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# MACROBENTHIC EFFECTS OF HURRICANES OPAL AND ERIN WITHIN THE GULF ISLANDS NATIONAL SEASHORE

Final Report submitted to the National Park Service
by

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## EXECUTIVE SUMMARY

In this report, we present a macrobenthic assessment of sustained (*i.e.*, one year post impact) hurricane effects on the nearshore habitats of the Florida district of Gulf Islands National Seashore (GUIS), by comparing pre-hurricane macrobenthic data originating from a large-scale faunal inventory conducted during 1993 with post-hurricane data collected one year after the 1995 disturbances caused by Hurricanes Opal and Erin. Types of nearshore habitats examined included both exposed and protected sandy beaches, as well as grassbed and lagoon stations. The overall objective of this study was to compare the extensive baseline information with post-hurricane macrobenthic data as a means to gauge the extent of sustained ecological impact to the nearshore resources of the Florida district of GUIS. This study utilized the same configuration of study locations as that which occurred within the Florida district during the 1993 macrobenthic inventory as well as comparable collecting methods and protocols to gauge macrobenthic effects.

Macrobenthic summary community metrics generally indicated that swash zone assemblages had largely recovered within the year following the hurricane disturbances. Species richness values at GUIS Florida district swash-zone stations of both protected and exposed sandy-beach sites did not show any consistent pattern between 1993 and 1996. Faunal diversity values (*i.e.*, H' on $\log_e$ scale) at swash-zone stations of exposed beach sites also were fairly similar between 1993 and 1996. However, higher diversity values ranging between 1.42 and 1.56 occurred among protected swash zone stations in 1993, whereas lower values varied between 0.97 and 1.39 in 1996. Two particular protected swash zone stations showed notably lower diversities in 1996, including Santa Rosa Island site 3 (SR3), for which H' was 1.16 in 1993, but only 0.24 in 1996, and Gulf Breeze site 2 (GB2), for which H' was 1.68 in 1993, but 1.00 in 1996. Variation in total geometric mean density was erratic between 1993 and 1996 among swash zone stations at both exposed and protected sites; however, densities were considerably higher among four of the five protected swash zone stations in 1993.

Macrobenthic summary community metrics generally conveyed that 15m subtidal assemblages of exposed beaches had largely recovered within the one year post-hurricane period, while some presumed residual effects were still apparent, especially among subtidal assemblages of protected beaches. Species richness was variable and similar among 15m subtidal stations at exposed beach sites, ranging between 9 and 14 taxa in 1993 and between 8 and 16 taxa in 1996, although values were higher at both Santa Rosa Island stations in 1993. Faunal diversity values among 15m subtidal exposed beach stations were fairly similar between 1993 and 1996, suggesting recovery of diversity had largely occurred at exposed stations. But total geometric mean densities were generally lower in 1996 among exposed subtidal stations, and total densities at the two exposed subtidal sites on Santa Rosa island were distinctly lower in 1996.

Considerably more discrepancies in summary community metrics occurred between years among subtidal stations than among swash-zone stations, and among protected subtidal stations than among exposed subtidal stations. Protected 15m subtidal beach stations showed conspicuously different ranges in species richness values between years. Also, diversity values among protected 15m subtidal stations ranged between 1.62 and 3.10 in 1993, and between 1.48 and 2.96 in 1996. Three protected subtidal stations showed notably lower diversities in 1996, including Santa Rosa site 1 (SR1), for which H' was 3.17 in 1993 and 1.69 in 1996, Gulf Breeze site 1 (GB1), for which H' was 2.72 in 1993 and 1.48 in 1996, and Gulf Breeze site 2 (GB2), for which H' was 2.78 in 1993 and 2.33 in 1996. These sites were located within the area of high disturbance. Total geometric mean densities also were generally substantially lower in 1996 among 15m subtidal stations from both exposed and protected beaches. Subtidal total densities at the two exposed Santa Rosa sites were distinctly lower in 1996, and total densities also were typically considerably lower in 1996 among the protected sites. Dominant taxa contributing to total macrobenthic densities among the subtidal stations differed considerably between 1993 and 1996. Differences in total macrobenthic densities between years were not consistently attributable to responses by particular taxa, indicating that density differences reflected possible community-level effects. Generally, dominance was shared by more taxa in 1993 than in 1996. Several of these dominant taxa were lacking among the same protected 15m subtidal stations in 1996, including *Capitella capitata*, *Heteromastus filiformis*, *Acanthohaustorius uncinata*, *Kalliapsuedes* sp A., and *Branchiostoma* cf. *floridana*.

PCO analyses of 23 common sandy-beach taxa were conducted separately for groups of swash-zone and 15m subtidal stations. Distinctive differences in faunal dissimilarity among the swash zone stations could not be attributed to hurricane effects, as PCO coordinates for the 1996 stations were not discernible from those of historical reference stations. Thus, essential recovery of the swash-zone community structure appeared to have occurred within the year following the GUIS hurricane disturbance. Differences in community structure attributable to hurricane effects were not apparent among 15m stations at exposed beach sites. However, distinctive differences in faunal dissimilarity were apparent among protected 15m sandy-beach stations, as seen for two of the 15m stations represented by two of the protected 15m PCO coordinates in 1996, one at Gulf Breeze and another at Santa Rosa Island. Coordinates for these two sites fell completely outside the reference area of the PCO plot along PCO axis 3. Macrobenthic assemblages occurring at these two stations in 1996 were influenced by large numbers of the haustoriid amphipod, *Lepidactylus* sp A., an invertebrate which was not characteristic of 15m subtidal protected beach habitats in autumn 1993. Thus, recovery of the 15m subtidal community of protected beaches was seemingly incomplete within the one-year post-hurricane period.

Paired comparisons of summary metrics among the grassbed stations between the October 1993 and October 1996 periods did not indicate any overall directional macrobenthic shifts. However, the lowest values of summary metrics occurred in 1996. Paired comparisons of summary metrics among the lagoon stations also failed to show any overall directional macrofaunal changes between

the October 1993 and October 1996 periods. Ranges of most summary metrics were fairly similar at lagoon stations between sampling periods. For example, total density values varied widely among lagoon stations, but were similar between years.

Between-year comparisons of relative abundances of taxa occurring in standard kicknet samples from grassbed and lagoon stations showed that the same taxa were generally dominant during both sample periods. Paired comparisons of abundances of infaunal taxa among the grassbed stations between the October 1993 and October 1996 periods failed to indicate any overall directional macrofaunal changes. Paired comparisons of abundances of micrograzer gastropods among the grassbed stations between the October 1993 and October 1996 periods also failed to show any overall directional shifts. Interestingly, overall decreases in several important epifaunal crustaceans among the grassbed stations was indicated by paired comparisons between the October 1993 and October 1996 periods. Four epifaunal crustacean taxa, including total ampithoids, *Hippolyte* spp., *Pagurus* spp., and total palaemonids, occurred in reduced numbers in 1996 at all seven grassbed stations, except for one instance. The same patterns were confirmed by lagoon stations in which grassbed habitat occurred.

As has been noted for offshore macrobenthos of exposed beaches, assemblages of relatively stable habitats like protected sandy-beaches, grassbeds, and lagoons, are richer and presumably less resilient than assemblages of exposed sandy beaches. Thus, the extent of macrobenthic effects of Hurricanes Erin and Opal conformed inversely to the degree of disturbance normally experienced by resident macrobenthic communities. Within one year of the hurricanes, few effects could be noted for exposed swash zone stations, while various faunal effects were apparent among protected swash-zone, exposed subtidal, and protected subtidal stations. Moreover, epibenthic crustacean populations of diverse and productive grassbed habitats still appeared to be affected following the one-year recovery period. Unfortunately, although we found various indications of residual sustained macrobenthic effects from Hurricanes Opal and Erin, owing to the lack of enough sampling frequency, such effects cannot be definitively established. We recommend that additional comprehensive GUIS macrobenthic inventories be conducted every five years to ensure the proper assessments of possible future damages to NPS aquatic resources.

## TABLE OF CONTENTS


INTRODUCTION ..... 5
1995 Storm Impacts ..... 5
Previous Macrobenthic Baseline Work ..... 6
Objectives ..... 8
METHODS ..... 9
Study Design ..... 9
Field Collection Methods ..... 9
Sample Processing ..... 12
Data Analysis and Interpretation ..... 13
RESULTS AND DISCUSSION ..... 17
Sand-Beach Collections ..... 17
Species Richness ..... 17
Faunal Diversity ..... 17
Total Macrobenthic Density ..... 19
Dominance Patterns ..... 22
PCO Ordination ..... 23
Grassbed and Lagoon Collections ..... 27
Faunal Summary Metrics ..... 27
Dominance Patterns ..... 31
Conclusions ..... 34
Caveats ..... 35
Recommendations ..... 36
ACKNOWLEDGEMENTS ..... 38
LITERATURE CITED ..... 39
APPENDICES ..... 43
Appendix 1. Summary Tables for Box-Core Samples ..... 43
Appendix 2. Summary Tables for Grassbed Kicknet Samples ..... 56
Appendix 3. Summary Tables for Lagoon Kicknet Samples ..... 63

# INTRODUCTION

## 1995 Storm Impacts

During late summer and autumn 1995, two consecutive hurricanes severely affected the western panhandle coast of Florida, Hurricanes Erin and Opal. The milder Category 1 Erin made landfall along Santa Rosa Island on 3 August 1995, where it displaced the upper foreshore berm gulfward over a wide area and displaced considerable sediment towards the island interior (Stone 1996). Some beach erosion also occurred, and substantial sediment was displaced from the beach and deposited to the dune system.

Compared to the relatively mild Erin, a much harsher Hurricane Opal devastated the same coastal region exactly two months later, on 4 October 1995, when it landed just east of Pensacola, Florida (Stone *et al.* 1996). Since 1900, Opal was the most severe storm to affect the immediate area in the vicinity of the eastern district of Gulf Islands National Seashore (GUIS). Opal neared Category 5 strength 12 hours before landing, as signaled by sustained wind speeds of over 65 m $s^{-1}$. Estimated storm surge levels reached 5 m, resulting in the overwash of most of Santa Rosa Island, which was the most intensely impacted section of the northern Gulf coast. Major erosion and sediment displacement occurred within the National seashore portion of Santa Rosa Island as a result of Opal. Vegetated stable foredunes reaching 5 m before Opal were entirely removed by the storm along Santa Rosa Island and Destin. However, between 95-99% of the sediment eroded from the beach-dune system was redeposited to the island interior and along the northern bay shoreline. Overwash fans were reported to extend bayward by almost 100 m in some areas. Although the south shoreline of the island was not displaced landward by the storm, a notable coarsening of the quartz sand beach sediments did occur. Considering the magnitude of the

environmental disturbances associated with the 1995 hurricanes, it is likely that the macrobenthic biota of both protected and exposed beaches as well as other shoreline habitats in the Florida district of GUIS were also severely impacted by the storms.

As part of a resource damage assessment response by the National Park Service, the USM IMS GCRL Benthic Systematics and Ecology Section was contracted to conduct a macrobenthic study of sustained hurricane effects on the nearshore habitats of the Florida district of GUIS. Unfortunately, logistical funding constraints prevented this assessment from being accomplished until one year after the hurricane disturbances. Nevertheless, through previous proactive efforts of GUIS, substantial macrobenthic assessments within GUIS had been conducted by USM IMS GCRL before the hurricanes occurred.

Previous Macrobenthic Baseline Work

Traditionally, the GUIS Region has recognized the utility of macrobenthic assessments and supported several macrobenthic studies by the Invertebrate Zoology Section of GCRL in various contexts. Previous NPS funded studies include a partial biotic inventory (Heard and Stuck 1989; Rakocinski *et al.* 1991), an oilspill study (McLelland and Heard 1991), a three-year beach renourishment study (Rakocinski *et al.* 1993, 1994, 1995), and an extensive baseline inventory in 1993 of the aquatic shoreline habitats, including protected and exposed sandy beaches, seagrass beds, and lagoons (Rakocinski, *et al.* 1995, in press). These former studies offer good standards of comparison with the present benthic resource assessment, and much relevant data from those former studies will be incorporated into the data analyses with data from the current study.

The extensive GUIS macrobenthic inventory of 1993 was conducted to fulfill the critical need to fill identified gaps in the baseline information, so that subsequent impact assessments of shallow

aquatic habitats could be made anywhere within the GUIS region (Rakocinski *et al.* 1995, in press). These macrobenthic surveys comprised a comprehensive parkwide inventory of communities occupying nearshore sandy bottom habitats, seagrass beds, and tidal embayments. The relative importance of habitat variation, seasonal variation, regional variation, and historic changes in macrobenthic community structure were considered, as well as a synthesis including much of the other GUIS macrobenthic data. The overall objective of the synthesis of former macrobenthic data was to provide a comprehensive baseline against which to gauge effects of subsequent impacts to GUIS aquatic resources. Thus, we considered various sources and scales of macrobenthic variation, including: (1) spatial macrobenthic variation among different shoreline habitats; (2) the seasonal component of temporal macrobenthic variation; (3) spatial macrobenthic variation among GUIS districts; and (4) the historical component of temporal macrobenthic changes.

From the comprehensive inventory we found that different macrobenthic community metrics, including species richness, diversity, total density, and community dissimilarity, varied on several spatiotemporal scales, including landscape, regional, historic, and seasonal levels. Community metrics all conveyed greater faunal complexity with decreasing exposure to wave disturbance, as expressed by both seaward distance/depth and shore side. Nesting of macrobenthic variation did not directly parallel the hierarchy of spatiotemporal scales. Rather, multivariate analyses showed hierarchically inclusive levels of community variation headed by the landscape scale, and successively followed by the regional scale, the historical scale, the habitat scale, and the seasonal scale. Macrobenthic assemblages were relatively similar between historical and contemporary collections from the same district. Moderate seasonal variability in community metrics usually revealed greater faunal complexity in summer and

autumn. Variability in total density across seasons, seaward distances, and sites was not driven by particular dominant taxa; and dominant taxa occurred more consistently across seasons at individual sites than across stations within any given season. However, distinctive distribution patterns for 23 selected common sandy-shore macrobenthic taxa used in multivariate analyses helped explain the observed scales of variation. Grassbed stations also showed interesting faunal variability apparently related to the patchy versus continuous nature of seagrass habitats. The value of this comprehensive macrobenthic inventory was that it provides a multi-year regional comparative reference for subsequent assessments of impacts on aquatic resources.

## Objectives

Macrobenthic communities make excellent ecological indicators because they integrate the effects of environmental stress. Baseline data from previous macrobenthic surveys for each of the habitat types should allow assessments of the sustained impacts from Hurricanes Erin and Opal. The overall objective of this study is to compare extensive baseline information to post-hurricane macrobenthic data obtained one year after the storm impacts as a means to gauge the extent of sustained ecological effects to the nearshore resources of the Florida district of GUIS. To accomplish this objective, we will consider: (1) pre- and post-hurricane variation in several important macrobenthic metrics, including species richness, diversity, and total abundance; and (2) multivariate variation in 23 selected sandy-beach taxa previously used to develop a historical reference framework; (3) findings from these analyses will be interpreted in light of abundance patterns expressed by individual indicator taxa; (4) for grassbed and lagoon stations, faunal metrics and between-period variability in abundances of indicator taxa also will be examined.

## METHODS

### Study Design

The study design of this hurricane impact assessment closely followed the design for the comprehensive 1993 macrobenthic inventory. For the inventory, sites were distributed among the GUIS barrier islands so as to allow comparisons with former GCRL studies and to serve as a balanced contemporaneous baseline study. To achieve a balanced study design, at least one exposed beach site and one protected beach site were located on each GUIS barrier island. At each beach site, three stations were sampled, including a mid-swash intertidal station, as well as 5m and 15m subtidal stations. Grassbed and lagoon sites also were located throughout the GUIS study region. Each grassbed site included two stations, while lagoon sites included three or four dispersed stations. Every island along the GUIS seashore was characterized at some level during the GCRL aquatic resource inventory. In the Florida district, sampling locations for the GUIS aquatic resource inventory included two sand beach sites (PK1, PK3), one grassbed site (PK2), and one lagoon site (PK4) at Perdido Key, two sand beach sites (GB1, GB2), and one grassbed site (GB3) at Gulf Breeze, and four sand beach sites (SR1, SR3, SR5, SR6), two grassbed sites (SR2, SR4), and one lagoon site (SR7) at Santa Rosa Island (Table 1; see Rakocinski *et al.* 1995 for map of study sites). This impact assessment utilized the same configuration of study locations in the Florida district to gauge sustained macrobenthic effects of the hurricanes.

### Field Collection Methods

The complete survey of the Florida district GUIS sites required efforts by a field crew of 6 people over a 4 day period between 28 and 31 October, 1996. We followed a very similar sampling scheme to that employed during the 1993 inventory (Rakocinski *et al.* 1995), except for several

Table 1. Fourteen sites sampled during the GUIS OPAL/ERIN macrobenthic impact study, along with descriptions of locations, an their position coordinates. Only one of the two grassbed stations from the 1993 inventory at site SR4 had seagrass present in 1996.

| Island | Site | Habitat Type | Location | Latitude | Longitude |
|---|---|---|---|---|---|
| Perdido Key | PK1 | Sand Beach | North Beach - FDNR range marker R63 | 30° 19' 08.6'' | 87° 19' 38.5'' |
| Perdido Key | PK2 | Grassbed | Grassbed adjacent to site PK1 | 30° 19' 08.6'' | 87° 19' 38.5'' |
| Perdido Key | PK3 | Sand Beach | South Beach - FDNR range marker R40 | 30° 18' 15.2'' | 87° 23' 31.9'' |
| Perdido Key | PK4 | Lagoon | Lagoon at Redfish Point - FDNR marker R51 | 30° 18' 57.0'' | 87° 21' 31.9'' |
| Gulf Breeze | GB1 | Sand Beach | North Beach - Naval Live Oaks campground | 30° 22' 12.8'' | 87° 08' 36.1'' |
| Gulf Breeze | GB2 | Sand Beach | South Beach - east of Naval Live Oaks Visitor Center | 30° 21' 49.5'' | 87° 07' 39.3'' |
| Gulf Breeze | GB3 | Grassbed | Grassbed adjacent to site GB2 | 30° 21' 47.6'' | 87° 07' 41.7'' |
| Santa Rosa Island | SR1 | Sand Beach | North Beach - Fort Pickens | 30° 18' 49.1'' | 87° 15' 07.9'' |
| Santa Rosa Island | SR2 | Grassbed | Grassbed adjacent to site SR1 | 30° 19' 10.7'' | 87° 15' 24.8'' |
| Santa Rosa Island | SR3 | Sand Beach | North Beach - Santa Rosa | 30° 21' 56.0'' | 86° 58' 05.8'' |
| Santa Rosa Island | SR4 | Grassbed | Grassbed adjacent to site SR3 | 30° 22' 01.9'' | 86° 58' 04.3'' |
| Santa Rosa Island | SR5 | Sand Beach | South Beach - Fort Pickens | 30° 19' 06.8'' | 87° 14' 45.0'' |
| Santa Rosa Island | SR6 | Sand Beach | South Beach - Santa Rosa | 30° 21' 41.9'' | 86° 58' 14.7'' |
| Santa Rosa Island | SR7 | Lagoon | Lagoon - Fort Pickens | 30° 19' 19.9'' | 87° 13' 49.2'' |

modifications, including the incorporation of only two shore distances at the sandy beach stations, 5m and 15m. We also did not take kicknet sweeps, yabby samples, or BPL samples at the sandy beach stations, as previous patterns have been based solely on benthic core data from sandy beach sites. Nor were qualitative yabby samples taken at grassbed and lagoon sites, as they were cost prohibitive. Owing to the lack of seagrass at one station, only one station was sampled at site SR4. Accordingly, we conducted the following sampling protocol:

1. All 8 established Florida district beach sites were sampled as follows:
   - (a) Eight quantitative 1/64 $m^2$ box-cores were taken at each of three stations located 0m, 5m, and 15m from shore;
   - (b) Sediment samples were collected at all sand-beach-site stations (ca. 450 cc from upper 3-5 cm of substrate);
   - (c) Water quality and habitat data, including salinity, dissolved oxygen (DO), pH, water temperature, depth, and substrate characteristics, were taken at each 5m subtidal station;
   - (h) Locality and weather information were noted, including latitude, longitude, habitat, time of day, tide cycle, cloud cover, air temperature, wind direction and strength, seas, distance from shore, etc.

