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LBL-8945
GOTEC-01

OCEAN THERMAL ENERGY CONVERSION ECOLOGICAL DATA REPORT FROM O. S. S. RESEARCHER IN GULF OF MEXICO (GOTEC-01) JULY 12-23, 1977

June 1979

Compiled by M. S. Quinby-Hunt

Contributions by

P. Wilde
J. C. Sandusky
C. J. W. Carmiggelt
M. L. Commins
D. J. Estrella
A. J. Horne
M. S. Quinby-Hunt
M. Tatro

Marine Sciences Group
Earth Sciences Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Prepared for the
U.S. Department of Energy
Division of Solar Technology
Ocean Systems Branch
Contract No. W-7405-ENG-48

FOREWORD

This is one in a series of data reports derived from oceanographic cruises in support of the OTEC Program. The purpose of such reports is to make the uninterpreted data available to data users and interested scientists as soon as possible after the usual post cruise corrections are made. Data will be available from:

National Oceanographic Data Center
Attn: E. Franklin Johnson
2001 Wisconsin Avenue, N.W.
Washington, D.C. 20235

In this manner, researchers can interpret the data as a function of their own experience. After the equivalent of one year's data are taken at any one site or region, an annual review will be published that will recapitulate the data in the cruise reports and include interpretations, summary graphs and tables, and topical discussions by the various project workers.

A number of archival studies of the ecosystem in the Gulf of Mexico have been made or are in progress:

Historical data on the thermal resource and currents (covering the years 1965-1976) were explored by Molinari and Festa (1978) and Craig et al. (1978). Data taken since then are analyzed in Thomas, Minton and Molinari (1979). Data concerning the loop current have been reported on by Tidwell, Cardwell, Molinari and Ortman (1978), and Molinari et al. (1977).

Cummings, Atwood and Parker (1979) reviewed the literature on nutrients aand dissolved oxygen of the area. Literature covering toxics in the Gulf (metals and others) is notably scarce although a survey is currently in progress at Lawrence Berkeley Laboratory (LBL).

El Sayed (1972) carried out an extensive survey at phytoplankton - which includes a review of previous studies in the area.

Currently at LBL, archival studies are in progress on a variety of topics: chemical (i.e., nutrients and toxics), physical, geological, and biological (i.e., phytoplankton, zooplankton, mammals, fish and biomass indicators).

CONTENTS

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I. INTRODUCTION

Ecological measurements important for environmental assessment of the effect of an operating Ocean Thermal Energy Conversion plant were initiated in July 1977 at the proposed Gulf of Mexico site off the coasts of Louisiana, Mississippi, Alabama and Florida (Fig. 1). The initial cruise of the OSS Researcher, in a joint effort with the Atlantic Oceanic and Meteorological Laboratories (AOML) of the National Oceanic and Atmospheric Administration (NOAA), and Lawrence Berkeley Laboratory (LBL) took place from 12-23 July 1977. The station log appears as Table 1. It covers only those stations at which ecological samples as well as physical-oceanographic samples were taken. Wherever possible the ecological station number is the same as the physical oceanographic station number. If ecological samples were taken and no physical measurements were made, the station number is derived by adding an A to the station number immediately preceding it. Samples were taken at two general locations: one off Cuba and the other at a possible OTEC site located off Mobile, Alabama (see Fig. 1). Stations at which samples were taken within the general area of the site are shown in Fig. 2.

The measurements were taken at 15 oceanographic stations to a maximum depth of 1000 m. Water was analyzed for trace metals, nutrients and chlorophyll *a* and ATP. Physical data, salinity and dissolved oxygen measurements were supplied by NOAA-AOML. Two bioassays were carried out using indigenous phytoplankton to estimate the effect of deep water on the rates of $^{14}CO_2$ uptake of photic zone algae (Stations 8 and 20). The Deep Scattering Layer (DSL) was monitored at the site by a continuously recording 12 kHz depth sounder at the Mobile site.

This report presents data collected during this cruise. The analysis of the physical oceanographic measurements which were made by AOML appear in Thomas, Minton, and Molinari (1979). Results taken from ecological stations are presented here. A more detailed analysis of the data will be published upon completion of a serial survey at this site. Appendix A gives the data graphically in profiles as a function of depth. Appendix B lists the station data in tables.

II. STATION MEASUREMENTS

Hydrocasts were made using a 12-bottle rosette sampler equipped with 1.7- and 2.5-liter Niskin bottles. Sea water from the hydrocasts was processed on deck as summarized in the station log (Table 1). Methods are described in Section III below. They will be described more fully in a report on analytical techniques which will be published later. The following samples and observations were made:

Temperature and Salinity

Data was taken at Stations 7, 9, 10, 11, 13, 16, 18, 20, 22, 25 and 28, and appear in tabular form in Appendix B and are plotted in Appendix A, Figs. A-1 through A-10. AOML-NOAA also took STD profiles, which appear in Thomas, Minton and Molinari (1979).

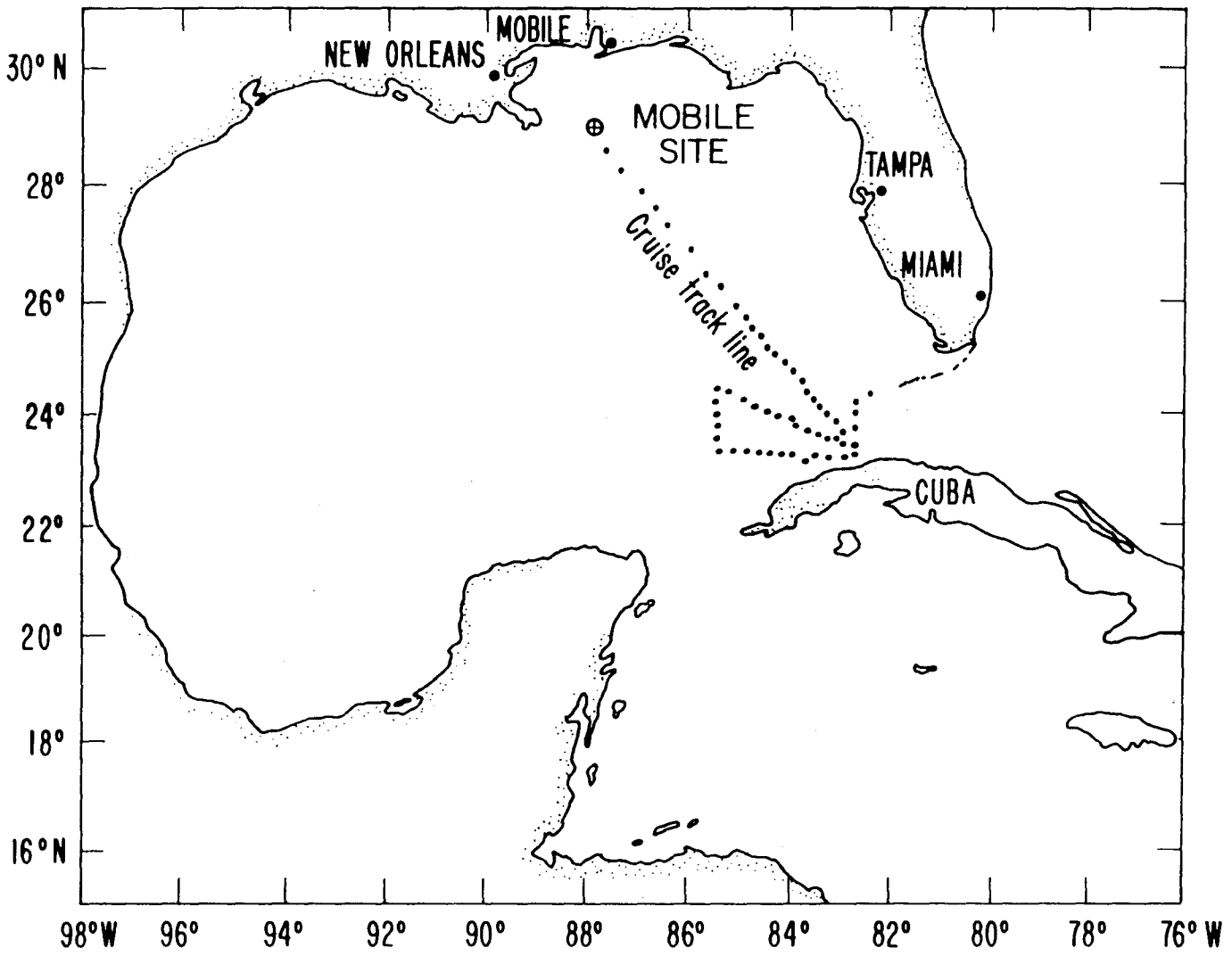

Figure 1. Gulf of Mexico GOTEC-01 Mobile Site Station Location off Mobile, Alabama.

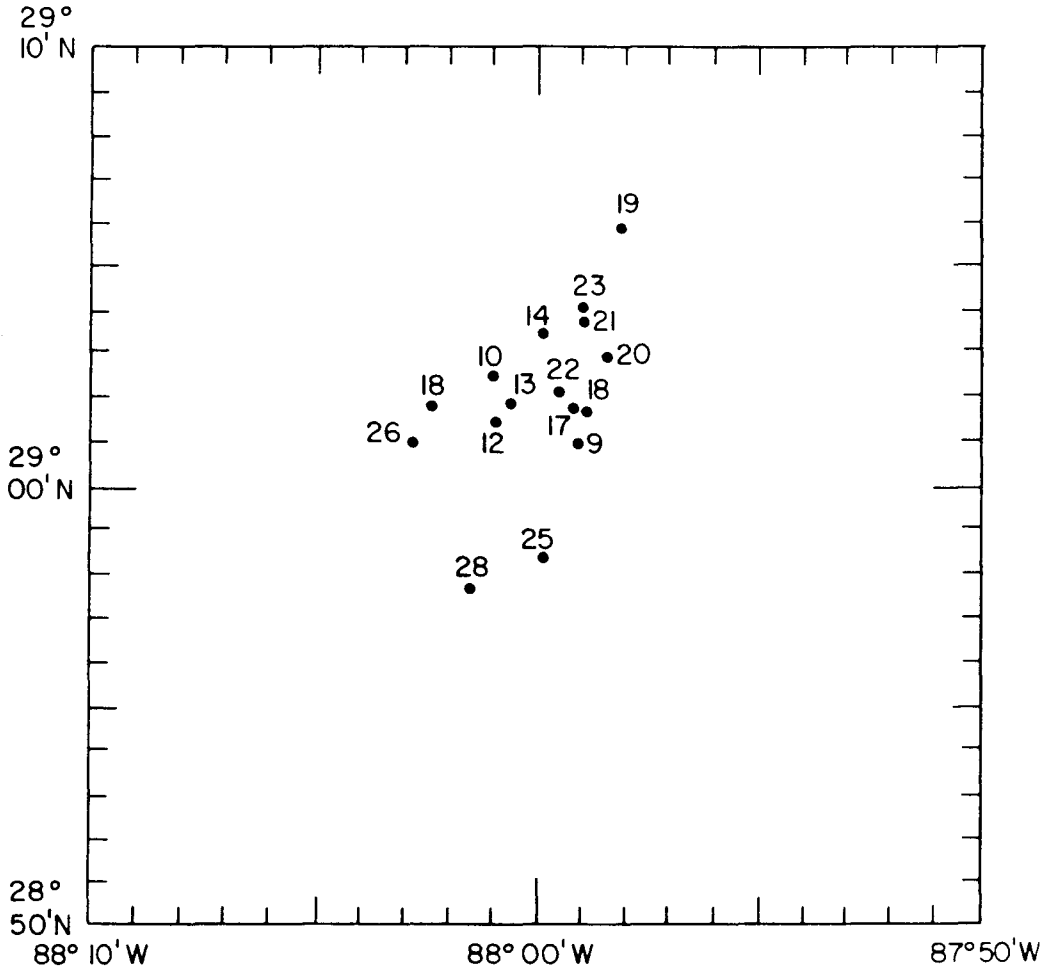

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Figure 2. Gulf of Mexico GOTEC-01 Mobile Site Station Location off Mobile, Alabama, Detail.

Table 1. OSS Researcher Station Log.

Station	Date	Time Z[a] (EDT)	Position	Operations[b]
5	13 July 1977	194:15:35Z (1135)	23°19.9'N x 82°47.0'W	ATP @ 500 m
6	13 July 1977	194:18:00Z (1400)	23°04.7'N x 82°45.2'W	ATP @ 5 and 500 m ORG @ 5 m
6A	14 July 1977	195:17:00Z (1300)	23°41.1'N x 83°49°.1'W	ATP @ 10,20,30,40,50,100,300 m Chl *a* @ 10,20,30,40,50 m
6B	16 July 1977	197:14:30Z (1030)	29°N x 88°W	Primary productivity (artificial substrates) test deployed
7	17 July 1977	198:05:48Z (0148)	29°01.8'N x 87°59.1'W	Temperature @ 40, 100, 600 and 1000 Salinity @ 10, 30, 40, 50, 100 and 800 m Chl *a* @ 10,20,30,40 m
8	17 July 1977	199:02:32Z (2230)	29°01.51'N x 88°01.9'W	Primary productivity - ^{14}C uptake from 25 and 1000 m
9	18 July 1977	199:06:22Z (0222)	29°02.25'N x 88°00.38'W	ATP @ 0,50,100,200,300,600,1000 m Temperature @ 800,1000 m Salinity @ 0,50,100,200,300,400,600,800,900, and 1000 m Dissolved oxygen @ 0,50,100,200,300,400,600, 800,900, and 1000 m
10	18 July 1977	199:18:00Z (1400)	29°02.5'N x 88°0.9'W	Chl *a* @ 10,20,30,40,60,100 m
11	18 July 1977	199:21:00Z (1700)	29°02.31'N x 88°1.9W	Chl *a* @ 5,50,100,150,200,300,400,600,800 m Temperature @ 25,50,200,400,600,800 m Salinity @ 5,50,100,150,200,300,400,500,600, 800,1000 m Dissolved oxygen @ 5,50,100,150,200,300,400, 500,600,800,1000 m
13	19 July 1977	200:06:02Z on bottom; 07:44Z (0344) on deck	29°01.9'N x 88°0.4'W	Chl *a* @ 0,25,50,100,300,400,500,600,800,1000 m Salinity and Dissolved oxygen @ 0,25,50,100, 150,200,300,400,500,600,800,1000 m
15	19 July 1977	200:16:00Z (1200)	29°3.73'N x 87°59.58'W	Chl *a* @ 25, 35, 60 m

Table 1. OSS Researcher Station Log (continued)

Station	Date	Time Z[a] (EDT)	Position	Operations[b]
16	19 July 1977	200:17:45Z (1345) on bottom; 1913Z(1513) on deck	29°01.8'N x 87°58.92'W	Chl a @ 0,25,50,100,150,200,300 m Temperature and Salinity @ 0,25,50,100,150, 200,300,400,500,600,800,1000 m Dissolved oxygen @ 0,25,50,100,150,200,300, 400,500,600 m
17	20 July 1977	201:05:12Z (0112); 0537(0137) on deck	29°03.2'N x 88°0.05.34'W	Chl a @ 15,20,25,30,35,60 m
18	20 July 1977	201:06:07Z (0207); 0614Z(0214) on bottom 0811Z(0411) on deck	29°01.7'N x 88°02.3'W	ATP @ 0,25,50,100,150,200,300,400,500,600 m Temperature @ 25, 600, 1000 m Salinity @ 0,25,50,100,150,200,300,400,500,600, 800,1000 m Dissolved Oxygen @ 0,50,100,150,207,300,400, 500,600,800,1000 m
20	20 July 1977	201:17:09Z (1309); 1740Z(1340) on bottom; 1853Z(1453) on deck	29°03.0'N x 87°58.3'W	Primary productivity - ^{14}C uptake from 25 and 1000 m Chl a @ 25,100,200,300,400,500 m Temperature @ 25,200,400,750 m Salinity @ 0,25,100,200,300,400,500,750, 1000 m Dissolved oxygen @ 0,25,100,200,300,400,500, 1000 m
22	21 July 1977	202:07:14Z (0314) on deck	29°02.1'N x 87°59.4'W	Temperature @ 25,50,600,1000 m Salinity @ 0,25,50,150,300,1000 m Dissolved oxygen @ 0,25,50,100,150,200,300,500, 600,800 and 1000 m
24	21 July 1977	202:16:40Z (1240)	29°06.35'N x 87°58.84'W	Metals @ 0, 20, 100, 300 m
25	21 July 1977	202:21:00Z (1700)	28°58.3'N, 87°59.8'W	Nutrients @ 0,30,50,150,300,400,500,600, 800, 1000 m ATP @ 0,30,50,100,150,300,1000 m Temperature @ 30,100,200,600,1000 m Salinity @ 0,30,50,100,150,300,400,1000 m Dissolved oxygen @ 0,30,50,100,150,200,300,400, 500,600,800,1000 m
27	22 July 1977	203:05:46Z (0146) on bottom; 0608Z(0208) on deck	29°02.45'N x 87°58.8'W	Metals @ 15,30,100,300 m

Table 1. OSS Researcher Station Log (continued)

Station	Date	Time Z[a] (EDT)	Position	Operations[b]
28	22 July 1977	203:10:45Z (0645) on deck	28°57.8'N x 88°1.5'W	ATP @ 0,25,50,100,150,200,300,500,600,800,1000 m Nutrients @ 50,100,150,200,800,1000 m Temperature @ 100,200,600, 1000 m Salinity @ 0,25,50,100,150,500,600,1000 m Dissolved oxygen @ 0,25,50,200, 300,400,500, 600,1000 m

[a]First time given (Z) is Greenwich Mean Time (GMT); second is Eastern Daylight time (EDT).
[b]Depths of operations are approximate.

Abbreviations and Procedures:

ATP = Adenosine triphosphate sea water filtered through 0.45 µm Millipore© filter placed in boiling tris buffer 5 min; test tube, filter, and buffer frozen.
ORG = Organisms, sea water killed with Lugol solution and filtered through 0.45 µm Millipore© filter; dried for microscope analysis.
Chl *a* = Chlorophyll *a*, sea water filtered through glass filter.
Metals = sea water decanted into 500 ml bottles, refrigerated.
Nutrients = sea water filtered with 0.45 µm Millipore© filter; decanted into 500 ml glass bottles and stored frozen.

Dissolved Oxygen

Samples were taken at Stations 9, 11, 13, 16, 18, 20, 22, 25 and 28. The results appear in tabular form in Appendix B, and in Figs. A-2 through A-10 in Appendix A.

Phytoplankton

Samples were collected on several stations; however, they were never quantitatively determined. A brief qualitative description is included in this report.

Nutrients

Samples were taken at Stations 25 and 28. Results appear in Figs. A-25 and A-26 in Appendix A, and in Table B-4 in Appendix B.

