FISH ASSEMBLAGES INHABITING AN OLIGOHALINE SEGMENT OF THE LOWER ST. JOHNS RIVER, FLORIDA

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EXECUTIVE SUMMARY

A pilot program was initiated during 1990 to 1991 to determine the usefulness of an Index of Biological Integrity (IBI) in the lower St. Johns River. The IBI is a numerical index, based on numbers and varieties of fish present in area, employed as a biological complement to chemistry measurements for assessing water quality. Successful IBI analysis requires complete characterization of the fishes inhabiting the area in question. A field sampling program was designed by District staff in cooperation with the inter-agency Biology Work Group. Net fishing was conducted by a contractor (Continental Shelf Associates, Inc., Jupiter, Fl.) assisted by SJRWMD personnel; electrofishing was simultaneously conducted by the Florida Game and Fresh Water Fish Commission.

Fish were sampled in four areas: one area was in a large embayment (Doctors Lake) and three stations were in coves on the mainstem of the St. Johns River (Julington Creek, Hallowes Cove, and Red Bay). All stations were located within an 11-mile portion of the river. The Doctors Lake, Julington Creek, and Red Bay sites were each altered somewhat by human intervention (i.e., receiving discharges and experiencing shoreline development) while the Hallowes Cove site was considered to be unaffected by human activities. All stations were located within a segment of the lower St. Johns River where the salinity regime is consistently oligohaline (0 to 5 ppt). Fish were collected using four different methods (trawl, seine, electroshocker, and gill net), with appropriate replication, both day and night. Stations were sampled quarterly beginning in summer 1990.

The four types of gear collected 77 fish species from nearshore, mid-water, and bottom habitats. Nearshore areas sampled by seine and electroshocker were inhabited mostly by species of freshwater origin, however marine species tolerant of low salinities were also present. The most numerous species occurring in the nearshore habitat were bluegill, redear sunfish, largemouth bass, silversides, and mosquitofish. Offshore bottom dwelling fish (sampled by trawling) were mostly fishes of marine origin such as Atlantic croaker, spot, and bay anchovy. Offshore midwater fish (sampled by gill net) were mostly gizzard shad and menhaden.

The data were analyzed by Continental Shelf Associates. Inc. under a separate contract. The total number of fish, the total weight of fish, and numbers of species varied seasonally and among stations for all sampling gear types. The reasons for this variation are many and the need to distinguish natural variability from variability due to impacts is essential when trying to detect human influence on the system. Differences among the stations in terms of fish species composition and abundance were slight. The Hallowes Cove site did appear to be somewhat dissimilar to the others, probably due to microhabitat and topography differences rather than degraded conditions related to human activities.

Although the pilot project did not produce a working IBI for the lower St. Johns River, several pieces of information were obtained: 1) a useful side-by-side comparison of various fish sampling methodologies; 2) an appreciation of the statistical strengths and weaknesses inherent in standard fish sampling methods; 3) an understanding that ichthyofaunal monitoring as a tool for measuring environmental health is useful at the community level, not at the species level; and 4) the ability to identify future goals of research and the ways to achieve meaningful results.

Future bioassessment studies in the lower St. Johns River should include a broad geographic coverage over the lower river; monthly sampling, total numbers and weights of each species collected; length measurements of 30 individuals of each species at each station/time; 7 to 10 short duration trawl tows; replicate gill net sets; test alternative nearshore sampling gear (throw traps or dropnets); and electroshocking where salinity regime will allow.

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1.0 INTRODUCTION

When compared with other major estuaries of the United States eastern seaboard, very little information exists concerning the fish communities inhabiting the lower St. Johns River, Florida. This lack of information is surprising considering that the St. Johns River drains an area of 22,792 km^2 and is the longest river entirely within Florida's boundaries. Community-level data are important not only for the sake of ecological description but also for assessment of environmental conditions within the watershed (e.g., Fausch et al., 1990; Karr, 1991). Studies providing relative abundance or seasonal dynamics of St. Johns River fishes have thus far been based on trawling alone, therefore the characterization of the fauna has been restricted to the demersal (or trawlable) species inhabiting the river's main channel (Tagatz, 1968; Snyder and Burgess, in prep.). Nevertheless, these studies show that the lower St. Johns River supports a diverse assemblage of estuarine, marine, and freshwater species along a natural salinity gradient from the mouth to at least 100 km upstream. While the demersal assemblage is an important component of this estuarine system, additional species assemblages inhabit the nearshore areas and tributaries of the lower river. Investigations in other estuaries have demonstrated the importance of gear selectivity when describing fish assemblages. For example, Felley (1989) showed that in Calcasieu estuary, Louisiana, seine and trawl samples from the same general area were complementary in terms of certain species groups. In St. Andrews Bay, Florida, researchers collected fishes using gill net (Pristas and Trent, 1978), trawl (Ogren and Brusher, 1977) and seine (Saloman and Naughton, 1978) and each survey found different species numerically dominating the catches. Again, these findings are also critical if the fish assemblages are to be used as indicators of environmental status of the estuary.

The objective of our study was to assess, as completely as possible, the ichthyofaunal assemblage inhabiting an oligohaline portion of the lower St. Johns River by sampling with four gear types in littoral, demersal, and pelagic habitats. Data from this investigation will contribute to the basic ecological knowledge of the lower St. Johns River and will also assist natural resource managers in planning future community-level bioassessment programs aimed at detecting degradation of habitat or water quality.

The St. Johns River Water Management District (SJRWMD), interested in advancing the fundamental understanding of the river's ichthyofauna as well as developing sound monitoring programs using fishes, designed and funded the one-year pilot survey. Field net sampling was conducted by Continental Shelf Associates, Inc. (CSA) and SJRWMD personnel. Laboratory and subsequent data analyses were performed by CSA. Electrofishing data were obtained from a simultaneous cooperative agreement carried out by Florida Game and Fresh Water Fish Commission staff, De Leon Springs Laboratory.

2.0 METHODS

2.1 STUDY SITES

Four sampling sites were chosen within a portion of the lower St. Johns River between 57.1 and 74.5 km (35.5 and 46.3 mi) from the mouth (**Figure 1**). Station 1 was located near Doctors Inlet in Doctors Lake, a westward embayment of the river's mainstem. Station 2 was designated near the mouth of Julington Creek, an eastern tributary to the river. Station 3 was placed in Hallowes Cove, a small cove along the eastern shore of the river. Station 4 was located near Red Bay, an even smaller western shore cove. Stations were chosen based on similar ecological conditions, including oligohaline salinity regime (0 to 4 ppt), depth (0 to 3 m), bottom type (sand and finer mud), and exposure to prevailing winds and fetch (exposed to southeast through west, sheltered from northeast through northwest). The four sites were also similar in having shorelines composed of wetland hardwood swamp-forest communities (or the remains of the same.) In addition, the littoral zone at all stations supported a submerged macrophyte community dominated by tapegrass, *Vallisneria americana*.

The sites differed in the degree of anthropogenic impact and associated environmental stress to the aquatic communities. Stations 1, 2, and 4 were in areas that have experienced shoreline development and are subject to numerous discharges, urban runoff, and sewage input. By contrast, Station 3 (Hallowes Cove) has not been subjected to any shoreline development or urban discharge.

2.2 SAMPLING METHODOLOGY

Stations 1, 2, and 3 were sampled quarterly (September 1990, January, April, and July 1991) while Station 4 was sampled April and July 1991. All stations were sampled using otter trawl, seine, electroshocker with dipnets, and multi-mesh gill net.

A 5-m (16-ft) otter trawl with 38-mm (1.5-in.) stretch mesh in the body and 1.27-cm (0.5-in.) mesh in the cod end was employed to sample deeper (approximately 3 m) waters at each site. Ten repetitive 2-min tows were made at each site during both daylight and nighttime hours. In other estuarine trawl surveys, seven 2-min tows have proven adequate to sample at least 90% of the trawlable species (Roessler, 1965; Livingston, 1976; Orth and Heck, 1980; Snyder and Burgess, in prep.); we collected 10 2-min tows throughout the study to further evaluate adequacy of this methodology in the lower St. Johns River. In the littoral areas of each site three seine hauls were made, during both daylight and nighttime hours, using a 21 x 1.8-m (70 x 6-ft) bag seine with 3-mm (1/8-in.) mesh. A boat-mounted Smith-Root 7.0 GPP electroshocker also was utilized to sample the littoral zone (three 10-min transects at each station). Day and night electroshocker samples were taken at Stations 1, 2, and 3 during the first two sampling periods

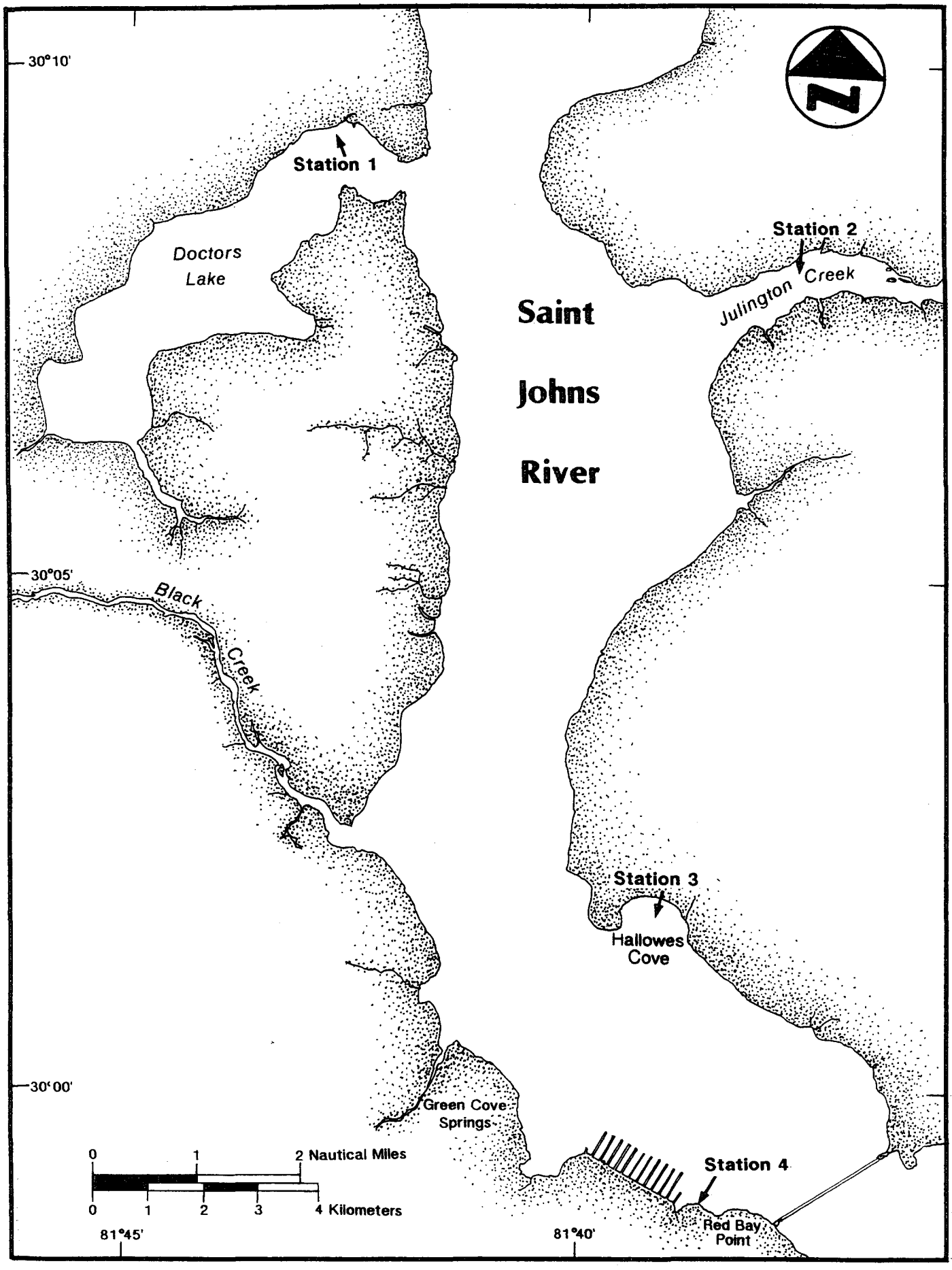

Figure 1. Lower St. Johns River study area.

(September and January) and only night sampling was performed in April and July. Station 4 received day and night sampling in April and only night sampling in July. A 114.3-m (375-ft) multi-mesh experimental gill net with five panels was set perpendicular to shore. Each of the five panels measured 22.8 m (75 ft) long with mesh sizes ranging from 25-mm (1-in.) to 127-mm (5-in.) bar mesh in five 2.54-cm (1-in.) increments. Fishes were removed from the net every 2 h for a 6-h period. During night sampling, nets were set 1 h prior to sunset.

After capture, all trawl and seine samples were placed in polypropylene buckets, preserved in 10% formalin, and transported to the laboratory. Fishes collected by gillnetting and electroshocking were sorted, counted, and weighed (in aggregate, by species) in the field, then discarded on-site. In the laboratory, the trawl and seine samples were rinsed in fresh water, sorted, identified, and weighed (in aggregate, by species). Representative series of all processed samples were transferred to 50% isopropanol and were archived in the Florida Museum of Natural History, Gainesville, FL.

Water temperature, salinity, dissolved oxygen, and pH were routinely measured using a Hydrolab at each station throughout the study.

2.3 DATA ANALYSIS

Data generated from each gear type were analyzed separately. Analyses included community measures (species diversity, evenness, and richness) numerical classification, ordination, analysis of variance (ANOVA) and power analyses. Also, summary statistics (means and standard errors) of weight, numbers of individuals, and species were calculated for each station-time combination.

2.4 COMMUNITY MEASURES

Community measures, Shannon-Weiner diversity (*H'*) and its associated evenness (*J*) were calculated for each gear type, station, and season. Shannon-Weiner diversity was calculated using the following formula:

$$H' = \sum_{i=1}^{S} (p_i)\,(\log_2 p_i)$$

where *S* is the total number of species and p_i is the observed proportion of individuals belonging to the *i*-th species ($i = 1, 2..., s$).

Evenness (J) was calculated as follows:

$$J = \frac{H'}{\log_2 S}$$

where H' is the Shannon-Weiner index and $\log_2 S$ the number of species in the sample.

Since diversity measures are related to sample size (Hurlbert, 1971) we used the expected number of species $E(S_n)$ to measure species richness in our collections. The expected number of species in a random sample of n individuals was calculated using Simblerloff's (1978) program of Hurlbert's (1971) formula:

$$E(S_n) = \sum_{i=1}^{S} \left\{ 1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right\}$$

where S is the total number of species in the collection, N is the total number of individuals in the collection, and N_i is the number of individuals in species i in the collection. Rarefaction curves were produced using $E(S_n)$ for each gear type by station. The use of rarefaction curves allowed comparison of species richness among stations using values that have been standardized to common numbers of individuals.

Sampling adequacy of trawling was estimated using Gaufin et al.'s (1956) P_k statistic which estimates the average probability that a new species will be contributed by the k-th replicate drawn from a total number of n replicates. P_k statistic was computed using the following formula:

$$P_k = \sum_{i=1}^{n-k+1} \frac{C_{n-k+1}^{i}(i)}{C_n^i(n-k+1)} \frac{S_i}{S}$$

Where C is the standard notation for a combinatorial. The average number of new species added by each repetitive trawl tow was examined by plotting species accumulation (SP_k) curves. The curves were examined to determine the number of tows required to achieve 90% of the species collected in all tows.

2.5 CLASSIFICATION AND ORDINATION

Numerical classification and ordination were employed to objectively explore spatial and temporal patterns of species co-occurrence. These analyses were performed separately by gear type on species by sample data matrices. Prior to the analyses, numerical data were log-transformed [$\log_{10}(x+1)$] to prevent certain abundant species from dominating the results. Gill net data were not subjected to classification or ordination.

Numerical classification or cluster analysis was performed using the Bray-Curtis similarity coefficient (Bray and Curtis, 1957). A matrix of similarities was generated using the coefficient to compare all possible pairs of samples by their species abundances. This matrix was then scanned for pairs of samples with high similarity values. Similar pairs of samples were then successively linked (clustered) using the group average sorting algorithm ($\beta = -0.25$) producing a dendrogram display of the final grouping of samples. This procedure, where samples are compared, is referred to as "normal analysis," while similarity between species based on their occurrence is termed "inverse analysis."

The Bray-Curtis similarity coefficient (Bray and Curtis, 1957) was calculated using the following formula:

$$B = \frac{\sum |X_{ij} - X_{ik}|}{\sum (X_{ij} + X_{ik})}$$

where X_{ij}, X_{ik} equals the number of individuals in species i in each sample j and k. To aid in the interpretation of the resulting dendrograms, the original data matrix was rearranged according to the results of inverse and normal analyses into a two-way table.

Ordination of the samples by species matrices for each gear type was achieved using reciprocal averaging or correspondence analysis (Hill, 1973). Reciprocal averaging allows simultaneous comparison of samples by their species attributes and species by their patterns of co-occurrence in the samples. Mathematically reciprocal averaging is similar to principal components analysis where a multidimensional set of data points are reduced by generating a smaller set of uncorrelated axes which explain the variance of that set of points. Of interest to ecologists are the scores assigned to samples (and species) for each axis extracted from the data matrix. These scores may be plotted in species or sample space to examine patterns in the data set. We performed reciprocal averaging using both abundance and presence-absence data sets.

2.6 ANALYSIS OF VARIANCE

Three-way analysis of variance (ANOVA) was used to examine the influence of site, season, time (day or night), and their interactions on the following dependent variables: 1) mean number of species; 2) mean number of individuals; and 3) mean weights. Three-way ANOVAs were performed for trawl and seine data, while two-way (sites and seasons) ANOVA was used on electrofishing data due to uneven sampling during the daylight hours. Only Stations 1 through 3 were used due to uneven sampling at Station 4. All data were log-transformed ($\log_{10}[x+1]$) prior to ANOVA if the mean and the variance were positively correlated. This transformation was used to more closely meet the assumptions of ANOVA (Steel and Torrie, 1969).

2.7 POWER ANALYSIS

Power or sensitivity of a statistical test is measured by $1-\beta$ (in hypothesis testing, β is the probability of accepting the null hypothesis when it is in fact false). Increasing the number of samples increases the power of a test; therefore, analyses of power can be used to determine statistically valid sample sizes needed in monitoring programs designed to detect levels of change in a response variable associated with some form of impact. We performed power analyses on the trawl, electroshocker, and seine data to estimate the number of samples required to detect an absolute change in mean species, and relative (percent) change in mean abundance or mean weight of fishes per sample. The tests followed the procedures of Dixon and Massey (1969) using a t-test comparison between two sample means ($\alpha=0.05$) performed at various levels of power ($\beta=0.1$, 0.3, 0.5, 0.7, and 0.9).

3.0 RESULTS

Mean values of water temperature, salinity, dissolved oxygen, and pH recorded at each station and sampling period are given in **Table 1**. Due to malfunction of the Hydrolab, no data were available for the April sampling period. Salinity values were usually below 1 ppt; however, in September salinity ranged from 7.6 to 8.1 ppt at Doctors Inlet (Station 1), from 6.3 to 6.8 ppt at Julington Creek (Station 2), and from 3.5 to 4.4 ppt at Hallowes Cove (Station 3). Temperature followed expected seasonal trends which were also reflected by dissolved oxygen concentrations.

Collection of fishes by all gear types yielded 59,597 individuals in 77 species in 34 families. **Table 2** gives a listing of all species collected during the study. Total numbers of species collected by each gear type were as follows: electroshocker (56), seine (53), trawl (39), and gill net (25). The 10 most numerous species (expressed as percentages) collected by each gear type were tabulated to show species composition differences among the catches (**Table 3**). Detailed results are presented separately for each gear type below. A summary of collection information and community indices for each gear type by station is given in **Table 4**.

3.1 TRAWL

3.1.1 Collection Summary

A total of 280 trawl tows yielded 39 species and 42,877 individuals weighing 97.19 kg in total. Trawl samples numerically represented about 72% of the total catch by all gear types. Two species, *Anchoa mitchilli* and *Micropogonias undulatus*, contributed over 90% of the individuals in the tows. Also important numerically were *Leiostomus xanthurus*, *Trinectes maculatus*, *Microgobius gulosus*, and *Gobionellus shufeldti*. Trawl samples consisted mostly of demersal euryhaline marine and estuarine species. **Table 5** lists all species collected in trawl samples from each station ranked by numerical abundance (for combined day and night samples). Other species which were seasonally common, but also absent during certain periods included *Cynoscion regalis*, *Ameiurus catus*, *Paralichthys lethostigma*, and *Citharichthys spilopterus*.

Figure 2 presents the mean values for species, number of individuals, and weights per tow at each station during each season. In terms of numbers of individuals, the highest average catches were made in April and September with January and July producing the lowest catches. The observed abundances reflect seasonal increases of *A. mitchilli* in September and *M. undulatus* in April. **Figure 3** shows the abundance of the numerically dominant species in the samples. Station 2 generally yielded the highest mean abundances, followed by Stations 1 and 3. Mean number of species per tow was highest at Stations 1 and 2.

Table 1. Mean (± SD) of environmental variables measured at each station during each sampling period in the lower St. Johns River study area. Due to malfunction of the Hydrolab, no data were available for April.

Season	Station	Temperature	Dissolved Oxygen	Salinity	pH
September	1	26.9(0.6)	9.4(1.4)	7.9(0.2)	7.75(0.18)
	2	26.5(1.2)	8.2(0.7)	6.5(0.2)	7.07(0.19)
	3	27.0(0.9)	8.2(1.2)	4.0(0.3)	7.26(0.32)
January	1	16.3(0.8)	9.1(0.1)	2.5(0.1)	6.91(0.49)
	2	15.5(0.5)	10.1(0.6)	1.7(0.2)	7.76(0.05)
	3	16.3(0.7)	9.7(0.4)	0.2(0.0)	7.64(0.32)
April	All	No data	No data	No data	No data
July	1	29.7(0.8)	8.0(1.9)	0	7.82(0.54)
	2	28.9(1.2)	5.1(1.3)	0	6.61(0.25)
	3	29.2(0.8)	4.6(2.7)	0	6.99(0.15)
	4	28.7(0.8)	4.0(0.7)	0	6.94(0.34)

SD = Standard deviation.