2. The 2 established Florida district lagoon sites were sampled as follows:
   - (a) One 20m epibenthic kicknet sweep (*i.e.*, 9.0 $m^2$) was made with a 0.5mm mesh kicknet at each lagoon station;
   - (b) Water quality and habitat data, including salinity, dissolved oxygen, pH, water temperature, depth, and substrate characteristics were taken at each station;
   - (c) Locality and weather information were noted, including latitude, longitude, habitat, time of day, tide cycle, cloud cover, air temperature, wind direction and strength, seas, distance from shore, etc.

3. The 4 established Florida district grassbed sites were sampled as follows:
   - (a) Two 5m replicate epibenthic kicknet sweeps (*i.e.*, 4.5 $m^2$) were made through submerged vegetation at each of two stations using a 0.5 mm mesh kicknet;
   - (b) One sediment sample was taken at each site, adjacent to submerged vegetation;
   - (c) Water quality and habitat data, including habitat type, salinity, dissolved oxygen, pH, water temperature, depth, submerged vegetation and substrate characteristics were taken at each station;
   - (d) Locality and weather information were noted, including latitude, longitude, habitat, time of day, tide cycle, cloud cover, air temperature, wind direction and strength, seas, distance from shore, etc.

## Sample Processing

In the field, stations were routinely placed using a marker line, and yabby-pumps were used to mark station positions. A field crew both sampled stations and processed samples in the field. At beach sites, infaunal and epifaunal macroinvertebrates were sampled from the upper 20-25 cm of sediment using a 0.016 $m^2$ stainless steel box-corer (12.5 cm on a side) covered with 0.5 mm screen tops (Saloman and Naughton 1977). Eight box-core samples were taken from each station. Eight cores provide a good compromise in sampling effort (Rakocinski *et al.* 1995). In the swash zone, box-core samples were spaced evenly by about 1 m at mid-swash, parallel with the shoreline. At subtidal stations, box-core samples were haphazardly scattered within a roughly 4 m x 6 m elliptical area (long side parallel with the shoreline) centered around the station marker. Standard kicknet samples were taken by two workers over a predetermined distance using a measuring tape. Sweeps were taken along the bottom sediment surface using the 0.45 m wide rectangular net.

Box-core samples were processed in the field to remove sand and fines. Small and/or light-bodied organisms were removed by elutriating samples five times with a dilute formalin solution through a 0.5 mm sieve. Remaining material, including sediment, was washed through a 1.0 mm sieve to recover large and heavy organisms. A quality control procedure demonstrated that this process was effective in removing more than 95% of the organisms (Rakocinski *et al*, 1991). Kicknet samples were first killed with dilute formalin and then passed through a 0.5 mm sieve in their entirety, preserved and labeled. All processed samples were labeled, fixed with 5-10% formalin, and returned to the laboratory.

In the laboratory, macrobenthic invertebrates were sorted into major groups and transferred to 70% ethanol. Quality control of sorting entailed resorting five percent of the samples for at least

90% accuracy. Later, specimens were identified to the lowest practical taxonomic level (usually species) using available literature and enumerated. Some poorly known groups were not identified to species. A voucher collection of all nominal taxa has been prepared for the GCRL zoology museum and a complete list of taxa occurring in samples during this study is presented in the database, OPALTAX.DBF. Grassbed and lagoon samples that contained excessive numbers of organisms were sieved into three size fractions using nested sieves. The coarsest fraction was visually sorted using a lighted magnifying glass and finer fractions were subsampled using a MATODA plankton splitter. Following identification and enumeration of subsamples true values were extrapolated by the appropriate split-factor. In certain cases, when small mollusks were superabundant they were enumerated using a gridded petri-dish of 62.2 $cm^2$ within which the organisms in 0.208 of the dish area (9 grid squares) were counted and extrapolated to estimate the actual number in the dish.

Collection and taxonomic data were entered into different DBase files and separate quantitative data files were created for box-core (OPALCORE.DBF) and kicknet samples (OPALKICK.DBF). Quality assurance of data entry was maintained through careful rechecking of report generated data printouts. These samples have been archived within the GCRL Invertebrate Zoology Section, where they may be accessed for future reference.

Data Analysis and Interpretation

We used the Matrix Report feature of the Community Analysis System 4.0 (CAS) (Bloom 1992) to generate hierarchical taxonomic listings of organism abundances and to calculate summary community metrics for individual collections. Various PC software were used to create finished taxonomic summary tables from the raw data, including DBase III+, CAS 4.0, Lotus123 3.0, and

WordPerfect 5.1. Taxonomic summary tables were constructed by island for box-core data, whereas they were constructed by habitat for lagoon and grassbed samples. Thus, 3 summary tables were created for box-core samples and 2 summary tables were each created for grassbed and lagoon samples. Summary table entries for box-core collections reflected combined abundances from all eight cores (0.125 $m^2$), whereas entries reflected abundances per each 20 m kicknet push (9.0 $m^2$) for lagoon collections or combined abundances for two 5m kicknet pushes (4.5 $m^2$) for grassbed collections.

Summary community metrics calculated by the CAS Matrix Report program included species richness (no. taxa per collection), total density, diversity (H'), evenness ($H'/H_{max}$), scaled evenness, and Simpson's Index ($\lambda$) (*i.e.*, measure of dominance). For box-core collections, species richness (S) was defined as the number of taxa collected by eight cores (*e.g.*, no. taxa/0.125 $m^{-2}$). Total density was defined as the total number of organisms projected on a square meter basis *(i.e.*, $\Sigma$ (no. organisms $\times$ $m^{-2}$). Diversity (H') was calculated on the $\log_e$ scale according to the Shannon-Wiener formula, $H' = -\Sigma\, p_i \log p_i$, where $p_i$ is the proportion of the collection made up by taxon i. $H_{max}$ is the maximum value H' could take for a given number of taxa and organisms in a collection (i.e., the H' value calculated for an even distribution of n total individuals among i taxa). The ratio of these two metrics then gives a normalized estimate of evenness. Finally, Simpson's Index of dominance was calculated as, $\lambda = \Sigma\, p_i^2$, where $p_i$ is the proportion of the collection made up by taxon i. Tables of CAS community metrics were generated for sand-beach, grassbed, and lagoon collections and species richness values were plotted and compared between 1993 and 1996 for sand-beach collections.

The BASIC program, SPECAR90.BAS calculated geometric mean densities and their standard errors for each sand-beach collection. For individual taxa as well as for totals, the program computes means of ln (N+1) values (*i.e.*, geometric means), expressed in no. per $m^2$, and reports back-converted densities, along with confidence intervals of two standard errors (ca. 95% CI on means). Densities were calculated separately for each set of eight cores per station. Along with accompanying confidence intervals of two standard errors, geometric mean densities were compared between sites in 1993 and 1996. Plots of total geometric mean densities and their confidence intervals were made in SigmaPlot Version 3 (Ulrich *et al.* 1995).

Multivariate analyses of both pre-hurricane and post-hurricane data helped to assess sustained residual effects of the hurricanes on variation in sandy-beach macrobenthic community structure. Every collection taken previously from the same 1996 sand-beach stations was included in the ordinations, yielding 19 cases representing the seven swash zone stations and 20 15 m subtidal cases representing the eight 15m subtidal stations. PCO ordination was then used to evaluate whether post-hurricane collections were uniquely discernible within the overall reference framework provided by both pre-hurricane and post-hurricane samples. Selected taxa for multivariate data analyses included the 23 most common taxa occurring in more than 5 percent of the 92 cases within the 1986/1987 data set. These same 23 taxa were used in earlier multivariate analyses (Rakocinski *et al.* 1991; 1995; in press). Initial case entries were geometric mean numbers per core (Inv [$\Sigma$ ln (N+1)/no. cores per case]) for each of the 23 taxa.

Separate PCO analyses were performed using the 19 swash zone cases and the 20 15m subtidal cases. PCO was a two stage process, requiring the initial calculation of a dissimilarity matrix using

the CAS program, SIMMATRX.EXE (Bloom 1992). The CAS program, ORDANA.EXE, performed the actual PCO with the dissimilarity matrix. Distances among PCO sample coordinates reflect the degree of similarity in taxonomic composition. Abundance data were transformed by the eth root just as they were for similar analyses in previous studies. Abundance data were not standardized, allowing moderate weighting of the ordination according to the relative abundances of various taxa. Gower's Distance Index was used to generate the dissimilarity matrix for the PCO ordination, as prescribed by Bloom (1992), where association values between each pair of two samples (jk) are calculated: $\alpha_{jk} = \Sigma (x_{ij} - x_{ik})^2$, for the i taxa. Sample coordinates arrayed themselves throughout PCO space in a manner that allowed us to assess potential residual hurricane impacts on community structure. PCO coordinates were labeled in plots of 3D PCO space to visually interpret the ordination.

To detect possible hurricane effects on grassbed and lagoon stations, various faunal metrics, including abundances of dominant taxa and the different faunal summary metrics, were compared between the two groups of stations representing pre-hurricane (October 1993) and post-hurricane (October 1996) periods. These comparisons were based on the idea that changes occurring in the same direction among all stations were likely to be different between the two periods. Where the normality assumption was met and the statistical power was ample, possible differences between sample periods were examined using paired t-tests; otherwise, non-parametric Wilcoxin Signed Rank tests were used (Siegel 1956). Normality was checked using the Kolmogorov-Smirnov test by the statistical package, SigmaStat Version 2.0, which was employed to accomplish all these

statistical tests (Fox *et al.* 1995). Bar graphs comparing values from the two periods among grassbed and lagoon stations were made in SigmaPlot Version 3 (Ulrich *et al.* 1995).

## RESULTS AND DISCUSSION

### Sand-Beach Collections

*Species Richness*

Species richness values at GUIS Florida district swash-zone stations of both protected and exposed sandy-beach sites did not show any consistent pattern between 1993 and 1996, suggesting recovery of the swash-zone species composition had largely occurred within a year following the hurricane impacts. Species richness was highly variable and similar among swash-zone stations during both years, ranging between 7-8 taxa in 1993 and 6-8 taxa in 1996 among exposed beach stations and ranging between 8 and 25 taxa in 1993 and between 7 and 26 taxa in 1996 among protected beach stations (Fig. 1). Likewise, species richness was variable and similar among 15m subtidal stations at exposed beach sites, ranging between 9 and 14 taxa in 1993 and between 8 and 16 taxa in 1996, although values were higher at both Santa Rosa Island stations in 1993. Protected 15m subtidal beach stations, however, had conspicuously different ranges in species richness values between years, ranging between 39 and 55 taxa in 1993 compared to between 24 and 46 taxa in 1996. Values were consistently and considerably lower in 1996 among the five eastern protected beach sites on Santa Rosa Island and Gulf Breeze, where the hurricane effects were strongest.

*Faunal Diversity*

Faunal diversity values (*i.e.*, H' on $\log_e$ scale) at GUIS Florida district exposed beach sites were fairly similar between 1993 and 1996 at both swash-zone and 15m subtidal stations, suggesting

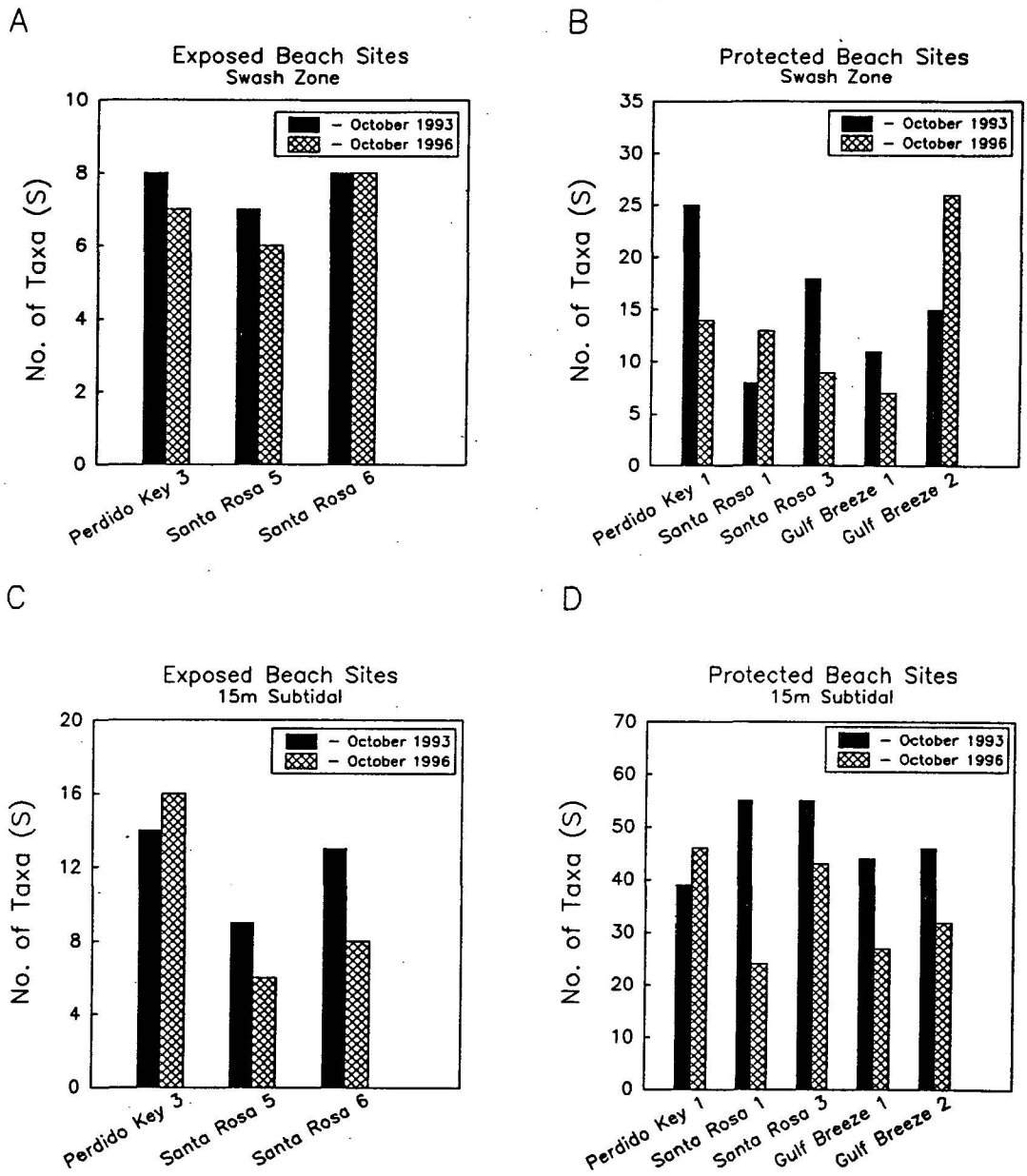



**FIGURE 1. SPECIES RICHNESS AMONG BEACH SITES.**

recovery of diversity had largely occurred at exposed sites within the year following the occurrence of hurricane impacts. Diversity values at exposed sites were typically a little higher in 1993, with values among swash zone stations ranging between 1.42 and 1.56 in 1993 and between 0.97 and 1.39 in 1996 (Fig. 2). Diversity values among 15m subtidal stations at exposed sites ranged between 1.57 and 1.83 in 1993 and between 1.31 and 1.78 in 1996. Considerably more discrepancies in diversity values occurred between years among stations at the protected sites. Higher values among protected swash zone stations in 1993 varied between 1.42 and 1.56, whereas lower values in 1996 varied between 0.97 and 1.39. Two protected swash zone stations showing notably lower diversities in 1996 were Santa Rosa Island site 3, for which H' was 1.16 in 1993 and only 0.24 in 1996, and Gulf Breeze site 2, for which H' was 1.68 in 1993 and 1.00 in 1996. Likewise, diversity values among protected 15m subtidal stations ranged between 1.62 and 3.10 in 1993 and between 1.48 and 2.96 in 1996. Three protected 15m subtidal sites showed notably lower diversities in 1996, including Santa Rosa site 1, for which H' was 3.17 in 1993 and 1.69 in 1996, Gulf Breeze site 1, for which H' was 2.72 in 1993 and 1.48 in 1996, and Gulf Breeze site 2, for which H' was 2.78 in 1993 and 2.33 in 1996. These sites were located well within the impact area. Thus, signature effects on faunal diversity from the hurricane were likely still evident on protected beaches after a year.

