ANNUAL ENVIRONMENTAL OPERATING REPORT

VOLUME 1 - NONRADIOLOGICAL

1/1/81 - 12/31/81

CRYSTAL RIVER - UNIT 3

FLORIDA POWER CORPORATION

FACILITY OPERATING LICENSE NO. DPR-72

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MARCH, 1982

APPROVED BY: MANAGER
NUCLEAR SUPPORT SERVICES

D E Mardis for P Y Baynard

DATE: March 31, 1982

I. **INTRODUCTION**

The Non-Radiological Environmental Surveillance Program at Crystal River Unit 3 is designed to determine any significant effects due to power operation, particularly unpredicted and catostropic changes. Studies to determine the Estuarine Ecosystem Metabolism and Community Struct.re effects were conducted prior to and have been continued throughout Crystal River Unit 3 operation. These studies indicate that the operation of Crystal River Unit 3 does not impact the Estuarine Ecosystem significantly beyond the impact of Crystal River Units 1 and 2 operation.

In 1981, most of the limiting conditions for operation were removed from the Crystal River Unit 3 Environmental Technical Specifications because they were adequately addressed by the NPDES permit. The two remaining Limiting Conditions for Operation relate to the use of chemical biocides and corrosion inhibitors. Each is addressed below.

- Environmental Technical Specifications 2.3.1 limits the amount and concentration of total residual chlorine in the discharge as the result of chlorination of the condenser water boxes. This chlorination is designed to inhibit the growth of marine organisms in the condensers. Due to the employment of mechanical means of cleaning the condensers, chlorination was not required during this reporting period.

- Environmental Technical Specification 2.3.2 prohibits the use of chromates as corrosion inhibitors in the circulating water system. No chromates were used as corrosion inhibitors in the circulating water system during the period of this report.

II. COMMUNITY STRUCTURE STUDY

The community structure study at the Crystal River site as required by Specifications 3.1.1 and 3.1.4 was conducted by Applied Biology, Inc. The data for the quarterly samples is in Appendix I as well as the analyses and conclusions.

The bimonthly disolved oxygen sample was not collected for the week of August 28, 1981 due to severe weather.

III. ANNUAL RECORD OF METABOLISM OF ESTUARINE ECOSYSTEMS

The annual record of metabolism of estuarine ecosystems at the Crystal River site as required by Specifications 3.1.1, 3.1.2, and 3.1.4 was conducted by the Department of Environmental Engineering Sciences, University of Florida. The data for the quarterly samples is in Appendix II, as well as the analyses and conclusions.

- The first and second quarter 1981 Spartina and Juncus dead weights were not within two standard deviations of the preoperational study results.
- The winter quarter 1981 Spartina and Juncus live weights exceeded the preoperational study results by greater than two standard deviations.

APPENDIX I

COMMUNITY STRUCTURE STUDY

AB-386

CRYST. RIVER BENTHIC

COMMUNITY STRUCTURE STUDY

Prepared for
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CRYSTAL RIVER BENTHIC
COMMUNITY STRUCTURE STUDY

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EXECUTIVE SUMMARY

INTRODUCTION

Three electric generating units at Florida Power Corporation's Crystal River Power Plant discharge heated effluents into a shallow basin adjacent to the plant site. The operation of these units elevates temperatures and salinities and reduces dissolved oxygen relative to levels observed in a basin unaffected by plant effluents (the control basin). Quarterly sampling, which began in 1977, was continued during 1981 to determine if the operation of Unit 3, a nuclear generator, has adversely affected benthic and salt marsh communities within the discharge basin.

Data collected during 1977 and 1981, the only years in which Unit 3 has operated throughout the entire summer, suggested that water temperatures may be raised 2° to 3°C above levels observed when only Units 1 and 2 are on-line. During these years, temperatures throughout the basin were elevated above levels reported to be lethal for many resident benthic organisms. However, in 1981, responses of benthic communities were generally not measureably different from those observed during years when only Units 1 and 2 were on-line.

MACROINVERTEBRATES

Throughout all operational years, densities, biomass and numbers of taxa of benthic macroinvertebrates were consistently greater in the control basin than in the discharge basin. Communities in both areas experienced dramatic seasonal fluctuations in community structure in

response to changing environmental conditions. However, communities in the control basin appeared more stable over time as evidenced by relatively high and constant diversity and evenness values. Quarterly mean diversities in the discharge basin have consistently been lower than those in the control basin throughout operational years. Differences in physical characteristics between basins prior to the time Unit 3 went on-line is probably responsible for many of these observed differences. Marked reductions in discharge diversities during summer sampling periods indicated that thermal effluents from the power plant were having a considerable negative impact on resident benthos. However, data collected during years of intermittent and full operation suggest that the operation of Unit 3 has had little additional impact above that exerted by Units 1 and 2. During the cooler months of 1981, discharge stations farthest from the point of discharge had community characteristics similar to comparable habitats in the control basin.

MACROPHYTES

Macrophytes in the control basin were more diverse and abundant than those in the discharge basin during 1981. A mosaic of substrate types in the control basin may account for much of the observed variation. Algae has essentially disappeared from the discharge basin during operational years. A relatively monospecific stand of the seagrass Halodule now exists. Its distribution was limited to areas away from the discharge canal and considerable reductions in biomass occurred throughout the basin during the summer. Stations farthest from the point of discharge supported a macrophyte assemblage whose biomass equaled that of a com-

munity occupying a similar habitat in the control basin. Macrophyte biomass in the discharge basin during 1981 was less than in the three previous years but similar to that observed during the preoperational study. Macrophyte assemblages outside of the inner discharge basin were more diverse, and their distributions appear unrelated to thermal conditions associated with power plant operations.

OYSTER REEFS

Oyster reefs in the study area were also affected by power plant operation. Few or no adult oysters and spat occurred at the stations closest to the point of discharge during the summer. However, the impact to both oysters and associated fauna diminished rapidly with distance from shore. Oyster reef communities at the outermost stations of the discharge basin were similar to those sampled in the control basin. The combined operation of all three generating units appears to have a greater impact on adult oysters than the sole operation of Units 1 and 2. However, oyster spat and associated fauna did not appear to have been measurably affected by the additional thermal load created by Unit 3.

SALT MARSH

In the salt marsh habitats adjacent to the plant, both Juncus and Spartina usually exhibited higher densities in areas not subjected to thermal effluents. Both species also attained greater heights in areas unaffected by power plant discharges. For Spartina, these observed differences appeared to be related to the additional thermal load imposed by Unit 3. However, other as yet undetermined factor(s) appear respon-

sible for observed patterns in Juncus. Biomass of salt marsh vegetation was similarly higher for both species in the control basin. Biomass data were inconclusive regarding the effect of Unit 3 operation. Densities of conspicuous salt marsh invertebrates were greater in the discharge marsh. If this difference was related to power plant operation, it would indicate that thermal effluents are stimulative rather than inhibitive.

A. INTRODUCTION

RATIONALE AND OBJECTIVES

Marine organisms living in or on submerged substrates respond to a variety of physicochemical factors, such as temperature, salinity, light, oxygen tension and substrate type. Plants and animals that have similar requirements tend to form integrated assemblages characteristic of prevailing environmental conditions. Benthic organisms are relatively immotile, however, and once established in an area can neither avoid nor escape subsequent environmental changes. They must either acclimate, regulate or be destroyed. Thus, fluctuations in community structure often indicate changing water quality. Consequently, benthic communities have been very useful in assessing the local impact of environmental perturbations, especially in coastal areas where they play an extremely important role in ecosystem dynamics (Holland et al., 1973; Reish et al., 1980).

In March 1981, Florida Power Corporation (FPC) contracted Applied Biology, Inc. (ABI), to conduct environmental monitoring at the FPC Crystal River Power Plant in Crystal River, Florida. The purpose of the monitoring was to assess the potential impact of thermal effluents on resident benthic communities and emergent shoreline vegetation of the surrounding marine area. Quarterly sampling began in April 1981 and continued in June, September and December. This report presents the findings of that study.

The FPC Crystal River Power Plant consists of three units with a combined generating capacity of 1815 MW. The current nonradiological monitoring program is mandated by technical specifications of the Nuclear Regulatory Commission (NRC) pursuant to the licensing and operation of Crystal River Unit No. 3, an 855-MW nuclear generator. However, all three units at the Crystal River Power Plant use a once-through seawater cooling system, receiving and discharging their cooling water from and into the Gulf of Mexico through common intake and discharge canals. Observed responses of benthic communities to heated effluents, therefore, reflect the cumulative operational impact of all three units. To separate the influence of Units 1 and 2 (both coal-fired units) from that of Unit 3, data collected since March 1977, when Unit 3 went on-line, were compared with data collected from 1972 through 1974, when only Units 1 and 2 were operating. However, comparisons were difficult to make because of changes in sampling methodologies since the preoperational study. Furthermore, the operation of Unit 3 has been intermittent, and only in 1977 and 1981 did it remain on-line throughout the entire summer, when potential impact is greatest. Data presented in this report reflect, for the first time, a year of continuous operation for Unit 3 and the full impact of all three units.

Methodologies used during 1981 conform to those used since 1977 with station locations, collection gear, replication and processing techniques remaining essentially unchanged. Macrophytes, epifaunal and infaunal macroinvertebrates, and oyster reefs were each examined to document spatial and temporal patterns of abundance and composition in their respec-

tive communities. The salt marsh habitat, a vital element of nearshore energetics, was also studied to provide seasonal data on densities, heights and biomass of dominant marsh vegetation species. Data collected during 1981 were compared with that reported for 1977 through 1980 and, where appropriate, with preoperational data gathered from 1972 through 1974.

The general approach taken during 1981, as in other operational years, was to compare selected community parameters between discharge stations subjected to thermal effluents and control stations spatially separated from them. Differences between areas supposedly would be attributable to any additional impact of Unit 3. However, these comparisons are to a large degree inappropriate, because the discharge and control basins had already developed noticeably different biological and physical characteristics prior to 1977 when Unit 3 went on-line (FPC, 1978). These differences resulted from a long history of physical separation by the canal jetty system, cutting and redirecting of tidal creeks adjacent to the plant site, and thermal effluents from the two fossil-fuel units.

In addition to interbasin comparisons, interstation comparisons within the discharge basin were also made during 1981 to more accurately assess the potential impact of heated effluents. Differences among stations were most likely related to differences in the intensity and degree of exposure to the discharge plume.

DESCRIPTION OF STUDY AREA

The FPC Crystal River Power Plant is located on the west coast of Florida (latitute 23°57'N, longitude 82°45'W) approximately 112 km north of Tampa, Florida (Figure A-1). This region is characterized by expansive stretches of salt marsh vegetation along the shoreline and long discontinuous oyster reefs in the shallow nearshore waters of the Gulf of Mexico. Hydrological conditions in the study area are estuarine, resulting from the mixing of saline Gulf waters with freshwater runoff from the Withlacoochee and Crystal Rivers and numerous tidal creeks.

Several man-made features disrupt the continuity of open water in the study area. The Cross Florida Barge Canal (CFBC) enters the Gulf approximately 5.4 km northwest of the plant site, and a dredged channel extends about 15.8 km seaward (Figure A-2). Along the southern edge of this channel are a series of relatively large spoil islands created during its construction. South of the CFBC and adjacent to the plant site, a system of jetties border the canals that direct cooling water into and away from the three units (Figure A-2). The intake canal, which also provides deep water access for coal barges supplying fuel to Units 1 and 2, extends 13.7 km into the Gulf. Spoil jetties extend 11.3 and 3.7 km from shore along the intake's northern and southern edges, respectively. Several breaks in the northern jetty allow the passage of boats. North of the intake canal, the discharge canal extends 2.4 km from the plant site to the point of discharge in the Gulf of Mexico. There, a dredged channel extends an additional 2.1 km seaward accompanied by a spoil jetty along its southern edge.

The area located between the spoil islands of the CFBC and the jetty system of the intake canal is referred to as the discharge area. Its physical characteristics differ noticeably from the control area located south of the intake canal.

The discharge area substrates consist primarily of a relatively homogeneous and often deep layer of fine sediments that have settled into the numerous basins created by the interlacing system of oyster bars. The primary source of sediments entering the discharge area has not been determined, but the restriction of circulation imposed by the spoil islands of the CFBC, the canal jetty system and abundant oyster reefs all contribute to relatively high sedimentation rates. By contrast, sediments of the control area are more heterogeneous consisting of mixtures of sand, shell and mud of various depths overlying a consolidated limestone layer. Often a hard substrate occurs when the limestone layer is not covered by the unconsolidated sediments.

Long-term United States Coast Survey hydrological data are available for the Cedar Keys region, which is slightly north of Crystal River (McNulty et al., 1972). Surface water temperatures range from about 5.0° to 33.4°C with monthly means being lowest in January (14.8°C) and highest in August (29.5°C). In addition to seasonal variations, temperatures within the study area are influenced by thermal effluents from the power plant. Differences between discharge and ambient water temperatures vary in relation to the number of units on-line and the capacity at which each is operating.

Within the discharge basin, plume waters do not affect all stations equally. Different isotherms exist and their positions are dependent upon the movement of the plume with tidal changes. At maximum flood tide, plume waters recede towards the salt marshes and move slightly north. As the tide ebbs, the plume waters narrow and extend westerly, parallel to the discharge canal spoil bank (van Tine, 1977). Isotherm configurations for the discharge area were reported by Klausewitz (1979). In the summer, during ebb flow, Stations 1, 7 and 6 are located in the +4° to +5°C isotherms (degrees above ambient; ΔT). Temperatures decline along a northerly gradient away from the spoil bank. At flood tide in the late summer, the entire basin is located in the +5° to +6°C isotherms (3-ft level). Winter isotherms are similar to the summer ones, although winter ΔTs are higher (up to +10°C). The stations closest to the point of discharge, therefore, are continually exposed to higher than ambient temperatures and as one moves either north or west from the point of discharge, the effects of the plume diminish.

Salinities within the study area are influenced by freshwater discharges from the Withlacoochee and Crystal Rivers (Figure A-2). The Withlacoochee has an average flow of 33 x 10^3 liters/sec (1183 cfs) and enters the Gulf 6.4 km northwest of the plant site. The Crystal River, which enters the Gulf 4.8 km southeast of the plant, has an average flow of 22.2 x 10^3 liters/sec (785 cfs). Additionally, freshwater runoff from the CFBC and numerous tidal creeks reduce nearshore salinities. Annual precipitation is about 140 cm (55 in.) with more than 50 percent of that amount falling from June through September (Grimes, 1971).

Longshore currents have historically produced a southerly net flow of nearshore Gulf waters, and Lyons et al. (1971) reported a north-to-south gradient of increasing salinities. However, since the construction of the CFBC and canal jetty system, circulation patterns have been altered and distinctly different salinity regimes now exist in discharge and control areas. High salinity offshore waters are drawn through the intake canal and channeled into the discharge basin so that salinities there are considerably higher than those in the control area. Furthermore, plant effluents often form a wedge under less saline water flowing south into the discharge area from the Withlacoochee River and CFBC (Griffin, 1971). When this occurs, an inverted thermal layer is produced, and benthic organisms are exposed to the full impact of heated waters.

Gulf waters in the study area are shallow, varying from intertidal around the oyster bars and near shore to about 3 m in the depressions between bars. Diurnal tidal range in the region is about 1 m. Although Dawson (1955) reported that the tops of many oyster reefs were exposed except during spring high tides, more recent personal observation suggests that most reefs are completely covered during normal high tides. Extremely low tides may occur during fall and winter when predominantly northeasterly winds force water seaward from inshore areas during ebb tides and retard the flow of incoming water during flood tides. Stations located close to shore may be exposed during these periods.

Emergent geological and biological structures form a series of relatively distinct basins throughout the study area. The basins nearest to shore in both discharge and control areas were selected as primary sampling sites during operational studies (Figure A-3 and Table A-1). Extensive transects seaward of these inshore basins were used to monitor macrophyte distribution and composition (Figure A-4). The location of oyster reef and salt marsh stations are presented in Figure A-5.

BACKGROUND

Construction of existing canals and dikes for the once-through seawater cooling system of the Crystal River Power Plant was completed in 1966. The following year, hydraulic dredging of the Cross Florida Barge Canal channel and construction of its associated spoil islands was finished. Prior to these activities, published information regarding the biology, hydrology and geology of the area was scarce.

Dawson (1955) conducted a survey of the oyster resources of the Crystal River area and provided a summary of existing hydrological conditions. He characterized most of the nearshore area as being very shallow with depths averaging not more than 1 m. Deeper areas were noted in the basins between oyster bars. From September 1951 to August 1952, salinities in the present study area fluctuated widely, ranging from about 8 to 28.4 ppt (mean of 16 ppt). The basin bottom consisted of various mixtures of sand, mud and broken oyster shell.

Several years later, Phillips (1961) provided a list of algae and seagrasses occurring in an area just south of the present study site. His observations on bottom type, water depths and hydrological conditions generally agreed with Dawson's.

Crystal River Unit 1 began operating in July 1966. At that time, other units were in various stages of planning and construction. Acting on recommendations from federal regulatory agencies, FPC and the Florida Department of Natural Resources joined in an effort to develop a monitoring program to assess potential effects of heated effluents on the marine environment adjacent to the plant site. An ecological survey was designed to provide baseline data during a period when thermal effects were minimal. It began in January 1969 and continued until July 1971. During November 1969, Unit 2 became operational.

Grimes (1971) presented the first in a series of papers reporting results of the baseline study. He described the substrate west of the plant site as hard sand to rock covered with mud near the natural shoreline and silt in areas where dredging and draglining had occurred. It was suggested that canal construction may have caused some of the observed siltation. Reference was also made to the occasional occurrence of inverse stratification within the discharge area due to the greater salinity of intake waters. It was also noted that fish species diversity in the discharge increased slightly in the winter and decreased in the summer relative to diversities of ichthyofauna in unaffected areas.

Lyons et al. (1971) reported collecting 286 taxa of invertebrates from the study area, most of which were molluscs and arthropods. Most of these invertebrates were estuarine forms having wide geographical ranges of distribution. Salinity was found to be more important than temperature in determining local invertebrate distributions.

Steidinger and Van Breedveld (1971) identified 106 taxa of marine algae and 5 species of seagrasses from areas near the plant site and provided seasonal and spatial information on each. They indicated that observed declines in species diversity between 1969 and 1970 were probably not attributable to thermal effluents. However, alteration of substrata caused by siltation from dredging operations was mentioned as one possible cause of these declines.

Grimes and Mountain (1971) further documented the existence of inverse thermal stratification as well as suppressed summer diversity of fishes in the discharge area. The pattern of increasing diversity of invertebrates from north to south was also documented for fishes. This pattern was apparently related to salinity gradients and/or to greater habitat destruction from dredging operations at northern stations during construction of the CFBC.

Mountain (1972) completed the series of Crystal River baseline reports with a summary of findings and an annotated list of 95 fish species collected during the two and one-half year study.

From 1972 to 1974, FPC contracted the Systems Ecology Group of the Department of Environmental and Engineering Sciences at the University of Florida to provide preoperational data for the Crystal River Power Plant in anticipation of the start-up of Unit 3. The resultant studies addressed a wide range of environmental concerns, the findings of which were presented in a four-volume report (FPC, 1974).

In March 1977, Unit 3 went on-line and a concurrent operational study was initiated. The consulting firm of Metcalf and Eddy conducted quarterly sampling at the Crystal River Power Plant from 1977 to 1980 (FPC, 1978, 1979, 1980, 1981). Where appropriate, operational data were compared with 1972 through 1974 preoperational data. However, considerable changes in sampling methodologies occurring between preoperational and operational studies made comparison difficult. Furthermore, Unit 3 was down from 3 March to 29 September 1978, 23 April to 1 August 1979, and 25 February to 13 August 1980. Thus, prior to 1981, no single year's data reflected an entire year of continuous plant operation.

In 1981, Applied Biology, Inc., assumed monitoring responsibilities for on-going, operational studies. Quarterly sampling began in April and continued through December. During the year, Unit 3 experienced only five periods when the plant was down for more than a few days. These outages ranged from 12 to 18 days. The plant remained on-line throughout the summer, except for two weeks in July.

One final aspect of the plant history regards resuspension of bottom sediments from dredging operations. Since the construction of the Cross Florida Barge Canal and canal system of the power plant, sedimentation rates in the study area have been high (Cottrell, 1974), and considerable shoaling in the intake canal has occurred. Periodic maintenance dredging has been required to keep canal depth at navigable levels. In February 1979, dredging began to increase the controlling depth of the intake canal to 20 ft to accomodate larger barges supplying coal to the plant site. Construction was completed in March 1981. Each of these dredging projects has added to the natural suspended sediment load in the low energy area between the Withlacoochee and Crystal Rivers.

STATEMENT OF INTENT

Due to the ecological importance of benthic organisms and their usefulness as indicators of localized environmental perturbation, the current nonradiological monitoring program was designed to meet the following objectives:

1. Determine the identity, abundance, diversity and distribution of plants and animals inhabiting the shallow coastal waters adjacent to the Crystal River Plant site;
2. Determine whether benthic communities exposed to power plant effluents are similar to assemblages in an unaffected area to the south, in terms of species composition, diversity, biomass and abundance;
3. Determine the impact of Unit 3 on resident benthos by comparing community structure during periods of continuous and intermittent operation with data collected during preoperational years.

Salt marsh habitats were also examined to determine if dominant grasses in the discharge basin differed, in terms of density, stem height and biomass, from those in the control area.

The biotic collections requested by Florida Power Corporation and the gear, number of stations, replication and sampling frequency used in the various programs are listed in Table A-2.

NUMERICAL METHODS

Statistical treatment of quantitative benthic community data was performed quarterly using both station and basin results. Station means were determined from replicate values. Basin means, standard deviations and ranges were derived from station means at seven discharge and five control locations. Differences between basin means were tested for significance with the t statistic. However, to improve the sensitivity of the tests, the number of observations for each basin was increased by using replicate values rather than station means. Thus, benthic core observations (5 replicates per station) increased from 7 (discharge) and 5 (control) to 35 and 25; macrophyte biomass observations (3 replicates per station) increased from 7 (discharge) and 5 (control) to 21 and 15; and oyster reef observations (2 replicates per station) increased from 6 (discharge) and 3 (control) to 12 and 6. In most instances, data transformed using $\log_e (x + 1)$ showed reduced coefficients of variance, and transformed data were used for statistical testing. Before applying the t statistic, basin results were tested for homogeneity of variance with an F statistic. If the null hypothesis was rejected (i.e., $S^2 = S^2$), an approximation of t based on unequal variances was computed. Unless otherwise noted, all figures presented in the text represent actual arithmetic means computed for untransformed data.

Differences among stations were tested for significance by analyses of variance (ANOVA). Variances were first tested for homogeneity and, where necessary, the data were transformed to meet test criteria. If significant differences were detected, Duncan's multiple range test was applied to determine which stations were different. Unless otherwise noted, all ANOVA and t-tests were conducted at the $P \leq 0.05$ probability level.

Various biological indices were used for examining differences in community structure between stations and basins. Their applications and formulae are presented in Table A-3 and summarized in Table A-4.

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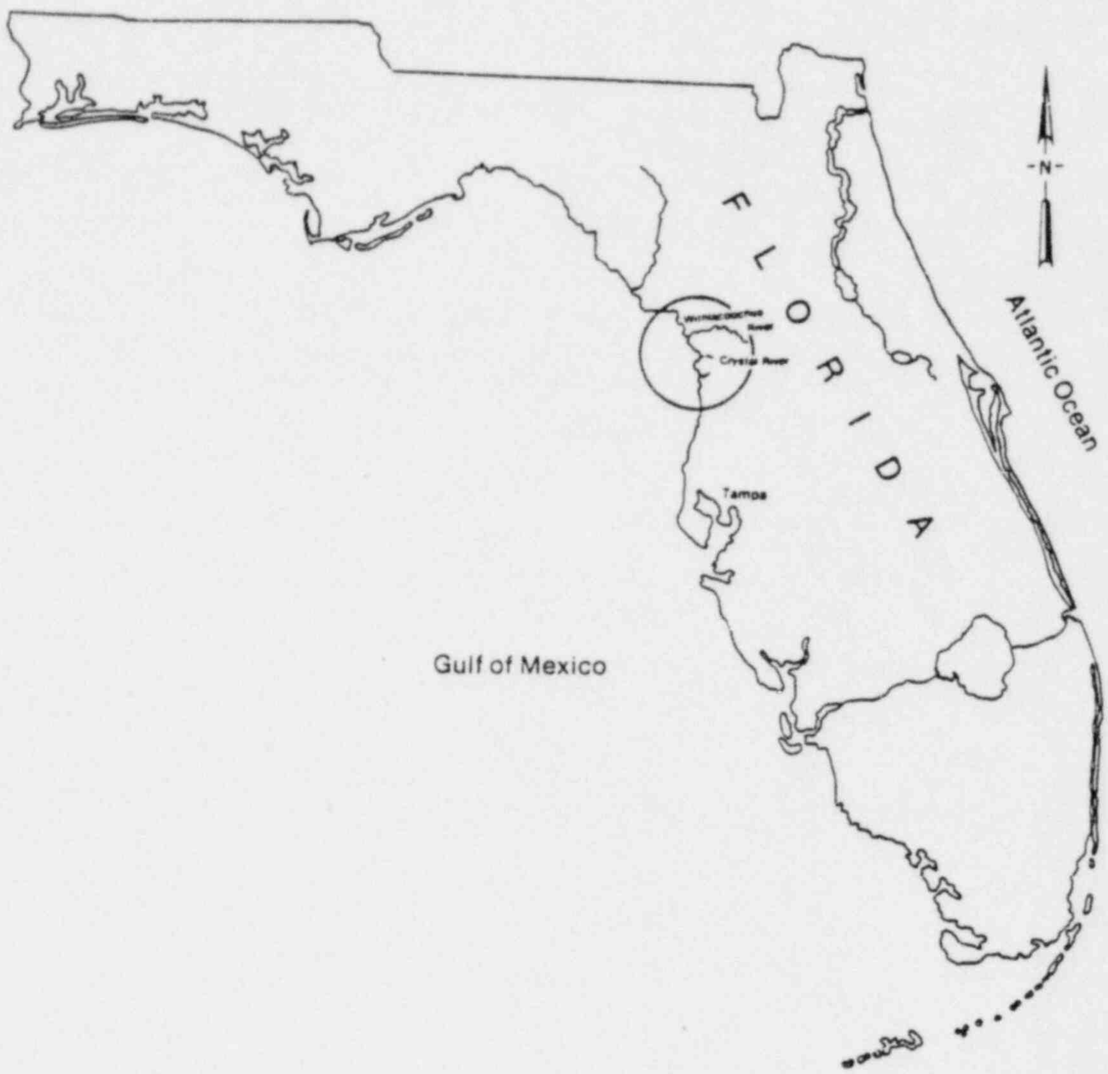

Figure A-1. Location of the Crystal River Power Plant.

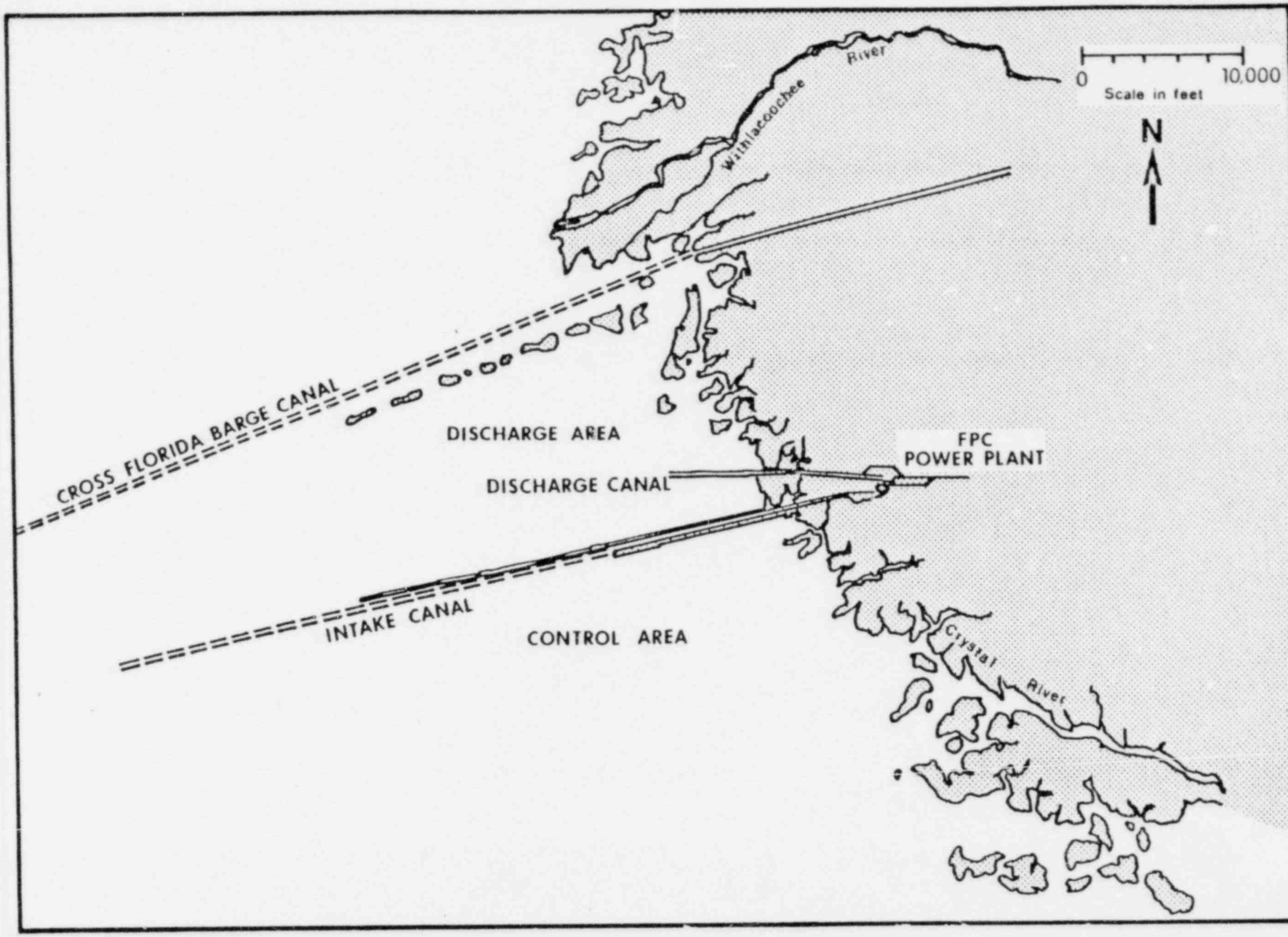

Figure A-2. Crystal River study area.

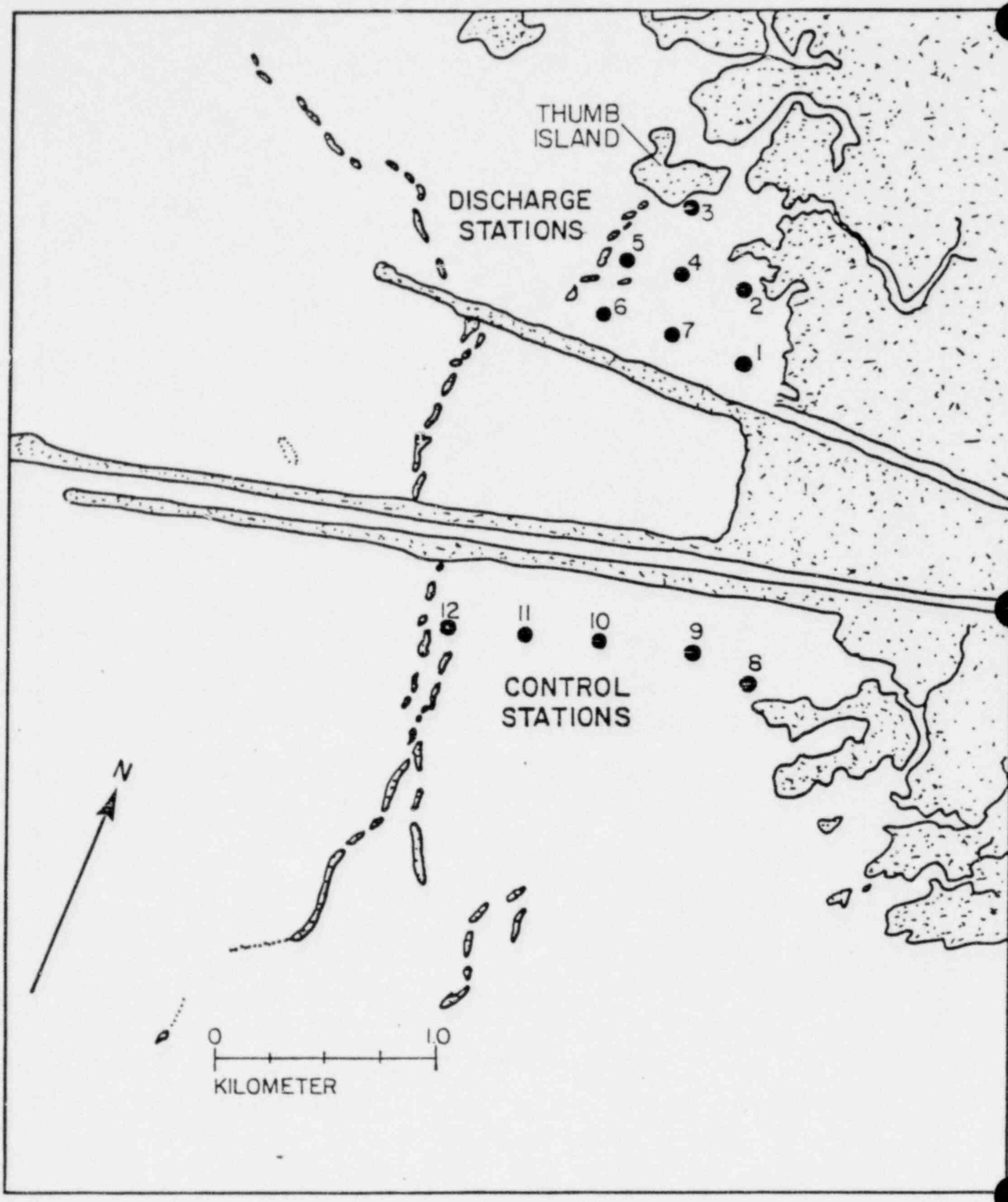

Figure A-3. Location of the 12 permanent stations used for collecting benthic core, sediment core, suction dredge and macrophyte biomass samples and taking physical measurements, Crystal River Project, 1981.

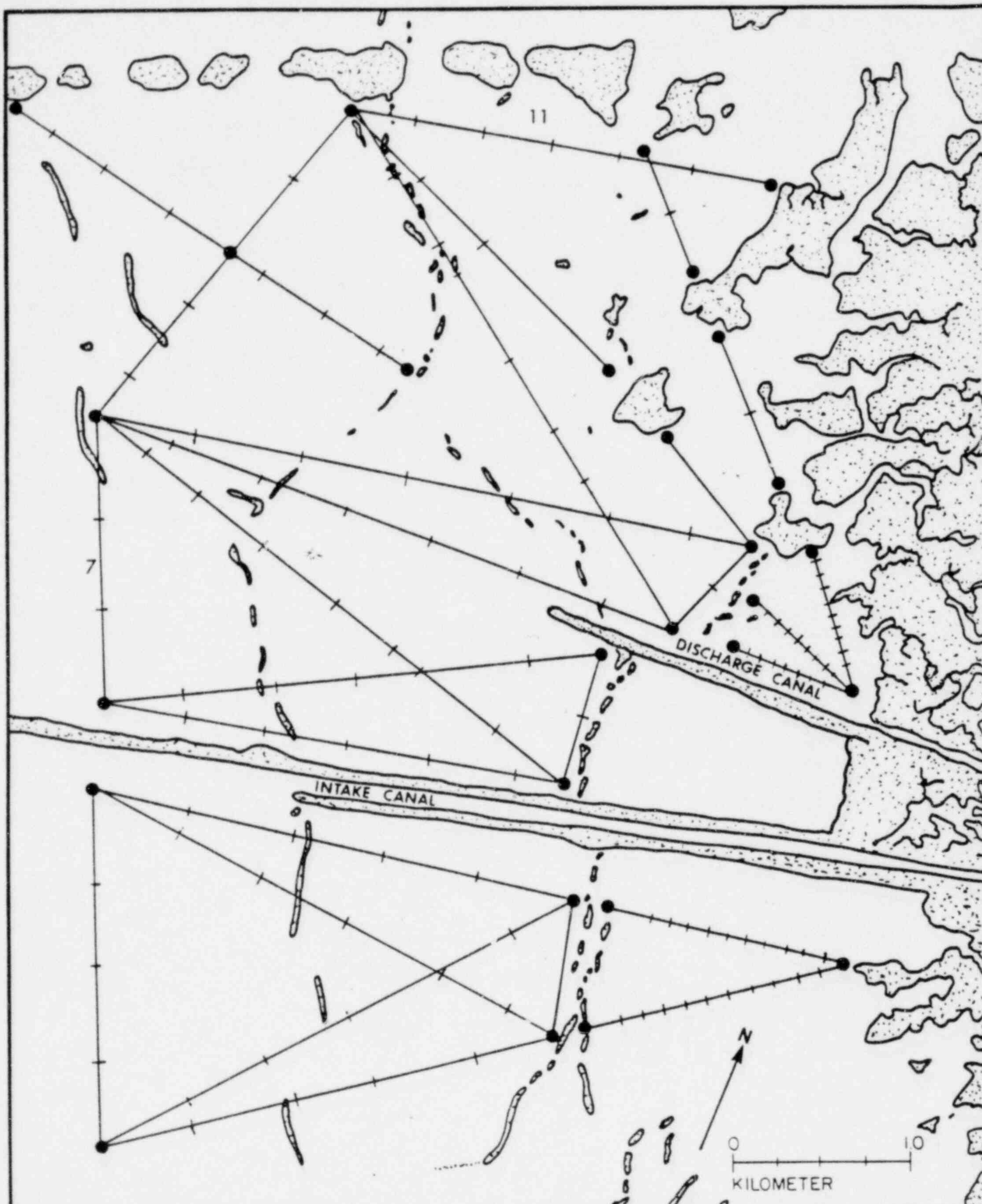

Figure A-4. Transects used for monitoring benthic macrophytes, Crystal River Project, 1981.

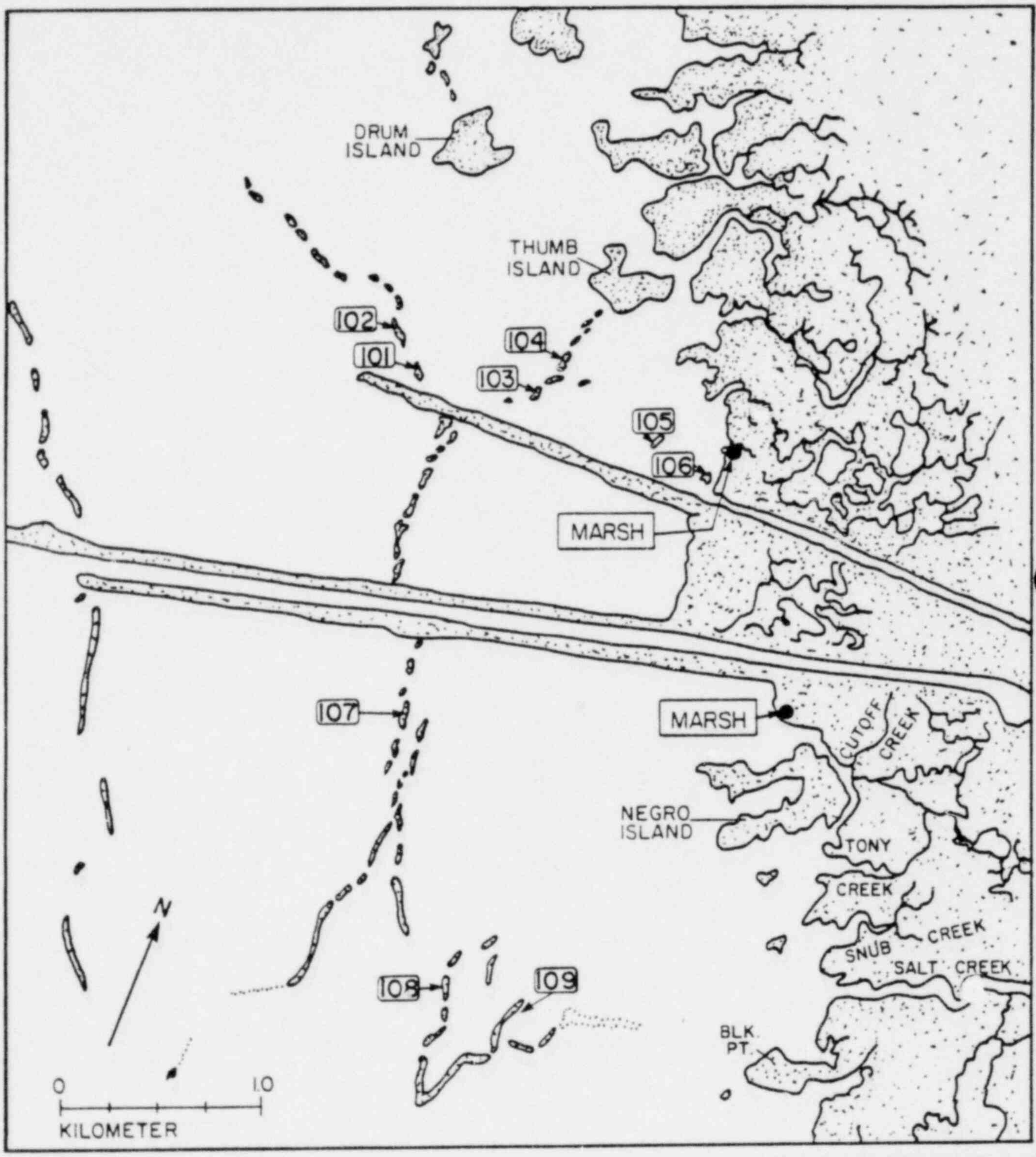

Figure A-5. Location of permanent stations used for examing oyster reef communities and salt marsh vegetation, Crystal River Project, 1981.

TABLE A-1

CHARACTERISTICS OF BENTHIC SAMPLING STATIONS
CRYSTAL RIVER PROJECT
1981

Station	Observed D.O. range (ppm)	Observed temperature range (°C)	Observed salinity range (ppt)	Depth relative to mean low water (cm)	Substrates	Macrophytes
1	4.7-9.5	22.5-37.5	28-32	18	Muddy sand	none
2	0.4-9.4	22.9-34.1	28-32	32	Muddy sand	*Halodule wrightii*
3	2.5-9.8	23.0-33.4	28-31	33	Muddy sand	Primarily *Halodule wrightii*, patches of *Thalassia testudinum* and red algae
4	3.2-10.0	22.2-33.7	28-32	47	Muddy sand	*Halodule wrightii*
5	3.9-10.4	22.5-34.7	28-32	49	Muddy sand	*Halodule wrightii*
6	4.9-10.2	21.9-36.5	28-32	62	Muddy sand	Primarily *Halodule wrightii*, patches of red algae
7	5.1-8.1	22.0-37.3	28-32	35	Muddy sand	none
8	5.8-9.9	21.0-30.6	20-28	28	Muddy sand	Primarily *Ruppia maritima*, patches of *Halodule wrightii* and mixed algae
9	4.6-9.9	19.8-30.5	20-28	40	Partially exposed limestone overlaid by gravelly sand	Primarily mixed algae, patches of *Ruppia maritima*
10	4.4-10.2	18.9-30.3	22-28	77	Partially exposed limestone overlaid by muddy sand	Mixed seagrasses and algae
11	5.5-8.8	18.5-30.3	22-30	78	Partially exposed limestone overlaid by sand and scattered large shells and rocks	Mixed algae
12	4.5-6.7	18.5-30.1	22-28	61	Partially exposed limestone overlaid by muddy sand and oyster shells	Mixed algae, primarily *Caulerpa* sp.

TABLE A-2

SUMMARY OF BENTHIC SAMPLING PROGRAM BEING PERFORMED
CRYSTAL RIVER PROJECT
1981

Type of gear	Biota sampled	Data sets	Number of stations	Number of replicates	Sampling frequency	Sieve size	Total samples annually
10-cm diameter corer	Small macroinvertebrate infauna and epifauna	Species composition Diversity Abundance Biomass	12	5	Quarterly	0.5 mm	240
Suction dredge	Large macroinvertebrate infauna and epifauna	Species composition Diversity Abundance Biomass	12	1	Quarterly	0.3 cm	48
50 x 50-cm box	Macrophytes	Species composition Biomass	12	3	Quarterly	N/A	144
Transect 1-m^2 quadrats	Macrophytes	Species composition Percentage coverage General condition	Approximately 150	5	Quarterly	N/A	Approximately 3000
50 x 50-cm box	Oyster reef fauna	Species composition Diversity Abundance Biomass	9	2	Quarterly	0.2 cm	72

TABLE A-2
(continued)
SUMMARY OF BENTHIC SAMPLING PROGRAM BEING PERFORMED
CRYSTAL RIVER PROJECT
1981

Type of gear	Biota sampled	Data sets	Number of stations	Number of replicates	Sampling frequency	Sieve size	Total samples annually
50 x 50-cm quadrats	Salt marsh grasses and epifauna	Abundance Biomass General condition	2	5 in *Juncus* 9 in *Spartina*	Quarterly	N/A	112

TABLE A-3

EXPLANATION OF METHODS USED IN THE ANALYSIS OF
BENTHIC COMMUNITY DATA
CRYSTAL RIVER PROJECT

DIVERSITY AND EVENNESS

Diversity indices are very useful for measuring the quality of the environment and the effect of induced stress on the structure of a biological community. Their use is based on the generally observed phenomenon that undisturbed environments support communities having large numbers of species with no individual species represented in overwhelming abundance (EPA, 1973). Many forms of stress tend to reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage.

The most widely used measure of species diversity is the information diversity index. This index considers two aspects of community species-numbers relationships: species richness (the number of species in relation to the number of individuals) and species evenness (the distribution of individuals among species). A decrease in either component of information means a decline in diversity.

The Shannon-Weaver information function (H') calculates mean diversity (i.e., the degree of uncertainty attached to the specific identity of any randomly selected individual; Pielou, 1966):

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where: s = total number of species in the sample, and

p_i = proportion of the total sample represented by the ith species.

However, as Lloyd et al. (1968) argued, if p_i's are to be estimated (i.e., the actual community composition is unknown) as $p_i = n_i/N$, then the formula for H' can be computed directly in terms of the observed n's, and the necessity for calculating proportions and their attendant rounding errors can be avoided. In an attempt to standardize the calculation of diversity, the EPA (1973) recommended the machine formula presented by Lloyd et al. (1968) using base 2 log:

$$H' = \frac{C}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where: C = 3.321928 (converts base 10 log to base 2),

N = total number of individuals, and

n_i = total number of individuals of the ith species.

To evaluate the component of diversity due to the distribution of individuals among the species (evenness), the calculated H' is compared with the maximum diversity possible for the same number of species (Pielou, 1966):

$$J' = H'/H'_{max}$$

where: $H'_{max} = \log_2 S$ (for H'computed with base 2 log).

Evenness values may range from zero to one.

RAREFACTION DIVERSITY (Sanders, 1968)

The rarefaction method of graphically calculating species diversity was formulated to directly compare samples of differing sizes. The usual difficulty inherent in such a comparison is that, as the sample size increases, individuals are added at a constant arithmetic rate but species accumulate at a decreasing logarithmic rate. The rarefaction method is dependent on the shape of the species abundance curve rather than on the absoulute number of specimens per sample. The procedure is to keep the percentage composition of the component species constant with that of a hypothetical sample of 1000 individuals while reducing the sample size, i.e., to artificially create the results that would have been obtained had smaller samples with identical faunal composition been taken. With this technique, the expected number of species in any size sample can be determined.

MCCLOSKEY'S (1970) INDEX OF FAUNAL DOMINANCE

This index ranks each species taken in a series of samples to determine the most dominant species. Use of this index disregards sample size. The species in each sample are ranked for dominance by their biological index value (BIV), which is obtained by giving 10 points to the species that numerically dominates that sample, 9 for each second dominant species, and so on. The "scores" of each species in the series of samples are then added to determine the total biological index value. The species having the highest total BIV is then the species of primary dominance.

MORISITA'S (1959) INDEX OF COMMUNITY SIMILARITY: $C\lambda$

This index is used to compare the faunal similarity of two samples by taking into account the abundances of common species, total abundances in each sample, and their respective diversities.

Morisita's index is based on Simpson's index of diversity (λ):

$$\lambda = \frac{\Sigma n_i(n_i-1)}{N(N-1)}$$

where: N = total number of individuals,

n_i = importance value (abundance, biomass, etc.) of the i^{th} species.

Using subscripts 1 and 2, the λ values of two samples may be differentiated:

$$\lambda_1 = \frac{\Sigma n_{i1}(n_{i1}-1)}{N_1(N_1-1)} \quad \text{and} \quad \lambda_2 = \frac{\Sigma n_{i2}(n_{i2}-1)}{N_2(N_2-1)}$$

Morisita's index of similarity between communities may then be calculated by the following formula:

$$C\lambda = \frac{2\Sigma n_{i1} n_{i2}}{(\lambda_1+\lambda_2)N_1N_2}$$

This index is almost uninfluenced by the sizes of N_1 and N_2. The value of $C\lambda$ will approach unity when samples demonstrate similarity in species abundance and diversity. Conversely, as $C\lambda$ approaches zero, the samples will have fewer species in common, which suggests that the samples have been drawn from dissimilar communities.

RELATIVE COMMONNESS

To characterize the structure of communities, it is essential to delineate those species that are most abundant and ubiquitous. Several methods have been used for ranking species according to their commonness. The two most commonly used in benthic studies are those proposed by Sanders (1960) and McCloskey (1970). Both of these methods produce a qualitative rather than a quantitative assessment of relative commonness. This study utilized a quantitative measure of relative commonness (I) given by the function:

$$I_i = (n_i/N)\ (c_i/C) \times 100 = A'U' \times 100$$

where: n_i = Total number of individuals of species i;

N = Total number of individuals of all species;

c_i = Total number of cores in which species i occurred;

C = Total number of cores taken.

Function A' is the relative abundance of species i and function U' is the relative frequency of occurrence (relative ubiquity) of species i. Assuming independence of A' and U', I_i is the percent probability that an individual randomly collected from the study area will be species i.

TABLE A-4

SUMMARY OF NUMERICAL METHODS USED FOR ANALYZING COMMUNITY STRUCTURE
CRYSTAL RIVER PROJECT
1981

Test	Description	Use
t-test (Sokal & Rohlf, 1969)	Parametric statistic used for comparing two sample means.	Used to determine if significant differences existed between discharge and control basins for a variety of community parameters.
ANOVA (Sokal & Rohlf, 1969)	Parametric statistic used for comparing more than two sample means.	Used to determine if significant differences existed among stations for a variety of community parameters.
Duncan's multiple range test (Sokal & Rohlf, 1969)	Parametric statistic for determining if sample means are significantly different.	Used in conjunction with ANOVA.
Shannon Weaver Index of diversity and evenness component (Lloyd et. al., 1968; Pielou, 1966)	Calculates mean diversity of a sample based on the number of species present and the way in which individuals are distributed among those species. The observed diversity is then compared to a hypothetical maximum diversity based on the number of species in the sample.	Used for measuring the quality of the environment and the effect of induced stress on community structure.
Rarefaction Diversity (Sanders, 1968)	Compares diversity graphically using species abundance curves that have been adjusted to render all samples equal in terms of number of individuals.	Produces species abundance curves (number of individuals plotted against number of component taxa) that are used for comparing diversity among stations.
McCloskey's (1970) Index of dominance	Assigns biological index values (BIV's) to species based on their numerical dominanca in each of a series of samples.	Used to compare dominant taxa collected at discharge and control stations.
Index of Relative Commonness (ABI, 1980)	Determines the percent probability of randomly selecting a particular species from a parent community.	Combines both relative abundance and frequency of occurrence of each species to determine dominant taxa.
Morisita's (1959) Index of Community Similarity	Utilizes the abundances of shared species, total abundances and diversities to compare two samples.	Produces trellis diagrams that are used for making interstation comparisons of faunal similarity.

B. PHYSICAL AND CHEMICAL MEASUREMENTS

INTRODUCTION

The physicochemical characteristics of water directly or indirectly determine the biotic composition of any aquatic ecosystem. In the marine environment, temperature, salinity and dissolved oxygen are among the most important water quality parameters affecting organisms.

Temperature influences behavior, regulates reproduction, metabolism, growth and development, and sets limits for survival (Phillips, 1960; Kinne, 1963; Prosser, 1973; Giese and Pearse, 1974; Patrick, 1974). Every species has a range of temperatures that it can tolerate. Within that range, optimal levels for survival vary depending on life history stage and prevailing environmental conditions (Kinne, 1967; Prosser, 1973). By acting on individuals, temperatures also affect community structure. Changes in abundance, biomass, productivity, species richness, diversity and species composition may result from perturbations in natural temperature regimes (Warinner and Brehmer, 1966; Bader and Roessler, 1972; Virnstein, 1972; Patrick, 1974; Blake et al., 1976).

Salinity is a measure of the salt content of water, and marine organisms vary in their ability to tolerate salinity changes. Through its influence on physiological processes, salinity can determine the distribution of organisms (Gunter, 1961). As with temperature, it can also strongly affect community composition (Phillips, 1960; Boesch, 1972; Humm, 1973; Boesch et al., 1976).

Adequate levels of dissolved oxygen are essential for the maintenance of marine life. The amount of dissolved oxygen in the water is affected by biological activities such as respiration and photosynthesis, as well as numerous other physical and chemical processes occurring in the environment. Dissolved oxygen, in turn, affects physiological activities and thereby sets limits for survival. In areas where dissolved oxygen levels fluctuate widely, community structure may undergo dramatic changes (Santos and Bloom, 1980; Santos and Simon, 1980).

Temperature, salinity and dissolved oxygen have measurable effects on biological systems. However, when acting in concert with other factors, they typically produce different effects than when acting alone (Kinne, 1967; Vernberg and Vernberg, 1974). Temperature, for example, indirectly acts upon biota by influencing the solubility of gases and solids in water, and changes in salinity and dissolved oxygen alter thermal tolerance limits of organisms (Prosser, 1973).

The purpose of the present monitoring program was to characterize existing physicochemical conditions within the study area and to relate observed seasonal and spatial patterns of water quality parameters to the abundance and distribution of resident benthic organisms.

MATERIALS AND METHODS

Surface and bottom water temperature, salinity and dissolved oxygen were monitored quarterly at seven discharge and five control stations (Figure B-1). Measurements were taken concurrently with benthic core

collections, and all stations were sampled on the same day. Temperature (to the nearest 0.1°C) and dissolved oxygen (to the nearest 0.1 ppm) were measured with a YSI Model 54 DO meter, and salinity (to the nearest 1 ppt) was determined with an American Optical temperature-compensated, hand-held refractometer.

RESULTS AND DISCUSSION

Mean bottom water temperatures in the discharge basin were significantly higher than those in the control basin during all sampling periods of 1981 except April (Figure B-2). Minimum temperatures in both basins were observed in late November, and annual maxima were observed in June. Because Quarter 3 measurements were taken on 31 August, two sets of summer temperature data are available. This is potentially the most critical period for benthos in the discharge basin because ambient temperatures are elevated toward and beyond lethal limits by thermal discharges from the power plant. During June, the warmest observed temperature in the discharge basin was 37.5°C (Station 1), and all discharge station values exceeded 33°C. By late August, temperatures had declined somewhat but remained above 31°C. Stations closest to the discharge canal were consistently the warmest, and temperatures decreased with increasing distance from the point of discharge (Stations 1, 7 and 6 in decreasing order).

By contrast, control basin temperatures never exceeded 31°C, and station temperatures varied only 1° to 2°C during all sampling periods. Station 8 consistently had the warmest temperatures, and Station 12 was the coolest.

Mean bottom salinities in the discharge basin were significantly greater than those in the control basin during all 1981 sampling periods (Figure B-3). In both basins, highest values were recorded in August and lowest values in April. Salinities differed among stations within each basin by no more than 2 ppt during any sampling period.

Seasonal variation of dissolved oxygen exhibited similar patterns in both discharge and control basins (Figure B-4) and these were in opposition to annual trends depicted for bottom water temperature (Figure B-4). Mean dissolved oxygen values were significantly greater in the control basin during all sampling months but November. Lowest values in both basins were observed in June. Highest values were observed in late November in the discharge basin and in April in the control basin. During the summer, dissolved oxygen levels in the discharge basin fell as low as 0.4 ppm at Station 2, and the dissolved oxygen range among discharge stations approached 5.0 ppm. Throughout the remainder of the year, discharge station values for a given period ranged only 2 to 3 ppm. In the control basin, observed dissolved oxygen levels were never below 4.4 ppm, and station values for a given period ranged only 1 to 2 ppm.

Water quality parameters are based on readings taken only one day each quarter. In the shallow waters around the plant site, temperature, salinity and dissolved oxygen are influenced by many factors including air temperature, water depth (tidal stage), wind direction and velocity, currents, precipitation, and, in the discharge basin, by plume configuration. Thus, at any one location, temperature, salinity and

dissolved oxygen may vary considerably over a relatively short time. More frequent monitoring and/or the use of permanently positioned recording devices (e.g. thermographs) would be required to accurately depict spatial and temporal patterns of these water quality parameters. Furthermore, the lack of stations in the discharge area beyond the inner discharge basin make it impossible to determine the total extent of plume influence.

Although data presented in this report depict only general trends, it is apparent that very high temperatures and low dissolved oxygen levels existed in the discharge basin during the summer. Furthermore, because of the relatively high salinity of plant effluents, thermal inversions probably occurred (Grimes and Mountain, 1971), thus exposing benthic communities to the warmest portion of the plume.

Operational Trends

Long-term temperature data showed a trend of consistently higher water temperatures in the discharge basin than in the control basin because of power plant operation (Figure B-5). During 1981, the mean bottom water temperature of the discharge basin (35.3°C) reached the highest level recorded since operational monitoring began in 1977. This was also the first year that Unit 3 remained on-line throughout the year.

Of primary ecological importance, mean summer water temperatures during surveys in the control basin have rarely exceeded 30°C and have never risen above 32°C. By comparison, mean summer temperatures in the

discharge basin have consistently exceeded 30°C and, during three of the five operational years, they have exceeded 32°C. Studies conducted at power plants throughout Florida suggest that temperatures above 32° to 33°C are harmful to local marine life when sustained over the natural tidal cycle. Where these high temperatures have persisted, changes in benthic community structure have occurred (Bader and Roessler, 1972; Virnstein, 1972; Thorhaug et al., 1978).

Similar to temperature patterns, long-term salinity data indicated that mean bottom salinities in the discharge basin have consistently been greater than those in the control basin (Figure B-6). Because salinities in the study area are influenced primarily by precipitation patterns and stream discharges, the lowest salinities are expected during fall following heavy summer rainfall. However, throughout operational years, salinities were highest during fall. Thus, lag-time between periods of greatest precipitation and highest stream discharges must be considerable. Data presented by McNulty et al. (1972) for 1964 and 1965 indicate that stream discharge in the area was greatest between December and May. This accounts for the low salinities generally observed during spring each year.

Preoperational Comparisons

Previous comparisons of preoperational and operational data have been made using annual mean temperatures of discharge and control basins. It seems more appropriate to examine maximum temperature data to determine greatest potential impact of plant operation on benthos in the

discharge. In 1973, when only Units 1 and 2 were on-line, discharge temperatures from June through August were consistently 35°C or greater along the discharge canal and about 32° to 33°C elsewhere in the basin (Smith, 1974). Between 1977 and 1981, when Unit 3 was operating intermittently, warmest summer temperatures were 37°C along the discharge canal and about 34°C elsewhere in the basin (FPC, 1981). During 1981, Unit 3 remained on-line throughout most of the summer, and water temperatures reached 37.5°C along the canal and approximately 34°C elsewhere in the discharge basin. Thus, it appears that Unit 3 may elevate bottom temperatures about 2° to 3°C above those occurring when only Units 1 and 2 are on-line. However, no information is available relative to the thermal histories of individual stations, and it is therefore difficult to determine the persistence of these high temperatures at a particular location. Furthermore, because reported temperature data for operational years were based on so few data points, it is possible that observed maxima are uncharacteristic of prevailing conditions. Nevertheless, it appears that discharge water temperatures approached reported lethal limits for many local benthic organisms when only Units 1 and 2 were on-line and exceeded them when all three units were operational.

Water temperatures for the control basin remain similar to those reported during the preoperational study, summer values averaging about 30°C.

SUMMARY

Three FPC electric generating units at Crystal River, Florida, release heated waters through a common discharge canal into a shallow basin adjacent to the plant site. Thermal effluents significantly increase water temperatures in the basin above ambient levels and, during the warm summer months, temperatures may exceed tolerance limits for many resident benthic macroinvertebrates. Because power plant discharges are more saline than typical basin waters, thermal inversions may occur, exposing benthic organisms to the full impact of thermal stress. Low summer dissolved oxygen levels in the discharge basin may further compound the problem by reducing thermal tolerance levels.

Parameters of water quality within the study area have the capacity for appreciable change over relatively short periods of time, and it is uncertain if measurements taken over a few days each quarter are representative of prevailing conditions. Furthermore, the persistence of high temperatures is equally as important in determining the effects of thermal stress as the absolute levels attained. Thus, thermal histories for each station would be required to accurately define the zone of greatest potential impact.

The operation of Unit 3 appears to raise discharge basin temperatures 2° to 3°C above those occurring when only Units 1 and 2 are on-line. If 32° to 33°C is considered the threshold of lethal temperatures for resident invertebrates, communities at Stations 1, 7 and 6 (in decreasing order) are exposed to lethal temperatures during summer

regardless of the operational status of Unit 3. Stations elsewhere in the basin experience sublethal conditions when only Units 1 and 2 are on-line and lethal levels when all three units are operating. Thus, the zone of greatest potential impact is widened by the additional thermal load exerted by Unit 3.

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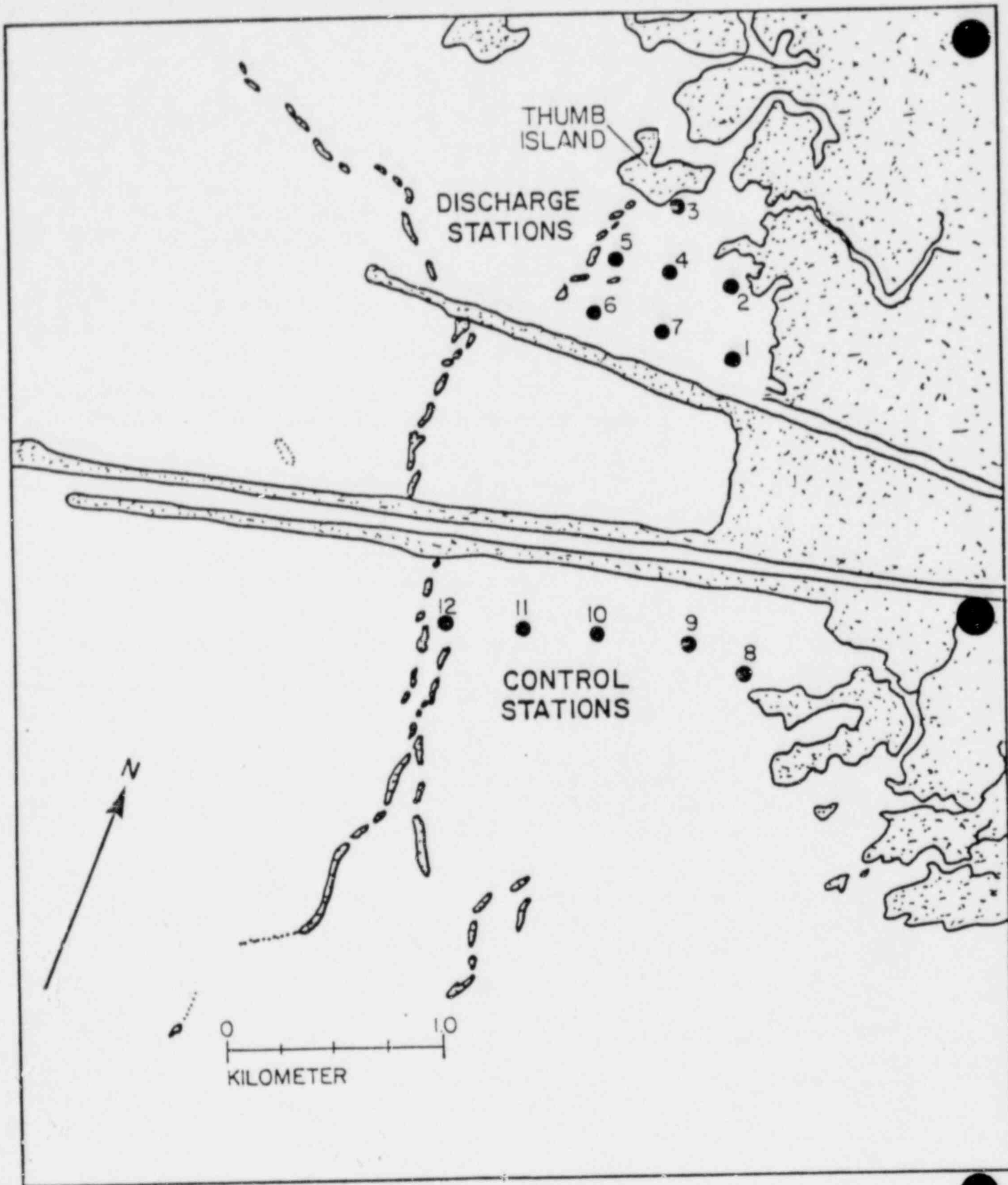

Figure B-1. Location of the 12 permanent stations used for physicochemical measurements, Crystal River Project, 1981.

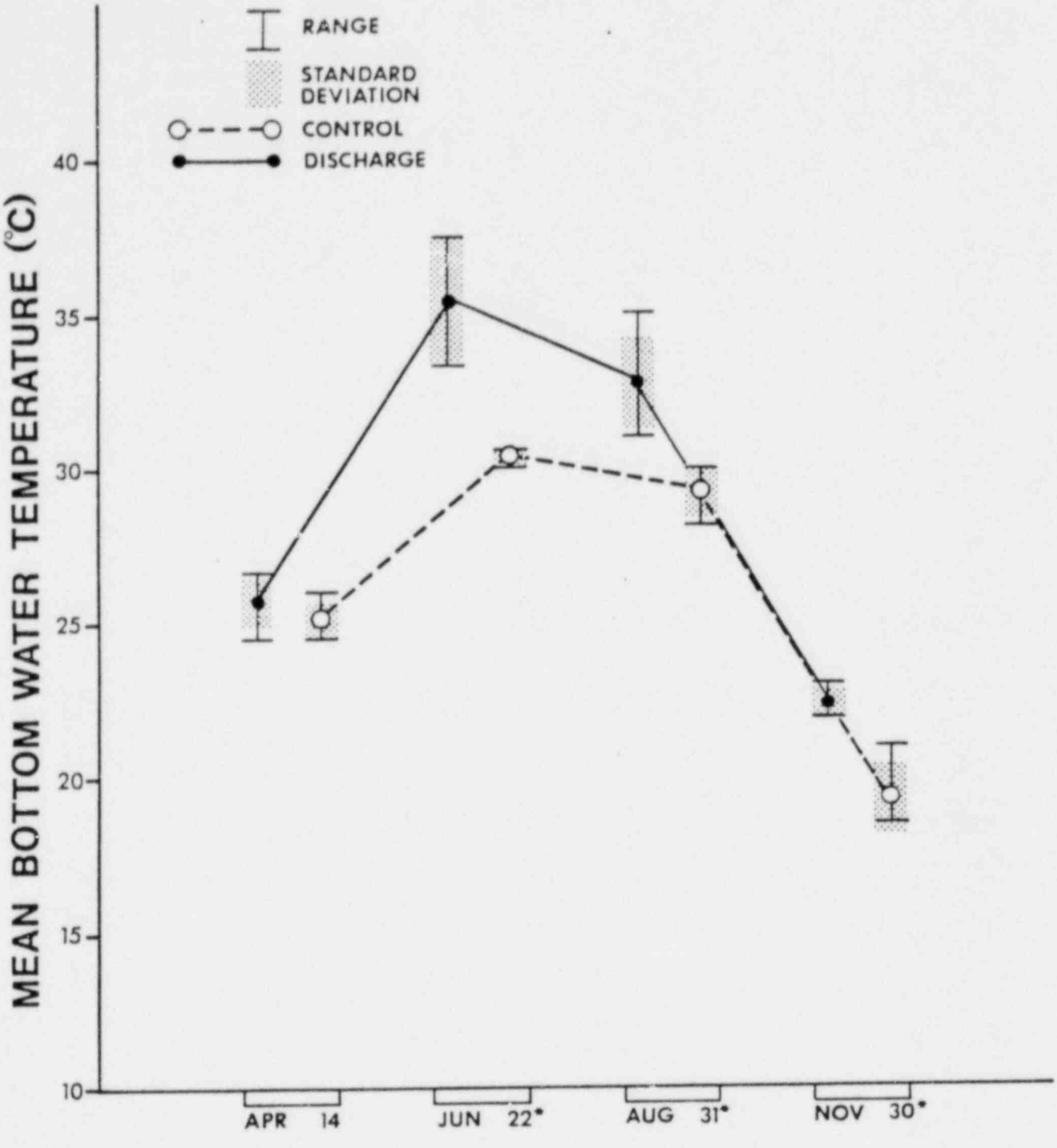

Figure B-2. Mean bottom water temperature of discharge and control basins based on readings taken quarterly at seven discharge and five control stations, Crystal River Project, 1981. (*Significant difference between basins)

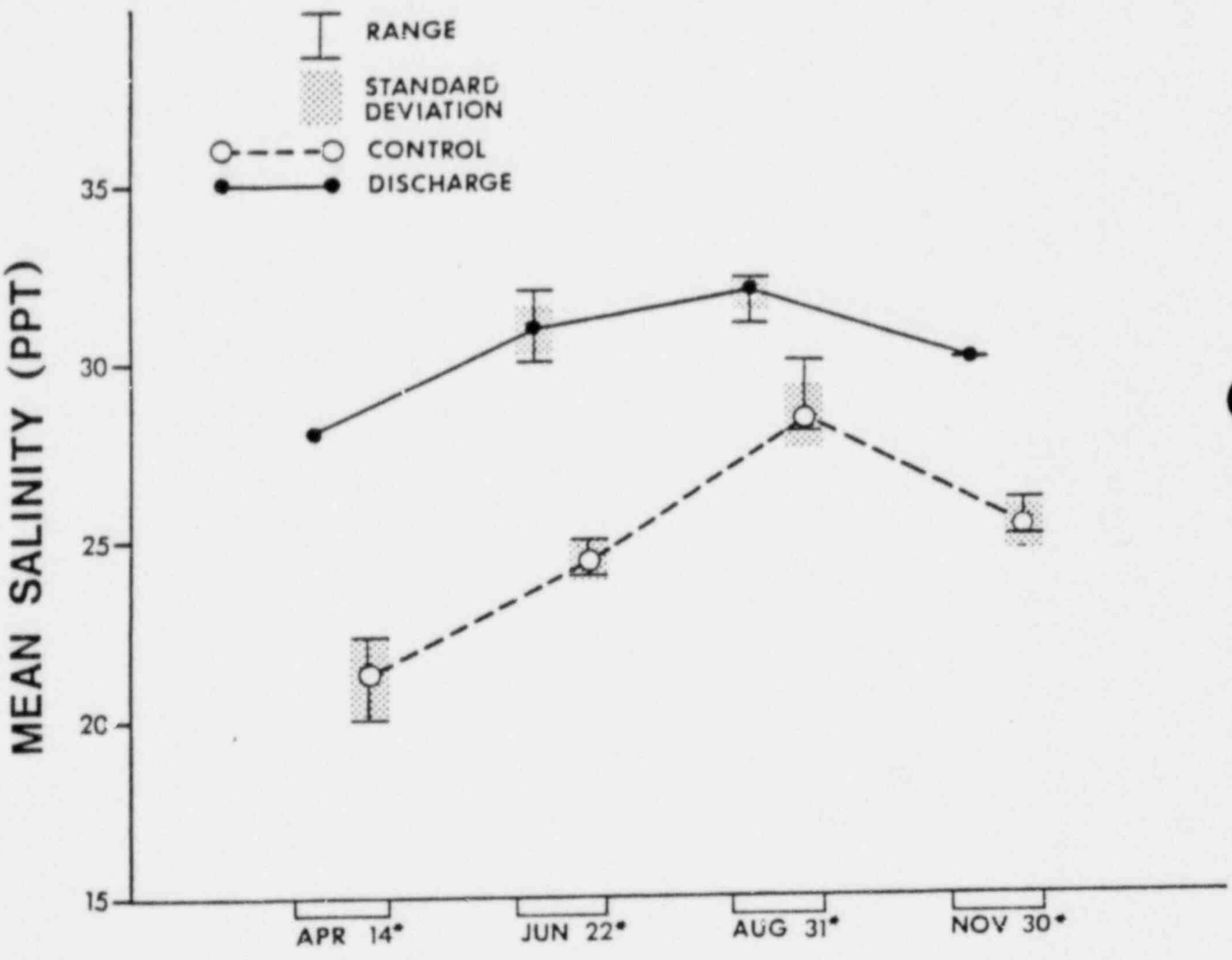

Figure B-3. Mean bottom salinities of discharge and control basins based on readings taken quarterly at seven discharge and five control stations, Crystal River Project, 1981. (*Significant difference between basins)

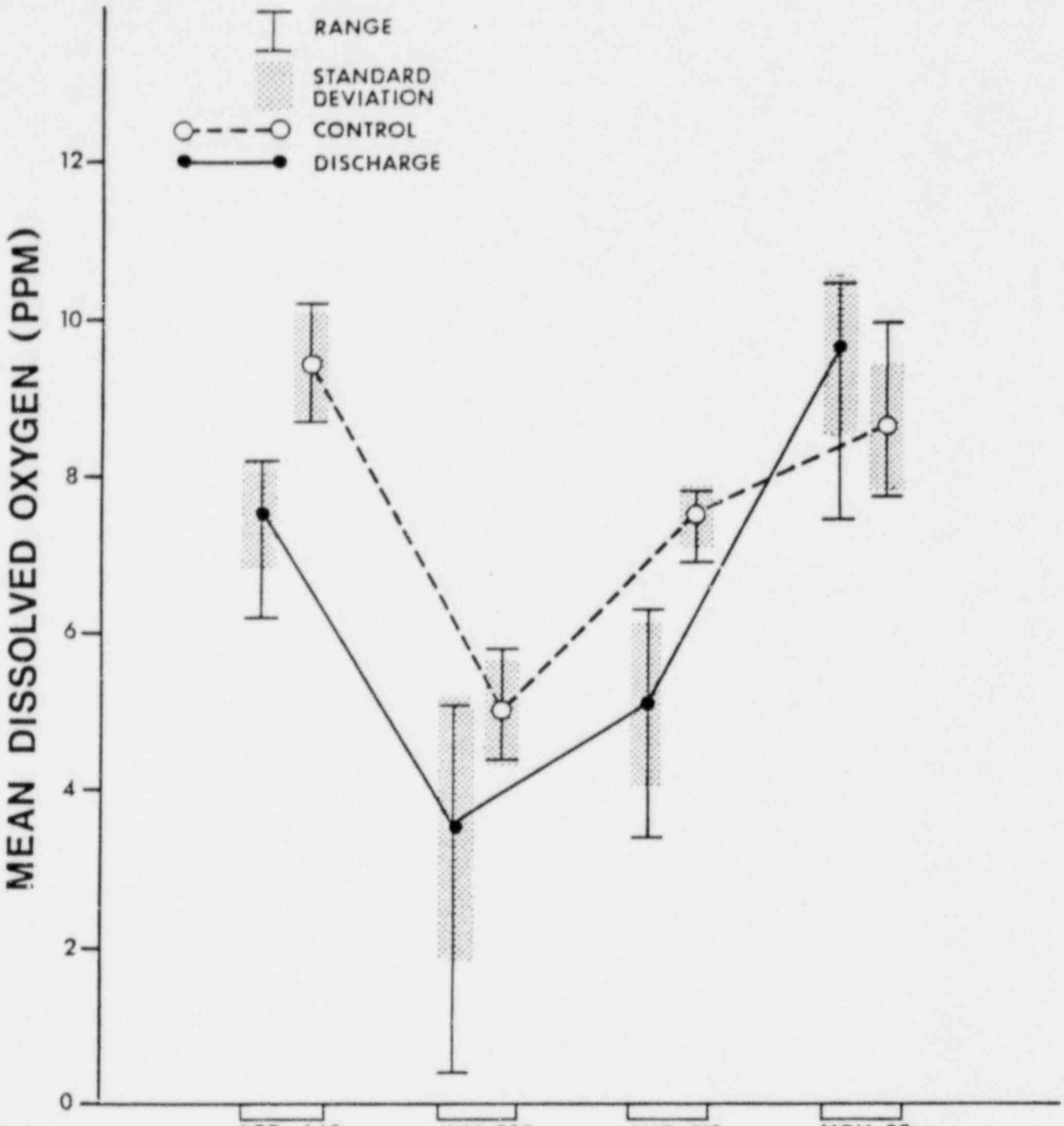

Figure B-4. Mean bottom dissolved oxygen values of discharge and control basins based on readings taken quarterly at seven discharge and five control stations, Crystal River Project, 1981. (*Significant difference between basins)

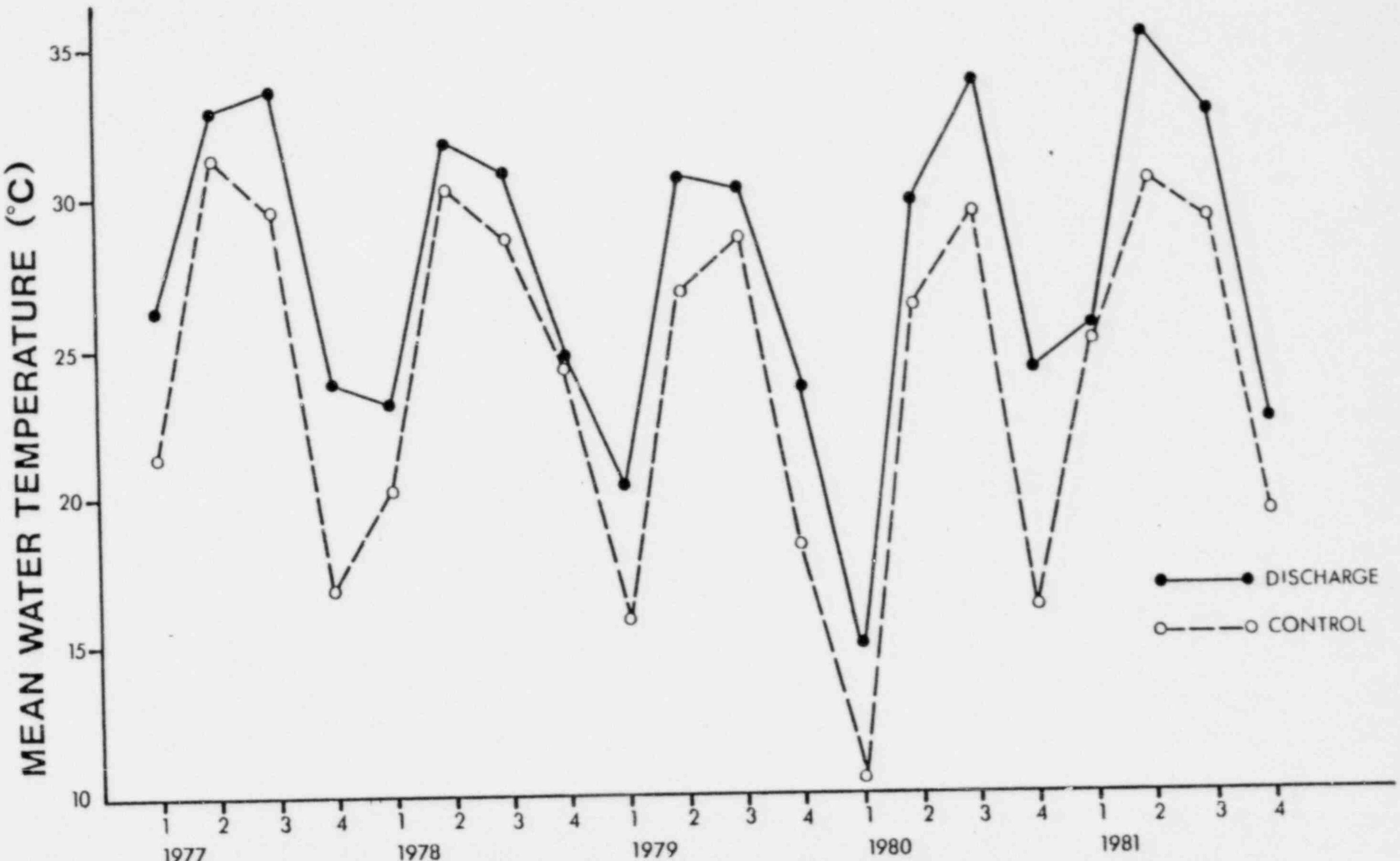

Figure B-5. Quarterly mean water temperatures of discharge and control basins, Crystal River Project, 1977-1981.

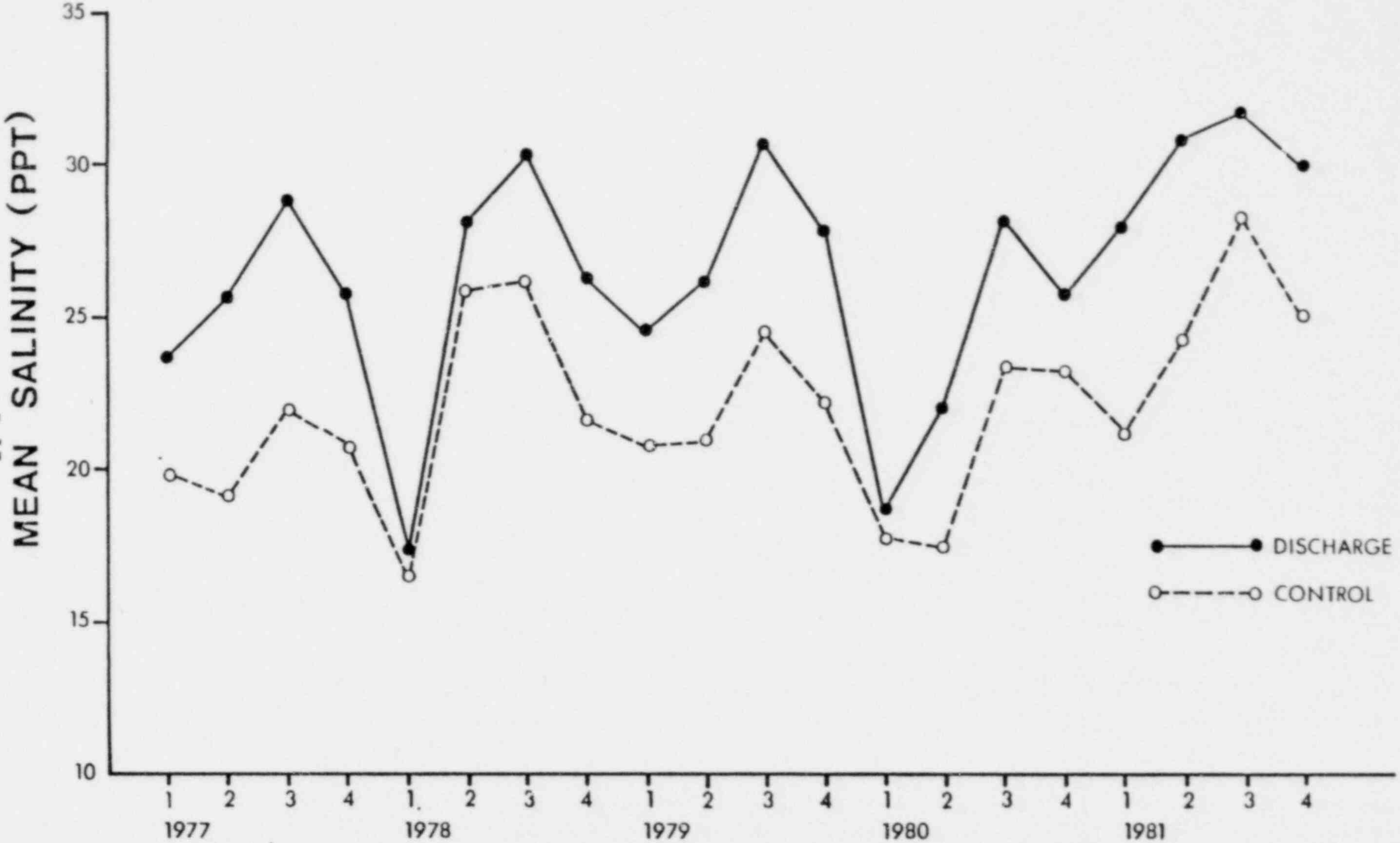

Figure B-6. Quarterly mean salinities of discharge and control basins, Crystal River Project, 1977-1981.

C. BENTHIC CORE

INTRODUCTION

The macroinvertebrate benthos is an essential component of coastal marine ecosystems. Benthic macroinvertebrates exhibit a vast diversity of form and function and, as a result, occupy a wide variety of microhabitats and virtually all trophic levels. Although most benthic macroinvertebrates are of no direct economic importance, they constitute a major food source for many economically important species. Consequently, the well-being of these important marine species depends upon the well-being of the benthic fauna.

The benthic fauna can also affect the chemical, physical and biological nature of the immediate environment. For example, the burrowing activities of certain species bring nutrients to surface layers of the substratum (Rhoads, 1973; Everest and Davis, 1979). This activity, coupled with the fragmentation of large detrital particles during feeding, can accelerate microbial respiration. Increased microbial respiration subsequently lowers dissolved oxygen levels and pH in the water column (Driscoll, 1975) and increases the rate of detrital decomposition (Fenchel, 1970, 1972; Driscoll, 1975). Through modification of the physicochemical nature of the environment and through direct biological interactions, the benthic fauna also influences the biological structure of the communities they inhabit (Woodin, 1976; Myers, 1977; Rhoads et al., 1977).

Because of their habitat preferences, low motility and relatively long life spans, benthic macroinvertebrates are particularly suitable as water quality indicators (Holland et al., 1973). For example, benthic communities have been used to assess the effects of temperature (Wariner and Brehmer, 1966; Virnstein, 1972), salinity (Boesch, 1972; Boesch et al., 1976; Rosenberg and Moller, 1979), water depth (Sanders, 1968), current (O'Gower and Wacasey, 1967), substrate (Sanders, 1958; McNulty et al., 1962; Bloom et al., 1972) and various pollutants (McNulty, 1961; Anger, 1977; Reish et al., 1980).

The benthic core program was designed to provide quantitative data relating to the structure of macroinvertebrate communities inhabiting the shallow coastal area adjacent to the Crystal River Power Plant. Because of the corer's size, it is selective for the smaller epifaunal and infaunal forms, which compose the majority of macroinvertebrate taxa and numbers of individuals. Comparisons of fauna collected by cores in the discharge and control basins may provide the most useful information on the effects of plant operation on benthic macroinvertebrate community structure.

MATERIALS AND METHODS

Field Procedures

Benthic core samples were taken quarterly at seven discharge and five control stations (Figure C-1). At each station, five replicates were obtained using a 10-cm diameter aluminum corer equipped with a top vent (Figure C-2). The corer was inserted 15 cm into the substrate, the

top vent closed and a core extracted. If substrate composition prevented penetration to 15 cm, the corer was inserted as deep as possible. All replicates were taken within a 15-m radius of the station marker and were spaced at least 3 m apart. Sediment temperature was measured at each station by inserting a mercury thermometer into one of the core samples.

The cores were sieved in the field in a bucket fitted with a 0.5-mm mesh screen (U.S. standard sieve No. 35). Material retained on the sieve screen was transferred to a labeled plastic container and preserved in 10-percent buffered seawater formalin containing Eosin B and Biebrich Scarlet stains (Williams, 1974).

Laboratory Procedures

In the laboratory, the samples were again rinsed on a No. 35 standard sieve to remove excess preservative and fine sediments. The material was sorted under a dissecting microscope at low power, and the fauna was removed, separated into major groups and preserved in 50-percent isopropyl alcohol. Individuals within each major group were subsequently enumerated and identified to the lowest practicable taxonomic level.

Both wet and dry weight biomass determinations were made for each phyla present in a replicate (except for molluscs and chordates, which were treated by class). Wet weights were obtained after straining the sample through a 0.272-mm mesh screen and then removing excess liquid with a paper towel. Dry weights were obtained after drying the sample in

an oven for 24 hours at 70°C. Both wet and dry weight determinations were made to the nearest 0.001 g using a Mettler E54AR side loading balance.

RESULTS AND DISCUSSION

Abundance

During 1981, 384 macroinvertebrate taxa (Table C-1) and almost 33,000 individuals were collected by benthic cores. The majority of individuals were taken from the control basin, even though sampling efforts within the discharge area were greater (seven discharge versus five control stations). When mean densities for each basin were statistically compared, significant differences were found during June, August and November (Figure C-3).

Annual trends were the same in both basins. Densities were highest in April, declined in late August and then increased to intermediate levels in late November (Figure C-3). Mean densities were especially reduced in the discharge basin during June and late August, a period of very high water temperatures (Figure B-2). Declining densities in the control basin over this same period suggest that reduced summer abundances of smaller benthic macroinvertebrates are a natural phenomenon within the study area; however, the magnitude of the difference between basins is significant. Even at their lowest levels, benthic fauna in the control basin outnumbered discharge benthos by a factor of three. Furthermore, density reduction in the discharge basin lasted for a longer portion of the year.

Within each basin, densities varied considerably among stations (Tables C-2, C-3 and C-4). Stations 1 and 7 in the discharge consistently had the lowest densities. These two stations are located closest to the point of discharge (Figure C-1) and were the only stations in the basin devoid of vegetation. The lack of vegetation reduced the number of available habitats, and stressful conditions imposed by the discharge plume reduced the suitability of the habitats that remained. These circumstances ultimately resulted in an impoverished fauna. During both June and late August, as water temperatures approached and exceeded lethal limits for many resident species, community characteristics at Stations 1 and 7 exhibited signs of extreme stress. Densities were below 1000 individuals/m^2, biomass values approached zero and fewer than 12 taxa were collected (Table C-2). By late August, macroinvertebrate abundance at Station 7 had declined to the lowest level observed for any station during the entire study (204 individuals/m^2 representing 3 taxa). However, densities at Stations 1 and 7 showed signs of recovery as water temperatures declined during the fall.

Elsewhere in the discharge basin, abundances were also reduced by rising summer water temperatures. However, at most stations, they remained above 4000 individuals/m^2. Station 2 was the only discharge station that consistently exhibited densities greater than 10,000/m^2.

In the control basin, station densities were always above 10,000 individuals/m^2 except in late August at Station 12 (Table C-3). The greatest number of organisms was repeatedly collected at Station 9, but

lowest densities varied among stations from one sampling period to the next.

Biomass

Macroinvertebrate biomass is affected by the number of individuals in a collection, their relative sizes and by the analytical techniques used to determine their weights. To provide comparative information on benthic communities at Crystal River, processing techniques during 1981 remained unchanged from previous operational studies. Weights were obtained for each major group by drying the entire organism for a specified period of time. This technique biases the biomass of a sample in favor of groups having shells or other rigid external features. Additional bias is introduced by the chance acquisition of a relatively large individual. When that occurs, the amount of bias depends on the kind of organism collected (i.e., gastropod, starfish, etc.) and its absolute size. Thus, biomass, especially as determined during the present study, is a rather poor indicator of community structure. Nevertheless, certain generalizations can be made concerning the 1981 data.

Mean biomass values for benthic macroinvertebrates collected by cores in the control basin were significantly greater than those for discharge benthos during every sampling period (Figure C-4). Even at its lowest level, control biomass was approximately the same as the highest mean biomass found for discharge benthos. Annual patterns of variation in both basins paralleled those for density, seasonal means being highest in April and lowest in late August.

Biomass varied considerably among stations within each basin but, with few exceptions, no consistent spatial patterns were apparent (Tables C-2 and C-3). In the discharge basin, the highest observed biomass was only about 11 g/m^2, and yet, high and low station values differed by as much as 8 or 9 g/m^2 during several sampling periods. Biomass at discharge Stations 1 and 7 approached zero during summer because of the paucity and small size of the organisms collected there (Table C-2).

Variations in biomass among stations in the control basin were much greater than in the discharge basin due to the extremely wide range of values obtained. During April, for example, highest and lowest values differed by 157 g/m^2. Only during late August were relatively low values obtained at all stations.

Because of the technique used for determining biomass, faunal composition played a major role in structuring community biomass. As will be demonstrated later, annelids, which are soft bodied forms, predominated overwhelmingly in the discharge basin. Thus, community biomass values were relatively low when compared to those for the control basin where substantially greater numbers of heavier-bodied molluscs, arthropods and echinoderms resided.

Station differences within each basin can often be explained in terms of environmental heterogeneity. The discharge basin, owing to its homogeneous soft substrate, monospecific flora and relatively harsh physical conditions favors annelids, and variability in biomass among sta-

tions basically reflects differences in the number of worms collected. However, the control basin exhibits an extremely heterogeneous environment that permits habitation by a much more diverse assemblage of organisms. For example, the hard substrate of several stations in the control basin provides attachment sites for relatively large sessile forms such as sponges and ascidians. The collection of only one or two of these individuals, as occurred at Station 12 during April and at Station 11 during November (Table C-3), can greatly exaggerate community biomass.

Number of Taxa

Species richness, based solely on the number of species in a collection, is the simplest measure of faunal diversity. During 1981, 383 taxa were collected by cores in both discharge and control basins combined (Table C-1). Annual trends in species richness were the same in both basins and corresponded to patterns noted for faunal density and biomass (Tables C-2 and C-3). The number of taxa collected in the control basin was seasonally more stable than in the discharge basin. Between April and late August, the number of taxa in the control basin declined by only 20 percent, whereas the discharge basin experienced an 80 percent decline over that same period.

The control basin consistently had a larger number of taxa than the discharge basin, and the magnitude of the differences between basins increased with the persistence of high summer water temperatures. Thus, in April when species richness was greatest, there were only 1.7 times as

many taxa collected in the control basin as in the discharge basin. However, by late August, after several months of high temperatures, control taxa outnumbered discharge taxa by a factor of six.

When samples for the entire year were combined, 357 different taxa were recorded from the control basin, but only 176 were collected in the discharge basin (Tables C-2 and C-3). This difference is even more appreciable when the greater sampling effort in the discharge is considered (140 discharge versus 100 control samples). One hundred fifty species collected were common to both basins. However, when examining the number of taxa taken exclusively in one basin or the other, a very large number (207) were found solely in the control area, and only 26 taxa were found exclusively in the discharge basin.

Inter-basin differences can generally be explained in terms of either prevailing physicochemical conditions or environmental heterogeneity. Both basins experienced large seasonal fluctuations in temperature and salinity, a phenomenon typical of estuarine systems. The organisms occupying these areas have developed physiological and behavioral mechanisms to cope with a dynamic environment (Vernberg and Vernberg, 1976). However, even eurytopic forms can tolerate only a certain range of conditions, and these ranges vary considerably among species and even among life history stages within a species.

Organisms living in warmwater areas such as Florida may, under natural conditions, be living relatively close to their upper thermal tolerance limits (Gunter, 1957; Naylor, 1965; Bader and Roessler, 1972). Studies conducted in other Florida estuaries suggest that the threshold for lethal levels is about 32° to 33°C, especially if these temperatures are sustained over several tidal cycles (Bader and Roessler, 1972; Virnstein, 1972). Organisms whose geographical ranges are centered farther north may have considerably lower tolerance limits. Thus, as summer temperatures increased in the discharge basin between April and June, an increasing number of organisms were unable to tolerate the elevated thermal regimes and were eliminated. With the persistence of high temperatures in the discharge basin throughout the summer, only the most tolerant species remained.

A similar situation existed in the control basin but, because absolute temperatures were considerably lower, only those species having relatively low thermal tolerances were affected. As Lyons et al. (1971) reported, many macroinvertebrate species at Crystal River have wide ranging distributions, and relatively few have purely cool- or warmwater affinities. The absence of a large temperate faunal component in the study area may account for the minor reduction in the number of taxa found in the control basin during summer sampling periods.

The greater species richness at control stations during cooler months is most probably related to environmental heterogeneity. As stated earlier, the discharge basin is characterized by a relatively

homogeneous substrate and monospecific flora, whereas the control basin has a diverse floral assemblage and a variety of substrates. Because the control basin is a more complex environment, it supports a greater number of macroinvertebrate species. For example, the larger proportion of epibenthic forms found in the control basin may be because of increased habitat complexity resulting from a rich benthic flora. Several investigators have indicated that above-ground plant biomass is positively correlated with both invertebrate species number and abundance (Heck and Wetstone, 1977; Gore et al., 1981). During every sampling period of 1981, macrophyte biomass in the control basin was significantly greater than that of the discharge (E. Macrophyte Biomass).

Species richness within each basin varied considerably among stations. In the discharge basin, high temperatures during April and late August greatly reduced the number of taxa collected at stations closest to the discharge canal. However, taxa that were excluded from these stations during the summer began to return as water temperatures declined. No other spatial patterns in species richness were apparent from the data.

In the control basin, the number of taxa also varied erratically from one sampling period to the next (Table C-3). Station 8, located closest to shore, generally had the fewest species. Of all the control stations, physical characteristics at Station 8 most closely approximated those of the discharge stations.

Diversity and Evenness

Diversity (H') based on the Shannon-Weaver information function (Pielou, 1966) is a more complex measure of faunal diversity than species richness. Diversity considers not only the number of species present, but also the number of individuals and the distribution of those individuals among the species. Communities in healthy non-stressed environments should theoretically have higher diversities than communities in similar systems experiencing various forms of physical stress (EPA, 1973).

Mean diversity of control benthos was substantially higher than that of discharge benthos during every sampling period of 1981 (Figure C-5). In the control basin, quarterly means fluctuated between 4.5 and 5.0, but the highest mean diversity in the discharge basin was only 3.1. Patterns in both basins generally corresponded to trends observed for other community parameters, diversities decreasing throughout summer to their lowest levels in late August. This pattern was much more pronounced in the discharge basin, where diversities exhibited greater seasonal fluctuations.

Because of the complex interaction of species richness, faunal abundance and evenness in the calculation of H', few generalities can be made concerning spatial variations in community diversity within each basin (Tables C-2 and C-3). For example, in apparent contradiction to species richness data, diversities at Stations 1 and 7 were relatively high when compared with other discharge stations. Although fewer individuals were

collected at those stations, they were evenly distributed among the taxa present, and diversity values reflected this high evenness component. Elsewhere in the discharge basin diversities fluctuated considerably and did not seem to fit any consistent pattern.

Diversities in the control basin were similarly erratic, the only consistent pattern occurring at Station 8. Benthic communities at that station repeatedly exhibited the lowest diversities of any control location. This most likely reflects the relatively low habitat complexity of the environment there.

Evenness values (J') numerically describe the distribution of individuals among the taxa present in a collection. In environments experiencing physical stress, certain organisms gain a competitive advantage, and they become numerically dominant. As dominance increases, evenness declines.

During 1981, mean evenness values of benthic communities in the control basin were consistently greater than corresponding values for those in the discharge basin (Figure C-5). However, the differences between basins were not as appreciable as might be expected considering the relatively harsh physical environment of the discharge basin. Evidently, none of the species capable of sustaining populations throughout the summer became overwhelmingly dominant, and evenness values remained relatively high during that period. Only when temperatures moderated and less tolerant species began to repopulate the area did evenness values decline.

The discharge stations that had the warmest temperatures (Stations 1 and 7) consistently had the highest evenness values. This can be explained by the extremely low densities during the summer, but during April and late November other factors must have been involved. One possible explanation is that, due to the dynamic physical environment of those stations, resident communities were in a constant state of transition and no single species was able to gain an overwhelming numerical advantage. This would also account for the relatively high diversity at those stations. The mechanisms whereby communities in transition may achieve higher diversity than when at equilibrium have been discussed by Gonor and Kemp (1978).

The diversity of a biological community varies in relation to the physical stability and habitat complexity of the surrounding environment. As discussed for species richness, observed differences in community structure, both within and between basins, can largely be attributed to one or both of these variables. Station differences can be graphically examined through the use of rarefaction diversity, whereby a set of station curves is produced depicting the annual relationship between species richness and faunal abundance. Curves with steep slopes represent communities having a relatively large number of taxa per unit number of individuals, and gentle slopes indicate fewer taxa for that same number of individuals. The absolute height of the curves represents species richness, and the end points represent faunal abundance.

In the discharge basin, where the environment is less stable and habitat complexity low, station curves had gentle slopes and low plateaus (Figure C-6). Conversely, in the control basin, where the habitats are more complex and the environment less harsh, station curves had relatively steep slopes and high plateaus. Station 8 represents a habitat similar to those encountered in the discharge basin but whose physical characteristics are less harsh. Consequently, it occupied an intermediate position between other control and all discharge stations.

The most apparent discrepancy between what is observed from the rarefaction curves and what might be expected is the positioning of curves for Stations 1 and 7. This results from their high evenness values and relatively low faunal densities. The slopes are steeper than those for other discharge stations indicating that, for a given number of individuals, more species will be collected there. Because the number of taxa collected at Stations 1 and 7 during any single sampling period was relatively small compared to other discharge stations, species turnover must have been appreciable. Rarefaction curves thus support the contention that communities at these stations are in a constant state of transition.

Community Composition

Data collected in 1981 support the suggestions of previous studies that community parameters of discharge and control benthos differ because of differences in faunal composition brought about by a divergence of prevailing environmental conditions following the construction of the

canal jetty system. The discharge area experiences greater fluctuations in physicochemical parameters and endures periods of severe physical stress. It is a relatively monotonous seascape consisting of monospecific patches of seagrass and homogeneous soft substrates. The control basin also experiences fluctuations in physicochemical conditions, but it is not exposed to the stressful summer temperatures and low dissolved oxygen levels encountered in the discharge basin. The seascape is varied, consisting of both consolidated and unconsolidated substrates and a diverse and productive assemblage of macrophytes. The importance of above-ground plant biomass to species richness and total abundance of epibenthic invertebrates has been stated (Heck and Wetstone, 1977; Gore et al., 1981), and the influence of substrate on faunal composition is universally acknowledged (Sanders, 1958; McNulty et al., 1962; Bloom et al., 1972).

During 1981, benthic macroinvertebrate communities within the study area were numerically dominated by annelid worms (Figue C-7). The contribution of annelids to total abundance was greatest in the discharge area, where they accounted for at least 85 percent of all individuals collected each sampling period. As temperatures increased during summer, the percentage contribution by worms increased to as high as 97 percent, which suggests that annelids are the most tolerant of stressful conditions. Similar observations of worms being the last group to be excluded and the first to recolonize have been made in other stressed environments (Rosenberg, 1976).

Annelids were also numerically dominant in the control basin, but generally to a lesser degree than in the discharge basin. Seasonal contributions to total fauna ranged from 55 percent in June to 77 percent in late November. Molluscs contributed a relatively large proportion of total individuals in June (24 percent), but during other sampling periods, the non-annelid contribution was uniformly distributed among major groups.

The proportion of total biomass contributed by different groups varied considerably, both among sampling periods and between basins (Figure C-7). In the discharge basin, worms predominated biomass because of their extreme numerical dominance. During cooler months when other forms were abundant, annelids made up only 55 percent of total biomass, but as temperatures increased and other groups diminished in abundance, they accounted for as much as 85 percent of community biomass. The disproportionate contribution to discharge biomass by molluscs in June and late November and by arthropods in late August was, in each case, attributable to the collection of one or two relatively large individuals. During April, echinoderms accounted for the disporportionate contribution by miscellaneous taxa.

In the control basin, other groups predominated biomass, and annelids did not contribute more than 35 percent during any sampling period. In June and late August, the presence of relatively large numbers of molluscs accounted for their major contributions to total community biomass (54 and 43 percent, respectively). The large proportion of

biomass composed of miscellaneous taxa during April (60 percent) and late November (66 percent) was caused by the collection of a large sponge and ascidian, respectively. As mentioned earlier, biomass is a rather poor indicator of community structure because of the bias introduced by these chance collections of large specimens.

The percentage contribution of each major group to total number of taxa was relatively consistent among quarters (Figure C-7). The discharge and control basins were remarkably similar in faunal composition during April and June, but they began to differ as warm summer temperatures in the discharge basin began to restructure the proportions of various taxa present. By late August, after a period of persistently high temperatures, the molluscan component of the benthos had almost disappeared from the discharge, which suggests that they may be the least tolerant of elevated temperatures. However, their capacity to recolonize the area once temperatures moderate was demonstrated by an increased contribution to total taxa in late November. The contribution to species richness by arthropods during late November was relatively minor when compared to those of other sampling dates.

The stability of benthic community structure in the control basin is very clearly illustrated by the greater similarity in the relative proportions of major groups among sampling periods. This does not suggest that species composition within each major group remained unchanged, as shifts in dominant taxa are quite possible. Within a community, population levels of constituent species may fluctuate widely, while the relative proportion of each major taxa remains constant.

Dominance

Community dynamics are largely influenced by population fluctuations of numerically dominant species (Frankenberg and Leiper, 1977). To determine if observed differences in community structure at Crystal River were caused by differences in dominant taxa between basins, an index of commonness was computed. This index considers both frequency of occurrence and relative abundance for every taxa collected during the year. It was used to assemble a list of the 10 dominant species at each station (Table C-5).

In the discharge basin, 25 taxa were classified as dominants at one or more stations during 1981. The majority of these were polychaete annelids, and Aricidea philbinae was the most ubiquitous and abundant. Aricidea taylori, Laeonereis culveri, Streblospio benedicti and Capitella capitata completed the list of the five most dominant taxa in the discharge basin. The two latter species are known to be opportunistic forms capable of monopolizing areas defaunated by environmental disturbances (Grassle and Grassle, 1974; McCall, 1977; Santos and Bloom, 1980). Lumbrineris culveri has been reported to undergo dramatic population increases in organically enriched environments and appears to be another good indicator of stressed environments (Young and Young, 1978). No information was available regarding the opportunistic tendencies of Aricidea spp., but owing to their overwhelming numerical dominance, it seems highly probable that they too are especially capable of exploiting stressed environments.

During 1981, 23 taxa were classified as dominants at one or more control stations (Table C-5). Again, annelids predominated the list. In the control area, another polychaete, Tharyx dorsobranchialis, was the most ubiquitous and abundant species. The remaining top five consisted of oligochaetes of the family Tubificidae, Nematoda spp. and the polychaetes Aricidea philbinae and Prionospio heterobranchia texana.

Several of the macroinvertebrate taxa ranked as dominants were species complexes rather than distinct species. The identity of individuals within these complexes could not be determined due either to taxonomic deficiencies or the physical condition of the organisms (i.e., juveniles or damaged specimens). For example, Calanoidea spp. (copepods) and Nematoda spp. represent large species complexes. Because of their small size, neither are quantitatively sampled with a 0.5-mm sieve. Thus, both groups have traditionally been treated as components of meiofaunal communities. Tubificidae spp. are quantitatively sampled but may include many species that cannot be identified because of their immature life stage. Mediomastus spp. includes damaged specimens of two species, both of which are relatively abundant in the study area. Consequently, organisms identified to supraspecies levels should probably be excluded when comparing basin differences in dominant taxa.

When species complexes were removed from the list of top 10 dominants, only A. philbinae and T. dorsobranchialis were common to both basins. Both species have wide local distributions and large populations. A. philbinae is dominant in the discharge area and T.

dorsobranchialis is dominant in the control basin. The lack of other shared dominant species probably accounts for a great deal of the observed variation in community structure between basins.

Community Similarity

To more completely examine spatial differences in the structure of benthic communities at Crystal River, Morisita's (1959) Index of Faunal Similarity ($C\lambda$) was applied to annual station data. This index is based upon the number of species shared among stations and their relative abundances. Station pairs having the largest number of numerically abundant species in common will have the highest $C\lambda$ values.

The trellis diagram displaying similarity indices among stations (Figure C-8) underscores the statements made previously concerning community structure of discharge and control benthos. Within the discharge basin, communities at Stations 2 through 6 were very similar to one another but only moderately similar to those at Stations 1 and 7. Stations 2 through 6 physically differed from Stations 1 and 7 by having more complex habitats (seagrasses were present) and less harsh physicochemical conditions (further removed from thermal effluents). Communities at Stations 1 and 7 were very similar to each other and experienced very hot water temperatures during the summer. Consequently, these communities underwent more dramatic seasonal fluctuations in species richness and faunal abundances.

In the control basin, the fauna at Stations 9, 10 and 11 were very similar to one another, but only moderately similar to those at Stations 8 and 12. Station 8 represented a less complex habitat and was understandably removed from the previous station grouping. However, the dissimilarity of the fauna at Station 12 and other control stations is not fully understood. Its location close to an oyster reef resulted in a very coarse-grained sediment texture, and this may have produced a relatively distinct fauna. However, many of the dominant taxa at Station 12 were shared with other control stations (Table C-5).

Communities at Stations 8 and 12 were the least similar of any control station assemblages. In fact, the fauna at Station 8 was more similar to those at the discharge stations than it was to the community at Station 12. Other faunal similarities between discharge and control stations were slight. These data again demonstrate the widespread distribution of dominant taxa within each basin and the general lack of shared dominants between basins.

The intermediate position of Station 8 between control and discharge environments is supported by both similarity and rarefaction data. Because of the absence of appropriate control stations in the discharge area, Station 8 may provide the only valid data base from which to make assessments pertaining to the impact of plant operations on resident benthic communities. Its soft homogeneous substrate and seagrass vegetation closely approximates the habitat complexity observed in the discharge basin. The major difference between areas is the lack of thermal effluents at Station 8.

A comparison was made between quarterly community parameters at Station 8 and those at discharge stations. However, the dissimilarities between Stations 1 and 7 and the other discharge stations were partitioned out by obtaining a discharge mean based solely on community data for Stations 2 through 6 (Table C-6). Densities during the cooler sampling periods were similar or slightly greater in the discharge basin than at Station 8 whereas, during the warm summer months, densities at Station 8 were appreciably larger. Biomass values were consistently greater at Station 8 than at comparable discharge stations.

During April, the number of taxa at discharge stations was slightly less than at Station 8. However, during the summer, discharge species richness was greatly reduced. Some recovery appears to have occurred by late November but the mean number of taxa at discharge stations still represented only half of that collected at Station 8. Both diversity and evenness values were always lowest in the discharge basin, even though seasonal variation in diversity followed the same pattern in both basins.

When all factors are considered and when compared to a similar environment in a thermally unaffected area, the operation of the Crystal River Power Plant during 1981 caused the macroinvertebrate community of the discharge basin to have reduced density and number of taxa during the summer and depressed biomass, diversity and evenness throughout the year. Both faunal abundance and species richness showed signs of recovery when temperature moderated, but only faunal abundance had recovered to springtime levels by the end of the year.

Operational Trends

During the past five years (1977 through 1981), benthic core samples have been collected quarterly at the same locations throughout the study area. This has generated the data necessary for examining long-term trends in macroinvertebrate community structure and allowed comparison of communities chronically exposed to thermal effluents with those spatially removed from them. The additional impact of Unit 3 on resident benthos can also be assessed by comparing data among years of intermittent and full operation of Unit 3.

Macroinvertebrate communities throughout the study area have experienced considerable seasonal fluctuations in densities during operational years (Figure C-9). In the control basin, mean densities have ranged from about 2300 to over 42,000 individuals/m^2 and, within a single year, mean densities have varied by as much as 33,000 individuals/m^2. Densities observed during 1981 were relatively high compared to previous years. Generally, faunal abundance has been lowest during Quarter 3 (September) and highest in Quarters 1 or 2 (March or June). However, these patterns are not precise, nor are the amplitudes consistent among years. The imprecision of sequential peaks of abundance among years is a phenomenon common to coastal benthic macroinvertebrate assemblages (Frankenberg, 1971; Livingston, 1976; Frankenberg and Leiper, 1977; Maurer et al., 1979) and does not necessarily imply that they are unstable. In fact, these assemblages may be quite stable over time, faunal composition remaining relatively constant but individual populations undergoing continual change in response to fluctuating environmental conditions (Livingston et al., 1976).

The stability of benthic communities in the control basin is illustrated by the relative constancy of faunal diversity throughout operational years (Figure C-10). The increase between 1980 and 1981 can be explained entirely in terms of differences in taxonomic precision. Many taxa previously identified to the supraspecies level (e.g., family or genus) were further separated into distinct species during 1981, thus yielding a greater number of taxa. Even though diversities were higher in 1981, they remained at a relatively uniform level throughout the year. Evenness values in the control basin have similarly remained high and stable during operational years (Figure C-10).

Similar to densities, mean biomass values in the control basin have varied considerably over the years, but repetitive patterns are less apparent (Figure C-9). Throughout the five years of operational study, mean quarterly biomass has ranged from less than 10 to more than 209 g/m^2. Values for 1981 fell within the range observed for other operational years.

In summary, the control basin can be characterized as having benthic assemblages that undergo marked seasonal fluctuations in abundance and biomass. Although annual patterns do not repeat themselves precisely each year, density and biomass are generally lowest during Quarter 3. This suggests that ambient summer water temperatures may be naturally inhibitive to certain species within the study area. However, control communities appear quite stable through time and maintain relatively high and constant faunal diversity and evenness.

Discharge benthos has, with few exceptions, been less numerous than control benthos, but has displayed the widely fluctuating seasonal densities characteristic of communities elsewhere in the study area (Figure C-9). Mean densities have ranged from about 4000 to 27,000 individuals/m^2 over the five-year period and, within a single year, they have varied by as much as 22,000 individuals/m^2. Mean density varies seasonally in a manner similar to that of the control basin, being lowest in Quarter 3 and highest in Quarters 1 or 2. It appears that maximum densities recorded in the discharge each year have continued to increase throughout the operational study, but this is probably coincidental and unrelated to plant operation.

It is obvious from discharge data that the persistence of high temperatures lowers faunal abundances during the summer. However, during most years, the differences between control and discharge densities during Quarter 3 are no greater than during other quarters.

The first year of continuous operation for Unit 3 was 1981. Unit 3 was on-line throughout the summer only during 1977 and 1981. Over the entire five-year period, Quarter 3 densities have varied by only 965 individuals/m^2, an extremely small variation compared to other quarters. In both 1977 and 1981, densities during Quarter 3 were equal to or higher than corresponding densities for 1978-1980. Thus, the additional thermal load imposed by Unit 3 does not appear to have had any greater effect on macroinvertebrate densities than the combined effects of Units 1 and 2.

Community biomass in the discharge basin has been substantially lower than control biomass during all but a few sampling periods (Figure C-9). Quarterly values for the five years have ranged from about 1 to 24 g/m^2. Annual patterns of biomass variation in the discharge basin correspond more closely to density patterns than they did in the control basin. Although values for 1981 fell within the range observed for other operational years, it appears that when Unit 3 has been operational during the summer, community biomass has been lower than when only Units 1 and 2 have been on-line.

Both diversity and evenness of benthic macroinvertebrate communities have consistently been lower in the discharge basin than in the control basin (Figure C-10). Values of both parameters have also exhibited greater seasonal fluctuations in the discharge basin. During Quarter 1 of 1981, diversity was the highest ever recorded. However, this high value was probably an artifact of more precise taxonomic work. The low diversities reported during Quarter 3 of each year probably indicate a system experiencing considerable environmental stress. However, the relatively high values obtained during other quarters suggest that community disruption is temporary, with species excluded during warm months being recruited to the area when temperatures moderate.

Comparative benthic community data do not exist for periods prior to the start-up of Unit 3. Inferences on the additional impact of its operation can only be made by comparing years of intermittent and full operation. During 1977 and 1981, Unit 3 operated continuously throughout

the summer. As water temperature attained maximum levels, benthic communities in the discharge basin experienced appreciable reductions in number of individuals, biomass and diversity. However, observed values were generally within the ranges of summer values reported for years when only Units 1 and 2 were on-line. Thus, it must be concluded that the additional thermal load created by Unit 3 has thus far had minimal impact beyond that exerted by Units 1 and 2. It should be noted that Unit 3 has never operated continuously for more than one year, and it is possible that sustained operation, especially during successive summers, may widen the zone of maximum impact. This could ultimately create a discharge community unique from those previously described.

SUMMARY

The shallow coastal waters of the Gulf of Mexico adjacent to the Crystal River Power Plant support a rich and diverse assemblage of benthic macroinvertebrates. The structure of these communities, as measured by abundance, biomass, species richness, diversity, evenness and faunal composition, often experiences marked seasonal fluctuations in response to changing environmental conditions. Community parameters are generally lowest during September, suggesting that warm summer temperatures are naturally inhibitive to a number of resident organisms.