Table 2. Species collected during this study. Common names follow Robins et al. (1990), scientific names follow most recent taxonomic revisions.

American shad	*Alosa sapidissima*
American eel	*Anguilla rostrata*
Atlantic croaker	*Micropogonias undulatus*
Atlantic needlefish	*Strongylura marina*
Atlantic stingray	*Dasyatis sabina*
bay anchovy	*Anchoa mitchilli*
bay whiff	*Citharichthys spilopterus*
black crappie	*Pomoxis nigromaculatus*
blackcheek tonguefish	*Symphurus plagiusa*
blue tilapia	*Oreochromis aurea*
bluefin killifish	*Lucania goodei*
bluegill	*Lepomis macrochirus*
bluespotted sunfish	*Enneacanthus gloriosus*
bowfin	*Amia calva*
brook silversides	*Labidesthes vanhyningi*
brown bullhead	*Ameiurus nebulosus*
chain pipefish	*Syngnathus louisianae*
chain pickerel	*Esox niger*
channel catfish	*Ictalurus punctatus*
clown goby	*Microgobius gulosus*
code goby	*Gobiosoma robustum*
dollar sunfish	*Lepomis marginatus*
eastern mosquitofish	*Gambusia holbrooki*
fat sleeper	*Dormitator maculatus*
flagfin mojarra	*Eucinostomus melanopterus*
Florida gar	*Lepisosteus platyrhincus*
freshwater goby	*Gobionellus shufeldti*
gafftopsail catfish	*Bagre marinus*
gizzard shad	*Dorosoma cepedianum*
golden shiner	*Notemigonus crysoleucas*
goldfish	*Carassius auratus*
gray snapper	*Lutjanus griseus*
gulf pipefish	*Syngnathus scovelli*
hardhead catfish	*Ariopsis felis*
highfin goby	*Gobionellus oceanicus*
hogchoker	*Trinectes maculatus*
inland silversides	*Menidia beryllina*
Irish pompano	*Diapterus auratus*
jack crevalle	*Caranx hippos*
ladyfish	*Elops saurus*
lake chubsucker	*Erimyzon sucetta*
largemouth bass	*Micropterus salmoides*
least killifish	*Heterandria formosa*
leatherjacket	*Oligoplites saurus*
longnose gar	*Lepisosteus osseus*
pinfish	*Lagodon rhomboides*
pirate perch	*Aphredoderus sayanus*
rainwater killifish	*Lucania parva*
red drum	*Sciaenops ocellatus*

Table 2. (Continued).

redbreast sunfish	*Lepomis auritus*
redear sunfish	*Lepomis microlophus*
redfin pickerel	*Esox americanus*
sailfin molly	*Poecilia latipinna*
Seminole killifish	*Fundulus seminolis*
sheepshead	*Archosargus probatocephalus*
silver perch	*Bairdiella chrysoura*
southern flounder	*Paralichthys lethostigma*
speckled worm eel	*Myrophis punctatus*
spinycheek sleeper	*Eleotris pisonis*
spot	*Leiostomus xanthurus*
spotted seatrout	*Cynoscion nebulosus*
spotted sunfish	*Lepomis punctatus*
striped mullet	*Mugil cephalus*
striped blenny	*Chasmodes bosquianus*
striped anchovy	*Anchoa hepsetus*
sunshine bass	*Morone saxatilis x chrysops*
swamp darter	*Etheostoma fusiforme*
tadpole madtom	*Noturus gyrinus*
taillight shiner	*Notropis maculatus*
threadfin shad	*Dorosoma petenense*
tidewater mojarra	*Eucinostomus harengulus*
warmouth	*Lepomis gulosus*
weakfish	*Cynoscion regalis*
white mullet	*Mugil curema*
white catfish	*Ameiurus catus*
yellow bullhead	*Ameiurus natalis*
yellowfin menhaden	*Brevoortia smithi*

Table 3. Most numerous species collected by each gear type expressed as percentages of total catch. Data were summed for all stations and seasons.

Species	Trawl	Seine	Electro-shocker	Gill Net
Leiostomus xanthurus	2.04	6.00	6.17	22.59
Anchoa mitchilli	51.95	21.79	5.04	---
Eucinostomus harengulus	0.14	5.64	7.99	---
Ameiurus catus	0.42	---	---	0.60
Lepomis macrochirus	---	4.14	13.05	---
Notemigonus crysoleucas	---	4.68	4.69	---
Micropogonias undulatus	41.83	---	---	---
Microgobius gulosus	1.12	---	---	---
Trinectes maculatus	0.80	---	---	---
Cynoscion regalis	0.58	---	---	---
Gobionellus schufeldti	0.16	---	---	---
Paralichthys lethostigma	0.16	---	---	---
Citharichthys spilopterus	0.16	---	---	---
Lucania parva	---	18.16	---	---
Menidia beryllina	---	9.34	---	---
Lucania goodei	---	3.57	---	---
Gambusia holbrooki	---	3.54	---	---
Fundulus seminolis	---	2.34	---	---
Lepomis microlophus	---	---	10.79	---
Mugil cephalus	---	---	10.05	---
Micropterus salmoides	---	---	8.71	---
Lepomis punctatus	---	---	5.27	---
Lepomis gulosus	---	---	3.73	---
Brevoortia smithi	---	---	---	56.41
Dorosoma cepedianum	---	---	---	11.03
Mugil cephalus	---	---	---	3.59
Elops saurus	---	---	---	1.40
Lepisosteus osseus	---	---	---	0.80
Ameiurus nebulosus	---	---	---	0.60
Lepisosteus platyrhincus	---	---	---	0.53
Ictalurus punctatus	---	---	---	0.53
Caranx hippos	---	---	---	0.40

Table 4. Summary of community measures for each station and gear type.

Gear Type Station	Number of Replicates		Total Species		Total Individuals		Diversity (H′)		Eveness (J)		Expected Number of Species $E(S_{250})$	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Electroshocker												
1	6	12	18	38	266	1,580	3.47	3.96	.819	.739	17.8	27.0
2	6	12	27	42	551	2,033	3.64	4.03	.767	.747	22.9	26.3
3	6	12	28	35	503	1,493	3.83	3.86	.796	.751	23.0	23.2
4	3	6	23	28	337	1,108	3.23	3.43	.735	.712	21.4	21.0
Trawl												
1	40	40	23	24	8,924	4,026	0.86	1.31	.189	.286	5.7	5.9
2	40	40	22	31	10,341	4,305	1.22	3.05	.275	.325	5.8	5.9
3	40	40	22	20	7,348	3,779	0.80	1.75	.179	.404	4.8	---
4	20	20	15	17	3,163	991	1.01	1.29	.258	.317	4.5	---
Seine												
1	12	12	35	38	1,112	989	3.66	3.48	.714	.649	24.5	34.6
2	12	12	31	31	848	1,025	3.50	3.61	.706	.748	23.7	27.7
3	12	12	23	28	1,117	453	2.79	3.41	.616	.702	16.7	22.4
4	6	6	25	30	636	744	3.47	3.42	.748	.706	20.5	23.0
Gillnet												
1	---	4	---	15	---	573	---	1.70	---	.436	---	---
2	---	4	---	13	---	296	---	2.12	---	.572	---	---
3	---	4	---	16	---	170	---	2.17	---	.543	---	---
4	---	2	---	5	---	6	---	---	---	---	---	---

Table 5. Species collected in 2-min trawl tows at each station in September, January, April, and July. Data are totals of repetitive tows (n = 10) summed within each station. Day and night samples were combined for each station.

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Anchoa mitchilli	2,458	6,220	3,714	233	821	2,579	491	148	439	212	4,676	107	484	151	22,733
Micropogonias undulatus	245	101	5	1,156	1,024	1,378	2,648	5,322	1,471	2,706	400	197	235	639	17,527
Leiostomus xanthurus	28	21	5	3	1	1	123	125	180	213	42	2	13	99	856
Microgobius gulosus	4	40	399	4	3	4	3	3	3	1	---	3	2	1	470
Trinectes maculatus	4	29	39	22	21	11	22	17	1	2	20	66	9	73	336
Cynoscion regalis	118	70	4	9	20	3	---	---	---	---	17	---	5	2	248
Ameiurus catus	---	---	---	2	1	---	1	---	1	1	---	167	---	3	176
Gobionellus schufeldti	---	1	2	2	7	---	6	3	---	2	6	16	---	24	69
Paralichthys lethostigma	2	1	2	---	---	---	33	7	11	5	3	---	---	2	66
Citharichthys spilopterus	2	---	---	---	---	---	25	21	6	3	7	---	---	2	66
Eucinostomus harengulus	6	2	18	30	---	---	1	1	---	---	---	---	---	2	60
Bairdiella chrysoura	18	3	7	---	---	---	---	---	---	---	5	---	---	---	33
Cynoscion nebulosus	9	4	11	2	1	---	1	---	---	---	---	---	---	---	28
Symphurus plagiusa	1	4	14	6	1	---	---	---	---	---	---	---	---	---	26
Gobiosoma robustum	---	2	15	---	1	1	1	---	3	1	1	---	---	1	26
Ameiurus nebulosus	5	4	3	---	1	4	2	2	---	---	---	---	1	---	22
Dorosoma petenense	1	1	12	1	2	1	---	2	---	---	---	---	---	---	20
Diapterus auratus	---	2	16	---	---	---	---	---	---	---	---	---	---	1	19
Elops saurus	---	---	---	---	---	---	7	2	2	2	---	---	2	---	15
Bagre marinus	7	---	---	---	---	---	---	---	---	---	3	---	1	---	11
Brevoortia smithi	1	---	---	---	2	---	---	1	---	---	3	---	---	3	10
Lutjanus griseus	---	8	2	---	---	---	---	---	---	---	---	---	---	---	10
Dasyatis sabina	---	1	1	---	1	---	2	---	2	1	---	---	---	---	8
Ameiurus natalis	---	---	---	---	---	---	---	---	---	---	6	---	---	---	6
Ariopsis felis	3	1	---	---	---	---	1	---	---	---	---	---	---	---	5
Anguilla rostrata	2	1	---	1	1	---	---	---	---	---	---	---	---	---	5
Lepomis microlophus	---	---	---	---	---	---	1	---	---	---	1	2	1	---	5
Syngnathus scovelli	---	---	2	---	---	---	2	---	---	1	---	---	---	---	5
Gobionellus oceanicus	---	---	---	---	---	---	---	2	---	1	---	---	---	---	3

Table 5. (Continued).

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Sciaenops ocellatus	---	---	1	---	---	---	1	---	---	---	---	---	---	---	2
Anchoa hepsetus	2	---	---	---	---	---	---	---	---	---	---	---	---	---	2
Syngnathus louisianae	2	---	---	---	---	---	---	---	---	---	---	---	---	---	2
Alosa sapidissima	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1
Lucania parva	---	---	---	---	---	---	---	---	1	---	---	---	---	---	1
Dorosoma cepedianum	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1
Ictalurus punctatus	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1
Pomoxis nigromaculatus	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1
Myrophis punctatus	---	1	---	---	---	---	---	---	---	---	---	---	---	---	1
Mugil cephalus	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1
TOTAL INDIVIDUALS	**2,918**	**6,517**	**4,272**	**1,471**	**1,910**	**3,982**	**3,371**	**5,656**	**2,120**	**3,151**	**5,190**	**563**	**753**	**1,003**	**42,877**
TOTAL SPECIES	**20**	**21**	**20**	**13**	**18**	**9**	**19**	**14**	**12**	**14**	**14**	**11**	**10**	**14**	**39**

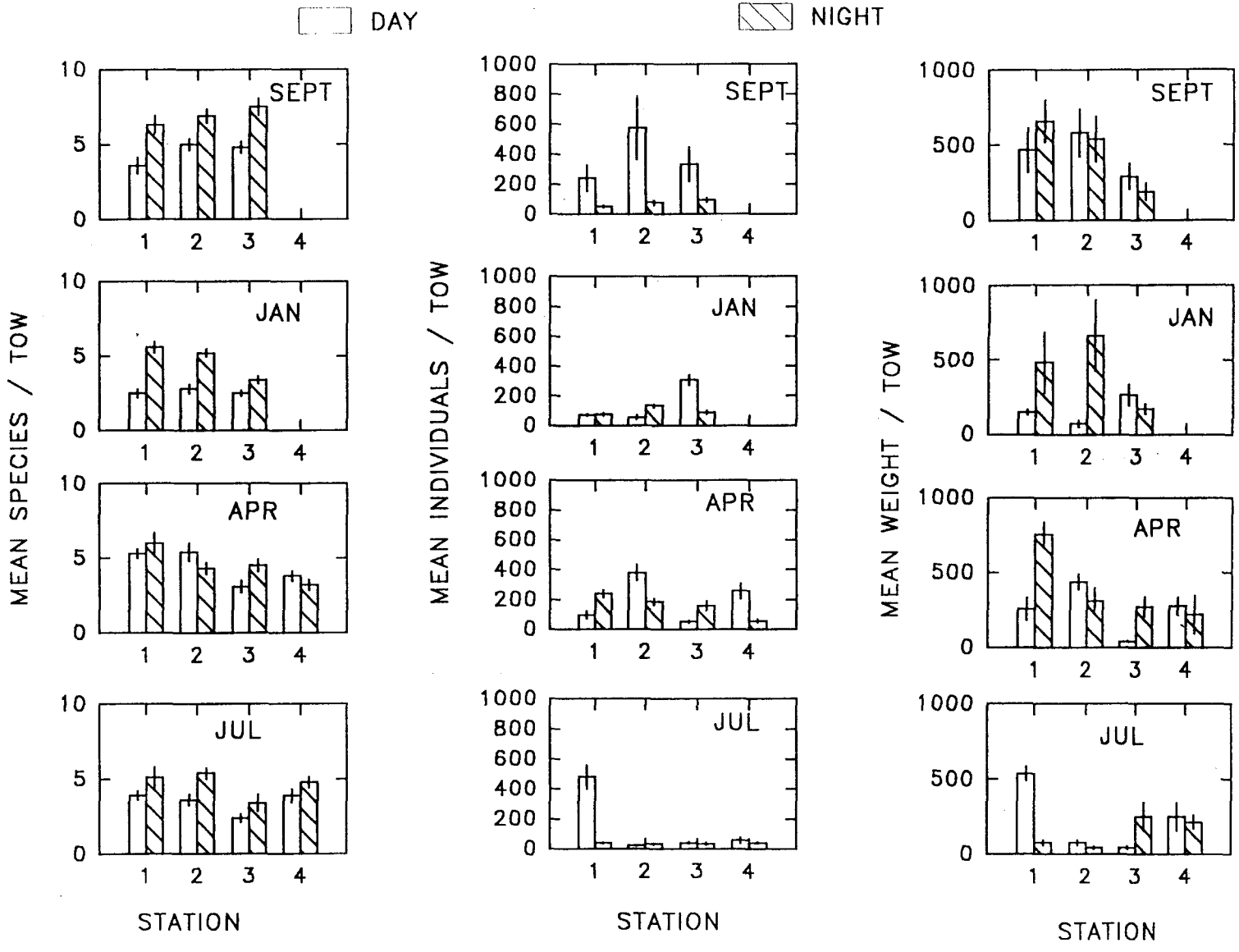

Figure 2. Mean number of species, number of individuals, and weight of fishes collected in 10 repetitive 2-min trawl tows from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error.

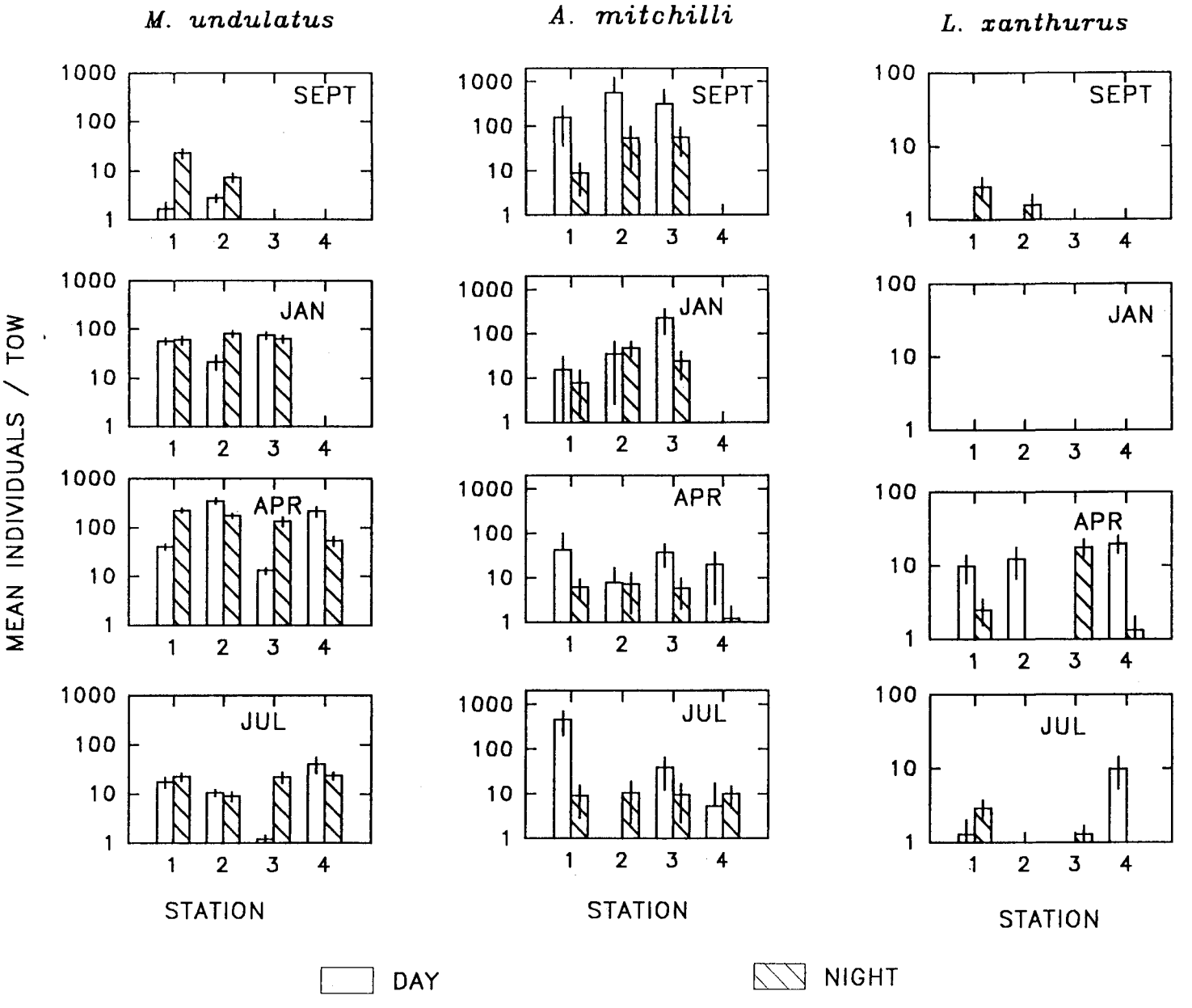

Figure 3. Mean numbers of *Micropogonias undulatus*, *Anchoa mitchilli*, and *Leiostomus xanthurus* collected in 10 repetitive 2-min trawl tows taken day and night from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error. Numbers for *L. xanthurus* in January were below 1.

3.1.2 Analysis of Variance

The three-way ANOVA detected significant interactions among station, season, and day-night for mean number of species ($F=2.84$, $df=6/215$, $P<0.0111$), mean number of individuals ($F=16.08$, $df=6/215$, $P<0.000$), and mean weights per trawl ($F=9.73$, $df=6/215$, $P<0.000$). The presence of interaction precludes further analysis of main effects.

3.1.3 Power Analyses

The results of power analyses performed on the variables mean species, mean individuals, and mean weight per trawl tow are given in **Figure 4**. The analyses provide an estimate of sensitivity of the response variables in terms of varying levels of power ($1-\beta$) and sample size. For the 10 replicates used in this study ($\beta=0.50$), we would be able to detect a change of 1.3 mean species per tow, a change of 97% in mean individuals per tow, and a change of 116% in mean weight per tow.

3.1.4 Community Measures

Species accumulation curves for day and night tows showed that the number of new species added on average per tow varied with season, station, and time of day (**Figure 5**). In September, eight tows were required to sample at least 90% of the species collected for day and night samples. By January, fewer tows were required to reach 90% (e.g., Station 1 leveled at four tows). As expected, the rate of species accumulation reflected seasonal and spatial patterns of species richness. Diversity and evenness were consistently lower at night with the exception of Station 2 in July (**Figure 6**). Diversity and evenness were appreciably higher in daytime samples at all stations in April. Rarefaction curves show that species richness among stations was quite similar when daylight samples of similar size are compared (**Figure 7**). At night, the rarefied samples showed Station 2 as having the highest species richness, followed by Stations 4 and 3, respectively.

3.1.5 Classification and Ordination

Normal analysis of the Bray-Curtis similarity among trawl samples (**Figure 8**) produced five groups which primarily sorted by season. Group A, consisting of four samples, was unlike the other four groups in that it did not express a seasonal influence; all samples were collected during the day from Stations 1 and 3. Eight samples composed the second group (Group B) which included all samples collected during January plus one September night sample from Station 1 and one July night sample from Station 3. The next group (Group C) consisted of 10 samples collected in either April or July. Only two samples made up Group D; both samples were from Station 2 in July (day and night). Group E included four samples from September: Station 2 (day and night) and Station 3 (day and night).

