LBL-9438 C.2
UC-64
GOTEC-03

OCEAN THERMAL ENERGY CONVERSION PRELIMINARY DATA REPORT FOR THE FEBRUARY, 1978 GOTEC-03 CRUISE TO THE GULF OF MEXICO, MOBILE SITE

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

June 1980

Prepared for the U.S. Department of Energy
under Contract W-7405-ENG-48

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 6782.

RECEIVED
LAWRENCE
BERKELEY LABORATORY

AUG 15 1980

LIBRARY AND
DOCUMENTS SECTION

LBL-9438 c.2

LEGAL NOTICE

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents [illegible] not [illegible]rin[illegible] [illegible]vately [illegible]ts. Reference [illegible]rein [illegible] specific co[illegible] [illegible]al product, process, or [illegible]e by trade r[illegible] [illegible] manufacturer, [illegible]therwise, do [illegible] necessarily constitute or [illegible] its endorse[illegible] [illegible]endation, or favor[illegible] the United [illegible]s G[illegible]ment or any agency [illegible]f. The vi[illegible] [illegible]nd opinions of authors ex[illegible]d herein [illegible] [illegible]ot necessarily state or reflect [illegible]f the Uni[illegible] States Government or any [illegible] thereof.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price Code: A03

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-9438
GOTEC-03

OCEAN THERMAL ENERGY CONVERSION PRELIMINARY DATA REPORT FOR THE FEBRUARY, 1978 GOTEC-03 CRUISE TO THE GULF OF MEXICO, MOBILE SITE

June 1980

Marine Sciences Group

Contributions by

C. J. W. Carmiggelt
M. L. Commins
C. P. Duncan
D. J. Estrella
J. D. Frisch
A. J. Horne
P. W. Johnson
A. T. Jones
K. Jones
J. C. Oldson
M. S. Quinby-Hunt
C. J. Ryan
J. C. Sandusky
S. R. Shannon
M. E. Tatro
P. Wilde

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

ABSTRACT

Preliminary physical, chemical, and biological data obtained on the GOTEC-03 cruise in February 27-March 3, 1978 to the Mobile Site near 29°N, 88°W are presented in tabular and graphic form. The physical and chemical data consists of salinities and dissolved oxygens derived from water samples and temperatures from XBT's. The biological data includes biomass indicators (chlorophyll a, phaeophytin, and adenosine triphosphate), and zooplankton samples. The XBT and other physical data including current data collected on the GOTEC-03 cruise are reported elsewhere in Molinari, Hazelworth, and Ortman (1979).

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.*

In this manner, researchers can interpret the data as it relates to their own experience. It is not the intent or purpose of these data reports to include detailed interpretations or critical review. 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.

P.W.

PREFACE

The operation of an Ocean Thermal Energy Conversion plant will involve the pumping of immense volumes of deep ocean and surface waters through heat exchangers or evacuation chambers followed by release into the environment. This operation could perturb the structure of the water column possibly affecting primary production and altering the local species composition. A list of the environmental concerns from OTEC operations are given in the Environmental Development Plan (U.S. Department of Energy, 1979). In order to assure adequate knowledge of the oceanic environment in which the OTEC plant is operating, a series of cruises to potential OTEC sites was initiated. These will allow more

---

*Data will be available from: National Oceanographic Data Center, Attention: E. Franklin Johnson, 2001 Wisconsin Avenue NW, Washington, D.C. 20235.

reliable prediction of the possible consequences of operating an OTEC plant on the oceanic environment and also the impact of the ocean on the OTEC plant.

One of the first sites to be investigated was the Mobile Site in the Gulf of Mexico. This report gives the data collected on the third cruise to that site. In addition 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 were explored by Molinari and Festa (1978), and Craig et al. (1978). Thermal data taken since 1977 was analyzed by 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 and dissolved oxygen of the area. Literature reporting concentrations of trace metals in the Gulf is notably scarce although a survey is currently in progress at Lawrence Berkeley Laboratory (LBL).

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

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

M.Q.H.

ACKNOWLEDGEMENT

The authors wish to thank the officers, crew and other scientists who participated in the data collection efforts on the cruise aboard the R/V Virginia Key. Scientists from LBL who participated in this cruise were J. Sandusky, M. Tatro and S. Shannon.

In particular we appreciate the efforts of the following analysts: R. Molinari who took the current meter and XBT data (Molinari, Hazelworth and Ortman, 1979), J. Sandusky who did the nutrient and biomass analyses and J. Steen who analyzed the zooplankton samples.

We also wish to thank our board of consultants, R. Beardsley, Woods Hole Oceanographic Institute, J. McGowan, Scripps Institution of Oceanography, H. Michel, University of Miami, and K. K. Turekian, Yale University, for reviewing this work.

ABSTRACT
FORWARD
PREFACE
ACKNOWLEDGEMENT

CONTENTS

I. INTRODUCTION. 1

Station Log

II. STATION MEASUREMENTS. 1

Physical Oceanographic Measurements. 1
Temperature and Salinity 1
Chemical Oceanographic Measurements. 2
Dissolved Oxygen 2
Nutrients. 2
Trace Metals 2
Biomass Indicators 2
Biological Oceanographic Measurements. 2
Bioassay 2
Zooplankton. 2

III. ANALYTICAL METHODOLOGY

Physical Oceanographic Measurements. 6
Temperature and Salinity 6
Chemical Oceanographic Measurements. 6
Dissolved Oxygen 6
Nutrients. 6
Orthophosphate 6
Nitrate and Nitrite. 6
Silicate 7
Trace Metals 7
Biomass Indicators 9
Chlorophyll a and Phaeophytin. 9
Adenosine Triphosphate 9
Biological Oceanographic Measurements. 9
Zooplankton. 9

IV. RESULTS

Physical Oceanographic Measurements. 10
Temperature and Salinity 10
Chemical Oceanographic Measurements. 10
Dissolved Oxygen 10

Nutrients, Trace Metals and Biomass Indicators 10
Biological Oceanographic Measurements. 10
Zooplankton. 10

V. REFERENCES

Appendix A: Figures Containing Data 15
Appendix B: Tabular Data. 22

I. INTRODUCTION

Ecological measurements important for assessment of the environmental impact of an operating Ocean Thermal Energy Conversion plant began with an initial cruise, GOTEC-01, to the Mobile Site located near 29°N, 88°W (see Figure 1), in July 1977 (Quinby-Hunt et al., 1979). The second cruise, GOTEC-02, occurred in November 1977 (Marine Sciences Group, 1980). The third cruise to the same site, GOTEC-03, on the R/V Virginia Key , took place from 27 February to 3 March 1978. This third cruise was also a joint effort between the Atlantic Oceanic and Meteorological Laboratories (AOML) of the National Oceanic and Atmospheric Administration (NOAA) and the Lawrence Berkeley Laboratory (LBL).

Oceanographic measurements were taken at sixteen stations (six physical/chemical and ten net tow stations) during GOTEC-03. The station log appears as Table 1.* Water was analyzed for nutrients, chlorophyll a (Chl a) phaeophytin (phaeo), and adenosine triphosphate (ATP). Physical data, salinity, temperature and dissolved oxygen, were measured and supplied by NOAA-AOML. Zooplankton samples were taken at ten stations and have been analyzed by John Steen of Gulf Coast Research Laboratory, Ocean Springs, Mississippi.