Benthic invertebrates inhabiting a small basin adjacent to the plant discharge canal are exposed to heated effluents from three electric generating units. These communities exhibit measureably different structures from those inhabiting an area unaffected by plant discharges

(control area). During all sampling periods of 1981, community parameters of the discharge benthos were lower than corresponding values for the control benthos and, when statistical tests were applied, most of these differences were found to be significant.

The community structure of macroinvertebrates in the discharge basin was particularly disrupted during summer in apparent response to high water temperatures. Stations closest to the plant discharge were most severely impacted during this period. Density, biomass and species richness values depicted a community under severe physical stress. Due to the seasonal nature of the disruption, the community structure at these stations is probably in a constant state of transition.

Faunal differences between basins were attributed primarily to differences in water quality and environmental heterogeneity. The discharge basin represents a less complex and more physically stressed environment. It is numerically dominated by annelid worms, many of which are opportunistic forms capable of exploiting stressed environments. Other major groups are less tolerant of warmwater temperatures, and their populations decline dramatically during summer. This causes species diversity to undergo marked seasonal fluctuations. In the control basin, macroinvertebrate assemblages are composed of greater proportions of other groups such as molluscs and arthropods. Because temperature regimes there are much more tolerable, these organisms are not excluded during summer, and diversities remain high and stable through time.

Benthic macroinvertebrate assemblages within the discharge and control basins have traditionally been compared to determine the effect of plant operation on community structure. However, due to the dissimilarity of environmental characteristics between basins, these comparisons are generally inappropriate. Station 8, in the control basin, appears to be the only valid control station. Its substrate, floral characteristics and water depth closely approximate conditions at most discharge stations, but it is not exposed to the stressful summer temperatures that prevail in the discharge area. During cooler months of the year, densities in the two areas were similar, but other community parameters were consistently lower in the discharge basin. Thus, it appears that community disruption from plant operations is persistent. However, discharge benthos do have the capacity to recover from impoverished summer density levels once temperatures moderate.

Long-term data suggest that the additional thermal load imposed by Unit 3 does not further reduce density, biomass, diversity and evenness below levels observed when only Units 1 and 2 are operating. However, the zone of impact may be increased by the operation of Unit 3, and the effect of sustained operation on community structure has yet to be determined.

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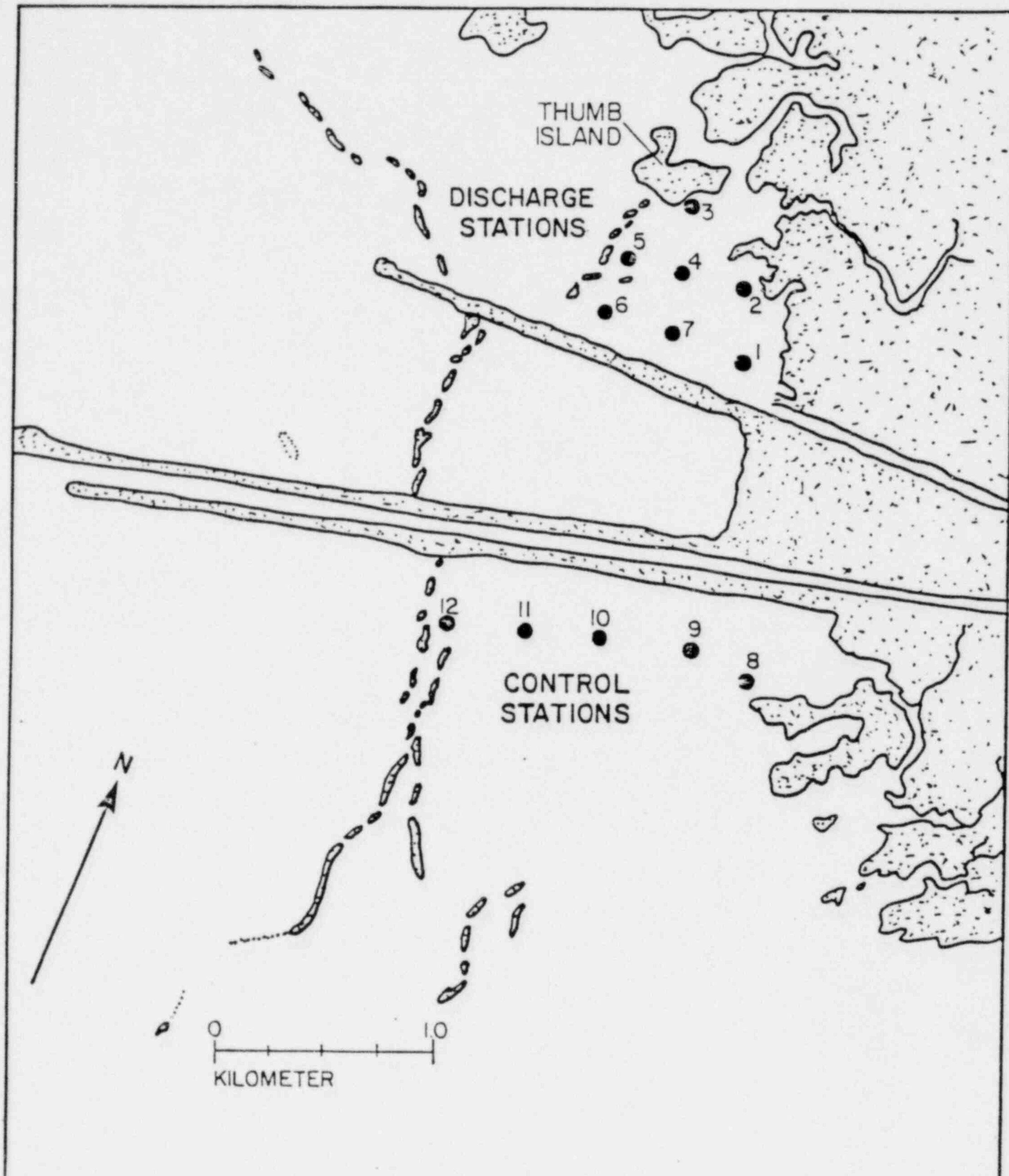

Figure C-1. Location of the 12 permanent benthic core stations, Crystal River Project, 1981.

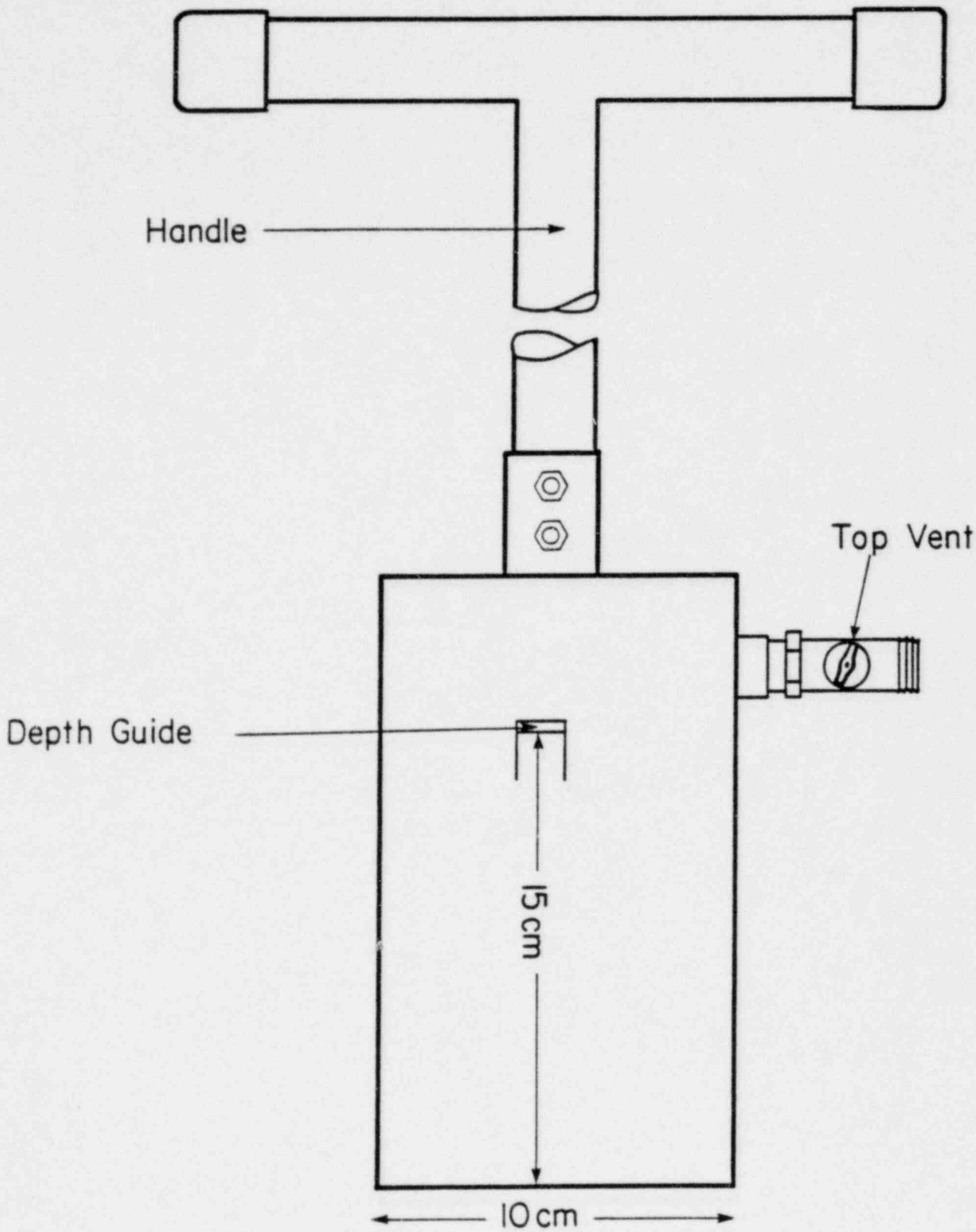

Figure C-2. Benthic core sampler, Crystal River Project, 1981.

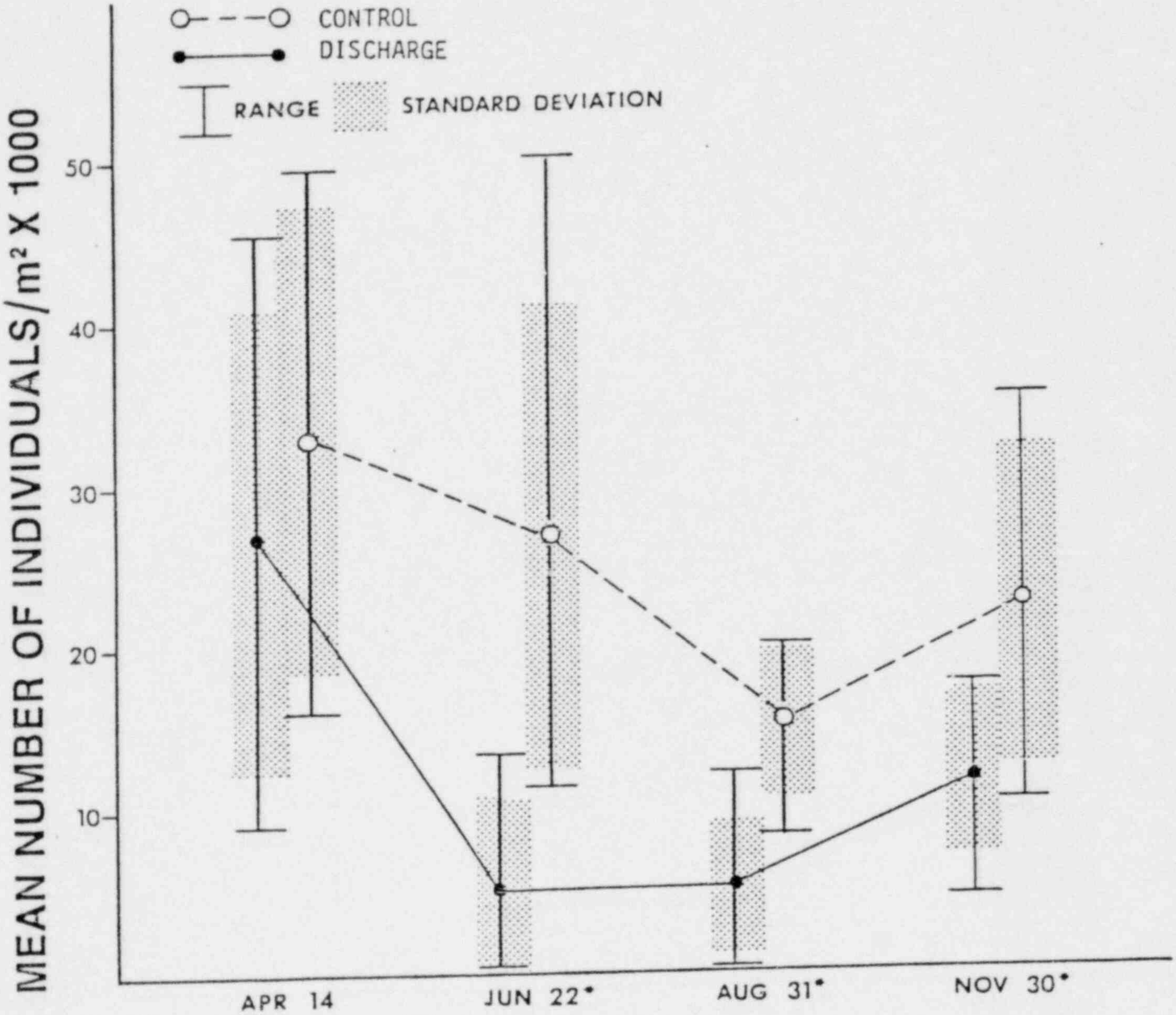

Figure C-3. Mean density of macroinvertebrates collected by benthic cores, Crystal River Project, 1981. (*Significant difference between basins)

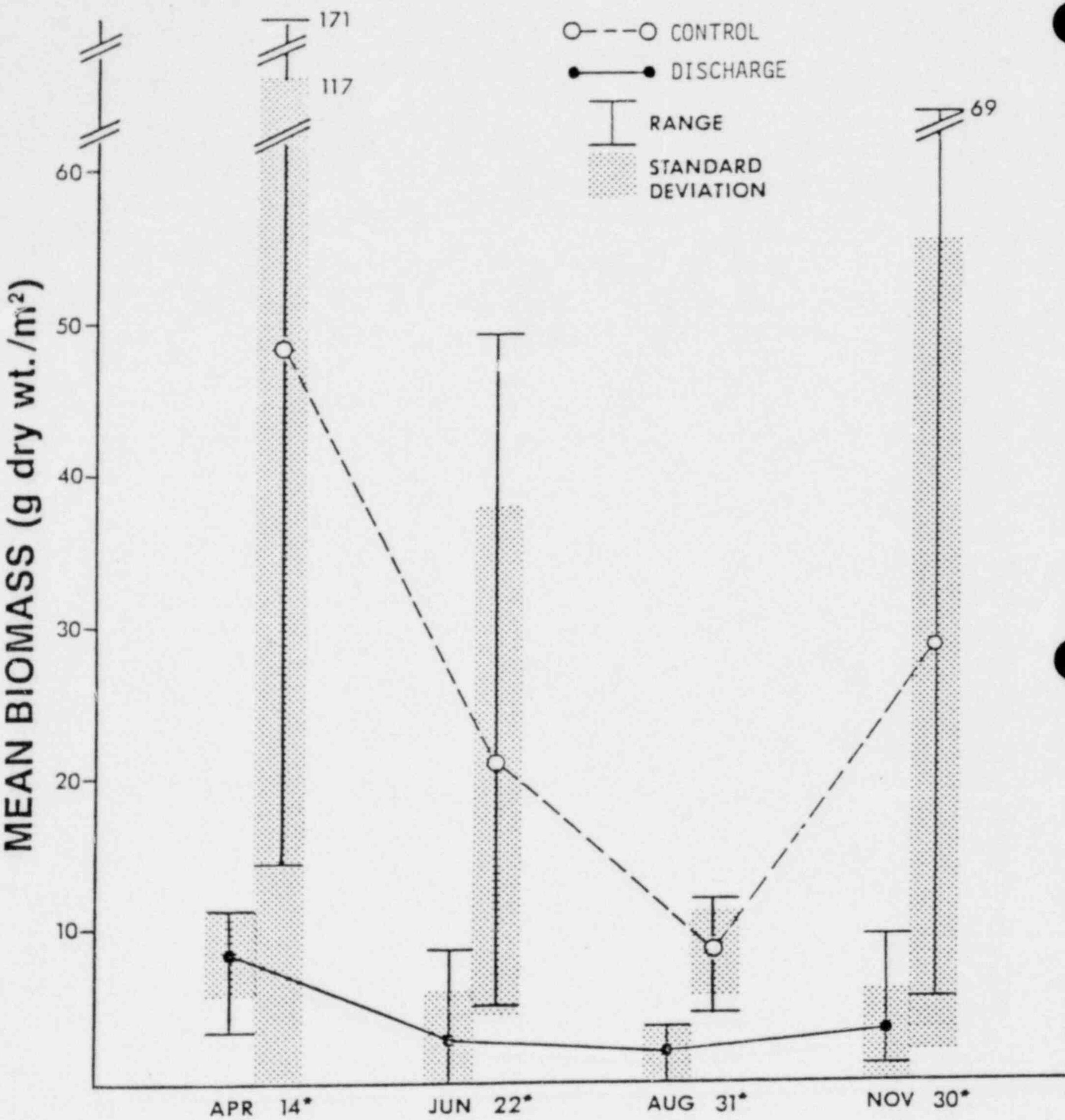

Figure C-4. Mean biomass of macroinvertebrates collected by benthic cores, Crystal River Project, 1981. (*Significant difference between basins).

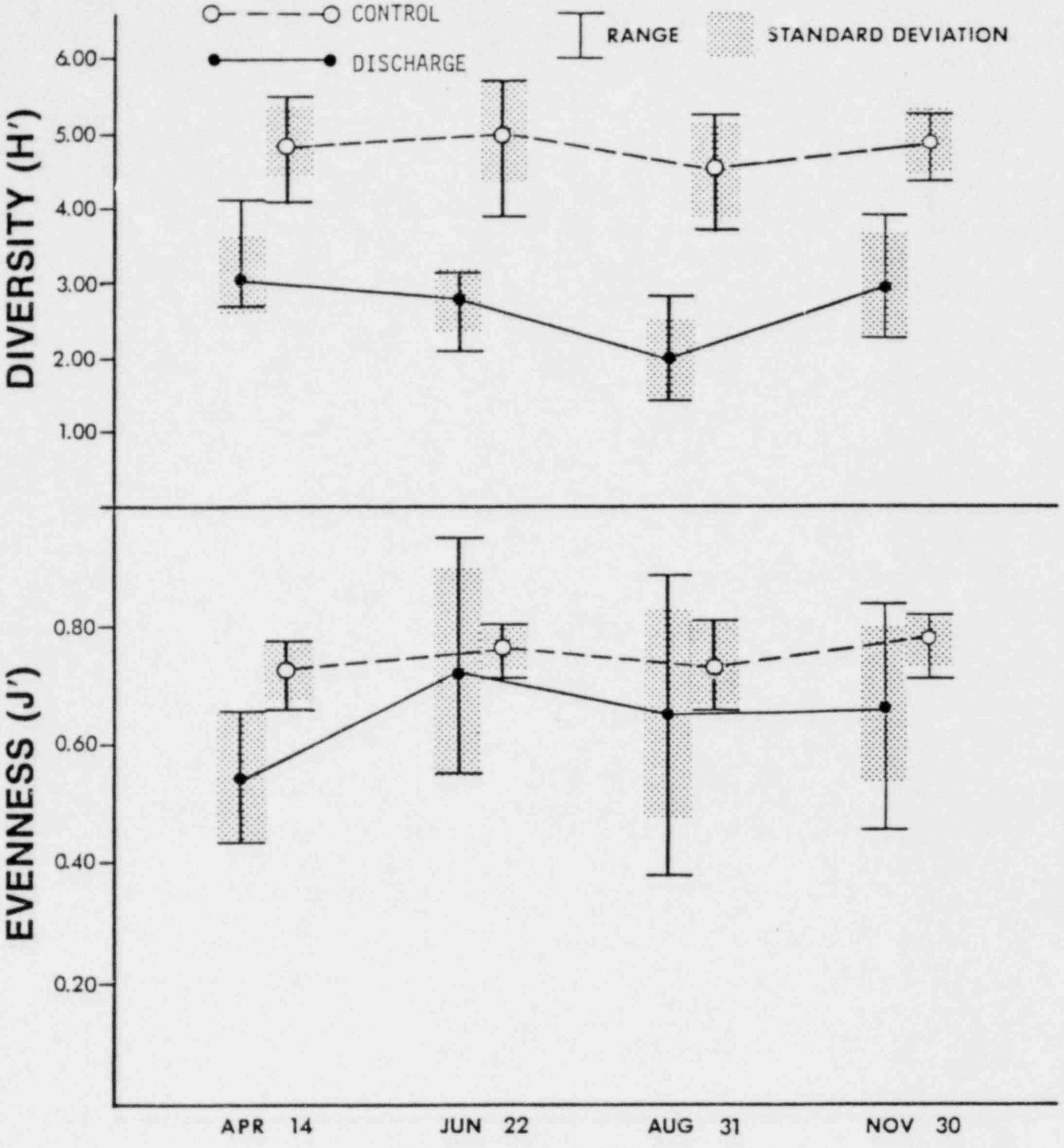

Figure C-5. Mean diversity and mean evenness of macroinvertebrates collected by benthic cores, Crystal River Project, 1981.

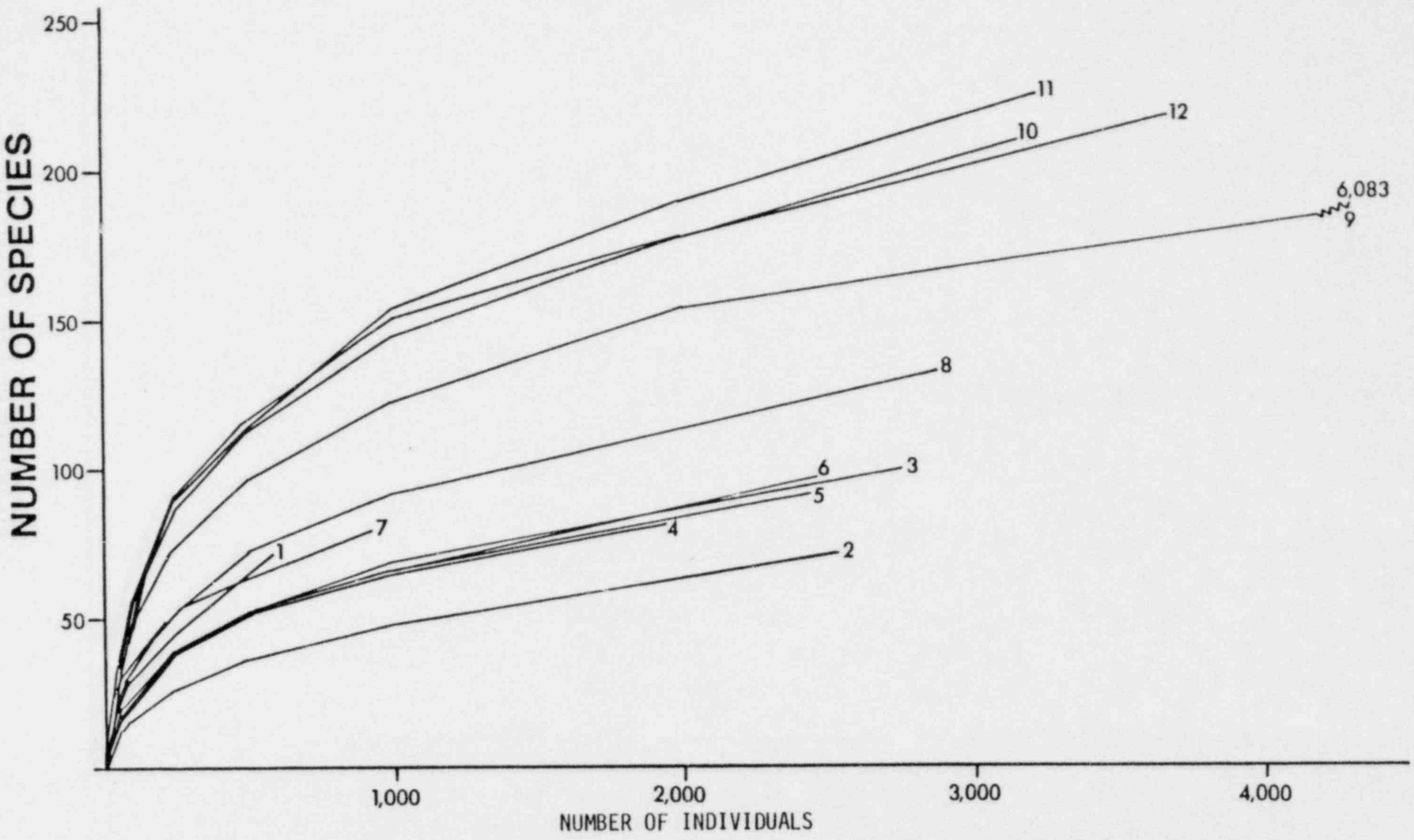

Figure C-6. Rarefaction diversity for macroinvertebrates collected by benthic cores at discharge Stations 1 through 7 and control Stations 8 through 11, Crystal River Project, 1981.

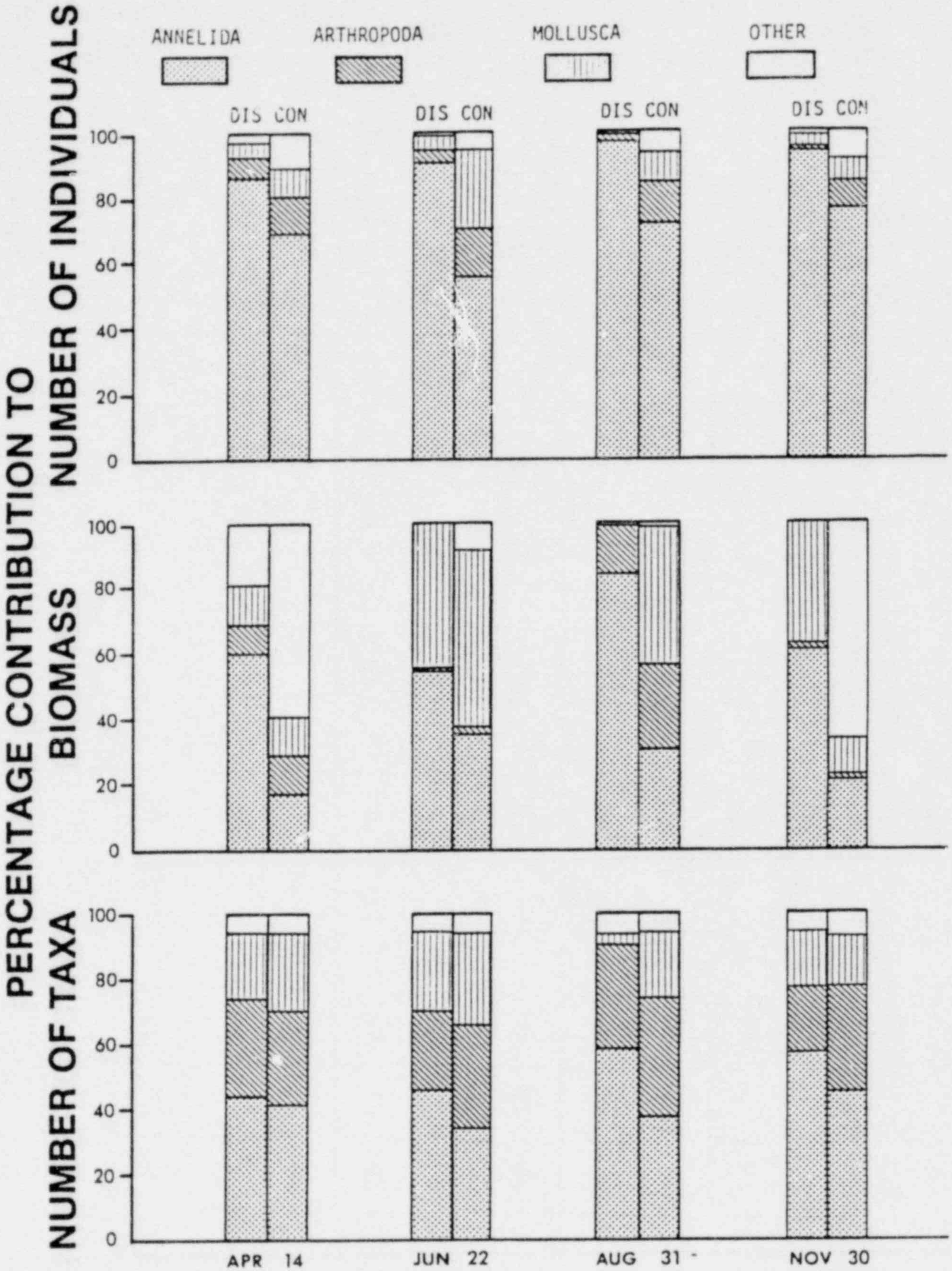

Figure C-7. Percentage contribution by major group to total faunal density, biomass and number of taxa for macroinvertebrates collected by benthic cores, Crystal River Project, 1981.

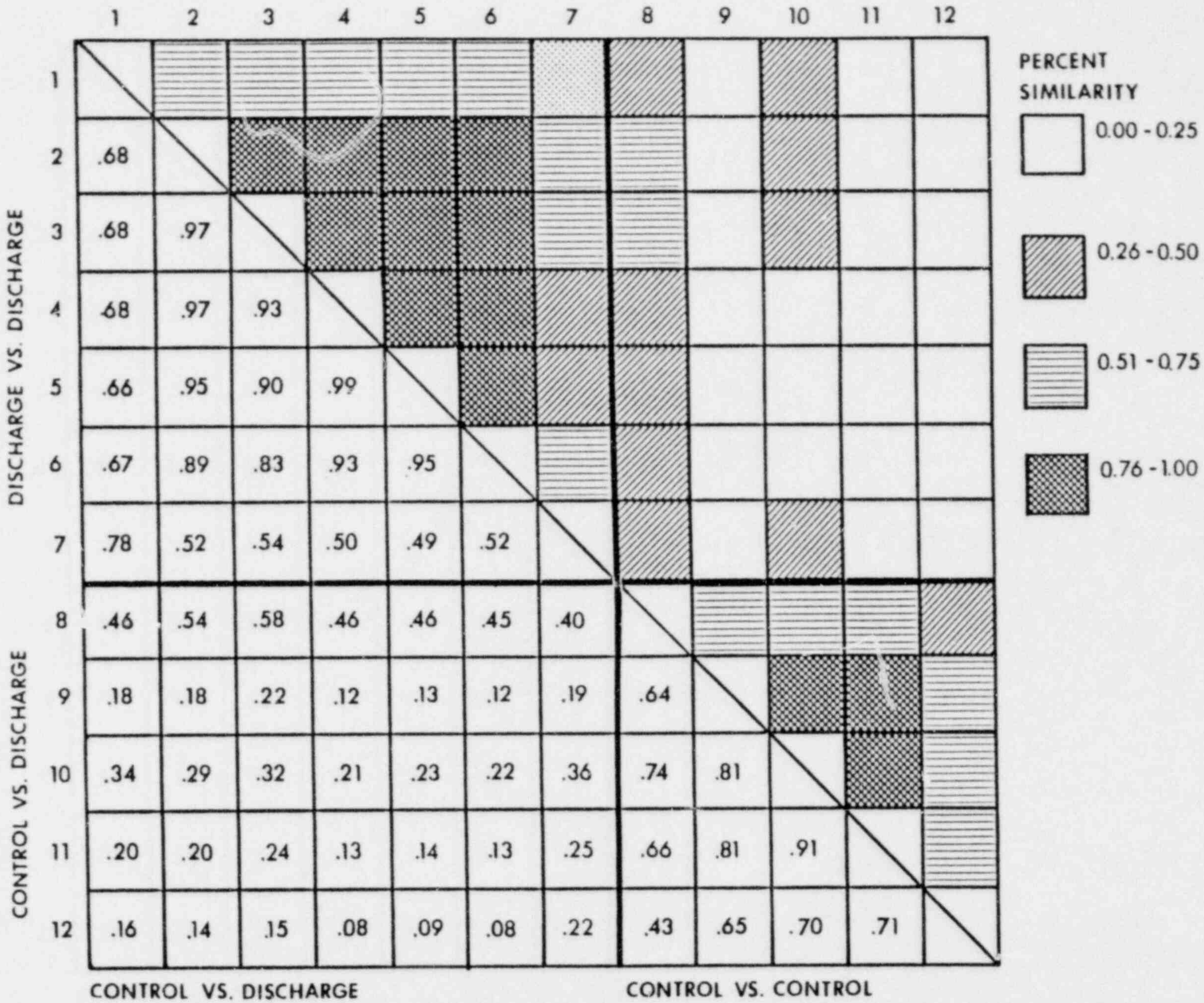

Figure C-8. Morisita indices of similarity among seven discharge and five control stations based on benthic core samples from all sampling periods, Crystal River Project, 1981.

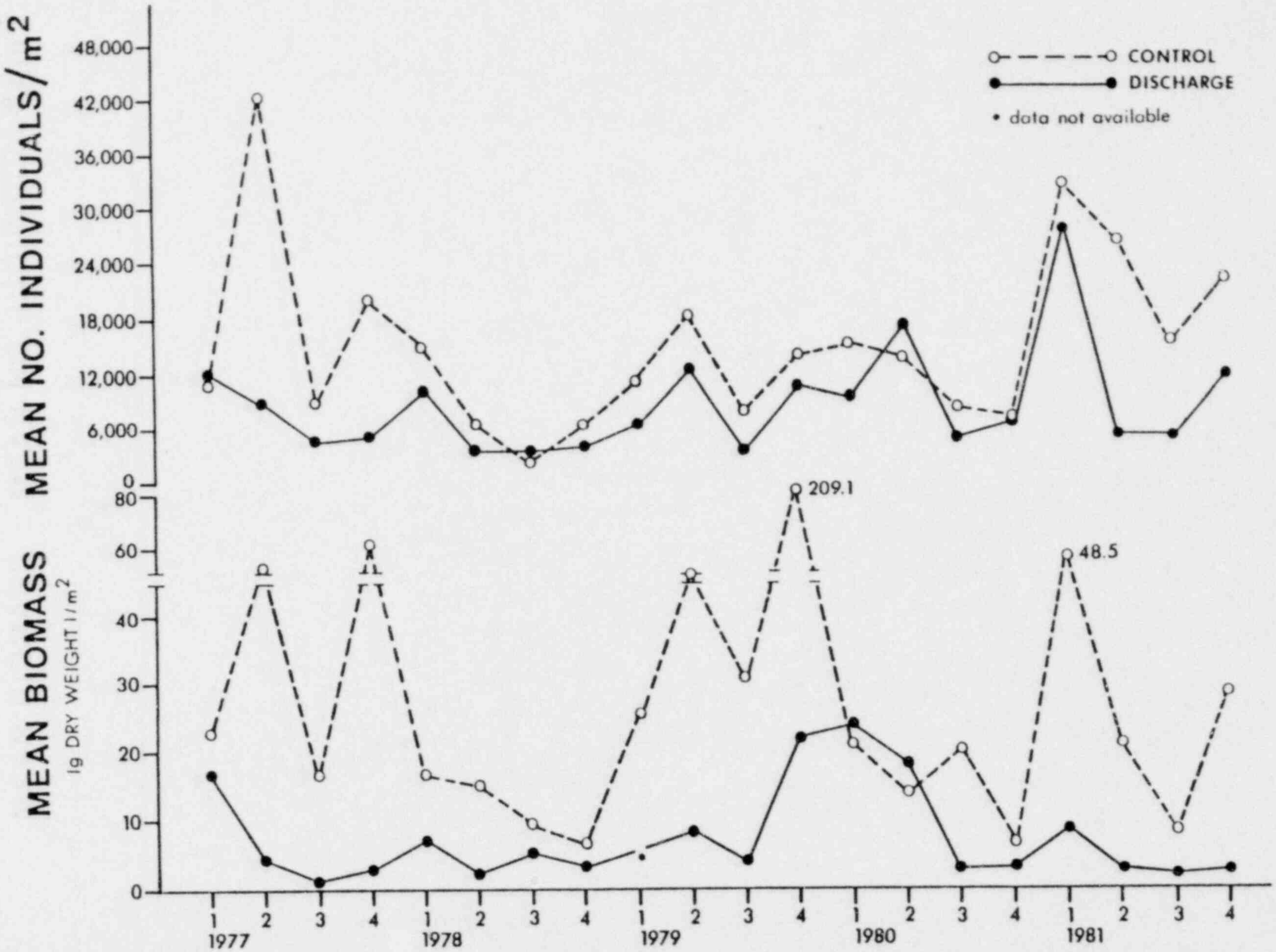

Figure C-9. Mean density and mean biomass of macroinvertebrates collected by benthic cores, Crystal River Project, 1977-1981.

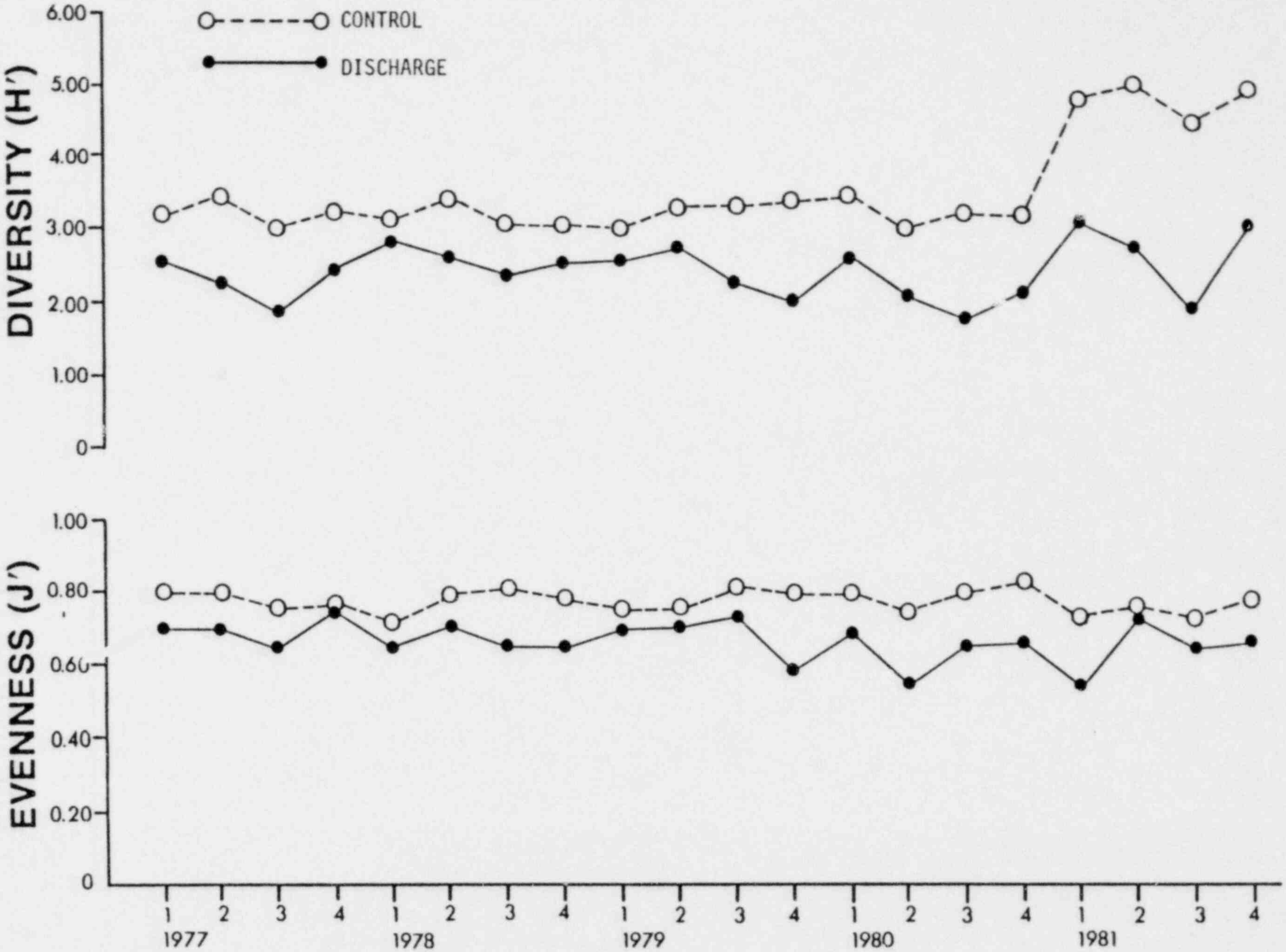

Figure C-10. Mean diversity and mean evenness of macroinvertebrates collected by benthic cores, Crystal River Project, 1977-19

TABLE C-1

TAXONOMIC LIST OF BENTHIC CORE MACROINVERTEBRATES AND
THEIR INDEX OF COMMONNESS FOR THE YEAR
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin	Taxa	Discharge basin	Control basin
ANNELIDS			ANNELIDS (continued)		
Amaeana trilobata	*	0.309	Lumbrineris spp.	*	
Amphicteis floridus	*	*	Lysidice ninetta	*	*
Arabella iricolor		0.001	Lysidice sp. A		*
Arenicola cristata		*	Magelona pettiboneae	0.004	0.479
Aricidea philbinae	35.845	5.183	Malmgrenia lunulata		*
Aricidea taylori	7.034	0.682	Marphysa sanguinea	0.047	0.055
Autolytus spp.		*	Mediomastus ambiseta	0.142	0.024
Axiothella mucosa	0.024	0.761	M. californiensis	0.141	0.087
Bhawania goodei		*	Mediomastus spp.	0.411	1.861
Boccardiella hamata		*	Melinna maculata	*	*
Boguella sp. A	0.003	0.098	Naineris cf. laevigata		*
Branchioasychis americanus	0.005	0.219	Naineris spp.	*	
Brania clavata	0.015	0.155	Neanthes acuminata	*	0.079
Cabira incerta		*	N. micromma		*
Capitella capitata	2.460	0.473	N. succinca	0.003	0.007
C. jonesi	0.009	0.005	Nematonereis hebes	0.001	*
Capitomastis aciculatus	0.005	*	Nereidae spp.		*
Carazziella hobsonae	0.032	0.359	Nereiphylla fragilis	*	0.002
Caulleriella alata		*	Notomastus hemipodus		*
C. killariensis		0.075	N. latericeus		*
Ceratonereis irritabilis		*	Odontosyllis enopla		*
Chone sp. A	0.030	0.629	Oligochaeta sp. A		0.001
Clymenella torquata	0.032	*	Onuphidae spp.	*	0.049
Diopatra cuprea	0.003	*	Onuphis simoni	0.053	1.234
Drilonereis magna		0.003	Orbiniidae spp.		*
Enoplobranchus sanguineus	*		Owenia fusiformis	0.001	
Eteone heteropoda	*	0.001	Parahesione luteola	*	0.002
Eumida sanguinea	*	0.185	Paraonides sp. A	0.016	1.278
Eunicidae sp. A		*	Paraonides sp. B	0.003	0.102
Eunicidae spp.	*	*	Paraprionospio pinnata	0.026	0.034
Exogone arenosa	*	*	Pectinaria gouldii		*
E. dispar		0.936	Phyllodoce arenae	0.007	0.003
E. verugera	*	0.111	Phyllodocidae spp.		0.003
Fabricia sp. A		*	Pista cristata	0.013	0.264
Fabriciola ? sp. A	*	*	P. palmata		*
Galathowenia sp. A	0.093	*	Platynereis dumerilii		0.016
Glycera americana	0.002	0.006	Podarke obscura		0.001
Glycinde solitaria		0.055	Polycirrus eximus		*
Grania macrochaeta		0.080	Polydora ligni	0.026	0.007
Gyptis brevipalpa	*	0.068	P. socialis	0.020	0.022
Haploscoloplos foliosus	0.010	0.168	Polynoidae sp. A		*
Haploscoloplos spp.	0.005	0.002	Polynoidae spp.		*
Heteromastus filiformis	0.564	0.002	Prionospio cirrifera	*	*
Hyboscolex longiseta		0.006	P. heterobranchia texana	0.127	2.794
Hydroides dianthus		0.020	P. pygmaea	*	
Hypsicomus phaeotaenia		*	Sabella micropthalma	*	0.009
Langerhansia cornuta	*	0.413	S. vulgaris		*
Laonereis culveri	5.727	0.222	Salmacina ? spp.		*
Lepidametria commensalis		*	Scalibregmidae sp. A		*
Loima viridis		*	Schistomeringos pectinata		*
Lumbrineris tenuis	0.039		S. rudolphi	*	0.015
L. verrilli	0.204	0.026	Scolelepis texana	0.111	0.096

TABLE C-1
(continued)
TAXONOMIC LIST OF BENTHIC CORE MACROINVERTEBRATES AND
THEIR INDEX OF COMMONNESS FOR THE YEAR
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin
ANNELIDS (continued)		
Scoloplos rubra	C.C04	0.224
Scoloplos spp.		*
Scyphoproctus sp. A		*
Scyphoproctus spp.		*
Serpulidae sp. A		0.582
Serpulidae sp. B		
Sphaerosyllis sp. A	*	0.140
S. taylori	*	0.046
Spio pettiboneae	*	*
Spiochaetopterus costarum oculatus		0.002
Spionidae spp.		0.004
Spirorbidae spp.		0.018
Streblosoma hartmanae		0.004
Streblospio benedicti	4.152	0.039
Syllidae spp.	*	*
Syllides floridanus		*
S. verrilli	*	
Syllides spp.		*
Terebella rubra		0.004
Terebellidae spp.		*
Terebellides stroemii	*	
Tharyx dorsobranchialis ?	0.400	10.460
Tubificidae spp.	0.960	9.282
Tubificoides spp.		0.674
Typosyllis annularis		0.008
Typosyllis hyalina	*	0.007
Typosyllis sp. A		0.012
Typosyllis sp. B	0.002	0.163
Typosyllis sp. C	0.023	0.622
MOLLUSCA		
Acanthochitona pygmaea		*
Acanthochitona sp. A		*
Acteocina sp. A	*	
Acteon punctostriatus	*	*
Aligena texasiana	0.005	*
Amygdalum papyrium		*
Astyris lunata	0.016	0.126
Bittium varium	*	0.027
Bivalvia spp.	0.001	0.002
Boonea impressa	*	0.008
Brachidontes spp.	*	0.123
Bulla striata	*	0.001
Bullidae spp.	*	
Caecum floridanum		*
C. pulchellum	0.008	1.488
Carditamera floridana		0.021
Cephalaspidea spp.		*
Cerithiidae spp.		*
Cerithiopsis emersoni		*
Cerithium muscarum		*
Cerithium spp.		*

Taxa	Discharge basin	Control basin
MOLLUSCA (continued)		
Circulus suppressus	*	
Codakia orbiculata		*
Costoanachis avara		*
C. semiplicata		*
Crepidula fornicata	*	
C. maculosa		0.077
C. plana	*	*
Crepidula spp.		*
Cumingia coarctata	*	*
C. tellinoides	*	*
Cyclichnella canaliculata	0.230	0.175
Cylindrobulla beauii		0.006
Dentimargo aureocincta		*
Elysia catula	0.001	*
Ensis minor	*	
Eulimidae spp.		*
Fargoa engonia ?	0.001	*
Fartulum strigosum		0.050
Gastropoda spp.	0.007	0.014
Geukensia demissa		0.003
Granulina ovuliformis		0.006
Haminoea succinea	0.120	0.035
Haminoea spp.		*
Haminoeidae spp.	*	*
Ischnochiton striolatus		0.110
Laevicardium mortoni		*
Lasaeidae spp.		0.027
Leptonidae sp. A	*	*
Leptonidae sp. B		*
Lucina nassula		*
Lyonsia floridana	*	0.009
Macoma tenta	*	*
Meloceras nitidum		0.018
Musculus lateralis		0.004
Mysella planulata	0.229	1.327
Mysella sp. A	*	
Nassarius vibex	*	*
Nuculana concentrica	*	
Nucula proxima	*	0.003
Odostomia laevigata		*
Odostomia sp. A		*
Olivella dealbata		*
O. dealbata ?		*
O. minuta		*
O. mutica		0.002
Olivella sp. A		*
Olivella sp. B		0.006
Olivella spp.		0.004
Opisthobranchia sp. A		*
Ostreola equestris		*
Oxynoidae spp.		*
Parastarte triquetra	*	
Phyllaplysia smaragda		*

TABLE C-1
(continued)
TAXONOMIC LIST OF BENTHIC CORE MACROINVERTEBRATES AND
THEIR INDEX OF COMMONNESS FOR THE YEAR
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin	Taxa	Discharge basin	Control basin
MOLLUSCA (continued)			ARTHROPODA (continued)		
Polyplacophora spp.		*	Apseudes sp. A		0.006
Prunum apicinum		0.007	Apseudes spp.		*
P. lavalleeanum		*	Asteropina setisparsa	0.035	0.024
Rissoina catesbyana		*	Bates catharinensis		0.032
Rissoina spp.		*	Bateidae spp.	*	
Sayella ? spp.		*	Bowmaniella brasiliensis		*
Semele purpurascens		*	B. dissimilis		*
Solariorbis blakei		0.003	Bowmaniella spp.		*
Stiliger sp. ?		0.001	Brachyura megalopa		0.002
Tagelus divisus	*		Branchiura spp.	*	0.002
Teinostoma biscaynensis		0.001	Calanoida spp.	0.348	0.036
Teinostoma sp. A		*	Callianassa spp.		*
Tellina alternata	*		Caprellidae spp.		*
T. mera		*	Caridea mysis	0.010	*
T. sybaritica	*	0.006	Caridea spp.	*	0.002
T. tenella		*	Carinobatea cuspidata		*
T. versicolor		*	Cerapus tubularis	*	*
Tellina spp.	*	*	Cerapus spp.	*	*
Tellinidae sp. A		*	Chirodotea arenicola ?		*
Tellinidae spp.		*	Cladocera spp.		*
Transennella conradina		*	Corophium acherusicum	*	
Turbonilla ? conradi	*	*	C. simile	*	0.040
Turbonilla dalli		*	Corophium spp.	*	0.003
T. interrupta		0.001	Cumacea sp. A		0.001
Turbonilla sp. B		*	Cyclaspis pustulata ?		*
Turbonilla sp. C		*	Cyclaspis varians	0.009	0.028
Turbonilla sp. D		*	Cyclopoida spp.	*	0.002
Turbonilla spp.		0.001	Cymadusa compta	*	0.058
Turridae sp. A		*	Cymadusa spp.	0.017	0.685
Vitrinella floridana	0.009	0.008	Cymodoce faxoni	*	0.031
Vitrinellidae spp.	*	*	Edotea montosa	*	0.011
			Edotea spp.		*
ARTHROPODA			Elasmopus levis	*	0.028
Acuminodeutopus naglei	0.009	0.154	E. rapax		*
Alpheus heterochaelis	*		Elasmopus spp.		0.005
Alpheus spp.		*	Erichsonella filiformis	0.017	0.031
Ambidexter symmetricus	*	*	Erichthonius brasiliensis	*	0.198
Ampelisca abdita	*	*	E. rubricornis		0.001
A. vadorum	*	0.013	Erichthonius spp.		0.038
A. verrilli	*	0.001	Eurypanopeus depressus		0.004
Ampelisca spp.	*	0.006	Excorallana tricornis		*
Amphilochidae spp.		*	Gitanopsis tortugae		0.028
Amphipoda spp.	*	0.014	Haplocytheridea ? sp. A	0.014	0.014
Ampithoe longimana		*	Hargeria rapax	0.003	0.034
Ampithoe spp.	*	0.006	Harpacticoida spp.	0.008	0.008
Ampithoidae spp.		*	Heterophilas seclusus		0.002
Anomura zooea	*		Hippolyte zostericola ?		0.001
Anoplodactylus pygmaeus	*		Hippolyte spp.		0.006
Anthuridae sp. A		*	Hippolytidae spp.		*
Anthuridae spp.		0.003	Hyallela azteca		*
Aoridae spp.	*	0.009	Hyalidae spp.		*
			Isopoda spp.		*

TABLE C-1
(continued)
TAXONOMIC LIST OF BENTHIC CORE MACROINVERTEBRATES AND
THEIR INDEX OF COMMONNESS FOR THE YEAR
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin	Taxa	Discharge basin	Control basin
ARTHROPODA (continued)			ARTHROPODA (continued)		
Kalliapseudes spp.		0.09	*Sarsiella* spp.		*
Lembos rectangulatus		*	Shpaeromatidae spp.		*
L. smithii		0.028	*Synchelidium americanum*	*	
Lembos spp.	0.073	0.653	Tanaidacea spp.		*
Leucothoe spinicarpa		0.017	*Tanais* sp. A	*	0.003
Libinia erinacea		*	*Taphromysis bowmani*	*	*
Listriella barnardi	*	0.034	*Upogebia affinis*		*
Luconacia ? incerta		*	*Upogebia* spp.		*
Lysianopsis alba		0.007	Xanthidae spp.	*	0.010
Melita appendiculata		0.001	*Xenanthura brevitelson*	0.007	*
M. elongata ?	*	0.011			
Melita spp.	*	0.017	MISCELLANEOUS TAXA		
Melitidae spp.		*	Porifera		
Mysidopsis bigelowi ?		0.003	Porifera spp.		*
Neopanope packardi		*	Cnidaria		
N. texana		0.003	Cnidaria spp.	*	0.008
Neopanope spp.		*	Platyhelminthes		
Notostraea spp.		0.007	Platyhelminthes spp.	*	0.006
Ostracoda sp. A		0.004	Nemertina		
Ostracoda spp.		*	Nemertinea spp.	0.108	0.617
Oxyurostylis smithii	0.035	0.057	Nematoda		
Paguroidea spp.	0.012	0.061	Nematoda spp.	0.002	4.089
Pagurus annulipes		0.001	Sipuncula		
Pagurus spp.		*	Sipuncula spp.	0.033	0.305
Palaemonidae spp.		*	Echinodermata		
Panopeus herbstii		*	*Amphioplus abditus*		0.002
Panothura formosa		0.002	*A. thrombodes*		0.002
Paracaprella tenuis	0.004	0.067	*Amphioplus* spp.		*
Parcaprella spp.		*	Amphiuridae spp.		*
Paracerceis spp.		*	*Leptosynapta* sp. A	0.194	0.063
Paraphoxus spinosus ?		0.001	*Ophiophragmus filograneus*		0.002
Paraphoxus spp.		*	Ophuroidea spp.		0.002
Parasterope pollex		*	*Thyone mexicana* ?	*	*
Periclimenes americanus	*	*	Enteropneusta		
Petrolisthes armatus		*	Enteropneusta spp.		*
Petrolisthes spp.		*	Chordata		
Philomedes paucichelata		0.017	Ascidiacea spp.		0.004
Philomedes spp.		*	*Hippocampus zosterae*		*
Photidae spp.		*	Chaetognatha		
Pinnixa chaetopterana		*	Chaetognatha spp.	0.009	*
P. sayana ?	*	*			
Pinnixa spp.	*	0.012			
Podocerus spp.	*				
Rhithropanopeus harrisii	*				
Sarsiella carinata		*			
S. zostericola	0.004	0.288			
Sarsiella sp. A		0.003			

*<0.001.

TABLE C-2

QUARTERLY COMMUNITY PARAMETERS FOR MACROINVERTEBRATES
COLLECTED IN BENTHIC CORE SAMPLES AT DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

Parameter	Quarter	Stations 1	2	3	4	5	6	7	Basin total	Basin mean
Number of individuals/m^2	14 Apr	9167	21645	35498	26356	45481	39827	12682	190656	27236.6
	22 Jun	509	13649	12936	4915	2648	1197	509	36363	5194.7
	31 Aug	688	12147	4253	7309	6112	4915	204	35628	5089.7
	30 Nov	4635	16909	17724	11001	8072	16960	7487	82788	11826.9
	Total	14999	64350	70411	49581	62313	62897	20881	-	-
	Annual mean	3749.7	16087.5	17602.7	12395.3	15578.3	15724.3	5220.3	-	12337.0
Biomass (gram dry weight/m^2)	14 Apr	8.633	3.361	11.281	7.538	7.920	10.110	11.026	59.868	8.553
	22 Jun	*	4.304	2.215	3.820	0.891	8.938	0.025	20.194	2.885
	31 Aug	*	2.445	3.310	3.463	3.336	0.840	*	13.395	1.914
	30 Nov	1.070	3.820	9.600	1.452	1.935	2.445	1.960	22.282	3.183
	Total	9.703	13.930	26.406	16.273	14.082	22.333	13.011	-	-
	Annual mean	2.426	3.483	6.602	4.068	3.521	5.583	3.253	-	4.134
Total number of taxa	14 Apr	34	44	67	52	70	75	51	137	56.1
	22 Jun	11	25	31	16	13	12	10	55	16.9
	31 Aug	7	14	16	13	10	8	3	29	10.6
	30 Nov	25	18	27	27	25	27	34	66	26.1
	Total	71	71	100	82	92	97	79	175	-
	Annual mean	19.3	25.3	35.3	27.0	29.5	30.5	24.5	-	27.4
Diversity (H')	14 Apr	3.355	2.990	3.284	2.671	2.746	2.736	4.131	-	3.131
	22 Jun	3.039	2.812	2.741	2.468	2.093	3.143	3.146	-	2.778
	31 Aug	2.293	1.470	2.845	1.843	2.044	2.016	1.406	-	1.988
	30 Nov	3.890	2.545	2.435	2.822	2.139	2.220	3.804	-	2.979
	Annual mean	2.306	2.454	2.826	2.451	2.256	2.529	3.122	-	-
Evenness (J')	14 Apr	0.659	0.548	0.541	0.469	0.448	0.439	0.728	-	0.547
	22 Jun	0.915	0.606	0.553	0.617	0.566	0.877	0.947	-	0.726
	31 Aug	0.817	0.386	0.711	0.498	0.615	0.672	0.887	-	0.655
	30 Nov	0.838	0.610	0.733	0.593	0.676	0.467	0.748	-	0.666
	Annual mean	0.807	0.538	0.635	0.544	0.576	0.614	0.828	-	-

*<0.001

TABLE C-3

QUARTERLY COMMUNITY PARAMETERS FOR MACROINVERTEBRATES
COLLECTED IN BENTHIC CORE SAMPLES AT CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

		Stations						
Parameter	Quarter	8	9	10	11	12	Basin total	Basin mean
Number of individuals/m^2	14 Apr	33130	49529	16017	21238	44538	164452	32890.6
	22 Jun	11587	50115	21722	27222	23504	134150	268[illegible].9
	31 Aug	18513	20041	15483	14082	8531	76650	15330.0
	30 Nov	10313	35218	27528	19786	17545	110390	22078.2
	Total	73543	154904	80749	82328	94119	-	-
	Annual mean	18385.7	38726.0	20187.3	20582.0	23529.7	-	24282.2
Biomass (gram dry weight/m^2)	14 Apr	21.238	17.393	18.437	14.541	171.1[illegible]	242.732	48.546
	22 Jun	4.915	19.430	16.527	15.890	49.2[illegible]	105.985	21.197
	31 Aug	4.558	8.149	10.003	11.994	[illegible]	42.348	8.470
	30 Nov	6.061	24.243	38.427	69.214	5.[illegible]22	143.266	28.648
	Total	36.772	69.215	83.394	111.639	[illegible].283	-	-
	Annual mean	9.193	17.304	20.848	27.910	[illegible].321	-	26.715
Total number of taxa	14 Apr	74	112	69	103	[illegible]	228	98.6
	22 Jun	44	108	109	133	97	223	98.2
	31 Aug	49	92	91	75	55	180	72.4
	30 Nov	55	97	100	76	87	185	83.0
	Total	33	222	210	226	219	357	-
	Annual mean	55.5	102.3	92.3	96.8	93.5	-	88.1
Diversity (H')	14 Apr	4.090	4.883	4.419	5.164	5.484	-	4.808
	22 Jun	3.901	5.119	5.278	5.663	5.090	-	5.010
	31 Aug	3.707	4.892	5.251	4.122	4.487	-	4.492
	30 Nov	4.382	4.711	5.251	4.893	5.275	-	4.903
	Annual mean	4.020	4.901	5.050	4.961	5.084	-	-
Evenness (J')	14 Apr	0.659	0.717	0.723	0.772	0.775	-	0.729
	22 Jun	0.715	0.758	0.780	0.803	0.771	-	0.765
	31 Aug	0.660	0.750	0.807	0.622	0.776	-	0.731
	30 Nov	0.758	0.714	0.790	0.783	0.819	-	0.773
	Annual mean	0.698	0.735	0.775	0.755	0.785	-	-

TABLE C-4

STATISTICAL COMPARISON OF MACROINVERTEBRATE DENSITY BY STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 14 APRIL

Source	DF	Sum of squares	Mean squares	F
Model	11	16.32313	1.48392	11.29*
Error	48	6.30808	0.13142	
Corrected total	59	22.63121		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST[a]: 14 APRIL

Grouping	Mean[b]	Station
A	48650	9
A B	45025	5
A B C	40790	12
A B C	38770	6
A B C	35155	3
B C D	28545	8
C D E	25665	4
D E F	19835	2
D E F	19235	11
E F	15935	10
F G	12435	7
G	8785	1

[a]Means with the same letter are not significantly different ($P \leq 0.05$).

[b]Geometric means of transformed replicate values ($\log_e [x+1]$) expressed as number of individuals.

TABLE C-4
(continued)
STATISTICAL COMPARISON OF MACROINVERTEBRATE DENSITY BY STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 22 JUNE

Source	DF	Sum of squares	Mean squares	F
Model	11	140.40607	12.76419	36.61*
Error	48	16.73664	0.34868	
Corrected total	59	157.14271		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST: 22 JUNE

Grouping	Mean	Station
A	40055	9
A B	25470	11
A B C	20795	10
A B C	20490	12
B C	11860	3
B C	11655	2
C	10870	8
D	4730	4
E	1835	5
E	1150	6
F	440	1
F	430	7

[a]Means with the same letter are not significantly different ($P \leq 0.05$).

[b]Geometric means of transformed replicate values ($\log_e [x+1]$) expressed as number of individuals.

TABLE C-4
(continued)
STATISTICAL COMPARISON OF MACROINVERTEBRATE DENSITY BY STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 31 AUGUST

Source	DF	Sum of squares	Mean squares	F
Model	11	87.36530	7.94230	24.32*
Error	47	15.34902	0.32657	
Corrected total	58	102.71432		

*Significant at P≤0.05.

DUNCAN'S MULTIPLE RANGE TEST: 31 AUGUST

Grouping	Mean	Station
A	15250	8
A	15210	10
A	14680	9
A B	11835	11
A B	10605	2
A B C	8460	12
A B C	7270	4
B C D	5785	5
D	4385	6
D	2960	3
E	650	1
F	230	7

[a]Means with the same letter are not significantly different (P≤0.05).

[b]Geometric means of transformed replicate values ($\log_e [x+1]$) expressed as number of individuals.

TABLE C-4
(continued)
STATISTICAL COMPARISON OF MACROINVERTEBRATE DENSITY BY STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 30 NOVEMBER

Source	DF	Sum of squares	Mean squares	F
Model	11	18.05911	1.64174	9.46*
Error	48	8.33260	0.17360	
Corrected total	59	26.39171		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST: 30 NOVEMBER

Grouping	Mean	Station
A	32955	9
A B	27105	10
B C	18660	11
B C	17190	3
B C D	15685	12
B C D	15540	2
B C D	15085	6
C D E	10450	4
D E	9320	8
E F	7545	5
E F	7135	7
F	4575	1

[a]Means with the same letter are not significantly different ($P \leq 0.05$)

[b]Geometric means of transformed replicate values ($\log_e [x+1]$) expressed in number of individuals/m^2.

TABLE C-5

DOMINANCE RANK[a] FOR TOP TEN MACROINVERTEBRATE TAXA COLLECTED BY BENTHIC CORES
CRYSTAL RIVER PROJECT
1981

	Discharge stations							Control stations					Basin	
Dominant species	1	2	3	4	5	6	7	8	9	10	11	12	Discharge	Control
ANNELIDA														
Amaeana trilobata									9					
Aricidea philbinae	1	1	1	1	1	1	1	2	7	3	6	9	1	3
A. taylori		3	2	2	2	3		7		10			2	
Axiothella mucosa										8				
Capitella capitata	2	7	9	4	5	4	6	10					5	
Carazziella hobsonae												5		
Chone sp. A												7		
Exogone dispar								9		9				
Fabricia sp. A									10		8			
Galathowenia sp. A							4							
Heteromastis filiformis		5	8	6									7	
Langerhansia cornuta										9				
Laonereis culveri	10	2	3	3	4	5	8	6					3	
Lumbrineris tenuis			10											
L. verrilli	8						3							
Marphysa sanguinea					8									
Mediomastus ambiseta				9		9	9							
M. californiensis	6													
Mediomastus spp.	7				6	8	2			5	5	6	8	6
Onuphis simoni			6						4		7			10
Paraonides sp. A								5	8					9
Prionospio heterobranchia texana					10			4	6	7		10		5
Scololepis texana				7										
Streblospio benedicti		6	7	5	3	2	5						4	
Tharyx dorsobranchialis ?		8	5					2	1	1	1	4	9	1
Tubificidae spp.		4	4		7			3	2	2	2	1	6	2
Tubificoides spp.											4			
MOLLUSCA														
Brachidontes spp.												8		
Caecum pulchellum									5			3		7
Cylichnella canalculata	4						7							
Haminoea succinea				8										
Mysella planulata					9	7				6	10			8

TABLE C-5
(continued)
DOMINANCE RANK[a] FOR TOP TEN MACROINVERTEBRATE TAXA COLLECTED BY BENTHIC CORES
CRYSTAL RIVER PROJECT
1981

	Discharge stations							Control stations					Basin	
Dominant species	1	2	3	4	5	6	7	8	9	10	11	12	Discharge	Control
ARTHROPODA														
Calanoidea spp.	3	10				6							10	
Cymadusa spp.								8						
Haplocytheridea ? sp. A		9												
MISCELLANEOUS														
Leptosynapta sp. A	5					10	10							
Nemertinea spp.	9			10										
Nematoda spp.									3	4	3	2		4

[a]Determined from Index of Commonness.

TABLE C-6

COMMUNITY PARAMETERS OF BENTHIC MACROINVERTEBRATES
AT COMPARABLE DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

	Month	Discharge basin mean (exclusive of Stations 1 and 7)	Station 8
Number of individuals/m^2	14 April	33,763	33,130
	22 June	7,069	11,587
	31 August	6,947	18,513
	30 November	14,133	10,313
	Annual mean	15,472	18,386
Biomass (gram dry weight/m^2)	14 April	8.043	21.238
	22 June	4.034	4.915
	31 August	2.679	4.558
	30 November	3.850	6.061
	Annual mean	4.652	9.193
Total number of taxa	14 April	62	74
	22 June	19	44
	31 August	12	49
	30 November	25	55
	Annual mean	30	56
Diversity (H')	14 April	2.885	4.090
	22 June	2.651	3.901
	31 August	2.044	3.707
	30 November	2.432	4.382
	Annual mean	2.503	4.070
Evenness (J')	14 April	0.489	0.659
	22 June	0.644	0.715
	31 August	0.576	0.660
	30 November	0.616	0.758
	Annual mean	0.581	0.698

D. SUCTION DREDGE

INTRODUCTION

The ecological importance of benthic macroinvertebrate communities and their usefulness as indicators of environmental perturbation were discussed previously (C. Benthic Core). The purpose of the suction dredge sampling program was to quantify the species composition, diversity, abundance and biomass of the larger benthic invertebrates in the control and discharge basins.

Because the area sampled by the suction dredge was considerably larger than that sampled by the benthic core, the suction dredge program provided more accurate data on the larger, more sparsely distributed benthic organisms. The suction dredge was also more effective than the benthic core in sampling the hard substrates that occur at several stations in the control basin. The suction dredge program thus compliments the benthic core program, which was more effective in sampling smaller organisms in soft substrate.

MATERIALS AND METHODS

Field Procedures

Suction dredge samples were collected quarterly at each of seven stations in the discharge and five stations in the control basin (Figure D-1). At each station, one sample was collected within a 15-m radius of the station marker.

Prior to sampling, a 1-m square by 0.5-m high aluminum frame box was worked into the substrate to a maximum depth of 20 cm. A Venturi-type suction dredge powered by a modified May Fluid Transformer was then used to remove all substrate and biota within the frame (Figure D-2). After the quadrat was excavated, the material retained by a 0.3-cm-square mesh collecting bag was fixed in a buffered 10 percent formalin-seawater solution containing Eosin B and Biebrich Scarlet stains (Williams, 1974).

Laboratory Procedures

In the laboratory, samples were sieved through 0.3-cm-square mesh netting material and then through a 2-mm mesh sieve to remove finer sediments. Organisms retained on the sieve were preserved in 50-percent isopropyl alcohol. All organisms were then identified to the lowest practicable taxonomic level and enumerated.

Both wet and dry weight biomass determinations were made for each major taxonomic component of each sample. Wet weights were obtained after blotting the sample with paper towels to remove excess liquid. Dry weights were obtained after drying the sample for 24 hours at 70°C.

RESULTS AND DISCUSSION

During 1981, 318 benthic taxa (Table D-1) and 20,368 individuals were collected by the suction dredge. Of these taxa, 151 were collected at discharge stations, and 287 were collected at control stations. Only 31 taxa were collected exclusively in the discharge area.

The vast majority of organisms collected by suction dredge were macroinvertebrates. However, 14 species of demersal fish and several ascideans were also represented. As in previous years, all taxa were included in 1981 data analyses.

Abundance

Mean densities of organisms in suction dredge samples varied considerably among quarters during 1981 (Tables D-2, D-3, Figure D-3). Though large seasonal fluctuations were noted in both basins, control basin densities were significantly higher than those in the discharge basin during every sampling period but April (Figure D-3).

At control stations, abundance was highest during either June or September, and, with one exception, lowest during December (Table D-2). Seasonal patterns of abundance in the control basin coincided with seasonal temperature patterns, suggesting that temperature may be important in determining fluctuations in abundance of the larger macroinvertebrate fauna.

In the discharge basin, stations closest to the discharge canal (Stations 1, 6 and 7) exhibited a uniform seasonal pattern of faunal abundance. At these stations, substantial decreases in abundance (Table D-3) coincided with large increases in temperature between April and June (Figure B-2). Temperatures remained high and faunal abundance low during September. Increases in faunal densities in December coincided with decreases in water temperature. The inverse relationship between water

temperature and faunal abundance at these stations is consistent with other studies conducted throughout Florida, which have indicated that temperatures above 32° to 33°C are harmful to local marine life when sustained over the natural tidal cycle (Bader and Roessler, 1972; Virnstein, 1972).

Seasonal patterns varied considerably among Stations 2, 3, 4 and 5 (Table D-3). At these stations, seasonal temperature fluctuations were less severe, and correlations between temperature and faunal density were less apparent. Calculated mean densities for all seven discharge stations show a seasonal pattern of faunal abundance in which densities decreased substantially in summer from spring peaks and remained low through winter (Figure D-3).

Biomass

Mean biomass values were significantly greater in the control basin than in the discharge basin during every quarter of 1981 (Figure D-4). Seasonal patterns also differed considerably between basins. In the control basin, biomass values were higher at most stations during September and December (Table D-2). No consistent relationships between density and biomass were apparent. Furthermore, fluctuations in biomass did not appear to be determined by any one environmental factor. Seasonal fluctuations in biomass may be caused by the random occurrence of a large organism in a sample or by seasonal fluctuations in densities of certain larger organisms. For example, high biomass values at Stations 9 and 10 in December were primarily due to increased densities

of large ascidians, and the substantial increase in biomass at Station 12 in December was attributable to the presence of one large specimen of the gastropod Melongena corona. A trend of increasing biomass between June and December was shown when biomass data for all control stations were combined (Figure D-4).

In the discharge basin, seasonal trends in faunal biomass were similar among stations closest to the discharge canal (Stations 1, 6 and 7; Table D-3). At these stations, fluctuations in biomass were similar to and coincided with fluctuations in faunal abundance. As with abundance, an inverse relationship between temperature and faunal biomass was shown at these stations. However, this relationship was not apparent at other discharge stations where relatively high biomass values were recorded during at least one of the two warmest sampling periods. Though considerable seasonal variation in biomass was noted at individual discharge stations, mean biomass values for the entire basin fluctuated little among quarters (Figure D-4).

Similar to the community at Station 12 in the control basin, seasonal peaks in faunal biomass at discharge stations were, on occasion, due to the presence of extremely low numbers of relatively large organisms. Because these large, sparsely distributed organisms are probably not adequately sampled even by the suction dredge, faunal biomass has limited value as an indicator of the effects of power plant effluents on the benthic communities of the study area.

Species Richness

In general, mean number of taxa (species richness) was substantially higher and less variable among quarters in the control basin than in the discharge basin (Tables D-2 and D-3). In the control basin, numbers of taxa were highest at most stations during the warmer sampling periods (June and September) and lowest during the cooler periods (April and December). This suggests a direct relationship with water temperature. Total number of taxa for the entire control basin varied little among the first three quarters but decreased somewhat in December. Decreased number of taxa in December coincided with a substantial decrease in bottom water temperature during that quarter, again suggesting that temperature may be important in determining the number of taxa present.

All discharge stations exhibited a uniform pattern of seasonal variations in number of taxa (Table D-3). Species richness at all stations was highest during April, decreased steadily through June and September then increased in December. Declines in species richness between April and June coincided with increases in temperature (Figure B-2). Bottom water temperatures exceeded 33°C at all discharge stations during June. Decreases in species richness during June were probably related to high temperatures, because temperatures greater than 32°C have been shown to be harmful to marine life (Bader and Roessler, 1972), and temperatures of 32° to 33°C have been associated with decreases in number of benthic species (Virnstein, 1972). Further declines in species richness during September were probably due to sustained high temperatures throughout the summer. Decreases in bottom water temperatures in

December coincided with increases in species richness at all discharge stations. It is probable that as temperatures became more tolerable in fall, new taxa were recruited into the discharge area.

Diversity and Evenness

During 1981, mean diversity values for the control basin were higher and less variable than those for the discharge basin (Figure D-5). Little variation in evenness values was noted among quarters in either basin; however, evenness was consistently higher in the control basin. Overall diversities for all stations sampled during 1981 were graphically compared using the rarefaction method of Sanders (1968). Rarefaction curves indicated that discharge stations were less diverse than control stations (Figure D-6). This was substantiated by the fact that annual mean diversity values were greater than 4.0 at all control stations and less than 4.0 at all discharge stations (Tables D-2, D-3). Rarefaction diversity at control Station 8 was similar to that of the discharge stations, probably as a result of their very similar substrates.

With the exception of Station 12, control station diversity values were highest in September and lowest in December, although differences among quarters were slight (Table D-2). Diversity values at Station 12 varied considerably among quarters and were highest in December and lowest in June. The relatively low diversity at Station 12 during June was apparently the result of decreased numbers of polychaete taxa and increased dominance of the mussel Brachidontes spp. Relatively high numbers of Brachidontes in June probably reflect natural seasonal variation

in density because a similar increase occurred during June at Station 11 (the only other station in which *Brachidontes* was collected in large numbers). A decline in the number of polychaete taxa present at Station 12 in June coincides with the period of highest water temperature, suggesting an inverse relationship with temperature. However, numbers of polychaete taxa at other control stations were not depressed in June. Some unknown, more localized factor was probably responsible for the decline in polychaete taxa at Station 12. Mean diversity values for the control basin varied little among quarters and remained high throughout 1981.

In general, evenness values remained high throughout the year at all control stations (Table D-2). The only exception occurred at Station 12 in June when increased numbers of *Brachidontes* resulted in a relatively low evenness value. Mean evenness values for the control basin varied only slightly among quarters and remained high throughout the year (Figure D-5).

In the discharge basin, diversities were highest at most stations during April, decreased through June and September, then increased in December (Table D-3). Mean diversity values for the entire basin varied in the same manner (Figure D-5). As with species richness, an inverse relationship between bottom water temperature and diversity was indicated.

Fluctuations in diversity usually coincided with fluctuations in species richness (Table D-3). An exception was noted at Station 7 where, although species richness was highest during April, diversity was lowest. Nevertheless, diversity values were very low at most discharge stations during June and September, apparently as a result of reduced numbers of taxa. As has already been discussed, these reductions are probably associated with high summer water temperatures.

Within the discharge basin, summer diversity values were least reduced at Station 3 (Table D-3). This was probably related to this station being farthest from the discharge and having the lowest summer water temperatures. Conversely, summer diversity values were most reduced at the stations experiencing the highest summer water temperatures.

Evenness values varied considerably among quarters at most discharge stations; however, no distinct seasonal pattern was indicated (Table D-3). It should be noted that a number of evenness values may be artificially high due to extremely small sample size. The EPA (1973) suggests that samples containing less than 100 specimens should be evaluated with caution.

Community Composition

Annelids usually dominated the number of individuals and number of taxa in the discharge basin, but no one group consistently dominated these parameters in the control basin (Figure D-7). Considerable seasonal variation in the contribution of each major group to total biomass was noted for both basins.

In the control basin, seasonal shifts in the contribution of major groups to total faunal density were shown (Figure D-7). These shifts were most probably attributable to natural seasonal variations in the density of dominant taxa. No one group appeared to be highly dominant because no group contributed more than 60 percent to total faunal density during any quarter. In general, numerical dominants were annelids in April, arthropods in June, and a combination of molluscs and arthropods in September. During December, the four major groups contributed about equally to the number of individuals.

Annelids dominated the number of individuals in the discharge basin, accounting for at least 73 percent of all individuals collected each quarter (Figure D-7). During June and September when water temperatures were highest, over 90 percent of the total faunal density in the discharge basin was contributed by annelids, suggesting that members of this group are more tolerant of thermal stresses than are other groups. Rosenberg (1976) reported that annelids were frequently the last group excluded from stressed environments and the first group to recolonize these areas when pollution had abated. The contribution of other groups to total density was highest in the discharge basin during December when temperatures were lowest.

Percentage contribution to biomass varied considerably among quarters in the control basin (Figure D-7). Because of their small size, relative to other groups in the control basin, annelids consistently contributed little to total faunal biomass. The large contribution by

miscellaneous taxa in April and June was primarily due to the presence of a few large ophiuroids, ascidians and demersal fish. In September, the presence of relatively large numbers of molluscs accounted for the major contribution to total biomass. Miscellaneous taxa and molluscs dominated the biomass in the control basin during December. The increased numbers of ascidians in December accounted for nearly 90 percent of the biomass attributable to miscellaneous taxa, and the chance collection of one large specimen of the conch Melongena corona accounted for much of the total molluscan biomass.

In the discharge basin, the presence of relatively large numbers of annelids, as well as the absence of any particularly large individuals in other major groups, accounted for the relatively high annelid component of biomass in April (Figure D-7). Relatively large contributions to total biomass during the remaining quarters were caused by the collection of a few large individuals.

Contributions of each major group to total number of taxa in the control basin changed little among quarters (Figure D-7). No one group was highly dominant over another during any quarter. The relatively even distribution of taxa among the major groups may reflect the greater diversity of habitats in the control basin. The presence of both hard and soft substrates and a diverse and productive assemblage of macrophytes in the control basin provides potential habitats for a variety of benthic organisms.

In the discharge basin, annelids predominated total number of taxa during each of the first three quarters of 1981 (Figure D-7). The relatively large proportions of annelid taxa may be attributable to the ability of members of this group to tolerate periods of thermal stress as well as the preference of many annelid species for soft substrates such as those that predominate in the discharge basin. The more even distribution of taxa among the major groups in December may be related to decreased water temperature in the discharge basin during this period. This decrease allowed species from groups previously excluded by high temperatures and low dissolved oxygen concentration to be recruited into the discharge basin.

Dominance

Considerable shifts in dominance occurred between quarters in both basins (Table D-4). However, the majority of the dominant taxa in the discharge basin were always annelids. A more equal distribution of dominants among annelids, molluscs and arthropods usually occurred in the control basin. Few dominant taxa were shared between basins during any quarter. When the 10 dominant taxa for the entire year were determined for each basin, Onuphis simoni and Pista cristata were found to be shared. Differences in dominants between basins are probably attributable to previously discussed differences in substrates and temperature regimes between the two areas.

Community Similarity

Morisita indices of community similarity were usually quite low when discharge stations were compared to control stations (Figure D-8). Of all control stations, the fauna at Station 8 was the most similar to those of the discharge stations. This was probably because substrates at control Station 8 were nearly identical to those in the discharge basin (I. Sediments). The influence of substrate on faunal composition is universally acknowledged (Sanders, 1958; McNulty et al., 1962; Bloom et al., 1972). Among discharge stations, Station 3 generally showed the highest faunal similarity with the control basin. This was probably because Station 3 was the most similar to the control basin with respect to macrophyte biomass. The relationship of plant biomass and epibenthic community structure is also well recognized (Heck and Wetstone, 1977; Gore et al., 1981). Furthermore, because Station 3 was the farthest removed of any discharge station from the point of discharge, the benthic fauna there would be expected to be less directly affected by thermal stress. The effects of thermal stress on benthic communities have been documented by Warinner and Brehmer (1966), Bader and Roessler (1972), Virnstein (1972) and Blake et al. (1976).

Within the discharge basin, the faunas of Stations 1 and 7 were most similar to each other and notably dissimilar from those of other discharge stations. This may be related to the effects of thermal discharges on both the macroinvertebrates themselves and the macrophytes that provide food and shelter. Stations 1 and 7 had the highest maximum temperatures and the lowest macrophyte biomass of all discharge stations

(E. Macrophyte Biomass). Among other discharge stations the benthic communities at Stations 1 and 7 were most similar to the benthic community at Station 6. Maximum summer water temperatures at Stations 1 and 7 most closely approximated those at Station 6. Again, temperature is suggested as important in determining benthic community structure.

Variations in community parameters among stations in the control basin were apparently not due to local differences in physicochemical characteristics of the water. Rather, these differences appear to be attributable to physical differences in substrates among stations. Control basin substrate types range from muddy sediments dominated by seagrasses (Station 8) to mostly rock and oyster shell outcroppings supporting dense beds of algae (Stations 12). Such divergent habitats would be expected to support relatively different benthic communities. Low community similarity among several control stations (Figure D-8) supports this premise.

Operational Trends

During operational monitoring (1977-1981), mean numbers of individuals in suction dredge samples have been consistently higher in the control basin than in the discharge basin (Figure D-9). Differences between basins during June and September of 1981 were the greatest since 1977, the last time that Unit 3 was operational throughout the summer. Though biomass was generally higher in the control basin than at the discharge basin during operational sampling, no consistent long-term or seasonal trends were apparent (Figure D-9).

Higher mean diversity values were recorded during 1981 than during any other year of operational monitoring (Figure D-10). This was probably accounted for by more precise taxonomic analysis during 1981. Diversity values have been consistently higher in the control basin than in the discharge basin throughout operational monitoring. Again, differences between basins were greatest during June and September of 1981 than in any year since 1977. During every year of monitoring, diversity in the discharge basin has decreased from June to September and increased from September to December. The lowest discharge diversity values for each year of study were recorded in September. This consistent seasonal pattern probably reflects the seasonal influence of heated effluents from the power plants.

Though evenness values were usually greater in the discharge basin than in the control basin prior to September 1979, control basin evenness has remained higher than discharge basin evenness since that time. However, discharge values may be artificially high as a result of the small size of the samples collected in June and September.

Preoperational Comparisons

Suction dredge data show that quarterly mean densities of the benthic organisms in the discharge basin were consistently higher during 1981 than during the preoperational period (Figure D-11). Because a similar trend was shown in the control basin (Figure D-12), this probably reflects overall higher densities throughout the study area during 1981.

Mean biomass values for the discharge basin were also consistently higher during 1981 than during the preoperational study (Figure D-13). However, preoperational means were consistently within two standard deviations of corresponding 1981 means. Preoperational mean biomass values for the control basin also remained within two standard deviations of 1981 means (Figure D-14). However, 1981 values were somewhat lower than preoperational values in June and considerably higher than preoperational values in December. This may either reflect long-term natural variability or result from the chance occurrence of one or two large organisms in suction dredge samples.

SUMMARY

The number of individuals collected by suction dredge in the control basin was significantly greater than in the discharge basin during the last three quarters of 1981. Biomass was significantly greater in the control basin during all quarters. Diversity and evenness were also consistently higher in the control basin. The variation of community parameters among control basin stations appeared to be largely controlled by differences in the substrate. Variations among discharge basin community parameters appeared to be a result of exposure to thermal effluents. Stations located closest to the discharge canal generally exhibited lower density, biomass, number of taxa and diversity than did stations farther away from the point of discharge. Densities, species richness and diversity at most discharge stations were lowest in the summer when thermal effluents elevated already high ambient water temperatures beyond tolerable levels. During winter as water temperatures moderated, diversities generally returned to springtime high levels.

The benthic community of the discharge basin was dominated by annelids and other taxa adapted to life in soft substrates. These soft substrates were available at every discharge station. At the control stations, the members of the benthic community were more evenly distributed among the major taxonomic groups, no one group maintaining dominance over the other groups throughout the year. This was attributed to the greater variety of substrate types in the control area.

Data collected in 1981 depicted a benthic fauna more abundant and diverse than those reported by previous preoperational and operational studies. Seasonal variation in community parameters followed patterns similar to those previously reported. In 1981, differences between discharge and control basin density and diversity were the greatest observed since 1977, the last year that Unit 3 was operational throughout the summer. Thus, it appears that effluents from Unit 3 have created additional thermal stress upon benthic communities inhabiting the discharge basin. However, deleterious effects were localized to the area immediately adjacent to the discharge canal. Communities at stations farthest from the point of discharge exhibited characteristics similar to those of a community inhabiting a comparable area in the control basin.

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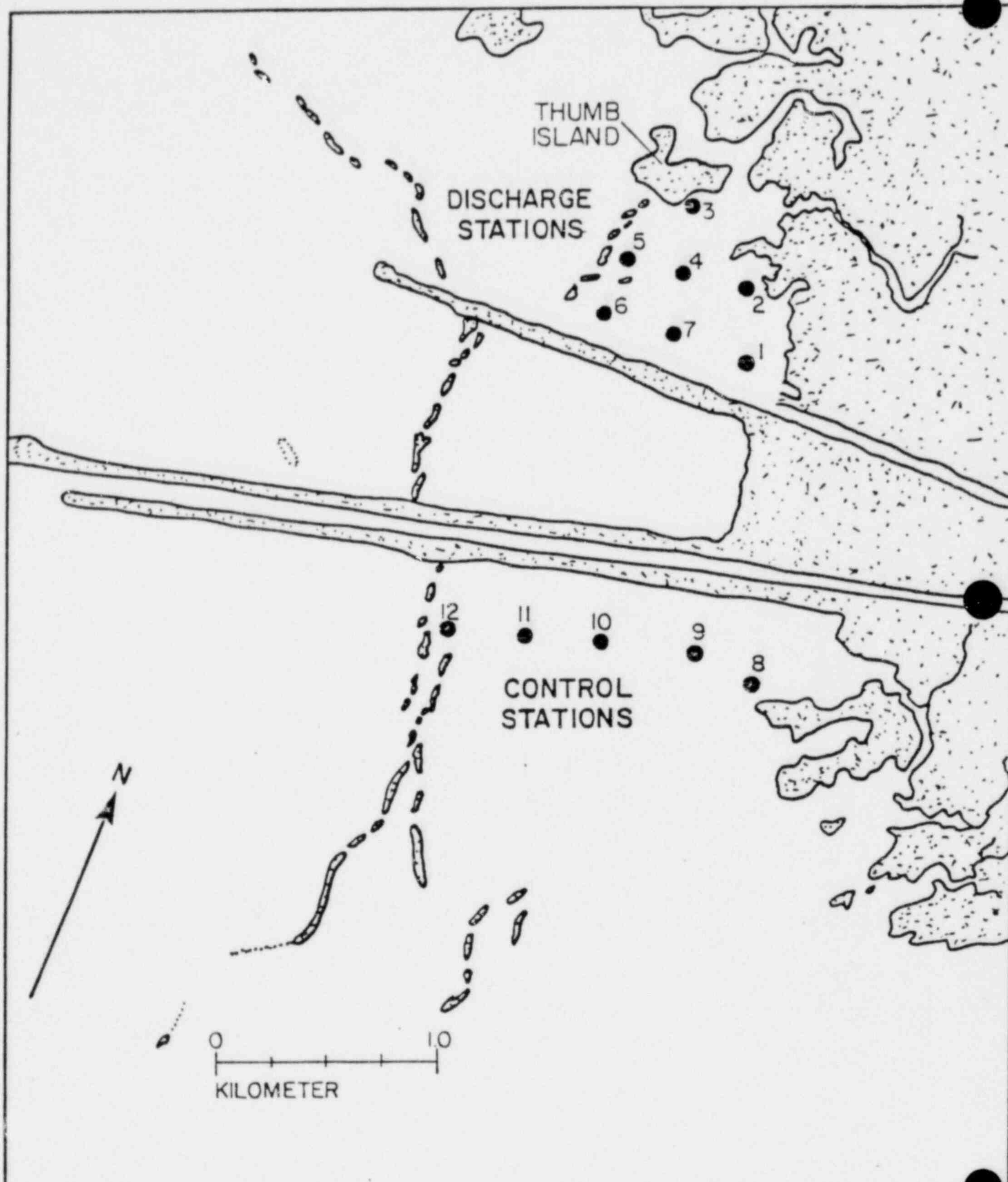

Figure D-1. Location of the 12 permanent stations used for collecting suction dredge samples, Crystal River Project, 1981.

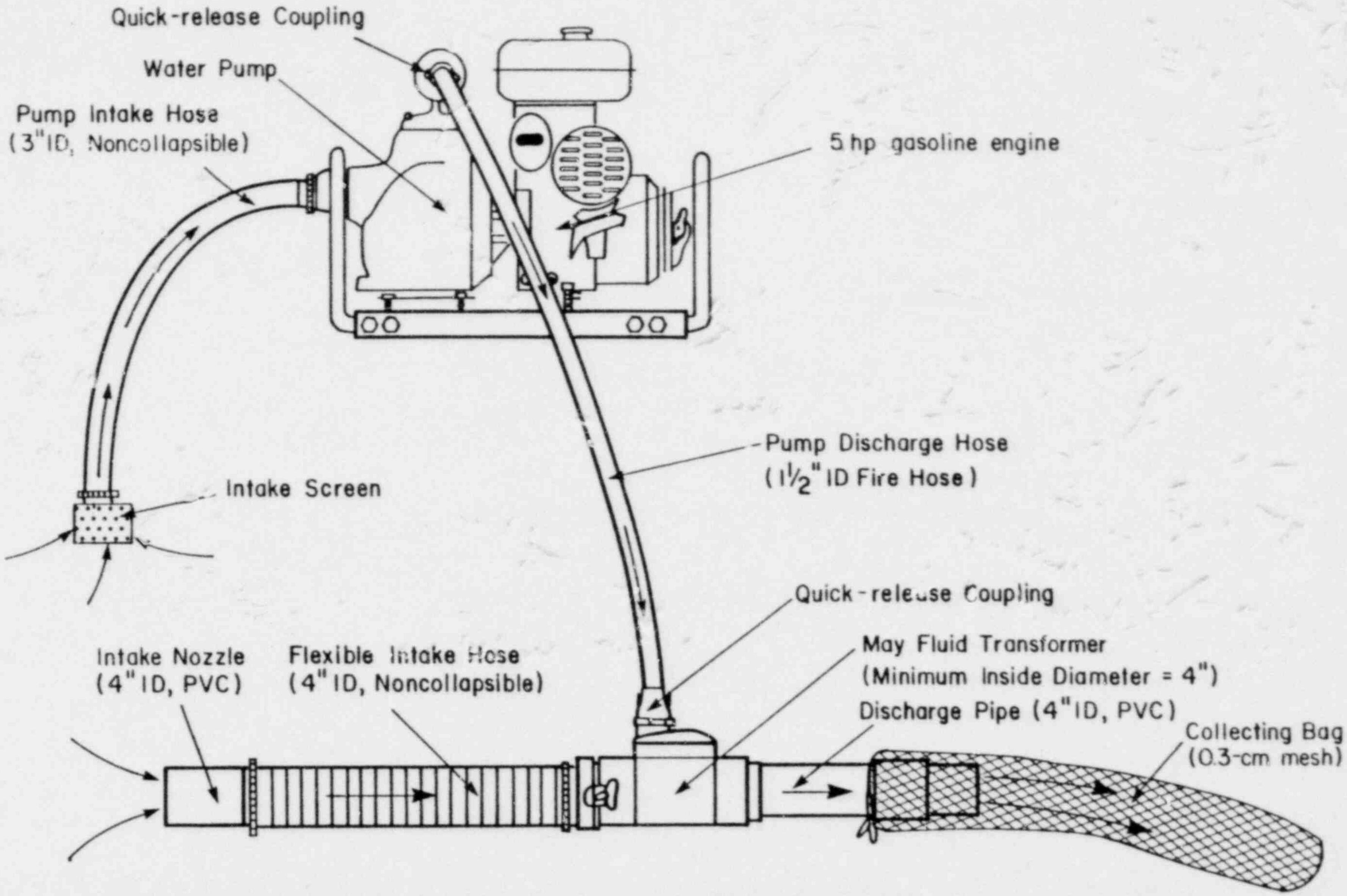

Figure D-2. Suction dredge (arrows indicate direction of flow), Crystal River Project, 1981.

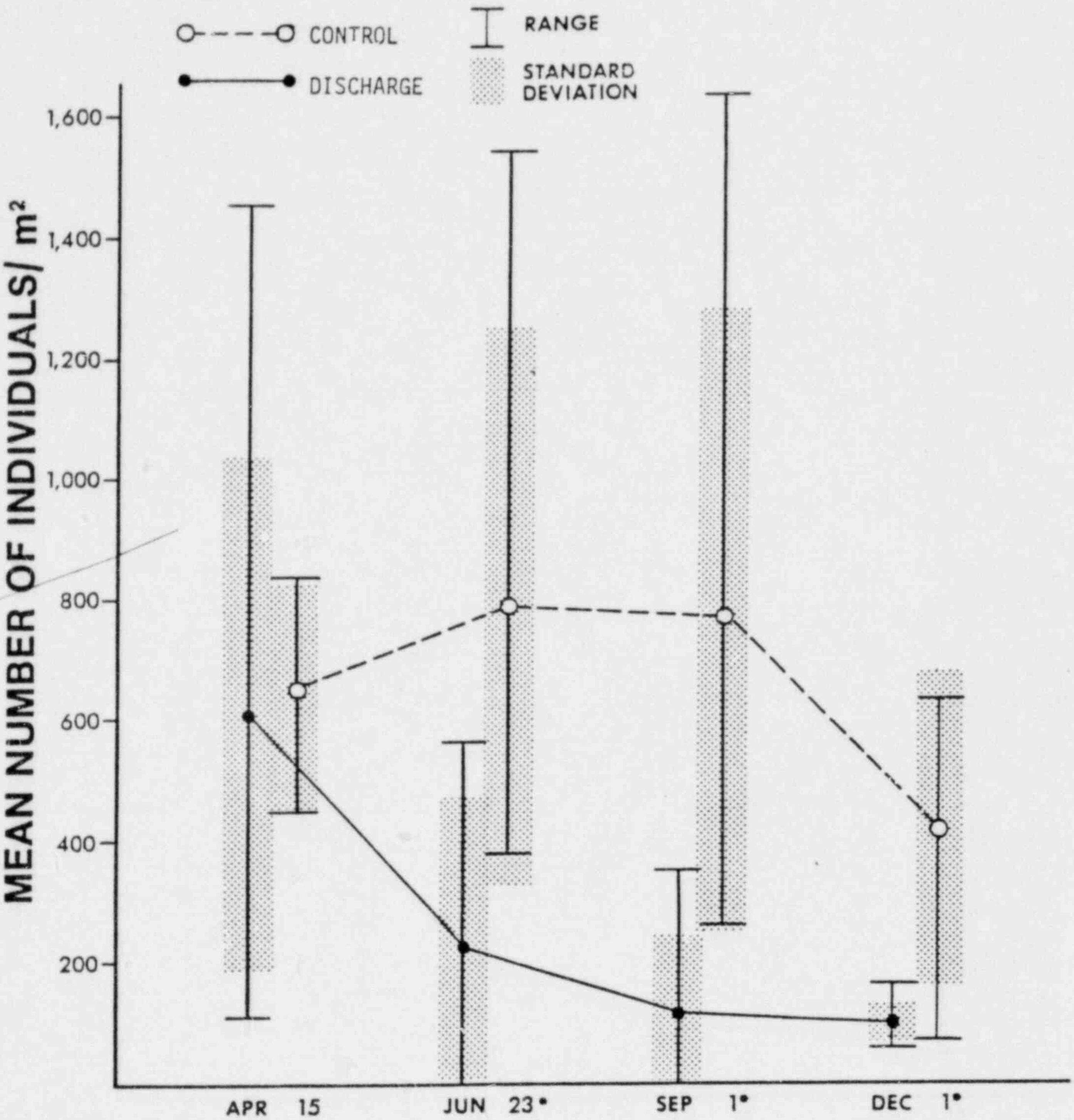

Figure D-3. Density of benthic fauna collected by suction dredge, Crystal River Project, 1981. (*Significant difference between basins).

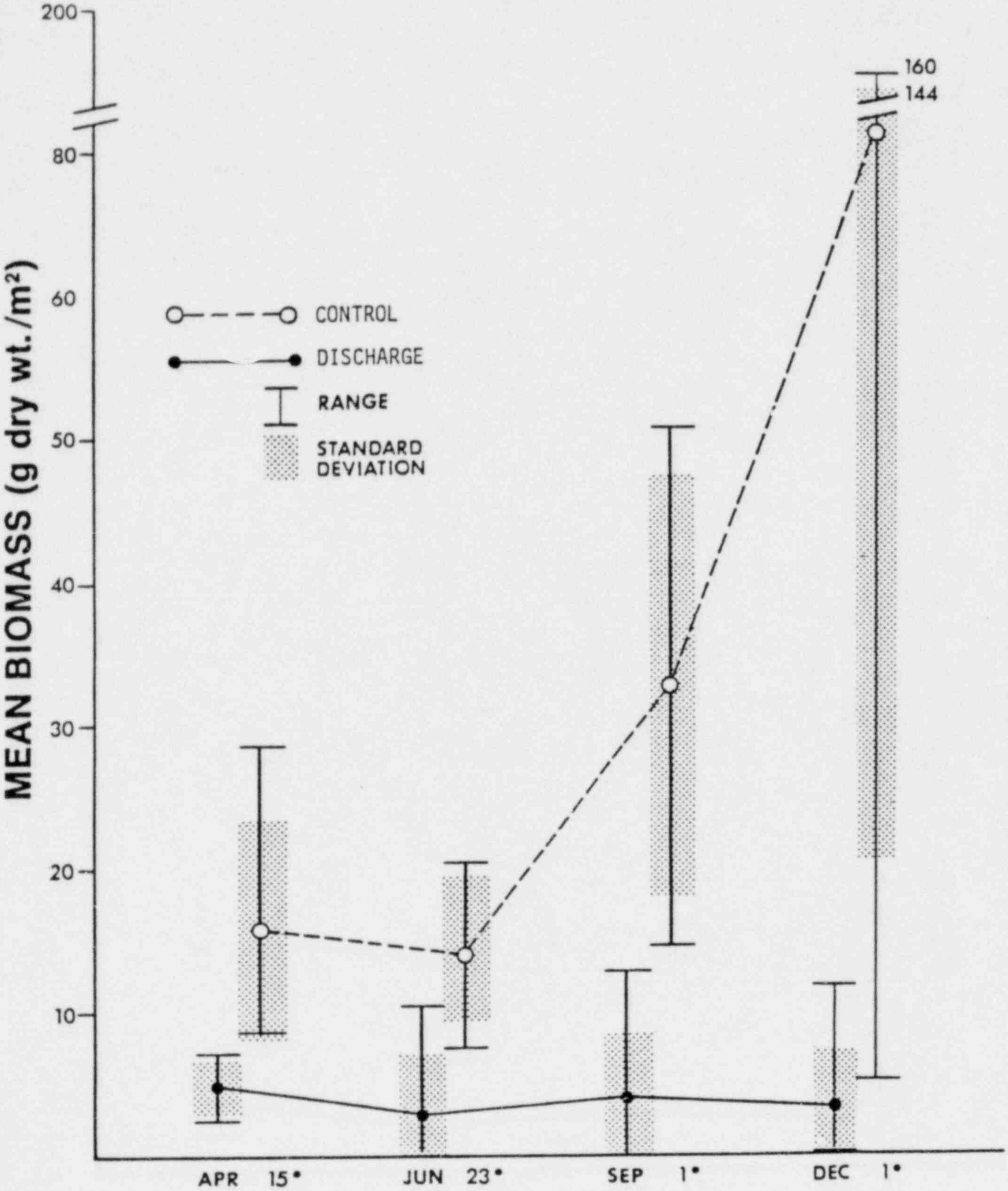

Figure D-4. Mean biomass of benthic fauna collected by suction dredge, Crystal River Project, 1981. (*Significant difference between basins).

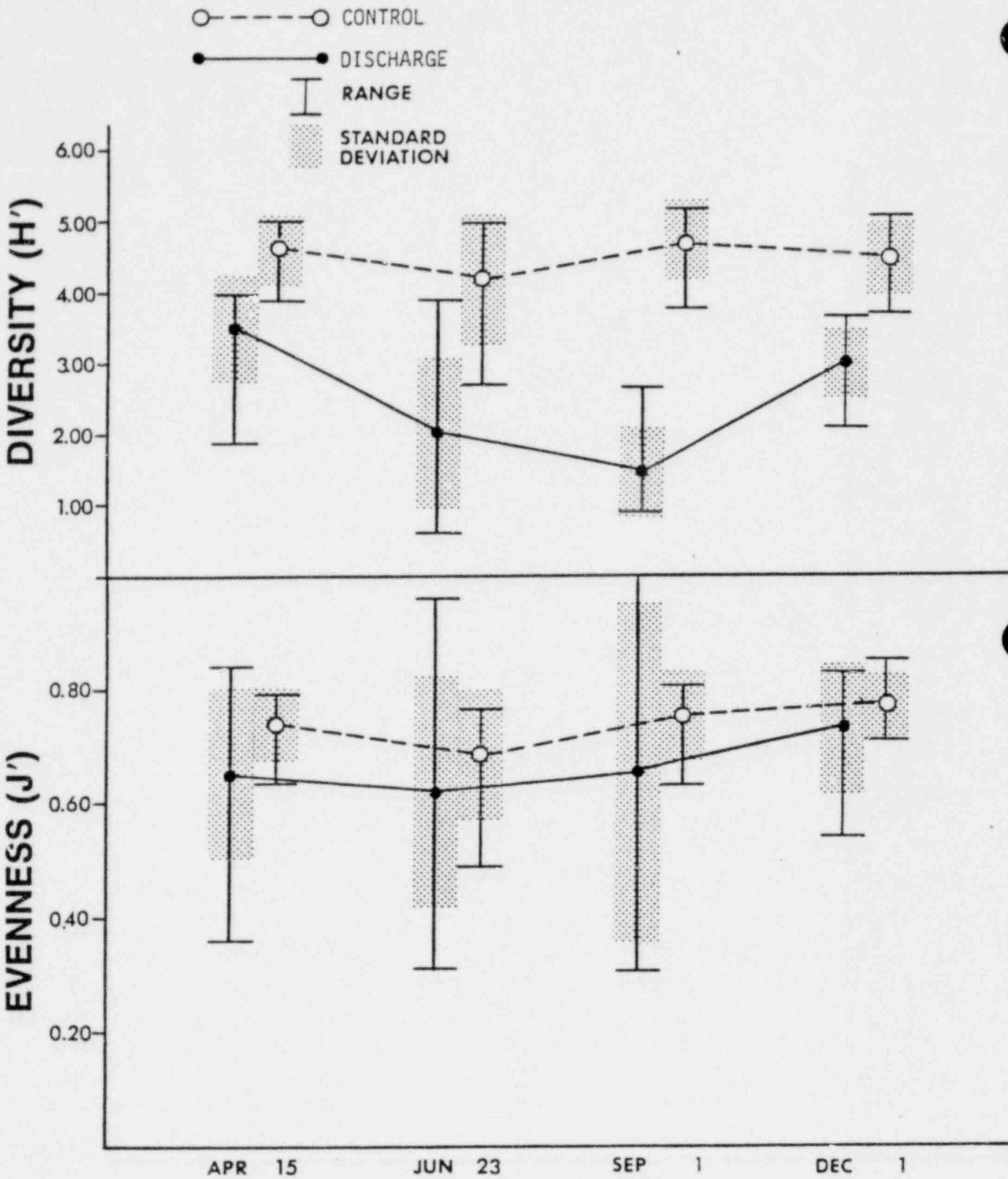

Figure D-5. Diversity and evenness values for benthic fauna collected by suction dredge, Crystal River Project, 1981.

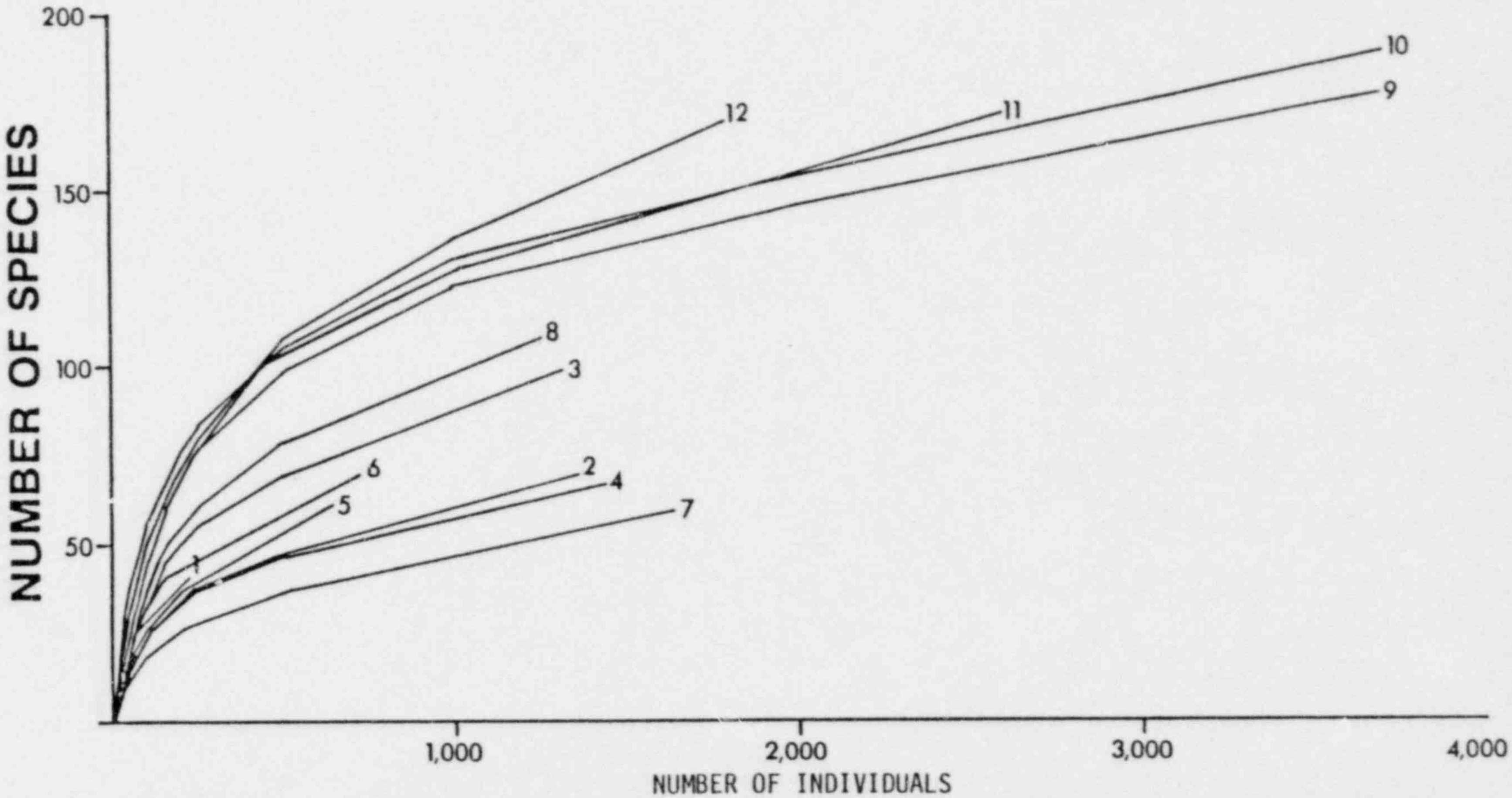

Figure D-6. Rarefaction curves for Stations 1 through 7 in the discharge basin and Stations 8 through 12 in the control basin, Crystal River Project, 1981.

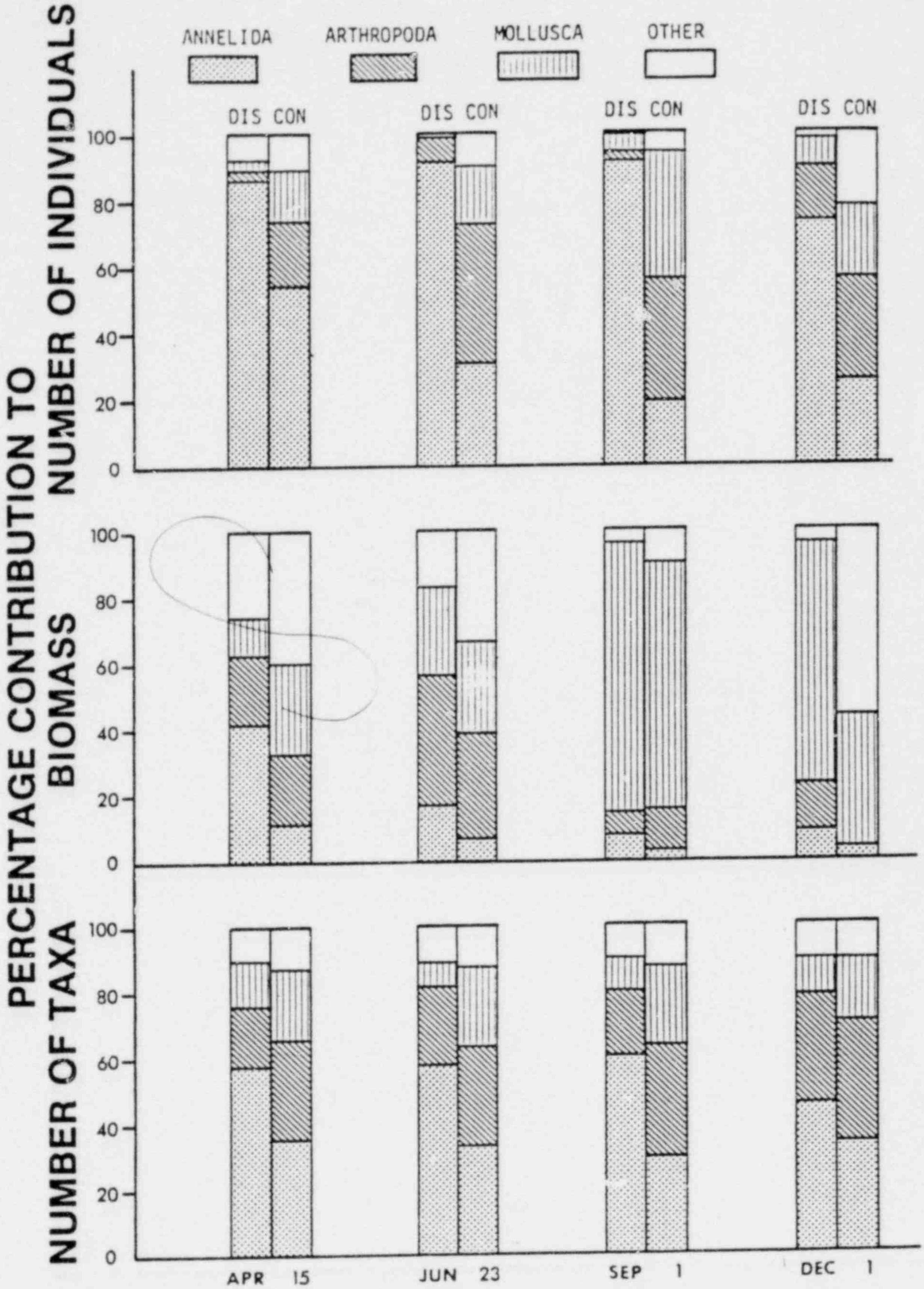

Figure D-7. Percentage contribution by major group to abundance, biomass and total number of taxa for organisms collected by suction dredge, Crystal River Project, 1981.

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.06											
3	.04	.46										
4	.09	.52	.28									
5	.13	.43	.28	.86								
6	.22	.10	.17	.26	.52							
7	.29	.05	.03	.04	.08	.20						
8	.11	.37	.34	.42	.46	.39	.02					
9	.02	.01	.21	.08	.13	.09	.00	.12				
10	.03	.03	.48	.18	.17	.13	.01	.13	.50			
11	.02	.02	.20	.10	.12	.07	.00	.11	.62	.68		
12	.02	.02	.06	.07	.11	.07	.00	.04	.16	.15	.44	

DISCHARGE VS. DISCHARGE (rows 1–7); CONTROL VS. DISCHARGE (rows 8–12)

DISCHARGE VS. CONTROL; CONTROL VS. CONTROL

PERCENT SIMILARITY

.00-.25

.26-.50

.51-.75

.76 - 1.00

Figure D-8. Morisita indices of similarity among seven discharge and five control stations based on suction dredge samples from all sampling periods, Crystal River Project, 1981.

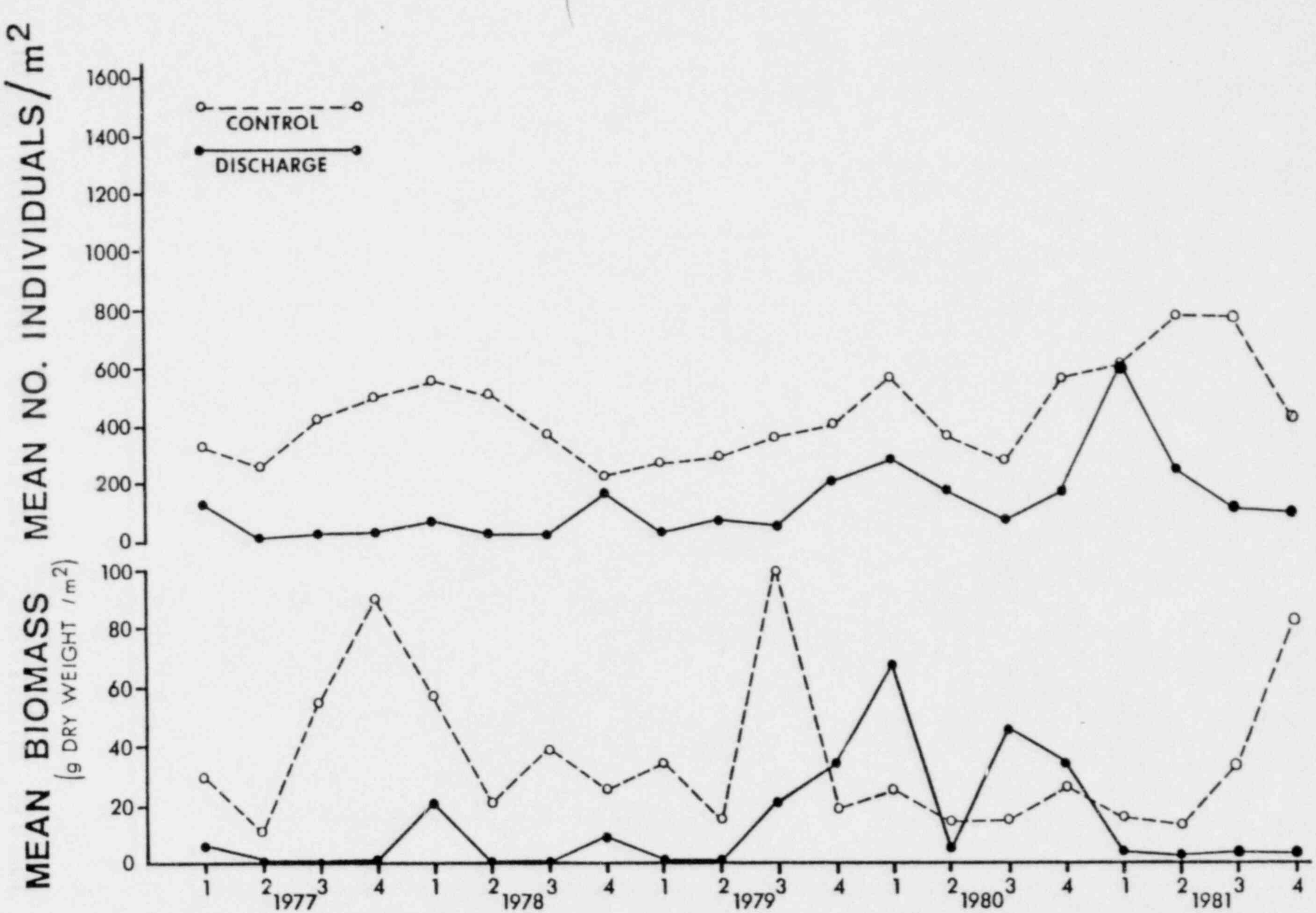

Figure D-9. Density and biomass of benthic fauna collected by suction dredge, Crystal River Project, 1977-1981.