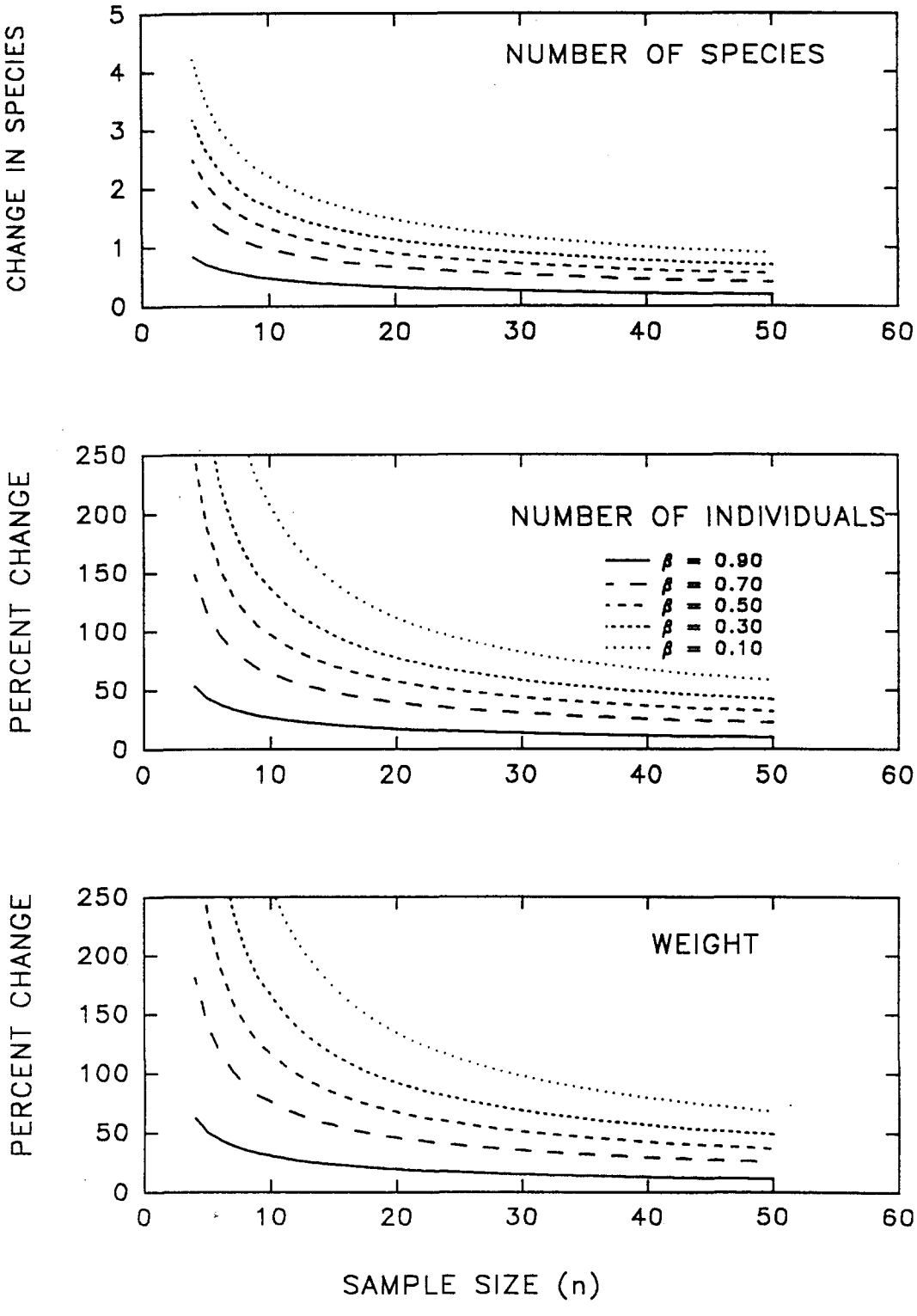

Figure 4. Detectable change in number of species and percent detectable change in mean number of individuals, and weight as functions of sample size (n) and degrees of power (1-β) at $\alpha = 0.05$ for trawl samples.

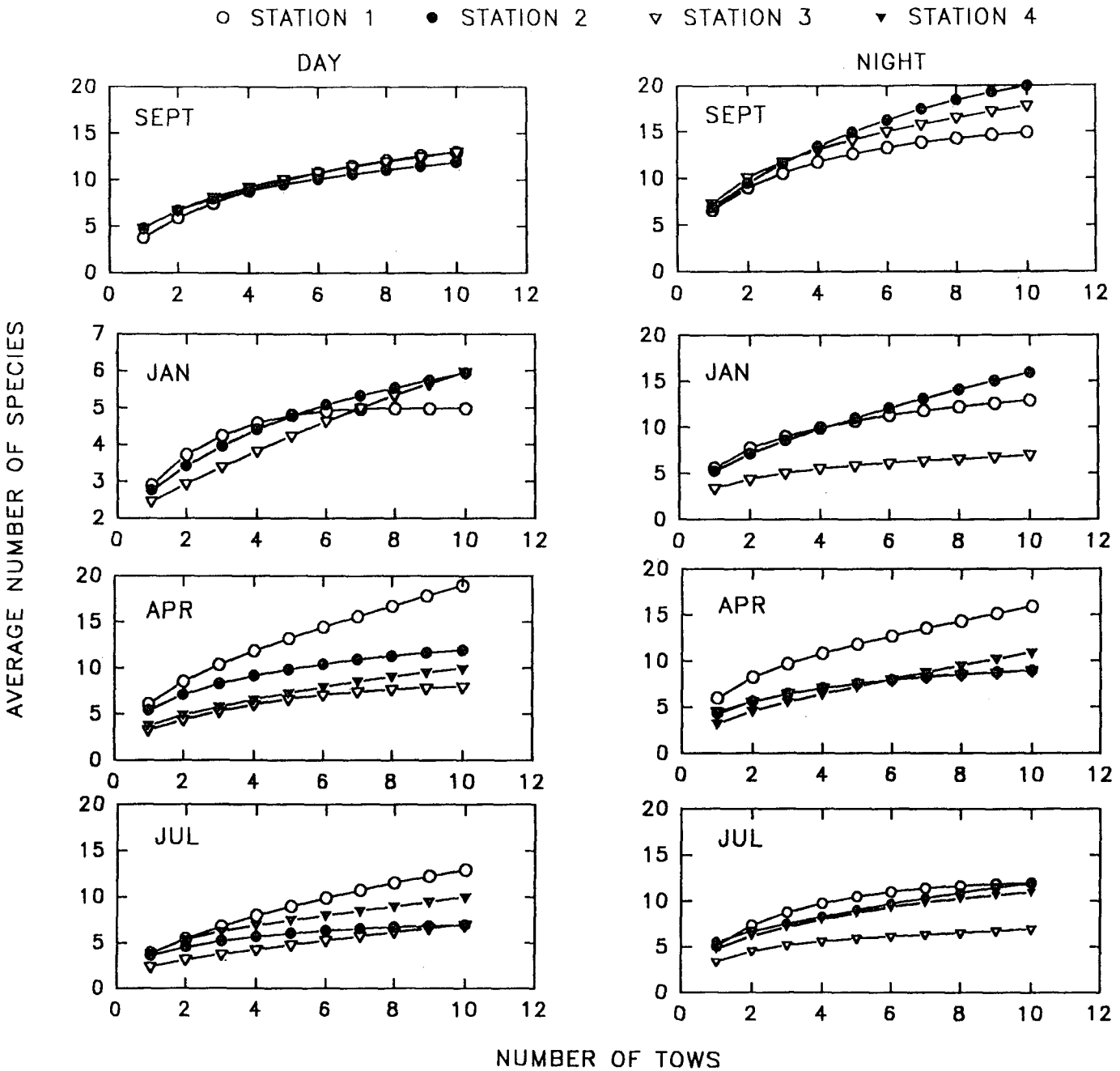

Figure 5. Species accumulation plots of SP_k (the average number of new species contributed by successive 2-min trawl tows for each station within each seasonal sampling period).

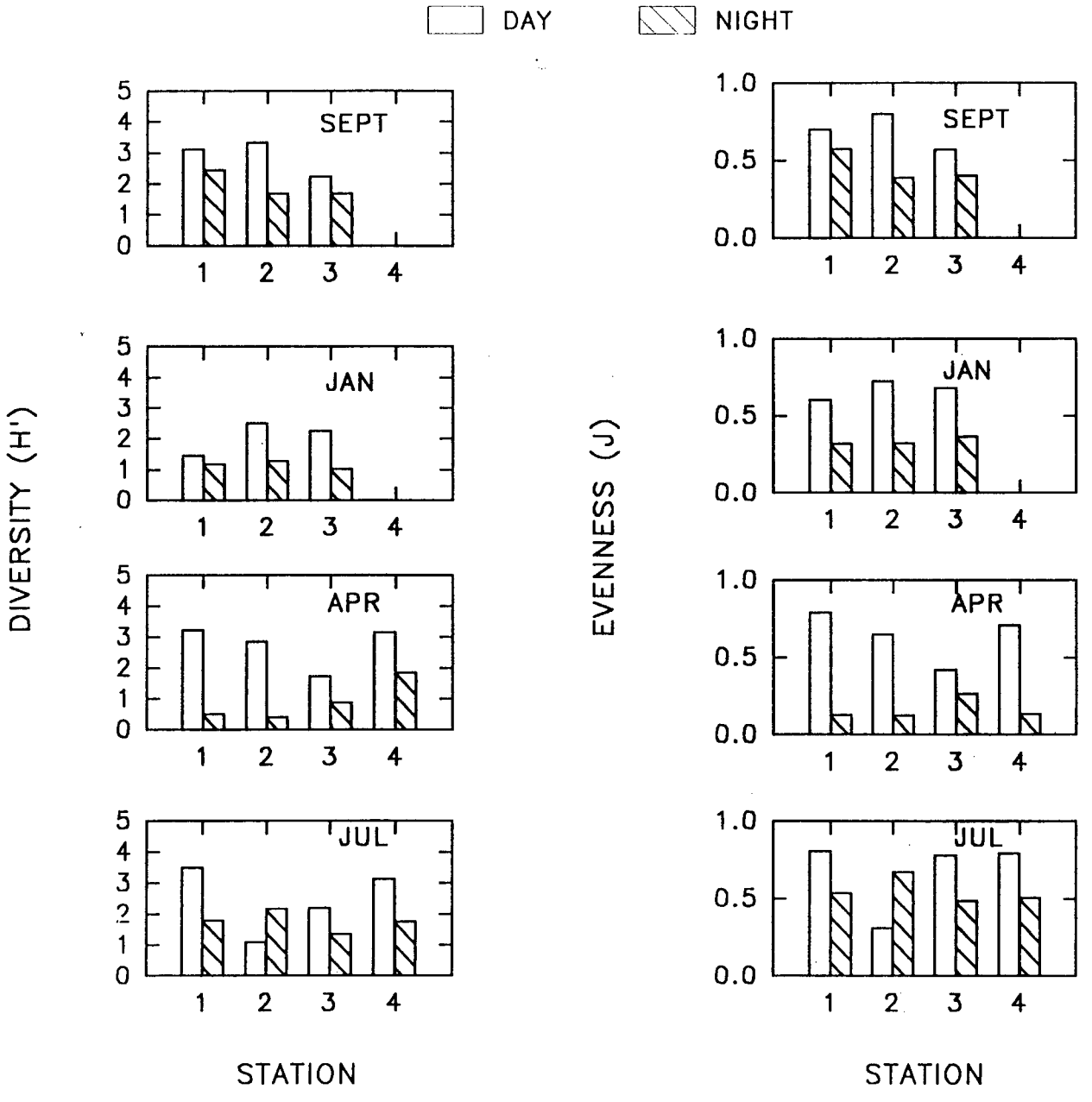

Figure 6. Diversity (H') and evenness (J) of fishes collected in 2-min trawl tows at each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples.

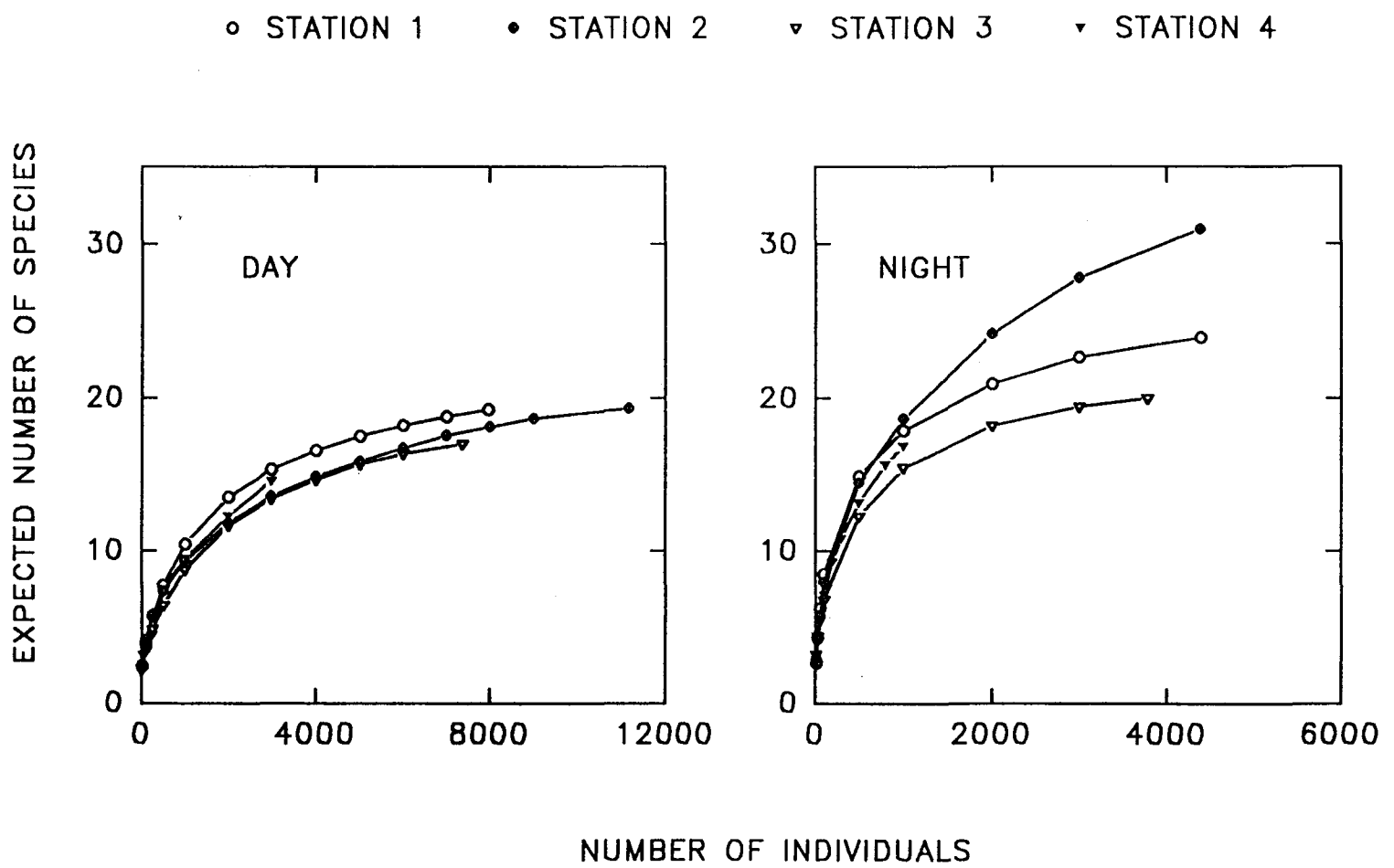

Figure 7. Rarefaction plots of expected number of species $E(S_n)$ per increasing sample size for day and night trawl collections at each station. Data from all seasons were summed within stations.

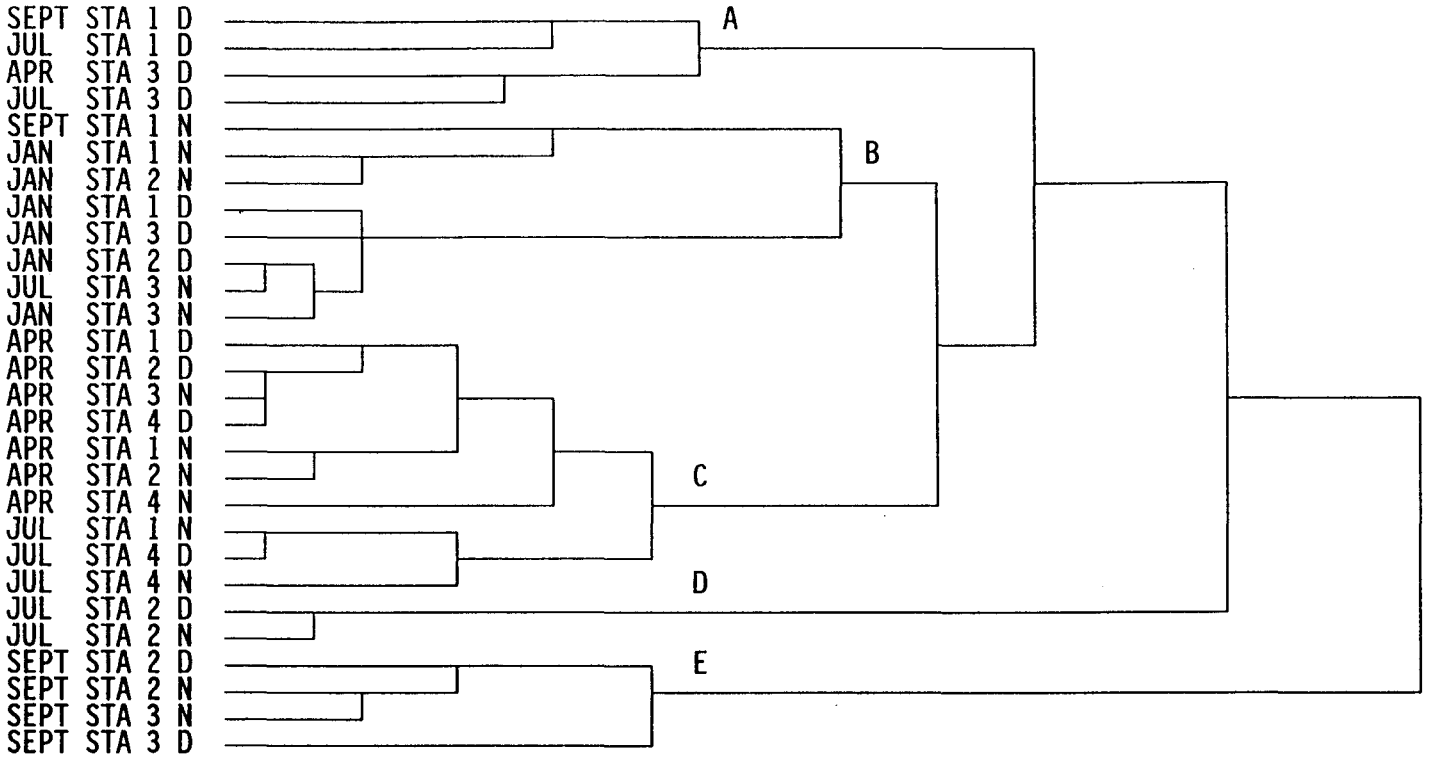

Figure 8. Normal dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity between trawl samples (station/season/time) taken in the study area.

The inverse analysis of species co-occurrence in trawl samples produced four groups (**Figure 9**). Group 1 consists of *Alosa sapidissima*, *Dorosoma cepedianum*, *Pomoxis nigromaculatus*, *Anchoa hepsetus*, and *Syngnathus louisianae*, and is an artifactual assemblage of single appearances in the trawl samples. Group 2, *Ariopsis felis* through *Eucinostomus harengulus*, is a natural grouping of euryhaline forms, plus two secondary freshwater species (*Anguilla rostrata* and *Dorosoma petenense*), that co-occurred primarily during September. Group 3, comprising *Bagre marinus* through *Mugil cephalus*, is an aggregation of euryhaline marine invaders and freshwater species found sporadically throughout the spatial and temporal spectrum. Group 4 included mostly euryhaline marine species which characterized trawl samples by their abundance and occurrence: *Anchoa mitchilli*, *Micropogonias undulatus*, *Trinectes maculatus*, and *Leiostomus xanthurus*. A two-way table was prepared from the original data matrix to simultaneously display the results of both normal and inverse analyses (**Table 6**).

Reciprocal averaging of trawl samples using presence-absence data showed good agreement with the normal cluster analysis as the order along Axis 1 appeared related to season (**Figure 10**). Axis 1 explained 35.6 % of the variance among the samples. Axis 2 explained 14.7 % of the variance in the samples and was loosely associated with some spatial-temporal component; samples collected during April extended higher along Axis 2 than did the other seasonal samples.

3.1.6 Major Species

The most abundant species in all collections was *Anchoa mitchilli*, a schooling planktivorous form that spends its entire life cycle within the river. *A. mitchilli* was represented mostly by juveniles and post larvae during the September sample. *Micropogonias undulatus* was the most numerous estuarine/marine species in the trawl collections. Age-0 fish spawned offshore enter the river during late winter and early spring, remain for 6 months to a year, then migrate back offshore. *M. undulatus* was most abundant in the January and April samples.