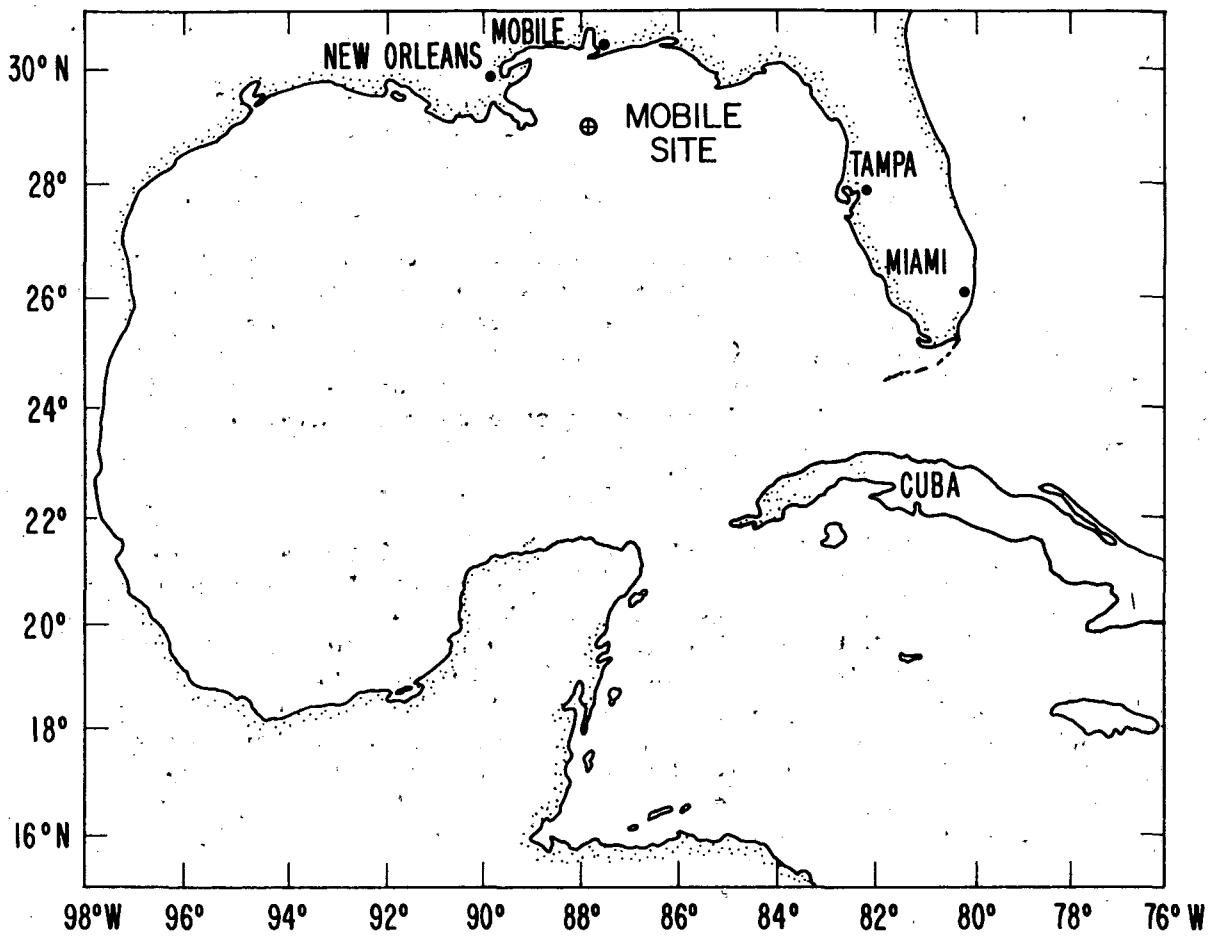
This preliminary report presents the physical, chemical and biological data collected during GOTEC-03. The data set is sparse and of uneven quality due to bad weather during the cruise. The XBT and current meter measurements obtained by NOAA-AOML on GOTEC-03 are presented elsehwere by Molinari, Hazelworth and Ortman (1979). A more detailed analysis of the data will be published upon completion of a serial survey at this site. The physical oceanographic measurements were made by NOAA-AOML and have been presented by Molinari, Hazelworth and Ortman (1979). Appendix A gives the data graphically as profiles as a function of depth. Appendix B lists the station data in tables.

II. STATION MEASUREMENTS

Station measurements were made using a Plessey 9060 self-contained chartrecording STD with a 12-bottle hydrocast with 2.5-liter Niskin™ bottles equipped with reversing thermometers. Sea water from the hydrocasts was processed on deck as summarized in the station log (Table 1). Analytical methods are described in Section III. They will be published in greater detail later this year. The following samples were taken and observations made:

---

*Times for each operation are given in the Station Log. In the results, the times of the messenger drop is used unless that time is unknown, then the operation time is used. NOAA/AOML give each physical/chemical operation a station number. Our station numbers agree with theirs for this series of cruises. They do not number biological operations, therefore biological operations have been given the number of the preceding station and an alphabetical indicator.



XBL 797-2048A

Figure 1. Gulf of Mexico (GOTEC-03): Station location off Mobile.

Table 1. Station Log, RV Virginia Key, Cruise GOTEC-03, Gulf of Mexico, Mobile Site, 27 February 1978 - 3 March 1978

Station	Date	Time Z (CST)[a]	Position	Operations
1	28 February 1978	059:15:20Z (1020) start hydrocast (1115) messenger down (1135) retake bottle 1 (1241) end hydrocast	29°00'N, 88°00'W	Hydrocast to 1000 m Temp at 75,100,150,200,250,300,350,400,500 m Sal at 75,100,150,200,250,300,350,400,500 m Nutr at 50,75,100,150,200,250,300,350,400,500 m
1A	28 February 1978	059:18:23Z (1323) lower net (1351) messenger down (1427) end tow	29°00'N, 88°02'W	Plankton net tow, obl. 1250 to 0 m (LBL-09)
1B	28 February 1978	059:20:07Z (1507) lower net (1608) end tow	29°00'N, 88°03'W	Plankton net tow, obl. 1300 to 900 m (LBL-10)
1C	28 February 1978	059:22:02Z (1702) start tow (1718) end tow	29°01'N, 88°00'W	Plankton net tow, obl. 80 to 0 m (LBL-11)
2	28 February 1978	059:23:20Z (1820) start hydrocast	28°39'N, 87°58'W	Hydrocast to 1000 m Temp at 25,1000 m Metals at 25,75,100,150,250,300,350, 400,500,750 m Bioassay, ^{14}C uptake
3	1 March 1978	060:02:00[b] (2100) start hydrocast (2138) messenger down (2149) on deck	28°58'N, 87°59'W	Hydrocast to 125 m, Water for 24 hour incubation
3A	1 March 1978	060:05:20Z (0020) start incubation 061:01:03Z (2003) on deck	28°59'N, 88°01'W	Bioassay, 24 hr incubation
4	1-2 March 1978	061:03:30Z[b] (2230) start hydrocast (2313) messenger down (2341) retake bottle 3 (0017) on deck	29°00'N, 88°00'W	Hydrocast to 300 m Temp, Sal, DO, Chl a, ATP, Org, Phaeo at 25,50,75,150,200,250,300 m
4A	2 March 1978	061:05:35Z (0035) start tow (0154) end tow	28°59'N, 88°02'W	Plankton net tow, obl. 80 to 0 m (LBL-12)
4B	2 March 1978	061:06:34Z (0134) start tow (0154) end tow	28°59'N, 88°02'W	Plankton net tow, obl. 200 to 0 m (LBL-13)

Table 1. Station Log, RV Virginia Key, Cruise GOTEC-03, Gulf of Mexico, Mobile Site, 27 February 1978 - 3 March 1978 (cont.)

Station	Date	Time Z (CST)[a]	Position	Operations
5	2 March 1978	061:08:15Z (0315) start hydrocast (0409) messenger down (0458) on deck	29°00'N, 88°00'W	Hydrocast to 1000 m Temp, Sal, DO at 0,50,100,200 300,500,750,1000 m Nutr at 0,50,100,200,300,500,1000 m
5A	2 March 1978	061:13:49Z (0849) start tow (0900) end tow	29°00'N, 88°02'W	Plankton net tow, obl. 90 to 0 m (LBL-14)
5B	2 March 1978	061:14:26Z (0926) start tow (0946) end tow	29°00'N, 88°03'W	Plankton net tow, obl. 200 to 0 m (LBL-15)
5C	2 March 1978	061:16:56Z (1156) start tow (1250) end tow	29°00'N, 88°01'W	Plankton net tow, obl. 1000 to 0 m (LBL-16)
5D	2 March 1978	061:18:35Z (1335)	29°00'N,88°00'W	Secchi disk
6	2 March 1978	061:18:43Z (1343) start hydrocast (1408) messenger down (1515) end hydrocast	29°00'N, 88°00'W	Hydrocast to 300 m Chl a, Phaeo, ATP, Org at 0,25,50,75, 100,125,150,300 m

Abbreviations and procedures:

ATP = Adenosine triphosphate - sea water filtered through 0.45 um Millipore filter, filter placed in boiling tris buffer for 20 min., then test tube, filter, and buffer frozen.