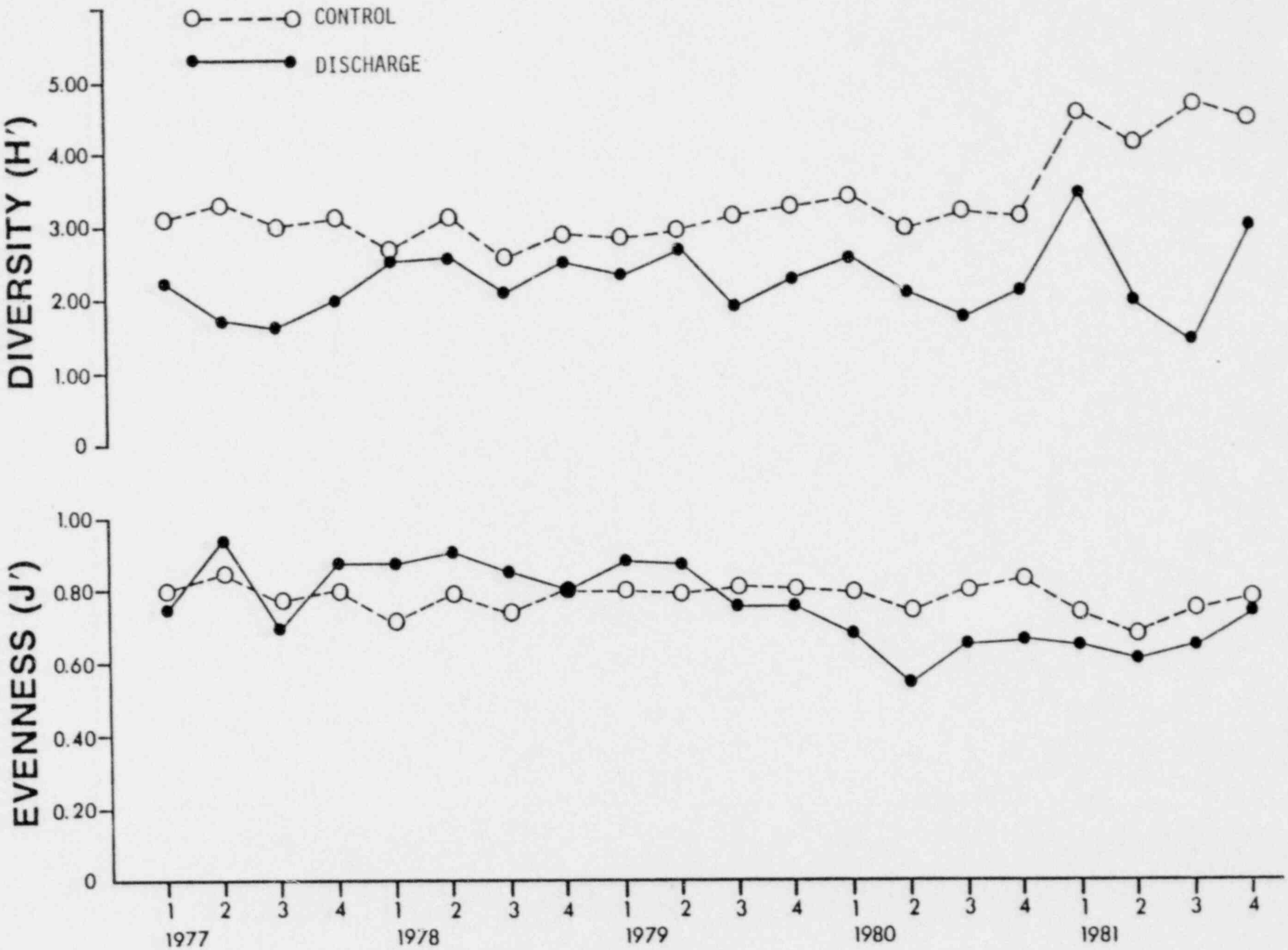

Figure D-10. Diversity and evenness of benthic fauna collected by suction dredge, Crystal River Project, 1977-1981.

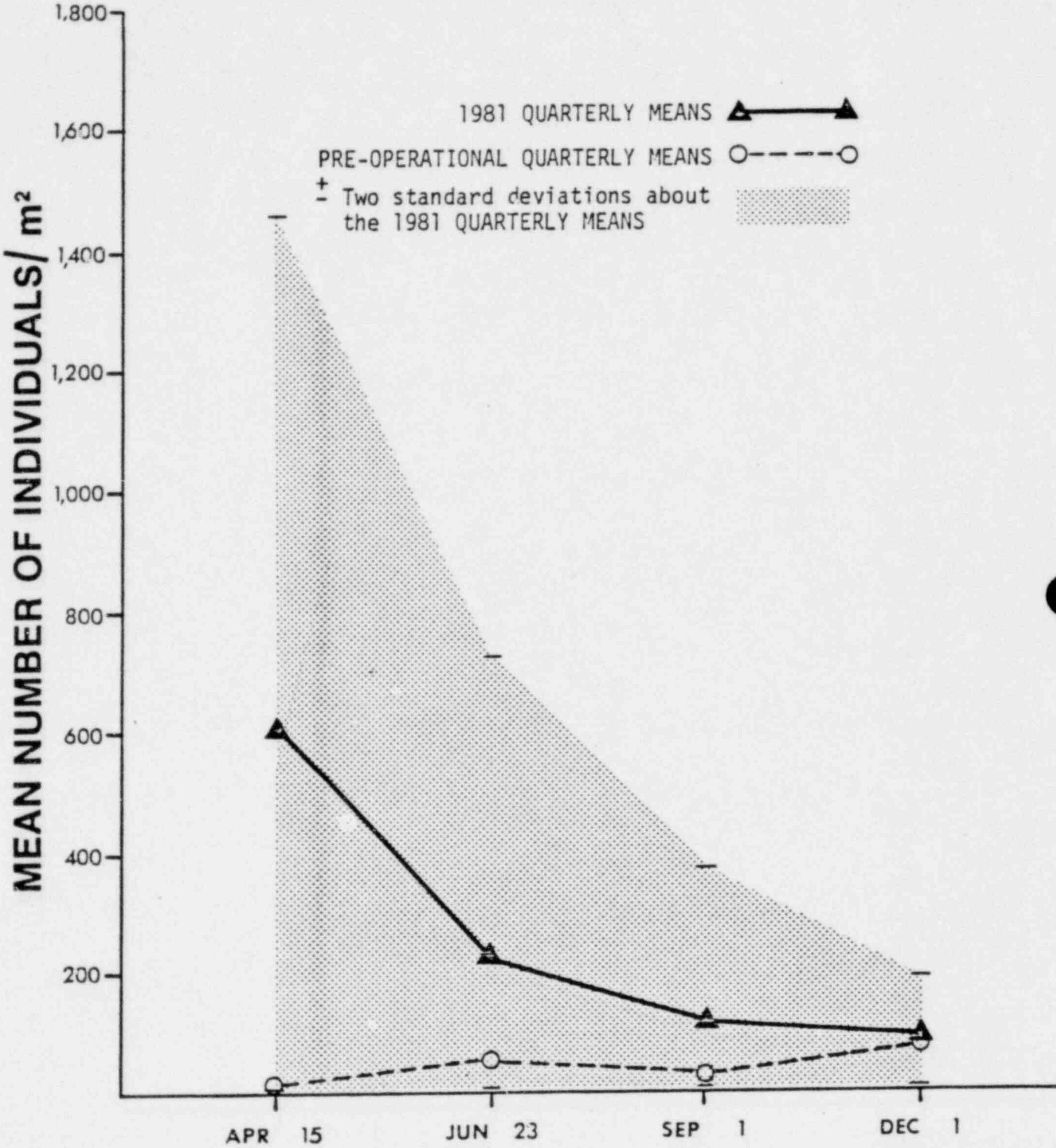

Figure D-11. Density of benthic fauna collected by suction dredge in the discharge basin, Crystal River Project, 1973 and 1981.

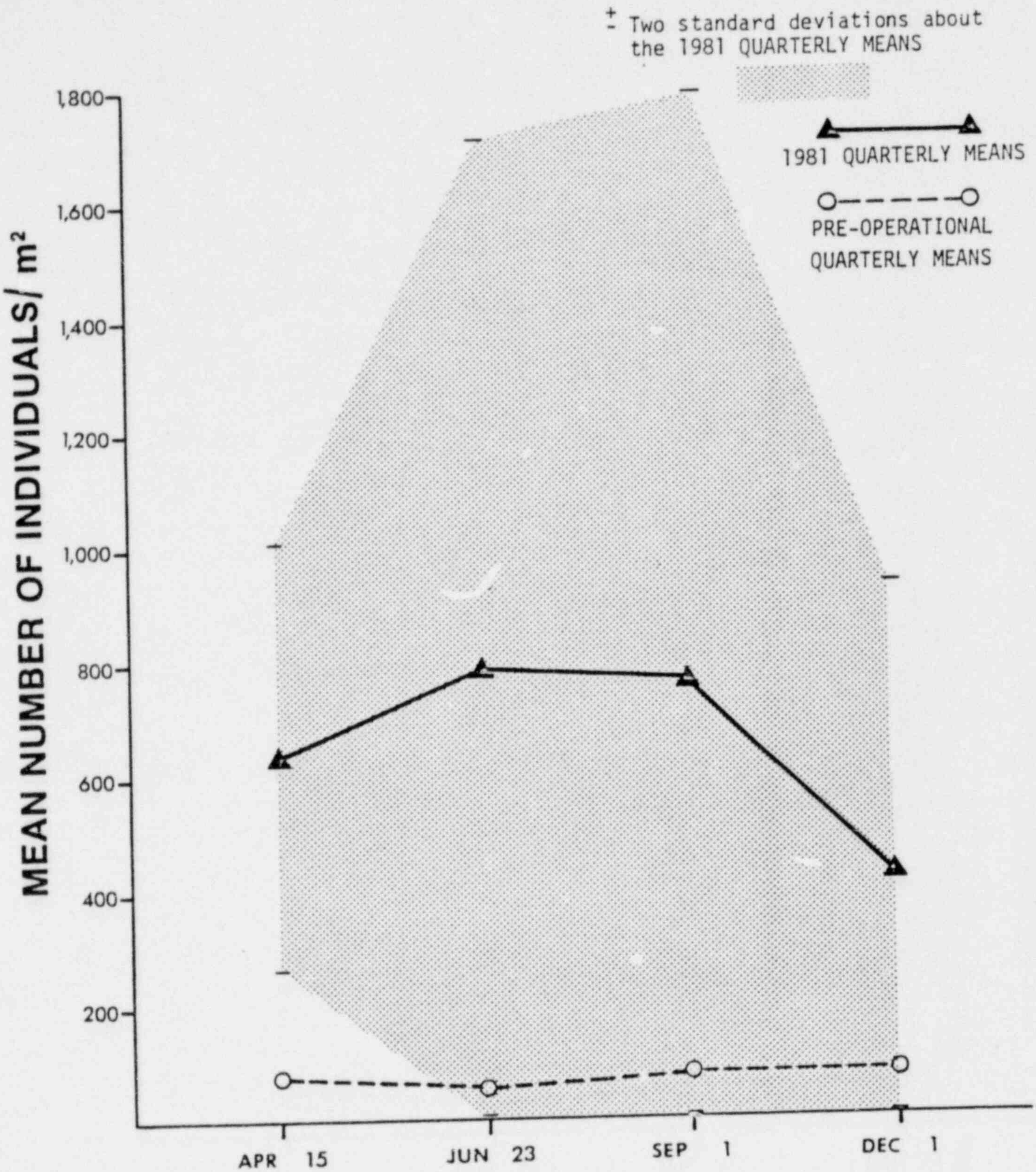

Figure D-12. Density of benthic fauna collected by suction dredge in the control basin, Crystal River Project, 1973 and 1981.

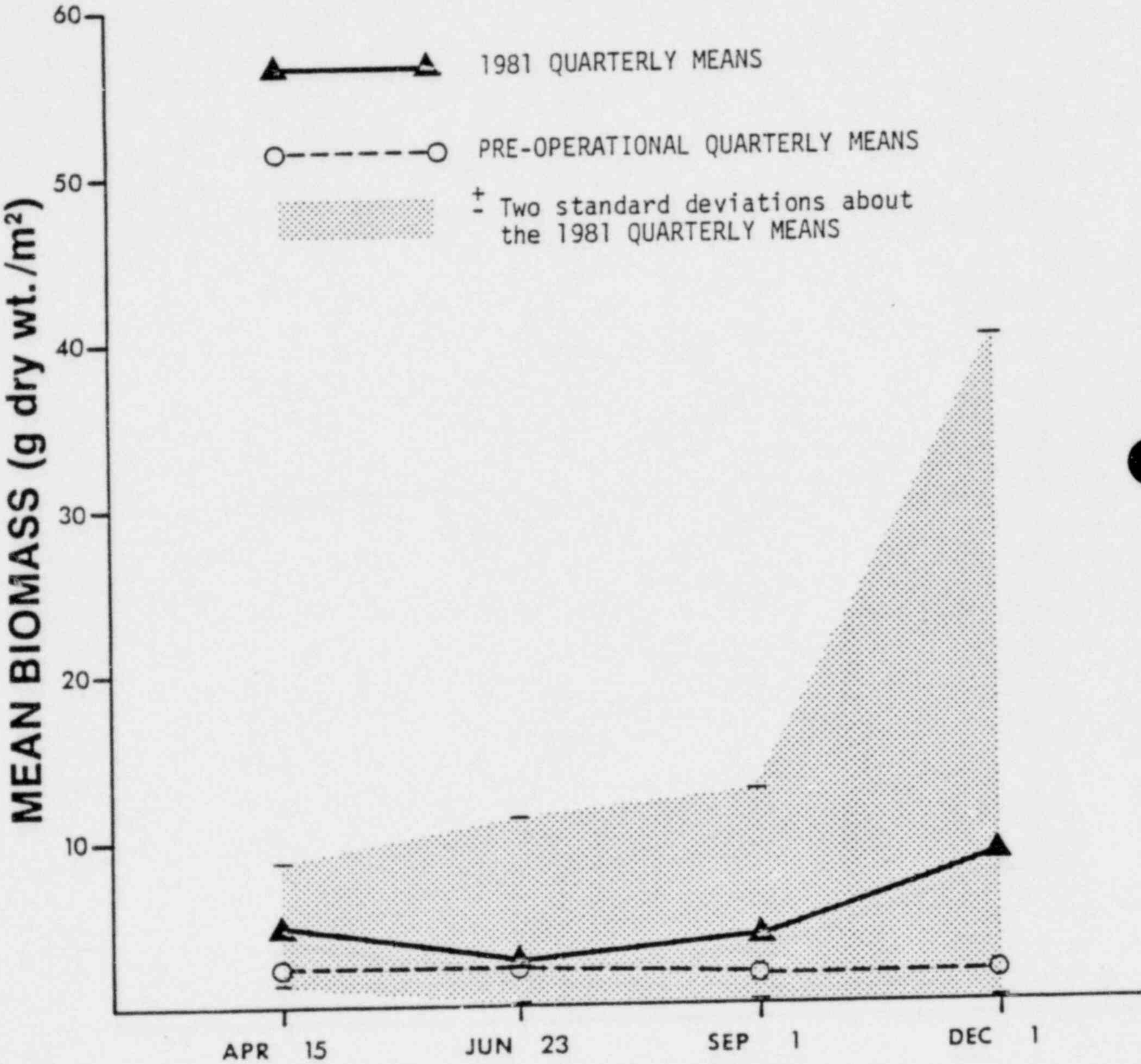

Figure D-13. Mean biomass of benthic fauna in the discharge basin collected by suction dredge, Crystal River Project, 1973 and 1981.

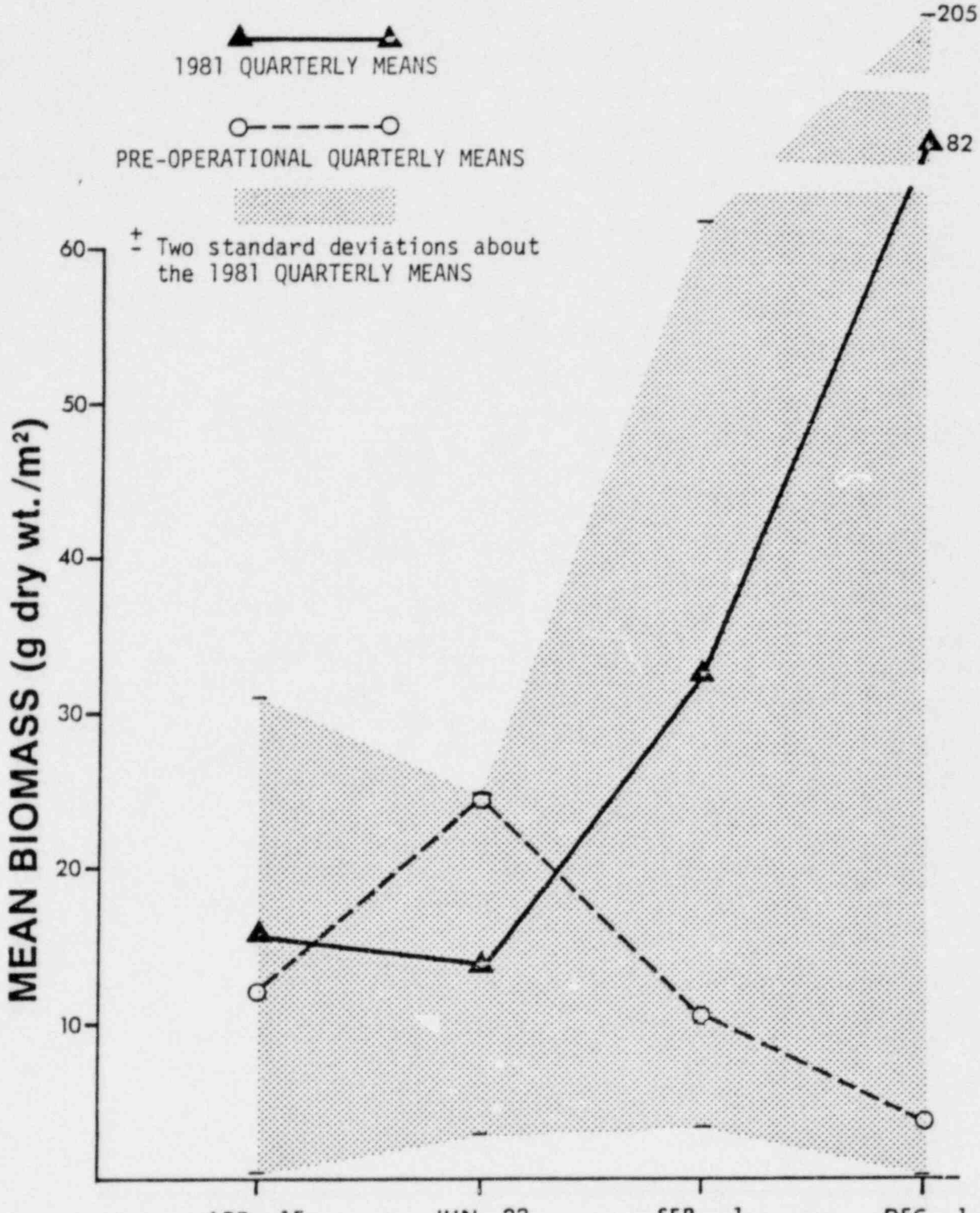

Figure D-14. Mean biomass of benthic fauna collected by suction dredge in the control basin, Crystal River Project, 1973 and 1981.

TABLE D-1

TAXONOMIC LIST OF SUCTION DREDGE FAUNA AND THEIR FREQUENCY OF OCCURRENCE[a]
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin
ANNELIDS		
Amaeana trilobata	3.6	60.0
Amphicteis floridus	10.7	5.0
Arabella iricolor		65.0
Arenicola cristata	3.6	20.0
Aricidea philbinae	28.6	10.0
Aricidea taylori	28.6	30.3
Axiothella mucosa	28.6	75.0
Boguella sp. A		20.0
Branchioasychis americanus	50.0	90.0
Capitella capitata	53.6	5.0
C. jonesi		5.0
Capitomastis aciculatus	10.7	
Chone sp. A	21.4	45.0
Clymenella torquata	25.0	10.0
Diopatra cuprea	50.0	35.0
Drilonereis magna		50.0
Enoplobranchus sanguineus	14.3	30.0
Eteone heteropoda	14.3	10.0
Eumida sanguinea		55.0
Eunicidae sp. A		10.0
Exogone dispar	3.6	30.0
E. verugera		10.0
Fabricia sp. A	3.6	15.0
Galathowenia sp. A	28.6	
Glycera americana	42.9	50.0
Glycinde solitaria	21.4	15.0
Gyptis brevipalpa	3.6	10.0
Haploscoloplos foliosus	14.3	50.0
Haploscoloplos robustus	7.1	80.0
Haploscoloplos spp.	3.6	10.0
Haplosyllis spongicola		10.0
Harmothoe aculeata	7.1	10.0
Heteromastus filiformis	42.9	30.0
Hyboscolex longiseta	3.6	10.0
Hydroides dianthus		65.0
Hypsicomus phaetaemia		15.0
Langerhansia cornuta		10.0
Laeonereis culveri	85.7	30.0
Lepidametria commensalis		20.0
Lepidonutus variabilis		20.0
Loimia viridis	7.1	
Lumbrineris spp.	7.1	10.0
Lumbrineris tenuis	10.7	15.0
L. verrilli	21.4	20.0
Lumbrineris cruzensis	21.4	
Magelona pettiboneae	14.3	60.0
Maldanidae sp. A	17.9	15.0
Marphysa sanguinea	85.7	75.0
Mediomastus ambiseta		5.0
M. californiensis	21.4	40.0
Mediomastus spp.	10.7	25.0
Megalomma bioculatum	7.1	
ANNELIDS (continued)		
M. lobiferum	3.6	
Megalomma spp.	3.6	
Melinna maculata	17.9	5.0
Naineris cf. laevigata	3.6	60.0
Neanthes acuminata		35.0
N. succinca	50.0	35.0
Nematonereis hebes		5.0
Nereidae spp.	3.6	
Nereiphylla fragilis		5.0
Nereis falsa		25.0
N. riisei		10.0
Notomastus hemipodus	7.1	
N. latericeus	10.7	10.0
Odontosyllis enopla		30.0
Onuphis simoni	14.3	80.0
Owenia fusiformis	10.7	
Paraonides sp. A	7.1	
Paraprionospio pinnata	39.3	40.0
Pectinaria gouldii	14.3	60.0
Perinereis floridana		5.0
Phyllodoce arenae	17.9	
Piromis eruca	10.7	10.0
P. cristata	21.4	75.0
P. palmata		20.0
Platynereis dumerilii	3.6	70.0
Poecilochaetus johnsoni	7.1	
Polycirrus eximius		20.0
Polydora ligni	7.1	10.0
P. socialis	25.0	30.0
P. websteri	3.6	
Prionospio cirrifera	10.7	5.0
P. heterobranchia texana	17.9	30.0
Sabella micropthalma		75.0
S. vulgaris		15.0
Salmacina ? spp.		5.0
Schistomeringos rudolphi		10.0
Scoleiepis texana		5.0
Scololoplos rubra	32.1	80.0
Scololoplos spp.		20.0
Spiochaetopterus costarum oculatus	10.7	30.0
Streblosoma hartmanae		55.0
Streblospio benedicti	7.1	
Terebella rubra		5.0
Terebellides stroemii	10.7	5.0
Tharyx dorsobranchialis ?	21.4	60.0
Tubificidae spp.	7.1	
Typosyllis annularis		55.0
Typosyllis hyalina		5.0
Typosyllis sp. A		10.0
Typosyllis sp. B	3.6	25.0
Typosyllis sp. C	17.9	60.0

CRYRIV6
TABLED-1

TABLE D-1
(continued)
TAXONOMIC LIST OF SUCTION DREDGE FAUNA AND THEIR FREQUENCY OF OCCURRENCE[a]
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin
MOLLUSCS		
Abra aequalis		20.0
Abra sp. A		5.0
Acanthochitona pygmaea		45.0
Acanthochitona sp. A		10.0
Aligena texasiana		10.7
Amygdalum papyrium	7.1	15.0
Anomia simplex		5.0
Astyris lunata		15.0
Bittium varium		10.0
Brachidontes modiolus		5.0
Brachidontes spp.		55.0
Bulla striata		15.0
Calotrophon ostrearum		20.0
Cardiomya costellata	3.6	
Carditamera floridana		70.0
Cerithium atratum		5.0
C. eburneum		10.0
C. lutosum		5.0
C. muscarum	3.6	15.0
Chione cancellata	3.6	5.0
Chione latilirata		
Codakia orbiculata		15.0
Costoanachis avara		20.0
Castoanachis semiplicata		25.0
Cassostrea virginica		5.0
Crepidula aculeata		30.0
C. convexa		5.0
C. fornicata		5.0
C. maculosa		70.0
C. plana		35.0
Cumingia coarctata		45.0
C. tellinoides		5.0
Cyclichnella canaliculata		10.0
Cylindrobulla beauii		10.0
Dentimargo aureocincta		5.0
Doridoida sp. A		5.0
Dosimia sp. A	3.6	
Fasciolaria lilium hunteria		20.0
Gastropoda sp. A		15.0
Granulina ovuliformis		5.0
Haminoea succinea	10.7	5.0
Haminoea spp.	3.6	5.0
Ischnochiton striolatus		50.0
Laevicardium mortoni	3.6	70.0
Leptonidae sp. A		5.0
Leptonidae sp. B	3.6	
Lima pellucida		5.0
Lucina nassula	3.6	
Lyonsia floridana	7.1	30.0
Macoma constricta-	32.1	10.0
M. tenta	3.6	5.0
MOLLUSCA (continued)		
Macoma sp. A		5.0
Marginellidae spp.		5.0
Melongena corona		5.0
Mitrella dichroa		5.0
Musculus lateralis		55.0
Nassarius vibex	35.7	45.0
Noetia ponderosa		5.0
Nuculana acuta	3.6	
Nucula proxima		45.0
Olivella mutica		10.0
Ostreola equestris		40.0
Polinices duplicatus		5.0
Polyplacophora spp.		5.0
Prunum apicinum		85.0
Pyrgocythara plicosa		5.0
Rissoina catesbyana		5.0
Semele purpurascens		10.0
Semelidae sp. A		5.0
Solenidae spp.	3.6	
Stiliger sp. ?		15.0
Tagelus divisus	14.3	
Tellina alternata		5.0
T. lineata		10.0
T. sybaritica	14.3	55.0
T. tampaensis		5.0
T. texana		5.0
T. versicolor	25.0	25.0
Tellinidae spp.	10.7	20.0
Trachycardium muricatum		5.0
Transennella conradina		50.0
Turbonilla dalli		5.0
Urosalpinx tampaensis		5.0
ARTHROPODS		
Alpheus armillatus		5.0
A. heterochaelis	46.4	55.0
A. normani		30.0
Alpheus spp.	7.1	30.0
Ambidexter symmetricus	28.6	30.0
Ampelisca vadorum	3.6	30.0
A. verrilli		5.0
Ampelisca spp.	3.6	25.0
Ampithoe longimana	3.6	10.0
Ampithoe sp. A		5.0
Ampithoe spp.		5.0
Anthuridae spp.		5.0
Apseudes sp. A		15.0
Bates catharinensis		5.0
Callianassa spp.		5.0
Callinectes sapidus	21.4	10.0
Callinectes spp.	10.7	5.0

TABLE D-1
(continued)
TAXONOMIC LIST OF SUCTION DREDGE FAUNA AND THEIR FREQUENCY OF OCCURRENCE[a]
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin	Taxa	Discharge basin	Control basin
ARTHROPODS			ARTHROPODS (continued)		
Caridea spp.	3.6	15.0	Panopeus spp.		
Caridea mysis		5.0	Paracaprella pusilla	3.6	
Caridea postlarva		5.0	P. tenuis		10.0
Carinobatea cuspidata		10.0	Paracerceis caudata		5.0
Corophium acherusicum		10.0	Paracerceis spp.		15.0
C. simile		20.0	Paracerceis ? sp. A		10.0
Corophium spp.		10.0	Pelia mutica		30.0
Cymadusa compta	7.1	60.0	Penaeid postlarvae	3.6	
Cymadusa spp.		60.0	Penaeus duorarum		30.0
Cymodoce faxoni	3.6	15.0	Penaeus spp.	25.0	55.0
Elasmopus levis		35.0	Periclimenes americanus	28.6	60.0
Elasmopus spp.	3.6	5.0	P. longicaudatus	7.1	15.0
Erichsonella filiformis	21.4	40.0	Petrolisthes armatus		50.0
Erichthonius brasiliensis	3.6	35.0	Petrolisthes spp.		35.0
E. rubricornis		30.0	Photidae spp.		5.0
Erichthonius spp.		35.0	Pinnixa sayana ?	3.6	5.0
Euceramus praelongus	3.6		Pinnixa spp.	10.7	15.0
Eurypanopeus depressus		55.0	Portunus spp.	3.6	5.0
Excorallana tricornis		15.0	Portunus gibbesii	3.6	
Excorallana spp.		15.0	Rhithropanopeus harrisii		5.0
Hargeria rapax	3.6	20.0	Tanais sp. A		20.0
Heterophlias seclusus		40.0	Taphromysis bowmani	7.1	
Hippolyte zostericola ?	3.6	65.0	Thor dobkini		15.0
Hippolyte spp.		20.0	Thor spp.		25.0
Hippolytidae spp.		15.0	Trachypenaeus spp.		5.0
Kalliapseudes spp.		5.0	Uogebia affinis	21.4	35.0
Lembos rectangulatus		5.0	Upogebia spp.		5.0
L. smithii		10.0	Xanthidae spp.	3.6	70.0
L. unicornis		5.0	Xenanthura brevitelson	3.6	
Lembos spp.	7.1	40.0			
Leucothoe spinicarpa		40.0	ECHINODERMS		
Libinia dubia		30.0	Amphioplus abditus	7.1	40.0
L. erinacea		15.0	A. thrombodes	3.6	25.0
Libinia spp.	3.6	10.0	Amphioplus spp		10.0
Lysianopsis alba		20.0	Amphiuridae spp.		10.0
Magidae spp.		5.0	Holothuroidea spp.		5.0
Melita appendiculata		35.0	Leptosynapta sp. A	28.6	30.0
M. elongata ?	3.6	20.0	Ophioderma spp.		10.0
Melita spp.	3.6	20.0	Ophiophragmus filograneus	14.3	25.0
Melitidae spp.		5.0	Ophiothrix angulata		10.0
Neopanope packardi		50.0	Othilla spp.		40.0
N. taxana	14.3	95.0	Pentamera pulcherrima		5.0
Neopanope spp.	17.9	85.0	Thyone mexicana	14.3	5.0
Ogyrides alphaerostris		5.0	Thyonella gemmata	3.6	5.0
Paguroidea spp.		50.0			
Pagurus annulipes	3.6	65.0	MISCELLANEOUS PHYLA		
P. longicarpus	3.6		Cnidaria spp.	10.7	50.0
Pagurus spp.	3.6	30.0	Nemertina spp.	28.6	80.0
Palaemonetes floridanus		40.0	Platyhelminthes spp.		30.0
P. intermedius	7.1	20.0	Porifera spp.		55.0
Palaemonetes spp.	17.9	45.0	Sipuncula spp.	3.6	60.0
Palaemonidae spp.		10.0	Hemichordata spp.		5.0
Panopeus herbstii		15.0			

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TABLED-18

TABLE D-1
(continued)
TAXONOMIC LIST OF SUCTION DREDGE FAUNA AND THEIR FREQUENCY OF OCCURRENCE[a]
CRYSTAL RIVER PROJECT
1981

Taxa	Discharge basin	Control basin	Taxa	Discharge basin	Control basin
CHORDATA			CHORDATA (continued)		
Achimus lineatus	3.6	15.0	Lucania parva		5.0
Ascidiacea spp.	7.1	85.0	Micrognathus criniger		5.0
Chasmodes suburrae		30.0	Microgobius gulosus	7.1	30.0
Gobiosoma robustum		55.0	M. thalassinus	7.1	
Hippocampus zosterae		15.0	Opsanus beta	3.6	55.0
Hippocampus spp.		5.0	Paralichthys albigetta	7.1	5.0
Lagodon rhomboides	10.7	20.0	Symphurus plagiusa	3.6	20.0
Leiostomus xanthurus	3.6	5.0			

[a]Percentage of samples taken during 1981 in which each taxa was collected (n for discharge basin = 28, n for control basin = 20).

TABLE D-2

QUARTERLY COMMUNITY PARAMETERS DETERMINED FOR BENTHIC FAUNA
COLLECTED IN SUCTION DREDGE SAMPLES AT SEVEN DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

Parameter	Month	Stations 1	2	3	4	5	6	7	Basin total	Basin mean
Number of individuals/m^2	15 April	107	567	663	674	287	537	1452	4287	612.4
	23 June	6	561	527	351	81	25	11	1562	223.1
	1 September	2	180	24	350	174	53	5	788	112.6
	1 December	110	54	92	70	90	115	162	693	99.0
	Total	225	1362	1306	1445	632	730	1630	-	-
	Annual mean	56.3	340.5	326.5	361.3	158.0	182.5	407.5	-	261.8
Biomass (gram dry weight/m^2)	15 April	2.454	4.584	4.168	7.023	3.287	7.144	5.173	33.833	4.833
	23 June	0.028	10.646	6.511	1.215	0.566	0.838	0.194	19.998	2.857
	1 September	0.033	5.009	12.754	4.091	4.250	1.335	0.031	27.503	3.929
	1 December	0.130	11.574	3.007	1.399	2.430	2.132	0.672	21.344	3.049
	Total	2.645	31.813	26.260	13.728	10.533	11.449	6.070	-	-
	Annual mean	0.661	7.953	6.610	3.432	2.633	2.862	1.518	-	3.667
Total number of taxa	15 April	23	46	56	51	40	49	37	130	43.1
	23 June	2	22	43	12	12	7	6	54	14.9
	1 September	2	10	8	8	6	5	4	20	6.1
	1 December	15	15	27	13	16	18	23	56	18.1
	Total	40	69	98	66	60	69	58	151	-
	Annual mean	10.5	23.3	33.5	21	18.5	19.7	17.5	-	20.5
Diversity (H')	15 April	3.816	3.656	3.926	3.749	3.980	3.531	1.875	-	3.505
	23 June	0.650	2.084	3.887	1.114	2.264	1.764	2.482	-	2.035
	1 September	1.000	1.170	2.667	0.921	1.084	1.514	1.922	-	1.468
	1 December	2.139	3.166	3.655	3.095	2.938	3.460	2.777	-	3.033
	Annual mean	1.901	2.519	3.533	2.220	2.567	2.567	2.264	-	-
Evenness (J')	15 April	0.884	0.662	0.676	0.661	0.748	0.629	0.360	-	0.654
	23 June	0.650	0.467	0.716	0.311	0.632	0.628	0.960	-	0.623
	1 September	1.000	0.352	0.881	0.307	0.419	0.652	0.961	-	0.654
	1 December	0.548	0.810	0.769	0.836	0.735	0.830	0.614	-	0.735
	Annual mean	0.771	0.573	0.761	0.529	0.634	0.685	0.724	-	-

CRYRIV6
TABLED-3

TABLE D-3

QUARTERLY COMMUNITY PARAMETERS DETERMINED FOR BENTHIC FAUNA
COLLECTED IN SUCTION DREDGE SAMPLES AT FIVE CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

Parameter	Month	Stations					Basin total	Basin mean
		8	9	10	11	12		
Number of individuals/m^2	15 April	450	839	829	484	587	3189	637.8
	23 June	478	1539	681	873	375	3946	789.2
	1 September	259	680	1630	653	600	3822	764.4
	1 December	72	630	581	588	216	2087	417.4
	Total	1259	3682	3721	2598	1778	-	-
	Annual mean	314.8	922.0	930.3	649.5	444.5	-	652.2
Biomass (gram dry weight/m^2)	15 April	14.116	13.343	8.691	14.044	28.754	78.948	15.790
	23 June	10.652	18.538	7.432	20.486	12.354	69.462	13.892
	1 September	14.490	21.052	50.553	38.751	38.306	163.152	32.630
	1 December	5.113	160.228	96.437	37.330	111.401	410.509	82.102
	Total	44.371	213.161	163.163	110.611	152.509	-	-
	Annual mean	11.093	53.290	40.778	27.653	38.127	-	36.104
Total number of taxa	15 April	50	83	68	78	99	178	75.6
	23 June	46	99	77	81	45	177	69.6
	1 September	59	80	100	86	61	181	77.2
	1 December	27	76	65	79	63	160	62.0
	Total	108	178	190	173	170	287	-
	Annual mean	45.5	84.5	77.5	81	67	-	71.1
Diversity (H')	15 April	4.320	4.957	3.880	4.998	4.835	-	4.598
	23 June	4.032	4.975	4.348	4.885	2.706	-	4.189
	1 September	4.753	5.139	4.886	5.024	3.767	-	4.714
	1 December	3.774	4.626	4.313	4.846	5.100	-	4.532
	Annual mean	4.220	4.924	4.357	4.938	4.102	-	-
Evenness (J')	15 April	0.765	0.778	0.637	0.795	0.729	-	0.741
	23 June	0.730	0.750	0.694	0.771	0.493	-	0.688
	1 September	0.808	0.813	0.735	0.782	0.635	-	0.755
	1 December	0.794	0.741	0.716	0.769	0.853	-	0.775
	Annual mean	0.774	0.771	0.696	0.779	0.678	-	-

CRYRIV6
TABLED-2

TABLE D-4

DOMINANCE RANK[a] FOR TOP TEN TAXA COLLECTED BY SUCTION DREDGE
CRYSTAL RIVER PROJECT
1981

Parameters	April Discharge	April Control	June Discharge	June Control	September Discharge	September Control	December Discharge	December Control	Annual Discharge	Annual Control
ANNELIDS										
Aricidea taylori	8		3		9				4	
Axiothella mucosa	9	2	9	8						6
Branchioasychis americana		6					10			
Capitella capitata					6					
Clymenella torquata	2								9	
Diopatra cuprea							7			
Galathowenia sp. A	1								6	
Heteromastus filiformis	5		2		4				3	
Laeonereis culveri			1		1		2		1	
Lumbrineris tenuis			7							
L. verrilli							1		6	
Marphysa sanguinea		8	5		2	10	3	9	2	
Mediomastus spp.							4			
Neanthes succinea			4							
Onuphis simoni	6	4	6	10				7	6	6
Owenia fusiformis	10									
Pista cristata	3	1		4		7			10	1
Paraprionospio pinnata	7						8			
Scoloplos rubra		7								
Tharyx dorsobranchialis ?					10					
Typosyllis sp. C								5		
MOLLUSCS										
Brachidontes spp.		3		1						2
Carditamera floridana						2		2		2
Costoanachis avara						1				9
Ischnochiton striolatus								8		
Macoma constricta					7					
Nassarius vibex					3	8	6		4	
Prunum apicinum						3		3		4
ARTHROPODS										
Alpheus heterochaelis					5		9		10	
Cymadusa compta				3						
Cymadusa spp.		10		2						9
Ericthonius spp.						6				
Neopanope texana		9		9		9				
Neopanope spp.				5		5				6

TABLE D-4
(continued)
DOMINANCE RANK[a] FOR TOP TEN TAXA COLLECTED BY SUCTION DREDGE
CRYSTAL RIVER PROJECT
1981

	April		June		September		December		Annual	
Parameters	Discharge	Control	Discharge	Control	Discharge	Control	Discharge	Control	Discharge	Control
Paguroidea spp.						4				
Pagurus annulipes								10		
Palaemonetes intermedius			8							
Penaeus spp.					8					
Periclimenes americanus							5	6		
Thor dobkini								4		
Xanthidae spp.				6						
Palaemonetes spp.			10							
OTHER										
Ascidiacea spp.				7				1		5
Leptosynapta sp. A	4	5								

[a] McCloskey, 1970.

E. MACROPHYTE BIOMASS

INTRODUCTION

Macroscopic marine plants (macrophytes), including seagrasses and algae, are important components of coastal ecosystems. They convert essential nutrients from the surrounding water and substrates into organic materials, which is then consumed by other organisms in the food webs (Wood et al., 1969). Although some animals feed directly on macrophytes, most of the primary production reaches higher trophic levels through detrital pathways (Thayer et al., 1975). Macrophytes provide sites of attachment for smaller epiphytic plants that may contribute appreciably to overall primary production (Humm, 1964). They also increase habitat complexity of coastal waters by providing food, living space and protection to a variety of fish and macroinvertebrates (Heck and Wetstone, 1977; Thayer and Phillips, 1977; Stoner, 1980). By stabilizing sediments, macrophytes reduce water turbidities and further enhance nutrient recycling (Phillips, 1978; Odum, 1970).

Benthic macrophytes respond to changes in temperature, salinity, depth, light, turbidity and nutrient levels (Humm, 1973). Near power plants, high water temperatures have resulted in reduced macrophyte coverage or shifts in species composition (Patrick, 1974; Thorhaug et al., 1978). Turbidity and salinity have also been shown to be important in determining macrophyte distribution (Zimmerman et al., 1971; Thompson and Wolcott, 1976). Unlike motile organisms, macrophytes are unable to avoid unfavorable physicochemical changes in the environment. Changes in

macrophyte community structure may, therefore, indicate local environmental perturbations (Steidinger and Van Breedveld, 1971).

Macrophytes are a conspicuous element of benthic communities in the Crystal River area. Five species of seagrasses and numerous species of macroalgae occur there (Phillips, 1961; Steidinger and Van Breedveld, 1971). As in previous years, macrophytes were sampled in both discharge and control areas during 1981 to determine if the operation of the Crystal River Power Plant was aff... ,g the abundance, distribution and species composition of these important elements of the benthic community.

MATERIALS AND METHODS

Macrophytes were collected quarterly at each of seven stations in the discharge basin and five stations in the control basin (Figure E-1). At each station, three replicates spaced at least 3 m apart were taken within a 15-m radius of the station marker. A 50 x 50-cm by 0.5-m high aluminum frame was placed on the bottom and worked into the substrate. All macrophytes within the frame including roots, rhizomes and holdfasts were removed by hand and preserved in 10-percent buffered seawater formalin.

In the laboratory, each sample was separated into seagrass and macroalgae fractions. Seagrasses were further separated by species and macroalgae by divisions (Chlorophyta, Phaeophyta and Rhodophyta). Length measurements of a maximum of 50 randomly selected leaves were taken for each seagrass species. Macroalgae were identified to genus and

representative material was retained for each taxon. Biomass was measured for each seagrass species and macroalgae division after oven drying the sample at 70°C for 24 hours.

RESULTS AND DISCUSSION

Macrophyte Composition and Distribution

In 1981, 23 genera of macroalgae and 5 species of seagrasses were collected in the Crystal River study area (Table E-1). Almost all of the algae collected were from the control stations, and vegetation in the discharge basin was composed almost entirely of seagrasses (Table E-2). Only 3 genera of algae were collected in the discharge, and 23 genera were recorded in the control basin.

The majority (65 percent) of the macroalgae genera collected were in the division Rhodophyta, the red algae. *Gracilaria* was the most commonly collected red alga, followed by *Ceramium*, *Spyridia*, *Chondria* and *Champia*. The Chlorophyta (green algae) composed 22 percent of the remaining genera and the Phaeophyta (brown algae) 13 percent. *Caulerpa* and *Sargassum* were the most commonly collected macroalgae within these two divisions, respectively.

With one exception, *Halodule wrightii* was the only seagrass recorded in the discharge basin. The exception was *Thalassia testudinum*. It was the dominant species at Station 3 in November, but it was not found at any other station or during any other sampling period. Previous reports from the study area have referred to *Halodule* material as *H. beaudettii*.

Because the validity of H. beaudettii as a distinct species is in doubt (Eiseman, 1980), this report will refer to all shoal grass as H. wrightii.

Except for Thalassia, all seagrass species were collected in the control basin. Seagrass distribution and abundance varied greatly among stations and seasons in the control basin. However, Stations 8 and 10 were the only stations where seagrasses were present in appreciable quantities during every quarter.

Biomass

Mean macrophyte biomass in the control basin was significantly greater ($P \leq 0.05$) than in the discharge basin during every sampling period (Figure E-2). Thus, the control basin not only supported a greater diversity of macrophytes, but a greater biomass as well.

In the discharge basin, the biomass of Halodule wrightii, after peaking in June, decreased rapidly through the summer months (Figure E-3). Although a summer die-back of Halodule is probably natural, as suggested by the summer decline of Halodule in the control basin (Figure E-4), it is probably accelerated by the increased temperatures in the discharge. By fall, Halodule biomass appeared to have recovered from the summer die-back in the control basin (Figure E-4), but it remained depressed in the discharge (Figure E-3).

Ruppia maritima was the most abundant seagrass in the control basin (Figure E-4). Its decline after June was perhaps in response to increased summer salinities. Optimum growth for *Ruppia* is in waters of low salinity (<25 ppt; Phillips, 1980). The other seagrasses in the control basin had relatively low biomass values, which fluctuated little through the year. Slight decreases were noted in August (Figure E-4).

Seagrasses in the control basin composed 29 percent of the total macrophyte biomass in June and less in other sampling periods. The major contributors to plant biomass in the control basin were the macroalgae (Table E-2). The stations that were dominated by seagrasses had about one-half of the total annual biomass of the stations dominated by macroalgae.

The steady decline of macrophyte biomass in the control basin after June (Figure E-2) paralleled the seasonal decline of two major groups of algae, Rhodophyta and Chlorophyta (Table E-3). Two genera of Chlorophyta, *Penicillus* and *Caulerpa*, collected at Stations 9 and 11, respectively, were no longer observed by November. Large accumulations of drift algae, predominantly Rhodophyta, were sampled during April and late November at stations farthest from shore. These algae growing attached to hard substrates in other areas are broken off by winter storms and swept into these inshore basins. Van Tine (1977), in an earlier study of this area, also found abundant unattached red algae in the winter flora. It is apparently a seasonal phenomenon of many bays on the west coast of Florida (Phillips, 1960a).

Seasonal fluctuations in macrophyte composition, distribution and biomass have already been noted. In general, the Rhodophyta showed biomass increases in the early spring and winter; the Phaeophyta reached its maximum biomass in the winter; the Chlorophyta were persistent throughout the year but had diminished by the winter. These are normal seasonal fluctuations for algal divisions inhabiting semi-tropical or warm-temperature regions such as Crystal River (Steidinger and Van Breedveld, 1971).

Macrophyte Leaf Lengths

Periods of seagrass growth can be inferred from increases in mean quarterly leaf lengths (Figure E-5). The late spring to early summer increases in Halodule leaf lengths paralleled the increases in Halodule biomass in both basins. There was very little difference in Halodule leaf lengths between basins during any quarter. Generally, leaf lengths increased slightly for all seagrass species through June, and then decreased during the remainder of the summer to low levels in late August. Ruppia usually regenerates in the early spring and the other seagrasses regrow leaves as warm weather advances (Phillips, 1960b). Ford et al. (1974) working in the Anclote estuary similarly found leaf growth for Syringodium filiforme and Thalassia testudinum to be greatest in late spring and reduced in the summer months.

Between-basin Comparisons

Differences in macrophyte composition, distribution and biomass between basins can be explained as a result of differences both in sediment

characteristics and in exposure to environmental stress. The unconsolidated mud or sand substrates in the discharge provide little hard substrate for algal attachment. Sedimentation is greater in the discharge than in the control basin as a result of accumulated sediments from adjacent saltmarsh tidal creeks disrupted by construction of the dikes and canals of the plant and from the Withlacoochee River and Cross Florida Barge Canal (van Tine, 1977). Additionally, temperatures were significantly higher in the discharge than in the control basin during most sampling periods of 1981 (Figure B-2). Macrophyte biomass values would be expected to be higher in the control area because of reduced sedimentation and temperatures that rarely departed from optimum levels for plant growth.

The high temperatures and sedimentation rates that characterize the discharge basin apparently inhibit all but the hardiest of seagrasses. These conditions are probably responsible for the virtually monospecific seagrass beds of Halodule wrightii presently found there. Halodule wrightii, a eurythermal, euryhaline species, is more tolerant of environmental fluctuations and is frequently found where other seagrasses are excluded (Phillips, 1960b; Thorhaug et al., 1978). Nevertheless, Halodule experienced a heavy die back in the summer when temperatures in excess of 35°C were recorded. Optimum temperatures for the growth of all seagrass species in Florida is 20° to 30°C. In Tampa Bay, an upper mean limit of 33°C for Halodule has been documented (Thorhaug et al., 1978).

Substrates in the control basin ranged from mud to rock and shell outcroppings. Macrophyte composition varied accordingly, with hard substrates supporting several algal species and unconsolidated sediments supporting seagrasses. Sediment analysis for all stations revealed that control Station 8 was not significantly different from stations in the discharge basin (I. Sediments). The predominantly monospecific seagrass composition at Station 8 was also most similar to that found in the discharge.

Within-basin Comparisons

Within the discharge basin, there were significant differences in Halodule biomass among stations. Duncan's multiple range tests (Table E-4) show that for the first two quarters, Stations 1 and 7 were significantly different from all the other discharge stations. After June, macrophyte biomass declined at Stations 4, 5 and 6 and these stations were no longer significantly different from Stations 1 and 7 for the rest of the year. During April and June, Station 3 was significantly different from all other stations, but it was not significantly different from Station 2 in August and November. Stations 4 and 5 were not significantly different from each other throughout the year.

Stations 2 and 3 were the only two discharge stations where Halodule was collected in August and November. Seasonal fluctuation in seagrass biomass for these two stations were similar to those of the two control stations, 8 and 10, where seagrasses were collected (Table E-2). The annual mean biomass of Halodule at Station 3, however, was almost twice

(91.6 g dry weight/m^2) that of Station 8 (45.6 g dry weight/m^2), the only seagrass-dominated control station.

Stations 1 and 7 were devoid of all macrophytes throughout the year. These stations were closest to the mouth of the discharge canal and, therefore, most directly impacted by the thermal effluent. The highest temperatures of the year were recorded there and exceeded all other discharge station bottom temperatures by 1° to 4°C. Because salinity differences among stations were neglible, they were not considered a variable to explain station differences.

An inverse relationship appears to exist between annual mean biomass of Halodule and maximum observed discharge station temperatures (Figure E-6). Maximum observed temperatures were selected because they may be more critical in defining lethal limits for macrophytes than mean temperatures. Despite the fact that these temperatures are based on one measurement in time and do not represent thermal histories for each station, they do reflect relative differences. Biomass decreased with increasing maximum temperatures, which is primarily a function of distance from the plant discharge. Station 3 received the least thermal impact and had the highest annual biomass values. Stations 1 and 7 had the highest maximum temperatures and no macrophytes. Seagrasses had disappeared from all discharge stations, except 2 and 3, by August (Figure E-3) as temperatures throughout the basin remained above 32°C.

As previously stated, station differences within the control basin correlated strongly with substrate types. Station 8, whose muddy substrate was most similar to those of the discharge stations, was dominated by Ruppia maritima for April, June and August. This species was most abundant in April, but it had largely been replaced by Halodule by November. Both seagrasses and macroalgae were common at Station 10, which had both mud and hard substrates. The four seagrasses there had very patchy distributions and it was difficult to determine which was dominant. Collectively, seagrasses predominated at Station 10 in April and June, and the Rhodophyta predominated in August and November. Sargassum was well established at Stations 9 and 11 year-round, growing attached to hard substrate. Red algae was also abundant at these stations. The substrate at Station 12 was mostly rock and oyster shell outcroppings, supporting dense beds of Caulerpa intermixed with red algae. With the onset of cold weather, this plant, known to have tropical affinities, died back and was not seen in November.

Overall, the control basin, with its wide range of habitats coupled with fluctuating environmental conditions, was a heterogeneous area with frequent shifts in macrophyte composition.

Operational Trends

During 1981, 23 genera of macroalgae were collected as compared to 15 to 16 in the other operational years. This increase is probably insignificant, however, because many of these genera were part of the drift algae and may not be indigenous to the study area.

The predominant genera within each macroalgae division have remained relatively unchanged through all operational years. Caulerpa and Sargassum have consistently been the predominant genera within the Chlorophyta and Phaeophyta, respectively. Gracilaria, Chondria and Spyridia were usually the predominant Rhodophyta genera.

Within the control basin, macroalgae have predominated the flora in all years, including the preoperational period (Figure E-7). However, seagrasses made a greater contribution to macrophyte biomass in 1981 in the control basin after exhibiting a gradual decline from 1977 (Figure E-7). They accounted for about 30 percent of the biomass in June. Three seagrasses, Halophila engelmannii, Ruppia maritima and Syringodium filiforme, were collected in the control basin every operative year. Halodule wrightii was collected in all but one year (1977) and Thalassia testudinum was collected there only in 1978. Because of the patchy distribution of most of the seagrasses in the control basin, it is not unusual to collect a species on one occasion and not another.

A monoculture of Halodule wrightii has been characteristic of the discharge basin throughout all operational years. The presence of Thalassia testudinum at one discharge station in November is interesting, because Thalassia usually declines in fall and early winter. It has not been collected in the discharge during any other operative years, but it was found in small patches well away from plume boundaries in the preoperational studies (van Tine, 1977).

When comparing quarterly operational biomass values (Figure E-8), it appears that seagrasses in the discharge basin not only recovered throughout the winter but were actually enhanced in 1978, 1979 and 1980. In those three years, seagrass biomass peaked in September at much higher levels than previously recorded. However, macroalgae in the control also reached high abundances in September of 1978, 1979 and 1980, so that fall increases may have only been a result of more favorable growing conditions during those years.

Apparently, the thermal load imposed by the operation of Unit 3 does not have any greater impact on the seagrasses in the winter than when only Units 1 and 2 are operating. However, when Unit 3 is on-line through the summer months, as it was in 1977 and 1981, seagrass biomass is reduced below levels reported when only the two fossil fuel plants are operating (Figure E-8). Throughout the summers of 1978, 1979 and 1980, Unit 3 was not on-line.

Preoperational Comparisons

Differences between the two basins with respect to floral composition existed prior to operation of Unit 3 at Crystal River. The discharge basin was already impacted by thermal effluents from two fossil fuel units and by relatively high sedimentation rates. Information about the vegetation of the discharge basin prior to 1973 is lacking.

No major differences in dominant seagrass and macroalgae taxa for the two basins were observed between preoperational and operational

years. The obvious changes have been with regard to the gradual loss of algae in the discharge area. In 1973, algae composed an average of 16 percent of the macrophyte biomass each quarter. By 1978, there was no significant amount of algae collected at any time of the year. In the intervening years, hard substrates that once supported algae may have become covered by sediments. Alternatively, algal biomass may have declined from the combined results of high temperatures and turbidities or from other factors associated with plant effluents.

In 1981, seagrasses contributed about the same amount to macrophyte biomass in the control as they did in 1973. Because of the wide variation in macroalgae/seagrass ratios through the years, it is difficult to distinguish a trend. Quarterly seagrass biomasses were similar in 1973 and in 1981. From these data, it appears that the additional thermal discharge from a third unit has had little impact on seagrass biomass in the discharge.

SUMMARY

A comparison of macrophyte biomass, composition and distribution between the control and the discharge basins is complicated by physical and biological differences between basins. However, these differences are apparently not a result of the operation of Unit 3 because they existed prior to the time Unit 3 went on-line. It does appear that the construction and operation of the two fossil fuel units may have contributed to changes within the discharge basin.

In the discharge basin, macrophytes consist almost exclusively of Halodule wrightii. Vegetation in the control basin is predominantly macroalgae mixed with several species of seagrasses. Diversity and biomass were greater in the control basin than in the discharge basin during all sampling periods of 1981.

During the summer, macrophytes generally declined in both basins, but they were more depressed in the discharge basin where several stations experienced an almost complete exclusion of Halodule. Effects of plume waters on the flora of discharge stations diminished with distance from the point of discharge. No vegetation was found at the two stations closest to the point of discharge.

Since Unit 3 became operational in 1977, macroalgae has essentially disappeared from the discharge basin. The annual mean biomass of seagrasses in the discharge was also less in 1981 than in the three previous years when Unit 3 was off-line in the summer. However, the seagrass biomass values for 1981 were not noticeably different from those of 1977 when Unit 3 was operating in the summer or in 1973, when only the two coal-fired units were on-line. Observed increases in macrophyte biomass in both basins during 1978, 1979 and 1980, make it difficult to determine if thermal loading by Unit 3 has added to the impact of the other two units.

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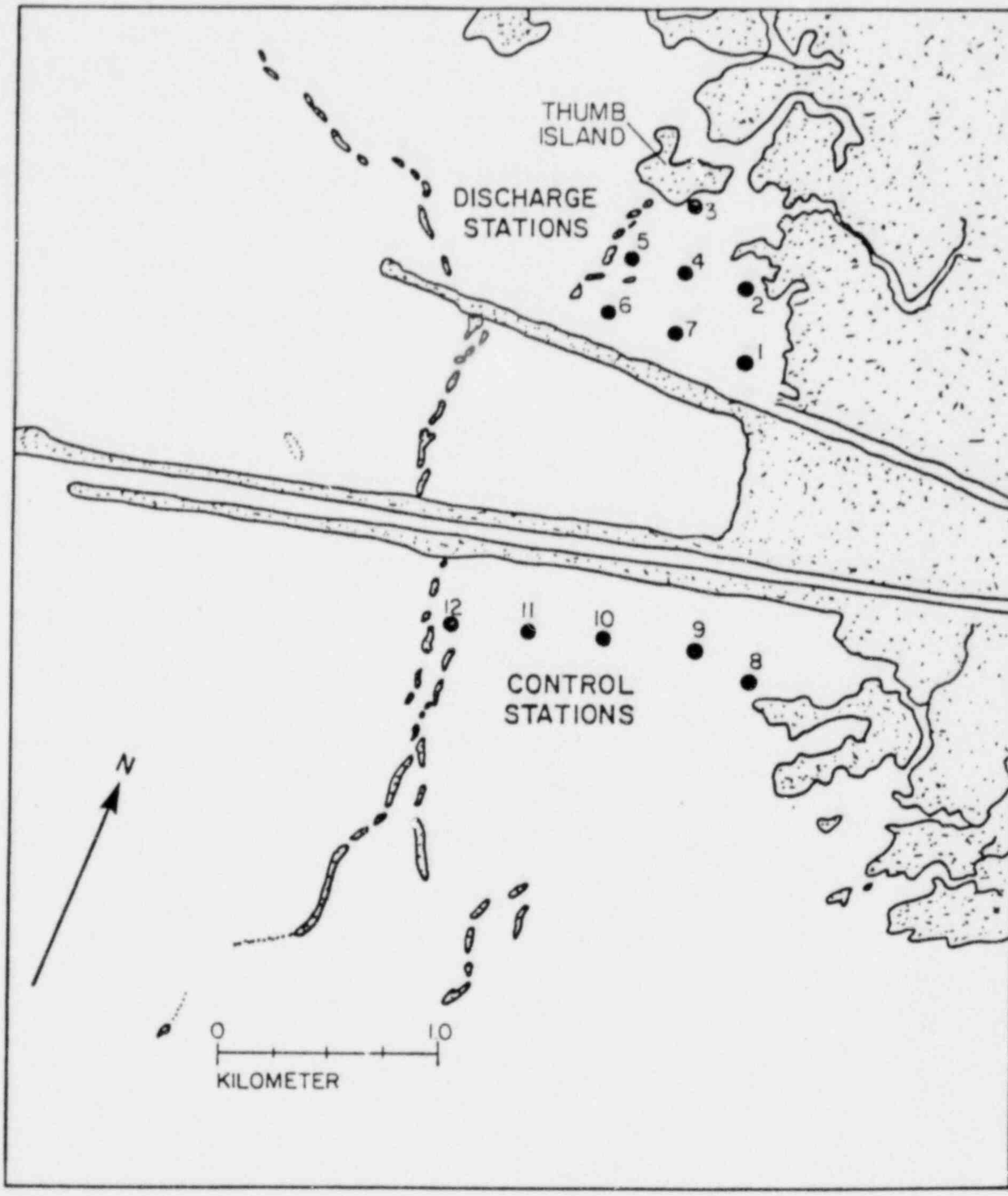

Figure E-1. Location of the 12 permanent stations used for collecting macrophyte biomass samples, Crystal River Project, 1981.

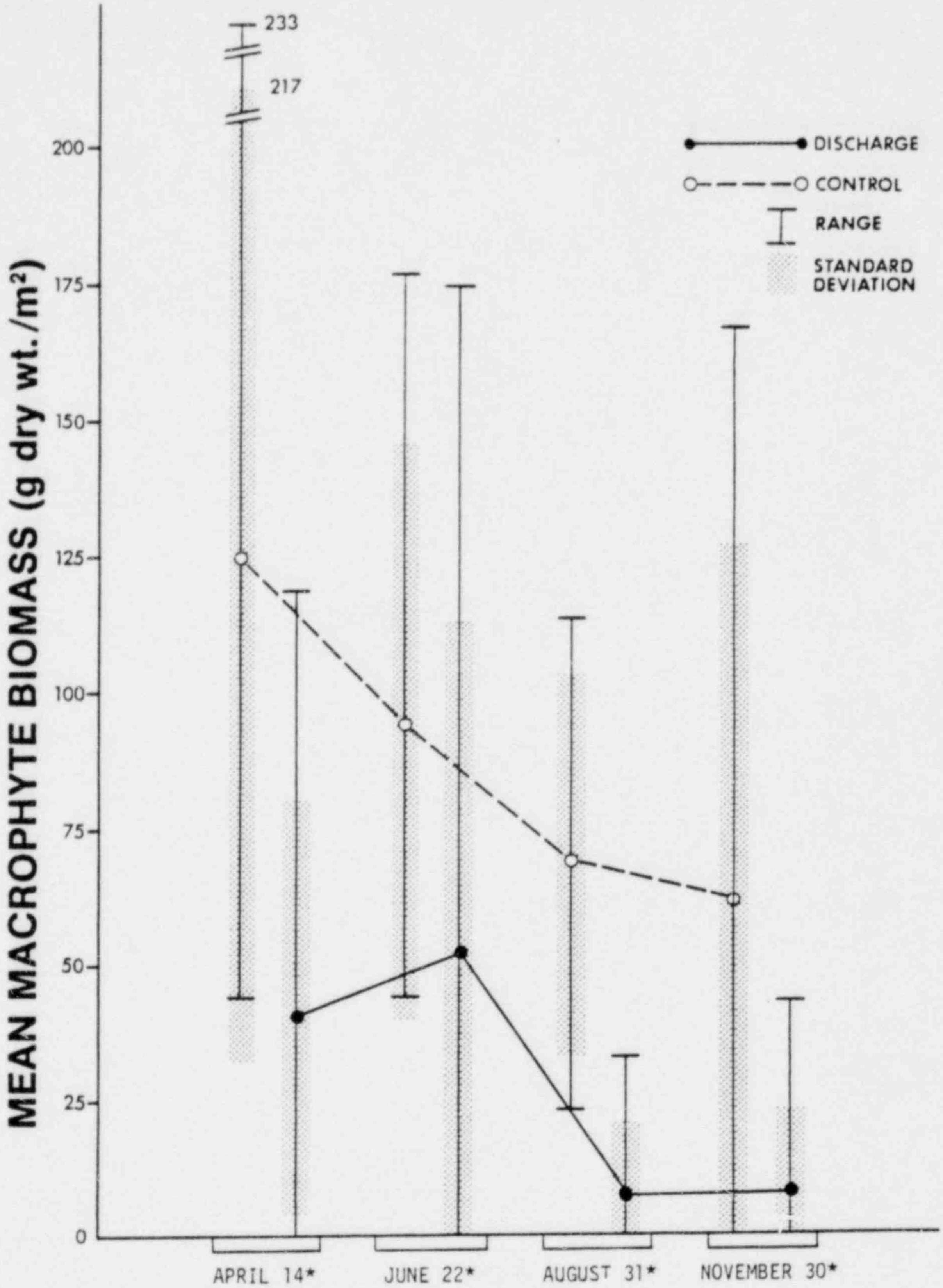

Figure E-2. Mean macrophyte biomass in the discharge and control basins, Crystal River Project, 1981. (*Significant difference between basins).

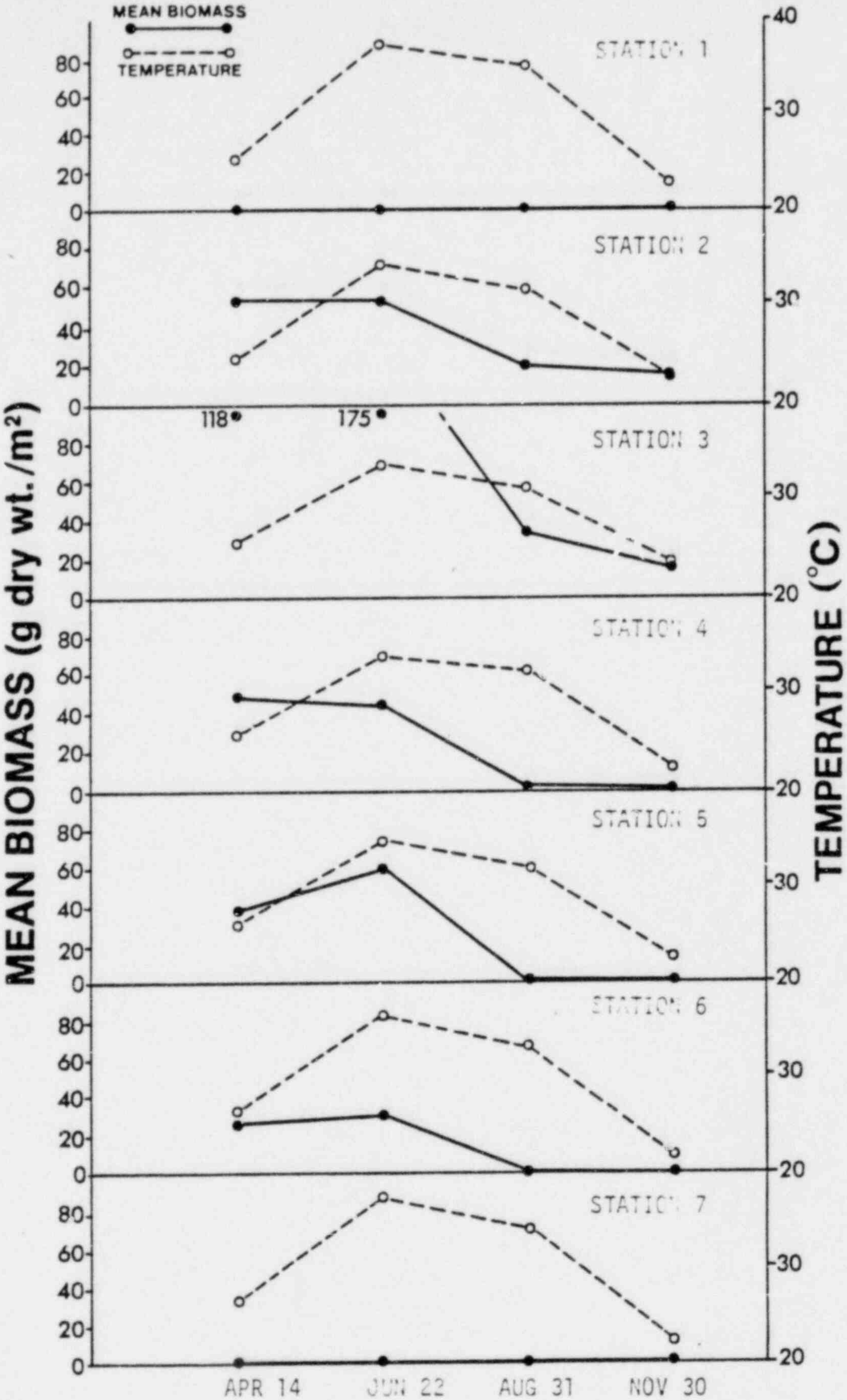

Figure E-3. Mean biomass of Halodule compared with maximum observed bottom water temperatures for each station in the discharge basin, Crystal River Project, 1981.

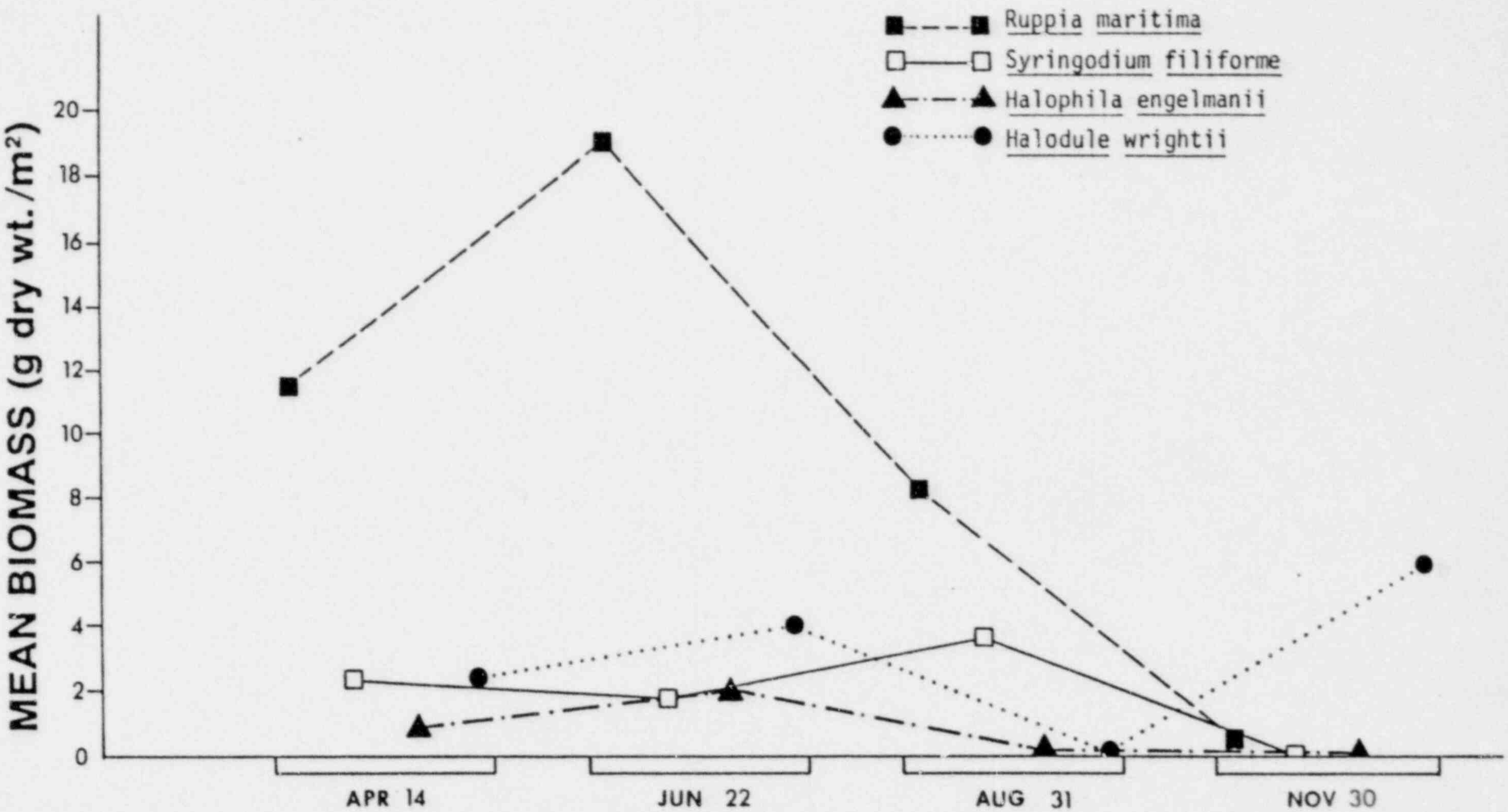

Figure E-4. Quarterly mean biomass of four seagrasses in the control basin, Crystal River Project, 1981.

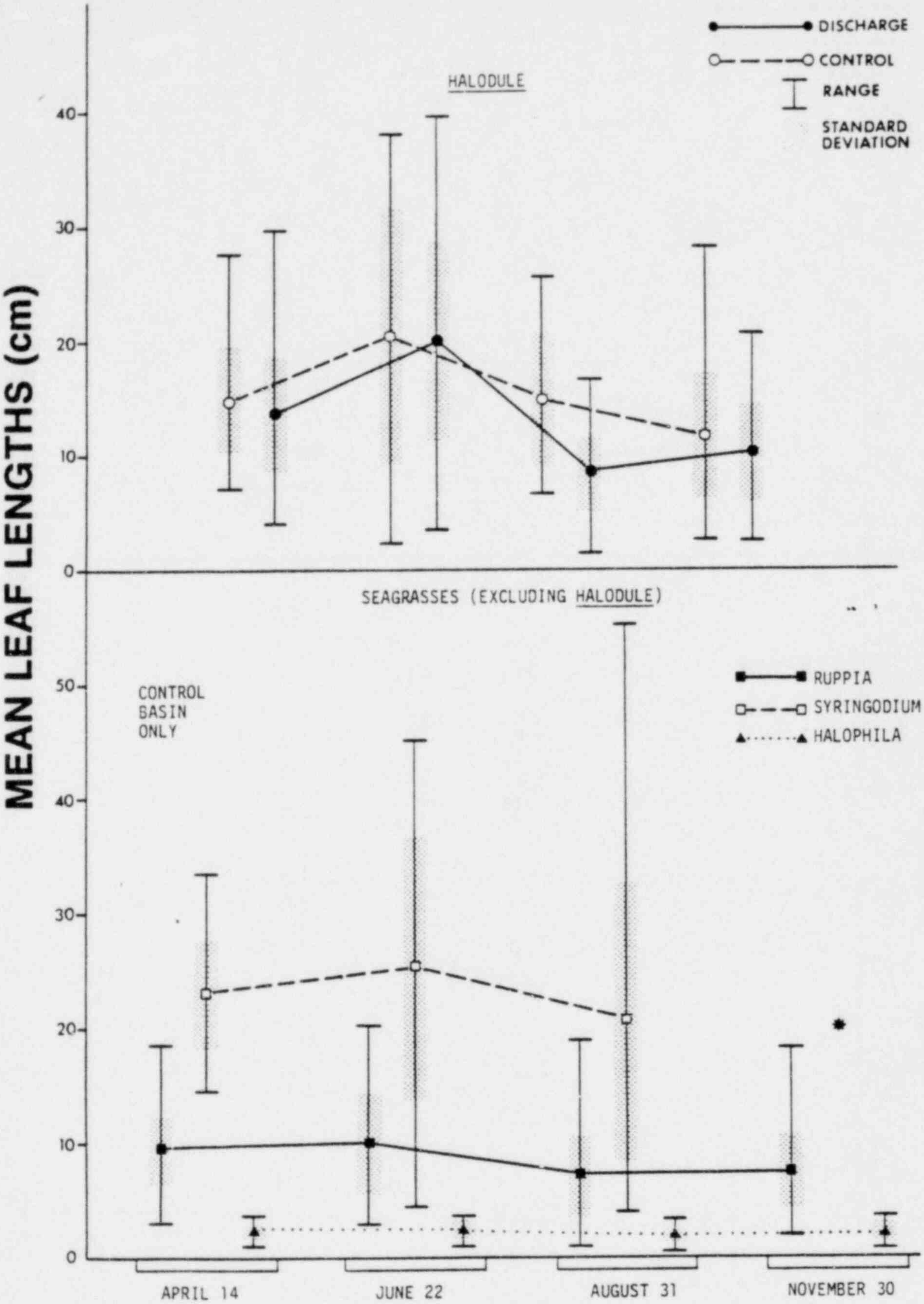

Figure E-5. Quarterly mean leaf lengths for Halodule, Ruppia, Syringodium and Halophila, Crystal River Project, 1981. (*No Syringodium filiforme was collected in November. Thalassia testudinum was excluded from the data because it was collected only once in 1981).

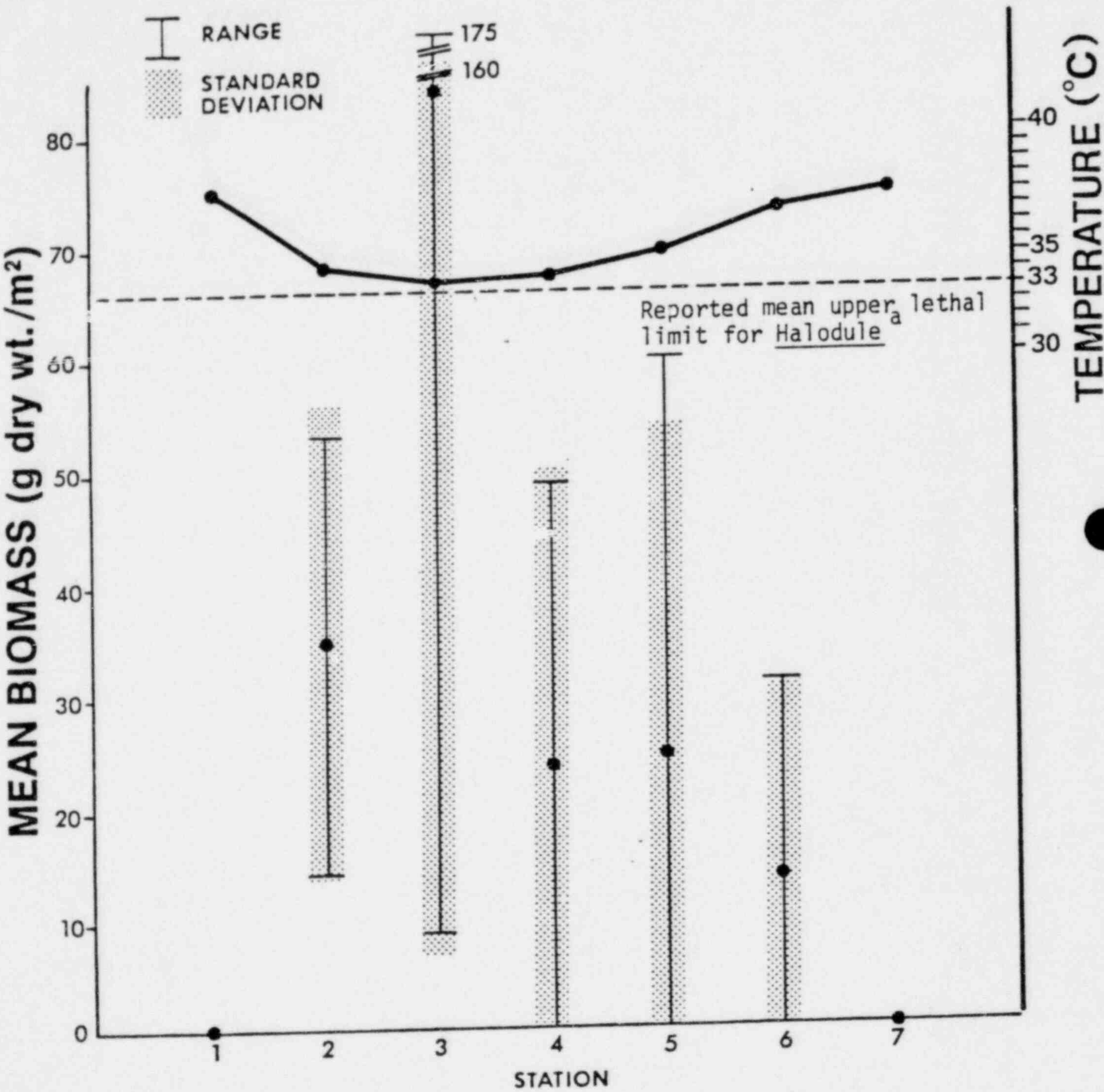

Figure E-6. Mean biomass of Halodule compared with maximum observed bottom water temperatures for each station in the discharge basin, Crystal River Project, 1981. ([a]Thorhaug et al., 1978).

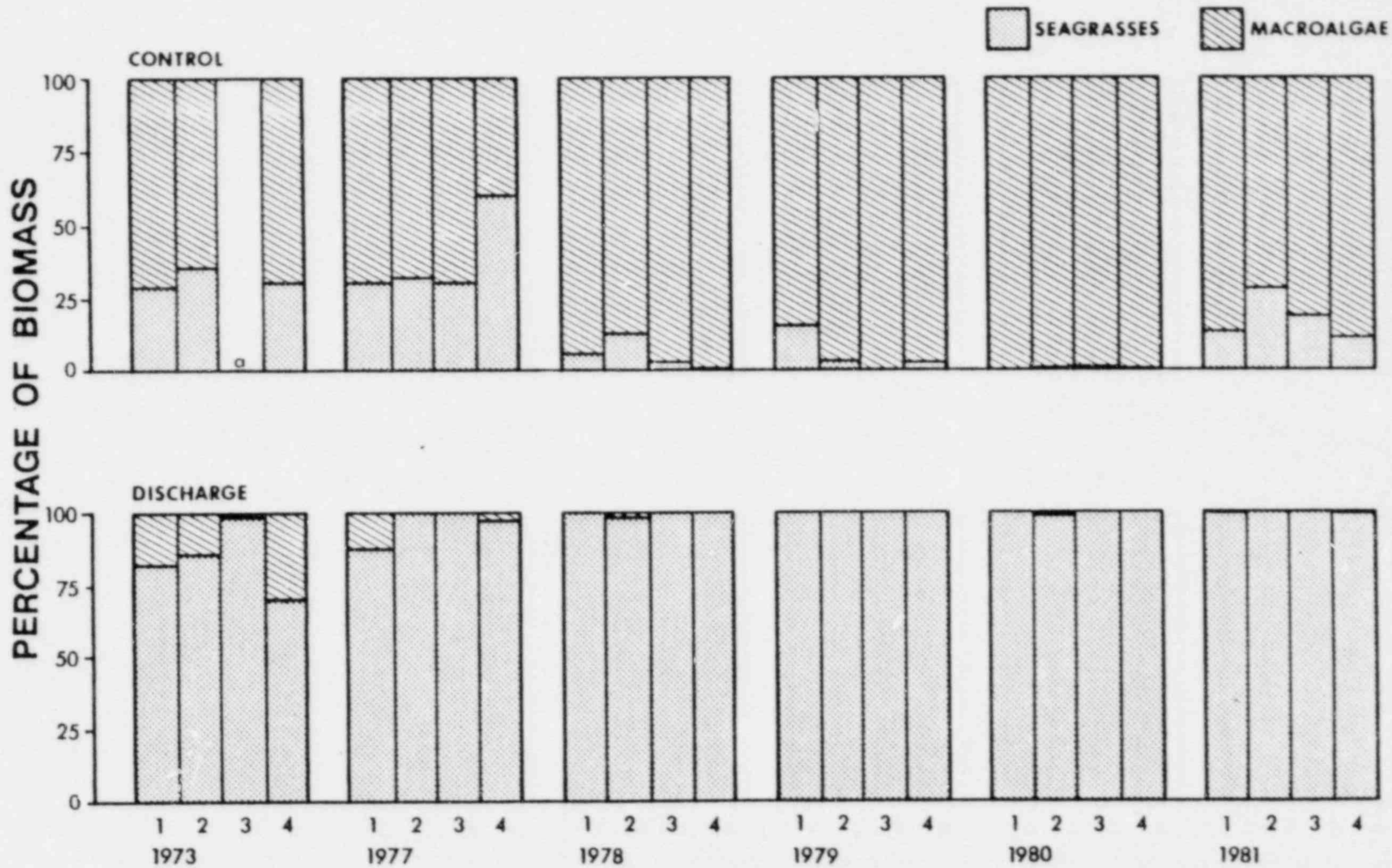

Figure E-7. Percentage contribution of seagrasses and macroalgae to total quarterly macrophyte biomass in discharge and control basins in preoperational and operational years, Crystal River Project, 1973 and 1977-1981. (a = data not available)

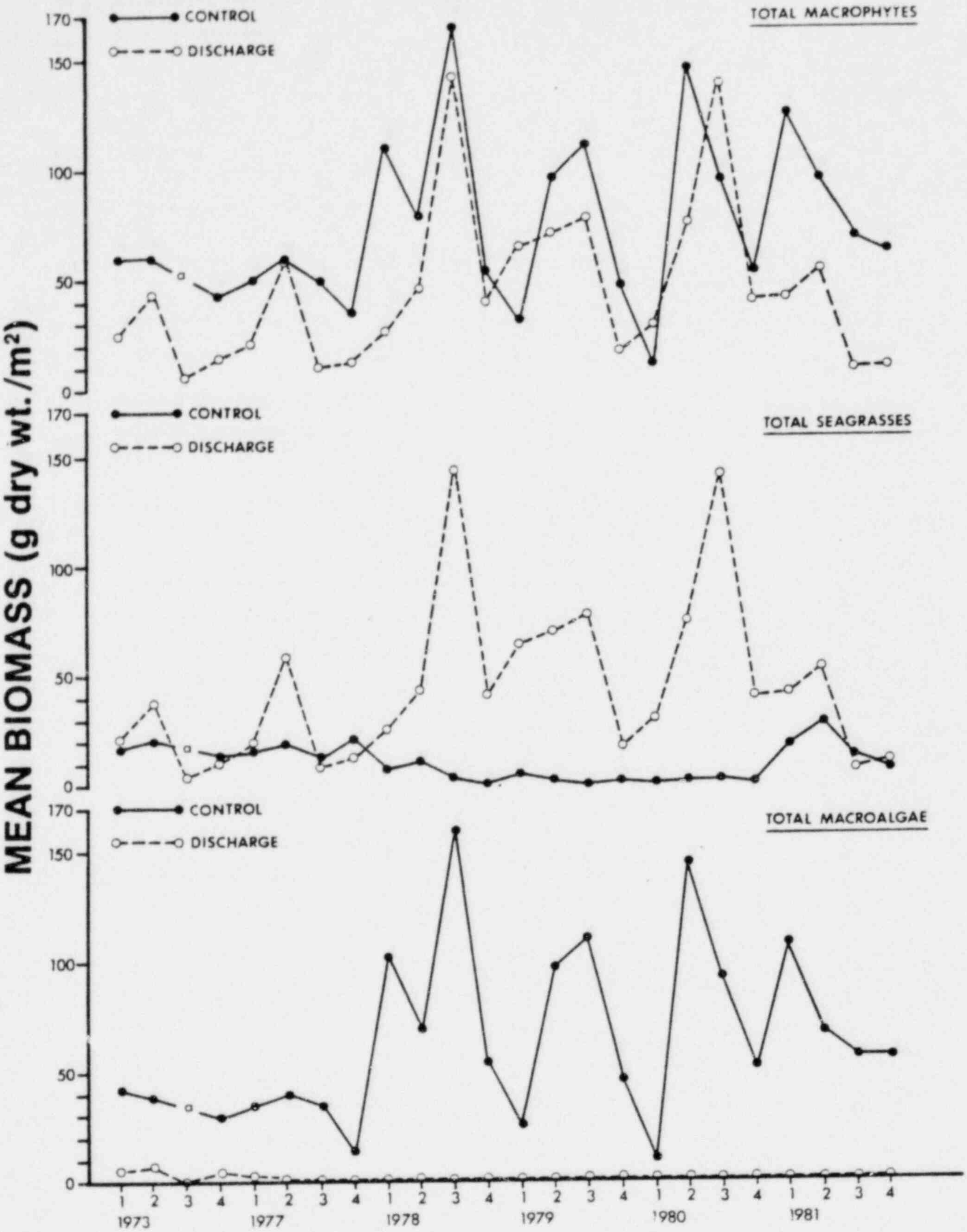

Figure E-8. Mean quarterly biomass for total macrophytes, seagrasses and macroalgae, Crystal River Project, 1973 and 1977-1981. (a = data not available).

TABLE E-1

TAXONOMIC LIST AND FREQUENCY OF OCCURRENCE[a] FOR BENTHIC MACROPHYTES
CRYSTAL RIVER PROJECT
1981

Taxa	Station												Frequency of occurrence by basin	
	1	2	3	4	5	6	7	8	9	10	11	12	Discharge	Control
SEAGRASSES														
Halodule wrightii		100	100	66.7	58.3	50		25		50			53.6	15
Halophila engelmanii										75			0	15
Ruppia maritima								100	16.7	66.7			0	36.7
Syringodium filiforme										50			0	10
Thalassia testudinum			8.3										1.2	0
Seagrass taxa	0	1	2	1	1	1	0	2	1	4	0	0	2	4
MACROALGAE														
Rhodophyta														
Acanthophora spp.			8.3								25		1.2	5
Centroceras spp.									75		25	8.3	0	21.7
Ceramium spp.									50	25	58.3	41.7	0	35
Champia spp.									50	16.7	50	25	0	28.3
Chondria spp.								8.3	33.3	16.7	58.3	25	0	28.3
Dasya spp.								8.3	25	8.3	16.7	8.3	0	13.3
Gracilaria spp.						8.3		8.3	75	58.3	75	75	1.2	58.3
Griffithsia spp.											8.3		0	1.7
Herposiphonia spp.									8.3				0	1.7
Hypnea spp.											33.3		0	6.7
Laurencia spp.								8.3	50	16.7	50	25	0	30
Polysiphonia spp.									33.3		41.7	8.3	0	16.7
Solieria spp.									25	16.7	8.3		0	10
Spermothamnion spp.											33.3		0	6.7
Spyridia spp.						25		16.7	75	41.7	25		3.6	31.7
Rhodophyta taxa	0	0	1	0	0	2	0	5	11	8	14	8	3	15
Chlorophyta														
Caulerpa spp.								75	8.3	16.7	8.3	75	0	36.7
Cladophora spp.									8.3				0	1.7
Enteromorpha spp.								8.3	8.3				0	3.3
Penicillus spp.									8.3	16.7			0	5
Udotea spp.									33.3	25	8.3		0	13.3
Chlorophyta taxa	0	0	0	0	0	0	0	2	5	3	2	1	0	5

TABLE E-1
(continued)
TAXONOMIC LIST AND FREQUENCY OF OCCURRENCE[a] FOR BENTHIC MACROPHYTES
CRYSTAL RIVER PROJECT
1981

Taxa	Station 1	2	3	4	5	6	7	8	9	10	11	12	Frequency of occurrence by basin: Discharge	Control
Phaeophyta														
Giffordia spp.											25		0	5
Sargassum spp.								8.3	100	25	83.3		0	43.3
Sphacelaria spp.									8.3				0	1.7
Phaeophyta taxa	0	0	0	0	0	0	0	1	2	1	2	0	0	3
TOTAL TAXON	0	1	3	1	1	3	0	10	19	16	18	9	5	23

[a] Percentage of replicates taken during 1981 (for each station, n=12; for discharge basin, n=84; for control basin, n=60) in which each taxon was contained.

TABLE E-2

BIOMASS (gram dry weight/m^2) OF SEAGRASS AND MACROALGAE BY QUARTER
AT DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

	14 April		20 June		31 August		30 November	
Station	Seagrass	Macroalgae	Seagrass	Macroalgae	Seagrass	Macroalgae	Seagrass	Macroalgae
Discharge stations								
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	52.4	0.0	53.2	0.0	19.6	0.0	14.3	0.0
3	118.1	0.0	174.9	0.0	32.8	0.0	40.4	0.3
4	49.1	0.0	44.0	0.0	0.8	0.0	0.0	0.0
5	38.1	0.0	60.0	0.0	0.0	0.0	0.0	0.0
6	25.6	1.1	31.1	0.0	0.0	0.0	0.0	0.2
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	40.5	0.2	51.9	0.0	7.6	0.0	7.8	0.1
Control stations								
8	42.8	1.1	80.7	0.3	44.5	3.8	14.5	2.4
9	0.0	81.6	0.9	108.7	0.0	113.1	0.0	74.6
10	42.5	6.4	53.2	1.3	20.1	46.8	19.8	30.6
11	0.0	2[illegible]4.1	0.0	44.3	0.0	23.3	0.0	167.5
12	0.0	233.9	0.0	176.9	0.0	89.6	0.0	0.0
Mean	17.1	107.4	27.0	66.3	12.9	55.3	6.9	55.0

TABLE E-3

BIOMASS (gram dry weight/m^2) OF MACROALGAE BY DIVISION
CONTROL STATIONS 8 THROUGH 12
CRYSTAL RIVER PROJECT
1981

Month	Station 8	9	10	11	12	Mean
RHODOPHYTA						
April	0.3	5.9	4.9	196.4	20.7	45.6
June	0.4	58.5	1.2	39.6	7.3	21.4
August	0.1	27.5	44.9	21.9	2.0	19.3
November	0.5	14.6	29.2	76.5	0.0	24.2
Mean	0.3	26.6	20.1	83.6	7.5	27.6
CHLOROPHYTA						
April	0.8	58.9	0.3	0.1	213.2	54.7
June	0.0	1.1	0.1	1.3	169.6	34.4
August	3.7	12.9	1.9	0.0	87.6	21.2
November	1.8	0.0	0.1	0.0	0.0	0.4
Mean	1.6	18.2	0.6	0.4	117.6	27.7
PHAEOPHYTA						
April	0.0	16.8	1.2	17.6	0.0	7.1
June	0.1	49.1	0.0	3.3	0.0	10.5
August	0.0	72.7	0.0	1.5	0.0	14.8
November	0.0	60.0	1.4	90.9	0.0	30.5
Mean	<0.1	49.7	0.7	28.3	0.0	15.7

TABLE E-4

COMPARISON OF *HALODULE* BIOMASS AT DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 14 APRIL

Source	DF	Sum of Squares	Mean squares	F
Model	6	31.84733554	5.30788926	135.92*
Error	14	0.54672999	0.03905214	
Corrected total	20	32.39406553		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST

Grouping	Mean	N	Station
A	28.9174	3	3
B	12.5390	3	2
B	12.2484	3	4
B	9.4373	3	5
C	6.2831	3	6
D	0.0000	3	1
D	0.0000	3	7

*Significant at $P \leq 0.05$.

TABLE E-4
(continued)
COMPARISON OF HALODULE BIOMASS AT DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 22 JUNE

Source	DF	Sum of Squares	Mean squares	F
Model	6	36.85477884	6.14246314	82.11*
Error	14	1.04724766	0.07480340	
Corrected total	20	37.90202649		

*Significant at P≤0.05.

DUNCAN'S MULTIPLE RANGE TEST

Grouping	Mean	N	Station
A	42.5947	3	3
B	14.7057	3	5
B C	12.8969	3	2
B C	9.9377	3	4
C	7.6564	3	6
D	0.0000	3	1
D	0.0000	3	7

*Significant at P≤0.05.

TABLE E-4
(continued)
COMPARISON OF HALODULE BIOMASS AT DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 31 AUGUST

Source	DF	Sum of Squares	Mean squares	F
Model	6	14.31816040	2.38636007	14.92*
Error	14	2.23873391	0.15990957	
Corrected total	20	16.55689431		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST

Grouping	Mean	N	Station
A	6.3295	3	3
A	4.5193	3	2
B	0.1888	3	4
B	0.0000	3	1
B	0.0000	3	5
B	0.0000	3	6
B	0.0000	3	7

*Significant at $P \leq 0.05$.

TABLE E-4
(continued)
COMPARISON OF HALODULE BIOMASS AT DISCHARGE STATIONS
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE: 30 NOVEMBER

Source	DF	Sum of Squares	Mean squares	F
Model	6	6.61619186	1.10269864	12.57*
Error	14	1.22826624	0.08773330	
Corrected total	20	7.84445810		

*Significant at $P \leq 0.05$.

DUNCAN'S MULTIPLE RANGE TEST

Grouping	Mean	N	Station
A	2.9047	3	2
A	2.0161	3	3
B	0.0000	3	1
B	0.0000	3	4
B	0.0000	3	5
B	0.0000	3	6
B	0.0000	3	7

*Significant at $P \leq 0.05$.

F. MACRONPHYTE MONITORING

INTRODUCTION

The ecological importance of benthic macrophytes and their usefulness as an indicator of environmental perturbation was discussed in Section E. Macrophyte Biomass. The purpose of the macrophyte monitoring program was to provide a qualitative survey of macrophyte distribution in the coastal waters near the Crystal River Power Plant. Because this survey covered both the inner and outer portions of the discharge and control areas, it augmented data generated by the macrophyte biomass study.

MATERIALS AND METHODS

The distribution, coverage and general condition of macrophytes near the Crystal River Power Plant were monitored quarterly. Within the nearshore discharge and control basins, macrophytes were surveyed at 0.1-km intervals along five preestablished transects (inside transects) adjacent to benthic core stations (Figure F-1). In the outer discharge and control basins, macrophytes were monitored at approximately 0.5-km intervals along 23 preestablished transects (outside transects).

Divers randomly dropped weighted 1-m^2 frames to the bottom and, within each quadrat, estimated the percentage cover and general condition of each seagrass species and noted the relative abundance of conspicuous macroalgae genera. The presence or absence of epiphytes was also recorded. Five replicate quadrats were analyzed at each transect station.

From the field data, mean percent coverage of seagrasses along discharge and control transects were calculated for each quarter. Distribution and coverage maps of total seagrasses (inside and outside transects) and of individual species (inside transects) were prepared and compared to postoperational data. Frequencies of occurrence based on the percentage of stations at which each division of macroalgae occurred were also determined for both basins.

RESULTS AND DISCUSSION

Total Seagrass Coverage

Inside Transects

Total seagrass coverage in the discharge basin was much greater along Transects 1 and 2 than along Transect 3 throughout the year (Figures F-2 through F-5). More than half the stations along Transect 3 had little or no seagrass cover, probably resulting from the proximity of this transect to the discharge canal. Seagrass distribution was most extensive in June and September when Transects 1 and 2 had greater than 50 percent coverage for most of their lengths (Figures F-3 and F-4).

Control basin Transects 26 and 27 also exhibited high percentages of seagrass coverage throughout the year, but the pattern of distribution was more varied and patchy along these radials than along transects in the discharge basin. Total seagrass coverage reached 100 percent in September at stations closest to shore, but it was generally less than 75 percent during the remaining seasons (Figures F-2 through F-5).

Outside Transects

Outside discharge transects consisted of patchy and sparse distributions of seagrasses throughout the year. Transects 5, 14, 15 and 20 were completely devoid of seagrasses during every sampling quarter, and an additional four transects (4, 6, 10 and 11) were devoid of seagrasses in December (Figures F-2 through F-5). Seagrass coverage was patchy but greatest (up to 100 percent cover) along Transects 6, 7, 9, 16, 17 and 18 during September (Figure F-4) and least during the winter (Figure F-5). In general, it appears that total seagrass coverage was greatest near oyster reefs and in the shallow water stations near shore. Water clarity throughout much of the discharge area was usually very poor, visibility sometimes being limited to less than 0.3 m. Thus, in deeper areas, light penetration may have been inadequate to promote substantial seagrass growth.

Total seagrass coverage along the six outside control transects was patchy and sparse in April and December 1981, but it was more continuous in June (26-75 percent) and September (up to 100 percent, Figures F-2 through F-5).

Seagrass Species Composition

Inside Transects

All five species of seagrasses that occur in the Crystal River area were observed along the control basin transects during one or more sampling quarters. *Halophila engelmannii* and *Thalassia testudinum* occurred rarely and were not mapped.

Halodule was patchy and sparsely distributed along control transects during April and June (Figures F-6 and F-7). This species was not observed during macrophyte monitoring in the control area after June. *Halodule* was dense and widely distributed along discharge transects during every sampling quarter (Figures F-8 through F-11). The difference in coverage between basins is most likely due to the greater availability in the discharge basin of soft substrates, which are necessary to support *Halodule* root systems.

Halodule was the only seagrass species observed in the discharge basin during monitoring for the entire year. Its persistence in the discharge basin is probably related to the general hardiness and high thermal tolerance of the species (Thorhaug et al., 1978). Coverage generally ranged from 26 to 100 percent from April to December 1981 along Transects 1 and 2, but it was patchy along Transect 2 during December. *Halodule* was absent from the middle stations of Transect 3 between spring and fall and completely absent along the entire transect in winter. This variability in distribution is probably due to the transect's proximity to the discharge canal and to the duration of exposure to high temperatures.

Syringodium filiforme was more widely distributed than *Halodule* along control transects in all sampling quarters except April, when *Syringodium* was completely absent from the control basin (Figures F-12 through F-14). Coverage generally ranged from 26 to 50 percent in June and September but reached 75 percent at some nearshore stations in December.

Ruppia maritima was the only other seagrass species that showed a persistent, though patchy, distribution along control transects during the year. Except for the winter quarter, _Ruppia_ coverage was generally more continuous nearshore than at stations farther out, ranging from 26 to 75 percent (Figures F-15 to F-17). Like _Halodule_, this species was completely absent along control transects in winter, whereas _Syringodium_ was widely distributed along both control transects during that period. _Ruppia_ was completely absent from the discharge basin throughout the year. This may be a result of _Ruppia_'s known preference for lower salinities (Phillips, 1978) and its possible low tolerance to thermal stress.

Outside Transects

Halodule and _Syringodium_ were the most widely distributed seagrasses along outside control transects throughout the sampling year. Mean percent coverage of both species was sparse (1 to 25 percent) in spring, but _Syringodium_ coverage increased to greater than 50 percent in summer and fall. _Halophila_ appeared to be widely distributed during the fall but was only occasionally observed during the other seasons.

Outside discharge Transects 6, 7, 9, 16, 17 and 18 consistently exhibited patchy but often dense seagrass coverage. All five species of seagrasses were observed at outer discharge transects during some portion of the year. However, with the exception of _Syringodium_, coverage was generally sparse (1 to 25 percent). _Syringodium_ occurred with greater than 50 percent coverage more frequently than did the other species. It was the most prevalent seagrass found along outside transects in both control and discharge outside basins.

Frequency of Occurrence of Macroalgae

Macroalgae of three phyla, Rhodophyta (red algae), Chlorophyta (green algae) and Phaeophyta (brown algae), were distributed with widely varying frequencies along the inner control transects. Red algae occurred at more than 60 percent of the sampling stations year-round (Figure F-18). Green algae occurred at more than 80 percent of the stations during spring, summer and fall, but dropped to 24 percent in winter. Brown algae was the least commonly found algal group and occurred at less than 40 percent of the stations during every season but fall, when it was found at 62 percent of the control basin stations.

The inner discharge basin supported only red algae species. They occurred at less than 25 percent of the sampling stations and only during April and December (Figure F-18). Macroalgae did not occur in the discharge basin in June or September. This suggests that thermal effluents affect the distribution and frequency of occurrence of macroalgae near the Crystal River Power Plant during the warmer months of the year. Other factors peculiar to discharge basin waters, such as high sedimentation rates and turbidities, probably affect algae occurrence as well. Additionally, distribution and extent of available substrate types also influences the distributional frequency of macroalgae. More hard substrate and oyster reefs were observed in the control basin than in the discharge, making the former a more suitable habitat for algae than the latter.

Operational Trends

Outside Transects

Three species of seagrasses were observed along the outside control transects during 1981: *Halodule wrightii*, *Syringodium filiforme* and *Halophila engelmannii*. In 1980, these three species plus *Ruppia maritima* were observed in that area. *Syringodium* continued to be the most prevalent seagrass. Overall distribution and percent coverage of all seagrasses in the outside control basin were different from that of 1980. In 1980, seagrasses were most widely distributed and dense in March and December and least abundant in September (FPC, 1981). However, in 1981, the reverse was true, seagrasses being most widely distributed and dense in September.

During 1981, data did not indicate any adverse effects of thermal effluents on seagrasses occurring in the outer discharge basins. All five species of seagrasses were found along the outside discharge transects during the summer and fall of 1981 and three of these, *Halodule*, *Syringodium* and *Halophila*, occurred throughout the entire year. During 1979 and 1980, these three species were also observed along the outside discharge transects. Since 1979, *Syringodium* has been the most prevalent species. Total seagrass coverage and distribution along outside discharge transects were greatest in September of 1981 and most sparse in December. During 1980, seagrass coverage along these transects was heaviest in winter and distribution most widespread in April.

Inside Transects

During 1980, four species of seagrasses were found along inside control transects: Rupia maritima, Halophila engelmannii, Halodule wrightii and Syringodium filiforme. In 1981, each of these species plus Thalassia testudinum were observed. Seagrasses have been reported throughout the control basin since 1977, and percent coverage has been sparse to moderate through 1981. Syringodium filiforme continued to predominate in the control basin as it has since 1979. Ruppia maritima also became an important component of the control basin seagrass system in 1981.

As in previous years, Halodule was the only species observed during macrophyte monitoring in the discharge basin in 1981. Halophila was the only other species of seagrass ever reported in the discharge basin, and it occurred only in June 1980 (FPC, 1981). Since 1977, Halodule continued to follow the trend of dense coverage and wide distribution throughout most of the inner discharge basin. Coverage of Halodule has consistently been lowest along the transect closest to the discharge canal.

SUMMARY

Distribution, coverage and general condition of aquatic macrophytes near the Crystal River Power Plant were monitored quarterly during 1981. Total seagrass distribution in the inner control basin was patchy but coverage was dense throughout the sampling year. Syringodium filiforme was the dominant seagrass occurring there, thus continuing a trend

observed since monitoring began in 1977. _Ruppia maritima_ was the only other species that persisted in the inner control basin although distribution was patchy.

In the inner discharge basin, seagrasses were more widely distributed, and coverage was generally dense. However, _Halodule wrightii_ was the only species observed there throughout 1981 monitoring. Coverage of this species was considerably reduced along more than half the stations closest to the discharge canal. This pattern has been evident since 1977. Seagrasses along outside discharge transects were most widely distributed and dense near oyster reefs and in other shallow water areas near the shore.

Numerous species of red, green and brown algae were frequently observed in the inner control basin throughout the sampling year. Only red algae was found in the inner discharge basin.

The monospecific stands of _Halodule_, a relatively heat tolerant species, in the discharge basin suggest that power plant effluents may be inhibitive to other local seagrasses. Within the basin, greatest plume effects occur in those areas immediately adjacent to the discharge canal that runs along the southern boundary of the basin. Elsewhere, _Halodule_ distribution is widespread even though coverage appears to be reduced during the warmer periods of the year. Due to considerable differences in salinities, turbidities and substrates between basins, it is difficult to determine if other observed patterns of macrophyte coverage and

distribution are related to power plant operation. The lack of suitable substrate, for example, might account for the paucity of macroalgae in the discharge basin.

Comparison of 1981 and other operational data indicate that Unit 3 has not impacted the seagrass community of the discharge basin any more severely than the combined operation of Units 1 and 2. The greatest impact of all three units appears to be confined to the innermost basin of the discharge area. In the outer basins, all seagrasses and numerous alga species have been observed and their distributions appear to be regulated more by water depth and substrate type than by temperatures.

LITERATURE CITED

FPC (Florida Power Corporation). 1981. Postoperational ecological monitoring program Crystal River Units 1, 2 and 3. 1980 annual report Vol. I, Part I. pp. I-106 - I-157.

Thorhaug, A., N. Blake and P.B. Schroeder. 1978. The effect of heated effluents from power plants on seagrass (Thalassia) communities quantitatively comparing estuaries in the subtropics to the tropics. Marine Pollution Bulletin 9(7):181-186.

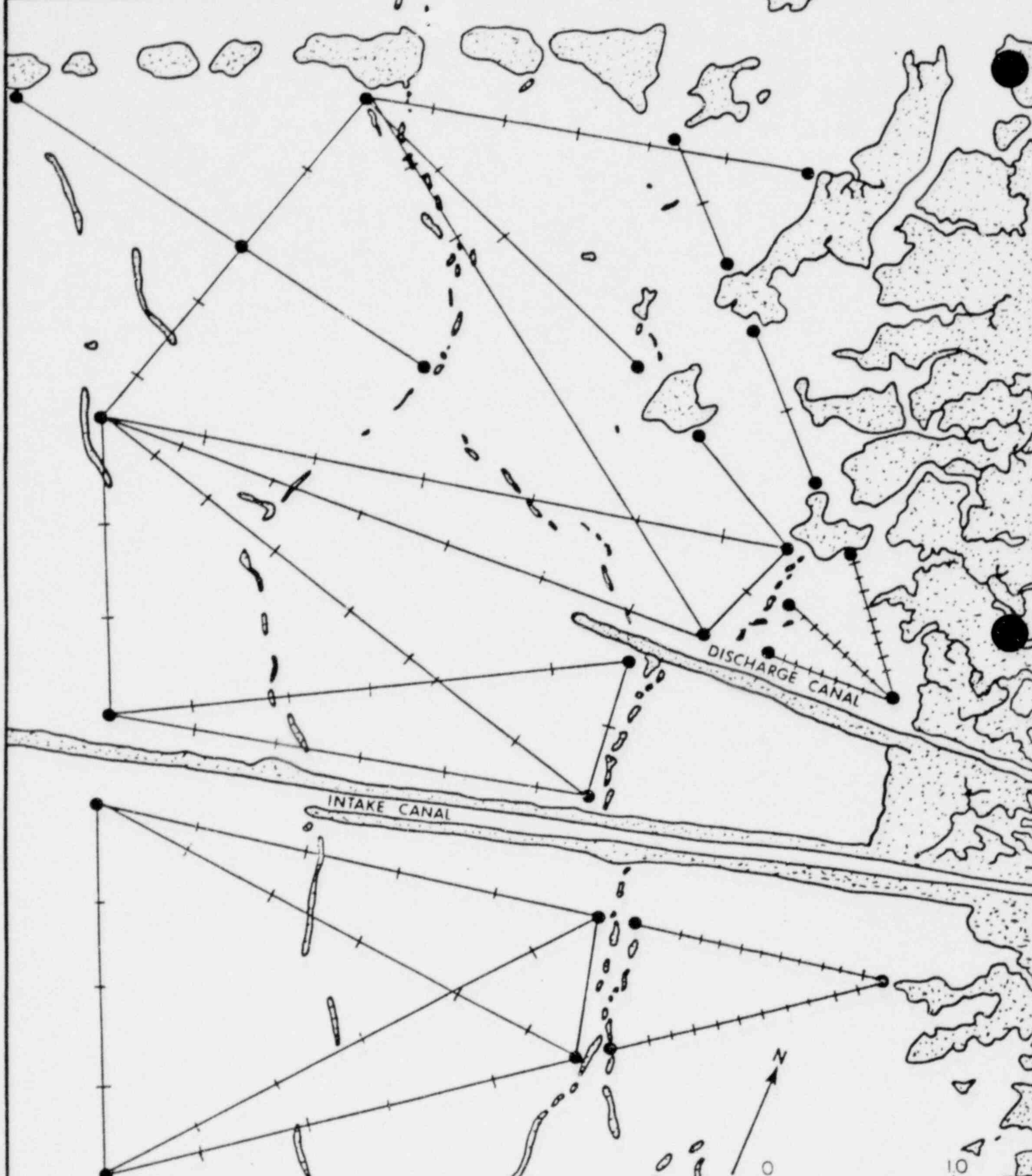

Figure F-1. Transects used for macrophyte monitoring, Crystal River Project, 1981.

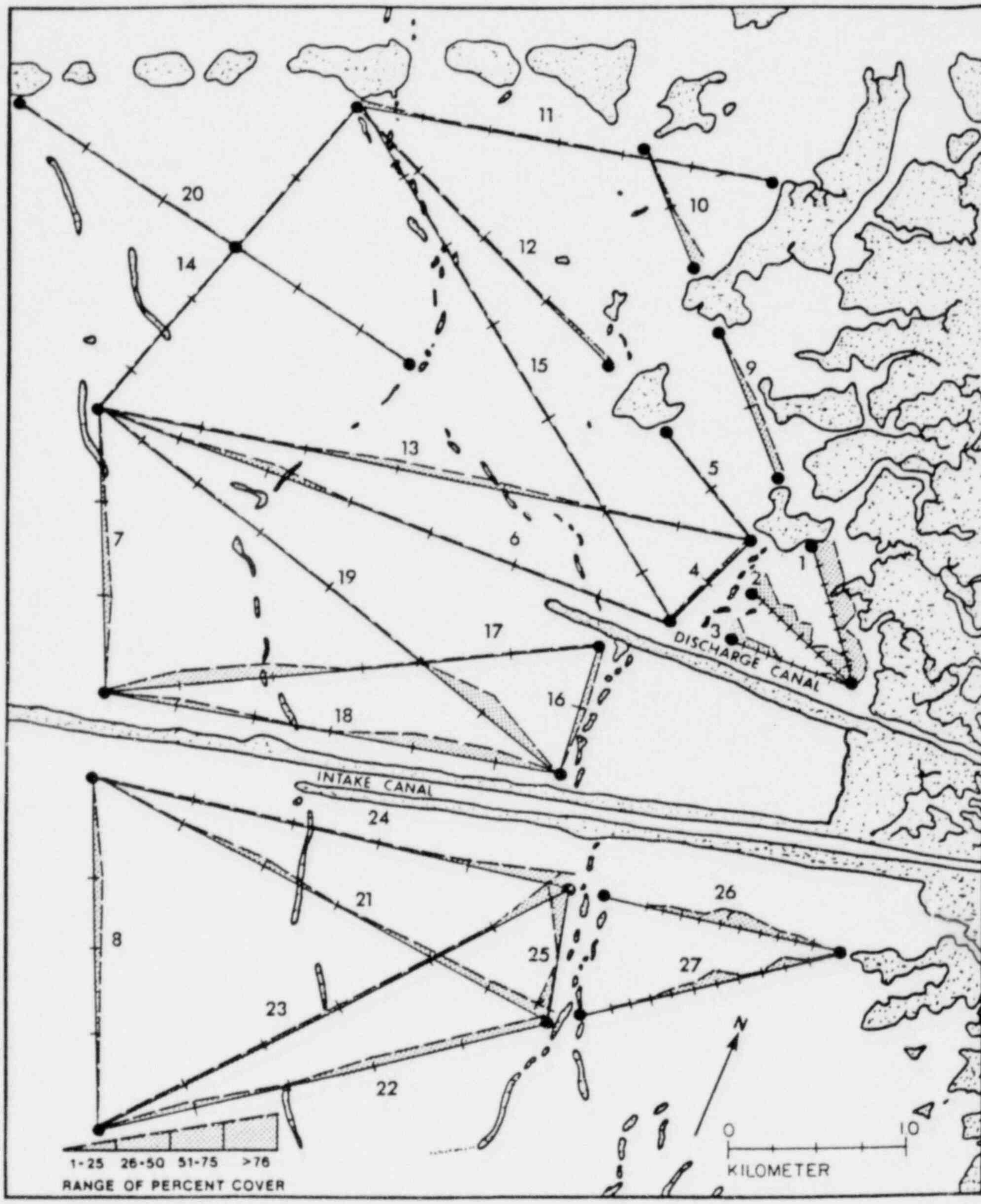

Figure F-2. Percentage cover and distribution of seagrasses, Crystal River Project, April 1981.