3.2 SEINE

3.2.1 Collection Summary

Seine hauls contributed 53 species and 6,964 individuals totaling 42.85 kg. Samples were numerically dominated by *Anchoa mitchilli*, *Lucania parva*, and *Menidia beryllina*; together these species contributed 46% of the total numbers taken. **Table 7** provides the rank order of abundance for all species collected in 84 seine hauls during the survey. Highest total numbers were taken in April (2,009) and September (1,577). Total numbers in July samples were lower (1,157), while January was much lower (841). Station 1 produced the highest total abundance (2,101), followed by Stations 2 (1,873) and 3 (1,610). Station 4, sampled only in April and July, yielded 1,380 individuals. Mean numbers of

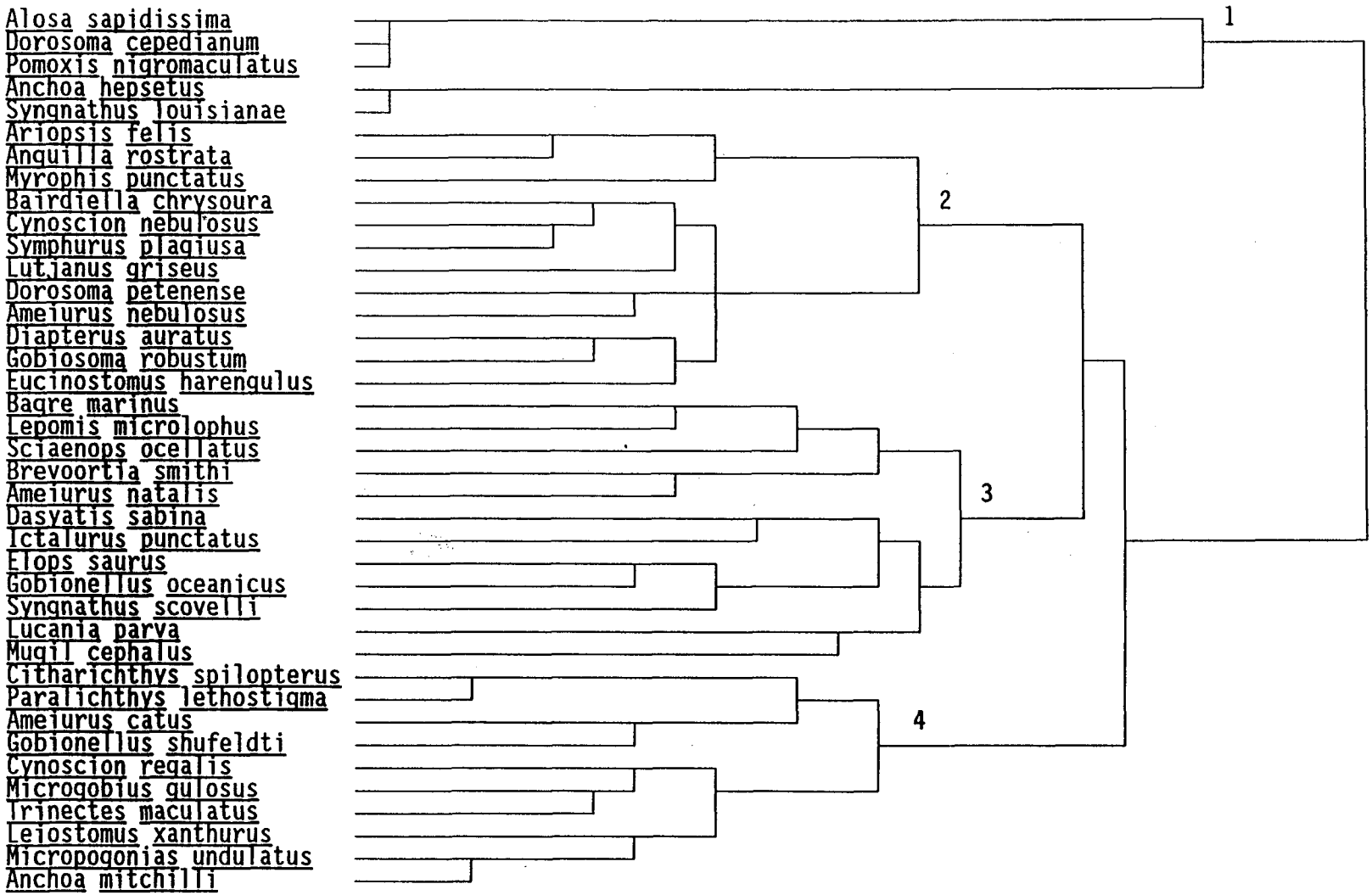

Figure 9. Inverse dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity among fish species in trawl samples.

Table 6. Two-way table of the samples by species matrix ordered by Bray-Curtis clustering. Values in the cells of the table are total abundances from trawl samples (n=10). The analysis was performed on $\log_{10}$ transformed data.

Survey	1	4	3	4	1	2	2	2	2	2	4	2	3	3	3	3	3	3	3	4	4	4	4	4	1	1	1	1
Station	1	1	3	3	1	1	2	1	3	2	3	3	1	2	3	4	1	2	4	1	4	4	2	2	2	2	3	3
Species	D	D	D	D	N	N	N	D	D	D	N	N	D	D	N	D	N	N	N	N	D	N	D	N	D	N	N	D
Alosa sapidissima	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
Dorosoma cepedianum	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
Pomoxis nigromaculatus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
Anchoa hepsetus	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Syngnathus louisianae	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ariopsis felis	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1	---	---
Anguilla rostrata	---	---	---	---	2	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
Myrophis punctatus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
Bairdiella chrysoura	---	3	---	---	18	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	1	2	7	---
Cynoscion nebulosus	---	---	---	---	9	2	1	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	1	3	4	7
Symphurus plagiusa	---	---	---	---	1	6	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	2	14	---
Lutjanus griseus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	5	2	---
Dorosoma petenense	1	---	---	---	---	1	2	---	1	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	1	12	---
Ameiurus nebulosus	3	---	---	---	2	---	1	---	1	---	1	3	1	1	---	---	1	1	---	---	---	---	---	---	2	2	2	1
Diapterus auratus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	2	4	12
Gobiosoma robustum	---	---	3	---	---	---	1	---	---	---	---	1	---	---	---	---	1	---	1	1	1	---	---	---	---	2	1	14
Eucinostomus harengulus	2	---	---	---	4	21	---	9	---	---	---	---	---	1	---	---	1	---	---	---	---	2	---	---	---	2	1	17
Bagre marinus	7	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---	---	---	---
Lepomis microlophus	---	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	2	---	---	---	---
Sciaenops ocellatus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	1
Brevoortia smithi	---	3	---	---	1	---	2	---	---	---	---	---	---	---	---	---	---	1	---	---	---	3	---	---	---	---	---	---
Ameiurus natalis	---	6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dasyatis sabina	---	---	---	---	---	---	1	---	---	---	---	---	2	---	2	---	---	---	1	---	---	---	---	---	1	---	---	1
Ictalurus punctatus	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Elops saurus	---	---	2	2	---	---	---	---	---	---	---	---	7	2	---	1	---	---	1	---	---	---	---	---	---	---	---	---
Gobionellus oceanicus	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---	1	---	---	---	---	---	---	---	---	---	---	---	---
Syngnathus scovelli	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---	1	---	---	---	---	---	---	---	---	---	---	2	---
Lucania parva	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mugil cephalus	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Citharichthys spilopterus	1	3	2	---	1	---	---	---	---	---	---	---	7	8	4	2	18	13	1	4	1	1	---	---	---	---	---	---
Paralichthys lethostigma	2	1	5	---	---	---	---	---	---	---	---	---	20	3	6	3	13	4	2	2	---	2	---	---	---	1	1	1
Ameiurus catus	---	---	---	---	---	2	1	---	---	---	---	---	---	---	1	---	1	---	1	---	1	2	102	65	---	---	---	---
Gobionellus shufeldti	---	1	---	---	---	2	7	---	---	---	---	---	1	---	---	2	5	3	---	5	7	1	7	6	10	---	1	11
Cynoscion regalis	9	8	---	---	109	9	17	---	3	3	5	---	---	---	---	---	---	---	---	9	1	1	---	---	11	59	2	2
Microgobius gulosus	1	---	---	1	3	4	3	---	---	---	1	4	---	3	3	---	3	---	1	---	1	---	1	2	11	29	268	131
Trinectes maculatus	1	1	---	1	3	19	17	3	1	4	8	10	7	10	1	1	15	7	1	19	20	53	18	48	9	20	33	6
Leiostomus xanthurus	---	13	---	---	28	3	---	---	---	1	13	1	98	123	180	200	25	2	13	29	99	---	2	---	5	16	5	---
Micropogonias undulatus	13	176	132	12	232	596	809	560	747	215	223	631	407	3559	1339	2164	2241	1763	542	224	404	235	106	91	28	73	5	---
Anchoa mitchilli	2370	4586	380	389	88	79	479	154	2333	342	95	246	429	77	59	200	62	71	12	90	53	98	2	105	5673	547	568	3146

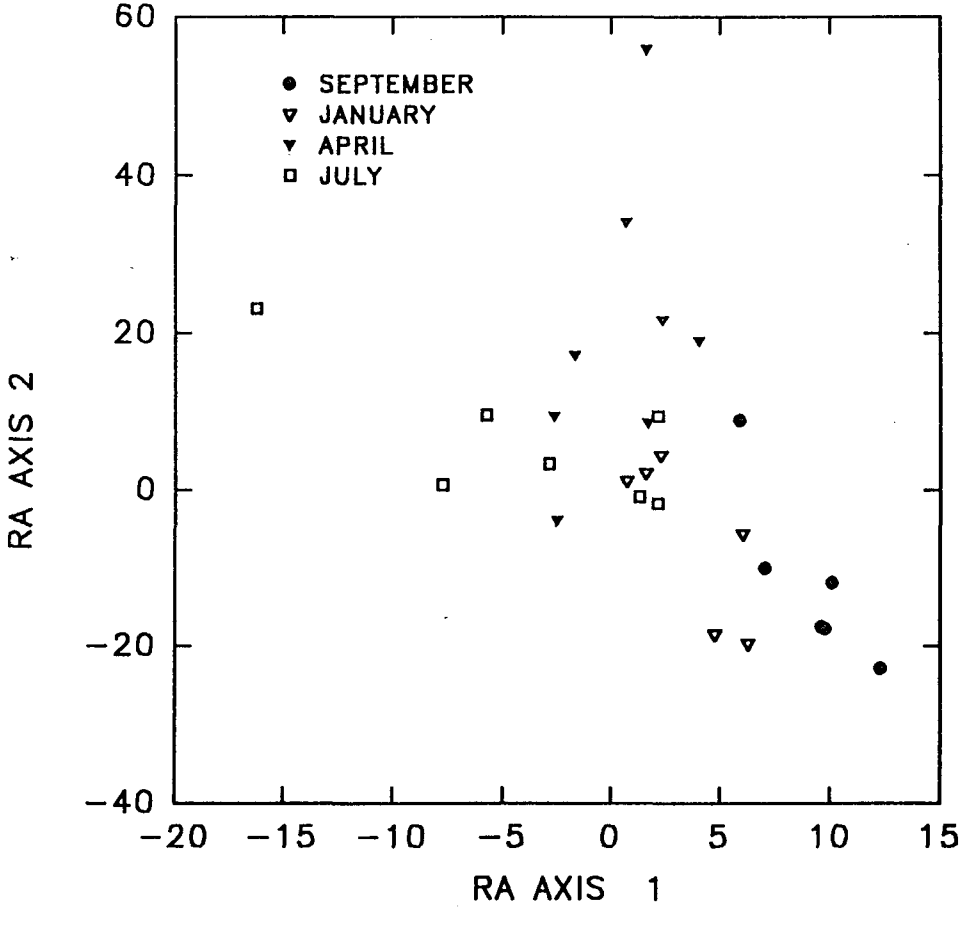

Figure 10. Reciprocal averaging ordination of trawl samples (based on species presence/absence) along Axes 1 and 2. Outliers were omitted.

Table 7. Species collected by seine at each station in September, January, April, and July. Data are totals of three hauls from each station-season combination. Day and night samples were combined.

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Anchoa mitchilli	59	---	---	2	---	62	140	66	325	67	376	214	169	9	1,489
Lucania parva	4	20	50	1	142	51	77	346	90	389	33	1	2	35	1,241
Menidia beryllina	128	100	63	11	73	12	96	30	1	54	53	1	3	13	638
Leiostomus xanthurus	55	---	---	---	---	---	136	104	2	80	15	1	---	17	410
Eucinostomus harengulus	36	1	---	93	---	---	99	48	---	69	---	---	---	39	385
Notemigonus crysoleucas	3	78	26	---	20	2	2	11	---	75	19	15	3	66	320
Lepomis macrochirus	7	7	22	2	33	21	---	3	28	107	9	13	2	29	283
Lucania goodei	---	---	211	---	---	10	---	---	21	2	---	---	---	---	244
Gambusia holbrooki	3	8	161	---	39	10	---	3	12	---	6	---	---	---	242
Fundulus seminolis	7	54	23	2	23	1	4	24	2	6	1	3	1	9	160
Lagodon rhomboides	5	---	---	16	6	---	61	31	2	24	3	---	1	10	159
Bairdiella chrysoura	127	---	---	4	---	---	---	---	---	---	21	---	2	---	154
Syngnathus scovelli	44	25	10	6	17	4	31	1	2	7	2	---	1	---	150
Lepomis microlophus	1	11	7	1	8	---	2	13	7	32	11	10	27	18	148
Micropterus salmoides	1	10	7	7	10	7	1	16	2	40	12	1	4	11	129
Trinectes maculatus	7	9	1	---	17	---	---	14	1	53	1	12	2	8	125
Micropogonias undulatus	18	---	---	22	6	---	15	6	2	1	5	3	---	---	78
Microgobius gulosus	2	---	---	1	2	---	10	13	---	33	---	---	---	3	64
Poecillia latipinna	---	12	15	---	2	---	6	2	20	---	1	---	---	---	58
Sciaenops ocellatus	4	---	---	24	6	---	12	3	2	2	---	---	---	---	53
Enneacanthus gloriosus	---	3	8	---	---	14	---	---	3	---	---	---	20	1	49
Mugil cephalus	13	19	---	---	10	---	---	1	---	2	---	2	---	---	47
Gobiosoma robustum	---	---	2	4	8	3	2	1	5	9	---	---	---	5	39
Lepomis punctatus	---	2	2	1	6	5	---	10	---	7	---	3	---	3	39
Strongylura marina	4	---	---	1	---	---	11	4	5	3	1	1	2	3	35
Ameiurus catus	---	---	---	---	---	---	---	1	---	---	2	29	---	---	32
Cynoscion nebulosus	10	4	---	2	2	---	7	1	---	---	---	---	---	---	26
Symphurus plagiusa	20	2	---	---	1	---	---	---	---	---	---	---	---	---	23
Gobionellus schufeldti	1	---	---	1	1	---	1	---	---	9	---	1	1	8	23
Heterandria formosa	---	---	12	---	---	---	---	---	2	---	1	---	---	---	15
Dorosoma petenense	12	---	---	---	---	1	---	---	---	---	---	---	---	---	13
Lepomis gulosus	1	---	2	---	1	1	---	---	---	---	---	---	1	6	12
Elops saurus	---	---	---	---	---	---	---	---	2	1	5	2	---	---	10

Table 7. (Continued).

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Lutjanus griseus	5	1	---	1	---	---	---	1	---	1	---	1	---	---	10
Ameiurus nebulosus	---	---	3	---	---	---	---	---	---	---	6	---	---	---	9
Diapterus auratus	4	---	---	---	---	---	---	1	---	---	---	---	---	2	7
Mugil curema	---	---	---	---	---	---	1	1	---	1	3	---	---	---	6
Lepomis auritus	---	---	---	---	---	---	---	---	---	---	---	3	1	2	6
Ameiurus natalis	---	---	---	---	---	---	1	---	---	---	5	---	---	---	6
Esox americanus	1	---	---	---	---	1	---	---	1	---	---	---	---	1	4
Paralichthys lethostigma	---	---	---	---	---	---	1	---	---	2	---	---	---	1	4
Lepisosteus osseus	---	---	---	---	---	---	---	---	---	---	4	---	---	---	4
Anguilla rostrata	---	---	---	---	---	---	---	---	---	1	---	---	---	2	3
Oligoplites saurus	3	---	---	---	---	---	---	---	---	---	---	---	---	---	3
Chasmodes bosquianus	---	---	---	---	---	---	1	---	---	---	---	---	---	---	1
Syngnathus louisianae	1	---	---	---	---	---	---	---	---	---	---	---	---	---	1
Citharichthys spilopterus	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1
Dorosoma cepedianum	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1
Oreochromis aurea	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1
Notropis maculatus	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1
Eucinostomus melanopterus	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1
Labidesthes vanhyningi	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1
Ictalurus punctatus	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1
TOTAL INDIVIDUALS	**586**	**366**	**625**	**202**	**434**	**205**	**717**	**755**	**537**	**1,077**	**596**	**318**	**243**	**303**	**6,964**
TOTAL SPECIES	**30**	**18**	**18**	**20**	**23**	**16**	**23**	**27**	**22**	**27**	**25**	**21**	**18**	**26**	**53**

species, individuals, and weight per seine haul during each season and at each station are shown in **Figure 11**.

3.2.2 Analysis of Variance

The three-way ANOVA revealed significant interactions (season and day-night [$F=5.49$, df 3/6, $P<0.0373$]), for mean species number per haul, and no significant differences for mean number of individuals or weights.

3.2.3 Power Analysis

Samples sizes required to detect specified percent changes in the variables (mean species, individuals, and weights per seine haul) at given levels of power ($1-\beta$) are given in **Figure 12**. These analyses indicate that for six hauls at a power of 0.50, the detectable change in number of species per haul is 6.4. Fifty hauls would be required to detect a 50% change in the number of individuals per haul at $\beta=0.50$. Greater than 50 hauls would be required to detect a 50% change in mean weight per haul.

3.2.4 Community Measures

Total species per station was highest at Station 1 (42) and lowest at Station 3 (30); Station 2 produced 33 species while Station 4 had 34 species after only two sampling periods. Total species summed within seasons (using Stations 1 through 3 only) were very similar: 37 in September, 32 in January, 36 in April, and 35 in July. Species diversity (H') did not show particular trends with respect to stations or seasons but was consistently higher across the stations within seasons than the same periods sampled by trawl (**Figure 13**). Rarefaction curves of $E(S_n)$ generated for combined data from each station are given in **Figure 14**. The curves show that species richness in day samples was highest at Stations 1 and 2, followed by Station 4 and Station 3. Night samples showed much higher richness for Station 1, followed by Stations 2, 4, and 3, which were all very similar with respect to expected numbers of species in size-adjusted samples. Mean abundances of the top three species in the samples are given in **Figure 15**.

3.2.5 Classification and Ordination

Similarity analysis of seine samples indicated a greater spatial influence on the formation of four primary groups (**Figure 16**). The first group (Group A) consisted entirely of samples from Station 1. All samples collected from Station 4 clustered with April samples from Station 2 to form the second group (Group B). Group C included samples from Stations 2 and 3 (September and January). The final group (Group D) exhibited more seasonal influence as it included samples from Stations 1, 2, and 3 collected only during July. The inverse analysis generated two major species groups, Group 1 and Group 2, which were each further divided into subgroups (**Figure 17**). Subgroup 1a was primarily a

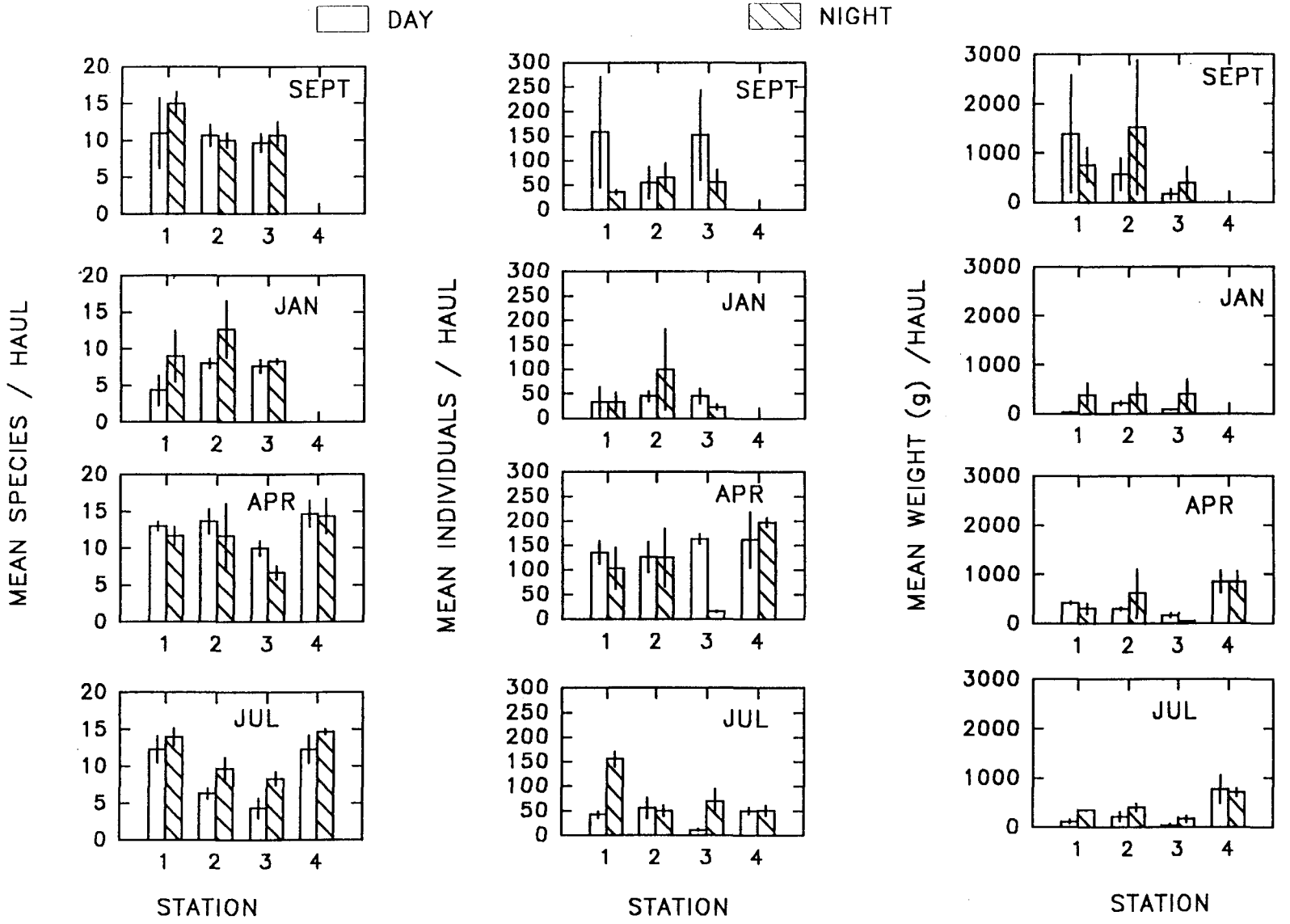

Figure 11. Mean number of species, number of individuals, and weight of fishes collected in three seine hauls from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error.

