been collected before.

I am very pleased with the outcome of this last cruise.

Daniel Pesante
Biological Coordinator

Trackline for OTEC CRUISE #3 (CR-803), 1-5 December 1978



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE: CR-803 STATION: B-2 REV DATE: 2 DECEMBER 1978 WEATHER: 10-15KT/030°, 80°, --, 1, ---

DATES: 1-5 DECEMBER 1978 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0600-1300 AST; XBT (0924), PLANKTON

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1000 DEPTH TO BOTTOM 1120 MAX SAMPLE 0 BAR 1015

XBT- 1

DEPTH (M)	TEMP (°C)
000	27.4
063	27
071	26
086	25
117	24
128	23
138	22
150	21
165	20
202	19
267	18
332	17
377	16
410	15
443	14
490	13
545	12
586	11
638	10
697	9
780	8

CRUISE CR-303 STATION R-3 Rev DATE 2 December 1973 WEATHER 15-20KT/030°, 82°, --, 1, --
DATES 1-5 December 1973 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 1200-1415 AST; Hydrocast (1300-1415), XBT (1522)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1700 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1019

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO4 (µG AT/L)	SiO2 (µG AT/L)	NO2 (µG AT/L)	NO3	XBT DEPTH (M)	XBT TEMP (°C)	TRANSMISSION DEPTH (M)	TRANSMISSION TRANS (%)	S T D DEPTH (M)	S T D TEMP (°C)	S T D SALIN (PPT)	S T D DENS (σ_t)	WATER CURRENTS DEPTH (M)	WATER CURRENTS DIR (DEG)	WATER CURRENTS SPEED (CM/S)
000	27.52	34.922	22.51	4.29	N.A.	N.A.	N.A.	1.05		•	•	000	27.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
048	27.40	34.922	22.57	4.29				0.20		•	•	070	27									
095	24.13	36.957	25.10	4.37				0.75		•	0.15	077	26									
143	20.77	36.904	26.02	4.21				0.97		•	•	082	25									
190	19.05	36.621	26.26	4.12				2.97		•	•	095	24									
238	18.17	36.556	26.44	3.96				4.72		•	1.05	110	23									
284	17.59	36.471	26.52	3.96				1.10		•	6.86	120	22									
378	15.20	36.093	26.79	3.47				1.10		•	15.19	135	21									
471	13.30	35.772	26.95	3.35				0.70		•	19.92	152	20									
565	11.77	35.545	27.08	2.97				0.80		•	23.44	190	19									
756	7.72	35.005	27.34	2.97				0.35		•	52.15	250	18									
954	5.77	34.916	27.54	3.71				0.90		•	32.90	299	17									
000	27.52	34.922	22.51									340	16									
010	27.52	34.922	22.51									393	15									
020	27.50	34.922	22.53									433	14									
030	27.48	34.922	22.54									497	13									
040	27.45	34.922	22.56									557	12									
050	27.40	34.922	22.58									584	11									
075	26.70	35.225	22.93									626	10									
100	23.50	36.970	25.25									680	9									
125	21.50	36.970	25.77									740	8									
150	20.30	36.850	26.05									835	7									
175	19.50	36.687	26.23																			
200	18.90	36.600	26.29																			
250	18.00	36.550	26.45																			
300	17.20	36.410	26.57																			
400	14.70	35.975	26.80																			
500	12.70	35.700	26.98																			
600	10.70	35.460	27.14																			
700	8.60	35.175	27.30																			
800	7.20	34.955	27.44																			
900	6.10	34.915	27.50																			
1000																						

CRUISE: CR-803 STATION: B-4 REV DATE: 2 DECEMBER 1978 WEATHER: 20KT/030°, 83°, --, --, --

DATES: 1-5 DECEMBER 1978 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 1430-1705 AST; XBT (1705), PLANKTON

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1830 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1014

XBT- 3

DEPTH (M)	TEMP (°C)
000	27.4
068	27
075	26
086	25
101	24
113	23
120	22
138	21
160	20
192	19
236	18
285	17
320	16
360	15
395	14
458	13
513	12
540	11
583	10
637	9
---	8
835	7

CRUISE CR-803 STATION B-5 Rev DATE 2 December 1978 WEATHER 14KT/070°, --, --, 1, 040°

DATES 1-5 December 1978 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE N.A.

GENERAL AREA Punta Tuna, P.R. TIME 1700-1825 AST; Current (1700-1820), XBT (1821)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2100 DEPTH TO BOTTOM 1120 MAX SAMPLE 500 BAR 1014

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	27.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	324	12
												065	27							075	060	14
												075	26							125	096	15
												039	25							200	072	10
												107	24							300	276	12
												120	23							481	228	10
												131	22									
												148	21									
												168	20									
												192	19									
												234	18									
												293	17									
												324	16									
												362	15									
												392	14									
												462	13									
												500	12									
												533	11									
												590	10									
												641	9									
												730	8									
												847	7									

CRUISE CR-803 STATION B-E Exx DATE 2-3 December 1978 WEATHER 16KT/090°, 81°, 80%, 3, 090°
DATES 1-5 December 1978 LOCATION 17° 52.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2300-0230 AST; Hydrocast (2300-0040), Current (0100-0230), XBT (2350)
SHIP Crawford MAR. SQ. 43 TIME GMT 0300 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 EAF 1015

												XBT		TRANSMISSIVITY		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O2 (ML/L)	CHLOR A* µG/L	PHAEO A* µG/L	ATP µG/L	PO_4 µG AT/L	SiO_3	NO_2 µG AT/L	N_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.49	34.922	22.54	4.29	N.A.	N.A.	N.A.	1.10		*	*	000	27.45	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	300	8
048	27.52	34.992	22.57	4.37				0.10		*	*	058	27							075	300	8
095	24.10	36.957	25.11	4.29				0.20		*	*	062	26							125	346	10
143	21.72	36.904	25.76	4.12				1.00		*	0.65	081	25							200	264	12
190	19.04	36.621	26.27	4.12				0.90		*	2.54	100	24							300	252	15
238	18.45	36.556	26.37	3.98				1.50		*	3.79	115	23							451	254	12
285	17.72	36.471	26.48	3.88				0.35		*	5.33	135	22							725	324	10
380	15.79	36.162	26.71	3.55				0.80		*	15.63	147	21									
475	13.22	--	---	3.60				*		*	4.97	157	20									
570	11.76	35.524	27.06	2.97				0.25		0.11	25.86	186	19									
760	8.12	.030	27.30	2.89				0.40		*	35.81	260	18									
949	6.06	34.915	27.50	3.55				0.90		*	39.59	334	17									
000	27.49	34.922	22.54									372	16									
010	27.49	34.935	22.55									415	15									
020	27.50	34.950	22.55									446	14									
030	27.50	34.962	22.56									478	13									
040	27.51	34.980	22.56									550	12									
050	27.52	35.008	22.57									570	11									
075	26.80	35.150	22.80									632	10									
100	23.60	36.900	25.13									700	9									
125	22.06	35.956	25.55									770	8									
150	20.80	36.860	25.83									852	7									
175	19.80	36.700	26.07																			
200	19.17	36.655	26.2[illegible]																			
250	18.20	36.515	26.39																			
300	17.40	36.430	26.53																			
400	15.30	36.075	26.75																			
500	12.80	35.737	26.94																			
600	10.90	35.437	27.1[illegible]																			
700	8.90	35.375	27.2[illegible]																			
800	7.45	34.985	27.35																			
900	6.42	34.925	27.46																			
1000																						

* Less than 0.1

CRUISE CR-803 STATION 5-7 Rev DATE 3 December 1978 WEATHER 20KT/110°, 81°, 81%, 2, 090°
DATES 1-5 December 1978 LOCATION 17° 57.6'N, 65° 51.9'W WIRE ANGLE N.A.
GENERAL AREA Punta Tuna, P.R. TIME 0600-0730 AST; Current (0600-0730), XBT (0725)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1000 DEPTH TO BOTTOM 1120 MAX SAMPLE 500 BAR 1016

												XBT		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHAEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	27.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	336	-
												068	27							075	060	-
												087	26							125	096	-
												093	25							200	132	-
												106	24							300	300	-
												116	23							475	264	-
												130	22									
												141	21									
												170	20									
												192	19									
												243	18									
												305	17									
												350	16									
												373	15									
												416	14									
												475	13									
												530	12									
												565	11									
												625	10									
												677	9									
												742	8									
												815	7									

Speed
did not
Record

CRUISE CR-803 STATION B-8 Rev-2 DATE 3 December 1978 WEATHER 13X1/130°, 83°F, 74%, 3K/090°
DATES 1-5 December 1978 LOCATION 17° 57.9'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME [illegible]-1400 AST; Biocast (1130-1230), Trans (1075-1130), XBT (1142), Current (1230-1400)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1430 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 BAR 1016

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O$_2$ (ML/L)	CHLOR'A' (µG/L)	PHEO'A' (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_2$ (µG AT/L)	NO$_3$ (µG AT/L)	N$_3$
000	---	34.893	---		.069	.048					
023	27.44	34.897	22.52		.090	.069					
047	27.46	34.901	22.52		.120	.081					
071	25.80	36.699	24.40		.183	.098					
094	24.60	36.923	24.94		.069	.048					
117	23.17	36.992	25.41		.039	.015					
141	21.04	36.857	25.91		.015	.015					
164	19.68	36.691	26.15		.003	.006					
188	19.06	36.609	26.25		.002	.006					
235	18.34	36.524	26.37		.002	.003					
282	17.40	36.413	26.52		.003	.001					
376	16.10	36.180	26.65		.003	.001					

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)
000	---	34.893	---
010	---	34.894	---
020	---	34.896	---
030	27.44	34.898	22.52
040	27.45	34.900	22.52
050	27.40	34.905	22.55
075	25.50	36.775	24.50
100	24.20	36.950	25.00
125	22.40	36.970	25.73
150	20.45	36.800	26.00
175	19.42	36.675	26.19
200	18.90	36.600	26.29
250	17.85	36.500	26.40
300	17.10	36.385	26.55
400			
500			
600			
700			
800			
900			
1000			

XBT-7A		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.4	020	95.5							
061	27	035	96.25							
072	26	065	96.5							
090	25	085	96.75							
118	24	105	94.5							
124	23	125	95.5							
133	22	155	95.75							
150	21	180	95.75							
174	20	210	95.75							
208	19	230	95.25							
267	18	253	96							
323	17	271	96.25							
390	16									
427	15									
462	14									
512	13									
567	12									
605	11									
665	10									
716	9									
810	8									
872	7									

CURRENT METER

MALFUNCTIONED

CRUISE CR-803 STATION P-1 REV DATE 3 DECEMBER 1978 WEATHER 11KT/180°, --, --, --, --

DATES 1-5 DECEMBER 1978 LOCATION 17° 54.5′-55.0′N, 65° 56.5′-57.5′W WIRE ANGLE N.A.

GENERAL AREA PATILLAS, P.R. TIME 1540-1657 AST; CURRENT (1540-1657), XBT (1642)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1940 DEPTH TO BOTTOM 1200 MAX SAMPLE 500 BAR 1014

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
EPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	27.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		NO DATA	
												066	27									
												082	26									
												095	25									
												105	24									
												119	23									
												127	22									
												144	21									
												153	20									
												200	19									
												250	18									
												300	17									
												352	16									
												397	15									
												440	14									
												487	13									
												527	12									
												570	11									
												632	10									
												682	9									
												725	8									
												838	7									

CRUISE CR-803 STATION S-1 Rev. DATE 3 December 1978 WEATHER 15-16KT/110°, 81°, 82%, 3-4, 110°

DATES 1-5 December 1978 LOCATION 17° 55.1'N, 65° 45'W WIRE ANGLE N.A.

GENERAL AREA South of Punta Tuna, P.R. TIME 1835-2000 AST; Current (1835-2000), XBT (1903)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2235 DEPTH TO BOTTOM 1200 MAX SAMPLE 500 BAR 1015

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHAEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	27.35	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		NO DATA	
												070	27									
												080	26									
												086	25									
												109	24									
												120	23									
												133	22									
												152	21									
												173	20									
												208	19									
												270	18									
												311	17									
												330	16									
												360	15									
												400	14									
												480	13									
												522	12									
												583	11									
												633	10									
												650	9									
												700	8									
												815	7									

CRUISE CR-803 STATION B-9 Rev-2 DATE 3 December 1978 WEATHER 16KT/110°, 79°F, 80%, 2-3FT/110°
DATES 1-5 December 1978 LOCATION 17° 57.6'N, 65° 53.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2200-2350 AST; Biocast (2155-2248), Transmission (2310-2350), XBT (2311)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0200 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 BAR 1015

												XBT-13A		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O$_2$ (ML/L)	CHLOR"A" (μG/L)	PHEO"A" (μG/L)	ATP (μG/L)	PO$_4$ (μG AT/L)	SiO$_3$ (μG AT/L)	NO$_2$ (μG AT/L)	NO$_3$	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.42	34.837	22.53		.069	.012						000	27.4	013	92.5							
024	27.40	34.902	22.54		.069	.021						060	27	030	91.5							
048	27.42	34.920	22.54		.099	0						070	26	050	92							
072	26.27	36.662	24.19		.237	.132						087	25	055	88.5							
096	24.63	36.920	24.92		.099	.081						110	24	075	91.5							
120	23.19	37.010	25.42		.048	.012						125	23	097	92							
144	21.87	36.905	25.72		.012	.012						141	22	123	91.5							
168	19.94	36.735	26.12		.009	.002						150	21	149	91.25							
192	19.24	36.651	26.24		.006	0						164	20	173	91.25							
240	13.49	36.548	26.35		.003	.002						198	19	197	91.5							
288	17.38	36.400	26.51		.002	.001						265	18	220	91.75							
384	15.86	36.180	26.70		.002	.001						301	17	245	91.5							
- - - - - - - - - - - -																						
000	27.42	34.897	22.53									380	16	269	92							
010	27.42	34.899	22.53									413	15	275	92							
020	27.42	34.901	22.54									450	14									
030	27.42	34.905	22.54									490	13									
040	27.42	34.910	22.54									549	12									
050	27.42	34.920	22.54									590	11									
075	26.25	36.725	24.35									630	10									
100	24.40	36.940	25.00									683	9									
125	22.90	36.990	25.50									760	8									
150	21.40	36.885	25.87									850	7									
175	19.75	36.715	26.15																			
200	19.10	36.625	26.30																			
250	18.10	36.525	26.43																			
300	17.20	36.375	26.55																			
400																						
500																						
600																						
700																						
800																						
900																						
1000																						

CRUISE CP-803 STATION Y-1 Rev-2 DATE 4 December 1978 WEATHER 13-15KT/090°, 82°F, 75%, 3-5', 090°

DATES 1-5 December 1978 LOCATION 18° 02.7-03.3'N, 65° 33.0-33.7'W WIRE ANGLE 40°

GENERAL AREA Punta Vaca, Vieques TIME 0700-1150 AST; Hydro/Biocast (1030-1140), XBT (0819), XBT (1040), Current (0905-1020), Plankton

SHIP SEAWARD MAR. SQ. 43 TIME GMT 1100 DEPTH TO BOTTOM 1200 MAX SAMPLE 700 BAR 1015

											XBT A		XBT B		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DIS O2 (ML/L)	CHLOR A* (µG/L)	PHEO A* (µG/L)	ATP (µG/L)	PO4, SiO4 (µG AT/L)	NO2 (µG AT/L)	NO3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (C)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.34	34.922	22.57	4.23	.138	.003	N.A.	*	.019	*	000	27.25	000	27.2	N.A.	N.A.	N.A.	N.A.	025	296	58
040	27.28	34.881	22.56	4.21	.159	.003		1.15	*	*	073	27	081	27					075	294	59
075	27.40	36.367	23.64	4.29	.210	.006		0.25	*	*	087	26	092	26					100	-	--
114	22.57	36.980	25.58	4.12	.018	.026		0.35	0.15	0.18	100	25	100	25					125	294	57
150	21.26	36.864	25.86	4.04	.039	.066		0.85	*	0.65	106	24	103	24					150	-	--
190	19.72	36.695	26.15	3.88	.006	.069		0.95	*	1.76	122	23	116	23					175	-	--
225	19.73	36.560	26.32	3.28	.002	.002		*	*	3.04	146	22	129	22					195	295	51
300	17.28	36.383	26.52	3.63	.002	.006		0.25	0.19	7.98	170	21	165	21					283	298	57
375	16.07	36.203	26.67	3.66	.002	.006		1.00	0.22	15.96	190	20	179	20					463	299	55
450	14.41	36.946	26.85	3.30	.001	.003		*	*	19.59	215	19	215	19					Vessel Drifting		
600	11.39	35.464	27.08	2.97	.001	.003		0.90	0.11	22.67	245	18	265	18							
745	7.40	34.945	27.34	2.97	.000	.003		0.90	*	26.19	305	17	310	17							
											357	16	360	16							
											400	15	408	15							
											455	14	453	14							
											510	13	520	13							
											561	12	562	12							
											595	11	603	11							
											628	10	643	10							
											695	9	697	9							
											750	8	745	8							
											830	7	825	7							

* Less than 0.10

- - - - - - - - - - - - - - -

000	27.34	34.922	22.57
010	27.34	34.910	22.57
020	27.34	34.900	22.57
030	27.34	34.890	22.57
040	27.28	34.881	22.56
050	27.34	34.880	22.60
075	27.40	36.367	23.64
100	24.20	36.835	25.20
125	22.20	36.980	25.68
150	21.26	36.864	25.86
175	21.10	36.750	26.07
200	19.55	36.650	26.22
250	18.10	36.500	26.40
300	17.28	36.383	25.52
400	15.45	36.125	26.75
500	13.40	35.780	26.93
600	11.39	35.464	27.08
700	6.80	35.100	27.29
800			
900			
1000			

CRUISE CR-003 STATION A-2 REV ___ DATE 4 December 1978 WEATHER 15KT/045°, 83°, 75%, 4-5, 045°

DATES 1-5 December 1978 LOCATION 18° 02.3′-02.4′N, 65° 39.2′-39.7′W WIRE ANGLE N.A.

GENERAL AREA Between P.R. and Vieques TIME 1217-1337 AST; Current (1217-1337), XBT (1313)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1617 DEPTH TO BOTTOM 1200 MAX SAMPLE 500 BAR 1015

												XBT-		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHAEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	000	27.2	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	034	25
												073	27							075	037	30
												036	26							125	025	32
												100	25							188	032	28
												112	24							263	060	30
												125	23							463	001	20
												137	22								VESSEL	
												160	21								DRIFTING	
												182	20									
												210	19									
												257	18									
												305	17									
												372	16									
												405	15									
												447	14									
												490	13									
												557	12									
												590	11									
												637	10									
												714	9									
												754	8									
												850	7									

SIZE CLASS	SIZE IN MILLIMETERS
1	< 0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 19.9
13	20.0 - 29.9
14	30.0 - 39.9
15	40.0 - 49.9
16	> 50.0

DATE:	2 December 1978
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1533
SAMPLE NUMBER:	#13
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	800-200
METERS OF WIRE:	810
ANGLE:	0
FLOWMETER START:	299208
FLOWMETER FINISH:	324182
LENGTH OF TOW:	20 min
LATITUDE:	17° 57.3 N
LONGITUDE:	65° 52 W
SEA STATE AND WEATHER:	SS #1-2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo		1													.14	2.3	1
Clausocalanus furcatus		2													.17	4.5	2
Euchaeta marina				1											.14	2.3	1
Farranula gracilis		1													.14	2.3	1
Haloptilus longicornis			4												.34	9.0	4
Metridia brevicauda			1												.14	2.3	1
Metridia princeps		1													.14	2.3	1
Mormonilla minor			1												.14	2.3	1
Oithona sp.		11	2												1.2	31.8	13+1
Oithona plumifera		3	7												.8	22.7	10
Oncaea mediterranea		2													.2	4.5	2
Oncaea venusta		5													.4	11.4	5
Rhincalanus cornutus				1											.14	2.3	1
																	43+1
																	44

Non-copepod crustacean	SIZE CLASSES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods		1															1
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae																	
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores						1											1
Hydromedusae																	
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods																	

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans				1	1												2
Chordates Fish																	
TOTAL PLANKTON COUNTED																	48
TOTAL PLANKTON/m^3																	±4
VOLUME OF WATER FILTERED BY NET																	296
ALIQUOT VOLUME																	250 ml
SUB SAMPLE																	10 ml

DATE:	2 December 1978
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1309
SAMPLE NUMBER:	#13A
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	1000-800m
METERS OF WIRE:	1000
ANGLE:	0°
FLOWMETER START:	272933
FLOWMETER FINISH:	299208
LENGTH OF TOW:	8 min
LATITUDE:	17° 57.3 N
LONGITUDE:	65° 52 W
SEA STATE AND WEATHER:	SS#1-2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Aetideus armatus			1												.1	1	1
Clausocalanus arcuicornis		8	1												1	8.9	9
Clausocalanus furcatus		5													.6	5	5
Corycaeus sp.		3	2												.6	5	5
Euchaeta marina			2												.2	2	2
Haloptilus longicornis		2	4	2											1	8.9	8+1
Lubbochia squillimana		1													.1	1	1
Oncaea mediterranea		4	1												.6	5	5
Oncaea venusta		7	1												1	7.9	8
Oithona plumifera		24	13												4	36.6	37
Paracalanus aculeatus		2	1												.4	3	3
Paracalanus parvus		4													.5	4	4
Pleuromamma abdominalis			1	3											.5	4	4
Pleuromamma piseki			6												.6	6	6
Scolecithricella vittata			1												.1	1	1
Undeuchaeta plumosa				1											.1	1	1
																	100+1

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods	2	13	5														20
Stomatopod larvae																	
Amphipoda					1												1
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae				1	1												2
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			1														1
Hydromedusae																	
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods																	24

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	125
TOTAL PLANKTON/m^3																	15
VOLUME OF WATER FILTERED																	311.9=312
ALIQUOT VOLUME																	300 ml
SUB SAMPLE																	8 ml

DATE:	2 December 1978
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1636
SAMPLE NUMBER:	14
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	200-SFC
METERS OF WIRE:	210
ANGLE:	0°
FLOWMETER START:	324185
FLOWMETER FINISH:	330980
LENGTH OF TOW:	---
LATITUDE:	17° 57.3 N
LONGITUDE:	65° 52 W
SEA STATE AND WEATHER:	SS #1-2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo		14													26	7.4	14
Candacia pachydactyla		1													2	.5	1
Clausocalanus furcatus		22	16												52	20	38
Corycaeus amazonicus		5													10	2.6	5
Corycaeus speciosus			1												2	.5	1
Corycaeus subulatus			2												4	1	2
Corycaeus sp.		8	1												17	4.8	9
Eucalanus attenuatus			1												2	.5	1
Farranula gracilis		6													11	3.1	6
Haloptilus longicornis		1	4												10	2.6	5
Lubbockia squillimana			2												4	1.0	2
Mecynocera clausi		12													22	6.3	12
Oithona plumifera	1	23	20												81	23.2	44
Oncaea mediterranea		4	1												10	2.6	5
Oncaea venusta		5													10	2.6	5
Paracalanus aculeatus		2													4	1.0	2
Paracalanus parvus		30	1												57	16.4	31
Pleuromamma piseki			1												2	.5	1
Temora turbinata		1	1												4	1.0	2
Undinula vulgaris			3												6	1.6	3
																	189

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods	2	3	1														6
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae																	
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			1		1			1									3
Hydromedusae	1																1
Polychaetes		1															1
Mollusks																	
Gastropods pterop.		1															1
Heteropods																	

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans		4	11	10	1												26
Chordates																	
Fish			1														1
TOTAL PLANKTON COUNTED																	228
TOTAL PLANKTON/m^3																	424
VOLUME OF WATER FILTERED BY NET																	80.67 m^3
ALIQUOT VOLUME																	300 ml
SUB SAMPLE																	2 ml

DATE: 3 December 1978

STATION NUMBER: BENCHMARK

SHIP: CRAWFORD

TIME: 2:50

SAMPLE NUMBER: CR 803-15

TYPE OF NET: CONICAL 5:1

MESH SIZE: 0.75 m

RING SIZE: 202μ

TYPE OF HAUL: HORIZONTAL

SAMPLING DEPTH: 25 m

METERS OF WIRE: 60

ANGLE: 60°

FLOWMETER START: 331010

FLOWMETER FINISH: 368064

LENGTH OF TOW: 10 min

LATITUDE: 17° 57.3 N

LONGITUDE: 65° 52 W

SEA STATE AND WEATHER: #1-2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo		20												6.4	18	12	20
Clausocalanus furcatus		48	56											33.4	94	16	104
Corycaeus sp.		14	5											6.4	18	12	20
Farranula gracilis		22												7.1	20	13	22
Haloptilus longicornis		1												0.3	1	3	1
Lubbockia squillimana		2												0.6	2	4	2
Macrosetella gracilis			2											0.6	2	5	2
Mecynocera clausi	1	12												4.2	12	11	13
Oithona plumifera			49											15.8	45	15	49
Oithona sp.		1												0.3	1	2	1

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran		1															1
Ostracods		2	1														3
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids							1										
Decapods																	
Caridean larvae			1	2													3
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			1		1												2
Hydromedusae																	
Polychaetes																	
Mollusks																	
Gastropods ptes					1												1
Heteropods																	

								SIZE CLASSES									
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates																	
Fish					1												1
TOTAL PLANKTON COUNTED																	323
TOTAL PLANKTON m^3																	294.61=295
VOLUME OF WATER FILTERED BY NET																	439.9
ALIQUOT VOLUME																	800 ml
SUB SAMPLE																	2 ml

DATE:	2 December 1978
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	2050
SAMPLE NUMBER:	CR 803-16
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	60°
FLOWMETER START:	379446
FLOWMETER FINISH:	414005
LENGTH OF TOW:	10 min.
LATITUDE:	17° 57.3 N
LONGITUDE:	65° 52 W
SEA STATE AND WEATHER:	

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalnus pavo		34												16	5.2	18	34
Clausocalanus furcatus		84	41											61	19.4	23	125+1
Candacia pachydactila				1										0.5	.15	5	1
Corycaeus speciosus			4											2	.61	9	4
Corycaeus sp.		65	12											38	11.9	21	77
Euchaeta marina		1	1											0.9	.3	7	2
Farranula gracilis		47	1											9	7.40	19	48
Haloptilus longicornis		1												0.5	0.15	4	1
Lubbackia squillimana			1											0.5	0.15	3	1
Lucicutia flavicornis		1	15											8	2.46	12	16
Macrosetella gracilis			1											0.5	.15	2	1
Mecynocera clausii		27												13	4.1	16	27
Oithona plumifera		12	87											49	15.6	22	99+2
Oithona sp.		2	4											2.9	.92	11	6
Oncaea mediterranea		25	1											13	4.0	15	26
Oncaea venusta		32												16	4.9	17	32
Paracalanus aculeatus		14	4											9	2.7	13	18
Paracalanus parvus		65	1											33	10.3	20	66+1
Pleuromamma piseki			1											0.4	.15	1	1
Sapphirina nigromaculata			2											0.9	.30	6	2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Scolecithrix danae		1	1											4	.30	8	2
Temora stylifera		5												5	.77	10	5
Temora turbinata	1	24	7											16	4.9	18	32
Undinula vulgaris			10	8										9	2.7	14	18
																	644+4
																	648

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran		1															1
Ostracods		5	3														8
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids					2	3		1									6
Decapods																	
Caridean larvae				2													2
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			2	3		1											6
Hydromedusae																	
Polychaetes		1	1	1	1				1								5
Mollusks																	
Gastropods																	
Heteropods																	

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans			1														1
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	677
TOTAL PLANKTON/m^3																	330.5=331
VOLUME OF WATER FILTERED BY NET																	410.28
ALIQUOT VOLUME																	400 ml
SUB SAMPLE																	2 ml

APPENDIX D

CRUISE REPORT AND DATA FROM OTEC CRUISE #4 (BA-804)

10-16 FEBRUARY 1979

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #4 (BA-804)

10-16 February 1979

by

Gary C. Goldman, Chief Scientist

CRUISE REPORT

OTEC CRUISE #4 (BA-804) 10-16 February 1979

I. Objectives:

A. Measure oceanic parameters relatable to OTEC AT Punta Tuna.
B. Measure variability of these oceanic parameters at Punta Vaca.
C. Measure water currents at 3 other stations.
D. Recover current meter mooring at a station.
E. Implant current meter moorings at 2 stations.

II. Research Vessel:

USNS BARTLETT (T-AGOR-13)

III. Supporting Agencies:

A. U.S. Department of Energy
B. Lawrence Berkeley Laboratory
C. P.R. Water Resources Authority
D. U.S.N. Underwater System Lab.
E. UPR/CEER

IV. Dates of Cruise:

10-16 February 1979

V. Cruise Plan:

See Appendix II (Not included)

VI. Scientific and Technical Personnel:

C. Carmiggelt - Visiting Scientist (LBL)
D. Corales - Technician (CEER)
M. Commins - Visiting Scientist (LBL)
M. Fecher - Oceanographer (USNUSL)
G. Goldman - Co-Chief Scientist (CEER)
E. Gonzalez - Technician (CEER)
T. Morgan - Scientific Assistant (CEER)
A. Nazario - Technician (CEER)
R. Noble - Co-Chief Scientist (USNUSL)
D. Pesante - Biological Coordinator (CEER)
M. Shafnacker - Technician (CEER)

VII. Station Locations:

See Attached Cruise Plan, Appendix II. (Not included)

VIII. Types of Sampling:

A. See attached Cruise Plan, Appendix II. (Not included)
B. Bottom sampling.

IX. Travel:

--- 9 Feb. 1979. USNS BARTLETT arrived at Malecon Port, Mayaguez, P. R. All above personnel (except Carmiggelt and Commins) were assembled by that time. Flat bed truck, and crane were used to move Mr. Noble's material from Guanajibo laboratory complex to Malecon and onto the vessel. CEER vehicles carried the rest of the materials.

--- 10 February 1979. All personnel assembled on board and ship departed about 1300 local time.

--- 16 February 1979. Flat bed truck and van were used from Mayaguez to carry the equipment from Roosevelt Roads Naval Base to Mayaguez. Equipment was transferred to vehicles by hand and using USN supplied cranes. Vehicles left Roosevelt Roads area about 1430 and arrived Mayaguez about 2015 carrying T. Morgan and D. Corales. Other CEER personnel were transported by taxi from Roosevelt Roads to Isla Verde airport, San Juan, from where, they travelled by air to Mayaguez, and by CEER vehicle to the Guanajibo Lab. LBL people departed on 16 Feb. also. USNUSL people were to depart 17 February.

X. Reason for termination of cruise:

Vessel suffered collision at sea with USN submarine, and suffered severe, but not fatal damage.

IX. Accomplishments:

A. Collected virtually all data from station "B"

(exception is nite horizontal plankton tow).

B. Collected all data from Station "A".
C. Collected all data from Station "F".
D. Recovered mooring from "A-1".
E. Implanted mooring at "F-1".
F. Did not get to Station "P".
G. Did not get to Station "V".
H. Did not implant mooring "A-2".
I. Did not collect any current meter profile data while vessel was drifting.

XII. Changes to be affected:

A. Evaluate reducing volume of chlorophyll water sample.
B. Evaluate separating mooring operation from hydro operations.
C. Evaluate coring operation in area.