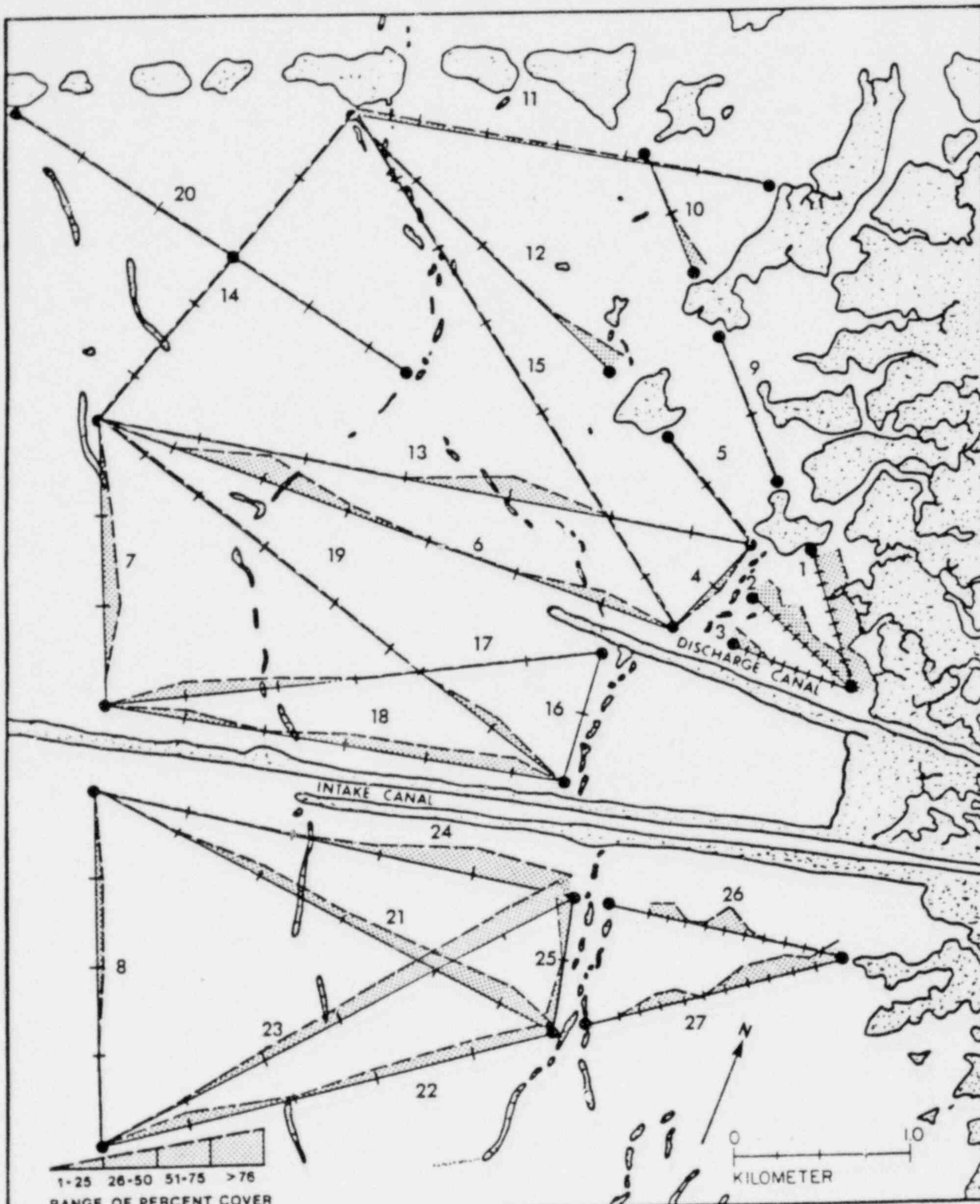

Figure F-3. Distribution and coverage of seagrasses, Crystal River Project, June 1981.

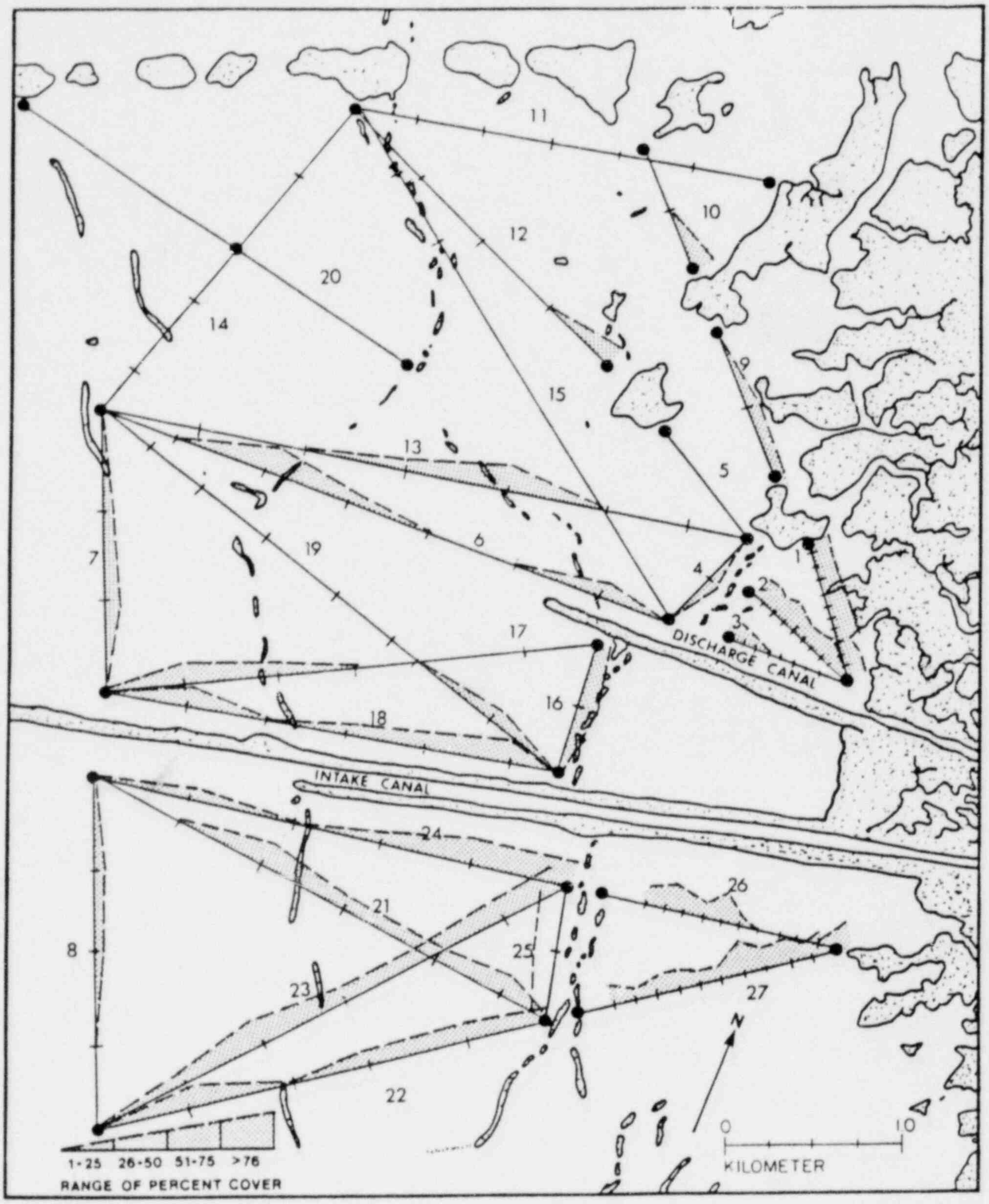

Figure F-4. Distribution and coverage of seagrasses, Crystal River Project, September 1981.

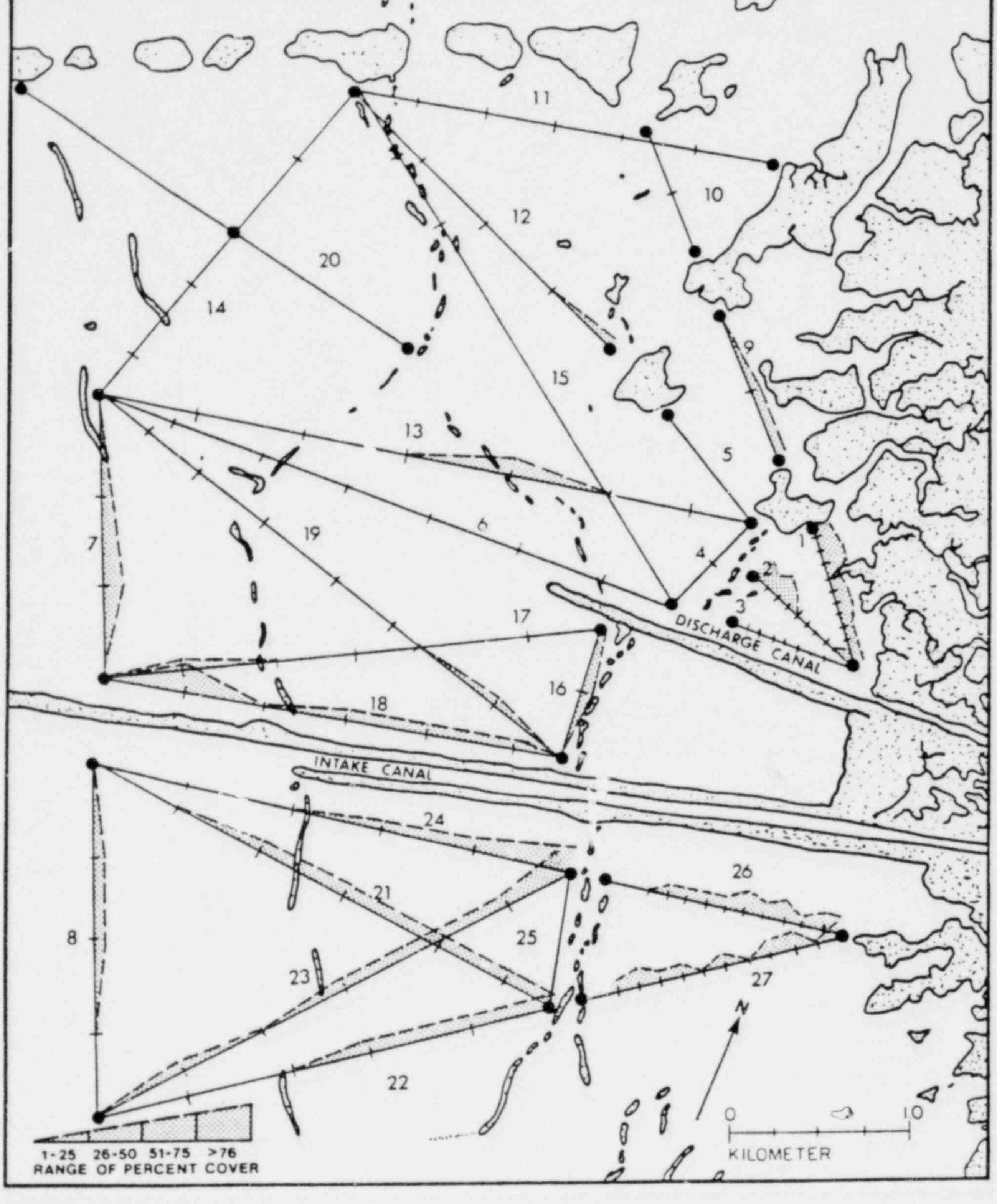

Figure F-5. Distribution and coverage of seagrasses, Crystal River Project, December 1981.

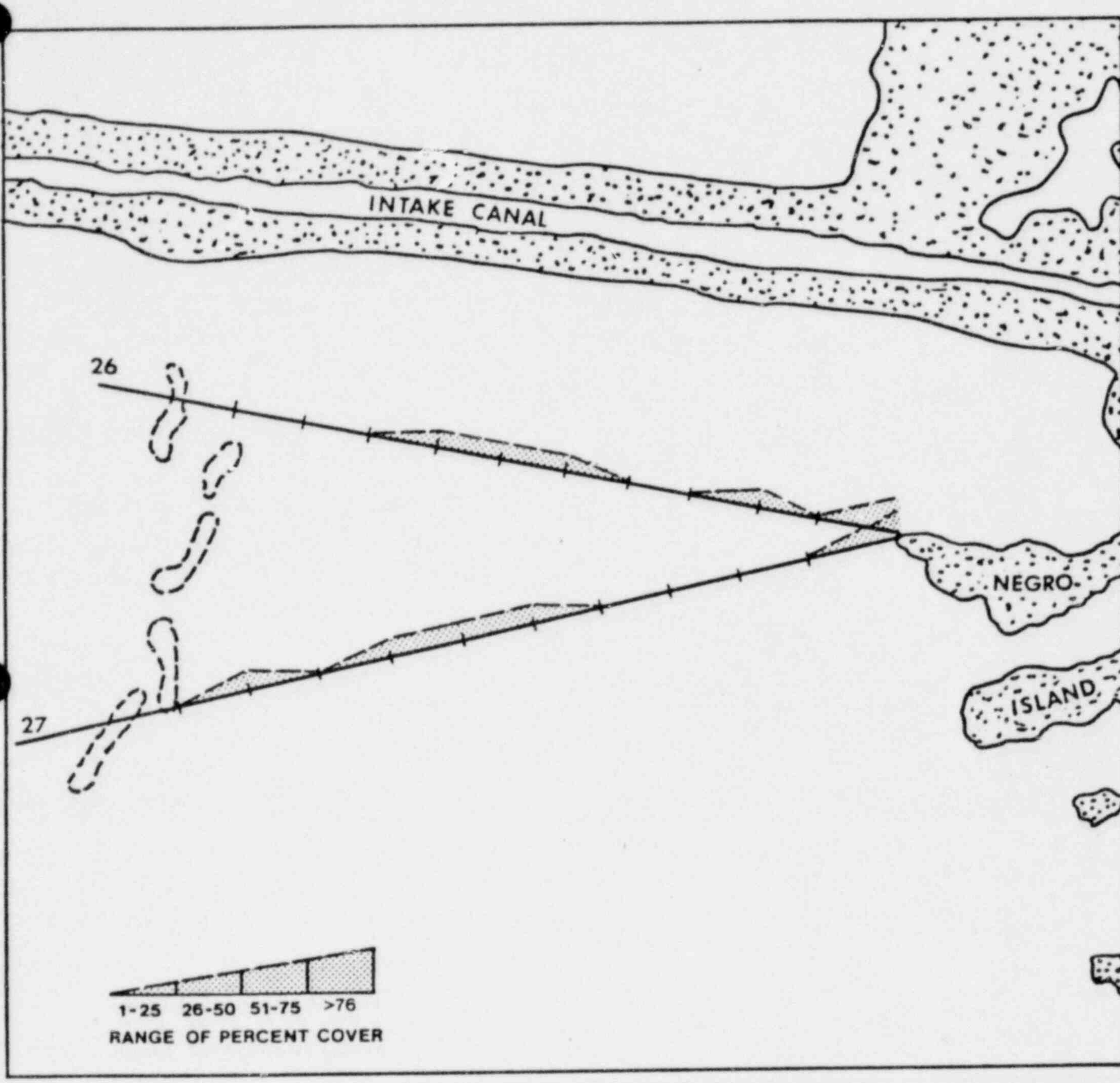

Figure F-6. Distribution of Halodule wrightii along inside transects of the control basin, Crystal River Project, April 1981.

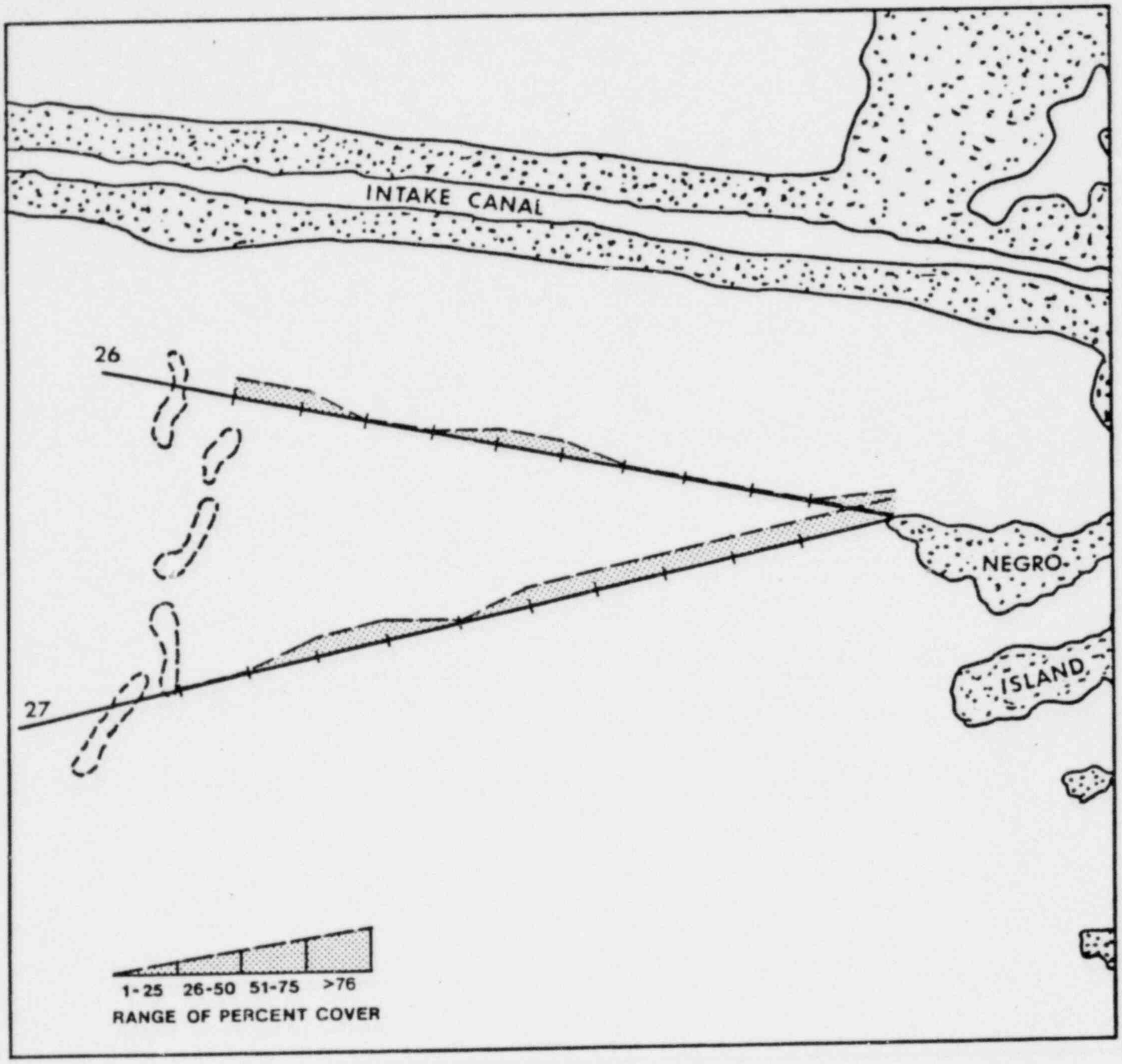

Figure F-7. Distribution of Halodule wrightii along inside transects of the control basin, Crystal River Project, June 1981.

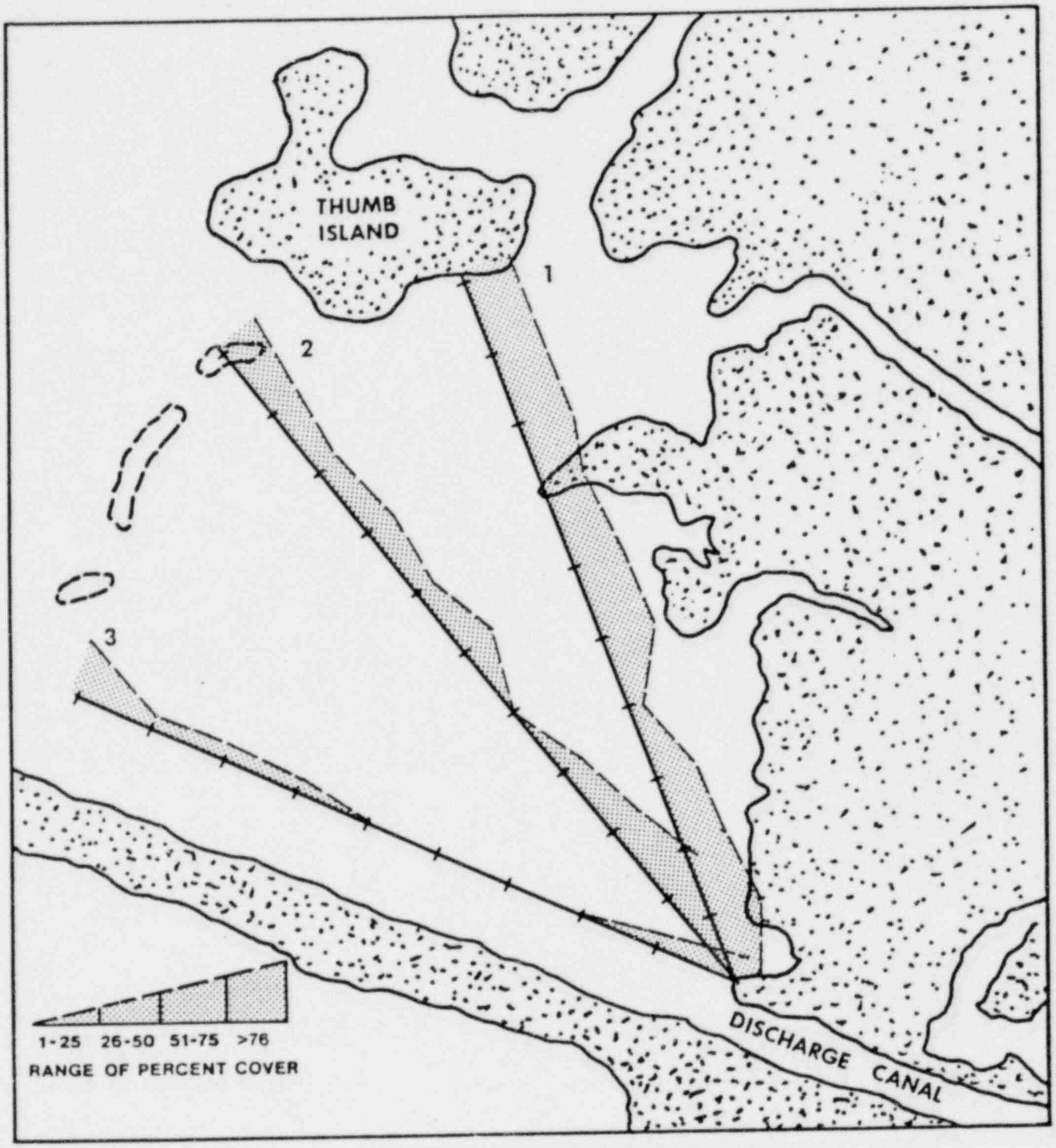

Figure F-8. Distribution of Halodule wrightii along inside transects of the discharge basin, Crystal River Project, April 1981.

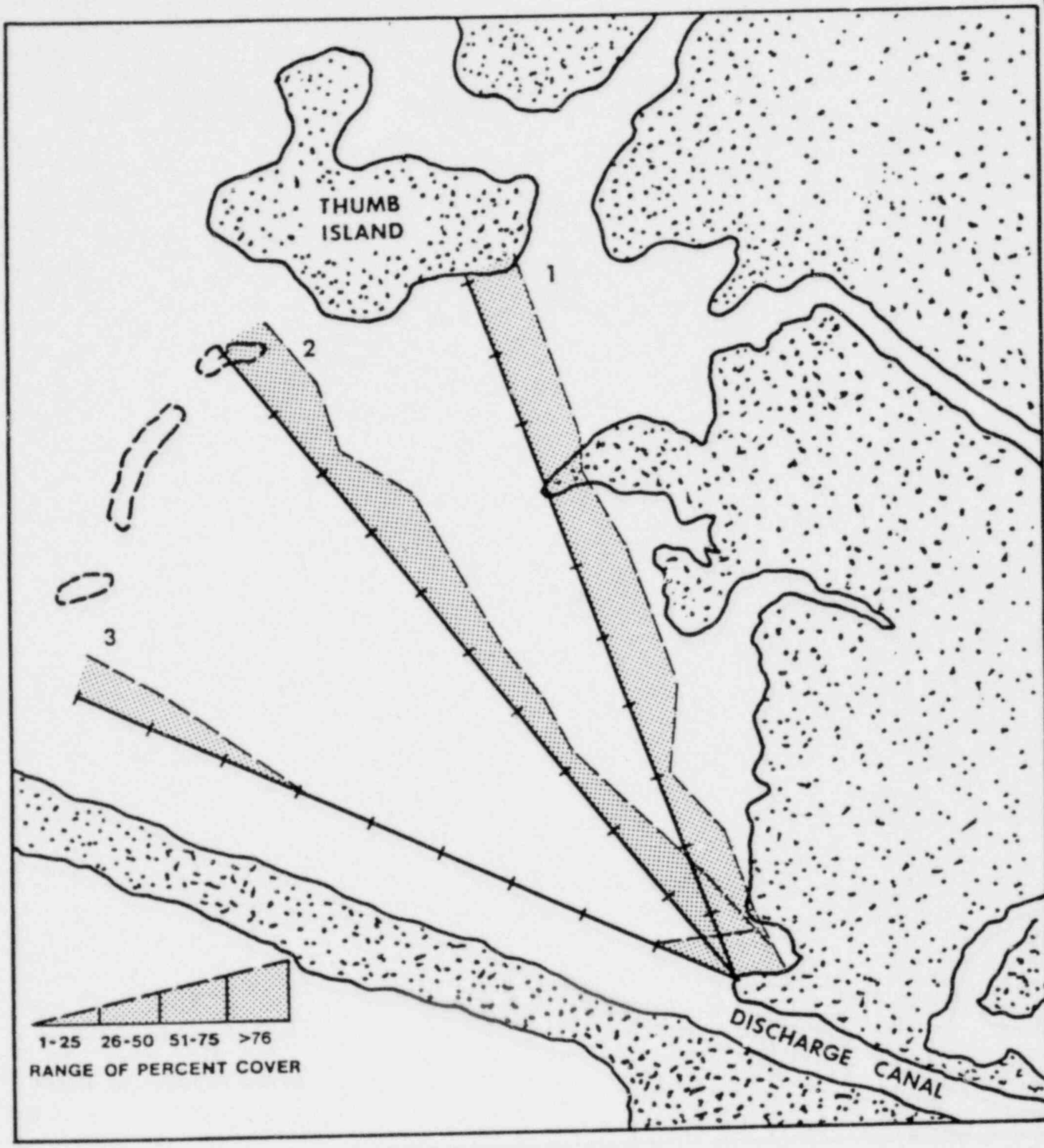

Figure F-9. Distribution of Halodule wrightii along inside transects of the discharge basin, Crystal River Project, June 1981.

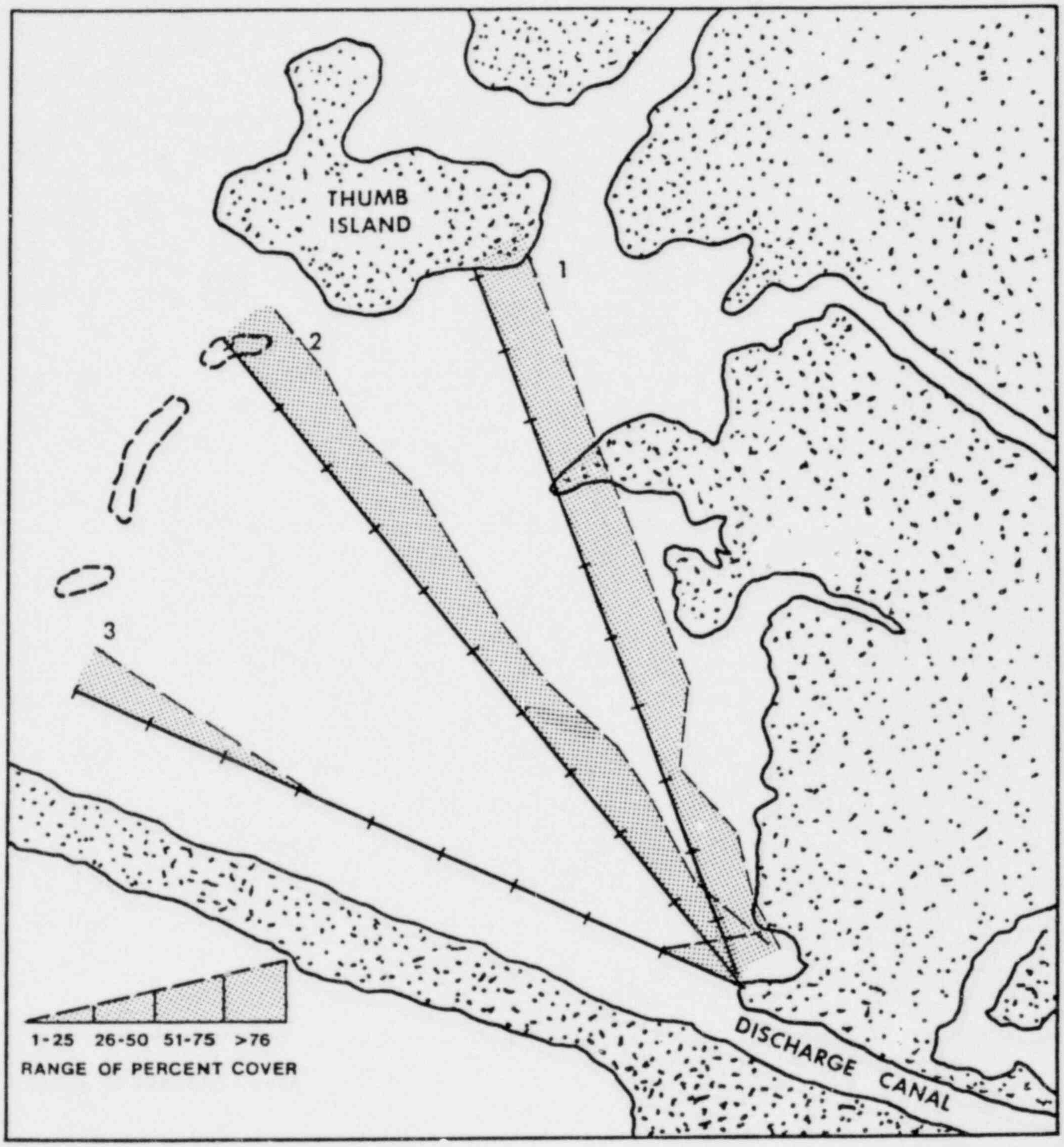

Figure F-10. Distribution of Halodule wrightii along inside transects of the discharge basin, Crystal River Project, September 1981.

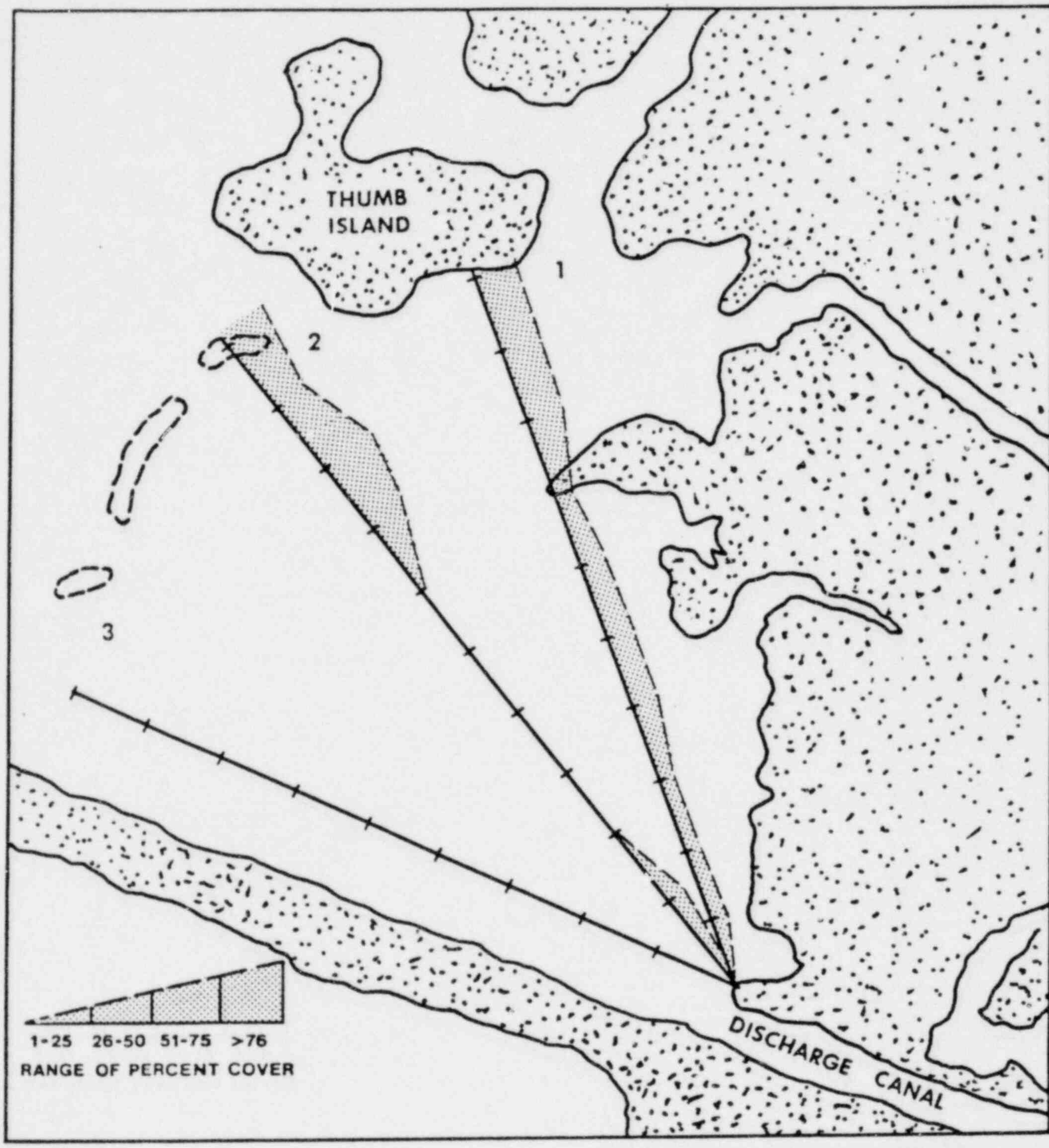

Figure F-11. Distribution of Halodule wrightii along inside transects of the discharge basin, Crystal River Project, December 1981.

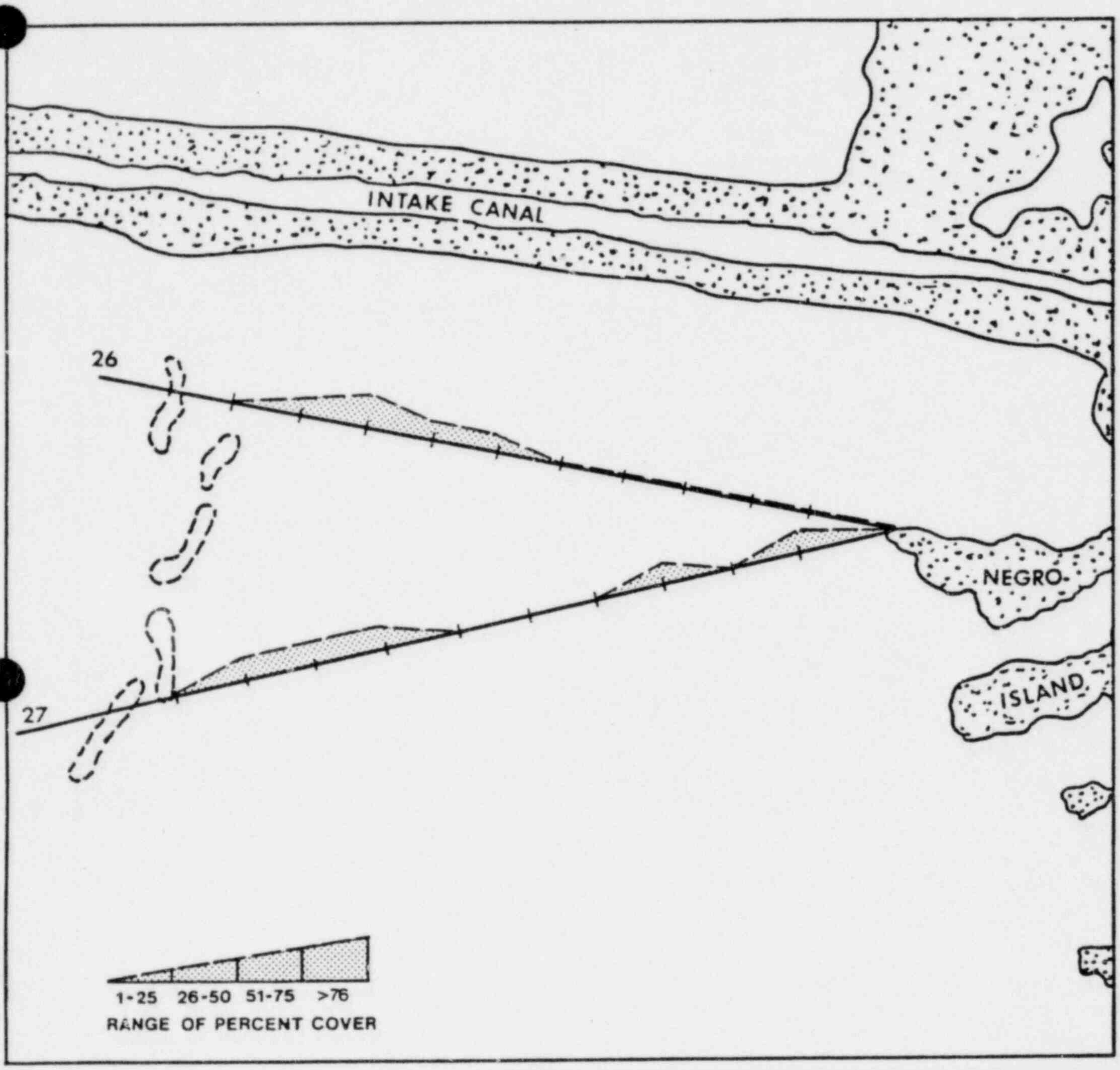

Figure F-12. Distribution of Syringodium filiforme along inside transects of the control basin, Crystal River Project, June 1981.

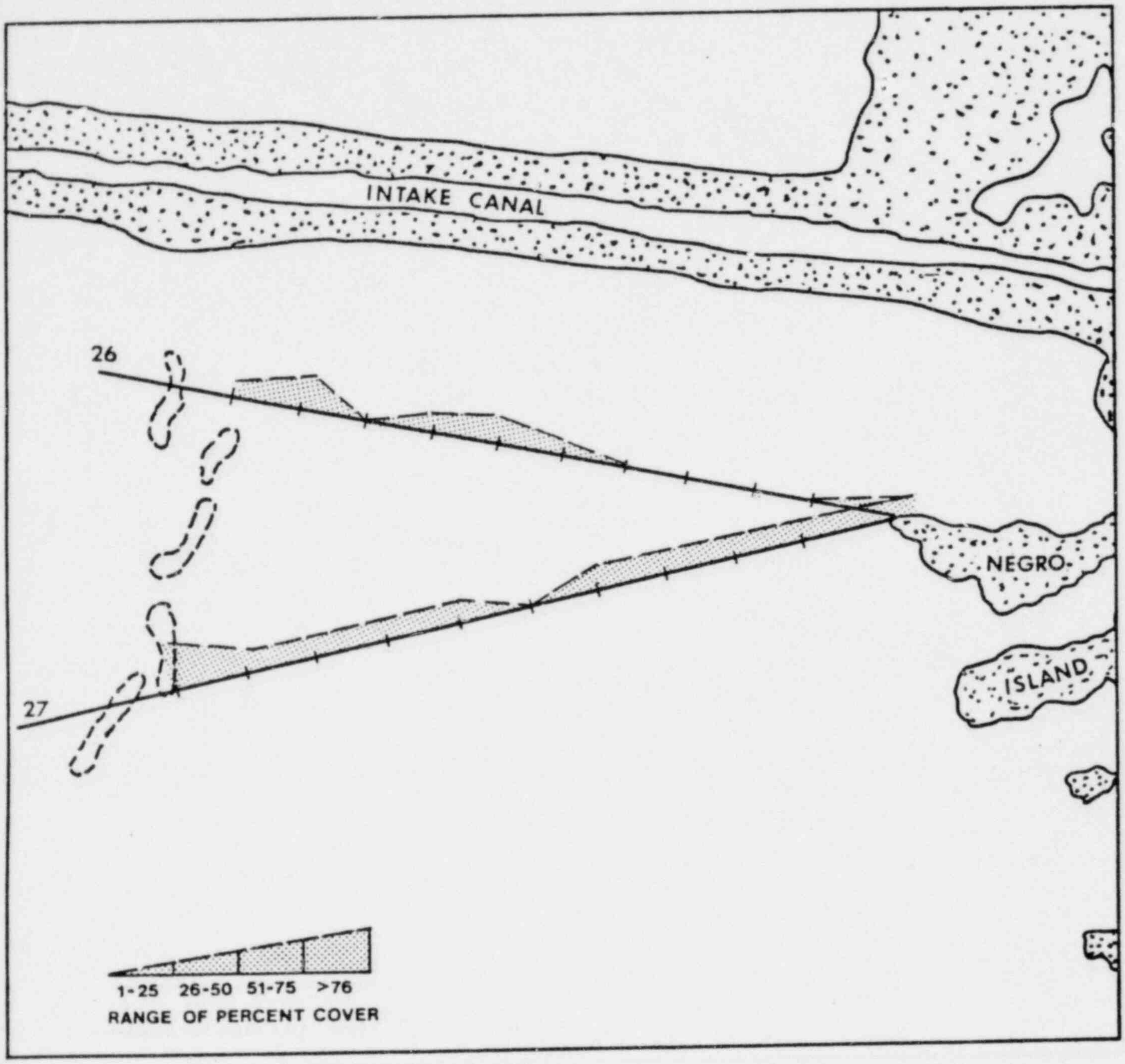

Figure F-13. Distribution of *Syringodium filiforme* along inside transects of the control basin, Crystal River Project, September 1981.

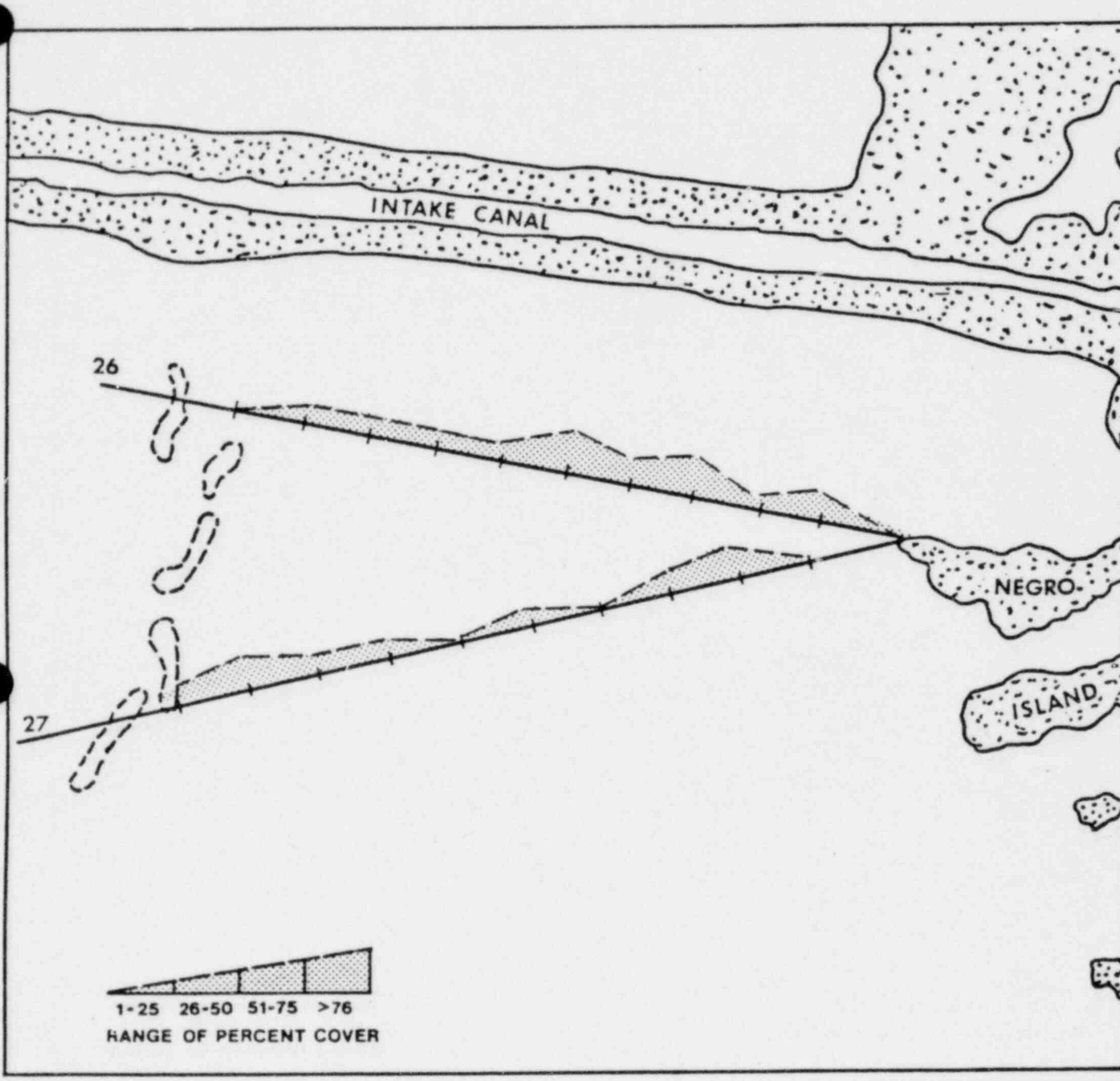

Figure F-14. Distribution of Syringodium filiforme along inside transects of the control basin, Crystal River Project, December 1981.

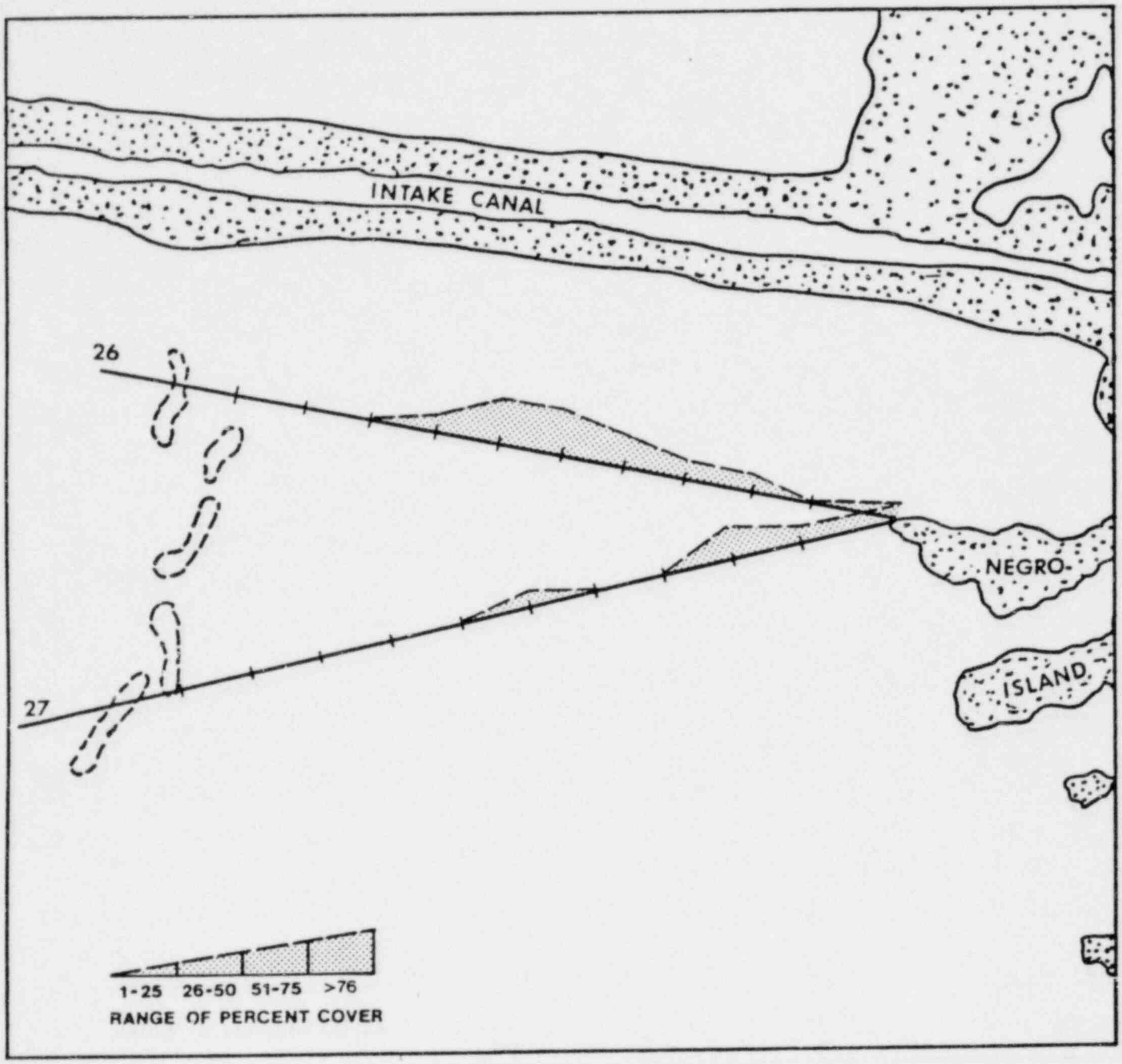

Figure F-15. Distribution of Ruppia maritima along inside transects of the control basin, Crystal River Project, April 1981.

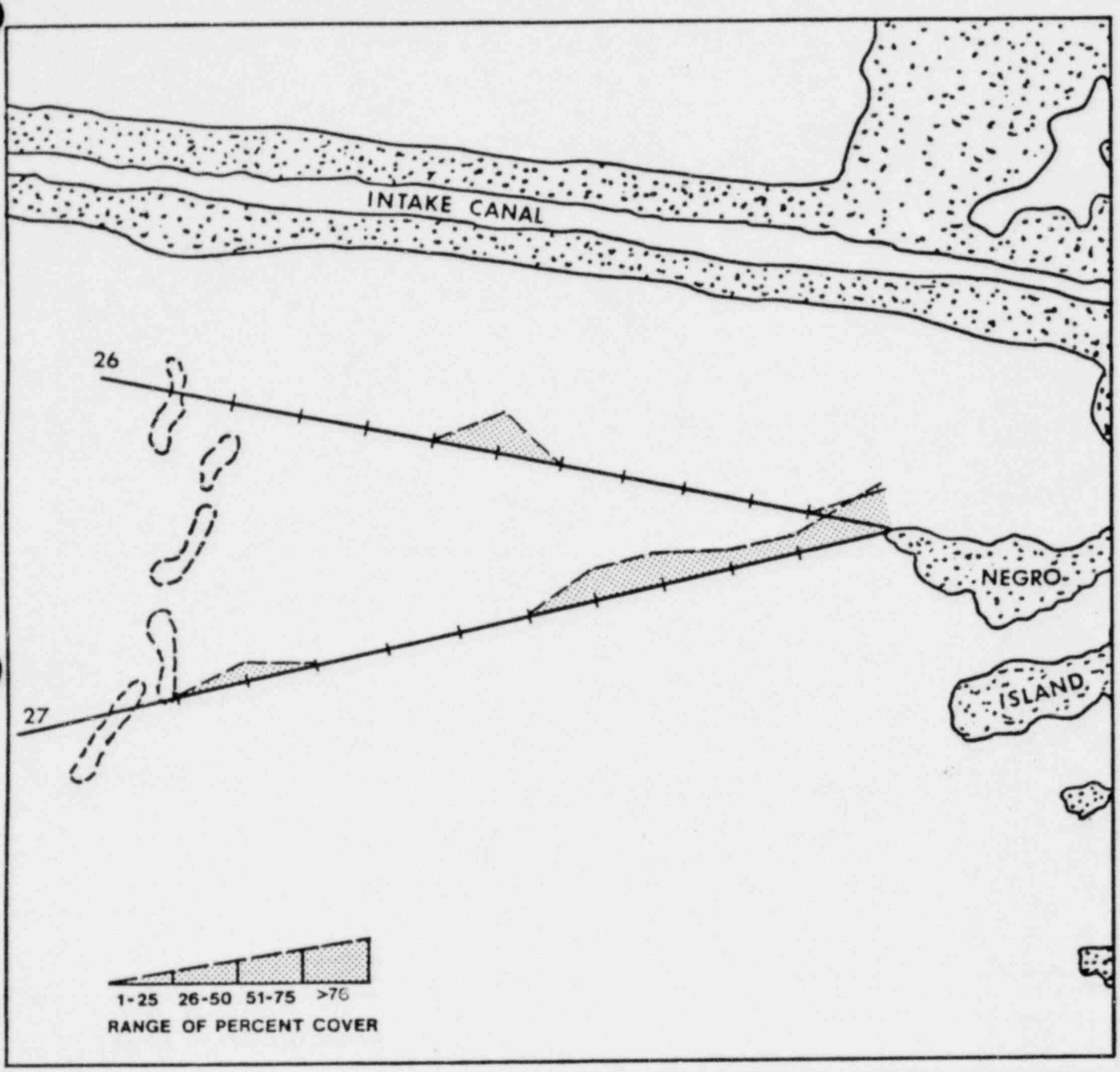

Figure F-16. Distribution of Ruppia maritima along the inside transects of the control basin, Crystal River Project, June 1981.

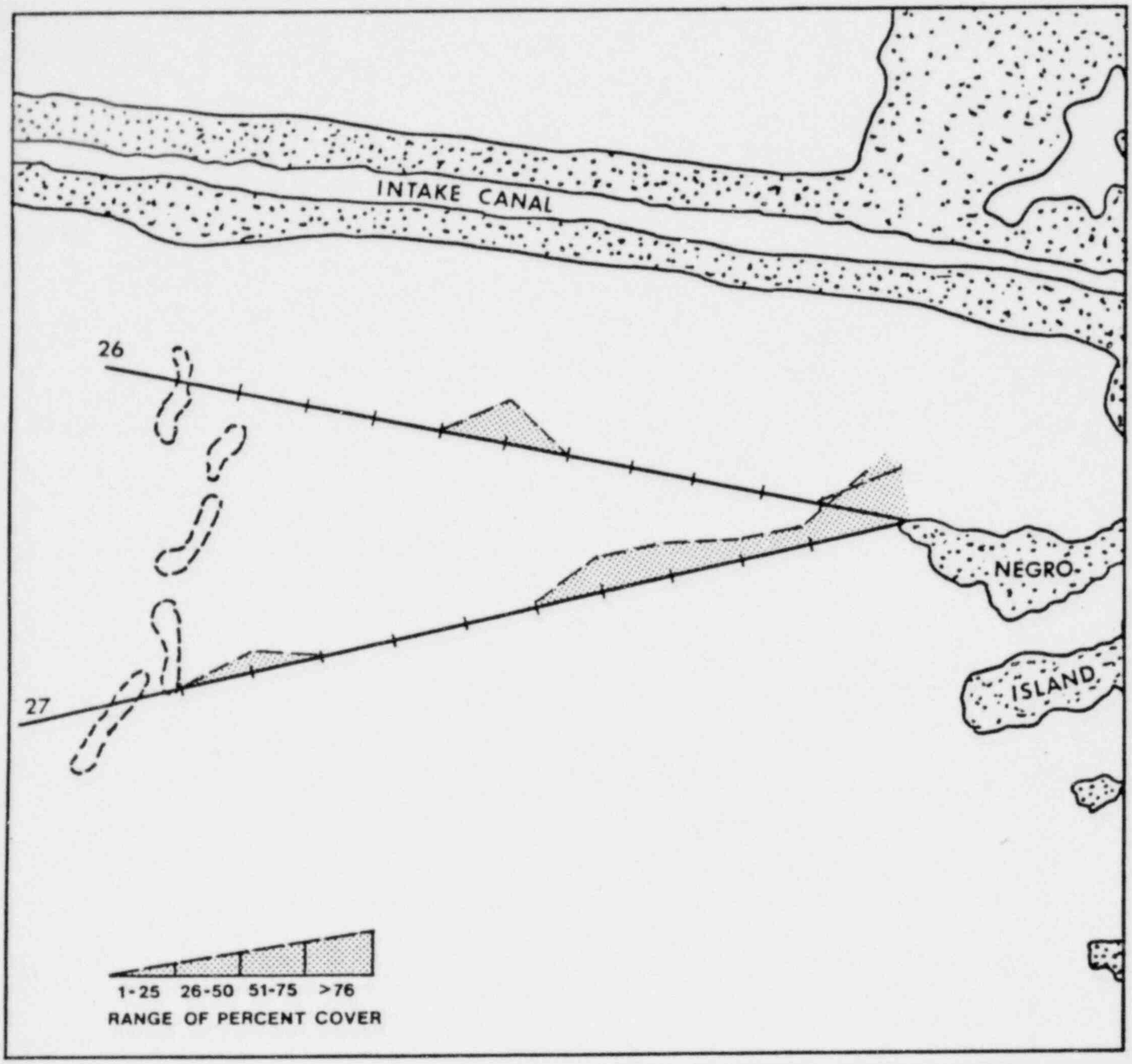

Figure F-17. Distribution of Ruppia maritima along inside transects of the control basin, Crystal River Project, September 1981.

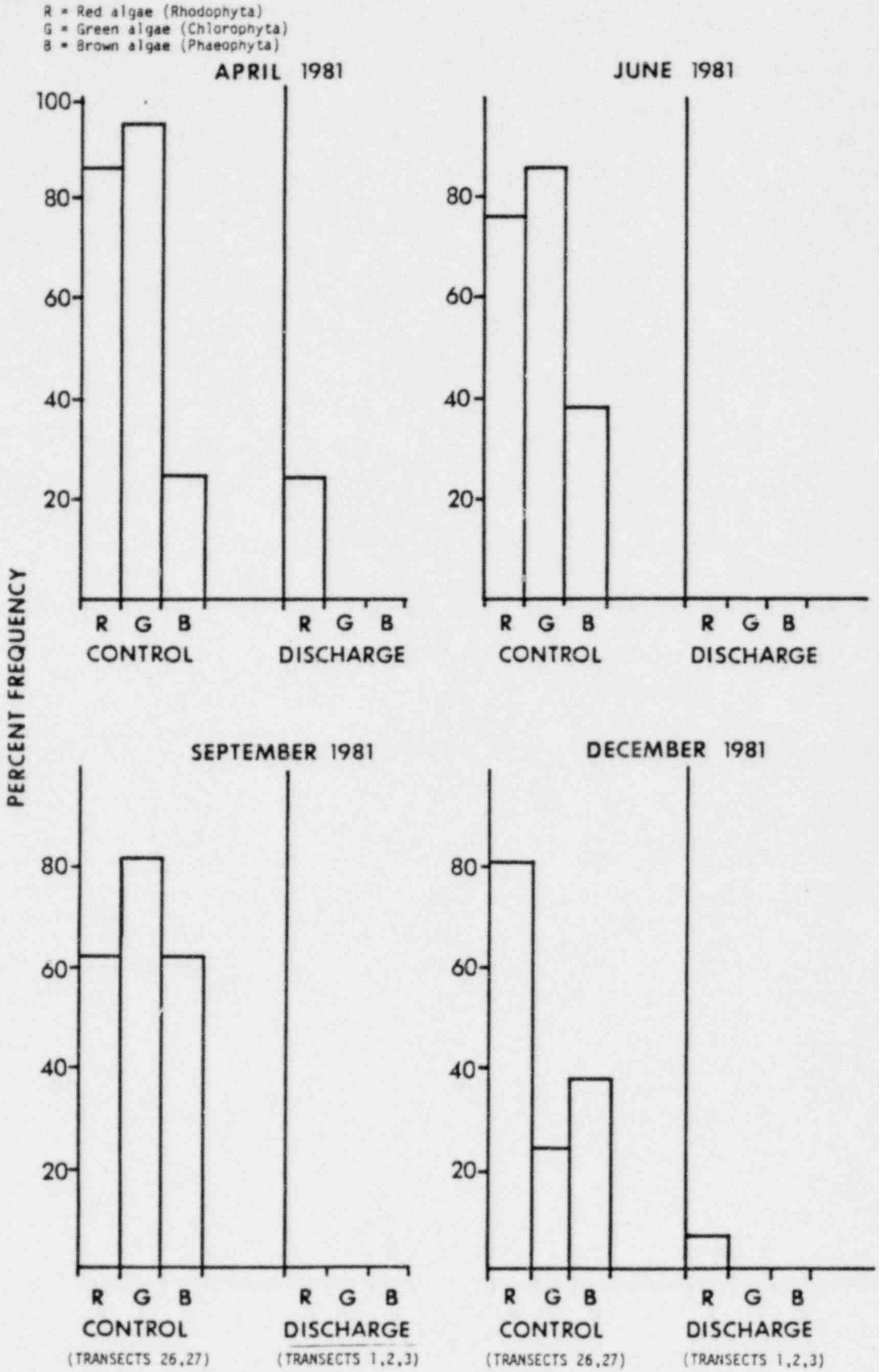

Figure F-18. Percentage of stations in control and discharge basins at which each macroalgae division was observed, Crystal River Project, 1981.

G. OYSTER REEFS

INTRODUCTION

Oyster reefs, composed primarily of *Crassostrea virginica*, extend for many miles parallel to shore in the shallow waters of the eastern Gulf of Mexico and are a prominent feature of the marine environment at the Crystal River study site. In the past, this area supported a large commercial oyster fishery (Dawson, 1955). Although the commercial fishery has since declined, most of the beds remain open to public harvesting (Florida Department of Natural Resources, personal communication).

In addition to their commercial importance, oyster reefs provide food, protection and living space for a variety of associated organisms (Wells, 1961; Galtsoff, 1964). Certain crabs, starfish and gastropod molluscs prey upon the oysters while inhabiting the reef. Many sessile organisms, such as barnacles, limpets and tube dwelling worms find attachment sites on the hard shells of the oysters while other, more active forms shelter among them.

A number of factors are known to influence the distribution and condition of living oysters and the associated reef fauna. Of these, temperature, salinity, water circulation and sedimentation are among the more important. Although moderately elevated temperatures can result in increased oyster size by artificially extending the length of the growing season, very high (above 32°C) or very low (below 15°C) temperatures are

detrimental (Menzel, 1956; Galtsoff, 1964; Tinsman and Maurer, 1974). In addition, rapid transition from low to high temperatures can result in increased mortality, even if the temperatures involved are well below the normal thermal death point (Tinsman and Maurer, 1974).

Salinity not only affects the oysters directly, but also indirectly through its effects on potential predators and competitors. In general, fewer associated species occur on reefs in low salinity areas, and many of the more important oyster predators are unable to survive there (Wells, 1961; Galtsoff, 1964, Menzel et al., 1966).

A steady, non-turbulent flow of water is required to provide food, remove wastes and enable new individuals to be recruited into the community. A low sedimentation rate is also essential for oyster survival, as suspended sediments may interfere with the animal's feeding mechanisms.

Although each of these factors is important individually, the ultimate survival of the reefs in a particular area is determined by their combined effects. The prominence of oyster reefs throughout the Crystal River study area, the sessile nature of the adult oysters, and the volume of information available on the biology of these commercially important organisms suggest that the oyster reef habitat may be a useful indicator of environmental changes occurring as a result of plant operation. During 1981, reefs subjected to the discharge plume of the power plant were compared with reefs spatially removed from potential plume effects

to determine if measured community parameters differed between the two areas.

MATERIALS AND METHODS

Oyster reef communities at the Crystal River study site were sampled quarterly at six stations in the discharge basin and three stations in the control basin (Figure G-1). These stations were established in previous studies and were retained in 1981 to maintain continuity and facilitate data comparisons. At each station, a sampling site was randomly selected and, during low tide, two replicates were obtained. One of the replicates was taken at the water's edge and the other approximately 2 m toward the center of the reef. Sample [illegible] collected by placing a 0.25-m^2 aluminum frame on the reef and removing, by hand, all material contained within it to a depth of approximately 10 cm. Each sample was then preserved in 10-percent buffered seawater-formalin containing Eosin B and Biebrich Scarlet stains and transported to the laboratory for sorting.

In the laboratory, clumps of oysters were randomly removed from the sample bucket and washed over a 2.0-mm sieve screen to remove fine sediments and unattached associated fauna. Shell lengths of the first 50 adult <u>Crassostrea virginica</u> (shell lengths greater than 2 cm) encountered were measured to the nearest millimeter, and the meat from these and all remaining adults were removed and stored. <u>Crassostrea</u> spat (shell lengths less than 2 cm) were removed from the shell material, and the right valve and attached meat retained. As the oyster clumps were pro-

cessed, a running tally of the number of living adults and spat was maintained.

Fauna found attached to the oyster shell material were removed and, with the unattached organisms retained on the sieve screen, separated by major group (Annelida, Mollusca, Arthropoda and other). Horse oysters (Ostreola equestris) were removed in the same manner as Crassostrea spat and placed with the Mollusca component. Subsequently, all associated fauna were identified to the lowest practicable taxonomic level.

Biomass determinations were made for adult Crassostrea, Crassostrea spat, and for the various groups of associated fauna (by class for Mollusca and Chordata, by phylum for other groups). Meat from the adult oysters was dried for 48 hours at 90°C and weighed to the nearest 0.1 g, and the spat and other organisms were dried for 24 hours at 70°C and weighed to the nearest 0.001 g.

RESULTS AND DISCUSSION

During 1981, the mean abundance and biomass of adult Crassostrea were consistently lower in the discharge than in the control basin (Figure G-2). Differences in abundance were significant ($P \leq 0.05$) every sampling period but April, and differences in biomass were significant during all four periods. In the control basin, the pattern of seasonal variation for both mean abundance and biomass appears to be positively related to temperature, with values peaking in June and declining in September and December (Figure B-2). This is not consistent with the

pattern of lower summer values for abundance and biomass recorded in 1980 (FPC, 1981). It is also contrary to the general trend of increased mortality at higher temperatures noted in the literature (Dawson, 1955; Tinsman and Maurer, 1974). However, the temperatures occurring in the control basin were well below the critical level for the species and the influence of other factors may be more important.

Seasonal abundance and biomass in the discharge basin remained relatively constant, with lowest levels observed in September (Figure G-2). Low densities in September probably resulted from the persistence of high temperatures (above 32°C) throughout the summer. The slight increase in mean abundance and biomass between September and December corresponds with a decrease in mean temperature during that period (Figure B-2).

Within the discharge basin, there was a general trend of increasing abundance and biomass from a low at Station 106 located at the point of discharge to a high at Station 101, the station farthest from the mainland (Table G-1). This trend was especially noticeable during June and September, when few or no adult oysters were found at Stations 105 and 106. Although water temperatures decreased in December, there was only a very slight increase in the numbers of adult oysters found at these innermost stations during that period. This is to be expected due to the time lag between the increased recruitment of spat during cooler months (Table G-2) and their attainment of adult size. Values for both abundance and biomass at Station 101 were consistently within the observed range for these parameters in the control basin. Thus, it

appears that the worst effects of the heated effluent are restricted to the area in the immediate vicinity of the point of discharge, with conditions rapidly approaching those of the control area as distance from shore increases.

The ratio of mean biomass to mean shell length has been used as an indicator of oyster condition, although there are some limitations to its use. One of the major drawbacks is a lack of knowledge of how the age/size class of the oysters affects the ratio. It is quite possible that the ratio changes as an oyster grows, thereby reducing its usefulness as an indicator of stress unless oysters of the same age/size class are compared. Additional factors, unrelated to plant operation, may also influence the ratios obtained.

Mean biomass to mean shell length ratios were higher in the control basin during all quarters of 1981 (Figure G-3), but the pattern of seasonal variation in the two basins was very different. In the control basin, ratios were lowest during the summer, indicating a decrease in average oyster biomass. This might reflect physiological responses to increased temperatures. However, the average biomass of oysters in the discharge basin appeared to increase steadily throughout the year showing no negative response to increasing temperatures.

Spat

As was the case for adult oysters, mean abundance and biomass of spat were consistently higher in the control basin than in the discharge

basin (Figure G-4). These differences were significant during every sampling period but December. The seasonal pattern of maximum spat abundance and biomass in winter and minimum abundance and biomass in summer reported previously (FPC, 1981) did not occur in 1981. On the contrary, these parameters in the control basin were highest in June and lowest in December. Data for 1981 agree more closely with data reported by Dawson (1955). He indicated that a substantial spat settlement in the Crystal River area occurred during June and July. In addition, Hayes and Menzel (1981) observed that spawning of Crassostrea in the northern Gulf of Mexico normally does not occur at temperatures below 25°C. Temperatures in the control basin had just reached this level during the April sampling period (Figure B-2).

Mean spat abundance and biomass in the discharge basin remained relatively constant during the first three quarters of 1981, but increased sharply between September and December as mean water temperatures decreased.

The same general trend of increasing abundance and biomass with increasing distance from the point of discharge observed for adult oysters was also exhibited by the spat, although with somewhat less consistency (Table G-2). No spat were found at the mouth of the discharge canal (Station 106) during June or September; however, both abundance and biomass increased in December when water temperatures were cooler. Values for abundance and biomass at the outermost station (Station 101) were generally within the range observed for these parameters in the

control basin, showing a minimal adverse effect of power plant effluent at this distance from the point of discharge.

Associated Fauna

In 1981, the fauna associated with oyster reefs was examined in detail for the first time. A total of 101 macroinvertebrate taxa were collected at stations within both discharge and control basins (Table G-3).

Mean abundance and biomass of annelids in the control basin were lower than in the discharge basin in April but higher in June, September and December (Figure G-5). However, none of the biomass differences were significant, and differences in abundance were significant only during September and December. In general, the pattern in the control basin was one of rising mean abundance and biomass from April through September. The number of annelid taxa (Table G-4) remained essentially the same during this period, however, indicating that the increase in abundance was primarily due to increasing numbers within species already present rather than a sudden influx of new species. Falling water temperatures in December were accompanied by a decrease in abundance and an increase in the number of taxa. This might have been due to the recruitment of species less able to tolerate the warm water encountered during the summer, but more competitive than permanent residents at lower temperatures.

In the discharge basin, the number of annelid taxa declined substantially between April and September, probably as a result of increased water temperatures. The trend of increased abundance between April and June was reversed in September as mean water temperatures remained high. Cooler temperatures in December led to increased mean abundance and number of taxa. The steadily declining mean biomass values occurring during periods of increasing abundance were probably the result of an increased number of small individuals within the community.

A comparison of annual mean annelid abundance and biomass for each discharge station shows no trend of increasing values with increasing distance from the point of discharge as was the case for oysters (Table G-5). The total number of taxa found was actually highest at the two stations nearest the canal (105 and 106) although the number found there during the summer months was substantially less than during the winter (Table G-4). This suggests that within the study area annelids may be most tolerant of high temperatures.

Mean mollusc abundance and biomass in the control basin were significantly higher than in the discharge basin during every quarter of 1981 (Figure G-6). Highest control basin values for mean abundance and number of taxa were found in December (Table G-4) and corresponded to low mean water temperatures. Biomass may also have been highest at this time if the presence of several especially large gastropods in June is discounted.

In the discharge basin, both mean abundance and biomass of molluscs remained relatively constant and very low throughout the year. The number of taxa present also remained low (Table G-4). This suggests that the recovery period for molluscs is longer than that necessary for other groups that are able to exploit improved temperature conditions more quickly.

As was the case for oysters, other molluscs exhibited lower mean abundance and biomass at stations near the point of discharge (Table G-5). This was particularly noticeable during June, September and December, when no molluscs other than oysters were found at Station 106 (Table G-4). This indicates that oysters are better able to tolerate the effects of heated water than are many other molluscs. This is not unexpected because of the oyster's ability to withstand extremes of temperature caused by exposure at low tide.

Mean arthropod abundance was consistently higher in the control than in the discharge basin (Figure G-7). However, differences between basins were not significant during any sampling period during 1981. The pattern of seasonal variation for mean abundance was similar in the two basins, but the reasons for the variation were somewhat different. In June, abundance in the control basin was influenced by an increased number of taxa (Table G-4) but, in the discharge basin, abundance appears to have been caused by increased numbers of individuals among species already present. The number of taxa and mean abundance decreased in both basins in September as exposure to higher summertime temperatures continued, and increased again in December as temperatures declined.

Biomass values obtained for arthropod samples varied greatly because of the wide range of sizes among component species inhabiting the oyster reefs (Figure G-7). No significant differences were found between basins during any sampling period.

The same general trend of increasing mean annual abundance and biomass with increasing distance from the mouth of the discharge canal noted for other groups also occurred in arthropods (Table G-5). However, values obtained for all stations except Station 106 fell within the range observed in the control basin. In addition, although number of taxa at the innermost stations decreased during the summer months, there were always some arthropods present at these stations, and mean annual abundance there was higher than for any other group. The highly motile nature of many arthropods is at least partially responsible for their apparent ability to withstand high temperatures, enabling them to move to slightly cooler areas to escape temporary increases in temperature. For example, the most dominant organism in the discharge basin was the highly motile xanthid crab Eurypanopeus depressus, and the most dominant control organism was the sessile bivalve Brachidontes spp. (Table G-6).

Mean biomass and abundance for the associated fauna as a whole were consistently higher in the control than in the discharge basin, reflecting the trend established for each of the major faunal components (Figure G-8). These differences were significant during every sampling period but April. Mean abundance in the control basin increased in June, partially because of an increase in the number of taxa. It remained at

the same level through September, even though there were fewer species present in the community during that period (Table G-4). Both number of taxa and mean abundance increased again in December as temperatures decreased and less heat tolerant species began to return. The same general pattern was found in the discharge basin, although the extreme temperatures encountered during the summer apparently resulted in a decrease in abundance as well as number of taxa during that time.

A clear trend of increasing mean abundance and biomass from Station 106 to Station 101 was observed in the data for total associated fauna (Table G-5). Values at Station 101 fell within the ranges recorded in the control basin. The effects of high temperatures were most noticeable at Stations 105 and 106 where the lowest number of taxa was observed during the summer months (Table G-4). Data collected during 1981 showed that the impact of power plant effluents upon the associated fauna decreased with increasing distance from the point of discharge.

Associated faunal abundance was positively correlated with oyster abundance in both the control and discharge basins during 1981 (correlation coefficient=0.74 for the control basin and 0.65 for the discharge basin, both significant at $P \leq 0.05$). However, it is impossible to determine from the data obtained in this study whether this is a cause-and-effect relationship or whether both groups of organisms are simply responding in a similar fashion to changes in environmental conditions.

Many taxa of invertebrates collected at oyster reef stations occurred as dominants in both the control and discharge basins during 1981 (Table G-6). Of the ten dominant species for each basin, six occurred in both basins.

In the discharge basin, both Balanus eburneus and Uca spp. occurred as dominants, whereas neither taxa was noted as a dominant in the control basin. B. eburneus is a barnacle, an intertidal species capable of withstanding extreme fluctuations in environmental conditions. Crabs of the genus Uca are semiterrestrial and as such are also highly tolerant of environmental variations. Uca spp. was not collected in the control basin and its presence as a dominant at Stations 105 and 106 in the discharge was probably due to both the proximity of these reefs to shore and their increased exposure at low tide.

In a number of cases, a species may have been among the dominants in both basins, but within basin or between basin ranks differed. For example, the xanthid crab Eurypanopeus depressus was ranked as one of the top two dominants at every station in the discharge basin, but its rank at control stations was considerably lower. This is probably a case where a heat tolerant species increased in dominance under stressful conditions as less tolerant species began to disappear. The reverse was true for the bivalve Brachidontes spp., which was the most dominant taxon at every control station, but ranked lower at stations in the discharge basin. Several species in the discharge basin showed a tendency to increase in dominance with increasing distance from the mouth of the

discharge canal. Included among these were the crab Petrolisthes armatus and the amphipod Parahyale hawaiensis. This indicates that these species are probably slightly less adaptable than those discharge dominants mentioned previously and are less able to tolerate the extreme thermal conditions found at Stations 105 and 106.

Operational Trends

The major operational trend noticeable for both adult oysters and spat is the consistently lower level of mean abundance and mean biomass in the discharge basin compared to the control basin (Table G-7; Figures G-9 and G-10). Temperatures greater than 32°C are known to result in reduced feeding activity of oysters (Galtsoff, 1964), and temperatures of 35°C appear to be especially lethal to oysters in spawning condition (Quick, 1971). Tinsman and Maurer (1974) suggest that oysters experience heat coma at temperatures in excess of 32°C. In contrast to t. control basin, mean summer temperatures in the discharge regularly exceeded this 32°C limit.

Operation of Unit 3 during the summer of 1981 was almost continuous for the first time since the unit went on-line in 1977. Although the resulting increase in water temperature (B. Physical and Chemical Parameters) might be expected to cause a further reduction in mean oyster abundance and biomass, such did not appear to be the case. In fact, values obtained for these parameters were slightly higher than those recorded during the summer c . '0, when Unit 3 was not in operation much of the time. This was true for both adult oysters and spat (Figures G-9 and G-10).

Differences in sedimentation rate and water circulation in the control and discharge basins may also affect the relative abundance and biomass of oysters in these two areas. Galtsoff (1964) states that a low sedimentation rate and good water circulation are both necessary for optimum oyster survival. While these conditions appear to prevail in the control basin, they do not in the discharge. The spoil islands of the Cross Florida Barge Canal to the north, the discharge and intake dikes to the south and the oyster reefs themselves all act to reduce water circulation and increase sedimentation within the discharge basin. It seems likely that the cumulative effect of these conditions over a long period of time would have a detrimental effect on the oyster population in this area.

The trend of decreasing annual mean biomass-to-shell length ratio noted in the past for both control and discharge basins continued during 1981 (Table G-7). However, the usefulness of this ratio as an indicator of oyster condition is limited and emphasis should not be placed on results obtained by its use.

Comparisons With Preoperational Data

Preoperational studies conducted during 1973 showed no significant differences in adult oyster abundance and biomass between the control and discharge basins (FPC, 1974). Results of the 1981 survey, using many of the same sampling locations, consistently showed significantly higher values for both parameters in the control basin.

During the 1973 study, no significant differences were found in spat biomass, however, abundance was shown to be significantly greater in the control basin (FPC, 1974). In 1981, both abundance and biomass were significantly greater in the control basin throughout most of the year.

Both abundance and biomass of associated fauna were found to be significantly greater in the control basin in 1973 and, except for April, such was also the case in 1981.

SUMMARY

Increased water temperatures resulting from the combined operation of three electric generating units at the Crystal River Power Plant have had a negative impact on adjacent oyster reef communities. However, the additional thermal load imposed by Unit 3 appears to have had an adverse effect primarily on the adult oyster component of the oyster reef communities. Comparisons of 1981 and preoperational data indicate that the operation of Unit 3 has not affected oyster spat or associated fauna any more than the sole operation of Units 1 and 2. In addition, within basin comparisons made during 1981 show that the most severe effects of the plume are restricted to an area in the immediate vicinity of the point of discharge and the condition of the reefs improves rapidly with increasing distance from this area. Values for measured community parameters at the reef farthest from the discharge canal were consistently within the ranges determined for those parameters within the control basin.

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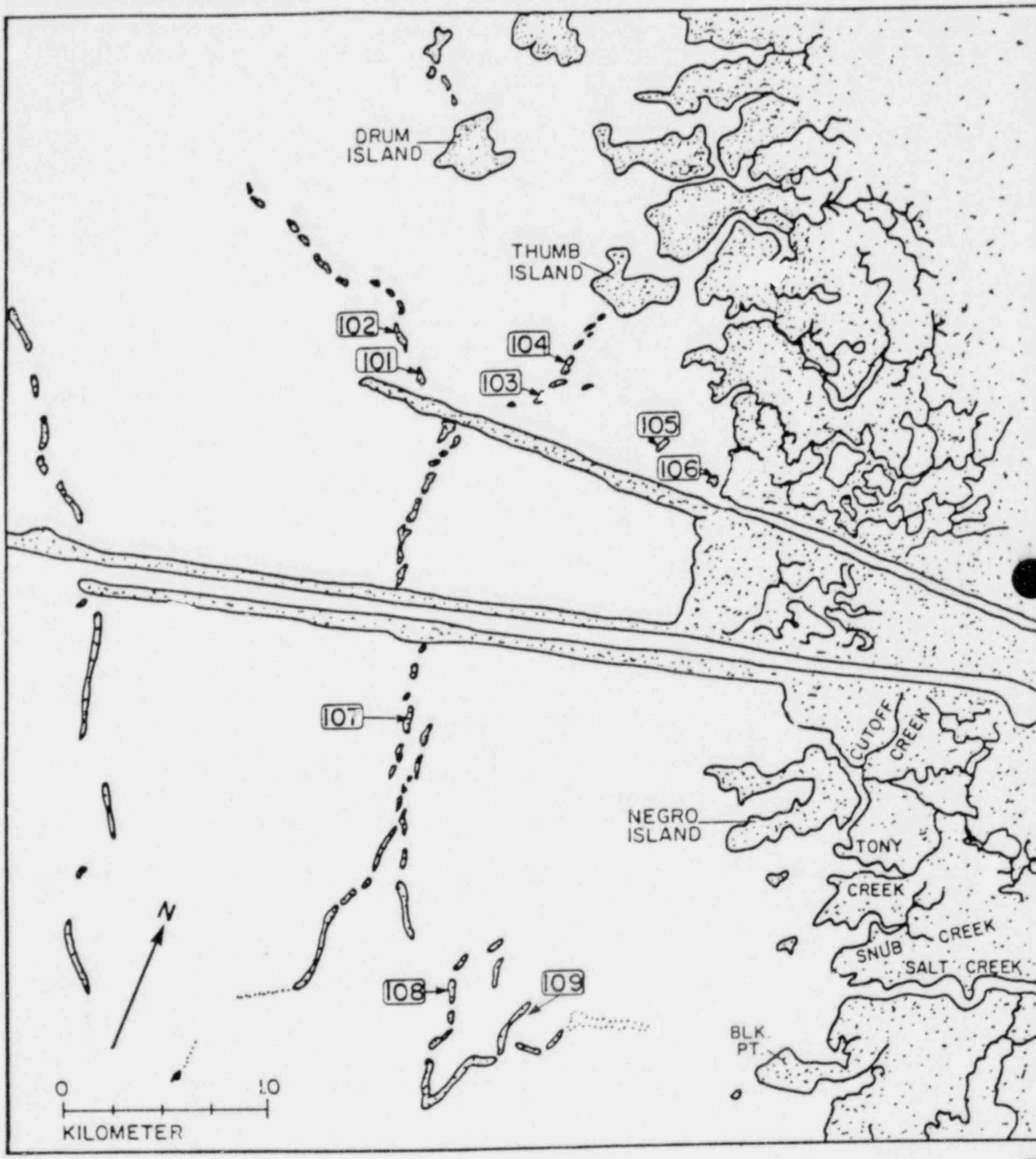

Figure G-1. Location of the nine permanent stations used for examining oyster reef communities, Crystal River Project, 1981.

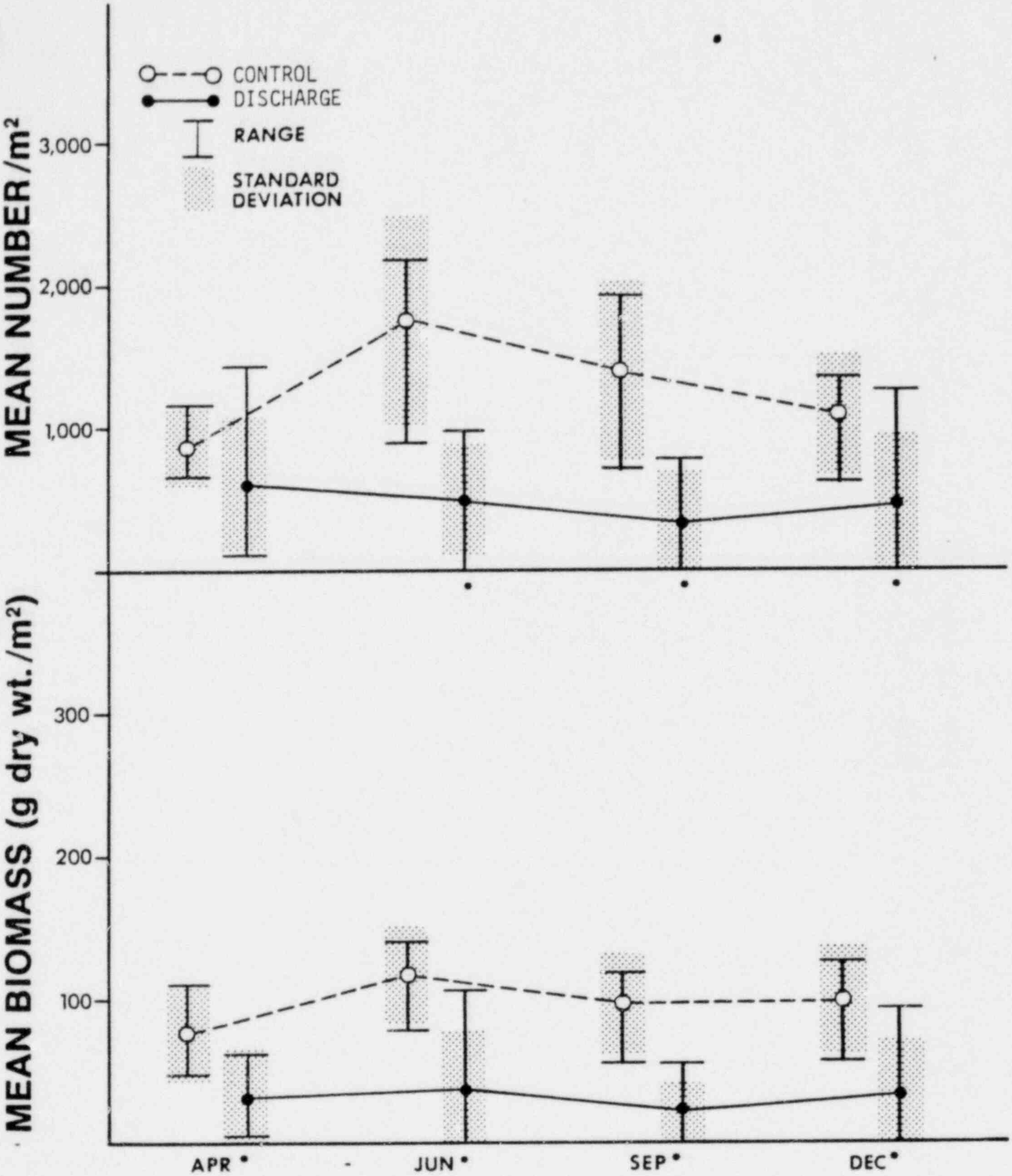

Figure G-2. Mean abundance and mean biomass of oysters greater than 2 cm at control and discharge oyster reef stations, Crystal River Project, 1981. (*Significant difference between basin means).

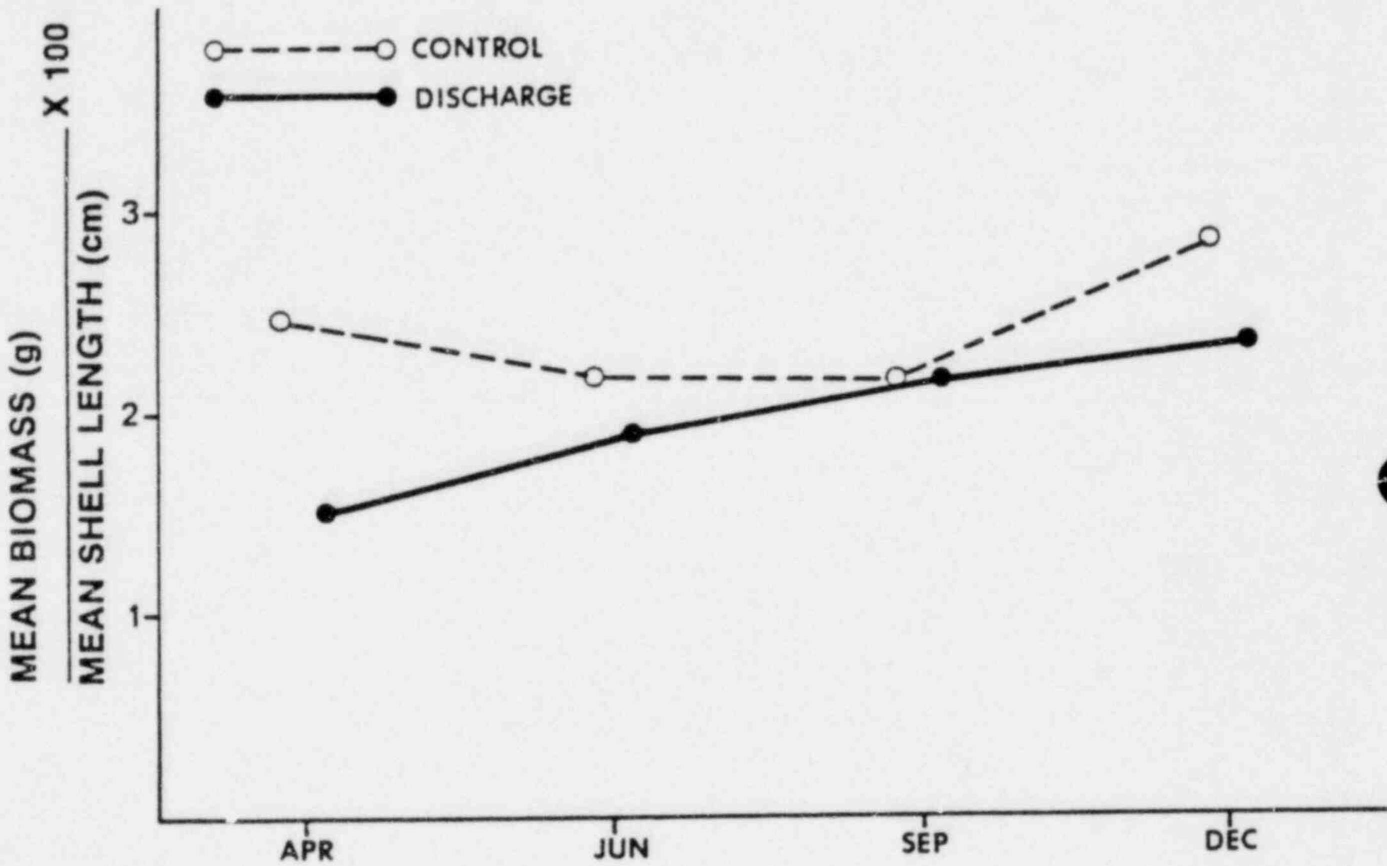

Figure G-3. Ratio of mean biomass to mean shell length of cysters greater than 2 cm long at control and discharge oyster reef stations, Crystal River Project, 1981.

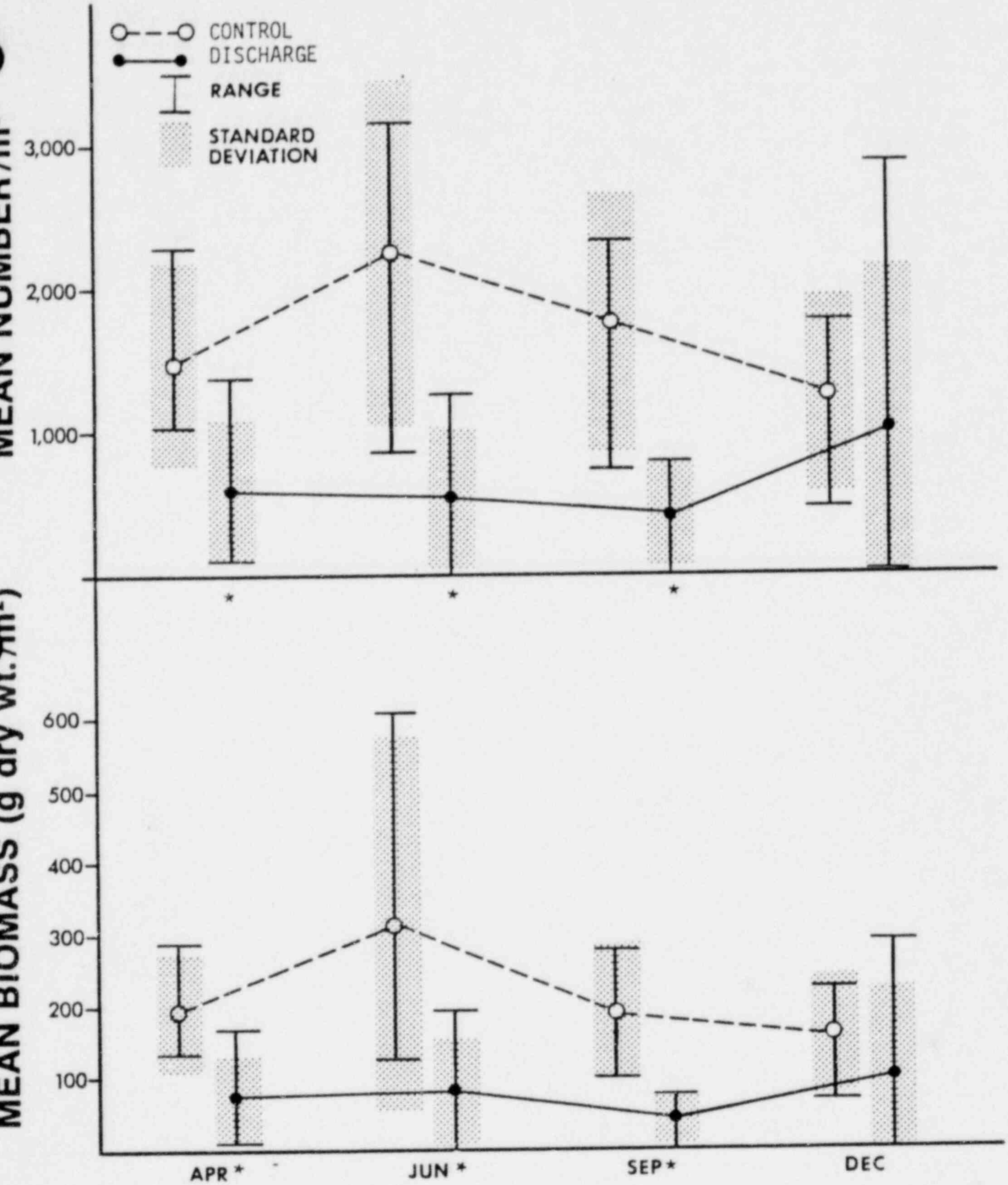

Figure G-4. Mean abundance and mean biomass of oyster spat at control and discharge oyster reef stations, Crystal River Project, 1981. (*Significant difference between basin means).

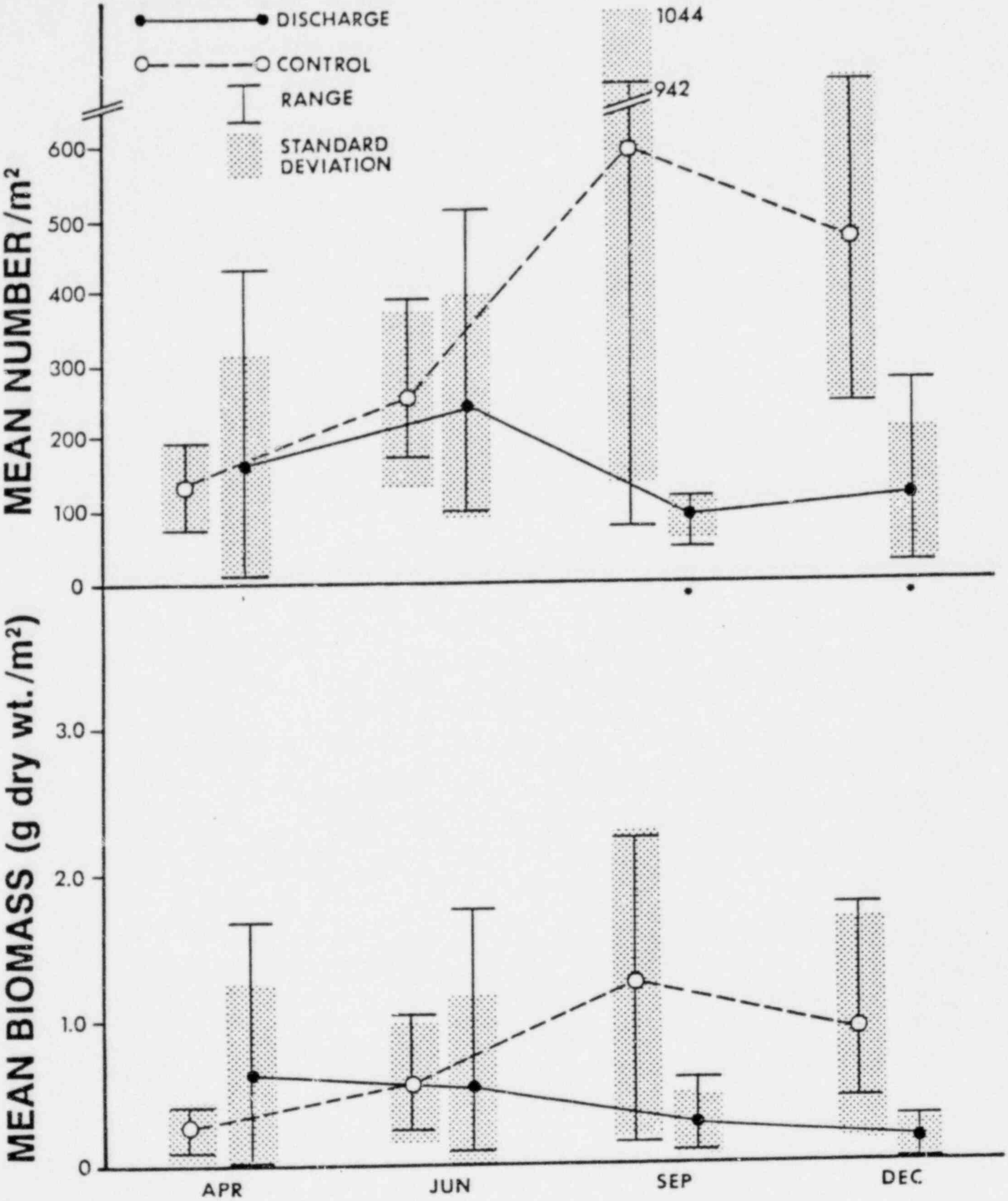

Figure G-5. Mean abundance and mean biomass for annelids at control and discharge oyster reef stations, Crystal River Project, 1981. (*Significant difference between basin means).

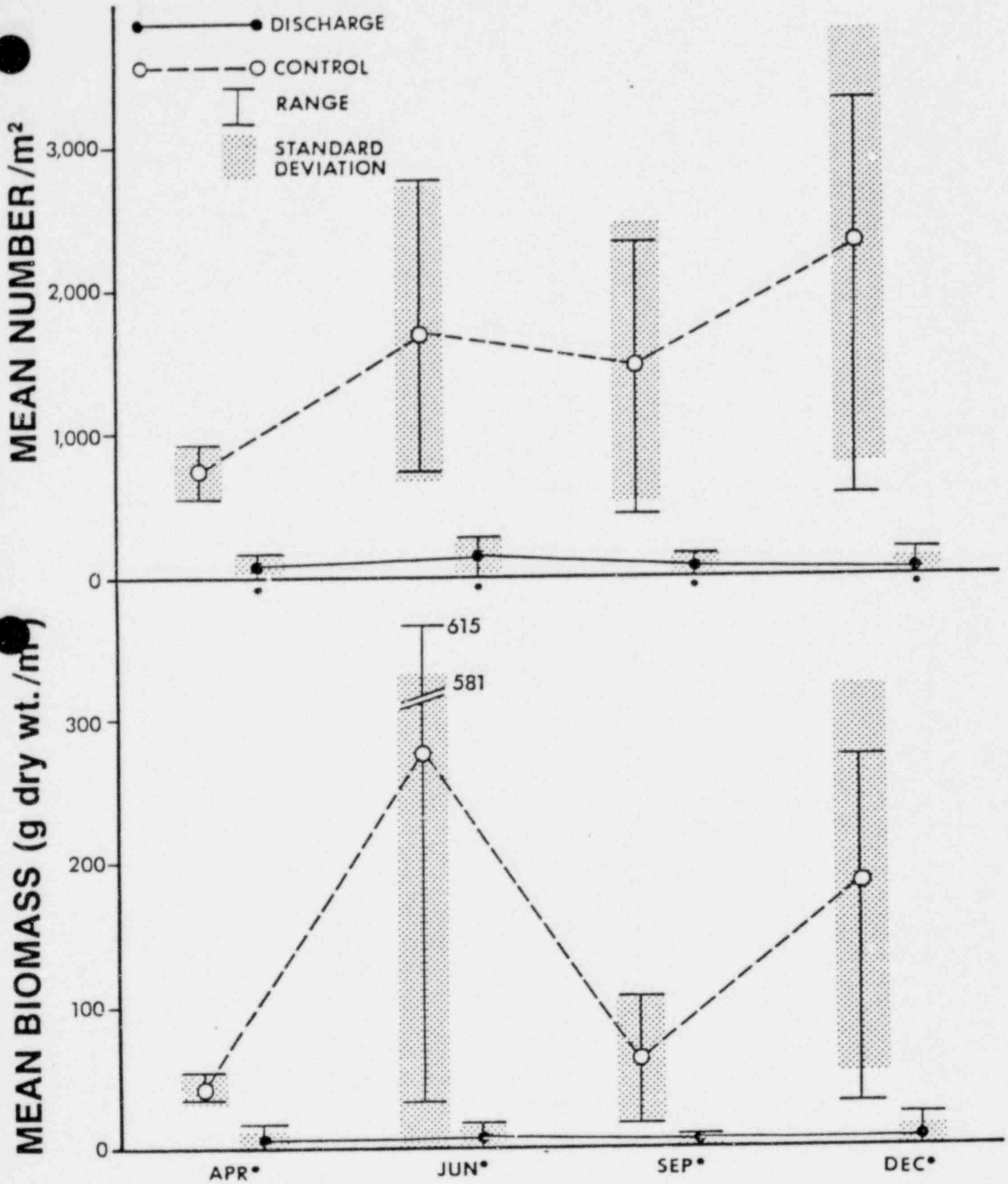

Figure G-6. Mean abundance and mean biomass for molluscs (excluding oysters) at control and discharge oyster reef stations, Crystal River Project, 1981. (*Significant difference between basin means).

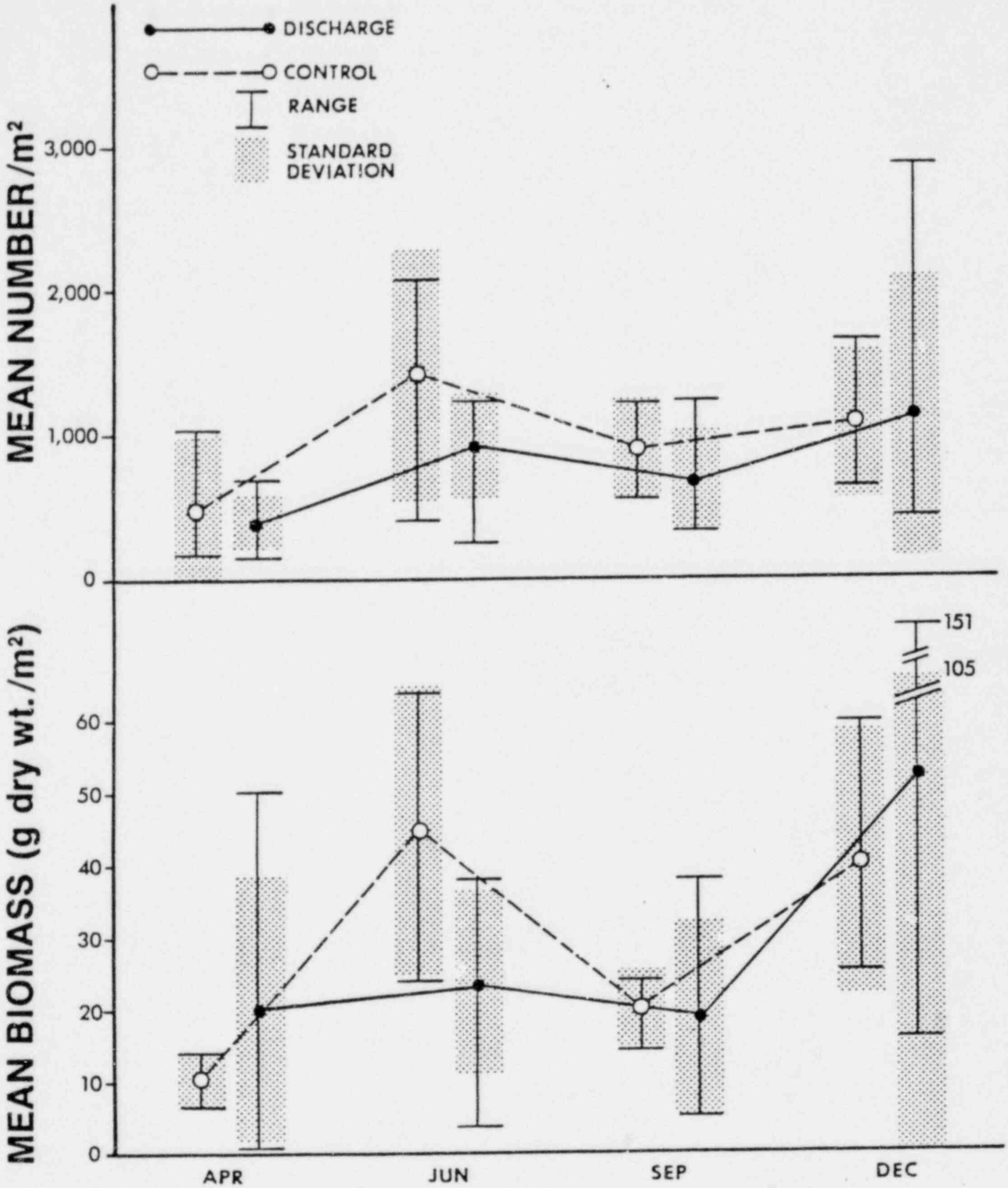

Figure G-7. Mean abundance and mean biomass for arthropods at control and discharge oyster reef stations, Crystal River Project, 1981.

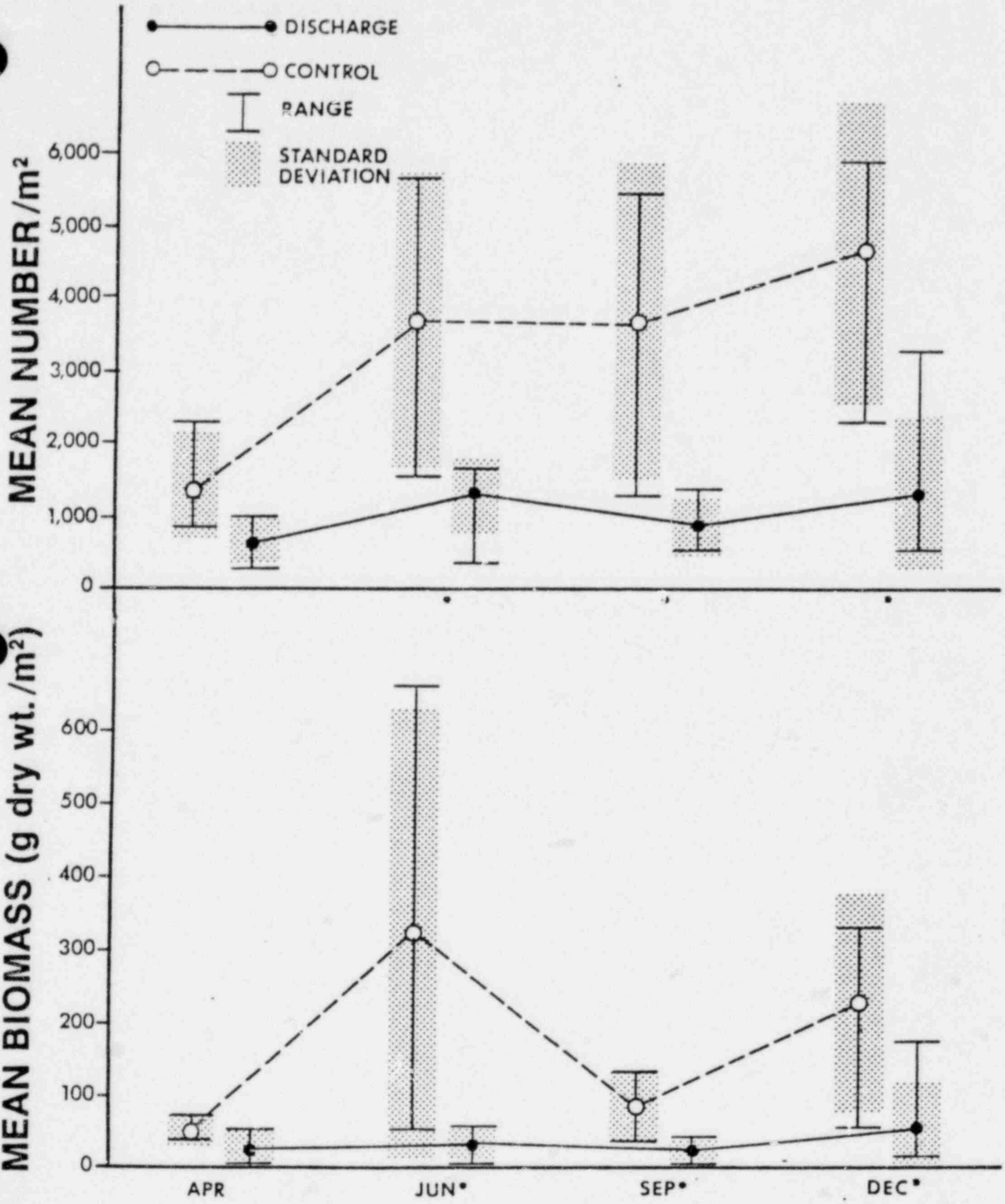

Figure G-8. Mean abundance and mean biomass for total associated fauna at control and discharge oyster reef stations, Crystal River Project, 1981. (*Significant difference between basin means).

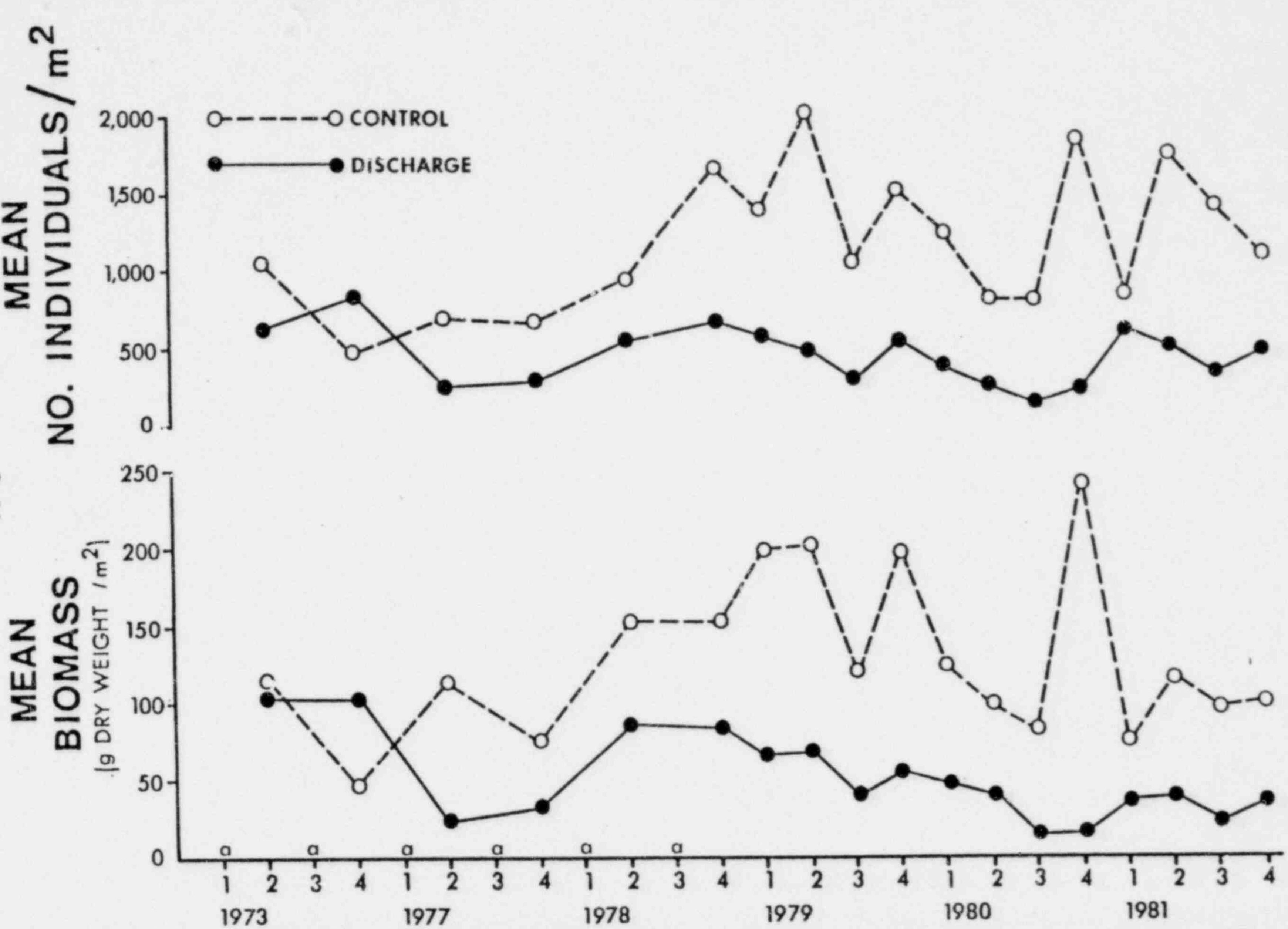

Figure G-9. Quarterly mean abundance and mean biomass for adult oysters from oyster reef stations in the control and discharge basins, Crystal River Project, 1973 and 1977-1981. ([a]Data not available).

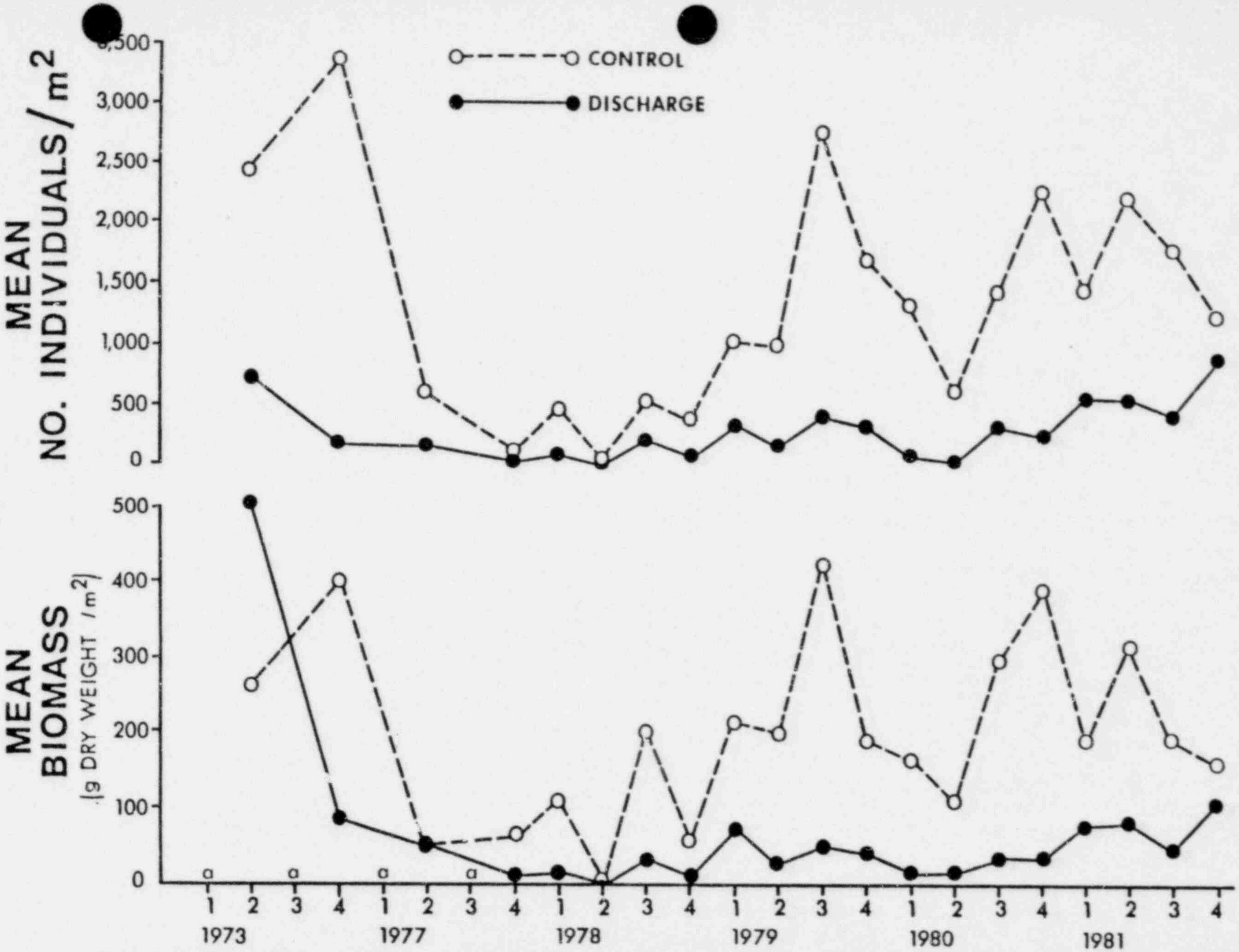

Figure G-10. Quarterly mean abundance and mean biomass for spat from oyster reef stations in the control and discharge basins, Crystal River Project, 1973 and 1977-1981. ([a]Data not available).