Biomass Indicators

Adenosine triphosphate samples were taken at Stations 5, 6, 6A, 9, 18, 25 and 28. Results appear in Fig. A-11, A-12, A-19, A-21, and A-22 in Appendix A and in Table B-2 in Appendix B.

Samples tested for chlorophyll a were taken at Stations 6A, 8, 10, 11, 13, 15, 16, 17 and 20. Results are shown in Figs. A-11, A-13, A-18 and A-20 in Appendix A, and in Table B-2 in Appendix B.

Primary Productivity

Ocean Water Mixing. Effects of deep-water additions to surface-water primary production were investigated using ^{14}C as a tracer and incubating on shipboard. Methods are described in Section III, below. (See the data on Primary Productivity, Stations 8 and 20, Appendix B, and Fig. A-23 and A-24 of Appendix A.)

Artificial Substrates. Short pieces of Tygon tubing were tied to the buoy and first 50 m of anchor line for the current meter mooring. After about 7 days incubation time, primary productivity measurements were made to determine autotrophic growth.

Sonic Observations of Deep Scattering Layer (DSL)

A Raytheon Precision Graphic Recorder (12 KHz) was run at 2-second sweep on the OTEC station from 18 July to 22 July 1977. The DSL during the day centered at approximately 240 fathoms (430 m uncorrected), rising to at least 40 fathoms (72 m uncorrected) at night.

Nekton

Schools of jacks (Carangidae) with sharks (Elasmobranchii) and dolphin fish, Mahi-Mahi (Coryphaena hippurus) appeared on 21/22 July. Squid (cephalopoda) were observed at night.

Birds

Birds were very scarce at the Mobile Site, only a few terns and two cattle egrets were sighted.

III. ANALYTICAL METHODOLOGY

Physical and Chemical Measurements

Temperature, salinity, depth, and dissolved oxygen data were provided by NOAA-AOML (see Molinari, 1979).

Nutrients

Samples for phosphate and nitrate analyses were collected by filtering sea water (0.2 μm millipore) and stored frozen in acid-washed citrate bottles. Storage time was approximately two weeks.

Orthophosphate. Reactive phosphate was determined using the method described by Murphy and Riley (1963). This procedure depends on the reduction of a stable phosphomolybdate complex by ascorbic acid in the presence of antimony. Absorbance of the blue sol ("molybdenum blue") is measured at 7700 Å and compared with standards made from potassium phosphate.

Nitrate plus Nitrite. Nitrate plus nitrite was determined using the methods described by Hendricksen (1965) and Mullin and Riley (1955). A buffered hydrazine-copper reagent is to reduce nitrate to nitrite. Diazotization of sulfanilamide by nitrite followed by a coupling reaction with N-(1-Naphthyl)-ethylenediamine dihydrochloride produces a red azo dye. Its absorbance was measured at 5430 Å and compared with standards made from potassium nitrate and surface sea water. Incubation times for hydrazine reduction were kept short (1/2 hour) by keeping the samples warm (37°C).

Care must be taken with interpretation of results obtained using hydrazine. Both reaction speed and total coloration depend on pH. Thus, standards made by adding known amounts of NO_3^- to deep sea water samples could result in absorbances different from those observed by using surface water as a base. The advantages of the hydrazine method are that it is a fast and inexpensive method.

Biochemical Measurements

Chlorophyll *a* and ATP were measured using the methods described by Strickland and Parsons (1972). Approximately 1 liter of seawater (absolute volume varied) was filtered for each chlorophyll *a* and ATP measurement. Chlorophyll *a* was extracted using 90% acetone and determined by measuring optical absorbance. Analyses were done at the Lawrence Berkeley Laboratory and the University of California Sanitary Engineering Research Laboratory.

Bioassay

Indigenous phytoplankton (unconcentrated and unfiltered) from the photic zone were used to assay the biostimulation or toxicity of deep-water additions (1000 m) on rates of photosynthesis in the upper waters. An

analogous system was used that reproduces some of the variability of the ocean but controls other factors. These analogs are routinely used at the University of California Sanitary Engineering Research Laboratory at Richmond on San Francisco Bay. The analog system consisted of a 12-hour light/12-hour dark illuminated water bath with a flow-through sea water system for temperature control. Light levels were set at approximately 20% of I_o, i.e., 20% of the surface illumination at noon. Water from the photic zone, generally 25 m in depth, was mixed with varying proportions of deep water to simulate possible modes of upwelling in an OTEC plant. To other samples from the photic zone, various mixtures of major and minor nutrients and trace vitamins were added. Controls were undiluted 25 m water. Each treatment was replicated using 125 ml borosilicate glass reagent bottles to which $NaH^{14}CO_3$ was added. Bottles were then incubated for 2 days to give sufficient time for differences in treatments to become measurable. Samples were killed using Lugol solution, filtered onto 0.45 µm Millipore© filters and stored cold. Counts were recorded in the laboratory using a Geiger-Mueller counter (Nuclear-Chicago).

Trace Metal Measurements

Water samples were collected with 2.5 liter Go-Flow© bottles and stored in acid-washed conventional polyethylene bottles. One week after collection, the samples were acidified to pH 2 with double distilled NBS nitric acid. Duplicate acidified subsamples were solvent extracted and analyzed by flameless atomic absorption spectroscopy at Lawrence Berkeley Laboratory. The extraction procedure consists of the following: 200 ml of acidified sea water is adjusted to pH 5.3 $\pm$ 0.2 with 2 M trisodium citrate, and extracted with 5.0 ml of 1% APDC-DDDC aqueous solution with 10.0 ml methylisobutyl ketone (MIBK). The MIBK extract is immediately back extracted with 2.0 ml 6N NBS HNO_3 to stabilize the trace metals in solution prior to flameless atomic absorption analyzing (AAS) analysis. All reagents are purified to reduce the metal contribution from reagent blank. The method is efficient for the determination of Cd, Cu, Fe, Ni, Pb and Zn in natural waters with a precision of better than 10% (Girvin and Tatro, in preparation).

IV. DATA

The results are listed in standard oceanographic format. As more field data are obtained, records will be kept on magnetic tape, using the NODC coding system and will be forwarded to NODC where it will be available to the public. Records are grouped into several categories: tables are presented in Appendix B of physical, chemical-nutrient, biological pigment, primary productivity, and trace metal data. Primary productivity results follow the biological tables and are descriptive. Serial data based on one year's results will be analyzed in a further report.

Temperature and Salinity

Temperature and salinity data are in general agreement with Austin (1971) and Molinari and Festa (1978). From previous studies of this region (for example, Sackett, 1972; Jones, 1973), we know there are several water masses involved: (1) Tropical Surface Water, (2) Subtropical Underwater, (3) Antarctic Intermediate Water, and (4) Bottom Water of long residence

time. Loop current intrusions are maximal in late summer-early fall, but might influence water in July at this station (Molinari, et al., 1977, Tidwell, et al., 1978). The main depths for ecological studies related to OTEC concern the mixed layer depth and the deep-water masses. In summer, there is a shallow mixed layer of 25 m. The Bottom Water is from a different source than the surface and has a residence time of 200 to 300 years (Matthews, et al., 1973).

Water Chemistry

Nutrient data shows results typical for a nutrient-limited stratified system and are in general agreement with the results of Cummings, Atwood and Parker (1979). It is clear from these profiles that upwelling could stimulate growth. Trace metal values are low, possibly due to preservation methods as well as expected low ambient concentrations.

Primary Productivity

Biomass Indicators. Chlorophyll a evidenced a large variability probably due to phytoplankton patchiness as well as to variability in chlorophyll a (Chl a) laboratory analysis (absorbances were very close to the limit of detection of the spectrophotometer). Even with this variability, the summer maximum of Chl a at about 100 m is deeper than normally might be expected, perhaps a result of strong surface light levels. It is unusual for chlorophyll a to persists at depth; non-zero values were seen at 200 m. The results will be checked on subsequent cruises to test their validity.

The ATP results appear to be somewhat erratic. Comparison of absolute values with those in the literature is not meaningful because of problems encountered with ATP standards supplied by Sigma Chemical Company. As reported by Sigma Chemical Company (Sigma Chemical Co., Urgent Bulletin, Feb. 1978), small amounts of vanadium contamination were found to inhibit enzyme activity. This resulted in an over-estimation of ATP values by a substantial amount (a possible factor of 10). Relative values are not affected, thus the depth profiles are comparable. Summer maxima were at 100-150 m with a substantial amount of between-cast variability.

Artificial Substrates. Analysis of attachment growths for the Tygon © tubing showed Chl a ranging from zero to 0.002 µg for a 2 in. long tube of 1/2-in. diameter. The ATP was undetectable. Visual scans with a light microscope revealed no identifiable cells.

Phytoplankton

Data available for this location (Balech, 1967) indicate Chaetoceros was the dominant genus (May, 1964). In our study, Rhizosolenia were also found. Rhizosolenia (a summer dominant) have a symbiotic relationship with Richelia, a nitrogen fixing blue-green algae (Mague, et al., 1974). This may be an important factor in the summer nitrogen cycle. Better preservation methods and live sample collection are currently under investigation.

Ocean Water Mixing

Results for nutrient addition experiments showed major nutrients to be in balance. That is, only additions of all the major nutrients produced significant increases in the rates of photosynthesis of photic zone zone algae. No one nutrient such as nitrogen, iron or phosphorus was in such short supply that its addition produced a significant increase of photosynthetic activity. Marked stimulation occurred only for combined nutrient and vitamin addition. No deep-water sample alone was measured on this cruise. Subsequent experiments have shown that deep samples may contain viable algae. Interpretation, therefore, awaits completion of deep-water culturing experiments now in progress.

V. References

Austin, H. (1971) The characteristics and relationships between the calculated geostrophic current component and selected indicator organisms in the Gulf of Mexico Loop Current system. PhD Dissertation, Dept. of Oceanogr., Florida State Univ., 369 pp.

Balech, E. (1967) Microplankton of the Gulf of Mexico and Carribbean Sea. Texas A&M Res. Found. 67-10-T., 144 pp.

Bogdanov, D. V., V. A. Sokolov and N. S. Khromov (1969) Regions of high biological and commerical productivity in the Gulf of Mexico and Carribbean Sea. Oceanology, 8, 371-381. (Trans. NSF).

Craig, H. L., T. Lee, H. Michel, S. Hess, R. Munier, and M. Perlmuttor (1978) A Source Book of Oceanographic Properties Affecting Biofouling and Corrosion of OTEC Plants at Selected Sites. Rosenstiel School of Marine and Atmospheric Science, Miami, FL, for Pacific Northwest Laboratory, Richland, DC. No. TR78-1, 25 pp.

Cummings, S. R., D. K. Atwood and 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 Northern Gulf of Mexico. AOML-NOAA, Miami, FL. NOAA Technical Memorandum ERL AOML-36, 67 pp.

Dussart, B. H. (1965) Le differentes categories de plancton. Hydrobiologia, 26, 72-74.

El-Sayed, S. Z. (1972) Primary productivity and standing crop of phytoplankton. In Chemistry, Primary Productivity and Benthic Algae of the Gulf of Mexico, Serial Atlas of the Marine Environment. Folio 22, American Geographical Society, p. 8-13.

El Sayed, S. Z. et al (1972). Chemistry, Primary Productivity and Benthic Algae of the Gulf of Mexico, Serial Atlas of the Marine Environment, Folio 22, Am. Geog. Soc., 29 pp.

Hendriksen, A. (1965) An automatic method for determining nitrite and nitrate in fresh and saline waters, Analyst, 90, 83-88.

Jones, J. I. (1973) Physical oceanography of the northeast Gulf of Mexico Florida continental shelf area. A Summary of Knowledge of the Eastern Gulf of Mexico. In: Florida State Univ. Syst. Inst. Oceanogr. (coord.) p. IIB-1-IIB-11.

Khromov, N. S. (1965) Distribution of plankton in the Gulf of Mexico and some aspects of its seasonal dynamics. In: Soviet-Cuban Fishery Research, A. S. Bogdanov, ed., U. S. Document TT 69-59016 (IPST translation) p. 36-56. .

LaRock, P. and H. L. Bittaker (1973) Chemical data of the estuarine and nearshore environments in the eastern Gulf of Mexico. In: A Summary of Knowledge of the Eastern Gulf of Mexico, Florida State Univ. Syst. Inst. Oceanogr. (Coord.) p. IIC-8-11- 86.

Mague, T. H., N. M. Weare, and O. Holm-Hansen (1974) Nitrogen fixation in the north Pacific Ocean. Marine Biology, 24, 109-119.

Matthews, T. D., A. D. Fredericks, and W. M. Sackett (1973) The geochemistry of radiocarbon in the Gulf of Mexico. In: Radioactive Contamination of the Marine Environment. Proc. Symp., Seattle, 1972 (IAEA-SM-158/48) p. 725-734.

Molinari, R. L. (1979), private communication.

Molinari, R. L., S. Baig, D. W. Behringer, G. A. Maul, R. Legeckis (1977) Winter instrusions of the Loop Current, Science, 189, 505-507.

Molinari, R. L. and T. F. Festa (1978) Ocean Thermal and Velocity Characteristics of the Gulf of Mexico Relative to the Placement of a Moored OTEC Plant. Atlantic Oceanographic and Meteorological Laboratories, Miami, Fl., October, 1978, National Oceanic and Atmospheric Administration, NOAA Technical Memo. ERL AOML-33, 106 pp.

Mullin, J. B. and J. P. Riley (1955) The spectrophotometric determination of nitrate in natural waters, with particular reference to sea water. Analytica Chimica Acta, 12, 464-480.

Murphy, J. and J. P. Riley (1962) A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27 31-36.

Sackett, W. M. (1972) "Chemistry." In: Chemistry, Primary Productivity and Benthic Algae of the Gulf of Mexico, Serial Atlas of the Marine Environment. Folio 22, American Geographic Society, p. 1-4.

Strickland, J. D. H. and T. R. Parsons (1972) A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada, Ottawa, Bulletin 167, 310 pp.

Thomas, G. G., S. M. Minton, and R. L. Molinari (1979) Data from The Atlantic Oceanographic and Meteorological Laboratories OTEC Plant Site Study in the Gulf of Mexico, July, 1977. Atlantic Oceanographic and Meteorological Laboratories, Miami, FL., January 1979, National Oceanographic and Atmospheric Administration, NOAA Technical Memo. ERL AOML-34, 15 pp.

Tidwell, D., C. Cardwell, R. L. Molinari and D. Ortman (1978) Data from the Atlantic Oceanographic and Meteorological Laboratories Loop Current Monitoring Cruises, May 1975, through August 1976. AOML-NOAA, Miami, FL, 1978, NOAA Technical Memo. ERL-AOML-29, 238 pp.

Appendix A. Figures Containing Data

This appendix contains figures displaying the results obtained on Cruise GOTEC-01 (12-23 July 1977) to the Gulf of Mexico.

Figures A-1 through A-10 show the physical oceanographic data for temperature, salinity and sigma-T. The standard deviations are too small to show in this scale and can be considered to be less than the size of the dot.

Figures A-11 through A-22 show the biomass indicators: Chlorophyll *a* and ATP (adenosine triphosphate). No statistical analysis can be made for the Chl *a* determinations as only one sample from each depth at each station was taken. This was due to constraints on the volume of water available for biological analysis from each hydrocast. The same constraints prevented replicate sampling to determine variance in the values for adenosine triphosphate.

Figures A-23 and A-24 show the primary productivity results. The variability of the measurement can be seen in the differences in the controls.

Figures A-25 and A-26 contain the nutrient data. Insufficient samples were collected to analyze replicate samples, so statistical parameters were not calculated.

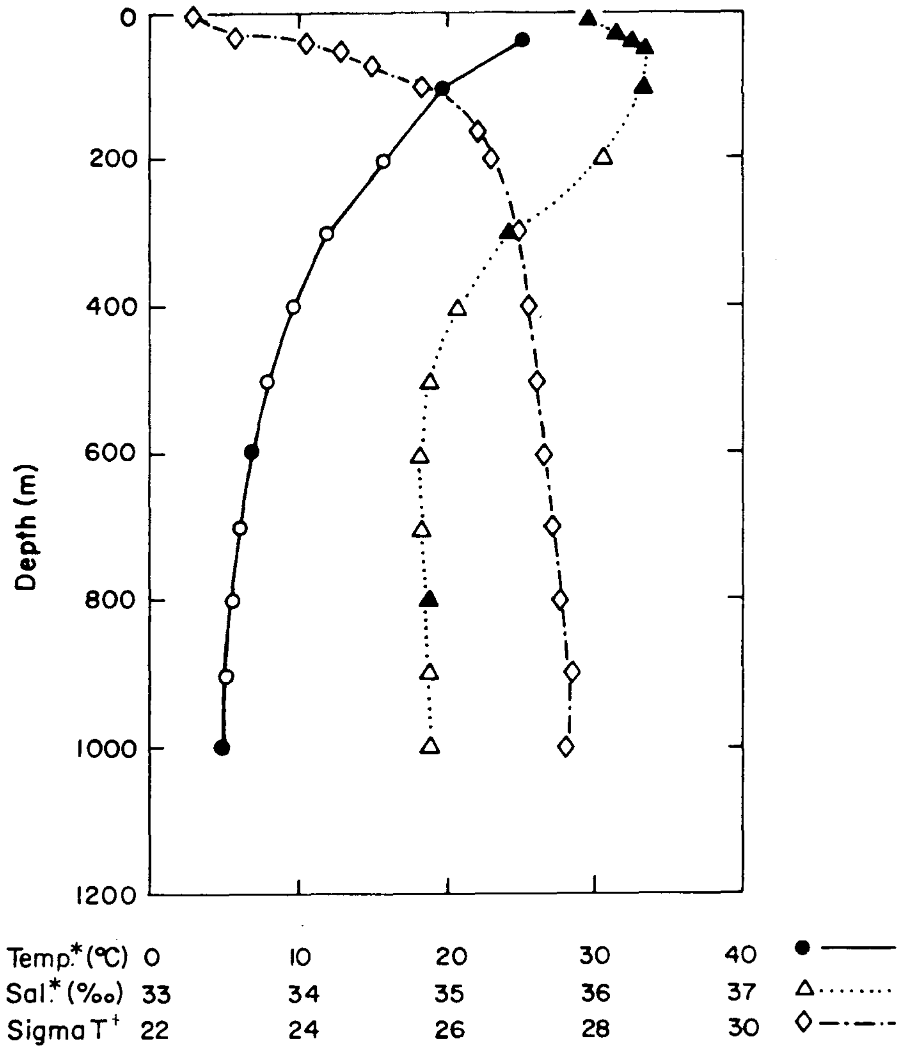
Figures A-27 and A-28 show the trace metal results. The standard deviations are shown, in Table B-5 in Appendix B.