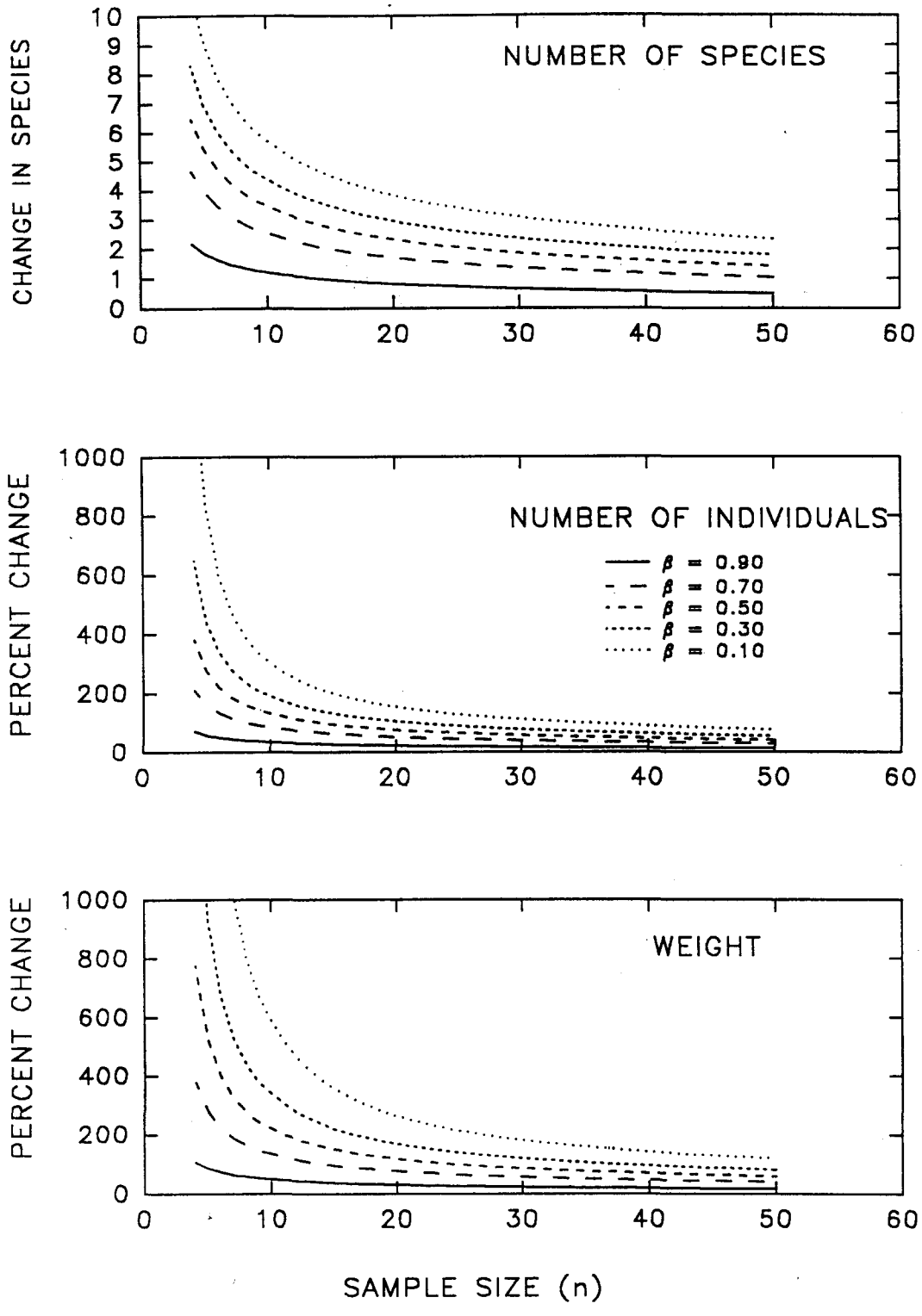

Figure 12. Detectable change in number of species and percent detectable change in mean number of individuals, and weight as functions of sample size (n) and degrees of power (1-β) at $\alpha = 0.05$ for seine samples.

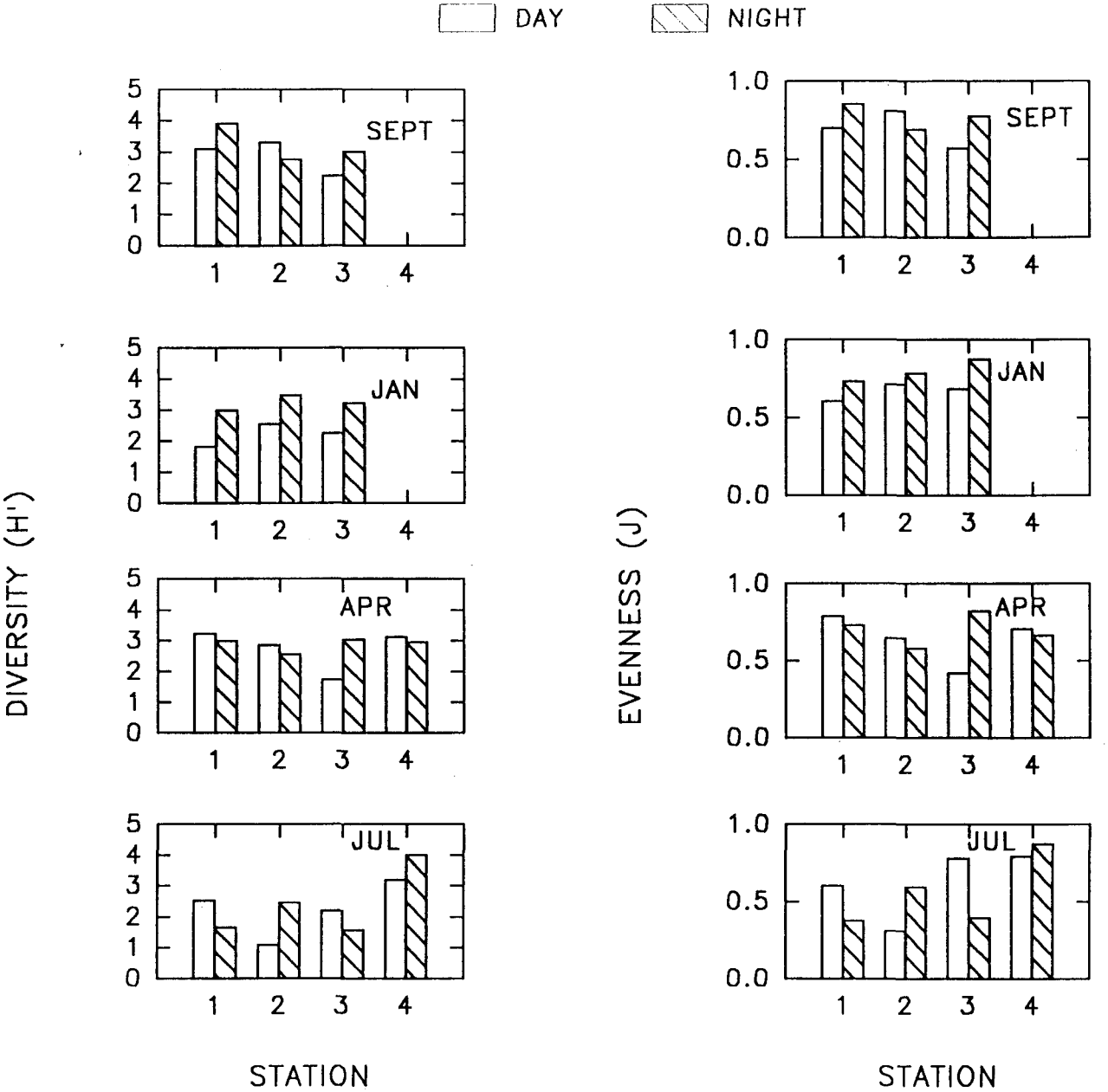

Figure 13. Diversity (H') and evenness (J) of fishes collected in three seine hauls at each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples.

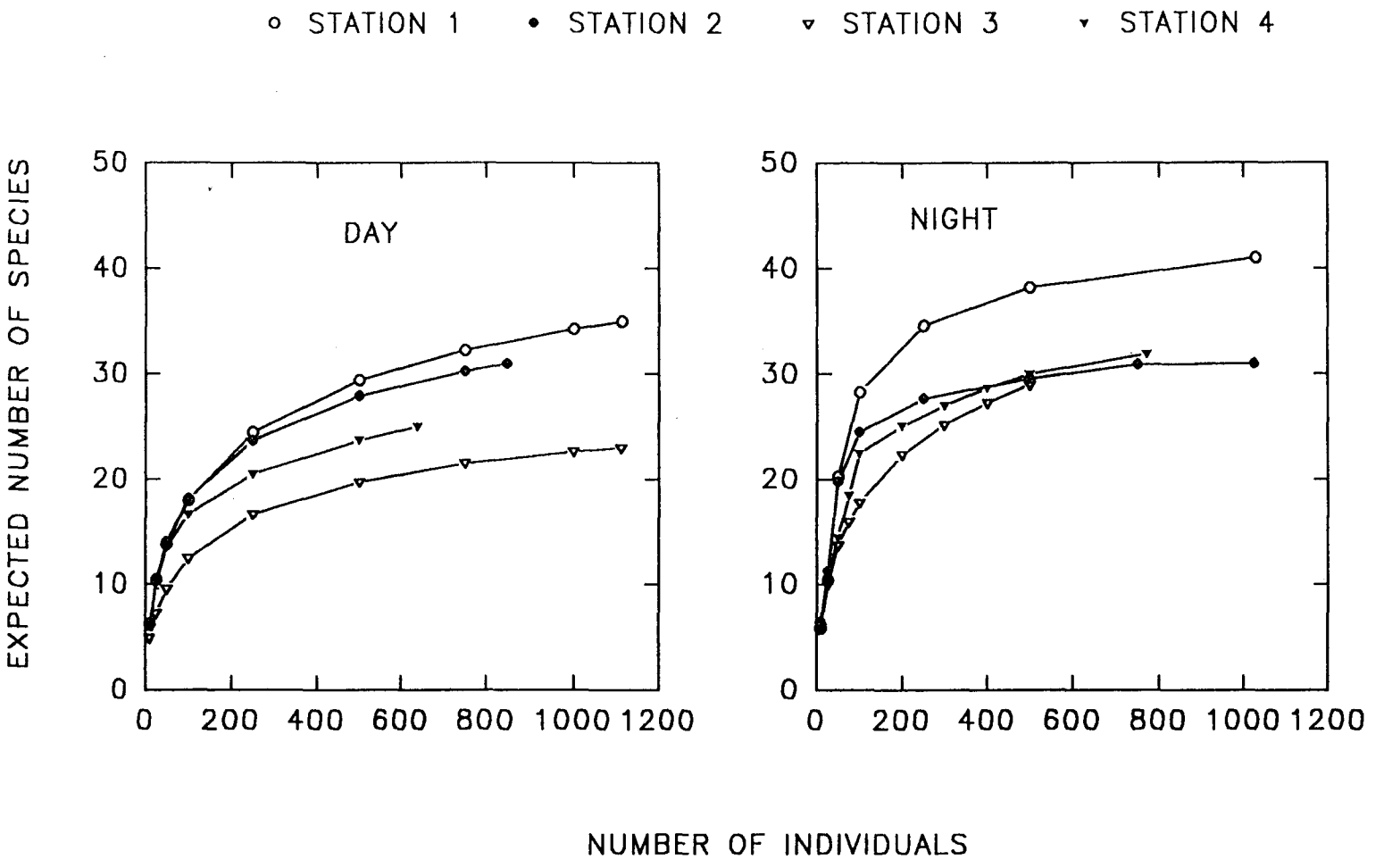

Figure 14. Rarefaction plots of expected number of species $E(S_n)$ per increasing sample size for day and night seine collections at each station. Data from all seasons were summed within stations.

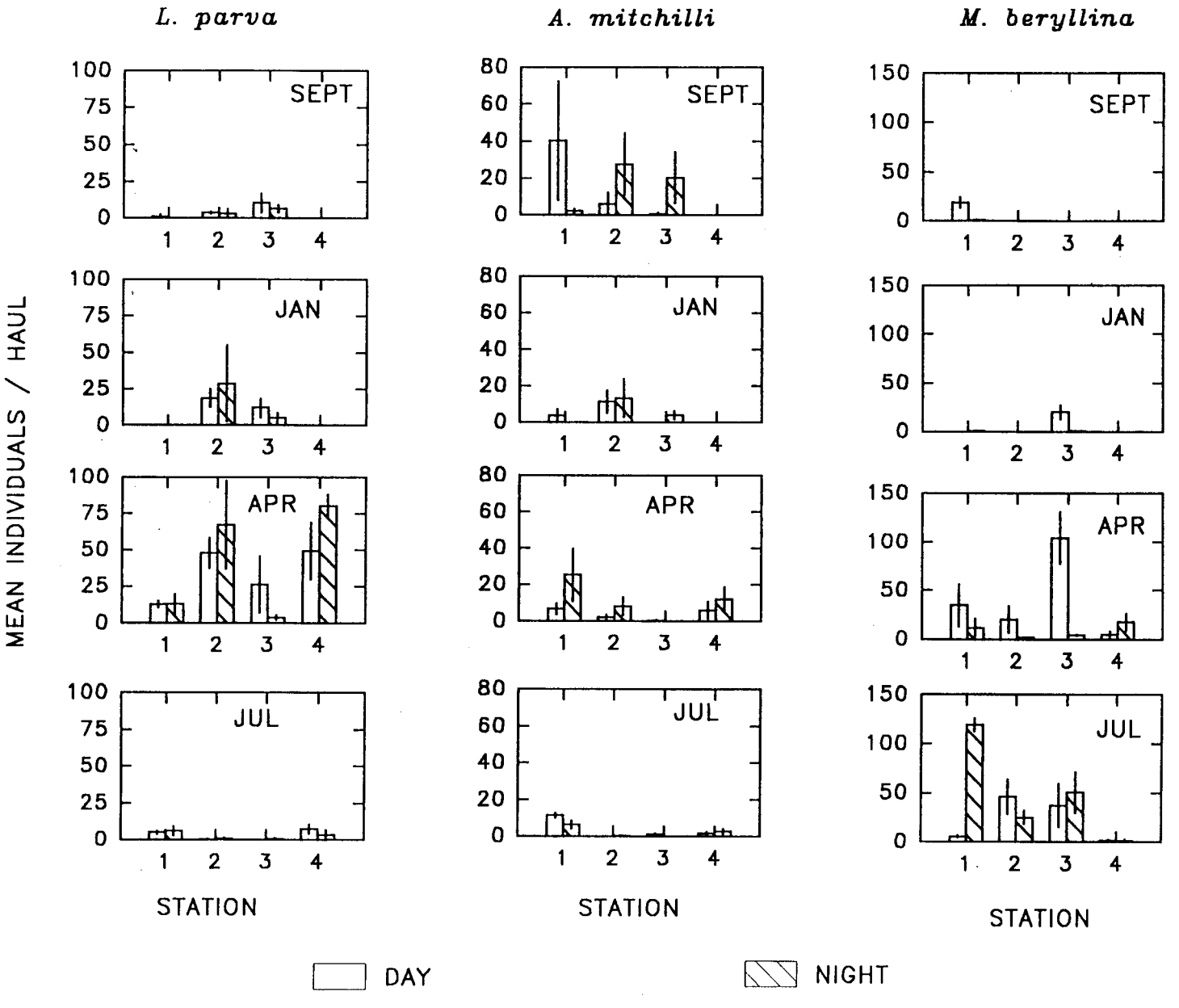

Figure 15. Mean numbers of *Lucania parva*, *Anchoa mitchilli*, and *Menidia beryllina* collected in three seine hauls taken day and night from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error.

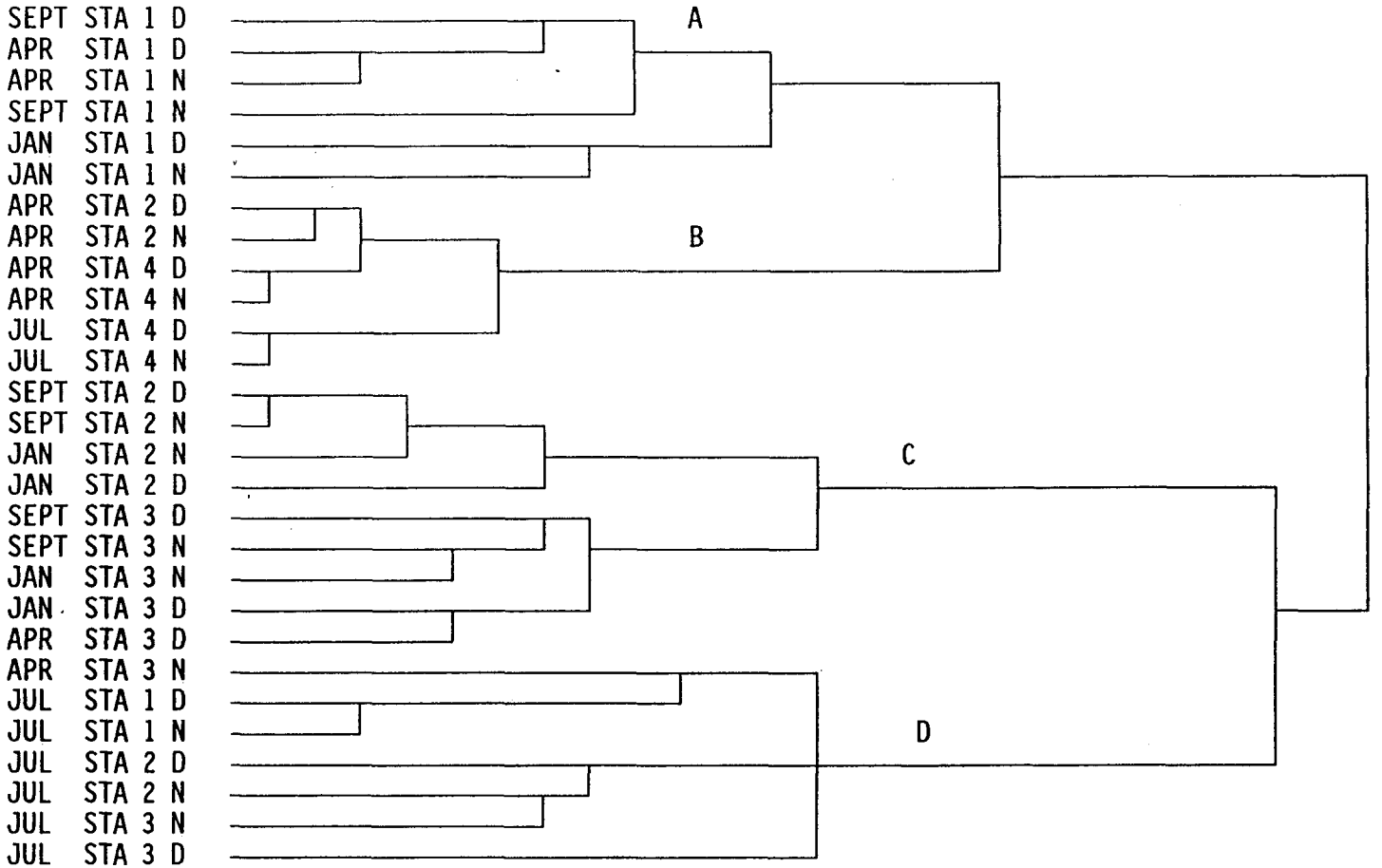

Figure 16. Normal dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity between trawl samples (station/season/time) taken in the study area.