*Total Macrobenthic Density*

Variation in total geometric mean density was erratic between 1993 and 1996 among swash zone stations at both exposed and protected sites (Fig. 3). However, densities were considerably higher among four of the five protected swash zone stations in 1993. Total geometric mean densities of exposed swash zone stations ranged between 98 and 1,374 $m^2$ in 1993 and between 226 and 1,116

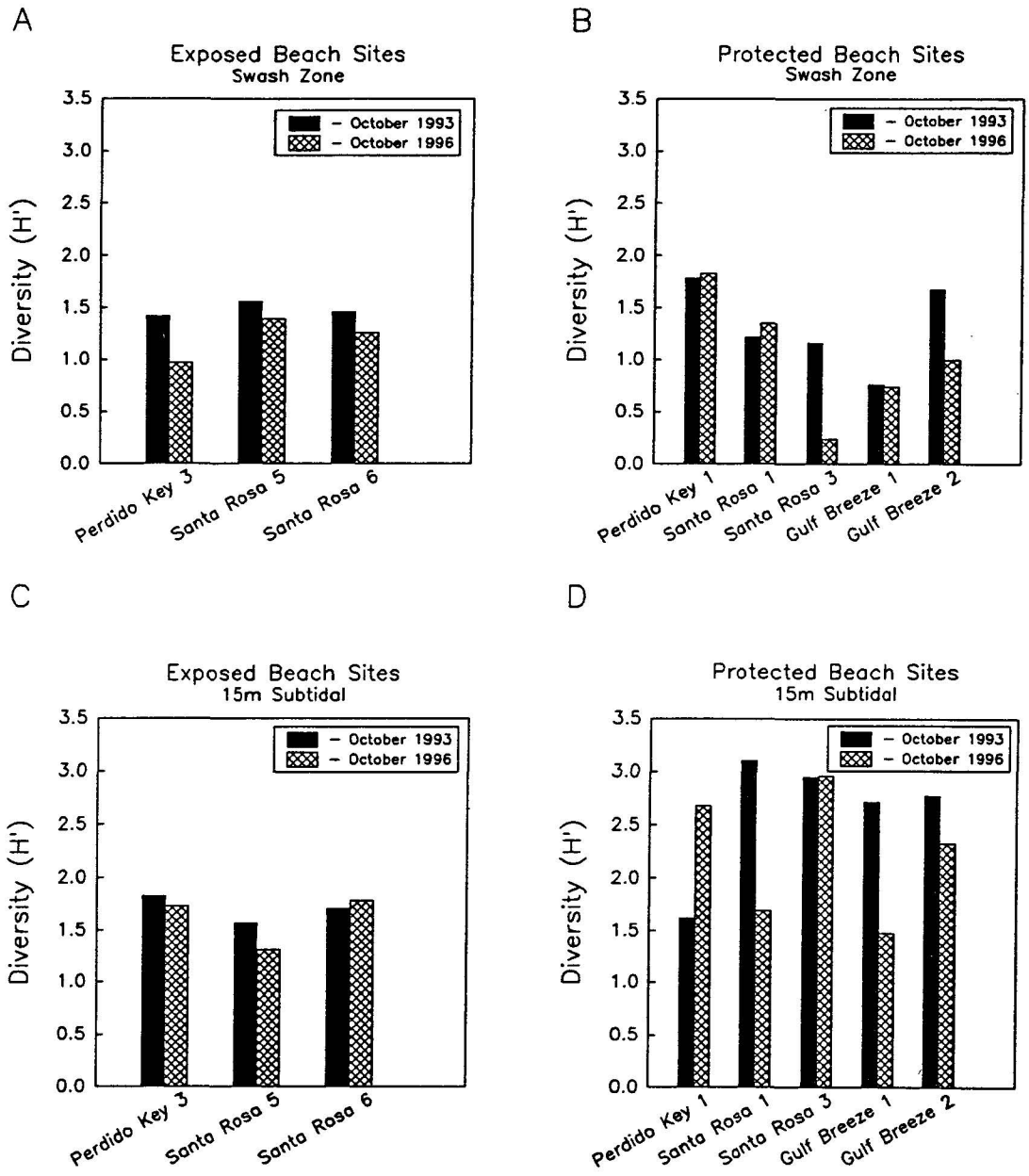



**FIGURE 2. FAUNAL DIVERSITY AMONG BEACH SITES.**

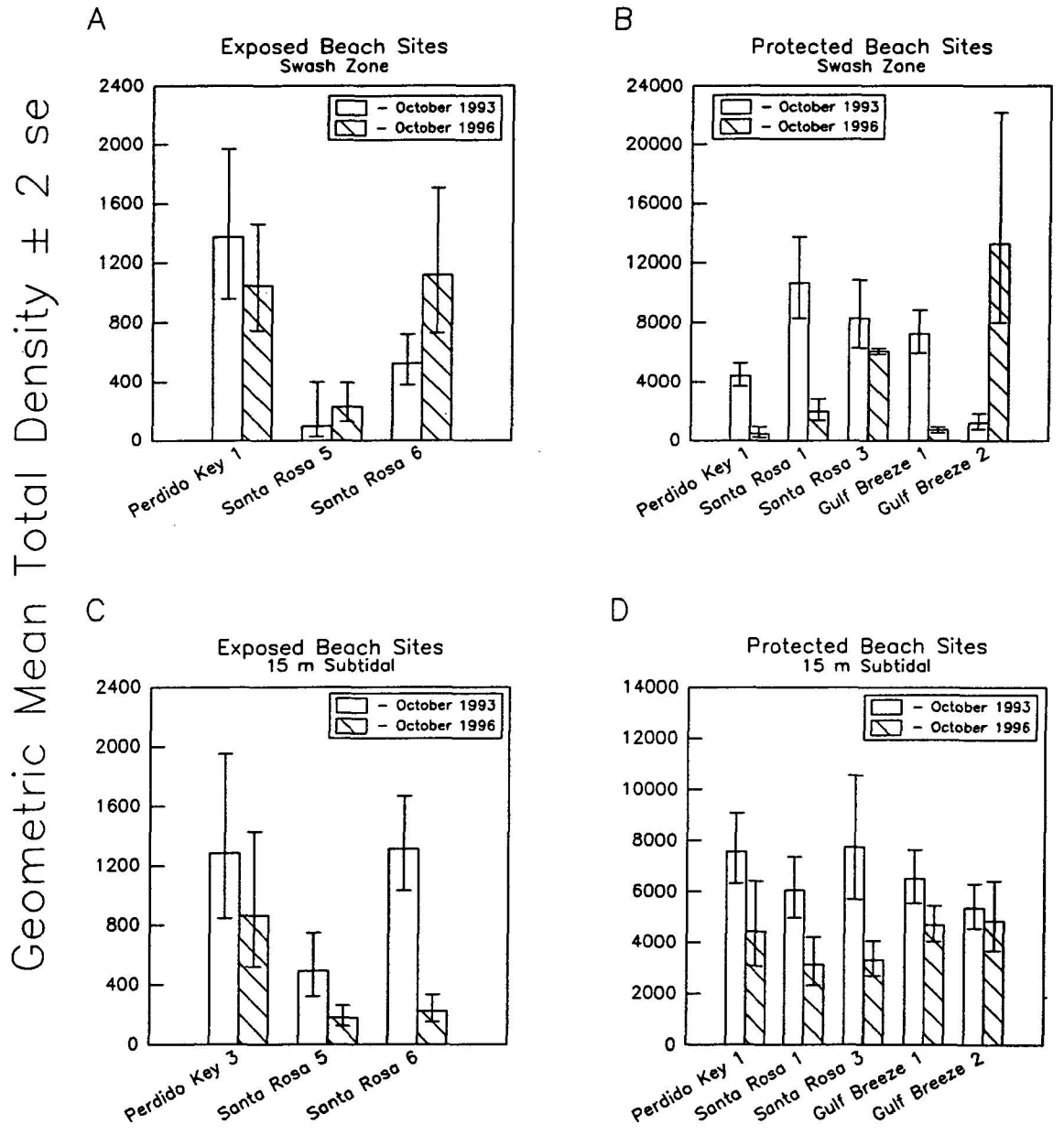



**FIGURE 3. TOTAL DENSITY AMONG BEACH SITES.**

$m^2$ in 1996. Among protected swash zone stations, geometric mean densities ranged between 1,197 and 10,658 $m^2$ in 1993 and between 449 and 13,320 $m^2$ in 1996. Total geometric mean densities were generally substantially lower in 1996 among 15m subtidal stations from both exposed and protected beaches. Geometric mean densities of exposed 15m subtidal stations ranged between 491 and 1,312 $m^2$ in 1993 and between 179 and 861 in 1996. Among protected 15m subtidal stations, geometric mean densities ranged between 5,353 and 7,757 $m^2$ in 1993 and between 3,109 and 4,857 $m^2$ in 1996. Subtidal total densities at the two exposed Santa Rosa sites were distinctly lower in 1996 and total densities also were typically considerably lower in 1996 among the protected sites throughout the Florida district, as shown by nonoverlapping error bars for four of the five protected subtidal stations.

*Dominance Patterns*

Dominant taxa contributing to total macrobenthic densities among the subtidal stations differed considerably between 1993 and 1996. Differences in total macrobenthic densities between years were not consistently attributable to responses by particular taxa, indicating that density differences reflected possible community-level effects. Generally, dominance was shared by more taxa in 1993 than in 1996. Thirteen dominant taxa occurring among the five protected 15m subtidal stations in 1993 comprised oligochaetes, and various polychaetes, including *Laeonereis culveri*, *Capitella capitata*, *Heteromastus filiformis*, *Paraeonis fulgens*, *Streptosyllis pettiboneae*, and *Polygordius* sp. A, Unidentified Nemerteans and Nemertea species B, Turbellarians, the lancelet, *Branchiostoma* cf. *floridana*, and several crustaceans, including *Kalliapsuedes* sp A and *Acanthohaustorius uncinus* (Appendix 1). Several of these dominant taxa were lacking among the same protected 15m subtidal stations in 1996, including *Capitella capitata*, *Heteromastus filiformis*, *Acanthohaustorius uncinata*,

*Kalliapsuedes* sp A., and *Branchiostoma* cf. *floridana*. Interestingly, *Branchiostoma* cf. *floridana* has been referred to as an equilibrium species in deeper subtidal habitats (Rakocinski *et al.* 1996). The lack of capitellids, *Capitella* and *Heteromastus*, may reflect a relatively low amount of organic matter in the newly disturbed and overwashed sediments in the protected beaches. Moreover, the haustoriid amphipod, *Lepidactylus* sp A., was a new dominant taxon at two of the protected 15m subtidal stations in 1996, a taxon which is frequently subtidally dominant in spring, but which was lacking at the same stations in autumn 1993 (Rakocinski *et al.* 1995; in press).

*PCO Ordination*

The PCO ordinations provided a simplified framework for assessing variation in community structure involving historical reference samples from the same stations in 1986, 1987, and 1993, against which 1996 samples could be compared. The same 23 taxa used for former ordinations were also used for this analysis (Rakocinski *et al.*1991; 1995; in press). The dissimilarity index, Gower's Distance Index, was used to calculate intersample faunal differences. Distances among sample coordinates in PCO plots then reflected the degree of community dissimilarity (Figs. 4 & 5). To assess the relative importance of residual hurricane effects on community structure, assignments of symbols in PCO plots reflected whether stations were from exposed or protected beaches and sample-coordinate labels indicated the year and station of the sample.

Forty-two percent of the variance in macrofaunal dissimilarity among the 19 swash zone stations was effectively explained by the first three PCO axes: Axis 1 represented 20.37% of the variance, Axis 2 represented 13.83% of the variance, and Axis 3 represented 8.03% of the variance. Explained variance declined sharply with added PCO dimensions: PCO Axes 4 - 19 together only accounted for 7.49% of the total variance, and all axes above PCO 5 had low eigenvalues that were

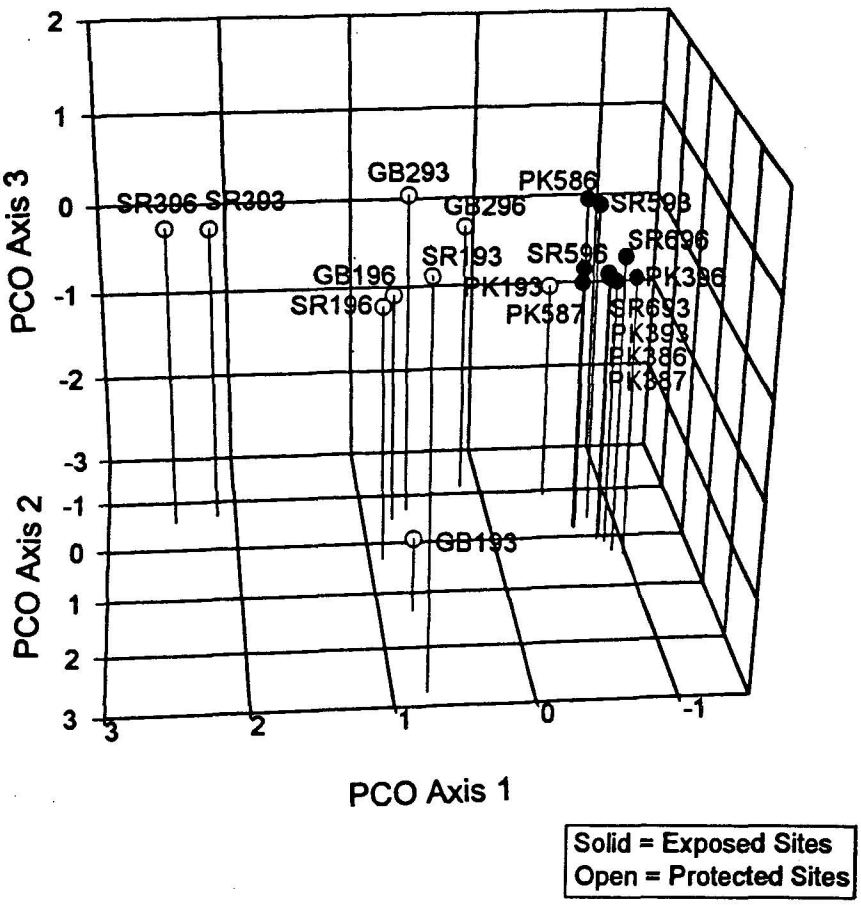



**FIGURE 4. SWASH ZONE ORDINATION.**

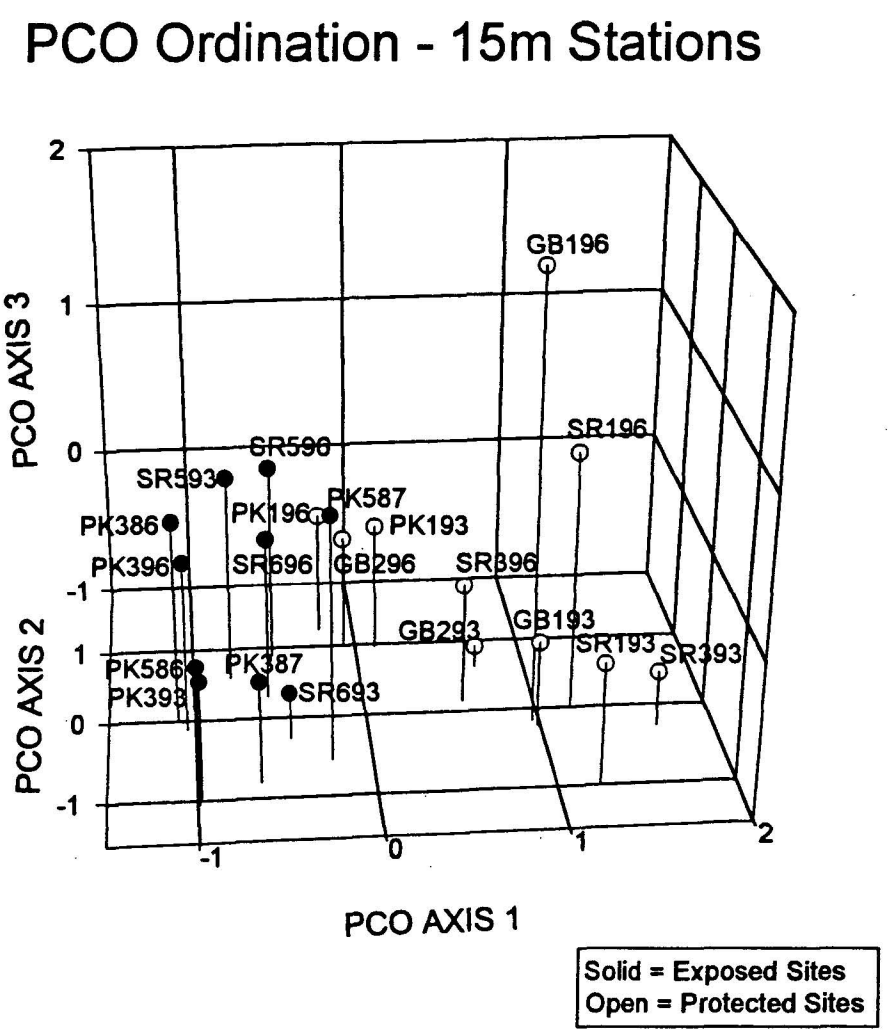



**FIGURE 5. SUBTIDAL ORDINATION.**

less than one. Most meaningful community variation among the swash zone stations could be examined within the first three PCO dimensions, as implied by a cumulative vector efficiency of 85% for the first three axes.

The pattern of swash-zone sample coordinates in 3-D PCO space showed much greater variability in community structure among the protected beach sites, which are characterized by a more diverse macrofauna (Fig. 4). Strongly aggregated groups of stations representing protected and exposed sites also were apparent. However, distinctive differences in faunal dissimilarity among the swash zone stations could not be attributed to hurricane effects, as PCO coordinates for the 1996 stations were not discernible from those of historical reference stations. Indeed, the most egregious swash-zone coordinate represented a protected Gulf Breeze site in 1993. Thus, essential recovery of the swash-zone community structure appeared to have occurred within the year following the hurricane disturbance. This was not surprising, because swash-zone habitats are subject to regular disturbances and the organisms which occupy them are adapted for living under such highly disturbed conditions. Swash zone organisms of exposed beaches apparently recovered from extensive beach restoration within one year at Perdido Key (Rakocinski *et al.* 1996).

Thirty-one percent of the variance in macrofaunal dissimilarity among the 20 15m subtidal stations was effectively explained by the first three PCO axes: Axis 1 represented 14.64% of the variance, Axis 2 represented 9.46% of the variance, and Axis 3 represented 6.82% of the variance. Explained variance declined sharply with added PCO dimensions: PCO Axes 4 - 20 together only accounted for 18.15% of the total variance, and all axes above PCO 9 had low eigenvalues that were less than one. Most meaningful community variation among the 15m subtidal stations could

be examined within the first three PCO dimensions, as implied by a cumulative vector efficiency of 63% for the first three axes.