0 0 0 5 3 0 5 4 7 2

Figure A-1

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Sigma-T

GOTEC-01, Station 7, Mobile site, 29° 01.8'N, 87° 59.1'W
17 July 1977, 0148 h EDT (198:05:48Z)



* *Curve partially constructed from STD data.*
Symbols for STD data points were: Temp. - o, Sal. - △

\+ *From STD data*

XBL 794-1161

Figure A-2

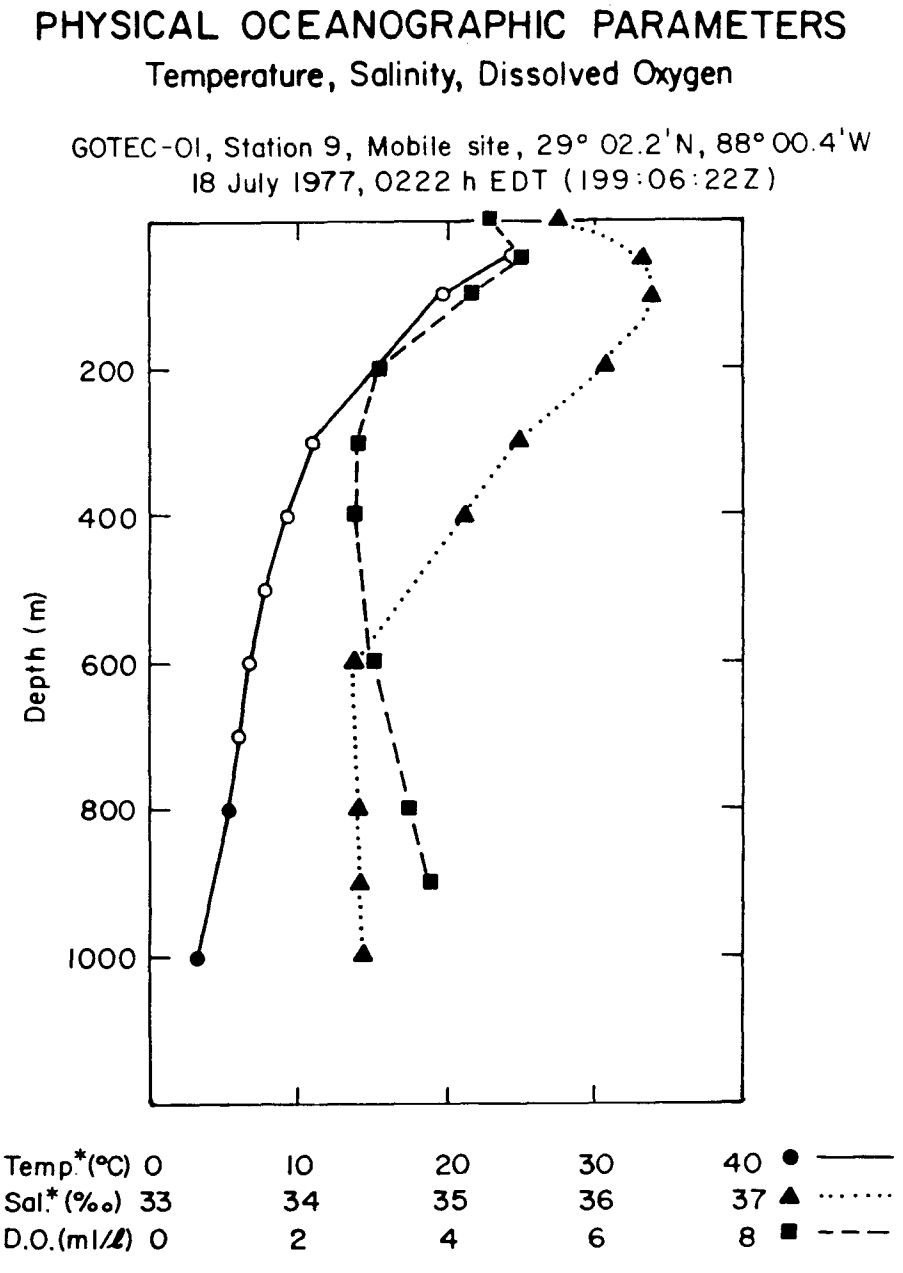

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Dissolved Oxygen
GOTEC-01, Station 9, Mobile site, 29° 02.2'N, 88° 00.4'W
18 July 1977, 0222 h EDT (199:06:22Z)
Depth (m)
200
400
600
800
1000
Temp.*(°C) 0 10 20 30 40
Sal.*(‰) 33 34 35 36 37
D.O.(ml/ℓ) 0 2 4 6 8
*Curve constructed partially from STD data.
Symbols for STD data points were: Temp. - o, Sal. - Δ
XBL 794-1163

Figure A-3

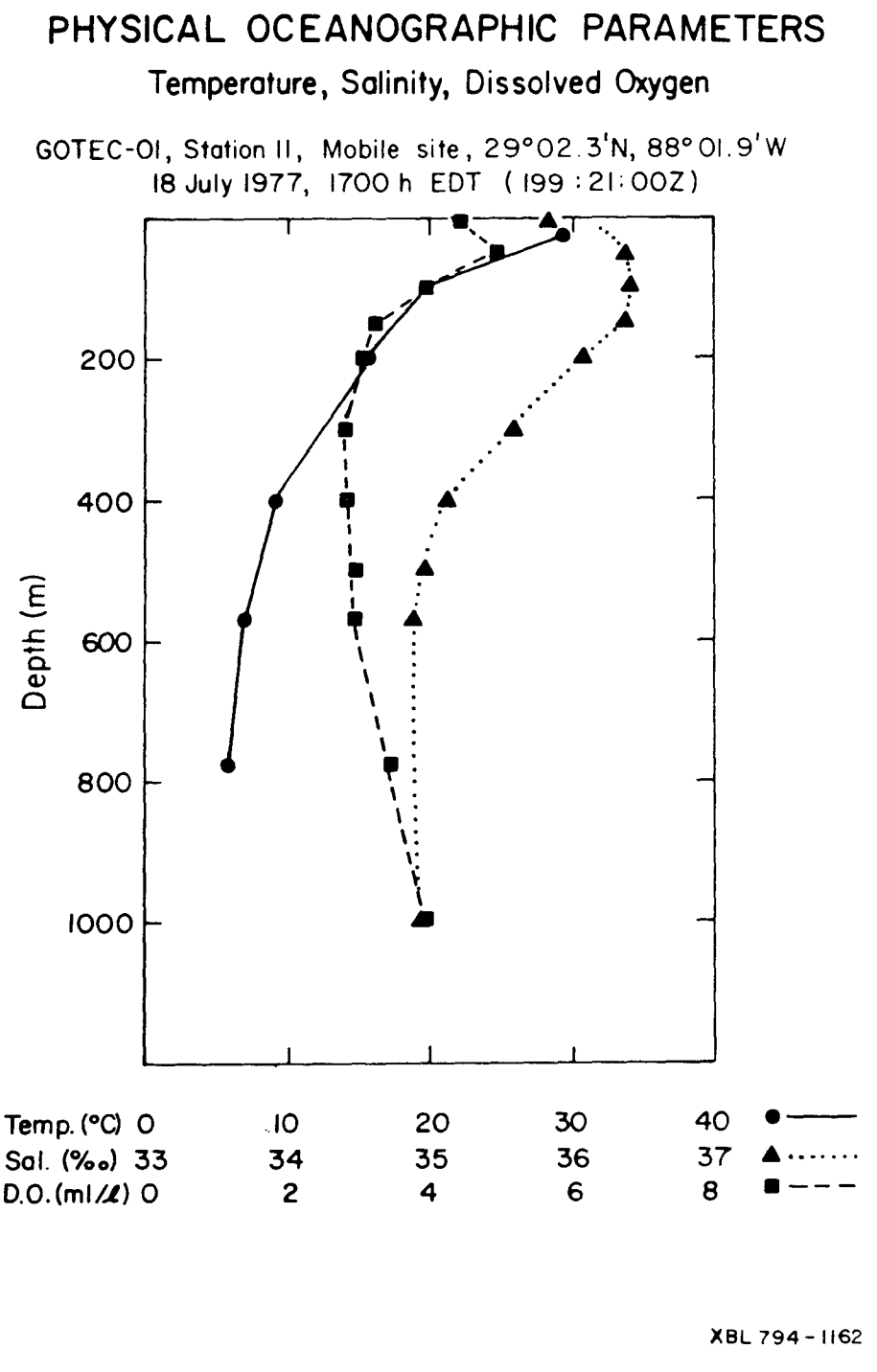

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Dissolved Oxygen
GOTEC-01, Station 11, Mobile site, 29°02.3'N, 88°01.9'W
18 July 1977, 1700 h EDT (199:21:00Z)
Depth (m)
200
400
600
800
1000
Temp. (°C) 0 10 20 30 40
Sal. (‰) 33 34 35 36 37
D.O. (ml/ℓ) 0 2 4 6 8
XBL 794-1162

Figure A-4

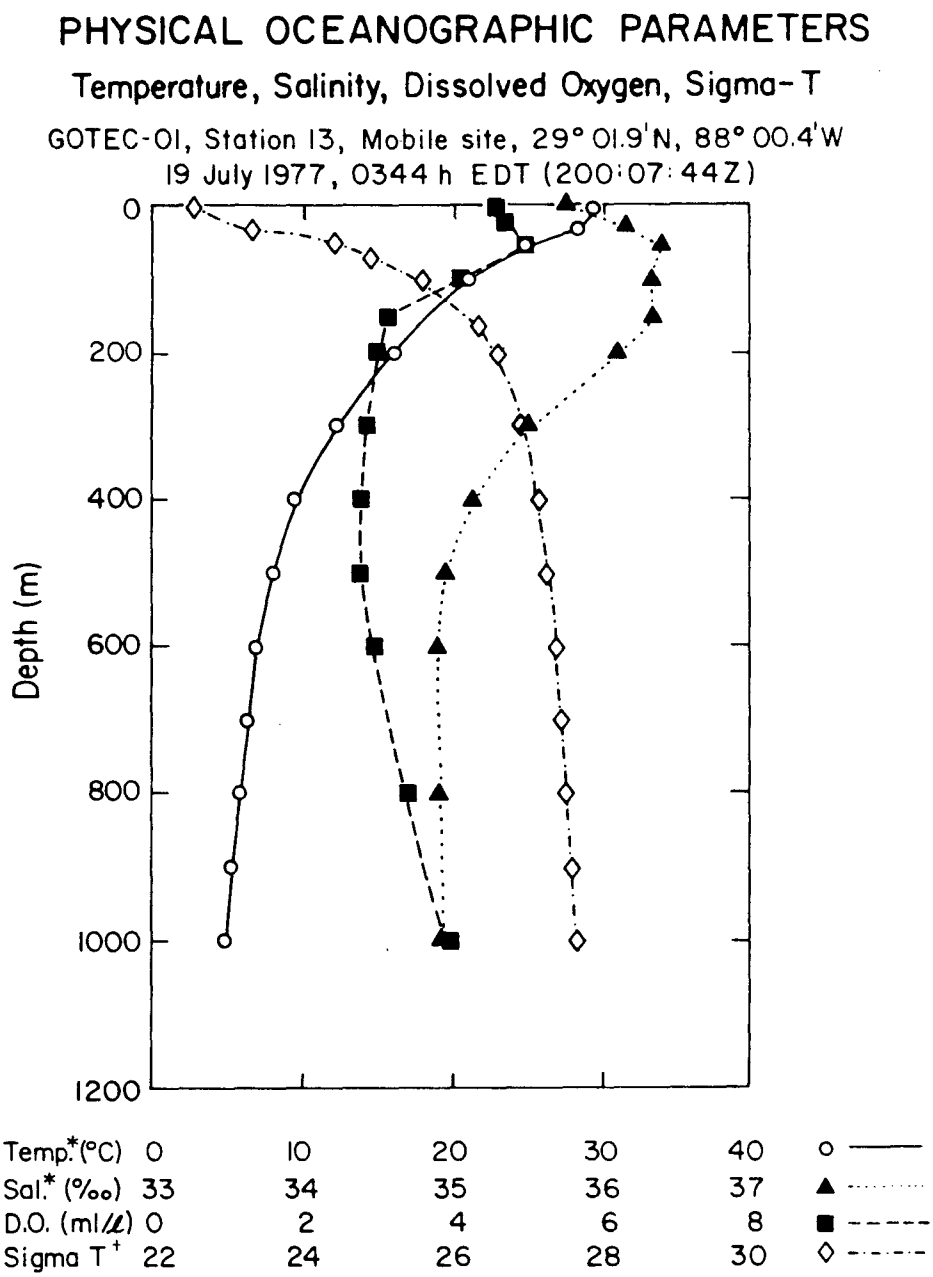
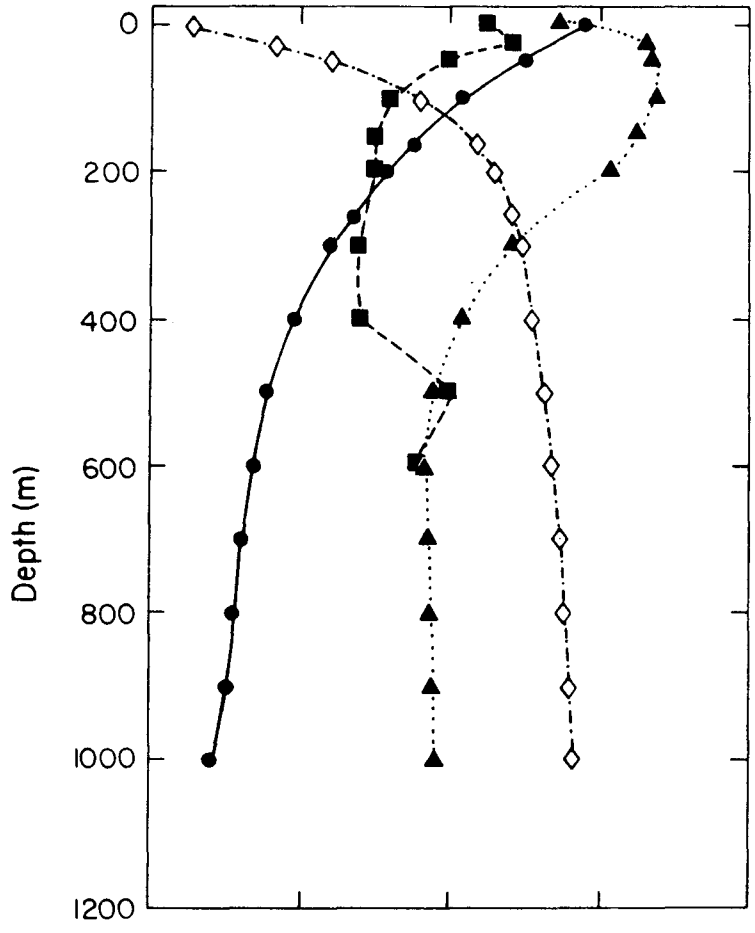

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Dissolved Oxygen, Sigma-T
GOTEC-01, Station 13, Mobile site, 29° 01.9'N, 88° 00.4'W
19 July 1977, 0344 h EDT (2000:07:44Z)
Depth (m)
0
200
400
600
800
1000
1200
Temp.*(°C) 0 10 20 30 40
Sal.* (‰) 33 34 35 36 37
D.O. (ml/ℓ) 0 2 4 6 8
Sigma T+ 22 24 26 28 30
* Curve constructed from STD data.
+ From STD data.
XBL 794-1164

Figure A-5

PHYSICAL OCEANOGRAPHIC PARAMETERS

Temperature, Salinity, Dissolved Oxygen, Sigma-T

GOTEC-01, Station 16, Mobile site, 29° 01.8'N, 87° 58.9'W
19 July 1977, 1347 h EDT (200:17:47Z)



Temp.*(°C)	0	10	20	30	40	● ——
Sal.* (‰)	33	34	35	36	37	▲ ·····
D.O. (ml/l)	0	2	4	6	8	■ - - - -
Sigma T†	22	24	26	28	30	◇ -·-·-

* *Curve partially constructed from STD data.*
Symbols for STD data points were: Temp. - o, Sal.- △
† *From STD data*