Org = Organisms - sea water doped with Lugol's solution, decanted into 500 ml polyethylene bottles for microscope analysis, quantitative analysis indicated by phaeophytin.

Chl a = Chlorophyll a - sea water filtered through glass filter.

Phaeo = Phaeophytins

Metals - sea water decanted into 500 ml bottles and refrigerated.

Nutr = Nutrients - sea water decanted into glass or polyethylene bottles and frozen.

Temp = Temperature.

Sal = Salinity.

DO = Dissolved oxygen.

a = Time is given as Universal Time (Zulu) with colons, and Central Standard Time in parentheses.

b = At these two stations, time given is from LBL and Steen's log. Molinari's time is one hour earlier.

Physical Oceanographic Measurements

Temperature and Salinity. Temperature and salinity were taken at Stations 1, 2 (temperature only), 4 and 5 as part of the NOAA/AOML effort. Results appear in tabular form in Molinari, Hazelworth and Ortman (1979) appear in Appendix B and are plotted in Appendix A, Figures A-1, A-2 and A-3.

Chemical Oceanographic Measurements

Dissolved Oxygen. Samples were taken at Stations 1 and 5. The results appear in tabular form in Appendix B and in Figures A-1 and A-3.

Nutrients. Samples were taken at Stations 1 and 5. Results have not yet been interpreted and will be presented elsewhere.

Trace Metals. Samples were taken on Station 2. Due to poor weather they were not filtered and were finally analyzed for total metals. The results were so erratic that they have been discarded as unreliable.

Biomass Indicators. Samples to be analyzed for chlorophyll a, phaeophytin and adenosine triphosphate were collected at Stations 4 and 6. Results are shown in Appendix A, Figures A-4 and A-5 and in tabular form in Appendix B.

Biological Oceanographic Measurements

Bioassay. Samples of water were taken for ^{14}C uptake experiments on Stations 2 and 3. However, the data obtained were impossible to interpret due to high levels of contamination by bacteria.

Zooplankton. Zooplankton samples were taken at 10 stations (1A, 1B, 1C, 3A, 4A, 4B, 5A, 5B, 5C, 5D). The results are illustrated in Appendix A, Figure A-6. The data are tabulated in Appendix B, Table B-2 through B-5. (See Table 2 for a description of the samples taken.)

Table 2. Zooplankton Tow Log from RV Virginia Key, Gulf of Mexico, Mobile Site, 27 February - 3 March 1978 (GOTEC-03)

Station No.	LBL Sample No.	Date	Ship Time (CST)	Depth (m)	Tow Length (min)	Vol. Water Filtered (m^3)
1A	09[a]	28 Feb	1324	1236-0	22 down 32 up	897
1B	10[a]	28 Feb	1500	1283-903	22	741
1C	11[b]	28 Feb	1700	80-0	15	187
4A	12[a]	1 Mar	0030	82-0	15	257
4B	13[a]	2 Mar	0130	209-0	16	351
5A	14[b]	2 Mar	0845	88-0	15	298
5B	15[a]	2 Mar	0930	204-0	17	322
5C	16[b]	2 Mar	1200	1000-0	21 down 23 up	836

[a]Samples analyzed, data presented in this report.
[b]Samples archived at Gulf Coast Research Laboratory.

III. ANALYTICAL METHODOLOGY

Physical Oceanographic Measurements

Temperature and Salinity. Thermometric temperatures and depths were calculated using the standard techniques discussed by La Fond (1951). These results were used by NOAA/AOML in conjunction with salinities (analyzed using a Guildline Autosal 8400 accurate to ±.003%). XBT traces were transmitted to National Oceanographic Data Center (NODC). STD and XBT data are tabulated and graphed in Molinari, Hazelworth and Ortman (1979).

Chemical Oceanographic Measurements

Dissolved Oxygen. Dissolved oxygen was determined using the classical Winkler method (Winkler, 1888). A divalent manganese solution ($MnCl_2$) followed by an alkali - iodide solution (NaOH - NaI) is added to the sample on board ship. Manganese hydroxides are formed in the bottle. Because of the instability of Mn(II) in an alkaline medium, any dissolved oxygen oxidizes an equivalent amount of Mn (II) to Mn(III), The solution is then acidified to pH of 2.5, the Mn(III) is reduced to Mn(II) and the equivalent amount of iodide in the solution is oxidized to I_2. The I_2 then reacts with the excess iodide in solution to form I_3, which is then determined using a standard thiosulfate titration with a starch indicator. The detection limit was 0.056 ml O_2. The standard deviation for water containing 5.00 ml O_2/L was typically ± 0.030 ml O_2/L. (Morse and Zullig, 1979)

Nutrients. More detailed procedures used for nutrients will be given when the data are presented. Samples for phosphate, nitrate plus nitrite and silicate analyses were collected by filtering sea water (0.2 millipore filter and stored frozen in acid washed polyethylene bottles.

(1) Orthophosphate was measured using the phospho-molybdate method described by Murphy and Riley (1962). This procedure depends on the reduction of a stable phospho-molybdate complex by ascorbic acid in the presence of antimony.

(2) Nitrate plus nitrite was measured using the method of hydrazine reduction followed by diazotization (Hendriksen, 1965 and Mullin and Riley, 1955).

(3) Silicate was measured using the methods of Strickland and Parsons (1972) which procedure involves the formation of a silicomolybdate complex, followed by reduction using oxalic acid and metol.

Trace Metals. Samples were analyzed using atomic absorption after extraction using APDC-DDDC (APDC = 1-pyrolidinidiethuldithiocarbamate and DDDC-diammoniumdiethyldithiocarbamate) and methylisobutyl ketone (Girvin et al., 1978). Despite this procedure the results were of poor quality showing considerable scatter.

Biomass Indicators. Samples for chlorophyll a and phaeophytin were analyzed by D.J. Estrella of LBL. A.T. Jones of LBL performed the ATP analyses.

(1) Chlorophyll a (chl a) and phaeophytin (phaeo) were measured using the fluorometric methods described by Strickland and Parsons (1972). About one liter of seawater (absolute volume varied) was filtered for each chl a and phaeo determination. Chl a was extracted using 90% acetone. Analyses were performed at Lawrence Berkeley Laboratory.

(2) Adenosine triphosphate was extracted using the boiling Tris buffer method previously described by Holm-Hansen (1973). Samples were assayed using the luciferin-luciferase reaction first adapted by Holm-Hansen and Booth (1966) for oceanic waters. The peak light emission from the chemiluminescent reaction was compared with standard values according to procedures outlined by Karl and Holm-Hansen (1978).

Biological Oceanographic Measurements

Zooplankton. The following methods, described by John Steen of the Gulf Coast Research Laboratory, were used to collect and analyze zooplankton samples.

A 0.75 meter 202 μm nylon mesh plankton net, equipped with a digital flow meter, was used to make each zooplankton tow. The net also was equipped with a double trip mechanism which allowed samples to be taken only at a determined depth and not be contaminated by return to the surface.

The length of each tow was timed with a stopwatch, beginning when a messenger opened the net and ending as the net was closed. The depth of each tow was determined trigonometrically using the angle of declination and the length of the wire out during the tow. The mean from eight wire angle measurements taken during each tow was used to calculate net depth. Wire length was determined from a meter block reading. The volume of water filtered during each tow was calculated from digital flow meter counts. When the nets were returned aboard ship, there were immediately washed down and the zooplankton was concentrated into a one-liter container and preserved in a 5% buffered formalin solution.

All eight of the zooplankton samples were taken to the Gulf Coast Research Laboratory but only five which best covered the water column were selected for analyses. From the five samples an aliquot containing approximately 200 to 600 copepods was taken by a Folsom Plankton Sample Splitter. The number of splits needed to obtain a proper aliquot was recorded and used later in calculating numbers of individuals per cubic meter of water sampled. Under a dissecting microscope the zooplankton were separated into taxonomic groups. Copepods were identified, if possible, to genus and species and all other plankters were identified to their smallest recognized taxonomic unit. Copepods also were separated according to sex and stage (adult, copepodid or juvenile). All

individuals were counted, measured and preserved for future reference. The portion of each sample that was not included in the analysis was retained for future analyses.