The pattern of 15m subtidal sample coordinates in 3-D PCO space also showed less variability in community structure between exposed and protected beaches. Aggregated groups of stations representing protected and exposed sites were separated in PCO space, indicating different faunal complements occurred on protected or exposed beaches (Fig. 5). Differences in community structure attributable to hurricane effects were not apparent among 15m stations at exposed beach sites. However, distinctive differences in faunal dissimilarity for two of the protected 15m stations were apparent, as shown by two of the 15m PCO coordinates representing protected beach sites in 1996, one at Gulf Breeze and one at Santa Rosa Island. Coordinates for these two sites fell completely outside the reference area of the PCO plot along PCO axis 3. As stated previously, macrobenthic assemblages occurring at these two stations in 1996 were influenced by large numbers of the haustoriid amphipod, *Lepidactylus* sp A., an invertebrate which was not characteristic of 15m subtidal protected beach habitats in autumn 1993. Thus, complete recovery of the 15m subtidal community of protected beaches may not have occurred within the year following the GUIS hurricane disturbance. Again, the difference between recovery of protected and exposed 15m subtidal stations might reflect differences in faunal adaptations to respective disturbance regimes usually occurring there.

## Grassbed and Lagoon Collections

### *Faunal Summary Metrics*

Paired comparisons of summary metrics between the October 1993 and October 1996 periods among the grassbed stations did not indicate any overall directional macrofaunal changes (Fig. 6).

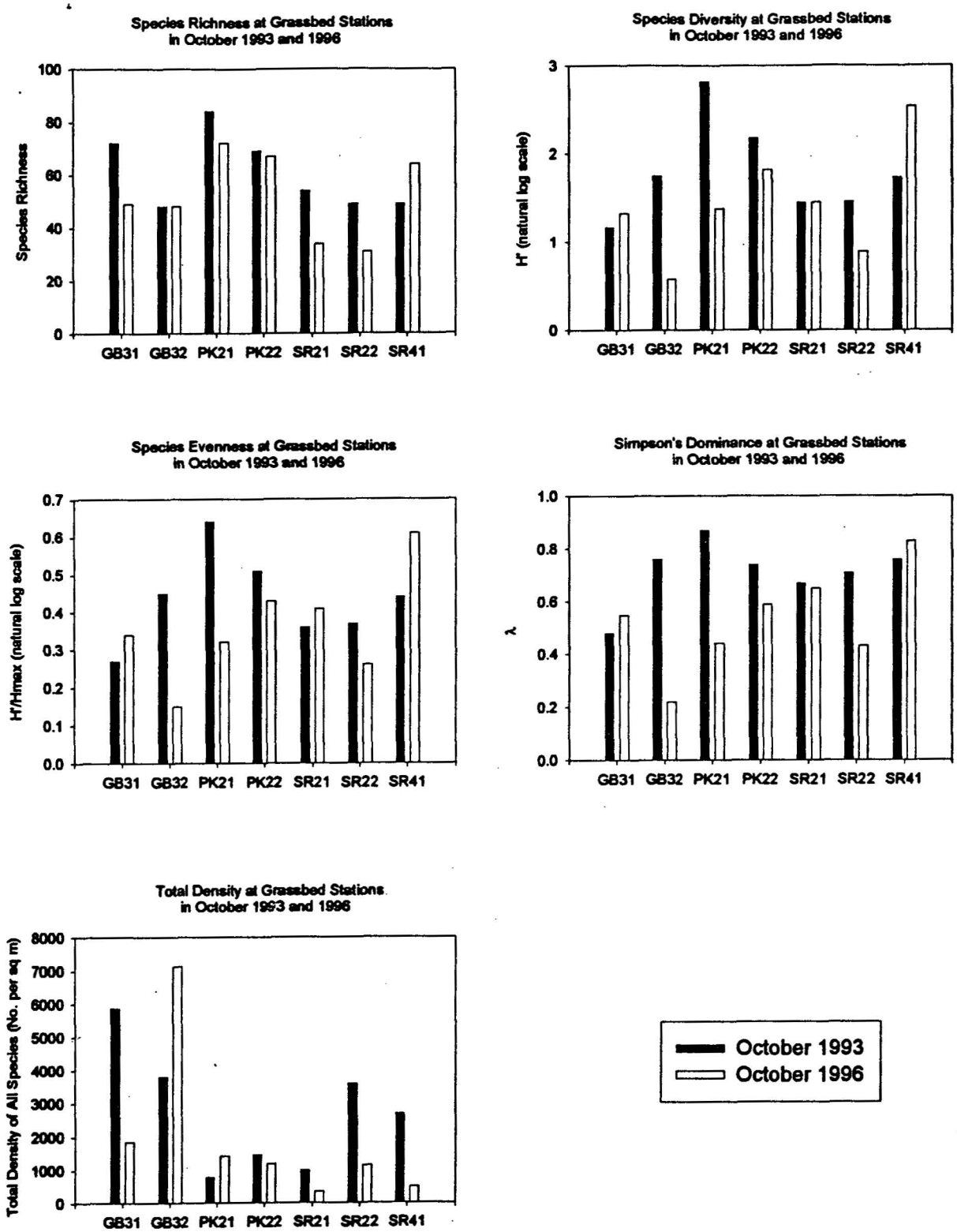



**FIGURE 6. GRASSBED FAUNAL SUMMARY METRICS.**

Wilcoxin Signed Rank tests comparing groups of grassbed stations between 1993 and 1996 were nonsignificant for every summary metric, including species richness, diversity, evenness, dominance, and total density ($0.469 > P_{exact} > 0.156$). However, the lowest values of summary metrics occurred in 1996. Species richness values among the seven GUIS Florida district grassbed stations varied between 48 and 84 in 1993, and somewhat lower, between 31 and 72 in 1996. Faunal diversity (H') values were similar between periods; and ranged between 1.17 and 2.82 in 1993, and between 0.58 and 2.54 in 1996. Evenness ($H'/H_{max}$) and dominance ($\lambda$) values paralleled variation in diversity values, with evenness ranging between 0.27 and 0.64 in 1993, and between 0.15 and 0.61 in 1996; and dominance ranging between 0.48 and 0.87 in 1993, and between 0.22 and 0.83 in 1996. Total density values varied widely among stations, but ranged similarly between years, with values spanning between 779 and 5,865 in 1993, and between 358 and 7,126 in 1996.

Paired comparisons of summary metrics among the lagoon stations also failed to indicate any overall directional macrofaunal changes between the October 1993 and October 1996 periods (Fig. 7). Wilcoxin Signed Rank tests comparing groups of lagoon stations between 1993 and 1996 were nonsignificant for every summary metric, including species richness, diversity, evenness, dominance, and total density ($1.0 > P_{exact} > 0.688$). Wide ranges for some summary metric values reflected the relatively high habitat heterogeneity among lagoon stations. However, ranges of most metrics were fairly similar between the sampling periods. Species richness values among the six Florida district lagoon stations varied between 17 and 69 in 1993, and, similarly, between 16 and 81 in 1996. Faunal diversity (H') values also were similar between years among lagoon

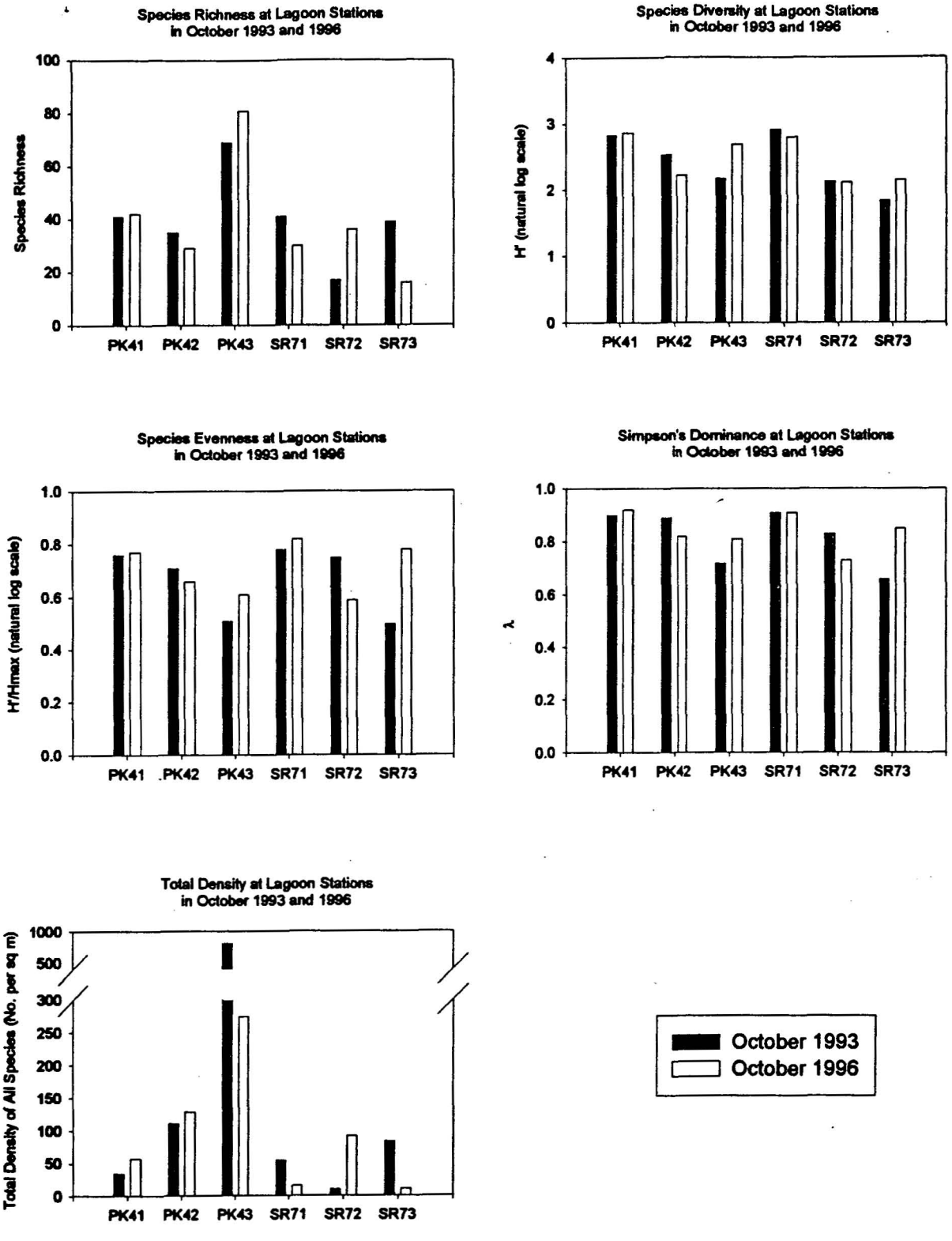



**FIGURE 7. LAGOON FAUNAL SUMMARY METRICS.**

stations, ranging between 1.84 and 2.91 in 1993, and between 2.11 and 2.87 in 1996. Again, evenness ($H'/H_{max}$) and dominance ($\lambda$) values paralleled diversity values, with evenness ranging between 0.50 and 0.78 in 1993, and between 0.59 and 0.82 in 1996; and dominance ranging between 0.66 and 0.91 in 1993, and between 0.73 and 0.92 in 1996. Total density values varied widely among lagoon stations, but were similar between years.

*Dominance Patterns*

Between-year comparisons of relative abundances of taxa occurring in kicknet samples from grassbed and lagoon stations showed that the same taxa were generally dominant during both pre- and post-hurricane periods (Appendices 2 & 3) (Rakocinski *et al.* 1995). Paired comparisons of abundances of infaunal taxa between the October 1993 and October 1996 periods among the grassbed stations did not indicate any overall directional macrofaunal changes. For example, a Wilcoxin Signed Rank test showed that the total numbers of syllid polychaetes were not generally different between years $P_{exact} = 0.84$). Total abundances of syllids ranged between 0 and 52 in 1993, and between 0 and 139 in 1996. Paired comparisons of abundances of micrograzer gastropods between the 1993 and 1996 periods among the grassbed stations also failed to show any overall directional shifts. Again, Wilcoxin Signed Rank tests showed that abundances of two dominant micrograzer snails, *Diastoma varium* and *Astyris lunata*, were neither generally different between years ($P_{exact} = 0.94$ for both taxa). Numbers of *D. varium* ranged similarly between 307 and 18,618 in 1993, and between 289 and 28,345 in 1996; while numbers of *A. lunata* ranged between 109 and 2,679 in 1993, and between 83 and 1,414 in 1996.

Interestingly, overall decreases in several important epifaunal crustaceans among the grassbed stations was indicated by paired comparisons between the October 1993 and October 1996 periods

(Fig. 8; Appendix 2). Four epifaunal crustacean taxa, including total ampithoids, *Hippolyte* spp., *Pagurus* spp., and total palaemonids, occurred in reduced numbers in 1996 at all seven grassbed stations, except for one instance. The same patterns were upheld by lagoon stations in which grassbed habitat occurred (Appendix 3). Paired-t tests of between-year-differences in abundances of the four taxa were warranted, based on the fulfillment of normality assumptions and power requirements. Numbers of ampithoids in grassbed kicknet samples ranged between 5 and 246 and averaged 127.1 (±35.6 se) in 1993, while in 1996 they ranged between 0 and 116 and only averaged 36.6 (±18.0 se). A paired t-test ($t = 2.542$; $P = 0.04$) confirmed that there was a significant between-year-difference in the numbers of ampithoids. The power for this test was 0.50 at $\alpha = 0.05$. Numbers of *Hippolyte* in grassbed samples ranged between 1,266 and 10,363 and averaged 5,224.1 (±1,292.5 se) in 1993, while in 1996 they ranged between 73 and 1,125 and averaged 447.9 (±165.8 se). A paired t-test ($t = 7.57$; $P < 0.001$) on ln transformed data also confirmed that there was a significant between-year difference in the numbers of *Hippolyte*. The power for this test was 1.0 at $\alpha = 0.05$. Numbers of *Pagurus* in grassbed samples ranged between 27 and 183 and averaged 103.1 1 (±20.9 se ) in 1993, while in 1996 they ranged between 0 and 44 and averaged 25.0 (±6.0 se ). A paired t-test ($t = 3.85$; $P = 0.008$) again confirmed that there was a significant between-year difference in numbers of *Pagurus*. The power for this test was 0.88 at $\alpha = 0.05$. Finally, numbers of palaemonids in grassbed samples ranged between 6 and 124 and averaged 47.4 (±15.2 se) in 1993, while in 1996 they ranged between 0 and 33 and averaged 10.6 (±5.0 se). A paired t-test ($t = 2.75$; $P = 0.03$) also confirmed that there was a significant between-year difference in numbers of palaemonids. The power for this test was 0.57 at $\alpha = 0.05$.

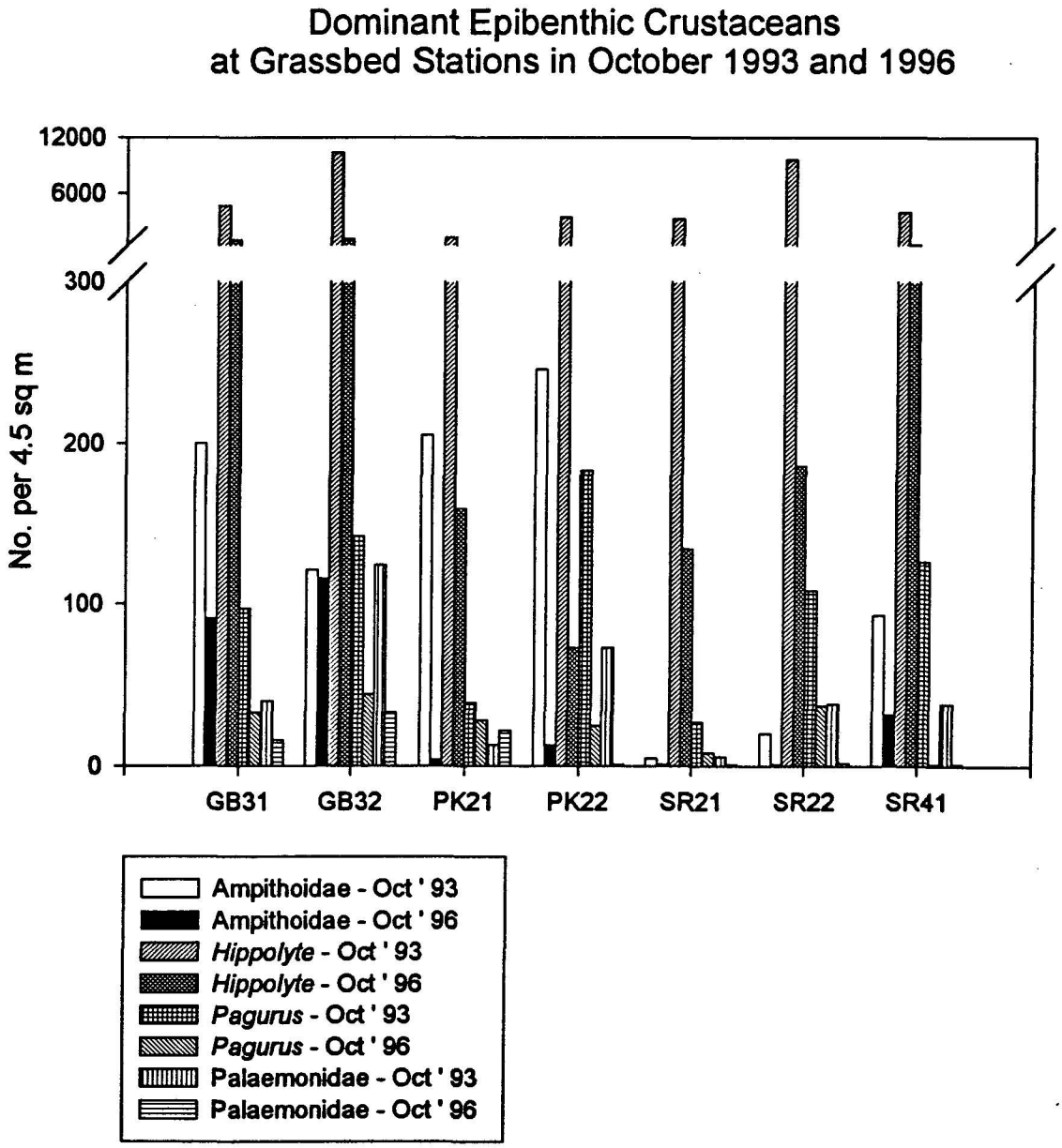



**FIGURE 8. BETWEEN-YEAR DIFFERENCES IN ABUNDANCES OF EPIBENTHIC CRUSTACEANS.**

## Conclusions

Although effects of severe weather events on macrobenthic communities are difficult to ascertain, various potential physical impacts by hurricanes on the biota include smothering by sediment deposition, turbidity impacts, suffocation from the decomposition of organic matter, erosion, osmotic stress due to sudden changes in salinity, physical stranding, and rapid changes in water temperature (cited in Saloman and Naughton 1977). In a thorough study of the effects of Hurricane Eloise on the swash-zone macrofauna of several exposed beach sites at Panama City Beach, Florida, Saloman and Naughton (1977) failed to find any major differences between pre- and post-hurricane periods despite substantial erosional alteration of the beach. Using the same quantitative box-corer device as was used in this study, they also found that abundances of swash-zone organisms were inherently variable. Post-hurricane samples were taken as soon as the following day after the storm, and at frequent intermittent intervals. The authors mainly attributed their failure to find many hurricane effects on the adaptations of organisms inhabiting this high-energy environment as well as on inherent variability in their abundances. They also cited other exemplary studies noting little change from hurricane impacts on the organisms inhabiting exposed beach sites (Keith and Hulings 1965, Croker 1968). But they also noted that Keith and Hulings (1965) did find dramatic hurricane effects on soft-sediment macrobenthos.