XBL 794-1165

Figure A-6

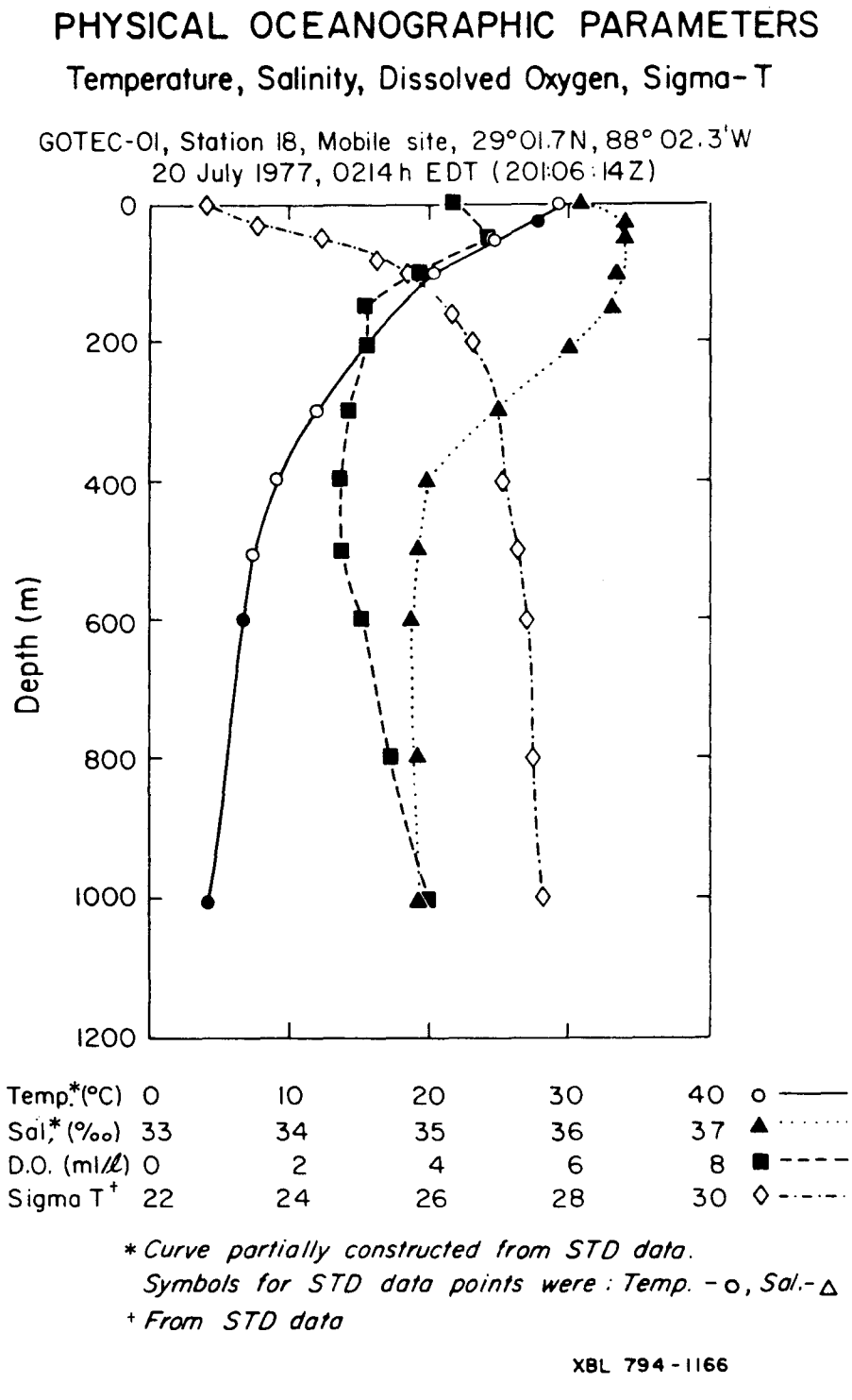
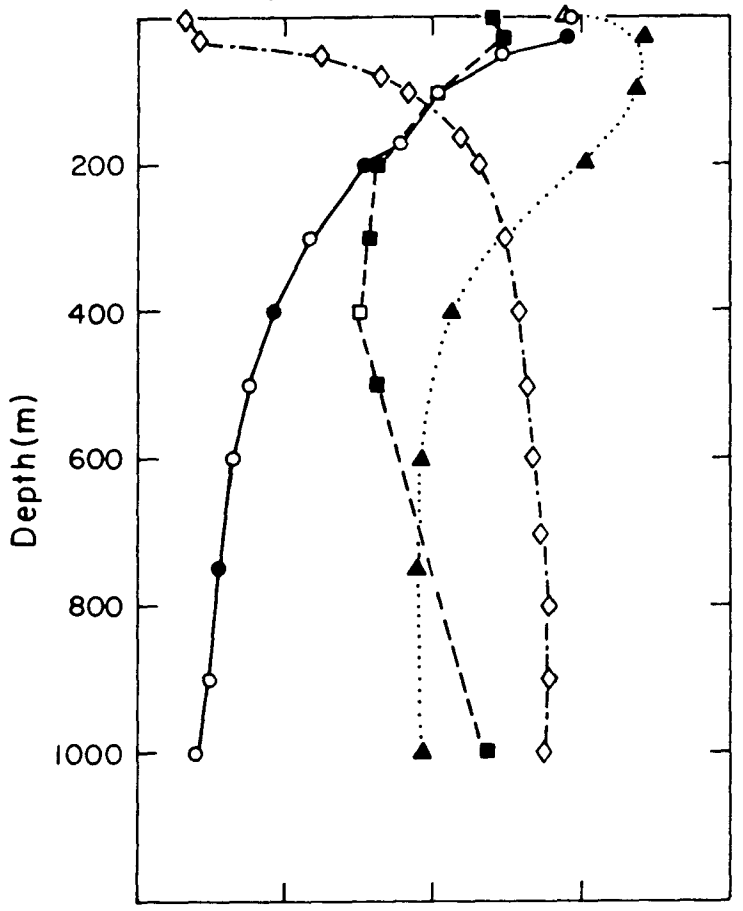

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Dissolved Oxygen, Sigma-T
GOTEC-01, Station 18, Mobile site, 29°01.7N, 88° 02.3'W
20 July 1977, 0214 h EDT (2001:06:14Z)
Depth (m)
0
200
400
600
800
1000
1200
Temp.*(°C) 0 10 20 30 40
Sal.* (‰) 33 34 35 36 37
D.O. (ml/ℓ) 0 2 4 6 8
Sigma T+ 22 24 26 28 30
* Curve partially constructed from STD data.
Symbols for STD data points were : Temp. - o, Sal.- Δ
+ From STD data
XBL 794-1166

Figure A-7

PHYSICAL OCEANOGRAPHIC PARAMETERS

Temperature, Salinity, Dissolved Oxygen, Sigma-T

GOTEC-01, Station 20, Mobile site, 29° 03.0'N, 87° 58.3'W
20 July 1977, 1340h EDT (2017:40Z) on bottom



Temp.* (°C)	0	10	20	30	40	● ——
Sal.* (‰)	35	34	35	36	37	▲ ·····
D.O.(ml/ℓ)	0	2	4	6	8	■ – – –
Sigma T†	22	24	26	28	30	◇ —·—·—

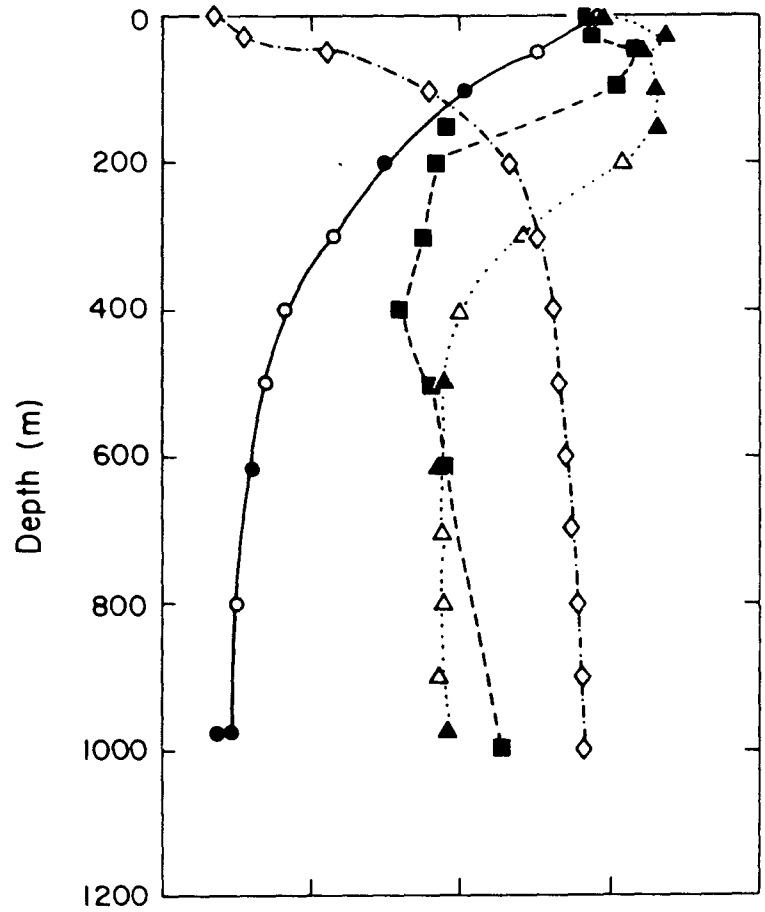
**Curve partially constructed from STD data.*
Symbols used for STD data points were: Temp - ○, Sal. - △
†From STD data

XBL 794-1167

Figure A-10

PHYSICAL OCEANOGRAPHIC PARAMETERS
Temperature, Salinity, Dissolved Oxygen, Sigma-T

GOTEC-01, Station 28, Mobile site, 28° 57.8'N, 88° 01.5'W
22 July 1977, 0645 h EDT (203:10:45Z)



Temp.*(°C)	0	10	20	30	40	o ——
Sal.*(‰)	33	34	35	36	37	▲ ·····
D.O. (ml/l)	0	2	4	6	8	■ - - - -
Sigma T †	22	24	26	28	30	◇ -·-·-

** Curve partially constructed from STD data.*
Symbols for STD data points were: Temp. - o, Sal. △
† From STD data

XBL 794-1169

Figure A-11

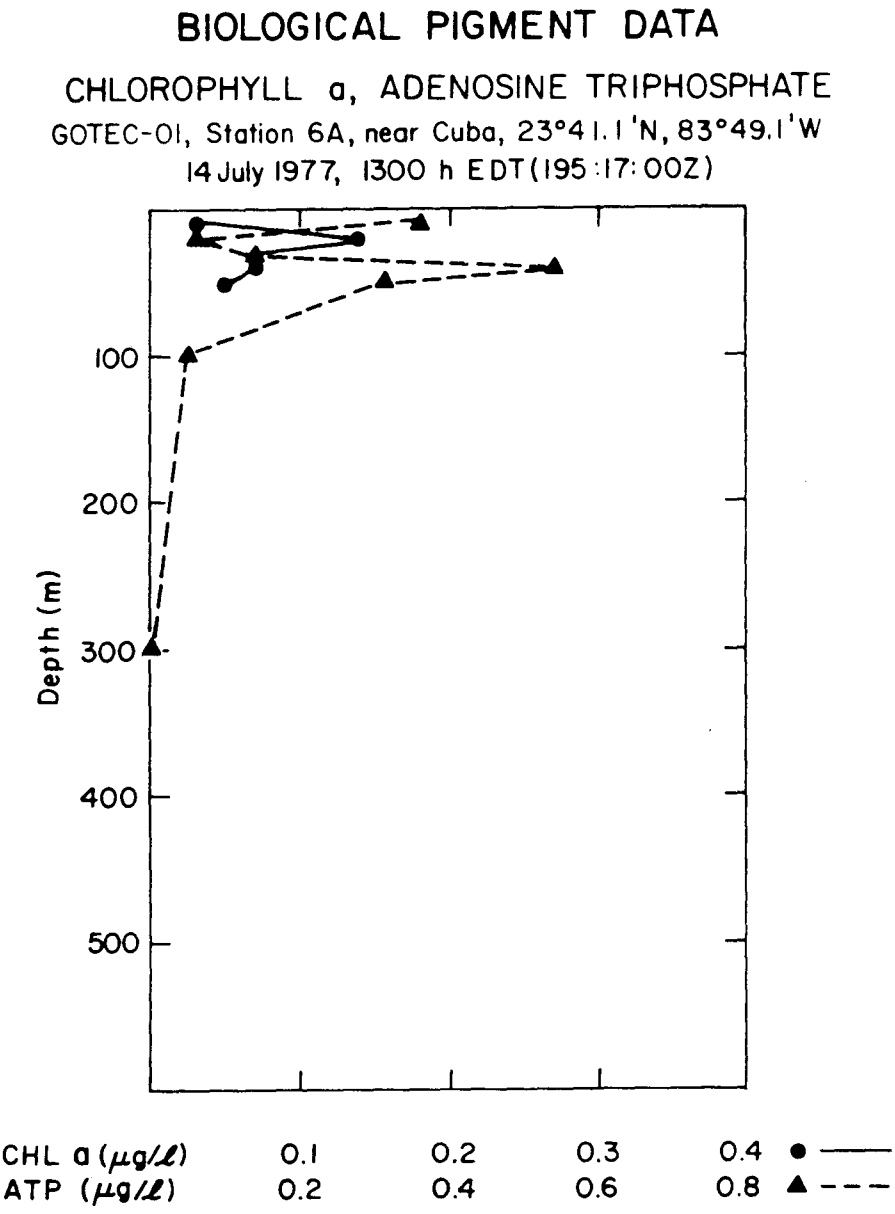

BIOLOGICAL PIGMENT DATA
CHLOROPHYLL a, ADENOSINE TRIPHOSPHATE
GOTEC-01, Station 6A, near Cuba, 23°41.1'N, 83°49.1'W
14 July 1977, 1300 h EDT (195:17:00Z)
Depth (m)
100
200
300
400
500
CHL a (μg/ℓ) 0.1 0.2 0.3 0.4
ATP (μg/ℓ) 0.2 0.4 0.6 0.8
XBL 794-1171

Figure A-12

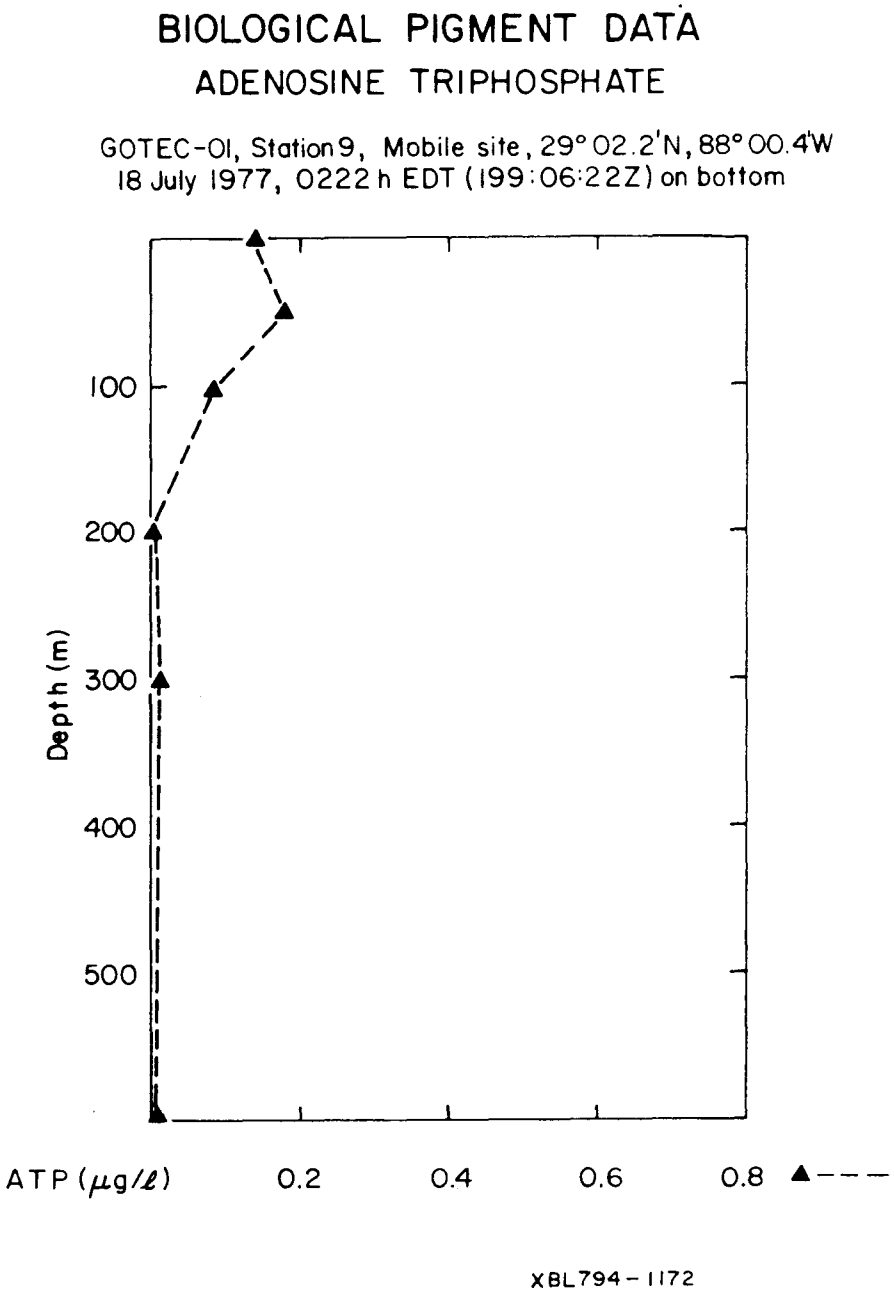

BIOLOGICAL PIGMENT DATA
ADENOSINE TRIPHOSPHATE
GOTEC-01, Station 9, Mobile site, 29° 02.2'N, 88° 00.4'W
18 July 1977, 0222 h EDT (199:06:22Z) on bottom
100
200
300
400
500
Depth (m)
ATP (μg/ℓ)
0.2
0.4
0.6
0.8
XBL794-1172