XIII. Stations Visited:

See Cruise Plan (Appendix II) for planned activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
A-1	11 Feb '79	0830-1030	65°39'-45'	18°02'	Recovered most of A-1 mooring	Recovery of 2 thermographs Recovery of 1 current meter Recovery of 5 glass floats Recovery of 5 protective "hats" Recovery of 2 acoustic releases
B-1	11 Feb '79	1200-1500	65°48	17°34	PLANKTON tow-1 (horizontal) XBT-1	Net closing after tow HYCROCAST-1 STD-1 EXTRA WATER CAST (Note-1)
B-2	11 Feb '79	1830-2145	65°51.9'W	17°57.6'N	CURRENT-1 EXTRA WATER-CAST (Note 1) XBT-2 STD-1	
B-3	11-12 Feb '79	2215-0100	65°51.9'W	17°57.6'N	HYDROCAST-2 CURRENT-2	STD-3 TRANSMISSION-1 XBT-3
B-4	12 Feb '79	0830-1030	65°51.9'W	17°57.6'N	CURRENT-3 XBT-4	STD-4
B-5	12 Feb '79	1030-1100	65°51.9'W	17°57.6'N	PLANKTON-2 (1000-0m) XBT-5	PLANKTON-3

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-6	12 Feb '79	1100-1553	65°51.9'W	17°57.6'N	HYDROCAST-1 XBT-6 STD-2 CURRENT-4 PLANKTON-3 (1000-800m) PLANKTON-4 (800-200m) PLANKTON-5 (200-0m) XBT-7	TRANSMISSION-2
B-7	12 Feb '79	2000-2100	65°51.9'W	17°57.6'N	GRAB SAMPLE	
B-8	12-13 Feb '79	2200-0100	65°51.9'W	17°57.6'N	BIOCAST-1 TRANSMISSION-1 XBT-8	
B-9			- - - - - - - - NOT NECESSARY- - - - - - -			
B-10	13 Feb '79	1010-1500	65°52'W	17°58'N	XBT-9 BIOCAST-2 TRANSMISSION-2 PLANKTON-1 (repeat)	
F-1	13-14 Feb '79	1600-0700	65°50'W	17°50'N	BATHYMETRY	
F-2	14 Feb '79	0800-1100	65°46.9'W	17°51.7'N	STD-3 XBT-10 GRAB SAMPLE	

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
F-1 (mooring)	14 Feb '79	1500-1930	65°46.9'N	17°51.7'N	Implanted "F-1" mooring	
A-2	14 Feb '79	1000-1130	65°39.7'W	18°02.2'N	XBT-11 BATHYMETRY	
"V-1"	15 Feb '79	?	65°32'W	18°03'N	(-Note 2-)	HYDROCAST-1 STD- TBT PLANKTON

Notes---

--1 Extra water cast for Mr. Carmiggelt - depths of 0, 25, 50, 75, 100, 125, 150, 200, 250 and 300 m - water

--2 Collision with another vessel at 0530 February, 1979 prevented the cruise from continuing. Both vessels steamed to Roosevelt Roads Naval Base to survey damage.

BIOLOGICAL REPORT

Some difficultes encountered with the sampling of zooplankton due to floating debris. However, all samples were collected except the 25m deep horizontal tow at night. This tow was to have been taken after station "V", and the cruise was aborted before that time.

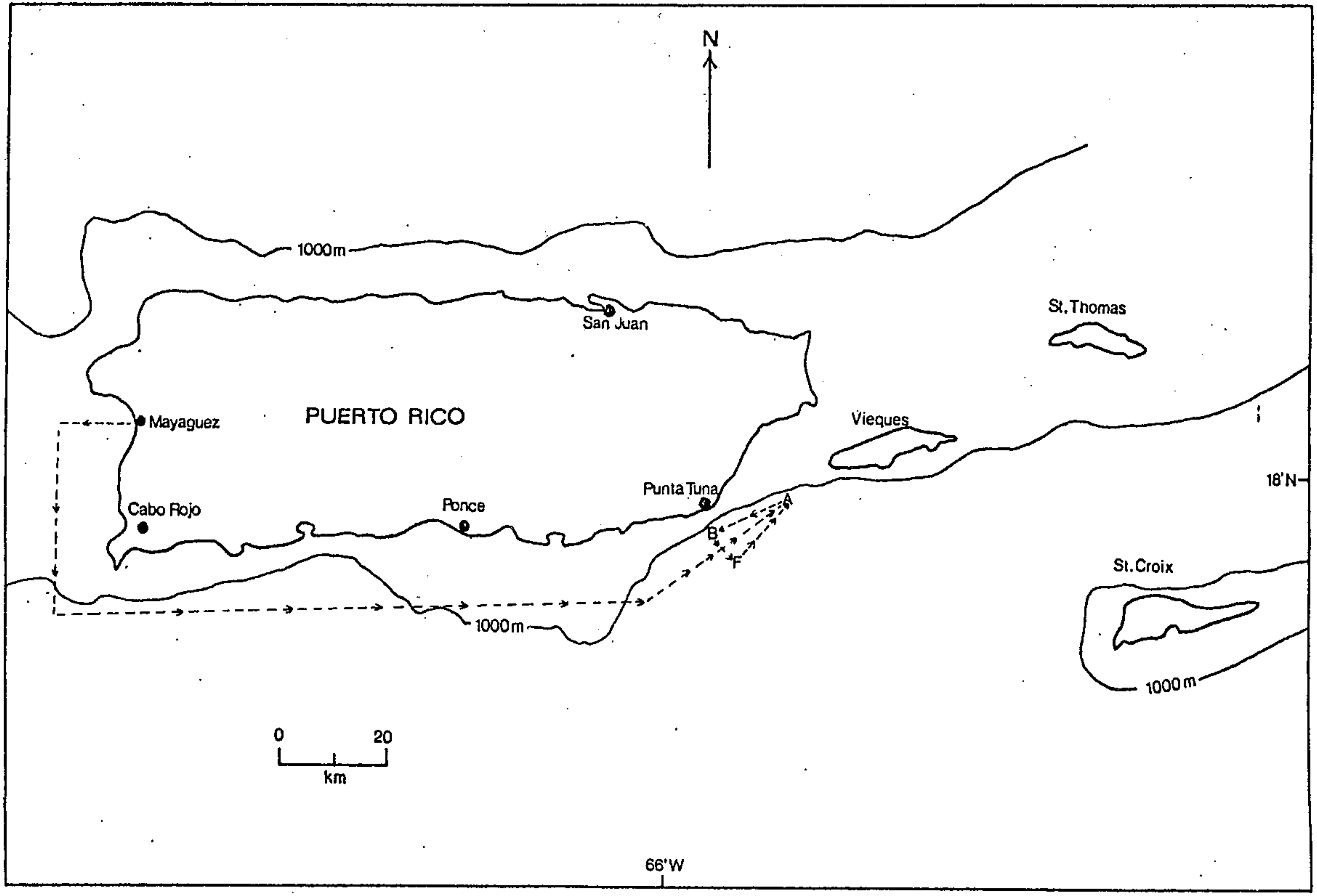
The samples collected were:

25m deep horizontal tow, day
1000-800m vertical tow
800-200m vertical tow
200-0m vertical tow
1000-0m vertical tow

During the cruise, Marcie Commins, of LBL, was aboard to oversee all zooplankton operations. Her main interest is to standardize sampling and analysis procedures.

Except for the fact that there were no sharks seen on the cruise, all other plants and animals already reported were sited.

Trackline for OTEC CRUISE #4 (BA-804), 10-16 February 1979



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE: BA-804 STATION: B-1 DATE: 11 FEBRUARY 1979 WEATHER: 6-10KT/110°, 89°F, 68%, 1M/110°

DATES: 10-16 FEBRUARY 1979 LOCATION: 17° 34'N, 65° 48' W WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 1200-1500 AST; PLANKTON, XBT (1554)

SHIP BARTLETT MAR. SQ. 43 TIME GMT 1600 DEPTH TO BOTTOM 1100 MAX SAMPLE 25 BAR 1020

XBT - 1

DEPTH (M)	TEMP (°C)
000	26.7
081	26
094	25
120	24
141	23
153	22
167	21
198	20
218	19
265	18
308	17
353	16
407	15
455	14
502	13
542	12
590	11
614	10
655	9
713	8
790	7
875	6

CRUISE BA-804 STATION B-2 DATE 11 FEBRUARY 1979 WEATHER 10KT/075°, 79°F, 72%, 1M/110°
DATES 10-16 FEBRUARY 1979 LOCATION 17° 57.6'N. 65° 51.9'W. (BUOY) WIRE ANGLE N.A.
GENERAL AREA PUNTA TUNA, P.R. TIME 1830-2145 AST; CURRENT (1830-2030), XBT (1810), STD (2030-2145)
SHIP BARTLETT MAR. SQ. 43 TIME GMT 2230 DEPTH TO BOTTOM 1120 MAX SAMPLE 700 BAR 1017

												XBT-2		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_2 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
												000	26.3			012	26.50	35.76	23.47	025	012	3
												083	26			019	26.47	35.76	23.48	050	180	7
												100	25			069	26.40	35.83	23.57	075	180	7
												128	24			075	26.51	36.17	23.75	100	348	3
												145	23			077	26.56	36.09	23.82	125	-	-
												160	22			084	26.02	36.75	24.45	150	264	8
												170	21			094	25.07	37.01	24.90	170	264	2
												195	20			116	24.07	37.08	25.23	210	216	2
												214	19			150	22.06	36.95	25.72	260	060	5
												261	18			164	21.00	36.83	25.92	350	060	5
												312	17			226	19.02	36.60	26.26	440	240	2
												355	16			277	18.06	36.51	26.44	700	228	2
												408	15			327	17.01	36.35	26.57			
												458	14			379	16.00	36.21	26.68			
												505	13			433	15.02	36.05	26.80			
												552	12			482	14.01	35.88	26.89			
												615	11			530	12.99	35.72	26.97			
												644	10			612	11.04	35.40	27.10			
												680	9			636	10.00	35.23	27.10			
												721	8			681	[illegible]	35.10	27.23			
												789	7			730	8.00	34.99	27.29			
												870	6			796	7.00	34.86	27.36			
																878	5.99	34.87	27.49			
																999	5.23	34.94	27.62			

CRUISE BA-204 STATION B-3 Ecy DATE 11-12 February 1979 WEATHER 12KT/050°, 77°F, 79%, 1'/030°
DATES 10-16 February 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2215-0100 AST; Hydrocast (2215-2340), Current (2345-0100)
SHIP BARTLETT MAR. SQ. 43 TIME GMT 0215 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1019

												XBT		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DIS.O2 (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO4 µG	SiO3 AT/L	NO3 µG AT/L	N'3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.44	35.716	23.46	4.43	N.A.	N.A.	N.A.	*		0.43	*	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	025	120	8
047	26.39	35.774	23.52	4.48				0.35		0.83	*									050	072	12
094	24.71	37.037	24.99	4.29				1.15		0.33	*									075	084	8
142	22.18	36.982	25.69	4.18				0.45		*	14.60									100	096	8
189	20.14	36.692	26.03	4.01				0.75		*	2.33									125	084	5
237	18.76	36.571	26.30	4.08				0.60		0.23	9.10									150	288	3
284	17.94	36.524	26.47	4.08				0.70		0.53	62.80									175	270	15
378	16.06	36.208	26.69	3.80				0.65		0.33	7.50									200	-	-
473	14.01	35.861	26.87	3.46				0.70		*	0.70									260	270	15
568	11.98	35.546	27.04	3.08				0.45		0.33	141.83									400	252	3
757	7.50	34.911	27.30	2.85				1.35		*	8.85									440	000	6
946	5.65	34.908	27.54	3.73				0.50		0.13	239.60									690	336	4

* Less than 0.10

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000	26.44	35.716	23.46
010	26.44	35.725	23.47
020	26.44	35.740	23.48
030	26.44	35.755	23.50
040	26.40	35.765	23.51
050	26.39	35.775	23.52
075	26.10	35.950	23.65
100	24.40	37.050	25.05
125	23.00	37.050	25.50
150	21.80	36.960	25.75
175	20.70	36.775	25.94
200	19.60	36.560	26.10
250	18.50	36.560	26.35
300	17.60	36.525	26.50
400	15.65	36.125	26.75
500	13.45	35.750	26.95
600	10.30	35.425	27.12
750	8.40	35.060	27.28
800	7.00	34.900	27.38
900	6.00	34.900	27.50
1000			

CRUISE: BA-804 STATION: B-4 DATE: 12 FEBRUARY 1979 WEATHER: 15KT/055°, 77°F, 82%, 1-2M/150°
DATES: 10-16 FEBRUARY 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 0830-1030 AST; CURRENT (0830-1030), XBT (0833)
SHIP BARTLETT MAR. SQ. 43 TIME GMT 1230 DEPTH TO BOTTOM 1120 MAX SAMPLE 500 BAR 1019

XBT-04

DEPTH (M)	TEMP (°C)
000	26.4
080	26
100	25
116	24
131	23
150	22
173	21
193	20
216	19
277	18
319	17
365	16
411	15
460	14
505	13
555	12
594	11
622	10
678	9
722	8
775	7
836	6

WATER CURRENTS

DEPTH (M)	DIRECTION (DEG)	SPEED (CM/S)
025	256	10
050	276	3
075	156	2
100	---	--
125	264	7
150	282	4
175	---	--
200	348	3
250	---	--
300	---	--
350	060	5
460	018	5

CRUISE: BA-804 STATION: B-5 DATE: 12 FEBRUARY 1979 WEATHER: 17KT/045°, 78°F, 79%, 1-3'/065-130

DATES: 10-16 FEBRUARY 1979 LOCATION: 17° 57.6'N, 65° 51.9'N (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 1030-1130 AST; PLANKTON 1000-0M, XBT (1123)

SHIP BARTLETT MAR. SQ. 43 TIME GMT 1430 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1020

XBT-05

DEPTH (M)	TEMP (°C)
000	26.4
085	26
104	25
113	24
130	23
148	22
165	21
187	20
221	19
282	18
335	17
378	16
428	15
483	14
533	13
567	12
610	11
650	10
695	9
734	8
789	7
893	6

CRUISE BA-804 STATION E-6 Rev DATE 12 February 1979 WEATHER 17-20KT/045°, 79°F, 72%, 1%/060°, 100%
DATES 10-16 February 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 1100-1753 AST; Hydrocast (1130-1220), Current (1400-1553), XBT (1230), XBT (1725), STD (1320-1430) P.M.
SHIP Bartlett MAR. SC. 43 TIME GMT 1500 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1019

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O$_2$ (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_3$	NO$_3$ (µG AT/L)	NH$_4$
000	26.39	35.691	23.45	4.49	N.A.	N.A.	N.A.	0.10		*	*
047	26.35	35.733	23.50	4.44				*		*	0.43
094	25.14	37.000	24.83	4.44				0.95		*	*
141	21.96	36.950	25.73	4.11				0.45		*	*
188	19.92	36.697	26.10	4.18				0.50		*	11.83
236	18.83	36.577	26.29	4.11				0.40		0.33	13.40
283	18.23	36.501	26.38	4.28				0.55		*	1.83
377	16.03	36.195	26.68	3.86				0.65		*	36.28
472	14.27	35.895	26.84	3.45				0.40		*	141.83
566	12.12	35.571	27.03	3.23				0.60		0.23	137.20
759	7.78	34.951	27.29	2.92				0.70		*	262.83
943	5.82	34.906	27.52	3.71				0.95		*	0.90

* Less than 0.10

XBT-6 DEPTH (F)	XBT-6 TEMP (°C)	XBT-7 DEPTH (M)	XBT-7 TEMP (C)	STD DEPTH (M)	STD TEMP (°C)	STD SALIN (PPT)	STD DENS (σ_T)	WATER CURRENTS DEPTH (M)	WATER CURRENTS DIR (DEG)	WATER CURRENTS SPEED (CM/S)
000	26.4	000	26.3	005	26.36	35.68	23.45	N.A.	N.A.	N.A
086	26	085	26	059	26.36	35.77	23.52			
100	25	104	25	063	26.41	35.80	23.53			
112	24	123	24	087	25.96	36.72	24.50			
128	23	131	23	104	25.00	37.02	24.91			
145	22	146	22	119	24.01	37.04	25.22			
160	21	161	21	133	23.00	37.01	25.50			
176	20	178	20	155	21.97	36.89	25.80			
224	19	215	19	185	19.99	36.70	26.11			
284	18	273	18	229	18.99	36.59	26.28			
330	17	312	17	282	18.01	36.47	26.41			
374	16	351	16	332	17.00	36.35	26.57			
420	15	400	15	382	15.96	36.17	26.69			
480	14	442	14	425	15.01	36.02	26.79			
530	13	493	13	520	13.01	35.72	26.97			
567	12	546	12	571	11.94	35.54	27.04			
597	11	590	11	605	11.07	35.36	27.10			
631	10	628	10	649	10.00	35.22	27.16			
684	9	657	9	701	8.99	35.09	27.21			
723	8	709	8	741	7.95	34.97	27.30			
795	7	770	7	793	6.99	34.87	27.36			
883	6	855	6	890	5.99	34.89	27.51			
				999	5.36	34.92	27.60			

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)
000	26.39	35.691	23.45
010	26.39	35.695	23.46
020	26.38	35.705	23.47
030	26.37	35.720	23.48
040	26.36	35.726	23.49
050	26.35	35.735	23.50
075	26.20	36.200	23.95
100	24.65	37.010	24.96
125	22.80	37.010	25.59
150	21.40	36.895	25.83
175	20.46	36.750	26.02
200	19.60	36.655	26.18
250	18.60	36.555	26.33
300	17.80	36.475	26.44
400	15.60	36.125	26.73
500	13.65	35.775	26.94
600	11.10	35.412	27.10
700	8.70	35.080	27.24
800	7.15	34.925	27.34
900	6.20	34.900	27.48
1000			

CRUISE BA-904 STATION B-8 Rev DATE 12-13 February 1979 WEATHER 15KT/060°, 76°F, 82%, 1-2M/060-100
DATES 10-16 February 1979 LOCATION 17° 57.6'N, 65° 51.9'W, (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2200-0100 AST; Biocast (2215-2310), Transmission (0000-0100), XBT (2211)
SHIP Crawford MAR. SQ. 43 TIME GMT 0200 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 BAR 1012

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_2 (µG AT/L)	NO_3
000	26.30	35.630	23.44		.195	0					
024	26.28	35.660	23.46		.120	0					
048	26.35	35.730	23.50		.078	0					
072	26.38	36.129	23.79		.138	.033					
095	24.60	37.032	25.02		.159	.195					
119	23.47	37.083	25.40		.150	.066					
143	22.08	36.960	25.70		.039	.015					
167	21.14	36.861	25.89		.012	.027					
191	20.02	36.715	26.08		.015	.006					
239	18.76	36.561	26.29		.002	.003					
287	17.24	36.480	26.46		.002	.006					
382	15.91	36.173	26.69		.002	.004					
- - - - - -											
000	26.30	35.630	23.44								
010	26.30	35.645	23.45								
020	26.30	35.655	23.45								
030	26.30	35.685	23.47								
040	26.33	35.710	23.49								
050	26.35	35.730	23.52								
075	26.35	36.250	24.25								
100	24.38	37.045	25.15								
125	23.10	37.075	25.50								
150	21.70	36.920	25.76								
175	20.60	36.800	25.98								
200	19.75	36.620	26.14								
250	18.50	36.525	26.35								
300	17.70	36.440	26.49								
400											
500											
600											
700											
800											
900											
1000											

XBT-08		TRANSMISSION:		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.2	016	90.5							
075	26	025	90							
096	25	040	90.5							
116	24	050	93.5							
130	23	063	89							
150	22	072	89							
172	21	090	85							
193	20	102	89.25							
220	19	120	89							
276	18	132	91.5							
326	17	146	91.5							
366	16	157	91							
425	15	171	91.5							
467	14	183	91.5							
506	13	198	90							
563	12	211	91.5							
610	11	224	90							
633	10	236	90.5							
660	9	251	90							
712	8	265	90							
770	7	Transmission Meter Erratic								
875	6									

CRUISE BA-804 STATION B-10 Rev DATE 13 February 1979 WEATHER 10/30°, 84°F, --, 1/2, --
DATES 10-16 February 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 10/30, 85°, --, 1
GENERAL AREA Punta Tuna, P.R. TIME [illegible]-1500 AST; Biocast (1010-1055), XBT (1002), Trans (1107-1200), Plankton
SHIP Bartlett MAR. SQ. 43 TIME GMT 1900 DEPTH TO BOTTOM 1100 MAX SAMPLE 400 BAR 1017

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O_2 (ML/L)	CHLOR"A" µG/L	PHEO"A" µG/L	ATP µG/L	PO_4 µG AT/L	SiO_3 µG AT/L	NO_3 µG AT/L	M^3
000	26.37	35.669	23.44		.159	0					
024	26.27	35.665	23.47		.159	.006					
048	26.27	35.673	23.48		.183	.018					
072	26.12	36.476	24.13		.183	.072					
095	24.83	37.041	24.96		.237	.186					
119	23.21	37.051	25.45		.120	.027					
143	21.56	36.909	25.81		.060	.003					
167	20.57	36.781	25.98		.021	.009					
191	19.93	36.702	26.10		.012	.003					
239	18.89	36.620	26.30		.002	.003					
287	18.34	36.516	26.36		.002	.003					
382	15.91	36.174	26.69		.002	.003					
- - - -	- - - -	- - - -	- - - -								
000	26.37	35.669	23.44								
010	26.33	35.667	23.45								
020	26.30	35.665	23.46								
030	26.27	35.668	23.47								
040	26.27	35.670	23.48								
050	26.25	35.675	23.48								
075	26.10	36.025	24.32								
100	24.50	37.070	25.10								
125	22.60	37.030	25.60								
150	21.00	36.855	25.88								
175	20.20	36.750	26.03								
200	19.65	36.675	26.12								
250	18.75	36.600	26.30								
300	18.15	36.480	26.45								
400											
500											
600											
700											
800											
900											
1000											

XBT		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.2	005	91							
080	26	012	91							
095	25	023	91							
105	24	028	91.5							
124	23	038	91							
135	22	046	92							
158	21	053	91							
184	20	058	91							
220	19	072	90							
293	18	082	91							
334	17	102	90.5							
360	16	126	90.5							
430	15	145	91							
482	14	163	91.5							
522	13	192	93							
567	12	206	91							
610	11	217	91							
640	10	240	90							
690	9	245	91							
733	8									
794	7	Transmission Meter Erratic								
887	6									

CRUISE: BA-804 STATION: F-2 DATE: 14 FEBRUARY 1979 WEATHER: 8KT/190°, 78°F, 79%, 1'/160°

DATES: 10-16 FEBRUARY 1979 LOCATION: 17° 51.7'N, 65° 46.9'W WIRE ANGLE: N.A.

GENERAL AREA: FLAT AREA SOUTH OF PUNTA TUNA, P.R. TIME: 0800-1100 AST; XBT (0807), STD (0830-0930), GRAB SAMPLE

SHIP BARTLETT MAR. SQ. 43 TIME GMT 1200 DEPTH TO BOTTOM 1950 MAX SAMPLE 1000 BAR 1017

XBT-10

DEPTH (M)	TEMP (°C)
000	26.3
075	26
097	25
113	24
133	23
154	22
167	21
186	20
216	19
283	18
345	17
380	16
412	15
465	14
510	13
551	12
587	11
611	10
668	9
718	8
773	7

STD-3

DEPTH (M)	TEMP (°C)	SALINITY (PPT)	DENSITY (σt)
000	26.41	35.72	23.47
016	26.40	35.70	23.49
030	26.47	35.81	23.52
068	26.74	36.27	23.86
078	26.01	36.77	24.40
100	24.88	37.05	24.96
112	23.91	37.03	25.29
133	22.97	37.05	25.51
153	22.01	36.96	25.75
179	20.02	36.68	26.12
216	19.00	36.60	26.25
283	18.00	36.47	26.42
347	16.99	36.33	26.56
422	15.05	35.98	26.79
473	13.93	35.82	26.88
520	12.99	35.69	26.94
597	11.04	35.36	27.06
619	9.99	35.17	27.13
667	9.00	35.07	27.20
723	8.01	34.94	27.24
801	7.01	34.86	27.34
885	6.00	34.85	27.46
895	6.00	34.85	27.46
997	5.25	34.90	27.60

CRUISE: BA-804 STATION: A-2 DATE: 14 FEBRUARY 1979 WEATHER: 8KT/120°, 80°F, 79%, 1M/120°

DATES: 10-16 FEBRUARY 1979 LOCATION: 18° 02.2'N, 65° 39.7'W WIRE ANGLE: N.A.

GENERAL AREA: BETWEEN PUNTA TUNA AND VIEQUES, TIME: 1000-1130 AST; XBT (1016), BATHYMETRY

SHIP BARTLETT MAR. SQ. 43 TIME GMT 1400 DEPTH TO BOTTOM 1200 MAX SAMPLE ______ BAR 1017

XBT-11

DEPTH	TEMP
000	26.4
071	26
090	25
112	24
130	23
146	22
168	21
179	20
204	19
263	18
309	17
357	16
393	15
446	14
494	13
542	12
588	11
627	10
658	9
698	8
801	7

SIZE CLASS	SIZE IN MILLIMETERS
1	<0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 - 19.9
13	20.0 - 29.9
14	30.0 - 39.0
15	40.0 - 49.9
16	>50.0

DATE: 11 February 1979

STATION NUMBER: BENCHMARK

SHIP: USNS BARTLETT

TIME: 1503

SAMPLE NUMBER: 804-21

TYPE OF NET: CONICAL

MESH SIZE: 202μ

RING SIZE: .75 m

TYPE OF HAUL: HORIZONTAL

SAMPLING DEPTH: 25 m

METERS OF WIRE: 60 m

ANGLE: 55-60°

FLOWMETER START: 665576

FLOWMETER FINISH: 711891

LENGTH OF TOW: 10 min

LATITUDE: 17° 34.91 N

LONGITUDE: 65° 48.89 W

SEA STATE AND WEATHER: SS#1

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata		4	4												2.2	6	8
Calocalanus pavo		1	28												8.0	21	29
Clausocalanus furcatus		19	46												17.8	47	65
Farranula gracilis		16													4.4	12	16
Corycaeus sp		31	7												10.4	28	38
Macrosetella gracilis			39												10.7	28	39
Mecynocena clausi		18													4.9	13	18
Miracia efferata		2	4												1.6	4	6
Oithona plumifera		19	51												19.1	51	70
Oithona spp		16													4.4	12	16
Oncaea mediterranea		1	1												0.5	1	2
Oncaea venusta		16													4.4	12	16
Paracalanus aculeatus		3	8												3.0	8	11
Paracalanus parvus		16													4.4	12	16
Sapphirina nigromaculata		2		1											0.8	2	3
Temora stylifera			7												1.9	5	7
Temora turbinata		3													0.8	2	3
Undinula vulgaris			1	1											0.5	1	2
																	365

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods																	
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae																	
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores																	
Hydromedusae																	
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods																	

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates Fish																	
TOTAL PLANKTON COUNTED																	
TOTAL PLANKTON/m^3																	
VOLUME OF WATER FILTERED BY NET																		549.8 m^3= 550
ALIQUOT VOLUME																	800
SUB SAMPLE																	2

DATE: 12 April 1979

STATION NUMBER: BENCHMARK

SHIP: USNS BARTLETT

TIME: 1310

SAMPLE NUMBER: 804-23

TYPE OF NET: CONICAL 5:1

MESH SIZE: 202

RING SIZE: .75 m

TYPE OF HAUL: VERTICAL

SAMPLING DEPTH: 1000-800 m

METERS OF WIRE: 1060

ANGLE: 0

FLOWMETER START: 760067

FLOWMETER FINISH: 798993

LENGTH OF TOW: 15 min

LATITUDE: 17° 57.5

LONGITUDE: 65° 51.7

SEA STATE AND WEATHER: #2 Clear day no clouds

12 April 1979
804-23
1000-800 m

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo		3															3
Candacia sp.		1															1
Clausocalanus furcatus		29	5														34
Clytemnestra scutellata		1															1
Corycaeus spp.		2	12														14
Euchaeta marina			2	1													3
Euchaeta spp.		15	6														21
Haloptilus longicornis		1	5	2													8
Farranula gracilis		2	1														3
Lubbockia squillimana			3														3
Lucicutia flavicornis		4	11														15
Macrosetella gracilis			2														2
Mecynocera clausi		5															5
Oithona plumifera		6	8														14
Oithona spp.		14	8														22
Oncaea mediterranea		6															6
Oncaea venusta		10															10
Paracalanus aculeatus		1															1
Paracalanus parvus		11															11
Pleuromama abdominalis			5														5

12 April 1979
804-23
1000-800 m

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Pleuromama piseke			7	3													10
Pleuromama xiphias			3														3
Sapphirina nigromaculata		2	1														3
Scolethitrix danae			1														1

12 April 1979
804-23

Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Cladoceran																	
Ostracods	15	32	9	2													57
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids												1					1
Decapods																	
Caridean larvae				2													2
Lucifer spp.																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores																	
Hydromedusae																	
Polychaetes																	
Mollusks																	
Gastropods			1	1													2
Heteropods																	

12 April 1979
804-23

Echinoderm larvae	SIZE CLASSES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans			10	1													11
Chordates																	
Fish																	
Total Plankton Counted																	272
Total Plankton/m																	50/m
Volume of water filtered by net																	462m
Subsample																	2 ml
Aliquot																	100 ml

DATE:	12 April 1979
STATION NUMBER:	BENCHMARK
SHIP:	USNS BARTLETT
TIME:	1615
SAMPLE NUMBER:	804-24
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	800-200 m
METERS OF WIRE:	860 m
ANGLE:	0
FLOWMETER START:	799105
FLOWMETER FINISH:	825357
LENGTH OF TOW:	20 min
LATITUDE:	17° 57.5
LONGITUDE:	65° 51.8
SEA STATE AND WEATHER:	#2-3 CLEAR-CALM SUNNY DAY

12 April 1979
804-24
800-200 m

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Clausocalanus furcatus		8	6														14
Euchaeta marina			2	3													5
Euchaeta spp.		1	1	1													3
Haloptilus longicornis				1													1
Lubbockia squillimana			2														2
Lucicutia flautcornis			3														3
Miracia efferata		3															3
Oithona plumifera		8	22														30
Oithona spp.		6	8														14
Oncaea mediterranea		7	1														8
Oncaea venusta		6															6
Paracalanus parvus		3															3
Pleuromama abdominalis		1	2	1													4
Pleuromama piseki		2	2	2													6
Pleuromama xiphias		1	1														2
																	104

12 April 1979
804-24

SIZE CLASSES

Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Cladoceran																	
Ostracods	1	9	7														17
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid		1															1
Euphausids							1										1
Decapods																	
Caridean larvae																	
Lucifer spp.																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores																	
Hydromedusae																	
Polychaetes				1	3												4
Mollusks																	
Gastropods	1																1
Heteropods		—															
Chaetognatha																	10

12 April 1979
804-24

SIZE CLASSES

Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates																	
Fish			1														1
Total Plankton Counted																	139
TOTAL PLANKTON/m^3																	45./m^3
Volume of water filtered by net																	312 m^3
Subsample																	4 ml
Aliquot																	400 ml

DATE:	12 February 1979
STATION NUMBER:	BENCHMARK
SHIP:	USNS BARTLETT
TIME:	1654
SAMPLE NUMBER:	804-25
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	0.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	200-0 m
METERS OF WIRE:	260 m
ANGLE:	0°
FLOWMETER START:	825143
FLOWMETER FINISH:	834923
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.52
LONGITUDE:	65° 51.91
SEA STATE AND WEATHER:	#2

12 February 1979
804-25
200 m-surface

COPEPODA	SIZE CLASSES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
unidentified		8															8
Acartia lillgeborgii			1														1
Calocalanus pavonicus	1																1
Calocalanus pavo	1	3															4
Clausocalanus furcatus		12	7														19
Corycacus spp		2	1														3
Corycacus (u) lautus		1															1
Corycacus speciosus				2													2
Farranula gracilis		2	1														3
Macrosetella gracilis			2														2
Mecynocera clausii	1	10															11
Oithona spp		15	2														17
Oncaea venusta		1															1
Paracalanus aculeatus		3															3
Paracalanus parvus		8															8
Pleuromama sp		1															1
Temora turbinata		1	1														2
Undinula vulgaris		2	2	2													6
																	93

12 February 1979
804-25
200 m-surface

	SIZE CLASSES																
Non-copepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Cladoceran		1															1
Ostracods	1	2															3
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae																	
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores			1	1													2
Hydromedusae			1														1
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods																	

12 February 1979
804-25
200 m-surface

SIZE CLASSES

Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans			8														8
Chaetognatha Chordates Fish				2		1		1				1					5
TOTAL PLANKTON COUNTED																	106
TOTAL PLANKTON/m^3																	183
VOLUME OF WATER FILTERED BY NET																	116 m^3
ALIQUOT VOLUME																	400 ml
SUB SAMPLE																	2 ml

DATE:	13 February 1979
STATION NUMBER:	BENCHMARK
SHIP:	USNS BARTLETT
TIME:	1624
SAMPLE NUMBER:	804-26
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	0.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	60°
FLOWMETER START:	880029
FLOWMETER FINISH:	975100
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.52
LONGITUDE:	65° 51.91
SEA STATE AND WEATHER:	SS#2

[illegible] February 1979
S04-25
25 m HORIZONTAL

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Calocalanus pavo	1	3															4
Copilia quadrata	1	3		1													5
Clausocalanus furcatus		15	36														51
Corycaeus spp		13	2														15
Farranula gracilis		4															4
Macrosetella gracilis			4														4
Mecynocera clausii		15															15
Oithona spp		6	7														13
Oithona plumifera		4	21														25
Oncaea mediterranea		1	2														3
Oncaea venusta		5															5
Paracalanus aculeatus		6	1														7
Paracalanus parvus		29	1														30
Scolecithrix danae			1														1
Sapphirina nigromaculata			1														1
Temora stylifera		1															1
Temora turbinata		3	16														19
Undinula vulgaris			5														5
																	207

13 February 1979
804-26
25 m HORIZONTAL

Non-copepod-crustacean	SIZE CLASSES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Cladoceran																	
Ostracods																	
Stomatopod larvae																	
Amphipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae																	
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores	1		3														4
hydromedusae																	
Echinopluteus		1															1
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods			2														2

13 February 1979
804-26
25 m HORIZONTAL

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Echinoderm larvae																	
Urochordates																	
Salpa/Doliolids																	
Larvaceans		2	4														6
Chaetognatha			1	3	1	5	1	1	1		1						13
Chordates																	
Fish					1					1							2
TOTAL PLANKTON COUNTED																	235
TOTAL PLANKTON/m^3																	125/m^3
VOLUME OF WATER FILTERED BY NET																	1128 m^3
ALIQUOT VOLUME																	600 ml
SUB SAMPLE																	1 ml

APPENDIX E

CRUISE REPORT AND DATA FROM OTEC CRUISE #5 (CR-805)

19-23 APRIL 1979

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #5 (CR-805)

19-23 April 1979

by

Gary C. Goldman, Chief Scientist

CRUISE REPORT

OTEC CRUISE #5 (CR-805) 19-23 April 1979

I. Objectives:
   A. Measure oceanic parameters relatable to OTEC at Punta Tuna.
   B. Measure variability of these oceanic parameters at Punta Vaca.
   C. Measure water temperature at three other stations.