In a recent study of the effects of extensive beach restoration on macrobenthic communities across exposed-beach transects, Rakocinski *et al.* (1996) hypothesized that diverse offshore subtidal assemblages are less resilient than contiguous nearshore sandy-beach assemblages. Faunal recovery near the beach was fairly rapid, being typically completed in less than one year. Indeed, Grant (1980, 1981) found that small patches of azoic beach sand could be completely colonized within

one month. Being adapted to frequent disturbance from high energy conditions confers considerable resilience to macrobenthic assemblages of exposed sandy beaches (Nelson 1993). Other studies of the impacts of beach nourishment also usually find macrobenthic recovery to be rapid and complete within the course of one year (Nelson 1989, 1993; Baca *et al.* 1991). However, like exposed offshore macrobenthos, assemblages of relatively stable habitats like protected sandy-beaches, grassbeds, and lagoons, are richer and presumably less resilient than assemblages of exposed sandy beaches (Rakocinski *et al.* 1991; Rakocinski *et al.* 1995).

The extent of macrobenthic effects of Hurricanes Erin and Opal conformed inversely to the degree of disturbance normally experienced by resident macrobenthic communities. Within one year of the hurricanes, few effects could be noted for exposed swash zone stations, while various faunal effects were apparent among protected swash-zone, exposed subtidal, and protected subtidal stations. Moreover, the key populations of diverse and productive grassbed habitats still appeared to be affected following the one-year recovery period.

Caveats

Unfortunately, although we saw numerous indications of sustained macrobenthic effects from Hurricanes Erin and Opal, such effects cannot be definitively established from the existing data. The best available pre-impact information originated from the GUIS 1993 macrobenthic inventory undertaken three years prior to the hurricane impacts. There is no way to ascertain with certainty whether the observed macrobenthic differences actually occurred from other causes during the interim. Another interpretation problem was the one-year post-impact lapse. The power to detect potential hurricane impacts would have been much better if several periodic post-hurricane sampling periods would have been initiated as soon as possible following the hurricane impacts.

This would have allowed us to examine faunal recovery trajectories. Finally, this study neglected one precept of a good environmental impact design by not encompassing a reference area completely outside of the impact area. This could have been afforded by the inclusion of sites from the Mississippi (western) district of GUIS, where hurricane impacts were not nearly as severe. Unfortunately, the lack of enough funding precluded the incorporation of all proper features of a good study design.

Despite some caveats, several strengths contributed to the success of this study. The existence of the extensive baseline information represented by the 1993 GUIS macrobenthic inventory and previous GUIS surveys afforded a standard of comparison for considering sustained hurricane effects. The spatial scale of the inventory provided a preexisting balanced arrangement of study sites throughout GUIS for the assessment of ecological impacts. The inclusion of multiple sites in the study design and the temporal periodicity of baseline data made available by the historical data of 1987 provided the necessary redundancy to detect important macrobenthic patterns. Established quantitative and semi-quantitative sampling methods and protocols also ensured comparability.

Recommendations

Macrobenthic communities provide good indicators of environmental stress, because they occur in association with sediments, where contaminants are deposited, they integrate multiple kinds and degrees of stresses, and they may be used in conjunction with other assessment techniques, such as sediment bioassays, to cross-reference ecosystem damage (Rakocinski *et al.* 1995). This study demonstrates the utility of having a comprehensive and current database on GUIS macrobenthic resources to promote sound management decisions. Without the extensive preexisting GUIS macrobenthic baseline database, especially the comprehensive GUIS macrobenthic inventory of

1993, the macrobenthic assessment of potential sustained hurricane effects presented here would have been impossible.

Within the 1993 GUIS macrobenthic inventory, extensive baseline information includes habitat, regional, historical, and seasonal levels of macrobenthic variation. As was seen in this study, this extensive baseline information provides a useful frame-of-reference for assessments of various impacts on GUIS aquatic resources. However, additional periodic GUIS macrobenthic inventories would greatly strengthen the power to assess GUIS aquatic resources. As noted by Rakocinski *et al.* (1995), scientists and resource managers are now aware that the value of long-term data cannot be overrated. Indeed, the National Science and Technology Council Committee on Environment and Natural Resources (1995) recently underscored the need for a national strategic commitment to long-term coastal research. From such integrated long-term programs, they cited several expected products, including assessments of resource and habitat change, land use impacts, and ecosystem health.

We recommend that additional comprehensive GUIS macrobenthic inventories be conducted every five years to ensure the proper assessment of possible damage to NPS aquatic resources. Periodic inventories also would ensure that long-term changes are not falsely attributed to more immediate impacts of concern. Certainly, we have seen here an example of both the utility of having sufficient information as well as the potential uncertainty of having to use insufficient information for assessments. Such information needs to be sound enough to withstand the scrutiny of litigation. It has now been five years since the last comprehensive GUIS macrobenthic inventory has been accomplished. In the 1995 inventory report, we recommended that continuous periodic macrobenthic inventories be performed on a similar scale roughly every five years (Rakocinski *et*

*al.* 1995). We asserted that this level of effort would be cost effective, given the potential for resource protection that it would afford. Further, this would also help fulfill the strategic framework proposed by the National Science and Technology Council Committee on Environment and Natural Resources (1995), which emphasized, "coordination of coastal science at all levels of government to accurately predict the impact of human-induced change and natural variability on our coastal ocean ecosystems".

**Acknowledgements**

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Appendix 1a. Species by station summaries of numbers of organisms sampled by box-core in October, 1996. Entries are number per 0.125 $m^2$ (8 cores combined).

GULF BREEZE

| TAXON | GB11 | GB13 | GB21 | GB23 |
|---|---|---|---|---|
| Phylum Annelida | | | | |
| Class Oligochaeta | | | | |
| Order Tubificida | | | | |
| Family Enchytraeidae | | | | |
| Grania sp. | - | - | 1 | - |
| Family Tubificidae | | | | |
| Unid. Tubificidae | - | 13 | 1544 | 162 |
| Class Polychaeta | | | | |
| Order Capitellida | | | | |
| Family Capitellidae | | | | |
| Capitella capitata | - | 2 | 58 | - |
| Heteromastus filiformis | - | - | 5 | - |
| Family Maldanidae | | | | |
| Axiothella mucosa | - | - | - | 14 |
| Order Cirratulida | | | | |
| Family Paraonidae | | | | |
| Aricidea philbinae | - | 1 | - | 21 |
| Order Orbiniida | | | | |
| Family Orbiniidae | | | | |
| Leitoscoloplos sp. | - | - | 30 | - |
| Order Phyllodocida | | | | |
| Family Glyceridae | | | | |
| Glycera sp. | - | - | - | 1 |
| Family Hesionidae | | | | |
| Micropthalmus sczelkowii | - | - | 2 | - |
| Family Nereididae | | | | |
| Laeonereis culveri | 1 | 40 | 148 | 181 |
| Neanthes succinea | - | 4 | 2 | 1 |
| Family Phyllodocidae | | | | |
| Hypereteone heteropoda | - | 1 | 6 | 17 |
| Family Pilargidae | | | | |
| Parandalia americana | - | 2 | - | 8 |
| Sigambra bassi | - | - | - | 5 |
| Family Syllidae | | | | |
| Grubeosyllis clavata | - | 6 | - | - |
| Sphaerosyllis taylori | - | - | - | 3 |
| Streptosyllis pettiboneae | - | - | 3 | 32 |
| Order Sabellida | | | | |
| Family Sabellidae | | | | |
| Chone sp. A | 1 | - | 5 | 10 |
| Family Serpulidae | | | | |
| Pomatoceros americanus | - | - | 1 | - |
| Order Spionida | | | | |
| Family Spionidae | | | | |
| Prionospio heterobranchia | - | - | - | 19 |
| Scolelepis texana | - | 14 | - | 58 |
| Order Terebellida | | | | |
| Family Pectinariidae | | | | |
| Pectinaria gouldii | - | - | - | 1 |
| Phylum Arthropoda | | | | |
| Class Copepoda | | | | |
| Order Calanoida | | | | |
| Unid. Calanoida | 2 | - | 3 | - |
| Order Cyclopoida | | | | |
| Unid. Cyclopoida | - | - | 4 | - |

Appendix 1a. GULF BREEZE, October 1996 (continued).

| TAXON | GB11 | GB13 | GB21 | GB23 |
|---|---|---|---|---|
| Class Malacostraca | | | | |
| Order Amphipoda | | | | |
| Family Amphilochidae | | | | |
| Gitanopsis sp. A | - | 1 | - | - |
| Family Ampithoidae | | | | |
| Unid. Ampithoidae | - | 1 | - | - |
| Family Atylidae | | | | |
| Atylus urocarinatus | - | - | 1 | - |
| Family Haustoriidae | | | | |
| Haustorius jayneae | 14 | 1 | - | - |
| Lepidactylus sp. A | 76 | 383 | 7 | - |
| Unid. Haustoriidae | 1 | - | 1 | - |
| Family Pariambidae | | | | |
| Deutella incerta | 1 | - | - | - |
| Order Cumacea | | | | |
| Family Diastylidae | | | | |
| Oxyurostylis smithi | - | 2 | 5 | 8 |
| Oxyurostylis sp. | - | 1 | 3 | 6 |
| Family Nannastacidae | | | | |
| Almyracuma cf proximoculi | - | - | - | 1 |
| Order Decapoda | | | | |
| Family Alpheidae | | | | |
| Leptalpheus forceps | - | 1 | - | 1 |
| Family Pinnotheridae | | | | |
| Pinnixa sp. A | - | - | - | 2 |
| Family Processidae | | | | |
| Ambidexter symmetricus | - | - | - | 1 |
| Order Isopoda | | | | |
| Family Idoteidae | | | | |
| Edotia triloba | - | - | 1 | - |
| Order Mysidacea | | | | |
| Family Mysidae | | | | |
| Americamysis bahia | - | 1 | - | - |
| Americamysis sp. | - | 2 | - | - |
| Bowmaniella dissimilis | - | 7 | 1 | 6 |
| Taphromysis bowmani | - | - | - | 1 |
| Taphromysis sp. | - | - | 1 | - |
| Order Tanaidacea | | | | |
| Family Paratanaidae | | | | |
| Hargeria rapax | - | - | 1 | - |
| Phylum Chordata | | | | |
| Class Leptocardii | | | | |
| Order Amphioxi | | | | |
| Family Branchiostomidae | | | | |
| Branchiostoma cf floridae | - | 1 | - | - |
| Phylum Cnidaria | | | | |
| Class Anthozoa | | | | |
| Unid. Anthozoa | - | - | - | 1 |
| Phylum Echinodermata | | | | |
| Class Holothuroidea | | | | |
| Order Apodida | | | | |
| Family Synaptidae | | | | |
| Leptosynapta crassipatina | - | - | - | 1 |
| Class Ophiuroidea | | | | |
| Order Ophiurida | | | | |
| Family Amphiuridae | | | | |
| Unid. Amphiuridae | - | - | - | 1 |

Appendix 1a. GULF BREEZE, October 1996 (continued).

| TAXON | GB11 | GB13 | GB21 | GB23 |
|---|---|---|---|---|
| Phylum Mollusca | | | | |
| Class Bivalvia | | | | |
| Order Veneroida | | | | |
| Family Cardiidae | | | | |
| Laevicardium sp. | - | - | - | 8 |
| Family Montacutidae | | | | |
| Mysella planulata | - | 7 | 22 | 29 |
| Family Tellinidae | | | | |
| Unid. Tellinidae | - | 4 | - | 1 |
| Family Veneridae | | | | |
| Anomalocardia auberiana | - | - | - | 45 |
| Phylum Nemertea | | | | |
| Nemertea sp. A | - | 1 | - | - |
| Nemertea sp. B | - | 13 | 174 | 4 |
| Nemertea sp. F | - | 14 | - | - |
| Unid. Nemertea | - | 73 | 2 | 2 |
| Phylum Platyhelminthes | | | | |
| Class Turbellaria | | | | |
| Unid. Turbellaria | - | 2 | - | - |

Appendix 1b. Species by station summaries of numbers of organisms sampled by box-core in October, 1996. Entries are number per 0.125 $m^2$ (8 cores combined).

PERDIDO KEY

| TAXON | PK11 | PK13 | PK31 | PK33 | PK34 |
|---|---|---|---|---|---|
| Phylum Annelida | | | | | |
| Class Oligochaeta | | | | | |
| Order Tubificida | | | | | |
| Family Enchytraeidae | | | | | |
| Grania sp. | - | 56 | 1 | 5 | 1 |
| Family Tubificidae | | | | | |
| Unid. Tubificidae | 33 | 178 | 1 | - | - |
| Class Polychaeta | | | | | |
| Order Capitellida | | | | | |
| Family Capitellidae | | | | | |
| Capitella capitata | 4 | - | - | - | - |
| Heteromastus filiformis | - | 14 | - | - | - |
| Family Maldanidae | | | | | |
| Axiothella mucosa | - | 1 | - | - | - |
| Order Cirratulida | | | | | |
| Family Paraonidae | | | | | |
| Aricidea philbinae | - | 35 | - | - | - |
| Paraonis fulgens | - | - | - | 4 | 24 |
| Order Eunicida | | | | | |
| Family Oenonidae | | | | | |
| Drilonereis sp. | - | 1 | - | - | - |
| Order Magelonida | | | | | |
| Family Magelonidae | | | | | |
| Magelona pettiboneae | - | 5 | - | - | - |
| Magelona sp. | - | 1 | - | - | - |
| Order Orbiniida | | | | | |
| Family Orbiniidae | | | | | |
| Leitoscoloplos sp. | 1 | - | - | 1 | 3 |
| Order Phyllodocida | | | | | |
| Family Hesionidae | | | | | |
| Micropthalmus sczelkowii | - | 15 | - | - | - |
| Family Nereididae | | | | | |
| Laeonereis culveri | - | 1 | - | - | - |
| Neanthes succinea | - | 2 | - | - | - |
| Family Phyllodocidae | | | | | |
| Hypereteone foliosa | - | 1 | - | 1 | 1 |
| Hypereteone heteropoda | 1 | 6 | - | - | - |
| Family Syllidae | | | | | |
| Grubeosyllis clavata | - | 4 | - | - | - |
| Sphaerosyllis taylori | - | 20 | - | - | - |
| Streptosyllis pettiboneae | - | 93 | - | - | - |
| Order Sabellida | | | | | |
| Family Sabellidae | | | | | |
| Chone sp. A | - | 5 | - | - | - |
| Family Serpulidae | | | | | |
| Pomatoceros americanus | - | 1 | - | - | - |
| Order Spionida | | | | | |
| Family Spionidae | | | | | |
| Dispio uncinata | - | - | - | 2 | - |
| Prionospio heterobranchia | - | 13 | - | - | - |
| Scolelepis squamata | - | - | - | 6 | 3 |
| Scolelepis texana | - | 19 | - | - | - |
| Unid. Spionidae | - | 1 | - | - | - |
| Order Terebellida | | | | | |
| Family Ampharetidae | | | | | |
| Hobsonia florida | - | 1 | - | - | - |

Appendix 1b. PERDIDO KEY, October 1996 (continued).

| TAXON | PK11 | PK13 | PK31 | PK33 | PK34 |
|---|---|---|---|---|---|
| Phylum Arthropoda | | | | | |
| Class Copepoda | | | | | |
| Unid. Copepoda | - | 1 | 1 | - | - |
| Order Harpacticoida | | | | | |
| Unid. Harpacticoida | - | 1 | - | - | - |
| Class Malacostraca | | | | | |
| Order Amphipoda | | | | | |
| Family Gammaridae | | | | | |
| Gammarus mucronatus | 20 | 11 | - | - | - |
| Family Haustoriidae | | | | | |
| Acanthohaustorius sp. A | - | - | - | - | 2 |
| Acanthohaustorius uncinus | - | 1 | - | - | - |
| Haustorius jayneae | - | - | 9 | 74 | 109 |
| Family Isaeidae | | | | | |
| Microprotopus raneyi | 3 | 1 | - | - | - |
| Family Melitidae | | | | | |
| Elasmopus levis | 1 | - | - | - | - |
| Order Cumacea | | | | | |
| Family Bodotriidae | | | | | |
| Spilocuma salomani | - | - | - | 12 | 7 |
| Family Nannastacidae | | | | | |
| Almyracuma cf proximoculi | 8 | 1 | - | - | - |
| Order Decapoda | | | | | |
| Family Albuneidae | | | | | |
| Lepidopa benedicti | - | - | - | 2 | - |
| Family Callianassidae | | | | | |
| Callichirus islagrande | - | - | - | - | 1 |
| Family Hippidae | | | | | |
| Emerita talpoida | - | - | 103 | - | - |
| Family Pinnotheridae | | | | | |
| Pinnixa chacei | - | - | - | 1 | - |
| Order Isopoda | | | | | |
| Family Hyssuridae | | | | | |
| Xenanthura brevitelson | - | 6 | - | - | - |
| Family Idoteidae | | | | | |
| Erichsonella attenuata | - | 2 | - | - | - |
| Order Mysidacea | | | | | |
| Family Mysidae | | | | | |
| Metamysidopsis swifti | - | - | - | 5 | - |
| Taphromysis bowmani | - | 9 | - | - | - |
| Order Tanaidacea | | | | | |
| Family Paratanaidae | | | | | |
| Hargeria rapax | 1 | - | - | - | - |
| Class Ostracoda | | | | | |
| Order Myodocopida | | | | | |
| Family Rutidermatidae | | | | | |
| Rutiderma darbyi | - | - | - | - | 1 |
| Order Podocopida | | | | | |
| Podocopida sp. C | 1 | - | - | - | - |
| Unid. Podocopida | - | 1 | - | - | - |
| Phylum Chaetognatha | | | | | |
| Class Sagittoidea | | | | | |
| Order Aphragmophora | | | | | |
| Family Sagittidae | | | | | |
| Sagitta friderici | - | - | - | 1 | - |