Figure A-13

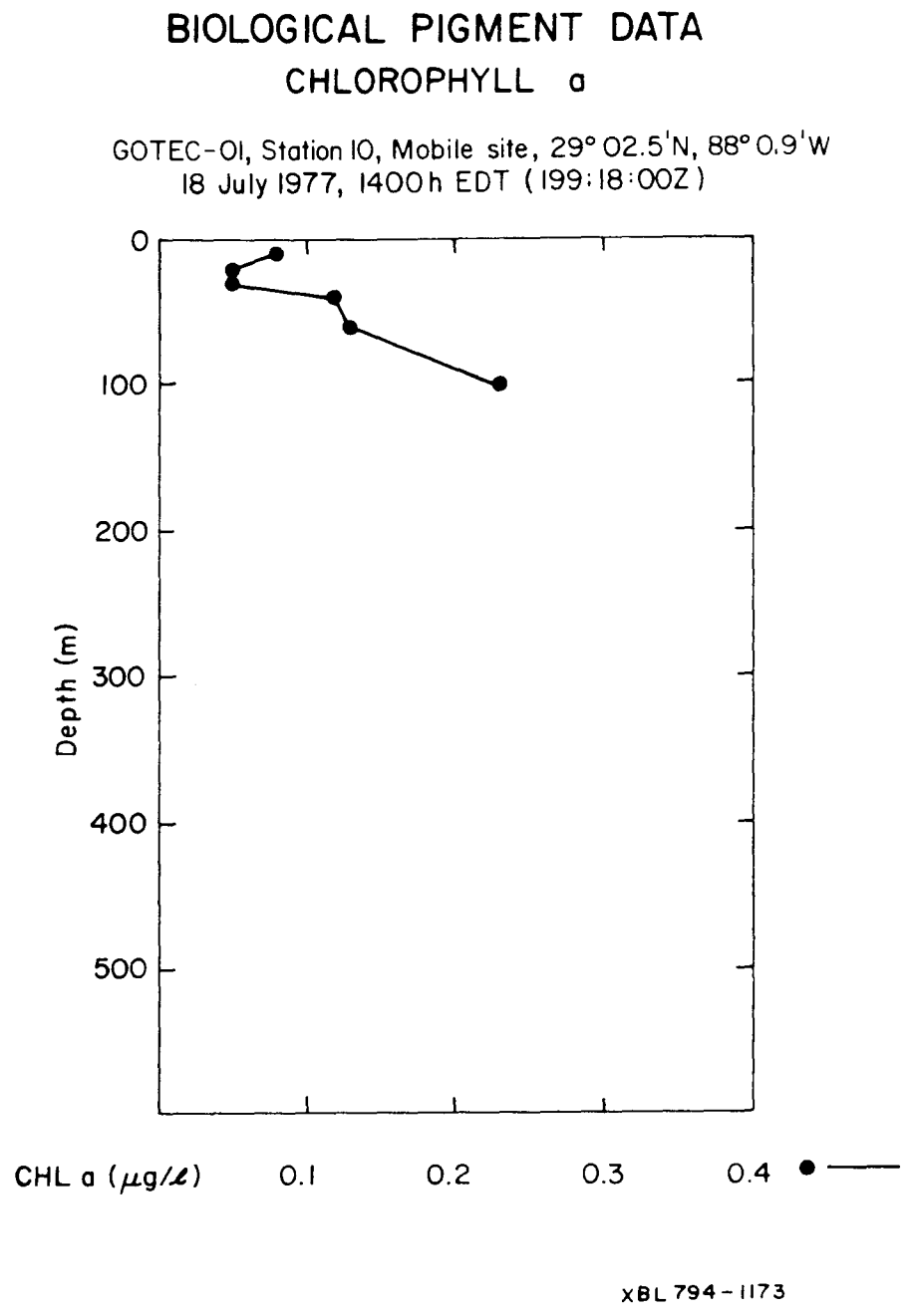
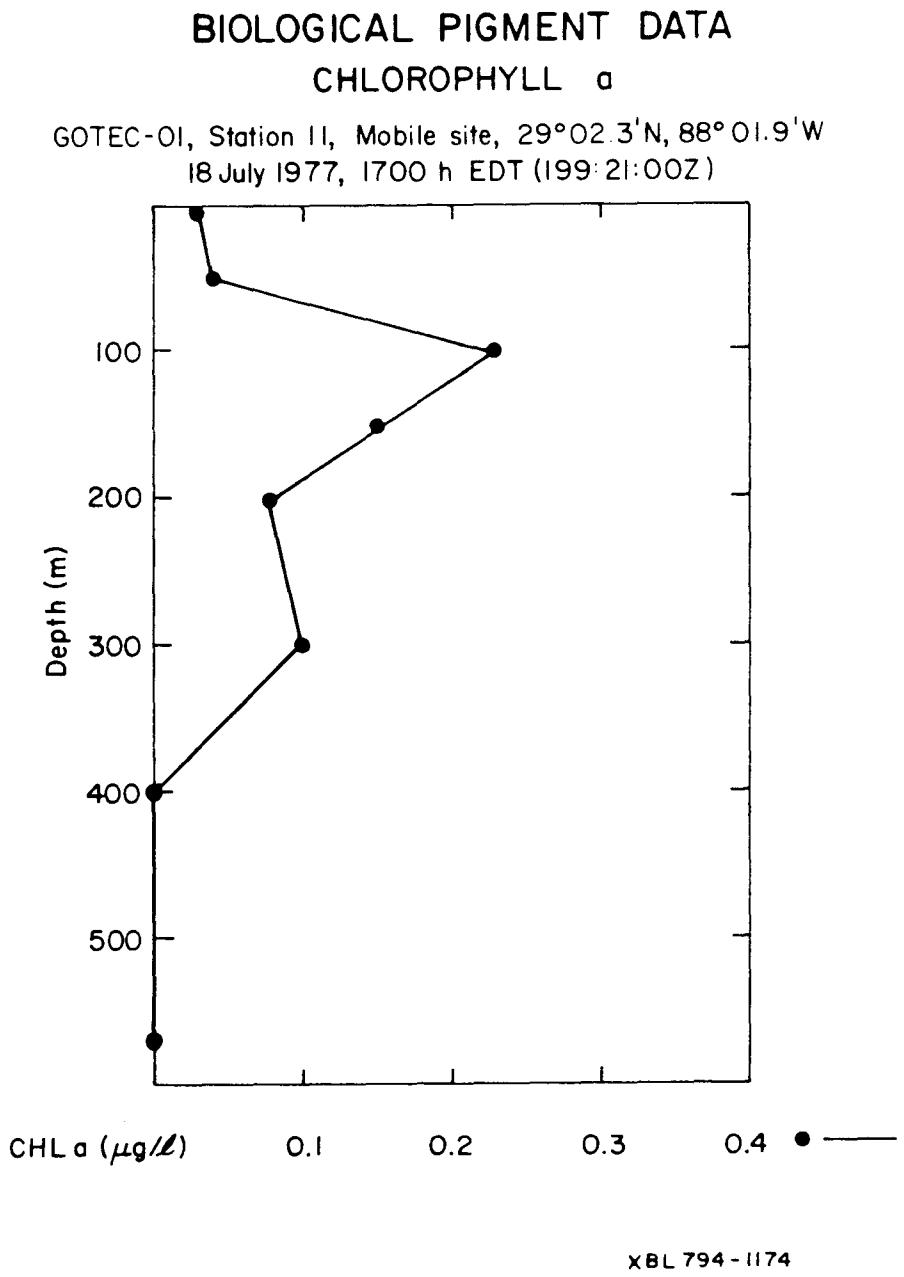

BIOLOGICAL PIGMENT DATA
CHLOROPHYLL a
GOTEC-01, Station 10, Mobile site, 29° 02.5'N, 88° 0.9'W
18 July 1977, 1400h EDT (199:18:00Z)
Depth (m)
0
100
200
300
400
500
CHL a (μg/ℓ)
0.1
0.2
0.3
0.4
XBL 794-1173

Figure A-14


BIOLOGICAL PIGMENT DATA
CHLOROPHYLL a
GOTEC-01, Station 11, Mobile site, 29°02.3'N, 88° 01.9'W
18 July 1977, 1700 h EDT (1999 21:00Z)
Depth (m)
100
200
300
400
500
CHL a (μg/ℓ)
0.1
0.2
0.3
0.4
XBL 794-1174

0 0 0 0 3 3 0 4 7 9

Figure A-15

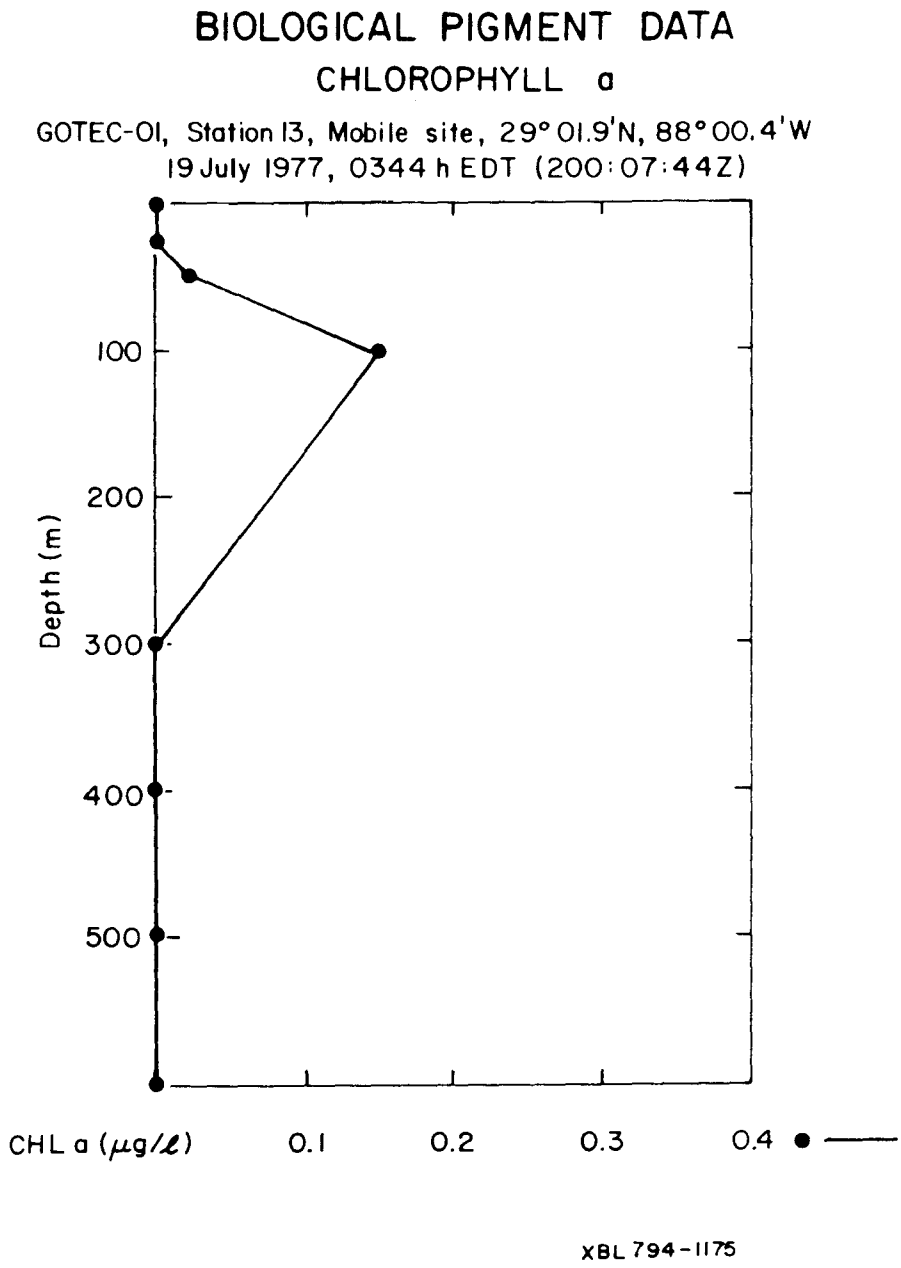


Figure A-18

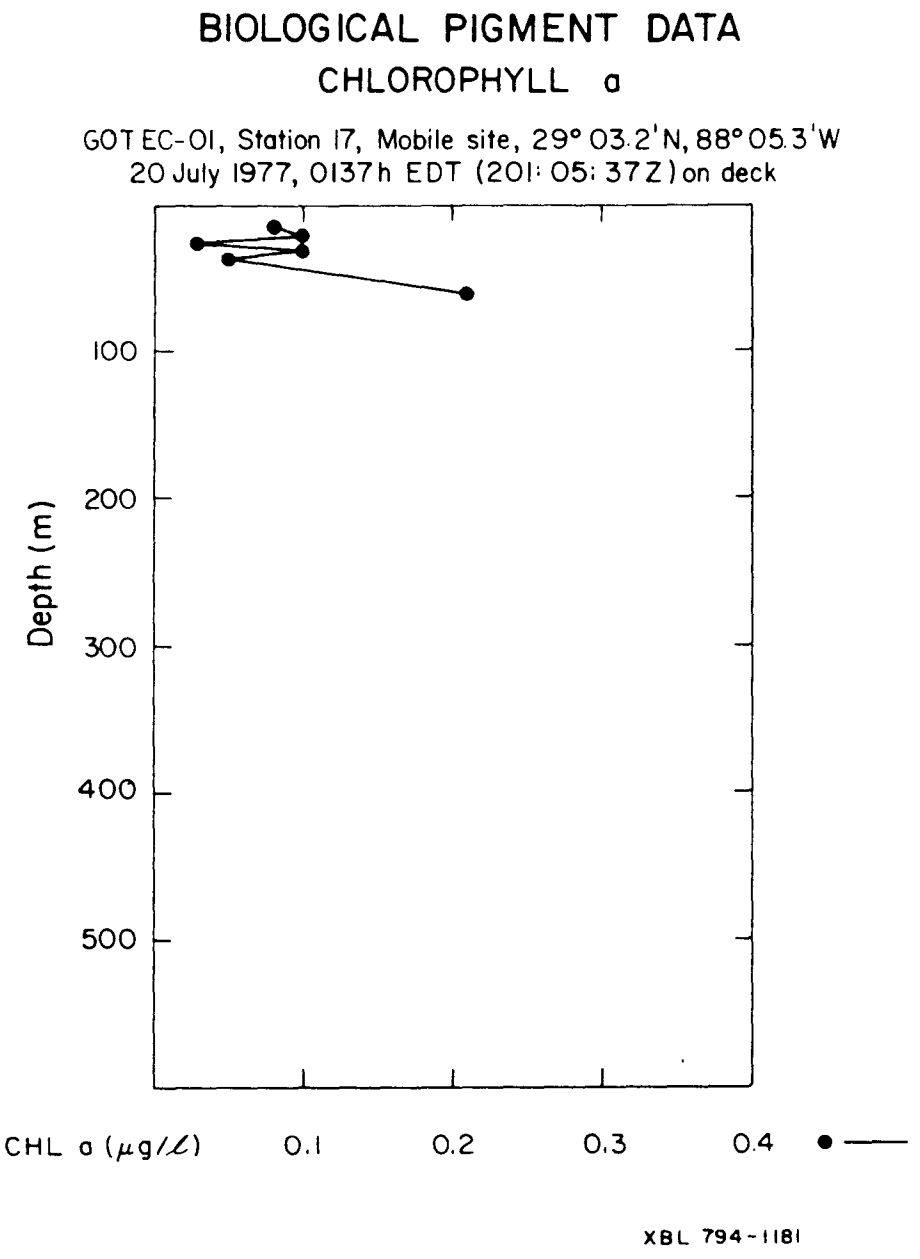

BIOLOGICAL PIGMENT DATA
CHLOROPHYLL a
GOT EC-01, Station 17, Mobile site, 29° 03.2'N, 88° 05.3'W
20 July 1977, 0137h EDT (2001: 05: 37Z) on deck
Depth (m)
100
200
300
400
500
CHL a (μg/ℓ)
0.1
0.2
0.3
0.4
XBL 794-1181

Figure A-19

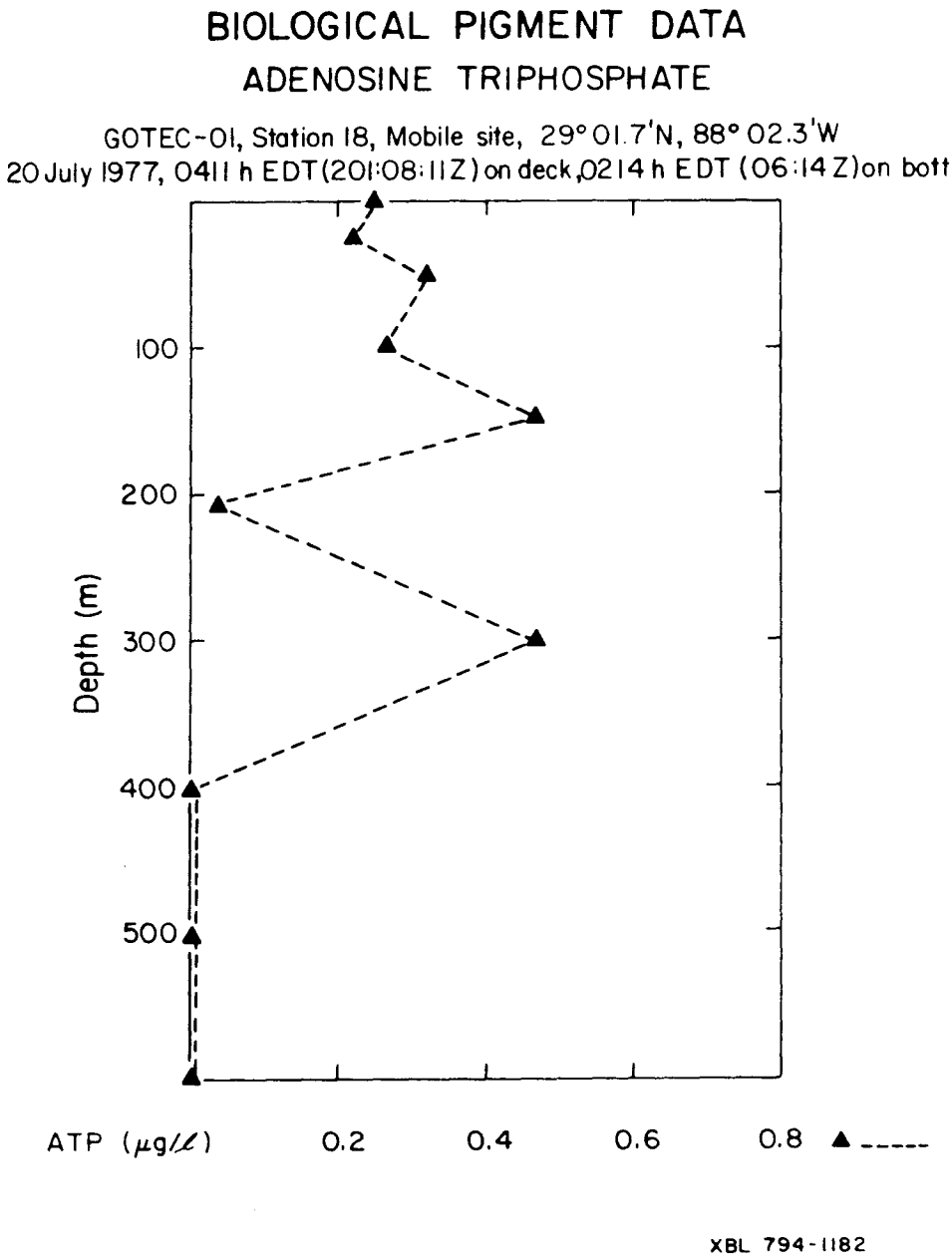

BIOLOGICAL PIGMENT DATA
ADENOSINE TRIPHOSPHATE
GOTEC-01, Station 18, Mobile site, 29° 01.7'N, 88° 02.3'W
20 July 1977, 0411 h EDT (2011:08:11Z) on deck, 0214 h EDT (06:14 Z) on bottom
Depth (m)
100
200
300
400
500
ATP (μg/ℓ)
0.2
0.4
0.6
0.8
XBL 794-1182