IV. RESULTS

Physical Oceanographic Measurements

Temperature and Salinity. Figures A-1, A-2 and A-3 are included here to provide background data to the biological results. Extensive listings and plots of data from this cruise are to be found in Molinari, Hazelworth and Ortman (1979).

Chemical Oceanographic Measurements

Dissolved Oxygen. Dissolved oxygen values are consistent, i.e. they fall within the envelope previously reported, with those recorded previously in the northern Gulf of Mexico (Cummings, Atwood, and Parker, 1979), although the near-surface values are somewhat high. The value of 6.96 ml/L at the surface is exceptionally high and is questionable. Dissolved oxygen decreased with depth until about 400 m when concentration is approximately 3 ml/L and then increases with depth to approximately 4.0 ml/L.

Nutrients, Trace Metals & Biomass Indicators. The nutrient data presented a number of anomalies which must be explained before they can be published.

The trace metal results were so erratic due to major contamination and sampling problems, as well as poor weather, that any further sampling for these parameters was postponed until a clean van and contamination-free sampling equipment could be obtained and routine methods of procedure developed.

The biomass indicators, chl a, phaeo and ATP, values were too erratic and the sampling frequency too coarse to accurately identify the biomass maximum, although the data suggest about 90 m. With depth, as is expected, values rapidly drop to near zero.

New analytical procedures were adapted and put into practice for GOTEC-04 to rectify the poor results obtained for GOTEC-02 (Marine Sciences Group, 1980) and as noted above.

Biological Oceanographic Measurements

Zooplankton. Eight zooplankton samples were collected at the times and depths stated in Table 2. Three were archived (unanalyzed) at the Gulf Coast Research Laboratory and five were analyzed by John Steen. The zooplankton were divided into 4 major groups: 1) copepods, 2) non-copepod crustaceans, 3) other invertebrates, and 4) fish larvae and eggs. The number of organisms in each of these groups and the total zooplankton density for each sample is shown in Table B-2. Total

zooplankton number ranged from 1519 organisms per m^3 in the 204m-0m day haul to 13 per m^3 in the 1283m-903m day sample. Numerically copepods dominated the samples and comprised two thirds of the total zooplankton. Most of the remaining zooplankton were noncopepod crustaceans (10%-20%) and other invertebrates (15%-30%). Fish eggs and larvae, when present, made up 0.1% of the sample. Calanoid copepods were generally about twice as numerous as cyclopoid copepods. Harpacticoids comprised only a small percentage of the copepods collected. From 24 to 27 copepod taxa were identified from each sample of which the dominant genera are shown in Table B-3.

Discrete stratified samples to cover the entire water column were not taken; however, an idea of the vertical distribution of the zooplankton can be drawn from a comparison of the samples which cover progressively deeper portions of the water column. The greatest numbers were found in the 204m-0m (day) sample followed closely by the 82m-0m (night) haul. Very few organisms occurred in the 1283m-903m (day) collection. The 1236m-0m (day) and the 209m-0m (night) hauls were intermediate in zooplankton density. As usual, greater numbers of organisms occured near the surface than in deeper water. Insufficient data prevent any more elaborate conclusions from being made.

Size class distribution is given in Tables B-4 - B-5 and Figure A-6. In most samples 70%-90% of the zooplankton fell in the 2nd and 3rd size classes (0.5mm-1.9mm) with the rest of the plankton more or less evenly distributed in the other size classes up to 9 (7.0mm-7.9mm). No organisms larger than 7.9mm were caught. The exception to this distribution is the 1283m-903m day sample where numbers of organisms in size classes 1-6 decreased steadily.

V. REFERENCES

Craig, H.L., T. Lee, H. Michel, S. Hess, R. Munier, and M. Perlmutter (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. 317 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. Atlantic Oceanographic and Meteorological Laboratories, Miami, FL. NOAA Technical Memorandum ERL AOML-36, 1979, 67 pp.

El-Sayed, S.Z., (1972) Chemistry, Primary Productivity and Benthic Algae of the Gulf of Mexico. In: Serial Atlas of the Marine Environment. V.C. Bushnell, editor, Folio 22, American Geographical Society, pp. 8-13.

Girvin, D., A.T. Hodgson, M.E. Tatro and R.N. Anaclerio Jr., (1978) Spatial and Seasonal Variations of Silver, Cadmium, Copper, Nickel, Lead and Zinc in South San Francisco Bay Water During Two Consecutive Drought Years, Univ. Calif. Rept. UCID 8008, 117 pp.

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

Holm-Hansen, O. (1973) Determination of microbial biomass by measurement of adenosine triphosphate. In: Estuarine Microbial Ecology. L.H. Stevenson and R.R. Colwell, editors, University of South Carolina Press. Columbia, South Carolina, pp.23-89.

Holm-Hansen, O. and C.R. Booth (1966) The measurement of Adenosine Triphosphate in the Ocean and its ecological significance. Limnology and Oceanography, 11, 510-519.

Karl, D.M. and O. Holm-Hansen (1978) Methodology and Measurement of Adenosine Adenylate Energy Charge Ratios in Environmental Samples. Marine Biology, 48, 185-197.

La Fond, E. C. (1951) Processing Oceanographic Data. U.S. Naval Hydrographic Office Pub. No. 614,

Marine Science Group (1980) Ocean Thermal Energy Conversion, Preliminary Data Report for the Nov. 1977 GOTEC-02 Cruise to the Gulf of Mexico, Mobile site. March 1980, Lawrence Berkeley Laboratory, LBL 9437, 20 pp.

Molinari, R.L., S. Baig, D.W. Behringer, G.A. Maul, R. Legeckis (1977) Winter intrusions 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 Memorandum ERL AOML-33, 106 pp.

Molinari, R.L., J.B. Hazelworth and D.A. Ortman (1979) Data from OTEC site characterization studies in the Gulf of Mexico and Tropical South Atlantic. Atlantic Oceanographic and Meteorological Laboratories, Miami, FL, National Oceanic and Atmospheric Administration, NOAA Technical Memorandum ERL AOML-39. 16 pp. and 13 Appendices.

Morse, J.W. and J.J. Zullig (1979) OTEC Gulf of Mexico, Oxygen and Nutrient Measurements, June 1978 - June 1979, Final Report Subcontract 4984002, Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, Miami, FL, 138 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.

Ocean Data Systems, Inc. (1977) OTEC Thermal Resource Report for Central Gulf of Mexico. Prepared under contract No. EC-77-C-01-4028 for the Department of Energy. p.5.

Quinby-Hunt, M.S. et al., (1979) Ocean Thermal Energy Conversion, Ecological Data Report from O.S.S. Researcher in Gulf of Mexico, July 12-23, 1977. Lawrence Berkeley Laboratory Report LBL-8945. 54 pp.

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., 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 Memorandum. 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 Memorandum. ERL-AOML-29, 238 pp.

United States Department of Energy (1979) Environmental Development Plan Ocean Thermal Energy Conversion. U.S. DOE/EDP-0034, 48 pp.

Winkler, L.W. (1888) The determination of dissolved oxygen in water. Ber. dtsch. chem. Ges. 21, 2843-2855.

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-3 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-4 and A-5 show the biomass indicators chlorophyll a, phaeophytin, and ATP (adenosine triphosphate).

Figure A-6 gives the Zooplankton Size Class Distribution.

No standard deviations were obtained for the biomass indicator 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 duplicate sampling to determine variance in the values for adenosine triphosphate.