Appendix 1b. PERDIDO KEY, October 1996 (continued).

| TAXON | PK11 | PK13 | PK31 | PK33 | PK34 |
|---|---|---|---|---|---|
| Phylum Echinodermata | | | | | |
| Class Echinoidea | | | | | |
| Order Clypeasteroida | | | | | |
| Family Mellitidae | | | | | |
| Mellita quinquiesperforata | - | - | - | 1 | 5 |
| Class Ophiuroidea | | | | | |
| Order Ophiurida | | | | | |
| Family Amphiuridae | | | | | |
| Ophiophragmus moorei | - | - | - | - | 2 |
| Unid. Amphiuridae | - | 2 | - | - | - |
| Phylum Mollusca | | | | | |
| Class Bivalvia | | | | | |
| Unid. Bivalvia | 1 | - | - | - | - |
| Order Pholadomyoida | | | | | |
| Family Lyonsiidae | | | | | |
| Lyonsia hyalina | - | 1 | - | - | - |
| Order Veneroida | | | | | |
| Family Cardiidae | | | | | |
| Laevicardium mortoni | - | 5 | - | - | - |
| Family Donacidae | | | | | |
| Donax texasianus | - | - | - | 13 | 19 |
| Donax variabilis | - | - | 21 | - | - |
| Family Tellinidae | | | | | |
| Tellina lineata | 4 | 41 | - | - | - |
| Family Veneridae | | | | | |
| Anomalocardia auberiana | 1 | 25 | - | - | - |
| Gemma gemma | - | 2 | - | - | - |
| Parastarte triquetra | - | 16 | - | - | - |
| Class Gastropoda | | | | | |
| Order Cephalaspidea | | | | | |
| Family Scaphandridae | | | | | |
| Acteocina canaliculata | - | 8 | - | - | - |
| Order Mesogastropoda | | | | | |
| Family Calyptraeidae | | | | | |
| Crepidula sp. | 2 | - | - | - | - |
| Order Neogastropoda | | | | | |
| Family Columbellidae | | | | | |
| Astyris lunata | - | 1 | - | - | - |
| Family Marginellidae | | | | | |
| Granulina ovuliformis | - | 1 | - | - | - |
| Family Nassariidae | | | | | |
| Nassarius vibex | - | 1 | - | - | - |
| Family Terebridae | | | | | |
| Hastula salleana | - | - | - | 1 | 1 |
| Phylum Nemertea | | | | | |
| Nemertea sp. F | - | 1 | - | - | - |
| Unid. Nemertea | - | 12 | 9 | 5 | 7 |
| Phylum Phoronida | | | | | |
| Family Phoronidae | | | | | |
| Phoronis sp. | - | 1 | - | - | - |

Appendix 1c. Species by station summaries of numbers of organisms sampled by box-core in October, 1996. Entries are number per 0.125 $m^2$ (8 cores combined).

SANTA ROSA ISLAND

| TAXON | SR11 | SR13 | SR31 | SR33 | SR51 | SR53 | SR61 | SR63 |
|---|---|---|---|---|---|---|---|---|
| Phylum Annelida | | | | | | | | |
| Class Oligochaeta | | | | | | | | |
| Order Tubificida | | | | | | | | |
| Family Enchytraeidae | | | | | | | | |
| Grania sp. | - | - | - | - | - | - | - | 9 |
| Family Tubificidae | | | | | | | | |
| Unid. Tubificidae | 2 | 22 | 12 | 53 | - | - | 71 | 4 |
| Class Polychaeta | | | | | | | | |
| Unid. Archiannelida | - | - | - | - | - | - | 1 | - |
| Order Capitellida | | | | | | | | |
| Family Capitellidae | | | | | | | | |
| Capitella capitata | - | 12 | - | - | - | - | - | - |
| Heteromastus filiformis | - | - | - | 1 | - | - | - | - |
| Order Cirratulida | | | | | | | | |
| Family Paraonidae | | | | | | | | |
| Paraonis fulgens | - | 22 | - | 17 | 1 | - | - | 3 |
| Order Orbiniida | | | | | | | | |
| Family Orbiniidae | | | | | | | | |
| Leitoscoloplos fragilis | - | - | - | 17 | - | - | - | - |
| Leitoscoloplos sp. | - | 3 | - | - | - | - | - | - |
| Order Phyllodocida | | | | | | | | |
| Family Hesionidae | | | | | | | | |
| Podarkeopsis levifuscina | - | 1 | - | 6 | - | - | - | - |
| Family Nereididae | | | | | | | | |
| Laeonereis culveri | - | - | - | 39 | - | - | - | - |
| Neanthes succinea | - | - | - | 29 | - | - | - | - |
| Unid. Nereididae | - | - | - | 1 | - | 1 | - | - |
| Family Phyllodocidae | | | | | | | | |
| Hypereteone foliosa | - | - | - | 2 | - | - | - | - |
| Hypereteone heteropoda | - | 2 | - | 17 | - | - | - | - |
| Phyllodoce arenae | - | - | - | 3 | - | - | - | - |
| Family Pilargidae | | | | | | | | |
| Parandalia americana | - | - | - | 1 | - | - | - | - |
| Parandalia sp. A | - | 1 | - | - | - | - | - | - |
| Family Syllidae | | | | | | | | |
| Streptosyllis pettiboneae | - | - | - | 4 | - | - | - | - |
| Order Polygordiida | | | | | | | | |
| Family Polygordiidae | | | | | | | | |
| Polygordius sp. A | - | 4 | - | - | - | - | - | - |
| Order Sabellida | | | | | | | | |
| Family Sabellidae | | | | | | | | |
| Chone sp. A | - | - | - | 2 | - | - | - | - |
| Family Serpulidae | | | | | | | | |
| Hydroides sp. | 1 | - | - | - | - | - | - | - |

Appendix 1c. SANTA ROSA ISLAND, October 1996 (continued).

| TAXON | SR11 | SR13 | SR31 | SR33 | SR51 | SR53 | SR61 | SR63 |
|---|---|---|---|---|---|---|---|---|
| Order Spionida | | | | | | | | |
| Family Spionidae | | | | | | | | |
| Prionospio heterobranchia | - | - | - | 38 | - | - | - | - |
| Scolelepis squamata | 2 | - | - | - | - | - | 4 | - |
| Scolelepis texana | - | 3 | - | 49 | - | - | - | - |
| Spiophanes bombyx | - | - | - | 1 | - | - | - | - |
| Phylum Arthropoda | | | | | | | | |
| Class Malacostraca | | | | | | | | |
| Order Amphipoda | | | | | | | | |
| Family Ampeliscidae | | | | | | | | |
| Ampelisca holmesi | - | - | - | 4 | - | - | - | - |
| Family Amphilochidae | | | | | | | | |
| Gitanopsis sp. B | - | - | 1 | - | - | - | - | - |
| Family Ampithoidae | | | | | | | | |
| Cymadusa compta | - | - | - | 1 | - | - | - | - |
| Family Haustoriidae | | | | | | | | |
| Haustorius jayneae | 35 | - | - | - | 2 | - | 1 | 2 |
| Lepidactylus sp. A | 174 | 113 | 728 | 16 | - | - | - | - |
| Unid. Haustoriidae | 14 | - | - | - | - | - | - | - |
| Family Isaeidae | | | | | | | | |
| Microprotopus raneyi | 28 | 3 | 2 | 1 | 6 | 12 | - | - |
| Family Liljeborgiidae | | | | | | | | |
| Listriella barnardi | - | - | - | 2 | - | - | - | - |
| Family Oedicerotidae | | | | | | | | |
| Monoculodes sp. A | - | - | - | 6 | - | - | - | - |
| Family Pariambidae | | | | | | | | |
| Paracaprella tenuis | - | - | - | 1 | - | - | - | - |
| Family Synopiidae | | | | | | | | |
| Tiron triocellatus | - | - | - | - | 1 | - | - | 2 |
| Order Cumacea | | | | | | | | |
| Family Diastylidae | | | | | | | | |
| Oxyurostylis smithi | - | - | - | 3 | - | - | - | - |
| Oxyurostylis sp. | - | - | - | 2 | - | - | - | - |
| Family Nannastacidae | | | | | | | | |
| Almyracuma cf proximoculi | 1 | - | - | - | - | - | - | - |
| Cumella sp. | - | - | - | - | - | - | 1 | - |
| Order Decapoda | | | | | | | | |
| Family Albuneidae | | | | | | | | |
| Lepidopa benedicti | - | - | - | - | - | 1 | - | - |
| Family Hippidae | | | | | | | | |
| Emerita talpoida | 5 | - | - | - | 13 | 2 | 61 | - |
| Family Hippolytidae | | | | | | | | |
| Hippolyte zostericola | - | - | - | 1 | - | - | - | - |
| Family Pinnotheridae | | | | | | | | |
| Pinnixa pearsei | - | - | - | 2 | - | - | - | - |
| Family Portunidae | | | | | | | | |
| Callinectes sapidus | - | 1 | - | - | - | - | - | - |
| Family Processidae | | | | | | | | |
| Ambidexter symmetricus | - | - | - | 1 | - | - | - | - |

Appendix 1c. SANTA ROSA ISLAND, October 1996 (continued).

| TAXON | SR11 | SR13 | SR31 | SR33 | SR51 | SR53 | SR61 | SR63 |
|---|---|---|---|---|---|---|---|---|
| Order Isopoda | | | | | | | | |
| Family Hyssuridae | | | | | | | | |
| Xenanthura brevitelson | - | 1 | - | 1 | - | - | - | - |
| Family Idoteidae | | | | | | | | |
| Erichsonella attenuata | - | - | - | 2 | - | - | - | - |
| Family Sphaeromatidae | | | | | | | | |
| Exosphaeroma diminutum | 2 | 8 | 5 | - | - | - | - | 1 |
| Order Mysidacea | | | | | | | | |
| Family Mysidae | | | | | | | | |
| Bowmaniella dissimilis | - | - | - | 8 | - | - | - | - |
| Metamysidopsis swifti | - | - | - | - | - | - | - | 1 |
| Order Tanaidacea | | | | | | | | |
| Family Kalliapseudidae | | | | | | | | |
| Kalliapseudes sp. A | - | 3 | - | - | - | - | - | - |
| Phylum Chaetognatha | | | | | | | | |
| Class Sagittoidea | | | | | | | | |
| Order Aphragmophora | | | | | | | | |
| Family Sagittidae | | | | | | | | |
| Flaccisagitta enflata | - | - | 1 | - | - | - | - | - |
| Phylum Chordata | | | | | | | | |
| Class Leptocardii | | | | | | | | |
| Order Amphioxi | | | | | | | | |
| Family Branchiostomidae | | | | | | | | |
| Branchiostoma cf floridae | - | 4 | - | - | - | - | - | - |
| Phylum Echinodermata | | | | | | | | |
| Class Holothuroidea | | | | | | | | |
| Order Apodida | | | | | | | | |
| Family Synaptidae | | | | | | | | |
| Leptosynapta crassipatina | - | 4 | - | 13 | - | - | - | - |
| Phylum Mollusca | | | | | | | | |
| Class Bivalvia | | | | | | | | |
| Unid. Bivalvia | - | - | - | 1 | - | - | - | - |
| Order Veneroida | | | | | | | | |
| Family Donacidae | | | | | | | | |
| Donax variabilis | - | - | - | - | - | - | 7 | - |
| Family Montacutidae | | | | | | | | |
| Mysella planulata | - | 3 | - | 5 | - | - | - | - |
| Family Tellinidae | | | | | | | | |
| Tellina lineata | - | 1 | - | 6 | - | - | - | - |
| Family Veneridae | | | | | | | | |
| Anomalocardia auberiana | - | 1 | - | 2 | - | - | - | - |
| Parastarte triquetra | - | - | 1 | 1 | - | - | - | - |
| Class Gastropoda | | | | | | | | |
| Order Cephalaspidea | | | | | | | | |
| Family Scaphandridae | | | | | | | | |
| Acteocina canaliculata | 1 | - | - | - | - | - | - | - |
| Order Mesogastropoda | | | | | | | | |
| Family Caecidae | | | | | | | | |
| Caecum imbricatum | - | 1 | - | - | - | - | - | - |

Appendix 1c. SANTA ROSA ISLAND, October 1996 (continued).

| TAXON | SR11 | SR13 | SR31 | SR33 | SR51 | SR53 | SR61 | SR63 |
|---|---|---|---|---|---|---|---|---|
| Family Naticidae | | | | | | | | |
| Tectonatica pusilla | 1 | - | - | - | - | - | - | - |
| Order Neogastropoda | | | | | | | | |
| Family Nassariidae | | | | | | | | |
| Nassarius vibex | - | - | - | 3 | - | - | - | - |
| Phylum Nemertea | | | | | | | | |
| Nemertea sp. A | - | - | - | - | - | 1 | - | - |
| Nemertea sp. B | - | - | - | 54 | - | - | - | - |
| Nemertea sp. F | - | 4 | - | 2 | - | - | - | - |
| Unid. Nemertea | 15 | 199 | 8 | 8 | 13 | 8 | 13 | 9 |
| Phylum Platyhelminthes | | | | | | | | |
| Class Turbellaria | | | | | | | | |
| Unid. Turbellaria | - | 1 | 1 | 2 | - | - | - | - |

Appendix 1d. Macrobenthic Summary Measures - Sandy Beach Sites.

OPAL/ERIN SANDY BEACH BOX CORES - GULF BREEZE - OCTOBER 1998

| Sample Characteristics | | GB11OC6C | GB13OC6C |
|---|---|---|---|
| Number of Species | : | 7 | 27 |
| Density of All Species | : | 768.00 | 4784.00 |
| Total numbers of specimens counted | : | 96.00 | 598.00 |
| Diversity (Hprime -log base e) | : | 0.74 | 1.48 |
| Diversity (Hprime -log base 10) | : | 0.32 | 0.64 |
| Evenness (Hprime/Hmax) | : | 0.38 | 0.45 |
| Evenness (Scaled) | : | 0.24 | 0.39 |
| Simpson's Index | : | 0.35 | 0.57 |
| Densities based on following units | : | $m^2$ | $m^2$ |

| Sample Characteristics | | GB21OC6C | GB23OC6C |
|---|---|---|---|
| Number of Species | : | 26 | 32 |
| Density of All Species | : | 16248.00 | 5208.00 |
| Total numbers of specimens counted | : | 2031.00 | 651.00 |
| Diversity (Hprime -log base e) | : | 1.00 | 2.33 |
| Diversity (Hprime -log base 10) | : | 0.43 | 1.01 |
| Evenness (Hprime/Hmax) | : | 0.31 | 0.67 |
| Evenness (Scaled) | : | 0.28 | 0.64 |
| Simpson's Index | : | 0.41 | 0.84 |
| Densities based on following units | : | $m^2$ | $m^2$ |

OPAL/ERIN SANDY BEACH BOX CORES - PERDIDO KEY - OCTOBER 1998

| Sample Characteristics | | PK11OC96 | PK13OC96 |
|---|---|---|---|
| Number of Species | : | 14 | 46 |
| Density of All Species | : | 648.00 | 4992.00 |
| Total numbers of specimens counted | : | 81.00 | 624.00 |
| Diversity (Hprime -log base e) | : | 1.83 | 2.68 |
| Diversity (Hprime -log base 10) | : | 0.79 | 1.16 |
| Evenness (Hprime/Hmax) | : | 0.69 | 0.70 |
| Evenness (Scaled) | : | 0.55 | 0.65 |
| Simpson's Index | : | 0.76 | 0.88 |
| Densities based on following units | : | $m^2$ | $m^2$ |

Appendix 1d. (continued).

| Sample Characteristics | | PK31OC96C | PK33OC96C |
|---|---|---|---|
| Number of Species | : | 7 | 16 |
| Density of All Species | : | 1160.00 | 1072.00 |
| Total numbers of specimens counted | : | 145.00 | 134.00 |
| Diversity (Hprime -log base e) | : | 0.97 | 1.73 |
| Diversity (Hprime -log base 10) | : | 0.42 | 0.75 |
| Evenness (Hprime/Hmax) | : | 0.50 | 0.62 |
| Evenness (Scaled) | : | 0.43 | 0.51 |
| Simpson's Index | : | 0.47 | 0.67 |
| Densities based on following units | : | $m^2$ | $m^2$ |

| Sample Characteristics | | PK34OC96 |
|---|---|---|
| Number of Species | : | 15 |
| Density of All Species | : | 1488.00 |
| Total numbers of specimens counted | : | 186.00 |
| Diversity (Hprime -log base e) | : | 1.53 |
| Diversity (Hprime -log base 10) | : | 0.66 |
| Evenness (Hprime/Hmax) | : | 0.56 |
| Evenness (Scaled) | : | 0.47 |
| Simpson's Index | : | 0.63 |
| Densities based on following units | : | $m^2$ |

OPAL/ERIN SANDY BEACH BOX CORES - SANTA ROSA ISLAND - OCTOBER 1998

| Sample Characteristics | | SR11OC96C | SR13OC96C |
|---|---|---|---|
| Number of Species | : | 13 | 24 |
| Density of All Species | : | 2248.00 | 3336.00 |
| Total numbers of specimens counted | : | 281.00 | 417.00 |
| Diversity (Hprime -log base e) | : | 1.35 | 1.69 |
| Diversity (Hprime -log base 10) | : | 0.59 | 0.73 |
| Evenness (Hprime/Hmax) | : | 0.53 | 0.53 |
| Evenness (Scaled) | : | 0.47 | 0.47 |
| Simpson's Index | : | 0.59 | 0.69 |
| Densities based on following units | : | $m^2$ | $m^2$ |

Appendix 1d. (continued).

| Sample Characteristics | | SR31OC96C | SR33OC96C |
|---|---|---|---|
| Number of Species | : | 9 | 43 |
| Density of All Species | : | 6072.00 | 3424.00 |
| Total numbers of specimens counted | : | 759.00 | 428.00 |
| Diversity (Hprime -log base e) | : | 0.24 | 2.96 |
| Diversity (Hprime -log base 10) | : | 0.10 | 1.29 |
| Evenness (Hprime/Hmax) | : | 0.11 | 0.79 |
| Evenness (Scaled) | : | 0.07 | 0.74 |
| Simpson's Index | : | 0.08 | 0.93 |
| Densities based on following units | : | $m^2$ | $m^2$ |

| Sample Characteristics | | SR51OC96C | SR53OC96C |
|---|---|---|---|
| Number of Species | : | 6 | 6 |
| Density of All Species | : | 288.00 | 200.00 |
| Total numbers of specimens counted | : | 36.00 | 25.00 |
| Diversity (Hprime -log base e) | : | 1.39 | 1.31 |
| Diversity (Hprime -log base 10) | : | 0.61 | 0.57 |
| Evenness (Hprime/Hmax) | : | 0.78 | 0.73 |
| Evenness (Scaled) | : | 0.66 | 0.50 |
| Simpson's Index | : | 0.73 | 0.68 |
| Densities based on following units | : | $m^2$ | $m^2$ |

| Sample Characteristics | | SR61OC96C | SR63OC96C |
|---|---|---|---|
| Number of Species | : | 8 | 8 |
| Density of All Species | : | 1272.00 | 248.00 |
| Total numbers of specimens counted | : | 159.00 | 31.00 |
| Diversity (Hprime -log base e) | : | 1.26 | 1.78 |
| Diversity (Hprime -log base 10) | : | 0.55 | 0.77 |
| Evenness (Hprime/Hmax) | : | 0.60 | 0.86 |
| Evenness (Scaled) | : | 0.55 | 0.73 |
| Simpson's Index | : | 0.65 | 0.82 |
| Densities based on following units | : | $m^2$ | $m^2$ |

Appendix 2a. Species by station summaries of numbers of organisms sampled by kicknet from Florida district grassbed stations in October, 1996. Entries are number per 4.5 $m^2$ (two 5m sweeps combined).