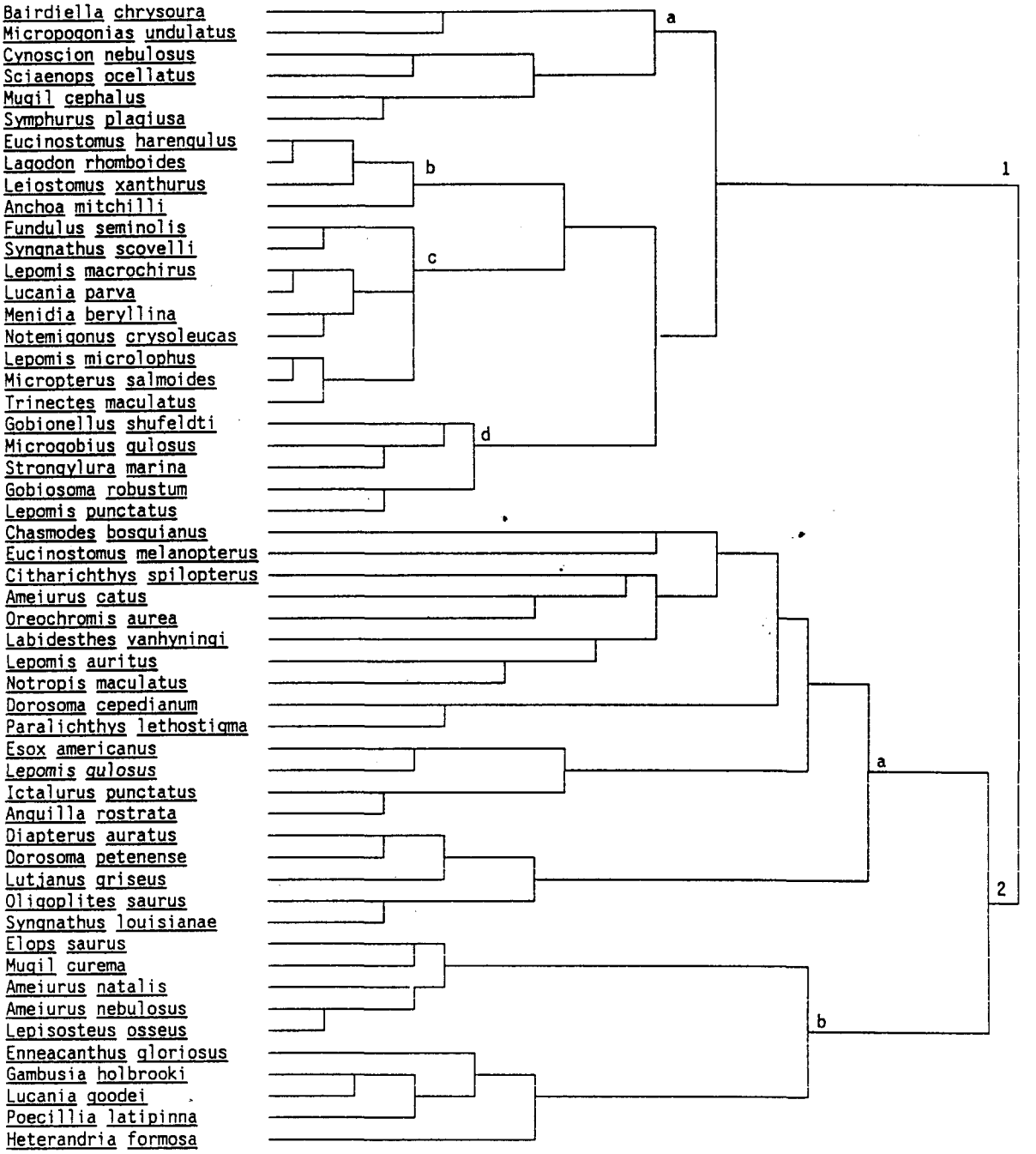

Figure 17. Inverse dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity among fish species in seine samples.

euryhaline marine group comprising *Bairdiella chrysoura*, *Micropogonias undulatus*, *Cynoscion nebulosus*, *Sciaenops ocellatus*, *Mugil cephalus*, and *Symphurus plagiusa* and was essentially confined to the more saline Stations 1 and 2. Another euryhaline group (Subgroup 1b) consisting of *Eucinostomus harengulus*, *Lagodon rhomboides*, *Leiostomus xanthurus*, and *Anchoa mitchilli* was most common at Stations 1 and 4 but was found at all stations. Subgroups 1c and 1d were the most important in terms of explaining the assemblage. A largely freshwater cluster (Subgroup 1c) comprising *Fundulus seminolis*, *Syngnathus scovelli*, *Lepomis macrochirus*, *Lucania parva*, *Menidia beryllina*, *Notemigonus crysoleucas*, *Lepomis microlophus*, *Micropterus salmoides*, and *Trinectes maculatus* was taken at virtually all station/season/time combinations. Subgroup 1d included *Gobionellus shufeldti*, *Microgobius gulosus*, and *Gobiosoma robustum* (all benthic dwellers), *Strongylura marina*, and *Lepomis punctatus*. The first three species are naturally related while the final two species are undoubtedly artifacts of the analysis. Members of Group 2 were taken in lesser numbers but contributed to the overall dynamics of the nearshore assemblage. Subgroup 2a included 24 sporadically-occurring species from *Chasmodes bosquianus* to *Syngnathus louisianae* (**Figure 17**). Although Subgroup 2b included two euryhaline marine species, *Elops saurus* and *Mugil curema*, it was primarily composed of freshwater species that are commonly associated with dense submerged vegetation including *Ameiurus natalis*, *Ameiurus nebulosus*, *Lepisosteus osseus*, *Enneacanthus gloriosus*, *Gambusia holbrooki*, *Lucania goodei*, *Poecilia latipinna*, and *Heterandria formosa*. The two-way arrangement of the data matrix for seine samples is shown in **Table 8**.

Analysis of seine samples by reciprocal averaging did not reveal much about the structure of presence/absence data. Axis 1 accounted for 22.8% of the variance among samples, and Axis 2 explained 11.2 % of the variance. An ordination of reciprocal averaging sample scores projected on Axes 1 and 2 is given in **Figure 18**.

3.2.6 Major Species

Anchoa mitchilli was the numerically dominant species in seine hauls, representing 22% of the catch and including both adults and juveniles. This species was abundant during April and July, and less numerous in September and January. In trawl collections, *A. mitchilli* was least abundant in April and January; the high numbers observed in April seine hauls suggest an inshore migration.

Lucania parva was nearly as abundant as *A. mitchilli* (18%) and was also represented by adults and juveniles. Strictly a brackish-freshwater shoreline species, this small killifish was most abundant in cool-water seasons: September (n=74), January (n=194), April (n=513), and July (n=36). Total abundance by station was highest at Station 4 (n=424) despite only two sampling seasons, and least abundant at Station 1 (n=115). *L. parva* prefers sandy bottom (McLane,

Table 8. A two-way table of seine samples by species matrix ordered according to Bray-Curtis clustering. Values in the cells of the table are total abundances from seine samples (n=3).

Species	Survey	1	3	3	1	2	2	3	3	3	3	4	4	1	1	2	2	1	1	2	2	3	3	4	4	4	4	4	4
	Station	1	1	1	1	1	1	2	2	4	4	4	4	2	2	2	2	3	3	3	3	3	3	1	1	2	2	3	3
		D	D	N	N	D	N	D	N	D	N	D	N	D	N	N	D	D	N	N	D	D	N	D	N	D	N	N	D
Bairdiella chrysoura		127	---	---	---	---	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13	8	---	---	---	2
Micropogonias undulatus		18	---	15	---	---	22	2	4	---	1	---	---	---	---	6	---	---	---	---	---	---	2	1	4	2	1	---	---
Cynoscion nebulosus		7	6	1	3	---	2	---	1	---	---	---	---	2	2	1	1	---	---	---	---	---	---	---	---	---	---	---	---
Sciaenops ocellatus		---	10	2	4	12	12	2	1	---	2	---	---	---	---	3	3	---	---	---	---	1	1	---	---	---	---	---	---
Mugil cephalus		---	---	---	13	---	---	1	---	---	2	---	---	16	3	10	---	---	---	---	---	---	---	---	---	1	1	---	---
Symphurus plagiusa		---	---	---	20	---	---	---	---	---	---	---	---	1	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---
Eucinostomus harengulus		26	78	21	10	57	36	31	17	48	21	24	15	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lagodon rhomboides		2	49	12	3	12	4	21	10	16	8	5	5	---	---	6	---	---	---	---	---	2	---	1	2	---	---	1	---
Leiostomus xanthurus		46	57	79	9	---	---	48	56	---	80	---	17	---	---	---	---	---	---	---	---	---	2	4	11	1	---	---	---
Anchoa mitchilli		56	104	36	3	---	2	61	5	14	53	5	4	---	---	---	---	---	---	2	60	312	13	17	359	139	75	152	17
Fundulus seminolis		3	4	---	4	---	2	14	10	6	---	6	3	39	15	4	19	13	10	---	1	1	1	1	---	---	3	1	---
Syngnathus scovelli		31	20	11	13	3	3	---	1	6	1	---	---	18	7	13	4	7	3	---	4	1	1	---	2	---	---	1	---
Lepomis macrochirus		6	---	---	1	2	---	3	---	48	59	16	13	3	4	26	7	14	8	10	11	23	5	8	1	3	10	2	---
Lucania parva		4	38	39	---	---	1	144	202	148	241	22	13	11	9	86	56	31	19	15	36	79	11	15	18	1	---	2	---
Menidia beryllina		121	20	76	7	11	---	6	24	18	36	5	8	18	82	39	34	2	61	12	---	1	---	34	19	---	1	---	3
Notemigonus crysoleucas		3	2	---	---	---	---	4	7	71	4	39	27	32	46	20	---	3	23	2	---	---	---	5	14	14	1	3	---
Lepomis microlophus		---	1	1	1	---	1	6	7	20	12	11	7	2	9	4	4	1	6	---	---	4	3	7	4	1	9	21	6
Micropterus salmoides		---	---	1	1	---	7	11	5	25	15	3	8	7	3	6	4	7	---	5	2	1	1	8	4	---	1	1	3
Trinectes maculatus		2	---	---	5	---	---	3	11	31	22	4	4	2	7	17	---	1	---	---	---	---	1	---	1	---	12	2	---
Gobionellus shufeldti		---	---	1	1	---	1	---	---	9	---	4	4	---	---	1	---	---	---	---	---	---	---	---	---	---	1	1	---
Microgobius gulosus		---	2	8	2	1	---	11	2	12	21	1	2	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---
Strongylura marina		2	8	3	2	---	1	3	1	2	1	---	3	---	---	---	---	---	---	---	---	5	---	---	1	---	1	1	1
Gobiosoma robustum		---	---	2	---	2	2	---	1	4	5	1	4	---	---	8	---	---	2	---	3	---	5	---	---	---	---	---	---
Lepomis punctatus		---	---	---	---	---	1	1	9	3	4	1	2	1	1	5	1	1	1	4	1	---	---	---	---	2	1	---	---
Chasmodes bosquianus		---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Eucinostomus melanopterus		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
Citharichthys spilopterus		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
Ameiurus catus		---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---	1	28	---	---
Oreochromis aurea		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
Labidesthes vanhyningi		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---
Lepomis auritus		---	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	2	1	1	---
Notropis maculatus		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---
Dorosoma cepedianum		---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 8. (Continued).

Species	Survey	1	3	3	1	2	2	3	3	3	3	4	4	1	1	2	2	1	1	2	2	3	3	4	4	4	4	4	4
	Station	1	1	1	1	1	1	2	2	4	4	4	4	2	2	2	2	3	3	3	3	3	3	1	1	2	2	3	3
		D	D	N	N	D	N	D	N	D	N	D	N	D	N	N	D	D	N	N	D	D	N	D	N	D	N	N	D
Paralichthys lethostigma		---	---	1	---	---	---	---	---	1	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Esox americanus		---	---	---	1	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---
Lepomis gulosus		---	---	---	1	---	---	---	---	---	---	---	6	---	---	---	1	---	2	1	---	---	---	---	---	---	---	1	---
Ictalurus punctatus		---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Anguilla rostrata		---	---	---	---	---	---	---	---	---	1	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Diapterus auratus		3	---	---	1	---	---	---	1	---	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dorosoma petenense		11	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---
Lutjanus griseus		4	---	---	1	---	1	1	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---
Oligoplites saurus		1	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Syngnathus louisianae		1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Elops saurus		---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	2	---	1	4	---	2	---	---
Mugil curema		---	---	1	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	---	---	---	---
Ameiurus natalis		---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5	---	---	---	---
Ameiurus nebulosus		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	---	---	---	---	3	3	---	---	---	---
Lepisosteus osseus		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	3	---	---	---	---
Enneacanthus gloriosus		---	---	---	---	---	---	---	---	---	---	---	1	3	---	---	---	1	7	6	8	3	---	---	---	---	---	18	2
Gambusia holbrooki		3	---	---	---	---	---	3	---	---	---	---	---	7	1	39	---	143	18	7	3	12	---	5	1	---	---	---	---
Lucania goodei		---	---	---	---	---	---	---	---	1	1	---	---	---	---	---	---	208	3	3	7	21	---	---	---	---	---	---	---
Poecilia latipinna		---	6	---	---	---	---	2	---	---	---	---	---	3	9	2	---	13	2	---	---	19	1	1	---	---	---	---	---
Heterandria formosa		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12	---	---	---	2	---	---	1	---	---	---	---

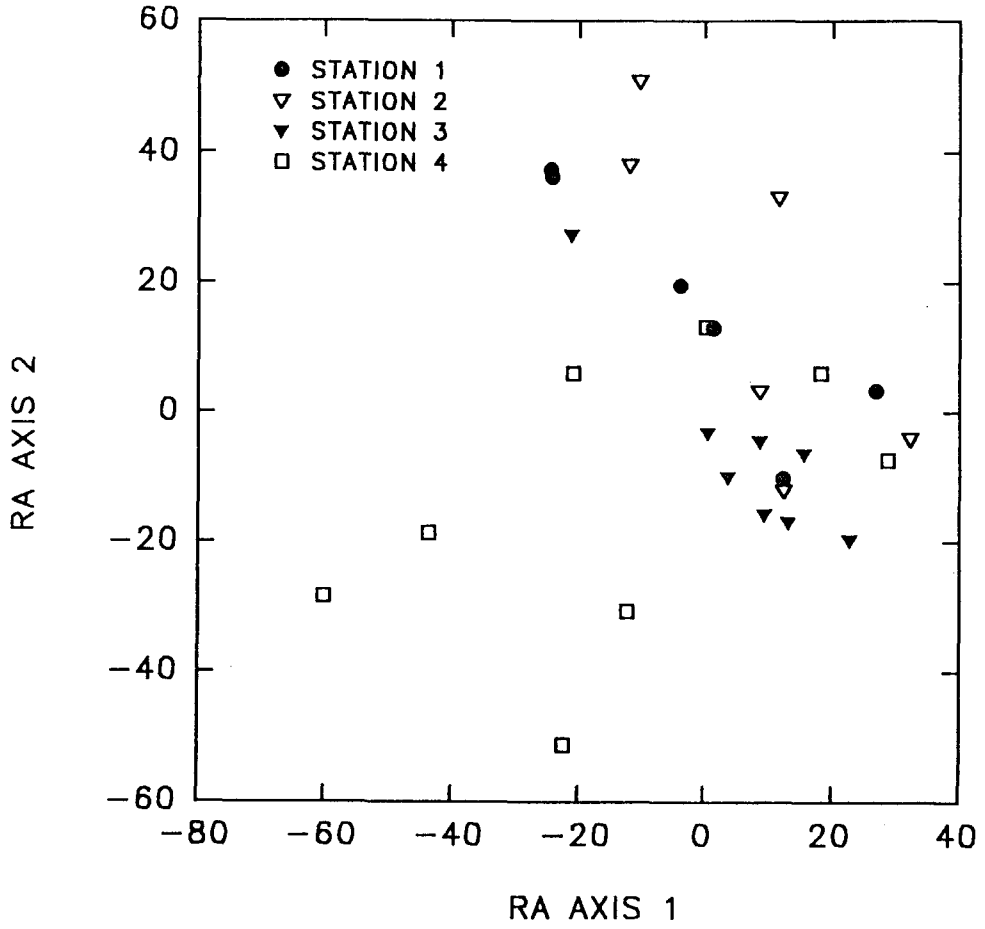

Figure 18. Reciprocal averaging ordination of seine samples (based on species presence/absence) along Axes 1 and 2. Outliers were omitted.

1955); this preference might explain its abundance at Stations 4 and 2 which both have sandy bottom.

Menidia beryllina, a schooling brackish-freshwater species confined to nearshore shallows, represented 9% of the catch and was most abundant in September (n=291) and April (n=127). The greatest numbers of individuals were produced at Stations 1 (n=288) and 2 (n=204) while Station 3 produced fewest (n=79). McLane (1955) states this species prefers sandy bottom.

Young of *Leiostomus xanthurus* comprised 6% of the catch. This euryhaline marine species is spawned in the ocean, then enters the river as an early juvenile. Their numbers peaked in April (n=242), dropped to 16 in July, while September yielded 55 individuals; none were collected in January. The April peak is probably the result of Age-0 fishes immigrating inshore. The few remaining in July and September are stragglers leaving the river; by January, they are out to sea. *Leiostomus xanthurus* was most abundant at Stations 1 and 2, and nearly absent at Station 3.

3.3 ELECTROSHOCKER

3.3.1 Collection Summary

Electroshocking produced 56 species and 7,871 individuals weighing 1,061.0 kg for all samples combined. The rank order of abundance of all species collected by this method are given in **Table 9**. Station 2 yielded the greatest total number of individuals (n=2,584), followed by Station 3 (n=1,846) and Station 1 (n=1,996). Station 4 (sampled only twice) produced 1,445 individuals. Abundances (for Stations 1, 2, and 3) by season were greater in January (n=1,969) and April (n=2,030), and less in July (n=1,005) and September (n=1,422). Total species per station were as follows: Station 1 (39), Station 2 (43), Station 3 (37), and Station 4 (31). Total species collected by season were as follows: September (42), January (38), April (40), and July (35). Mean numbers of species per sample were similar during all four sampling periods. Average numbers of individuals and weights per transect were highest during April (**Figure 19**).

3.3.2 Analysis of Variance

The two-way ANOVA, performed on night samples only, detected significant interaction between station and season for numbers of species ($F=6.56$, $df=6/24$, $p<0.0003$) and number of individuals ($F=5.65$, $df=6/24$, $p<0.0009$).

3.3.3 Power Analysis

Power analysis indicated that three 10-min electroshocking samples will detect a change of approximately three species between two samples with $\beta=0.50$

Table 9. Species collected during 10-min electroshocking transects at each station in September, January, April, and July. Data are totals of transects (n=3) summed within stations.

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Lepomis macrochirus	10	59	43	18	47	72	42	129	115	207	25	54	59	142	1,022
Lepomis microlophus	24	47	18	53	122	60	56	96	51	161	14	45	41	57	845
Mugil cephalus	22	58	25	17	235	26	23	17	19	76	164	6	43	56	787
Micropterus salmoides	45	55	73	43	89	47	41	71	52	47	19	33	29	38	682
Eucinostomus harengulus	6	7	---	103	138	2	158	145	9	39	11	---	---	8	626
Leiostomus xanthurus	31	15	---	6	31	13	180	90	9	17	60	1	2	34	489
Lepomis punctatus	7	55	19	12	83	50	6	42	56	28	3	19	15	18	413
Anchoa mitchilli	1	---	---	3	18	1	43	57	11	145	57	13	18	28	395
Notemigonus crysoleucas	9	42	53	7	17	67	6	40	55	21	5	8	26	11	367
Lepomis gulosus	4	11	37	5	31	111	---	5	55	10	---	4	18	1	292
Lepomis auritus	1	1	---	4	3	2	18	14	3	127	6	6	1	43	229
Micropogonias undulatus	58	20	20	9	14	---	50	12	1	---	5	2	---	---	191
Lagodon rhomboides	64	44	1	---	---	---	20	18	1	2	27	---	---	4	181
Diapterus auratus	---	1	---	---	121	---	7	9	---	35	---	---	1	4	178
Ameiurus nebulosus	19	23	53	---	---	9	1	8	19	6	5	7	10	2	162
Fundulus seminolis	4	8	11	6	28	45	6	12	17	---	4	7	10	3	161
Brevoortia smithi	1	---	89	---	---	---	---	---	---	---	---	---	---	---	90
Erimyzon sucetta	---	2	24	---	1	24	---	---	20	---	---	---	12	---	83
Cynoscion nebulosus	15	19	---	14	12	1	16	2	---	---	---	---	---	---	79
Lepisosteus platyrhincus	6	19	14	---	1	13	---	4	5	3	---	7	6	---	78
Gambusia holbrooki	---	---	52	---	4	---	2	3	1	6	---	---	---	2	70
Labidesthes vanhyningi	6	---	---	4	18	5	---	---	6	3	13	---	---	3	58
Sciaenops ocellatus	7	4	---	1	7	---	27	---	---	---	6	---	---	---	52
Strongylura marina	---	---	2	3	---	17	4	1	8	1	2	---	3	9	50
Anguilla rostrata	3	3	2	2	8	4	1	1	3	3	6	1	7	2	46
Ameiurus catus	4	4	---	2	2	5	---	---	1	4	2	8	---	4	36
Esox niger	---	---	6	---	---	11	---	---	5	1	---	---	4	---	27
Lutjanus griseus	1	5	---	---	1	---	1	1	---	3	6	3	---	5	26
Trinectes maculatus	---	4	---	---	---	---	2	1	---	10	---	5	---	3	25
Paralichthys lethostigma	---	2	---	---	1	---	---	---	3	2	1	6	2	2	19
Dorosoma petenense	1	---	---	8	7	1	---	---	---	---	---	---	---	---	17
Ameiurus natalis	---	---	4	---	1	9	---	---	---	---	---	---	1	---	15
Lepisosteus osseus	---	---	1	---	---	1	---	1	1	2	3	2	---	---	11
Bairdiella chrysoura	---	---	---	---	---	---	2	---	---	---	8	---	---	---	10

Table 9. (Continued).