Figure A-1

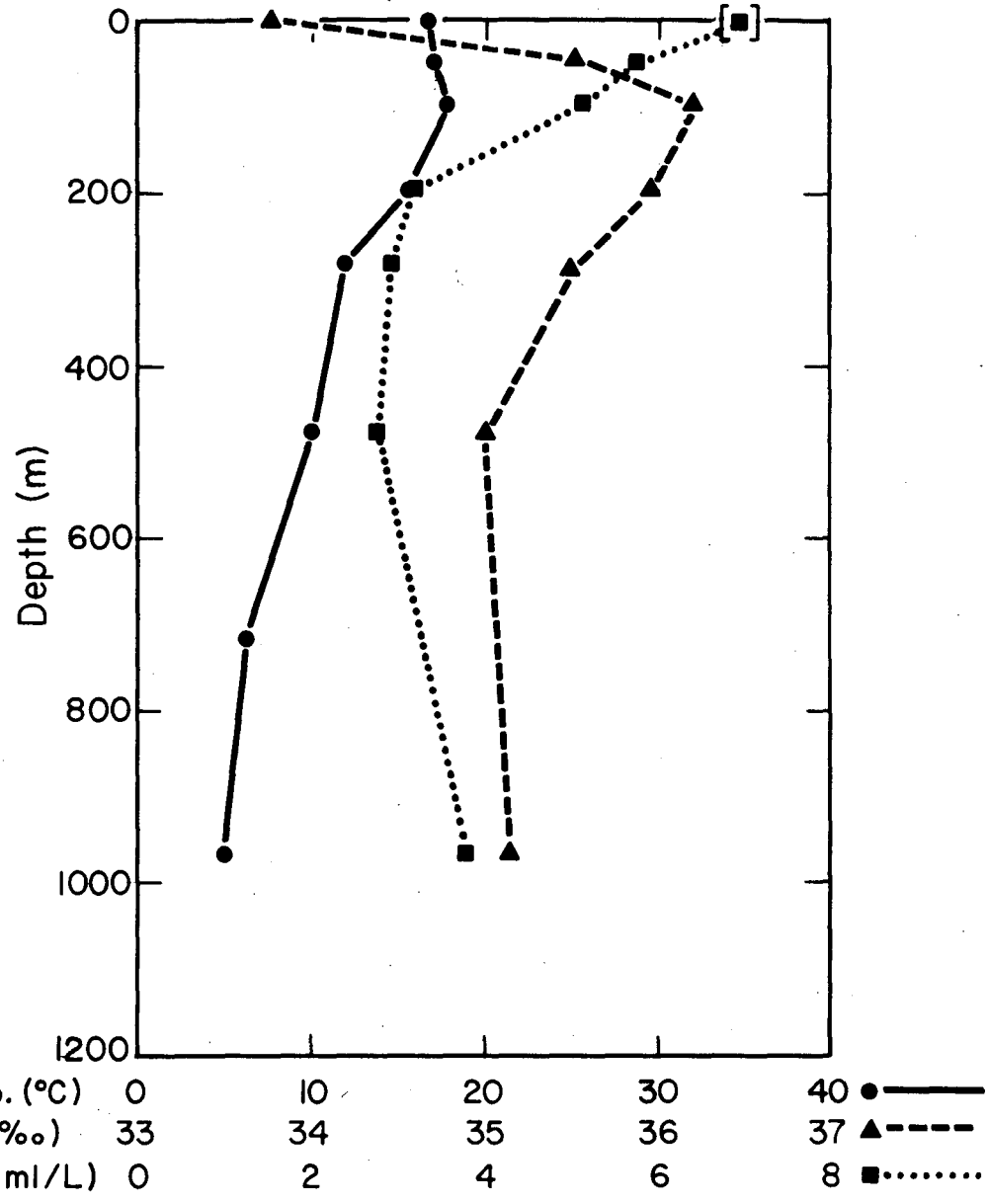
PHYSICAL OCEANOGRAPHIC PARAMETERS

Temperature, Salinity, Dissolved Oxygen

GOTEC-03

Station 5: Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W

2 March 1978, 0409h CST (061:10:09Z)



[■] *Point in brackets indicate questionable results*

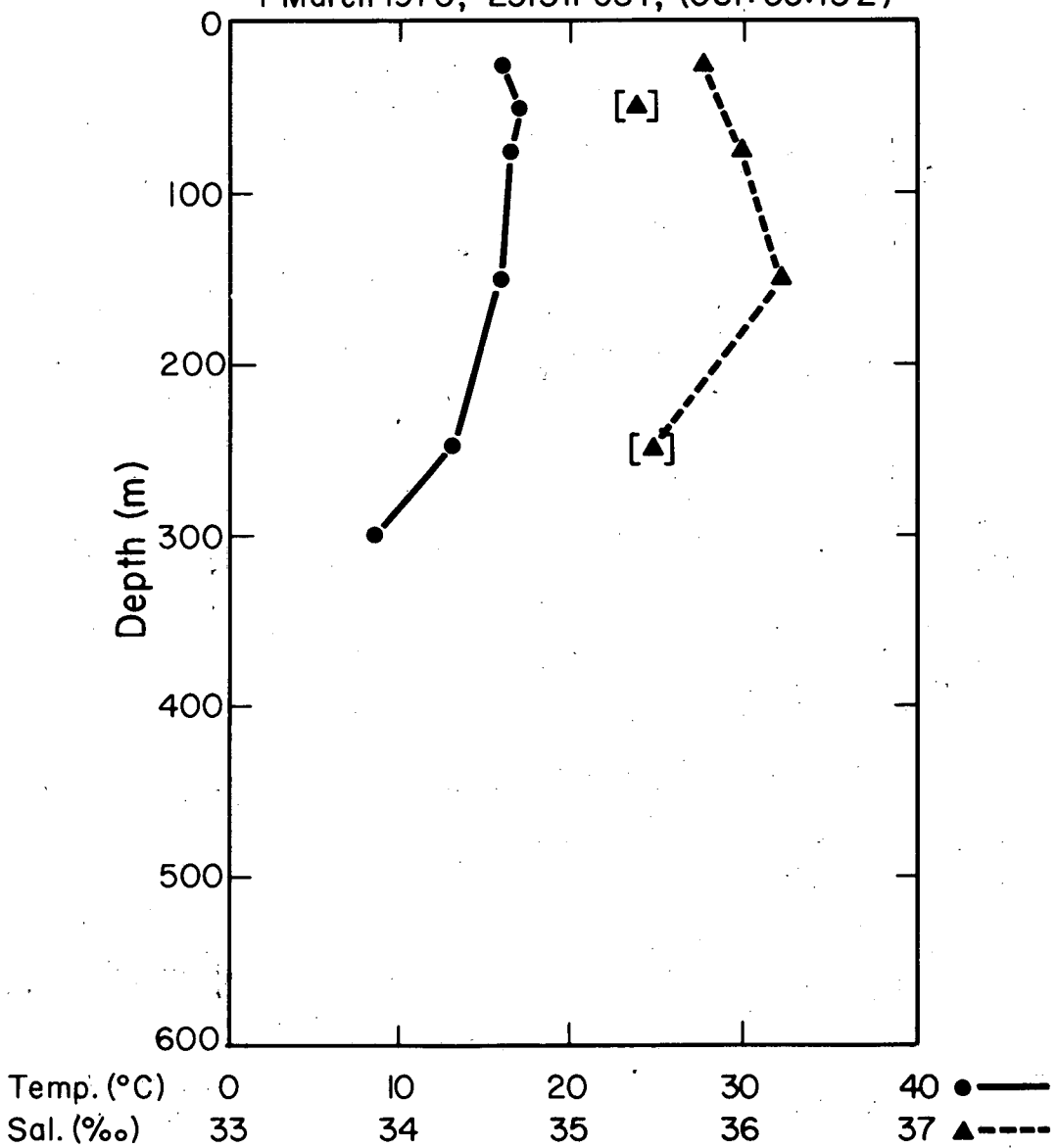
XBL 7912-5321

Figure A-2

PHYSICAL OCEANOGRAPHIC PARAMETERS

Temperature, Salinity

GOTEC-03
Station 4: Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W
1 March 1978, 2313h CST, (061:05:13Z)