FLORIDA DISTRICT GRASSBED KICKNETS - OCTOBER 1996

| TAXON | GB31 | GB32 | PK21 | PK22 | SR21 | SR22 | SR41 |
|---|---|---|---|---|---|---|---|
| Phylum Annelida | | | | | | | |
| Class Oligochaeta | | | | | | | |
| Order Tubificida | | | | | | | |
| Family Tubificidae | | | | | | | |
| Tectidrilus squalidus | - | - | 14 | 3 | - | - | - |
| Unid. Tubificidae | - | 1 | 1 | - | - | - | 1 |
| Class Polychaeta | | | | | | | |
| Order Capitellida | | | | | | | |
| Family Arenicolidae | | | | | | | |
| Arenicola cristata | - | 1 | 1 | 5 | - | - | - |
| Family Maldanidae | | | | | | | |
| Axiothella mucosa | 101 | - | - | 28 | - | - | - |
| Order Cirratulida | | | | | | | |
| Family Paraonidae | | | | | | | |
| Aricidea philbinae | 1 | - | 1 | - | - | - | - |
| Order Opheliida | | | | | | | |
| Family Opheliidae | | | | | | | |
| Armandia maculata | - | - | - | 1 | 1 | - | - |
| Order Orbiniida | | | | | | | |
| Family Orbiniidae | | | | | | | |
| Leitoscoloplos sp. | - | 1 | 4 | - | - | - | - |
| Order Phyllodocida | | | | | | | |
| Family Goniadidae | | | | | | | |
| Glycinde solitaria | - | - | - | - | - | - | 1 |
| Family Nereididae | | | | | | | |
| Laeonereis culveri | - | - | 3 | - | - | - | - |
| Neanthes succinea | - | - | 3 | 4 | - | 2 | 46 |
| Nereis riisei | - | - | 8 | 1 | 2 | - | 14 |
| Platynereis dumerilii | 2 | 2 | 1 | - | - | - | - |
| Unid. Nereididae | - | - | - | - | - | 1 | - |
| Family Phyllodocidae | | | | | | | |
| Hypereteone heteropoda | - | - | - | - | 3 | - | 10 |
| Phyllodoce arenae | - | - | - | - | - | - | 1 |
| Family Polynoidae | | | | | | | |
| Malmgreniella sp. C | - | - | - | - | - | - | 17 |
| Family Syllidae | | | | | | | |
| Exogone dispar | - | - | 10 | 54 | - | - | - |
| Grubeosyllis clavata | 12 | 11 | 39 | 82 | - | - | - |
| Sphaerosyllis taylori | - | - | 2 | 2 | - | - | 4 |
| Streptosyllis pettiboneae | - | 1 | - | 1 | 1 | - | 24 |
| Unid. Syllidae | 1 | - | - | - | - | - | - |
| Order Sabellida | | | | | | | |
| Family Sabellidae | | | | | | | |
| Chone sp. A | 6 | 6 | - | 2 | 1 | - | 46 |
| Fabricinuda trilobata | 7 | 1 | 68 | 7 | - | - | - |
| Potamilla sp. | - | - | 1 | - | - | - | - |
| Sabella micropthalma | - | 1 | 8 | - | - | - | - |
| Family Serpulidae | | | | | | | |
| Hydroides dianthus | - | - | 94 | 5 | - | - | - |
| Pomatoceros americanus | 21 | 78 | 126 | 65 | - | 1 | 3 |
| Order Spionida | | | | | | | |
| Family Spionidae | | | | | | | |
| Polydora commensalis | - | - | 1 | - | - | - | - |
| Polydora cornuta | - | - | 1 | 5 | - | - | 5 |
| Prionospio heterobranchia | 9 | 3 | 10 | 10 | 2 | 2 | 108 |

Appendix 2a. FLORIDA DISTRICT GRASSBED KICKNETS, October 1996 (continued).

| TAXON | GB31 | GB32 | PK21 | PK22 | SR21 | SR22 | SR41 |
|---|---|---|---|---|---|---|---|
| Scolelepis texana | 2 | - | - | - | - | - | 3 |
| Order Terebellida | | | | | | | |
| Family Pectinariidae | | | | | | | |
| Pectinaria gouldii | - | - | - | 1 | - | - | - |
| Phylum Arthropoda | | | | | | | |
| Class Branchiura | | | | | | | |
| Order Arguloida | | | | | | | |
| Family Argulidae | | | | | | | |
| Argulus sp. | - | - | - | 1 | - | - | - |
| Class Malacostraca | | | | | | | |
| Order Amphipoda | | | | | | | |
| Family Ampeliscidae | | | | | | | |
| Ampelisca holmesi | - | - | - | - | 2 | 4 | 27 |
| Ampelisca sp. | 1 | - | 2 | 3 | - | - | 2 |
| Family Amphilochidae | | | | | | | |
| Gitanopsis sp. A | 11 | 45 | 78 | 99 | - | - | - |
| Gitanopsis sp. B | - | - | - | - | 3 | 8 | 1 |
| Family Ampithoidae | | | | | | | |
| Cymadusa compta | 91 | 116 | 4 | 13 | - | - | 32 |
| Family Aoridae | | | | | | | |
| Grandidierella bonnieroides | 6 | 3 | 27 | 38 | - | - | 7 |
| Family Atylidae | | | | | | | |
| Atylus urocarinatus | - | - | - | - | 2 | 2 | - |
| Family Gammaridae | | | | | | | |
| Gammarus mucronatus | - | - | 1 | 20 | - | - | - |
| Family Haustoriidae | | | | | | | |
| Lepidactylus sp. A | - | - | - | - | - | - | 3 |
| Unid. Haustoriidae | - | - | - | - | - | - | 2 |
| Family Isaeidae | | | | | | | |
| Microprotopus raneyi | - | - | 1 | 5 | - | 2 | - |
| Family Melitidae | | | | | | | |
| Elasmopus levis | - | - | 56 | 121 | - | - | - |
| Melita elongata | 1 | - | - | - | - | - | - |
| Family Oedicerotidae | | | | | | | |
| Monoculodes sp. A | - | - | - | - | - | - | 3 |
| Family Pariambidae | | | | | | | |
| Paracaprella tenuis | 1 | 4 | - | - | 1 | 1 | 8 |
| Order Cumacea | | | | | | | |
| Family Bodotriidae | | | | | | | |
| Cyclaspis cf varians | - | - | - | - | - | - | 3 |
| Family Diastylidae | | | | | | | |
| Oxyurostylis smithi | - | - | - | - | - | - | 9 |
| Oxyurostylis sp. | - | - | - | - | - | - | 7 |
| Order Decapoda | | | | | | | |
| Family Hippolytidae | | | | | | | |
| Hippolyte sp. | 53 | 67 | 4 | - | 9 | 12 | 377 |
| Hippolyte zostericola | 947 | 1058 | 155 | 73 | 125 | 174 | 81 |
| Latreutes parvulus | - | - | - | - | 4 | - | - |
| Tozeuma carolinense | - | - | - | - | - | 6 | 11 |
| Family Paguridae | | | | | | | |
| Pagurus longicarpus | - | - | - | - | - | - | 1 |
| Pagurus maclaughlinae | 33 | 44 | 28 | 25 | 8 | 37 | - |
| Family Palaemonidae | | | | | | | |
| Palaemonetes cf intermedius | 3 | - | 10 | - | - | - | - |
| Palaemonetes sp. | - | 1 | 2 | - | - | 1 | - |
| Palaemonetes vulgaris | 1 | - | 10 | - | - | - | - |
| Periclimenes americanus | 12 | 32 | - | - | - | - | - |
| Periclimenes longicaudatus | - | - | - | - | 1 | 1 | - |

Appendix 2a. FLORIDA DISTRICT GRASSBED KICKNETS, October 1996 (continued).

| TAXON | GB31 | GB32 | PK21 | PK22 | SR21 | SR22 | SR41 |
|---|---|---|---|---|---|---|---|
| Family Penaeidae | | | | | | | |
| Penaeus aztecus | - | - | 3 | - | - | - | - |
| Penaeus sp. | 10 | 4 | 4 | 15 | 49 | 39 | 6 |
| Family Portunidae | | | | | | | |
| Callinectes sapidus | 1 | - | 1 | 4 | 3 | 2 | 2 |
| Callinectes similis | - | - | - | - | - | - | 2 |
| Portunus sp. | - | - | - | - | 1 | - | - |
| Family Xanthidae | | | | | | | |
| Unid. Xanthidae | 4 | 4 | 3 | 4 | - | - | - |
| Order Isopoda | | | | | | | |
| Family Bopyridae | | | | | | | |
| Bopyrina abbreviata | 6 | 4 | 5 | 3 | 1 | - | - |
| Family Idoteidae | | | | | | | |
| Edotia triloba | 5 | 2 | 1 | 4 | 2 | - | - |
| Erichsonella attenuata | 9 | 1 | 10 | 35 | 5 | 16 | 26 |
| Family Sphaeromatidae | | | | | | | |
| Harrieta faxoni | 92 | 8 | 65 | 54 | 12 | 10 | 14 |
| Order Mysidacea | | | | | | | |
| Family Mysidae | | | | | | | |
| Bowmaniella dissimilis | - | 1 | - | - | 1 | - | 21 |
| Taphromysis bowmani | 2 | 1 | 41 | 280 | - | - | 11 |
| Taphromysis sp. | - | - | 26 | 109 | - | - | 7 |
| Order Tanaidacea | | | | | | | |
| Family Paratanaidae | | | | | | | |
| Hargeria rapax | - | - | - | 3 | - | - | 1 |
| Class Ostracoda | | | | | | | |
| Order Myodocopida | | | | | | | |
| Family Sarsiellidae | | | | | | | |
| *Eusarsiella zostericola* | - | 4 | - | 4 | - | - | - |
| Order Podocopida | | | | | | | |
| Podocopida sp. C | 9 | - | - | - | - | - | - |
| Family Loxoconchidae | | | | | | | |
| Loxoconcha purisubrhomboidea | - | - | - | 1 | - | - | - |
| Phylum Chaetognatha | | | | | | | |
| Class Sagittoidea | | | | | | | |
| Order Aphragmophora | | | | | | | |
| Family Sagittidae | | | | | | | |
| Ferosagitta hispida | 19 | 39 | 12 | 14 | - | - | 19 |
| Phylum Cnidaria | | | | | | | |
| Class Anthozoa | | | | | | | |
| Order Actiniaria | | | | | | | |
| Family Edwardsiidae | | | | | | | |
| Edwardsia? sp. | - | - | - | - | - | - | 10 |
| Class Hydrozoa | | | | | | | |
| Order Hydroida | | | | | | | |
| Unid. Hydroida | - | - | 1 | - | - | - | - |
| Unid. Hydromedusa | - | 3 | 10 | 5 | - | - | - |
| Family Bouganvilliidae | | | | | | | |
| Garveia? sp. | - | 2 | - | - | - | - | - |
| Family Campanulariidae | | | | | | | |
| Clytia cylindrica | - | 1 | - | - | - | 1 | - |
| Obelia bicuspidata | - | - | - | - | - | 1 | - |
| Phylum Echinodermata | | | | | | | |
| Class Holothuroidea | | | | | | | |
| Order Apodida | | | | | | | |
| Family Synaptidae | | | | | | | |
| Leptosynapta crassipatina | - | - | - | - | - | - | 2 |
| Class Ophiuroidea | | | | | | | |
| Unid. Ophiuroidea | - | - | 5 | 6 | - | - | - |

Appendix 2a. FLORIDA DISTRICT GRASSBED KICKNETS, October 1996 (continued).

| TAXON | GB31 | GB32 | PK21 | PK22 | SR21 | SR22 | SR41 |
|---|---|---|---|---|---|---|---|
| Order Ophiurida | | | | | | | |
| Family Amphiuridae | | | | | | | |
| Unid. Amphiuridae | - | - | - | - | - | - | 2 |
| Phylum Mollusca | | | | | | | |
| Class Bivalvia | | | | | | | |
| Unid. Bivalvia | - | - | - | 1 | - | - | - |
| Order Arcoida | | | | | | | |
| Family Arcidae | | | | | | | |
| Anadara sp. | - | - | 1 | - | - | - | - |
| Order Myoida | | | | | | | |
| Family Pholadidae | | | | | | | |
| Martesia cuniformis | - | - | 1 | - | - | - | - |
| Order Mytiloida | | | | | | | |
| Family Mytilidae | | | | | | | |
| Amygdalum papyrium | - | - | - | 2 | - | - | 2 |
| Ischadium recurvum | 1 | - | 2 | - | - | - | - |
| Order Ostreoida | | | | | | | |
| Family Anomiidae | | | | | | | |
| Anomia simplex | - | - | - | 2 | - | - | - |
| Family Ostreidae | | | | | | | |
| Crassostrea virginica | - | - | 1 | - | - | - | - |
| Order Pholadomyoida | | | | | | | |
| Family Lyonsiidae | | | | | | | |
| Lyonsia hyalina | - | 1 | - | 4 | - | - | 1 |
| Order Veneroida | | | | | | | |
| Family Cardiidae | | | | | | | |
| Laevicardium mortoni | 4 | 3 | 2 | 18 | 5 | 9 | 6 |
| Laevicardium sp. | - | - | 1 | - | - | - | - |
| Family Montacutidae | | | | | | | |
| Mysella planulata | - | - | - | - | - | - | 4 |
| Family Tellinidae | | | | | | | |
| Tellina lineata | 5 | 1 | 1 | 2 | - | - | 6 |
| Tellina mera | - | - | - | - | - | - | 1 |
| Family Veneridae | | | | | | | |
| Anomalocardia auberiana | - | - | 1 | 3 | 3 | - | 4 |
| Gemma gemma | - | - | - | 1 | - | - | - |
| Parastarte triquetra | - | - | - | 13 | - | - | 27 |
| Class Gastropoda | | | | | | | |
| Order Cephalaspidea | | | | | | | |
| Family Scaphandridae | | | | | | | |
| Acteocina canaliculata | 1 | 9 | - | - | 2 | - | 7 |
| Order Mesogastropoda | | | | | | | |
| Family Caecidae | | | | | | | |
| Caecum pulchellum | - | - | - | 2 | - | - | - |
| Family Calyptraeidae | | | | | | | |
| Crepidula maculosa | 12 | 48 | 174 | 253 | - | - | - |
| Crepidula plana | - | - | 1 | 8 | - | - | - |
| Crepidula sp. | - | - | - | - | - | - | 1 |
| Family Cerithiidae | | | | | | | |
| Cerithium atratum | - | - | 90 | 28 | - | - | - |
| Diastoma varium | 5339 | 28345 | 4765 | 3363 | 556 | 3749 | 289 |
| Family Epitoniidae | | | | | | | |
| Epitonium sp. | - | - | - | - | - | 1 | 1 |
| Order Neogastropoda | | | | | | | |
| Family Columbellidae | | | | | | | |
| Astyris lunata | 1151 | 1414 | 83 | 105 | 755 | 1019 | 734 |
| Costoanachis floridana | - | 1 | 4 | - | - | - | - |
| Family Marginellidae | | | | | | | |
| Granulina ovuliformis | - | - | 158 | 220 | - | - | - |

Appendix 2a. FLORIDA DISTRICT GRASSBED KICKNETS, October 1996 (continued).

| TAXON | GB31 | GB32 | PK21 | PK22 | SR21 | SR22 | SR41 |
|---|---|---|---|---|---|---|---|
| Marginella apicina | - | - | 3 | 5 | - | - | - |
| Family Nassariidae | | | | | | | |
| Nassarius vibex | 10 | 2 | 2 | 8 | 24 | 11 | 17 |
| Family Turridae | | | | | | | |
| Pyrgocythara hemphilli | 18 | 31 | 22 | 15 | 1 | - | - |
| Order Nudibranchia | | | | | | | |
| Nudibranchia sp. C | 2 | 6 | 6 | 3 | 13 | 5 | 16 |
| Unid. Nudibranchia | 2 | - | - | 1 | - | - | - |
| Order Pyramidellida | | | | | | | |
| Family Pyramidellidae | | | | | | | |
| Fargoa dux | - | - | 1 | - | - | - | - |
| Order Pyramidelloida | | | | | | | |
| Boonea impressa | 109 | 493 | 5 | - | - | 1 | - |
| Odostomia gibbosa | 1 | - | - | - | - | - | 1 |
| Odostomia laevigata | 14 | - | 3 | 3 | - | - | - |
| Odostomia sp. | - | - | 2 | - | - | - | - |
| Odostomia weberi | 139 | 154 | 58 | 26 | 2 | 15 | 39 |
| Phylum Nemertea | | | | | | | |
| Nemertea sp. B | - | - | - | - | - | - | 16 |
| Nemertea sp. F | - | - | - | - | - | - | 5 |
| Nemertea sp. H | 3 | 6 | - | 34 | - | - | 13 |
| Unid. Nemertea | - | - | 13 | - | 5 | 2 | - |
| Phylum Platyhelminthes | | | | | | | |
| Class Turbellaria | | | | | | | |
| Unid. Turbellaria | 2 | 5 | - | - | 5 | 1 | 14 |
| Phylum Porifera | | | | | | | |
| Unid. Porifera | - | - | - | 2 | - | - | - |

Appendix 2b. Macrobenthic Summary Measures - Grassbed Sites.