TABLE G-1

ABUNDANCE (number/m^2) AND BIOMASS (gram dry weight/m^2) OF ADULT OYSTERS (>2 cm) COLLECTED QUARTERLY AT EACH OYSTER REEF STATION
CRYSTAL RIVER PROJECT
1981

		Station									Basin	
		Discharge basin						Control basin			Discharge	Control
Parameter	Month	101	102	103	104	105	106	107	108	109	mean	mean
Abundance (number/m^2)	April	784	120	1440	560	434	296	656	760	1152	606	856
	June	982	728	588	606	52	0	904	2188	2168	493	1753
	September	760	168	498	694	0	0	706	1906	1566	353	1393
	December	1268	652	648	250	0	10	622	1348	1308	471	1093
	Annual mean	949	417	794	528	122	77	722	1551	1549	481	1274
Biomass (gram dry weight/m^2)	April	61.0	4.0	79.8	33.0	12.4	9.8	67.4	47.0	110.4	33.3	74.9
	June	107.2	55.0	34.2	26.0	1.2	0.0	79.6	140.8	134.8	37.3	118.4
	September	54.8	16.2	32.7	29.4	0.0	0.0	57.4	117.2	119.8	22.2	98.1
	December	95.0	51.2	43.4	22.0	0.0	1.0	57.8	114.4	127.2	35.4	99.8
	Annual mean	79.5	31.6	47.5	27.6	3.4	2.7	65.6	104.9	123.1	32.1	97.8

TABLE G-2

ABUNDANCE (number/m^2) AND BIOMASS (gram dry weight/m^2) OF OYSTER SPAT
COLLECTED QUARTERLY AT EACH OYSTER REEF STATION
CRYSTAL RIVER PROJECT
1981

		Station									Basin	
		Discharge basin						Control basin			Discharge	Control
Parameter	Month	101	102	103	104	105	106	107	108	109	mean	mean
Abundance (number/m^2)	April	944	106	1384	454	230	472	1032	1108	2284	598	1475
	June	1264	742	542	686	18	0	800	2694	3152	542	2242
	September	788	650	684	440	0	0	736	2226	2318	427	1760
	December	2872	1304	1584	198	84	26	476	1784	1492	1011	1251
	Annual mean	1467	701	1049	445	83	125	781	1953	2312	645	1682
Biomass (gram dry weight/m^2)	April	97.1	11.6	170.3	56.8	39.5	69.0	134.6	152.3	284.5	74.0	190.5
	June	194.6	105.0	94.8	91.8	3.5	0.0	126.2	215.4	612.0	81.6	317.9
	September	70.0	76.8	57.5	55.3	0.0	0.0	99.7	194.4	278.8	43.3	191.1
	December	293.2	142.2	172.8	24.9	1.2	2.6	70.2	224.0	187.1	106.2	160.4
	Annual mean	163.7	83.9	123.9	57.2	11.1	17.9	107.7	196.4	340.6	76.3	215.0

TABLE G-3

TAXONOMIC LIST AND FREQUENCY OF OCCURRENCE
OF ASSOCIATED FAUNA ON OYSTER REEF STATIONS SAMPLED QUARTERLY
CRYSTAL RIVER PROJECT
1981

	Frequency of occurrence[a]										
	Discharge stations						Control stations			Basins	
Species	101	102	103	104	105	106	107	108	109	Discharge	Control
ANNELIDA											
Aricidea philbinae					12.5	25				6.3	
A. taylori					12.5	12.5				4.2	
Capitella capitata	50	37.5	62.5	62.5	50	50	50	75	87.5	52.1	70.8
Caulleriella alata						12.5	12.5			2.1	4.2
Ceratonereis irritabilis								12.5			4.2
Eumida sanguinea					12.5					2.1	
Fabricia sp. A	25		12.5							6.3	
Glycera americana						12.5				2.1	
Glycinde solitaria					12.5					2.1	
Haploscoloplos foliosus				12.5	12.5	25				8.3	
Hydroides dianthus						12.5				2.1	
Laeonereis culveri		12.5				25		12.5		6.3	4.2
Lumbrineris verrilli					37.5					6.3	
Lumbrineris spp.					12.5	12.5				4.2	
Lysidice ninetta					37.5	25				10.4	
Marphysa sanguinea	25	12.5	50	50	87.5	37.5			12.5	43.8	4.2
Marphysa spp.	12.5		12.5		12.5	12.5				8.3	
Mediomastus ambiseta			12.5			12.5				4.2	
M. californiensis			50		50	37.5	12.5	50	37.5	22.9	33.3
Mediomastus spp.		12.5		12.5		12.5	25	12.5		6.3	12.5
Nainereis cf. laevigata									12.5		4.2
Neanthes succinea	25		62.5	50	75	87.5				50	
Nematonereis hebes					12.5					2.1	
Nereiphylla fragilis	100	87.5	75	62.5	25	25	100	100	87.5	63.5	95.8
Nereis falsa					25	12.5	12.5	12.5	12.5	6.3	12.5
Perinereis floridana	75	37.5	62.5	62.5		25	100	87.5	87.5	43.8	91.7
Phyllodoce arenae					12.5					2.1	
Platynereis dumerilii									12.5		4.2
Polydora websteri	75	25	25	50	50	25		12.5	25	41.7	12.5
Prionospio heterobranchia texana						25				4.2	
Sabella microphthalma					12.5					2.1	
Sabellaria vulgaris					25				12.5	4.2	4.2
Spionidae spp.						12.5				2.1	
Streblospio benedicti	12.5				25					6.3	
Tharyx dorsobranchialis?			12.5						12.5	2.1	4.2
Tubificidae sp. A							12.5				4.2
Tubificidae spp.	50		50	50	50			12.5		33.3	4.2
Tubificoides spp.								12.5	25		12.5
Typosyllis sp. A	75	87.5	62.5	25	25	37.5	87.5	87.5	100	52.1	91.7
Typosyllis sp. B	12.5									2.1	
MOLLUSCA											
Aeolidoidea sp. A									12.5		4.2
Amygdalum papyrium		12.5					12.5			2.1	4.2
Bivalvia spp.		12.5					12.5	12.5	25	2.1	16.7
Boonea impressa									12.5		4.2
Brachidontes modiolus	12.5	12.5		25			12.5		12.5	8.3	8.3
Brachidontes spp	100	75	100	100	37.5	25	100	100	100	72.9	100
Calotrophon ostrearum								12.5			4.2
Carditamera floridana								37.5	25		20.8
Cerithiidae spp.									12.5		4.2
Cerithium atratum									12.5		4.2
C. muscarum								12.5	12.5		8.3
Chione cancellata					12.5			12.5		2.1	4.2
Corbula swiftiana								12.5	12.5		8.3
Crepidula fornicata								12.5			4.2
C. plana					25		50	87.5	87.5	4.2	75
Crepidula spp.							12.5				4.2
Cumingia coarctata					12.5					2.1	
Gastropoda spp.									12.5		4.2
Geukensia demissa	75	12.5	25	62.5			12.5	50	50	29.2	37.5
Lithophaga bisulcata	12.5								12.5	2.1	4.2
Lioberus castaneus			12.5							2.1	
Lucinidae sp. A					12.5					2.1	
Melongena corona								25			8.3

TABLE G-3
(continued)
TAXONOMIC LIST AND FREQUENCY OF OCCURRENCE
OF ASSOCIATED FAUNA ON OYSTER REEF STATIONS SAMPLED QUARTERLY
CRYSTAL RIVER PROJECT
1981

	Frequency of occurrence[a]										
	Discharge stations						Control stations			Basins	
Species	101	102	103	104	105	106	107	108	109	Discharge	Control
MOLLUSCA (continued)											
Mytilidae spp.	12.5			12.5			12.5		12.5	4.2	8.3
Ostreola equestris								62.5	50		37.5
Seila adamsi								12.5	12.5		8.3
Semele proficua							25	25	12.5		20.8
S. purpurascens								37.5	12.5		16.7
ARTHROPODA											
Anurida maritima?	25		25	12.5		12.5		25		12.5	8.3
Balanus eburneus	100	75	87.5	100	87.5	50	50	62.5	100	83.3	70.8
Balanus sp. A	62.5	37.5	50	37.5		12.5	37.5	25	50	33.3	37.5
Balanus sp. B	50	37.5	37.5	37.5		37.5	25	37.5	37.5	14.6	33.3
Balanus spp.	25		12.5	12.5	25	12.5	12.5	12.5		33.3	8.3
Callinectes spp.					25	12.5				6.3	
Caridea spp.						12.5	12.5			2.1	4.2
Chironomidae spp.		12.5	12.5			12.5	12.5	25		6.3	12.5
Corophium acherusicum					25					4.2	
Eurypanopeus depressus	100	87.5	100	100	100	100	87.5	100	100	97.9	95.8
Grapsidae spp.	12.5	12.5	12.5			12.5	12.5			8.3	4.2
Hargeria rapax							12.5				4.2
Melita sp. A			12.5		25					6.3	
Neopanope spp.					12.5					2.1	
Oxyurostylis smithi						12.5				2.1	
Palaemonetes spp.						12.5				2.1	
Panopeus herbstii	37.5	37.5	37.5	37.5			37.5	37.5	25	25	33.3
P. herbstii?							25				8.3
P. occidentalis	12.5	12.5		37.5			12.5	12.5	12.5	10.4	12.5
Panopeus spp.	87.5	75	75	75	12.5	25	87.5	75	87.5	58.3	83.3
Paracerceis spp.								25	25		16.7
Paracerceis ? sp. A									12.5		4.2
Parhyale hawaiensis	62.5	75	12.5	12.5		12.5	100	87.5	100	29.2	95.8
Petrolisthes armatus	100	75	62.5	50	25	50	87.5	75	100	60.4	87.5
Sphaeromatidae spp.			12.5							2.1	
Tanais sp. A								12.5	12.5		8.3
Uca spp.	37.5	25	25	50	62.5	50				41.7	
Xanthidae spp.	100	87.5	100	100	100	100	100	100	100	97.9	100
OTHER											
Asicidacea spp.					12.5			12.5		2.1	4.2
Cnidaria spp.		12.5					87.5	87.5	87.5	2.1	87.5
Nemertinea spp.	50	62.5	25		12.5		75	100	100	25	91.7
Platyhelminthes spp.	100	75	62.5	87.5	12.5	12.5	75	75	75	58.3	75
Sipuncula spp.	12.5					12.5			25	4.2	8.3

[a]Percentage of replicates taken during 1981 in which each taxa was collected (n for each station = 8; n for discharge basin = 48; n for control basin = 24).

TABLE G-4

NUMBER OF TAXA OF ASSOCIATED FAUNA COLLECTED QUARTERLY AT
OYSTER REEF STATIONS
CRYSTAL RIVER PROJECT
1981

Group	Month	Station: Discharge stations 101	102	103	104	105	106	Control stations 107	108	109	Basin: Control total	Discharge total
ANNELIDA	April	5 (0)[a]	2 (0)	9 (2)	5 (1)	18 (10)	8 (1)	5 (0)	5 (0)	4 (0)	6 (0)	23 (17)
	June	8 (1)	6 (1)	6 (0)	5 (0)	6 (2)	4 (0)	6 (1)	6 (0)	6 (1)	8 (2)	12 (7)
	September	6 (0)	5 (0)	7 (1)	7 (0)	3 (0)	3 (0)	3 (0)	5 (1)	5 (1)	6 (2)	9 (5)
	December	8 (1)	4 (0)	8 (0)	7 (0)	12 (5)	16 (7)	6 (0)	10 (1)	11 (2)	15 (4)	28 (17)
	Annual mean	12 (1)	8 (0)	13 (0)	10 (0)	23 (6)	23 (4)	9 (1)	12 (1)	13 (2)	19 (5)	35 (21)
MOLLUSCA	April	2 (0)	0 (0)	2 (0)	3 (0)	5 (3)	1 (0)	3 (1)	6 (4)	3 (0)	8 (5)	7 (4)
	June	4 (0)	3 (0)	2 (1)	4 (0)	1 (0)	0 (0)	5 (2)	8 (3)	8 (1)	13 (9)	6 (2)
	September	2 (0)	2 (1)	1 (0)	2 (0)	0 (0)	0 (0)	2 (0)	3 (0)	5 (2)	5 (3)	3 (1)
	December	3 (0)	2 (0)	2 (0)	1 (0)	0 (0)	0 (0)	4 (0)	11 (3)	15 (7)	18 (15)	3 (0)
	Annual mean	5 (0)	5 (0)	3 (1)	4 (0)	5 (2)	1 (0)	9 (1)	15 (3)	19 (5)	25 (16)	12 (3)
ARTHROPODA	April	10 (1)	3 (0)	12 (1)	9 (0)	6 (1)	10 (0)	8 (0)	6 (0)	8 (0)	9 (0)	17 (8)
	June	11 (0)	12 (0)	5 (0)	9 (0)	4 (0)	4 (1)	14 (2)	9 (0)	10 (2)	16 (4)	14 (2)
	September	9 (1)	10 (0)	9 (0)	7 (0)	4 (0)	5 (0)	7 (0)	10 (2)	8 (0)	11 (2)	11 (2)
	December	8 (0)	8 (0)	10 (1)	7 (0)	9 (2)	9 (2)	9 (0)	12 (2)	8 (0)	14 (3)	19 (8)
	Annual mean	14 (0)	13 (0)	16 (1)	13 (0)	11 (2)	17 (2)	16 (2)	15 (0)	13 (1)	20 (5)	23 (8)
OTHER	April	2 (0)	2 (0)	1 (0)	1 (0)	2 (0)	2 (1)	3 (0)	2 (0)	3 (0)	3 (1)	3 (1)
	June	3 (0)	3 (0)	1 (0)	1 (0)	0 (0)	0 (0)	3 (0)	3 (0)	4 (0)	4 (0)	4 (0)
	September	1 (0)	2 (0)	1 (0)	1 (0)	0 (0)	0 (0)	3 (0)	3 (0)	4 (1)	4 (2)	2 (0)
	December	1 (0)	2 (0)	2 (0)	1 (0)	1 (0)	0 (0)	3 (0)	4 (0)	3 (0)	4 (1)	3 (0)
	Annual mean	3 (0)	3 (0)	2 (0)	1 (0)	3 (0)	2 (0)	3 (0)	4 (0)	4 (0)	5 (0)	5 (0)

TABLE G-4
(continued)
NUMBER OF TAXA OF ASSOCIATED FAUNA COLLECTED QUARTERLY AT
OYSTER REEF STATIONS
CRYSTAL RIVER PROJECT
1981

		Station									Basin	
		Discharge stations						Control stations				
Group	Month	101	102	103	104	105	106	107	108	109	Control total	Discharge total
TOTAL ASSOCIATED FAUNA	April	19 (1)	7 (0)	24 (3)	18 (1)	31 (14)	21 (2)	19 (1)	19 (4)	18 (0)	26 (6)	50 (30)
	June	26 (1)	24 (1)	13 (1)	19 (0)	11 (2)	8 (0)	28 (5)	26 (3)	28 (5)	41 (16)	36 (11)
	September	18 (1)	19 (1)	18 (1)	17 (0)	7 (0)	8 (0)	15 (0)	21 (3)	22 (3)	26 (9)	25 (8)
	December	20 (1)	16 (0)	22 (0)	16 (0)	22 (6)	25 (9)	22 (0)	37 (6)	37 (8)	50 (23)	53 (25)
	Annual mean	34 (1)	29 (0)	34 (2)	28 (0)	42 (10)	43 (6)	37 (4)	46 (4)	49 (8)	69 (26)	75 (32)

[a] Number in parentheses is the number of taxa found only at that station or basin.

TABLE G-5

MEAN ABUNDANCE (number/m^2) AND MEAN BIOMASS (gram dry weight/m^2)
OF ASSOCIATED FAUNA COLLECTED QUARTERLY AT EACH OYSTER REEF STATION
CRYSTAL RIVER PROJECT
1981

		Station								
		Discharge basin						Control basin		
Group		101	102	103	104	105	106	107	108	109
Annelida	mean abundance (number/m^2)	236	86	134	74	279	104	163	417	503
	mean biomass (g dry wt/m^2)	0.888	0.142	0.252	0.140	0.771	0.123	0.336	0.518	1.352
Mollusca	mean abundance (number/m^2)	145	101	73	111	23	5	616	1790	2271
	mean biomass (g dry wt/m^2)	10.972	4.051	3.262	11.656	0.927	0.053	29.628	245.008	150.687
Arthropoda	mean abundance (number/m^2)	1307	831	921	748	491	310	438	1121	1330
	mean biomass (g dry wt/m^2)	53.832	27.437	34.580	32.759	14.329	9.142	18.464	34.291	33.584
Total associated fauna	mean abundance (number/m^2)	1721	1032	1143	942	548	423	1541	3702	4764
	mean biomass (g dry wt/m^2)	65.728	31.645	38.125	44.559	16.084	9.328	48.880	280.210	186.504

TABLE G-6

DOMINANCE RANK[a] FOR TOP TEN TAXA OF ASSOCIATED FAUNA
SAMPLED QUARTERLY AT OYSTER REEF STATIONS
CRYSTAL RIVER PROJECT
1981

Group	Species	Station: Discharge stations 101	102	103	104	105	106	Control stations 107	108	109	Basin: Control	Basin: Discharge
Annelida	*Capitella capitata*				10		10					
	Marphysa sanguinea					7	8					
	Mediomastus californiensis					6	6					10
	Neanthes succinea					3	5					
	Nereiphylla fragilis	9	7	7	7		9	6	5	5	6	
	Perinereis floridana	6	10	6	6			9	9	7	9	6
	Tubificidae spp.			8								
	Typosyllis sp. A		9	9			7	7	10	10	8	
Mollusca	*Brachidontes modiolus*				8							
	Brachidontes spp.	5	4	3	3	10		1	1	1	1	3
	Crepidula plana								8		9	
Arthropoda	*Anurida maritima*	10										
	Balanus eburneus	4	6	4	4	4	3					5
	Balanus sp. B			10								
	Balanus spp.					9						
	Eurypanopeus depressus	2	2	1	1	2	1	10	6	8	7	1
	Melita sp. A					8						
	Panopeus spp.	8	8					8				9
	Parhyale hawaiensis	7	5					4	7	2	3	8
	Petrolisthes armatus	1	1	5	5			3	2	4	5	4
	Uca spp.					5	4					7
	Xanthidae spp.	3	3	2	2	1	2	5	4	6	3	2
Other	Cnidaria spp.							2	3	3	2	
	Platyhelminthes spp.				9					9		

[a] McCloskey, 1970.

TABLE G-7

ANNUAL MEAN VALUES FOR MEASURED COMMUNITY PARAMETERS AT OYSTER REEFS
IN THE CONTROL AND DISCHARGE BASINS
CRYSTAL RIVER PROJECT
1977-1981

Group	Parameter	1977		1978		1979		1980		1981	
		Control	Discharge	Control	Discharge	Control	Discharge	Control	Discharge	Control	Discharge
Adult oysters	Mean abundance (number/m^2)	543	278	1018	466	1470	455	1178	258	1274	481
	Mean biomass (g dry wt/m^2)	69.72	31.50	113.99	68.05	178.41	57.95	136.80	29.06	97.8	32.1
	Mean biomass (G) x 230[a] / Mean shell length (cm)	9.5	5.9	8.9	9.3	7.9	8.3	7.4	6.3	5.5	4.5
Spat	Mean abundance (number/m^2)	315	187	797	176	1614	310	1407	174	1682	645
	Mean biomass (g dry wt/m^2)	54.10	49.34	144.49	28.86	253.94	47.59	238.16	26.99	215.0	76.3

[a] Ratio adjusted to a constant sample size of 230 for comparative purposes (FPC, 1981).

H. SALT MARSH

INTRODUCTION

Salt marshes are plant communities found in the intertidal zone along coasts of low energy and gradual slope. They may occupy a narrow fringe of coastline or vast coastal areas. As a transition zone between the sea and land, salt marshes are the site of the production of large quantities of organic matter, the habitat of a few plant and numerous animal species, and the area providing protection to the adjacent low-lying uplands from saltwater intrusion, coastal erosion and salt spray (Humm, 1973).

Dominant salt marsh plants in the eastern Gulf of Mexico, including the Crystal River area, are smooth cordgrass, *Spartina alterniflora*, and black needlerush, *Juncus roemarianus*. Almost pure stands of these two plants form distinct zones controlled by tidal inundation, substrate composition, rate of saltwater percolation and similar factors (Humm, 1973). In Florida, *Spartina* forms the relatively narrow seaward band of salt marsh, where it endures the longest inundation by salt water during high tides. *Juncus*, however, occupies slightly higher ground just landward of the *Spartina* zone. It may cover vast areas that are inundated for shorter periods.

Because salt marshes may be measurably affected by thermal effluents (Young, 1974), studies to assess potential impact resulting from the thermal discharge of Crystal River Unit 3 have been conducted con-

tinuously since 1977 (Kosik, 1981). In 1981, measurements of salt marsh parameters made in an area subjected to thermal addition were compared to an area outside of any potential thermal influence. These measurements were then compared to those obtained during prior years of study.

MATERIALS AND METHODS

Two sites were chosen for study: one in the discharge area which received thermal effluent from the power plant, and the other (the control) in an area outside of any potential thermal influence (Figure H-1). In preoperational studies, control data were collected on the offshore islands adjacent to the sites where all operational data were collected.

Collections were made quarterly at each of the two preestablished salt marsh stations. Samples for standing crop biomass were taken by randomly throwing a 50 x 50-cm frame into the grasses and, with hand shears, clipping all plant material to within 1 to 2 cm of the substrate surface. As the grasses were harvested, the number of fiddler crab (*Uca* spp.) burrows and periwinkles (the snail *Littorina irrorata*) in each quadrat were counted. The marsh samples were placed in plastic bags and frozen until processing began. Nine quadrats in the *Spartina* zone and five in the *Juncus* zone were sampled per quarter.

In the laboratory, plant material was separated and the number of dead stems, live stems and flowering stems for each species was determined. Live plant material was further subdivided into 20-cm size

classes for Spartina and 25-cm size classes for Juncus, and the number of stems in each category were counted. Dry weight biomass was determined by species for both live and dead material by drying the samples for 24 hours at 70°C and weighing to the nearest 0.1 gram.

All data were analyzed statistically as outlined previously (A. Introduction). Where significant station differences occurred, thermal impact was often assumed to be the probable cause. This assumption takes the conservative (worst-case) approach because other factors, such as differences in water percolation rates, sediments and nutrients, were not considered.

RESULTS AND DISCUSSION

Spartina Density

Mean density of live Spartina stems did not vary significantly between stations at any time during 1981. At both control and discharge stations, highest stem numbers were observed during December (Table H-1). Mean density of dead stems generally decreased from spring to winter at both control and discharge marshes. Dead stem densities were significantly higher at the discharge than at the control marsh during September and December. No flowering stems were observed until December, when mean flower stem density at the discharge station was significantly greater than that at the control station.

Spartina stem density in both discharge and control areas followed the same general seasonal pattern in 1981 as during previous years

(Figures H-2 and H-3). That is, both dead and live stem densities were high in the winter and/or spring, following the period of maximum plant production, and then lower during the remainder of the year due to attrition, tissue breakdown and the recycling of nutrients back into the system.

The major difference observed among 1981 data and data of previous years was found in comparison of live Spartina stem density at the discharge and control stations (Figure H-2). In years prior to 1981, densities at the discharge were higher than at the control. In 1981, however, densities were usually higher at the control. For the years 1978 through 1980, trends of density increase are apparent at both discharge and control areas. This density trend continued into 1981 at the control; however, at the discharge the densities fell. Because live stem densities at the discharge were similar during 1977 and 1981, the only years Unit 3 was on-line during the summer, it appears likely that thermal effluents from Unit 3 have an adverse effect on live stem densities in the discharge marsh.

Juncus Density

Mean density of live Juncus stems was significantly higher at the control than at the discharge during most of 1981 (Table H-1). Highest live stem density occurred in December at the discharge and in June at the control (Table H-1). Mean density of dead stems was highest at both discharge and control in June. Dead stem densities were consistently higher at the control than at the discharge, but the only significant

difference was in December. Flowering Juncus stems were only found during June at the control marsh and during April and December at the discharge marsh.

Juncus stem density (Figures H-4 and H-5) does not follow the fairly consistent seasonal pattern shown by Spartina (Figures H-2 and H-3). Where Juncus density may be high in winter one year, whether at discharge or control, it may be just as high or higher in the summer of the next year. Because Juncus density varies so much naturally, establishing cause and effect relationships (thermal effects) is especially difficult.

Mean densities of live and dead Juncus stems at the discharge were lower in 1981 than in previous years (Figures H-4 and H-5). These lower 1981 densities could appear to result from thermal impact; however, densities were also high in the summer of 1977, the only other summer that Unit 3 was continuously on-line. This indicates that thermal effluents were not likely the cause of low stem densities in 1981. Live and dead stem densities at the control station in 1981 were similar to those of previous years (Figures H-4 and H-5).

Spartina Stem Lengths

Spartina stems in the 41 to 60-cm or 61 to 80-cm size classes comprised the highest stem densities at the discharge marsh in 1981 (Figures H-6 and H-7). In the control marsh, the highest densities consisted of stems in the 81 to 100-cm size class. When stem lengths were analyzed statistically, mean lengths were shown to be significantly

greater at the control than at the discharge during every quarter except December (Table H-2).

The occurrence of shorter mean stem lengths at the discharge marsh is consistent with the data obtained in earlier years (Figure H-8). The higher temperatures of the discharge marsh water may have resulted in Spartina stems being shorter in that area. This is supported by the mean stem length difference between discharge and control marshes, which was greater in June and September, the months of higher water temperatures, than in December (Table H-2). However, within the discharge marsh, mean stem length was greater in June and September than in December (Table H-2). This observation contradicts the premise that higher discharge water temperatures caused the difference in stem lengths.

Juncus Stem Lengths

Juncus stems in the 76 to 100-cm and 101 to 125-cm size classes comprised the highest stem densities at the discharge marsh in 1981 (Figures H-9 and H-10). The highest densities in the control marsh were of stems in the 101 to 125-cm or 126 to 150-cm size classes. At both discharge and control marshes, peak densities in April consisted of slightly shorter stems than those which accounted for peak densities during the other quarters. Statistical analysis showed that mean stem lengths were greater at the control than at the discharge during every 1981 sampling quarter (Table H-2).

Shorter *Juncus* mean stem length at the discharge marsh has been consistent over the past five years of study (Figure H-11). High discharge water temperature is a likely cause of this difference in stem lengths, particularly because differences between control and discharge stations in 1981 were greater during June and September when discharge water temperatures were highest. In addition, mean stem lengths in the discharge marsh were shorter in June and September that in December.

Spartina Biomass

Spartina mean live stem biomass was higher at the control marsh than at the discharge marsh during every 1981 sampling quarter. Differences were statistically significant in April and June (Table H-3). The highest mean live biomass values were found in June at both marshes. Mean dead stem biomass, with the exception of the September quarter, was also higher at the control marsh. Highest dead biomass values were found in June at the discharge and in December at the control.

Live and dead *Spartina* biomass values over the past study years have usually been higher at the control marsh than at the discharge marsh (Figures H-12 and H-13). This difference in biomass values indicates thermal impact. However, other environmental variables, such as sediments and nutrients, could also cause differences in the amount of biomass produced.

The 1981 mean values for *Spartina* biomass at the discharge marsh consistently fell outside two standard deviations of the 1973 biomass

means (Table H-4). Mean live stem biomass was higher in 1981 than in 1973 during winter and fall quarters while 1973 was higher in the spring quarter. For mean dead stem biomass, 1981 was higher in winter, summer and fall while 1973 was higher in the spring. Overall, 1981 had higher combined live and dead stem biomass than did 1973. Higher biomass in 1981 suggests that if there is a thermal effect, it would be to enhance production rather than inhibit it. It must be added, however, that mean dead Spartina stem biomass values were unusually high in 1981 (Figure H-13) and that this accounts for much of the difference between 1981 and 1973 values. The reason(s) for the high 1981 dead biomass values, which occurred at both discharge and control marshes, are not known.

Juncus Biomass

Juncus mean biomass, both live and dead, was significantly higher at the control marsh than at the discharge marsh during every 1981 sampling period (Table H-3). The highest mean live stem biomass was found in June at the control and in December at the discharge. The highest mean dead stem biomass was found in December at the control and in June at the discharge. This seasonal distribution of live and dead stem biomass at discharge and control areas is strongly indicative of thermal impact. However, 1981 was an unusual year in biomass values because it was the first year values were higher at the control marsh than at the discharge marsh (Figures H-14 and H-15). Values for 1977, the only previous year that Unit 3 was on-line in the summer, would be expected to have been lower if thermal effluent was affecting Juncus biomass.

The 1981 mean values for *Juncus* biomass at the discharge marsh was usually within two standard deviations of the 1973 biomass mean (Table H-4). The only exception was in mean dead stem biomass in the spring quarter which, in 1981, was below the 1973 range. As previously mentioned, *Juncus* biomass values in 1981 were atypical of those obtained during other years of operational studies. When biomass from 1977 through 1981 is compared to the 1973 preoperational study, 1981 values are similar to those obtained in 1973 while 1977 through 1980 values are higher than in 1973. These comparisons do not show any adverse thermal impact on *Juncus* biomass.

Invertebrate Activity

Periwinkles (the snail *Littorina irrorata*) and fiddler crabs (*Uca* spp.) are common salt marsh inhabitants. They are easily seen, abundant and stay within limited areas relative to most other inhabitants of the marshes. Therefore, they make good subjects to study potential changes within a marsh; in this case, changes that may have resulted from thermal impact.

No periwinkles were observed at the *Spartina* control marsh in any 1981 sampling quarter (Table H-5). At the *Spartina* discharge marsh, periwinkle mean density was highest in June. Periwinkle densities at the *Juncus* marshes were also higher at the discharge than at the control; differences being significant in the September sampling quarter. Periwinkle densities have also been higher at the discharge marshes than at the control marshes in previous study years (Figures H-16 and H-17).

Periwinkle densities increased from 1977 to 1980 and then decreased in 1981. Because this trend occurred at both discharge and control marshes, the changes are attributed to natural population variations. The fact that densities have been higher at the discharge than at the control may result from thermal effect or some other, as yet unidentified, difference between the marshes. If periwinkles were influenced by the thermal effluent, the effect was to stimulate population growth rather than inhibit it.

The mean 1981 densities of fiddler crab burrows varied considerably both among quarters and between marshes (Table H-5). Densities were highest at the discharge marshes (both Spartina and Juncus) in June and at the control marshes in December. Spartina and Juncus control marsh burrow densities were significantly higher than discharge marsh burrow densities in December. Burrow density in the Juncus discharge marsh was significantly higher than that of the control marsh in September. Generally higher burrow densities at the discharge marshes than at the control marshes during the years of operational study (Figures H-18 and H-19) suggest the possibility of thermal impact. As with the periwinkles, if there is a thermal effect on fiddler crabs, it would be to stimulate population growth rather than inhibit it.

SUMMARY

Live stem densities of Spartina in 1981 were usually higher at the control marsh than at the discharge marsh, while Spartina dead stem densities were usually higher at the discharge marsh. Live and dead stem

densities of Juncus in 1981 were always higher at the control marsh than at the discharge marsh. Flower stems were not found throughout the year at either marsh. The only significant differences in flower stem densities were found in December for Spartina, when densities were higher at the discharge than at the control, and in June for Juncus, when densities were higher at the control than at the discharge.

The major difference observed among 1981 data and data of previous years was found in comparison of live Spartina stem density at the discharge and control marshes. In years prior to 1981, densities at the discharge were higher than at the control. In 1981, however, densities were usually higher at the control. Comparison of Spartina and Juncus live stem densities between 1977 and 1981, the only two years Unit 3 was on-line during the summer, showed that thermal effects were a likely cause of lower stem densities at the Spartina discharge marsh, but unlikely to have caused the lower stem densities at the Juncus discharge marsh.

Spartina and Juncus stems were longer at the control marsh than at the discharge marsh in 1981, a difference consistent with data from previous study years. Higher water temperatures are a possible cause of shorter stems at the discharge marsh, but the data were not conclusive.

Spartina and Juncus biomass was greater at the control marsh than at the discharge marsh in 1981. This difference also occurred during previous study years at the Spartina marshes. During previous study years

at the Juncus marshes, however, biomass values were greater at the discharge than at the control. Trends in biomass values were contradictory and neither fully supported nor refuted impact resulting from thermal effects. The 1981 mean biomass values often fell outside two standard deviations of the 1973 biomass means. In the majority of these instances, the 1981 values were higher than those from 1973.

Densities of periwinkles and fiddler crab burrows were higher at the discharge marsh than at the control marsh in 1981, which is generally consistent with results from previous study years. Higher densities at the discharge may result from the thermal effluent. If this is the case, however, the thermal effect was to stimulate population growth rather than inhibit it.

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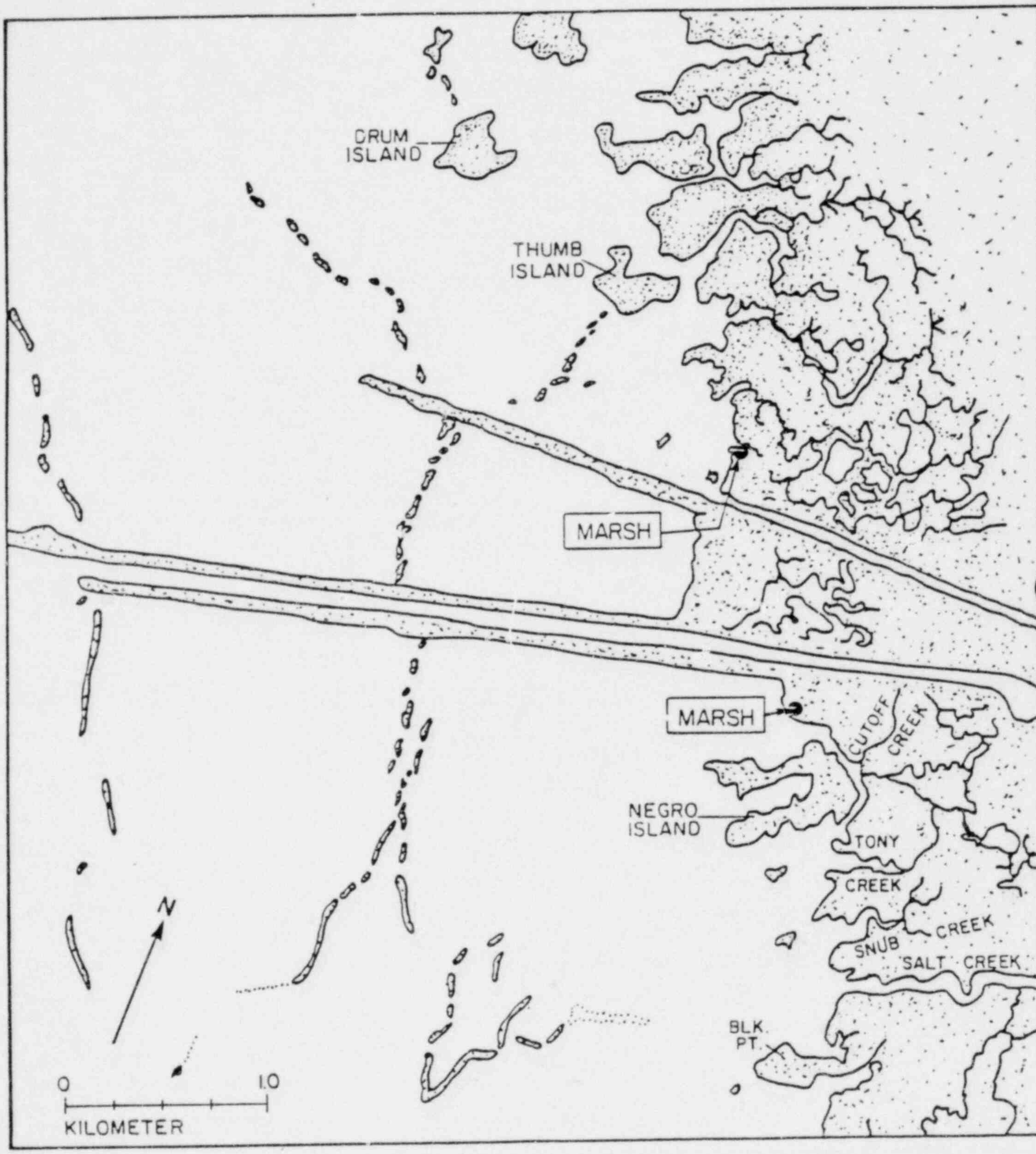

Figure H-1. Location of salt marsh sampling areas, Crystal River Project, 1981.

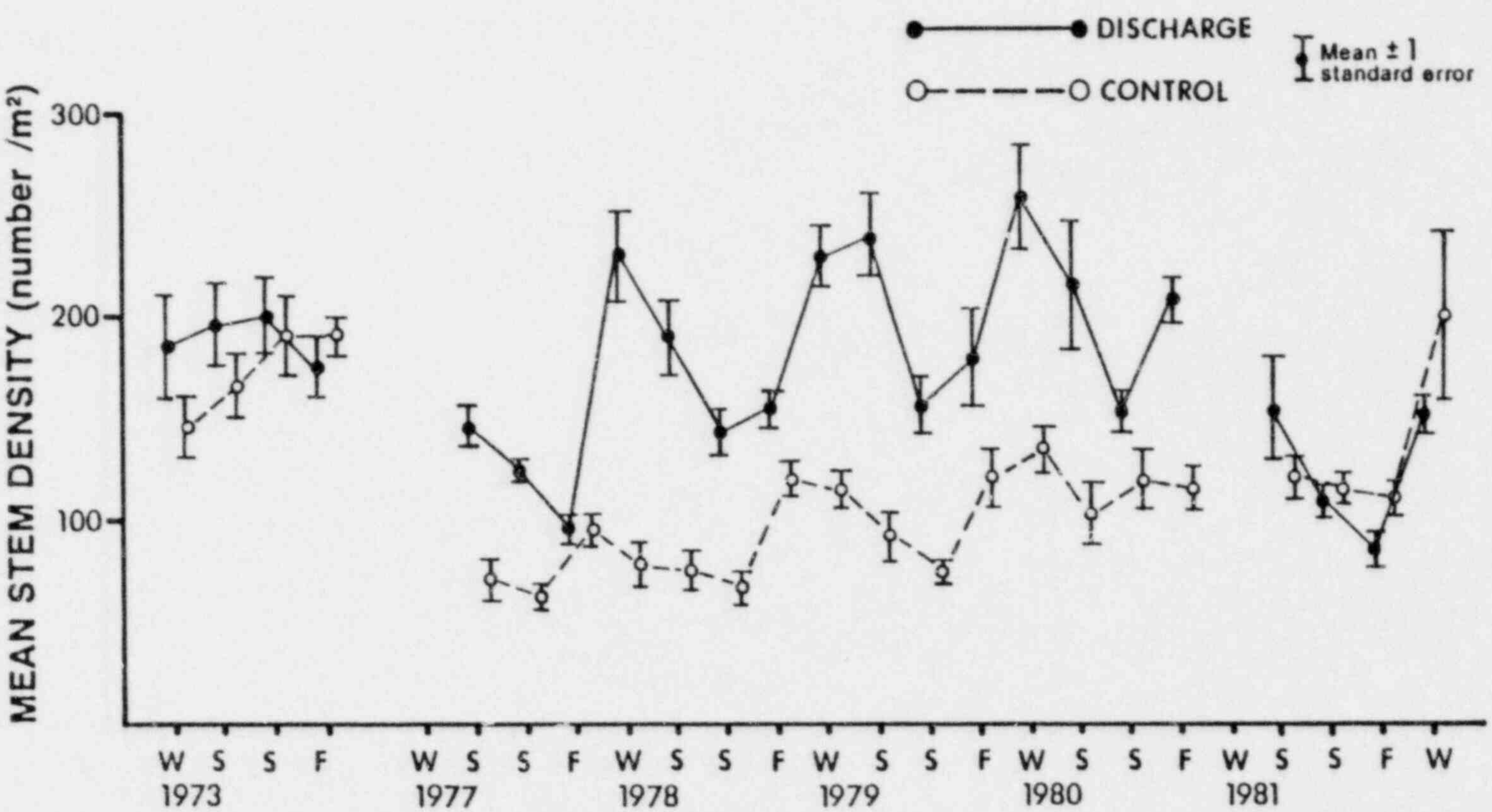

Figure H-2. Mean density of live *Spartina* stems during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

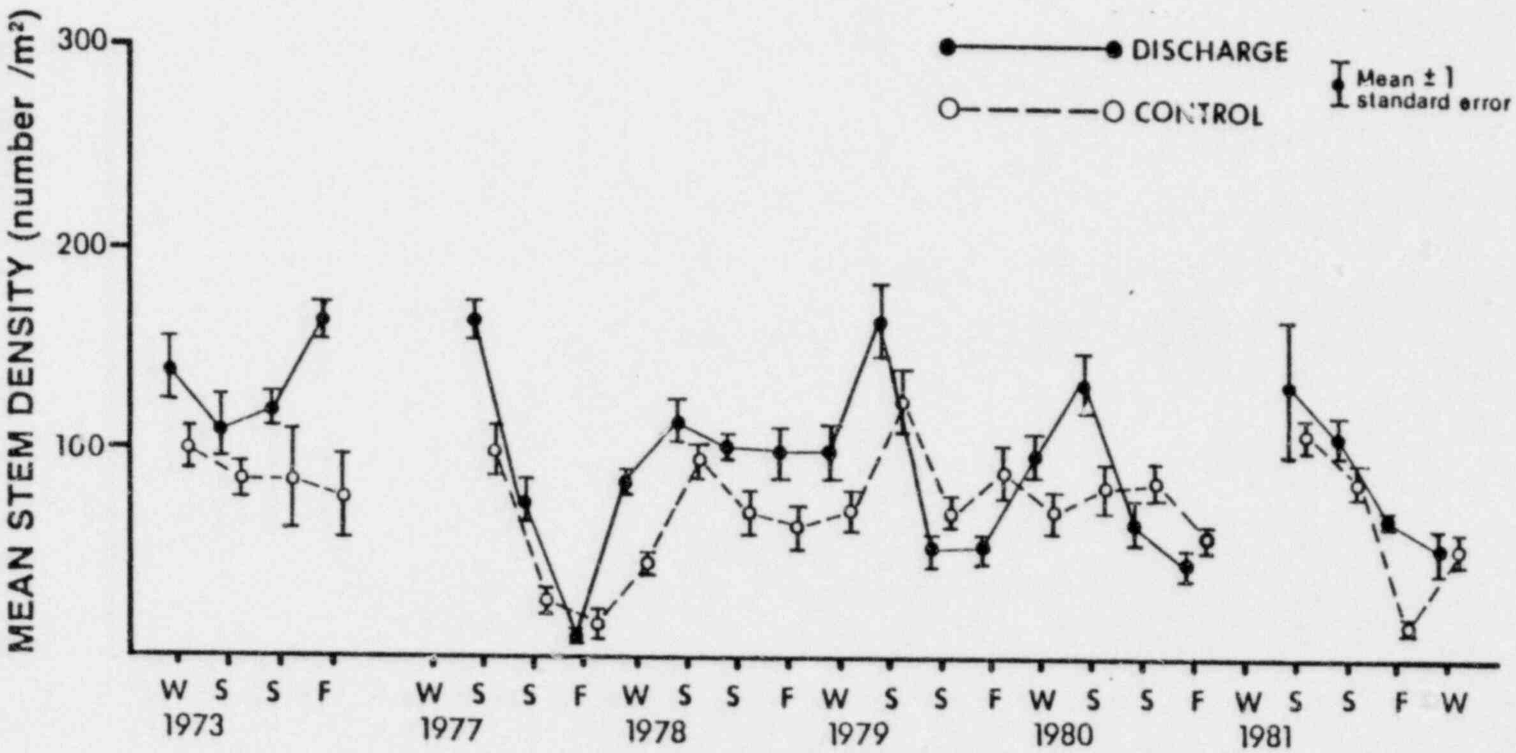

Figure H-3. Mean density of dead Spartina stems during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

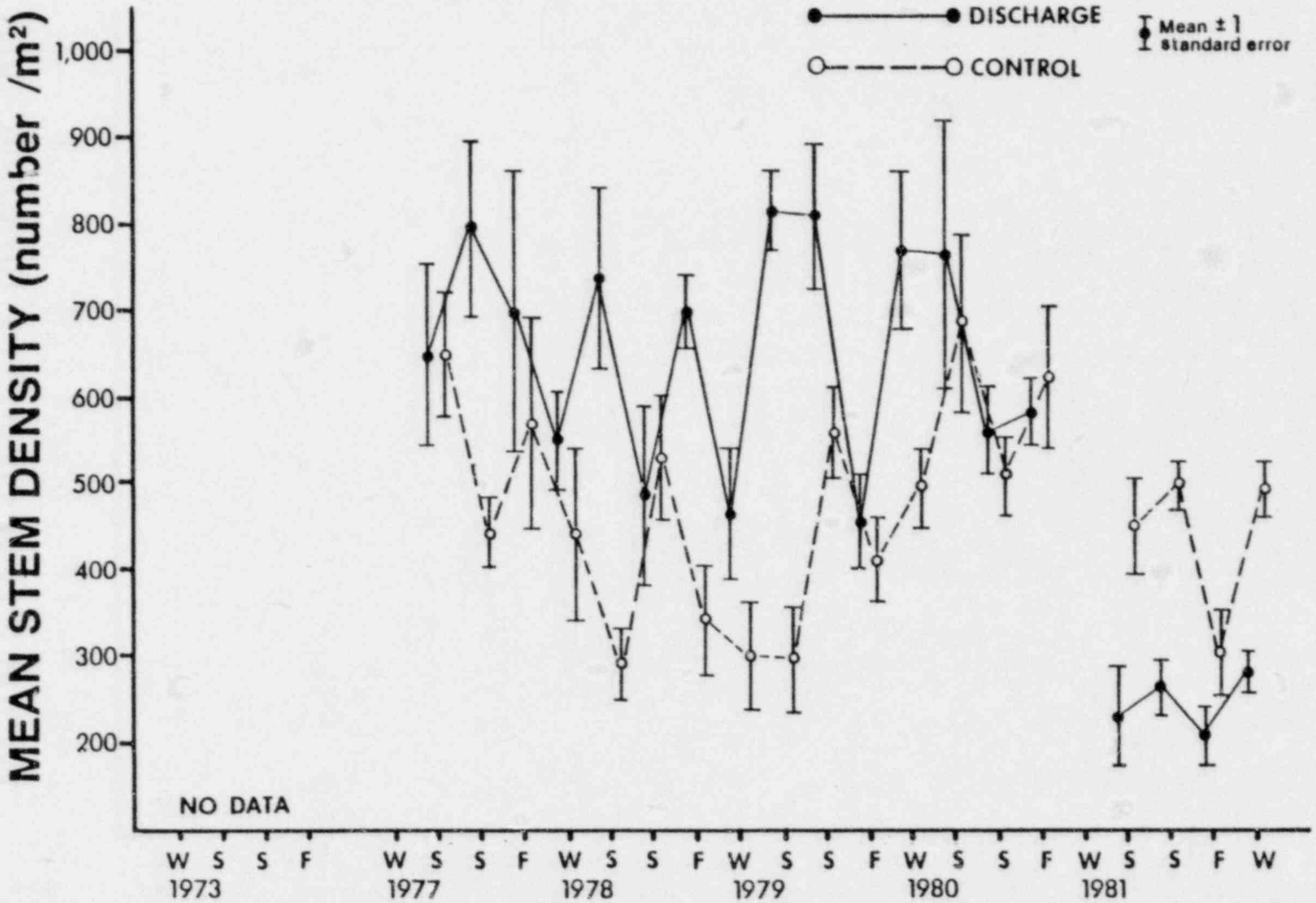

Figure H-4. Mean density of live *Juncus* stems during 19,7-1981 operational monitoring, Crystal River Project.

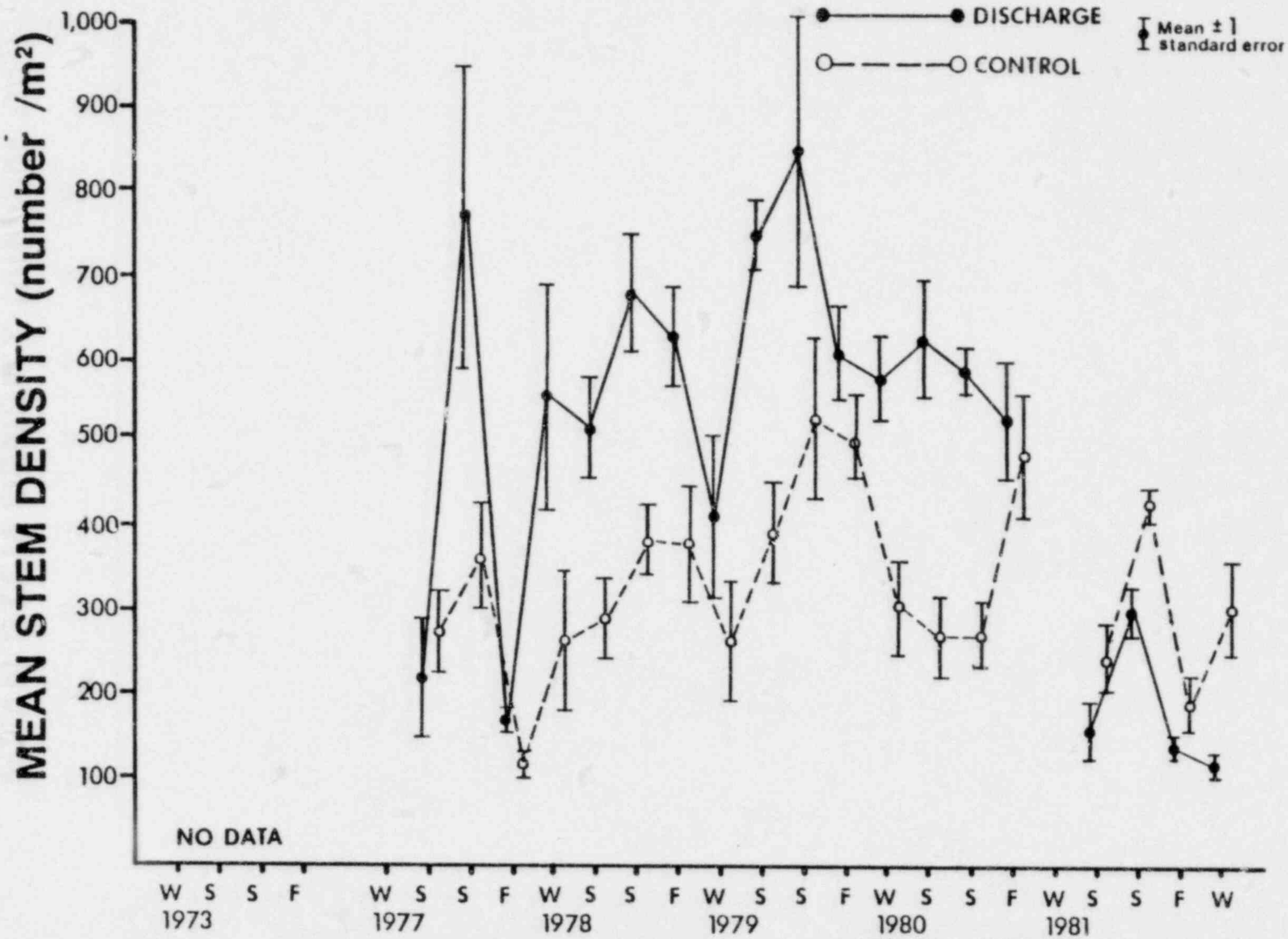

Figure H-5. Mean density of dead Juncus stems during 1977-1981 operational monitoring, Crystal River Project.

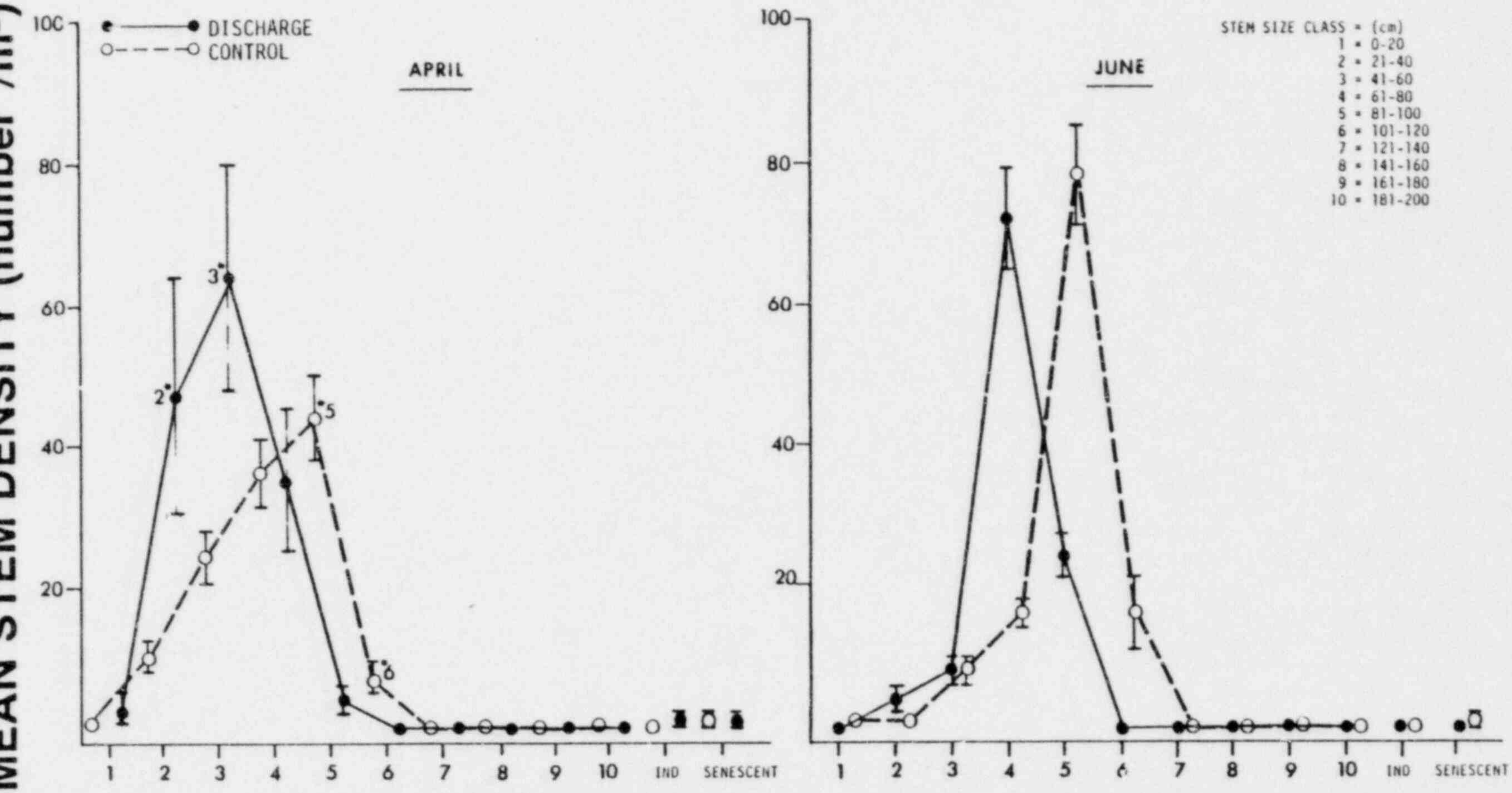

Figure H-6. Size distribution of Spartina stems, Crystal River Project, April and June 1981.

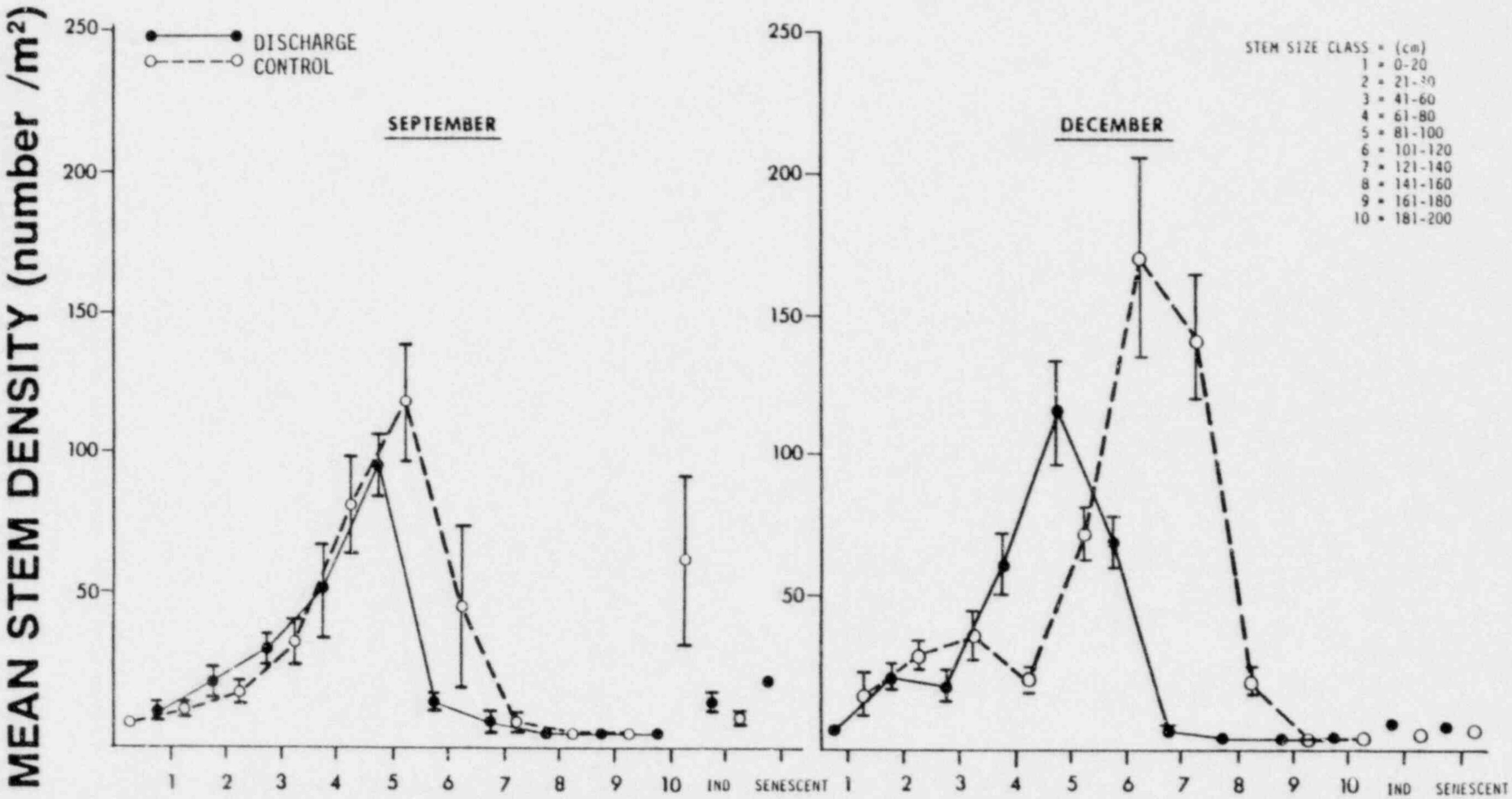

Figure H-7. Size distribution of Spartina stems, Crystal River Project, September and December 1981.

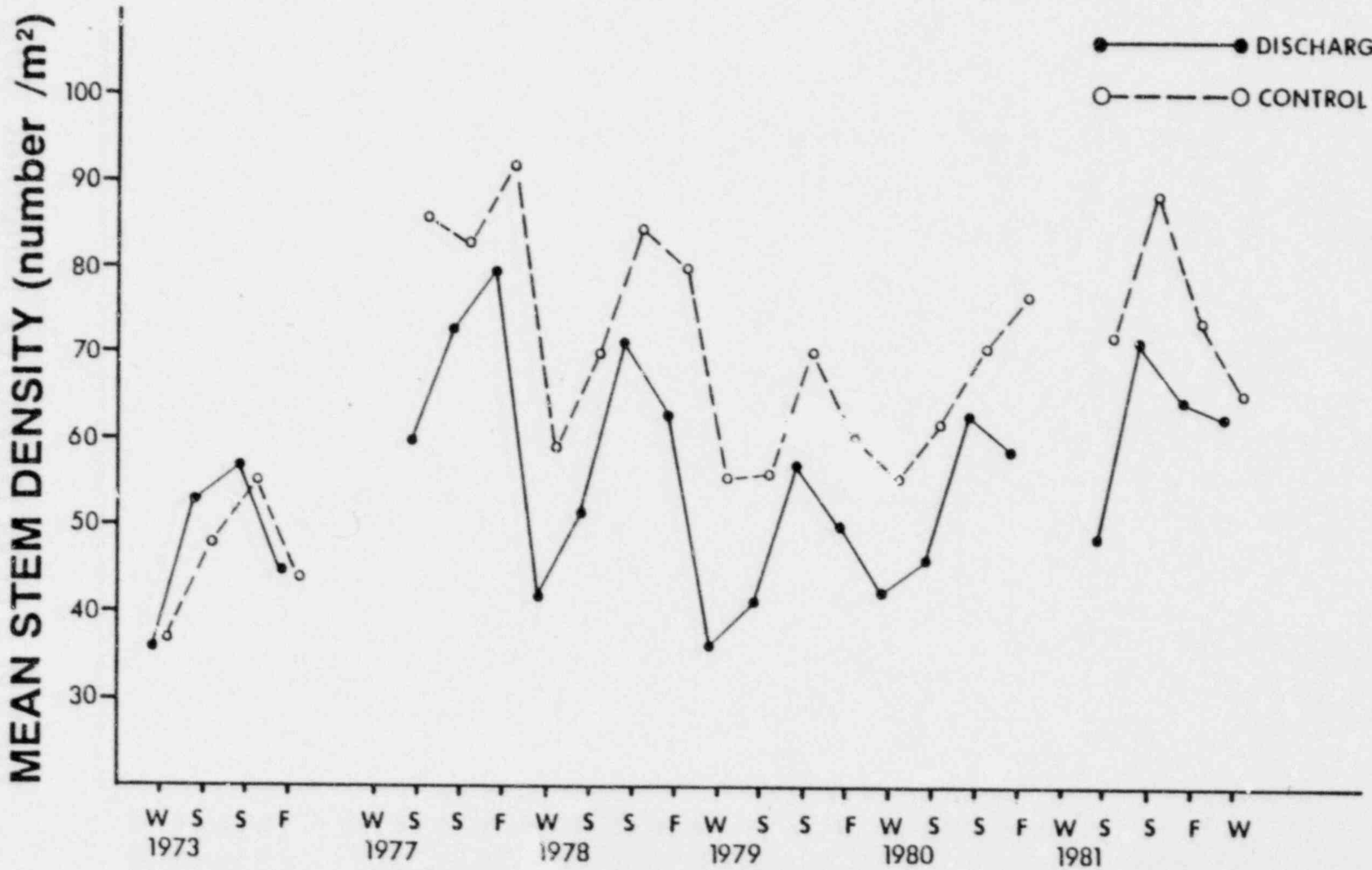

Figure H-8. Mean stem length of _Spartina_ during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project. (One standard error is always less than ± 3 cm).

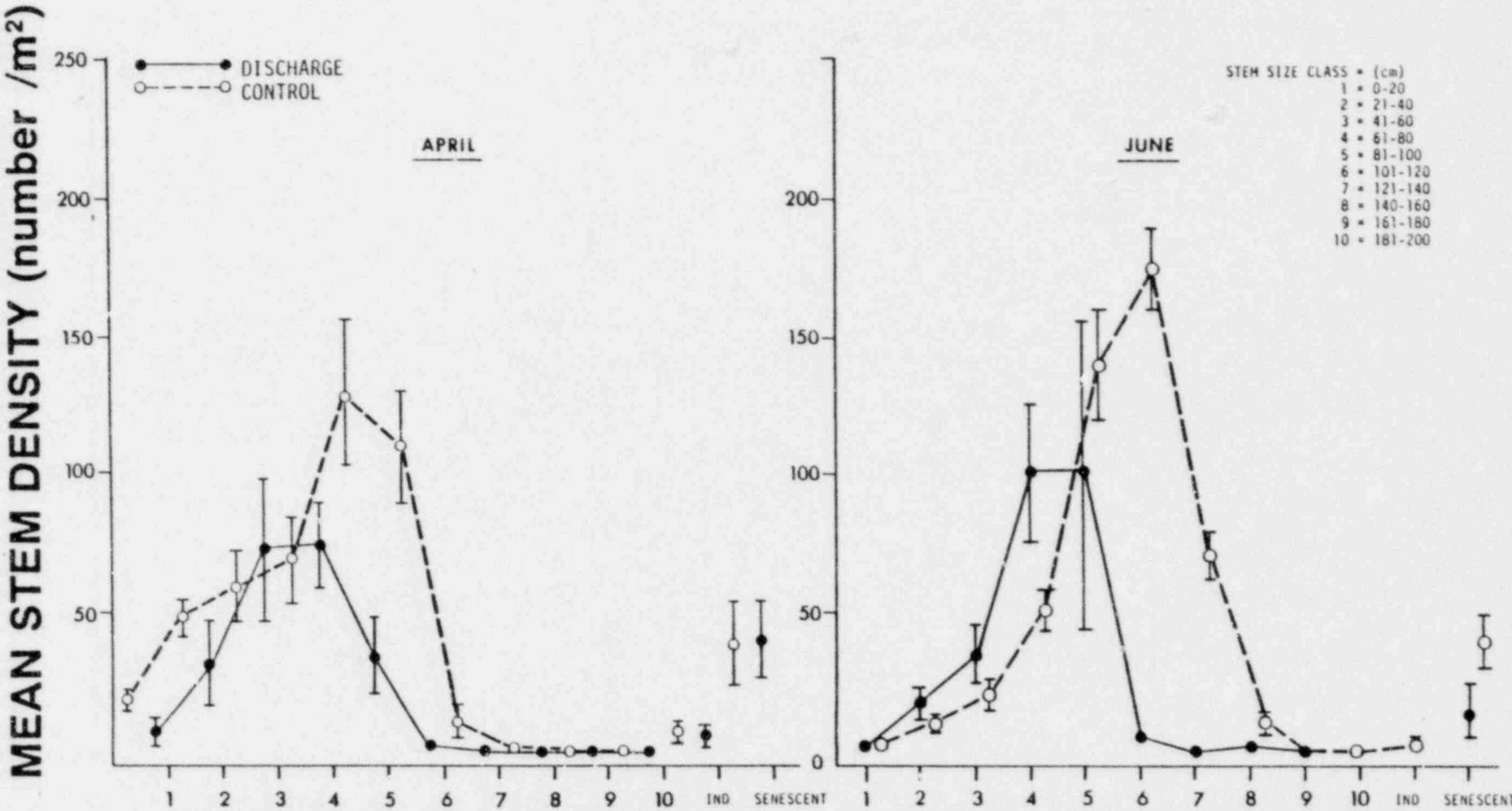

Figure H-9. Size distribution of Juncus stems, Crystal River Project, April and June 1981.

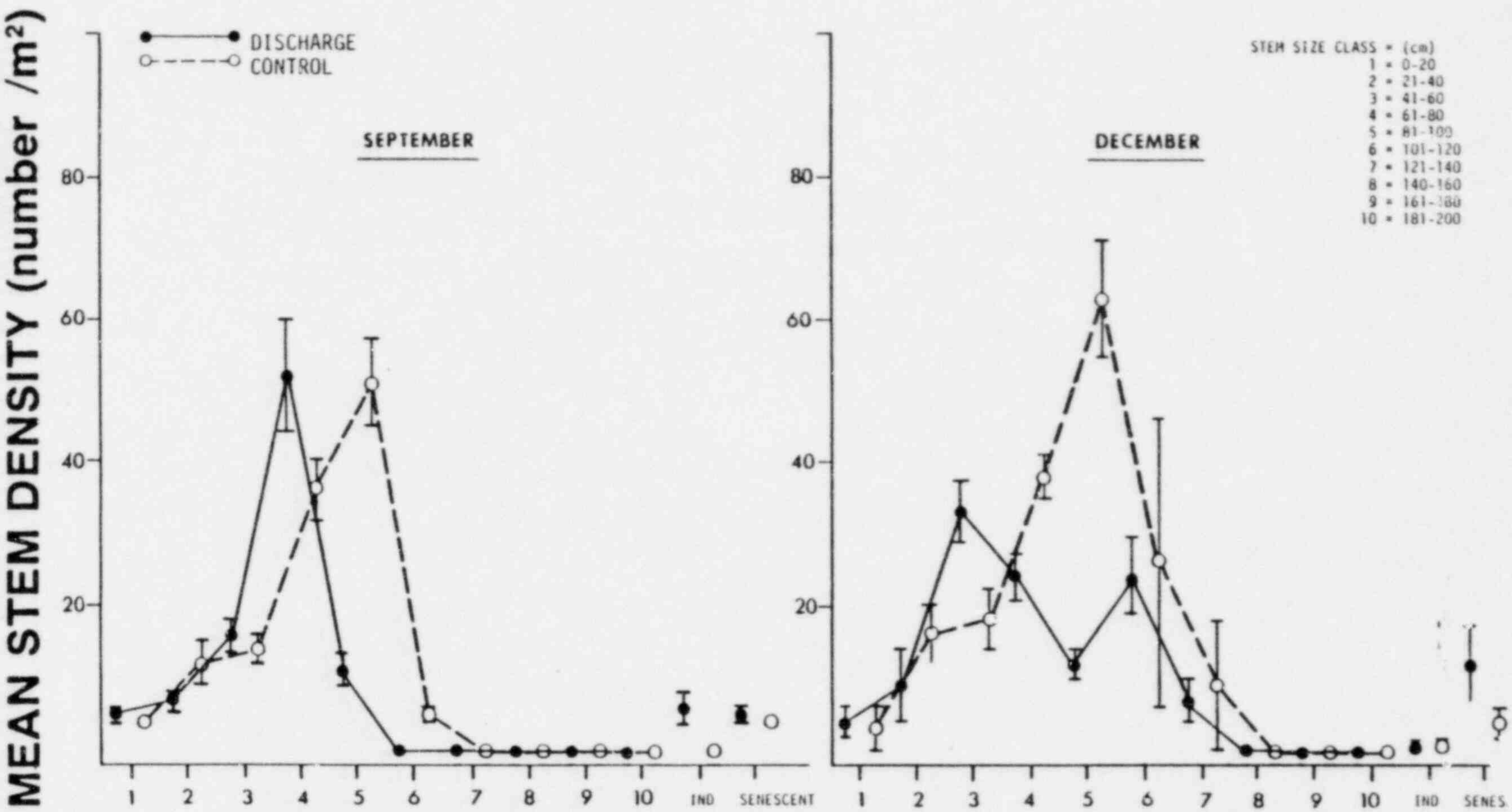

Figure H-10 Size distribution of Juncus stems, Crystal River Project, September and December 1981.

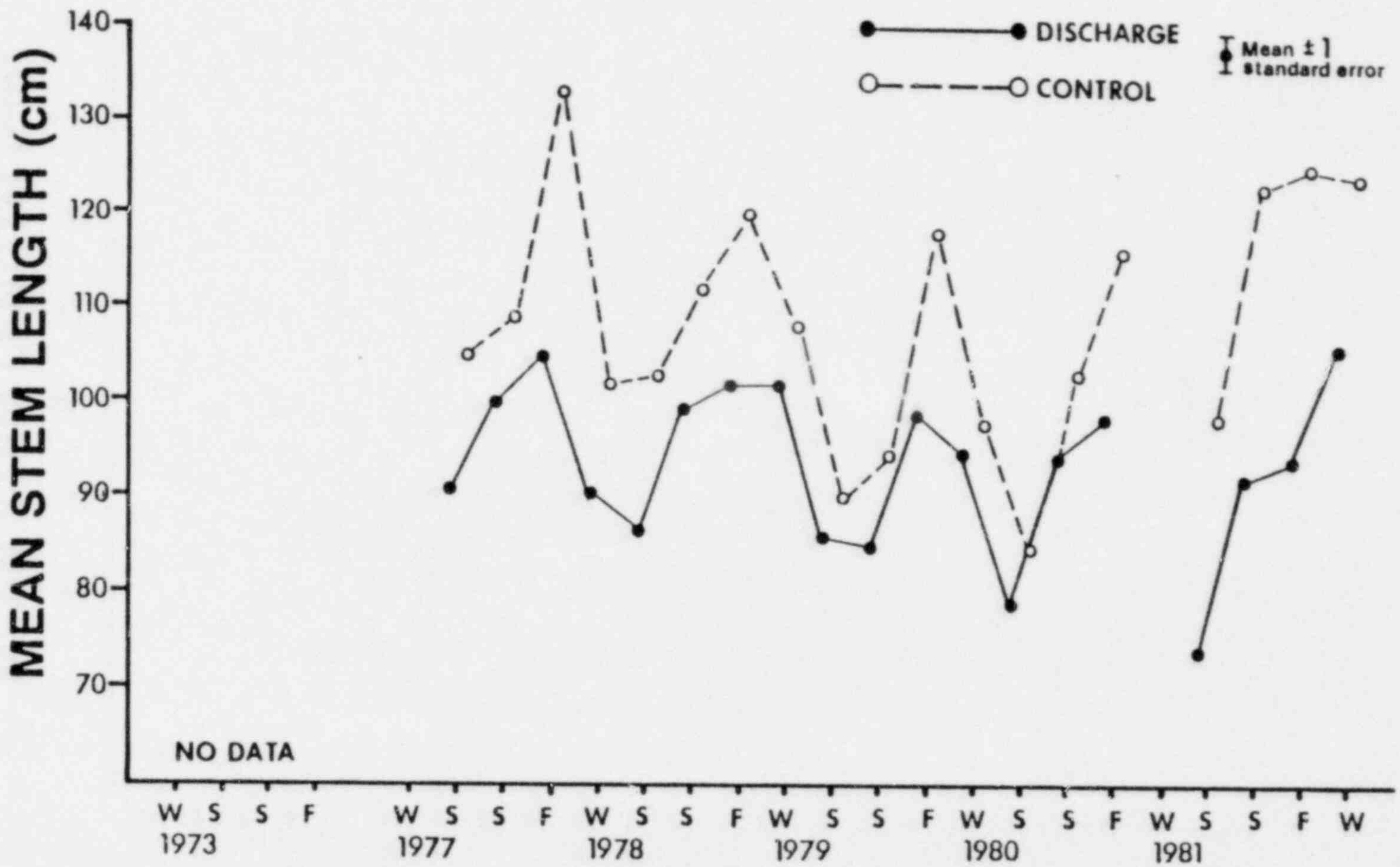

Figure H-11. Mean stem length of Juncus during 1977-1981 operational monitoring, Crystal River Project. (One standard error is always less than ± 3 cm).

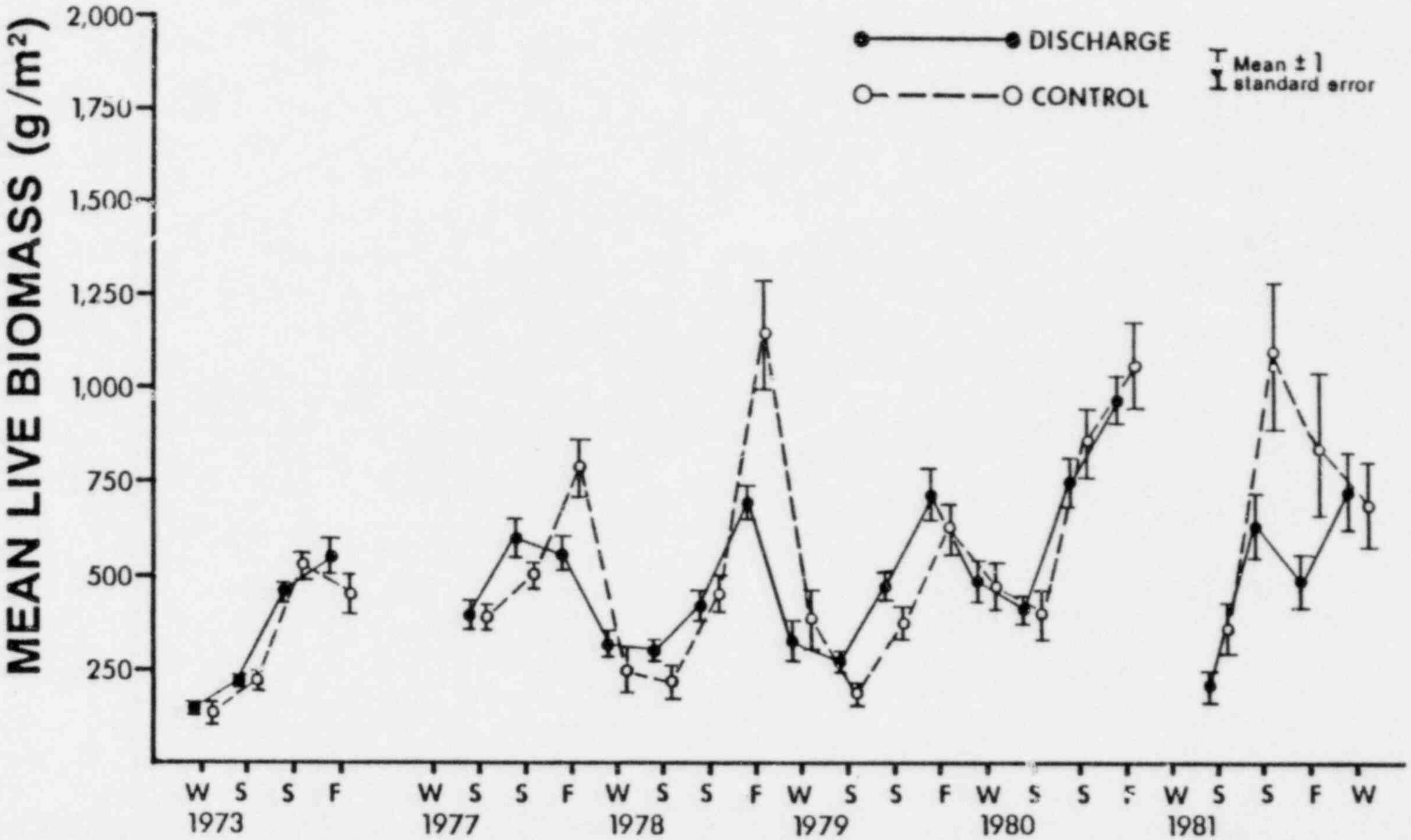

Figure H-12. Mean biomass of live Spartina during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

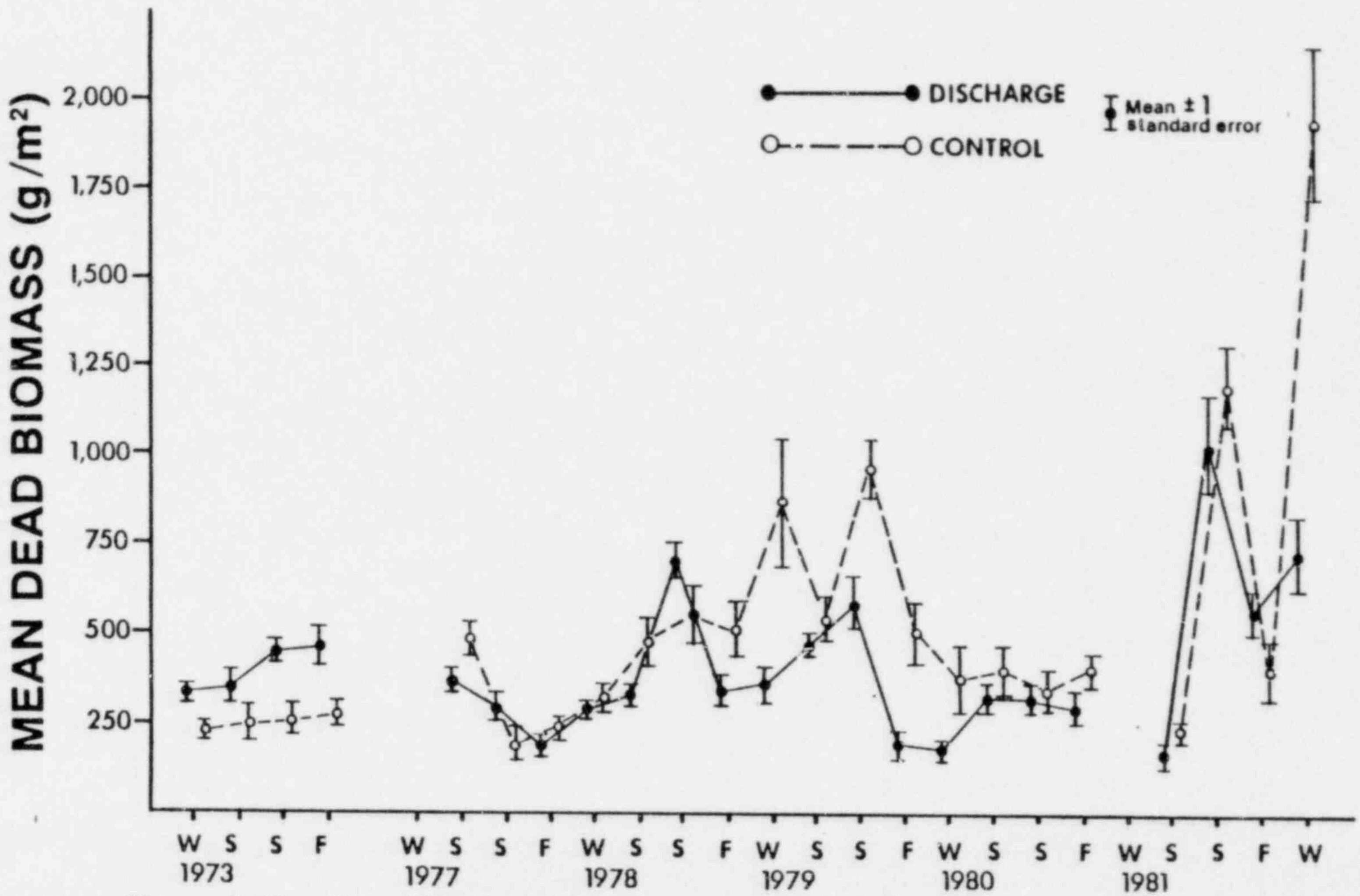

Figure H-13. Mean biomass of dead *Spartina* during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

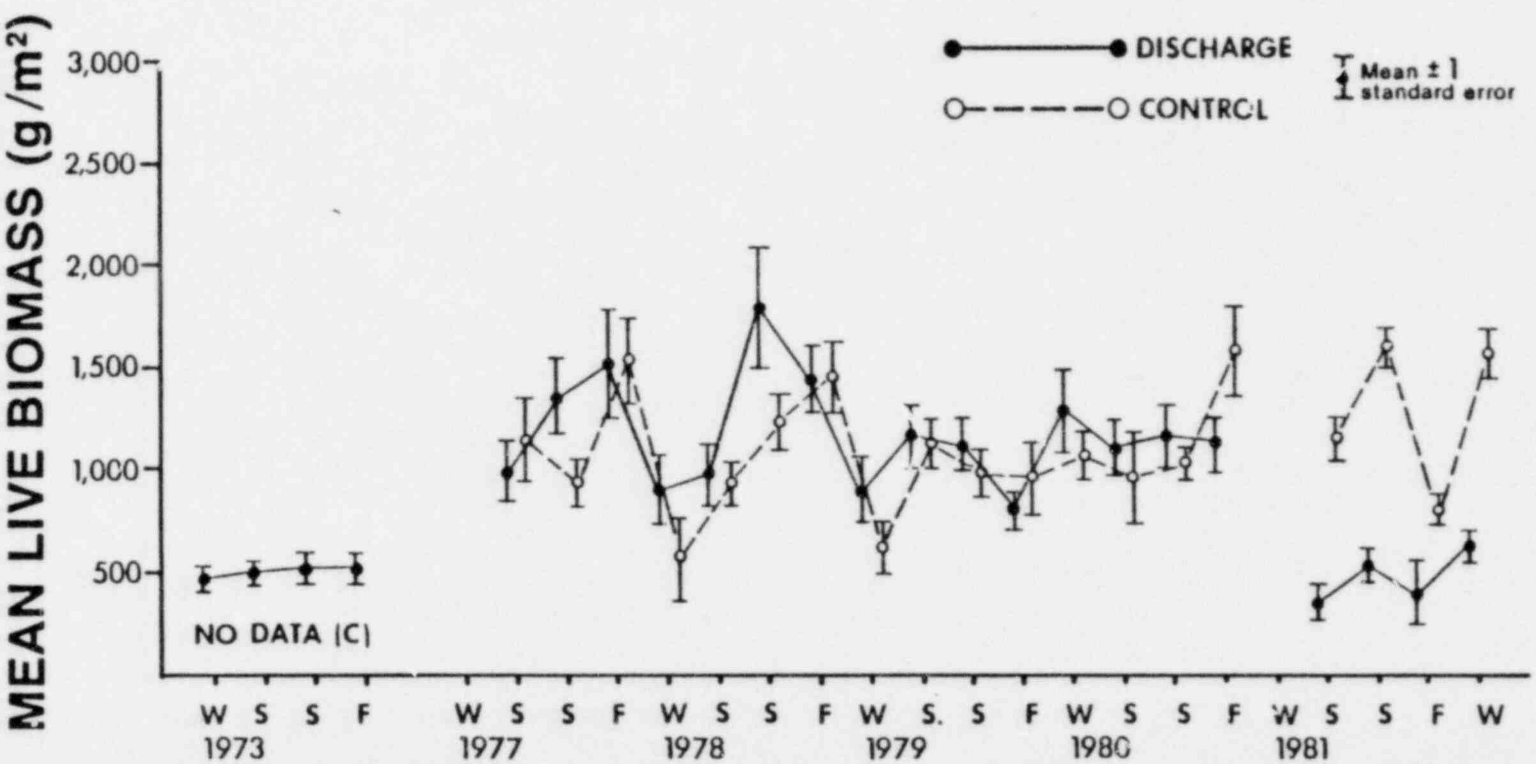

Figure H-14. Mean biomass of live *Juncus* during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

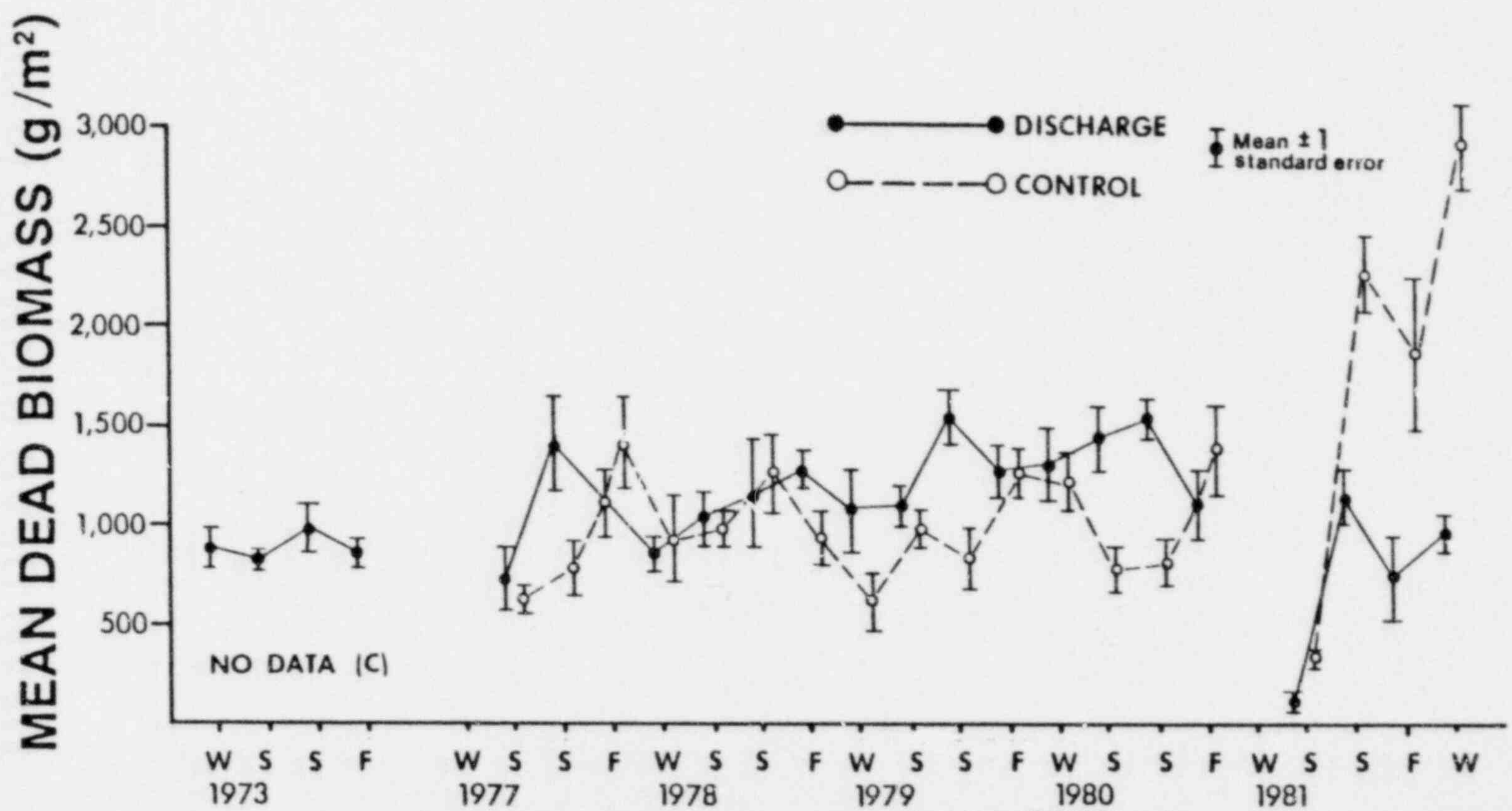

Figure H-15. Mean biomass of dead *Juncus* during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

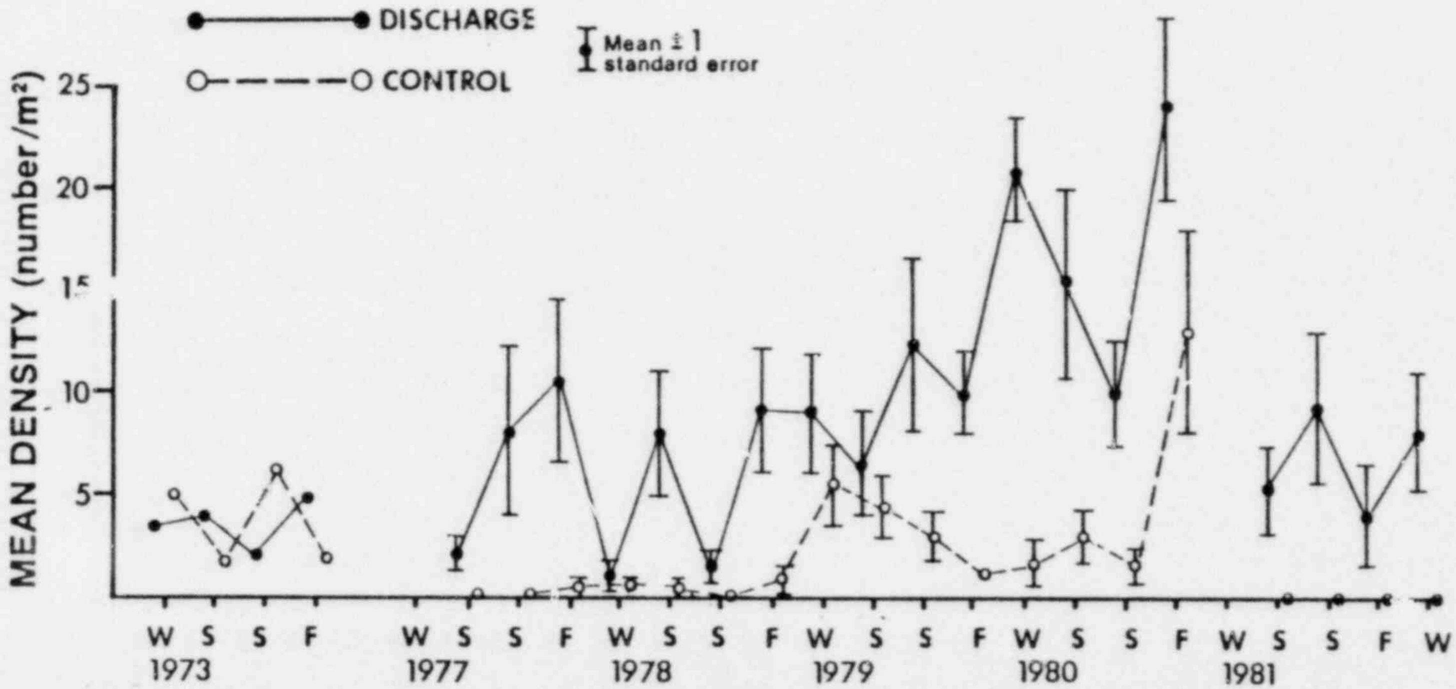

Figure H-16. Mean density of periwinkles in *Spartina* marshes during 1973 pre-operational and 1977-1981 operational monitoring, Crystal River Project.

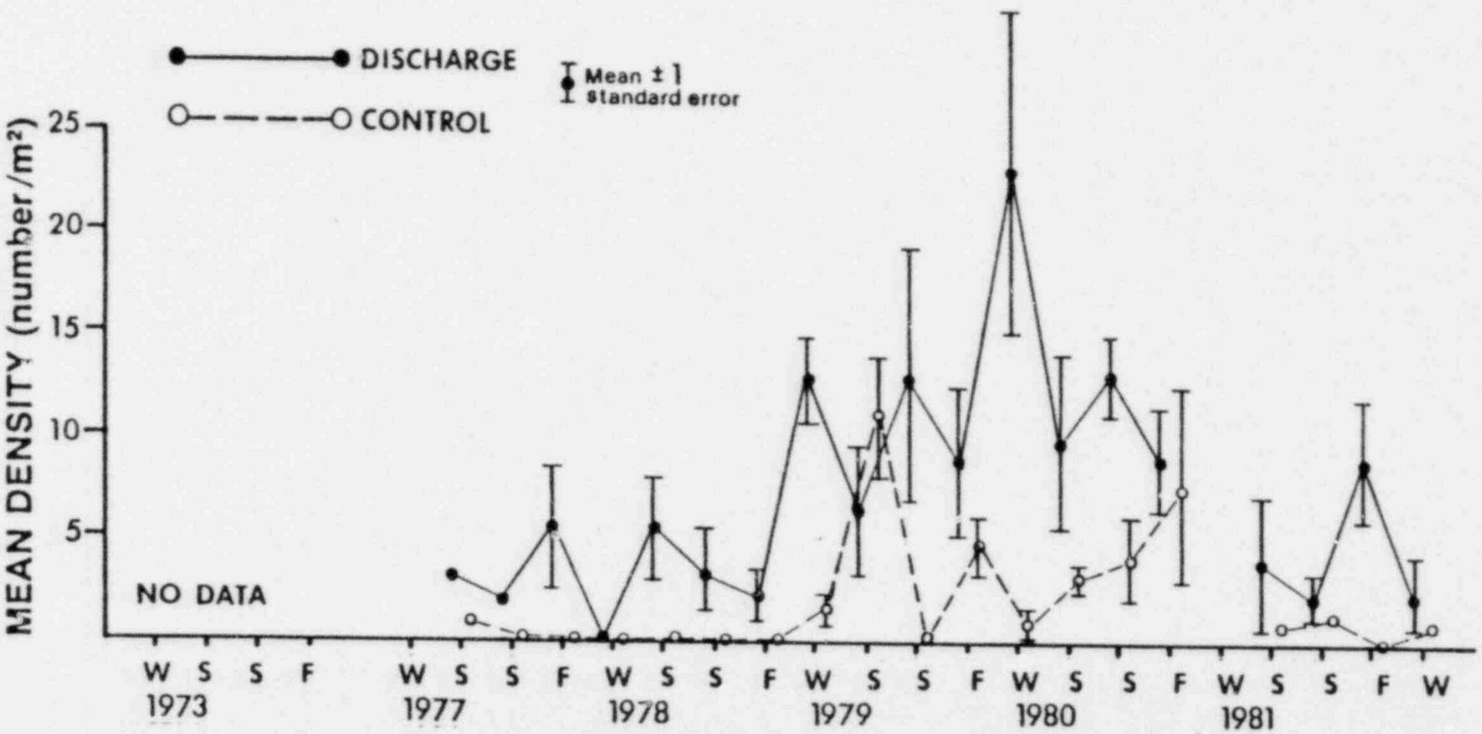

Figure H-17. Mean density of periwinkles in Juncus marshes during 1977-1981 operational monitoring, Crystal River Project.

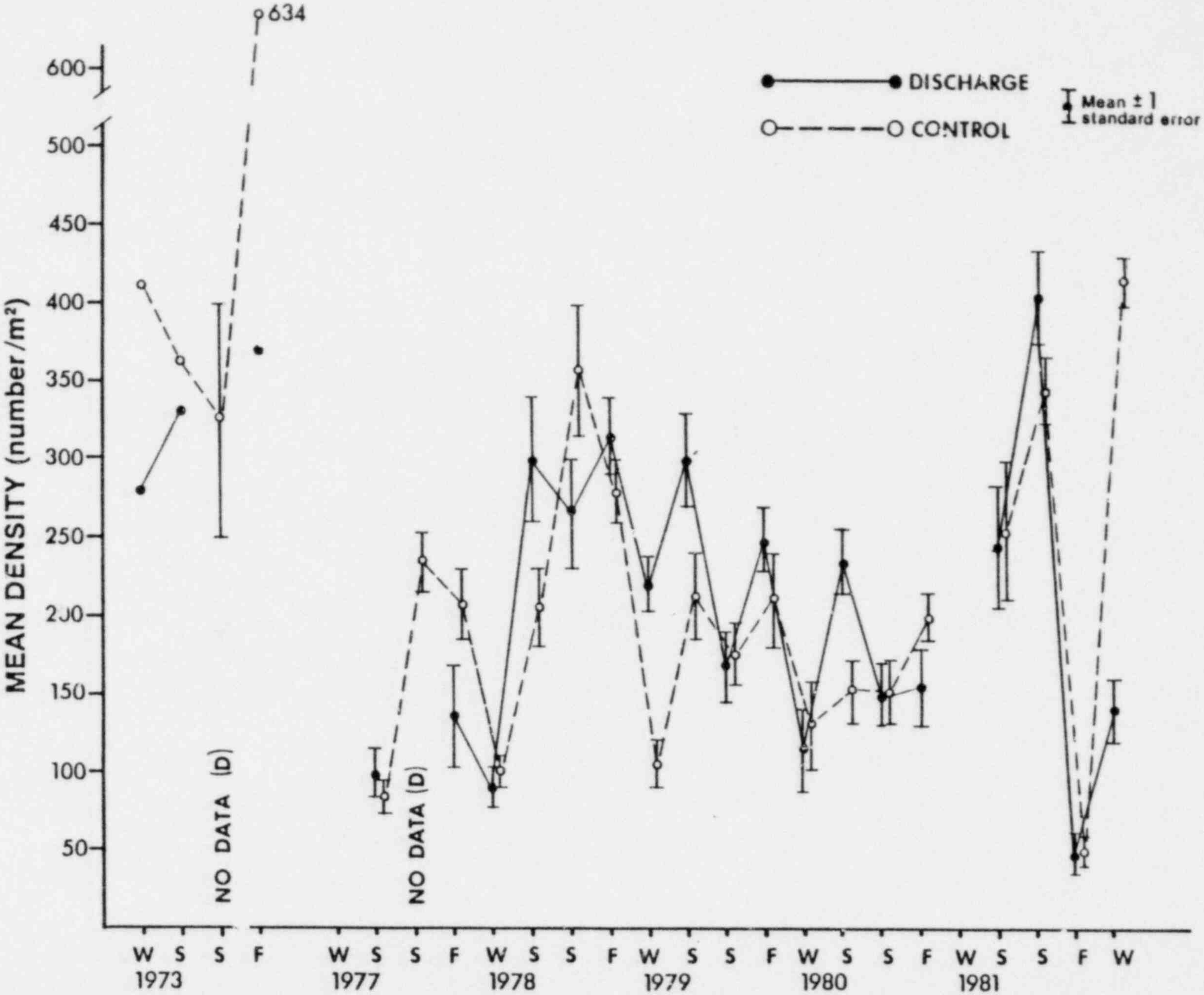

Figure H-18. Mean density of fiddler crab burrows in Spartina marshes during 1973 preoperational and 1977-1981 operational monitoring, Crystal River Project.

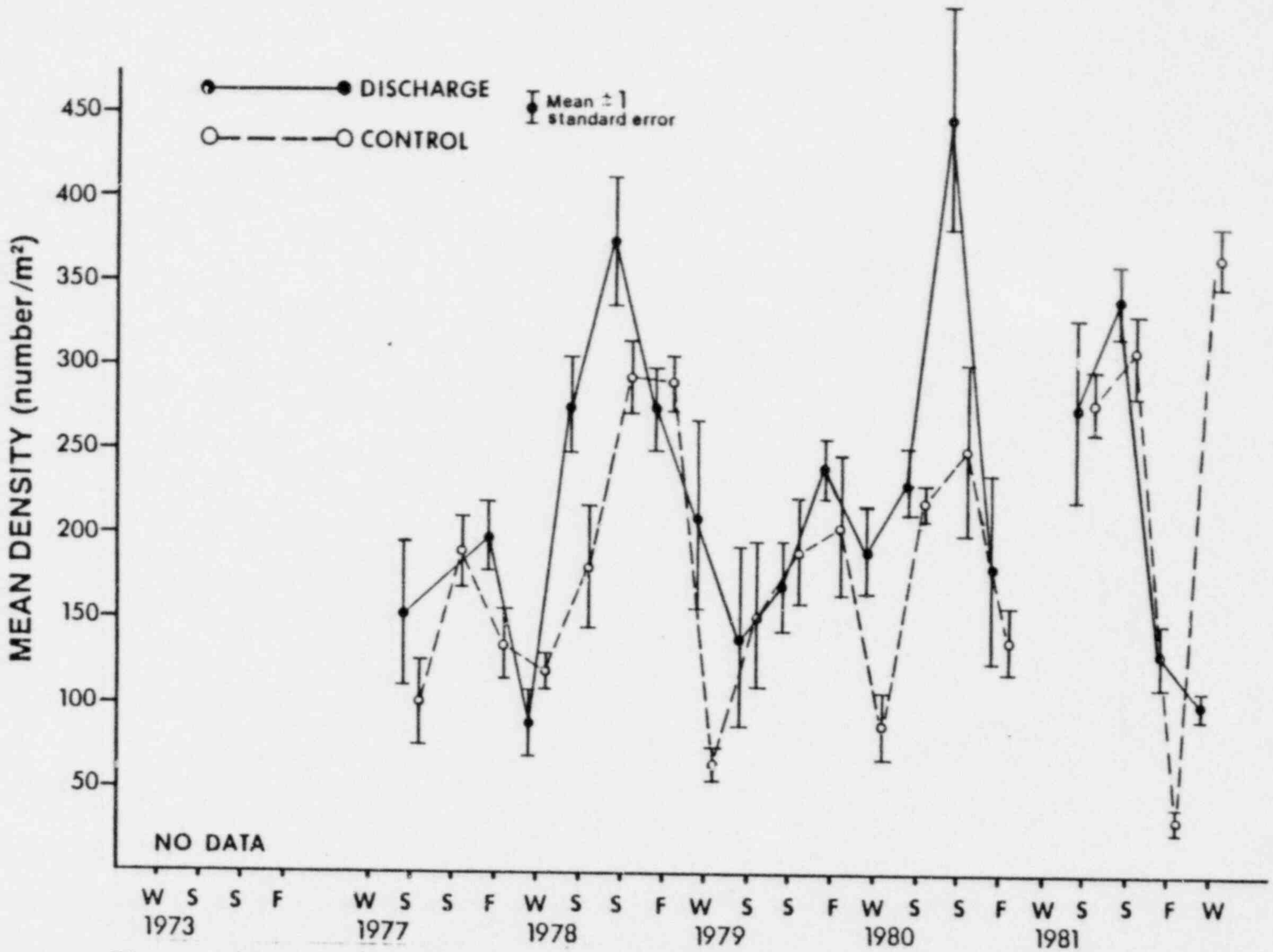

Figure H-19. Mean density of fiddler crab burrows in Juncus marshes during 1977-1981 operational monitoring, Crystal River Project.

TABLE H-1

MEAN LIVE, DEAD AND FLOWER STEM DENSITY AT DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

Mean live stem density (number/m^2)

	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E	Geometric mean	Log_e mean	±S.E.
April	136.2	4.9	0.2	117.3	4.8	0.1	201.1*	5.3	0.3	437.5*	6.1	0.1
June	107.5	4.7	0.1	112.5	4.7	0.1	251.4*	5.5	0.2	495.6*	6.2	<0.13
September	81.9	4.4	0.1	108.2	4.7	0.1	200.4	5.3	0.1	288.8	5.7	0.2
December	149.9	5.0	0.1	178.2	5.2	0.1	279.0*	5.6	0.1	485.0*	6.2	0.1

Mean dead stem density (number/m^2)

	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.
April	102.7	4.6	0.3	106.1	4.7	0.1	146.8	5.0	0.2	229.2	5.4	0.2
June	104.8	4.7	0.1	80.2	4.4	0.1	293.6	5.7	0.1	426.1	6.7	<0.14
September	66.7*	4.2	<0.14	13.3*	2.7	0.7	137.9	4.9	0.1	175.6	5.2	0.2
December	48.0*	3.9	0.2	15.0*	2.8	0.5	115.7*	4.8	0.1	232.4*	5.5	0.1

Mean flower stem density (number/m^2)

	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.
April	0	0	0	0	0	0	2.0	1.1	0.5	0	0	0
June	0	0	0	0	0	0	0*	0	0	25.1*	3.3	0.2
September	0	0	0	0	0	0	0	0	0	0	0	0
December	30.5*	3.5	0.3	3.1*	1.4	0.4	0.3	0.2	0.2	0	0	0

*Significant differences between means of the same species ($P \leq 0.05$).

TABLE H-2

MEAN STEM LENGTH AT DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

	Spartina marsh				Juncus marsh			
	Control		Discharge		Control		Discharge	
Month	Arithmetic mean	Standard error	Arithmetic mean	Standard error	Arithmetic mean	Standard error	Arithmetic mean	Standard error
April	72.2*	1.3	48.9*	0.9	98.3*	1.6	74.0*	1.53
June	88.4*	0.9	72.1*	0.9	123.4*	1.2	92.2*	1.3
September	73.8*	1.2	64.7*	1.2	124.9*	2.6	94.1*	1.7
December	65.3	1.6	63.2	1.9	123.9*	1.7	106.1*	1.5

*Significant difference between means of the same species ($P \leq 0.05$)

TABLE H-3

MEAN LIVE AND DEAD BIOMASS AT DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

	Mean live biomass (grams dry weight/m^2)											
	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E	Geometric mean	Log_e mean	±S.E.
April	197.4*	5.3	0.2	322.9*	5.8	0.2	302.2*	5.7	0.3	1120.7*	7.0	0.1
June	601.1*	6.4	0.1	979.9*	6.9	0.2	477.8*	6.2	0.2	1583.6*	7.4	0.1
September	459.5	6.1	0.1	684.4	6.5	0.2	415.9*	6.0	0.6	785.2*	6.7	0.2
December	543.5	6.3	0.1	626.9	6.4	0.1	597.6*	6.4	0.1	1507.8*	7.3	0.1

	Mean dead biomass (grams dry weight/m^2)											
	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.
April	114.7	4.8	0.4	217.3	5.4	0.1	91.8*	4.5	0.3	316.7*	5.8	0.1
June	955.0	6.9	0.1	1155.2	7.1	0.1	1078.1*	7.0	0.1	2189.5*	7.7	0.1
September	536.4	6.3	0.1	340.7	5.8	0.2	651.3*	6.5	0.2	1730.5*	7.5	0.2
December	672.2*	6.5	0.2	1834.8*	7.5	0.1	921.9*	6.8	0.1	2821.7*	7.9	0.1

*Significant differences between means of the same species ($P \leq 0.05$).

TABLE H-4

MEAN LIVE AND DEAD DENSITY OF SPARTINA AND JUNCUS BIOMASS
AT THE DISCHARGE MARSH IN 1973 AND 1981
CRYSTAL RIVER PROJECT
1981

	Spartina biomass (mean grams dry weight/m^2)					
	Live			Dead		
Quarter	1973	± 2 standard deviations	1981	1973	± 2 standard deviations	1981
Winter	225	175	564[a]	350	170	723[a]
Spring	420	200	216[a]	450	133	167[a]
Summer	560	232	634	465	266	1026[a]
Fall	150	220	490[a]	335	150	561[a]

	Juncus biomass (mean grams dry weight/m^2)					
	Live			Dead		
Quarter	1973	± 2 standard deviations	1981	1973	± 2 standard deviations	1981
Winter	515	228	611	830	150	948
Spring	525	320	342	980	430	110[a]
Summer	520	310	538	860	360	1131
Fall	475	210	484	880	140	728

[a]1981 mean (arithmetic) outside the 1973 range of 2 standard deviations from the 1973 mean.

TABLE H-5

MEAN DENSITY OF PERIWINKLES AND FIDDLER CRAB BURROWS AT DISCHARGE AND CONTROL STATIONS
CRYSTAL RIVER PROJECT
1981

	Mean density of periwinkles (number/m^2)											
	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E	Geometric mean	Log_e mean	±S.E.
April	2.9	1.4	0.4	0	0	0	1.4	0.9	0.6	0.4	0.3	0.3
June	5.1*	1.8	0.4	0*	0	0	1.5	0.9	0.3	0.5	0.4	0.3
September	1.2	0.8	0.4	0	0	0	7.4*	2.1	0.3	0*	0	0
December	4.6*	1.7	0.4	0*	0	0	0.8	0.6	0.4	0.4	0.4	0.2

	Mean density of crab burrows (number/m^2)											
	Spartina						Juncus					
	Discharge			Control			Discharge			Control		
Month	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.	Geometric mean	Log_e mean	±S.E.
April	219.0	5.4	0.2	225.9	5.4	0.2	252.0	5.5	0.2	276.7	5.6	0.1
June	396.1	6.0	0.1	339.7	5.8	0.1	338.2	5.8	0.1	305.0	5.7	0.1
September	26.3	3.3	0.5	45.7	3.8	0.2	126.5*	4.8	0.1	27.9*	3.4	0.3
December	128.2*	4.9	0.2	412.9*	6.0	<0.14	99.3*	4.6	0.1	364.4*	5.9	0.1

*Significant difference between means of the same species ($P \leq 0.05$).

I. SEDIMENTS

INTRODUCTION

Aquatic systems are sites of accumulation of solid detrital material of inorganic and organic origin. These materials include terrigenous materials from the breakdown of igneous and sedimentary rock, inorganic precipitates, and inorganic and organic products from the breakdown of animal and plant material.

Sedimentary debris settles through the water and may be carried laterally by currents. The settling velocity of a sediment particle depends on its specific gravity, size and shape and on the physical properties of the water that transports it. When water velocity is insufficient to transport the particle, deposition occurs. Settling, however, can be prolonged by lunar or aeolian (wind-driven) tidal activity or any currents that result in turbulence. In general, greater water velocities can support larger and heavier particles. Conversely, only very fine sands and silts remain suspended in relatively slow moving currents. Generally, regions least affected by currents tend to accumulate small-sized sediments.

While the geological significance of sediment grain size is still unclear (Folk, 1961), many biologists have correlated grain size parameters with the distribution of organisms, particularly macroinvertebrates (Sanders, 1958). There is a sharp distinction between the fauna associated with hard and soft substrates, and within unconsolidated sedi-

ments. Species may exhibit preferences for coarse or fine particle sizes.

MATERIALS AND METHODS

Duplicate sediment samples were taken quarterly with a 7.6-cm PVC core sampler at seven pre-established stations in the discharge basin and five pre-established stations in the control basin (Figure I-1). Collections were made concurrently with benthic macroinvertebrate collections at each of the 12 stations. Cores were taken at le... 3 m apart and within a 15-m radius of the station marker. The samples were placed on ice and shipped to the laboratory where they remained frozen until analysis could begin.

After thawing, a sample was mixed well and a 10- to 20-g subsample was withdrawn for total organic carbon (TOC) and total carbonates (TCO_3) analyses. TOC and TCO_3 analyses were conducted using an Oceanography International Total Carbon System. Simply stated, this device converts organic carbon in a sediment sample to carbon dioxide gas using potassium persulfate as an oxidizing agent. The quantity of carbon in the gas given off is then measured by an infrared analyzer. A modification of the method allows determination of TCO_3 on the same device. Data from the analyses were reported as the percentage of total sediment weight that is comprised of TOC-carbon or TCO_3-carbon.

Quantitative measurements of the mean diameter and the distribution of the particles of a sample among the several size classes (sorting) are

required for precise sediment analysis. Grain size scales are based on a naturally observed, constant ratio of two between successive classes (Wentworth, 1922). More recent data are nearly always stated in phi (ϕ) units, which are logarithmic transformations of the Wentworth scale (Krumbein, 1936). Phi terms will be used throughout the presentation of sediment data from the Crystal River Plant study area.

Grain size analysis was conducted using methods outlined by Folk (1961), Royce (1970) and W.S. Tyler, Inc. (1973). In these methods, a subsample of approximately 100 g of rinsed, air-dried sediment is placed in a nest of sieves which, when shaken for 15 minutes on a Tyler Ro-Tap sieve shaker, separates the sample into various fractions or size classes based on particle diameters. These fractions are:

Phi (ϕ) unit	Particle size	Size class
<-1	>2 mm	gravel
-1 to 0	2 to 1 mm	very coarse sand
0 to 1	1 to 0.5 mm	coarse sand
1 to 2	0.5 to 0.25 mm	medium sand
2 to 3	0.25 to 0.125 mm	fine sand
3 to 4	0.125 to 0.063 mm	very fine sand
>4	<0.063 mm	silt and clay

The sediment retained on each sieve is then weighed to the nearest 0.01 g. Sediments smaller than 4ϕ are further analyzed using the ASTM method D422 (ASTM, 1980). This method allows separation of the silt and clay size classes in the following manner:

Phi (ϕ) unit	Particle size	Size class
4 to 5	0.063 to 0.031 mm	coarse silt
5 to 6	0.031 to 0.0156 mm	medium silt
6 to 7	0.0156 to 0.0078 mm	fine silt
7 to 8	0.0078 to 0.0039 mm	very fine silt
>8	<0.0039 mm	clay

Once the weights of the various size classes of the sediment sample have been obtained, the mean sediment particle diameter (in ϕ units) and the sorting coefficient (i.e., standard deviation of the mean diameter) of the sample may be found using the method of moments calculation of Folk (1961). In this method,

$$M = \frac{\Sigma D_i W_i}{\Sigma W} \quad \text{and} \quad \Sigma_0 \quad \frac{\Sigma[W_i(M_0 - D_i{}^2]}{\Sigma W}$$

where: M_0 = mean sediment particle diameter (ϕ units),

D_i = mid-point of the ith class interval (ϕ units),

W_i = weight of the ith class interval (in grams),

W = total weight of the sample (in grams), and

Σ_0 = sorting coefficient (ϕ units).

Mean particle size and percentage TOC and TCO_3 data were analyzed statistically using analysis of variance to compare annual means from each station. Student's t-tests were used to compare annual means from control and discharge basins. In addition, Morisita's index of community similarity ($C\lambda$) was used to compare stations annually on the basis of percentage compositions of the various size classes composing the sediments at each station.

RESULTS AND DISCUSSION

Percentage Composition Analysis

Sediments at all of the stations near the Crystal River Power Plant were primarily composed of sand-sized particles. Annual mean sand percentage composition was 91.00 percent in the discharge basin (range of 89.19 to 93.66 percent among discharge stations) and 82.17 percent in the control basin (range of 62.30 to 93.47 percent among control stations; Table I-1). Most of the wide variation in mean sand percentage composition in the control basin was attributable to Stations 9 and 12, which consistently had much less sand and more gravel-sized sediments than the other control stations. Gravel was far more prevalent in the control basin, and silt and clay formed relatively small components of sediment in either basin. All of the gravel-sized sediment and nearly all of the very coarse sand (-1 to 0ϕ), coarse sand (0 to 1ϕ) and medium sand (1 to 2ϕ) fractions were composed of mollusc shell fragments, while only a small percentage was composed of terrigenous material.

Despite considerable quarterly variation among stations (Table I-1), statistical analysis of the major sediment fractions indicated that the gravel fraction was significantly larger in the control basin, and sand, silt and clay fractions were significantly larger in the discharge basin (Table I-2). When stations were compared using Morisita's index of similarity, all of the stations showed high degrees of similarity except Stations 9 and 12, the stations with the highest percentage gravel fractions (Figure I-2). Similarity of the discharge stations with control Stations 10 and 11 seems to be exaggerated by Morisita's index when other

factors such as mean grain size and carbon content are considered. Control Station 8 sediments, however, appear to be nearly identical to the discharge station sediments (Table I-1). Cottrell (1974) reported that sedimentation rates were greatest near shore and diminished with distance from shore. His observations appear to hold true when similarities between Station 8 and the discharge stations during 1981 are considered.