[▲] *Points in brackets indicate questionable results*

XBL 7912-5323

Figure A-3

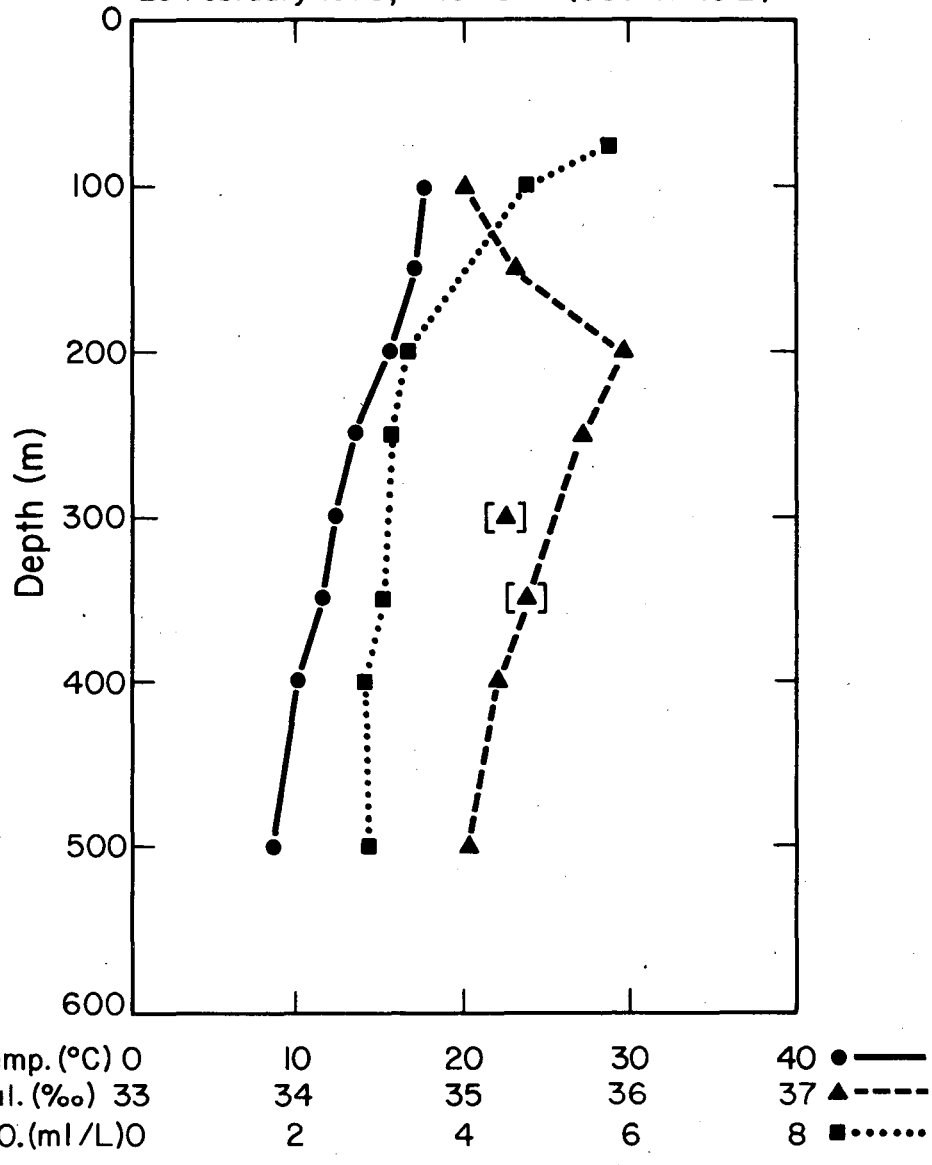
PHYSICAL OCEANOGRAPHIC PARAMETERS

Temperature, Salinity, Dissolved Oxygen

GOTEC-03

Station 1: Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W

28 February 1978, 1115h CST (059:17:15 Z)



[▲] *Points in brackets indicate questionable results*

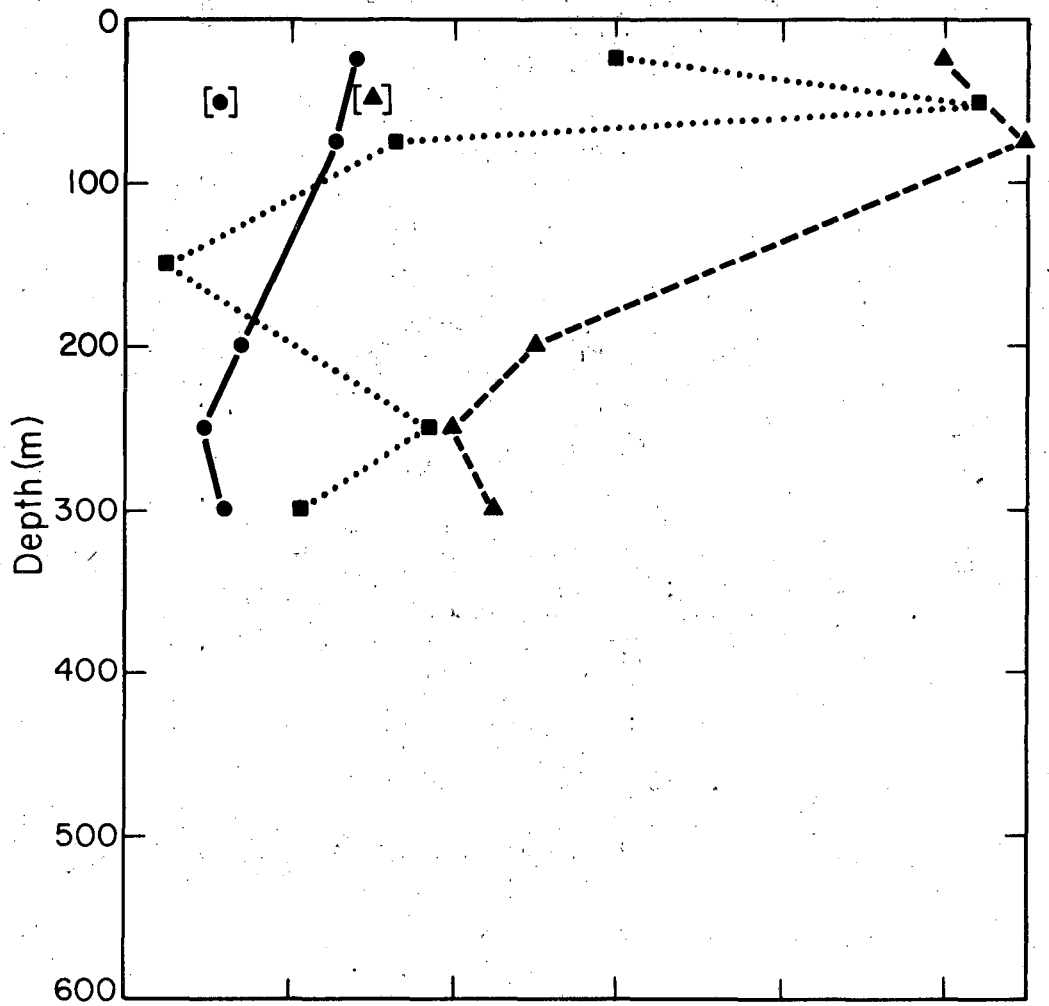
XBL 7912-5322

Figure A-4

BIOMASS INDICATORS

Chlorophyll a, Phaeophytin, Adenosine Triphosphate

GOTEC-03
Station 4: Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W
2 March 1978, 2313h CST (061:05:13 Z)



Chl a (μg/L)	0.1	0.2	0.3	0.4	0.5	●——
Phaeo (μg/L)	0.04	0.08	0.12	0.16	0.20	▲- - - -
ATP (μg/L)	0.02	0.04	0.06	0.08	0.10	■·····