II. Research Vessel:

R/V CRAWFORD

III. Supporting Agencies:
   A. U.S. Department of Energy
   B. Lawrence Berkeley Laboratory
   C. P.R. Water Resources Authority
   D. UPR/CEER

IV. Dates of Cruise:

19-23 April 1979

V. Cruise Plan:

See Appendix II (Not included)

VI. Scientific and Technical Personnel:

Bonafe, C. - Technician (CEER)
Corales, D. - Technician (CEER)
Goldman, G. - Chief Scientist (CEER)
Gonzalez, E. - Technician (CEER)
Morgan, T. - Scientific Assistant (CEER)
Nazario, A. - Technician (CEER)
Pesante, D. - Biological Coordinator (CEER)
Rivera, J. - Scientific Assistant (CEER)
Shafnacker, M. - Technician (CEER)
Steen, J. - Visiting Scientist (Gulf Coast Research Lab)

VII. Station Locations:

See Attached Plan, Appendix II (Not included)

VIII. Types of sampling:

   A. See Attached Cruise Plan, Appendix II (Not included)
   B. Water Sampling for Foam OTEC Experiment
   C. Chlorophyll sampling for LBL

IX. Travel:

--- 19 April 1979. R/V CRAWFORD arrived at Malecon Port, Mayaguez, P. R. All personnel, except Mr. Morgan, were assembled at CEER (Cornelia) Lab. All equipment and personnel were transported from Cornelia lab to Malecon by CEER vehicles. Mr. Morgan had separate transportation from Main Lab to Malecon with his (Dr. Kay's) supplies. Ship departed about 1530 local time.

--- 23 April 1979. R/V CRAWFORD returned to Malecon Port, Mayaguez about 0330. All equipment and personnel were removed from the vessel by 0700, as she was forced to vacate her berth to allow another vessel to arrive. Equipment and personnel were again transported to their respective laboratories by CEER vehicles. R/V CRAWFORD returned to Magueyes.

X. Reason for termination of cruise:

All work was completed.

IX. Accomplishments:

A. Collected virtually all data from Station "B" (exception transmission data, and some current data).
B. Collected temperature data from Station "F".
C. Collected temperature data from Station "A".
D. Collected temperature data from Station "P".
E. Collected all data at Station "V".

IIX. Changes to be affected:

A. Repair transmissometer.
B. Consider increasing XBT stations.
C. Correct current meter intermittent malfunction.

XIII. Stations Visited:

See Cruise Plan (Appendix II) for planned Activity at each station.

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-1	20 April '79	0800-0820	17°57.6'N	65°51.9'W	PLANKTON-1 (25m) XBT-1	
B-2	20 April '79	1005-1110	17°57.6'N	65°51.9'W	HYDROCAST-1 XBT-2	
B-3	20 April '79	1130-1200	17°57.6'N	65°51.9'W	PLANKTON-2 (1000-0m) PLANKTON-3 (1000-800m) PLANKTON-4 (800-200m) PLANKTON-5 (200-0m) XBT-3	
B-4	20 April '79	1715-1920	17°57.6'N	65°51.9'W	CURRENT-1 XBT-4	
B-5	20-21 April '79	2255-0245	17°57.6'N	65°51.9'W	HYDROCAST-2 XBT-5 CURRENT-2	Current meter malfunction
B-6	21 April '79	0600-0800	17°57.6'N	65°51.9'W	CURRENT-3 XBT-6	Current meter malfunction
B-7	21 April '79	0930-1430	17°57.6'N	65°51.9'W	K-CAST-1 (Note 1) BIOCAST-1 CURRENT-4 COEW-CAST (Note 3) XBT-7	TRANSMISSION-1 (Note 2) Current meter malfunction
B-8	21 April '79	2130-2315	17°57.6'N	65°51.9'W	FOAM-CAST (Note 4) BIOCAST-2 XBT-8	TRANSMISSION-2 (Note 2)

Station	Day	Time (local)	Longitude	Latitude	Accomplished	Not Accomplished
B-9	22 April '79	0030-0205	17°57.6'N	65°51.9'W	PLANKTON-6 (25m) XBT-9	-
F	22 April '79	0600	17°52'N	65°47'W	XBT-10	-
A	22 April '79	0750	18°02'N	65°40'W	XBT-11	-
"V"	22 April '79	0930-1240	18°03'N	65°32'W	HYDRO/BIOCAST K-CAST-2 (Note 1) XBT-12 XBT-13 PLANKTON-7(800-200m) PLANKTON-8(200-0m)	-
"P"	22 April '79	1532			XBT-14	-

Notes---

--1 Cast for Dr. M. Kay (Foam OTEC) 0, 10, 25m.

--2 Apparent short circuit in electric cable.

--3 Cast for Mr. C. Carmiggelt (LBL) - performed by Mr. Steen - for chlorophyll samples 0, 25, 50, 75, 100, 150, 200, 250m.

--4 Cast for Dr. M. Kay (Foam OTEC) 5 gal (3-4 casts) to 10m.

BIOLOGICAL REPORT

This cruise was carried out without any hardship. Zooplankton were sampled from:

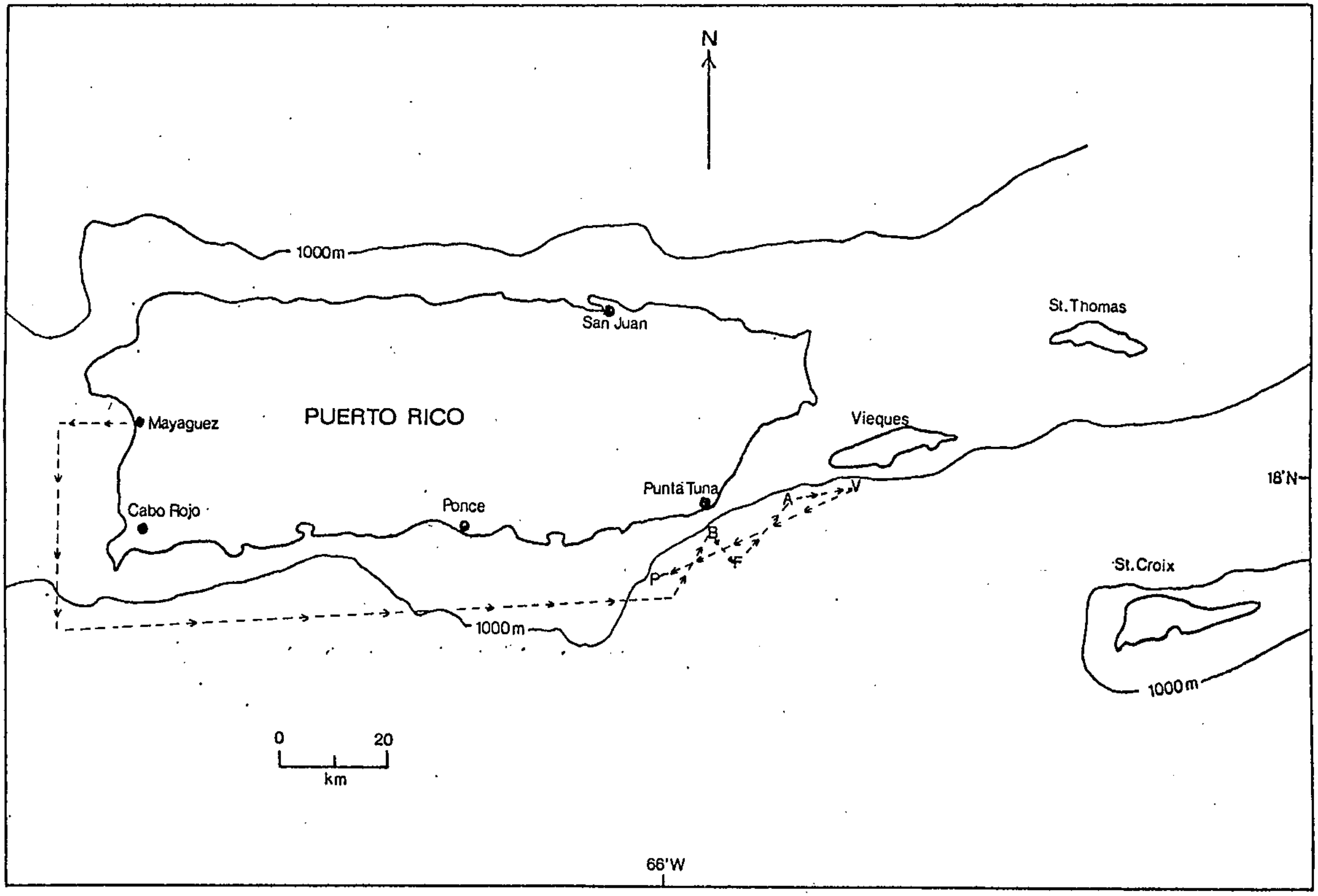
1000-800m
800-200m
200-SFC
1000-SCF
25 meter horizontal-day
25 meter horizontal-night

Samples of organisms that live attached to the mooring buoy were obtained during a snorkling effort. These will be identified at a later date.

No new fish were seen, although the same as previously reported were present.

Heavy overcast was present about 75% of the time.

Trackline for OTEC CRUISE #5 (CR-805), 19-23 April 1979



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE: CR-805 STATION: B-1 DATE: 20 APRIL 1979 WEATHER: 9-10KT/090°, 80°, 80%, 1/2, 100°
DATES: 19-23 APRIL 1979 LOCATION: 17° 57.6'N, 65° 51.9'W WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 0800-0820 AST; PLANKTON (0800-0820), XBT (0806)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1200 DEPTH TO BOTTOM 1100 MAX SAMPLE 25 BAR 1018

XBT-1

DEPTH (M)	TEMP (°C)
000	26.6
051	26
060	25
095	24
124	23
135	22
160	21
193	20
225	19
287	18
336	17
380	16
419	15
458	14
504	13
536	12
550	11
610	10
654	9
703	8
780	7

COURSE CR-805 STATION B-2 DATE 20 APRIL 1979 WEATHER 11KT/090°, 80°, 80%, 1/2, 090°
DATES 19-23 APRIL 1979 LOCATION 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE 0°
GENERAL AREA PUNTA TUNA, P.R. TIME 1005-1110 AST; HYDROCAST (1005-1110), XBT (1040)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1405 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1018

												XBT		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHYEO"A" (μG/L)	ATP (μG/L)	PO_4 μG AT/L	SiO_2 AT/L	NO_2 μG AT/L	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.36	36.195	23.84	4.50	N.A.	N.A.	N.A.	1.40	N.A.	*	0.45	000	26.3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
048	25.94	36.203	23.98	4.50				1.15		*	0.30	029	26									
095	24.02	36.903	25.10	4.50				1.85		0.1	1.30	055	26									
143	21.58	36.831	25.74	4.29				0.90		0.1	1.10	070	25									
190	19.79	36.721	26.15	3.80				1.30		0.1	4.05	096	24									
238	18.55	36.532	26.32	4.01				1.35		*	5.40	118	23									
285	17.48	36.388	26.48	3.91				0.65		*	7.35	136	22									
380	15.50	36.088	26.72	3.66				1.50		*	44.55	155	21									
475	13.23	35.692	26.90	3.06				2.40		*	1.25	182	20									
570	11.03	35.329	27.04	2.81				2.25		*	11.00	213	19									
761	7.49	34.906	27.30	2.90				3.05		*	23.65	262	18									
951	5.59	34.874	27.53	3.82				1.45		*	14.30	313	17									
												357	16									
												393	15									
												438	14									
												476	13									
												527	12									
												555	11									
												595	10									
												645	9									
												696	8									
												675	7									
												880	6									

* = LESS THAN 0,1

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DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)
000	26.36	36.195	23.84
010	26.32	36.195	23.87
020	26.20	36.196	23.90
030	26.12	36.198	23.93
040	26.00	36.200	23.96
050	25.85	36.205	23.98
075	25.15	36.550	24.14
100	23.85	36.925	25.20
125	22.20	36.900	25.60
150	21.20	36.825	25.84
175	20.35	36.760	26.05
200	19.60	36.698	26.18
250	18.30	36.500	26.38
300	17.20	36.350	26.50
400	15.00	36.010	26.75
500	12.75	35.590	26.95
600	10.60	35.175	27.12
700	8.55	34.975	27.24
800	6.85	34.900	27.36
900	5.80	34.875	27.49
1000			

CRUISE: CR-805 STATION: B-3 DATE: 20 April 1979 WEATHER: 9KT/090°, 82°, 78%, 1/2, 090°

DATES: 19-23 April 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE: N.A.

GENERAL AREA: Punta Tuna, P.R. TIME: 1130-1600 AST; XBT (1335), Plankton (1130-1600)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1530 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1018

XBT-3

Depth (M)	Temp (°C)
000	26.4
062	26
083	25
100	24
130	23
156	22
172	21
192	20
220	19
276	18
311	17
358	16
390	15
442	14
482	13
523	12
564	11
612	10
660	9
704	8
775	7
899	6

CRUISE: CR-805 STATION: B-4 DATE: 20 APRIL 1979 WEATHER: 10-11KT/090°-135°, 80°, 30%, 1/2, 090°
DATES: 19-23 APRIL 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 1715-1920 AST; XBT (1825), CURRENT (1715-1920)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2115 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1016

XBT-4

DEPTH (M)	TEMP (°C)
000	26.4
043	26
056	25
091	24
123	23
139	22
158	21
172	20
208	19
260	18
334	17
368	16
422	15
467	14
502	13
548	12
583	11
623	10
655	9
697	8
763	7
877	6

WATER CURRENT

DEPTH (M)	DIRECTION (DEG)	SPEED (C/SEC)
025	228	12
050	192	10
075	240	17
100	252	17
125	240	22
150	240	12
175	276	7
200	324	8
250	264	5
300	312	7
400	264	7
500	264	7
750	072	8

CRUISE CE-805 STATION E-5 DATE 20-21 April 1979 WEATHER 6-7KT/090°, 80°, 80%, 1/2, 090°
DATES 19-23 April 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2255-0246 AST; Hydrocast (2255-0040), XBT (0040), Current (0046-0245)
SHIP CRAWFORD MAR. SC. 43 TIME GMT 0255 DEPTH TO BOTTOM 1120 MAX SAMPLE 900 BAR 1017

												XBT		TRANSMISSOMETER		S.T.D.				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS. O_2 (ML/L)	CHLOR A* (µG/L)	PHAEO A* (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_2 (µG AT/L)	N_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.39	36.142	23.79	4.52	N.A.	N.A.	N.A.	1.05	N.A.	•	0.60	000	26.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		INSTRUMENT	
047	26.33	36.190	23.85	4.53				1.00		•	0.45	063	26									
094	24.06	36.897	25.08	4.54				1.50		•	0.50	078	25								MAL-	
141	---	36.923	---	4.41				1.40		•	0.15	104	24									
188	19.94	36.720	26.11	3.91				2.95		•	4.10	130	23								FUNCTION	
235	18.62	36.542	26.31	4.15				1.00		0.20	3.40	155	22									
282	17.71	36.428	26.45	4.00				1.30		0.10	4.15	168	21									
376	15.55	36.095	26.71	3.63				1.65		0.50	7.75	194	20									
462	13.70	35.763	26.86	3.20				2.10		•	15.95	225	19									
572	7.44	34.924	27.32	2.94				2.90		•	29.15	251	18									
846	6.46	34.846	27.39	3.22				3.00		•	27.50	319	17									
940	5.68	34.886	27.53	3.74				2.50		•	30.25	369	16									
												411	15									
000	26.39	36.142	23.79									442	14									
010	26.38	36.142	23.80									495	13									
020	26.37	36.160	23.81									524	12									
030	26.35	36.170	23.83									563	11									
040	26.34	36.180	23.84									597	10									
050	26.33	36.200	23.85									648	9									
075	25.70	36.335	24.42									713	8									
100	24.00	36.900	25.20									780	7									
125	22.65	36.925	25.63																			
150	21.45	36.900	25.88																			
175	20.45	36.790	26.08																			
200	[illegible]	[illegible]	26.18																			
250	18.30	36.525	26.35																			
300	17.20	36.385	26.50																			
400	15.05	35.000	26.75																			
500	13.10	35.640	26.93																			
600	[illegible]	35.305	27.12																			
700	8.65	35.025	27.25																			
800	6.85	34.665	27.38																			
900	5.50	34.855	27.46																			
1000																						

* = Less than 0.1

CRUISE: CR-805 STATION: B-6 DATE: 21 APRIL 1979 WEATHER: 9-10KT/090°, 82°, 80%, 1/2, 110°

DATES: 19-23 APRIL 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0545-0800 AST; CURRENT (0600-0800), XBT (0545)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0945 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1016

XBT-6

DEPTH (M)	TEMP (°C)
000	26.5
030	26
055	25
080	24
119	23
135	22
145	21
167	20
190	19
238	18
290	17
342	16
392	15
433	14
483	13
527	12
572	11
604	10
663	9
676	8
787	7
855	6

WATER CURRENT

DEPTH (M)	DIRECTION (DEG)	SPEED (C/SEC)

INSTRUMENT MALFUNCTION

CRUISE CR-205 STATION B-7 DATE 21 April 1979 WEATHER 9-12KT/070°-090°, 80°, 75%, 1/2, 030°
DATES 19-23 April 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 0830-1430 AST; N/Cast (0830-1000), Biocast (1030-1349), Current (1200-1500), XBT (1117)
Core Cast (1400-1430)
SHIP Crawford MAR. SQ. 43 TIME GMT 1345 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 EAS 101E

DEPTH (M)	TEM (°C)	SALIN (PPT)	SIGMA (σ_T)	DIS.O. (ML/L)	CHLOR'A' (µG/L)	PHEO'A' (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_3 (µG AT/L)	NH_3
000	26.54	36.178	23.77	N.A.	0.09	0	N.A.	N.A.	N.A.	N.A.	N.A.
023	26.42	36.170	23.80		0.10	0					
047	26.10	36.285	23.99		0.16	0					
071	24.90	36.650	24.64		0.27	0.02					
095	24.01	36.896	25.09		0.22	0.12					
118	23.35	36.932	25.32		0.16	0.09					
141	22.01	36.874	25.66		0.12	0.10					
165	20.75	36.758	25.92		0.02	0.01					
190	19.63	36.674	26.15		0.01	0.01					
236	18.56	36.519	26.31		0.01	0					
283	17.64	36.420	26.46		0	0					
377	15.99	36.158	26.66		0	0					

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DEPTH (M)	TEM (°C)	SALIN (PPT)	SIGMA (σ_T)
000	26.54	36.178	23.77
010	26.50	36.175	23.78
020	26.45	36.175	23.79
030	26.35	36.200	23.85
040	26.20	36.233	23.95
050	25.90	36.300	24.07
075	24.80	36.750	24.75
100	23.90	36.912	25.13
125	22.90	36.920	25.47
150	21.60	36.850	25.76
175	20.20	36.725	26.02
200	19.35	36.625	26.12
250	18.20	36.495	26.35
300	17.35	36.390	26.50
400			
500			
600			
700			
800			
900			
1000			

XBT

DEPTH (M)	TEMP (°C)
000	26.5
034	26
055	26
059	25
094	24
118	23
138	22
151	21
177	20
208	19
265	18
328	17
373	16
415	15
446	14
476	13
522	12
555	11
610	10
693	9
700	8
770	7
865	6

TRANSMISSION

DEPTH (M)	TRAN (%)
Inst. Mal- Function	

DEPTH (M)	TEM (°C)	SALIN (PPT)	DENS (σ_T)
N.A.	N.A.	N.A.	N.A.

NOAA CURRENTS

DEPTH (M)	DIR (DEG)	SPEED (CM/S)
Instrument Mal- Function		

CRUISE CR-805 STATION B-R DATE 21 April 1979 WEATHER 12-14KT/090°, 78°, 80% 1/2, 100°
DATES 19-23 April 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA Punta Tuna, P.R. TIME 2130-2335 AST; Biocast (2200-2315), XBT (2335), Foamcast (2130-2200)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0330 DEPTH TO BOTTOM 1120 MAX SAMPLE 900 BAR 1018

												XBT		TRANSMISSOMETER		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O$_2$ (ML/L)	CHLOR'A' (µG/L)	PHEO'A' (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_3$ (µG AT/L)	NO$_3$ (µG AT/L)	NO$_2$	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.43	36.220	23.84	N.A.	0.14	0	N.A.	N.A.	N.A.	N.A.	N.A.	000	26.4	Instr.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
023	26.36	36.213	23.85		0.12	0						035	26									
047	25.97	36.209	23.98		0.12	0						052	26	Mal-								
071	24.49	36.800	24.88		0.31	0.05						058	25	Function								
095	23.69	36.917	25.20		0.88	1.14						074	24									
118	22.74	36.907	25.47		1.52	1.67						114	23									
141	21.93	36.887	25.69		0.20	0.45						136	22									
164	20.61	36.706	25.92		0.29	0						156	21									
188	19.64	36.668	26.15		0.02	0.01						173	20									
235	18.39	36.501	26.34		0	0.01						203	19									
282	17.64	36.420	26.46		0	0.01						262	18									
376	16.07	36.186	26.66		0	0.01						328	17									
- - - - - - - - - - - - -																						
000	26.43	36.220	23.84									379	16									
010	26.43	36.220	23.84									419	15									
020	26.40	36.215	23.85									446	14									
030	26.30	36.212	23.85									476	13									
040	26.10	36.210	23.90									512	12									
050	25.70	36.225	23.99									561	11									
075	24.40	36.805	24.90									605	10									
100	23.45	36.920	25.30									637	9									
125	22.50	36.905	25.56									695	8									
150	21.45	36.825	25.80									750	7									
175	20.25	36.590	26.07									847	6									
200	19.38	[illegible]	[illegible]																			
250	18.20	36.480	26.39																			
300	17.40	36.400	26.52																			
400																						
500																						
600																						
700																						
800																						
900																						
1000																						

CRUISE: CR-805 STATION: B-9 DATE: 22 APRIL 1979 WEATHER: 12-14KT/090°, 78°, 80%, 1/2, 100°

DATES: 19-23 APRIL 1979 LOCATION: 17° 57.6'N, 65° 51.9'W WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0015-0205 AST; XBT (0015), PLANKTON (0030-0205)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0415 DEPTH TO BOTTOM 1100 MAX SAMPLE 25 BAR 1017

XBT-9

DEPTH (M)	TEMP (°C)
000	26.5
066	26
074	25
092	24
113	23
145	22
165	21
193	20
228	19
285	18

RECORD

UNUSABLE

↓

CRUISE: CR-805 STATION: F DATE: 22 APRIL 1979 WEATHER: N.A.
DATES: 19-23 APRIL 1979 LOCATION: 17° 52′N, 65° 47′W WIRE ANGLE: N.A.
GENERAL AREA: SOUTH OF PUNTA TUNA, P.R. TIME: 0600 AST; XBT (0600)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1000 DEPTH TO BOTTOM 1950 MAX SAMPLE XBT BAR 1017

XBT-10	
DEPTH (M)	TEMP (°C)
000	26.3
068	26
079	25
102	24
116	23
134	22
147	21
155	20
190	19
262	18
324	17
375	16
413	15
450	14
482	13
518	12
567	11
602	10
639	9
693	8
760	7
872	6

CRUISE: CR-805 STATION: A DATE: 22 APRIL 1979 WEATHER: 13KT/045°, 80°, --, 1, --

DATES: 19-23 APRIL 1979 LOCATION: 18° 02'N, 65° 40'W WIRE ANGLE: N.A.

GENERAL AREA: BETWEEN PUERTO RICO AND VIEQUES TIME: 0750 AST; XBT (0750)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1150 DEPTH TO BOTTOM 1200 MAX SAMPLE XBT BAR 1018

XBT-11

DEPTH (M)	TEMP (°C)
000	26.3
058	26
074	25
094	24
116	23
123	22
153	21
163	20
200	19
252	18
300	17
354	16
386	15
440	14
484	13
525	12
572	11
614	10
675	9
715	8
777	7

CRUISE CE-805 STATION V DATE 22 April 1979 WEATHER 20KT/045°, 75°, --, 1, --

DATES 19-23 April 1979 LOCATION 18° 03'N, 65° 32'W WIRE ANGLE 14°

GENERAL AREA Punta Vaca, Vieques TIME 0930-1240 AST; Hydro Biocast (1010-1115), K/Cast (0930-0945), XBT (1049), XBT (1150) Plankton (1130-1230)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1330 DEPTH TO BOTTOM 1200 MAX SAMPLE 1000 BAR 1012

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σt)	DIS.O2 (ML/L)	CHLOR"A" (µg/L)	PHEO"A" (µg/L)	ATP (µg/L)	PO4 (µg AT/L)	SiO3 (µg AT/L)	NO3 (µg AT/L)	N3
000	26.36	36.182	23.83	4.59	0.17	0	N.A.	1.15	N.A.	•	0.40
046	25.58	36.389	24.23	4.61	0.10	0.14		0.60		0.1	0.10
093	24.00	36.872	25.03	4.72	0.14	0.21		0.90		0.1	0.15
139	22.17	36.885	25.62	4.45	0.03	0.23		1.75		0.15	1.25
186	19.43	36.596	26.15	4.32	0.03	0.01		1.00		•	2.35
233	18.40	36.501	26.34	4.32	0.01	0.01		1.30		0.10	3.85
279	17.73	36.432	26.45	4.32	0.01	0		0.70		•	6.15
372	16.03	36.170	26.66	3.85	0.02	0		1.10		•	12.65
465	13.93	35.804	26.84	3.29	0	0.01		1.95		•	14.30
558	11.92	35.482	27.00	3.10	0	0.01		2.3		•	48.95
744	7.84	34.935	27.27	2.89	0.01	0.02		2.50		•	29.70
930	5.78	34.869	27.50	3.70	0.02	0.01		2.20		•	25.85

BT DEPTH (M)	BT TEMP (°C)	DEPTH (M)	RW (%)	STD DEPTH (M)	STD TEMP (°C)	STD SALIN (PPT)	STD DENS (σt)	WATER CURRENTS DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	26.6	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
047	26									
072	25									
112	24									
135	23									
150	22									
170	21									
183	20									
222	19									
285	18									
333	17									
402	16									
436	15									
474	14									
523	13									
561	12									
599	11									
638	10									
700	9									
752	8									
837	7									

- - - - - - - - - - - - - - - - -

000	26.36	36.182	23.83
010	26.25	36.200	23.90
020	26.15	36.225	23.97
030	25.90	36.285	24.07
040	25.70	36.340	24.19
050	25.50	36.400	24.30
075	24.80	36.650	24.72
100	23.80	36.890	25.20
125	22.75	36.900	25.50
150	21.40	36.825	25.70
175	20.00	36.645	25.92
200	19.20	36.565	26.25
250	18.15	36.488	26.40
300	17.40	36.390	26.52
400	15.50	35.050	25.73
500	13.30	35.670	26.90
600	11.00	35.320	27.03
700	8.60	35.035	27.25
800	7.10	34.885	27.38
900	6.10	34.870	27.47
1000			

X B T - 13

DEPTH (M)	TEMP. (°C)
000	26.6
056	26
086	25
116	24
140	23
157	22
173	21
183	20
216	19
276	18
316	17
378	16
419	15
455	14
500	13
549	12
580	11
625	10
[illegible]	9
[illegible]	8
728	7

CRUISE: CR-805 STATION: P. DATE: 22 APRIL 1979 WEATHER: 23KT/060°, 88°, --, 2, --
DATES: 19-23 APRIL 1979 LOCATION: 17° 55'N, 66° 00'W WIRE ANGLE: N.A.
GENERAL AREA: SOUTH OF PATILLAS, P.R. TIME: 1532 AST; XBT (1532)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1932 DEPTH TO BOTTOM 1200 MAX SAMPLE XBT BAR 1017

XBT-14

DEPTH (M)	TEMP (°C)
000	26.6
072	26
088	25
117	24
147	23
163	22
179	21
202	20
227	19
291	18
343	17
386	16
437	15
481	14
518	13
550	12
593	11
638	10
682	9
722	8
770	7
889	6

ZOOPLANKTON

SIZE CLASS	SIZE IN MILLIMETERS
1	<0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 - 19.9
13	20.0 - 29.9
14	30.0 - 39.9
15	40.0 - 49.9
16	>50.0

DATE:	20 April 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	0800
SAMPLE NUMBER:	805-27
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	0.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	60°
FLOWMETER START:	975150
FLOWMETER FINISH:	1003240
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.52
LONGITUDE:	65° 51.91
SEA STATE AND WEATHER:	#2