Comparison of 1981 major fraction percentage composition data with 1974 and 1980 data showed good agreement (Figure I-3). Current data were actually somewhat closer to 1974 (baseline) data in many cases than were the 1980 data. Sediment deposition rates and, therefore, sediment grain size distributions may change somewhat from year to year because of variations in rainfall, runoff, winds, storms or other factors.

Grain-size Analysis

When stations were compared statistically, all but one of the discharge stations (Station 6), plus Station 8 in the control basin, were found to have significantly finer mean grain sizes than Stations 9 through 12 of the control basin (Table I-3). Mean grain sizes ranged from 2.21ϕ at Station 9 to 3.93ϕ at Station 1. As shown in the percentage composition analyses, Stations 9 and 12 showed the greatest difference from the other control stations. Mean grain sizes in the discharge and control basins were finest in June and coarsest in December (Figure I-4). There was much less variation among the discharge stations than among the control stations as indicated by the smaller standard deviations about the mean grain sizes.

Mean particle size for the discharge basin (3.74 ± 0.38ϕ) was finer than that of the control basin (2.91± 0.69ϕ), showing a greater proportion of fine sediment in the discharge basin (Table I-4). Both of these basin means show the general presence of finer sediments than were found during the 1980 operational study (FPC, 1981).

Historically, the prevalence of finer sediments in the discharge basin has been attributed primarily to higher sedimentation rates there (Cottrell, 1974; FPC, 1981). Cottrell (1974) reported discharge sedimentation rates were 5 times greater than those observed in the control basin. Sources of sedimentation in the discharge area include 1) runoff from tidal creeks, 2) dredge spoils, either dumped into the area or circulated through the plant from the intake canal, 3) erosion from the spoil islands to the north, 4) erosion flow from the mouth of the Cross Florida Barge Canal, and 5) erosion flow from the mouth of the Withlacoochee River. Sediment distribution from the three latter sources is aided by southward-flowing longshore currents. This sediment input is contained by the intake and discharge canal dikes on the south and Thumb Island on the north. In addition, extensive oyster reefs act as baffles within the basin. These factors combine to create slower water movement in the discharge basin than in the control basin. This allows the suspended sediment to settle out at a faster rate in the discharge basin. Despite the relatively low rainfall of 1981 that created less runoff and erosion than normal, data from the present study agree with the findings of Cottrell (1974).

Organic Carbon and Carbonates Analysis

Statistical analysis of total organic carbon (TOC) percentage composition data showed very consistent TOC values among all stations regardless of the basin (Table I-5). Exceptions were Stations 2 and 12, which had significantly greater percentages of TOC than other stations. TOC percentages ranged from 0.34 percent at Station 6 to 0.79 percent at Station 12. Sediment TOC at the discharge and control stations varied in a similar manner over the course of 1981 with TOC values being lowest in June and highest in December (Figure I-5). Wider standard deviations show that sediment TOC content was slightly more variable in the control basin than in the discharge basin. Statistical comparison of the basins indicated that annual mean TOC percentage composition in the control basin was significantly greater than in the discharge basin (Table I-6).

Statistical analysis of total carbonates (TCO_3) percentage composition data showed considerably more variation among stations than was found with the TOC data (Table I-7). TCO_3 values ranged from 0.87 percent at Station 8 to 2.12 percent at Station 12. Variation in TCO_3 is primarily a function of mollusc distribution because mollusc shells are composed of calcium carbonate, and fragments of mollusc shells entirely account for the larger fractions of sediments near the Crystal River Plant. In addition, molluscs were more commonly found in the control basin during the macroinvertebrate sampling portions of the present study. With the exception of Station 8, all of the higher TCO_3 values were found in the control basin (Table I-7). TCO_3 mean values were always higher and more variable in the control basin than in the

discharge basin (Figure I-6). Statistical comparison of the basins indicated that TCO_3 percentage composition in the control basin was significantly greater than in the discharge basin (Table I-6).

Both TOC and TCO_3 percentages were lower in 1981 than those found in 1980. It is presumed that this is a result of the change to a more sophisticated method of analysis in 1981. The current TOC and TCO_3 methods measured the percentage of total sediment weight composed of carbon only. Previous methods also measured the weight of all other elements chemically bonded to the carbon atoms of the sediment in their estimations of percentage "organic matter" and percentage carbonates. While the two methods yield data that are not directly comparable, they reveal similar trends in sediment composition. Considering the difference in methods, the trends in data from 1981 were consistent with previous data.

SUMMARY

The sediments of all stations near the Crystal River Power Plant were primarily composed of sand-sized sediment particles. Comparison of data showed that sediments in the discharge basin were composed of finer particles than sediments in the control basin. Control Station 8 was very similar to the discharge basin stations and Stations 9 and 12 were the most dissimilar. The latter two stations accounted for most of the variation between discharge and control basin mean values of major size class percentage compositions. There was little variation among stations in the discharge basin.

Mean grain size was 3.74ϕ in the discharge basin and 2.91ϕ in the control basin. While mean grain sizes varied throughout 1981, discharge basin sediments were always finer and less variable than control basin sediments. The primary cause of the finer sediment deposition in the discharge basin appear to be the relatively confined nature of the discharge area, which allows faster sedimentation rates.

Percentage composition of total sediment weight contributed by organic carbon and carbonates was significantly greater in the control basin. The larger percentage composition of carbonates in the control basin is primarily the result of larger mollusc populations at the control stations.

Overall, there was good agreement among data from the 1974 preoperational and 1980 and 1981 operational studies. No new trends concerning size class percentage compositions or mean grain sizes were found.

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	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	1.00											
3	1.00	1.00										
4	0.99	1.00	1.00									
5	0.99	1.00	1.00	1.00								
6	0.98	1.00	1.00	1.00	1.00							
7	1.00	1.00	1.00	1.00	1.00	0.98						
8	1.00	1.00	1.00	1.00	1.00	0.99	1.00					
9	0.67	0.77	0.74	0.80	0.75	0.78	0.73	0.71				
10	0.94	1.00	0.99	1.00	1.00	1.00	0.98	0.98	0.87			
11	0.95	1.00	0.99	1.00	0.99	1.00	0.99	0.97	0.89	1.00		
12'	0.58	0.64	0.61	0.68	0.61	0.63	0.63	0.59	1.00	0.73	0.77	

PERCENT SIMILARITY
- 0.00 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00

Figure I-2. Morisita indices of similarity between seven discharge and five control stations based on sediment percentage composition by size class, Crystal River Project, 1981.

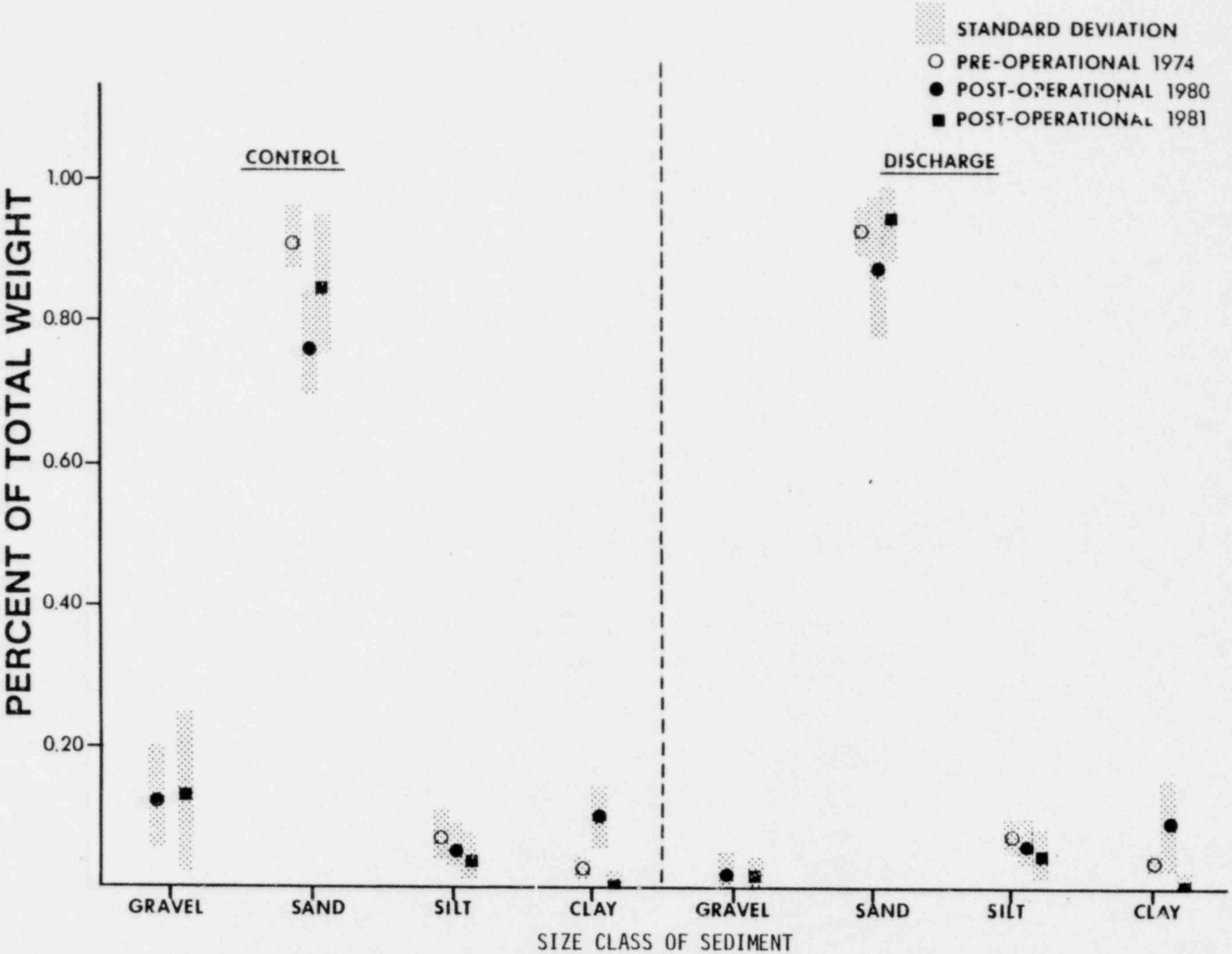

Figure I-3. Comparison of preoperational and postoperational data on mean sand, silt and clay percentage composition, Crystal River Project, 1974-1981.

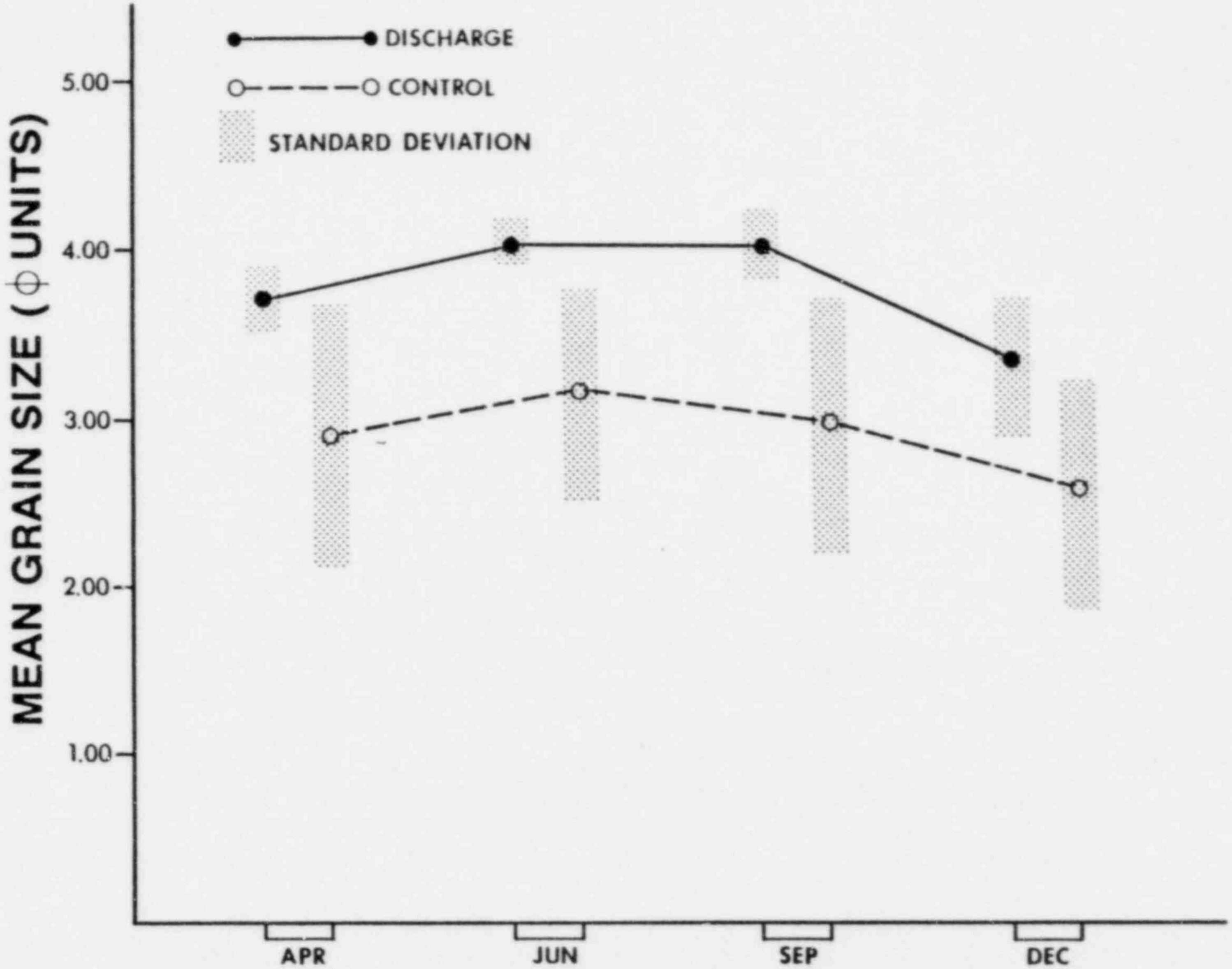

Figure I-4. Variation in mean grain size of sediments in discharge and control basins, Crystal River Project, 1981.

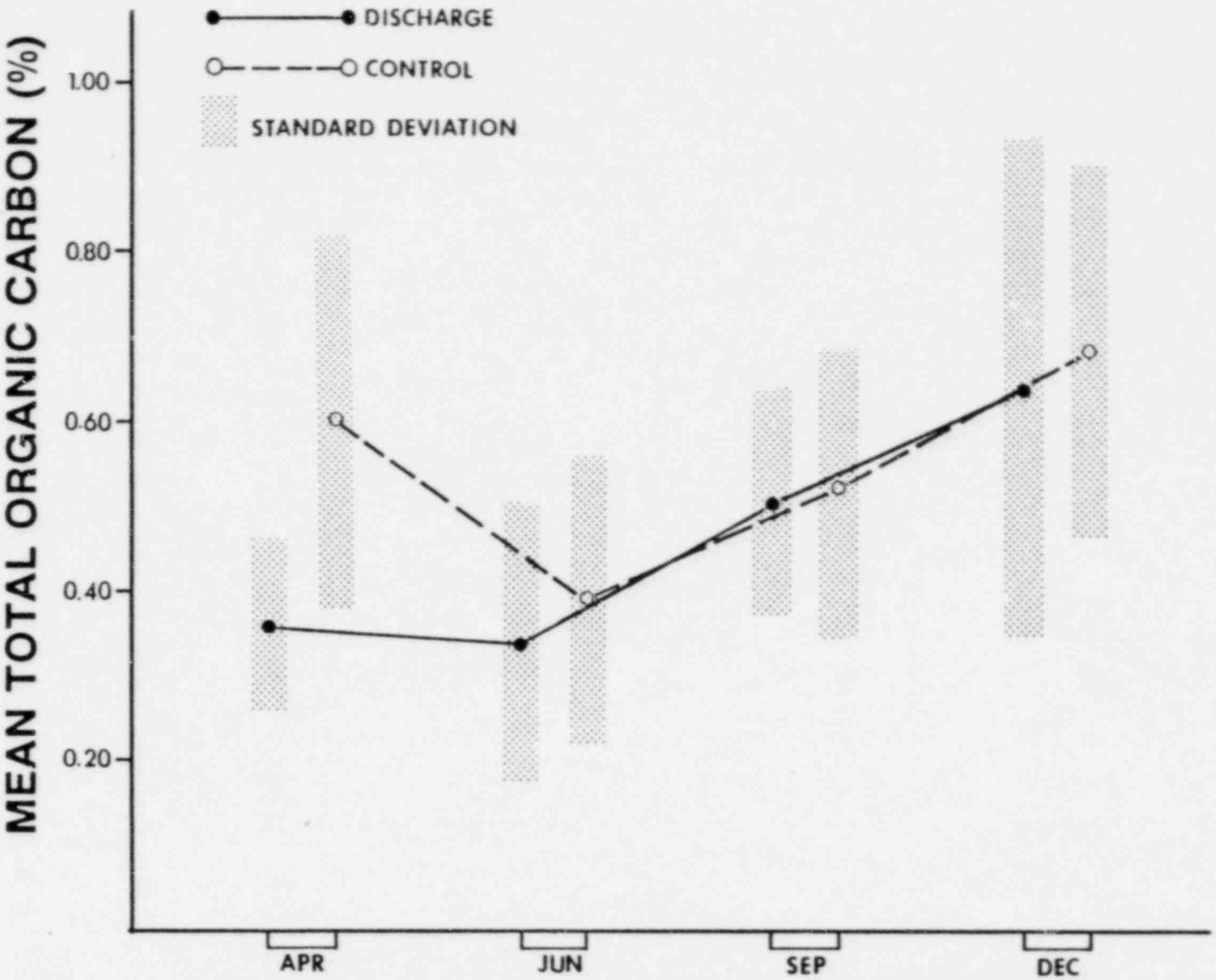

Figure I-5. Variation in mean percentage composition of total organic carbon in sediments, Crystal River Project, 1981.

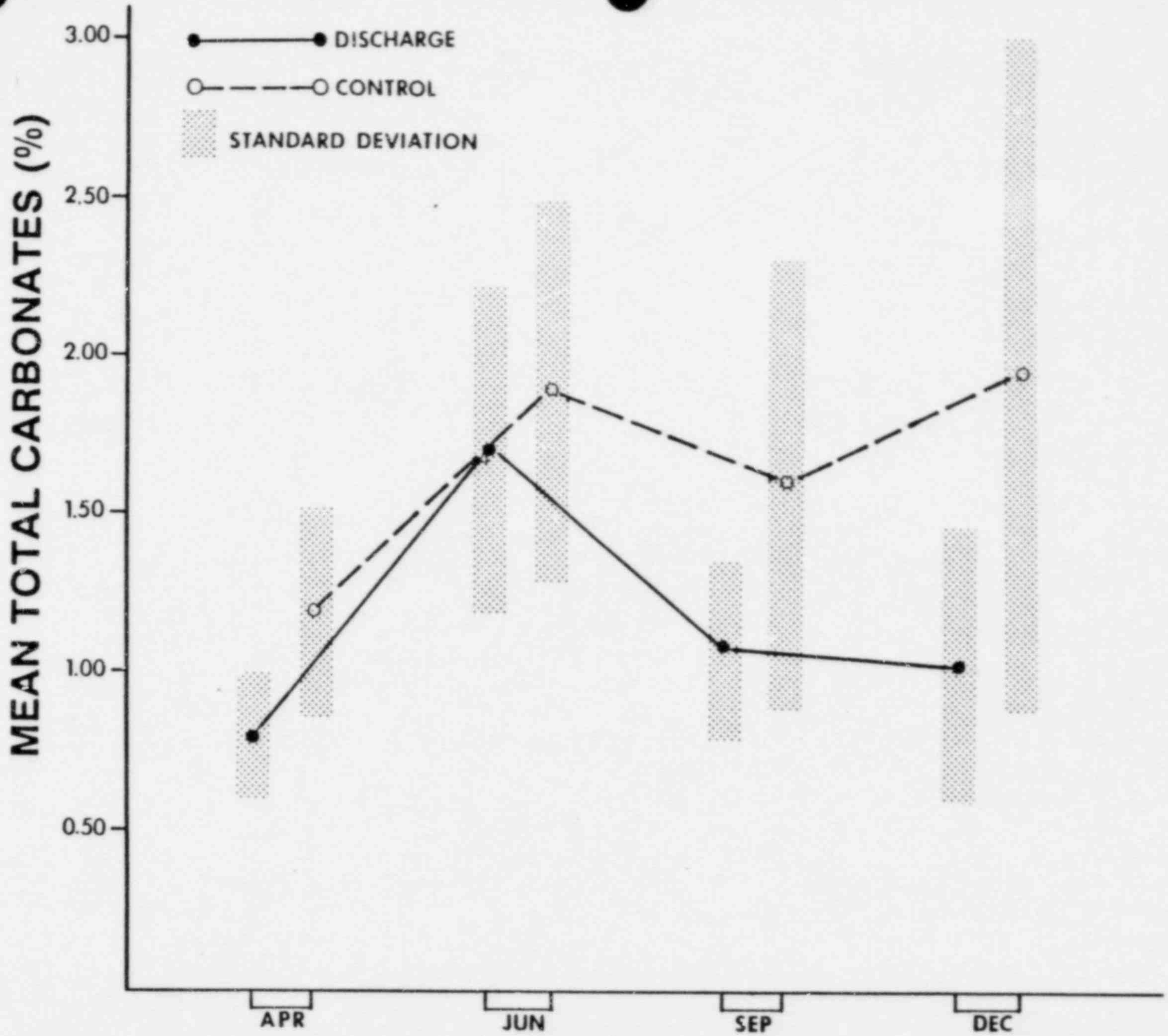

Figure I-6. Variation in mean percentage composition of total carbonates in sediments, Crystal River Project, 1981.

TABLE I-1

PERCENTAGE COMPOSITION OF SEDIMENTS BY MAJOR CLASS SIZE
CRYSTAL RIVER PROJECT
1981

Station	Month	Replicate	Percentage Composition: Gravel (<-1Φ)	Sand (-1Φ-4Φ)	Silt (4Φ-8Φ)	Clay (>8Φ)
1	April	A	1.45	91.06	6.48	1.00
		B	3.93	90.67	4.67	0.73
	June	A	0.10	90.76	7.91	1.23
		B	0.19	89.86	8.62	1.34
	September	A	0.07	89.16	9.32	1.45
		B	0.14	88.44	9.89	1.53
	December	A	0.80	96.15	2.96	0.91
		B	0.39	95.35	3.93	0.33
Mean ± standard deviation			0.88±1.23	91.43±2.63	6.72±2.45	0.96±0.50
2	April	A	0.30	96.36	2.83	0.51
		B	2.72	93.69	3.05	0.54
	June	A	0.00	85.47	12.30	2.22
		B	0.00	84.30	13.28	2.42
	September	A	0.00	81.70	15.52	2.78
		B	0.00	84.65	13.02	2.33
	December	A	0.60	94.27	4.87	0.27
		B	0.72	95.36	3.64	0.28
Mean ± standard deviation			0.54±0.87	89.48±5.58	8.56±5.07	1.42±1.03
3	April	A	0.13	98.01	1.62	0.25
		B	0.31	97.00	2.33	0.36
	June	A	0.00	89.80	8.84	1.36
		B	0.00	91.30	7.57	1.14
	September	A	0.00	95.56	3.89	0.55
		B	0.15	89.41	9.06	1.38
	December	A	5.00	91.23	3.52	0.26
		B	0.74	96.94	2.15	0.18
Mean ± standard deviation			0.79±1.61	93.66±3.33	4.87±2.91	0.69±0.49
4	April	A	1.89	92.77	4.67	0.67
		B	5.55	90.25	3.72	0.48
	June	A	0.00	86.29	12.15	1.57
		B	0.07	86.91	11.53	1.49
	September	A	0.00	86.13	12.28	1.60
		B	0.00	84.25	13.94	1.81
	December	A	1.24	93.48	4.70	0.57
		B	8.43	85.43	5.86	0.29
Mean ± standard deviation			2.15±2.96	88.19±3.28	8.61±3.96	1.06±0.57

TABLE I-1
(continued)
PERCENTAGE COMPOSITION OF SEDIMENTS BY MAJOR CLASS SIZE
CRYSTAL RIVER PROJECT
1981

			Percentage Composition			
Station	Month	Replicate	Gravel (<-1ϕ)	Sand (-1ϕ-4ϕ)	Silt (4ϕ-8ϕ)	Clay (>8ϕ)
5	April	A	0.64	97.53	1.63	0.21
		B	0.35	96.78	2.40	0.48
	June	A	0.89	86.37	11.78	1.76
		B	0.16	88.87	9.58	1.39
	September	A	0.00	89.01	9.44	1.55
		B	0.58	89.21	9.33	1.41
	December	A	4.39	92.87	2.50	0.24
		B	0.77	95.62	3.20	0.41
Mean ± standard deviation			0.81±1.38	92.03±3.96	6.23±3.89	0.93±0.61
6	April	A	0.86	95.55	3.15	0.45
		B	0.72	95.71	3.10	0.48
	June	A	0.10	86.80	11.41	1.69
		B	0.16	88.77	9.61	1.46
	September	A	0.67	88.19	9.76	1.38
		B	0.45	90.62	7.87	1.06
	December	A	3.53	93.56	2.65	0.26
		B	3.46	92.66	3.35	0.53
Mean ± standard deviation			1.24±1.32	91.48±3.18	6.36±3.42	0.91±0.51
7	April	A	2.29	92.10	5.00	0.62
		B	3.07	94.06	2.55	0.32
	June	A	0.94	94.08	4.44	0.55
		B	0.23	90.11	8.61	1.06
	September	A	0.27	93.16	5.85	0.72
		B	0.61	88.58	9.61	1.19
	December	A	0.19	94.81	4.46	0.54
		B	17.91	79.19	2.55	0.35
Mean ± standard deviation			3.19±5.65	90.76±4.81	5.38±2.41	0.67±0.29
8	April	A	1.17	96.77	1.89	0.17
		B	0.97	97.01	1.87	0.16
	June	A	0.70	92.45	6.30	0.55
		B	0.14	91.20	7.97	0.69
	September	A	0.13	88.22	10.72	0.93
		B	0.00	89.88	9.31	0.81
	December	A	1.32	97.29	1.28	0.11
		B	3.17	94.97	1.76	0.11
Mean ± standard deviation			0.95±0.96	93.47±3.30	5.14±3.63	0.44±0.32

TABLE I-1
(continued)
PERCENTAGE COMPOSITION OF SEDIMENTS BY MAJOR CLASS SIZE
CRYSTAL RIVER PROJECT
1981

			Percentage Composition			
Station	Month	Replicate	Gravel (<-1Φ)	Sand (-1Φ-4Φ)	Silt (4Φ-8Φ)	Clay (>8Φ)
9	April	A	21.00	77.65	1.24	0.11
		B	32.68	66.02	1.20	0.09
	June	A	12.24	82.78	4.58	0.40
		B	20.73	70.37	8.20	0.71
	September	A	25.03	71.97	2.[illegible]	0.30
		B	21.39	76.38	2.02	0.21
	December	A	13.31	84.56	1.92	0.20
		B	19.00	80.08	0.91	0.00
Mean ± standard deviation			20.67±6.04	76.23±5.98	2.85±2.30	0.25±0.21
10	April	A	0.21	97.32	2.22	0.25
		B	0.26	96.51	2.90	0.33
	June	A	2.97	85.61	10.31	1.12
		B	4.27	83.18	11.29	1.26
	September	A	5.20	89.60	4.74	0.47
		B	15.83	79.91	3.84	0.43
	December	A	1.77	94.73	3.03	0.48
		B	6.41	92.57	0.91	0.11
Mean ± standard deviation			4.62±4.73	89.93±6.05	4.91±3.57	0.56±0.39
11	April	A	5.74	91.58	2.39	0.30
		B	5.00	92.68	2.07	0.26
	June	A	11.13	80.62	7.34	0.91
		B	6.55	85.09	7.38	0.99
	September	A	9.32	87.44	2.93	0.32
		B	2.60	91.74	5.04	0.62
	December	A	3.43	93.82	2.47	0.2[illegible]
		B	7.55	88.42	3.53	0.50
Mean ± standard deviation			6.42±2.69	88.92±4.17	4.14±2.05	0.52±0.27
12	April	A	26.16	70.35	3.11	0.38
		B	19.09	74.83	5.41	0.68
	June	A	32.15	59.47	7.46	0.92
		B	30.41	60.55	8.05	0.99
	September	A	23.96	60.12	14.16	1.76
		B	26.48	58.30	13.60	1.63
	December	A	37.52	57.58	4.26	0.64
		B	39.90	57.18	2.73	0.19
Mean ± standard deviation			29.46±6.52	62.30±6.15	7.35±4.16	0.90±0.52

TABLE I-1
(continued)
PERCENTAGE COMPOSITION OF SEDIMENTS BY MAJOR CLASS SIZE
CRYSTAL RIVER PROJECT
1981

	Percentage Composition			
	Gravel (<-1ϕ)	Sand (-1ϕ-4ϕ)	Silt (4ϕ-8ϕ)	Clay (>8ϕ)
Control basin mean and standard deviation	12.42$\pm$11.80	82.17$\pm$12.67	4.88$\pm$3.57	0.54$\pm$0.42
Discharge basin mean and standard deviation	1.37$\pm$2.80	91.00$\pm$4.27	6.68$\pm$3.80	0.95$\pm$0.65

TABLE I-2

RESULTS OF T-TEST COMPARISON OF PERCENTAGE COMPOSITION
OF SEDIMENTS BY SIZE CLASS BETWEEN CONTROL AND DISCHARGE BASINS
CRYSTAL RIVER PROJECT
1981

	Mean basin percentage				
Size class	Control	Discharge	Calculated t value	Critical t value	Result[a]
Gravel	12.42±11.80	1.37±2.80	-6.676	1.645	control>discharge
Sand	82.17±12.67	91.00±4.27	4.797	1.645	discharge>control
Silt	4.88±3.57	6.68±3.80	2.326	1.645	discharge>control
Clay	0.54±0.42	0.95±0.65	3.495	1.645	discharge>control

[a]A result indicates a significant difference between basins at $P \leq 0.05$.

TABLE I-3

MEAN GRAIN SIZE BY STATION
STATISTICAL ANALYSIS OF SEDIMENT
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	Calculated F value
Model	11	1.9781	0.1798	20.02*
Error	84	0.7545	0.0090	
Total	95	2.7326		

DUNCAN'S MULTIPLE RANGE TEST

Grouping[a]	Ranked mean(ϕ)	Station
A	3.93	1
A	3.84	2
A	3.72	3
A	3.72	7
A	3.71	5
A	3.71	8
A	3.66	4
A B	3.58	6
B C	3.25	10
C	3.15	11
D	2.24	12
D	2.21	9

*Significant difference at $P \leq 0.05$; critical F=1.92.

[a]Means with the same grouping letter are not significantly different at $P \leq 0.05$.

TABLE I-4

MEAN GRAIN SIZE, SORTING COEFFICIENT, TOTAL ORGANIC CARBON CONTENT AND TOTAL CARBONATE CONTENT OF SEDIMENTS
CRYSTAL RIVER PROJECT
1981

Station	Month	Replicate	Grain size: Mean (φ)	Grain size: Standard deviation (φ)	Total organic carbon (%)	Total carbonate (%)
1	April	A	3.95	1.04	0.21	0.58
		B	3.75	1.49	0.20	0.49
	June	A	4.08	1.36	0.20	1.06
		B	4.13	1.32	0.20	1.97
	September	A	4.00	1.31	0.51	1.18
		B	4.17	1.42	0.43	0.91
	December	A	3.68	1.18	0.56	0.65
		B	3.69	1.22	0.47	0.89
Mean ± standard deviation			3.93±0.19	1.29±0.13	0.35±0.15	0.97±0.44
2	April	A	3.49	1.28	0.54	0.93
		B	3.26	1.29	0.44	0.93
	June	A	4.12	1.35	0.77	2.66
		B	4.25	1.38	0.21	2.24
	September	A	4.37	1.34	0.65	1.46
		B	4.26	1.35	0.82	1.38
	December	A	3.49	1.18	0.76	1.13
		B	3.46	1.20	0.88	1.18
Mean ± standard deviation			3.84±0.42	1.30±0.069	0.63±0.21	1.49±0.59
3	April	A	3.58	1.05	0.50	0.58
		B	3.63	1.55	0.41	0.55
	June	A	4.01	1.36	0.36	1.61
		B	3.96	1.36	0.56	1.74
	September	A	3.86	1.34	0.55	0.93
		B	4.06	1.33	0.56	0.98
	December	A	3.20	1.25	0.50	0.65
		B	3.46	1.26	0.55	0.74
Mean ± standard deviation			3.72±0.28	1.31±0.13	0.50±0.07	0.97±0.43
4	April	A	3.65	1.31	0.35	0.82
		B	3.41	1.40	0.38	0.85
	June	A	4.11	1.35	0.26	1.87
		B	4.10	1.26	0.32	1.24
	September	A	4.05	1.48	0.44	0.87
		B	4.22	1.36	0.48	1.07
	December	A	3.36	1.19	1.39	0.82
		B	2.34	1.70	0.94	1.68
Mean ± standard deviation			3.66±0.59	1.38±0.15	0.57±0.37	1.15±0.39

TABLE I-4
(continued)
MEAN GRAIN SIZE, SORTING COEFFICIENT, TOTAL ORGANIC CARBON CONTENT
AND TOTAL CARBONATE CONTENT OF SEDIMENTS
CRYSTAL RIVER PROJECT
1981

			Grain size			
Station	Month	Replicate	Mean (ϕ)	Standard deviation (ϕ)	Total organic carbon (%)	Total carbonate (%)
5	April	A	3.40	1.40	0.36	0.74
		B	3.46	0.96	0.43	0.71
	June	A	4.16	1.35	0.27	2.32
		B	3.95	1.39	0.37	2.09
	September	A	4.02	1.38	0.58	0.78
		B	3.90	1.31	0.45	0.78
	December	A	3.07	1.23	0.79	0.91
		B	3.76	1.37	0.33	0.59
Mean ± standard deviation			3.72±0.35	1.30±0.14	0.45±0.16	0.87±0.60
6	April	A	3.47	1.16	0.29	0.93
		B	3.48	1.11	0.36	1.10
	June	A	4.01	1.36	0.37	1.29
		B	3.96	1.34	0.14	1.19
	September	A	3.78	1.33	0.37	1.75
		B	3.79	1.41	0.43	1.10
	December	A	3.04	1.34	0.44	2.12
		B	3.09	1.24	0.28	1.21
Mean ± standard deviation			3.58±0.35	1.29±0.10	0.34±0.09	1.34±0.37
7	April	A	3.59	1.19	0.23	0.95
		B	3.47	1.32	0.30	1.00
	June	A	3.75	1.40	0.30	0.92
		B	4.03	1.29	0.39	1.59
	September	A	3.83	1.36	0.43	1.04
		B	4.00	1.36	0.27	0.82
	December	A	3.75	1.21	0.48	1.14
		B	3.29	1.25	0.52	0.75
Mean ± standard deviation			3.72±0.24	1.30±0.07	0.37±0.10	1.03±0.24
8	April	A	3.57	1.23	0.59	0.94
		B	3.54	1.17	0.54	0.73
	June	A	3.88	1.40	0.25	1.17
		B	4.00	1.26	0.51	0.83
	September	A	4.17	1.38	0.50	0.64
		B	4.07	1.32	0.49	0.64
	December	A	3.41	1.22	0.72	0.61
		B	3.04	1.28	0.72	0.61
Mean ± standard deviation			3.71±0.36	1.28±0.75	0.54±0.14	0.77±0.19

TABLE I-4
(continued)
MEAN GRAIN SIZE, SORTING COEFFICIENT, TOTAL ORGANIC CARBON CONTENT
AND TOTAL CARBONATE CONTENT OF SEDIMENTS
CRYSTAL RIVER PROJECT
1981

			Grain size			
Station	Month	Replicate	Mean (ϕ)	Standard deviation (ϕ)	Total organic carbon (%)	Total carbonate (%)
9	April	A	2.18	1.16	0.42	0.86
		B	1.67	1.33	0.49	1.09
	June	A	2.54	1.63	0.60	1.70
		B	2.56	1.43	0.19	2.18
	September	A	2.12	1.64	0.47	1.84
		B	2.12	1.54	0.37	2.70
	December	A	2.34	1.45	0.73	2.89
		B	2.15	1.46	0.57	2.74
Mean ± standard deviation			2.21±0.27	1.46±0.15	0.48±0.15	2.0±0.72
10	April	A	3.50	1.27	0.51	0.06
		B	3.61	1.41	0.43	1.24
	June	A	3.68	1.39	0.19	1.78
		B	3.75	1.37	0.29	1.62
	September	A	3.08	1.41	0.45	1.66
		B	2.59	1.52	0.46	2.56
	December	A	3.17	1.18	0.49	0.45
		B	2.64	1.33	0.37	2.37
Mean ± standard deviation			3.25±0.43	1.36±0.096	0.40±0.10	1.47±0.81
11	April	A	3.20	1.24	0.42	1.43
		B	3.18	1.18	0.60	1.53
	June	A	3.21	1.44	0.55	2.36
		B	3.42	1.44	0.62	2.05
	September	A	2.93	1.49	0.44	1.51
		B	3.33	1.32	0.39	1.71
	December	A	2.92	1.32	0.67	1.53
		B	3.00	1.33	0.51	2.09
Mean ± standard deviation			3.15±0.17	1.35±0.099	0.53±0.09	1.78±0.32
12	April	A	1.89	1.83	1.12	1.27
		B	2.79	1.75	0.84	1.79
	June	A	2.28	1.72	0.36	2.89
		B	2.34	1.71	0.35	2.23
	September	A	2.77	1.50	0.84	1.68
		B	2.63	1.54	0.84	0.91
	December	A	1.80	1.49	0.84	3.05
		B	1.43	1.60	1.15	3.15
Mean ± standard deviation			2.24±0.46	1.64±0.12	0.79±0.28	1.87±0.83

TABLE I-4
(continued)
MEAN GRAIN SIZE, SORTING COEFFICIENT, TOTAL ORGANIC CARBON CONTENT AND TOTAL CARBONATE CONTENT OF SEDIMENTS
CRYSTAL RIVER PROJECT
1981

	Grain size			
	Mean (ϕ)	Standard deviation (ϕ)	Total organic carbon (%)	Total carbonate (%)
Control basin Mean ± standard deviation	2.91±0.69	1.42±0.17	0.55±0.21	1.58±0.77
Discharge basin Mean ± standard deviation	3.74±0.38	1.31±0.17	0.46±0.22	1.12±0.50

TABLE I-5

STATISTICAL ANALYSIS OF PERCENTAGE TOTAL ORGANIC CARBON
IN SEDIMENTS BY STATION
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	Calculated F value
Model	11	0.6022	0.0547	3.70*
Error	84	1.2415	0.0148	
Total	95	1.8437		

DUNCAN'S MULTIPLE RANGE TEST

Grouping[a]	Ranked mean (%)	Station
A	0.79	12
A	0.63	2
B C	0.57	8
B C	0.54	4
B C	0.52	11
B C	0.50	3
B C	0.48	9
B C	0.45	5
C	0.40	10
C	0.36	7
C	0.35	1
C	0.34	6

*Significant difference at $P \leq 0.05$; critical F=1.92.

[a]Means with the same grouping letter are not significantly different at P=0.05.

TABLE I-6

RESULTS OF T-TEST COMPARISON OF PERCENTAGE COMPOSITION OF CARBON IN SEDIMENTS BETWEEN CONTROL AND DISCHARGE BASINS
CRYSTAL RIVER PROJECT
1981

Carbon species	Mean basin percentage: Control	Mean basin percentage: Discharge	Calculated t value	Critical t value	Result[a]
Total organic carbon	0.55±0.21	0.46±0.22	2.006	1.645	control>discharge
Total carbonates	1.58±0.77	1.12±0.50	3.595	1.645	control>discharge

[a]A result indicates a significant difference between basins at $P \leq 0.05$.

TABLE I-7

STATISTICAL ANALYSIS OF PERCENTAGE CARBONATES
IN SEDIMENTS BY STATION
CRYSTAL RIVER PROJECT
1981

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	Calculated F value
Model	11	2.7505	0.2500	5.26*
Error	84	3.9903	0.0475	
Total	95	6.7408		

DUNCAN'S MULTIPLE RANGE TEST

Grouping[a]	Ranked mean (%)	Station
A	2.12	12
A B	2.00	9
A B	1.78	11
A B C	1.59	10
A B C	1.49	2
B C D	1.33	6
C D E	1.15	4
C D E	1.11	5
C D E	1.02	7
D E	0.97	3
D E	0.97	1
D E	0.87	8

*Significant difference at $P \leq 0.05$; critical F=1.92.

[a]Means with the same grouping letter are not significantly different at P=0.05.

APPENDIX II

ANNUAL RECORDS OF METABOLISM OF ESTUARINE ECOSYSTEMS

RECORD OF ESTUARINE AND SALT MARSH METABOLISM AT CRYSTAL RIVER, FLORIDA, 1977–1981

Robert L. Knight
and
William F. Coggins

C. L. MONTAGUE, PRINCIPAL INVESTIGATOR

FINAL SUMMARY REPORT
TO FLORIDA POWER CORPORATION
CONTRACT QEA-000045

SYSTEMS ECOLOGY AND ENERGY ANALYSIS GROUP
Department of Environmental Engineering Sciences
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Gainesville, Florida
32611

March 1982

CONTENTS

ABSTRACT

Four years of metabolism studies for estuarine and salt marsh ecosystems receiving thermal discharges from three generating units near Crystal River, Florida, are presented. Power generation significantly increased temperature, turbidity, and salinity of inshore bay ecosystems. System metabolism of the Inner Discharge Bay was significantly reduced compared to control sites, while the metabolism of the Middle Discharge Bay was stimulated compared to its control. Plankton metabolism was not significantly altered in the discharge estuary compared to the control site. Threshold water temperature for metabolism inhibition in the Crystal River estuary was approximately 32°C. Seasonal patterns of stimulation or inhibition were observed for both estuarine and salt marsh ecosystems apparently in response to temperature. Total metabolism of discharge salt marsh systems was significantly reduced by power plant output compared to control marshes. No long-term recovery of estuarine metabolism was noted during this 4-year study; however, _Juncus_ and _Spartina_ marshes exposed to thermal addition underwent morphological adaptations including smaller stalk size and greater stalk density.

INTRODUCTION

Electric power generation requires the disposal of large quantities of waste heat to the environment (typically 60–80% of the heat content of the fuel is lost [Bregman 1969]). Of the various options for disposal of this heat, once-through cooling using estuarine water is often used on the west coast of Florida. This process may result in major changes in estuarine water circulation, annual and diurnal temperature regimes, and estuarine water chemistry. Short-term acute effects of such heat disposal are often variable, such as stimulation or reduction in photosynthesis, enhancement or decline of fish populations, and changes in species composition.

In addition to the use of short-term measurements of acute effects for decision making, it is also necessary to protect against long-term community changes resulting from chronic stressful conditions. Biological adaptations by selection of tolerant organisms may occur. On the other hand, the multiple effects of power production may take several years to manifest themselves. Documentation of the long-term response of ecosystems to power plant operation is necessary if regulations are to adequately take account of biological complexity.

A difficulty exists for the researcher who wishes to study these chronic changes of ecosystem condition by studying populations of indicator species in that the particular organisms chosen for study may disappear from the system when exposed to new environmental stresses. One

alternative is to monitor system-level parameters such as trophic-level standing stocks and overall energy flux (McKellar and Smith 1981). These parameters can be measurable under any new configuration that the biological system may take and are also comparable between different systems.

One such system parameter that integrates biological variability is ecosystem metabolism or gross biological energy flow. Ecosystem metabolism can be estimated by measuring system gross primary production based on changes in dissolved oxygen (DO) in aquatic systems and carbon dioxide changes in terrestrial ecosystems. Ecosystem metabolism has additional importance derived from the observation that this parameter typically increases during successional maturation of biological systems and responds very closely to changes in external energy sources. Thus the sinusoidal pattern of solar input is closely tracked by the rhythm of ecosystem metabolism in healthy ecosystems, and stressful events result in sharp decreases in energy fixation.

As one component of an Environmental Technical Specifications (ETS) study required to document changes resulting from a third generating unit at Crystal River, Florida, this report summarizes nearly 4 years of ecosystem metabolism measurements of estuarine and salt marsh ecosystems receiving thermal effluent. Three questions about the environmental effects of the power plants are investigated: 1. What are the system-level effects on the estuarine and salt marsh ecosystems of the combined power plant output? 2. What are the additional effects of a third power unit on the Crystal River estuary and salt marsh? and 3. Have any clear long-term adaptations taken place in the structure or functioning of these coastal ecosystems?

Study Site

The Florida Power Corporation has three electric-power generating units on-line and is in the process of building two additional units near the Gulf of Mexico at Crystal River, Florida. Two coal-fired units, Units 1 and 2, with a combined capacity of 964 megawatts (MW), came on-line in 1966 and 1969, respectively. These two units require approximately 2415 $m^3 \cdot min^{-1}$ (638,000 gpm) of cooling water. This water is drawn from offshore via a 12.5-km intake canal and is discharged inshore via a 3.8-km discharge canal.

A third unit with 855 MW capacity and fired by nuclear power, came on-line in 1977 using once-through cooling via the same intake and discharge canals. This unit pumps an additional 2574 $m^3 \cdot min^{-1}$ (680,000 gpm) of estuarine water for cooling purposes.

The Crystal River power plants are approximately 5 km north of the Crystal River and about 6 km south of the Cross Florida Barge Canal and the Withlacoochee River (Fig. 1). The coastline in this area has low wave energies and a drowned karst topography. Tidal marshes are dominated by black needlerush, Juncus roemerianus, with a narrow band of smooth cordgrass, Spartina alterniflora, fronting the Juncus on the seaward side. Numerous oyster bars occur roughly parallel to the coastline extending 3 to 4 km seaward.

Under natural conditions with freshwater inflow from the Crystal and Withlacoochee rivers, the inshore estuarine bays near the plant are characteristically less saline than the more thoroughly mixed offshore bays (Carder et al. 1973). Submerged vegetation is characteristically a mixture of macroalgae and seagrasses such as Halodule wrightii, Ruppia mari-

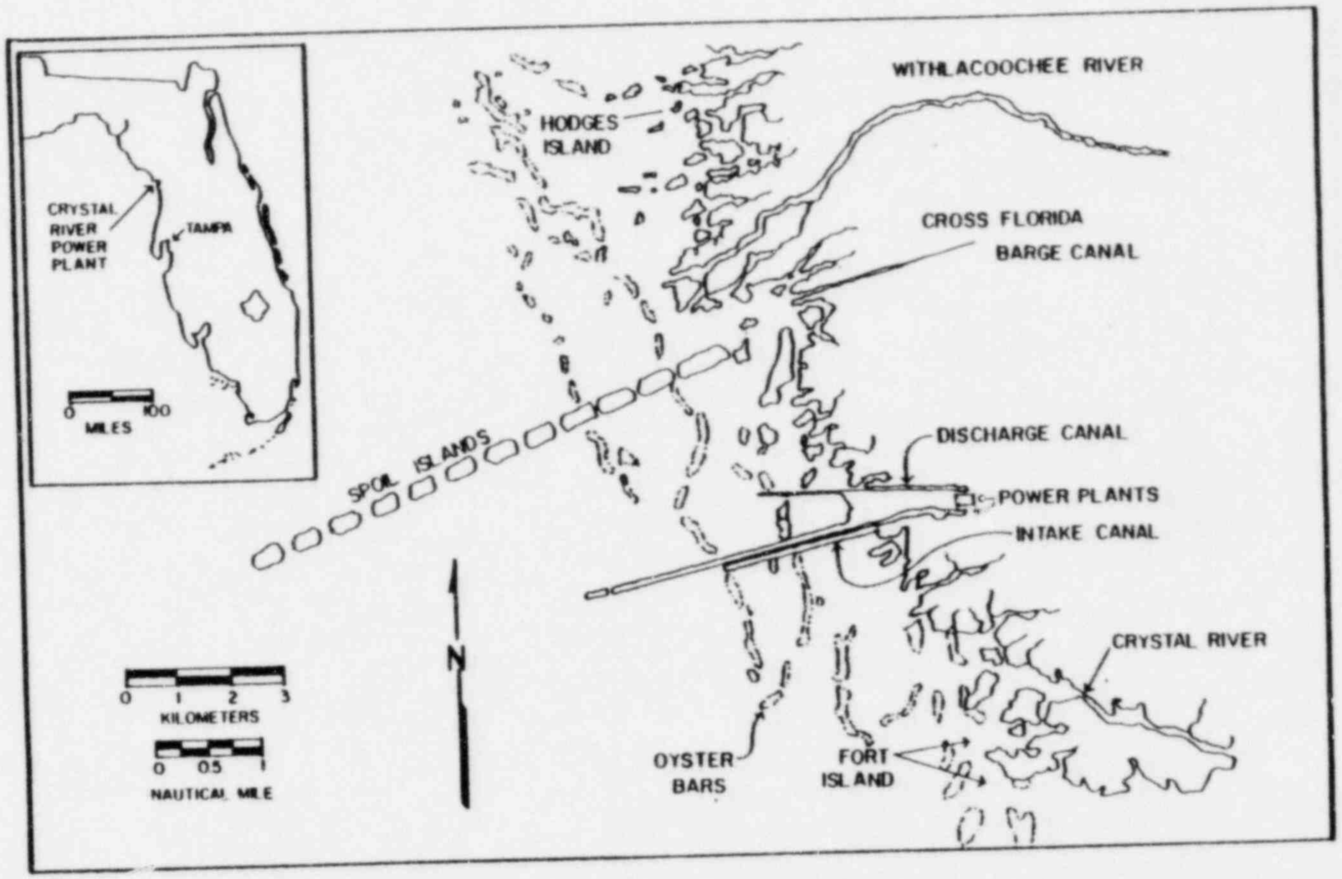

Figure 1. The Crystal River power plants in relation to the major features of the regional coastline.

tima, and Syringodium filiforme. Primary productivity of the water column is dominated by phytoplankton. Complex consumer food chains include many species of zooplankton, marine invertebrates, fishes, marine mammals, and birds. Rainfall during the study period averaged 136 cm per year with more than half falling during June, July, and August (NOAA 1977–1980).

Six estuarine bays and two salt marsh sites were routinely monitored during this 4-year study (see Fig. 2). Since the estuarine bays are divided by oyster bars, location of sampling areas was simplified. The Inner Discharge Bay (Bay A) is situated such that it was the first natural estuarine area to receive thermal effluent from the discharge canal. The Inner Control Bay (Bay E) is located south of the intake canal, between the shoreline marshes and the first oyster bar. The Middle Discharge Bay (Bay B) is situated along the discharge canal further seaward between the first and second oyster bars, and its control, the Middle Control Bay (Bay D), is located under similar circumstances south of the intake canal. The Outer Discharge and Control bays (Bays OB and C, respectively) are located in comparable areas beyond the second oyster bar from shore. The control bays were chosen to replicate their discharge bays in terms of depth and tidal flushing. The primary differences between these control and discharge areas were assumed to be the effects of either the power plant operation—thermal enrichment of the water and increased circulation of offshore water in the discharge area due to the pumping of cooling water—or the power plant siting—presence of long canal spoil bars.

Figure 2 also shows the locations of the discharge and control salt marsh sites. The discharge marshes are located approximately 100 m from the point where the discharge canal opens into the inner discharge bay. As with the bays, the discharge and control marshes are similar areas in

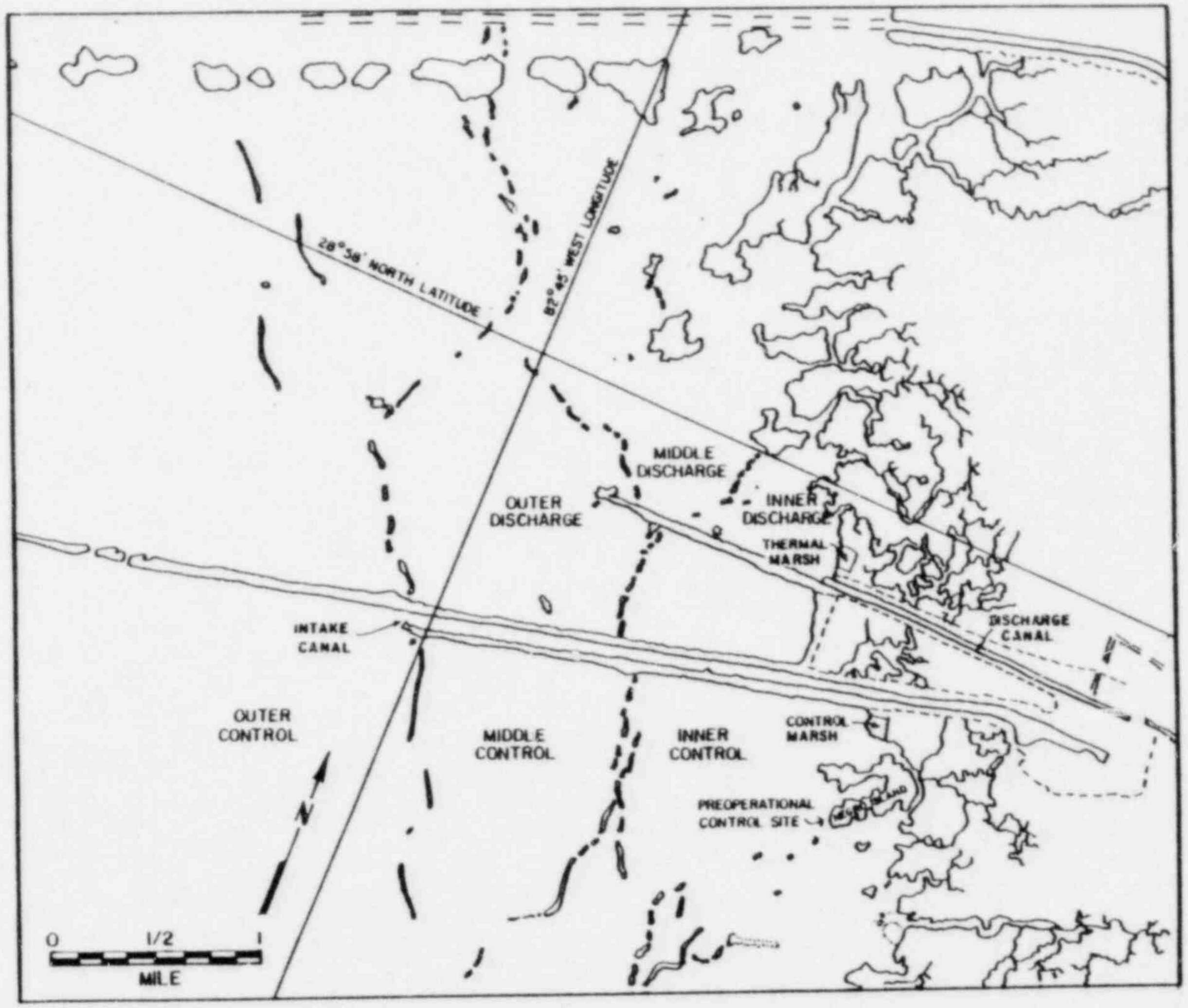

Figure 2. Locations of the Inner, Middle, and Outer Discharge Bays and their Controls along with the Discharge and Control salt marsh sites.

terms of natural tidal flows, but quite different in terms of the thermal and circulation effects of the power plants.

Previous Crystal River Research

The estuarine and salt marsh ecosystems adjacent to the Crystal River power plants have been the site for a multidisciplinary research effort since 1971. During the period 1971–1974, research established some base-line ecological conditions present in this estuary prior to the discharge of additional heated water from Unit 3. Postoperational studies continued from 1977 until 1981 in order to determine changes that may have occurred in response to the new power-generating unit.

Early primary productivity measurements using Carbon-14 techniques were made by Fox and Moyer (1972) in the intake and discharge canals. The metabolism of the Inner Discharge Bay and Control Bay was studied using oxygen change techniques by Smith (1976). The metabolism of the next set of bays in the seaward direction was measured by McKellar (1975). Several papers summarizing this research have been published (Smith et al. 1974; McKellar 1977; Kemp et al. 1977). More recent bay metabolism studies since the addition of Unit 3 have been presented as annual reports (Odum et al. 1978; Caldwell et al. 1979, 1980; Montague et al. 1981) and are summarized in this report. Community structure studies have monitored phytoplankton and chlorophyll (Gibson et al. 1974; Connell, Metcalf and Eddy, Inc. 1978, 1979; Metcalf and Eddy 1980); zooplankton (Maturo et al. 1974; Benkert 1980); nekton (Grimes and Mountain 1971; Adams et al. 1974; Odum et al. 1974; Snedaker et al. 1974; Homer 1976); oysters (Lehman 1974); and benthic plants and animals (Adams et al. 1974; Evink and Green

1974; Van Tine 1974; Connell, Metcalf and Eddy, Inc. 1978, 1979; Metcalf and Eddy 1980; Van Tine and Davis 1982).

Preoperational studies were conducted by Odum et al. (1974) and Young (1974) at the salt marsh sites. Postoperational research in the salt marshes has included work by Hornbeck (1979) and by Odum et al. (1978), Caldwell et al. (1979, 1980), and Montague et al. (1981). The report that follows summarizes the data presented in the annual progress reports for the Crystal River salt marshes.

METHODS

Sampling Plan

Monitoring for the ETS studies began with an initial testing period during the first quarter of 1977, resulting in the development of a routine of sampling that was continued without significant alteration until the spring of 1981. The response of estuarine metabolism to power plant operation was measured in an area that was large enough to give a range of possible effects from acute to no significant effect. The discharge estuary was divided into three zones for study, and control areas with similar physical features were chosen for comparison. Based on preoperational research by Carder et al. (1973), the Inner Discharge Bay represented the zone of maximum temperature change, the Middle Discharge Bay a zone of more moderate effect, and the Outer Discharge Bay was chosen to represent near background conditions in terms of temperature elevation and salinity changes.

The yearly cycle of estuarine metabolism was estimated by biweekly sampling of planktonic and system production and respiration. Each quarter two consecutive 24-hour intensive sampling studies were conducted. These quarterly data receive equal treatment in the analyses that follow. Metabolism of the Spartina and Juncus marsh systems was measured only on a quarterly basis with two to four values of each metabolism parameter collected during a sampling period. Measurement of marsh structure and

metabolism was limited to one station near the point of discharge and therefore a gradient of salt marsh response to decreasing power plant influence was not obtained over a spatial dimension.

Estuarine Metabolism

Estuarine metabolism was broken into two components for study: namely, the planktonic subsystem and the overall system of plankton and benthos. Metabolism of the benthic subsystem was estimated by subtracting planktonic metabolism from the total system metabolism.

Planktonic metabolism was measured biweekly by use of the light-dark bottle method (APHA 1975) during two consecutive 12- or 24-hour sampling periods. Details of the modifications utilized during this study can be found in previous annual reports (Montague et al. 1981; Odum et al. 1978; Caldwell et al. 1979, 1980). Metabolism parameters measured include plankton net productivity, plankton respiration, and plankton gross productivity in units of dissolved oxygen change per area per time.

System metabolism was also measured by changes in DO concentrations. The open water diurnal oxygen method used was developed by Odum (1956), Odum and Hoskins (1958), and Odum and Wilson (1962) and was adapted to the specific needs of the Crystal River study as discussed in Montague et al. (1981). In addition to intensive 24-hour sampling of dissolved oxygen changes on a quarterly basis, biweekly measurements were routinely made by use of the dawn-dusk-dawn method of McConnell (1962) and McKellar (1975). The details of the methods used at Crystal River have been discussed thoroughly in annual project reports such as Montague et al. (1981).

In order to obtain metabolism values from DO changes, the diffusion of oxygen through the air-water interface had to be estimated. On a number of occasions the floating dome diffusion method of Copeland and Duffer (1964) as modified by Smith (1975) and McKellar (1975) was used to measure oxygen diffusion in these bays. These diffusion corrections were applied to all data in order to obtain values of system gross productivity, system net productivity, and respiration.

Several physical factors were measured concurrently with metabolism in order to establish cause-effect relationships that might exist in the study area. At the time of collection of each DO sample, water temperature, salinity, water depth, and secchi disk depth were recorded. Continuous recordings of insolation were made concurrently with sample collection. The ecological efficiency of the biological system was estimated by converting gross productivity measurements to Calories and dividing by insolation. Details of the measurement of these physical parameters are presented elsewhere (Montague et al. 1981).

Salt Marsh Structure and Metabolism

The metabolism of *Juncus*-dominated and *Spartina*-dominated salt marshes was measured quarterly in the discharge and control areas. Metabolism of the living plants was measured *in situ* by recording changes in atmospheric CO_2 concentration of air flowing through plastic enclosures over the plants during two or four consecutive 24-hour periods. Details of the methods employed can be found in Brown (1978), Hornbeck (1979), and Montague et al. (1981).

The plants within the enclosures were harvested after metabolism measurement, and stalk height, stalk density, and live weight were recorded. In addition, population densities of the salt marsh periwinkle (Littorina irrorata) and of fiddler crab burrows (Uca spp.) were estimated at each of the four sites.

Data Analysis

Statistical comparisons between discharge and control sites were made using seasonal means and Student's t-test statistic (SAS 1981). Standard error bars are excluded from the graphs for the sake of clarity; however, any reference to significant differences between stations are based on 95% confidence limits.

To illustrate and analyze the effect of power plant operation on the various parameters, monthly differences between the discharge and control data were plotted versus total power plant output. Total power output in megawatt-hours (MWH) per month was chosen as the best integrative parameter for the combined effects of thermal and circulatory changes caused by the three generating units. The best fit for each comparison was made using linear regression analysis (SAS 1981). A regression equation of the form

$$Y = mX + b$$

was used where Y is the dependent variable, m is the slope, X is the independent variable, and b is equal to the Y-intercept when X = 0.

RESULTS

Estuarine Ecosystems

The data presented here are in the figures that follow; estuarine parameters have been presented as seasonal means. Means were calculated as follows: Winter—January, February, and March; Spring—April, May, and June; Summer—July, August, and September; and Fall—October, November, and December. A summary of measurements is included as an appendix.

Physical Parameters

Recorded insolation values during the 4 years of study were between 159 and 7400 Cal/m^2·day (Fig. 3). Seasonal trends were typical for central Florida with the yearly maximum in spring or summer and the yearly minimum in the fall or winter. Total insolation for 1978 through 1980 appeared to be lower than 1977 and 1981 based on the days when measurements were taken.

Water temperatures in the Inner, Middle, and Outer Bays are compared in Figure 4. Temperatures in the three control bays were always similar. Highest water temperatures were recorded for the Inner Discharge Bay with a few measurements over 37°C during the 1977 summer season. Maximum temperatures were approximately 1°C lower in the Middle Discharge Bay and 2°C lower in the Outer Discharge Bay compared to the Inner Discharge Bay.

Salinity values in the estuarine ecosystems are presented in Figure 5. Some seasonal periodicity was noted with highest salinities occurring

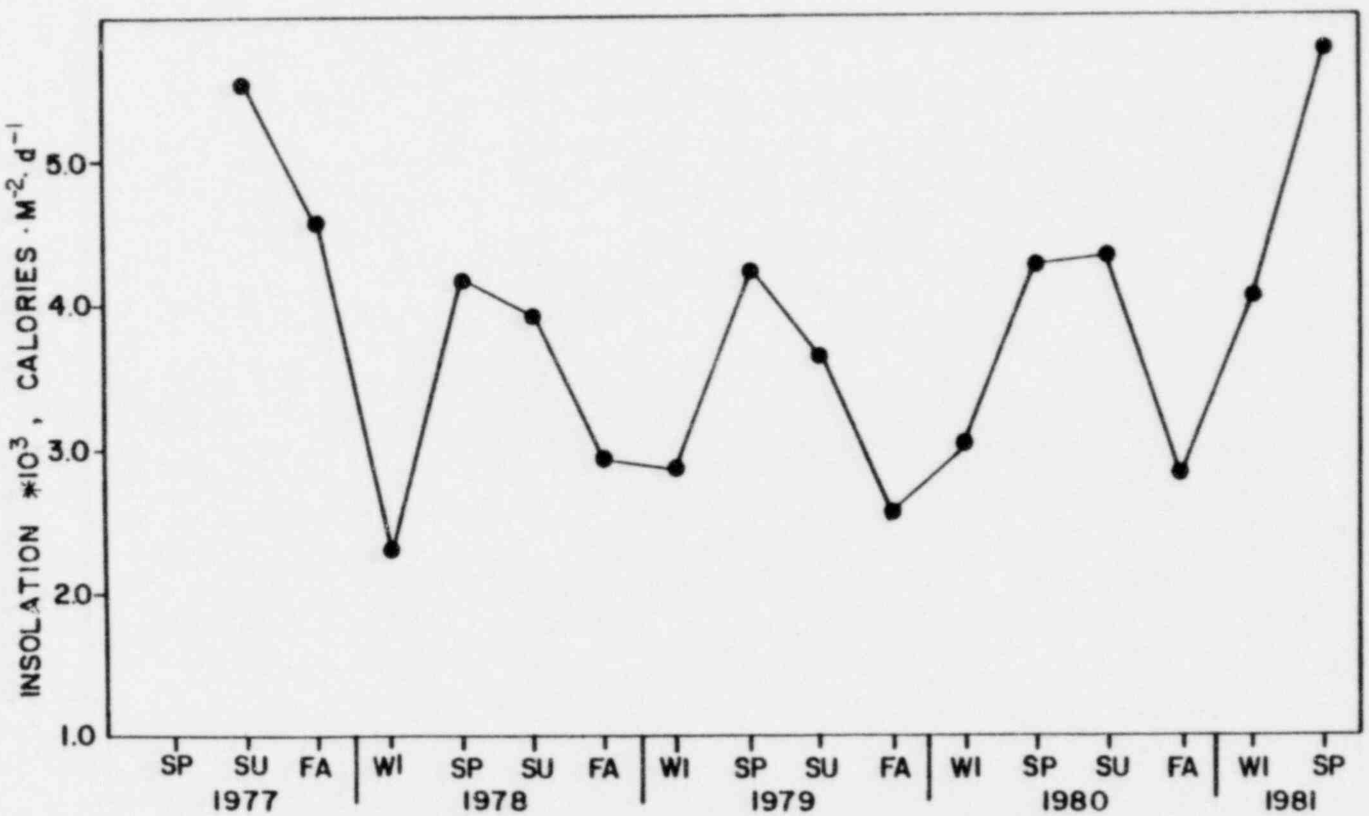

Figure 3. Seasonal mean insolation at the Crystal River power plants recorded during the 4-year study period.

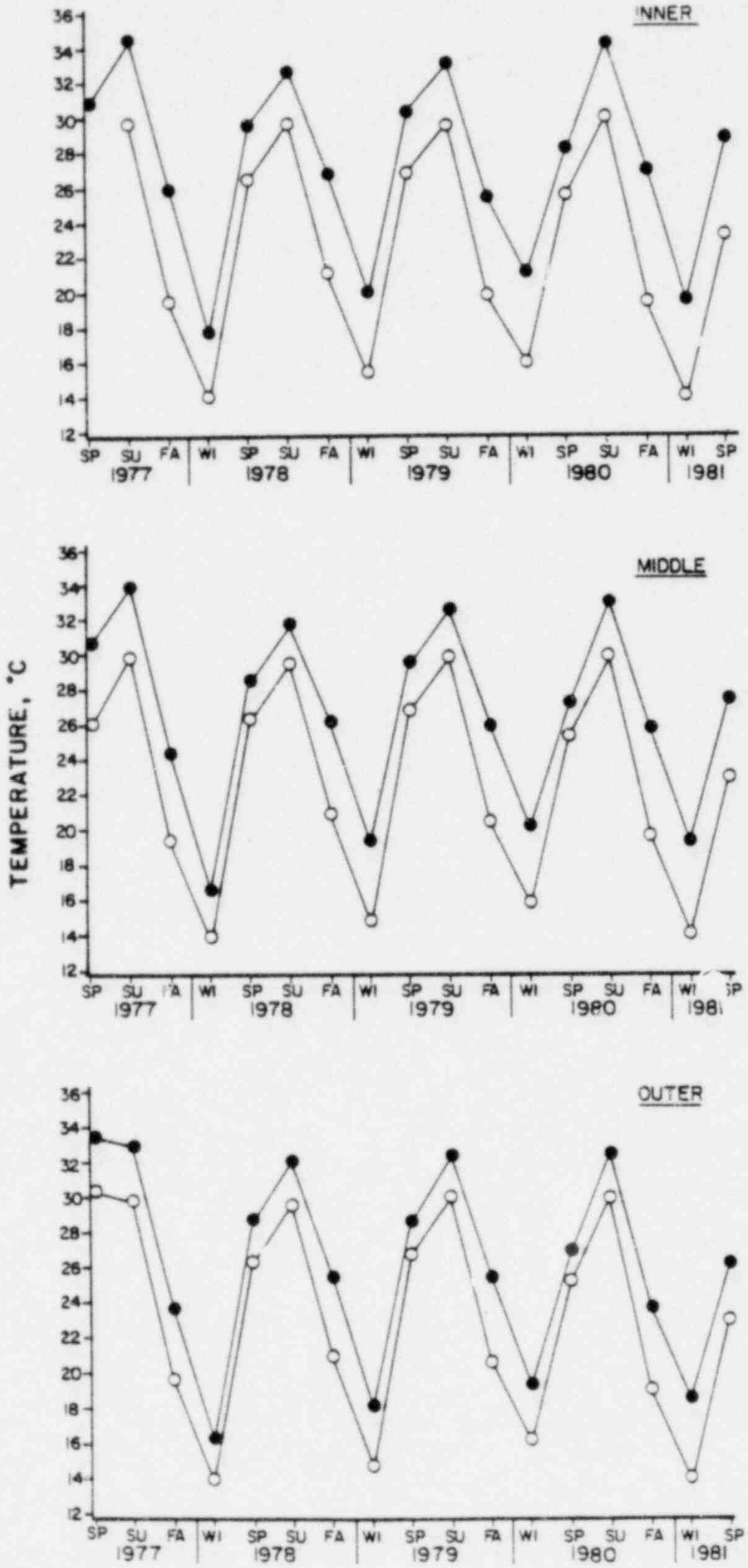

Figure 4. Seasonal mean water temperatures for the Discharge (●) and Control (○) Bays.

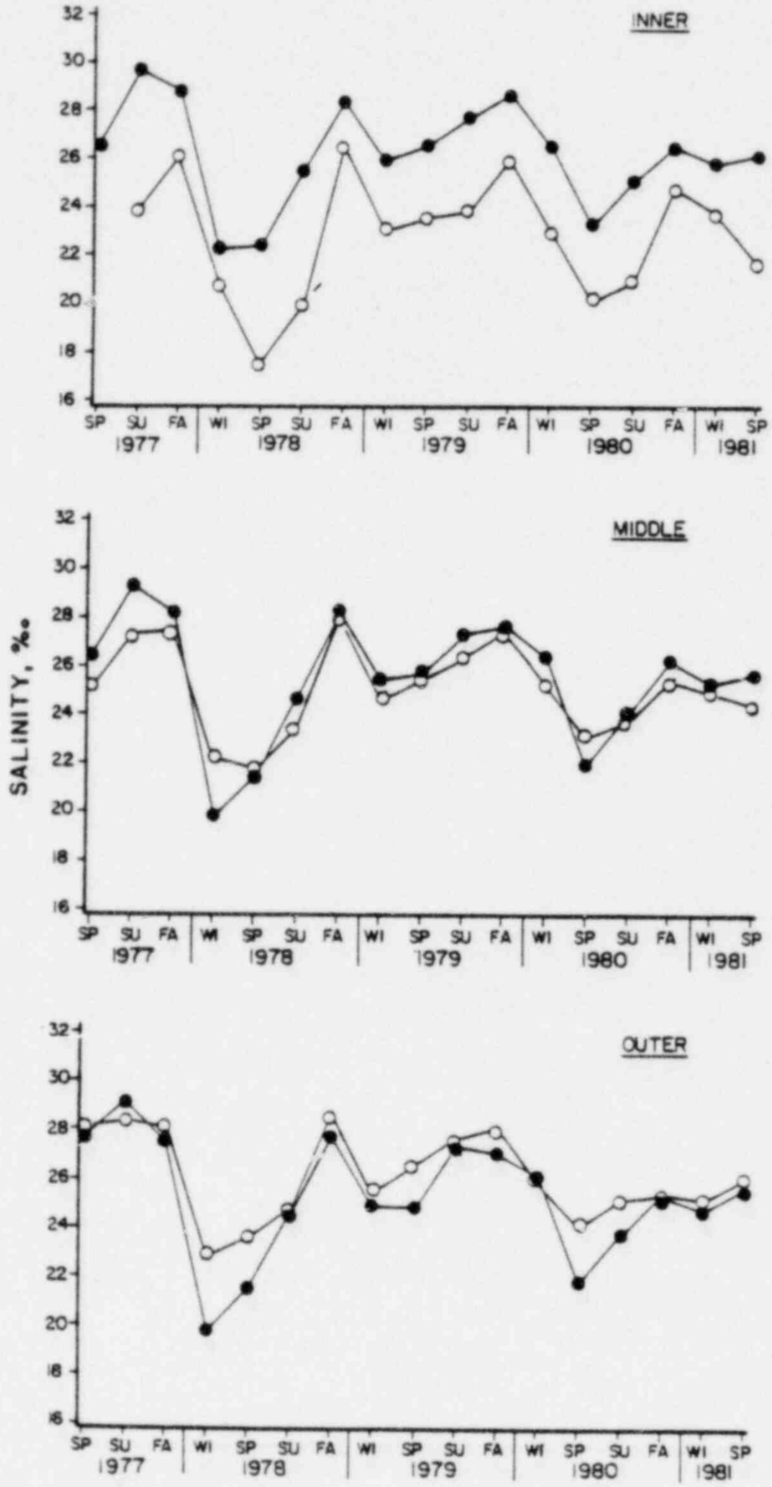

Figure 5. Seasonal mean salinities for the Discharge (●) and Control (○) Bays.

in the summer and fall and lowest values recorded during the winter and spring months. This pattern may be explained by the seasonal cycle of evaporation from the water's surface in spite of greater rainfall during the summer and smaller amounts during the winter. Salinity was significantly higher in the Inner Discharge Bay than in its control (Fig. 5) by approximately 3 ppt. Salinity in the Middle and Outer Discharge Bays was rarely significantly different from control values.

Seasonal means for light extinction are presented in Figure 6 for the three pairs of bays. Light extinction was significantly higher in the Inner Discharge Bay than in its control throughout the study period, although no clear seasonal trends were observed. Light extinction was not significantly different between the Middle and Outer Discharge Bays and their controls (Fig. 6). Light extinction in the Outer bays went through seasonal cycles with maximum values in the spring and minimum values during the winter.

<u>Plankton Metabolism</u>

Plankton gross productivity showed no consistent differences between discharge and control bays (Fig. 7). Seasonal cycles of plankton gross productivity tracked insolation in all of the bays. Plankton productivity increased from the inner to the outer bays. This trend was probably in response to the greater depth of the outer bays, which resulted in higher areal productivity values. Plankton productivity on a volume basis was not significantly different between the Middle and Outer Control Bays, although it was significantly lower in the Inner Control Bay. Volumetric plankton productivity was similar in all three of the discharge bays.

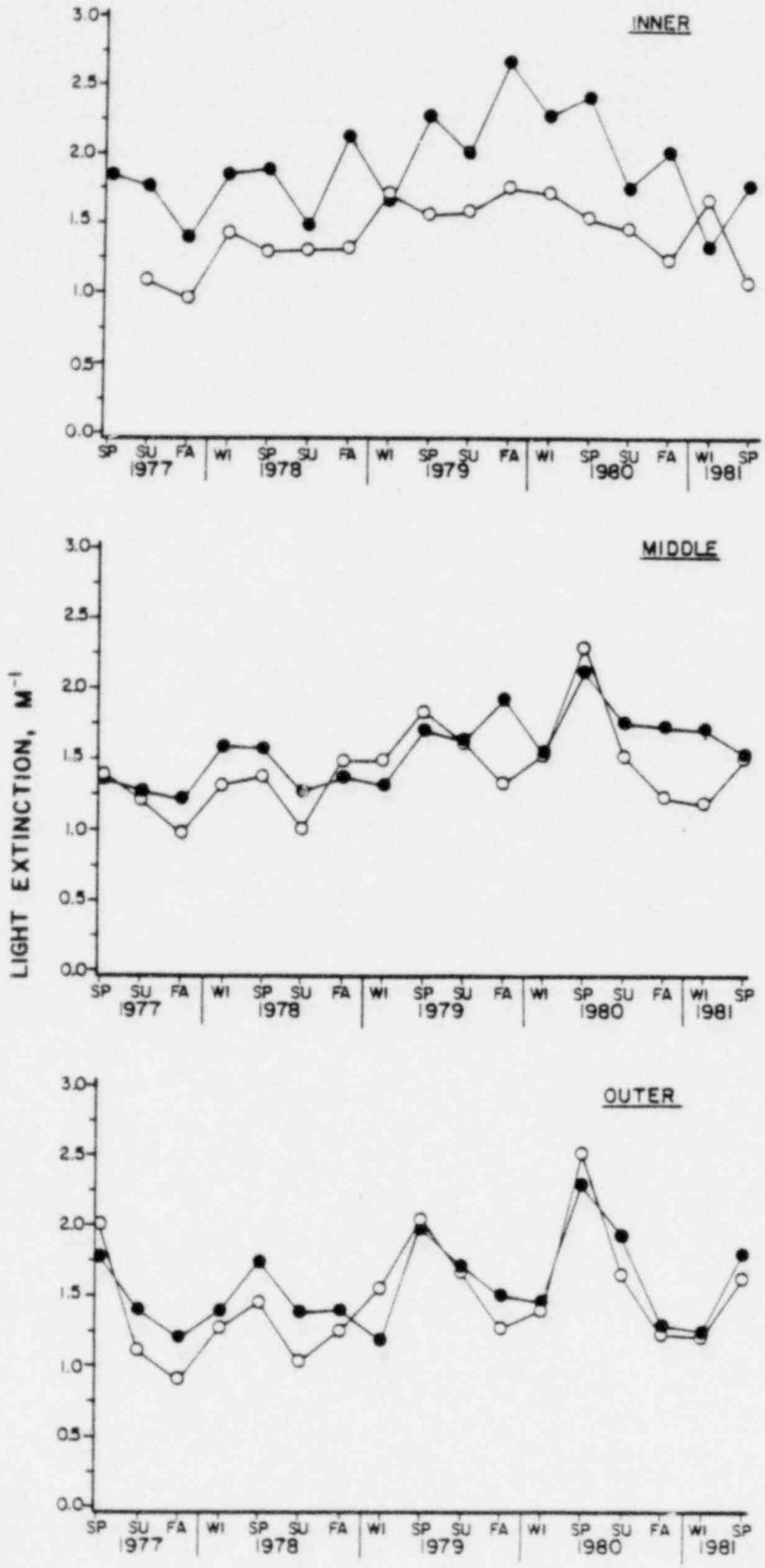

Figure 6. Seasonal mean light extinctions for the Discharge (●) and Control (○) Bays.

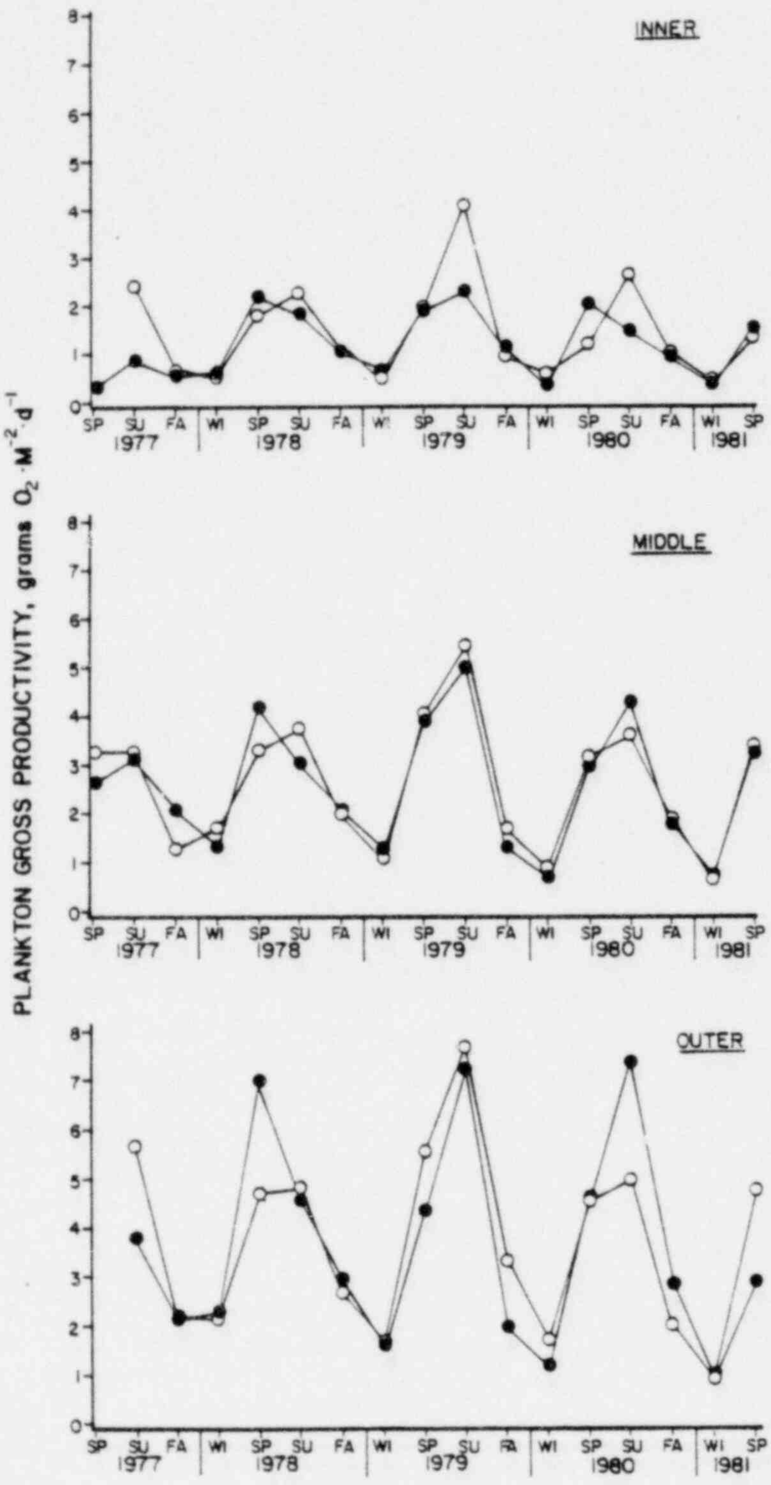

Figure 7. Seasonal mean plankton gross productivity for the Discharge (●) and Control (○) Bays.

Plankton net productivity did not have any clear trend in response to the power plant operation (Fig. 8). Seasonal cycles were evident and once again the outer bays were more productive than the middle and inner bays on an areal basis, due largelv to their greater depth.

Plankton respiration was consistently lower in the three discharge bays compared to their controls although the differences were rarely significant (Fig. 9). Weak seasonal patterns were evident and unlike gross and net plankton productivity, there was little difference between the plankton respiration per area of the inner bays as compared to the middle and outer bays. Thus, plankton respiration on a volume basis was higher in the inner bays than in the outer bays.

System Metabolism

System gross productivity was consistently lower in the Inner Discharge Bay relative to its control bay (Fig. 10). On the other hand, the gross productivity of the Middle Discharge Bay was consistently higher than its control although the differences were often small. No consistent stimulation or inhibition was found between the Outer Discharge Bay and its control. System gross productivity was generally highest in the nearshore areas of the control estuary than in the deeper offshore areas. The periodicity of system gross productivity in all of the study bays closely correlated with the cyclic pattern of insolation.

System net productivity of the Inner Discharge Bay was consistently lower than that of its control bay (Fig. 11). This parameter was consistently higher in the Middle Discharge Bay relative to its control, although the apparent difference was small. In the outer bays, there was no consistent stimulation of net productivity observed.

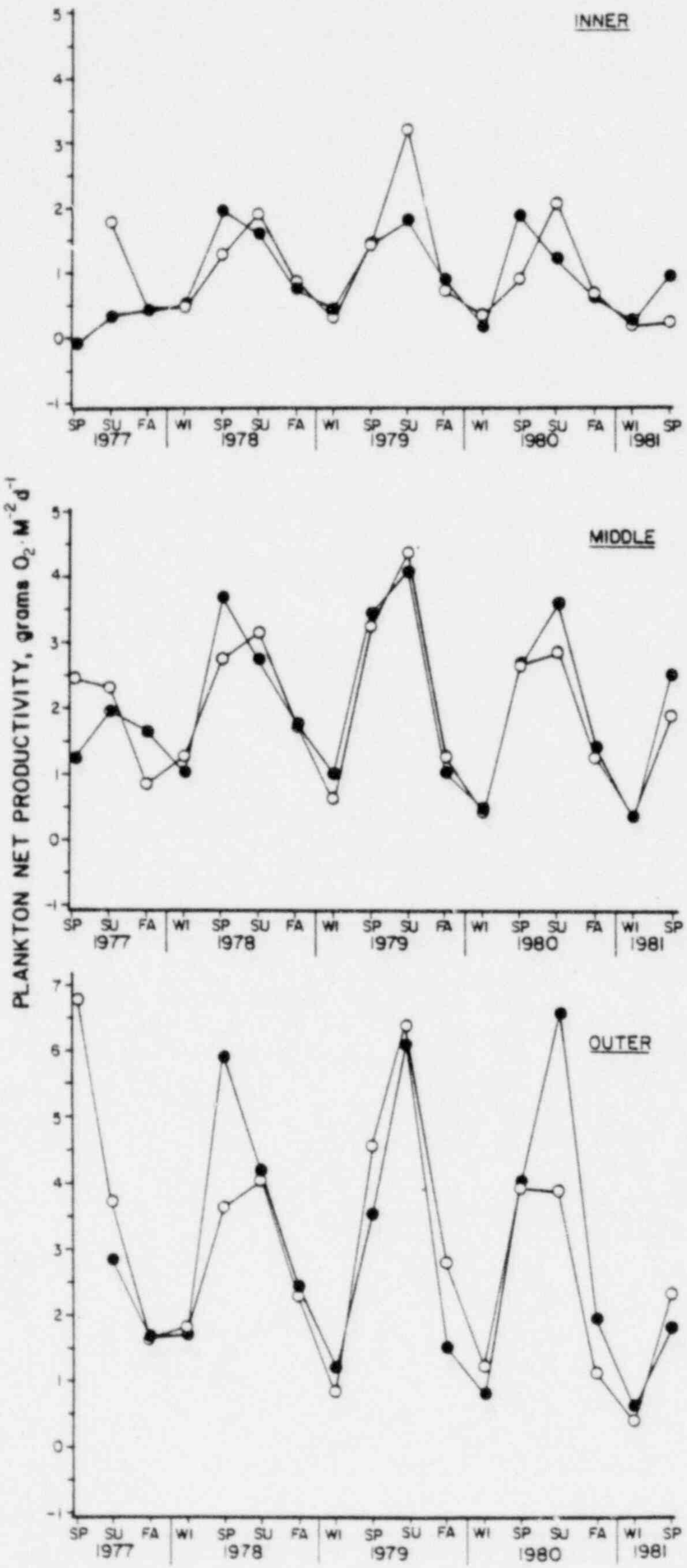

Figure 8. Seasonal mean plankton net productivity for the Discharge (●) and Control (○) Bays.

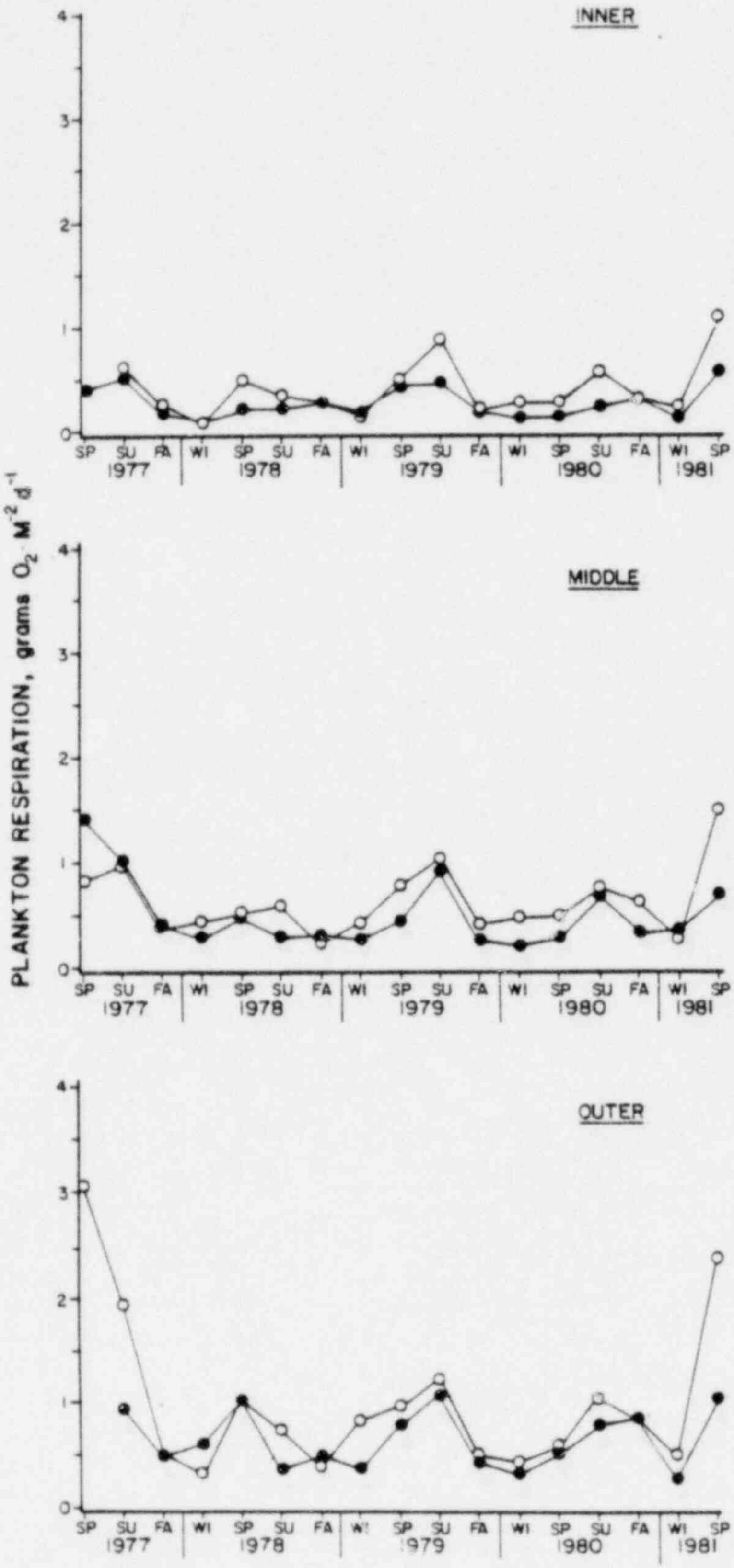

Figure 9. Seasonal mean plankton respiration for the Discharge (●) and Control (○) Bays.

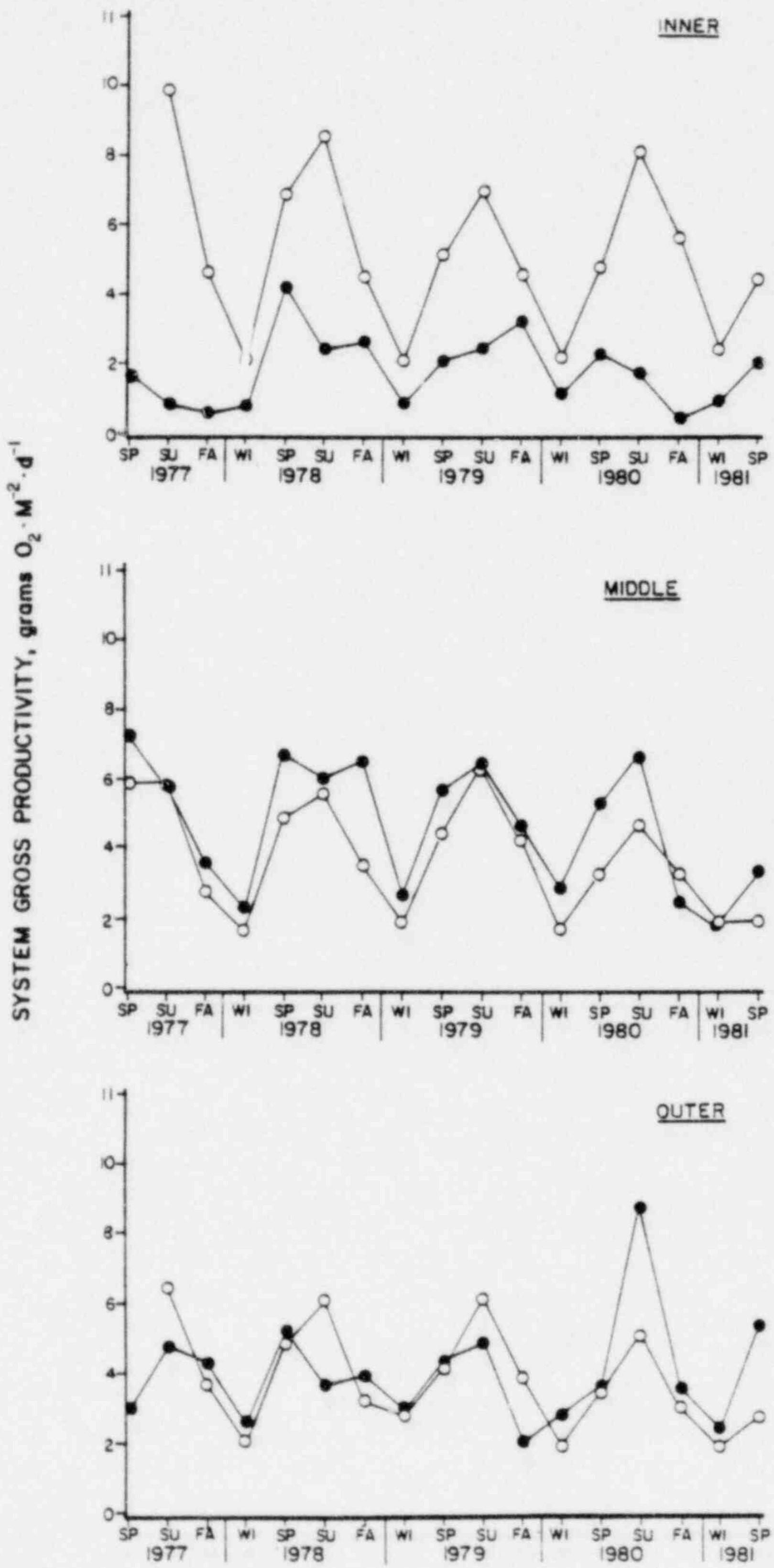

Figure 10. Seasonal mean system gross productivity for the Discharge (●) and Control (○) Bays.

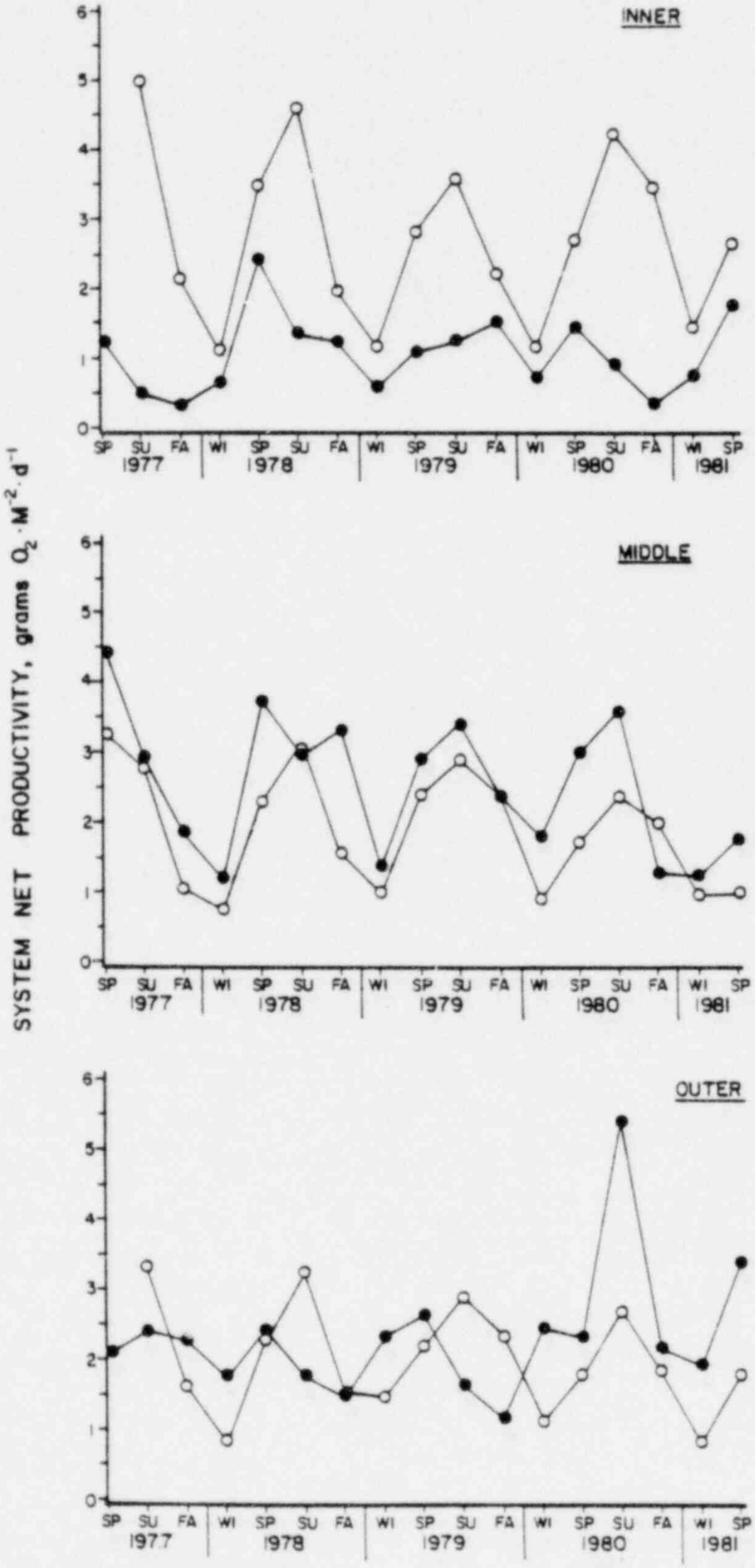

Figure 11. Seasonal mean system net productivity for the Discharge (●) and Control (○) Bays.

System respiration was also depressed in the Inner Discharge Bay relative to its control bay (Fig. 12). This parameter was generally higher in the Middle Discharge Bay compared to its control, while there was very little difference between the two outer bays. The pattern of system respiration closely followed insolation and productivity in all of the bays.

Ecological efficiency data for all of the estuarine bays are presented in Figure 13. Unlike the productivity values, ecological efficiency generally reached maximum levels during the fall season (October, November, and December), rather than during the summer season. This parameter underwent a declining trend in the Inner and Middle bays during the 4 years of study.

Salt Marsh Ecosystems

Structure

Live weight data for the control and thermal salt marsh plants are presented in Figure 14. There was no consistent difference in live weight between control and thermal marshes for either *Spartina* or *Juncus*. *Juncus* live weight values fluctuated between 600 and 1700 $g \cdot m^{-2}$ for both marshes, and *Spartina* live weights were generally lower with values ranging between 300 and 1000 $g \cdot m^{-2}$.

A seasonal summary of live stalk density for the Crystal River salt marshes is given in Figure 15. Stalk density was consistently greater at the discharge marsh sites than at the control marsh sites for both *Spartina* and *Juncus*. Combining these data with information on live weight presented in Figure 14 shows that the specific weight (weight per stalk)

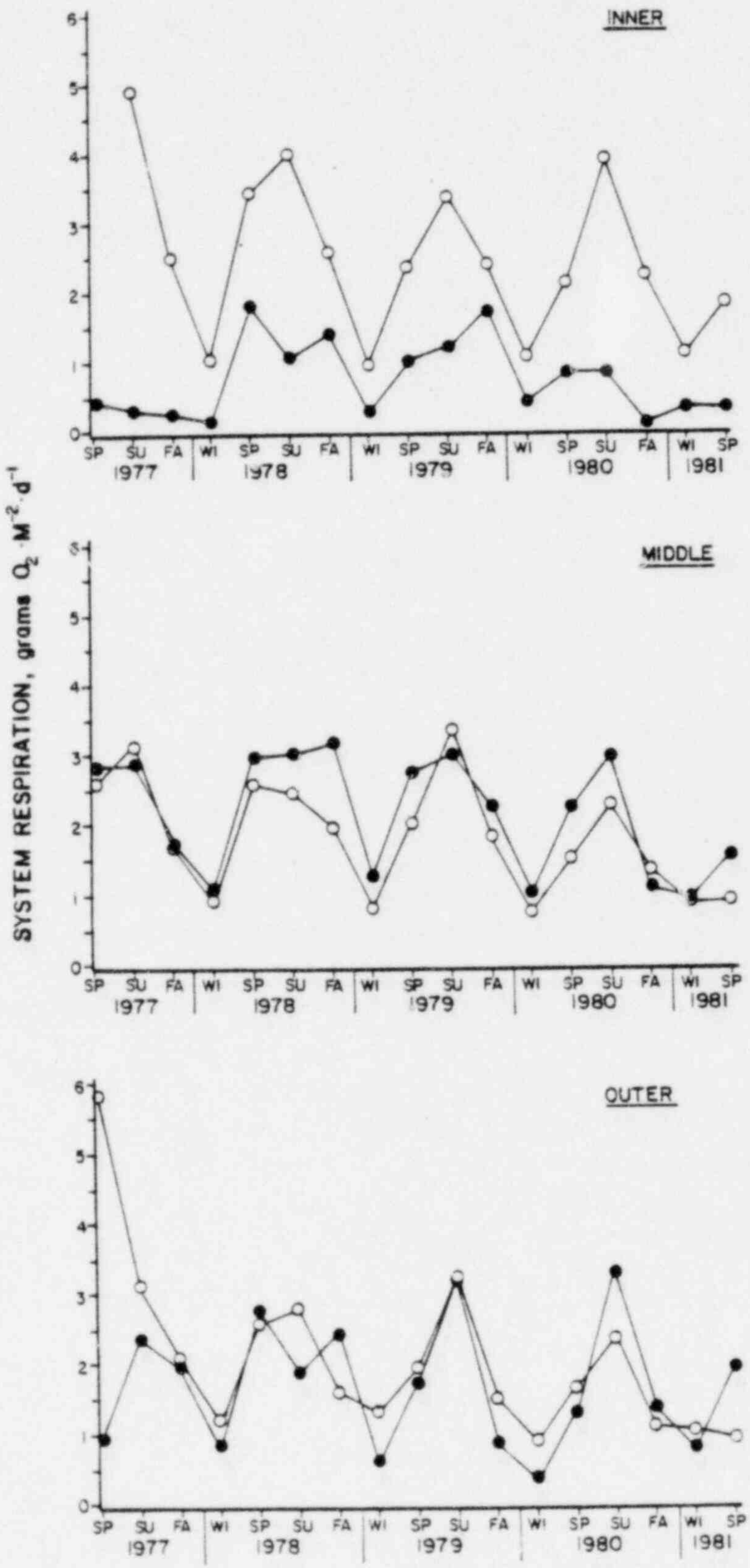

Figure 12. Seasonal mean system respiration for the Discharge (●) and Control (○) Bays.

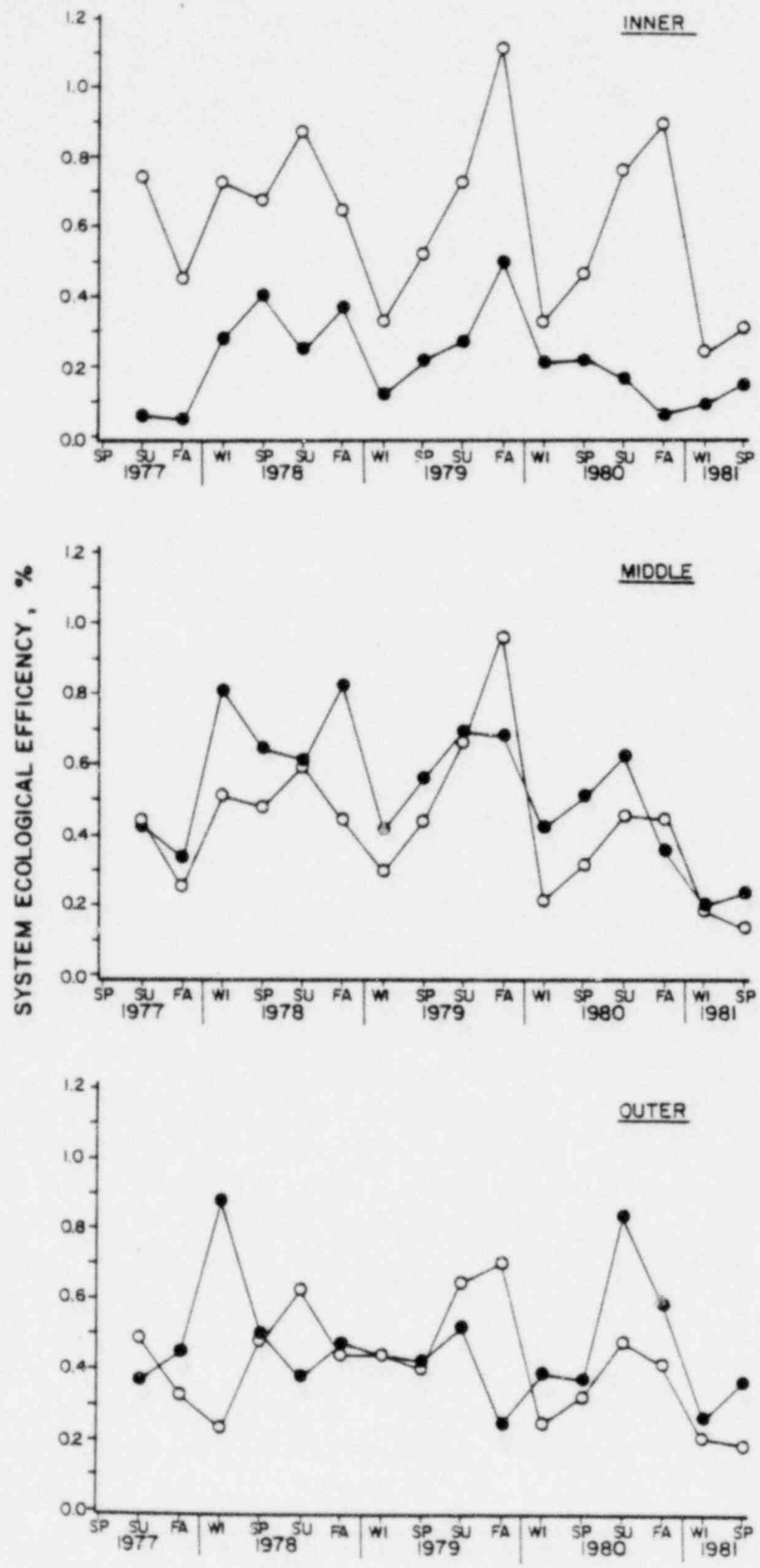

Figure 13. Seasonal mean ecological efficiencies for the Discharge (●) and Control (○) Bays.

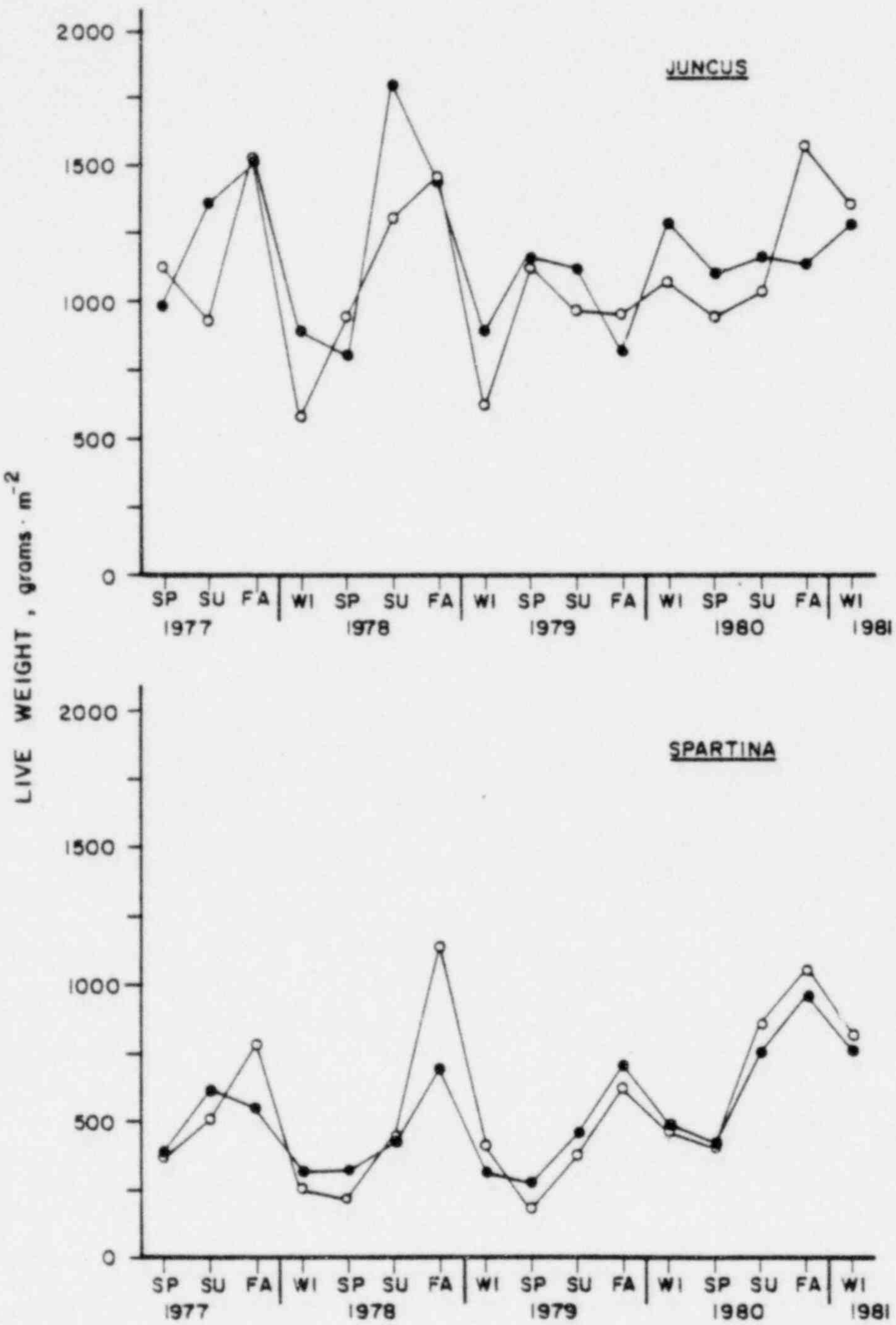

Figure 14. Seasonal mean live weights for the Discharge (●) and Control (○) Marshes.

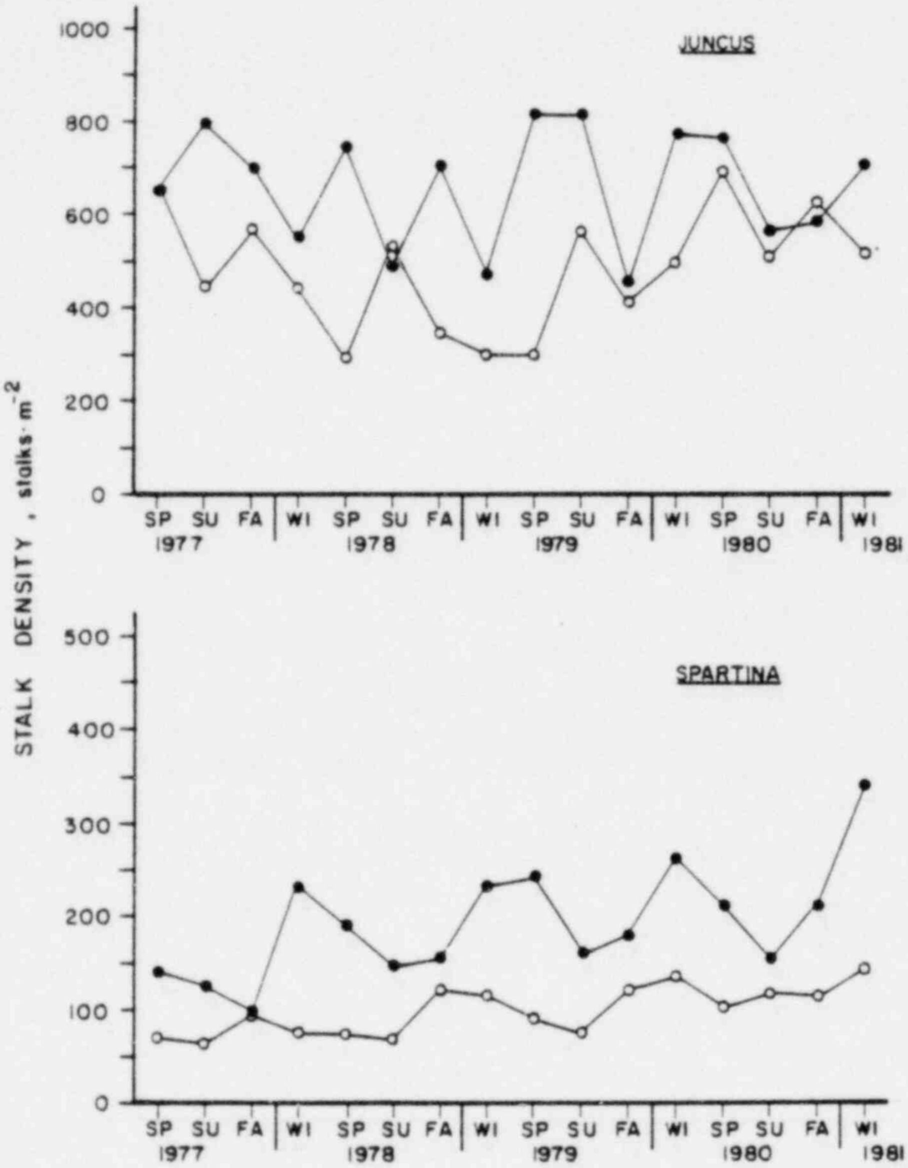

Figure 15. Seasonal mean live stalk densities for the Discharge (●) and Control (○) Marshes.

of both the Spartina and Juncus plants was consistently lower in the discharge marsh than in its control.

Stalk height of the salt marsh plants during the study period is presented in Figure 16. For both Spartina and Juncus, stalk height was consistently shorter in the discharge marsh compared to its control.

Snail and Fiddler Crab Densities

The density of the marsh periwinkle, Littorina irrorata, in both Spartina and Juncus marshes of the discharge side was found to be consistently greater than that of the controls (Fig. 17). Snail density was similar in both Juncus and Spartina marshes.

No consistent differences in fiddler crab burrow density was found between any of the marshes (Fig. 18).

Metabolism

Metabolism data for the salt marsh ecosystems at Crystal River are presented in Figures 19–21.

Figure 19 shows the 4-year trends in salt marsh gross productivity. There was no clear stimulation or inhibition of gross productivity observed for either salt marsh species, although, a seasonal shift was consistently recorded for Spartina with the discharge marsh attaining maximum productivity values several months earlier than the control marsh. Juncus was generally more productive than Spartina, averaging approximately 5.5 g $C \cdot m^{-2} \cdot d^{-1}$ for the former compared to 3.5 g $C \cdot m^{-2} \cdot d^{-1}$ for the latter.

Salt marsh net productivity measurements are presented in Figure 20. Once again no trends of stimulation or inhibition of this parameter were found in either salt marsh community. Net productivity of the Spartina marshes was generally lower than the corresponding Juncus sites.