[●] *Points in brackets indicate questionable results*

XBL 7912-5318

Figure A-5

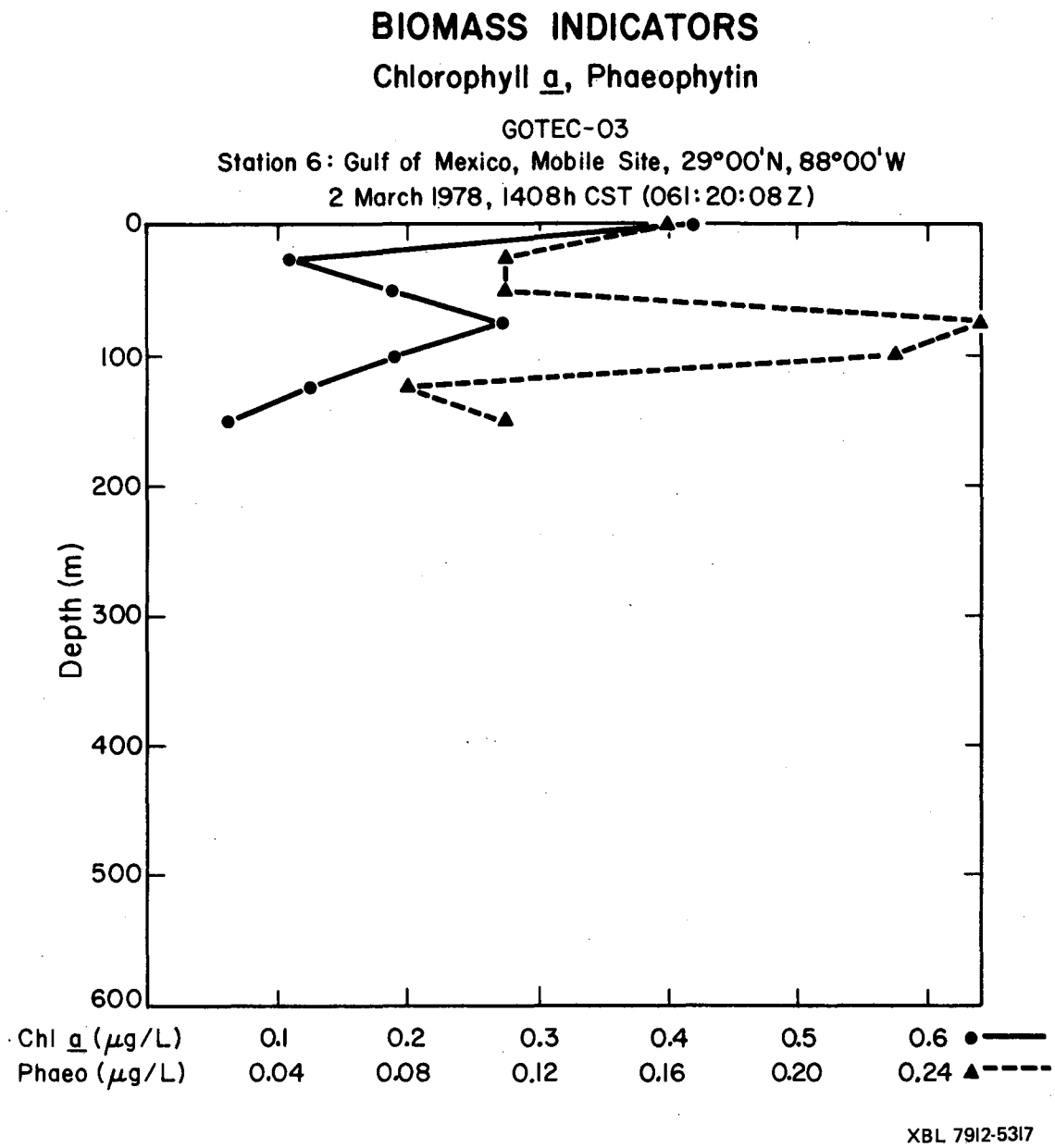
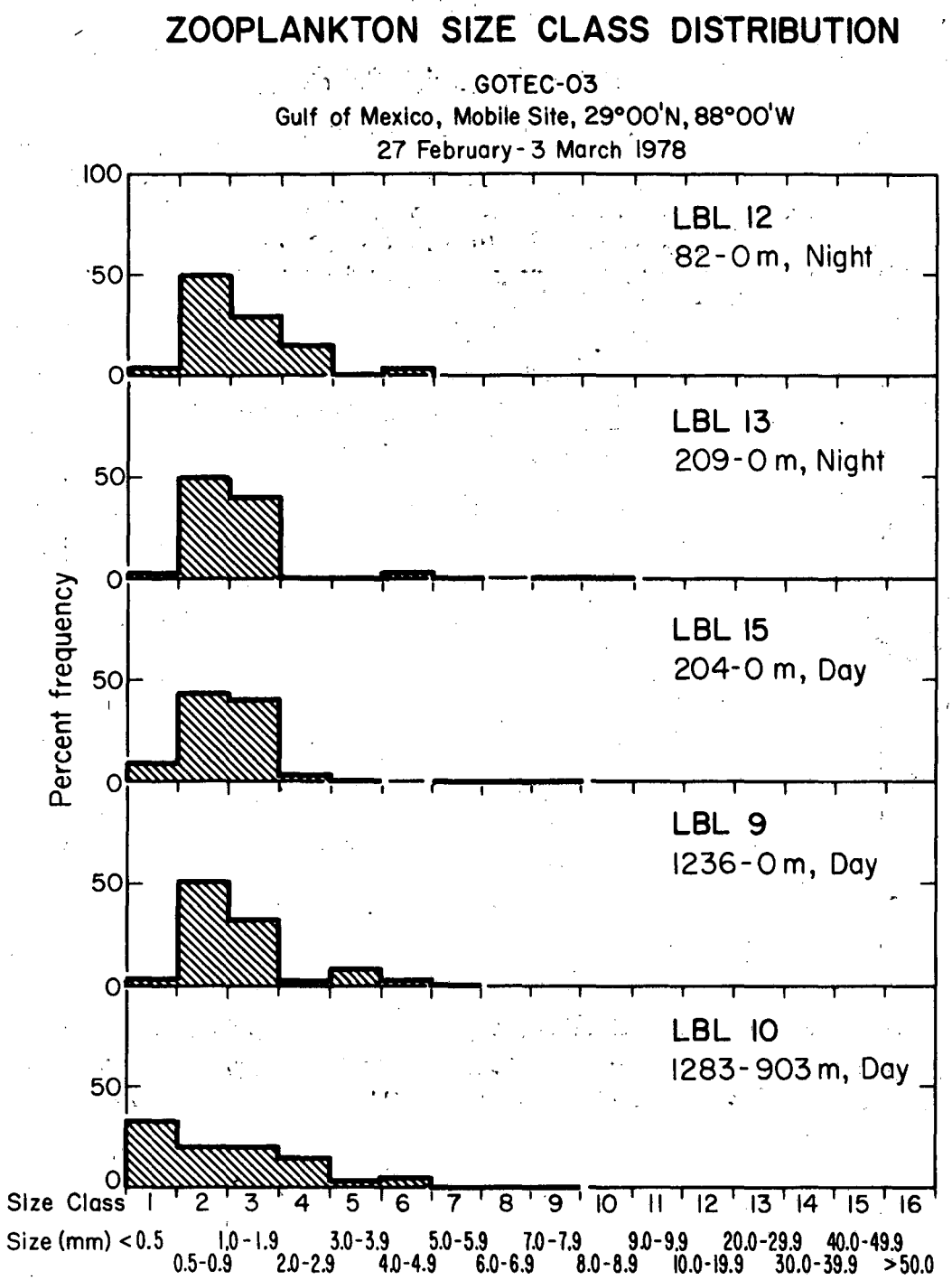

BIOMASS INDICATORS
Chlorophyll a, Phaeophytin
GOTEC-03
Station 6: Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W
2 March 1978, 1408h CST (061:20:08 Z)
Depth (m)
0
100
200
300
400
500
600
Chl a (μg/L) 0.1 0.2 0.3 0.4 0.5 0.6
Phaeo (μg/L) 0.04 0.08 0.12 0.16 0.20 0.24
XBL 7912-5317

Figure A-6


ZOOPLANKTON SIZE CLASS DISTRIBUTION
GOTEC-03
Gulf of Mexico, Mobile Site, 29°00'N, 88°00'W
27 February - 3 March 1978
LBL 12
82-0 m, Night
LBL 13
209-0 m, Night
LBL 15
204-0 m, Day
LBL 9
1236-0 m, Day
LBL 10
1283-903 m, Day
Percent frequency
100
50
0
Size Class 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Size (mm) <0.5 0.5-0.9 1.0-1.9 2.0-2.9 3.0-3.9 4.0-4.9 5.0-5.9 6.0-6.9 7.0-7.9 8.0-8.9 9.0-9.9 10.0-19.9 20.0-29.9 30.0-39.9 40.0-49.9 >50.0
XBL 7912-5316

Appendix B

Tabular Data

Table B-1	Physical Oceanographic Data
Table B-2	Zooplankton Abundances
Table B-3	Zooplankton Taxonomic Composition
Table B-4	Zooplankton Size Class Distribution
Table B-5	Zooplankton Size Classes

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

		Precision Expected of Instrument
Temperature:	Bottle thermometers	±0.01
	STD's	±0.02
Salinity:	Salinometer	±0.003
	STD (Plessey 9060)	±0.1

As has been mentioned in the introduction to Appendix A, volume constraints prevented statistical analysis for the biological data.