Figure A-20

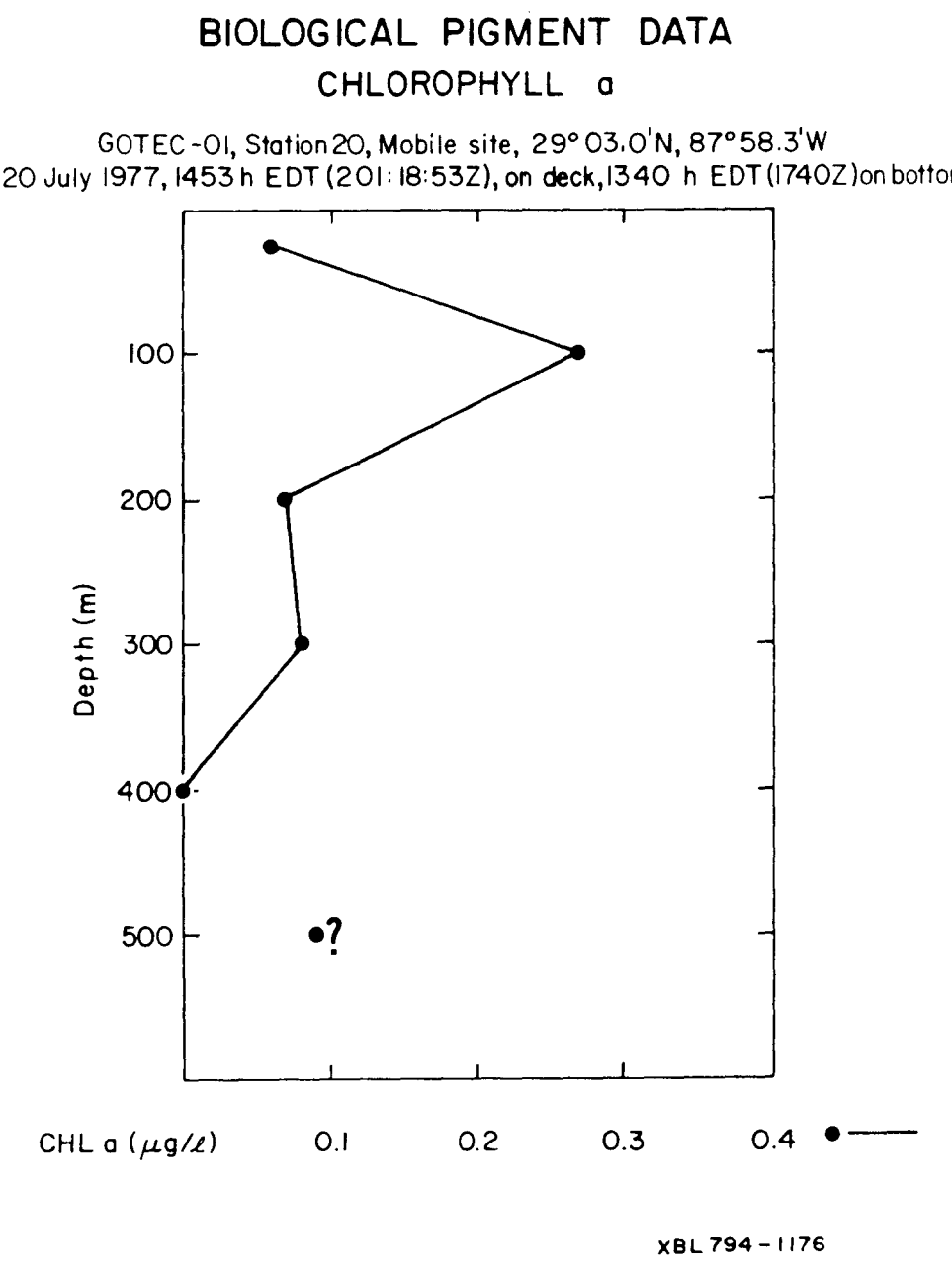

BIOLOGICAL PIGMENT DATA
CHLOROPHYLL a
GOTEC-01, Station 20, Mobile site, 29° 03.0'N, 87° 58.3'W
20 July 1977, 1453 h EDT (201: 18:53Z), on deck, 1340 h EDT (1740Z) on bottom
Depth (m)
100
200
300
400
500
?
CHL a (μg/ℓ)
0.1
0.2
0.3
0.4
XBL 794-1176

Figure A-21

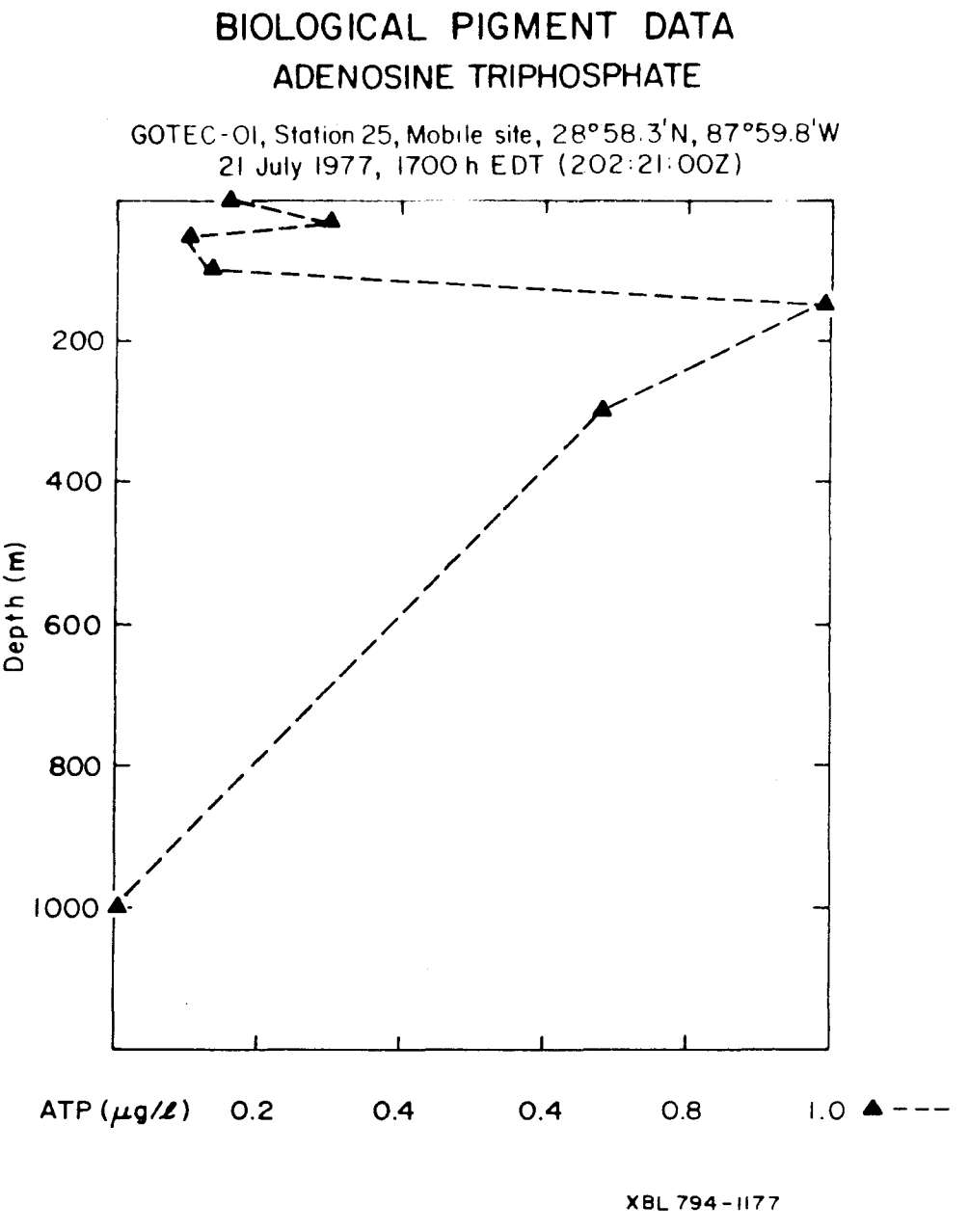

BIOLOGICAL PIGMENT DATA
ADENOSINE TRIPHOSPHATE
GOTEC-01, Station 25, Mobile site, 28°58.3'N, 87°59.8'W
21 July 1977, 1700 h EDT (202:21:00Z)
Depth (m)
200
400
600
800
1000
ATP (μg/ℓ)
0.2
0.4
0.4
0.8
1.0
XBL 794-1177

Figure A-22

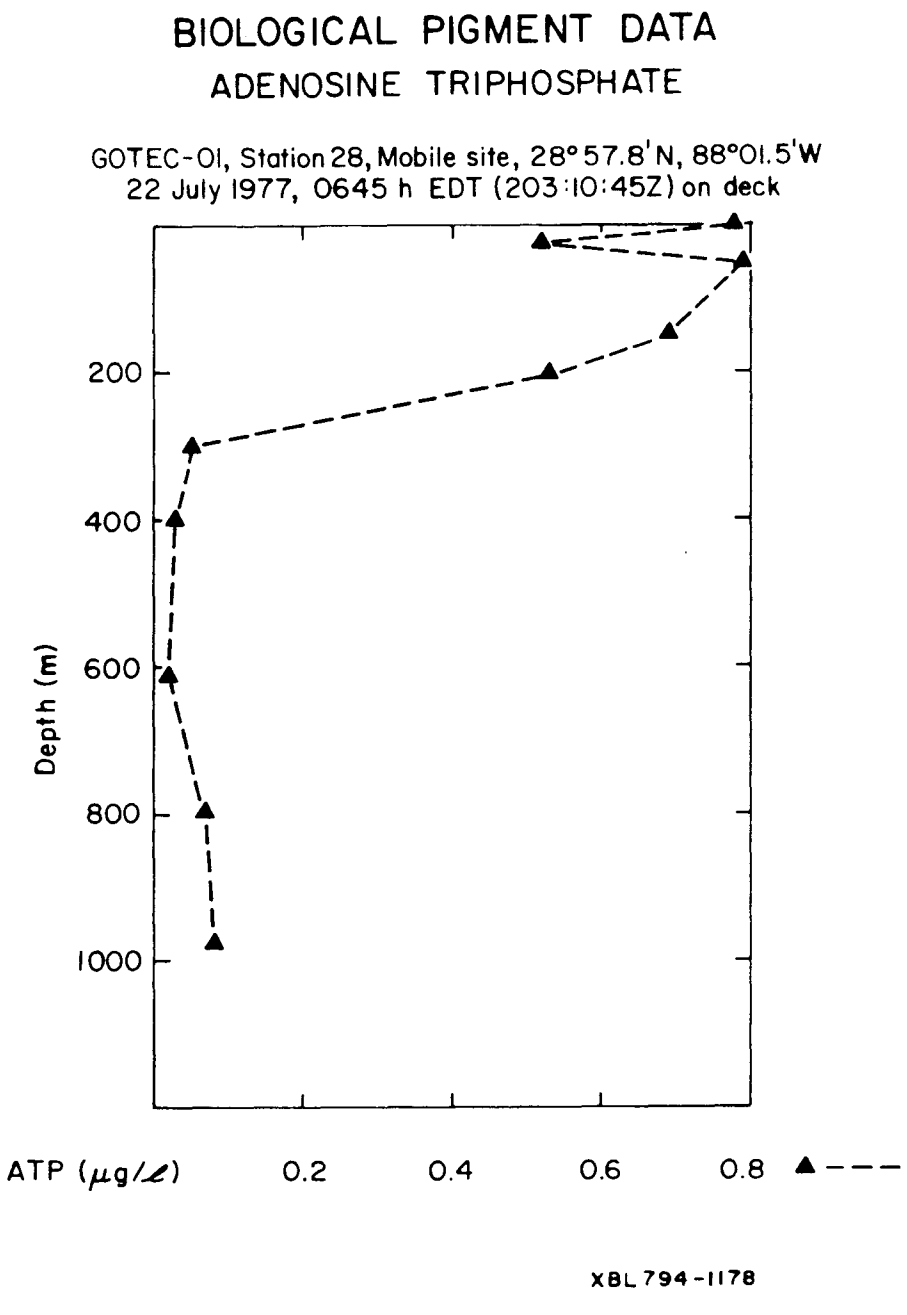

BIOLOGICAL PIGMENT DATA
ADENOSINE TRIPHOSPHATE
GOTEC-01, Station 28, Mobile site, 28° 57.8' N, 88°01.5'W
22 July 1977, 0645 h EDT (203:10:45Z) on deck
200
400
600
800
1000
Depth (m)
ATP (μg/ℓ)
0.2
0.4
0.6
0.8
XBL 794-1178

Figure A-23

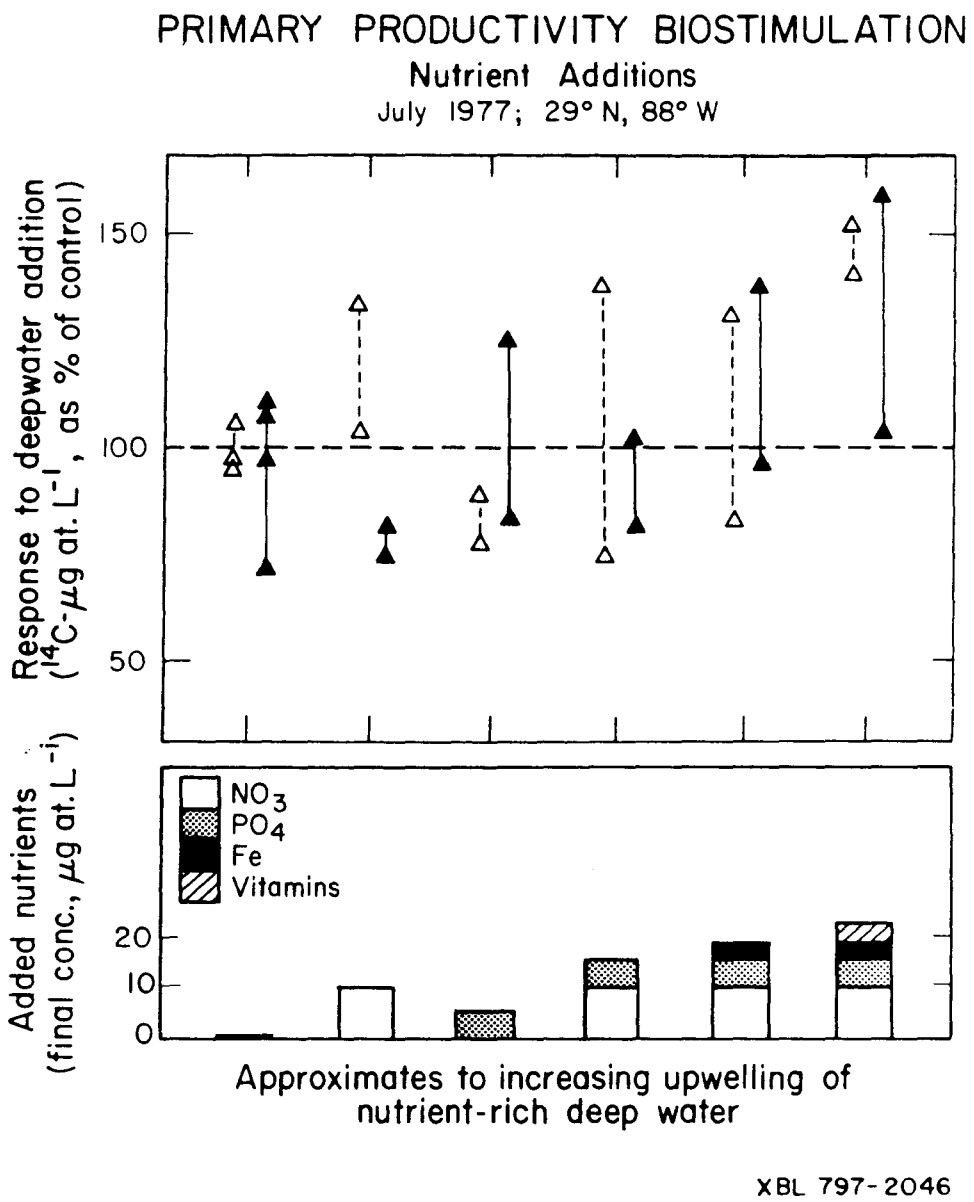
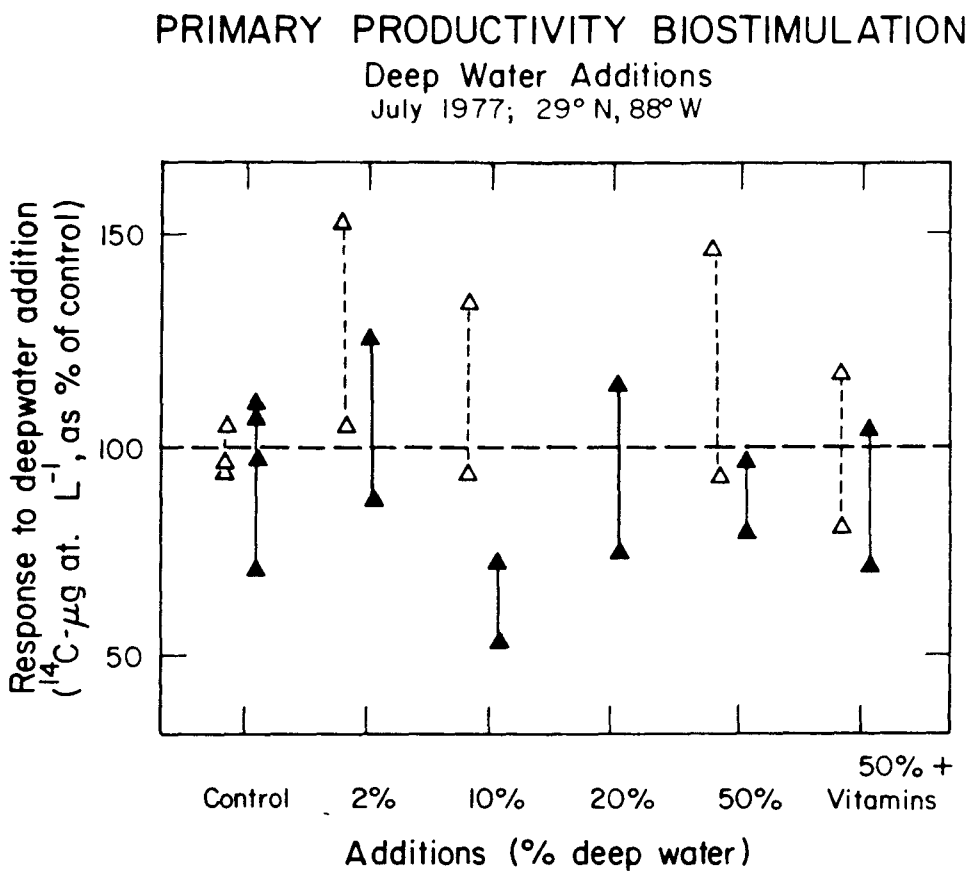


Figure A-23. Nutrient addition bioassay of surface water (25 m) using the photosynthetic carbon uptake of phytoplankton indigenous to the OTEC site. Open triangles are 17 July 1977; closed triangles are 21 July 1977. This bioassay separates the effect of each major nutrient that would be present if deep (1000 m) water were mixed with surface water, as proposed in some OTEC operations. Note that the general trend is a lack of consistent ecologically important stimulation unless all major nutrients and growth factors were added. Shipboard incubation was for 56 hours.

Figure A-24



XBL 797-2047

Figure A-24. Bioassay of surface water (25 m) using the photosynthetic carbon uptake of phytoplankton indigenous to the OTEC site. This bioassay determines the direct, short term biostimulation of the deep water (1000 m) that will be upwelled by an OTEC plant. Note that there is no consistent ecologically important stimulation shown during this 2-3 day period. Photosynthetic inhibitors (possibly ionic copper) could account for the lack of response and discrepancy between this figure and the stimulation shown by simple nutrient addition in Figure A-23. Open triangles are 17 July 1977; closed triangles are 21 July 1977. Shipboard incubation was for 56 hours.