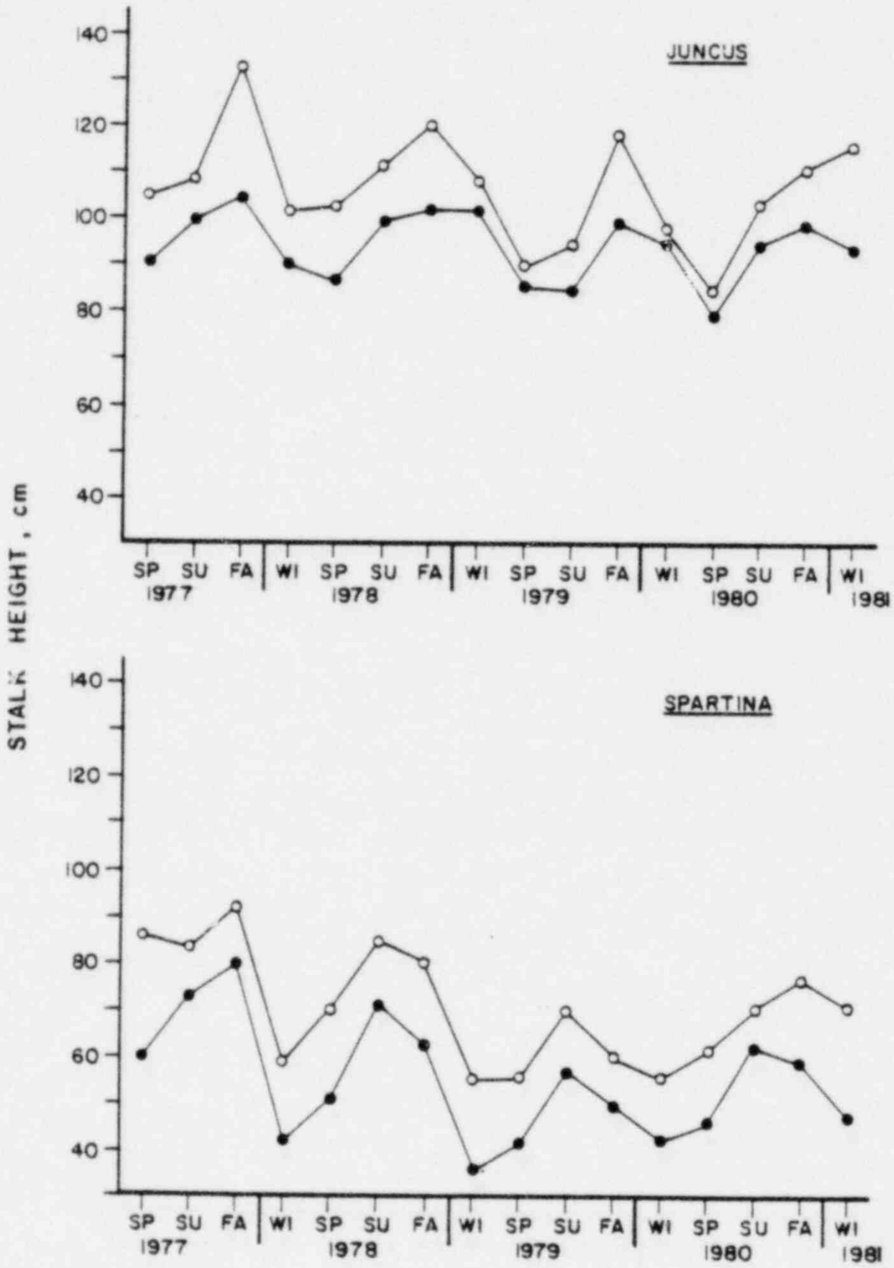

Figure 16. Seasonal mean stalk heights for the Discharge (●) and Control (○) Marshes.

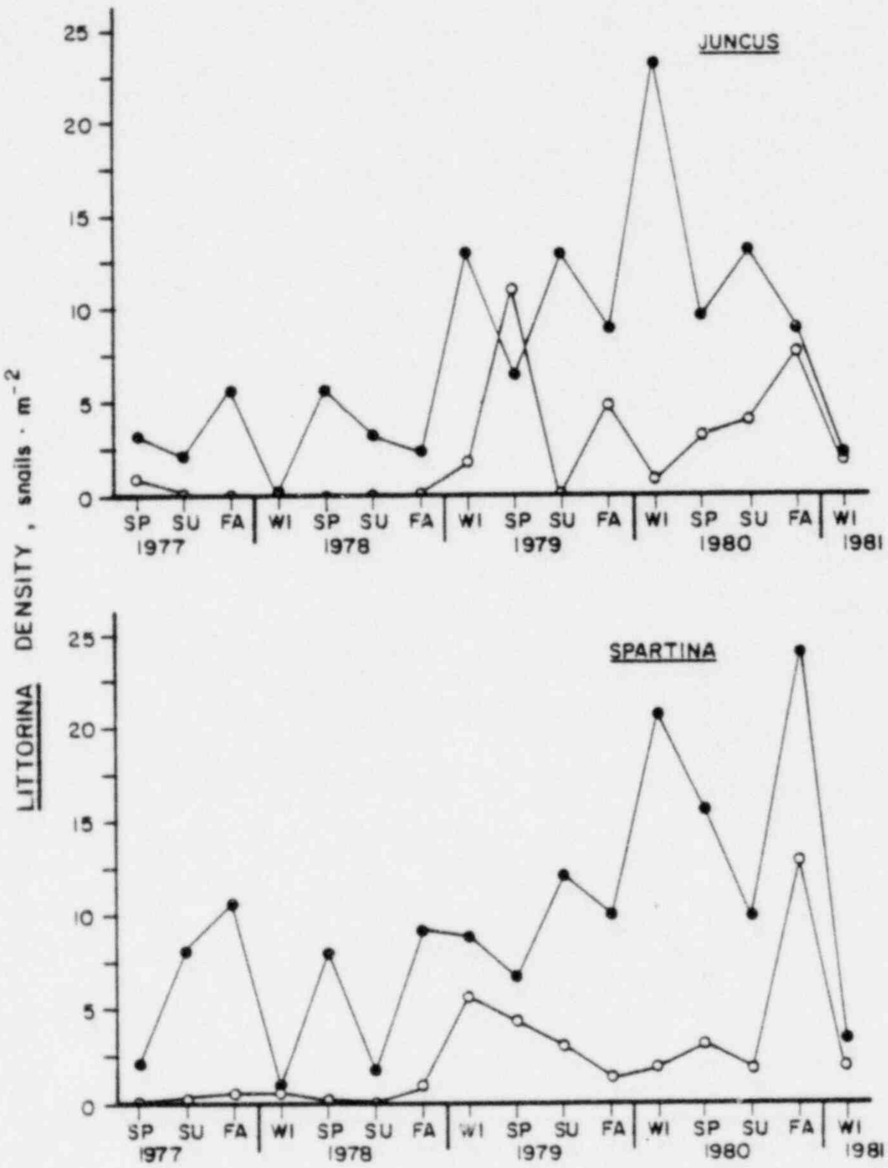

Figure 17. Seasonal mean marsh periwinkle (Littorina irrorata) densities for the Discharge (●) and Control (○) Marshes.

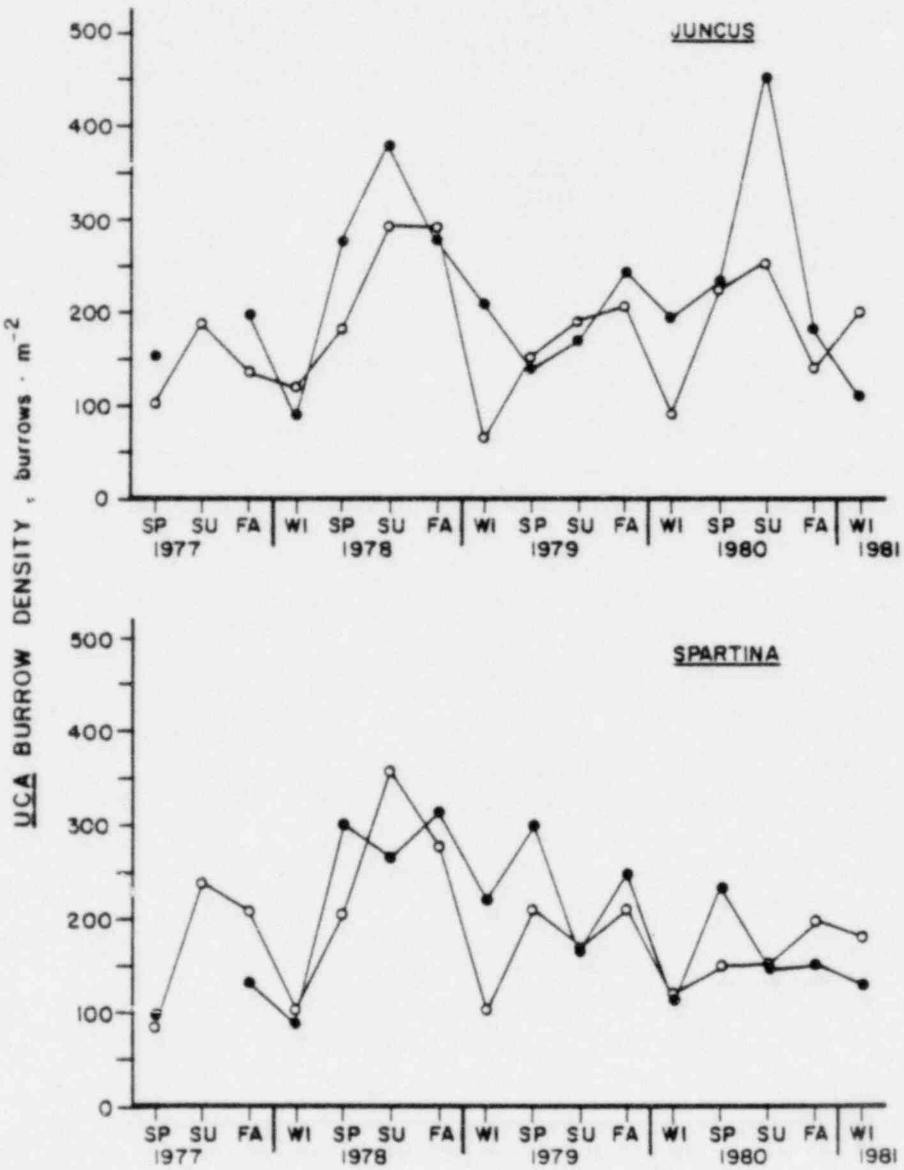

Figure 18. Seasonal mean fiddler crab (Uca spp.) burrow densities for the Discharge (●) and Control (○) Marshes.

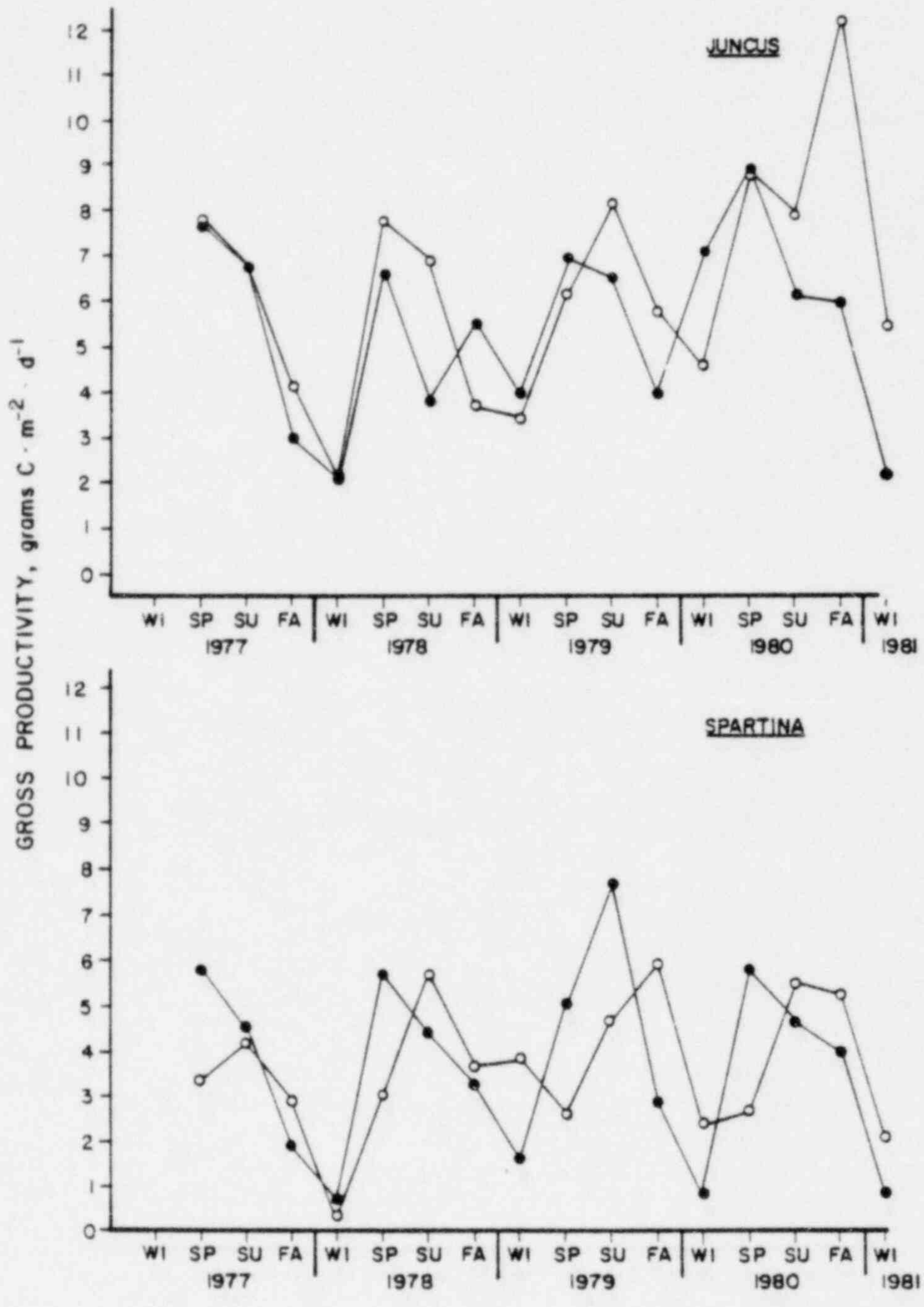

Figure 19. Seasonal mean gross productivities for the Discharge (●) and Control (○) Marshes.

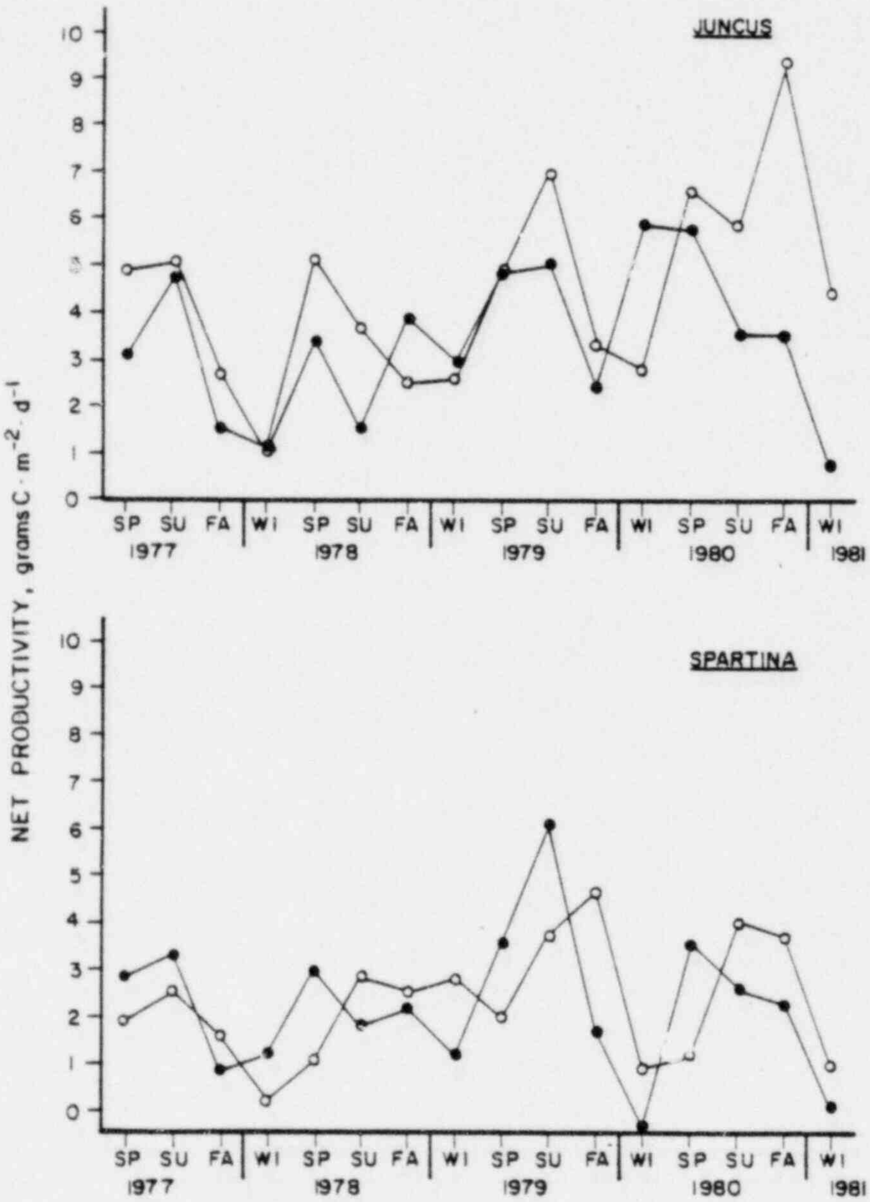

Figure 20. Seasonal mean net productivities for the Discharge (●) and Control (○) Marshes.

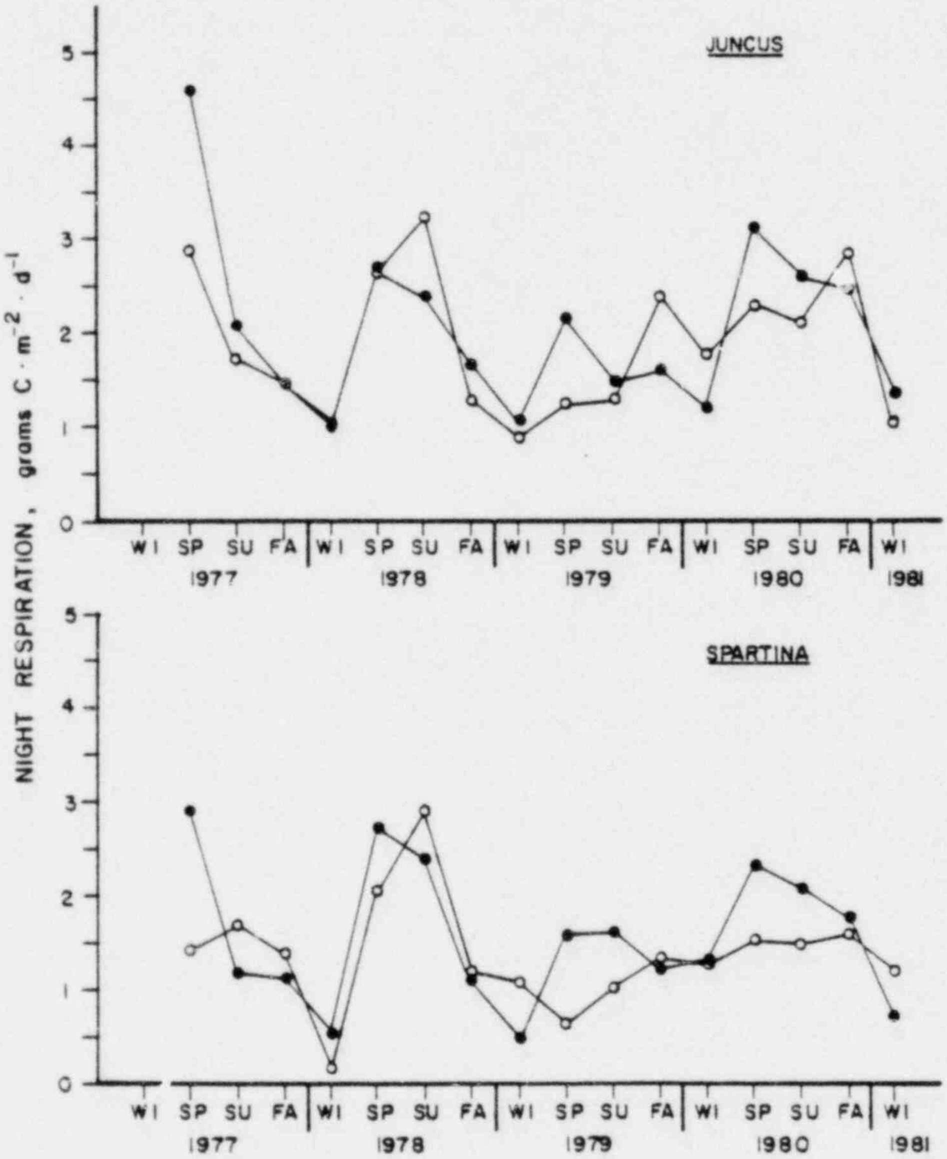

Figure 21. Seasonal mean night respiration for the Discharge (●) and Control (○) Marshes.

Night respiration data for the salt marsh ecosystems is summarized in Figure 21. Power plant operation had no consistent effect on this variable. Night respiration in the *Juncus* marsh was generally higher than that of the adjacent *Spartina* marsh.

DISCUSSION

Power Plant as a Forcing Function

System parameters such as structure and metabolism represent an integration of numerous physical and environmental variables. These environmental factors are often the result of forces or processes occurring outside the system of study and are referred to as "external forcing functions."

One of the most important aspects of the Crystal River metabolism study was the determination of the overall effect of the power plants on the structure and function of estuarine systems. The dominant factors resulting from power plant operation that had effects on the estuarine system were: temperature increase in discharge waters (Grimes and Mountain 1970; Smith et al. 1974); increase in water circulation in the discharge area (Carder et al. 1973); an increase in turbidity due to dredging and barge traffic; and an increase in nutrients in the discharge area (Odum et al. 1974). Some information allowing a factoring of effects such as temperature and turbidity data on estuarine processes was obtained during the course of the study. Other potentially important factors such as water circulation and nutrient availability were insufficiently sampled to draw definite conclusions concerning their role in estuarine metabolism. The parameter that provided the most valuable integrative record of the factors listed above was total power output on a monthly basis. Linear

regression analysis between power output and the measured estuarine parameters provides a basis for making conclusions concerning the impact of the power-generating units on the Crystal River estuary.

In determining the actual effect of the power plants on the estuarine systems it is also necessary to factor out the background changes in these parameters due to environmental factors other than those caused by the power generating units. The control data presented in the Results section of this report can be used for such a purpose. In the analysis that follows, control data have been subtracted from corresponding discharge data measured concurrently, providing "delta" values for regression analysis with power plant output.

Power Output

A summary of monthly power output from the three units combined, and from Unit 3 alone, is presented in Figure 22. Total monthly output varied between 200,000 and 1,100,000 MWH during the period of study from 1977 to 1981. The rated maximum possible output of these units is 1,353,335 MWH for a 30-day month. Figure 22 illustrates the importance of Unit 3 in providing power output greater than 500,000 MWH per month. During the last 3 years of study, Unit 3 supplied no appreciable output during May, June, and July.

Water Temperature

Figure 23 presents the temperature differential (ΔT) recorded between the discharge and control estuaries, graphed as a function of total monthly output. This ΔT was positive for all measurements taken and was significantly highly explained by power output ($R^2 \geq 0.50$) for all three bay systems. Average ΔT's for the bays were: Inner, 4.45°C; Middle,

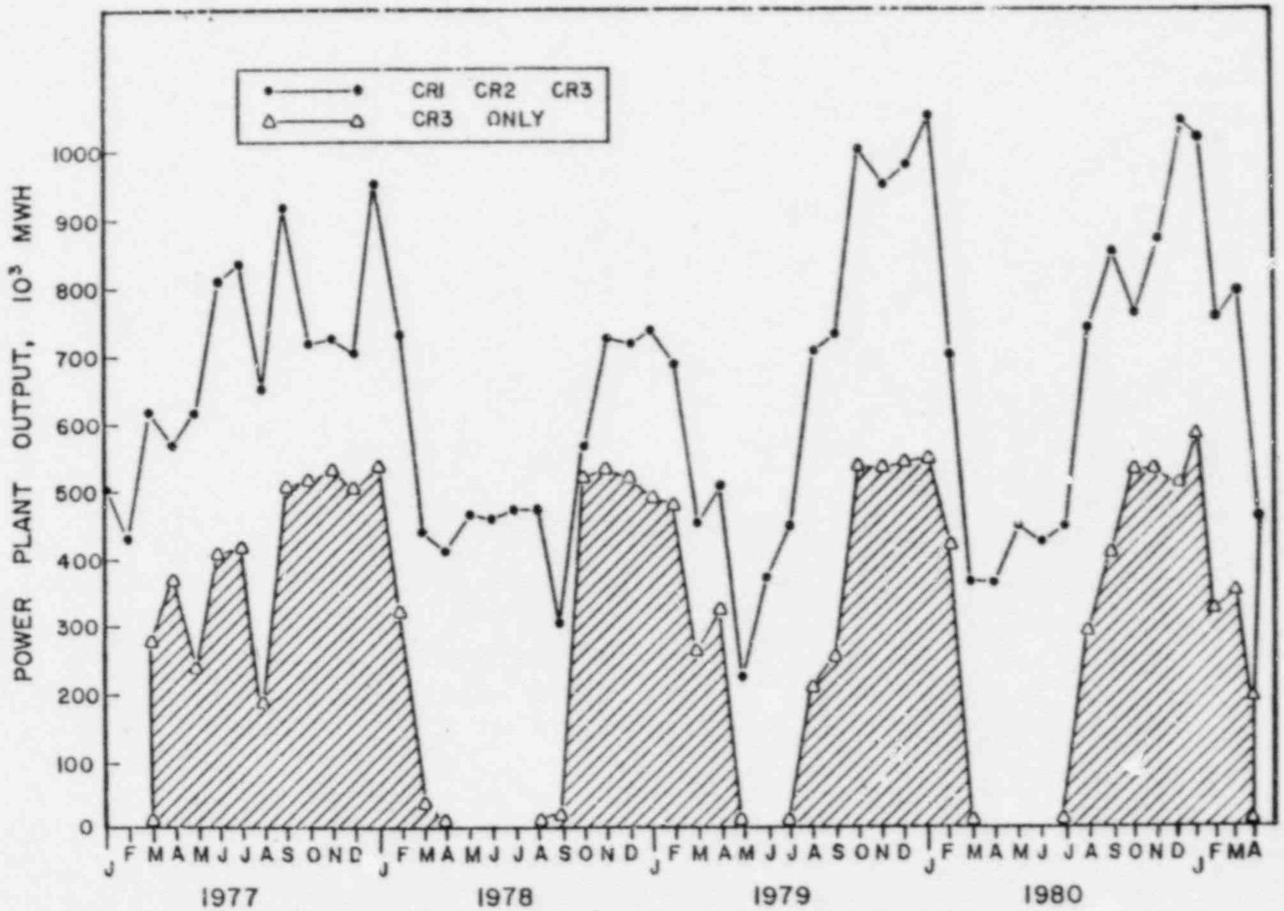

Figure 22. Monthly power output from the three units combined and from Unit 3 alone.

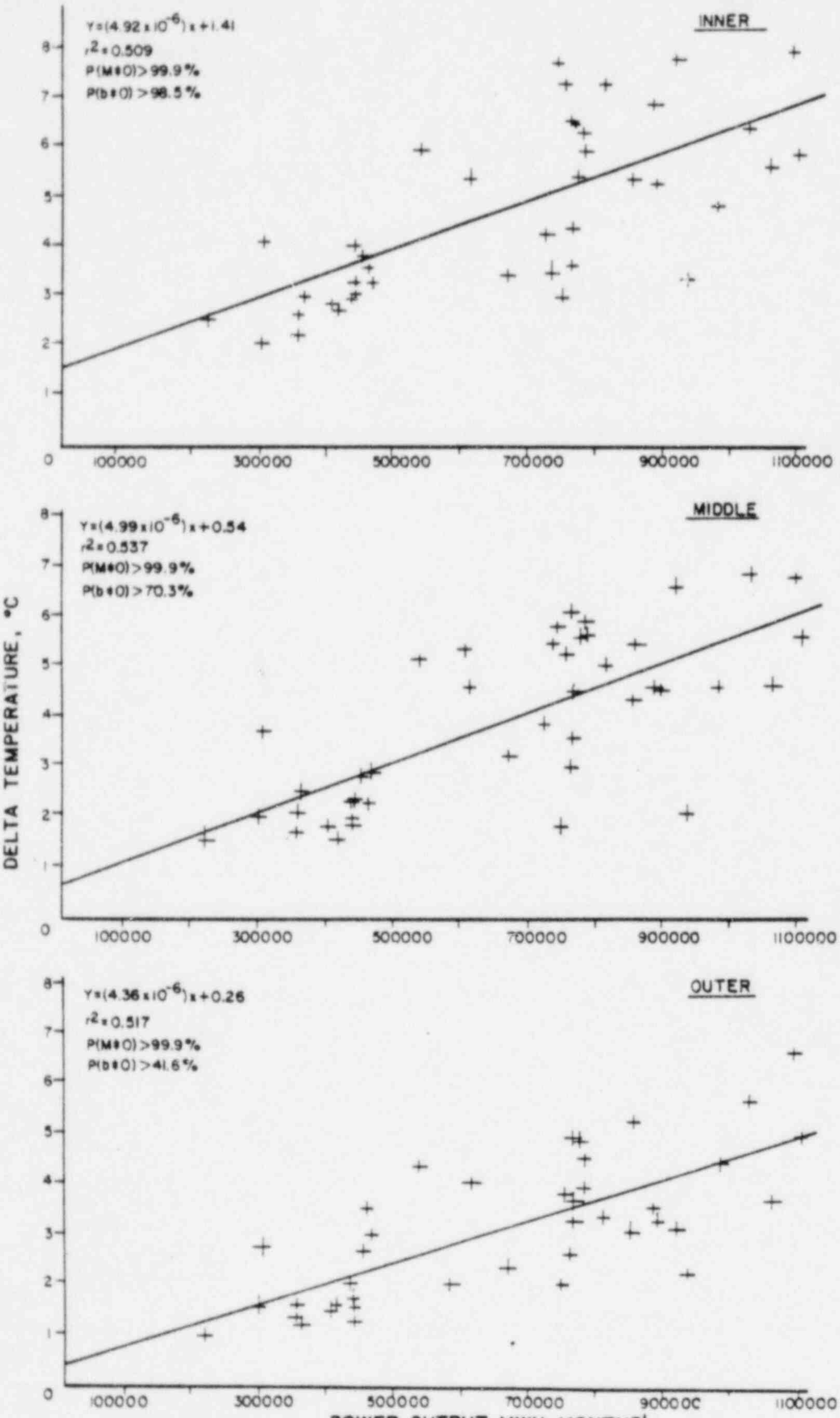

Figure 23. Regression of monthly temperature differential between the Discharge and Control Bays against total power output.

3.79°C; and Outer, 3.12°C. The fact that the intercept value for the Inner bays was significantly positive indicates that the Inner Discharge Bay has a higher background water temperature than its control bay. This may possibly result from a shallower mean depth at the sampling point in the discharge bay compared to the control.

Salinity and Light Extinction

The correlation between power output and the salinity differential in the three bay systems is presented in Fig. 24. Although the salinity of the Inner Discharge Bay was consistently higher than that of its control bay, this differential was not explained by the power output of the Crystal River units. Smaller salinity differentials in the middle and outer bays had a slight positive relationship with power output.

Similar results were found for light extinction measurements as indicated in Fig. 25. Once again, the light extinction differential was not explained by power plant output for the inner bays and only slightly dependent on output in the middle and outer bays.

These regressions clarify an important consideration in comparing the discharge bays to their control bays. The Inner Discharge Bay is fundamentally altered in terms of salinity and turbidity compared to its control because of the pumping of offshore water to its inshore location. The absence of a significant relationship with total power output may be explained by a threshold level of effect below the lowest pumping rate of the plants. Thus, whenever any of the power plants are in operation, the water in the Inner Discharge Bay is almost entirely of offshore origin rather than from inshore sources. The regression analysis confirms the earlier field and modelling studies (Carder et al. 1973; Klausewitz 1973;

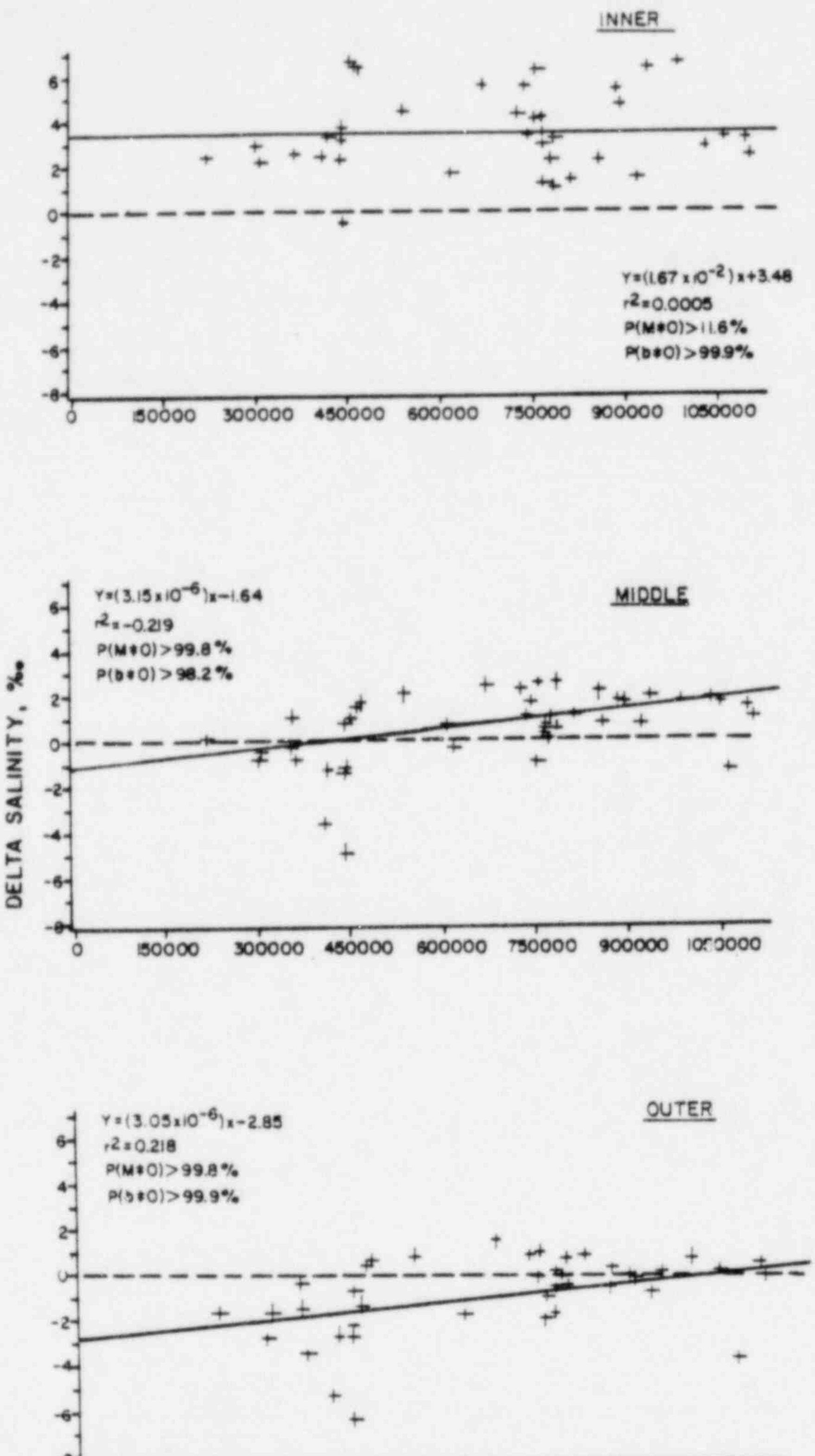

Figure 24. Regression of monthly salinity differential between the Discharge and Control Bays against total power output.

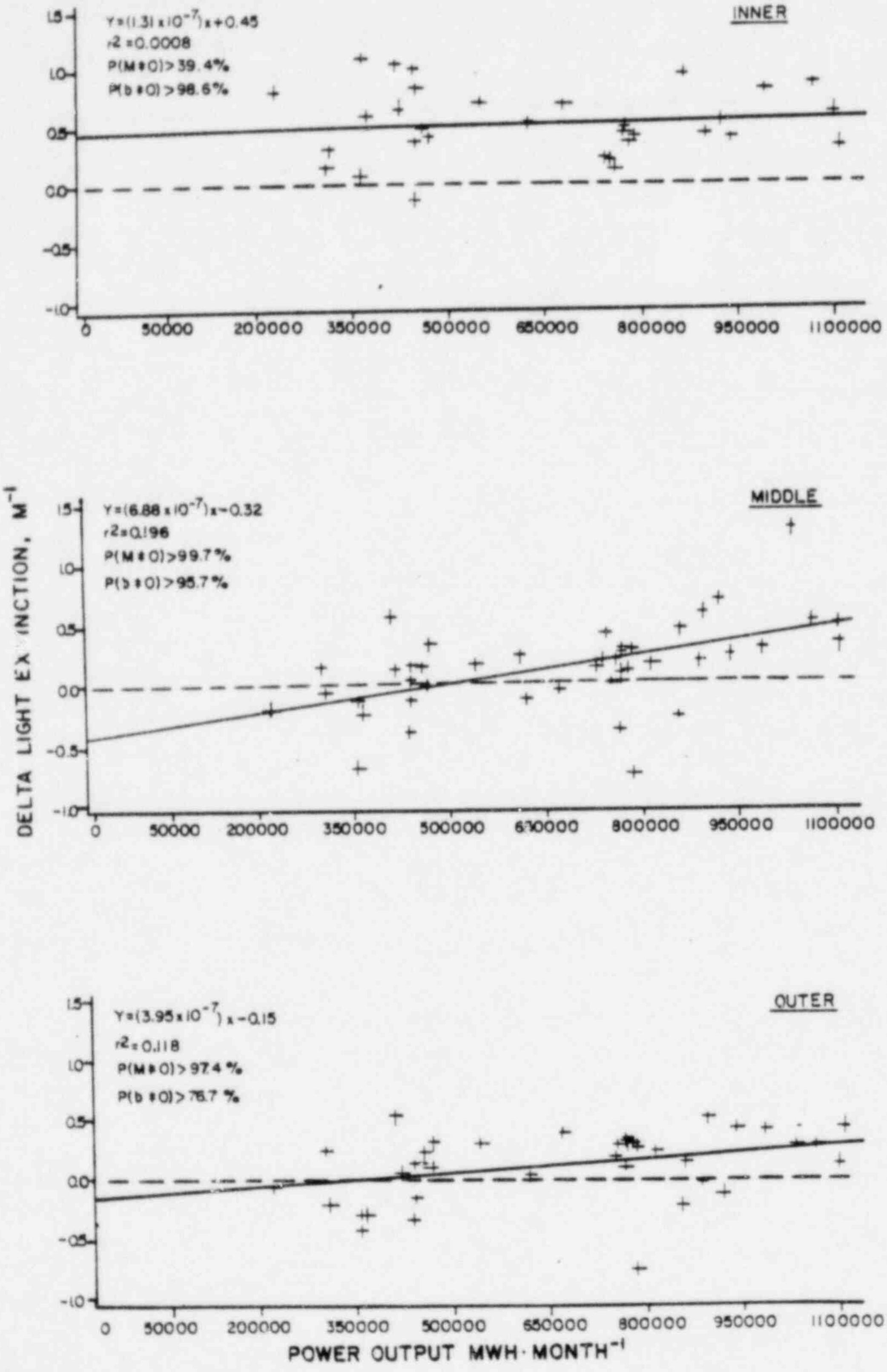

Figure 25. Regression of light extinction differential between the Discharge and Control Bays against total power output.

Cottrell 1974) that documented the flushing of the Inner Discharge Bay and the high flux of sediment to this basin. The slight positive regressions found in the middle and outer bays indicate that at the observed power plant pumping rates, these systems were not completely overwhelmed by offshore water. Also, the negative intercept values indicate that the Middle and Outer Control bays may have higher background salinity values than the corresponding discharge bays.

Plankton Metabolism

Figure 26 presents the regression graphs of plankton gross productivity differential against power plant output. No significant effect on this parameter attributable to power plant operation was detected. As noted earlier, there was also no consistent stimulation or inhibition of plankton productivity between any of the discharge and control bays. McKellar (1975) and Smith (1976) found similar results for phytoplankton productivity during their studies in the discharge bays prior to the start-up of Unit 3.

The linear regression analysis in Figure 26 is not designed to detect possible seasonal patterns of stimulation or inhibition in plankton gross productivity, so average seasonal means throughout the study period have been computed and are presented in Table 1. Seasonal effects were found in the Inner Discharge Bay where plankton gross productivity was significantly enhanced during the spring season and significantly inhibited during the warm summer months.

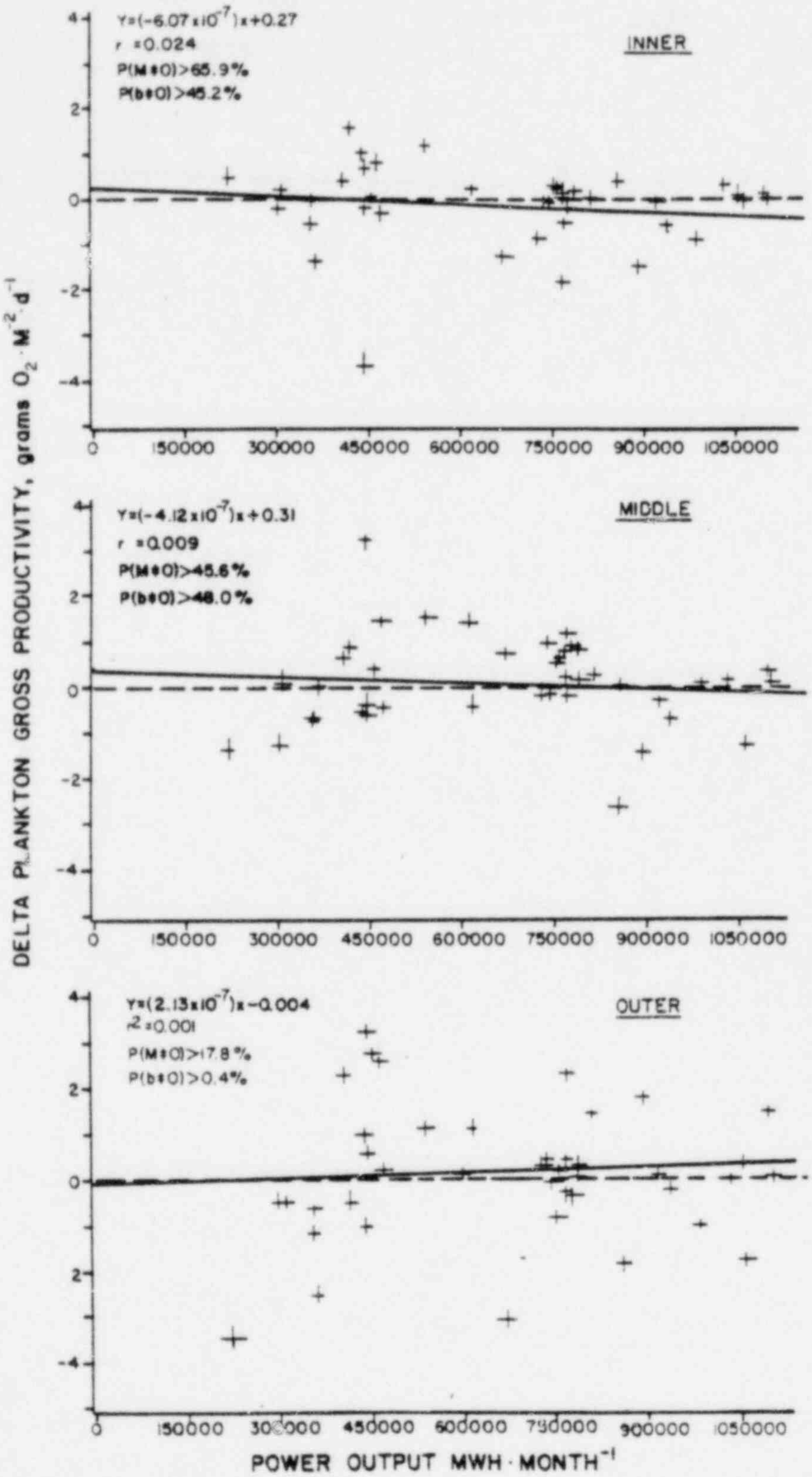

Figure 26. Regression of monthly plankton gross productivity differential between the Discharge and Control Bays against total power output.

Table 1. Differential plankton gross productivity data between discharge and control bays at Crystal River, Florida, during the period 1977–1981. Values are means ± two standard errors (n = 147).

	Season			
Bay	Winter	Spring	Summer	Fall
Inner	-0.01 ± 0.10	0.45 ± 0.38	-1.07 ± 0.48	-0.04 ± 0.16
Middle	-0.07 ± 0.08	0.14 ± 0.62	0.01 ± 0.60	0.18 ± 0.40
Outer	-0.19 ± 0.27	0.25 ± 0.88	0.58 ± 0.67	-0.21 ± 0.42

System Metabolism

The regression of differential system gross productivity data on power output is displayed in Figure 27. Although confirming that system gross productivity was consistently lower in the Inner Discharge Bay than in the Inner Control Bay, and consistently higher in the Middle Discharge Bay relative to its control, the regression analysis found only a slight negative relationship with power plant output. No effect of power plant operation was visible in the gross productivity data for the outer bays.

The possibility of seasonal effects on system gross productivity was also investigated. The 4-year seasonal means of these delta values are summarized in Table 2. Average inhibition of system metabolism in the Inner Discharge Bay increased from -1.3 to -6.2 g $O_2 \cdot m^{-2} \cdot d^{-1}$ between the winter and summer seasons. The stimulation observed in the Middle Discharge Bay occurred during the cooler seasons and was not significant during summer.

Marsh Metabolism

Gross productivity differential between discharge and control marsh sites is plotted versus power output in Figure 28. *Juncus* gross productivity was not significantly affected by power output in the Discharge Marsh, but *Spartina* productivity did show significant inhibition. The night respiration differential analysis between discharge and control marshes is presented in Figure 29. Night respiration of both species was significantly inhibited by increasing power plant output.

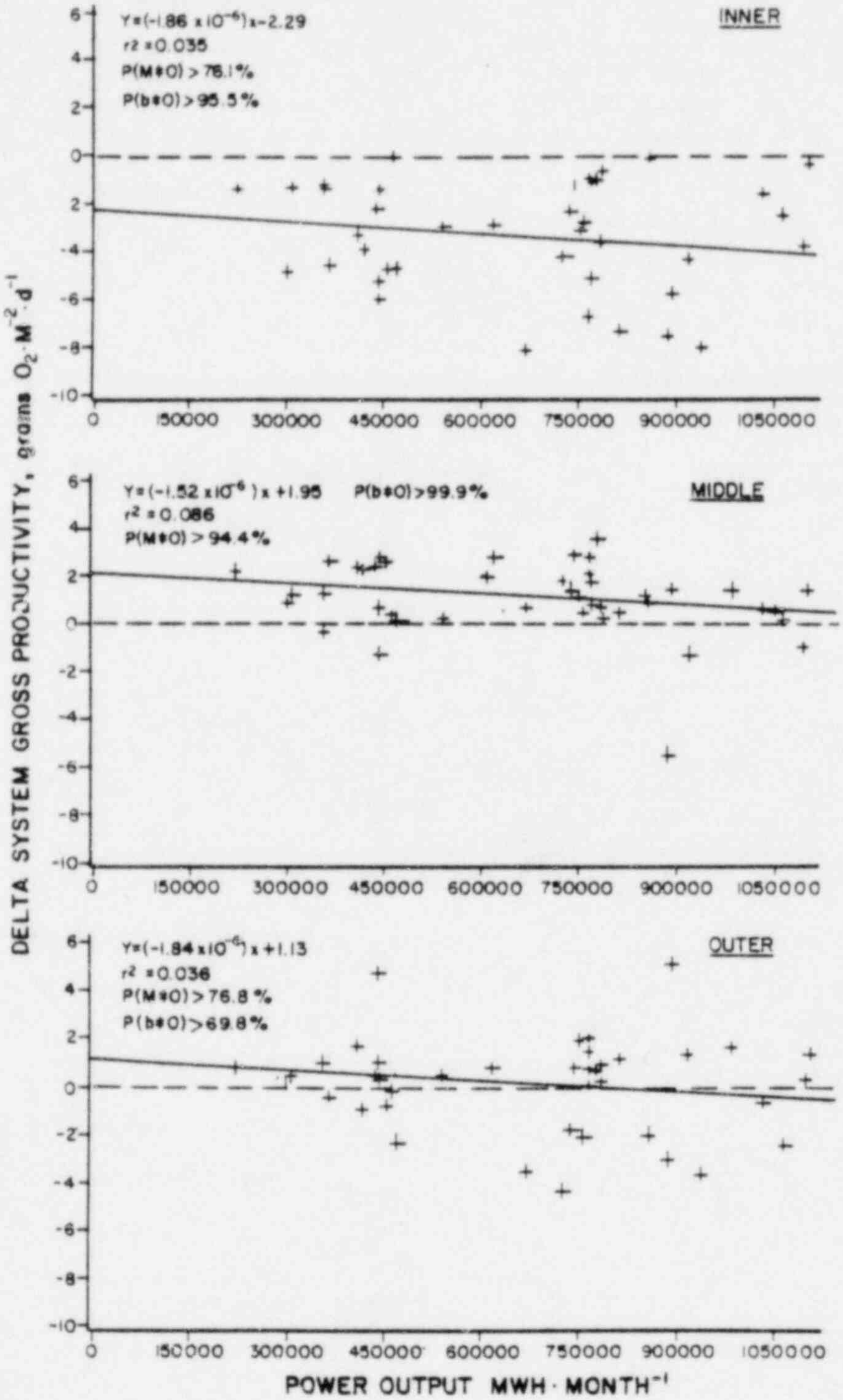

Figure 27. Regression of monthly system gross productivity differential between the Discharge and Control Bays against total power output.

Table 2. Differential system gross productivity data between discharge and control bays at Crystal River, Florida, during the period 1977–1981. Values are means ± two standard errors (n = 168).

Bay	Season			
	Winter	Spring	Summer	Fall
Inner	-1.28 ± 0.30	-2.70 ± 0.70	-6.16 ± 0.88	-3.02 ± 0.85
Middle	0.67 ± 0.40	1.69 ± 0.58	0.75 ± 0.94	0.89 ± 0.71
Outer	0.56 ± 0.45	0.20 ± 0.80	-0.09 ± 1.09	-0.10 ± 0.76

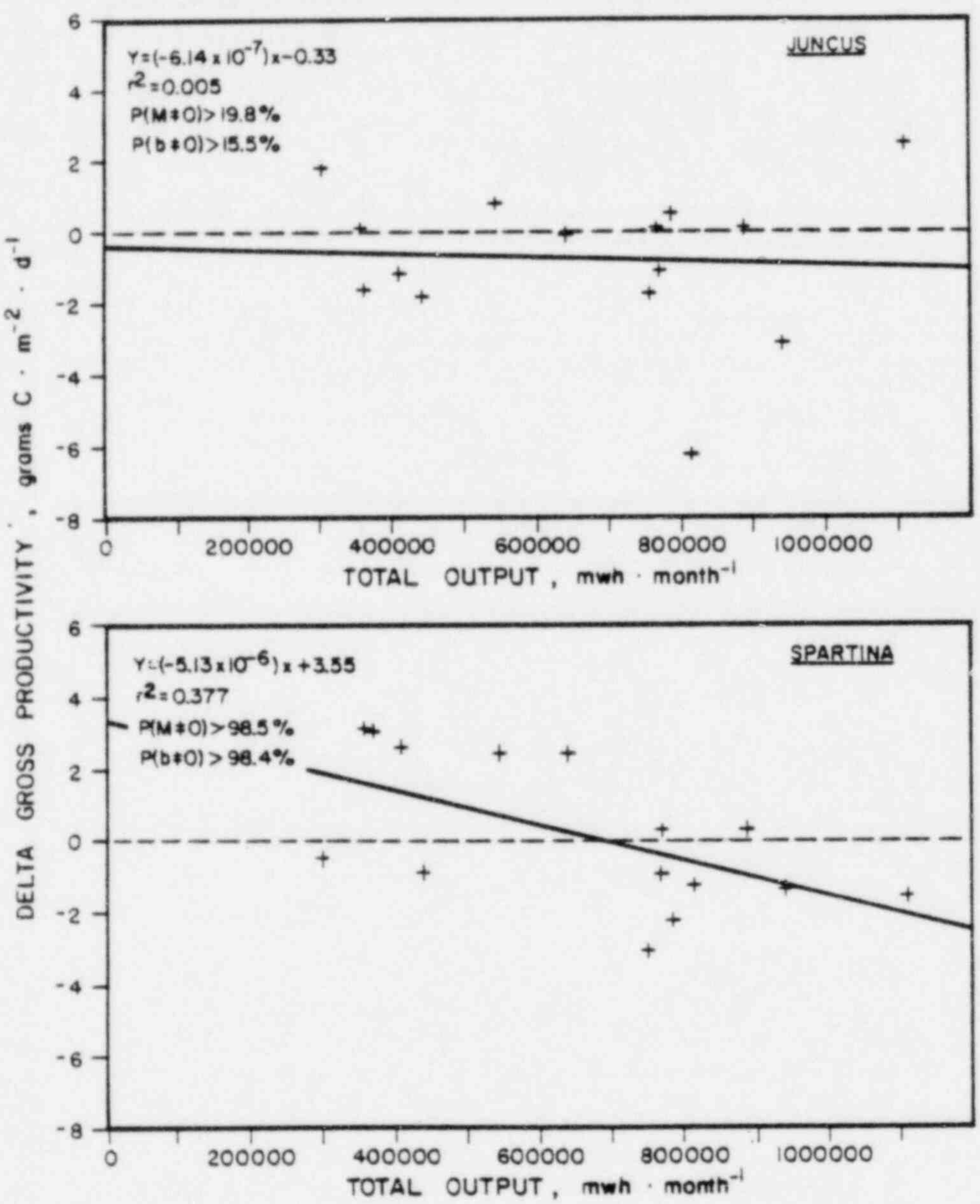

Figure 28. Regression of monthly gross productivity differential between the Discharge and Control Marshes against total power output.

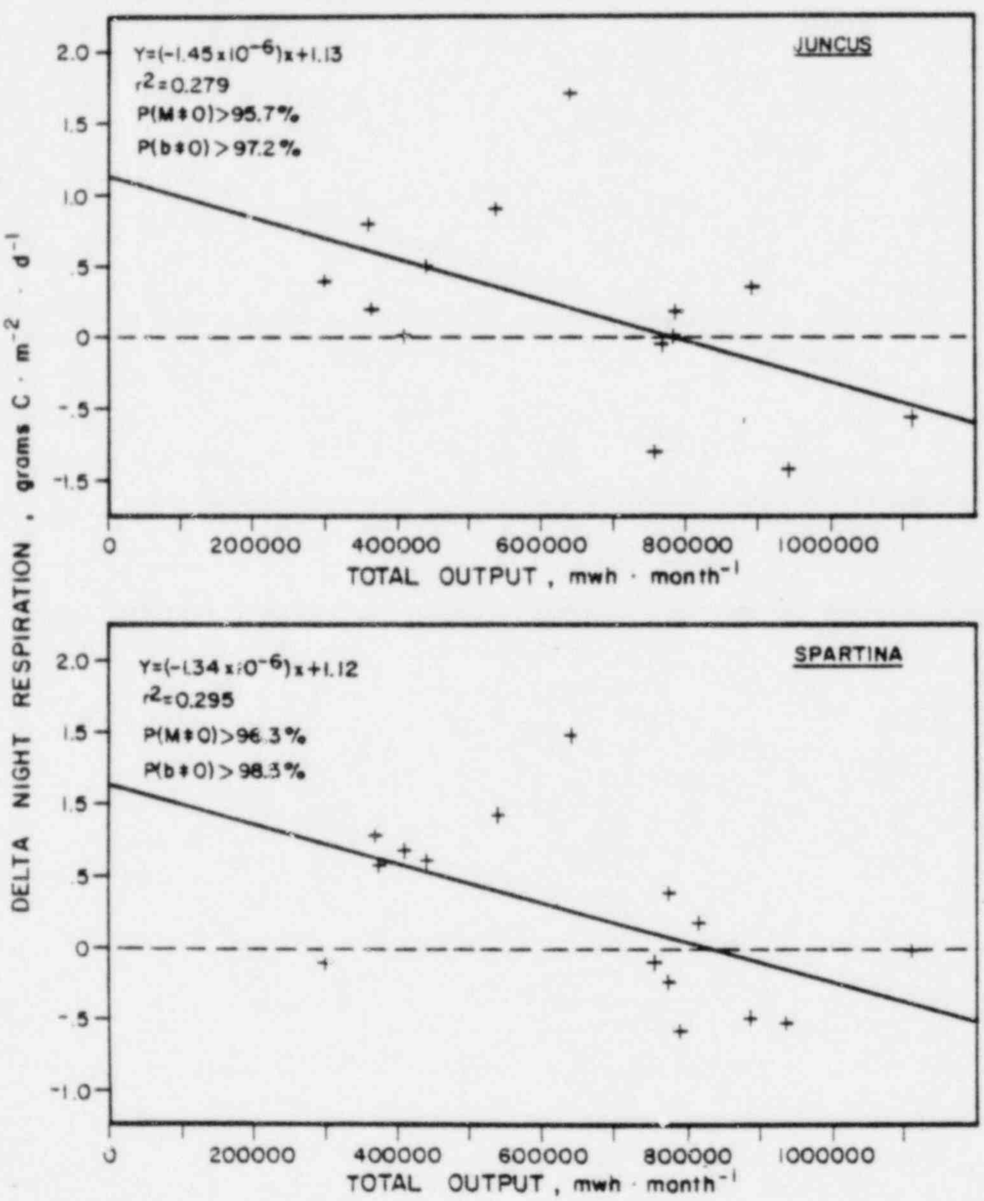

Figure 29. Regression of monthly night respiration differential between the Discharge and Control Marshes against total power output.

Additional Effects of Unit 3

The graphs presented in the preceding section are useful in determining the average impact of the additional capacity of Unit 3 at Crystal River. All of the points on Figures 23 to 29 where power output was above 500,000 MWH per month, were the result of the additional output of Unit 3. If a vertical line is drawn on those graphs at the 500,000 MWH per month output value, changes occurring to the right of this line can be attributed to the additional capacity of Unit 3.

For water temperature (Fig. 23), this additional power output resulted in an average additional temperature rise of approximately 2°C between the Inner Discharge and Control bays, resulting in combined ΔT's as high as 9.6°C during Unit 3 operation.

The operation of Unit 3 had no significant additional impact on salinity, light extinction, or plankton gross productivity values in the Inner Discharge Bay, and slightly increased salinity and light extinction levels in the middle and outer bays relative to their controls (Figs. 24–26).

The average inhibitory effect of Unit 3 operation on system gross productivity in the Inner and Middle Discharge Bays was approximately 1 g $O_2 \cdot m^{-2} \cdot d^{-1}$. This represents from one-fourth to one-half of the total average system gross productivity remaining in these systems.

Unit 3 operation reduced the average Spartina gross productivity by nearly 2 g $C \cdot m^{-2} \cdot d^{-1}$ (Fig. 28). This reduction is nearly 50% of the average gross productivity in the Spartina Discharge Marsh.

In their analysis of the Crystal River estuarine data presented in this report, Benkert and Lucas (in prep.) documented a significant corre-

lation between water temperature and metabolism. Figures 30 and 31, which are borrowed from that report, illustrate the decline in system and plankton gross productivity at temperatures above 32°C. This finding has critical importance in interpreting the effect of additional heated water discharge to these estuarine systems. As long as the temperature of water in the discharge area is less than 32°C, gross metabolism is enhanced by power plant operation. But, when water temperatures are naturally highest during the summer season due to high insolation, the estuarine ecosystems respond to additional thermal loading by decreases in metabolism. The summer outages for Unit 3 during the last 3 years of this study may have prevented even greater metabolism decreases in the Inner Discharge Bay than those documented in this report. During the one summer season when Unit 3 had significant power output (1977), record lows for plankton (Figs. 7 and 8) and system (Figs. 10 and 11) productivity were recorded in this bay. This inhibitory effect of Unit 3 summer operation was apparently limited to the Inner Discharge Bay, covering an area of approximately 100 hectares (250 acres).

Estuarine and Marsh Adaptations

Adaptations by the estuarine communities to the new physical regimes caused by the addition of Unit 3 were expected to occur during the long time span of this study (Odum et al. 1974). However, no recovery of the heavily impacted Inner Discharge Bay system was observed. In fact, system gross productivity (Fig. 10) and respiration (Fig. 12) for these bays gradually decreased during the last 3 years of study. Enhanced metabolism in the Middle Discharge Bay relative to its control may have been a physi-

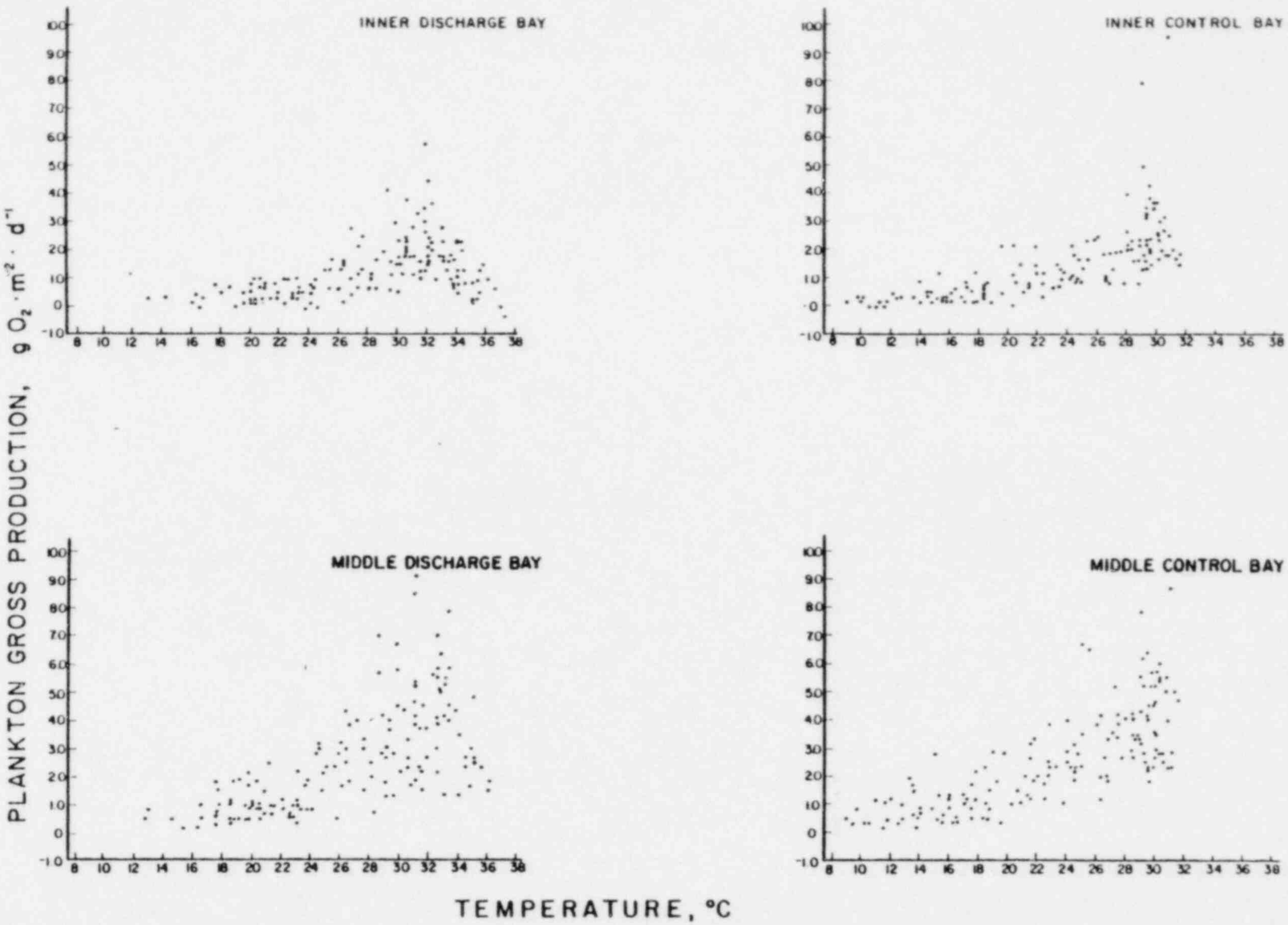

Figure 30. Response of system gross productivity to water temperature for the Inner and Middle Bays (from Benkert and Lucas in prep.).

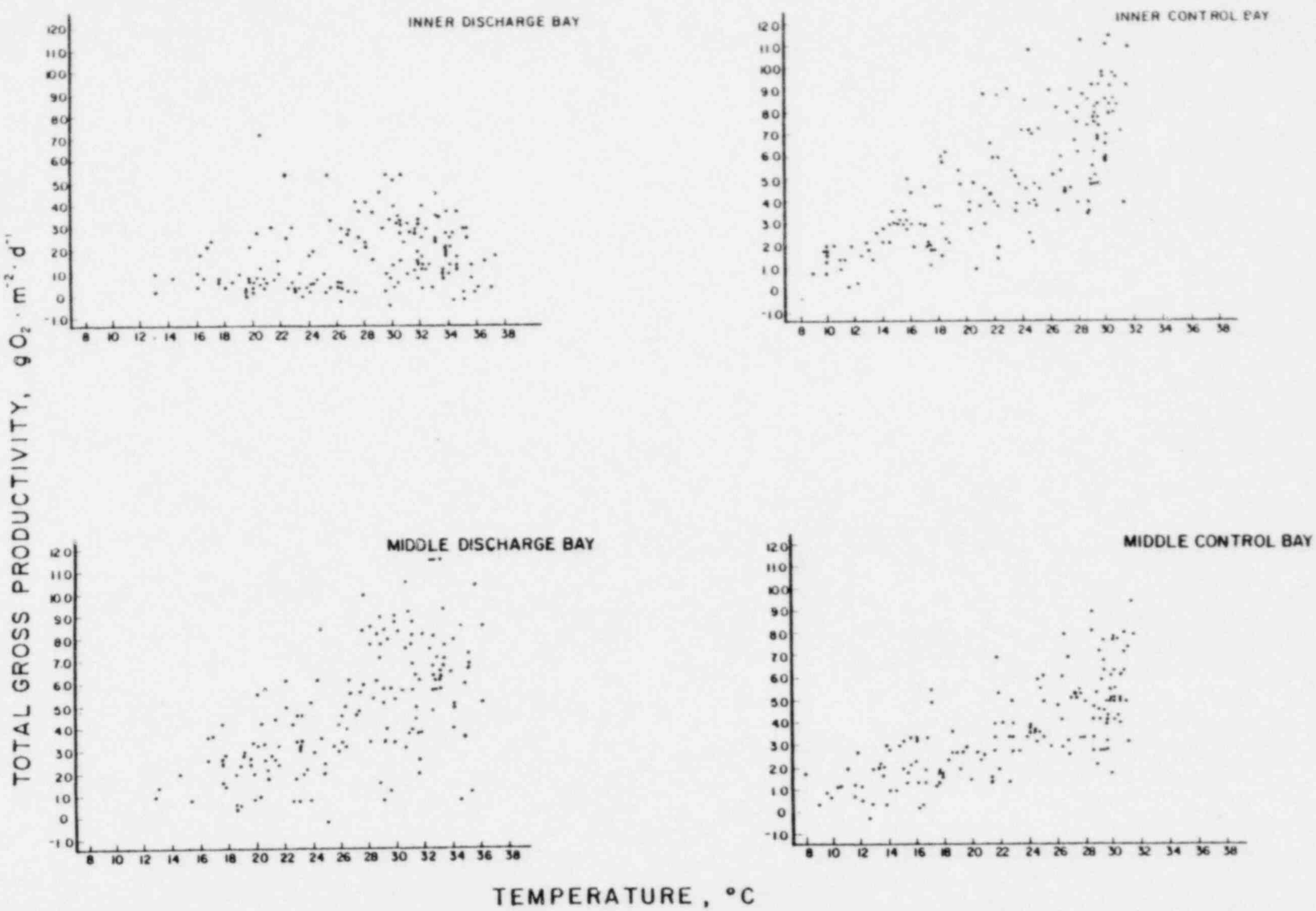

Figure 31. Response of plankton gross productivity to water temperature for the Inner and Middle Bays (from Benkert and Lucas in prep.).

cal response to higher temperatures or an adaptation through changes in species dominance.

It is interesting to note that water temperatures above 32°C were never recorded in the control bays during the course of this study and that this temperature appeared to be a critical metabolism maxima as discussed in the previous section. This connection leads to the interesting speculation that local producer populations at Crystal River may not contain species that are adapted for high productivity at high water temperatures, if indeed such species do exist elsewhere. In fact, Thorhaug (1974), working in a south Florida estuary, noted biomass maxima for several marine macrophytes and macroalgae at 31°C and senescence and death above 32°C.

If any adaptations did occur, they must have occurred soon after the start-up of Unit 3. It is likely that even to maintain reduced metabolism levels, the impacted estuarine systems had undergone some morphological and taxonomic adaptations to the new regimes. For example, in the Inner Discharge Bay, the planktonic community replaced the benthic community as the dominant component in system metabolism as compared to the preoperational period studied by Smith (1976). An adaptation phenomena was better documented for the _Spartina_ and _Juncus_ salt marsh ecosystems. Although metabolism of these systems was not consistently altered due to treatment, obvious morphological differences were found between the discharge and control sites. For both marsh plant species, the predominant growth form changed to greater numbers of shoots and smaller size per shoot in the discharge marshes compared to the control marshes. This apparent adaptation resulted in similar total biomass and system metabolism between the two treatment areas.

CONCLUSIONS

1. Power plant operation near Crystal River, Florida, significantly increased temperature, salinity, and turbidity of inshore bay systems during the 4 years of study.
2. Planktonic productivity and respiration were neither consistently stimulated nor inhibited by power plant operation, although seasonal inhibition of plankton gross productivity by water temperatures above 32°C was observed.
3. A mixed response of system gross productivity to power plant operation was observed in the estuarine bays. The Inner Discharge Bay productivity was consistently lower compared to its control, with greatest inhibition during the summer months when water temperatures were above 32°C. On the other hand, in the cooler Middle Discharge Bay system productivity was generally enhanced compared to its control bay. The Outer Discharge Bay was more productive than its control during the colder months.
4. System net productivity and respiration were reduced in the Inner Discharge Bay compared to its control bay.
5. Live plant weight, _Uca_ burrow density, and salt marsh gross productivity, net productivity, and respiration were not consistently altered between discharge and control _Spartina_ and _Juncus_ sites, although significant seasonal shifts were observed in timing of productivity.

6. Linear regression analysis indicated that increased power output from the three units at Crystal River significantly reduced Spartina gross productivity and night respiration and Juncus night respiration of the discharge marshes compared to their controls.
7. The primary effect of the addition of Unit 3 was the occurrence of stressful temperatures in the Inner Discharge Bay during the warmer months with some compensation through stimulation of metabolism during the colder months. During the last 3 years of the 4-year study period, Unit 3 supplied no appreciable output during May, June, and July.
8. T overall detrimental effect of the three power plants on metabolism of Crystal River estuarine and salt marsh ecosystems during the study period (1977–1981) appears to have been limited to an area no larger than the Inner Discharge Bay—100 hectares (250 acres).

ACKNOWLEDGMENTS

This report is based on the energy and efforts of many persons who are currently or were formerly affiliated with the University of Florida. The principal investigator during the 4 years of field studies at Crystal River was Dr. Howard T. Odum. Dr. Odum played the main role in the instigation and completion of this research.

Mr. John W. Caldwell was project coordinator and led field and office activities for the first 3 years of the Crystal River study. Dr. Clay L. Montague was project coordinator during the last year of the project.

The following graduate and undergraduate student assistants provided the greatest amount of time to the completion of the project goals: K. Benkert, D. Campbell, G. Goforth, P. Goren, K. Herndon, J. Higman, D. Hoelzer, D. Hornbeck, J. Kosik, K. Limburg, J. Lucas, K. Riddell, L. Schwartz, P. Wallace, and A. Watson.

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APPENDIX A

SUMMARY OF DATA FROM THE DISCHARGE AND CONTROL BAYS

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
1	SP77	0.40	0.14	0.26	0.24	0.21	0.03	.	26.3	24.6	1.90	.	0.6000	4	23	77
2	SP77	2.99	2.39	0.60	0.39	-0.39	0.78	.	35.3	29.4	1.80	.	0.1304	6	97	77
3	SU77	0.18	-0.10	0.28	0.29	-0.65	0.94	4200	35.1	28.0	2.00	0.017143	1.6111	7	0	77
4	SU77	1.80	1.50	0.00	-0.39	-0.92	0.53	7400	37.3	29.3	1.30	0.097297	-0.2167	7	37	77
5	SU77	0.43	0.18	0.25	0.04	-0.45	0.49	5570	37.1	29.8	1.10	0.030880	0.0930	7	43	77
6	SU77	-0.13	-0.45	0.32	0.14	-0.04	0.18	4700	34.9	30.1	2.30	-0.010879	-1.0769	8	30	77
7	SU77	-0.28	-0.45	0.17	2.03	0.25	1.78	6030	34.3	30.9	2.30	-0.018574	-7.2500	8	33	77
8	SU77	1.45	0.44	0.84	1.44	1.16	0.28	3870	30.1	28.1	1.70	0.149871	0.9931	8	73	77
9	SU77	2.45	1.75	0.70	1.84	1.73	0.11	5230	30.7	26.3	1.40	0.187380	0.7510	8	77	77
10	SU77	1.70	1.35	0.35	0.73	0.53	0.20	6579	33.8	29.6	1.90	0.103359	0.4294	9	27	77
11	SU77	0.15	0.15	0.00	1.55	1.15	0.40	6062	35.8	32.5	1.90	0.099285	10.3333	9	63	77
12	SU77	0.49	0.39	0.10	0.97	0.72	0.25	4896	35.9	32.5	1.70	0.040033	1.9796	9	67	77
13	FA77	1.92	0.13	1.79	0.66	0.37	0.29	5466	33.8	31.2	1.50	0.140505	0.3438	10	3	77
14	FA77	0.83	0.16	0.67	0.97	0.78	0.19	5238	33.4	31.1	2.10	0.063383	1.1667	10	7	77
15	FA77	0.27	0.27	0.00	0.56	0.42	0.14	6062	26.7	28.5	1.30	0.016713	2.0741	10	57	77
16	FA77	0.48	0.48	0.00	0.66	0.40	0.26	6227	26.1	28.0	1.10	0.030833	1.3750	10	60	77
17	FA77	0.16	0.06	0.10	0.68	0.56	0.12	2961	27.3	29.7	1.40	0.021614	4.2500	11	3	77
18	FA77	0.27	0.27	0.00	0.49	0.27	0.22	4441	19.5	29.3	1.40	0.024319	1.8148	11	47	77
19	FA77	0.39	0.39	0.00	0.61	0.31	0.30	4347	23.3	30.0	1.40	0.035887	1.5641	11	50	77
20	FA77	0.39	0.37	0.02	0.06	-0.01	0.07	2619	23.8	25.6	1.20	0.059565	0.1538	11	97	77
21	FA77	0.37	0.29	0.08	.	1.00	.	3416	25.4	25.9	1.10	0.043326	.	11	99	77
22	FA77	0.63	0.63	0.00	0.54	0.37	0.17	.	22.7	29.0	.	.	0.8571	12	63	77
23	FA77	0.48	0.48	0.00	0.28	0.24	0.04	.	22.9	28.5	.	.	0.5833	12	67	77
24	WI78	0.23	0.13	0.10	0.29	0.20	0.09	159	13.0	23.8	.	0.578616	1.2609	2	3	78
25	WI78	0.93	0.49	0.44	0.40	0.33	0.07	453	13.1	24.5	.	0.821192	0.4301	2	7	78
26	WI78	0.51	0.51	0.00	0.79	0.79	0.00	1013	17.4	26.9	.	0.201382	1.5490	2	60	78
27	WI78	0.49	0.49	0.00	0.51	0.29	0.22	1358	18.0	26.5	0.27	0.144330	1.0408	2	63	78
28	WI78	0.64	0.64	0.00	0.65	0.54	0.11	2028	18.4	22.7	1.70	0.126233	1.0156	3	13	78
29	WI78	2.27	2.15	0.12	.	.	.	4221	19.8	19.1	2.27	0.215115	.	3	63	78
30	WI78	0.45	0.41	0.04	0.68	0.68	0.00	4404	20.8	17.4	3.40	0.040672	1.5111	3	97	78
31	WI78	0.80	0.44	0.36	0.90	0.73	0.17	4383	21.5	16.7	1.53	0.073009	1.1250	3	99	78
32	SP78	3.01	1.52	1.49	1.01	0.78	0.23	4201	26.8	20.1	2.83	0.286598	0.3355	4	23	78
33	SP78	3.78	2.08	1.70	1.40	1.07	0.33	4599	27.5	20.0	2.43	0.328767	0.3704	4	27	78
34	SP78	5.33	3.00	2.33	1.27	1.07	0.20	5400	25.3	21.6	1.36	0.394231	0.2383	4	73	78
35	SP78	3.38	1.49	1.89	1.68	1.60	0.08	3551	25.5	22.6	1.55	0.380738	0.4970	4	77	78
36	SP78	5.35	3.03	2.32	3.83	3.78	0.05	4924	34.5	23.8	1.79	0.434606	0.7159	5	27	78
37	SP78	2.85	1.88	0.96	3.35	2.75	0.60	2921	31.3	23.7	1.36	0.390277	1.1754	5	30	78
38	SP78	4.68	1.72	2.96	1.99	1.67	0.32	2664	29.1	20.8	2.83	0.702703	0.4252	5	67	78
39	SP78	9.58	6.33	3.25	2.25	2.08	0.17	3569	30.5	21.2	1.89	0.680095	0.2349	5	70	78
40	SP78	2.87	2.02	0.85	1.99	1.42	0.23	4278	33.8	24.0	1.70	0.268350	0.5749	6	27	78
41	SP78	2.29	1.33	0.96	2.36	2.36	0.00	4036	33.8	23.7	1.36	0.226957	1.0306	6	30	78
42	SP78	3.15	2.12	1.03	2.85	2.63	0.23	4116	31.1	24.6	1.55	0.306122	0.9048	6	77	78
43	SP78	.	.	.	2.39	2.20	0.19	3551	.	.	.	.	.	6	80	78
44	SU78	0.46	-0.49	0.95	1.76	1.74	0.02	3830	32.8	24.5	1.42	0.048042	3.8261	7	23	78
45	SU78	0.72	-0.31	1.03	1.44	1.35	0.09	4149	31.8	24.3	1.42	0.069414	2.0000	7	27	78
46	SU78	2.02	1.58	0.44	3.06	2.78	0.28	4036	31.8	25.4	1.70	0.200198	1.5149	7	70	78
47	SU78	1.17	0.87	0.30	2.32	1.99	0.33	3794	32.3	26.2	1.62	0.123353	1.9829	7	73	78
48	SU78	3.56	2.67	0.89	1.83	1.56	0.27	3874	33.0	23.0	.	0.367579	0.5140	8	17	78
49	SU78	2.33	0.69	1.64	1.63	1.53	0.10	2502	33.1	24.2	.	0.372502	0.6996	8	20	78
50	SU78	3.76	3.00	0.76	0.79	0.52	0.27	4762	33.8	25.7	.	0.315834	0.2101	8	93	78
51	SU78	3.85	2.94	0.91	1.32	1.30	0.02	4762	34.4	26.1	.	0.323394	0.3429	8	97	78
52	SU78	3.33	1.72	1.61	2.63	1.86	0.77	3511	31.8	27.6	1.42	0.379379	0.7898	9	70	78
53	SU78	2.76	0.80	1.96	1.34	1.30	0.04	7936	31.4	27.6	1.31	0.280488	0.4855	9	73	78
54	FA78	5.12	2.10	3.02	1.39	1.60	0.29	2972	29.9	30.1	.	0.689098	0.3691	10	3	78
55	FA78	3.13	2.25	0.88	1.25	0.50	0.75	3830	31.8	30.3	1.70	0.326693	0.3994	10	20	78
56	FA78	0.75	0.39	0.36	1.44	0.66	0.78	4149	29.8	30.8	2.43	0.072307	1.9200	10	23	78
57	FA78	1.07	0.46	0.61	1.20	0.82	0.38	3227	29.4	28.7	1.55	0.132631	1.1215	10	77	78
58	FA78	2.49	2.14	0.35	1.13	0.96	0.17	.	27.9	28.8	4.25	.	0.4538	11	37	78
59	FA78	4.24	1.51	2.73	1.19	0.72	0.47	.	27.2	28.8	2.13	.	0.2807	11	40	78
60	FA78	4.30	1.26	3.04	0.74	0.74	0.00	2582	27.9	27.9	2.00	0.666150	0.1721	11	93	78
61	FA78	2.15	0.47	1.68	1.04	1.04	0.00	2340	28.1	27.9	1.31	0.367521	0.4837	11	99	78
62	FA78	2.78	1.10	1.68	0.17	0.01	0.16	1775	20.2	26.1	.	0.626479	0.0612	12	50	78
63	FA78	1.68	1.25	0.43	0.58	0.56	0.02	2743	21.7	25.1	.	0.244987	0.3452	12	53	78
64	FA78	1.22	0.68	0.54	0.62	0.62	0.00	2663	20.5	27.0	1.55	0.183232	0.5082	12	57	78
65	WI79	1.87	1.10	0.77	0.56	0.43	0.07	2662	16.3	27.0	.	0.280992	0.2674	1	17	79
66	WI79	0.74	0.56	0.18	0.33	-0.16	0.49	1775	14.2	28.2	.	0.166761	0.4459	1	20	79
67	WI79	0.39	0.00	0.39	0.53	0.41	0.12	2080	20.0	26.9	.	0.075000	1.3590	1	77	79
68	WI79	.	.	.	0.34	0.34	0.00	3224	19.9	26.2	.	.	.	1	80	79
69	WI79	0.54	0.54	0.00	0.25	0.25	0.00	1750	20.1	24.5	1.42	0.123429	0.4630	2	53	79
70	WI79	0.58	0.45	0.13	0.77	0.51	0.26	2022	19.9	24.8	1.89	0.114738	1.3276	3	7	79
71	WI79	0.46	0.46	0.00	1.04	0.72	0.32	2980	22.4	25.1	.	0.061745	2.2609	3	10	79
72	WI79	0.13	0.07	0.06	0.44	0.29	0.15	3246	20.0	25.5	1.85	0.016020	3.3846	3	57	79
73	WI79	0.86	0.61	0.25	0.99	0.55	0.44	4417	20.3	26.1	1.59	0.077881	1.1512	3	60	79
74	WI79	2.01	1.42	0.59	1.17	1.13	0.04	4533	27.2	24.6	1.54	0.177366	0.5821	3	99	79
75	SP79	1.62	0.77	0.85	1.73	1.34	0.39	4193	28.4	24.7	1.70	0.154943	1.0479	4	3	79

Inner Discharge Bay (A)

OBS	TIME	PG	PN	R	PLANBPG	PLANKPN	PLANKR	IXSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
76	SP79	0.53	0.29	0.24	1.16	0.80	0.36	3639	30.2	26.0	2.43	0.05626	2.1887	4	70	79
77	SP79	-0.41	-0.46	0.05	2.92	2.44	0.48	3536	29.8	26.2	.	-0.04638	-7.1220	4	73	79
78	SP79	5.34	3.45	1.89	1.71	1.71	0.00	3410	29.6	26.7	2.62	0.62639	0.3202	5	17	79
79	SP79	3.41	1.64	1.77	.	.	.	3410	29.7	25.4	2.62	0.40000	.	5	20	79
80	SP79	2.51	1.68	0.83	2.46	2.20	0.26	5260	27.6	23.4	2.43	0.19097	0.9801	5	60	79
81	SP79	1.98	1.34	0.64	2.15	1.95	0.20	5470	27.3	25.8	2.13	0.14479	1.0859	5	63	79
82	SP79	3.69	1.16	2.53	1.38	1.03	0.35	3466	33.3	26.1	2.83	0.43335	0.3740	6	27	79
83	SP79	2.53	1.06	1.47	2.86	2.51	0.35	4334	32.9	26.9	2.27	0.23350	1.1304	6	30	79
84	SP79	1.48	1.11	0.37	0.95	0.41	0.54	5303	32.6	28.9	1.89	0.11163	0.6419	6	83	79
85	SP79	0.37	0.08	0.29	1.42	-0.13	1.55	4367	32.1	29.5	1.70	0.03389	3.8378	6	86	79
86	SU79	2.71	1.94	0.77	2.26	1.67	0.59	4680	34.3	27.9	2.46	0.23162	0.8339	7	27	79
87	SU79	2.63	1.96	0.69	2.36	2.02	0.34	4783	34.0	28.0	2.07	0.22162	0.8966	7	30	79
88	SU79	1.38	0.66	0.72	3.45	2.92	0.53	3016	31.8	27.4	1.70	0.18302	2.5000	7	77	79
89	SU79	1.56	0.87	0.69	5.87	5.01	0.86	3328	31.7	26.9	1.62	0.18750	3.7628	7	81	79
90	SU79	3.00	2.18	0.82	0.76	0.55	0.21	3262	34.9	27.4	.	0.36787	0.2533	8	19	79
91	SU79	1.11	0.43	0.68	1.37	1.15	0.22	3170	34.6	27.4	.	0.14006	1.2342	8	23	79
92	SU79	5.15	3.05	2.10	2.06	1.77	0.31	4265	32.2	27.4	.	0.48300	0.4039	8	61	79
93	SU79	4.51	2.38	2.13	2.37	1.92	0.45	4506	33.1	27.8	2.83	0.40036	0.5255	8	65	79
94	SU79	1.33	-0.06	1.39	1.80	1.39	0.41	3562	31.9	27.6	1.31	0.14935	1.3534	9	27	79
95	SU79	1.18	-0.21	1.39	2.19	1.10	1.09	3343	32.0	28.5	1.70	0.14119	1.8559	9	30	79
96	SU79	2.27	0.47	1.80	0.51	0.38	0.13	2005	34.0	28.0	2.27	0.45287	0.2247	9	77	79
97	FA79	3.07	1.15	1.92	1.70	1.20	0.50	4263	31.6	26.2	2.60	0.28806	0.5537	10	16	79
98	FA79	3.94	1.87	2.07	2.26	1.99	0.27	3781	29.9	26.5	2.27	0.41682	0.5736	10	19	79
99	FA79	3.54	1.11	2.43	1.20	1.01	0.19	3008	30.2	28.8	2.83	0.47074	0.3390	10	61	79
100	FA79	3.23	1.08	2.15	1.87	1.87	0.00	2812	30.3	29.5	.	0.45946	0.5789	10	65	79
101	FA79	3.82	1.05	2.77	0.60	0.36	0.24	2213	28.6	29.4	2.83	0.69047	0.1571	11	7	79
102	FA79	3.08	1.83	1.25	.	.	.	2870	26.2	29.7	1.89	0.42927	.	11	10	79
103	FA79	5.44	2.92	2.52	1.06	0.76	0.30	2478	22.3	28.8	.	0.87813	0.1949	11	53	79
104	FA79	7.26	3.79	3.47	0.98	0.80	0.18	2651	20.6	28.3	.	1.09544	0.1350	11	57	79
105	FA79	2.21	1.64	0.57	0.33	0.19	0.14	3077	16.8	28.9	3.40	0.28729	0.1493	11	99	79
106	FA79	2.42	1.16	1.26	.	.	.	2328	16.9	28.4	.	0.41581	.	12	3	79
107	FA79	0.50	0.38	0.12	0.17	0.05	0.12	980	26.2	29.1	.	0.20408	0.3400	12	48	79
108	FA79	0.19	0.19	0.00	0.71	0.71	0.00	231	25.3	29.6	.	0.32900	3.7368	12	52	79
109	WI80	0.97	0.55	0.42	0.03	-0.09	0.12	646	19.0	27.3	1.59	0.60155	0.0309	1	13	80
110	WI80	0.71	0.46	0.25	0.02	-0.02	.	2351	16.4	27.6	2.24	0.12080	0.0282	1	16	80
111	WI80	2.98	0.96	2.02	0.27	0.16	0.11	1810	22.7	28.5	.	0.65856	0.0906	1	58	80
112	WI80	2.58	1.42	1.16	0.22	0.04	0.18	2616	22.3	28.8	.	0.39450	0.0853	1	61	80
113	WI80	0.41	0.41	0.00	.	.	.	3952	19.6	27.1	3.40	0.04150	.	2	4	80
114	WI80	0.55	0.55	0.00	.	.	.	3120	19.7	25.9	3.40	0.07051	.	2	7	80
115	WI80	1.03	0.75	0.28	0.44	0.26	0.18	3773	23.2	27.1	1.62	0.10920	0.4272	2	79	80
116	WI80	0.70	0.64	0.06	0.08	0.03	0.05	2139	24.4	26.3	.	0.13090	0.1143	2	82	80
117	WI80	0.82	0.82	0.00	.	.	.	3818	19.8	24.6	1.62	0.08591	.	3	26	80
118	WI80	0.59	0.59	0.00	0.76	0.40	0.36	2525	21.1	23.7	1.70	0.09347	1.2881	3	29	80
119	WI80	0.96	0.60	0.36	0.52	0.48	0.04	4145	23.2	25.3	2.83	0.09264	0.5417	3	68	80
120	WI80	1.06	0.82	0.24	0.37	0.37	0.00	5080	21.8	25.5	1.89	0.08346	0.3491	3	71	80
121	SP80	0.64	0.18	0.46	0.63	0.53	0.10	2184	24.2	24.2	2.18	0.11722	0.9844	4	13	80
122	SP80	1.89	1.31	0.58	0.11	0.11	0.00	5125	24.0	23.8	2.61	0.14731	0.0582	4	17	80
123	SP80	2.00	1.62	0.38	0.93	0.85	0.08	4605	24.2	25.1	.	0.17372	0.4650	4	60	80
124	SP80	1.09	0.89	0.20	1.30	1.28	0.02	3550	25.0	25.2	2.83	0.12282	1.1927	4	63	80
125	SP80	2.43	1.91	0.52	1.46	1.19	0.27	5259	26.2	21.6	2.27	0.18483	0.6008	5	10	80
126	SP80	2.75	1.97	0.78	2.77	2.45	0.32	5125	26.8	21.1	.	0.21463	1.0073	5	13	80
127	SP80	2.73	1.77	0.96	2.13	2.07	0.06	4189	30.6	22.0	2.83	0.26068	0.7802	5	52	80
128	SP80	3.14	1.82	1.32	2.52	2.48	0.04	3387	30.4	22.4	2.83	0.37083	0.8025	5	55	80
129	SP80	3.45	1.79	1.66	2.03	1.88	0.15	4546	30.5	22.8	2.27	0.30356	0.5884	5	99	80
130	SP80	2.94	1.70	1.24	4.10	3.73	0.37	4902	29.3	23.0	3.40	0.23990	1.3946	6	3	80
131	SP80	1.84	0.74	1.10	2.52	2.40	0.12	5140	32.1	25.9	1.36	0.14319	1.3696	6	57	80
132	SP80	2.93	2.05	0.88	3.72	3.72	0.00	4768	32.3	25.4	1.62	0.24581	1.2696	6	60	80
133	SP80	1.61	0.99	0.62	1.84	1.49	0.35	2303	30.5	19.7	2.13	0.27964	1.1429	6	99	80
134	SU80	4.04	2.58	1.46	4.56	4.44	0.12	5467	31.9	20.0	2.22	0.29559	1.1287	7	3	80
135	SU80	1.03	0.57	0.46	1.90	1.68	0.22	5306	33.4	22.5	1.79	0.08230	1.8447	7	55	80
136	SU80	1.22	0.31	0.91	1.60	1.44	0.16	4019	33.4	22.2	1.62	0.12142	1.3115	7	58	80
137	SU80	1.09	0.17	0.92	1.19	0.91	0.27	3758	34.0	21.1	1.62	0.11692	1.0826	8	10	80
138	SU80	1.45	0.42	1.03	1.37	0.98	0.39	4724	33.9	21.1	2.27	0.12278	0.9448	8	13	80
139	SU80	1.87	1.14	0.73	1.33	1.00	0.33	4442	34.4	23.0	1.31	0.16839	0.7112	8	52	80
140	SU80	1.44	0.84	0.60	1.29	1.28	0.00	4709	35.5	23.8	1.31	0.12232	0.8889	8	55	80
141	SU80	1.46	0.57	0.89	0.79	0.57	0.22	4575	34.5	26.6	2.27	0.12765	0.5411	8	94	80
142	SU80	0.74	0.49	0.25	0.47	0.03	0.44	4397	35.4	27.1	2.00	0.06732	0.6351	8	97	80
143	SU80	2.69	0.80	1.89	1.67	1.60	0.07	4075	32.1	29.1	1.55	0.26405	0.6208	9	40	80
144	SU80	1.05	0.88	0.17	0.87	0.51	0.36	3692	34.1	29.7	2.00	0.11376	0.8286	9	43	80
145	SU80	2.57	1.31	1.26	0.96	0.71	0.25	3207	35.2	29.6	1.40	0.32055	0.3735	9	90	80
146	SU80	1.66	1.51	0.15	0.63	0.34	0.29	3663	36.4	30.1	1.28	0.18127	0.3795	9	93	80
147	FA80	0.98	0.69	0.29	1.18	0.93	0.25	3678	31.1	27.6	1.89	0.10658	1.2041	10	48	80
148	FA80	1.20	0.64	0.56	1.44	0.46	0.58	1394	31.5	27.1	.	0.14311	0.8667	10	52	80
149	FA80	0.47	0.47	0.00	0.52	0.45	0.07	2228	30.1	26.4	.	0.08438	1.1064	10	99	80
150	FA80	0.15	0.15	0.00	0.73	0.29	0.44	4163	29.4	26.8	.	0.01441	4.8667	11	3	80

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	[illegible]PLK	MONTH	DAY	YEAR
151	FA80	-0.16	-0.16	0.00	1.63	0.79	0.84	1792	26.2	26.2	1.36	-0.035714	-10.180	11	47	80
152	FA80	0.59	0.58	0.01	1.28	1.01	0.27	2663	26.0	26.9	1.55	0.088622	2.169	11	50	80
153	FA80	0.62	0.62	0.00	0.78	0.57	0.21	3607	24.1	26.3	2.83	0.068755	1.258	11	97	80
154	FA80	0.11	0.11	0.00	1.00	0.86	0.14	.	23.1	25.3	2.83	.	9.091	11	99	80
155	FA80	0.21	0.21	0.06	0.43	0.36	0.07	1537	24.0	26.3	1.55	0.054652	2.048	12	52	80
156	FA80	-0.04	-0.04	0.00	0.52	0.29	0.23	2249	23.6	25.8	.	-0.007114	-13.000	12	55	80
157	WI81	0.54	0.54	0.00	.	.	.	3631	18.5	25.8	.	0.059162	.	1	13	81
158	WI81	0.76	0.43	0.33	.	.	.	3162	17.4	26.1	.	0.096142	.	1	16	81
159	WI81	0.99	0.83	0.16	0.09	0.09	.	2934	13.4	26.3	.	0.134469	0.091	1	52	81
160	WI81	0.41	0.41	.	.	.	.	.	13.3	26.1	.	.	.	1	55	81
161	WI81	0.74	0.74	.	0.39	0.28	0.11	4645	20.7	26.5	.	0.063724	0.527	1	97	81
162	WI81	0.60	0.60	.	.	.	.	3993	20.5	26.8	.	0.060105	.	1	99	81
163	WI81	0.04	0.04	.	0.24	0.17	0.07	2829	19.6	25.5	.	0.005674	6.000	2	46	81
164	WI81	0.41	0.41	.	0.23	0.09	0.14	4026	20.0	26.2	.	0.040735	0.561	2	53	81
165	WI81	0.79	0.54	0.25	0.40	0.09	0.31	4727	20.2	25.7	.	0.066850	0.506	2	96	81
166	WI81	3.00	2.10	0.90	0.41	0.30	0.11	4531	21.2	26.4	.	0.260642	0.137	2	99	81
167	WI81	0.22	-0.01	0.23	0.42	0.35	0.07	2152	23.8	25.0	.	0.040892	1.909	3	42	81
168	WI81	0.53	0.53	.	0.52	0.52	.	5200	24.5	25.3	.	0.040769	0.981	3	45	81
169	WI81	1.87	1.63	0.24	0.48	0.29	0.19	5575	19.7	24.3	1.54	0.134170	0.257	3	87	81
170	WI81	1.83	1.46	0.37	0.31	0.27	0.04	4662	20.7	24.8	1.13	0.157014	0.169	3	90	81
171	SP81	3.00	2.61	0.39	1.49	0.92	0.57	5444	28.3	25.9	2.00	0.220426	0.497	4	33	81
172	SP81	1.07	0.86	0.21	.	.	.	6015	29.1	26.3	1.54	0.071155	.	4	37	81

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
1	SU77	8.00	3.68	4.32	.	.	.	5570	30.3	24.4	1.10	0.57451	.	7	43	77
2	SU77	4.90	1.89	3.01	.	.	.	4700	29.1	25.9	1.20	0.41004	.	8	30	77
3	SU77	7.52	3.55	3.97	4.05	3.69	0.46	3870	28.0	22.1	1.10	0.77726	0.538584	8	73	77
4	SU77	15.92	9.39	6.53	1.74	1.27	0.47	5230	28.6	19.8	1.10	1.21759	0.109296	8	77	77
5	SU77	13.12	7.12	6.00	2.58	1.58	1.00	6579	30.8	23.5	1.10	0.79769	0.196646	9	27	77
6	SU77	10.94	5.05	5.89	1.63	0.94	0.69	6462	30.1	25.9	1.00	0.67719	0.148995	9	63	77
7	SU77	8.66	4.16	4.50	1.84	1.42	0.42	4096	30.4	25.4	1.00	0.70752	0.212471	9	67	77
8	FA77	7.49	4.64	2.85	2.34	1.68	0.66	5466	28.8	25.0	1.10	0.54812	0.312417	10	3	77
9	FA77	4.74	1.23	3.51	1.38	0.63	0.75	5230	28.9	25.2	1.10	0.36197	0.291139	10	7	77
10	FA77	6.12	2.88	3.24	0.76	0.52	0.24	6462	18.4	28.3	1.00	0.37883	0.124183	10	57	77
11	FA77	5.85	2.66	3.20	0.53	0.29	0.24	6227	18.3	28.4	0.90	0.37576	0.090598	10	60	77
12	FA77	4.72	1.44	3.28	0.88	0.51	0.37	2961	20.5	29.5	0.90	0.63762	0.186441	11	3	77
13	FA77	3.60	1.74	1.86	0.14	0.14	0.00	4441	14.7	29.3	0.90	0.32425	0.038889	11	47	77
14	FA77	2.83	2.98	0.75	0.29	0.26	0.03	4347	15.7	29.4	0.90	0.26041	0.102473	11	50	77
15	FA77	3.81	1.71	2.10	0.21	0.20	0.01	2619	17.8	23.8	0.90	0.58190	0.055118	11	97	77
16	FA77	4.76	1.46	3.30	0.44	0.26	0.18	3416	19.5	23.0	0.90	0.55738	0.092437	11	99	77
17	FA77	3.60	2.48	1.12	0.16	-0.06	0.22	.	15.4	24.0	.	.	0.044444	12	63	77
18	FA77	3.17	1.15	2.02	0.24	0.24	0.00	.	15.8	21.0	.	.	0.075710	12	67	77
19	WI78	0.85	0.54	0.31	0.17	0.14	0.03	159	9.0	22.6	1.42	2.13836	0.200000	2	3	78
20	WI78	0.72	0.26	0.46	0.40	0.26	0.14	453	10.1	21.0	.	0.63576	0.555556	2	7	78
21	WI78	2.28	1.22	1.06	0.79	0.79	0.00	1013	14.1	21.7	.	0.90030	0.346491	2	60	78
22	WI78	2.87	1.35	1.52	0.16	0.00	0.16	1358	14.1	22.5	.	0.84536	0.055749	2	63	78
23	WI78	3.14	1.85	1.29	1.09	1.09	0.00	2028	15.3	17.8	1.06	0.61933	0.347134	3	13	78
24	WI78	2.54	1.46	1.08	.	.	.	4221	13.6	21.0	1.31	0.24070	.	3	63	78
25	WI78	2.01	0.67	1.34	0.61	0.57	0.04	4404	17.3	20.0	1.89	0.18256	0.303483	3	97	78
26	WI78	2.40	1.34	1.06	.	.	.	4383	18.5	19.2	1.42	0.21903	.	3	99	78
27	SP78	7.17	3.83	3.34	0.96	0.63	0.33	4201	24.5	19.2	1.31	0.60269	0.133891	4	23	78
28	SP78	7.02	2.34	4.68	0.89	0.72	0.17	4599	24.8	19.2	1.21	0.61057	0.126781	4	27	78
29	SP78	8.73	4.31	4.44	0.84	0.73	0.11	5408	22.3	16.9	.	0.64719	0.096000	4	74	78
30	SP78	5.97	2.93	3.04	1.09	1.09	0.00	3551	22.2	17.2	1.21	0.67249	0.182580	4	77	78
31	SP78	4.46	2.89	1.57	1.28	0.81	0.47	4924	27.0	16.5	1.48	0.36231	0.286996	5	27	78
32	SP78	3.99	1.42	2.57	2.61	1.51	1.10	2921	28.0	16.3	1.55	0.54639	0.654135	5	30	78
33	SP78	5.21	1.47	3.74	1.79	1.05	0.72	2664	26.3	15.4	1.70	0.78228	0.343570	5	67	78
34	SP78	9.04	6.38	2.66	2.46	1.66	0.80	5569	26.1	15.9	1.55	0.64931	0.272124	5	70	78
35	SP78	6.63	3.06	3.59	2.42	1.45	0.97	4278	30.0	17.1	1.17	0.62179	0.363910	6	27	78
36	SP78	7.02	3.61	3.41	2.64	2.32	0.32	4036	30.1	16.4	1.13	0.69574	0.376068	6	30	78
37	SP78	9.00	4.70	4.30	1.99	1.49	0.49	4116	27.4	19.0	0.94	0.87464	0.220000	6	77	78
38	SP78	8.15	4.46	3.69	2.00	1.66	0.34	3551	28.0	20.1	0.94	0.91805	0.245399	6	80	78
39	SU78	7.95	4.35	3.60	3.30	2.56	0.74	3830	29.2	18.3	1.13	0.83029	0.415094	7	23	78
40	SU78	8.28	4.91	3.37	3.52	2.95	0.57	4149	29.2	19.8	1.13	0.79826	0.425121	7	27	78
41	SU78	11.29	7.57	3.72	2.32	2.19	0.13	4036	28.3	18.0	.	1.11893	0.205492	7	70	78
42	SU78	9.15	5.81	3.34	1.86	1.46	0.40	3794	28.9	18.9	1.06	0.96468	0.203279	7	73	78
43	SU78	7.76	4.18	3.58	1.70	1.36	0.34	3874	29.2	14.4	1.13	0.80124	0.219072	8	17	78
44	SU78	4.76	2.08	2.68	1.85	1.57	0.28	2502	29.4	16.9	1.00	0.76099	0.388655	8	20	78
45	SU78	9.21	5.06	4.15	1.50	1.14	0.36	4762	31.4	21.4	1.90	0.77362	0.162866	8	93	78
46	SU78	10.93	6.22	4.71	1.75	1.55	0.20	4762	31.5	21.3	1.90	0.91810	0.160110	8	97	78
47	SU78	9.10	2.60	6.50	2.29	2.04	0.25	3511	29.6	[illegible]	1.31	1.03674	0.251648	9	70	78
48	SU78	6.79	2.86	3.93	2.08	2.02	0.06	3936	29.6	25.2	1.13	0.69004	0.306333	9	73	78
49	FA78	8.28	3.59	4.69	1.01	0.87	0.14	2972	26.5	27.2	1.15	1.11440	0.121981	10	3	78
50	FA78	3.51	1.47	2.04	1.20	0.76	0.44	3830	26.4	28.7	1.31	0.36658	0.341880	10	20	78
51	FA78	4.70	1.99	2.71	1.20	1.05	0.15	4149	23.7	29.2	1.55	0.45312	0.255319	10	23	78
52	FA78	5.40	2.37	3.03	1.54	1.09	0.45	3227	23.2	28.1	1.31	0.66935	0.285185	10	77	78
53	FA78	3.95	1.15	2.80	1.11	0.80	0.31	.	22.1	27.1	.	.	0.281013	11	37	78
54	FA78	4.44	2.13	2.31	1.58	1.58	0.00	.	21.7	27.6	1.21	.	0.355856	11	40	78
55	FA78	6.58	2.30	4.28	2.12	2.12	0.00	2582	21.8	24.4	1.13	1.01936	0.322188	11	97	78
56	FA78	3.66	1.32	2.34	1.26	-0.03	1.29	2340	23.4	24.3	1.55	0.62564	0.344262	11	99	78
57	FA78	3.08	1.90	1.18	0.49	0.33	0.16	1775	14.8	24.6	.	0.69406	0.159091	12	50	78
58	FA78	3.04	1.57	1.47	0.58	0.58	0.00	2743	14.6	24.7	.	0.44331	0.190789	12	53	78
59	FA78	2.53	1.46	1.07	0.32	0.30	0.02	2663	13.6	25.3	.	0.38002	0.126482	12	57	78
60	WI79	1.43	1.35	0.08	0.12	0.12	0.00	2662	10.1	25.8	.	0.21480	0.083916	1	17	79
61	WI79	1.51	0.92	0.59	0.30	-0.22	0.52	1775	12.4	24.9	.	0.34028	0.198675	1	20	79
62	WI79	2.00	0.86	1.14	0.20	0.09	0.11	2000	11.8	23.0	1.70	0.38462	0.100000	1	77	79
63	WI79	.	.	.	0.34	0.34	0.00	3224	12.7	21.6	3.40	.	.	[illegible]	80	79
64	WI79	2.91	1.16	1.75	0.27	0.27	0.00	1750	16.7	19.0	1.21	0.66314	0.092784	2	53	79
65	WI79	2.05	0.91	1.14	0.67	0.44	0.23	2022	16.2	23.0	0.91	0.40554	0.326829	3	7	79
66	WI79	2.16	0.80	1.36	0.91	0.84	0.07	2980	17.3	22.6	1.62	0.28993	0.421296	3	10	79
67	WI79	1.21	0.79	0.42	0.10	-0.22	0.32	3246	17.4	24.1	2.13	0.14911	0.082645	3	57	79
68	WI79	1.70	1.13	0.57	1.13	1.13	0.00	4417	17.7	24.4	1.42	0.15395	0.664706	3	60	79
69	WI79	3.72	2.40	1.32	0.56	0.30	0.26	4533	21.0	21.0	1.24	0.32826	0.150538	3	99	79
70	SP79	3.71	2.55	1.16	0.39	0.10	0.29	4193	22.2	19.7	1.21	0.35392	0.105121	4	3	79
71	SP79	2.50	1.49	1.01	0.80	0.37	0.43	3639	24.4	22.6	1.55	0.27480	0.320000	4	70	79
72	SP79	4.57	3.20	1.37	1.11	1.11	0.00	3536	24.2	21.2	.	0.51697	0.242888	4	73	79
73	SP79	4.68	2.94	1.74	1.91	0.92	0.99	3410	27.2	21.9	1.40	0.54897	0.408120	5	17	79
74	SP79	7.91	4.70	3.21	.	.	.	3410	27.3	20.5	.	0.92786	.	5	20	79
75	SP79	4.04	2.61	1.43	1.39	1.13	0.26	5260	25.1	25.7	1.70	0.30722	0.344059	5	60	79

OBS	TIME	PC	PN	R	PLANKPC	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	FERPLK	MONTH	DAY	YEAR
76	SP79	2.24	1.21	1.03	1.61	1.01	0.60	5470	26.7	25.8	1.62	0.16380	0.71875	5	63	79
77	SP79	8.33	2.42	5.91	1.08	1.20	0.68	3406	30.7	24.4	1.70	0.97827	0.22569	6	27	79
78	SP79	7.71	3.65	4.06	4.26	3.34	0.92	4334	29.4	25.3	1.55	0.71158	0.55253	6	30	79
79	SP79	5.99	3.35	2.64	3.64	2.82	0.82	5303	29.9	25.4	1.26	0.45182	0.60768	6	83	79
80	SP79	4.75	2.73	2.02	2.24	2.21	0.08	4367	29.2	26.1	1.89	0.43508	0.48211	6	86	79
81	SU79	9.60	6.23	3.37	9.59	8.09	1.50	4680	30.8	25.9	1.77	0.82051	0.99896	7	27	79
82	SU79	9.26	5.51	3.75	.	.	1.06	4783	30.3	26.3	1.77	0.77441	.	7	30	79
83	SU79	5.53	3.34	2.19	5.01	4.20	0.81	3016	28.9	22.6	1.36	0.73342	0.90597	7	77	79
84	SU79	5.05	2.38	2.67	8.92	6.86	1.16	3328	29.0	22.8	1.40	0.60697	1.58812	7	81	79
85	SU79	7.63	3.55	4.08	2.29	1.43	0.77	3262	29.3	22.3	1.13	0.93562	0.28834	8	19	79
86	SU79	6.19	3.09	3.10	3.24	2.30	0.94	3170	29.3	23.7	1.40	0.78107	0.52742	8	23	79
87	SU79	8.41	4.41	4.00	2.37	1.51	0.86	4265	29.6	23.7	2.43	0.78875	0.28181	8	61	79
88	SU79	8.62	4.95	3.67	2.31	1.74	0.57	4506	29.9	23.0	1.55	0.76520	0.26798	8	65	79
89	SU79	5.15	1.49	3.66	1.31	0.79	0.52	3562	29.3	22.8	1.13	0.57833	0.25437	9	27	79
90	SU79	3.64	0.72	2.92	2.11	1.56	0.55	3343	28.8	25.1	1.62	0.43554	0.57467	9	30	79
91	FA79	7.13	3.23	3.90	2.30	2.01	0.29	4263	25.3	22.2	1.98	0.66901	0.32258	10	16	79
92	FA79	8.59	5.38	3.21	2.09	2.03	0.06	3781	24.2	22.7	1.40	0.90875	0.24331	10	19	79
93	FA79	3.77	1.33	2.44	1.26	0.85	0.41	3008	25.0	26.5	1.89	0.50133	0.33422	10	61	79
94	FA79	4.54	2.04	2.50	1.71	1.37	0.34	2812	25.3	26.4	.	0.64580	0.37665	10	65	79
95	FA79	7.19	2.28	4.91	0.99	0.92	0.07	2213	23.9	25.3		1.29959	0.13769	11	7	79
96	FA79	6.04	3.46	2.58	.	.	.	2870	22.0	25.5	1.31	0.84181	.	11	10	79
97	FA79	2.95	1.72	1.23	0.34	-0.09	0.43	2478	15.5	28.1	.	0.47619	0.11525	11	53	79
98	FA79	4.40	2.69	1.71	0.20	0.03	0.17	2631	16.1	27.7	.	0.66390	0.04565	11	57	79
99	FA79	1.98	1.14	0.84	-0.04	-0.04	0.00	3077	10.5	27.5	2.13	0.25739	-0.02020	11	99	79
100	FA79	1.36	1.17	0.19	.	.	.	2328	11.0	28.9	.	0.23360	.	12	3	79
101	FA79	3.67	1.26	2.41	0.00	0.00	0.00	980	20.2	24.8	.	1.49796	0.02180	12	48	79
102	FA79	3.04	0.65	2.39	0.25	0.00	0.26	231	18.3	24.8	.	5.26407	0.08553	12	52	79
103	WI80	0.45	0.02	0.43	0.54	0.54	.	645	12.2	26.2	1.76	0.27907	1.20000	1	13	80
104	WI80	1.01	0.61	0.40	-0.06	-0.06	.	2351	11.0	26.9	1.46	0.17184	-0.05941	1	16	80
105	WI80	3.09	1.49	1.60	0.11	-0.07	0.18	1810	17.0	24.4	.	0.68287	0.03560	1	58	80
106	WI80	4.53	2.50	2.03	0.14	-0.09	0.23	2616	17.1	25.1	.	0.69266	0.03091	1	61	80
107	WI80	1.91	1.33	0.58	.	.	.	3952	10.0	25.5	.	0.19332	.	2	4	80
108	WI80	1.79	0.70	1.09	.	.	.	3120	10.1	25.9	.	0.22949	.	2	7	80
109	WI80	1.89	1.12	0.77	0.44	0.08	0.36	3773	17.5	21.7	1.42	0.20037	0.23280	2	79	80
110	WI80	2.27	1.20	1.07	0.22	0.22	0.00	2139	18.8	19.8	1.13	0.42450	0.09692	2	82	80
111	WI80	1.53	1.29	0.24	0.83	0.83	0.00	3818	18.2	20.9	1.42	0.16029	0.54248	3	26	80
112	WI80	2.78	1.00	1.78	1.23	0.45	0.78	2525	20.2	18.6	1.80	0.44040	0.44245	3	29	80
113	WI80	1.10	0.31	0.79	1.43	1.07	0.36	4145	20.7	19.8	3.40	0.10615	1.30000	3	68	86
114	WI80	3.70	2.07	1.63	0.64	0.42	0.22	5000	18.2	20.6	1.21	0.29134	0.17297	3	71	80
115	SP80	2.09	0.71	1.38	0.09	0.55	0.34	2184	22.3	18.5	1.62	0.38278	0.42584	4	13	80
116	SP80	4.57	3.49	1.08	0.63	0.63	0.00	5125	21.2	18.8	1.43	0.35668	0.13786	4	17	80
117	SP80	1.31	1.31	0.00	0.77	0.43	0.32	4605	22.3	21.8	1.55	0.11379	0.57252	4	60	80
118	SP80	2.94	1.61	1.33	0.86	0.86	0.00	3550	21.3	22.2	1.36	0.33127	0.29252	4	63	80
119	SP80	4.07	2.52	1.55	0.67	0.30	0.37	5259	23.6	20.7	1.42	0.30956	0.16462	5	10	80
120	SP80	4.00	2.16	1.84	1.77	1.50	0.27	5125	24.5	21.4	1.62	0.31220	0.44250	5	13	80
121	SP80	6.89	4.22	2.67	0.83	0.70	0.13	4189	27.8	19.6	1.79	0.65791	0.12046	5	52	80
122	SP80	4.65	2.48	2.17	1.75	1.46	0.29	3387	27.5	19.1	1.62	0.54916	0.37634	5	55	80
123	SP80	6.05	3.31	2.74	0.84	0.51	0.33	4546	26.7	18.6	1.42	0.53234	0.13884	5	99	80
124	SP80	5.37	3.29	2.08	1.85	1.08	0.77	4902	26.8	19.8	1.40	0.43819	0.34451	6	3	80
125	SP80	8.69	4.95	3.74	0.90	0.60	0.30	5140	28.8	21.5	0.89	0.67626	0.10357	6	57	80
126	SP80	6.94	2.79	4.15	1.49	1.47	0.02	4768	29.4	22.7	1.55	0.58221	0.21470	6	60	80
127	SP80	4.07	1.67	2.40	1.74	1.30	0.44	2303	28.7	16.9	2.08	0.70690	0.42752	6	99	80
128	SU80	7.31	5.11	2.20	2.36	2.22	0.14	5467	29.6	16.4	1.44	0.53405	0.32285	7	3	80
129	SU80	11.30	6.01	5.29	2.04	1.50	0.54	5006	30.3	19.2	1.21	0.90292	0.18053	7	55	80
130	SU80	5.76	2.73	3.03	1.65	1.06	0.59	4019	29.9	18.0	3.40	0.57328	0.28646	7	58	80
131	SU80	3.94	2.35	1.59	1.70	1.27	0.43	3758	31.3	17.9	1.55	0.41937	0.43147	8	10	80
132	SU80	7.20	3.52	3.68	2.06	1.65	0.41	4724	31.1	17.8	1.40	0.60963	0.28611	8	13	80
133	SU80	9.60	5.25	4.35	3.70	2.81	0.89	4442	29.7	16.9	0.94	0.86440	0.38542	8	52	80
134	SU80	9.76	5.09	4.67	2.63	2.13	0.50	4709	30.6	18.7	1.21	0.82905	0.26947	8	55	80
135	SU80	8.36	4.40	3.96	3.89	3.29	0.60	4575	29.4	23.1	1.70	0.73093	0.46531	8	94	80
136	SU80	9.76	4.91	4.85	3.48	2.79	0.69	4397	29.8	23.6	1.36	0.88788	0.35656	8	97	80
137	SU80	6.16	3.18	2.98	2.15	1.32	0.83	4075	28.0	25.7	1.10	0.60466	0.34903	9	40	80
138	SU80	8.87	4.24	4.63	1.96	1.46	0.50	3692	28.2	26.1	1.03	0.96100	0.22097	9	43	80
139	SU80	8.49	4.13	4.36	2.99	2.35	0.64	3207	30.3	24.1	1.25	1.05893	0.35218	9	90	80
140	SU80	7.92	3.41	4.51	3.09	2.51	0.58	3663	30.5	23.9	1.13	0.96486	0.39015	9	93	80
141	FA80	5.15	3.90	1.35	1.08	0.74	0.34	3678	23.6	26.7	.	0.56009	0.20871	10	48	80
142	FA80	10.77	6.67	4.10	0.99	0.97	0.02	3354	24.5	26.1	.	1.28444	0.09192	10	52	80
143	FA80	8.90	5.16	3.74	0.65	0.64	0.01	2228	23.0	24.1	1.06	1.59785	0.07303	10	99	80
144	FA80	8.72	5.35	3.37	0.86	0.64	0.22	4163	21.2	25.2	.	0.83745	0.09862	11	3	80
145	FA80	5.47	3.00	2.47	2.19	1.10	1.09	1792	19.4	25.8	1.17	1.22098	0.40037	11	47	80
146	FA80	4.01	1.50	2.51	2.14	1.11	1.03	2663	20.2	24.5	1.31	0.60233	0.53367	11	50	80
147	FA80	2.14	1.59	0.55	0.40	0.35	0.05	3607	14.6	24.6	1.70	0.23732	0.18692	11	97	80
148	FA80	2.99	2.71	0.28	0.38	0.28	0.10	.	14.9	24.3	.	.	0.12709	11	99	80
149	FA80	2.92	1.54	1.38	0.42	0.42	0.00	1537	16.1	23.3	0.97	0.75992	0.14384	12	52	80
150	FA80	5.03	2.76	2.27	0.41	0.11	0.30	249	15.8	22.7	1.17	8.08032	0.08151	12	55	80