20 April 1979
305-27
25 m HORIZONTAL

	SIZE CLASSES																
COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata		1	2														3
Acartia tonsa		1															1
Candacia bispinata			1														1
Candacia pachydactilla			1														1
Calocalanus pavo		10															10
Clausocalanus furcatus		4	10														14
Corycaeus speciosus			2	1													3
Corycaeus spp	1	38	5														44
Farranula gracilis		12	1														13
Lucicutia flavicornis			1														1
Macrosetella gracilis			2														2
Mecynocera clausii		9															9
Oithona sp		1															1
Oithona plumifera		3	7														10
Oncaea mediterranea		3															3
Oncaea venusta		10															10
Paracalanus aculeatus		1															1
Saphirina nigromaculata		2															2
Temora turbinata	11	36															47
Temora stylifera		5	10														15

23 April 1979
805-27
25 m HORIZONTAL
(Cont.)

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Undinula vulgaris		2															2
																	194

20 April 1979
305-27
25 m HORIZONTAL

Non-cupepod crustacean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Cladoceran	1	1															2
Ostracods																	
Stomatopod larvae																	
Ampnipoda																	
Gammarid																	
Hyperiid																	
Euphausids																	
Decapods																	
Caridean larvae			3	9	4												16
Lucifer spp																	
Protozoans																	
Radiolarians																	
Foraminiferans																	
Coelenterates																	
Siphonophores				3													3
Hydromedusae																	
Brachyuran			1														1
Polychaetes																	
Mollusks																	
Gastropods																	
Heteropods																	

20 April 1979
805-27
25 m HORIZONTAL

SIZE CLASSES

Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urocnordates		3	5														8
Salpa/Doliolids																	
Larvaceans																	
Chaetognatha						1	3	2			1	5					
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	224
TOTAL PLANKTON/m^3																	201/m^3
VOLUME OF WATER FILTERED BY NET																	333 m^3
ALIQUOT VOLUME																	~~600 ml~~
SUB SAMPLE																	2 ml

DATE:	20 April 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1305
SAMPLE NUMBER:	805-29
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	0.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	1000-800 m
METERS OF WIRE:	1060
ANGLE:	0
FLOWMETER START:	84577
FLOWMETER FINISH:	139257
LENGTH OF TOW:	
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	

	SIZE CLASSES																
COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Unidentified		1	3	5											1	4.9	9
Candacia sp			1	2											0.3	1.6	3
Clausocalanus furcatus		3	3												0.7	3.2	6
Corycaeus spp		6													0.7	3.2	6
Euchaeta sp		2	4	5											1	5.9	11
Haloptilus longicornis		1	6	3											1	5.4	10
Heterorhabus abyssalis			1												.1	0.5	1
Lubbockia squillimana			1												.1	0.5	1
Lucicutia flavicornis		2	8												1	5.4	10
Macrosetella gracilis		1	3												0.5	2.2	4
Mecynocera clausi		7													0.8	3.8	7
Oithona plumifera		6	6												1.4	6.5	12
Oithona spp		14	4												2.0	9.7	18
Oncaea mediterranea		6	2												0.9	4.3	8
Oncaea venusta		14	1												2	8.1	15
Oncaea ornata			4												0.9	2.2	4
Paracalanus parvus		9													1	4.9	9
Pleuromama abdominalis		1	5												0.7	3.2	6
Pleuromama piseki			14	2											2	8.6	16
Pleuromama xiphias			2	3	1	1									0.8	3.8	7

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Pleuromama sp		1	11	4											2	8.1	16
Sapphirina nigromaculata		3	4												0.8.	3.8	7
																	186

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Dolioids																	
Larvaceans																	
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	186
TOTAL PLANKTON/m^3																	
VOLUME OF WATER FILTERED BY NET																	649
ALIQUOT VOLUME																	300
SUB SAMPLE																	4

DATE: 20 April 1979

STATION NUMBER: BENCHMARK

SHIP: CRAWFORD

TIME: 1407

SAMPLE NUMBER: 805-30

TYPE OF NET: CONICAL 5:1

MESH SIZE: 202µ

RING SIZE: 0.75 m

TYPE OF HAUL: VERTICAL

SAMPLING DEPTH: 800-200 m

METERS OF WIRE: 800 m

ANGLE: 0

FLOWMETER START: 182475

FLOWMETER FINISH: 209882

LENGTH OF TOW:

LATITUDE: 17° 57.6'N

LONGITUDE: 65° 51.9'W

SEA STATE AND WEATHER:

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Clausocalanus furcatus															1.1	11	23
Haloptilus longicornis		1	16	13	1										1.5	14.8	31
Lubbockia squillimana			4												0.2	1.9	4
Lucicutia flavicornis			15												0.7	7.2	15
Oncaea mediterranea		20													1.0	9.6	20
Oncaea ornata		4													0.2	1.9	4
Oncaea venusta		28													1.4	13.4	28
Oithona spp		2	21												1.1	11	23
Paracalanus parvus		20													1	9.6	20
Pleuromama abdominalis			3	8	2	1									0.7	6.7	14
Pleuromama piseki			4	5	1										0.5	4.8	10
Pleuromama xiphias			1	3	3	4									0.6	5.3	11
Rhincalanus cornutus					2										1.1	0.9	2
Rhincalanus nasutus			3												0.1	1.4	3
																	209

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	209
TOTAL PLANKTON/m^3																	
VOLUME OF WATER FILTERED BY NET																	737 m^3
ALIQUOT VOLUME																	300
SUB SAMPLE																	8

DATE: 20 April 1979

STATION NUMBER:

SHIP: CRAWFORD

TIME: 1518

SAMPLE NUMBER: 805-31

TYPE OF NET: CONICAL 5:1

MESH SIZE: 202µ

RING SIZE: 0.75 m

TYPE OF HAUL: VERTICAL

SAMPLING DEPTH: 200-SFC

METERS OF WIRE: 260

ANGLE: 0

FLOWMETER START: 209885

FLOWMETER FINISH: 221091

LENGTH OF TOW:

LATITUDE: 17° 57.6'N

LONGITUDE: 65° 51.9'W

SEA STATE AND WEATHER:

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia tonsa		1													.3	.64	1
Calocalanus pavo		8													2	5.2	8
Candacia pachydactylla			1												.3	0.64	1
Candacia spp			1	2											.9	1.95	3
Clausocalanus furcatus		9	3												4	7.79	12
Copilia quadrata		2													.6	1.29	2
Coricaeus speciosus			1												.3	0.64	1
Coricaeus spp		1	9												8	6.49	10
Euchaeta marina				2											.6	1.29	2
Euchaeta spp				5											2	3.25	5
Farranula gracilis		12													4	7.79	12
Haloptilus longicornis			3	1											1	2.59	4
Lubbockia squilliman			3												.9	1.95	3
Lucicutia flavicornis			5												2	3.24	5
Macrosetella gracilis			2												.6	1.29	2
Mecynocera clausii		2													.6	1.29	2
Miracia efferata		3													.9	1.95	3
Microsetella rosea			1												.3	0.64	1
Oithona plumifera		7	15												5	1.29	2
Oithona spp		2	2												1	2.59	4

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oncaea mediterranea		6													2	3.89	6
Oncaea venusta		7													2	4.54	7
Paracalanus aculeatus		7													2	4.54	7
Paracalanus parvus		8													2	5.19	8
Sapphirina nigromaculata		3	1	1											2	3.24	5
Scolethitrix danae			4	1											2	3.24	5
Temora turbinata		1													.3	0.64	1
Temora stylifera			2												.6	1.29	2
Undinula vulgaris			2	8											3	6.49	10
																	154

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates Fish																	
TOTAL PLANKTON COUNTED																	154
TOTAL PLANKTON/m^3																	
VOLUME OF WATER FILTERED BY NET																	132 m^3
ALIQUOT VOLUME																	400
SUB SAMPLE																	10

DATE:	21 April 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	0205
SAMPLE NUMBER:	805-32
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	0.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	60°
FLOWMETER START:	030190
FLOWMETER FINISH:	60860
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	SS#1-2

SIZE CLASSES

COPEPODA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata			4												3	0.8	4
Calocalanus pavo		36													30	7.5	36
Clausocalanus furcatus		79	58												113	28.7	137
Candacia pachydactyla			3	1											3	0.8	4
Candacia spp		1	5												5	1.3	6
Copilia quadrata			1	1	1										2	0.6	3
Corycaeus speciosus			2												2	0.4	2
Corycaeus spp		55	5												49	12.6	60
Euchaeta marina			1	3											3	0.8	4
Euchaeta spp			1												1	0.2	1
Farranula gracilis		31													26	6.5	31
Lubbochia squillimana		1	2												2	0.6	3
Lucicutia flavicornis		3	19												18	4.6	22
Macrosetella gracilis			3												2	0.6	3
Mecynocera clausi			2												2	0.4	2
Oithona spp		5	59												53	13.4	64
Oithona plumifera		5	34												32	8.2	39
Oncaea venusta		6													5	1.3	6
Oncaea mediterranea		4													3	0.8	4
Paracalanus aculeatus		14	4												15	3.8	18

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Pleuromama xiphias				1											1	0.2	1
Pleuromama abdominalis			1	5											5	1.3	6
Sapphirina nigromaculata			3												2	0.6	3
Scolethitrix danae		2	2												3	0.8	4
Temora stylifera			4												3	0.8	4
Temora turbinata		6													5	1.3	6
Undinula vulgaris				5											4	1.0	5
																	478

	SIZE CLASSES																
Echinoderm larvae	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Urochordates																	
Salpa/Doliolids																	
Larvaceans																	
Chordates																	
Fish																	
TOTAL PLANKTON COUNTED																	478
TOTAL PLANKTON/m^3																	
VOLUME OF WATER FILTERED BY NET																	364 m^3
ALIQUOT VOLUME																	600
SUB SAMPLE																	2

APPENDIX F

CRUISE REPORT AND DATA FROM OTEC CRUISE #6 (CR-806)

4-9 JUNE 1979

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO

CRUISE REPORT

OTEC CRUISE #6 (CR-806)

4-9 June 1979

by

Gary C. Goldman, Chief Scientist

CRUISE REPORT

P.R. OTEC CRUISE #6 (CR-806) 4-9 June 1979

I. Objectives:

- A. Measure oceanic parameters relatable to OTEC at Punta Tuna.
- B. Measure variability of these oceanic parameters at Punta Vaca, Punta Borinquen, and Cabo Rojo.
- C. Measure temperature at three other sites.
- D. Measure variation of oceanic parameters as a function of distance from Benchmark and distance from shore at 10 stations.
- E. Sample for water characteristics for foam OTEC program at 2 stations.

II. Research Vessel:

R/V CRAWFORD

III. Supporting Agencies:

- A. U.S. Department of Energy
- B. Lawrence Berkeley Laboratory
- C. P.R. Water Resources Authority
- D. UPR/CEER

IV. Dates of Cruise:

4-9 June 1979

V. Cruise Plan:

See Appendix II (Not included)

VI. Scientific and Technical Personnel:

Altschuler, S. - Biologist
Bonafé, C. - Technician
Cabassa, P. - Technician
Carmiggelt, C. - Visiting Sci. (LBL)
Corales, D. - Technician
Goldman, G. - Chief Scientist
Gonzâlez, E. - Technician
Jones, K. - Visiting Sci. (LBL)
Morgan, T. - Scientist Ass't.
Nazario, A. - Technician

Pesante, D. - Biological Coordinator
Rivera, J. - Scientific Ass't.
Saddler, T. - Technician
Shafnacker, M. - Technician

VII. Station Locations:

See Cruise Plan, Appendix II (Not included)

VIII. Types of Sampling:

A. See Cruise Plan, Appendix II (Not included)
B. Five Gallon sample at 10 m for Foam Experiment
C. Water samples for LBL
D. Phytoplankton net samples for LBL

IX. Travel:

-- 4 June 1979. R/V CRAWFORD arrived at Malecón Port, Mayaguez, P.R. at about 1030 AST after leaving Mayaguez about 0600-0700. The personnel assembled at CEER, CORNELIA LAB, along with the equipment at that location, were transported to the vessel. Other personnel and their equipment (Morgan from the main CEER LAB, and Carmiggelt and Jones from Hotel) arrived via CEER vehicles or rented vehicles. The ship departed about 1400 AST.

-- 9 June 1979. R/V CRAWFORD returned to Malecón Port, Mayaquez about 0530 AST. Equipment and personnel were removed from the vessel by 0730-0800 AST, and were transported to their destinations by CEER vehicles. R/V CRAWFORD returned to Mayaguez about 1100 A.S.T.

X. Reason for termination of cruise:

As neither the leased fathometer, nor either of the onboard fathometers were functioning, I determined the probability too great of loosing a string of hydrographic bottles and reversing thermometer if we attempted to visit the inner stations scheduled for the return trip. These stations are located on a sharp drop-off, and a slight navigation error could have put the vessel in too shallow water. All other work was completed.

XI. Accomplishments:

A. Collected virtually all data from Station "B" (except transmission data).
B. Collected all scheduled data from Stations "R", "C", and "F", three high-priority OTEC sites.

C. Collected all data from Station "V".

D. Collected all scheduled data from Stations "GO", "MO", "SO", "JO", all deep water stations with OTEC Potential.

XII. Stations Visited:

See Cruise Plan (Appendix II) for planned activity at each station.

Station	Date	Time (A.S.T.)	Latitude	Longitude	Accomplished	Not Accomplished
"R"	4 June '79	1600-1730	18° 27.5'N	67° 15'W	HYDRO/BIOCAST-1 XBT-1	(Note 1)
"C"	4-5 June '79	2215-0130	17° 51'N	67° 11'W	HYDRO/BIOCAST-2 XBT-2 SED GRAB-1 R/PLANKTON-1	
Trolling	4-9 June '79	in transit between all stations along the south coast - no fish caught				
"GO"	5 June '79	0413-0630	17° 49'N	66° 47'W	HYDRO/BIOCAST-3 XBT-3 R/PLANKTON-2	SED GRAB-2 (Note 2)
"MO"	5 June '79	0900-1115	17° 48'N	66° 28.5'W	HYDRO/BIOCAST-4 (Note 3) XBT-4 R/PLANKTON-3 SED GRAB-3	
"SO"	5 June '79	1235-1500	17° 48'N	66° 17.5'W	HYDRO/BIOCAST-5 R/PLANKTON-4 XBT-5 SED GRAB-4	
"JO"	5 June '79	1703-1930	17° 48'N	66° 04'W	HYDRO/BIOCAST-6 R/PLANKTON-5 XBT-6 SED GRAB-5	
"PO"	5 June '79	---	17° 50'N	66° 00'W	(NOTE 4)	HYDRO/BIOCAST R/PLANKTON XBT SED GRAB

Station	Date	Time (A.S.T.)	Latitude	Longitude	Accomplished	Not Accomplished
"B-1"	5 June '79	2100-2400	17° 57.6'N	65° 51.9'W	PLANKTON-1 (25 m Horz.) HYDROCAST-1 XBT-7 DRIFT FISHING	K/CAST (Note 5) LIFT NET FISHING (Note 6)
"B-2"	6 June '79	0800-1130	17° 57.6'N	65° 51.9'W	PLANKTON-2 (1000- 0 m) PLANKTON-3 (800-200 m) PLANKTON-4 (200- 0 m) PLANKTON-5 (1000-800 m) XBT-8	
"B-3"	6 June '79	1130-1342	17° 57.6'N	65° 51.9'W	HYDROCAST-2 K/CAST-1 K/CAST-2 XBT-9 COEN/CAST (Note 7)	
"B-4"	6 June '79	1400-1800	17° 57.6'N	65° 51.9'W	XBT-10 PLANKTON	T/PLANKTON (Note 8)
"B-5"	6 June '79	---	17° 57.6'N	65° 51.9'W	(Note 9)	PLANKTON XBT
"B-6"	6 June '79	2030-2300	17° 57.6'N	65° 51.9'W	CURRENT-1 XBT-11	
"B-7"	6-7 June '79	2310-0030	17° 57.6'N	65° 51.9'W	BIOCAST-1 K/CAST-3 K/CAST-4 XBT-12 TRANSMISSION-1 (Note 10)	
"B-8"	7 June '79	0230-0500	17° 57.6'N	65° 51.9'W	CURRENT-2 (Note 11) XBT-13	

Station	Date	Time (A.S.T.)	Latitude	Longitude	Accomplished	Not Accomplished
"B-9"	7 June '79	0814-1100	17° 57.6'N	65° 51.9'W	CURRENT-3 XBT-14	
"B-10"	7 June '79	1110-1345	17° 57.6'N	65° 51.9'W	BIOCAST-2 XBT-15 (Note 12)	TRANS. (Note 11)
"B-11"	7 June '79	1430-1700	17° 57.6'N	65° 51.9'W	CURRENT-4 XBT-16	
"B-12"	8 June '79	0330-0600	17° 57.6'N	65° 51.9'W	CURRENT-5 (Note 11)	XBT (Note 13)
"V-1"	8 June '79	0840-1130	18° 03'N	65° 32'W	HYDRO/BIOCAST-7 XBT-17 K/CAST-5 K/CAST-6 PLANKTON-(800-200 m) PLANKTON-(200- 0 m)	
"A"	8 June '79	1228	18° 02'N	65° 40'W	XBT-18	
"B-13"	8 June '79	1335	17° 57.6'N	65° 51.9'W	PLANKTON-6 (25 m Horz.)	
"F"	8 June '79	1445-1551	17° 51.7'N	65° 46.9'W	HYDRO/BIOCAST-8 XBT-19 SPECIAL/CAST (Note 14)	
"PO"	8 June '79	1720	17° 50'N	66° 00'W	XBT-20	(Note 4)
"PI"	8 June '79	---	17° 56'N	66° 00'W	NOT VISITED	(Note 15)
"JI"	8 June '79	---	17° 54'N	66° 05'W	NOT VISITED	(Note 15)
"SI"	8 June '79	---	17° 50'N	66° 17.5'W	NOT VISITED	(Note 15)

Station	Date	Time (A.S.T.)	Latitude	Longitude	Accomplished	Not Accomplished
"MI"	8 June '79	---	17° 54'N	66° 28.5'W	NOT VISITED	(Note 15)
"GI"	8 June '79	---	17° 57'N	66° 47'W	NOT VISITED	(Note 15)
"KI"	---	---	18° 02'N	65° 48'W	NOT VISITED	(Note 9) (Note 15)
"KO"	---	---	18° 00'N	65° 47.5'W	NOT VISITED	(Note 9) (Note 15)

Notes---

--1 EDO Transducer and Gifft Recorder leased from Tracor Marine was used at this station, and no return signal could be detected, although the depth was about 675 fathoms.

--2 As Fathometer was not working, depth could only be estimated, and due to angle of cable, Grab Sampler never touched bottom.

--3 Due to drift of vessel and no Fathometer, bottom bottle in Hydrocast was dragged along the bottom-sediment in bottle, but no damage.

--4 Station "PO" was skipped due to the late hour, and its close proximity to station "JO".

--5 These two K/CASTS were postponed until the next night.

--6 The Lift Net Fishing experiment was unseccessful due to the motion of the vessel.

--7 The COEN/CAST was to draw water for LBL experiment from depths of 0, 25, 50, 75, 100, 125, and 150 m.

--8 None of the equipment was brought on board for the T/PLANKTON experiments.

--9 As the original plan called for breaking away from the mooring to go to Yabucoa at this time, and there was no further need to go to Yabucoa, we did not separate from the mooring at this time, but simply postponed this Horizontal Plankton tow for 8 June.

--10 Again Transmissometer did not function properly (in spite of using only a 100 ft. cable and no depth probe). The instrument was not used again.

--11 Recorder in the Current Meter did not advance, resulting in no data. This Cast was repeated 8 June successfully.

--12 The Hydrowhinch Control Circuit malfunctioned, causing a delay of about 1 hour until the remaining 6 Hydrobottles could be recovered.

--13 XBT was forgotten at this station.

--14 Four Casts were made to 10 m to recover 5 gallons of water for Dr. Kay's Foam OTEC experiment

--15 Because there was no working Fathometer and these stations are located in areas of fast changing Bathymetry, the chance of loosing Hydrobottles and reversing Thermometers was too great to risk visiting these stations.

BIOLOGICAL REPORT FOR CRUISE 806

During the days comprising the fourth to the ninth of June 1979 the following was accomplished:

--All Zooplankton samples were effectively collected.

--25 m horizontal day

--25 m horizontal night

--1000-sec-vertical

--1000-800-vertical

--800-200-vertical

--200-sec-vertical
while on station

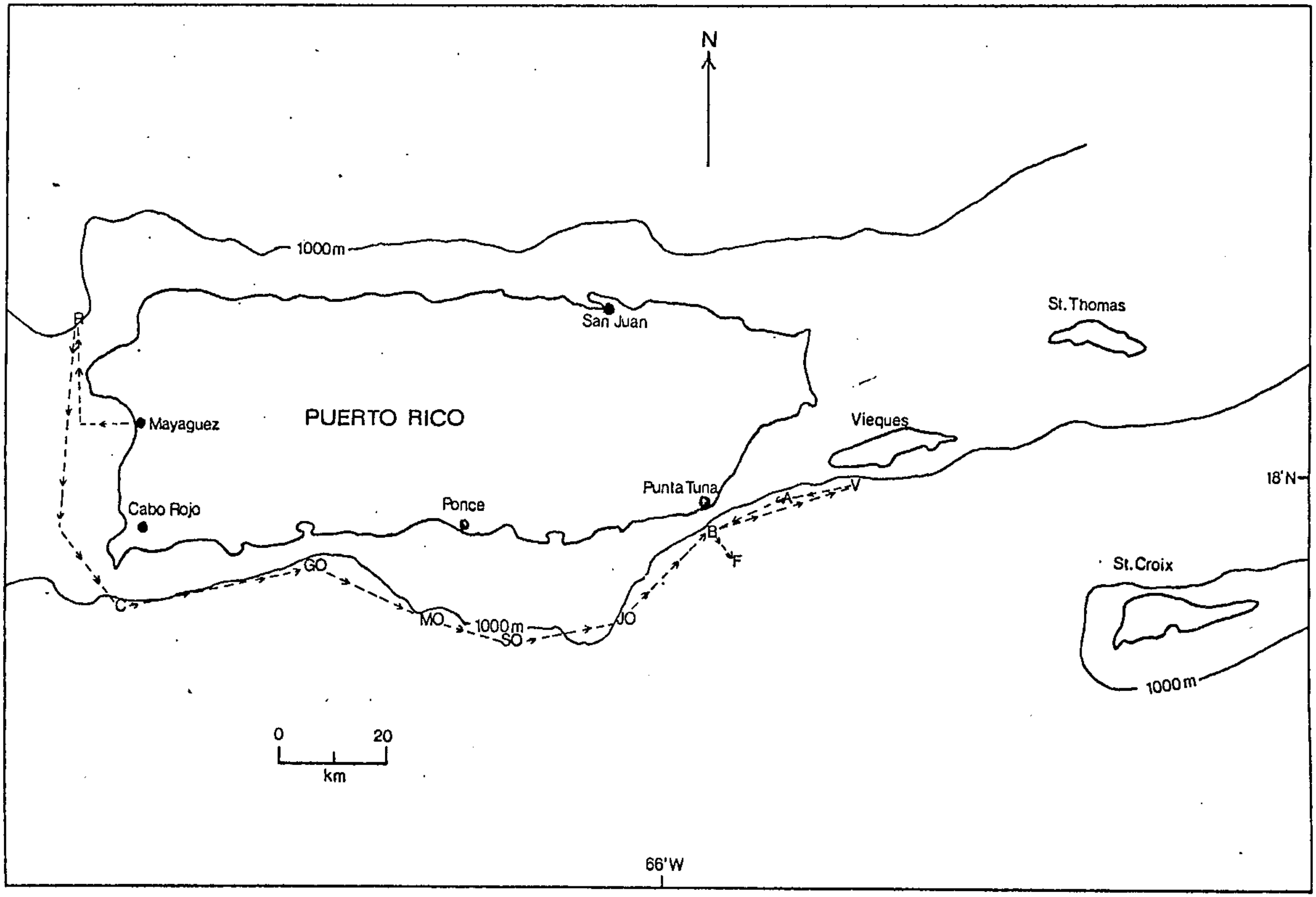
As usual all the fish and organisms collected during the cruise are being identified for the Final Report.

An inspection dive was conducted at the buoy in which the state of the cable was checked down to 160 feet. Organisms from the cable and rope were collected and will be included in the Final Report.

Daniel Pesante

Biological Coordinator

Trackline for OTEC CRUISE #6(CR-806), 4-9 June 1979



WEATHER CODE FOR DATA SHEETS

(All times are Atlantic Standard Time (AST) = GMT - 4 hours)

7 KT/130°, 91°, 47%, 1, 150°

7 KT = Wind Speed (KT)

130° = Wind Direction - from (Deg)

91° = Air Temperature (°F)

47% = Relative Humidity (%)

1 = Wave Height (m)

150° = Wave Direction - from (Deg)

CRUISE CR-806 STATION 8 DATE 9 June 1979 WEATHER 7KT/060°, 84°, 30%, 1/2, 225°

DATES 8-9 June 1979 LOCATION 19° 27.5'N, 67° 15'W WIRE ANGLE 12°

GENERAL AREA West of Rincon, P.R. TIME 1600-1730 AST; Hydro/Biocast (1625-1730), XBT (1730)

SHIP Crawford MAR. SQ. 43 TIME GMT 2030 DEPTH TO BOTTOM 1200 MAX SAMPLE 520 BAR 1011

												XBT		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O_2 (ML/L)	CHLOR A* (µG/L)	PHEO A* (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_3 (µG AT/L)	NH_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.86	35.576	22.89	4.488	.02	.01	N.A.	0.75	--	--	--	000	28.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
046	26.90	36.187	23.66	4.462	.03	.05		0.62	--	--	--	044	27									
093	24.60	36.607	24.70	4.287	.08	.04		1.22	--	0.31	0.37	079	26									
135	21.19	36.771	25.81	4.147	.02	.01		1.12	--	--	--	089	25									
185	19.14	--	---	4.095	.02	.01		0.95	--	--	--	100	24									
230	18.47	--	---	4.287	.02	.01		0.93	--	0.28	3.46	114	23									
276	17.66	36.424	26.46	3.850	.02	0		0.54	--	--	---	125	22									
369	16.01	36.227	26.71	3.500	.01	.01		1.37	--	0.27	28.22	145	21									
461	14.26	35.993	26.92	3.500	.01	0		0.60	--	0.20	39.84	163	20									
553	12.98	35.769	27.01	3.263	.01	0		2.00	--	--	---	188	19									
737	9.13	35.225	27.29	3.237	.01	.01		2.75	--	0.32	49.29	241	18									
921	7.0	35.114	27.53	3.762	.01	.01		0.42	--	--	---	311	17									
												372	16									
												430	15									
												481	14									
												555	13									
												589	12									
												620	11									
												655	10									
												740	9									
												800	8									
												873	7									

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000	27.86	35.576	22.89
010	27.70	35.675	23.02
020	27.50	35.800	23.20
030	27.30	35.950	23.38
040	27.05	36.100	23.55
050	26.80	36.250	23.75
075	25.70	36.510	24.25
100	24.00	36.660	24.83
125	21.90	36.750	25.63
150	20.30	36.770	25.90
175	19.40	36.720	26.05
200	18.80	36.625	26.16
250	18.10	36.490	26.40
300	17.25	36.375	26.58
400	15.40	36.170	26.82
500	13.75	35.895	26.99
600	12.00	35.580	27.08
700	9.80	35.300	27.24
800	8.15	35.175	27.40
900	7.15	35.125	27.52
1000			

CRUISE CE-506. STATION C DATE 4-5 June 1979 WEATHER 11KT 098°, 82°, 95%, 1, 090°
DATES 4-9 June 1979 LOCATION 17° 51'N, 67° 11'W WIRE ANGLE 12°
GENERAL AREA South of Cabo Rojo, P.R. TIME 2215-0130 AST; Hydro/Biocast (2215-2330), XBT (2335), SED (2350-0115), Plankton (0115-0130)
SHIP [illegible] MAR. SQ. 43 TIME GMT 0215 DEPTH TO BOTTOM 1200 MAX SAMPLE 880 EAP 1011

												XBT-2		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	SIG (σ_t)	DIS.O. (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO_4 µG AT/L	SiO_3 µG AT/L	NO_3 µG AT/L	N_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.85	35.625	22.93	4.357	.11	0	N.A.	0.60	--	--	--	000	27.75	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
042	27.35	35.620	23.24	4.287	.40	.13		0.49	--	--	--	054	27									
085	24.75	36.876	24.86	4.346	.17	.01		0.30	--	--	--	070	26									
127	22.90	36.956	25.46	4.112	.03	.03		0.86	--	0.45	30.55	079	25									
169	20.20	36.852	26.14	4.025	.02	.01		0.80	--	--	--	098	24									
211	18.79	36.578	26.30	4.200	.01	0		0.64	--	--	--	128	23									
253	18.22	36.548	26.42	4.156	.01	.01		1.15	--	0.41	11.80	140	22									
338	17.09	36.373	26.56	3.482	.01	.01		0.75	--	--	--	156	21									
423	15.20	36.150	26.83	3.386	.01	.01		0.95	--	--	--	172	20									
509	12.90	35.690	26.97	2.922	.01	0		0.76	--	--	--	202	19									
693	8.82	35.204	27.33	2.695	0	0		1.06	--	--	--	289	18									
880	6.16	34.968	27.53	3.351	.01	0		0.81	--	--	--	340	17									
												385	16									
												415	15									
												440	14									
												490	13									
												531	12									
												580	11									
												620	10									
												665	9									
												710	8									
												768	7									

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000	27.85	35.625	22.93
010	27.80	35.650	22.97
020	27.65	35.675	23.03
030	27.50	35.725	23.13
040	27.40	35.800	23.23
050	27.00	36.350	23.40
075	25.60	36.800	24.35
100	23.85	36.930	25.10
125	23.00	36.950	25.45
150	21.65	36.925	25.90
175	19.90	36.830	25.20
200	19.00	36.620	26.29
250	18.22	36.548	26.40
300	17.60	36.480	26.50
400	15.70	35.225	26.77
500	13.20	35.750	26.96
600	10.55	35.490	27.15
700	6.65	35.200	27.33
800	7.15	35.060	27.48
900			
1000			

CRUISE CE-206 STATION 60 DATE 5 June 1979 WEATHER 11KT/090°, 81°, 95%, 1, 090°
DATES 4-9 June 1979 LOCATION 17° 49'N, 66° 47'W WIRE ANGLE 20°
GENERAL AREA South of Guayanilla, P.R. TIME 0413-0630 AST; Hydro/Biocast (0413-0522), XBT (0525), Plankton (0525-0630)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0813 DEPTH TO BOTTOM 1200 MAX SAMPLE 900 BAR 1012

												XBT-3		ILLUMINATION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O$_2$ (ML/L)	CHLOR A (µG/L)	PHEO A (µG/L)	ATP (µG/L)	PO$_4$ (µG AT/L)	SiO$_3$	NO$_3$ (µG AT/L)	NH$_3$	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.62	35.579	22.97	4.471	.01	.03	N.A.	0.53	—	0.32	1.10	000	27.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
044	27.26	36.775	23.99	4.480	.03	.06		0.89	--	--	--	058	27									
088	25.15	36.996	24.82	4.243	.05	.14		0.52	--	0.30	3.16	069	26									
133	22.57	36.943	25.54	4.497	.03	.03		0.61	--	--	--	092	25									
177	20.36	36.832	26.08	4.278	.01	.01		0.67	--	--	--	110	24									
220	19.09	36.661	26.28	4.095	.01	.01		0.90	--	--	--	129	23									
265	18.29	36.549	26.40	4.243	.01	0		0.98	--	--	--	149	22									
353	16.86	36.318	26.59	3.990	.01	0		1.13	--	--	--	170	21									
442	14.84	36.015	26.81	3.543	.01	0		1.60	—	--	—	190	20									
530	12.32	35.579	26.99	2.992	.01	0		2.14	--	0.32	34.44	224	19									
712	8.45	35.087	27.29	2.966	.01	0		2.82	--	--	--	290	18									
897	6.11	35.001	27.56	3.657	.01	.01		2.08	--	0.30	2.65	341	17									
												388	16									
												432	15									
												460	14									
												498	13									
												532	12									
												575	11									
												625	10									
												658	9									
												725	8									
												795	7									