OPAL/ERIN GRASSBED KICKNET SAMPLES - OCTOBER 1998

| Sample Characteristics | | GB31OC96K | GB32OC96K |
|---|---|---|---|
| Number of Species | : | 49 | 48 |
| Density of All Species | : | 1842.67 | 7126.44 |
| Total numbers of specimens counted | : | 8292.00 | 32069.00 |
| Diversity (Hprime -log base e) | : | 1.33 | 0.58 |
| Diversity (Hprime -log base 10) | : | 0.58 | 0.25 |
| Evenness (Hprime/Hmax) | : | 0.34 | 0.15 |
| Evenness (Scaled) | : | 0.33 | 0.15 |
| Simpson's Index | : | 0.55 | 0.22 |

| Sample Characteristics | | PK21OC96K | PK22OC96K |
|---|---|---|---|
| Number of Species | : | 72 | 67 |
| Density of All Species | : | 1413.56 | 1186.00 |
| Total numbers of specimens counted | : | 6361.00 | 5337.00 |
| Diversity (Hprime -log base e) | : | 1.37 | 1.82 |
| Diversity (Hprime -log base 10) | : | 0.59 | 0.79 |
| Evenness (Hprime/Hmax) | : | 0.32 | 0.43 |
| Evenness (Scaled) | : | 0.30 | 0.42 |
| Simpson's Index | : | 0.44 | 0.59 |

| Sample Characteristics | | SR21OC96K | SR22OC96K |
|---|---|---|---|
| Number of Species | : | 34 | 31 |
| Density of All Species | : | 357.78 | 1141.33 |
| Total numbers of specimens counted | : | 1610.00 | 5136.00 |
| Diversity (Hprime -log base e) | : | 1.45 | 0.89 |
| Diversity (Hprime -log base 10) | : | 0.63 | 0.39 |
| Evenness (Hprime/Hmax) | : | 0.41 | 0.26 |
| Evenness (Scaled) | : | 0.38 | 0.25 |
| Simpson's Index | : | 0.65 | 0.43 |

Appendix 2b. (continued).

| Sample Characteristics | | SR41OC96K |
|---|---|---|
| Number of Species | : | 64 |
| Density of All Species | : | 485.33 |
| Total numbers of specimens counted | : | 2184.00 |
| Diversity (Hprime -log base e) | : | 2.54 |
| Diversity (Hprime -log base 10) | : | 1.10 |
| Evenness (Hprime/Hmax) | : | 0.61 |
| Evenness (Scaled) | : | 0.58 |
| Simpson's Index | : | 0.83 |

Appendix 3a. Species by station summaries of numbers of organisms sampled by kicknet from Florida district lagoon stations in October, 1996. Entries are number per 9.0 $m^2$ (one 20m sweep).

FLORIDA DISTRICT LAGOON KICKNETS - OCTOBER 1996

| TAXON | PK41 | PK42 | PK43 | SR71 | SR72 | SR73 |
|---|---|---|---|---|---|---|
| Phylum Annelida | | | | | | |
| Class Oligochaeta | | | | | | |
| Order Tubificida | | | | | | |
| Family Enchytraeidae | | | | | | |
| Grania sp. | - | 1 | 1 | - | - | - |
| Family Tubificidae | | | | | | |
| Tectidrilus squalidus | 1 | - | 3 | - | - | - |
| Unid. Tubificidae | - | - | 2 | - | - | - |
| Class Polychaeta | | | | | | |
| Order Capitellida | | | | | | |
| Family Arenicolidae | | | | | | |
| Arenicola cristata | - | 1 | 5 | 1 | 3 | - |
| Family Capitellidae | | | | | | |
| Capitella capitata | - | - | 1 | 1 | - | 1 |
| Family Maldanidae | | | | | | |
| Axiothella mucosa | 1 | 73 | 1 | - | - | - |
| Order Cirratulida | | | | | | |
| Family Paraonidae | | | | | | |
| Aricidea philbinae | 2 | 2 | 2 | - | - | - |
| Order Opheliida | | | | | | |
| Family Opheliidae | | | | | | |
| *Armandia maculata* | 10 | - | 4 | - | - | - |
| Order Orbiniida | | | | | | |
| Family Orbiniidae | | | | | | |
| Leitoscoloplos sp. | - | 69 | 25 | - | 1 | - |
| Order Phyllodocida | | | | | | |
| Family Hesionidae | | | | | | |
| Podarkeopsis levifuscina | - | - | 1 | - | - | - |
| Family Nereididae | | | | | | |
| Laeonereis culveri | 25 | 3 | 16 | - | - | - |
| Neanthes succinea | - | - | 2 | 7 | 25 | - |
| Nereis riisei | - | - | 9 | 1 | - | - |
| Family Phyllodocidae | | | | | | |
| Hypereteone heteropoda | - | - | - | 1 | - | - |
| Family Syllidae | | | | | | |
| Exogone dispar | 2 | 2 | 26 | - | - | - |
| Grubeosyllis clavata | 6 | 3 | 106 | 1 | 2 | - |
| Sphaerosyllis taylori | 64 | 66 | 8 | - | - | - |
| Streptosyllis pettiboneae | 28 | 136 | 1 | 1 | 3 | 15 |
| Order Sabellida | | | | | | |
| Family Sabellidae | | | | | | |
| Chone sp. A | 3 | 1 | 1 | 4 | 34 | 3 |
| Fabricinuda trilobata | - | - | 2 | - | - | - |
| Sabella micropthalma | 1 | - | 3 | - | - | - |
| Family Serpulidae | | | | | | |
| Hydroides dianthus | - | - | - | - | 2 | - |
| Pomatoceros americanus | - | - | 22 | - | 1 | - |
| Order Spionida | | | | | | |
| Family Spionidae | | | | | | |
| Polydora cornuta | - | - | 4 | - | - | - |
| Prionospio heterobranchia | 14 | 20 | 93 | 4 | - | - |
| Order Terebellida | | | | | | |
| Family Ampharetidae | | | | | | |
| Hobsonia florida | - | - | - | 12 | - | - |
| Unid. Ampharetidae | - | 3 | 1 | - | - | - |

Appendix 3a. FLORIDA DISTRICT LAGOON KICKNETS, October 1996 (continued).

| TAXON | PK41 | PK42 | PK43 | SR71 | SR72 | SR73 |
|---|---|---|---|---|---|---|
| Phylum Arthropoda | | | | | | |
| Class Malacostraca | | | | | | |
| Order Amphipoda | | | | | | |
| Family Ampeliscidae | | | | | | |
| Ampelisca sp. | - | - | 2 | - | - | - |
| Ampelisca vadorum | - | - | 1 | - | - | - |
| Family Amphilochidae | | | | | | |
| Gitanopsis sp. A | - | - | 42 | - | - | - |
| Family Ampithoidae | | | | | | |
| Cymadusa compta | - | - | 14 | - | - | - |
| Family Aoridae | | | | | | |
| Grandidierella bonnieroides | 7 | 1 | 46 | 16 | 415 | - |
| Family Atylidae | | | | | | |
| Atylus urocarinatus | - | - | - | 3 | - | - |
| Family Corophiidae | | | | | | |
| Corophium louisianum | - | - | - | - | 2 | - |
| Family Gammaridae | | | | | | |
| Gammarus mucronatus | 5 | - | 16 | - | 13 | - |
| Family Isaeidae | | | | | | |
| Microprotopus raneyi | 2 | 1 | - | - | 2 | - |
| Family Ischyroceridae | | | | | | |
| Cerapus sp. B | 2 | - | - | - | - | - |
| Family Melitidae | | | | | | |
| Elasmopus levis | - | - | 8 | - | - | - |
| Melita elongata | - | - | 13 | - | 4 | - |
| Melita longisetosa | - | - | - | - | 3 | - |
| Order Cumacea | | | | | | |
| Family Diastylidae | | | | | | |
| Oxyurostylis sp. | 3 | - | - | - | - | - |
| Family Nannastacidae | | | | | | |
| Almyracuma cf proximoculi | 4 | - | - | 4 | 4 | 12 |
| Order Decapoda | | | | | | |
| Family Alpheidae | | | | | | |
| Alpheus sp. | - | - | 1 | - | - | - |
| Family Hippolytidae | | | | | | |
| Hippolyte sp. | - | - | 11 | - | - | - |
| Hippolyte zostericola | - | - | 235 | 2 | 4 | - |
| Tozeuma carolinense | - | - | 2 | - | - | - |
| Family Paguridae | | | | | | |
| Pagurus maclaughlinae | - | - | 5 | - | - | - |
| Family Palaemonidae | | | | | | |
| Palaemonetes cf intermedius | - | - | 20 | - | - | - |
| Palaemonetes sp. | - | - | 16 | - | 2 | - |
| Palaemonetes vulgaris | - | - | 25 | - | - | - |
| Family Penaeidae | | | | | | |
| Penaeus sp. | - | - | 22 | 1 | - | 1 |
| Family Portunidae | | | | | | |
| Callinectes sapidus | 1 | - | 1 | 1 | 5 | - |
| Family Xanthidae | | | | | | |
| Dyspanopeus texanus | - | - | 1 | - | - | - |
| Panopeus turgidus | - | - | - | - | 1 | - |
| Unid. Xanthidae | - | - | 5 | - | 2 | - |
| Order Isopoda | | | | | | |
| Family Bopyridae | | | | | | |
| Bopyrina abbreviata | - | - | 2 | - | - | - |
| Family Idoteidae | | | | | | |
| Cleantoides planicauda | - | - | 2 | - | - | - |
| Edotia triloba | - | - | 2 | 4 | 1 | - |
| Erichsonella attenuata | - | - | 10 | - | - | - |

Appendix 3a. FLORIDA DISTRICT LAGOON KICKNETS, October 1996 (continued).

| TAXON | PK41 | PK42 | PK43 | SR71 | SR72 | SR73 |
|---|---|---|---|---|---|---|
| Family Sphaeromatidae | | | | | | |
| Harrieta faxoni | 1 | - | 37 | - | - | - |
| Order Mysidacea | | | | | | |
| Family Mysidae | | | | | | |
| Americamysis bahia | 1 | - | - | - | - | - |
| Bowmaniella dissimilis | 1 | - | - | - | - | - |
| *Taphromysis bowmani* | 92 | 104 | 91 | 35 | 31 | 3 |
| Taphromysis sp. | 31 | 63 | 52 | - | - | - |
| Order Tanaidacea | | | | | | |
| Family Paratanaidae | | | | | | |
| Hargeria rapax | - | - | 15 | 2 | 41 | - |
| Class Ostracoda | | | | | | |
| Order Myodocopida | | | | | | |
| Family Sarsiellidae | | | | | | |
| Eusarsiella zostericola | - | - | 12 | - | - | - |
| Order Podocopida | | | | | | |
| Podocopida sp. C | - | 2 | - | - | - | - |
| Phylum Chaetognatha | | | | | | |
| Class Sagittoidea | | | | | | |
| Order Aphragmophora | | | | | | |
| Family Sagittidae | | | | | | |
| Ferosagitta hispida | 14 | 1 | 22 | 1 | - | 1 |
| Phylum Cnidaria | | | | | | |
| Class Anthozoa | | | | | | |
| Order Actiniaria | | | | | | |
| Family Edwardsiidae | | | | | | |
| Edwardsia? sp. | 2 | 7 | - | - | - | - |
| Phylum Echinodermata | | | | | | |
| Class Ophiuroidea | | | | | | |
| Order Ophiurida | | | | | | |
| Family Amphiuridae | | | | | | |
| Unid. Amphiuridae | 4 | 1 | 6 | - | - | - |
| Phylum Mollusca | | | | | | |
| Class Bivalvia | | | | | | |
| Unid. Bivalvia | - | - | - | 4 | 18 | - |
| Order Mytiloida | | | | | | |
| Family Mytilidae | | | | | | |
| Amygdalum papyrium | - | - | 1 | 1 | 5 | - |
| Order Ostreoida | | | | | | |
| Family Anomiidae | | | | | | |
| Anomia simplex | - | - | 1 | - | - | - |
| Order Pholadomyoida | | | | | | |
| Family Lyonsiidae | | | | | | |
| Lyonsia hyalina | 7 | 27 | 2 | 6 | 14 | 15 |
| Order Veneroida | | | | | | |
| Family Cardiidae | | | | | | |
| *Laevicardium mortoni* | - | 3 | 2 | 6 | 13 | - |
| Laevicardium sp. | 8 | - | - | - | - | 11 |
| Family Montacutidae | | | | | | |
| Mysella planulata | - | - | 3 | - | - | - |
| Family Solecurtidae | | | | | | |
| Tagelus plebeius | - | - | - | 3 | - | - |
| Family Tellinidae | | | | | | |
| Tellina lineata | 1 | - | 14 | 5 | 5 | 3 |
| *Tellina mera* | - | 57 | - | - | - | - |
| Family Veneridae | | | | | | |
| Anomalocardia auberiana | 19 | 52 | 6 | 8 | 8 | 28 |
| Parastarte triquetra | 49 | 424 | 7 | - | - | 1 |

Appendix 3a. FLORIDA DISTRICT LAGOON KICKNETS, October 1996 (continued).

| TAXON | PK41 | PK42 | PK43 | SR71 | SR72 | SR73 |
|---|---|---|---|---|---|---|
| Class Gastropoda | | | | | | |
| Unid. Gastropoda | - | - | - | - | 26 | - |
| Order Archaeogastropoda | | | | | | |
| Family Neritidae | | | | | | |
| Neritina reclivata | - | - | - | - | 5 | - |
| Order Cephalaspidea | | | | | | |
| Family Scaphandridae | | | | | | |
| Acteocina canaliculata | 3 | - | - | - | - | - |
| Order Mesogastropoda | | | | | | |
| Family Caecidae | | | | | | |
| Caecum pulchellum | - | - | 9 | - | - | 1 |
| Family Calyptraeidae | | | | | | |
| Crepidula maculosa | 1 | 2 | 40 | - | - | - |
| Crepidula plana | - | - | 3 | - | - | - |
| Crepidula sp. | - | - | - | - | 9 | - |
| Family Cerithiidae | | | | | | |
| Cerithium atratum | - | - | 3 | - | - | - |
| Diastoma varium | 58 | - | 1022 | - | 36 | 1 |
| Order Neogastropoda | | | | | | |
| Family Columbellidae | | | | | | |
| Astyris lunata | 6 | - | 76 | - | 78 | - |
| Costoanachis floridana | - | - | 1 | - | - | - |
| Family Marginellidae | | | | | | |
| Granulina ovuliformis | 11 | 24 | 32 | - | - | - |
| Marginella apicina | - | - | 5 | - | - | - |
| Family Nassariidae | | | | | | |
| Nassarius vibex | 11 | - | 18 | - | - | - |
| Family Turridae | | | | | | |
| Pyrgocythara hemphilli | - | - | 40 | - | - | - |
| Unid. Turridae | - | - | 2 | - | 1 | - |
| Order Nudibranchia | | | | | | |
| Nudibranchia sp. C | - | - | 1 | - | - | - |
| Order Pyramidelloida. | | | | | | |
| Boonea impressa | - | - | 8 | - | - | - |
| Odostomia laevigata | - | - | 3 | - | 2 | 2 |
| Odostomia weberi | 1 | - | 89 | - | - | - |
| Phylum Nemertea | | | | | | |
| Nemertea sp. F | 2 | - | - | 2 | - | - |
| Nemertea sp. H | 1 | - | 3 | - | - | - |
| Unid. Nemertea | - | - | - | 1 | - | 1 |
| Phylum Platyhelminthes | | | | | | |
| Class Turbellaria | | | | | | |
| Unid. Turbellaria | 1 | 2 | - | 1 | - | - |
| Phylum Porifera | | | | | | |
| Unid. Porifera | - | - | 1 | - | - | - |

Appendix 3b. Macrobenthic Summary Measures - Lagoon Sites.

OPAL/ERIN LAGOON KICKNET SAMPLES - OCTOBER 1998

| Sample Characteristics | | PK41OC96K | PK42OC96K |
|---|---|---|---|
| Number of Species | : | 42 | 29 |
| Density of All Species | : | 56.22 | 127.89 |
| Total numbers of specimens counted | : | 506.00 | 1151.00 |
| Diversity (Hprime -log base e) | : | 2.87 | 2.22 |
| Diversity (Hprime -log base 10) | : | 1.25 | 0.97 |
| Evenness (Hprime/Hmax) | : | 0.77 | 0.66 |
| Evenness (Scaled) | : | 0.73 | 0.64 |
| Simpson's Index | : | 0.92 | 0.82 |

| Sample Characteristics | | PK43OC96K | SR71OC96K |
|---|---|---|---|
| Number of Species | : | 81 | 30 |
| Density of All Species | : | 274.22 | 15.44 |
| Total numbers of specimens counted | : | 2468.00 | 139.00 |
| Diversity (Hprime -log base e) | : | 2.69 | 2.80 |
| Diversity (Hprime -log base 10) | : | 1.17 | 1.22 |
| Evenness (Hprime/Hmax) | : | 0.61 | 0.82 |
| Evenness (Scaled) | : | 0.59 | 0.72 |
| Simpson's Index | : | 0.81 | 0.91 |

| Sample Characteristics | | SR72OC96K | SR73OC96K |
|---|---|---|---|
| Number of Species | : | 36 | 16 |
| Density of All Species | : | 91.22 | 11.00 |
| Total numbers of specimens counted | : | 821.00 | 99.00 |
| Diversity (Hprime -log base e) | : | 2.11 | 2.15 |
| Diversity (Hprime -log base 10) | : | 0.92 | 0.93 |
| Evenness (Hprime/Hmax) | : | 0.59 | 0.78 |
| Evenness (Scaled) | : | 0.55 | 0.68 |
| Simpson's Index | : | 0.73 | 0.85 |