Table B-1. Oceanographic parameters from RV Virginia Key, Gulf of Mexico, Mobile site, 27 February - 3 March 1978 (GOTEC-03)

	PHYSICAL			BIOLOGICAL		
Observed Depth (m)	Temp (°C)	Salinity (‰)	Diss. Oxygen (ml/l)	Chl a (ug/l)	Phaeo (ug/l)	ATP (ug/l)
Station 1. Position: 29°00'N, 88°00'W (Mobile Site), Time: 28 February 1978, 059:15:20Z (1020 h CST) messenger down						
50[a]	-[b]	-	-	-	-	-
75[a]	x	x	5.77	-	-	-
100	17.51	35.004	4.78	-	-	-
150	16.914	35.288	x	-	-	-
200[a]	15.6[d]	35.952	3.32	-	-	-
250	13.48	35.722	3.13	-	-	-
300	[12.35]	[35.247]	x	-	-	-
350[a]	11.6[d]	[35.362]	3.03	-	-	-
400	10.24	35.218	2.80	-	-	-
500	8.48	35.026	2.87	-	-	-
Station 4. Position: 29°00'N, 88°00'W (Mobile Site), Time: 1-2 March 1978 061:04:13Z (2313 h CST) messenger down						
25[a]	16.3[d]	35.775	-	0.14	0.20	0.06
50[a]	17.1[d]	[35.383]	-	0.06	0.06	0.10
75[a]	16.9[d]	35.970	-	0.13	0.22	0.03
150[a]	16.3[d]	36.225	-	x	x	0.005
200[a]	x	x	-	0.07	0.10	x
250	13.33	[35.471]	-	0.05	0.08	0.04
300	8.88	x	-	0.06	0.09	0.02
Station 5. Position: 29°00'N,88°00'W (Mobile Site), Time: 2 March 1978, 061:09:09Z (0409 CST) messenger down						
0	16.8[d]	33.735	[6.96]	-	-	-
47	17.0[d]	35.511	5.76	-	-	-
95	17.7[d]	36.191	5.13	-	-	-
190	15.6[d]	35.971	3.13	-	-	-
286	11.98	35.489	2.98	-	-	-
477	10.08	35.028	2.76	-	-	-
715	6.25	-	-	-	-	-
965	5.25	35.153	3.87	-	-	-
Station 6. Position: 29°00'N, 88°00'W (Mobile Site), Time: 2 March 1978, 061:19:08Z (1408 CST) messenger down						
0	-	-	-	0.42	0.16	0.56
25[a]	-	-	-	0.11	0.11	0.06
50[a]	-	-	-	0.19	0.11	-
75	17.72	-	-	0.27	0.29	-
100[a]	-	-	-	0.19	0.23	-
125	17.75	-	-	0.13	0.08	-
150[a]	-	-	-	0.06	0.11	0.06

[a] Wire out
[b] Not taken
[c] Bottle broke
[d] XBT temperature
[e] Data in brackets is questionable
[f] Nitrates plus nitrites given

Table B-2. Zooplankton Abundance Data from RV Virginia Key, Gulf of Mexico, Mobile Site, 27 February - 3 March 1978 (GOTEC-03)

LBL sample no. and tow description	Copepods		Non-copepod Crustaceans		Other invertebrates		Fish larvae and eggs		Total zooplankton
	Density[a]	Percent	Density	Percent	Density	Percent	Density	Percent	Density
09. 1236-0 m obl. day	296.3	58.9	82.8	16.5	123.6	24.6	-	-	502.7
10. 1283-903 m obl day	8.7	65.4	1.6	12.0	3.0	22.6	-	-	13.3
12. 82-0 m obl. night	927.0	64.2	251.7	17.4	263.7	18.3	2.0	0.1	1444.4
13. 209-0 m obl. night	519.7	61.2	91.2	10.8	237.7	28.0	-	-	848.6
15. 204-0 m obl. day	1031.4	67.9	217.5	14.3	268.7	17.7	1.6	0.1	1519.2

[a]Density measured as number of organisms per cubic meter

Table B-3. Zooplankton Taxonomic Composition from RV Virginia Key, Gulf of Mexico, Mobile Site, 27 February - 3 March 1978 (GOTEC-03)

LBL Sample No.	Tow type	Depth[a] (m)	Dominant genera (% total copepods)		% composition by order		No. of taxa
09	Obl. day	1236-0	Paracalanus	10.0	Calanoida	75.7	27
			Eucalanus	8.9	Cyclopoida	24.1	
			Oithona	6.7	Harpacticoida	0.2	
			Oncaea	4.8			
			Clausocalanus	4.1			
10	Obl. day	1283-90	Oncaea	12.6	Calanoida	79.0	30
			Pleuromamma	9.6	Cyclopoida	20.4	
			Calocalanus	7.2	Harpacticoida	0.6	
			Eucalanus	7.2			
			Conaea	4.2			
			Lucicutia	4.2			
12	Obl. night	82-0	Eucalanus	12.0	Calanoida	81.0	32
			Oithona	10.7	Cyclopoida	18.9	
			Clausocalanus	9.5	Harpacticoida	0.1	
			Oncaea	6.4			
			Paracalanus	5.5			
13	Obl. night	209-0	Oithona	11.5	Calanoida	77.2	32
			Oncaea	9.0	Cyclopoida	22.5	
			Eucalanus	5.2	Harpacticoida	0.3	
			Paracalanus	5.1			
			Clausocalanus	3.9			
15	Obl. day	204-0	Eucalanus	21.2	Calanoida	66.0	30
			Oncaea	15.4	Cyclopoida	33.5	
			Oithona	14.7	Harpacticoida	0.5	
			Paracalanus	11.6			
			Clausocalanus	7.6			

[a]Depths given are starting and ending depths
[b]Represents number of species identified plus genera not identified to species level

Table B-4. Zooplankton Size Class Distribution Data from RV Virginia Key, Gulf of Mexico, Mobile Site, 27 February - 3 March 1978 (GOTEC-03)

	LBL tow number and description									
	09 1236-0 m day		10 1283-903 m day		12 82-0 m night		13 209-0 m night		15 204-0 m day	
Size Class[a]	Density[b]	%	Density	%	Density	%	Density	%	Density	%
1	14.4	3.0	4.0	32.4	32.0	2.2	20.4	2.4	132.8	8.7
2	246.0	51.0	2.7	21.9	710.0	49.2	427.6	50.4	654.4	43.1
3	154.8	32.1	2.6	21.1	430	29.8	349.2	41.2	622.4	41.0
4	10.8	2.2	1.8	14.6	220.0	15.2	10.4	1.2	65.6	4.3
5	40.8	8.5	0.44	3.6	12.0	0.8	4.4	0.5	11.2	0.7
6	14.4	3.0	0.60	4.9	40.	2.8	20.4	2.4	-	-
7	1.2	0.3	0.04	0.3	-	-	2.8	0.3	14.4	1.0
8	-	-	0.08	0.7	-	-	-	-	17.6	1.2
9	-	-	0.08	0.7	-	-	11.6	1.4	1.6	0.1
10	-	-	-	-	-	-	1.6	0.2	-	-

No organisms in classes 11-16

[a]See Table b-5 for size class descriptions

[b]Density measured as number of organisms per size class per cubic meter

Table B-5. Zooplankton Size Classes

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

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720