Figure A-25

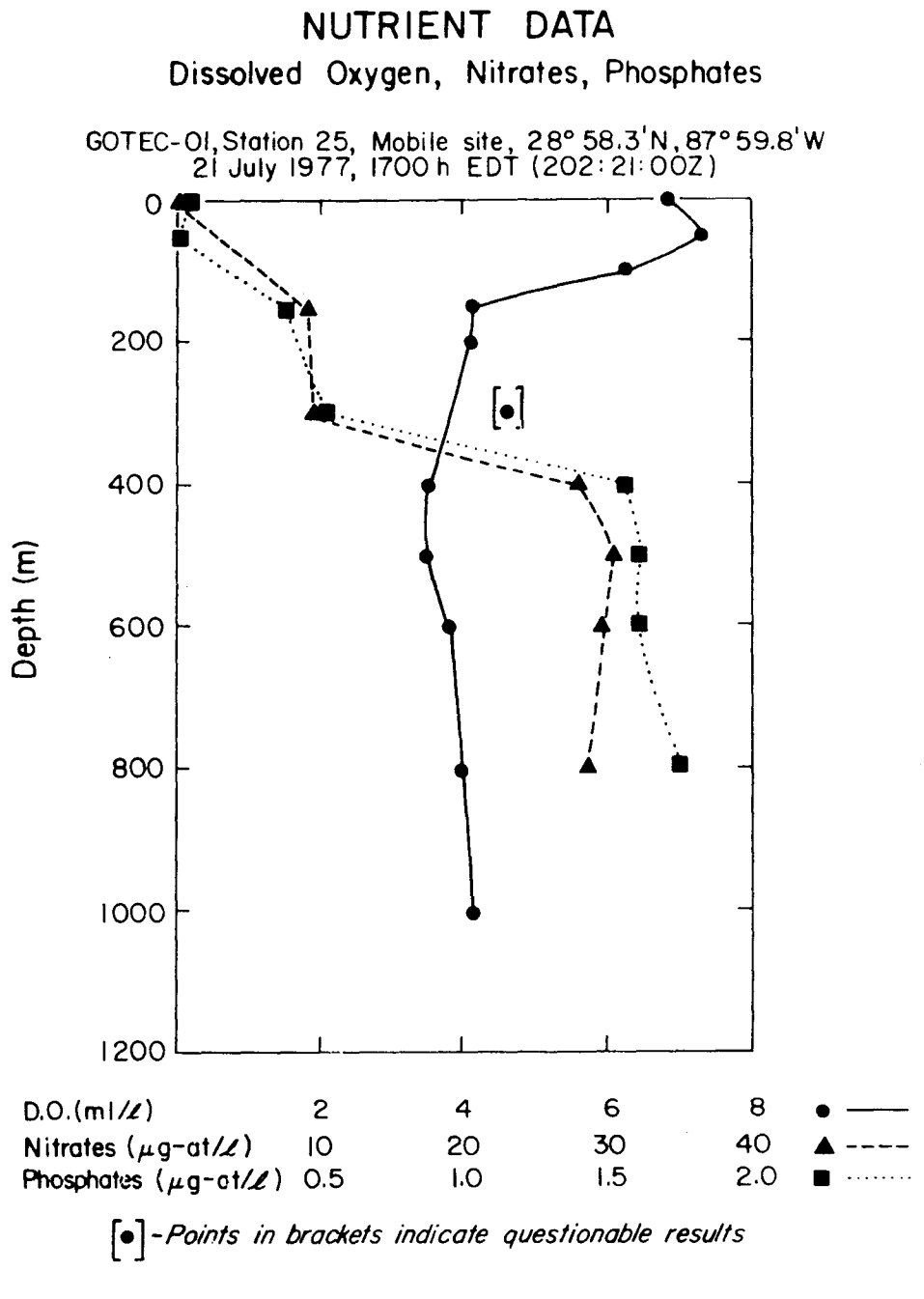

NUTRIENT DATA
Dissolved Oxygen, Nitrates, Phosphates
GOTEC-01, Station 25, Mobile site, 28° 58.3'N, 87° 59.8'W
21 July 1977, 1700 h EDT (202:21:00Z)
Depth (m)
0
200
400
600
800
1000
1200
[•]
D.O.(ml/ℓ) 2 4 6 8
Nitrates (μg-at/ℓ) 10 20 30 40
Phosphates (μg-at/ℓ) 0.5 1.0 1.5 2.0
[•]-Points in brackets indicate questionable results
XBL 794-1184

Figure A-26

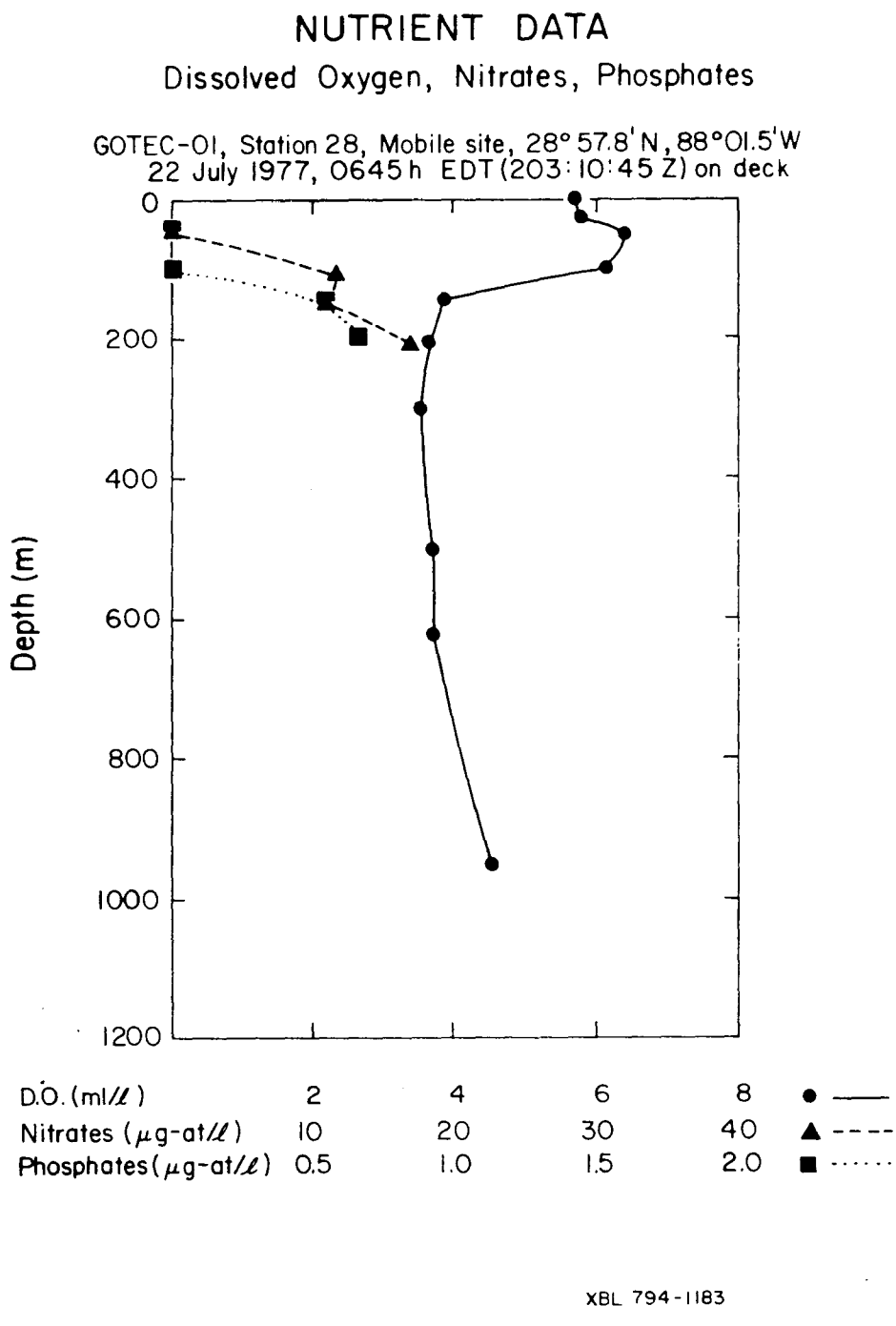
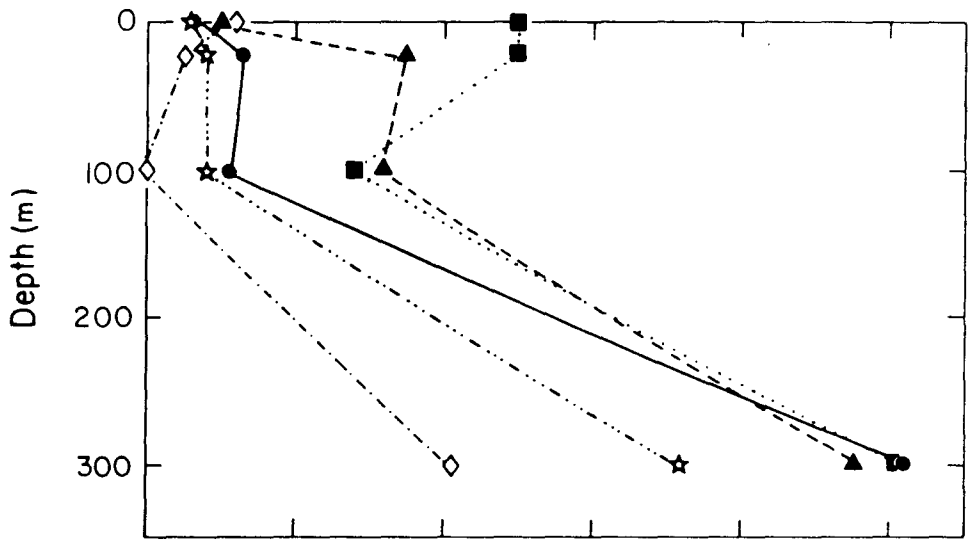

NUTRIENT DATA
Dissolved Oxygen, Nitrates, Phosphates
GOTEC-01, Station 28, Mobile site, 28° 57.8' N, 88°01.5'W
22 July 1977, 0645 h EDT (203:10:45 Z) on deck
Depth (m)
0
200
400
600
800
1000
1200
D.O. (ml/ℓ) 2 4 6 8
Nitrates (μg-at/ℓ) 10 20 30 40
Phosphates (μg-at/ℓ) 0.5 1.0 1.5 2.0
XBL 794-1183

Figure A-27

TRACE METALS

Cadmium, Copper, Nickel, Lead, Zinc

GOTEC-01, Station 24, Mobile site, 29° 06.4'N, 87°58.8'W
21 July 1977, 1325 h EDT (202:17:25Z) on deck



Cd (ng/ℓ)	10	20	30	40	50 ● —
Cu (μg/ℓ)	0.04	0.08	0.12	0.16	0.2 ▲ ---
Ni (μg/ℓ)	0.1	0.2	0.3	0.4	0.5 ■ ·····
Pb (μg/ℓ)	0.2	0.4	0.6	0.8	1.0 ◇ -·-·
Zn (μg/ℓ)	1.0	2.0	3.0	4.0	5.0 ☆ -···-

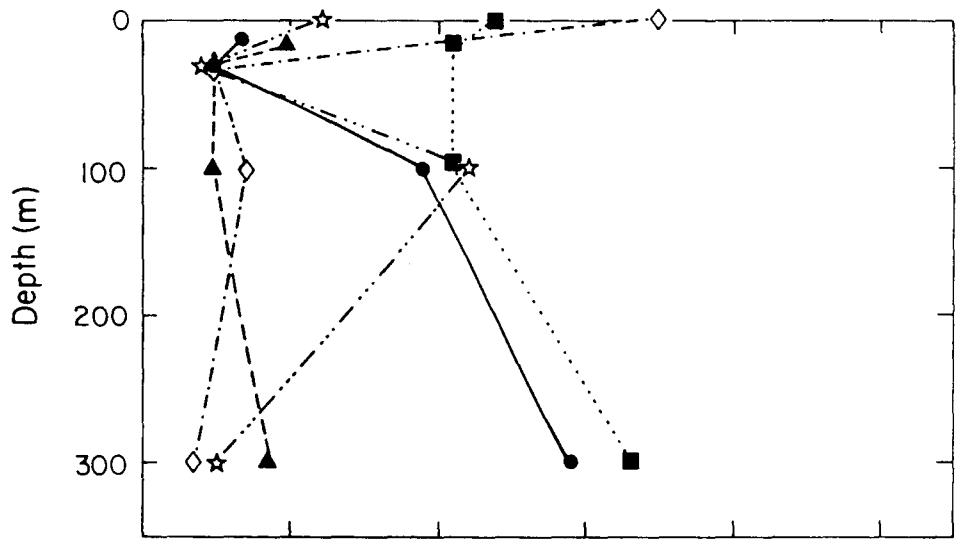
XBL 794-1186

Figure A-28

TRACE METALS

Cadmium, Copper, Nickel, Lead, Zinc

GOTEC-01, Station 27, Mobile site, 29° 02.4'N, 82°58.8'W
22 July 1977, 0208 h EDT (203:06:08Z) on deck



Cd (n g/ℓ)	10	20	30	40	50	● ——
Cu (μg/ℓ)	0.04	0.08	0.12	0.16	0.2	▲ ----
Ni (μg/ℓ)	0.1	0.2	0.3	0.4	0.5	■ ·····
Pb (μg/ℓ)	0.2	0.4	0.6	0.8	1.0	◇ -·-·-
Zn (μg/ℓ)	1.0	2.0	3.0	4.0	5.0	☆ -···-

XBL 794-1185

Appendix B. Tabular Data

Statistical parameters were not routinely calculated for the data in Tables B-1 through B-4. Generally the following instrumental variabilities may be expected:

Temperature:	Bottle thermometer	0.01°
	STD's	0.02°
Salinity:		0.003°/oo

As has been mentioned in the introduction to Appendix A, volume constraint prevented statistical analysis for the biological data. The nutrient data are generally considered to be within 10%, although a detailed analysis is currently underway to establish actual variability. Table B-5 contains the standard deviations observed for the trace metals.

Table B-1. Physical oceanographic parameters from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1).

Observed				Interpolated			Computed
Observed depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved oxygen (ml/L)	Standard depth (m)	Temp. (°C)	Salinity (°/oo)	σ_t
Station 7. Position:29° 01.8'N x 87°59.1'W (Mobile Site), 17 July 1977, Time: 198:05:48Z, 0148 EDT							
0	---	---	Not taken	0	29.480	35.886	22.588
10[a]	---	35.952	Not taken	10	29.493	35.901	22.595
30[a]	---	36.154	Not taken	30	28.792	36.296	23.128
40	25.06	36.247	Not taken	40	25.188	36.091	24.128
50[a]	---	36.342	Not taken	50	24.312	36.316	24.564
100	19.69	36.337	Not taken	100	20.271	36.282	25.685
200[a]	---	---	Not taken	200	15.856	36.050	26.606
300[a]	---	---	Not taken	300	11.991	35.431	26.944
400[a]	---	---	Not taken	400	9.571	35.079	27.106
599	6.75	---	Not taken	600	6.772	34.830	27.337
800	---	34.880	Not taken	800	5.566	34.851	27.510
1005	4.87	---	Not taken	1000	4.866	34.887	27.622
Station 9. Position:29°02.2'N x 88°00.4'W (Mobile Site), 18 July 1977, Time: 199:06:22Z, 0222 EDT (on bottom)							
0	-	35.747	4.62	NOT AVAILABLE			
50[a]	-	36.335	5.00	NOT AVAILABLE			
100[a]	-	36.369	4.35	NOT AVAILABLE			
200[a]	-	36.087	3.10	NOT AVAILABLE			
300[a]	-	35.498	2.82	NOT AVAILABLE			
400[a]	-	35.117	2.76	NOT AVAILABLE			
500[a]	-	-	-	NOT AVAILABLE			
600[a]	-	34.883	3.07	NOT AVAILABLE			
700[a]	-	-	-	NOT AVAILABLE			
804	5.54	34.902	3.54	NOT AVAILABLE			
900[a]	-	34.918	3.79	NOT AVAILABLE			
1003	4.83	34.934	-	NOT AVAILABLE			
Station 11. Position:29° 02.3'N x 88° 01.9'W (Mobile Site), 18 July 1977; Time: 199:21:00Z, 1700 EDT							
0	-	35.820	4.42	NOT AVAILABLE			
25	29.42	-	-	NOT AVAILABLE			
50[a]	19.90	36.389	4.96	NOT AVAILABLE			
98	-	36.412	4.00	NOT AVAILABLE			
150[a]	-	36.365	3.28	NOT AVAILABLE			
203	15.68	36.090	3.10	NOT AVAILABLE			
300[a]	-	35.574	2.83	NOT AVAILABLE			
400	9.35	35.134	2.88	NOT AVAILABLE			
500[a]	-	34.972	2.94	NOT AVAILABLE			
570	7.00	34.894	2.94	NOT AVAILABLE			
777	5.64	-	3.45	NOT AVAILABLE			
1000[a]	-	34.934	3.96	NOT AVAILABLE			

Table B-1. Physical oceanographic parameters from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1), cont'd.

Observed				Interpolated			Computed
Observed depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved oxygen (ml/L)	Standard depth (m)	Temp. (°C)	Salinity (°/oo)	σ_t
Station 13. Position: 29°01.9'N x 88°00.4'W (Mobile site), 19 July 1977; Time 200:07:44Z (on deck), 0344 EDT.							
0	-	35.752	4.56	0	29.307	35.686	22.497
25[a]	-	36.149	4.68	20	29.486	35.956	22.639
50[a]	-	36.403	4.99	50	24.765	36.312	24.429
100[a]	-	36.320	4.10	100	20.881	36.367	25.584
150[a]	-	36.384	3.10	160	17.710	36.286	26.345
200[a]	-	36.090	2.97	200	15.976	36.078	26.599
300[a]	-	35.489	2.85	300	12.219	35.474	26.933
400[a]	-	35.122	2.76	400	9.289	35.053	27.132
500[a]	-	34.946	2.75	500	7.758	34.889	27.243
600[a]	-	34.888	2.95	600	6.822	34.841	27.339
800[a]	-	34.897	3.42	800	5.569	34.863	27.520
1000[a]	-	34.936	3.94	1000	4.893	34.897	27.627
Station 16. Position: 29°01.8'N x 87°58.9'W (Mobile site), 19 July 1977; Time: 200:19:13Z, 1513 EDT (on deck) 1747Z, 1345 EDT on bottom.							
0	29.27	36.293	4.50	0	29.235	35.728	22.552
25[a]	27.82	36.392	4.82	20	27.969	36.140	23.283
50[a]	24.58	36.394	4.07	50	24.988	36.348	24.383
100[a]	19.50	36.338	3.18	100	20.873	36.371	25.590
150[a]	17.56	36.103	3.07	160	17.496	36.256	26.375
200[a]	15.78	35.502	3.03	200	16.076	36.085	26.582
300[a]	13.89	35.136	2.72	300	11.942	35.425	26.948
400[a]	9.50	34.934	2.80	400	9.589	35.086	27.108
500[a]	7.69	34.880	4.02	500	7.764	34.890	27.243
600[a]	6.71	34.901	3.56	600	6.679	34.838	27.356
800[a]	5.49	36.184	-	800	5.499	34.864	27.529
1000[a]	4.83	34.934	-	1000	4.543	34.903	27.638
Station 18. Position: 29°01.7'N X 88°02.3'W (Mobile site), 20 July 1977; Time: 201:08:11Z, 0411 EDT, on deck, 0614 EDT, on bottom							
0	-	36.088	4.35	0	29.110	36.081	22.860
25[a]	-	36.442	-	20	-	36.112	22.887
50[a]	-	36.399	4.87	50	24.777	36.368	24.463
100[a]	-	36.354	3.90	100	20.416	36.330	25.683
150[a]	-	36.312	3.08	140	18.875	36.386	26.129
207	15.55	36.070	3.11	200	15.697	36.066	26.654
300[a]	-	35.503	2.84	300	12.018	35.490	26.984
400[a]	-	35.090	2.73	400	9.154	35.074	27.171
500[a]	-	34.934	2.74	500	7.632	34.916	27.283
599	6.71	34.882	3.04			NOT AVAILABLE	
800[a]	-	34.902	3.46			NOT AVAILABLE	
1003	4.85	34.938	4.00			NOT AVAILABLE	

Table B-1. Physical oceanographic parameters from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1), cont'd.