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000	27.62	35.579	22.97
010	27.60	35.685	23.20
020	27.60	35.875	23.45
030	27.50	36.100	23.70
040	27.30	36.500	23.92
050	27.00	36.825	24.12
075	26.00	36.965	24.63
100	24.50	37.000	25.03
125	23.00	36.965	25.45
150	21.60	36.910	25.80
175	20.50	36.845	26.05
200	19.70	36.760	26.20
250	18.60	36.590	26.38
300	17.80	36.475	26.49
400	15.65	36.180	26.70
500	13.20	35.725	25.94
600	10.65	35.300	27.12
700	8.70	35.105	27.29
800	7.20	35.030	27.45
900			
1000			

CRUISE CR-106 STATION 20 DATE 5 June 1979 WEATHER 5KT/115°, 85°, 80%, 1, 135°

DATES 4-9 June 1979 LOCATION 17° 48'N, 66° 28.5' W WIRE ANGLE 13°

GENERAL AREA South East of Isla Caja de Muertos P.R. TIME 0000-1115 AST; Hydro/Stocast (0900-1021), XBT (1035), STD (1025-1100), Plankton (1100-1115)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1300 DEPTH TO BOTTOM 1200 MAX SAMPLE 810 BAR 1016

												XBT		TRANSPARENCY		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DISS O_2 (ML/L)	CHLOR A (µG/L)	PHAEO A (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_3 (µG AT/L)	K_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.59	35.529	22.95	4.462	.07	.03	N.A.	0.83	--	0.44	0.85	000	27.8	N.A.	N.A.	N.A.	N..A	N.A.	N.A.	N.A.	N.A.	N.A
046	27.17	35.790	23.28	4.375	.20	0		0.65	--	--	--	049	27									
095	24.38	36.884	24.97	4.436	.21	0		0.53	--	0.38	1.06	059	26									
136	22.34	36.965	25.63	4.375	.07	0		0.69	--	--	--	078	25									
182	20.01	36.710	26.08	4.200	.02	.02		0.90	--	--	--	112	24									
226	18.71	36.641	26.37	4.200	.01	.01		0.62	--	--	--	128	23									
272	13.11	36.554	26.45	4.200	.01	.01		0.95	--	--	--	150	22									
363	16.33	36.311	26.70	3.613	.01	.01		1.05	--	0.33	22.49	164	21									
453	13.94	35.873	26.89	3.237	.01	.01		2.11	--	--	--	186	20									
544	11.84	35.533	27.05	2.773	.01	.01		2.13	--	0.32	17.71	215	19									
706	8.25	35.065	27.31	2.870	.01	..01		3.31	--	--	--	290	18									
806	7.06	34.930	27.38	3.045	0	.04		4.32	--	--	--	334	17									
												376	16									
												410	15									
												440	14									
												488	13									
												522	12									
												575	11									
												600	10									
												650	9									
												714	8									

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000	27.59	35.529	22.95
010	27.60	35.575	22.99
020	27.55	35.625	23.05
030	27.40	35.685	23.12
040	27.35	35.755	23.22
050	27.00	35.850	23.32
075	26.00	36.250	23.82
100	24.20	36.895	25.06
125	22.90	36.960	25.55
150	21.60	36.910	25.78
175	20.30	36.750	26.03
200	19.40	36.690	26.20
250	18.30	36.600	26.42
300	17.60	36.480	26.49
400	15.30	36.150	26.78
500	12.80	35.690	26.96
600	10.20	35.355	27.15
700	8.35	35.080	27.30
800	7.08	34.930	27.38
900			
1000			

CRUISE CC-308 STATION 50 DATE 5 June 1979 WEATHER 7K1/110°, 83°, 78%, 1, 110°

DATES 4-9 June 1979 LOCATION 17° 48'N, 66° 17.5'W WIRE ANGLE 15°

GENERAL AREA South of Salinas, P.R. TIME 1235-1500 AST: Hydro/Biocast (1235-1246), XBT (1355), SED (1400-1445), Plankton (1445-1500)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1635 DEPTH TO BOTTOM 1200 MAX SAMPLE 920 BAR 1016

												XBT-S		TRANSMISSOMETER		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	SIGMA (σ_t)	DISS O_2 (ML/L)	CHLOR A (μG/L)	PHAEO A (μG/L)	ATP (μG/L)	PO_4 μG AT/L	SiO_3 μG AT/L	NO_3 μG AT/L	N_2	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.81	35.616	23.69	4.525	.02	.01	N.A.	0.59	--	--	--	000	28.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
045	26.47	36.226	23.83	4.552	.27	0		0.78	--	--	--	048	27									
092	24.52	37.012	25.03	4.344	.11	.04		0.84	--	--	--	056	26									
137	22.17	36.916	25.64	4.344	.11	0		0.91	--	--	--	080	25									
182	20.08	36.795	26.13	4.235	.03	.02		0.58	--	0.33	3.49	101	24									
226	18.93	36.657	26.32	4.226	.02	.01		0.84	--	--	--	129	23									
272	18.14	36.560	26.45	4.280	.01	.01		0.88	--	0.31	13.71	145	22									
354	16.12	36.271	26.71	3.819	.01	.01		0.85	--	--	--	165	21									
455	13.53	35.820	26.94	3.194	.01	0		0.85	--	--	--	192	20									
547	11.72	35.459	27.02	2.896	.02	.01		0.89	--	--	--	229	19									
728	7.77	34.982	27.31	2.868	.01	0		3.04	--	0.27	23.36	282	18									
916	5.82	34.911	27.53	3.801	.01	0		2.41	--	--	--	320	17									
												368	16									
												408	15									
												441	14									
												492	13									
												540	12									
												556	11									
												599	10									
												630	9									
												710	8									
												799	7									

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000	27.81	35.616	23.69
010	27.60	35.640	23.70
020	27.25	35.650	23.75
030	26.90	35.800	23.48
040	26.60	36.100	23.80
050	26.20	36.475	23.85
075	25.10	36.900	24.65
100	24.00	37.010	25.20
125	22.65	36.975	25.55
150	21.30	36.850	25.78
175	20.40	36.760	26.10
200	19.60	36.700	26.25
250	18.55	36.625	26.38
300	17.50	36.570	26.52
400	15.10	36.075	26.82
500	12.50	35.635	27.00
600	10.60	35.265	27.10
700	8.35	35.010	27.28
800	6.70	33.935	27.42
900	5.90	34.915	27.52
1000			

CRUISE CE-806 STATION 10 DATE 5 June 1979 WEATHER 11KT/110°, 81°, 83%, 1, 110°

DATES 4-9 June 1979 LOCATION 17° 48'N, 66° 04' W WIRE ANGLE 20°

GENERAL AREA South East of Jobos, P.R. TIME 1703-1930 AST; Hydro/Biocast (1703-1803), XBT (1814), STD (1810-1915), Plankton (1915-1930)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2103 DEPTH TO BOTTOM 1200 MAX SAMPLE 890 SAP 1013

												XBT		TRANSMISSOMETER		STD				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σt)	DIS.O2 (ML/L)	CHLOR"A" (μG/L)	PHEO"A" (μG/L)	ATP (μG/L)	PO4 (μG AT/L)	SiO3 (μG AT/L)	NO3 (μG AT/L)	NH3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σt)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.73	35.700	23.03	4.778	.03	0	N.A.	0.90	--	--	--	000	27.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
043	27.44	35.847	23.23	4.669	.03	0		0.76	--	--	--	053	27									
087	24.87	36.725	24.70	4.850	.23	0		0.71	--	--	--	066	26									
130	22.26	36.963	25.65	4.706	.03	.02		0.47	--	0.32	2.12	090	25									
174	20.03	36.748	26.10	4.525	.02	.02		0.86	--	--	--	111	24									
217	18.94	36.618	26.29	4.669	.01	.01		0.69	--	--	--	125	23									
261	18.24	36.565	26.43	4.669	.01	0		0.72	--	0.30	3.89	140	22									
347	16.40	36.242	26.63	4.144	.01	.01		1.31	--	--	--	168	21									
434	14.63	36.000	26.84	3.801	.01	.01		0.59	--	0.32	22.72	175	20									
521	12.65	35.661	26.99	3.366	.01	0		1.97	--	--	--	224	19									
703	8.05	34.992	27.28	3.058	.01	0		3.03	--	--	--	285	18									
890	5.89	34.917	27.52	3.801	.01	.01		3.34	--	--	--	339	17									
												371	16									
												413	15									
												455	14									
												521	13									
												533	12									
												562	11									
												612	10									
												650	9									
												705	8									
												778	7									

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000	27.73	35.700	23.03
010	27.70	35.720	23.03
020	27.70	35.740	23.05
030	27.60	35.770	23.12
040	27.40	35.815	23.20
050	27.15	35.875	23.41
075	26.10	36.550	24.30
100	24.30	36.865	25.10
125	22.50	36.960	25.62
150	21.18	36.940	25.90
175	20.[illegible]	[illegible]	26.10
200	19.[illegible]	[illegible]	26.22
250	18.40	36.600	26.40
300	17.40	36.450	26.55
400	16.2[illegible]	[illegible]	26.77
500	13.10	35.762	26.95
600	10.4[illegible]	35.375	27.11
700	8.10	[illegible]	27.25
800	6.55	34.925	27.40
900			
1000			

CRUISE CB-80C STATION B-1 DATE 5 June 1979 WEATHER 10KT/090°, 83°, 87%, 1, 120°
DATES 4-9 June 1979 LOCATION 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA South of Punta Tuna, P.R. TIME 2100-2400 AST; Hydrocast (2220-2323), XBT (2335), Plankton (2100-2200)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0100 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1015

												XBT- 7		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHAEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2 (μG AT/L)	NO_2 (μG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.79	35.591	23.52	4.558	N.A.	N.A.		0.81	1.57	0.36	0.82	000	28.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
047	26.02	36.375	24.08	4.576				0.85	0.59	0.36	1.19	041	27									
094	24.27	36.839	24.97	4.802				0.57	--	0.34	0.87	060	26									
144	22.28	36.893	25.59	4.558				0.62	--	0.28	0.27	080	25									
191	19.92	36.698	26.10	4.454				0.65	0.69	0.31	3.06	104	24									
238	18.73	36.580	26.31	4.454				0.96	1.02	0.27	1.52	124	23									
282	18.05	36.495	26.42	4.355				0.84	1.05	0.26	0.59	146	22									
375	16.37	36.344	26.71	3.932				1.35	2.80	0.33	32.23	172	21									
470	14.43	35.926	26.83	3.445				1.57	5.13	0.24	12.29	194	20									
563	12.09	35.570	27.03	3.219				8.83	2.08	--	---	221	19									
751	7.07	34.903	27.35	2.958				3.32	20.16	0.22	16.22	290	18									
939	5.50	34.954	27.60	4.002				3.25	24.22	0.25	14.32	352	17									
- - - - - -	- - - -	- - - -	- - - -									393	16									
000	27.79	35.591	23.52									450	15									
010	27.40	35.750	23.65									510	14									
020	27.05	35.975	23.78																			
												538	13									
030	26.70	36.160	23.90									566	12									
040	26.35	36.325	24.05									588	11									
050	26.00	36.450	24.13																			
												605	10									
075	25.00	36.700	24.58									655	9									
100	24.00	36.265	25.00									695	8									
125	22.90	36.910	25.38																			
												776	7									
150	21.80	36.890	25.68									830	6									
175	20.70	36.805	25.98																			
200	19.70	36.680	26.15																			
250	18.50	36.560	26.33																			
300	17.70	36.480	26.49																			
400	15.95	36.270	26.76																			
500	13.75	35.810	26.88																			
600	11.10	35.440	27.12																			
700	8.25	35.000	27.30																			
800	6.65	34.905	27.45																			
900	5.70	34.930	27.58																			
1000																						

CRUISE: CR-806 STATION: B-2 DATE: 6 JUNE 1979 WEATHER: 12KT/110°, 84°, 76%, 1, 130°

DATES: 4-9 JUNE 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0800-1130 AST; PLANKTON (0800-1130), XBT (0920)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1200 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1015

XBT- 8

DEPTH (M)	TEMP (°C)
000	27.9
035	27
051	26
069	25
101	24
125	23
142	22
170	21
194	20
228	19
291	18
350	17
385	16
430	15
482	14
535	13
579	12
602	11
624	10
660	9
701	8
778	7

CRUISE [illegible] STATION [illegible] DATE [illegible] 1979 WEATHER [illegible] 27° [illegible] 1, 115°

DATES [illegible] June 1979 LOCATION 17° 57.[illegible] [illegible] WIRE ANGLE 0°

GENERAL AREA South of Punta Tuna, P.R. TIME [illegible] AST; [illegible] ([illegible]), [illegible], [illegible] ([illegible]), [illegible] ([illegible]-1250)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1530 DEPTH TO BOTTOM [illegible] MAX SAMPLE 1000 BAR 1015

												XBT		TRANSMISSOMETER		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO_4 µG-AT/L	SiO_2	NO_2 µG-AT/L	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.83	35.622	22.95	4.437	N.A.	N.A.	N.A.	0.75	2.06	0.23	0.10	000	28.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
047	26.11	36.335	24.03	4.524				0.77	1.43	0.32	1.75	040	27.0									
094	24.40	36.659	24.95	4.524				0.51	0.60	0.30	1.52	059	26									
141	22.52	36.945	25.57	4.445				0.51	1.77	0.31	1.13	061	25									
188	20.31	35.719	26.01	4.297				0.88	1.70	0.37	3.05	105	24									
235	18.67	36.549	26.31	4.350				0.90	1.23	0.27	2.91	132	23									
282	17.87	---	---	---				0.84	1.55	0.37	4.44	150	22									
- - - - -												170	21									
000	27.83	35.622	22.95									191	20									
010	27.60	35.750	23.18									221	19									
020	27.35	35.925	23.32									282	18									
030	26.75	36.100	23.70									342	17									
040	26.40	36.250	23.90									401	16									
050	26.00	36.400	24.10									452	15									
075	25.10	36.710	24.58									491	14									
100	24.20	36.875	24.98									530	13									
125	23.30	36.925	25.35									560	12									
150	22.05	36.910	25.65									588	11									
175	21.00	36.825	25.90									600	10									
200	19.95	36.700	26.10									633	9									
250	18.40											680	8									
300												776	7									
400																						
500																						
600																						
700																						
800																						
900																						
1000																						

CRUISE: CR-806 STATION: B-4 DATE: 6 JUNE 1979 WEATHER: 11KT/110°, 88°, 73%, 1, 110°
DATES: 4-9 JUNE 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 1400-1800 AST; PLANKTON (1400-1800), XBT (1715)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1800 DEPTH TO BOTTOM 1120 MAX SAMPLE 1000 BAR 1014

XBT-10	
DEPTH (M)	TEMP (°C)
000	28.1
045	27
062	26
082	25
109	24
138	23
159	22
179	21
190	20
211	19
262	18
304	17
342	16
398	15
425	14
522	13
546	12
585	11
620	10
646	9
696	8
762	7
890	6

CRUISE: CR-806 STATION: B-6 DATE: 6 June 1979 WEATHER: 10KT/118°, 83°, 80%, 1, 120°

DATES: 4-9 June 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (Buoy) WIRE ANGLE: N.A.

GENERAL AREA: Punta Tuna, P.R. TIME: 2030-2300 AST; Current (2030-2300), XBT (2100)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0030 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1015

XBT-11

Depth (M)	Temp (°C)
000	28.0
041	27
062	26
080	25
105	24
133	23
153	22
175	21
204	20
232	19
296	18
346	17
376	16
411	15
449	14
528	13
550	12
579	11
608	10
638	9
714	8
810	7

Current-1

Depth (M)	Dir. (DEG)	Speed (CM/SEC)
025	264	7
050	096	5
075	060	8
100	024	5
125	348	7
150	264	12
175	252	12
200	240	7
250	348	4
300	336	8
400	324	7
500	036	10
750	048	3

CRUISE CI-806 STATION B-7 DATE 6-7 JUNE 1979 WEATHER 10KT/118°, 63°, 80%, 1, 120°
DATES 4-9 JUNE 1979 LOCATION 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE 0°
GENERAL AREA SOUTH OF PUNTA TUNA, P.R. TIME 2310-0030 AST; BIOCAST (2342-0027), N/CAST (2310-2320), XBT (2335), TRANSMISSION (2320-2340)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0310 DEPTH TO BOTTOM 1120 MAX SAMPLE 400 BAR 1016

												XBT-12		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DIS.O2 (ML/L)	CHLOR"A" (µG/L)	PHAEO"A" (µG/L)	ATP (µG/L)	PO4 (µG AT/L)	SiO3 (µG AT/L)	NO3 (µG AT/L)	NH3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σT)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.81	35.627	22.95	N.A.	.10	0	N.A.	N.A.	N.A.	N.A.	N.A.	000	28.0	INSTRUMENT	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
023	27.46	35.628	23.05		.08	.05						032	27									
047	25.93	36.398	24.13		.14	0						051	26	MAL-								
071	24.84	36.802	24.77		.15	.03						070	25	FUNCTION								
094	24.10	36.895	25.07		.09	.08						100	24									
118	23.13	36.990	25.42		.05	.06						125	23									
141	22.57	36.911	25.53		.03	.04						151	22									
165	21.63	36.865	25.76		.04	.02						176	21									
188	20.17	36.710	26.04		.03	.03						200	20									
235	18.80	36.563	25.28		.01	.01						229	19									
283	18.14	36.534	26.43		.01	0						300	18									
377	16.34	36.257	26.65		.01	0						354	17									
												390	16									
												426	15									
												460	14									
												525	13									
												561	12									
												589	11									
												612	10									
												651	9									
												712	8									
												796	7									
												911	6									

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000	27.81	35.627	22.95
010	27.70	35.627	23.00
020	27.55	35.628	23.04
030	27.40	35.630	23.15
040	26.60	36.000	23.60
050	25.90	36.525	24.25
075	24.80	36.825	24.85
100	23.80	36.920	25.15
125	23.00	36.925	25.40
150	22.30	36.910	25.60
175	21.00	36.825	25.86
200	19.95	36.670	26.10
250	18.55	36.570	26.33
300	17.75	36.525	26.48
400			
500			
600			
700			
800			
900			
1000			

CRUISE: CR-806 STATION: B-8 DATE: 7 JUNE 1979 WEATHER: 12KT/110°, 82°, 82%, 1, 115°
DATES: 4-9 JUNE 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 0230-0500 AST; CURRENT (0230-0500), XBT (0230)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0630 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1015

XBT-13

DEPTH (M)	TEMP (°C)
000	28.0
038	27
059	26
085	25
110	24
138	23
155	22
178	21
200	20
229	19
279	18
325	17
362	16
405	15
457	14
548	13
579	12
598	11
615	10
650	9
695	8
759	7
862	6

CURRENT-2

DEPTH (M)	DIR. (DEF)	SPEED (CM/SEC)

INSTRUMENT
MALFUNCTION

CRUISE: CR-806 STATION: B-9 DATE: 7 June 1979 WEATHER: 8KT/120°, 83°, 72%, 1, 120°

DATES: 4-9 June 1979 LOCATION: 17° 57.6'N, 51.9'W (Buoy) WIRE ANGLE: N.A.

GENERAL AREA: Punta Tuna, P.R. TIME: 0810-1100 AST; Current (0830-1100), XBT (0810)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1210 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1015

XBT-14

Depth (M)	Temp (°C)
000	27.9
036	27
055	26
076	25
101	24
135	23
158	22
178	21
198	20
219	19
274	18
323	17
362	16
413	15
450	14
522	13
558	12
590	11
624	10
650	9
711	8
788	7
919	6

Current-3

Depth (M)	Dir. (DEG)	Speed (CM/SEC)
025	300	12
050	072	10
075	072	6
100	060	5
125	000	5
150	---	--
175	144	7
200	---	--
250	072	10
300	036	10
400	---	--
500	060	10
750	144	5

CRUISE CR-306 STATION B-10 DATE 7 June 1979 WEATHER 5KT/120°, 87°, 70%, 1, 120°
DATES 4-9 June 1979 LOCATION 17° 57.5'N, 65° 51.9'W (Buoy) WIRE ANGLE 0°
GENERAL AREA South of Punta Tuna, P.R. TIME 1110-1345 AST; Biocast (1110-1345), XBT (1310)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1510 DEPTH TO BOTTOM 1120 MAX SAMPLE 902 BAR 1016

												XBT-15		TRANSMISSION		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DIS.O_2 (ML/L)	CHLOR"A" (µG/L)	PHEO"A" (µG/L)	ATP (µG/L)	PO_4 (µG AT/L)	SiO_3 (µG AT/L)	NO_2 (µG AT/L)	NO_3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRANS (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_T)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	27.92	35.624	22.91	N.A.	.03	0	N.A.	N.A.	N.A.	N.A.	N.A.	000	28.25	INSTRUMENT		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
023	27.70	35.629	22.99		.02	.01						010	28									
047	26.07	36.448	24.12		.04	0						035	27	MAL-								
071	25.02	36.719	24.65									062	26	FUNCTION								
094	24.26	36.877	25.00		.19	0						087	25									
118	23.68	36.880	25.18		.15	0						110	24									
141	22.99	36.899	25.40		.10	0						148	23									
165	21.64	36.866	25.75		.09	0						164	22									
188	20.02	36.886	26.21		.04	0						172	21									
235	18.79	36.588	26.31		.02	0						190	20									
283	17.94	36.477	26.43		.02	0						230	19									
377	16.27	36.275	26.68		.02	0						287	18									
- - - -	- - - -	- - - -	- - - -																			
000	27.92	35.624	22.91									331	17									
010	27.80	35.625	22.95									385	16									
020	27.70	35.628	22.96									425	15									
030	27.20	35.950	23.45									454	14									
040	26.60	36.275	23.90									519	13									
050	26.00	36.460	24.20									560	12									
075	24.90	36.750	24.72									588	11									
100	24.05	36.877	25.02									611	10									
125	23.50	36.890	25.25									644	9									
150	22.55	36.875	25.50									705	8									
175	21.10	35.675	26.02									782	7									
200	19.50	36.850	26.27									900	6									
250	18.60	36.530	26.35																			
300	17.40	36.440	26.48																			
400																						
500																						
600																						
700																						
800																						
900																						
1000																						

CRUISE: CR-806 STATION: B-11 DATE: 7 JUNE 1979 WEATHER: 5KT/115°, 83°, 82%, 1/2, 120°
DATES: 4-9 JUNE 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.
GENERAL AREA: PUNTA TUNA, P.R. TIME: 1430-1700 AST; CURRENT (1430-1700), XBT (1628)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1830 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1014

XBT-16	
DEPTH (M)	TEMP (°C)
000	28.6
012	28
046	27
065	26
085	25
125	24
150	23
157	22
164	21
184	20
216	19
269	18
318	17
375	16
425	15
456	14
526	13
565	12
595	11
606	10
638	9
689	8
775	7
886	6

CURRENT-4		
DEPTH (M)	DIR. (DEG)	SPEED (CM/SEC)
025	072	7
050	---	--
075	072	8
100	---	--
125	252	8
150	300	6
175	060	6
200	084	12
250	084	7
300	084	6
400	024	4
500	036	10
750	036	3

CRUISE: CR-806 STATION: B-12 DATE: 8 JUNE 1979 WEATHER: 5KT/120°, 83°, 83%, 1/2, 120°

DATES: 4-9 JUNE 1979 LOCATION: 17° 57.6'N, 65° 51.9'W (BUOY) WIRE ANGLE: N.A.

GENERAL AREA: PUNTA TUNA, P.R. TIME: 0330-0600 AST; CURRENT (0330-0600)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 0730 DEPTH TO BOTTOM 1120 MAX SAMPLE 750 BAR 1015

CURRENT-5

DEPTH (M)	DIR. (DEG)	SPEED (CM/SEC)
025	084	10
050	072	12
075	120	5
100	252	5
125	240	5
150	084	7
175	012	10
200	012	7
250	084	7
300	012	5
400	---	--
500	072	6
750	036	5

CRUISE CR-606 STATION Y DATE 6 June 1979 WEATHER 5KT/130°, 85°, 778, 1/2, 090°

DATES 4-9 June 1979 LOCATION 18° 63'N, 65° 32'W WIRE ANGLE 15°

GENERAL AREA South of Punta Vaca, Vieques, P.R. TIME 0840-1130 AST; Hydro/Biocast (0905-1005), XBT (1012), Plankton (1005-1130), K/Cast (0840-0900)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1290 DEPTH TO BOTTOM 1200 MAX SAMPLE 1000 BAR 1015

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O_2 (ML/L)	CHLOR"A" (μG/L)	PHEO"A" (μG/L)	ATP (μG/L)	PO_4 (μG AT/L)	SiO_2	NO_2 (μG AT/L)	NO_3
000	27.78	35.702	23.02	4.550	.14	0	N.A.	1.25	--	0.32	1.20
046	26.34	36.256	23.89	4.502	.25	0		1.60	--	0.36	1.13
092	24.92	36.725	24.69	4.655	.08	.06		.88	--	--	--
138	23.09	36.861	25.34	4 655	.15	0		1.45	--	0.33	2.98
184	20.39	36.752	26.01	4 462	.02	.03		1.78	--	0.29	3.82
230	18.51	36.550	26.35	4.420	.02	.01		1.85	--	0.32	59.94
276	17.58	36.471	26.52	4.348	.01	.01		1.07	--	0.32	16.24
368	15.99	36.205	26.69	4.042	.01	.01		1.95	--	0.27	9.51
460	14.21	35.913	26.87	3.640	.01	.01		1.94	--	--	--
552	12.60	35.657	27.00	3.386	.01	.01		0.71	--	--	--
736	7.72	34.962	27.31	2.887	0	.03		3.40	--	0.26	23.60
920	5.83	34.928	27.54	3.736	.01	.02		1.72	--	0.32	41.97

XBT-17 DEPTH (M)	XBT-17 TEMP (°C)
000	28.0
035	27
052	26
098	25
113	24
141	23
152	22
175	21
200	20
221	19
261	18
335	17
374	16
424	15
461	14
520	13
564	12
590	11
620	10
661	9
711	8
778	7

TRANSMISSION DEPTH (M)	TRANS (%)	STD DEPTH (M)	STD TEMP (°C)	STD SALIN (PPT)	STD DENS (σ_t)	WATER CURRENTS DEPTH (M)	DIR (DEG)	SPEED (CM/S)
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A

- - - - - - - - - - - - - - - -

DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)
000	27.78	35.702	23.02
010	27.45	35.740	23.25
020	27.15	35.810	23.45
030	26.80	35.950	23.60
040	26.50	36.175	23.75
050	26.20	36.340	23.95
075	25.40	36.610	24.40
100	24.60	36.765	24.78
125	23.60	36.850	25.15
150	22.40	36.865	25.50
175	21.00	36.800	25.85
200	19.65	36.650	26.15
250	18.05	36.510	26.45
300	17.10	36.410	26.58
400	15.45	36.110	26.75
500	13.70	35.800	26.92
600	11.30	35.500	27.12
700	8.50	35.100	27.27
800	6.75	34.900	27.40
900	6.00	34.910	27.53
1000			

CRUISE: CR-806 STATION: A DATE: 8 June 1979 WEATHER: 6KT/130°, 85°, 77%, 1/2, 120°

DATES: 4-9 June 1979 LOCATION: 18° 02'N, 65° 40'W WIRE ANGLE: N.A.