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Poecillia latipinna	---	---	5	---	---	---	1	---	1	---	---	---	---	---	7
Amia calva	---	2	1	---	2	1	---	---	---	---	---	---	---	---	6
Elops saurus	---	1	1	1	---	---	---	---	---	---	2	---	---	---	5
Oreochromis aurea	---	---	---	---	---	4	---	1	---	---	---	---	---	---	5
Lucania goodei	---	---	1	---	---	1	---	1	---	---	---	1	1	---	5
Lepomis marginatus	---	---	2	---	---	---	---	2	---	---	---	---	---	---	4
Gobiosoma bosci	---	---	---	---	---	---	2	---	---	---	---	---	---	1	3
Dormitator maculatus	---	1	---	---	1	---	---	---	---	---	---	1	---	---	3
Archosargus probatocephalus	---	---	---	---	---	---	---	1	---	---	2	---	---	---	3
Heterandria formosa	---	---	---	---	---	---	---	---	---	3	---	---	---	---	3
Syngnathus scovelli	---	2	---	---	---	---	---	---	---	---	---	---	---	---	2
Etheostoma fusiforme	---	---	---	---	---	---	1	---	---	---	---	1	---	---	2
Microgobius gulosus	---	---	---	---	---	---	2	---	---	---	---	---	---	---	2
Caranx hippos	---	---	---	---	---	---	---	---	---	1	---	---	---	---	1
Aphredoderus sayanus	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1
Symphurus plagiusa	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1
Eleotris pisonis	---	1	---	---	---	---	---	---	---	---	---	---	---	---	1
Morone saxatilis x chrysops	---	---	---	---	---	---	---	---	---	1	---	---	---	---	1
Enneacanthus gloriosus	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1
Carassius auratus	---	---	---	1	---	---	---	---	---	---	---	---	---	---	1
Citharichthys spilopterus	---	1	---	---	---	---	---	---	---	---	---	---	---	---	1
Menidia beryllina	---	---	---	---	---	---	1	---	---	---	---	---	---	---	1
TOTAL INDIVIDUALS	**349**	**516**	**557**	**322**	**1,044**	**603**	**719**	**784**	**527**	**964**	**456**	**240**	**309**	**481**	**7,871**
TOTAL SPECIES	**24**	**30**	**25**	**22**	**29**	**28**	**28**	**28**	**26**	**28**	**25**	**23**	**20**	**25**	**56**

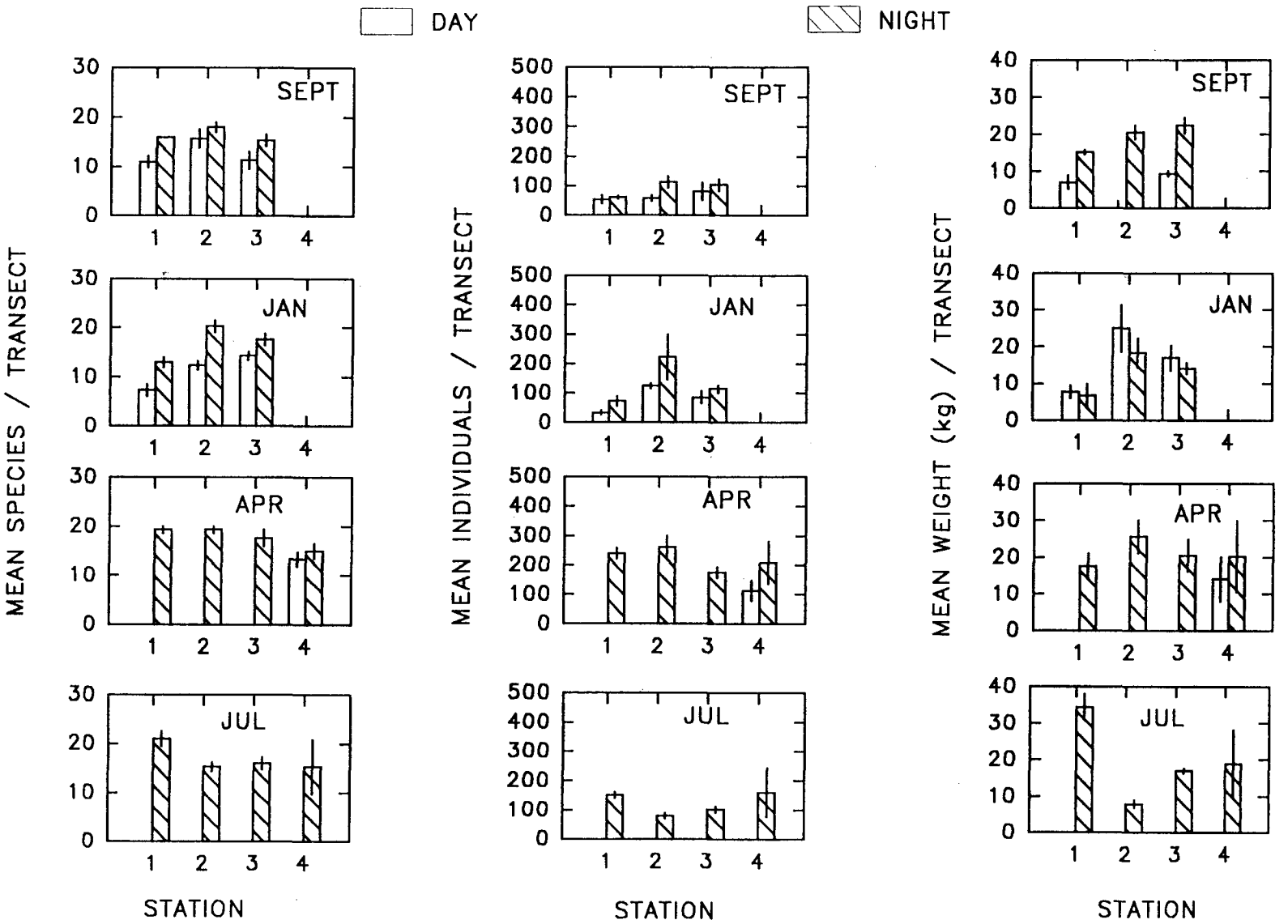

Figure 19. Mean number of species, number of individuals, and weight of fishes collected in three 10-min electroshocking transects from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error.

(**Figure 20**). A 70% change in mean numbers per transect and 80% change in mean weight per transect would be detectable from three 10-min transects at $\beta = 0.50$. Six transects at $\beta = 0.50$ would detect a 46% change in numbers and 50% change in weight.

3.3.4 Community Measures

There was little fluctuation in diversity or evenness values across sites and seasons. Station 2 generally showed the highest values of diversity (**Figure 21**). Rarefaction curves of $E(S_n)$ for day and night samples summed for each station show higher species richness for night samples at each station (**Figure 22**). Many more specimens were collected at night, but when similar sized samples are compared only Station 2 showed significantly higher species richness (expected number of species) at night. **Figure 23** shows mean numbers of numerically dominant species collected per electroshocking transect for all stations and seasons.

3.3.5 Classification and Ordination

Five groups developed from the clustering of electroshocking samples by Bray-Curtis similarity (**Figure 24**). Group A was formed with only September samples from Stations 1 and 2 (day) clustered together. Group B was made up of eight samples from Stations 1 and 2 only, including at least one from each sampling season. A third group (Group C) included all samples taken at Station 4 including one day and two night samples. Group D included all samples from Station 3.

The inverse analysis illustrated in **Figure 25** generated two major species groups which subdivided into several subgroups. Within Group 1, the most significant smaller cluster (Subgroup 1b), comprised *Brevoortia smithi*, *Gambusia holbrooki*, *Poecilia latipinna*, *Erimyzon sucetta*, *Esox niger*, and *Ameiurus natalis*, represents a group of species that are closely allied with heavy aquatic vegetation. This group was essentially confined to Station 3, which offered the best developed submerged vegetation of the four stations. The other subgroups consisted of irregularly occurring species and did not warrant further analysis. Within Group 2, three subgroups were also important. Subgroup 2a was composed of four marine species (*Cynoscion nebulosus*, *Micropogonias undulatus*, *Lagodon rhomboides*, *Sciaenops ocellatus*) and one freshwater species (*Dorosoma petenense*). This subgroup was heavily represented at Stations 1 and 2 and largely lacking at Stations 3 and 4. Subgroup 2b was composed of 12 euryhaline marine species, one secondary freshwater species (*Anguilla rostrata*), and three freshwater species (*Ameiurus catus*, *Labidesthes vanhyningi*, and *Lepomis auritus*). The latter four, plus *Strongylura marina*, *Lutjanus griseus*, *Trinectes maculatus*, *Paralichthys lethostigma*, *Diapterus auratus*, *Eucinostomus harengulus*, *Leiostomus xanthurus*, and *Anchoa mitchilli*, were irregularly distributed among station-season-time combinations, but were not an important constituent at Station 3. Subgroup 2c

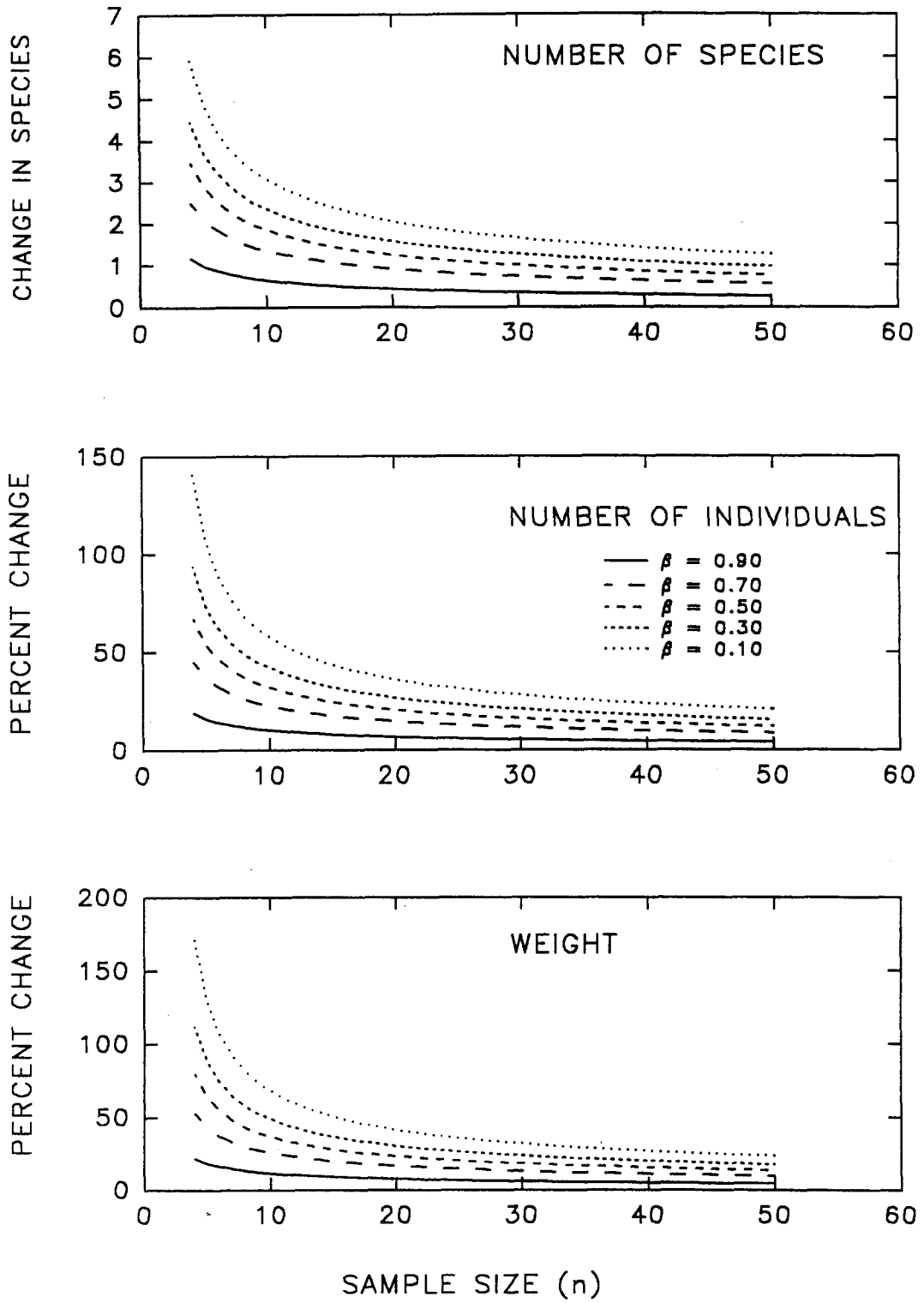

Figure 20. Detectable change in number of species and percent detectable change in mean number of individuals, and weight as functions of sample size (n) and degrees of power (1-β) at $\alpha = 0.05$ for electroshocker samples.

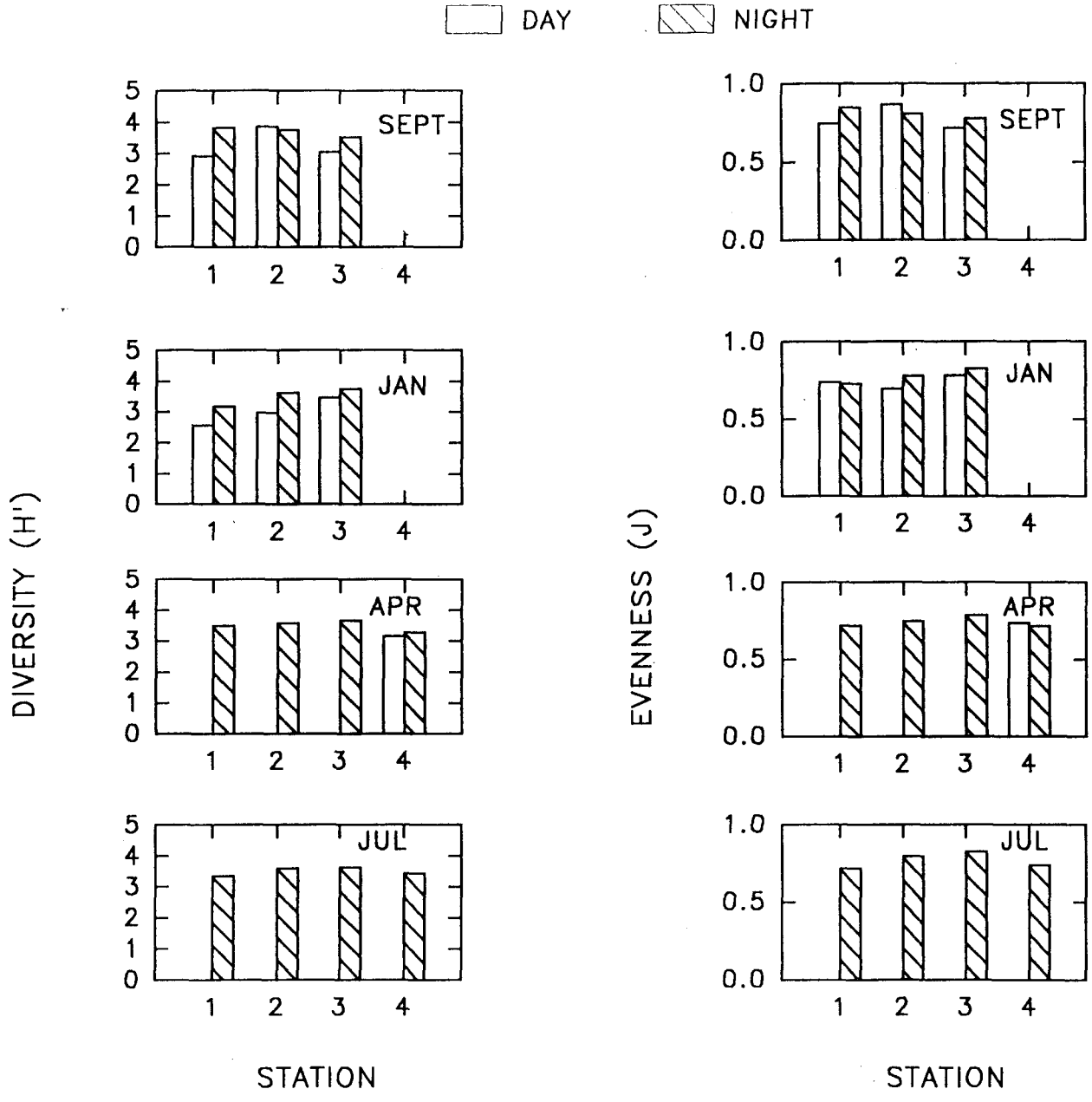

Figure 21. Diversity (H') and evenness (J) of fishes collected in three 10-min electroshocking transects at each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples.

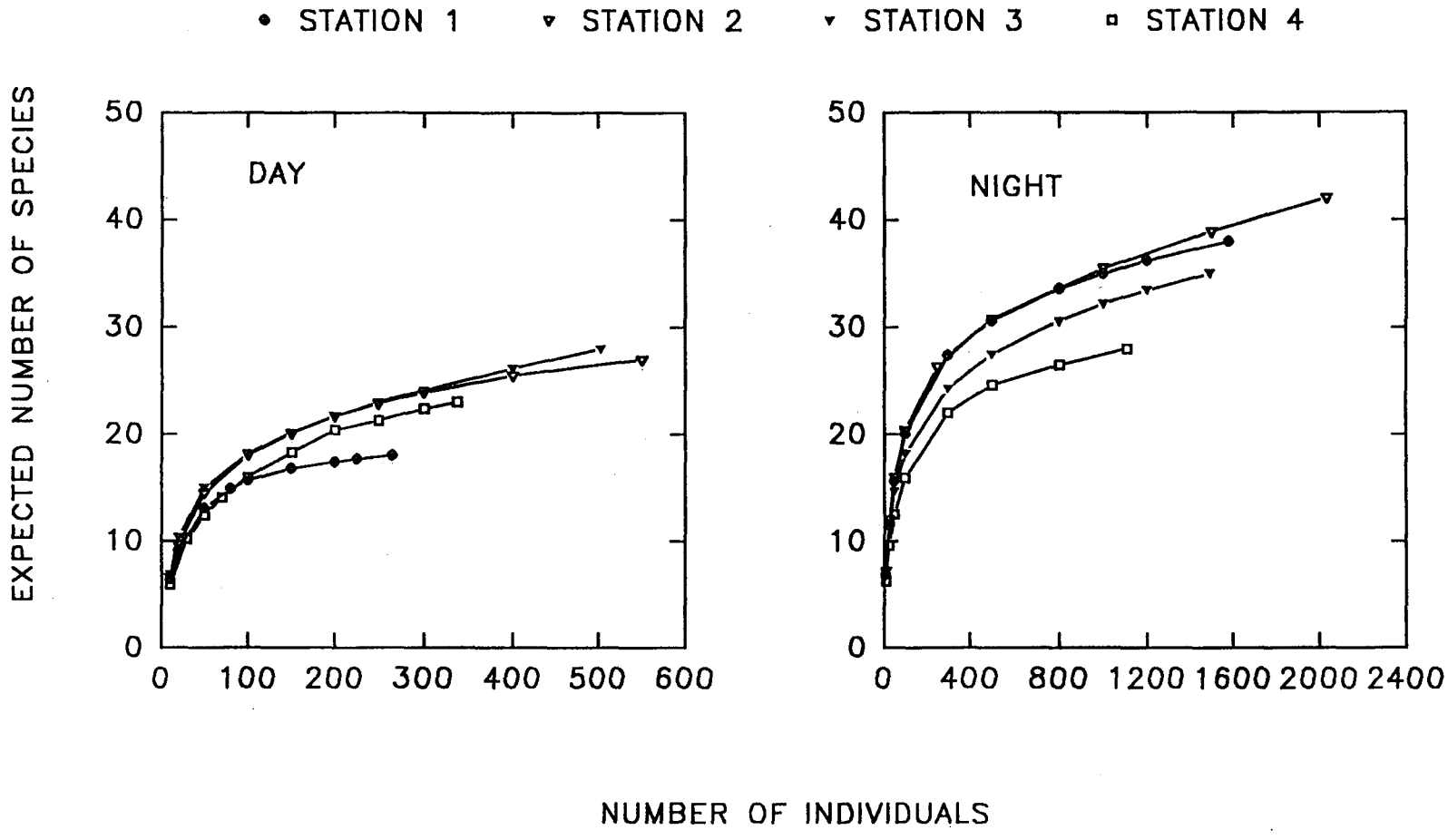

Figure 22. Rarefaction plots of expected number of species $E(S_n)$ per increasing sample size for day and night electroshocking collections at each station. Data from all seasons were summed within stations.

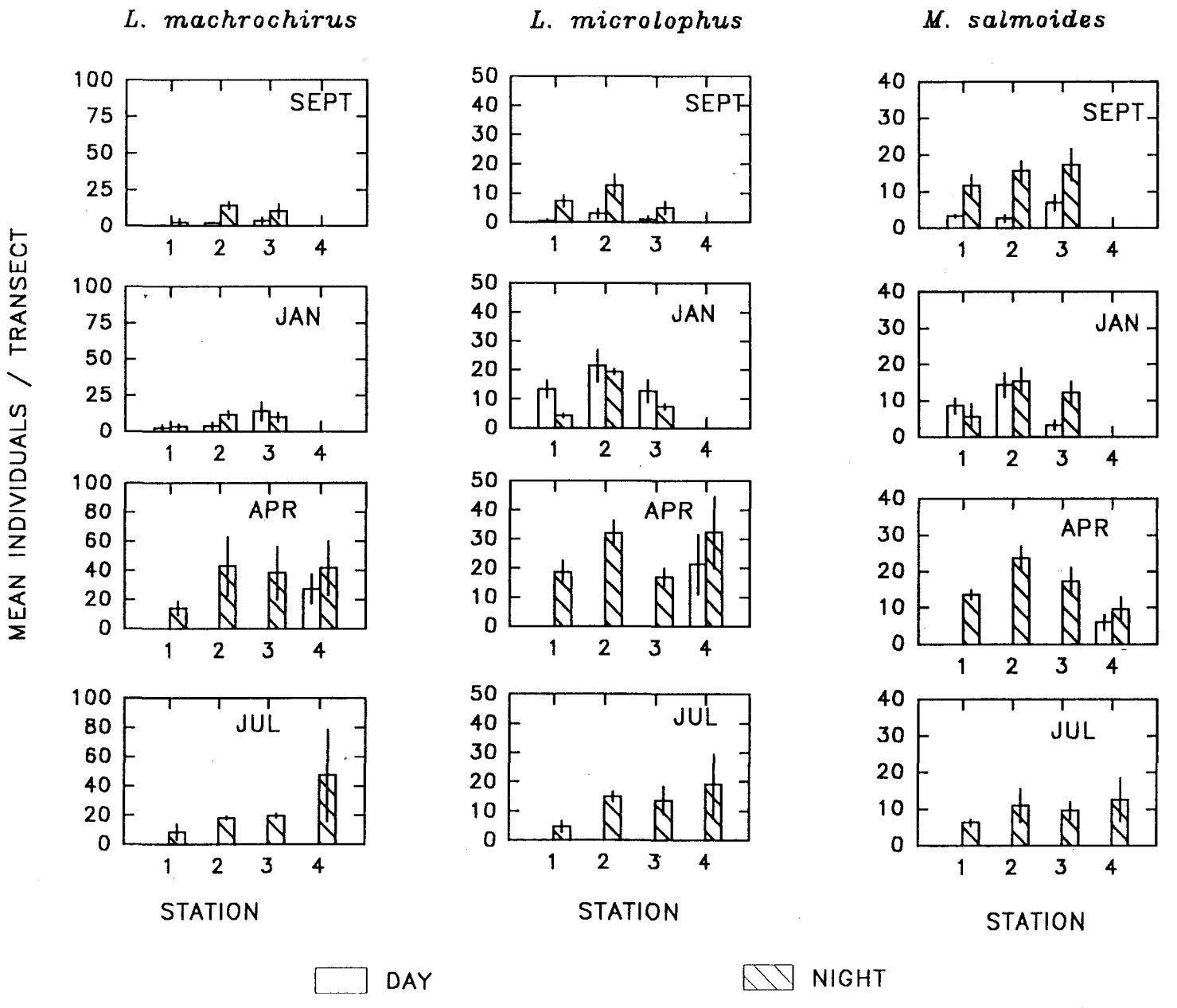

Figure 23. Mean numbers of *Lepomis macrochirus*, *Lepomis microlophus*, and *Micropterus salmoides* collected during three 10-min electroshocking transects taken from each station during September, January, April, and July. Open bars represent day samples and hatched bars represent night samples. Vertical bars indicate positive standard error.