Observed				Interpolated			Computed
Observed depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved oxygen (ml/l)	Standard depth (m)	Temp. (°C)	Salinity (o/oo)	σ_t
Station 20. Position: 29°03.0'N x 87°58.3'W (Mobile site), 20 July 1977, Time: 201:18:53Z, 1453 EDT, on deck: 1740Z, 1340 EDT on bottom.							
0	-	35.890	4.81	0	29.277	35.896	22.666
25[a]	28.05	36.425	4.95	20	29.035	36.329	23.071
100[a]	-	36.370	4.04	100	20.448	36.342	25.683
205	15.57	36.015	3.26	200	15.947	36.110	26.630
300[a]	-	35.426	3.15	300	11.946	35.475	26.986
400	9.23	35.124	3.04	400	9.326	35.089	27.154
500[a]	-	34.940	3.28	500	7.678	34.923	27.281
749	5.64	34.916	-	740	5.742	34.601	27.513
1000[a]	-	34.946	4.77	1000	4.874	34.911	27.641
Station 22. Position: 29°02.1'N x 87°59.4'W (Mobile site), 21 July 1977; Time: 202:07:14Z, 0314 EDT (on deck) 0455Z on bottom.							
0	-	35.711	5.66	0	29.424	35.704	22.471
25	28.91	36.228	5.84	20	29.151	36.207	22.940
50[a]	-	36.402	6.72	50	24.903	36.375	24.430
113	-	-	5.17	100	20.849	36.436	25.646
150[a]	-	36.376	4.27	140	18.793	36.401	26.162
182	-	-	4.07	180	16.707	36.211	26.531
300[a]	-	35.423	3.50	300	11.897	35.465	26.988
400[a]	-	-	-	400	8.888	35.050	27.195
500[a]	-	34.907	2.96	500	7.330	34.904	27.317
599	6.53	34.879	3.35	600	6.553	34.876	27.403
800[a]	-	34.884	3.42	800	5.490	34.893	27.553
1006	4.87	34.935	4.38	1000	4.867	34.911	27.641
Station 25. Position: 28°58.3'N x 87°59.8'W (Mobile site), 21 July 1977; Time: 202:21:00Z, 1700 EDT							
0	-	36.129	5.83	0	29.565	36.157	22.763
30	28.30	36.321	5.99	30	28.670	36.364	23.220
50[a]	-	36.176	6.34	50	25.403	36.225	24.163
96	20.30	36.347	5.28	100	20.887	36.321	25.548
150[a]	-	36.338	4.12	140	18.724	36.329	26.125
202	15.47	-	4.13	200	15.889	36.077	26.619
300[a]	-	35.024	4.64	300	11.807	35.431	26.979
400[a]	-	34.894	3.53	400	8.694	35.022	27.204
500[a]	-	-	3.53	500	7.169	34.888	27.328
601	6.36	-	3.80	600	6.413	34.873	27.419
800[a]	-	-	3.96	800	5.456	34.888	27.553
1009	4.83	34.934	4.15	1000	4.869	34.916	27.646

Table B-1. Physical oceanographic parameters from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1), cont'd.

Observed				Interpolated			Computed
Observed depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved oxygen (ml/L)	Standard depth (m)	Temp. (°C)	Salinity (o/oo)	σ_t
Station 28. Position: 28°57.8'N x 88°1.5'W (Mobile site), 22 July 1977; Time: 203:10:45Z, 0645 EDT, on deck							
0	-	35.950	5.71	0	29.331	35.949	22.656
25[a]	-	36.372	5.77	20	29.195	36.203	22.923
50[a]	-	36.218	6.37	50	25.065	36.157	24.216
100	20.10	-	6.12	100	20.646	36.346	25.633
150[a]	-	36.340	3.83	160	17.561	36.320	26.408
204	14.96	-	3.63	200	15.732	36.095	26.668
300	-	-	3.51	300	11.534	35.428	27.029
400	-	-	3.16	400	6.352	34.991	27.233
500	-	34.899	3.71	500	7.192	34.896	27.337
615	6.24	34.884	3.73	600	6.436	34.876	27.418
800[a]	-	-	-	800	5.394	34.904	27.574
972	4.88	34.935	4.56	980	4.875	34.930	27.656

[a]Wire out

[b]A dash indicates that the parameter was not measured at this depth.

Table B-2. Biological Data from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-I)

Biomass Indicators			Biomass Indicators		
Observed Depth	Chlorophyll a (µg/L)	ATP (µg/L)	Observed Depth	Chlorophyll a (µg/L)	ATP (µg/L)
Station 5, Position: 23°20'N x 82°47'W (near Cuba), 13 July 1977 Time: 194:15:35Z, 1135 EDT			Station 7, Position: 29°01.8'N x 87°59.1'W (Mobile site), 17 July 1977, Time: 198:05:48Z, 0148 EDT		
500[a]	--[b]	X[c]	10[a]	X	--
			20[a]	X	--
			30[a]	X	--
			40	X	--
Station 6, Position: 23°4.7'N x 82°45.2'W (near Cuba), 13 July 1977 Time: 194:18:00Z, 1400 EDT			Station 9, Position: 29°02.2'N x 88°00.4'W (Mobile site), 18 July 1977, Time: 199:06:22Z, 0222 EDT on bottom		
5[a]	--	X	0	--	0.14
500[a]		X	50[a]	--	0.18
			100[a]	--	0.10
			200[a]	--	0.00
			300[a]	--	0.01
			600[a]	--	0.00
			1003	--	0.00
Station 6A, Position: 23°41.1'N x 83°49.1'W (near Cuba), 14 July 1977 Time: 195:17:00Z, 1300 EDT (on deck)			Station 10, Position: 29°02.5'N x 88°00.9'W (Mobile site), 18 July 1977, Time: 199:18:00Z, 1400 EDT		
10[a]	0.03	0.36	10[a]	0.08	--
20[a]	0.14	0.06	20[a]	0.05	--
30[a]	0.07	0.14	30[a]	0.05	--
40[a]	0.07	0.54	40[a]	0.12	--
50[a]	0.05	0.31	60[a]	0.13	--
100[a]	--	0.05	100[a]	0.23	--
300[a]	--	0.00			

[a]Wire Out

[b]A dash indicates that the parameter was not measured at this depth.

[c]An X indicates that there was an error in the analysis.

Table B-2. Biological Data from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1) (Continued)

Biomass Indicators		
Observed Depth	Chlorophyll a (µg/L)	ATP (µg/L)
Station 11, Position: 29°02.3'N x 88°01.9'W (Mobile site), 18 July 1977, Time: 199:21:00Z, 1700 EDT		
0	0.03	--
50[a]	0.04	--
98	0.23	--
150[a]	0.15	--
203	0.08	--
300[a]	0.10	--
400	0.00	--
570	0.00	--
777	0.00	--
Station 13, Position: 29°01.9'N x 88°00.4'W (Mobile site), 19 July 1977, Time: 200:07:44Z, 0344 EDT (on deck)		
0	0.00	--
25[a]	0.00	--
50[a]	0.02	--
100[a]	0.15	--
300[a]	0.00	--
400[a]	0.00	--
500[a]	0.00	--
600[a]	0.00	--
800[a]	0.00	--
1000[a]	0.00	--

Biomass Indicators		
Observed Depth	Chlorophyll a (µg/L)	ATP (µg/L)
Station 15, Position: 29°03.7'N x 87°59.6'W (Mobile site), 19 July 1977, Time: 200:16:00Z, 1200 EDT		
25[a]	0.02	--
35[a]	0.04	--
60[a]	0.10	--
Station 16, Position: 29°01.8'N x 87°58.9'W (Mobile site), 19 July 1977, Time: 200:19:13Z, 1513 EDT (on deck); 1745Z, 1345 EDT (on bottom)		
0	0.00	--
25[a]	0.22	--
50[a]	0.16	--
100[a]	0.09	--
150[a]	0.06	--
200[a]	0.07	--
300[a]	0.00	--
Station 17, Position: 29°03.2'N x 88°05.3'W (Mobile site), 20 July 1977, Time: 201:05:37Z, 0137 EDT (on deck)		
15[a]	0.08	--
20[a]	0.10	--
25[a]	0.03	--
30[a]	0.10	--
35[a]	0.05	--
60[a]	0.21	--

[a]Wire out.

Table B-2. Biological Data from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1) (Continued)

Biomass Indicators			Biomass Indicators		
Observed Depth	Chlorophyll a (μg/L)	ATP (μg/L)	Observed Depth	Chlorophyll a (μg/L)	ATP (μg/L)
Station 18, Position: 29°01.7'N x 88°02.3'W (Mobile site), 20 July 1977, Time: 201:08:11Z, 0411 EDT (on deck); 06:14Z, 0214 EDT (on bottom)			Station 25, Position: 28°58.3'N x 87°59.8'W (Mobile site), 21 July 1977, Time: 202:21:00Z, 1700 EDT		
0	--	0.25	0	--	0.16
25[a]	--	0.22	30	--	0.30
50[a]	--	0.32	50[a]	--	0.10
100[a]	--	0.27	96	--	0.13
150[a]	--	0.47	150[a]	--	0.99
207	--	0.04	300[a]	--	0.68
300[a]	--	0.47	1009	--	0.00
400[a]	--	0.00			
500[a]	--	0.00			
599	--	0.00			
800[a]	--	0.00			
Station 20, Position: 29°03.0'N x 87°58.3'W (Mobile site), 20 July 1977, Time: 201:18:53Z, 1453 EDT (on deck); 17:40Z, 1340 EDT (on bottom)			Station 28, Position: 28°57.8'N x 88°1.5'W (Mobile site), 22 July 1977, Time: 203:10:45Z, 0645 EDT (on deck)		
25[a]	0.06	--	0	--	0.78
100[a]	0.27	--	25[a]	--	0.52
205	0.07	--	50[a]	--	0.79
300[a]	0.08	--	150[a]	--	0.69
400	0.00	--	204	--	0.53
500[a]	0.09	--	300	--	0.05
			500	--	0.03
			615	--	0.02
			800[a]	--	0.07
			972	--	0.08

[a]Wire out.

Table B-3. Primary Productivity Results from OSS Researcher, Gulf of Mexico (GOTEC-1)

Station 6B: 29°N, 88W; Mobile Site, 16 July 1977, Time deployed 197:14:30Z(1030 EDT), (on deck) 203:19:00Z (1500 EDT), (Total incubation time) 6 da. 4 hr. 30 min.

Incubation: At depth attached to buoy mooring.

Description: Test attachment potential of primary producers. Tygon tubing (2 in. length, 1/2 in. dia.) was tied to buoy mooring line. After one week, biotic growth was measured as chl a (as fluorescence) and ATP.

Sample	Chl a (μg)	PHAEO (μg)	ATP (μg)
Buoy	0.0005	0.0009	0.01
Buoy	0.0017	0.0034	0.01
10 m	0.0007	0.0043	0.01
20 m	0.0	0.0	0.01
30 m	0.0002	0.0002	0.01
40 m	0.0	0.0	0.01

Station 8: 29°01.5'N, 88°01.9'W; Mobile site, 17 July 1977, Time (start) 198:05:50Z(01:50 EDT), (finish) 200:14:00Z(1000 EDT), (total time) 56 hr. 10 min., (time with light on) 30 hr. 45 min.

Incubation: In water bath at surface temperature (approximately 28°C). Light level at approximately 20% of incident surface radiation.

Description: a) Test effect on primary productivity of deep water additions (DWA) of 1000 m sea water to surface water (25 m) b) Test effects of nutrient additions on surface productivity. Nutrients added were NO_3 (14.3 μg at L^{-1}), PO_4 (3.23 μg-at L^{-1}), Fe (0.18 μg-at L^{-1}) and vitamins (100 μg L^{-1} thiamine HCL, 0.5 μg L^{-1} biotin, 0.5 μg L^{-1} B_{12}). C^{14} uptake (as measured by a GM counter) is recorded as counts per liter of seawater (surface plus deep water in the case of additions) per microcurie of added C^{14}. Estimated counting error is about 2% (average).

Bottle	Sample	Counts	Bottle	Sample	Counts
18	Control	1264	6	NO_3	1560
21	Control	1176	15	NO_3	1256
14	Control	1200	2	PO_4	1104
8	1:49 DWA	1816	17	PO_4	992
23	1:49 DWA	1296	13	NO_3 + PO_4	952
10	1:9 DWA	1736	22	NO_3 + PO_4	1616
19	1:9 DWA	1296	11	NO_3 + PO_4 + Fe	1032
9	1:1 DWA	2320	20	NO_3 + PO_4 + Fe	1528
24	1:1 DWA	3440	1	NO_3 + PO_4 + Fe + Vit	1680
4	1:1 DWA + Vit	2784	16	NO_3 + PO_4 + Fe + Vit	1760
7	1:1 DWA + Vit	2104			

Table B-3. Primary Productivity Results from OSS Researcher, Gulf of Mexico (GOTEC-1) (Continued)

Station 20: 29°03.0'N, 87°58.3'W; Mobile site, 17 July 1977, Time (start) 201:20:15Z(1615 EDT), (finish) 204:02:40(2240 EDT), (total time) 54 hr. 25 min., (time with light on) 34 hr. 55 min.

Incubation: In water bath at surface temperature (approximately 28°C). Light level at approximately 20% of incident surface radiation.

Description: a) Test effects of primary productivity of deep water additions (DWA) of 1000 m sea water to surface water (25 m). b) Test effects of nutrient additions of surface productivity. Nutrients added were NO_3 (14.3 µg-at L^{-1}), PO_4 (3.23 µg-at L^{-1}), Fe (0.18 µg-at L^{-1}) and vitamins (100 µg L^{-1} thiamine HCL, 0.5 µg at L^{-1} biotin, 0.5 µg L^{-1} B_{12}). C^{14} uptake is recorded as counts per minute per liter of sea water (surface plus deep water in case of additions) per microcurie of added C^{14}. Estimated counting error is about 2% (average).

Bottle	Sample	Counts	Bottle	Sample	Counts
8	Control	1120	13	1:1 DWA + Vit	2256
23	Control	1648	22	1:1 DWA + Vit	3072
10	Control	1496	11	NO_3	1160
19	Control	1632	20	NO_3	1208
9	1:49 DWA	1344	1	PO_4	1224
24	1:49 DWA	1880	16	PO_4	1816
4	1:9 DWA	1272	3	NO_3 + PO_4	1232
7	1:9 DWA	904	12	NO_3 + PO_4	1496
6	1:4 DWA	1456	18	NO_3 + PO_4 + Fe	1432
15	1:4 DWA	1320	21	NO_3 + PO_4 + Fe	2000
2	1:1 DWA	2496	5	NO_3 + PO_4 + Fe + Vit	1520
17	1:1 DWA	2904	14	NO_3 + PO_4 + Fe + Vit	2248

Table B-4. Nutrient Data from OSS Researcher, Gulf of Mexico, 13-22 July 1977 (GOTEC-1)

Observed Depth (m)	Dissolved Oxygen (ml/L)	Phosphates (µg-at/L)	Nitrates + Nitrates (µg-at/L)
	Observed Nutrients		
Station 25: Position 28°58.3'N, 87°59.8'W (Mobile site), 21 July 1977, Time 202:21:00Z, 1700EDT			
0	5.83	x	0.1
30	5.99	0.05	x
50[a]	6.34	0.02	x
96	5.28	--	--
150[a]	4.12	0.37	9.1
202	4.13	--	--
300[a]	4.64	0.52	9.5
400[a]	3.53	1.56	28.0
500[a]	3.53	1.61	31.3
601	3.80	1.61	29.7
800[a]	3.96	1.74	28.7
1009	4.15	--	--
Station 28: Position 28°57.8'N, 88°01.5'W (Mobile site), 22 July 1977, Time 203:10:45Z, 0645 EDT (on deck)			
0	5.71	--	--
25[a]	5.77	--	--
50[a]	6.37	0.0	0.0
100	6.12	0.6	0.0
150[a]	3.83	0.6	11.0
204	3.63	0.8	16.2
300	3.51	--	--
500	3.71	--	--
615	3.73	--	--
972	4.56	1.61	--

[a]Wire Out.

Table B-5. Trace metal Data from OSS Researcher, Gulf of Mexico, 13-22 July, 1977 (GOTEC-1)

Observed - Metals and Toxics					
Observed Depth (m)	Cd (ng/L)	Cu (µg/L)	Ni (µg/L)	Zn (µg/L)	Pb (µg/L)
Station 24: Position 29°06.4'N, 87°58.8'W (Mobile site), 21 July 1977, Time 202:17:25Z, 1325 EDT (on deck)					
0	3.3 ± 0.0	0.021 ± 0.002	0.30 ± 0.00	0.27 ± 0.07	0.14 ± 0.00
20[a]	6.5 ± 0.0	0.072 ± 0.000	0.30 ± 0.00	0.37 ± 0.00	0.10 ± 0.00
100[a]	5.5 ± 0.0	0.063 ± 0.003	0.19 ± 0.00	0.37 ± 0.00	0.01 ± 0.02
300[a]	52.4 ± 0.0	0.171 ± 0.000	0.51 ± 0.00	3.6 ± 0.00	0.14 ± 0.02
Station 27: Position 29°02.4'N, 87°58.8'W (Mobile site), 22 July 1977, Time 203:06:08Z, 0208 EDT (on deck)					
15[a]	6.8 ± 0.0	0.038 ± 0.001	0.24 ± 0.00	1.20 ± 0.00	0.70 ± 0.00
30[a]	5.1	0.19	0.21	0.40	0.10
100[a]	18.2 ± 3.2	0.019 ± 0.008	0.21 ± 0.00	2.2 ± 0.00	0.14 ± 0.03
300[a]	29.4 ± 5.4	0.034 ± 0.008	0.33 ± 0.00	0.5 ± 0.06	0.07 ± 0.00

[a]Wire out.

U.S. GPO: 19/9-689-169(F-51)