GENERAL AREA: Between Punta Tuna and Vieques TIME: 1228 AST: XBT (1228)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1628 DEPTH TO BOTTOM 1200 MAX SAMPLE XBT BAR 1015

XBT-13

Depth (M)	Temp (°C)
000	28.1
040	27
058	26
081	25
120	24
140	23
152	22
170	21
196	20
233	19
260	18
318	17
368	16
415	15
464	14
510	13
558	12
589	11
634	10
656	9
698	8
748	7
928	6

CRUISE CE-806 STATION F DATE 8 June 1979 WEATHER 7KT/130°, 86°, 77%, 1/2, 120°

DATES 4-9 June 1979 LOCATION 17° 51.7'N, 65° 46.9'W WIRE ANGLE 13°

GENERAL AREA South East of Punta Tuna, P.R. TIME 1445-1555 AST; Hydro/Biocast (1500-1551), XBT (1555)

SHIP CRAWFORD MAR. SQ. 43 TIME GMT 1845 DEPTH TO BOTTOM 1950 MAX SAMPLE 900 BAR 1019

												XBT-19		TRANSPARENCY		S T D				WATER CURRENTS		
DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DIS.O2 (ML/L)	CHLOR A* (µG/L)	PHEO A* (µG/L)	ATP (µG/L)	PO4 (µG AT/L)	SiO3 (µG AT/L)	NO3 (µG AT/L)	NH3	DEPTH (M)	TEMP (°C)	DEPTH (M)	TRAN (%)	DEPTH (M)	TEMP (°C)	SALIN (PPT)	DENS (σ_t)	DEPTH (M)	DIR (DEG)	SPEED (CM/S)
000	28.14	35.642	22.85	4.550	.03	0	N.A.	1.43	--	0.32	23.12	000	28.4									
047	26.30	36.279	23.92	4.537	.02	.05		1.12	--	0.21	0.51	014	28									
092	24.42	36.836	24.92	4.637	.25	0		1.18		0.33	0.35	036	27									
139	22.64	36.830	25.44	4.663	.05	0		1.23	--	0.23	0.64	062	26									
186	20.16	36.765	26.08	4.392	.03	.05		1.43	--	0.36	0.95	089	25									
231	18.68	36.542	26.30	4.462	.01	.01		1.53	--	0.27	2.56	115	24									
273	18.12	36.521	26.42	4.488	.01	.01		1.73	--	0.23	3.60	133	23									
371	16.27	36.261	26.67	3.337	.01	.01		1.33	--	0.27	7.94	151	22									
463	13.48	35.799	26.93	3.500	.01	.01		1.68	--	0.29	22.92	176	21									
557	12.02	35.553	27.03	3.386	.01	.02		1.70	--	0.40	37.66	200	20									
741	7.65	34.942	27.30	2.948	.01	0		2.13	--	0.43	58.56	228	19									
926	5.69	34.919	27.55	3.762	.02	0		2.12	--	0.27	20.90	292	18									
- - - - - - -	- - -	- - -	- - -									350	17									
000	28.14	35.642	22.85									371	16									
010	27.35	35.725	22.98									401	15									
020	27.40	35.875	23.18																			
												440	14									
030	26.95	36.010	23.40									485	13									
040	26.45	36.165	23.70									550	12									
050	26.10	36.320	24.00																			
												601	11									
075	25.05	36.685	24.62									628	10									
100	24.10	36.860	25.02									670	9									
125	23.20	36.900	25.30																			
												719	8									
150	22.00	36.825	25.60									781	7									
175	20.55	36.735	25.37									891	6									
200	19.60	35.720	26.15																			
250	18.40	36.530	26.38																			
300	17.70	36.488	26.48																			
400	15.70	36.150	26.75																			
500	13.30	35.665	26.98																			
600	10.90	35.470	27.13																			
700	8.45	35.080	27.25																			
800	6.65	34.900	27.40																			
900	5.80	34.900	27.50																			
1000																						

CRUISE: CR-806 STATION: PO DATE: 8 June 1979 WEATHER: ---
DATES: 4-9 June 1979 LOCATION: 17° 50 N, 66° 00'W WIRE ANGLE: N.A.
GENERAL AREA: South of Patillas, P.R TIME: 1720 AST; XBT (1720)
SHIP CRAWFORD MAR. SQ. 43 TIME GMT 2120 DEPTH TO BOTTOM 1200 MAX SAMPLE XBT BAR 1014

XBT-20

Depth (M)	Temp (°C)
000	28.3
031	27
049	26
079	25
110	24
145	23
166	22
173	21
180	20
221	19
299	18
339	17
372	16
410	15
450	14
490	13
525	12
665	11
725	10
762	9

SIZE CLASS	SIZE IN MILLIMETERS
1	< 0.5
2	0.5 - 0.9
3	1.0 - 1.9
4	2.0 - 2.9
5	3.0 - 3.9
6	4.0 - 4.9
7	5.0 - 5.9
8	6.0 - 6.9
9	7.0 - 7.9
10	8.0 - 8.9
11	9.0 - 9.9
12	10.0 19.9
13	20.0 - 29.9
14	30.0 - 39.9
15	40.0 - 49.9
16	> 50.0

DATE:	5 June 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	0915
SAMPLE NUMBER:	806-35
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	55°
FLOWMETER START:	180124
FLOWMETER FINISH:	202841
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	1, cloudy

The quantities in the following data sheets are #/m^3

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata			7.585														7.585
Acrocalanus longicornis			5.689														6.689
Calocalanus pavo		22.756	3.793														26.549
Calocalanus pavoninus		5.689															5.689
Candacia sp.		9.481															9.481
Clausocalanus sp.		17.067	26.548														43.615
Corycaeus catus			1.896														1.896
Corycaeus latus		3.793	17.067														20.86
Corycaeus speciosus			1.896														1.896
Eucalanus elongatus					1.896												1.896
Eucalanus sp.				1.896													1.896
Euchaeta marina				3.793	7.585												11.378
Farranula gracilis		26.548															26.548
Lubbockia squillimana			1.896														1.896
Lucicutia spp.			9.482														9.482
Macrosetella gracilis			3.793														3.793
Miracia efferata			1.896														1.896
Miracia sp.			1.896														1.896
Nannocalanus minor			5.688														5.688
Oithona spp.			37.926														37.926

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oncaea venusta		5.689	20.859														26.548
Pleuromamma gracilis			5.689														5.689
Pontellina plumata		1.896															1.896
Sapphirina sp.			3.793														3.793
Scolecithrix danae		3.793															3.793
Temora stylifera		22.755	24.651														47.406
Temora turbinata		3.793	1.896														5.689
Undinula vulgaris			95.711	22.755													119.466
Unidentified Calanoids		26.548															26.548

SIZE CLASSES

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Amphipods (Hyperids)		1															1
Barnacle cypris																	
Branchiopod larvae																	
Chaetognaths						1	5	1		1		1					9
Decapoda																	
Protozoa			1														1
zoea			2	3			1										6
Dinoflagellida (Gymnodinium)		7															7
Euphausiacea					1	4		1		1							7
Fish (larval)			1														1
Foraminifera	15																15
Gymnostomata (Heteropoda)			1	3													4
Hydromedusae																	
Isopoda		1															1
Larvacea																	
<u>Fritillaria sp.</u>																	
<u>Oikopleura sp.</u>			7														7
Nauplius																	
Ostracoda		1															1
Plecypoda	2																2

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Polychaeta			2	4		1											7
Radiolaria	2	1															3
Siphonophore																	
bracts			1	2													3
nectophores																	
pneumatophores																	
Thaliacea																	
Salpidae			2	1	2												5
Thecostomata																	
Limacina sp.	14			1													15
Peraclis sp.		1															1

DATE:	6 June 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	0930
SAMPLE NUMBER:	806-37
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202μ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	1000-800 m
METERS OF WIRE:	1060 m
ANGLE:	0
FLOWMETER START:	271034
FLOWMETER FINISH:	317623
LENGTH OF TOW:	
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	SS#1-2, 75% cloudy

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia sp.		.018															.018
Aegisthus aculeatus			.004	.007													.011
Aetideus armatus			.011														.011
Calocalanus pavo		.011															.011
Chiridiella sp.				.004													.004
Conaea gracilis		.029															.029
Eucalanus sp.				.007													.007
Euchirella venusta					.004												.004
Gaetanus minor			.004	.012													.016
Gaetanus minutus				.004													.004
Haloptilus sp.			.004	.004	.004												.012
Heterorhabdus sp.			.004														.004
Lucicutia spp.			.011	.004													.015
Metridia sp.			.004	.007		.004											.015
Microsetella norvegica		.004															.004
Monacilla tenera			.004	.004													.008
Mormonilla minor			.112														.112
Oithona spp.		.011	.022														.033
Oncaea sp.		.213	.008														.221
Pachyptilus sp.				.004	.004												.008

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Pleuromamma abdominalis			.007		.004												.011
Pleuromamma xiphias						.004											.004
Spinocalanus sp.			.004														.004
Temora stylifera		.007															.007
Temoropia mayumbaensis		.014															.014
Unidentified Calanoids		.043	.159	.008													.21
Unidentified Cyclopoids		.004															.004

SIZE CLASSES

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Amphipods (Hyperids)												1					1
Barnacle cypris																	
Branchiopod larvae		1															
Chaetognaths				5		3	1			1		1					11
Decapoda																	
Protozoa			1														1
zoea																	
Dinoflagellida (Gymnodinium)		6															6
Euphausiacea																	
Fish (larval)																	
Foraminifera	9																9
Gymnostomata (Heteropoda)																	
Hydromedusae																	
Isopoda																	
Larvacea																	
Fritillaria sp.																	
Oikopleura sp.			5														5
Nauplius		6															6
Ostracoda		4	2														6
Plecypoda																	

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Polychaeta			1	2													3
Radiolaria		1	1														2
Siphonophore																	
bracts				41	17	22											80
nectophores						1	4										5
pneumatophores						11											11
Thaliacea																	
Salpidae			1														1
Thecostomata																	
<u>Limacina</u> <u>sp</u>.																	
<u>Peraclis</u> <u>sp</u>.																	

DATE:	6 June 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1100
SAMPLE NUMBER:	806-38
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	800-200 m
METERS OF WIRE:	810
ANGLE:	0
FLOWMETER START:	317888
FLOWMETER FINISH:	344354
LENGTH OF TOW:	
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata			.026														.026
Acartia sp.		.063	.006														.069
Aegisthus aculeatus		.006															.006
Calocalanus pavo		.095	.032														.127
Calocalanus pavoninus		.006															.006
Candacia sp.		.006		.012													.018
Conaea gracilis		.013															.013
Corycaeus latus			.012														.012
Corycaeus speciosus			.012														.012
Euaetideus giesbrechti			.019														.019
Euchaeta sp.		.006	.013														.019
Gaetanus sp.				.006													.006
Haloptilus sp.			.025	.006													.031
Ischnocalanus sp.			.006														.006
Lubbockia aculeata			.006														.006
Lubbockia squillimana			.006														.006
Lucicutia spp.			.012														.012
Mecynocera clausii			.013														.013
Metridia sp.		.006	.013														.019
Microsetella norvegica		.013															.013

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oithona spp.			.223														.223
Oncaea sp.		.133															.133
Pleuromamma abdominalis				.006	.019												.025
Pleuromamma piseki					.006												.006
Scolecithrix danae			.006	.006													.012
Temora stylifera		.044	.038														.082
Temoropia mayumbaensis		.006															.006
Undinula vulgaris			.076	.031													.107
Unidentified Calanoids		.171	.140														.310

	SIZE CLASSES																
Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Amphipods (Hyperids)				1													1
Barnacle cypris																	
Branchiopod larvae																	
Chaetognaths						18		2	2	1							23
Decapoda																	
Protozoa																	
zoea																	
Dinoflagellida (Gymnodinium)		2	2														4
Euphausiacea										1		1					2
Fish (larval)			1														1
Foraminifera	1																1
Gymnostomata (Heteropoda)																	
Hydromedusae																	
Isopoda																	
Larvacea																	
Fritillaria sp.																	
Oikopleura sp.			8	1													9
Nauplius		5	2														7
Ostracoda	1		2	2													5
Plecypoda			1														1

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Polychaeta																	
Radiolaria		3															3
Siphonophore																	
bracts						16											16
nectophores			10		17		5										32
pneumatophores				1					1								2
Thaliacea																	
Salpidae		1		3				1				1					6
Thecostomata																	
Limacina sp.																	
Peraclis sp.																	
Amphioxus										1							1
Stomatopod zoea				1													1

DATE:	6 June 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1215
SAMPLE NUMBER:	806-39
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	VERTICAL
SAMPLING DEPTH:	200 SFC
METERS OF WIRE:	200
ANGLE:	0
FLOWMETER START:	349132
FLOWMETER FINISH:	380590
LENGTH OF TOW:	
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	SS#2, 50% cloudy

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia danae		.548	.547														1.095
Acartia lilljeborgii			.136														.136
Acrocalanus longicornis			.272														.272
Calocalanus pavo		1.644															1.644
Calocalanus pavoninus		1.917															1.917
Candacia sp.				.136													.136
Clausocalanus sp.		.274	0.822														1.096
Corycaeus clausi			.136														.136
Corycaeus latus		.547															.547
Corycaeus limbatus			1.096														1.096
Corycaeus speciosus			.274	.136													.410
Euchaeta marina			.136		.274												.410
Farranula gracilis		1.096															1.096
Farranula rostrata		.136															.136
Lubbockia squillimana		.136															.136
Lucicutia spp.		.274	1.507		.136												1.917
Macrosetella gracilis			.272														.272
Mecynocera clausii		.959															.959
Miracia sp.		.136	.136														.272
Oithona spp.		.134	13.835														13.969

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Oncaea mediterranea		1.507	1.411														1.918
Oncaea venusta		1.507	1.959														2.466
Paracalanus sp.		2.877	1.274														3.151
Rhincalanus cornutus					.136												.136
Scolecithrix danae				.822													.822
Temora stylifera		2.329	3.836														6.165
Undinula vulgaris			0.136	0.821													0.957
Unidentified		2.19															2.19

SIZE CLASSES

Miscellaneous Zooplanton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Amphipods (Hyperids)		1															1
Barnacle cypris																	
Branchiopod larvae																	
Chaetognaths																	
Decapoda																	
Protozoa			3														3
zoea																	
Dinoflagellida (Gymnodinium)		143															143
Euphausiacea																	
Fish (larval)																	
Foraminifera	8																8
Gymnostomata (Heteropoda)																	
Hydromedusae																	
Isopoda																	
Larvacea																	
Fritillaria sp.																	
Oikopleura sp.																	
Nauplius		7															7
Ostracoda																	
Plecypoda																	

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Polychaeta																	
Radiolaria		5															5
Siphonophore					2			1									3
bracts																	
nectophores																	
pneumatophores																	
Thaliacea																	
Salpidae			1	5	4						1						11
Thecostomata																	
Limacina sp.			5														5
Peraclis sp.																	

DATE:	7 June 1979
STATION NUMBER:	BENCHMARK
SHIP:	CRAWFORD
TIME:	1335
SAMPLE NUMBER:	CR-806-42
TYPE OF NET:	CONICAL 5:1
MESH SIZE:	202µ
RING SIZE:	.75 m
TYPE OF HAUL:	HORIZONTAL
SAMPLING DEPTH:	25 m
METERS OF WIRE:	60 m
ANGLE:	55°
FLOWMETER START:	490248
FLOWMETER FINISH:	515730
LENGTH OF TOW:	10 min
LATITUDE:	17° 57.6'N
LONGITUDE:	65° 51.9'W
SEA STATE AND WEATHER:	

The quantities in the following data sheets are #/m^3.

SIZE CLASSES

COPEPODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Acartia spinata		3.379	3.379														6.758
Acrocalanus longicornis			3.379														3.379
Calocalanus pavo		33.795															33.795
Calocalanus pavoninus		6.758															6.758
Clausocalanus		246.706	54.073														300.779
Copilia mirabilis			3.379														3.379
Corycaeus catus			6.759														6.759
Corycaeus latus			3.379														3.379
Eucalanus sp.			13.518	3.379													16.897
Farranula gracilis		101.386	67.591														168.977
Macrosetella gracilis			3.379														3.379
Oithona spp.		37.175	20.277														57.452
Paracalanus sp.		10.139	6.759														16.898
Sapphirina sp.		3.379															3.379
Scolecithrix danae				3.379													3.379
Temora stylifera			20.277														20.277
Undinula vulgaris			94.627	74.349													168.976

SIZE CLASSES

Miscellaneous Zooplankton	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Amphipods (Hyperids)			1														1
Barnacle cypris																	
Branchiopod larvae																	
Chaetognaths						1		2									3
Decapoda																	
Protozoa		1															
zoea		1	1	1	2	1	3										9
Dinoflagellida (Gymnodinium)	36																36
Euphausiacea																	
Fish (larval)				1													1
Foraminifera	4																4
Gymnostomata (Heteropoda)																	
Hydromedusae				1													1
Isopoda																	
Larvacea																	
<u>Fritillaria sp.</u>			1														1
<u>Oikopleura sp.</u>			3														3
Nauplius	1	2															3
Ostracoda																	
Plecypoda																	

SIZE CLASSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Polychaeta			1														1
Radiolaria	3																3
Siphonophore																	
bracts																	
nectophores																	
pneumatophores																	
Thaliacea																	
Salpidae				1		1											2
Thecostomata																	
<u>Limacina</u> <u>sp</u>.	1																1
<u>Peraclis</u> <u>sp</u>.																	

APPENDIX G - TYPICAL CRUISE PLAN

CRUISE PLAN CEER

I.	Research Vessel	R/V CRAWFORD
II.	Supporting Agency	U.S. DOE/PRWRA
III.	Cruise Name and Number	CR-805
IV.	Dates	19-23 April 1979
V.	Total Days	5 (estimated)

VI. Objectives:

Measure oceanic parameters relatable to OTEC at Punta Tuna.
Measure variability of these oceanic parameters at Punta Vaca.
Measure temperature at two other sites.

VII. Personnel:

G. Goldman, Chief Scientist
D. Pesante, Biological Coordinator
M. Shafnacker, Technician
C. Bonafé, Technician
E. Gonzâlez, Technician
A. Nazario, Technician
J. Rivera, Scientific assistant
D. Corales, Technician
T. Morgan, Scientific assistant
Scientist (unnamed)
Scientist (unnamed)

VIII. Stations:

"B"-Benchmark Station--	17°57.6'N	by 65°51.9'W	--1120 m
"A"-Augmented Station--about	18°02'N	by 65°40'W	--1200 m
"P"-Ancillary Station--about	17°55'N	by 66°00'W	--1200 m
"F"-Ancillary Station--about	17°51.7'N	by 65°46.9"W	--1950 m
"V"-Ancillary Station--about	18°03'N	by 65°32'W	--1200 m

IX. Equipment: See accompanying list.

X. Type of Samples:

Hydrocasts for temperature, salinity, dissolved oxygen, nutrients, chlorophyll, phytoplankton.
XBT
Current Profiles
Plankton Hauls (horizontal and oblique)
Transmissivity

XI. Travel:

At mid-moring of 19 April, personnel shall transport all equipment and personnel gear to the CRAWFORD at Malecon port, Mayaguez, using all necessary vehicles. About mid-moring of April 23 personnel and equipment shall be removed from CRAWFROD at Malecon port, Mayaguez.

CRUISE SCHEDULE CR-805

DATE	TIME	EVENT
19 April	0700	CRAWFORD depart Magueyes
	1100	CRAWFORD arrive Malecon port, Mayaguez
	1100-1400	Transport personnel and equipment to CRAWFORD
	1600	CRAWFORD depart Mayaguez for Punta Tuna, Station "B"
20 April	0500	Arrive Punta Tuna, Station "B"
"B-1"	0900-0930	XBT-1 Plankton-1 (25 m horizontal-10 min)
	0930-1000	Secure to buoy
"B-2"	1000-1200	HYDROCAST-1 XBT-2
	1100	WEATHER
"B-3"	1200-1600	PLANKTON-2 (1000 m-0 m) PLANKTON-3 (1000 m-800 m) PLANKTON-4 (800 m-200 m) PLANKTON-5 (200 m-0 m) XBT-3 Run Oxygen Analysis Filter Nutrient Samples
	1400	WEATHER
	1500-1700	Prepare for CURRENT
"B-4"	1700-1830	CURRENT-1 XBT-4
	1700	WEATHER
	2000	WEATHER
	2230-2300	Prepare for HYDRO, XBT

20 April "B-5"	2300-0130	HYDROCAST-2 XBT-5 WEATHER (2300) CURRENT-2
21 April	0000-0200	Run Oxygen Analysis Filter Nutrient Samples
	0200	WEATHER
	0500	WEATHER
"B-6"	0600-0800	CURRENT-3 XBT-6
	0800	WEATHER
	0900-1000	Prepare for BIOCAST, XBT, TRANSMISSION, CURRENT
"B-7"	1000-1400	BIOCAST-1 TRANSMISSION-1 XBT-7 CURRENT-4 WEATHER (1100) WEATHER (1400) Filter for chlorophyll
	1700	WEATHER
	2000	WEATHER
	2100-2200	Prepare for BIOCAST, XBT, TRANSMISSION
21-22 April "B-8"	2200-0100	BIOCAST-2 XBT-8 TRANSMISSION-2 WEATHER (2300) Filter for chlorophyll
22 April	0100-0130	Release from mooring
"B-9"	0130-0200	PLANKTON-6 (25 m-horizontal-10 min) XBT-9
	0200-0700	Remain in area
	0700-0730	Steam to Station "F"
"F-1"	0730-0745	At Station "F" XBT-10

	0745-0900	Steam to Station "A"
"A-1"	0900-0915	At Station "A" XBT-11
	0915-1030	Steam to Station "V" Prepare for HYDROCAST, PLANKTON, XBT, OXYGEN, CHLOROPHYLL, NUTRIENTS
"V-1"	1030-1600	At Station "V" HYDRO/BIOCAST-1 XBT-12 PLANKTON-7 (25 m horizontal tow) PLANKTON-8 PLANKTON-9 XBT-13 Run Oxygen Filter for nutrients Filter for chlorophyll
	1600-1930	Steam to Station "P"
"P-1"	1930-1945	At "P" XBT-14
	1945	Depart for Mayaguez
23 April	0900	Arrive at Malecon port, Mayaguez
	0900-1100	Remove equipment and personnel from CRAWFORD
	1100	CRAWFORD depart Mayaguez for Magueyez
	1500	CRAWFORD arrives Magueyez

CODE

HYDROCAST - Hydrostation, bottle samples at depths of 0, 50, 100, 150, 200, 250, 300*,400*, 600, 800, 1000 m (*=both protected and unprotected for thermometric depth), read temp (protected, unprotected, auxiliary), wire angles, meter depth, collect samples for salinity, nutrients, dissolved oxygen.

BIOCAST - Hydrocast for biological parameters, bottle samples, (depths of 0, 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 400 m), read temp, wire angle, meter depth, collect samples for salinity, chlorophyll.

WEATHER - Standard weather observations: time, wind, dir., wind speed, air temp (wet and dry bulb), actual "weather state", barometer, cloud type and cover, visibility, wave ht., wave dir., wave period. The times indicated correspond with the U.S. Weather Station at the Punta Tuna Light (USCG)

XBT - Expendable bathythermograph-automatic record time, set probe and fire.

CURRENT - Stationary current profile - profile of current speed and direction vs. depth. All is internally recorded--must use hydro winch and lower the meter and read--wire angle and meter depth. Each depth shall be set for about 10 minutes. Depths used shall be 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 400, 500, 750 m.

PLANKTON - Plankton tow--either horizontal tow or vertical tow.

TRANS - Transmissivity--measured by lowering instrument and reading out remotely. Reading shall be sensor reference, depth at about 10-20 meter intervals, both lowering and raising.

HYDRO/BIOCAST - Hydrocast for both physical and biological parameters, bottle samples will be taken at depths of 1, 10, 20, 30, 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, and 1000 m. Data taken will include protected and unprotected thermometer, wire angle, meter depth, collect samples for salinity, nutrients, chlorophyll, dissolved oxygen.

EQUIPMENT LIST--CR-805

- STATION DATA SHEETS-20
- TRANSMISSOMETER DATA SHEETS-5
- WATER SAMPLING BOTTLES/NISKIN-13
- TUBING FOR SAMPLING BOTTLES-25 ft
- MESSENGERS-ALL
- SPARTS FOR NISKIN BOTTLES
- METER WHEEL-1
- WIND SPEED METER-1
- SEA STATE GUIDE-1
- CLOUD GUIDE-1
- PSYCHROMETER-1
- PSYCHROMETER THERMOMETER SPARE-1
- PSYCHROMETER WICKS
- XBT
  - PROBES-15
  - TEST CANISTER-1
  - CHART-2
  - RECORDER
  - LAUNCHER, HAND-1
  - MANUAL
- REVERSING THERMOMETERS-ALL
- REVERSING THERMOMETER READER-2
- FLASHLIGHTS-1 large, 1 small
- REVERSING THERMOMETER CORRECTING SHEETS-?
- MISC WRITING MATERIALS
- TIMER-1
- CURRENT METER-1 135 TD
  - SPARE PARTS KIT-1
  - MANUAL-1
  - GEAR SET-1
  - CHART PAPER-2
- PLANKTON
  - NET-
  - BRIDDLE
  - DOUBLE TRIP MECHANISM
  - FORMALIN & BUFFER
  - PLASTIC JARS
  - TWEEZERS
  - BUCKET
  - COD END JARS
  - CHOCKER BAND & LINE
  - WIRE STOP
  - NET RING
- TRANSMISSOMETER-1
  - WIRE TIES
  - READOUT-1
  - BATTERY
  - CABLE-1000 ft
  - DEPTH SENSOR-1
  - MANUAL-1
- CALCULATORS-2
- STROBE LIGHT-1

LOG BOOKS-3

DISTILLED H_2O

SILICONE GREASE

BATTERY CHARGING CABLE (50')

SOLDERING IRON

NUCLEOPORE FILTERS-1 box

GAF FILTERS-1 box

NUTRIENT/SALINITY BOTTLES-6 boxes

CHLOROPHYLL BOTTLES-18

CHLOROPHY FILTER CONTAINERS-ALL

PARAFILM

MARKING PEN-6

CLIP BOARDS-3/4

CHLOROPHYLL CHEMICALS & EYE DROPER

TOOL BOX-2

MULTIMETER

WEATHER LOG-6

BOTTLE RACKS-3

BOTTLE RACK SCREWS

SAFETY CLIPS-16

MESSENGER BUCKET

COTTON LINE-1 coil

TAPE MISC.

PAPER TOWELS-6

PIPETTES

BURRETTES

FLASKS

TIME SHEETS-10

HAND VACUUM

CARBOY

CHLOROPHYLL BUCKETS

DRILL & BITS

THERMOMETER (SHIELDED)-1

DISSOLVED OXYGEN BOTTLES-15

COMPLETE DIVE SETS-2

TEST TUBE RACK-1

FREEZER CONTAINER-2

ICE CHEST-2

INSULATION

TIDE TABLE-1 set

SCREWS

CR LUBRICANT

DESCICANT OR SILICA GEL

MAGNESIUM CARBONATE SUSPENSION

SAFETY HARNESS

NYLON LINE-1 coil

RAIN GEAR (FROM SULTANA)

SHACKLES-4

SAFETY WIRE-10 ft

FILTERING SET UP

PUMPS-2

TUBING

WATER TRAP

VACUUM FLASK

GLASSWARE & CLAMPS

DROPPERS

MAGNESIUM SULFATE SOLUTION FOR OXYGEN

ALKILINE IODINE SOLUTION FOR OXYGEN

SULFURIC ACID (CON) FOR OXYGEN

THIOSULFATE SOLUTION FOR OXYGEN

FUNNEL

APPENDIX H

PROCEDURE FOR DETERMINATION OF DISSOLVED OXYGEN

I. Reagents

1. $MnSO_4$. Use 367 g/L. Filter. This solution is stable but should not be used directly from the stock bottle.

2. KI - NaOH. Use 360 g of NaOH + 150 g of KI/L. This solution will develop some turbidity in time. If this occurs it sould be discarded.

3. H_2SO_4. Use 50% v:v.

4. $Na_2S_2O_3$. Use 5 grams per 2 liters (approx .01 N). Add 0.50 g sodium borate as a preservative.

5. Starch indicator. Add 10 g of starch to 25 ml cold, distilled water. Make paste. Pour rapidly into one liter of boiling distilled water. Preserve with 50 mg HgI.

6. Standards: $KH(IO_3)_2$. Use 0.325 g/L (0.01 N).

II. Sampling

Oxygen samples should be drawn from reversing bottles before any other samples are collected and as soon as possible after the bottle is retrieved. Place a length of rubber tubing on the top. Expel all air from the tube, rinse O_2 sample bottle. Fill sample bottle always keeping the end of the tube below the water level as it fills. The stopper must be replaced in such a way that no bubbles are trapped.

III. Addition to Reagents

1. Immediately after collection introduce the following reagents from an automatic pipette, the tip of which is kept under the surface of the water.

   A. 1 ml of $MnSO_4$.

   B. 1 ml of KI-NaOH.

2. Shake thoroughly and allow precipitate to settle (25 min). Shake a second time and again allow the precipitate to settle 2/3 of way to bottom.

C. Add 1 ml of 50% H_2SO_4.

3. Shake thoroughly until all precipitate has dissolved. Maximum 12-18 hours before titration.

IV. Titration

1. Pipette 50 ml of the treated sample into a 125 ml Erlenmeyer flask.

2. Titrate with standardized $Na_2S_2O_3$ until the yellow color has almost disappeared.

3. Add 4 drops of starch indicator. (Not used).

4. Titrate until solution is colorless.

5. Repeat at least twice, or until difference is less than 0.03 ml.

V. Reagent Blank

1. To 50 ml of distilled water in an Erlenmeyer flask add:

A. 1 ml of 50% H_2SO_4.

B. Swirl

C. 1 ml of KI-NaOH.

D. Swirl

E. 1 ml of $MnSO_4$.

F. Swirl and then titrate as above. This value should be zero.

VI. Standardization of $Na_2S_2O_3$ at room temperature.

1. Pipette 50 ml of distilled water into a 125 ml Erlenmeyer flask.

2. Add in order:

A. 1 ml of 50% H_2SO_4.

B. 1 ml KI-NaOH.

C. 1 ml $MnSO_4$.

D. 5 ml .01 N $KH(IO_3)_2$ (exactly: use volumetric pipette).

3. Titrate as above.

4. Repeat at least three times or until reproduction is within .02 ml $Na_2S_2O_3$.

VIII. Calculations:

1. Normality of $Na_2S_2O_3$ = $\frac{V_1 \times N_1}{V_2}$

2. Concentration of O_2 in the water sample = O_2 (ml/L)

$$= N \times (V_2 - b) \times \frac{B}{B-2} \times 5.6 \times \frac{1000}{S}.$$

Where N = normality of $Na_2S_2O_3$; N_1 = normality of $KH(IO_3)_2$; V_1 = ml of standard $KH(IO_3)_2$ solution; V_2 = ml of $Na_2S_2O_3$; B = volume of sample bottles; S = volume of sample titrated; and b = blank titer obtained under V.

*Excerpt from Instruction Manual for Routine Measurements for the U.S. Program in Biology, International Indian Ocean Expedition. August 1962, David Menzel, WHOI.