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLN	MONTH	DAY	YEAR
151	WI81	1.34	0.96	0.38	0.22	-0.01	0.23	3651	11.2	23.9	.	0.146809	0.164179	1	13	81
152	WI81	1.67	0.96	0.71	.	.	.	3162	10.0	24.7	.	0.211259	.	1	16	81
153	WI81	1.84	1.43	0.41	0.31	0.23	0.08	2934	9.7	23.1	1.79	0.250852	0.168478	1	52	81
154	WI81	2.78	1.80	0.98	.	.	.	.	7.6	23.8	1.88	.	.	1	55	81
155	WI81	2.27	1.38	0.89	0.26	-0.42	0.68	4645	12.8	23.8	.	0.195479	0.114537	1	97	81
156	WI81	1.77	1.05	0.72	.	.	.	3493	13.1	23.6	0.81	0.177310	.	1	99	81
157	WI81	0.21	0.21	.	0.06	0.01	0.05	2820	11.4	23.9	2.12	0.029787	0.285714	2	46	81
158	WI81	1.40	0.60	0.80	.	.	.	4026	13.2	24.6	3.40	0.139096	.	2	53	81
159	WI81	2.02	1.02	1.00	0.45	0.21	0.24	4727	17.4	24.9	.	0.170933	0.222772	2	96	81
160	WI81	5.93	2.91	3.02	0.58	0.34	0.24	4531	18.3	23.5	.	0.523560	0.097808	2	99	81
161	WI81	2.60	1.13	1.47	0.44	0.39	0.05	2152	16.5	24.9	.	0.483271	0.169231	3	42	81
162	WI81	4.64	2.54	2.10	0.47	0.35	0.12	5200	16.4	24.5	1.13	0.356923	0.101293	3	45	81
163	WI81	3.31	2.02	1.29	0.44	0.13	0.31	5575	18.4	21.9	1.13	0.237409	0.132931	3	87	81
164	WI81	1.83	1.57	0.26	0.58	0.34	0.24	4662	19.6	21.0	1.06	0.137014	0.316940	3	90	81
165	SP81	3.45	2.00	1.45	1.30	0.21	1.09	5444	22.9	22.0	1.21	0.253490	0.376812	4	33	81
166	SP81	5.34	3.20	2.14	.	.	.	6015	23.3	21.2	0.94	0.355112	.	4	37	81

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLN	MONTH	DAY	YEAR
1	SP77	4.14	2.45	1.69	2.09	2.27	0.63	.	25.7	24.3	1.62	.	0.69807	4	23	77
2	SP77	10.39	6.44	3.95	2.39	0.21	2.20	.	35.6	28.5	1.13	.	0.23003	6	7	77
3	SU77	1.20	-0.30	1.50	.	0.75	.	4200	35.3	28.7	1.50	0.11429	.	7	3	77
4	SU77	8.57	4.88	3.69	1.53	-1.38	2.91	7400	36.1	29.0	1.10	0.46324	0.17853	7	7	77
5	SU77	5.20	1.83	3.43	1.78	0.29	1.49	5570	35.9	29.6	0.93	0.37343	0.34231	7	43	77
6	SU77	0.75	-0.48	1.23	2.68	1.01	1.67	4780	34.5	29.7	1.50	0.06276	3.57333	8	.	77
7	SU77	9.02	4.16	4.86	5.82	5.11	0.71	3870	29.7	26.9	1.40	0.93230	0.64523	8	3	77
8	SU77	5.04	2.65	2.39	1.39	1.14	0.25	6030	34.0	30.9	1.20	0.33433	0.27579	8	3	77
9	SU77	8.83	5.23	3.60	6.69	6.06	0.63	5230	29.7	25.9	1.10	0.67533	0.75764	8	7	77
10	SU77	3.98	1.98	2.00	3.44	2.51	0.93	6567	33.9	31.5	1.40	0.24261	0.86432	9	3	77
11	SU77	8.53	4.67	3.86	2.31	1.81	0.50	6579	34.6	29.7	1.30	0.51862	0.27081	9	7	77
12	SU77	6.91	4.76	2.15	2.42	2.37	0.05	4896	34.9	31.3	1.30	0.56454	0.35022	9	7	77
13	FA77	6.19	3.12	3.07	5.55	4.62	0.93	5466	33.1	30.6	1.50	0.45298	0.89661	10	3	77
14	FA77	5.81	2.64	3.17	3.83	3.20	0.63	5238	32.4	30.0	1.50	0.44368	0.65921	10	7	77
15	FA77	5.11	2.19	2.92	1.80	1.43	0.37	6462	23.7	27.5	1.20	0.31631	0.35225	10	57	77
16	FA77	3.44	1.71	1.73	2.12	1.77	0.35	6227	23.1	26.7	1.10	0.22097	0.61628	10	60	77
17	FA77	3.24	1.44	1.80	2.58	1.88	0.70	2961	26.3	29.7	1.40	0.43769	0.79630	11	3	77
18	FA77	1.98	1.13	0.85	1.24	0.99	0.25	4441	18.6	29.4	1.20	0.17834	0.62626	11	4	77
19	FA77	2.41	1.45	0.96	0.96	0.65	0.31	4347	21.6	29.6	1.40	0.22176	0.39834	11	5	77
20	FA77	3.06	1.38	1.68	1.08	0.84	0.24	2619	23.1	25.5	1.10	0.46735	0.35294	11	97	77
21	FA77	2.44	1.25	1.19	1.56	1.18	0.38	3416	24.8	25.5	1.10	0.28571	0.63934	11	99	77
22	FA77	3.28	2.20	1.08	1.11	0.82	0.30	.	19.9	27.8	1.00	.	0.33841	12	63	77
23	FA77	2.68	2.10	0.58	0.96	0.81	0.15	.	21.3	28.0	0.92	.	0.35821	12	67	77
24	WI78	0.93	0.06	0.93	0.57	0.41	0.16	159	12.8	23.3	1.29	2.33962	0.61290	2	3	78
25	WI78	1.47	0.54	0.93	0.77	0.39	0.38	453	12.9	23.7	.	1.29801	0.52381	2	7	78
26	WI78	1.62	1.03	0.59	1.82	1.46	0.36	1013	17.6	26.6	1.40	0.63968	1.12346	2	60	78
27	WI78	3.59	1.81	1.78	0.57	0.57	0.00	1358	16.6	23.8	1.55	[illegible]	0.15877	2	63	78
28	WI78	1.42	1.33	0.09	1.58	1.37	0.21	2928	17.7	20.8	1.62	0.28008	1.11268	3	13	78
29	WI78	3.63	2.47	1.16	.	.	.	4221	17.1	13.1	1.79	0.34399	.	3	63	78
30	WI78	2.32	0.93	1.39	1.77	1.57	0.20	4404	18.7	13.5	1.70	0.21072	0.76293	3	97	78
31	WI78	3.41	1.54	1.87	2.14	1.49	0.65	4383	19.8	13.7	1.70	0.31120	0.62757	3	99	78
32	SP78	4.52	2.49	2.03	3.24	2.42	0.82	4201	25.9	18.1	2.43	0.43037	0.71681	4	23	78
33	SP78	6.30	3.24	3.06	3.79	3.11	0.68	4599	26.4	17.9	2.43	0.54795	0.60159	4	27	78
34	SP78	8.48	4.82	3.66	3.24	2.77	0.47	5408	24.5	20.6	1.42	0.62722	0.38208	4	73	78
35	SP78	6.26	5.08	1.18	2.87	2.64	0.23	3551	24.3	21.2	1.48	0.70515	0.45847	4	77	78
36	SP78	8.11	5.34	2.77	6.94	6.57	0.36	4924	28.5	22.9	1.33	0.65801	0.85573	5	27	78
37	SP78	5.33	1.97	3.36	6.64	5.96	0.72	2921	21.8	23.4	1.36	0.72989	1.25328	5	30	78
38	SP78	3.38	1.35	2.03	2.46	2.00	0.46	2664	28.1	19.8	1.55	0.50751	0.72781	5	67	78
39	SP78	8.33	5.34	2.99	2.62	2.22	0.40	5569	28.9	19.6	1.42	0.59831	0.31453	5	70	78
40	SP78	7.18	4.35	2.83	5.19	4.37	0.82	4273	32.8	22.8	1.48	0.67134	0.72284	6	27	78
41	SP78	5.80	2.43	3.37	6.38	6.29	0.09	4036	32.8	23.0	1.55	0.57483	1.10000	6	30	78
42	SP78	10.64	4.95	5.69	2.39	2.02	0.37	4116	30.4	24.2	1.36	1.03401	0.22462	6	77	78
43	SP78	5.79	3.27	2.52	4.24	4.04	0.19	3551	30.2	24.1	1.13	0.65221	0.73921	6	80	78
44	SU78	3.78	1.39	2.39	3.69	3.52	0.16	3830	31.7	23.3	1.42	0.39478	0.97354	7	23	78
45	SU78	5.86	3.29	2.57	1.80	1.38	0.42	4149	31.1	23.5	1.31	0.56496	0.30717	7	27	78
46	SU78	8.26	5.22	3.04	5.14	4.64	0.50	4036	30.9	24.2	1.31	0.81863	0.62228	7	70	78
47	SU78	6.97	4.08	2.89	4.24	3.93	0.31	3794	31.0	25.2	1.27	0.73464	0.60832	7	73	78
48	SU78	6.22	1.88	4.34	2.11	1.81	0.30	3874	31.5	22.7	1.42	0.64223	0.33927	8	17	78
49	SU78	3.85	1.47	2.38	1.54	1.46	0.12	2502	31.6	22.8	1.06	0.61551	0.41039	8	20	78
50	SU78	8.05	4.05	4.00	3.48	2.98	0.50	4762	34.0	23.4	1.31	0.67619	0.43230	8	93	78
51	SU78	6.50	3.97	2.53	4.38	4.13	0.25	4762	33.8	25.1	1.15	0.54599	0.67385	8	97	78
52	SU78	6.42	2.63	3.79	2.25	2.14	0.11	3511	31.2	27.1	1.21	0.73142	0.35047	9	70	78
53	SU78	3.90	1.73	2.17	1.74	1.49	0.25	3936	30.7	26.5	1.21	0.39634	0.44615	9	73	78
54	FA78	9.12	4.59	4.53	1.64	1.50	0.14	2972	30.7	30.1	1.42	1.22746	0.17982	10	3	78
55	FA78	7.64	4.03	3.61	2.69	2.04	0.65	3830	30.6	29.9	1.42	0.79791	0.35209	10	20	78
56	FA78	8.47	4.65	3.82	1.58	1.29	0.29	4145	27.6	29.7	1.31	0.81659	0.18654	10	23	78
57	FA78	3.45	1.65	1.80	1.91	1.45	0.46	3227	28.9	28.7	1.48	0.42764	0.55362	10	77	78
58	FA78	9.97	5.54	4.43	3.37	3.08	0.29	.	27.6	28.6	1.48	.	0.33801	11	37	78
59	FA78	8.65	4.34	4.31	4.03	3.66	0.37	.	27.9	28.7	1.42	.	0.46590	11	40	78
60	FA78	5.99	2.65	3.14	3.08	2.50	0.58	2582	27.4	28.2	1.48	0.92796	0.51419	11	97	78
61	FA78	5.58	2.27	3.31	.	.	.	2340	27.3	27.9	1.55	0.95385	.	11	99	78
62	FA78	5.53	2.44	3.09	0.99	0.73	0.26	1775	19.9	25.6	1.21	1.24620	0.17902	12	50	78
63	FA78	3.49	2.17	1.32	0.77	0.77	0.00	2743	20.5	26.5	1.06	0.50893	0.22063	12	53	78
64	FA78	3.35	1.82	1.53	0.77	0.73	0.04	2663	19.7	26.7	1.31	0.50319	0.22985	12	57	78
65	WI79	2.65	1.50	1.15	1.00	0.94	0.06	2662	16.4	27.0	1.35	0.39820	0.37736	1	17	79
66	WI79	1.99	1.15	0.84	0.51	-0.41	0.92	1775	14.4	27.5	.	0.44645	0.25628	1	20	79
67	WI79	0.37	0.20	0.17	0.95	0.83	0.12	2080	18.5	26.5	1.28	0.07115	2.56757	1	77	79
68	WI79	.	.	.	1.59	1.59	0.00	3224	19.8	26.5	1.70	.	.	1	80	79
69	WI79	4.17	1.89	2.28	1.82	1.25	0.57	1750	20.2	24.3	1.31	0.95314	0.43646	2	53	79
70	WI79	2.90	1.31	1.59	1.76	1.27	0.49	2022	19.1	24.1	1.17	0.57369	0.60690	3	7	79
71	WI79	2.76	1.11	1.65	2.53	2.53	0.00	2980	21.0	24.6	1.42	0.37047	0.91667	3	10	79
72	WI79	2.97	1.37	1.60	0.51	0.51	0.00	3246	19.0	24.4	1.03	0.36599	0.17172	3	57	79
73	WI79	2.65	1.62	1.03	0.57	0.52	0.00	4417	19.5	25.2	1.06	0.23998	0.19623	3	60	79
74	WI79	3.38	2.22	1.16	1.73	1.22	0.51	4533	26.1	24.4	1.52	0.29826	0.51183	3	99	79
75	SP79	5.62	3.17	2.45	1.79	1.22	0.56	4193	26.6	24.4	1.36	0.53613	0.31673	4	3	79

Middle Discharge Bay (B)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	IXSOL	TEMP	SAL	EXTINCT	ECOLEFF	PCRPLK	MONTH	DAY	YEAR
76	SP79	3.31	1.57	1.74	4.46	3.99	0.47	3639	29.8	26.2	1.48	0.36384	1.3474	4	70	79
77	SP79	1.59	0.46	1.13	4.11	4.11	0.00	3536	28.8	26.0	1.69	0.17986	2.5849	4	73	79
78	SP79	7.90	3.94	3.91	4.24	3.62	0.62	3016	28.7	25.7	2.00	0.92669	0.5367	5	17	79
79	SP79	9.00	4.41	4.59	.	.	.	3410	28.7	24.5	2.00	1.05572	.	5	20	79
80	SP79	4.61	3.07	1.54	4.08	3.64	0.44	5260	26.9	24.9	2.27	0.35057	0.8850	5	60	79
81	SP79	4.02	2.03	1.99	4.33	3.73	0.60	5470	26.3	24.7	2.27	0.29347	1.0771	5	63	79
82	SP79	7.29	3.36	3.93	3.94	3.68	0.26	3406	33.3	23.1	1.21	0.85614	0.5405	6	27	79
83	SP79	8.11	3.97	4.14	5.91	5.83	0.00	4334	32.6	26.1	1.79	0.74630	0.7189	6	30	79
84	SP79	8.16	4.46	3.70	2.59	1.92	0.67	5303	31.7	27.4	1.17	0.61530	0.3174	6	83	79
85	SP79	2.56	1.40	1.16	3.67	2.81	0.86	4367	31.4	28.1	1.31	0.23449	1.4336	6	86	79
86	SU79	9.49	5.97	3.52	5.78	4.78	1.00	4680	33.3	27.5	1.70	0.81111	0.6091	7	27	79
87	SU79	7.76	4.62	3.14	7.84	7.00	0.84	4783	33.2	27.6	1.53	0.64097	1.0103	7	30	79
88	SU79	2.06	1.51	0.55	4.58	4.02	0.56	3016	31.6	27.5	1.42	0.27321	2.2233	7	77	79
89	SU79	5.76	3.68	2.08	8.55	8.09	0.46	3328	31.1	26.9	1.36	0.69231	1.4844	7	81	79
90	SU79	3.58	2.21	1.37	2.94	2.39	0.55	3262	34.7	27.7	2.13	0.43899	0.8212	8	19	79
91	SU79	6.73	3.79	2.94	4.83	4.37	0.46	3170	35.0	28.0	1.26	0.84921	0.7177	8	23	79
92	SU79	11.61	5.82	5.79	7.04	5.15	1.89	4265	32.5	27.7	1.89	1.08886	0.6604	8	61	79
93	SU79	11.59	6.09	5.50	4.13	3.37	0.76	4506	33.0	27.9	1.79	1.02085	0.3563	8	65	79
94	SU79	3.92	1.03	2.89	3.36	3.25	0.61	3562	31.0	26.3	1.48	0.44020	0.9847	9	27	79
95	SU79	3.13	0.74	2.39	3.35	2.10	1.25	3343	30.5	26.5	1.70	0.37431	1.0703	9	30	79
96	SU79	4.77	1.98	2.79	2.10	0.47	1.63	2005	32.4	27.3	1.79	0.95162	0.4403	9	77	79
97	FA79	5.36	1.95	3.41	0.72	0.25	0.47	4263	28.2	21.4	2.52	0.50293	0.1343	10	16	79
98	FA79	7.77	4.59	3.18	1.95	1.76	0.19	3781	28.0	22.7	2.28	0.82200	0.2510	10	19	79
99	FA79	4.45	1.86	2.59	2.29	2.12	0.17	3088	31.2	28.9	2.00	0.59176	0.5146	10	61	79
100	FA79	5.05	2.23	2.82	2.40	1.95	0.45	2812	31.2	29.6	1.59	0.71835	0.4732	10	65	79
101	FA79	5.74	2.56	3.18	1.33	0.66	0.67	2213	29.1	29.6	1.55	1.03751	0.2317	11	7	79
102	FA79	4.75	3.20	1.55	.	.	.	2870	27.2	29.3	1.89	0.66202	.	11	10	79
103	FA79	3.28	3.09	0.19	0.99	0.74	0.25	2478	21.4	26.9	.	0.52946	0.3018	11	53	79
104	FA79	6.13	2.25	3.88	0.83	0.59	0.24	2651	21.9	27.4	.	0.92493	0.1354	11	57	79
105	FA79	4.32	2.99	1.33	0.59	0.31	0.28	3077	21.3	29.0	1.21	0.56159	0.1366	11	99	79
106	FA79	5.85	2.93	2.92	0.47	0.47	0.00	2328	20.6	28.1	2.43	1.00515	0.0803	12	3	79
107	FA79	3.10	1.08	2.02	0.46	0.27	0.19	980	25.8	29.3	.	1.26531	0.1484	12	48	79
108	FA79	-0.27	-0.27	0.00	2.40	2.40	0.00	231	25.0	30.1	.	-0.46733	-0.8889	12	52	79
109	WI80	0.62	0.31	0.31	0.29	0.16	0.13	645	18.5	27.0	1.57	0.38450	0.4677	1	13	80
110	WI80	0.71	0.49	0.22	0.14	0.13	0.01	2351	15.3	26.8	2.09	0.12080	0.1972	1	16	80
111	WI80	4.27	2.59	1.68	0.58	0.38	0.20	1810	22.5	28.6	0.85	0.94365	0.1358	1	58	80
112	WI80	3.35	2.05	1.30	0.49	0.37	0.12	2616	22.8	28.7	0.94	0.51223	0.1463	1	61	80
113	WI80	2.56	1.43	0.93	0.26	-0.16	0.42	3952	17.4	27.6	2.83	0.25911	0.1016	2	4	80
114	WI80	4.15	2.27	1.88	0.65	0.32	0.33	3120	17.5	26.3	1.42	0.53205	0.1566	2	7	80
115	WI80	5.01	3.06	1.95	1.09	0.97	0.12	3773	22.1	27.1	1.42	0.53114	0.2176	2	79	80
116	WI80	4.54	2.91	1.63	0.56	0.17	0.39	2139	22.7	26.6	1.17	0.84699	0.1233	2	82	80
117	WI80	2.45	1.75	0.70	0.99	0.89	0.10	3818	19.6	24.0	1.06	0.25660	0.4041	3	26	80
118	WI80	1.72	1.14	0.58	1.42	1.05	0.37	2525	20.7	24.0	1.26	0.27248	0.8256	3	29	80
119	WI80	1.92	1.30	0.62	0.85	0.70	0.15	4145	23.2	25.0	2.43	0.18528	0.4427	3	68	80
120	WI80	2.57	1.94	0.63	0.96	0.88	0.08	5080	20.6	25.1	1.55	0.20236	0.3735	3	71	80
121	SP80	3.02	1.63	1.39	0.53	0.62	0.21	2184	24.1	24.2	1.88	0.55311	0.2748	4	13	80
122	SP80	3.24	2.36	0.88	0.34	0.03	0.31	5125	22.9	22.5	2.21	0.25288	0.1049	4	17	80
123	SP80	4.63	2.85	1.78	2.15	1.74	0.41	4605	23.0	22.6	1.89	0.40217	0.4044	4	60	80
124	SP80	2.17	1.03	1.14	1.71	1.71	0.00	3550	23.5	23.1	1.89	0.24451	0.7880	4	63	80
125	SP80	3.29	1.85	1.44	2.25	1.79	0.46	5259	25.4	19.3	2.13	0.25024	0.6834	5	10	80
126	SP80	4.96	3.26	1.70	2.96	2.65	0.31	5125	26.2	19.8	2.27	0.38712	0.5968	5	13	80
127	SP80	8.39	5.06	3.33	2.23	2.08	0.15	4189	29.9	21.2	2.43	0.80115	0.2658	5	52	80
128	SP80	5.70	3.02	2.68	2.89	2.80	0.09	3387	29.6	22.0	1.79	0.67316	0.5070	5	55	80
129	SP80	7.98	3.94	4.04	3.65	3.56	0.09	4546	29.3	22.3	1.89	0.70216	0.4574	5	99	80
130	SP80	6.26	3.76	2.50	5.63	5.16	0.47	4902	28.5	22.7	3.40	0.51081	0.8994	6	3	80
131	SP80	8.70	4.95	3.75	4.60	4.15	0.45	5140	31.0	24.8	1.42	0.67704	0.5287	6	57	80
132	SP80	5.87	2.86	3.01	5.34	5.34	0.00	4768	30.9	27.8	1.48	0.49245	0.9097	6	60	80
133	SP80	4.02	2.37	1.65	4.07	3.23	0.84	2303	29.3	17.5	2.95	0.69822	1.0124	6	99	80
134	SU80	7.71	5.22	2.49	9.23	8.63	0.60	5467	30.9	17.5	2.23	0.56411	1.1971	7	3	80
135	SU80	7.66	4.08	3.58	5.67	5.40	0.27	5006	32.2	21.2	2.00	0.61207	0.7402	7	55	80
136	SU80	6.46	2.96	3.50	5.50	4.86	0.64	4019	32.4	21.7	2.13	0.64295	0.8514	7	58	80
137	SU80	6.13	2.94	3.19	5.05	4.68	0.37	3758	32.7	18.5	2.00	0.65247	0.8238	8	10	80
138	SU80	6.68	3.90	2.78	5.32	3.53	1.79	4724	32.9	19.0	1.70	0.56562	0.7964	8	13	80
139	SU80	6.90	3.73	3.17	4.56	4.01	0.55	4442	33.2	22.6	1.21	0.62134	0.6609	8	52	80
140	SU80	5.25	2.14	3.11	3.56	3.40	0.16	4709	34.0	22.8	1.17	0.44595	0.6781	8	55	80
141	SU80	6.35	3.31	3.04	3.00	2.16	0.84	4575	32.6	25.6	2.00	0.55319	0.4724	8	94	80
142	SU80	5.81	3.08	2.73	4.17	3.33	0.84	4397	33.0	25.9	1.89	0.52054	0.7177	8	97	80
143	SU80	6.80	3.96	2.84	3.93	3.51	0.42	4075	32.5	29.1	1.89	0.66748	0.5779	9	40	80
144	SU80	6.45	3.36	3.09	1.30	0.78	0.52	3692	32.9	28.9	1.26	0.69881	0.2016	9	43	80
145	SU80	7.31	4.64	2.67	2.69	1.74	0.95	3207	34.9	29.9	1.82	0.91176	0.3680	9	90	80
146	SU80	5.93	3.31	2.62	1.67	0.76	0.91	3663	34.8	29.7	1.60	0.64756	0.2816	9	93	80
147	FA80	7.15	3.37	3.78	2.78	2.51	0.27	3678	28.8	27.1	1.42	0.77760	0.3888	10	48	80
148	FA80	5.15	2.32	2.83	2.97	2.49	0.48	3354	29.0	27.0	1.26	0.61419	0.5767	10	52	80
149	FA80	1.17	1.17	0.00	1.40	1.34	0.06	2228	29.4	26.3	1.36	0.21035	1.1966	10	99	80
150	FA80	0.86	0.86	0.00	.	.	.	4163	29.0	26.7	1.79	0.08259	.	11	3	80

Middle Discharge Bay (B)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PCRPLN	MONTH	DAY	YEAR
151	FA80	3.67	1.39	2.28	2.92	2.08	0.84	1792	24.6	26.1	1.31	0.819196	0.79564	11	47	80
152	FA80	1.97	1.10	0.87	2.09	1.78	0.31	2663	24.7	26.3	1.48	0.295907	1.06091	11	50	80
153	FA80	0.79	0.79	0.00	0.84	0.75	0.09	3607	23.8	26.4	4.25	0.087607	1.06329	11	97	80
154	FA80	1.70	0.92	0.78	1.08	1.05	0.03	.	22.8	25.4	1.62	.	0.63529	11	99	80
155	FA80	0.71	0.29	0.42	1.21	0.60	0.61	1537	23.1	25.9	1.13	0.184776	1.70423	12	52	80
156	FA80	0.84	0.64	0.20	0.62	0.26	0.36	2249	22.5	26.0	1.70	0.149460	0.73810	12	55	80
157	WI81	2.87	1.93	0.94	0.97	-1.42	2.39	3631	17.6	25.5	.	0.314434	0.33798	1	13	81
158	WI81	2.41	1.70	0.71	.	.	.	3162	17.4	26.0	.	0.304870	.	1	16	81
159	WI81	1.68	.	.	0.23	0.17	0.06	2934	16.2	26.2	2.12	0.229039	0.13690	1	52	81
160	WI81	.	.	0.41	.	.	.	.	15.2	26.0	2.12	.	.	1	55	81
161	WI81	1.09	1.09	.	0.91	0.55	0.36	4645	20.2	26.6	1.06	0.093864	0.83486	1	97	81
162	WI81	0.86	0.60	0.26	0.50	0.23	0.27	3993	19.8	26.9	2.12	0.086151	0.58140	1	99	81
163	WI81	0.67	0.67	.	0.47	0.47	0.06	2820	18.8	25.5	2.27	0.095635	0.70149	2	46	81
164	WI81	0.35	0.35	.	0.52	0.36	0.16	4026	18.5	25.8	1.79	0.034774	1.48571	2	53	81
165	WI81	1.94	1.00	0.94	0.79	0.64	0.15	4727	19.7	24.0	.	0.164163	0.40722	2	96	81
166	WI81	2.20	1.04	1.16	0.73	0.62	0.11	4531	20.8	25.7	.	0.194218	0.33182	2	99	81
167	WI81	1.35	0.48	0.87	0.77	0.42	0.35	2152	21.9	24.6	1.13	0.250929	0.57037	3	42	81
168	WI81	4.88	3.00	1.88	1.00	0.87	0.13	5200	23.0	24.7	1.13	0.375365	0.20492	3	45	81
169	WI81	2.89	1.73	1.16	1.01	0.94	0.07	5575	20.7	23.2	.	0.207354	0.34948	3	87	81
170	WI81	2.50	1.25	1.25	0.84	0.58	0.26	4662	21.1	23.6	.	0.214500	0.33600	3	90	81
171	SP81	3.47	1.93	1.54	3.23	2.53	0.70	5444	27.0	25.4	1.54	0.254960	0.93084	4	33	81
172	SP81	3.21	1.60	1.61	.	.	.	6015	27.9	26.1	1.54	0.213466	.	4	37	81

Middle Control Bay (D)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLN	MONTH	DAY	YEAR
1	SP77	2.36	0.96	1.40	1.51	1.34	0.17	.	20.4	23.7	1.37	.	0.63983	4	23	77
2	SP77	9.32	5.58	3.74	5.04	3.58	1.46	.	31.3	26.4	1.40	.	0.54077	6	7	77
3	SU77	7.26	3.73	3.53	4.07	2.75	1.32	4200	30.8	26.9	1.50	0.69143	0.56061	7	3	77
4	SU77	6.34	2.30	4.04	2.35	1.48	0.87	5570	30.7	27.1	1.10	0.45534	0.37066	7	3	77
5	SU77	8.01	3.93	4.08	4.72	2.40	2.32	7400	31.6	27.2	0.97	0.43297	0.58926	7	37	77
6	SU77	1.87	-0.42	2.29	3.65	3.02	0.63	4780	29.7	28.2	1.10	0.15649	1.95187	8	.	77
7	SU77	4.98	2.65	2.33	3.78	2.40	1.38	3870	27.9	24.9	1.50	0.51473	0.79420	8	3	77
8	SU77	6.33	2.88	3.45	2.95	1.50	1.05	6030	29.2	28.4	1.10	0.41990	0.40284	8	3	77
9	SU77	8.16	4.13	4.03	3.53	2.88	0.65	5230	28.4	22.5	1.70	0.62409	0.43260	8	7	77
10	SU77	4.06	1.95	2.11	2.32	2.02	0.30	6462	29.5	30.9	0.90	0.25132	0.57143	9	3	77
11	SU77	5.66	2.79	2.87	2.67	2.35	0.32	4846	29.9	30.0	0.80	0.46242	0.47173	9	7	77
12	SU77	6.23	3.83	2.40	2.91	2.00	0.91	6379	30.4	26.7	1.40	0.37878	0.46709	9	7	77
13	FA77	4.88	1.73	3.15	4.15	3.07	1.08	9466	28.5	28.3	0.90	0.35712	0.85041	10	3	77
14	FA77	3.49	1.12	2.37	2.66	1.86	0.80	5738	22.6	28.5	1.10	0.26651	0.76218	10	7	77
15	FA77	2.00	0.36	1.64	0.90	0.77	0.16	6462	18.8	28.0	1.00	0.12380	0.45000	10	57	77
16	FA77	3.58	1.91	1.67	1.02	0.62	0.40	6227	18.6	27.6	1.10	0.22997	0.28492	10	60	77
17	FA77	2.61	0.85	1.76	0.92	0.67	0.25	2961	20.8	29.3	1.10	0.35259	0.35249	11	3	77
18	FA77	2.13	1.06	1.07	0.60	0.31	0.29	4347	15.6	30.0	0.90	0.19600	0.28169	11	5	77
19	FA77	2.09	0.51	1.58	.	0.65	.	4441	15.0	29.3	1.10	0.18825	.	11	47	77
20	FA77	1.39	0.96	0.43	0.86	0.74	0.12	2619	17.4	24.7	0.90	0.21229	0.61871	11	97	77
21	FA77	2.70	0.53	2.17	0.51	0.29	0.22	3416	18.6	24.7	0.90	0.31616	0.18889	11	99	77
22	FA77	1.89	1.29	0.60	0.55	0.23	0.33	.	15.2	26.5	.	.	0.29630	12	63	77
23	FA77	3.39	1.32	2.07	0.30	0.23	0.07	.	15.6	24.5	0.71	.	0.08850	12	67	77
24	WI78	0.41	0.05	0.36	0.40	0.34	0.14	159	9.1	23.5	1.06	1.03145	1.17073	2	3	78
25	WI78	0.85	0.39	0.46	0.76	0.27	0.49	453	9.7	22.7	0.85	0.75055	0.89412	2	7	78
26	WI78	1.62	1.23	0.39	1.74	1.43	0.31	1013	13.4	24.8	0.74	0.63960	1.07407	2	60	78
27	WI78	1.91	0.38	1.53	1.55	0.99	0.56	1358	13.5	25.7	1.70	0.56259	0.81152	2	63	78
28	WI78	3.13	1.26	1.87	2.87	2.50	0.37	2028	15.0	21.5	1.42	0.61736	0.91693	3	13	78
29	WI78	0.95	0.95	0.00	.	.	.	4221	14.5	21.4	1.42	0.09003	.	3	63	78
30	WI78	1.54	0.58	0.96	2.19	1.69	0.50	4404	17.7	19.4	1.84	0.13987	1.42208	3	97	78
31	WI78	2.74	1.12	1.62	2.31	1.67	0.64	4383	18.5	18.6	1.40	0.25046	0.84307	3	99	78
32	SP78	3.63	1.65	1.98	2.30	1.91	0.39	4201	24.3	22.2	1.55	0.34563	0.63361	4	23	78
33	SP78	3.19	1.54	1.65	3.23	2.61	0.62	4599	24.4	22.2	1.55	0.27745	1.01254	4	27	78
34	SP78	5.07	2.88	2.19	2.06	1.62	0.44	5408	22.7	22.0	1.31	0.37590	0.40631	4	74	78
35	SP78	3.37	0.54	2.83	2.44	2.44	0.00	3551	22.7	23.8	1.55	0.37961	0.72404	4	77	78
36	SP78	6.18	3.30	2.88	4.23	3.87	0.36	4924	26.3	21.2	1.40	0.50203	0.68447	5	27	78
37	SP78	5.47	2.54	2.93	4.11	3.03	1.08	2921	27.4	21.1	1.79	0.74906	0.75137	5	30	78
38	SP78	4.13	1.49	2.64	1.99	1.43	0.56	2604	26.3	18.1	1.17	0.62012	0.48184	5	67	78
39	SP78	8.05	4.64	3.41	2.61	2.45	0.16	5569	26.4	19.5	1.26	0.57820	0.32422	5	70	73
40	SP78	5.20	1.35	3.85	4.65	3.65	1.00	4278	29.9	20.4	1.36	0.48621	0.89423	6	27	78
41	SP78	5.16	3.01	2.15	5.44	4.80	0.64	4036	30.2	21.8	1.26	0.51140	1.05426	6	30	78
42	SP78	5.59	3.26	2.33	3.79	3.30	0.48	4116	27.4	23.6	1.06	0.54325	0.67621	6	77	78
43	SP78	3.31	1.34	1.97	2.69	2.19	0.50	3551	27.7	24.5	1.21	0.37285	0.81269	6	80	78
44	SU78	4.40	2.52	1.88	4.07	3.28	0.79	3830	29.5	21.5	1.13	0.45953	0.92500	7	23	78
45	SU78	2.83	2.01	0.82	4.17	3.09	1.08	4149	29.6	22.9	1.06	0.27284	1.47350	7	27	78
46	SU78	8.42	5.96	2.46	3.95	3.52	0.43	4036	28.5	21.9	1.00	0.88404	0.44283	7	70	78
47	SU78	6.04	3.76	2.28	5.46	4.59	0.87	3794	29.1	23.2	1.13	0.63679	0.90397	7	73	78
48	SU78	6.72	3.88	2.84	2.88	1.96	0.92	4762	29.2	19.4	0.85	0.56447	0.42857	8	17	78
49	SU78	4.25	1.49	2.76	1.85	1.36	0.49	4762	29.6	21.4	1.10	0.35699	0.43529	8	20	78
50	SU78	6.31	3.00	3.31	3.46	2.80	0.66	3874	30.0	24.0	0.81	0.65152	0.54834	8	93	78
51	SU78	7.11	4.32	2.79	5.08	4.90	0.18	2502	30.8	24.5	0.83	1.13669	0.71449	8	97	78
52	SU78	4.13	1.36	2.77	3.11	2.72	0.39	3511	29.0	27.6	1.06	0.47052	0.75303	9	70	78
53	SU78	4.50	2.60	1.90	3.40	3.40	0.00	3936	29.0	27.7	1.06	0.45732	0.75556	9	73	78
54	FA78	6.95	3.00	3.95	1.87	1.82	0.00	2972	26.8	28.8	1.24	0.93540	0.26187	10	3	78
55	FA78	3.04	1.78	1.26	1.19	0.87	0.32	3830	26.2	31.2	1.42	0.31749	0.39145	10	20	78
56	FA78	4.05	1.88	2.17	2.80	2.38	0.42	4149	24.0	31.8	1.42	0.39046	0.69136	10	23	78
57	FA78	3.98	1.66	2.32	3.76	2.80	0.96	3227	22.7	28.2	2.00	0.49334	0.94472	10	77	78
58	FA78	4.03	2.39	1.64	1.96	1.59	0.37	.	21.9	28.5	1.21	.	0.48635	11	37	78
59	FA78	5.46	2.30	3.16	3.25	3.25	0.00	.	21.8	28.5	1.42	.	0.59524	11	40	78
60	FA78	3.95	1.72	2.23	2.67	2.42	0.25	2582	21.6	26.2	1.36	0.61193	0.67595	11	97	78
61	FA78	2.87	1.32	1.55	2.35	2.35	0.00	2340	22.7	26.4	1.48	0.49060	0.81882	11	99	78
62	FA78	1.00	0.26	0.74	0.81	0.71	0.10	1775	14.1	25.2	0.85	0.22535	0.81000	12	50	78
63	FA78	2.80	1.51	1.29	0.65	0.63	0.02	2743	14.1	25.9	.	0.40831	0.23214	12	53	78
64	FA78	0.44	-0.65	1.09	0.53	0.53	0.00	2663	13.8	26.4	2.43	0.06609	1.20455	12	57	78
65	WI79	1.27	0.99	0.28	0.34	0.34	0.00	2662	10.2	25.6	1.04	0.19083	0.26772	1	17	79
66	WI79	2.80	1.58	1.22	0.45	-0.35	0.80	1775	11.8	25.8	0.75	0.63099	0.16071	1	20	79
67	WI79	0.55	0.16	0.39	1.23	0.23	1.00	2000	12.0	23.4	1.28	0.10577	2.23636	1	77	79
68	WI79	.	.	.	.	.	.	3224	12.8	22.6	4.25	.	.	1	80	79
69	WI79	2.93	1.38	1.55	0.87	0.87	0.00	1750	14.8	23.3	1.10	0.66971	0.29693	2	53	79
70	WI79	1.49	0.86	0.63	1.33	0.95	0.38	2022	15.3	24.6	1.48	0.29476	0.89262	3	7	79
71	WI79	1.45	0.62	0.83	1.40	1.07	0.33	2900	16.1	24.8	0.95	0.19463	0.96552	3	10	79
72	WI79	1.11	0.43	0.68	1.16	0.56	0.60	3246	17.3	25.8	1.36	0.13678	1.04505	3	57	79
73	WI79	1.73	1.31	0.42	1.48	1.53	0.15	4417	17.4	27.0	1.36	0.15667	0.97110	3	60	79
74	WI79	2.89	1.63	1.26	0.97	0.46	0.51	4533	20.3	23.0	1.35	0.25502	0.33564	3	99	79
75	SP79	2.71	1.45	1.26	1.16	0.70	0.46	4193	21.5	21.7	1.24	0.25853	0.42804	4	3	79

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	DOSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLX	MONTH	DAY	YEAR
76	SP79	3.60	1.89	1.79	2.11	1.63	0.48	3639	24.4	24.8	1.62	0.40451	0.5734	4	70	79
77	SP79	3.69	2.34	1.35	2.55	1.17	1.38	3536	24.0	24.0	1.36	0.41742	0.6911	4	73	79
78	SP79	5.36	2.31	2.99	3.52	2.16	1.36	3410	26.9	24.2	1.89	0.62170	0.6642	5	17	79
79	SP79	5.45	3.31	2.14	.	.	.	3410	27.3	22.2	1.55	0.63930	.	5	20	79
80	SP79	3.07	2.04	1.03	6.58	6.58	0.00	5260	25.6	26.8	3.09	0.23346	2.1433	5	60	79
81	SP79	3.34	1.80	1.54	6.71	5.60	.	5470	24.9	26.2	2.83	0.24424	2.0090	5	63	79
82	SP79	4.95	2.00	2.95	2.55	2.15	0.40	3406	30.5	26.3	1.10	0.58133	0.5152	6	27	79
83	SP79	5.09	2.74	2.35	4.51	3.75	0.76	4334	29.7	26.8	2.27	0.46977	0.8861	6	30	79
84	SP79	5.69	3.19	2.50	5.24	4.41	0.83	5303	30.1	28.0	1.55	0.42919	0.9209	6	83	79
85	SP79	5.56	3.27	2.29	5.61	4.30	1.31	4367	29.8	28.8	1.70	0.50927	1.0126	6	89	79
86	SU79	7.38	3.55	3.83	8.64	7.03	1.61	4680	31.0	27.9	1.89	0.63077	1.1707	7	27	79
87	SU79	8.02	3.55	4.47	5.58	4.48	1.10	4783	30.7	28.6	2.02	0.67071	0.6958	7	30	79
88	SU79	7.81	4.39	3.42	6.13	5.15	0.98	3016	29.2	24.7	1.48	1.03581	0.7869	7	77	79
89	SU79	7.16	3.39	3.77	7.86	6.05	1.81	3320	29.1	25.4	1.26	0.86038	1.0978	7	81	79
90	SU79	5.09	2.35	2.74	3.02	2.26	0.76	3262	30.1	24.6	1.13	0.62416	0.5933	8	19	79
91	SU79	6.16	2.85	3.31	5.09	4.11	0.98	3170	29.8	25.4	1.55	0.77729	0.8263	8	23	79
92	SU79	7.71	3.71	4.00	5.62	4.57	1.05	4265	29.9	26.5	2.00	0.72309	0.7289	8	61	79
93	SU79	7.83	4.17	3.66	6.02	5.13	0.89	4506	30.2	26.0	1.79	0.69507	0.7688	8	65	79
94	SU79	2.86	0.50	2.36	2.78	2.15	0.63	3562	29.2	26.9	1.36	0.32117	0.9720	9	27	79
95	SU79	2.21	0.38	1.83	3.39	2.82	0.57	3343	28.8	27.9	1.79	0.26443	1.5339	9	30	79
96	FA79	4.87	2.77	2.10	3.85	3.43	0.42	4263	25.9	27.0	1.98	0.45696	0.7906	10	16	79
97	FA79	5.92	3.25	2.67	2.34	2.10	0.24	3781	24.5	26.2	1.47	0.62629	0.3953	10	19	79
98	FA79	5.53	2.74	2.79	2.81	2.60	0.21	3008	24.8	27.1	1.48	0.73537	0.5081	10	61	79
99	FA79	6.30	3.62	2.68	3.46	2.23	1.23	2812	25.1	27.8	1.31	0.89616	0.5492	10	65	79
100	FA79	3.40	1.22	2.18	1.00	1.00	0.00	2213	23.8	26.4	1.00	0.61455	0.2941	11	7	79
101	FA79	3.34	2.21	1.13	1.09	1.09	0.00	2870	22.4	26.7	1.13	0.46551	0.3263	11	10	79
102	FA79	5.05	3.37	1.68	1.40	0.70	0.70	2478	16.9	28.4	.	0.81517	0.2772	11	53	79
103	FA79	5.57	3.39	2.18	1.03	0.75	0.28	2651	17.0	28.1	.	0.84044	0.1849	11	57	79
104	FA79	3.05	2.06	0.99	0.19	-0.06	0.25	3077	13.8	29.1	1.13	0.39649	0.0623	11	99	79
105	FA79	1.92	1.60	0.12	2.07	0.60	1.47	2328	13.2	27.9	1.13	0.32940	1.0781	12	3	79
106	FA79	3.06	1.39	1.67	0.30	0.26	0.04	980	19.6	26.9	.	1.24698	0.0980	12	48	79
107	FA79	2.33	0.65	1.68	0.56	0.56	0.00	231	18.2	27.4	.	4.03463	0.2403	12	52	79
108	WI80	-0.21	-0.36	0.15	0.28	0.11	0.17	640	12.5	27.1	1.42	-0.13023	-1.3333	1	13	80
109	WI80	0.85	0.39	0.46	0.15	0.05	0.10	2351	11.4	27.6	1.32	0.14462	0.1765	1	16	80
110	WI80	1.41	0.65	0.76	0.44	0.26	0.18	1810	16.4	26.3	0.68	0.31160	0.3121	1	58	80
111	WI80	1.98	0.98	1.00	0.28	0.06	0.22	2616	16.6	26.5	0.68	0.30275	0.1414	1	61	80
112	WI80	1.21	1.19	0.02	0.13	0.06	0.07	3952	11.9	27.1	1.31	0.12247	0.1074	2	4	80
113	WI80	2.10	1.21	0.89	1.09	1.09	0.00	3129	10.9	25.1	1.42	0.26923	0.5190	2	7	80
114	WI80	0.25	0.20	0.05	0.80	0.40	0.40	3773	16.1	25.7	1.42	0.02650	3.2000	2	79	80
115	WI80	1.70	0.73	0.97	1.24	1.00	0.24	2139	17.8	23.3	1.00	0.31791	0.7294	2	82	80
116	WI80	3.33	1.97	1.36	.	.	.	3818	16.7	23.0	1.62	0.34687	.	3	26	80
117	WI80	2.77	1.12	1.65	1.45	-1.31	2.76	2525	18.8	20.9	2.00	0.43891	0.5235	3	29	80
118	WI80	1.54	1.09	0.45	2.00	1.28	0.72	4145	21.3	24.6	3.78	0.14861	1.2987	3	68	80
119	WI80	2.71	1.56	1.15	1.85	1.56	0.29	5000	19.2	25.6	1.70	0.21339	0.6827	3	71	80
120	SP80	1.43	0.43	1.00	1.70	1.08	0.62	2184	22.4	21.7	1.86	0.26190	1.1888	4	13	80
121	SP80	3.33	1.80	1.53	3.14	2.67	0.47	5125	21.5	22.5	2.01	0.25940	0.9429	4	17	80
122	SP80	1.43	1.28	0.15	1.32	0.72	0.60	4605	21.3	24.9	2.43	0.12421	0.9231	4	60	80
123	SP80	2.00	0.78	1.22	1.86	1.86	0.00	3550	21.7	24.7	2.13	0.22535	0.9300	4	63	80
124	SP80	2.71	1.39	1.32	2.30	1.59	0.71	5259	23.3	23.1	2.43	0.20612	0.8487	5	10	80
125	SP80	3.73	2.06	1.73	4.02	3.16	0.86	5125	24.1	22.8	2.62	0.29112	1.0777	5	13	80
126	SP80	3.48	1.85	1.63	3.34	3.02	0.32	4189	27.6	21.6	2.62	0.33230	0.9598	5	52	80
127	SP80	5.23	2.86	2.37	5.17	4.69	0.48	1387	27.3	22.5	2.43	0.61766	0.9885	5	55	80
128	SP80	2.57	1.29	1.28	1.93	1.56	0.37	4546	26.8	21.8	2.43	0.22613	0.7510	5	99	80
129	SP80	3.13	1.67	1.46	3.31	2.79	0.52	4902	26.8	27.5	2.62	0.25541	1.0575	6	3	80
130	SP80	5.36	3.06	2.30	3.42	3.01	0.41	5140	28.7	25.1	1.21	0.41712	0.6381	6	57	80
131	SP80	4.62	2.27	2.35	5.21	4.58	0.63	4768	29.2	25.4	1.89	0.38758	1.1277	6	60	80
132	SP80	2.81	1.45	1.36	4.28	3.85	0.43	2303	29.0	20.9	3.03	0.48806	1.5231	6	99	80
133	SU80	5.27	3.03	2.24	5.70	5.50	0.20	5467	29.7	20.8	2.02	0.38559	1.0816	7	3	80
134	SU80	4.06	1.85	2.21	2.56	1.80	0.76	5006	30.4	22.0	1.62	0.32441	0.6305	7	55	80
135	SU80	4.28	2.49	1.79	2.37	1.36	1.01	4019	30.1	21.2	2.62	0.42598	0.5537	7	58	80
136	SU80	4.98	2.30	2.68	2.41	1.88	0.53	3758	31.0	19.4	1.55	0.53007	0.4839	8	10	80
137	SU80	3.23	1.40	1.83	2.81	1.67	1.14	4724	30.9	19.7	1.62	0.27350	0.8700	8	13	80
138	SU80	5.09	2.78	2.31	2.20	1.59	0.61	4442	29.5	21.3	1.03	0.45835	0.4322	8	52	80
139	SU80	4.39	2.19	2.20	2.76	2.21	0.55	4709	30.2	22.1	1.06	0.37290	0.6287	8	55	80
140	SU80	3.21	1.69	1.52	6.34	5.40	0.94	4573	29.5	26.0	2.43	0.28066	1.9751	8	94	80
141	SU80	4.38	2.03	2.35	4.51	3.76	0.75	4397	29.6	25.6	1.70	0.39845	1.0297	8	97	80
142	SU80	2.89	1.12	1.77	3.47	2.67	0.80	4075	28.4	28.4	1.10	0.28368	1.2007	9	40	80
143	SU80	4.25	2.58	1.67	3.04	2.61	0.43	3692	28.5	29.1	0.97	0.46646	0.7153	9	43	80
144	SU80	7.95	4.33	3.62	3.48	2.68	0.80	3207	30.1	26.6	1.04	0.99158	0.4377	9	90	80
145	SU80	6.21	2.72	3.49	5.25	4.20	1.05	3663	30.2	27.0	1.04	0.67813	0.8454	9	93	80
146	FA80	3.90	1.68	2.22	1.82	1.50	0.32	3678	24.6	25.8	1.13	0.42414	0.4667	10	48	80
147	FA80	5.08	2.92	2.16	2.26	1.32	0.94	1354	25.0	23.7	1.06	0.60594	0.4449	10	52	80
148	FA80	3.35	1.83	1.52	2.33	1.66	0.67	2228	22.7	25.7	1.31	0.60144	0.6953	10	99	80
149	FA80	7.02	4.32	2.70	3.32	2.23	1.09	4165	21.8	26.3	1.31	0.67419	0.4729	11	3	80
150	FA80	2.03	1.48	0.35	2.98	1.93	0.95	1792	19.0	25.9	1.31	0.45312	1.4187	11	47	80

Middle Control Bay (D)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
151	FA80	1.68	1.07	1.61	2.86	1.89	0.97	2663	19.7	25.5	1.42	0.252347	1.70238	11	50	80
152	FA80	2.32	1.81	0.51	1.18	1.18	0.00	3607	15.9	25.7	1.62	0.257278	0.50862	11	97	80
153	FA80	3.22	2.02	1.20	1.17	0.72	0.45	.	15.9	24.5	1.31	.	0.36335	11	99	80
154	FA80	0.49	0.03	0.46	0.40	0.40	0.00	1537	16.2	24.9	0.87	0.127521	0.81633	12	52	80
155	FA80	3.31	2.43	0.88	0.75	-0.08	0.84	2249	15.9	24.3	1.00	0.588706	0.22961	12	55	80
156	WI81	1.32	0.56	0.76	0.09	-0.29	0.38	3651	11.4	25.1	0.94	0.144618	0.06818	1	13	81
157	WI81	1.15	0.69	0.46	0.31	0.27	0.04	3162	10.6	25.8	.	0.145478	0.26957	1	16	81
158	WI81	1.10	0.71	0.39	0.30	0.12	0.18	2934	9.4	24.4	0.85	0.149966	0.27273	1	52	81
159	WI81	1.88	0.87	1.01	.	.	.	.	8.0	25.2	1.54	.	.	1	55	81
160	WI81	0.39	0.06	0.33	0.46	0.28	0.18	4645	12.8	24.6	.	0.033564	1.17949	1	97	81
161	WI81	2.13	0.81	1.32	0.64	0.13	0.51	3993	13.0	24.9	.	0.213373	0.30047	1	99	81
162	WI81	1.30	0.93	0.37	0.95	0.82	0.14	2820	11.7	24.9	1.79	0.184397	0.73846	2	46	81
163	WI81	1.94	1.02	0.92	1.01	0.72	0.29	4026	12.7	25.3	1.48	0.192747	0.52062	2	53	81
164	WI81	1.99	1.20	0.79	0.46	0.36	0.10	4727	17.5	26.4	.	0.168394	0.23116	2	96	81
165	WI81	2.45	1.09	1.36	0.57	0.30	0.27	4531	18.3	25.7	.	0.216288	0.23265	2	99	81
166	WI81	1.22	0.18	1.04	0.76	0.49	0.27	2152	16.8	24.4	1.06	0.226766	0.62295	3	42	81
167	WI81	3.74	1.93	1.81	0.56	0.52	0.04	5200	16.8	24.7	0.81	0.287692	0.14973	3	45	81
168	WI81	2.55	1.39	1.16	1.02	0.57	0.45	5575	17.8	23.8	1.21	0.182960	0.40000	3	87	81
169	WI81	2.72	1.93	0.79	1.04	0.38	0.66	4662	19.1	23.3	1.00	0.233376	0.38235	3	90	81
170	SP81	2.34	1.25	1.09	3.39	1.89	1.50	5444	22.5	24.8	1.70	0.171932	1.44872	4	33	81
171	SP81	1.48	0.73	0.75	.	.	.	6015	23.4	24.1	1.31	0.098421	.	4	37	81

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	FERPLK	MONTH	DAY	YEAR
1	SP77	2.99	2.08	0.91	.	.	.	.	33.38	27.68	1.79	.	.	6	99	77
2	SU77	4.85	1.88	2.97	.	.	.	4200	33.38	27.68	1.48	0.46190	.	7	3	77
3	SU77	5.30	2.77	2.53	.	.	.	5570	35.00	29.01	1.22	0.38061	.	7	43	77
4	SU77	0.15	-2.21	2.36	.	.	.	4700	33.30	30.10	1.62	0.01255	.	8	30	77
5	SU77	5.69	2.36	3.33	0.80	-0.14	0.94	3870	29.52	26.74	1.31	0.56011	0.14060	8	73	77
6	SU77	4.90	3.40	1.50	7.24	6.23	1.03	5230	29.52	26.74	1.36	0.37476	1.48163	8	77	77
7	SU77	4.32	2.92	1.50	5.19	4.17	1.02	6579	34.77	29.70	1.06	0.26265	1.20179	9	27	77
8	SU77	7.67	4.54	3.13	2.38	1.14	1.24	6462	33.78	31.48	1.48	0.47478	0.31030	9	63	77
9	SU77	5.26	3.68	1.58	3.31	2.84	0.47	4986	33.78	31.48	1.70	0.42198	0.62928	9	67	77
10	FA77	9.26	4.41	4.85	3.50	2.34	1.16	5466	32.64	30.17	1.29	0.67764	0.37797	10	3	77
11	FA77	7.04	2.50	4.54	4.66	3.51	0.55	5238	32.73	29.98	1.43	0.53761	0.57670	10	7	77
12	FA77	5.02	3.14	1.88	2.75	2.12	0.63	6462	22.46	26.38	1.17	0.31074	0.54781	10	57	77
13	FA77	3.46	1.66	0.80	2.58	1.93	0.65	6227	22.46	26.38	1.06	0.22226	0.74566	10	60	77
14	FA77	6.19	2.54	3.65	2.23	2.00	0.23	2961	24.30	28.37	1.42	0.83620	0.36026	11	3	77
15	FA77	3.08	1.91	1.17	2.05	1.08	0.97	4441	19.98	29.30	1.36	0.27741	0.66558	11	47	77
16	FA77	4.08	2.73	1.35	1.69	1.29	0.31	4347	19.98	29.30	1.31	0.37543	0.39216	11	50	77
17	FA77	2.46	1.37	1.09	0.96	0.89	0.07	2619	23.40	25.16	1.13	0.37572	0.39024	11	97	77
18	FA77	3.82	1.57	2.25	1.49	1.16	0.33	3416	23.40	25.16	1.26	0.44731	0.39005	11	99	77
19	FA77	1.67	1.67	0.00	1.28	0.96	0.32	.	18.40	25.20	0.89	.	0.76047	12	63	77
20	FA77	1.44	1.44	0.00	1.19	1.02	0.17	.	20.30	27.50	0.94	.	0.82639	12	67	77
21	WI78	1.29	1.08	0.21	0.55	0.23	0.32	159	13.00	22.90	1.13	3.24528	0.42636	2	3	78
22	WI78	0.95	0.64	0.31	0.76	0.41	0.35	453	12.40	23.40	0.81	0.83805	0.80000	2	7	78
23	WI78	2.80	2.74	0.06	2.64	2.02	0.62	1013	16.30	26.90	1.17	1.10563	0.94286	2	60	78
24	WI78	1.47	0.99	0.48	0.87	0.49	0.60	1358	16.30	27.00	1.40	0.43299	0.55782	2	63	78
25	WI78	0.46	0.46	0.00	2.87	2.81	0.00	2028	17.60	20.80	1.40	0.09073	6.10870	3	13	78
26	WI78	5.39	3.94	1.45	.	.	.	4221	16.20	11.40	1.55	0.51078	.	3	63	78
27	WI78	2.28	0.56	1.72	3.87	2.64	1.23	4404	18.80	12.80	1.89	0.20708	1.69737	3	97	78
28	WI78	6.29	3.72	2.57	4.45	3.29	1.16	4383	20.00	13.00	1.62	0.57404	0.70747	3	99	78
29	SP78	3.80	1.41	2.39	5.00	3.04	1.96	4201	25.90	17.90	2.13	0.36182	1.31579	4	23	78
30	SP78	5.11	2.49	2.62	4.61	3.59	1.02	4599	25.90	16.90	2.43	0.44444	0.90215	4	27	78
31	SP78	8.42	5.76	2.66	6.73	5.88	0.85	5408	24.30	19.80	2.13	0.62278	0.79929	4	73	78
32	SP78	5.29	2.07	3.22	6.77	4.73	2.04	3551	24.20	20.10	1.94	0.59589	1.27977	4	77	78
33	SP78	5.04	2.00	3.04	12.00	11.57	0.43	4924	29.40	23.70	1.79	0.40942	2.38095	5	27	78
34	SP78	6.13	4.68	1.45	13.13	12.15	0.98	2921	30.10	23.90	1.40	0.83944	2.14192	5	30	78
35	SP78	1.28	-1.66	2.94	3.54	2.90	0.64	2664	30.50	20.70	1.62	0.19219	2.76563	5	67	78
36	SP78	5.10	1.49	3.61	2.93	2.45	0.48	5569	30.20	20.70	1.40	0.36631	0.57451	5	70	78
37	SP78	4.50	2.03	2.47	6.08	5.13	0.95	4278	32.90	23.40	1.26	0.42076	1.35111	6	27	78
38	SP78	.	.	.	.	.	.	4036	31.20	23.50	1.42	.	.	6	30	78
39	SP78	7.30	3.24	4.06	9.10	8.23	0.87	4116	30.30	24.10	1.40	0.70943	1.24658	6	77	78
40	SP78	5.15	3.24	1.91	.	.	.	3551	30.00	23.70	1.70	0.50012	.	6	80	78
41	SU78	2.21	-1.54	3.75	5.05	4.79	0.26	3830	31.70	23.30	1.53	0.23601	2.28507	7	23	78
42	SU78	1.31	-0.95	2.26	5.81	5.49	0.32	4149	31.00	23.20	1.42	0.12630	4.43511	7	27	78
43	SU78	5.27	4.34	0.93	.	.	.	4036	31.60	25.20	1.42	0.52230	.	7	70	78
44	SU78	4.49	2.70	1.79	4.55	3.88	0.67	3794	31.50	24.90	1.70	0.47338	1.01336	7	73	78
45	SU78	2.70	1.52	1.18	4.56	4.01	0.55	3874	33.00	23.70	1.30	0.27878	1.68889	8	17	78
46	SU78	2.19	1.46	0.73	4.20	4.20	0.00	2502	32.40	23.60	1.42	0.35012	1.91781	8	20	78
47	SU78	2.56	1.03	1.53	4.14	3.08	1.06	4762	33.50	24.60	1.13	0.21504	1.61719	8	93	78
48	SU78	4.54	3.38	1.16	5.07	4.61	0.46	4762	33.60	25.40	1.17	0.38135	1.11674	8	97	78
49	SU78	5.81	2.69	3.12	3.79	3.79	0.00	3511	31.00	25.90	1.42	0.66192	0.63683	9	70	78
50	SU78	5.46	3.15	2.31	3.94	3.94	0.00	3934	30.60	25.50	1.26	0.55488	0.72161	9	73	78
51	FA78	1.91	0.10	1.81	4.34	3.23	1.11	2972	31.00	30.30	1.58	0.25707	2.27225	10	3	78
52	FA78	7.79	4.15	3.64	3.03	2.03	1.00	3830	31.00	29.70	1.42	0.81358	0.38896	10	20	78
53	FA78	5.50	2.43	3.07	3.05	2.24	0.81	4149	27.70	28.20	1.42	0.53025	0.55455	10	23	78
54	FA78	4.64	3.13	1.51	4.27	3.20	1.07	3227	26.10	27.20	1.31	0.57515	0.92026	10	77	78
55	FA78	9.25	1.20	8.05	4.23	3.42	0.81	.	27.30	28.40	1.65	.	0.45730	11	37	78
56	FA78	2.22	1.67	0.55	4.72	4.72	0.00	.	27.20	28.20	1.59	.	2.12613	11	40	78
57	FA78	3.46	1.38	2.08	3.61	3.61	0.00	2582	26.30	27.80	1.42	0.53607	1.04335	11	97	78
58	FA78	1.45	0.77	0.68	0.19	0.06	0.13	2340	26.80	27.90	1.48	0.24786	0.13103	11	99	78
59	FA78	3.76	0.00	3.76	1.09	0.88	0.21	1775	19.40	25.50	1.06	0.84732	0.28989	12	50	78
60	FA78	1.68	1.00	0.08	1.80	1.77	0.03	2743	18.80	25.90	1.17	0.24499	1.07143	12	53	78
61	FA78	1.40	0.00	1.40	1.91	1.64	0.27	2663	18.40	26.00	1.31	0.21029	1.36429	12	57	78
62	WI79	5.28	4.72	0.56	2.02	1.90	0.12	2662	15.30	26.70	1.01	0.79339	0.38258	1	17	79
63	WI79	2.50	2.50	0.00	0.89	-0.48	1.37	1775	14.40	27.30	0.73	0.56338	0.35600	1	20	79
64	WI79	1.36	0.50	0.86	1.42	1.29	0.13	2080	15.20	24.20	1.10	0.26154	1.04412	1	77	79
65	WI79	.	.	.	1.31	1.31	0.00	3224	17.50	25.80	1.70	.	.	1	80	79
66	WI79	1.43	1.32	0.11	1.51	1.15	0.36	1750	19.90	24.40	1.79	0.32686	1.05594	2	53	79
67	WI79	2.55	2.22	0.33	1.92	1.42	0.50	2022	18.20	24.00	1.21	0.50445	0.75294	3	7	79
68	WI79	4.49	3.07	1.42	3.51	3.51	0.00	2980	19.10	24.30	0.83	0.60268	0.78174	3	10	79
69	WI79	3.21	2.13	1.08	1.03	0.63	0.40	3244	18.60	23.80	1.10	0.39556	0.32087	3	57	79
70	WI79	2.24	2.08	0.16	1.36	1.36	0.00	4417	18.60	24.30	1.15	0.20285	0.60714	3	60	79
71	WI79	3.46	2.43	1.03	0.98	0.05	0.93	4133	24.80	24.20	1.23	0.30532	0.28324	3	99	79
72	SP79	3.48	2.32	1.16	1.03	-0.09	1.12	4193	25.70	24.40	1.24	0.33198	0.29598	4	3	79
73	SP79	4.62	2.64	1.98	4.67	3.81	0.81	1379	29.00	26.10	2.62	0.50783	1.00000	4	70	79
74	SP79	4.07	2.49	1.58	7.52	6.56	0.96	3536	27.90	26.10	2.43	0.46641	1.84767	4	73	79
75	SP79	5.73	3.28	2.45	.	.	.	3410	28.30	25.70	2.27	0.67214	.	5	17	79

Outer Discharge Bay (OB)

OBS	TIME	PG	PN	R	PLANBPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PCRPLN	MONTH	DAY	YEAR
76	SP79	3.20	1.99	1.21	.	.	.	3410	28.7	23.6	2.43	0.37537	.	5	20	79
77	SP79	4.86	3.52	1.34	4.49	3.79	0.70	5260	23.6	22.9	2.43	0.36958	0.9239	5	60	79
78	SP79	4.62	2.48	2.14	4.37	3.48	0.89	5470	25.1	22.7	2.43	0.33784	0.9459	5	63	79
79	SP79	2.37	1.24	1.13	2.65	1.93	0.72	3406	31.4	21.6	1.48	0.27833	1.1181	6	27	79
80	SP79	4.71	2.51	2.20	7.35	7.07	0.28	4334	30.7	23.6	1.89	0.43470	1.5605	6	30	79
81	SP79	5.14	3.74	1.40	3.67	2.78	0.84	5303	31.5	27.4	1.31	0.38771	0.7043	6	83	79
82	SP79	5.29	2.95	2.34	3.28	2.47	0.81	4367	30.7	27.3	1.26	0.46454	0.6200	6	86	79
83	SU79	5.15	2.78	2.37	6.88	5.10	1.78	4600	33.3	27.2	1.76	0.44017	1.3359	7	27	79
84	SU79	6.79	3.68	3.11	8.49	7.46	1.03	4783	32.6	26.9	1.65	0.56784	1.2504	7	30	79
85	SU79	8.07	5.16	2.91	7.18	6.17	1.01	3016	29.9	28.1	1.42	1.07029	0.8897	7	77	79
86	SU79	7.73	3.89	3.84	10.31	9.52	0.79	3328	29.6	28.1	1.55	0.92909	1.1338	7	81	79
87	SU79	1.23	-0.75	1.98	5.19	4.44	0.75	3262	35.5	27.5	1.48	0.15083	4.2195	8	19	79
88	SU79	2.19	0.83	1.36	9.40	8.26	1.14	3170	35.1	27.7	1.62	0.27634	4.2922	8	23	79
89	SU79	3.94	1.65	2.29	7.03	5.56	1.47	4265	32.1	27.2	2.00	0.36952	1.7843	8	61	79
90	SU79	4.52	1.90	2.72	6.43	5.44	0.99	4506	32.8	27.5	2.00	0.40124	1.4226	8	65	79
91	SU79	4.54	-1.37	5.91	6.24	5.17	1.07	3562	31.6	27.1	1.48	0.50993	1.3744	9	27	79
92	SU79	4.33	-1.25	5.58	4.84	4.01	0.83	3343	30.5	26.6	2.13	0.51810	1.1178	9	30	79
93	FA79	3.98	0.62	3.36	2.60	1.58	1.02	4263	27.9	19.7	2.71	0.37345	0.6533	10	16	79
94	FA79	6.10	2.20	3.90	4.17	3.65	0.52	3781	27.1	20.8	2.02	0.64533	0.6836	10	19	79
95	FA79	1.18	0.10	1.08	2.92	2.62	0.30	3009	30.7	28.2	1.70	0.15691	2.4746	10	61	79
96	FA79	1.53	1.39	0.14	4.24	3.23	1.01	2812	29.7	28.3	1.55	0.21764	2.7712	10	65	79
97	FA79	1.29	0.13	1.16	1.53	0.97	0.56	2213	29.9	29.5	1.42	0.23317	1.1860	11	7	79
98	FA79	0.83	0.06	0.77	1.82	1.72	0.10	2870	28.8	29.9	1.53	0.11568	2.1928	11	10	79
99	FA79	1.34	1.34	0.00	1.11	0.64	0.47	2478	23.1	28.2	1.00	0.21630	0.8284	11	53	79
100	FA79	3.09	3.09	0.00	2.09	1.43	0.66	2631	21.6	27.0	0.94	0.46624	0.6764	11	57	79
101	FA79	2.58	2.58	0.00	0.65	0.29	0.36	3077	18.3	28.0	1.36	0.33539	0.2519	11	99	79
102	FA79	1.99	1.99	0.00	0.74	0.48	0.26	2328	18.4	27.3	1.55	0.34192	0.3719	12	3	79
103	FA79	0.73	0.73	0.00	0.50	0.47	0.03	980	25.5	28.7	1.13	0.29796	0.6849	12	48	79
104	FA79	-0.25	-0.25	0.00	1.18	1.18	0.00	231	24.0	29.2	1.06	-0.43290	-4.7200	12	52	79
105	WI80	0.30	0.30	0.00	0.31	0.21	0.10	645	18.3	26.8	1.42	0.18605	1.0333	1	13	80
106	WI80	2.70	1.84	0.86	0.40	0.36	0.04	2351	15.7	26.4	1.90	0.45938	0.1481	1	16	80
107	WI80	2.25	2.25	0.00	0.59	0.52	0.07	1810	21.1	28.2	1.10	0.49724	0.2622	1	58	80
108	WI80	2.75	2.75	0.00	0.79	0.36	0.43	2616	21.8	28.5	1.03	0.42049	0.2873	1	61	80
109	WI80	0.49	0.49	0.00	0.81	0.42	0.39	3952	18.7	27.1	2.00	0.04960	1.6531	2	4	80
110	WI80	3.30	3.30	0.00	0.20	0.10	0.10	3120	15.9	25.6	1.36	0.42308	0.0606	2	7	80
111	WI80	5.26	4.22	1.04	1.67	1.63	0.04	3773	20.4	27.1	1.26	0.55765	0.3175	2	79	80
112	WI80	3.91	3.17	0.74	0.91	0.35	0.56	2139	21.3	26.9	1.06	0.73118	0.2327	2	82	80
113	WI80	4.14	4.14	0.00	1.50	1.08	0.42	3818	18.0	24.5	1.42	0.43373	0.3623	3	26	80
114	WI80	2.57	2.16	0.41	2.19	1.03	1.16	2525	19.0	25.1	1.17	0.40713	0.8521	3	29	80
115	WI80	1.55	0.83	0.72	2.24	1.85	0.39	4145	22.1	25.5	2.13	0.14958	1.4452	3	68	80
116	WI80	4.54	3.95	0.59	2.36	2.01	0.35	5080	19.8	21.8	1.55	0.35746	0.5198	3	71	80
117	SP80	2.81	1.51	1.30	1.75	1.36	0.39	2184	24.0	24.3	2.10	0.51465	0.6228	4	13	80
118	SP80	3.02	2.67	0.35	1.33	0.35	0.98	5125	23.2	23.0	2.19	0.23571	0.4404	4	17	80
119	SP80	3.30	2.78	0.52	2.44	2.28	0.16	4605	22.3	21.8	1.89	0.28664	0.7394	4	60	80
120	SP80	2.80	1.78	1.02	2.66	2.66	0.00	3550	23.2	23.0	2.27	0.31549	0.7357	4	63	80
121	SP80	2.34	2.03	0.31	2.09	2.22	0.67	3259	24.9	19.0	2.27	0.17748	1.2350	5	10	80
122	SP80	2.93	2.40	0.53	4.60	4.29	0.31	5125	25.6	19.4	2.13	0.22868	1.5700	5	13	80
123	SP80	7.52	5.29	2.23	6.15	5.63	0.52	4189	29.5	21.1	2.43	0.71807	0.8178	5	52	80
124	SP80	4.47	2.34	2.13	7.38	6.63	0.75	3387	29.1	21.7	2.13	0.52790	1.6510	5	55	80
125	SP80	3.95	1.47	2.48	6.19	5.42	0.77	4546	28.8	22.1	3.09	0.34756	1.5671	5	99	80
126	SP80	4.84	3.06	1.78	7.99	7.34	0.65	4902	28.2	22.5	3.40	0.39494	1.6508	6	3	80
127	SP80	1.33	0.09	1.24	4.84	4.17	0.67	5140	30.2	24.3	1.36	0.10350	3.6391	6	57	80
128	SP80	4.28	3.61	0.67	7.13	7.13	0.00	4768	30.4	23.6	1.70	0.35906	1.6659	6	60	80
129	SP80	3.70	1.24	2.46	4.62	3.64	0.98	2303	30.2	18.2	2.83	0.64264	1.2486	6	99	80
130	SU80	14.05	11.32	2.73	13.01	12.29	0.72	5467	30.4	16.8	2.44	1.02799	0.9260	7	3	80
131	SU80	7.63	3.83	3.80	7.27	6.60	0.67	5006	31.9	21.1	1.70	0.60967	0.9528	7	55	80
132	SU80	7.42	4.57	2.85	6.59	5.88	0.71	4019	32.1	22.0	2.13	0.73849	0.8881	7	58	80
133	SU80	11.55	5.74	5.81	7.31	6.18	1.13	3758	32.8	19.2	2.43	1.22938	0.6329	8	10	80
134	SU80	1.78	0.57	1.21	7.07	6.06	1.01	4724	32.7	18.8	1.89	0.15072	3.9719	8	13	80
135	SU80	7.91	6.33	1.58	5.39	4.83	0.56	4442	32.4	22.5	1.21	0.71229	0.6814	8	52	80
136	SU80	6.52	4.30	2.22	8.00	7.94	0.06	4709	33.5	22.8	1.53	0.55383	1.2270	8	55	80
137	SU80	8.97	5.03	3.94	7.45	6.80	0.65	4575	32.5	23.3	2.62	0.78426	0.8305	8	94	80
138	SU80	7.39	3.81	3.58	7.31	6.16	1.15	4397	32.6	26.1	2.83	0.67228	0.9892	8	97	80
139	SU80	8.34	4.07	4.27	6.28	5.63	0.65	4075	31.3	28.8	1.62	0.81865	0.7530	9	40	80
140	SU80	10.13	5.83	4.30	5.68	4.78	0.90	3692	31.0	27.5	1.62	1.09751	0.5607	9	43	80
141	SU80	10.59	8.15	2.44	5.33	4.43	0.90	3207	34.0	29.5	1.59	1.32036	0.5033	9	90	80
142	SU80	10.74	6.51	4.23	8.56	7.28	1.28	3663	34.4	29.6	1.40	1.17281	0.7970	9	93	80
143	FA80	6.59	3.12	3.47	4.60	4.01	0.59	3678	27.0	25.6	1.42	0.71669	0.6980	10	48	80
144	FA80	6.38	4.13	2.25	4.01	3.78	0.23	3354	28.7	27.0	1.36	0.76038	0.6285	10	52	80
145	FA80	1.86	1.79	0.07	2.96	2.09	0.87	2228	26.9	25.5	1.55	0.33343	1.5914	10	99	80
146	FA80	1.41	1.41	0.00	2.89	2.08	0.81	4165	25.9	25.4	1.31	0.13541	2.0496	11	3	80
147	FA80	7.98	3.13	4.85	3.48	2.23	1.25	1792	22.1	26.1	1.17	1.78125	0.4361	11	47	80
148	FA80	3.15	2.00	1.15	2.11	1.05	1.06	2663	22.7	26.5	1.26	0.47315	0.6698	11	50	80
149	FA80	2.06	1.30	0.76	1.58	1.50	0.38	3607	19.0	22.6	1.42	0.22944	0.9126	11	97	80
150	FA80	1.96	1.36	0.60	1.48	0.60	0.88	.	19.4	23.6	1.06	.	0.7531	11	99	80

Outer Discharge Bay (OB)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
151	FA80	2.30	1.73	0.57	2.72	1.09	1.63	1537	22.8	25.9	1.00	0.598569	1.18261	12	52	80
152	FA80	1.56	1.56	0.00	2.05	1.09	0.96	2249	22.7	26.0	1.36	0.277457	1.31410	12	55	80
153	WI81	2.29	2.06	0.23	0.50	-0.32	0.82	3651	17.1	25.0	1.21	0.250890	0.21834	1	13	81
154	WI81	2.38	2.03	0.35	.	.	.	3162	16.6	25.6	1.19	0.301075	.	1	16	81
155	WI81	3.09	3.09	.	.	.	.	2934	14.6	26.2	.	0.530334	.	1	52	81
156	WI81	2.07	2.07	.	.	.	.	.	14.9	26.2	1.54	.	.	1	55	81
157	WI81	2.45	2.45		0.47	0.28	0.19	4645	18.8	25.0	0.85	0.210980	0.19184	1	97	81
158	WI81	1.45	1.10	0.35	0.92	0.17	0.75	3993	17.9	26.2	1.48	0.145254	0.63448	1	99	81
159	WI81	1.62	1.62	.	0.92	0.75	0.17	2829	18.3	25.3	1.89	0.229787	0.56799	2	46	81
160	WI81	1.41	1.41	.	0.86	0.57	0.29	4026	18.2	25.4	1.54	0.140059	0.60993	2	53	81
161	WI81	1.43	0.48	0.55	1.12	0.92	0.20	4727	19.3	23.3	0.85	0.121047	0.78322	2	96	81
162	WI81	3.60	2.60	1.00	0.65	0.63	0.02	4531	20.0	24.6	.	0.317811	0.18333	2	99	81
163	WI81	3.70	0.89	2.81	1.01	0.90	0.11	2152	20.9	23.9	0.92	0.687732	0.27297	3	42	81
164	WI81	2.83	2.28	0.55	1.47	1.34	0.13	5200	22.5	24.8	1.26	0.217692	0.51943	3	45	81
165	WI81	2.44	2.44	.	1.23	1.01	0.22	5575	20.6	22.8	1.13	0.175067	0.50410	3	87	81
166	WI81	1.86	1.40	0.46	0.99	0.59	0.40	4662	20.8	22.8	1.00	0.159568	0.53226	3	90	81
167	SP81	4.25	2.46	1.79	2.87	1.81	1.06	5444	26.0	25.2	1.79	0.312270	0.67529	4	33	81
168	SP81	6.42	4.33	2.09	.	.	.	6015	26.4	26.1	1.79	0.426933	.	4	37	81

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	PERPLK	MONTH	DAY	YEAR
1	SP77	11.84	6.02	5.82	9.89	6.83	3.05	.	30.34	28.12	2.00	.	0.83446	6	99	77
2	SU77	7.87	3.81	4.06	7.18	4.80	2.38	4290	30.34	28.12	1.79	0.7495	0.91233	7	3	77
3	SU77	9.20	4.80	4.40	8.63	4.36	4.29	7400	31.82	28.64	0.93	0.4973	0.94022	7	37	77
4	SU77	8.33	4.70	3.63	3.76	1.54	2.22	5570	30.97	28.45	0.96	0.5946	0.45030	7	43	77
5	SU77	0.99	0.69	0.30	6.26	4.05	2.21	4780	29.30	29.54	1.06	0.0628	6.32323	8	30	77
6	SU77	5.33	2.03	3.30	2.48	0.86	1.62	6030	29.30	29.54	1.26	0.3536	0.46529	8	33	77
7	SU77	8.40	4.77	3.63	9.89	8.79	1.11	3870	28.04	24.64	1.13	0.8682	1.17262	8	73	77
8	SU77	11.86	5.84	6.02	4.28	2.47	1.81	5230	22.04	24.64	0.94	0.9071	0.36088	8	77	77
9	SU77	4.32	1.40	2.92	3.46	1.97	1.49	6379	29.80	28.10	1.13	0.2627	0.80093	9	27	77
10	SU77	5.32	3.43	1.89	5.34	4.21	1.13	6462	29.64	31.08	1.00	0.3293	1.00376	9	63	77
11	SU77	2.56	1.67	0.89	5.01	4.16	1.01	4894	29.64	31.08	0.85	0.2092	1.95703	9	67	77
12	FA77	6.27	2.61	3.66	5.44	4.09	1.35	5464	28.74	29.88	0.82	0.4588	0.86762	10	3	77
13	FA77	4.54	1.47	3.07	3.52	2.78	0.74	5238	28.74	29.96	0.82	0.3467	0.77533	10	7	77
14	FA77	4.01	1.70	2.31	2.89	2.66	0.22	6462	19.08	27.48	1.00	0.2482	0.71820	10	57	77
15	FA77	3.85	2.09	1.85	2.10	1.59	0.51	6227	19.08	27.48	0.94	0.2473	0.54545	10	60	77
16	FA77	2.64	1.48	1.16	2.60	1.81	0.79	2961	21.17	28.70	1.03	0.3566	0.98485	11	3	77
17	FA77	3.49	1.32	2.17	2.12	1.92	0.20	4441	15.58	29.98	1.10	0.3143	0.60745	11	47	77
18	FA77	4.41	2.11	2.30	1.42	1.07	0.35	4347	15.58	29.98	1.10	0.4058	0.32200	11	50	77
19	FA77	1.74	0.66	1.08	0.73	0.43	0.30	2619	18.14	25.30	0.94	0.2658	0.41954	11	97	77
20	FA77	2.59	0.73	1.86	1.11	0.86	0.25	3416	18.14	25.30	0.92	0.3033	0.42857	11	99	77
21	FA77	2.93	1.68	1.25	1.47	0.59	0.88	.	15.40	27.90	0.61	.	0.50171	12	63	77
22	FA77	4.23	1.93	2.30	0.59	0.18	0.37	.	15.70	26.70	0.64	.	0.12941	12	67	77
23	WI78	-1.37	-1.47	0.10	0.77	0.57	0.20	159	9.20	23.80	1.08	-3.4465	-0.56204	2	3	78
24	WI78	2.67	1.08	1.59	1.19	0.63	0.47	453	9.80	23.50	0.90	2.3576	0.41199	2	7	78
25	WI78	2.69	1.37	1.32	2.58	2.09	0.49	1013	12.90	25.50	0.79	1.0622	0.95911	2	60	78
26	WI78	1.85	0.38	1.47	1.27	1.21	0.06	1358	13.10	26.60	1.36	0.5449	0.68649	2	63	78
27	WI78	3.71	1.76	1.95	3.63	3.65	0.00	2028	14.60	23.50	1.70	0.7318	0.98383	3	13	78
28	WI78	2.26	1.80	0.46	.	.	.	4221	15.00	22.60	1.36	0.2142	.	3	63	78
29	WI78	2.29	1.25	1.04	2.35	1.94	0.41	4404	17.90	18.50	1.55	0.2080	1.02620	3	97	78
30	WI78	2.21	0.48	1.73	3.25	2.62	0.63	4383	18.40	18.30	1.42	0.2017	1.47059	3	99	78
31	SP78	2.13	0.90	1.23	3.84	3.61	0.23	4201	24.20	23.10	1.55	0.2028	1.81221	4	23	78
32	SP78	1.72	0.05	1.77	3.44	2.61	0.83	4599	24.30	23.00	1.55	0.1496	2.00000	4	27	78
33	SP78	7.05	5.42	2.03	2.36	1.66	0.70	5400	23.10	24.40	1.70	0.5214	0.33475	4	73	78
34	SP78	4.78	0.82	3.96	4.17	2.22	1.95	3551	23.00	25.20	1.70	0.5384	0.87238	4	77	78
35	SP78	5.24	2.63	2.61	5.19	4.64	0.55	4924	26.10	23.10	1.48	0.4257	0.99046	5	27	78
36	SP78	5.02	2.63	2.39	9.41	8.09	1.32	2921	26.90	23.30	1.89	0.6874	1.87450	5	30	78
37	SP78	3.05	0.77	2.28	2.84	2.18	0.66	2664	26.60	19.60	1.26	0.4580	0.93115	5	67	78
38	SP78	4.79	2.45	2.34	3.71	2.62	1.09	5569	26.70	21.20	1.36	0.3440	0.77453	5	70	78
39	SP78	5.67	2.52	3.15	.	.	.	4278	29.50	24.00	1.36	0.5302	.	6	27	78
40	SP78	.	.	.	.	.	.	4036	29.30	23.90	1.31	.	.	6	30	78
41	SP78	7.71	4.42	3.29	6.30	4.73	1.57	4116	27.20	25.90	1.06	0.7493	0.81712	6	77	78
42	SP78	5.81	2.77	3.04	5.35	4.00	1.35	3551	27.90	26.30	1.21	0.6545	0.92083	6	80	78
43	SU78	4.42	1.95	2.47	3.74	2.68	1.06	3830	29.60	22.50	1.13	0.4616	0.84615	7	23	78
44	SU78	5.17	2.57	2.60	4.34	3.74	0.60	4149	29.80	24.30	1.13	0.4984	0.83946	7	27	78
45	SU78	9.80	5.53	4.27	6.14	6.14	0.00	4036	28.50	23.90	1.00	0.9713	0.62653	7	70	78
46	SU78	8.47	4.88	3.59	7.87	6.50	1.37	3794	28.80	25.20	1.10	0.8930	0.92916	7	73	78
47	SU78	4.61	2.46	2.15	3.11	1.96	1.15	3874	29.20	21.50	0.87	0.4760	0.67462	8	17	78
48	SU78	4.29	1.97	2.32	3.29	2.61	0.68	2502	29.40	23.10	1.03	0.6859	0.76690	8	20	78
49	SU78	4.72	2.93	1.79	3.67	2.95	0.72	4762	31.10	24.90	0.85	0.3965	0.77754	8	93	78
50	SU78	7.77	4.77	3.00	6.98	6.41	0.57	4762	30.90	25.00	0.97	0.6327	0.89833	8	97	78
51	SU78	6.46	2.90	3.56	5.09	4.16	0.89	3511	29.20	28.30	1.10	0.7360	0.78173	9	70	78
52	SU78	4.46	2.40	2.06	3.61	3.29	0.32	3936	29.40	28.50	1.10	0.4533	0.80942	9	73	78
53	FA78	4.22	2.26	1.96	2.57	2.57	0.00	2972	26.30	29.70	1.36	0.5680	0.60900	10	3	78
54	FA78	5.08	3.20	1.88	.	.	.	3830	26.30	32.10	1.21	0.5305	.	10	20	78
55	FA78	3.35	1.70	1.65	.	.	.	4149	24.40	32.00	1.42	0.3230	.	10	23	78
56	FA78	4.15	1.50	2.65	3.77	2.71	1.06	3227	22.70	28.50	1.55	0.5144	0.90843	10	77	78
57	FA78	2.88	1.44	1.44	1.93	1.58	0.35	.	22.00	28.50	1.16	.	0.67014	11	37	78
58	FA78	2.66	1.41	1.25	5.21	5.21	0.00	.	21.90	28.50	1.03	.	1.95865	11	40	78
59	FA78	4.72	2.16	2.56	2.74	1.93	0.81	2582	21.70	27.70	1.17	0.7312	0.58051	11	97	78
60	FA78	3.22	1.26	1.96	4.14	3.14	1.00	2340	22.60	27.80	1.55	0.5504	1.28571	11	99	78
61	FA78	1.32	0.72	0.60	0.56	0.47	0.09	1775	13.90	26.10	0.89	0.2975	0.42424	12	50	78
62	FA78	1.90	1.00	0.90	1.02	0.87	0.15	2743	14.00	26.30	0.69	0.2771	0.53684	12	53	78
63	FA78	1.20	0.51	0.69	1.90	1.90	0.00	2663	14.00	26.90	1.48	0.1802	1.58333	12	57	78
64	WI79	2.94	1.66	1.28	0.38	0.38	0.00	2662	10.10	25.70	1.12	0.4418	0.12925	1	17	79
65	WI79	2.40	1.66	0.74	0.81	-0.20	1.01	1775	11.60	26.30	0.81	0.5408	0.33750	1	20	79
66	WI79	2.95	1.22	1.73	1.70	-0.02	1.72	2000	12.30	24.80	1.36	0.5673	0.57627	1	77	79
67	WI79	.	.	.	1.39	-0.87	2.26	3224	12.70	24.30	4.25	.	.	1	80	79
68	WI79	3.12	1.72	1.40	1.07	1.07	0.00	1750	14.30	24.50	1.31	0.7131	0.34295	2	53	79
69	WI79	2.66	1.21	1.45	2.09	1.30	0.79	2022	15.30	25.20	0.92	0.5262	0.78571	3	7	79
70	WI79	2.31	1.17	1.14	3.33	2.62	0.71	2900	15.90	25.40	1.48	0.3101	1.44156	3	10	79
71	WI79	1.99	1.17	0.82	1.72	0.96	0.76	3246	17.20	26.90	1.42	0.2452	0.86432	3	57	79
72	WI79	3.39	1.99	1.40	2.51	2.31	0.20	4417	17.30	27.20	1.42	0.3070	0.74041	3	60	79
73	WI79	3.31	1.45	1.86	1.60	0.73	0.87	4533	20.10	23.80	1.33	0.2921	0.48338	3	99	79
74	SP79	2.35	1.11	1.24	0.92	0.41	0.51	4193	21.00	23.10	1.27	0.2242	0.39149	4	3	79
75	SP79	3.80	1.51	2.29	4.39	2.82	1.57	3639	24.50	26.10	1.79	0.4177	1.15526	4	70	79

OBS	TIME	PG	PN	R	PLANPG	PLANKPN	PLANKR	DOSOL	TEMP	SAL	EXTINCT	ECOLEFF	PCRPLX	MONTH	DAY	YEAR
76	SP79	4.52	2.75	1.77	4.39	3.81	0.58	3536	24.1	25.0	2.270	0.51131	0.9712	4	73	79
77	SP79	3.15	1.24	1.91	2.38	1.90	0.78	3410	26.6	25.9	1.890	0.36950	0.8500	5	17	79
78	SP79	4.66	2.85	1.81	.	.	.	3410	27.0	25.0	.270	0.54663	.	5	20	79
79	SP79	3.91	3.01	0.90	6.58	5.80	0.78	5260	25.6	26.4	2.830	0.29734	1.6829	5	60	79
80	SP79	3.61	1.23	2.38	9.16	7.65	1.51	5479	24.8	26.1	2.830	0.26359	2.5374	5	63	79
81	SP79	4.29	1.82	2.47	5.47	4.75	0.72	3466	30.3	27.0	2.000	0.50362	1.2751	6	27	79
82	SP79	4.70	2.36	2.34	8.60	8.07	0.53	4334	29.6	27.3	2.270	0.43378	1.8298	6	30	79
83	SP79	5.63	3.14	2.49	4.93	3.72	1.21	5303	30.0	29.4	1.420	0.42467	0.8757	6	83	79
84	SP79	4.52	2.96	1.56	8.08	6.53	1.55	4367	29.8	30.0	1.400	0.41401	1.7876	6	86	79
85	SU79	6.43	2.83	3.60	7.00	5.04	1.96	4600	31.1	28.6	1.900	0.54957	1.2131	7	27	79
86	SU79	7.12	3.60	3.52	8.91	7.40	1.51	4783	30.8	29.0	2.230	0.59544	1.2514	7	30	79
87	SU79	6.27	3.71	2.56	8.98	7.94	1.04	3016	29.3	27.0	1.420	0.83156	1.4322	7	77	79
88	SU79	6.62	3.36	3.26	11.17	9.73	1.44	3328	29.3	28.2	1.420	0.79567	1.6873	7	81	79
89	SU79	5.94	2.74	2.80	4.57	3.51	1.06	3262	30.4	25.9	1.210	0.67934	0.8249	8	19	79
90	SU79	7.02	3.19	3.83	6.79	6.79	0.00	3170	29.8	26.2	1.490	0.88580	0.9672	8	23	79
91	SU79	8.82	4.67	4.15	7.19	5.71	1.48	4265	30.0	27.0	1.890	0.82720	0.8152	8	61	79
92	SU79	7.97	4.17	3.80	8.20	6.90	1.30	4506	30.3	27.1	1.890	0.70750	1.0289	8	65	79
93	SU79	2.35	-0.18	2.53	5.31	4.12	1.19	3562	29.1	28.4	1.360	0.26390	2.2596	9	27	79
94	SU79	2.60	0.67	1.93	7.35	6.10	1.25	3343	29.0	29.0	1.890	0.31110	2.8269	9	30	79
95	FA79	3.41	1.82	1.59	5.39	4.92	0.47	4263	26.1	28.1	2.350	0.31996	1.5806	10	16	79
96	FA79	5.66	3.10	2.56	4.79	4.40	0.39	3781	24.8	27.7	1.720	0.59878	0.8463	10	19	79
97	FA79	5.27	2.99	2.28	3.76	3.29	0.47	3000	24.8	27.6	1.360	0.70000	0.7135	10	61	79
98	FA79	7.90	5.08	2.82	7.01	5.58	1.43	2812	25.0	28.3	1.360	1.12376	0.8873	10	65	79
99	FA79	3.34	1.23	2.14	2.43	2.43	0.00	2213	23.8	28.0	1.100	0.60371	0.7275	11	7	79
100	FA79	3.21	2.22	0.99	2.65	2.02	0.63	2870	22.6	28.3	1.210	0.44739	0.8255	11	10	79
101	FA79	3.24	3.24	0.00	4.65	4.15	0.50	2478	17.2	28.0	1.000	0.52300	1.4352	11	53	79
102	FA79	5.80	3.32	2.48	3.87	2.02	1.85	2631	17.2	27.9	0.850	0.87514	0.6672	11	57	79
103	FA79	3.59	2.55	1.04	2.70	2.70	0.00	3077	14.7	28.5	1.310	0.46669	0.7521	11	99	79
104	FA79	2.01	1.59	0.42	1.45	1.36	0.09	2328	13.8	27.9	1.420	0.34536	0.7214	12	3	79
105	FA79	1.21	0.53	0.68	0.60	0.47	0.13	900	19.0	28.0	0.710	0.49388	0.4959	12	48	79
106	FA79	1.11	0.07	1.04	0.24	0.07	0.17	231	18.1	28.5	0.760	1.92208	0.2162	12	52	79
107		3.81	1.73	2.08	4.40	3.26	1.14	2228	22.7	26.1	1.481	0.68402	1.1549	0	9	80
108	WI80	4.76	2.99	1.77	4.42	3.47	0.95	4165	22.1	26.0	1.481	0.45714	0.9286	1	3	80
109	WI80	0.21	0.21	.	0.39	-0.08	0.43	645	12.6	27.3	0.890	0.13023	1.6667	1	13	80
110	WI80	0.45	0.06	0.39	0.68	0.13	0.55	2351	11.9	27.4	1.280	0.07656	1.5111	1	16	80
111	WI80	0.43	0.43	0.00	0.77	0.77	0.00	1810	16.1	27.4	0.790	0.09503	1.7907	1	58	80
112	WI80	1.03	0.46	0.57	-0.01	-0.01	0.00	2616	16.4	28.1	0.770	0.15749	-0.0097	1	61	80
113	WI80	0.03	0.03	0.00	0.55	0.28	0.27	3952	13.2	26.9	1.700	0.00304	18.3333	2	4	80
114	WI80	5.48	3.43	2.05	1.20	1.20	0.00	3120	13.0	24.5	1.260	0.70256	0.2190	2	7	80
115	WI80	1.97	1.11	0.86	1.09	0.64	0.45	3773	15.9	26.7	1.130	0.20865	0.5533	2	79	80
116	WI80	2.15	1.33	0.82	0.86	0.29	0.59	2139	17.8	24.5	0.790	0.40206	0.4093	2	82	80
117	WI80	2.26	1.27	0.93	.	.	.	3818	15.8	24.2	1.620	0.23049	.	3	26	80
118	WI80	2.99	1.07	1.92	2.79	1.98	0.81	2525	17.9	22.4	1.420	0.47366	0.9331	3	29	80
119	WI80	0.56	0.40	0.16	3.73	2.97	0.76	4145	20.6	25.8	3.490	0.05404	6.6607	3	68	80
120	WI80	2.90	1.47	1.23	3.78	3.25	0.53	5000	19.4	23.7	1.550	0.22835	1.3934	3	71	80
121	SP80	1.62	0.59	1.03	1.88	1.66	0.22	2184	22.1	23.4	2.290	0.29670	1.1605	4	13	80
122	SP80	3.60	2.08	1.52	3.94	3.81	0.13	5125	21.5	23.4	2.340	0.28098	1.0944	4	17	80
123	SP80	1.83	1.35	0.48	2.55	1.68	0.87	4605	21.3	25.6	2.430	0.15896	1.3934	4	60	80
124	SP80	1.01	0.57	0.44	1.65	1.41	0.24	3550	21.6	25.4	2.620	0.11380	1.6337	4	63	80
125	SP80	2.85	1.28	1.57	2.94	2.10	0.84	5259	23.2	23.2	2.430	0.21677	1.0316	5	10	80
126	SP80	3.61	1.25	2.36	4.49	3.09	1.36	5125	23.9	23.3	2.620	0.28176	1.2327	5	13	80
127	SP80	4.53	2.77	1.76	5.32	5.32	0.00	4189	27.2	23.0	3.490	0.43256	1.1744	5	52	80
128	SP80	3.86	1.90	1.96	5.47	5.47	0.00	3387	27.0	24.1	2.830	0.45586	1.4171	5	55	80
129	SP80	3.74	1.88	1.86	3.85	3.71	0.14	4546	26.7	22.8	2.430	0.32908	1.0294	5	99	80
130	SP80	4.08	2.19	1.89	8.26	6.60	1.66	4402	26.8	23.4	2.830	0.33293	2.0245	6	3	80
131	SP80	6.26	3.73	2.53	4.51	3.47	1.04	5140	28.2	26.5	1.260	0.48716	0.7204	6	57	80
132	SP80	5.36	2.44	2.92	8.47	8.23	0.24	4768	28.7	26.4	2.130	0.44966	1.5802	6	60	80
133	SP80	2.04	0.96	1.08	5.26	4.29	0.97	2303	29.2	22.7	2.800	0.35432	2.5637	6	99	80
134	SU80	5.64	3.48	2.16	8.25	8.02	0.23	5467	29.6	22.1	2.090	0.41266	1.4628	7	3	80
135	SU80	4.74	2.10	2.60	4.80	3.90	0.90	5006	30.3	22.6	1.790	0.37585	1.0213	7	55	80
136	SU80	4.34	2.31	2.03	3.98	3.04	0.94	4019	30.0	21.5	2.830	0.43195	0.9171	7	58	80
137	SU80	5.13	2.24	2.89	3.65	2.98	0.67	3758	31.1	21.1	2.130	0.54604	0.7115	8	10	80
138	SU80	4.01	2.11	1.90	4.35	2.98	1.37	4724	31.1	21.0	2.130	0.33954	1.0848	8	13	80
139	SU80	4.99	2.73	2.26	4.29	3.30	0.99	4442	29.4	24.2	1.170	0.44935	0.8597	8	52	80
140	SU80	5.04	3.10	1.94	4.36	2.48	1.88	4709	30.2	24.4	1.030	0.42812	0.8631	8	55	80
141	SU80	6.36	3.22	3.14	6.63	5.18	1.45	4575	29.5	27.0	2.000	0.55607	1.0425	8	94	80
142	SU80	6.08	3.46	2.62	5.15	3.98	1.17	4397	29.6	27.0	2.130	0.55310	0.8470	8	97	80
143	SU80	3.20	1.38	1.82	4.16	3.35	0.81	4075	28.6	29.1	1.100	0.31411	1.3000	9	40	80
144	SU80	4.20	2.37	1.83	3.19	2.22	0.97	3692	28.6	29.6	1.030	0.45504	0.7595	9	43	80
145	SU80	5.62	3.67	1.95	5.01	4.19	0.82	3207	30.1	28.4	1.040	0.70097	0.8915	9	90	80
146	SU80	6.00	2.62	3.38	6.26	4.74	1.52	3663	30.3	28.8	0.950	0.63520	1.0433	9	93	80
147	FA80	4.56	2.09	2.47	2.42	1.45	0.97	3678	24.3	25.3	1.210	0.45892	0.5307	10	49	80
148	FA80	5.99	3.22	2.77	3.23	1.46	1.77	3354	24.7	25.5	1.060	0.71437	0.5392	10	52	80
149	FA80	2.07	1.45	0.62	2.43	1.46	0.97	1792	19.0	26.2	1.360	0.46205	1.1739	11	47	80
150	FA80	1.79	1.01	0.78	2.37	1.42	0.95	2663	19.7	26.0	1.360	0.26887	1.3240	11	50	80

Outer Control Bay (C)

OBS	TIME	PG	PN	R	PLANKPG	PLANKPN	PLANKR	INSOL	TEMP	SAL	EXTINCT	ECOLEFF	FERPLK	MONTH	DAY	YEAR
151	FA80	2.05	1.97	0.08	2.09	0.90	1.19	3607	16.2	25.2	1.17	0.227336	1.01951	11	97	80
152	FA80	3.82	3.46	0.36	1.37	1.11	0.41	.	15.8	24.4	1.48	.	0.39791	11	99	80
153	FA80	2.03	0.99	1.04	0.73	0.60	0.15	1537	16.4	25.5	1.06	0.528302	0.36946	12	52	80
154	FA80	1.13	0.51	0.62	0.96	0.60	0.36	2249	15.8	25.3	1.03	0.200978	0.84956	12	55	80
155	WI81	1.52	0.63	0.89	0.43	-0.51	0.94	3651	11.4	25.8	2.03	0.166530	0.28289	1	13	81
156	WI81	0.94	0.46	0.48	.	.	.	3162	10.9	25.9	1.94	0.118912	.	1	16	81
157	WI81	1.00	0.80	0.20	0.40	0.10	0.30	2934	9.0	25.1	0.92	0.136373	0.40000	1	52	81
158	WI81	-0.26	-0.49	0.23	.	.	.	.	8.6	25.9	0.89	.	.	1	55	81
159	WI81	2.95	0.17	2.78	0.41	-0.12	0.53	4645	12.6	25.4	.	0.254037	0.13898	1	97	81
160	WI81	2.49	0.69	1.80	0.85	-0.03	0.88	3993	12.7	24.8	1.10	0.249437	0.34137	1	99	81
161	WI81	1.14	0.87	0.27	0.81	0.78	0.03	2820	11.7	24.5	.	0.161702	0.71053	2	46	81
162	WI81	1.58	0.76	0.82	0.87	0.54	0.33	4026	12.5	24.8	.	0.156980	0.55663	2	53	81
163	WI81	2.48	1.25	1.23	0.82	0.65	0.17	4727	17.6	26.1	0.60	0.209658	0.33465	2	96	81
164	WI81	4.42	1.76	2.66	0.87	0.47	0.35	4531	18.0	26.2	0.85	0.390201	0.18552	2	99	81
165	WI81	2.36	0.99	1.37	1.19	0.45	0.70	2152	16.9	24.6	1.00	0.438462	0.48729	3	42	81
166	WI81	2.03	1.50	0.53	0.86	0.86	.	5200	17.0	24.9	1.21	0.156154	0.42365	3	45	81
167	WI81	1.57	0.79	0.78	1.55	1.04	0.51	5575	17.7	24.3	1.70	0.112646	0.98726	3	87	81
168	WI81	1.89	1.42	0.47	1.48	0.61	0.87	4662	19.1	23.8	1.00	0.162162	0.78307	3	90	81
169	SP81	1.97	1.38	0.59	4.69	2.31	2.38	5444	22.6	26.4	1.70	0.144747	2.30071	4	33	81
170	SP81	3.46	2.19	1.27	.	.	.	6015	23.4	25.5	1.54	0.230091	.	4	37	81

SUMMARY OF DATA FROM THE
THERMAL AND CONTROL MARSHES

OBS	SPECIES	SEAS	MONTH	DAY	YEAR	TREAT	IN?OL	PN	HIGHTR	TG	LVSTK	CITY	PR	LVBIU	ORIO	SPAT	STHT	LITT	UCA	FLOWER
1	J	SP	5	8	77	C	3211	4.88	2.88	7.77	650.0	274.0	1.37	1140	634	1.8	105.0	0.8	102	16.0
2	J	SU	7	20	77	C	4593	5.06	1.73	6.78	446.0	303.0	1.86	941	770	2.1	109.0	0.0	189	0.0
3	J	FA	10	10	77	C	3361	2.68	1.47	4.15	569.0	118.0	1.66	1530	1330	2.9	133.0	0.0	134	2.4
4	J	WI	2	2	78	C	493	1.07	1.05	2.12	438.0	266.0	0.73	575	925	2.1	102.0	0.0	120	0.0
5	J	SP	4	8	78	C	6761	5.07	2.67	7.74	290.0	290.0	1.91	939	970	2.0	103.0	0.0	181	6.2
6	J	SU	7	1	78	C	2407	3.66	3.28	6.93	529.0	345.0	1.05	1230	1280	2.3	112.0	0.6	293	0.0
7	J	FA	9	24	78	C	2679	2.48	1.27	3.75	341.0	370.0	1.58	1450	930	3.0	120.0	0.0	290	0.0
8	J	WI	1	6	79	C	2119	2.59	0.87	3.46	298.0	246.0	2.25	634	610	2.0	108.0	1.6	45	0.0
9	J	SP	4	6	79	C	3679	4.94	1.24	6.19	294.0	394.0	2.73	1130	971	1.8	90.1	11.2	152	4.8
10	J	SU	6	14	79	C	5370	6.94	1.26	8.20	561.0	532.0	2.69	938	830	1.7	94.7	0.0	134	3.2
11	J	FA	9	12	79	C	2401	3.44	2.38	5.82	410.0	566.0	1.25	952	1250	2.3	118.0	4.8	295	0.0
12	J	WI	1	3	80	C	2315	2.82	1.76	4.56	495.0	304.0	1.52	1070	1210	2.2	97.7	0.8	88	0.0
13	J	SP	3	28	80	C	2598	6.60	2.33	8.83	688.0	270.0	1.99	546	759	1.4	64.3	3.2	222	1.6
14	J	SU	7	4	80	C	3491	5.86	2.11	7.98	509.0	272.0	1.61	1020	808	2.0	103.0	4.0	252	0.0
15	J	FA	10	5	80	C	2477	9.42	2.84	12.26	626.0	467.0	2.13	1570	1370	2.5	116.0	7.6	133	0.0
16	J	WI	1	4	81	C	1733	4.49	1.06	5.55	518.0	331.0	.	1353	1125		116.0	1.8	202	0.0
17	J	SP	5	1	77	T	4259	3.09	4.60	7.64	650.0	222.0	1.02	988	715	1.5	91.0	3.2	193	2.4
18	J	SU	7	24	77	T	4461	4.71	2.09	6.80	795.0	773.0	1.62	1350	1390	1.7	100.0	2.0		.
19	J	FA	10	6	77	T	4141	1.52	1.48	3.00	696.0	173.0	1.12	1510	1110	2.2	105.0	5.6	197	0.0
20	J	WI	1	31	78	T	905	1.14	1.01	2.15	552.0	557.0	1.17	692	950	1.6	90.7	0.0	83	0.0
21	J	SP	4	11	78	T	5460	3.39	2.68	6.57	738.0	518.0	1.28	950	1040	1.4	86.7	5.7	277	6.7
22	J	SU	7	6	78	T	.	1.49	2.36	3.85	487.0	682.0	0.76	1790	1140	2.5	99.4	3.3	377	0.0
23	J	FA	9	26	78	T	995	3.90	1.66	5.56	700.0	633.0	1.77	1439	1280	1.8	102.0	2.3	276	0.0
24	J	WI	1	13	79	T	2654	2.97	1.06	4.02	467.0	415.0	2.17	891	1070	1.9	102.0	12.8	210	0.0
25	J	SP	3	31	79	T	3333	4.82	2.16	6.98	816.0	751.0	1.83	1160	1040	1.4	85.7	6.4	139	0.0
26	J	SU	6	15	79	T	4337	5.08	1.48	6.56	812.0	832.0	1.83	1120	1540	1.4	84.9	12.8	170	0.0
27	J	FA	9	11	79	T	3100	2.41	1.61	4.03	453.0	610.0	1.19	804	1260	1.8	99.0	8.6	242	0.0
28	J	WI	1	5	80	T	2196	5.93	1.21	7.14	770.0	580.0	3.50	1280	1030	1.7	94.9	23.2	191	0.0
29	J	SP	3	26	80	T	2693	5.81	3.13	8.91	766.0	624.0	1.84	1100	1400	1.9	78.8	9.6	233	0.8
30	J	SU	7	11	80	T	2643	3.59	2.61	6.20	561.0	507.0	1.02	1160	1520	2.2	94.6	13.1	450	0.0
31	J	FA	10	11	80	T	2815	3.55	2.50	6.04	586.0	530.0	1.22	1130	1090	1.9	98.7	8.8	182	0.0
32	J	WI	1	6	81	T	2767	0.78	1.32	2.10	701.0	494.0	.	1270	848	.	93.6	2.2	110	0.0
33	S	SP	5	8	77	C	3440	1.94	1.42	3.36	71.0	101.0	1.19	388	484	6.0	86.0	.	84	0.0
34	S	SU	7	16	77	C	2038	2.50	1.69	4.19	62.5	37.1	1.22	510	187	8.4	83.0	0.6	237	
35	S	FA	10	10	77	C	3361	1.51	1.38	2.89	93.1	14.0	1.13	786	243	8.4	92.0	0.4	207	11.1
36	S	WI	2	2	78	C	493	0.19	0.18	0.37	77.0	46.0	0.99	250	321	3.8	59.0	0.6	101	0.0
37	S	SP	4	8	78	C	6761	1.03	2.04	3.07	75.0	56.0	0.67	224	472	2.8	70.1	0.4	205	0.0
38	S	SU	7	1	78	C	2407	2.82	2.90	5.72	67.0	69.0	0.91	453	553	6.8	84.7	0.0	357	
39	S	FA	9	24	78	C	2679	2.50	1.19	3.69	120.0	63.0	1.79	1140	518	9.4	80.0	0.9	278	13.8
40	S	WI	1	6	79	C	2119	2.79	1.07	3.86	115.0	70.7	2.04	413	871	3.5	55.7	5.7	104	0.0
41	S	SP	4	6	79	C	3679	1.98	0.65	2.63	92.0	125.0	1.93	184	542	2.0	55.9	4.4	213	0.0
42	S	SU	6	14	79	C	5370	3.72	1.03	4.69	73.8	70.2	1.91	374	454	5.4	70.0	3.1	175	
43	S	FA	9	12	79	C	2401	4.62	1.34	5.96	121.0	89.8	2.18	626	500	5.6	60.1	1.3	212	4.9
44	S	WI	1	3	80	C	2315	0.90	1.33	2.43	134.0	71.1	1.12	476	377	3.4	55.7	1.8	132	5.3
45	S	SP	3	26	80	C	3098	1.19	1.52	2.71	103.0	82.2	0.90	400	400	3.9	61.9	3.1	152	1.3
46	S	SU	7	4	80	C	3691	4.05	1.49	5.54	119.0	64.0	1.59	868	347	7.6	70.7	1.8	152	
47	S	FA	10	5	80	C	2477	3.69	1.59	5.28	114.0	57.8	1.68	1060	410	5.5	77.1	12.9	197	24.4
48	S	WI	1	4	81	C	1733	0.94	1.20	2.13	.	.	.	.	.	.	.	.	.	.
49	S	SP	5	1	77	T	4322	2.86	2.91	5.77	146.0	160.0	1.07	395	364	2.8	60.0	2.0	97	0.0
50	S	SU	7	24	77	T	4448	3.32	1.20	4.52	126.0	79.7	1.82	609	290	4.9	73.0	8.0		
51	S	FA	10	6	77	T	4141	0.81	1.14	1.95	97.5	9.6	0.86	564	182	5.6	80.0	10.6	134	7.1
52	S	WI	1	31	78	T	905	1.18	0.56	0.73	230.0	65.0	0.51	322	283	1.4	42.0	1.1	90	0.0
53	S	SP	4	11	78	T	5460	2.45	2.73	5.68	190.0	115.0	1.06	312	324	1.8	51.5	8.0	303	0.0
54	S	SU	7	6	78	T	.	1.79	2.29	4.38	144.0	102.0	0.84	424	704	3.0	71.4	1.6	267	
55	S	FA	9	26	78	T	995	2.19	1.09	3.28	154.0	100.0	1.85	695	343	4.8	63.0	9.3	316	2.2
56	S	WI	1	13	79	T	2654	1.17	0.49	1.65	229.0	101.0	2.03	329	357	1.4	36.4	8.9	220	0.0
57	S	SP	3	31	79	T	3333	3.52	1.57	5.09	229.0	165.0	1.60	272	471	1.1	41.6	6.7	301	0.0
58	S	SU	6	15	79	T	4337	6.06	1.62	7.66	157.0	53.3	1.94	472	584	3.0	57.2	12.4	167	
59	S	FA	9	14	79	T	3100	1.70	1.23	2.93	179.0	52.9	1.12	729	199	4.4	50.0	10.2	248	7.1
60	S	WI	1	5	80	T	2196	-0.39	1.32	0.92	259.0	58.2	0.41	485	170	1.9	42.6	20.9	116	7.6
61	S	SP	3	26	80	T	2653	3.51	2.31	5.82	215.0	135.0	1.30	412	323	2.0	46.2	15.6	234	3.1
62	S	SU	7	11	80	T	2643	2.60	2.09	4.64	153.0	66.4	0.94	754	323	5.0	62.8	10.0	146	
63	S	FA	10	11	80	T	2815	2.28	1.77	4.03	209.0	45.8	1.13	970	290	4.7	59.1	24.0	156	36.0
64	S	WI	1	6	81	T	2767	0.05	0.74	0.54	.	.	.	.	.	.	.	.	.	.

APPENDIX B

OXYGEN MEASUREMENTS IN OUTER BAY AND DISCHARGE CANAL

INTRODUCTION

Pursuant to Section 3.1.4 a-b of the Crystal River ETS Program, dissolved oxygen concentrations in the outer bay and discharge canals were measured bi-weekly during 1981. Prior to May, 1981 (Quarter 1), these data were collected by the University of Florida as part of their estuarine and salt marsh metabolism studies. Metabolism studies at Crystal River were completed during April, 1981 at which time Florida Power Corporation staff assumed responsibility for collecting the outer bay and discharge canal oxygen data. This report presents oxygen data collected during the period May-December, 1981. (Quarters II-IV)

RESULTS

Table 1 summarizes water quality data collected at Crystal River during Quarters II-IV, 1981. Station locations were consistent with those reported in previous Annual Reports.

Temperature values in the Crystal River estuary follow seasonal patterns consistent with those exhibited in other near shore coastal areas of Florida. The minimum winter temperture recorded in the outer bay was 12.0°C. Maximum values in the outer bay and discharge canal were 33.0 and 39.5°C, respectively.

Minimum and maximum dissolved oxygen values at station 1 ranged from 2.0 to 10.8 ppm, respectively. Similarily, minimum and maximum values recorded at station 2, discharge canal, were 3.9 and 13.6 ppm, respectively. There were no consistent between station variations evident in the data.

TABLE 1: Summary of Chemical-Physical Data Collected at Crystal River During the Period April-December, 1981

SAMPLING QUARTER	STATION		DISSOLVED OXYGEN (ppm)		TEMPERATURE (°C)		SALINITY (ppt)	
			mean	min/max	mean	min/max	mean	min/max
II	1	Dusk	6.7	3.0/11.1	27.8	23.0/32.0	27.7	23.6/29.2
		Dawn	6.3	2.1/10.8	25.8	21.0/25.7	27.1	24.6/28.3
	2	Dusk	8.3	5.1/14.2	33.4	28.1/38.8	30.2	27.2/32.5
		Dawn	8.6.	5.0/13.6	31.9	28.0/35.0	29.6	27.3/31.6
III	1	Dusk	5.8	2.0/10.0	31.1	28.5/33.0	30.4	27.3/33.6
		Dawn	4.2	2.5/6.0	29.1	25.6/31.0	30.7	29.1/33.8
	2	Dusk	5.7	4.3/7.3	37.2	33.4/39.5	31.9	30.2/35.1
		Dawn	5.8	5.0/9.0	36.1	32.5/38.0	31.4	30.3/32.5
IV	1	Dusk	7.9	6.2/9.5	19.8	15.3/24.8	28.1	27.5/30.8
		Dawn	6.8	3.9/9.1	18.2	12.0/23.2	29.6	14.7/30.7
	2	Dusk	7.1	5.4/8.6	24.6	18.0/31.[illegible]	29.5	25.6/33.8
		Dawn	6.8	5.0/8.4	23.1	17.0/29.0	28.8	18.1/32.1

ATTACHMENT