APPENDIX I

LISTINGS OF THE COMPUTER PROGRAMS USED FOR ANALYSIS OF THE MOORED CURRENT METER DATA

OCEAN2.F4

This Program Computes all the Basic Statistics
Resulting from the Current Meter Data

```
***** THIS IS 'OCEAN1.F4' PROGRAM *************
C===========================================================
C      IN SITU OCEAN CURRENTS PROGRAM WITH MAGNETIC TO     =
C      GEOGRAPHIC ANGLE CONVERSION                          =
C===========================================================
C
      DOUBLE PRECISION IFILE
       INTEGER TIME,TIPER,TIMER
       REAL  GEANG(5000)
       DIMENSION VEL(5000),ANGRD(5000),X(5000),Y(5000),
      .XOUT(2500),YOUT(2500),RTOUT(2500),PHIOUT(2500),IDA(2)

       DIMENSION FORMT1(3),FORMT2(3),TITLE(20),HEADIN(20)


     1 FORMAT(20A4)
     2 FORMAT(2(/),40X,20A4)
     3 FORMAT(9G)
     4 FORMAT(3A4)
     5 FORMAT(1H1,26(/),40X,'OCEAN1',5X,'DATE',2X,2A5,5X,A5)
     6 FORMAT(1H1,T50,'VELOCITY VECTORS AT 1 HOUR INTERVALS')
    13 FORMAT(1H1,7(/),T30,20A4,/,T30,20A4,/,T30,'START TIME',2X,2I2,
     $2X,I2,'/',I2,'/',I2,4X,'SAMPLE RATE',I5,' MIN',5X, 'RECORD '
     *,'LENGTH= ',I4,' HOURS')
    17 FORMAT(/1X,'NUMBER',3X,'DATE',3X,'TIME',3X,'GEOGRAPHIC ANGLE',3X,'
     1VEL(CM/SEC',4X,'X',8X,'Y',6X,'X-COMP.',3X,'Y-COMP.',4X,'RT',5X,'AN
     2GLE',3X,'AVEL',4X,'SX',3X,'STAB(PC)'/)
    18 FORMAT(T3,I4,T9,I2,'-',I2,'-',I2,T18,I4,T27,F5.0,T46,F6.2,T55,F
     16.2,T64,F6.2)
    19 FORMAT(T74,F6.2,T84,F6.2,T92,F6.2,T102,F5.1,T109,F6.2,T116,F6.2,T
     124,F5.1)
    22 FORMAT(' ',20A4)
    23 FORMAT(/' INT. NUMBER',3X,'X-COMP.',3X,'Y-COMP.',3X,'AVG VEL(CM/SE
     1C)',3X,'RT',6X,'ANGLE',5X,'SX',4X,'STAB'/)
    24 FORMAT(/T5,I2,T15,F6.2,T25,F6.2,T39,F6.2,T51,F6.2,T62,F5.1,T70,F6.
     12,T77,F5.1)
    38 FORMAT(1H1,25X,'DATA BASED STATISTICS'/)
    39 FORMAT(/25X,'RESULTS BASED STATISTICS'/)
    40 FORMAT(/1X,'SUM OF VELOCITIES  =',F8.2,10X,'SUM OF X  =',
     1F8.2,10X,'SUM OF Y  =',F8.2)
    41 FORMAT(/1X,'TOTAL  RESULTANT   =',F8.2,10X,'RESULTANT ANGLE
     1 =',F7.2)
    42 FORMAT(/1X,'STANDARD  DEVIATION= ',F7.2)
    43 FORMAT(/1X,'AVERAGE  VELOCITY  =',F8.2,10X,'AVERAGE X =',F8.2,10X,
     1'AVERAGE Y =',F8.2)
    44 FORMAT(/,1X,'AVERAGE RESULTANT VELOCITY =',F8.2)
    47 FORMAT(2(/),40X,'NUMBER OF DATA MEASUREMENTS =',I6)
   144 FORMAT(A4)
   196 FORMAT(3(3F6.2,F6.1))
   232 FORMAT(1H1,/,T23,'VELOCITY VECTORS AT ',I2,' HOUR INTERVALS')
   477 FORMAT(' ',I6,2X,2I2,2X,3I4)
```

```
      OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',FILE='FOR06.DAT',
     *DISPOSE='LIST')

      READ(4,144) LIST
      READ(4,1) TITLE
      READ(4,1) HEADIN
      READ(4,4)FORMT1
      READ(4,4)FORMT2
      CALL DATE(IDA)
      CALL TIME(IT)
      WRITE(6,5)IDA,IT
      WRITE(6,2) TITLE
      READ(4,3) N,MONTH,IDAY,IYEAR,TIMEH,TIMEM,VARIA,INCR,MTH
      READ(4,FORMT1) (GEANG(I),I=1,N)
      DO 101 I=1,N
      IF(GEANG(I).LT.VARIA) GEANG(I)=GEANG(I)+360.
  101 GEANG(I)=GEANG(I)-VARIA
      READ(4,FORMT2) (VEL(I),I=1,N)
      WRITE(6,47) N
      N1=N*INCR/60

      WRITE(6,13) TITLE,HEADIN,TIMEH,TIMEM,MONTH,IDAY,IYEAR,INCR,N1
      CALL HISTOS(VEL,GEANG,N,TITLE,HEADIN,TIMEH,TIMEM,MONTH,IDAY,
     *IYEAR,INCR,N1)

C
C**********************************************************
C       GEOGRAPHIC ANGLES ARE CHANGED TO ARITHMETIC RADIANS *
C       AND VELOCITY COMPONENTS ARE DETERMINED              *
C**********************************************************
C
      CALL INITIA
      DO 7 I=1,N
      ANGRD(I)=(450.-GEANG(I))*3.1416/180.
      X(I)=VEL(I)*COS(ANGRD(I))
      Y(I)=VEL(I)*SIN(ANGRD(I))
      CALL SUMS(VEL(I),X(I),Y(I),0.0,0.0)
    7 CONTINUE
      CALL START(0,N)
C
C*************************************************************
C       THIS SECTION WILL COMPUTE AND PRINT AVERAGES ON AN      *
C       HOURLY BASIS AND WILL PRINT INPUT INFORMATION           *
C*************************************************************
C
      CALL INITIA
C
      IF(LIST.EQ.'LIST') WRITE(6,6)
      IF(LIST.EQ.'LIST') WRITE(6,17)
      IHOURS = TIMEH
      MINUTS = TIMEM
      IDATE1=MONTH
      IDATE2=IDAY
```

```
      IDATE3=IYEAR
      INTERV=INCR
      ITIMEM=TIMEM
      LIFT=60/INCR
      JN=1
      KFINAL = N/2
      KFINAL = 2*KFINAL
      DO 6 K=1,KFINAL,LIFT
      AVGXX=0.0
      AVGYY=0.0
      AVEL=0.0
      DO 21 L=K,K+LIFT-1
      IF(L.EQ.1) GO TO 9
      CALL OMEGA(ITIME,IHOURS,MINUTS,IDATE1,IDATE2,IDATE3,INTERV,ITIMEM,
     *MTH)
      GO TO 10
    9 ITIME=IHOURS*100+MINUTS
   10 IF(LIST.EQ.'LIST') WRITE(6,18)L,IDATE1,IDATE2,IDATE3,ITIME,
     *                  GEANG(L),VEL(L),X(L),Y(L)
      AVGXX=AVGXX+X(L)
      AVGYY=AVGYY+Y(L)
      AVEL=AVEL+VEL(L)
   21 CONTINUE
      AVGXX=AVGXX/LIFT
      AVGYY=AVGYY/LIFT
      AVEL=AVEL/LIFT
      RT= (AVGXX**2+AVGYY**2)**.5
      SRT = SRT + RT
      PHI=ATAN(AVGYY/AVGXX)*(180./3.1416)
      IF(AVGXX.LE.0.) PHI=270-PHI
      IF((90.-PHI).GT.0.) PHI=90.-PHI
      SX=((2*AVEL)**2-2*(AVEL**2))**.5
      IF(AVEL.EQ.0.) STAB=0.
      IF(AVEL.EQ.0.) GO TO 80
      STAB=(RT/AVEL)*100.
   80 CALL SUMS(AVEL,AVGXX,AVGYY,RT,STAB)
      IF(LIST.EQ.'LIST') WRITE(6,19)AVGXX,AVGYY,RT,PHI,AVEL,SX,STAB
      XOUT(JN)=AVGXX
      YOUT(JN)=AVGYY
      RTOUT(JN)=RT
      PHIOUT(JN)=PHI
      JN=JN+1
    8 CONTINUE
       IF(KFINAL.LT.N) GO TO 69
      GO TO 71
   69  KFINAL = KFINAL + 1
      CALL OMEGA(ITIME,IHOURS,MINUTS,IDATE1,IDATE2,IDATE3,INTERV,ITIMEM,
     *MTH)
      RESTAR = 356790.
      J = KFINAL
      IF(LIST.EQ.'LIST') WRITE(6,18)J,IDATE1,IDATE2,IDATE3,ITIME,
     *                  GEANG(J),VEL(J),X(J),Y(J)
      IF(KFINAL.LT.N)GO TO 69
```

```
C
C=====================================================================
C          THIS SECTION COMPUTER STATISTICS FOR THE                   *
C            INPUT DATA AND FOR THE OUTPUT RESULTS.                   *
C=====================================================================
C
71    OPEN(UNIT=5,DEVICE='DSK',ACCESS='SEQOUT',FILE='HR501.DAT',
     * DISPOSE='SAVE')
      WRITE(5,22) TITLE
      WRITE(5,22) HEADIN
      WRITE(5,198) (XOUT(JN),YOUT(JN),RTOUT(JN),PHIOUT(JN),JN=1,N1)
      CLOSE(UNIT=5)

      INCR2=60
      WRITE(6,13) TITLE,HEADIN,TIMEH,TIMEM,MONTH,IDAY,IYEAR,INCR2,N1
      CALL HISTOS(RTOUT,PHIOUT,N1,TITLE,HEADIN,TIMEH,TIMEM,MONTH,IDAY,
     *IYEAR,INCR2,N1)

      CALL STA*RT(1,N1)


C
C=====================================================================
C     THIS SECTION WILL COMPUTE COMPONENTS AT 6,12,18,24,36,          *
C     AND 48 HOURS INTERVAL AND WILL ALSO PPINT THE RESULTS.          *
C=====================================================================
C
      DO 15 L=1,8
      IF(L.EQ.5.OR.L.EQ.7) GO TO 15
      CALL INITIA
      KM=L*6
      IF(LIST.EQ.'LIST') WRITE(6,232)  KM
      IF(LIST.EQ.'LIST') WRITE(6,23)
      KJ=L*6*LIFT
      ISTOP = N/KJ
      M=1
      DO 11 I=1,N,KJ
      IF(M.GT.ISTOP)  GO TO 11
      XPRO=0.0
      YPRO=0.0
      VELPRO=0.0
      DO 12 J=I,I+KJ-1
      XPRO = XPRO + X(J)
      YPRO = YPRO + Y(J)
      VELPRO = VELPRO + VEL(J)
   12 CONTINUE
      AVGVEL = VELPRO/KJ
      AVGX= XPRO/KJ
      AVGY=YPRO /KJ
      RT=(AVGX**2+AVGY**2)**.5
      PHI=ATAN(AVGY/AVGX)*(180./3.1416)
      XOUT(M) = AVGX
      YOUT(M) = AVGY
```

```
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   213                      RTOUT(M) = RT
   214                      PHIOUT(M) = PHI
   215                      IF(AVGX.LE.0.)  PHI=270.-PHI
   216                      IF((90.-PHI).GT.0.)   PHI=90.-PHI
   217                      SX=(((KJ)*AVGVEL)**2-KJ*(AVGVEL**2))/(KJ-1))**.5
   218                      IF(AVGVEL.EQ.0.)  STAB=0.
   219                      IF(AVGVEL.EQ.0.)  GO TO 50
   220                      STAB=(RT/AVGVEL)*100
   221            50        IF(LIST.EQ.'LIST') WRITE(6,24)M,AVGX,AVGY,AVGVEL,RT,PHI,SX,STAB
   222                      CALL SUMS(AVGVEL,AVGX,AVGY,RT,STAB)
   223                      M=M+1
   224                 11   CONTINUE
   225                      CALL STAMRT(KM,ISTOP)
   226                      CALL FILEAS(L,IFILE)
   227                      OPEN(UNIT=5,DEVICE='DSK',ACCESS='SEQOUT',FILE=IFILE,
   228                     * DISPOSE='SAVE')
   229                      WRITE(5,22) TITLE
   230                      WRITE(5,22) HEADIN
   231                      WRITE(5,198) (XOUT(JN),YOUT(JN),RTOUT(JN),PHIOUT(JN),JN=1,ISTOP)
   232                      CLOSE(UNIT=5)
   233                 15   CONTINUE
   234
   235                      CLOSE(UNIT=6)
   236
   237                      STOP
   238                      END

      CONSTANTS

      0       000000000006    1       422471320100    2       000000000000    3       516132147652    4       521004020100
      5       000000000000    6       432372230154    7       272110152100    10      000000000000    11      462232352100
      12      000000000000    13      202622077713    14      210550000000    15      206712272756    16      207550000000
      17      223534333000    20      000000000005    21      442452330142    22      272110152100    23      000000000000
      24      516032642500    25      000000000000    26      000000000001    27      211416000000

      SUBPROGRAMS

      FORSE.  .JBFF   ALPHO.  ALPHI.  ALLIO.  TFMT.   INTO.   INTI.   FLOUT.  FLIRT.  OPN40.  DATE    TIME    HISTOS  INITIA
      COS     SIN     SUMS    STAMRT  OMEGA   EXP3.2  ATAN    CLS40.  EXP3.0  FILEAS  EXIT

      SCALARS

      LIST    1750            IT      1751            N       1752            MONTH   1753            IDAY    1754
      IYEAR   1755            TIMEH   1756            TIMEM   1757            VARIA   1760            INCR    1761
      MIN     1762            I       1763            N1      1764            IHOURS  1765            MINUTS  1766
      IDATE1  1767            IDATE2  1770            IDATE3  1771            INTERV  1772            ITIMEM  1773
      LIFT    1774            JN      1775            FFINAL  1776            K       1777            AVGXX   2000
      AVGYY   2001            AVEL    2002            L       2003            ITIME   2004            RT      2005
      SRT     2006            PHI     2007            SX      2010            STAB    2011            RESTAR  2012
      J       2013            INCR2   2014            KM      2015            KJ      2016            ISTOP   2017
      M       2020            XPRO    2021            YPRO    2022            VELPRO  2023            AVGVEL  2024
      AVGX    2025            AVGY    2026            IFILE   2027
```

```
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        ARRAYS

        GEANG   2036          VEL     13640          ANGRD   25450          X        37260          Y       51070
        XOUT    62700         YOUT    67604          RTOUT   74510          PHIOUT   101414         IDA     106320
        FORMT1  106322        FORMT2  106325         TITLE   106330         HEADIN   106354
```

```
C
C
      SUBROUTINE OMEGA(ITIME,IHOURS,MINUTS,IDATE1,IDATE2,IDATE3,INTERV,I
     1ITIMEM,MTH)
      MINUTS=MINUTS + INTERV
      IF(MINUTS.EQ.60) GO TO 75
      IF(MINUTS.GT.60) GO TO 65
      GO TO 90
 65   MINUTS=MINUTS-60
      IHOURS=IHOURS+1
      GO TO 90
  75  MINUTS = 00
      IHOURS = IHOURS + 1
 90   IF((IHOURS*100+MINUTS).GE.2400) GO TO 31
      GO TO 100
 31   IHOURS = 00
      IF(ITIMEM.EQ.30.AND.MINUTS.EQ.60) MINUTS=MINUTS-ITIMEM
      IF(MINUTS.EQ.60) IHOURS=IHOURS+1
      IF(MINUTS.EQ.60) MINUTS = 0
      IDATE2 = IDATE2 + 1
      GO TO(60,61,60,62,60,62,60,60,62,60,62,60),IDATE1
 61   IF(IDATE2.EQ.28+MTH)  IDATE2 = 1
 62   IF(IDATE2.EQ.31)  IDATE2 = 1
 60   IF(IDATE2.EQ.32)  IDATE2 = 1
      IF(IDATE2.EQ.1)   IDATE1 =IDATE1 + 1
      IF(IDATE1.EQ.12)  IDATE3 = IDATE3 + 1
      IF(IDATE1.EQ.12)  IDATE1= 1
 100  ITIME=(IHOURS*100)+MINUTS
      RETURN
      END

GLOBAL DUMMIES

ITIME   174          IHOURS  175          MINUTS  176          IDATE1  177          IDATE2  200
IDATE3  201          INTERV  202          ITIMEM  203          MTH     204

SCALARS

OMEGA   205          MINUTS  176          INTERV  202          IHOURS  175          ITIMEM  203
IDATE2  200          IDATE1  177          MTH     204          IDATE3  201          ITIME   174
```

```
C


        SUBROUTINE HISTOS(V,D,NTOT,TITLE1,TITLE2,NHR,NMIN,NMO,NDAY,
       *NYR,INC,NI)

C==============================================
C   PROGRAMA PARA PRODUCIR TABLAS DE HISTOGRAMAS =
C   PROGRAMADO POR:  LUIS F. RICO   12-JUL-79    =
C   PARA USO DEL DEPARTAMENTO DE CIENCIAS MARINAS=
C   RECINTO UNIVERSITARIO DE MAYAGUEZ, P.R.      =
C==============================================
        DIMENSION V(NTOT),D(NTOT),VP(20),DP(24),MAGN(4),GEOG(4)
        INTEGER T(24,20),VTOTAL(20),DTOTAL(24),A(25),S(21),TOTALO
        INTEGER DSUM,VSUM
        DIMENSION TITLE1(16),TITLE2(16),FMTV(6),FMTD(6)
        DATA MAGN/'MAGNE','TIC  ',' DEGR','EES  '/
        DATA GEOG/'GEOGR','APHIC',' DEGR','EES  '/
        DO 10 J=1,20
        VP(I)=0.0
        DP(I)=0.0
        VTOTAL(I)=0
        DTOTAL(I)=0
        DO 10 I=1,24
        T(I,J)=0
   10   CONTINUE

        DO 15 I=20,24
        DP(I)=0.0
        DTOTAL(I)=0
   15   CONTINUE

C==============================================
C   SEARCH FOR MAXIMUM VALUE OF THE VELOCITIES.  =
C==============================================
     20  VMAX=0.0
        DO 50 I=1,NTOT
         VMAX=AMAX1(VMAX,V(I))
     50 CONTINUE
        N=0
C
     60 N= N+1
         IF(VMAX.LT.(N*100.)) GO TO 70
        GO TO 60
     70  VMAX=N*100.
         NMAX=VMAX
         KINT=NMAX/20
C
         TOTALO=0
        DO 600 I = 1,NTOT
          IF(V(I).EQ.0.0)  GO TO 550
          LINE=D(I)/15. + 1.
```

```
                IF(LINE .EQ. 25)  LINE = 24
                KOL = V(I)/KINT+1
                IF(KOL .EQ. 21)  KOL=20
                T(LINE,KOL) = T(LINE,KOL) + 1
                GO TO 600
        550     TOTALO=TOTALO+1
        600 CONTINUE
              POP=FLOAT(TOTALO)/FLOAT(NTOT)
              NTOTAL=NTOT-TOTALO
C*************************************************
C               FIND SUMS OF DIRECTIONS.         *
C*************************************************
              DO 700 I=1,24
               DSUM=0
                DO 650 J=1,20
                DSUM=DSUM+T(I,J)
        650    CONTINUE
                DTOTAL(I)=DSUM
                DP(I)=FLOAT(DTOTAL(I))/FLOAT(NTOT)*100.
        700 CONTINUE
C*************************************************
C               FIND SUMS OF VELOCITIES.         *
C*************************************************
              DO 800 J=1,20
                VSUM=0
              DO 750 I=1,24
                VSUM=VSUM+T(I,J)
        750 CONTINUE
                VTOTAL(J)=VSUM
                VP(J)=FLOAT(VTOTAL(J))/FLOAT(NTOT)*100.
        800 CONTINUE
C
C
C
              DO 850 I=1,24
                A(I)=(I-1)*15
        850 CONTINUE
               A(25)=360
C
              DO 900 I=1,20
               S(I)=(I-1)*KINT
        900 CONTINUE
              S(21)=NMAX
C
C
C
               WRITE(6,1020) GEOG
              DO 400 I=1,24
              WRITE(6,100)A(I),A(I+1)
               IF(T(I,1).NE.0)     WRITE(6,105) T(I,1)
        110    IF(T(I,2).NE.0)     WRITE(6,115) T(I,2)
        120    IF(T(I,3).NE.0)    WRITE(6,125) T(I,3)
        130    IF(T(I,4).NE.0)    WRITE(6,135) T(I,4)
```

```
 140  IF(T(I,5).NE.0)    WRITE(6,145) T(I,5)
 150  IF(T(I,6).NE.0)    WRITE(6,155) T(I,6)
 160  IF(T(I,7).NE.0)    WRITE(6,165) T(I,7)
 170  IF(T(I,8).NE.0)    WRITE(6,175) T(I,8)
 180  IF(T(I,9).NE.0)    WRITE(6,185) T(I,9)
 190  IF(T(I,10).NE.0)   WRITE(6,195) T(I,10)
 200  IF(T(I,11).NE.0)   WRITE(6,205) T(I,11)
 210  IF(T(I,12).NE.0)   WRITE(6,215) T(I,12)
 220  IF(T(I,13).NE.0)   WRITE(6,225) T(I,13)
 230  IF(T(I,14).NE.0)   WRITE(6,235) T(I,14)
 240  IF(T(I,15).NE.0)   WRITE(6,245) T(I,15)
 250  IF(T(I,16).NE.0)   WRITE(6,255) T(I,16)
 260  IF(T(I,17).NE.0)   WRITE(6,265) T(I,17)
 270  IF(T(I,18).NE.0)   WRITE(6,275) T(I,18)
 280  IF(T(I,19).NE.0)   WRITE(6,285) T(I,19)
 290  IF(T(I,20).NE.0)   WRITE(6,295) T(I,20)
 300 WRITE(6,305) DTOTAL(I),DP(I)
C
 400 CONTINUE
     WRITE(6,1200)
     WRITE(6,1210) (S(J),J=1,21)
     WRITE(6,1230) (VTOTAL(J),J=1,20),NTOTAL
     WRITE(6,1240) (VP(J),J=1,20)
     WRITE(6,1200)
     WRITE(6,1200)
     WRITE(6,1250) TOTALD,POP
     WRITE(6,1260) NTOT
 100 FORMAT(3X,I3,'-',I3)
 105 FORMAT(1H+,13X,I5)
 115 FORMAT(1H+,18X,I5)
 125 FORMAT(1H+,23X,I5)
 135 FORMAT(1H+,28X,I5)
 145 FORMAT(1H+,33X,I5)
 155 FORMAT(1H+,38X,I5)
 165 FORMAT(1H+,43X,I5)
 175 FORMAT(1H+,48X,I5)
 185 FORMAT(1H+,53X,I5)
 195 FORMAT(1H+,58X,I5)
 205 FORMAT(1H+,63X,I5)
 215 FORMAT(1H+,68X,I5)
 225 FORMAT(1H+,73X,I5)
 235 FORMAT(1H+,78X,I5)
 245 FORMAT(1H+,83X,I5)
 255 FORMAT(1H+,88X,I5)
 265 FORMAT(1H+,93X,I5)
 275 FORMAT(1H+,98X,I5)
 285 FORMAT(1H+,103X,I5)
 295 FORMAT(1H+,108X,I5)
 305 FORMAT(1H+,117X,I4,3X,F5.1)
1020 FORMAT(//,'  DIRECTION',3X,4A5,'NORTH',80X,'SUM  PER.CT.',//)
1200 FORMAT(1X,/)
1210 FORMAT(4X,'SPEED',2X,21(I5))
1230 FORMAT(2X,'SUM',9X,20I5,6X,I5)
```

```
        1240 FORMAT(2X,'PER.CT.',5X,20F5.1)
        1250 FORMAT(5X,'NUMBER OF ZERO SPEED AVERAGES = ',I5,10X,
            *'PERCENTAGE ZERO SPEED AVERAGES = ',F5.2)
        1260 FORMAT(5X,'TOTAL NUMBER OF OBS. = ',I5,10(/))
             RETURN
             END

CONSTANTS

0       000000000001    1       204740000000

GLOBAL DUMMIES

V       1156            D       1157            NTOT    1160            TITLE1  1161            TITLE2  1162
NHR     1163            NMIN    1164            NMO     1165            NDAY    1166            NYR     1167
INC     1170            NI      1171

SUBPROGRAMS

ADJ.    AMAXI   FLOAT   INTO.   INTI.   FLOUT.  FLIRT.  ALPHO.  ALPHI.

SCALARS

HISTOS  1173            NTOT    1160            J       1174            I       1175            VMAX    1176
K       1177            NMAX    1200            KINT    1201            TOTAL0  1202            LINE    1203
KOL     1204            POP     1205            NTOTAL  1206            DSUM    1207            VSUM    1210
NHR     1163            NMIN    1164            NMO     1165            NDAY    1166            NYR     1167
INC     1170            NI      1171

ARRAYS

V       1156            D       1157            VF      1211            DP      1235            MAGN    1265
GEOG    1271            T       1275            VTOTAL  2235            DTOTAL  2261            A       2311
S       2342            TITLE1  1161            TITLE2  1162            FMIV    2367            FMTD    2375
```

```
                SUBROUTINE FILEAS(L,IFILE)
                DOUBLE PRECISION IFILE
        C
        C  THIS SUBROUTINE SELECTS THE NAME OF A FILE
        C  TO BE OPENED DEPENDING THE TIME INTERVAL
        C

                GO TO (6,12,18,24,30,36,42,48),L
              6 IFILE = 'HRS06.DAT'
                RETURN
             12 IFILE = 'HRS12.DAT'
                RETURN
             18 IFILE = 'HRS18.DAT'
                RETURN
             24 IFILE = 'HRS24.DAT'
                RETURN
             30 IFILE = 'HRS30.DAT'
                RETURN
             36 IFILE = 'HRS36.DAT'
                RETURN
             42 IFILE = 'HRS42.DAT'
                RETURN
             48 IFILE = 'HRS48.DAT'
                RETURN
                END

CONSTANTS

0     442452330154   1    272110152100   2    442452330544   3    272110152100   4    442452330560
5     272110152100   6    442452331150   7    272110152100   10   442452331540   11   272110152100
12    442452331554   13   272110152100   14   442452332144   15   272110152100   16   442452332160
17    272110152100

GLOBAL DUMMIES

L     107            IFILE  110

SCALARS

FILEAS  112          L      107           IFILE  110
```

```
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                        SUBROUTINE SUMS(A,B,C,D,E)
                        COMMON SUMVEL,SUMX,SUMY,SUMSTA,STAMAX,STAMIN
                        COMMON RT,PHI,SX,SUMRT

                  C
                  C  THIS SUBROUTINE SUMS UP THE VALUES FOR STATISTICS
                  C

                        SUMVEL = SUMVEL + A
                        SUMX   = SUMX   + B
                        SUMY   = SUMY   + C
                        SUMRT  = SUMRT  + D
                        SUMSTA = SUMSTA + E
                        STAMIN = AMIN1(E,STAMIN)
                        STAMAX = AMAX1(E,STAMAX)

                        RETURN
                        END

       GLOBAL DUMMIES

       A       45               B       46               C       47               D       50               E       51

       COMMON

       SUMVEL  /.COMM./+0       SUMX    /.COMM./+1       SUMY    /.COMM./+2       SUMSTA  /.COMM./+3       STAMAX  /.COMM./+4
       STAMIN  /.COMM./+5       RT      /.COMM./+6       PHI     /.COMM./+7       SX      /.COMM./+10      SUMRT   /.COMM./+11

       SUBPROGRAMS

       AMIN1   AMAX1

       SCALARS

       SUMS    52               SUMVEL  0                A       45               SUMX    1                B       46
       SUMY    2                C       47               SUMRT   11               D       50               SUMSTA  3
       E       51               STAMIN  5                STAMAX  4                RT      6                PHI     7
       SX      10
```

```
                SUBROUTINE INITIA
                COMMON SUMVEL,SUMX,SUMY,SUMSTA,STAMAX,STAMIN
                COMMON RT,PHI,SX,SUMRT

          C
          C  INITIALIZE VALUES
          C

                SUMVEL = 0.0
                SUMX   = 0.0
                SUMY   = 0.0
                SUMPT  = 0.0
                SUMSTA = 0.0
                STAMIN = 999999999.
                STAMAX = -99999999.
                RETURN
                END

     CONSTANTS

     0       236734654477    1       233575360377

     COMMON

     SUMVEL  /.COMM./+0      SUMX    /.COMM./+1      SUMY    /.COMM./+2      SUMSTA  /.COMM./+3      STAMAX  /.COMM./+4
     STAMIN  /.COMM./+5      RT      /.COMM./+6      PHI     /.COMM./+7      SX      /.COMM./+10     SUMRT   /.COMM./+11

     SCALARS

     INITIA  26              SUMVEL  0               SUMX    1               SUMY    2               SUMRT   11
     SUMSTA  3               STAMIN  5               STAMAX  4               RT      6               PHI     7
     SX      10
```

```
OCEAN2.F4       F40     V27(360)        29-OCT-79       19:41   PAGE 15

                SUBROUTINE STAWRT(KM,M)
                COMMON SUMVEL,SUMX,SUMY,SUMSTA,STAMAX,STAMIN
                COMMON RT,PHI,SX,SUMRT

          C
          C  THIS SUBROUTINE COMPUTES PHI, RT, SX & PRINTS THESE
          C  VALUES INCLUDING SUMS AND AVERAGES
          C
                AVGVEL = SUMVEL/M
                AVGX   = SUMX/M
                AVGY   = SUMY/M
                PHI    = ATAN( SUMY/SUMX)*(180./3.1416)
                RT     = ( SUMX**2.0 + SUMY**2.0 )**0.5
                SX     = (( 2.0*AVGVEL)**2.0 - 2.0*(AVGVEL)**2.0 )**0.5
                AVGSTA = SUMSTA/M
                AVGRT  = SUMRT/M

                IF(KM.EQ.0) WRITE(6,38)
                IF(KM.NE.0) WRITE(6,39) KM
                WRITE(6,40) SUMVEL,SUMX,SUMY
                WRITE(6,43) AVGVEL,AVGX,AVGY
                IF(KM.NE.0) WRITE(6,44) AVGRT
                WRITE(6,41) RT,PHI
                WRITE(6,42) SX
                IF(KM.NE.0) WRITE(6,45) SUMSTA,AVGSTA,STAMAX,STAMIN
             38 FORMAT(1H1,18(/),40X,'DATA BASED STATISTICS',///)
             39 FORMAT(1H1,18(/),40X,'RESULTS BASED STATISTICS'I5
               *,' HOURS INTERVALS'///)
             40 FORMAT(/1X,'SUM OF VELOCITIES',10X,'=',F13.2,10X,'SUM OF X  =',
               1F13.2,10X,'SUM OF Y  =',F13.2)
             41 FORMAT(/1X,'TOTAL  RESULTANT ',10X,'=',F13.2,10X,'RESULTANT ANGLE
               1 =',F7.2)
             42 FORMAT(/1X,'STANDARD  DEVIATION',8X,'=',F13.2)
             43 FORMAT(/1X,'AVERAGE  VELOCITY',10X,'=',F13.2,10X,'AVERAGE X ='
               *,F13.2,10X,'AVERAGE Y =',F13.2)
             44 FORMAT(/,1X,'AVERAGE RESULTANT VELOCITY =',F13.2)
             45 FORMAT(/,1X,'SUM OF STABILITIES ',8X,'=',F13.2,
               *//,1X,'AVERAGE STABILITY   ',7X,'=',F13.2,
               *//,1X,'   STABILITY RANGE  :',
               */,15X,'MAXIMUM       =',F13.2,
               */,15X,'MINIMUM       =',F13.2)
                RETURN
                END

        CONSTANTS

        0       206712272756

        GLOBAL DUMMIES

        KM      364             M       365

        COMMON
```

```
OCEAN2.F4       F40I    V27(360)        29-OCT-79       15:41   PAGE 16


        SUMVEL  /.COMM./+0      SUMX    /.COMM./+1      SUMY    /.COMM./+2      SUMSTA  /.COMM./+3      STAMAX  /.COMM./+4
        STAMIN  /.COMM./+5      RT      /.COMM./+6      PHI     /.COMM./+7      SX      /.COMM./+10     SUMRT   /.COMM./+11

        SUBPROGRAMS

        ATAN    EXP3.2  EXP3.4  INTO.   INTI.   FLOUT.  FLIRT.

        SCALARS

        START   367             AVGVEL  370             SUMVEL  0               M       365             AVGX    371
        SUMX    1               AVGY    372             SUMY    2               PHI     7               RT      6
        SX      10              AVGSTA  373             SUMSTA  3               AVGRT   374             SUMRT   11
        KM      364             STAMAX  4               STAMIN  5
```

PROPL4,F4

This Program Uses the Computer to Plot Progressive Vectors

from the Current Meter Data

```
      C=============================================
      C    THIS IS PROGRESIVE VECTOR PLOTTING PROGRAM   =
      C=============================================
            IMPLICIT INTEGER(F)
            DIMENSION X(0/1000),Y(0/1000),XX(1000),YY(1000),TITLE(16),
           *  HEADING(7),NDATES(6),MONTH(12),EQUIS(5),YES(5),FMT(6)
           *,TITLE2(10),M(4),TITLE3(4)
            DATA MONTH/5H-JAN-,5H-FEB-,5H-MAR-,5H-APR-,5H-MAY-,5H-JUN-,
           *  5H-JUL-,5H-AUG-,5H-SEP-,5H-OCT-,5H-NOV-,5H-DEC-/
            CALL DEFINE FILE(21,30,NV,0,0,0)
            INTEGER HOUR
            LOGICAL DEBUG
            READ(5,1) TITLE
            READ(5,1) TITLE2
            READ(5,6) TITLE3
            READ(1,2) FMT
            READ(1,3) NTOT,HOUR,MINUTS,NDAY,MONTHS,NYEAR,FEB,INCR,INCRD,
           *              SCALE
            READ(1,4) (M(I),I=1,4)
            READ(1,5) NAST
          1 FORMAT (1X,16A5)
          2 FORMAT (6A5)
          3 FORMAT (10G)
          4 FORMAT(4G)
          5 FORMAT(A5)
          6 FORMAT(4A5)
      C=============================================
      C          READ THE X-Y COMPONENTS.              =
      C=============================================

            READ(5,FMT) (X(N),Y(N),N=1,NTOT)
      C
      C  CHANGE THE COMPONENTS TO PLOTTER UNITS.
      C
            ESCALA = 2.0/(2.54*SCALE)
            DO 100 N = 1,NTOT
             X(N)=X(N)*ESCALA
             Y(N)=Y(N)*ESCALA
        100 CONTINUE
            XWIDTH = 0.454545454545
            DATA (EQUIS(I),I=1,5)/2*0.0,2*1.0,0.0/
            DATA (YES(I),I=1,5)/0.0,2*1.0,2*0.0/

            N=0
            DMAX=20.
            NGRAPH= 0
      C
      C  THIS SECTION ARRANGES THE COMPONENTS
      C
        150 NFIRST=N+1
            DEBUG=.TRUE.
            SUMX=0.0
            SUMY=0.0
```

```
            XMAX=-9999999.
            YMAX=-9999999.
            XMIN= 9999999.
            YMIN= 9999999.
      C
      C  CHANGE COMPONENTS INTO PROGRESSIVE VECTORS.
      C
       200  XX(N)=SUMX+X(N)
            YY(N)=SUMY+Y(N)
            IF(N.GT.(NFIRST+10)) DEBUG=.FALSE.
            SUMX=XX(N)
            SUMY=YY(N)
      C
      C  FIND MINIMUM AND MAXIMUM DISPLACEMENTS.
      C
            XMAX=AMAX1(XX(N),XMAX)
            YMAX=AMAX1(YY(N),YMAX)
            XMIN=AMIN1(XX(N),XMIN)
            YMIN=AMIN1(YY(N),YMIN)
      C
            DELTAX=XMAX-XMIN
            DELTAY=YMAX-YMIN
      C
      C  CHECK IF DISPLACEMENTS EXCEED PLOTTER BOUNDARIES.
      C
            IF(DELTAX.GT.DMAX.OR.DELTAY.GT.DMAX) GO TO 250
            IF(DELTAX.EQ.DMAX.OR.DELTAY.EQ.DMAX) GO TO 300
            IF( N .GT. NTOT ) GO TO 250
            N=N+1
            GO TO 200
        250 N=N-1
      C   SECTION TO PLOT THE PROGRESSIVE VECTORS.
      C
      300   NGRAPH=NGRAPH+1
      C
      C  INITIALIZE POSITIONS OF FRAMES AND RELATED.
      C
            YFIRST=YMIN
            XFIRST=XMIN
            XFINAL=(XMIN+DMAX)
            YFINAL=(YMIN+DMAX)
            XWIDTH=.454545454545  = 10/22
            YWIDTH=.454545454545  = 10/22
            XCORNR=.113636363636  = 2.5/22
            YCORNR=.022727272727  = 2.5/22
            HEIGHT= 5.0
            HEDSPC=0.0
            HECARD=0.375
            ITIME=HOUR*100+MINUTS
            NTIME=HOUR*100+MINUTS
            FDAY=NDAY
            FIDAY=FDAY
            FMONTH=MONTHS
```

```
        FYEAR=NYEAR
        TX=0.0
        TY=0.0
C
        CALL PETPGT(LASTX,LASTY,NEWX,NEWY)
        DO 600 K = NFIRST,N
        MORE=2
        DO 315 I=1,4
          IF(NTIME.EQ.M(I)) MORE=1
  315   CONTINUE
          GO TO (340,350),MORE
  340   WRITE(21#1,7)NTIME
7       FORMAT(1X,I4,'S')
        READ(21#1,8)IFINAL
  8       FORMAT(1X,A5)
        GO TO 375
  350   IFINAL=' S '
  375   REL=1.0
        NSIGN='VS '
        IF(NDAY.EQ.FDAY) GO TO 400
        REL=1.1
        NSIGN= NAST
        FDAY=NDAY
  400   HX=XX(K)
        HY=YY(K)
        CALL ARRPLT(TX,TY,HX,HY,XFIRST,YFIRST,XFINAL,YFINAL,XWIDTH,
     *   YWIDTH,XCORNR,YCORNR,' S ',NSIGN,RELHIT,RELSPC,RELARO*REL,
     *   LASTX,LASTY,IFINAL)
        CALL ARRPLT(TX,TY,HX,HY,XFIRST,YFIRST,XFINAL,YFINAL,XWIDTH,
     *   YWIDTH,XCORNR,YCORNR,' $ ',NSIGN,RELHIT,RELSPC,RELARO*REL,
     *   LASTX,LASTY,IFINAL)
  470   TX=HX
        TY=HY
        CALL TIMEAD(NTIME,HOUR,MINUTS,MONTHS,NDAY,NYEAR,FEB,INCR,INCRO)
  600   CONTINUE
C
        G34 = XWIDTH * .3722
        CALL DSHPLT(EQUIS,YES,1,5,0.0,0.0,1.0,1.0,G34,0.4772727272,
     *0.1772727272,0.01136363636,1.,0.0,LASTX,LASTY)
        CALL DSHPLT(EQUIS,YES,1,5,0.0,0.0,1.0,1.0,0.0909090909,
     *0.1772727272,0.01136363636,0.01136363636,1.0,0.0,LASTX,LASTY)
        K1 = FMONTH
        K2 = MONTHS
        WRITE(21#2,310)FDAY,MONTH(K1),FYEAR,NDAY,MONTH(K2),NYEAR
  310   FORMAT('DATE: ',I2,A5,I2,'  TO  ',I2,A5,I2)
        READ(21#2,320) NDATES
        TYPE 321,NDATES
  321   FORMAT(1X,6A5)
  320    FORMAT(6A5)
C
        SCALES = SCALE
        CALL LETTER(TITLE,SCALES,TITLE2,TITLE3,NDATES,NGRAPH)
        CALL LETTER(TITLE,SCALES,TITLE2,TITLE3,NDATES,NGRAPH)
```

```
     160                  CALL PENPLT(LASTX,LASTY,NEWX,NEWY)
     161                  CALL PENEND(LASTX,LASTY,NEWX,NEWY)
     162                  TYPE 30,NGRAPH
     163               30 FORMAT(/,1X,'DIAGRAM # ',I2,'  COMPLETED',/)
     164            C   IF N IS LESS THAN NTOT PROCEED
     165            C   TO GENERATE A NEW DIAGRAM.  IF N EQUAL TO NTOT
     166            C   STOP EXECUTION OF THE PROGRAM AND FINISH.
     167                  CALL TIMEX(NTIME,HOUR,MINUTS,MONTHS,NDAY,NYEAR,FEB,INCR,INCRD)
     168                  IF( N - NTOT ) 150,325,325
     169            325   STOP
     170                  END

        CONSTANTS

        0       000000000025   1    000000000030   2    000000000000   3    202505075341   4    177721350564
        5       230461131770   6    175721350564   7    173564272134   10   201104020100   11   531104020100
        12      201540314031   13   201104020100   14   000000000000   15   173564272135   16   000000000001
        17      000000000005   20   201400000000   21   177750564272   22   175642721350   23   172564272135
        24      175564272135   25   172564272131

        SUBPROGRAMS

        FORSE.  JOBFF  OFFINE  ALPHO.  ALPHI.  ADDIO.  AMAX1  AMIN1  PENBGN  RECNO.  RANAC.  INTO.  INTI.  ARUPLT  TIMEX
        DSHPLT  LETTER  PENPLT  PENEND  EXIT

        SCALARS

        NV      1017            NTOT     1020           HOUR    1021            MINUTS  1022            NDAY    1023
        MONTHS  1024            NYEAR    1925           FEB     1026            INCR    1027            INCRD   1030
        SCALE   1031            I        1032           NAST    1033            N       1034            ESCALA  1035
        XWIDTH  1036            DFAX     1037           NGRAPH  1040            NFIRST  1041            DEBUG   1042
        SUMX    1043            SUMY     1044           XMAX    1045            YMAX    1046            XMIN    1047
        YMIN    1050            DEGFAX   1051           DEGFAY  1052            YFIRST  1053            XFIRST  1054
        XFINAL  1055            YFINAL   1056           YWIDTH  1057            XCURNR  1060            YCURNR  1061
        PEGHIT  1062            REGSPC   1063           REGARD  1064            ITIME   1065            NTIME   1066
        FDAY    1067            FIDAY    1070           FMONTH  1071            FYEAR   1072            TX      1073
        TY      1074            LASTX    1075           LASTY   1076            NEWX    1077            NEWY    1100
        K       1101            MORE     1102           IFINAL  1103            REL     1104            NSIGN   1105
        NX      1106            NY       1107           U34     1110            K1      1111            K2      1112
        SCALES  1113

        ARRAYS

        X       1114            Y        3065           XX      5036            YY      7006            TITLE   10756
        HEADIN  10776           NDATES   11005          MONTH   11013           EQUIS   11027           YES     11034
        FMT     11041           TITLE2   11047          M       11067           TITLE3  11073
```

```
C
C
C
C
C=========================================
C       THIS SUBROUTINE KEEPS TRACK OF THE  =
C       TIME , THE DAY , MONTH AND YEAR.    =
C===========================================


      SUBROUTINE TIMEX(ITIME,HOUR,MINUTS,MONTHS,DAY,YEAR
     *,MTH,INCR,INCRD)
      INTEGER HOUR,DAY,YEAR

      IF(INCR.EQ.0) GO TO 15
      HOUR=HOUR+INCR
      IF(HOUR.LT.24) GO TO 10
      HOUR=HOUR-24
      DAY = DAY+1
 10   IF(INCRD.EQ.0) GO TO 20
 15   DAY = DAY+INCRD
 20   GO TO(31,29,31,30,31,30,31,31,30,31,30,31),MONTHS

 29   IF(DAY.LE.(28+MTH)) GO TO 60
      DAY = DAY-(28+MTH)
      GO TO 50
 30   IF(DAY.LE.30) GO TO 60
      DAY=DAY-30
      GO TO 50
 31   IF(DAY.LE.31) GO TO 60
      DAY=DAY-31
 50   IF(DAY.EQ.0) DAY=1
      MONTHS= MONTHS+1
      IF(MONTHS.GT.12) YEAR=YEAR+1
      IF(MONTHS.GT.12) MONTHS=1
 60   ITIME=HOUR*100+MINUTS
      RETURN
      END

GLOBAL DUMMIES

ITIME    142       HOUR     143       MINUTS   144       MONTHS   145       DAY      146
YEAR     147       MTH      150       INCR     151       INCRD    152

SCALARS

TIMEX    153       INCR     151       HOUR     143       DAY      146       INCRD    152
MONTHS   145       MTH      150       YEAR     147       ITIME    142       MINUTS   144
```

HISPLT.F4

This Program Plots the Speed and Direction Histograms
from the Current Meter Data

```
      DIMENSION TITLE1(16),TITLE2(16),TITLE3(4),
     * DP(25),VP(21),CUM(21),U(2),V(2)

      CALL PLOTS(IREADY)
100   CALL PLOT(10.,0.,3)


      READ(4,1,END=200) TITLE1
      READ(4,1) TITLE2
      READ(4,2) TITLE3
      READ(4,3) (DP(I),I=1,24)
      READ(4,4) (VP(I),I=1,20)
1     FORMAT(16A5)
2     FORMAT(4A5)
3     FORMAT(12G)
4     FORMAT(10G)

      DX= 0.25
      YHIGH= 5.0

      CALL SYMBOL(1.0,20.5,0.20,TITLE1,0.0,80)
      CALL SYMBOL(1.0,20.5,0.20,TITLE1,0.0,80)
      CALL SYMBOL(1.0,20.0,0.20,TITLE2,0.0,80)
      CALL SYMBOL(1.0,20.0,0.20,TITLE2,0.0,80)
      CALL SYMBOL(1.0,19.5,0.20,TITLE3,0.0,20)
      CALL SYMBOL(1.0,19.5,0.20,TITLE3,0.0,20)

      CALL AXIS(2.0,12.0,'DIRECTION HISTOGRAM',-19,6.0,0.0,0.0,60.0)
      CALL AXIS(2.0,12.0,'DIRECTION HISTOGRAM',-19,6.0,0.0,0.0,60.0)
      CALL AXIS(2.0,12.0,'RELATIVE FREQUENCY',18,5.0,90.0,0.0,20.0)
      CALL AXIS(2.0,12.0,'RELATIVE FREQUENCY',18,5.0,90.0,0.0,20.0)
      DO 10 I=1,24
      A = 2.0 + (I-1)*DX
      CALL BARS(A,DP(I),DX,2.0,12.0,YHIGH)
10    CONTINUE

      CALL PLOT(10.0,12.0,3)
      CALL AXIS(10.0,12.,'SPEED HISTOGRAM-CM/SEG',-22,5.,0.,0.,20.)
      CALL AXIS(10.0,12.,'SPEED HISTOGRAM-CM/SEG',-22,5.,0.,0.,20.)
      CALL AXIS(10.0,12.,'RELATIVE FREQUENCY',18,5.0,90.,0.,20.)
      CALL AXIS(10.0,12.,'RELATIVE FREQUENCY',18,5.0,90.,0.,20.)

      DO 20 I=1,20
      A = 10.0 + (I-1)*DX
      CALL BARS(A,VP(I),DX,10.0,12.0,YHIGH)
20    CONTINUE

      CUM(1)= 0.0
      DO 30 I=2,21
      CUM(I)=CUM(I-1)+VP(I-1)
30    CONTINUE

      DO 35 I=21,1,-1
```

```
            IF(VP(I).NE.0.0) GO TO 40
      35    CONTINUE
      40    LIMIT=I

            CALL AXIS(6.,5.,'CUM. SPEED DISTR.-CM/SEG',-24,5.,0.,0.,20.)
            CALL AXIS(6.,5.,'CUM. SPEED DISTR.-CM/SEG',-24,5.,0.,0.,20.)
            CALL AXIS(6.,5.,'CUMULATIVE FREQUENCY',20,5.,90.,0.,20.)
            CALL AXIS(6.,5.,'CUMULATIVE FREQUENCY',20,5.,90.,0.,20.)

            IF(LIMIT.GE.20) LIMIT = 19
            DO 50 I=1,LIMIT
            U(1)=6.0 + (I-1)*DX
            U(2)=6.0 + I*DX
            V(1)=5.0 + CUM(I)*YHIGH
            V(2)=5.0 + CUM(I+1)*YHIGH

            CALL LINE(U,V,2,1)
            CALL LINE(U,V,2,1)

            CALL SYMBOL(U(1)-0.05,V(1)-0.05,0.10,'*',0.0,1)
            CALL SYMBOL(U(1)-0.05,V(1)-0.05,0.10,'*',0.0,1)
      50    CONTINUE

            CALL SYMBOL(U(2)-0.05,V(2)-0.05,0.10,'*',0.0,1)
            CALL SYMBOL(U(2)-0.05,V(2)-0.05,0.10,'*',0.0,1)


            CALL PLOT(20.0,0.0,-3)
            GO TO 100
     200    TYPE 9
       9    FORMAT(1X,'HISPLOT COMPLETED')
            STOP
            END

    CONSTANTS

    0     204500000000   1    000000000000   2    000000000003   3    201400000000   4    205510000000
    5     176031463146   6    000000000120   7    205500000000   10   205470000000   11   000000000024
    12    202400000000   13   204600000000   14   422232242606   15   522231747100   16   442232352236
    17    436450140500   20   000000000000   21   203600000000   22   206740000000   23   512131440650
    24    446550520214   25   512132152612   26   472073120100   27   000000000000   30   000000000022
    31    203500000000   32   207550000000   33   516410542610   34   202211151650   35   476172240632
    36    266071527646   37   426164020100   40   000000000000   41   416531527100   42   516410542610
    43    202111151650   44   511345541632   45   276470543500   46   000000000000   47   416531552630
    50    406511153212   51   202152242642   52   520131041662   53   000000000000   54   000000000002
    55    000000000001   56   174631463146   57   175631463146   60   251004020100   61   000000000000

    SUBPROGRAMS

    FORSE.  .JBFF   PLOTS   PLOT    END.    ALPHO.  ALPHI.  ALLIO.  SYMBOL  AXIS    BARS    LINE    EXIT

    SCALARS
```

```
HISPLT.F4      F40I    V27(360)        29-NOV-79      11:28  PAGE 3

          IREADY  664             I        665        DX       666           YHIGH   667            A       670
          LIMIT   671

          ARRAYS

          TITLE1  672             TITLE2   712        TITLE3   732           DP      736            VP      767
          COM     1014            U        1041       V        1043
```

```
HISPLT.F4      F40I   V27(360)        29-NOV-79       11:28  PAGE 4




          SUBROUTINE BARS(A,B,DX,XFIRST,YFIRST,YHIGH)
          DIMENSION X(4),Y(4)

          X(1) = A
          X(2) = A
          X(3) = A + DX
          X(4) = A + DX
          Y(1) = YFIRST
          Y(2) = YFIRST + B*YHIGH
          Y(3) = YFIRST + B*YHIGH
          Y(4) = YFIRST

          CALL LINE(X,Y,4,1)
          CALL LINE(X,Y,4,1)

          RETURN
          END

CONSTANTS

0        000000000004    1        000000000001

GLOBAL DUMMIES

A        64              B        65              DX       66              XFIRST   67              YFIRST   70
YHIGH    71

SUBPROGRAMS

LINE

SCALARS

BARS     72              A        64              DX       66              YFIRST   70              B        65
YHIGH    71              XFIRST   67

ARRAYS

X        73              Y        77
```

MULPLT.F4

This Program Plots a Variable, Such as Current Speed
Versus Time from the Current Meter Data

```
C
C      PROGRAM MULTIPLOT
C
       DIMENSION DATA(6000),MONTHS(12),MONEND(12),FMT(10),LABEL1(16)
       DIMENSION LABEL2(16),X(6000),ISYMBL(1)
       INTEGER PNTDEN
       DATA MONTHS/'JAN','FEB','MAR','APR','MAY','JUNE','JULY',
      1'AUG','SEPT','OCT','NOV','DEC'/
       DATA MONEND/31,28,31,30,31,30,31,31,30,31,30,31/
C
C      READ THE NUMBER OF VARIABLES TO BE PLOTTED
C      ALSO THE OVERALL SCALE INDICATOR 'JAVA'
C
       READ(1,10)NVARBL,JAVA,HEIGHT,LEAPYR
    10 FORMAT(4G)
       WRITE(6,11)NVARBL,JAVA,HEIGHT,LEAPYR
    11 FORMAT(//T15,'INPUT PARAMETERS'//T5,'NVARBL',T17,'JAVA',T25,
      1'HEIGHT',T35,'LEAPYR'//2I10,F10.3,I10)
       CALL PLOTS(1)
       CALL PLOT(0.0,0.0,JAVA)
       CALL SYMBOL(0.0,7.5,0.4,'MULTYPLOT DIAGRAM',90.0,17)
       CALL SYMBOL(0.0,7.5,0.4,'MULTYPLOT DIAGRAM',90.0,17)
       LONG=0
       Y=3.0
       WRITE(6,12)
    12 FORMAT(//T3,'SERIES #',T13,'XPOSTN',T21,'SCALE',T28,'PNTDEN',T36,
      1'LENGTH',T44,'KINPUT',T53,'IOPTN',T59,'NDECY',T67,
      2'FORMAT :')
C
C      START THESE PLOTS AT X=0.0
C
       DO 5000 M=1,NVARBL
C
C      READ INFORMATION SPECIFIC TO EACH VARIABLE
C
       READ(1,20)XPOSTN,SCALE,PNTDEN,LENGTH,KINPUT,IOPTN,NDECY
    20 FORMAT(7G)
       READ(1,30) FMT
    30 FORMAT(10A5)
       READ(5,40) LABEL1
       READ(5,40) LABEL2
       READ(5,41)
    41 FORMAT(20X)
    40 FORMAT(16A5)
       WRITE(6,21)M,XPOSTN,SCALE,PNTDEN,LENGTH,KINPUT,IOPTN,
      1                  NDECY,FMT
    21 FORMAT(//I10,2F8.4,4I8,T61,I4,3X,10A5)
       X(1)=XPOSTN
C
C      READ THE DATA FROM THE PROPER INPUT DEVICE AND IN THE RIGHT FORMAT
C
       READ(5,FMT)(DATA(I),I=1,LENGTH)
C
```

```
C     KEEP A CHECK ON THE LARGEST NUMBER OF POINTS INVOLVED
C
      IF(LENGTH-LONG)43,43,35
   35 LONG=LENGTH
      JUMP=PRIDEN
      SAVE=APOSIN
   43 FACT=1.0/PRIDEN
      DO 47 L=2,6000
   47 X(L)=X(L-1)+FACT
C
C     EVALUATE THE MAX AND MIN OF EACH SERIES
C     DETERMINE PLOT SIZE FROM MAX,MIN AND ISCALE PARAMETER
C
   49 XMAX=-99999.
      XMIN=9999999.
      DO 50 I=1,LENGTH
      XMIN=AMIN1(XMIN,DATA(I))
   50 XMAX=AMAX1(XMAX,DATA(I))
      IF( XMIN.GT.0.0 ) XMIN = 0.0
      IF(XMIN)59,51,51
   51 MINPLT=XMIN/SCALE
      MAXPLT=XMAX/SCALE+1
      ALLPLT=MAXPLT-MINPLT
      LIMIT=MAXPLT-MINPLT+1
      KKK=ALLPLT/2
      BELOW=KKK
      ABOVE=ALLPLT-BELOW
      DO 58 KRAMER=1,LENGTH
   58 DATA(KRAMER)=DATA(KRAMER)/SCALE-MINPLT+Y
      GO TO 65
   59 MAXPLT=XMAX/SCALE+1
      MINPLT=ABS(XMIN)/SCALE+1
      ABOVE=MAXPLT
      BELOW=MINPLT
      ALLPLT=ABOVE+BELOW
      LIMIT=ALLPLT+1
C
C     CONVERT DATA TO PLOTTER UNITS
C
      DO 200 I=1,LENGTH
  200 DATA(I)=(DATA(I)/SCALE)+Y+BELOW
C
C     START DRAWING THE AXIS
C
   65 CALL PLOT(6.0,Y,3)
      CALL PLOT(6.0,Y+ALLPLT,2)
C
C     NUMBER THE 'Y' AXIS
C
      XV=MAXPLT*SCALE
      YDIGIT=ALOG10(XV)
      XX=6.0-((2.0*HEIGHT)/3.0)
      XNUMB=XX-0.40*(1+NDECY)*HEIGHT
```

```
      XLABEL=XNUMB-((3.0+IDIG(I))*HEIGHT)
      YPOSTN=Y+ALLPLT
      DO 100 I=1,LIMIT
      CALL NUMBER(XNUMB,YPOSTN-(HEIGHT/2.0),HEIGHT,XY,0.0,NDECY)
      CALL NUMBER(XNUMB,YPOSTN-(HEIGHT/2.0),HEIGHT,XY,0.0,NDECY)
      CALL SYMBOL(XX,YPOSTN,HEIGHT,'-',0.0,1)
      CALL SYMBOL(XX,YPOSTN,HEIGHT,'-',0.0,1)
      YPOSTN=YPOSTN-1.0
  100 XY=XY-SCALE
C
C     LABEL THE AXIS
C
      CENTRY=Y+(ALLPLT/2.0)-(10.0*HEIGHT)
      CALL SYMBOL(XLABEL,CENTRY,HEIGHT,LABEL2,90.0,80)
      CALL SYMBOL(XLABEL,CENTRY,HEIGHT,LABEL2,90.0,80)
      CALL SYMBOL(XLABEL-2.0*HEIGHT,CENTRY,HEIGHT,LABEL1,90.0,80)
      CALL SYMBOL(XLABEL-2.0*HEIGHT,CENTRY,HEIGHT,LABEL1,90.0,80)
  221 CALL LINE(X,DATA,LENGTH,1)
C
C     ADJUST THE Y VALUE WHEN DONE PLOTTING THIS VARIABLE
C
      IF(XMIN)250,251,251
  250 CALL PLOT(X(LENGTH),Y+BELOW,3)
      CALL PLOT(0.00,Y+BELOW,2)
  251 Y=Y+ALLPLT+1.0
      IF(KINPUT-5)4999,5000,4999
 4999 REWIND KINPUT
 5000 CONTINUE
      IF(Y-25.0)300,298,298
  298 WRITE(6,299)
  299 FORMAT(///10X,'BETTER USE LARGE PAPER SINCE OVERALL PLOT EXCEEDS
     125 UNITS'//)
C
C     READ IN THE TIME INFORMATION AND DISPLAY IT ON THE PLOT
C
  300 READ(1,301)NOWDAY,ITIS,NOWHR,NOWMIN,IDADD,IHRADD,MINADD,XINCRM
  301 FORMAT(8G)
C     ADJUST FOR LEAPYR IF NECESSARY
      IF(LEAPYR)302,305,302
  302 MONEND(2)=29
  305 II=(SAVE-0.0)/XINCRM
      IDU=LONG/(JUMP*XINCRM)+II+2
      YPOSTN=0.0
      YPOSTN=3.0
      CALL TIMEPT(YPOSTN,NOWDAY,ITIS,NOWHR,NOWMIN,IDADD,IHRADD,MINADD,
     1XINCRM,IDU,MONTHS,MONEND,YPOSTN,HEIGHT)
      WRITE(6,306)
  306 FORMAT(///20X,'MULTYPLT COMPLETED')
      CALL PLOT(0.0,3.0,2)
      CALL PLOT(X(LENGTH)+10.0,0.0,-3)
      STOP
      END
```

```
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      CONSTANTS

      0        000000000000   1      203740000000   2      177631463146   3      466531452262   4      502311752100
      5        422230143644   6      406324020100   7      000000000000   10     207550000000   11     000000000021
      12       221600470000   13     230461131770   14     203600000000   15     000000000003   16     000000000002
      17       202600000000   20     265004020100   21     000000000000   22     000000000001   23     201400000000
      24       000000000120   25     205620000000

      SUBPROGRAMS

      MOPSC.   SUBPP   ADDIO.  TRMT.   INTO.    INTI.   FLOUT.  FLIRT.  PLOTS   PLOT    SYMBOL  ALPHO.  ALPHI.  AMIN1   AMAX1
      ABS      ALOG10  NUMBER  LINE    TPFCH.   TIMEPT  EXIT

      SCALARS

      NVARBL   1065             JAVA     1066              HEIGHT   1067              LEAPYR   1070             I        1071
      LONG     1072             Y        1073              M        1074              XPOSIN   1075             SCALE    1076
      PNTURN   1077             LENGTH   1100              KINPUT   1101              IOPTN    1102             NDECY    1103
      JUMP     1104             SAVE     1105              FACT     1106              L        1107             XMAX     1110
      XMIN     1111             MINPLT   1112              MAXPLT   1113              ALLPLT   1114             LIMIT    1115
      KKK      1116             BELOW    1117              ABOVE    1120              KNAMER   1121             XY       1122
      IDIGIT   1123             XX       1124              XNUMB    1125              XLABEL   1126             YPOSIN   1127
      CENTRY   1130             MONDAY   1131              ITIS     1132              NUMMX    1133             NUMMIN   1134
      IDADD    1135             INRADD   1136              MINADD   1137              XINCRM   1140             II       1141
      IDD      1142             IPOSIN   1143

      ARRAYS

      DATA     1144             MONTHS   14724             MONEND   14740             FMT      14754            LABEL1   14766
      LABEL2   15006            X        15026             ISYMBL   30606
```

```
      SUBROUTINE TIMEPT(XX,NOWDAY,ITIS,NOWHR,NOWMIN,IDADD,IHRADD,MINADD,
     1XINCRM,IDD,MONTHS,MONEND,Y,HEIGHT)
      DIMENSION MONTHS(1),MONEND(1)
      IF(IHRADD)222,10,60
   10 IF(MINADD)222,12,60
C
C     BOTH IHRADD AND MINADD ARE ZERO IE, DAILY INCREMENTS
C
   12 XXSAVE=XX
      Z=HEIGHT/2.0
      YDAY=Y-HEIGHT-.4
      YMONTH=YDAY-HEIGHT-Z
      DO 50 I=1,IDD
      CALL SYMBOL(XX+0.5*HEIGHT,Y-(2.0*HEIGHT/3.0),HEIGHT,'-',90.0,1)
      S=0.0
      IF(NOWDAY.GE.10) S=0.5
      CALL NUMBER(XX-S*HEIGHT,YDAY,HEIGHT,FLOAT(NOWDAY),0.0,-1)
      NOWDAY=NOWDAY+IDADD
      IF(NOWDAY-MONEND(ITIS))30,30,20
   20 NOWDAY=NOWDAY-MONEND(ITIS)
      XDIST=XX-XXSAVE
      XBAR=(XDIST/2.0)+XXSAVE
      IF(XBAR-XXSAVE-2.5)28,28,26
   26 CALL SYMBOL(XBAR-HEIGHT*2.0,YMONTH,HEIGHT,MONTHS(ITIS),0.0,4)
   28 XXSAVE=XX
      ITIS=ITIS+1
      IF(ITIS-12)30,30,29
   29 ITIS=1
   30 XX=XX+XINCRM
   50 CONTINUE
      XF=XX-XINCRM
      XDIST=XF-XXSAVE
      XBAR=XDIST/2.0+XXSAVE
      IF(XBAR-XXSAVE-2.0)250,51,51
   51 CALL SYMBOL(XBAR-HEIGHT*2.0,YMONTH,HEIGHT,MONTHS(ITIS),0.0,4)
      GO TO 250
C
C     SMALL TIME INCREMENT LOOP
C
   60 YHOUR=Y-HEIGHT-.4
      Z=HEIGHT/2.0
      YDAY=YHOUR-HEIGHT-Z
      YMONTH=YDAY-HEIGHT-Z
  166 XXSAVE=XX
      DO 100 I=1,IDD
      XH=XX-2.0*HEIGHT
      XM=XX+2.0*HEIGHT
      CALL SYMBOL(XX+0.5*HEIGHT,Y-(2.0*HEIGHT/3.0),HEIGHT,'-',90.0,1)
      CALL SYMBOL(XX-.40*HEIGHT,YHOUR,HEIGHT,':',0.0,1)
      S=1.5
      IF(NOWHR.GE.10) S = 2.5
      CALL NUMBER(XX-S*HEIGHT,YHOUR,HEIGHT,FLOAT(NOWHR),0.0,-1)
      CALL NUMBER(XX+.3*HEIGHT,YHOUR,HEIGHT,FLOAT(NOWMIN),0.0,-1)
```

```
                S=0.0
                IF(NOWDAY.GE.10) S=0.5
                CALL NUMBER(XX-S*HEIGHT,YDAY,HEIGHT,FLOAT(NOWDAY),0.0,-1)
                NOWMIN=NOWMIN+MINADD
                IF(NOWMIN-60)80,75,75
             75 NOWMIN=NOWMIN-60
                NOWHR=NOWHR+IHRADD
             80 NOWHR=NOWHR+IHRADD
                IF(NOWHR-24)90,85,85
             85 NOWHR=NOWHR-24
                NOWDAY=NOWDAY+1
             90 NOWDAY=NOWDAY+IDADD
                IF(NOWDAY-MONEND(ITIS))150,150,100
            100 NOWDAY=NOWDAY-MONEND(ITIS)
                XDIST=XX-XXSAVE
                XBAR=(XDIST/2.0)+XXSAVE
                IF(XBAR-XXSAVE-2.0)104,102,102
            102 CALL SYMBOL(XBAR-HEIGHT*2.0,YMONTH,HEIGHT,MONTHS(ITIS),0.0,4)
            104 XXSAVE=XX
                ITIS=ITIS+1
                IF(ITIS-12)150,150,105
            105 ITIS=1
            150 XX=XX+XINCRM
            106 CONTINUE
                XF=XX-XINCRM
                XDIST=XF-XXSAVE
                XBAR=XDIST/2.0+XXSAVE
                IF(XBAR-XXSAVE-2.0)250,151,151
            151 CALL SYMBOL(XBAR-HEIGHT*2.0,YMONTH,HEIGHT,MONTHS(ITIS),0.0,4)
                GO TO 250
            222 WRITE(5,800)
            800 FORMAT(//10X,'ERROR IN THE TIME SUBROUTINE'//)
            250 CALL PLOT(XF,Y,3)
                RETURN
                END

CONSTANTS

0   777031403140    1   202600000000    2   205004020100    3   000000000000    4   207550000000
5   000000000001    6   202400000000    7   000000000004    10  351004020100    11  000000000000
12  777403140314    13  000000000003

GLOBAL DUMMIES

XX      636         NOWDAY  637         ITIS    640         NOWHR   641         NOWMIN  642
IDADD   643         IHRADD  644         MINADD  645         XINCRM  646         IDD     647
MONTHS  650         MONEND  651         Y       652         HEIGHT  653

SUBPROGRAMS

SYMBOL  NUMBER  FLOAT   PLOT

SCALARS
```

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        TIMEPT  657             IHRADD  644             MINADD  645             XXSAVE  660             XX      636
        Z       661             HEIGHT  653             IDAT    662             Y       652             IFONIN  663
        I       664             IDD     647             S       665             NO*DAY  637             IDADD   643
        ITIS    630             XDIST   656             XBAP    667             XINCR*  646             XF      670
        IHOUR   671             XP      672             XM      673             NO*HR   641             NO*MIN  642

        ARRAYS

        MONTHS  650             MONEND  651
```