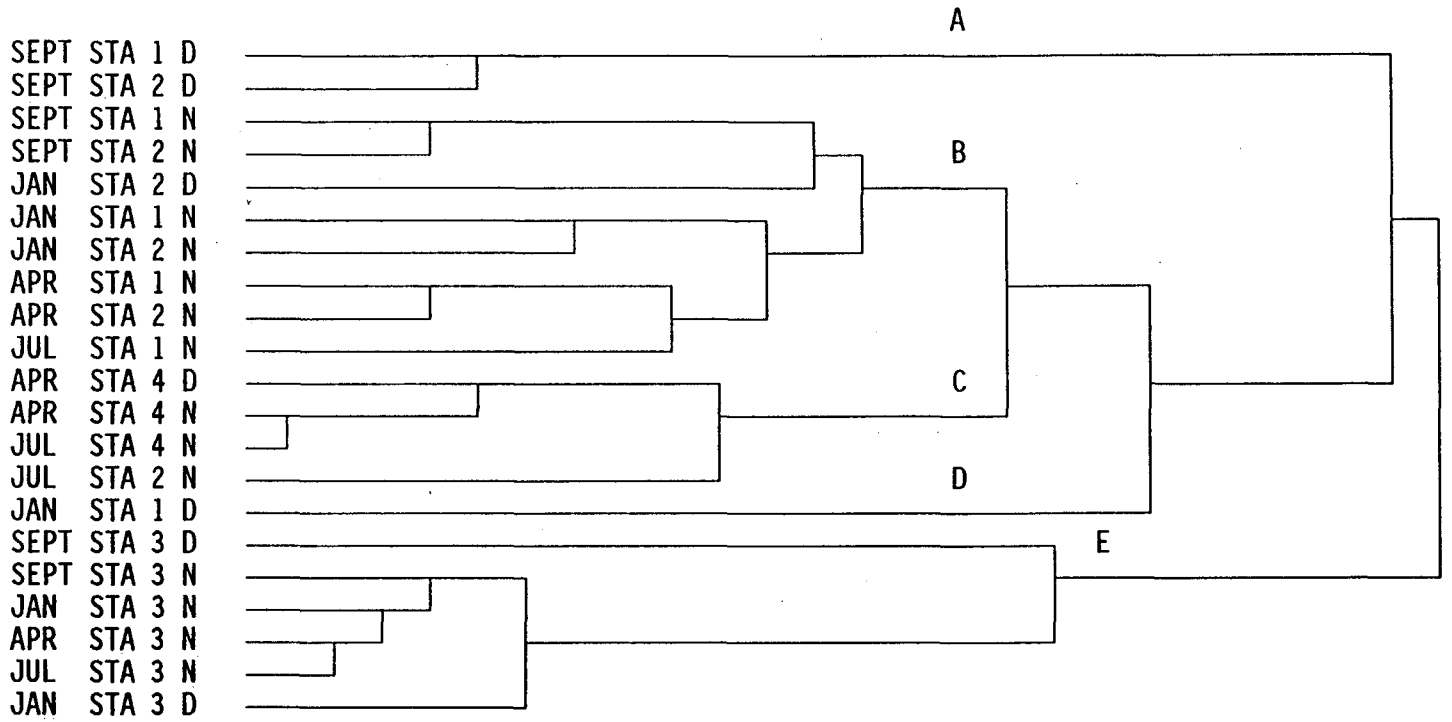

Figure 24. Normal dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity between electroshocking samples (station/season/time) taken in the study area.

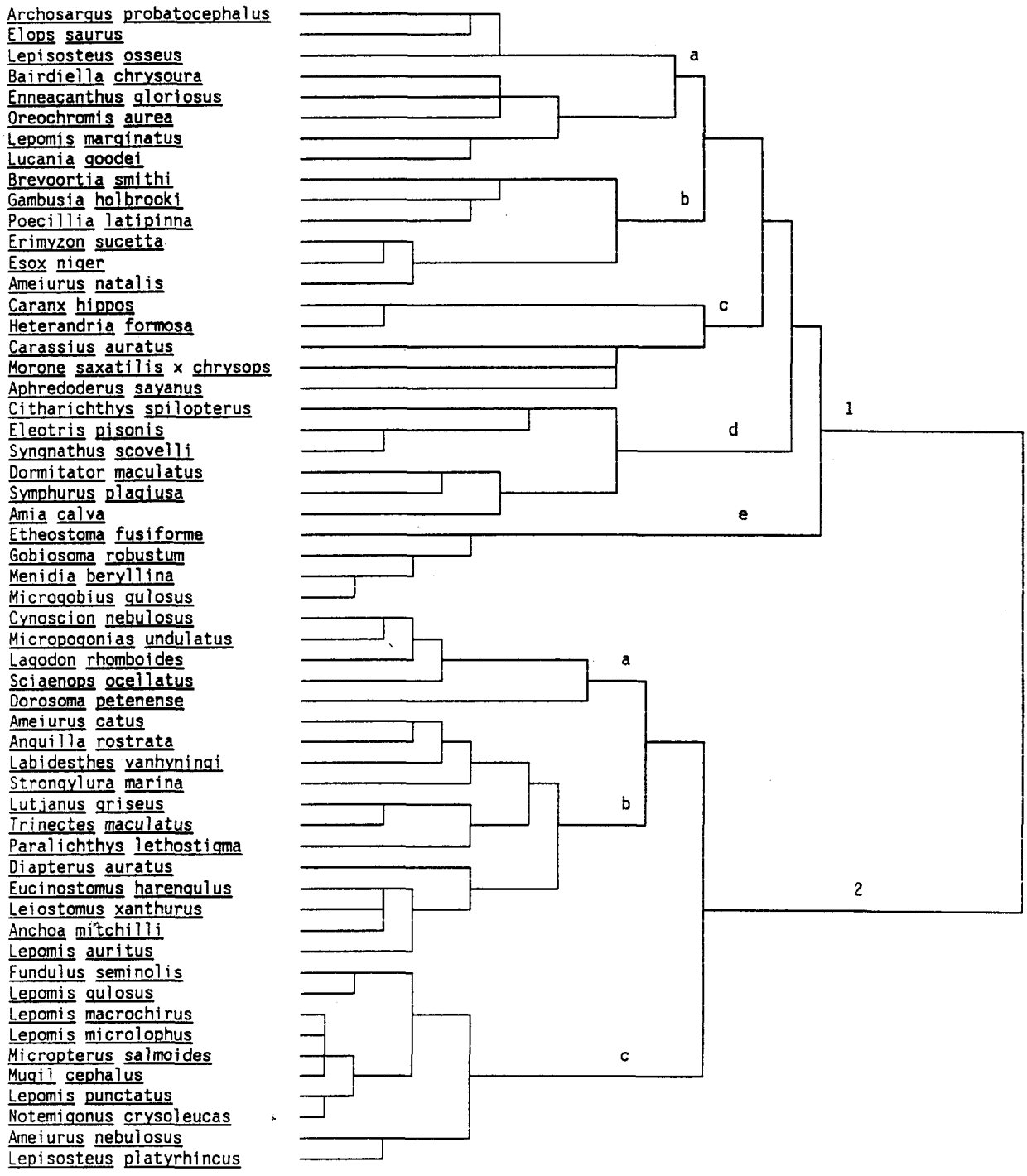

Figure 25. Inverse dendrogram produced by clustering (group average sorting) of Bray-Curtis similarity among fish species in electroshocking samples.

included the freshwater species *Fundulus seminolis*, *Lepomis gulosus*, *Lepomis macrochirus, Lepomis microlophus, Micropterus salmoides, Mugil cephalus, Lepomis punctatus, Notemigonus crysoleucas, Ameiurus nebulosus*, and *Lepisosteus platyrhincus*. These species were the most abundant and frequently caught in the electroshocking samples at all stations. A two-way representation of the normal and inverse Bray-Curtis analyses is given in **Table 10**.

Ordination of sample scores (based on abundance data) on RA Axes 1 and 2 showed some spatial influence, particularly as all samples from Station 3 clustered above the others along Axis 2 (**Figure 26**).

3.3.6 Major Species

The major species grouping identified by clustering the electroshocking data consisted of freshwater species. *Lepomis macrochirus* is a freshwater resident of nearshore areas at all stations and seasons within the study area. Its abundance remained relatively constant by season, except during April when numbers rose dramatically, presumably as a result of pre-spawning aggregations. This species spawns in the St. Johns River from May through October with peaks during May and June (McLane, 1955). McLane also found this species to be the most abundant species collected, and found no changes in seasonal abundance except for spawning-related events. In our study area, *L. macrochirus* was least abundant at Station 1, perhaps as a result of the more saline nature of the water and less developed microhabitat. Stations 2 and 3 were equal in numbers of individuals collected (n=289), and Station 4, despite only two sampling periods, had 392 individuals.

Lepomis microlophus was another freshwater resident found for all station and season combinations. Its abundances were lowest in July and September and highest in January and April. McLane (1955) indicates that *L. microlophus* moves into shallow coves and bays in the spring; our data show similar patterns. McLane (1955) claims *L. microlophus* moves "to deeper portions" during other seasons. Station-by-station comparisons indicate lowest abundance at Station 1 (n=147), as explained above, and greatest abundance at Station 2 (n=310), possibly because the substrate was harder (*L. microlophus* occurs over soft bottoms but prefers "firm sandy or clayey bottoms" [McLane, 1955]). Abundance was almost as low at Station 3 as at Station 1 (n=170), most likely due to the soft, flocculent substrate, and high at Station 4 (218 in only two samples), where the highest number would be expected over all four seasons. Again, Station 4 offered the best habitat for this species.

Mugil cephalus, a marine invader, was taken year-round at all stations. It was taken most commonly in January and July, less commonly in September, and least commonly in April. The drop from July to September could indicate a loss of adults to offshore spawning runs (if adults are involved). McLane (1955) indicates that this species is "seasonally very abundant during the warm summer, fall and

Table 10. A two-way table of the electroshocking samples by species matrix ordered according to Bray-Curtis clustering. Values in the cells of the table are total abundances from 10-min electroshocking samples (n=3).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Survey	1	1	1	1	2	2	2	3	3	4	3	3	4	4	2	1	1	2	3	4	2
Station	1	2	1	2	2	1	2	1	2	1	4	4	4	2	1	3	3	3	3	3	3
Species	D	D	N	N	D	N	N	N	N	N	D	N	N	N	D	D	N	N	N	N	D
Archosargus probatocephalus	--	--	--	--	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	--
Elops saurus	--	--	--	1	--	1	--	--	--	2	--	--	--	--	--	--	1	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--	--	--	1	3	1	1	--	2	--	--	1	1	1	--	--
Bairdiella chrysoura	--	--	--	--	--	--	--	2	--	8	--	--	--	--	--	--	--	--	--	--	--
Enneacanthus gloriosus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Oreochromis aurea	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	2	--	--	2
Lepomis marginatus	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	1	1	--	--	--	--
Lucania goodei	--	--	--	--	--	--	--	--	1	--	--	--	--	1	--	--	1	--	--	1	1
Brevoortia smithi	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	89	--	--	--	--	--
Gambusia holbrooki	--	--	--	--	3	--	1	2	3	--	3	3	2	--	--	49	3	--	1	--	--
Poecilia latipinna	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	4	1	--	1	--	--
Erimyzon sucetta	--	--	--	2	--	--	1	--	--	--	--	--	--	--	--	7	17	12	20	12	12
Esox niger	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	4	2	5	5	4	6
Ameiurus natalis	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	2	2	6	--	1	3
Caranx hippos	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Heterandria formosa	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--
Carassius auratus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--
Morone saxatilis x chrysops	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--
Aphredoderus sayanus	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Citharichthys spilopterus	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Eleotris pisonis	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Syngnathus scovelli	--	1	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dormitator maculatus	--	1	--	--	1	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
Symphurus plagiusa	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amia calva	--	1	--	1	2	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1
Etheostoma fusiforme	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	--	--	--	--	--
Gobiosoma bosci	--	--	--	--	--	--	--	2	--	--	--	--	1	--	--	--	--	--	--	--	--
Menidia beryllina	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Microgobius gulosus	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Cynoscion nebulosus	10	13	5	6	1	14	11	16	2	--	--	--	--	--	--	--	--	1	--	--	--
Micropogonias undulatus	53	18	5	2	--	9	14	50	12	5	--	--	--	2	--	20	--	--	1	--	--
Lagodon rhomboides	36	21	28	23	--	--	--	20	18	27	2	--	4	--	--	--	1	--	1	--	--

Table 10. (Continued).

Species	Survey	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Station	1	2	1	2	2	1	2	1	2	1	4	4	4	2	1	3	3	3	3	3	3
		D	D	N	N	D	N	N	N	N	N	D	N	N	N	D	D	N	N	N	N	D
Sciaenops ocellatus		5	1	2	3	2	--	5	27	--	6	--	--	--	--	1	--	--	--	--	--	--
Dorosoma petenense		--	--	1	--	--	8	7	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Ameiurus catus		--	--	4	4	--	2	2	--	--	2	3	1	4	8	--	--	--	4	1	--	1
Anguilla rostrata		--	--	3	3	3	2	5	1	1	6	1	2	2	1	--	1	1	4	3	7	--
Labidesthes vanhyningi		--	--	6	--	--	4	18	--	--	13	--	3	3	--	--	--	--	--	6	--	5
Strongylura marina		--	--	--	--	--	3	--	4	1	2	--	1	9	--	--	--	2	17	8	3	--
Lutjanus griseus		--	2	1	3	--	--	1	1	1	6	2	1	5	3	--	--	--	--	--	--	--
Trinectes maculatus		--	--	--	4	--	--	--	2	1	--	7	3	3	5	--	--	--	--	--	--	--
Paralichthys lethostigma		--	2	--	--	--	--	1	--	--	1	--	2	2	6	--	--	--	--	3	2	--
Diapterus auratus		--	--	--	1	--	--	121	7	9	--	22	13	4	--	--	--	--	--	--	1	--
Eucinostomus harengulus		1	2	5	5	37	103	101	158	145	11	24	15	8	--	--	--	--	1	9	--	1
Leiostomus xanthurus		24	15	7	--	1	6	30	180	90	60	--	17	34	1	--	--	--	13	9	2	--
Anchoa mitchilli		--	--	1	--	1	3	17	43	57	57	3	142	28	13	--	--	--	--	11	18	1
Lepomis auritus		1	1	--	--	1	--	2	18	14	6	56	71	43	6	4	--	--	1	3	1	1
Fundulus seminolis		--	--	4	8	14	3	14	6	12	4	--	--	3	7	3	1	10	40	17	10	5
Lepomis gulosus		1	2	3	9	18	4	13	--	5	--	1	9	1	4	1	8	29	55	55	18	56
Lepomis macrochirus		2	17	8	42	12	10	35	42	129	25	82	125	142	54	8	12	31	30	115	59	42
Lepomis microlophus		2	9	22	38	64	13	58	56	96	14	64	97	57	45	40	3	15	22	51	41	38
Micropterus salmoides		10	8	35	47	43	17	46	41	71	19	18	29	38	33	26	21	52	37	52	29	10
Mugil cephalus		6	20	16	38	113	13	122	23	17	164	21	55	56	6	4	6	19	8	19	43	18
Lepomis punctatus		2	16	5	39	55	2	28	6	42	3	8	20	18	19	10	2	17	24	56	15	26
Notemigonus crysoleucas		--	6	9	36	--	2	17	6	40	5	10	11	11	8	5	2	51	48	55	26	19
Ameiurus nebulosus		5	7	14	16	--	--	--	1	8	5	2	4	2	7	--	4	49	9	19	10	--
Lepisosteus platyrhincus		5	14	1	5	1	--	--	--	4	--	2	1	--	7	--	8	6	3	5	6	10

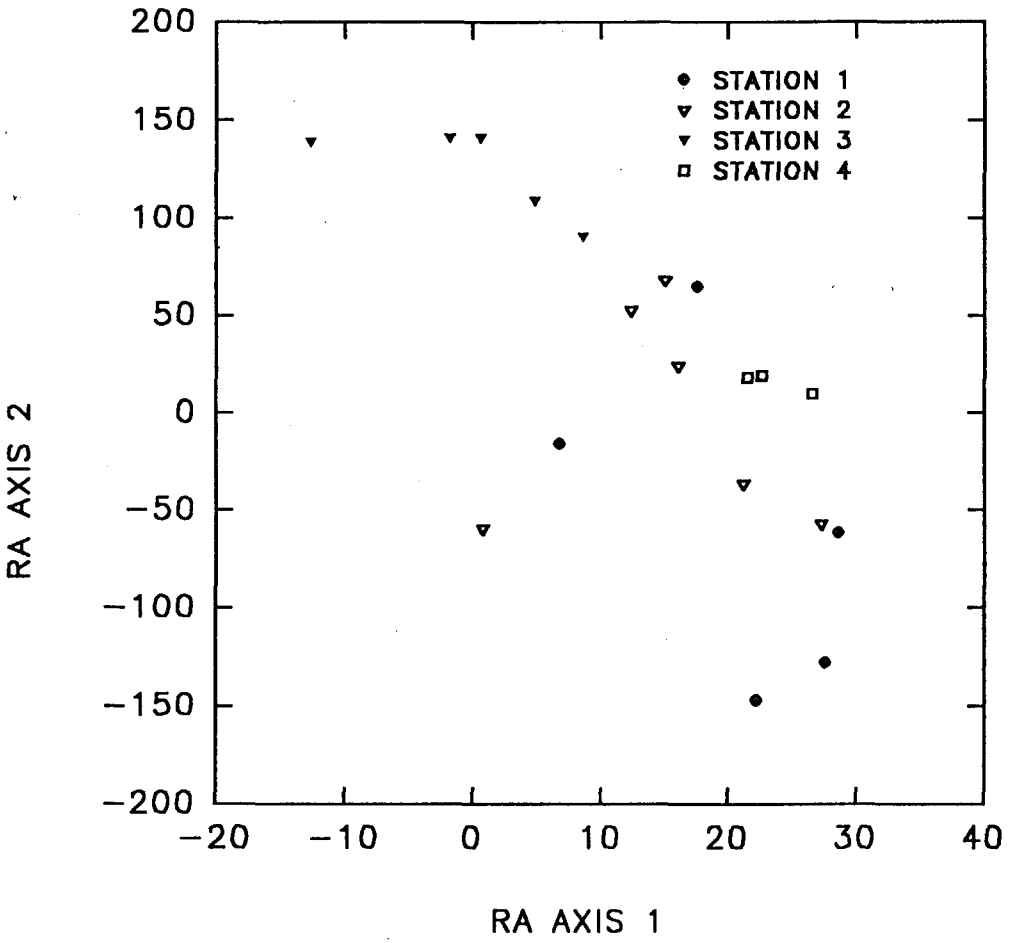

Figure 26. Reciprocal averaging ordination of electroshocking samples (based on species abundance) along Axes 1 and 2. Outliers were omitted.

early winter months," which would indicate that our April lows are not artificial. The observed abundance was highest at Station 2 (n=316), followed by Station 1 (n=226), Station 4 (despite only 2 samples [n=132]), and least at Station 3 (n=113). Considering this species "was observed most commonly over sandy bottom areas where rooted vegetation was abundant" (McLane, 1955), the somewhat harder bottom of Station 2 and soft bottom of Station 3 would be expected to dictate highs and lows.

Micropterus salmoides, another freshwater resident, was taken at all station and season combinations. This species was amazingly consistent in abundance (September [n=173], January [n=179], April [n=164]) except for July (n=81), when it left the shallows presumably in reaction to higher water temperatures and lower dissolved oxygen. On a station-to-station basis, *M. salmoides* was most common at Stations 2 (n=248) and 3 (n=201), and less common at Station 1 (n=148). Station 4 was similar to Stations 2 and 3 during two surveys, suggesting similar numbers over the entire year. This is the same pattern described above for *Lepomis* spp.; Station 1 tends to have a more saline character and therefore fewer freshwater species. *M. salmoides* is very flexible in microhabitat requirements (McLane, 1955) thus it is not surprising that Stations 2 through 4 have similar numbers. **Figure 23** presents mean numbers of *M. salmoides* from the electroshocking samples.

Eucinostomus harengulus, a euryhaline marine invader, was seasonally abundant. It was collected year-round, but very few were taken in July and September. It was numerous in January and April. Abundances show it to be most common at Stations 1 and 2 (n=278 and 290, respectively), nearly nonexistent at Station 3, and uncommon (n=45) in two surveys at Station 4.

3.4 GILL NET

3.4.1 Collection Summary

Total catch from the multi-mesh gill net was 25 species and 1,548 individuals weighing 412.31 kg. The most abundant species were adults of *Brevoortia smithi*, *Leiostomus xanthurus*, and *Dorosoma cepedianum* which together comprised 90% of the catch by numbers (**Table 11**). Other species of lesser importance in the catches were *Mugil cephalus*, *Elops saurus*, *Lepisosteus osseus*, *Ameiurus catus*, *Ictalurus punctatus*, and *Lepisosteus platyrhincus*. **Table 8** gives the rank order of abundance for species caught during 6-h sets at each station. Catches from Stations 1, 2, and 3 were similar in species composition and rank abundance; only four individuals were caught at Station 4. **Figure 27** presents total species, numbers, and weights of fishes collected in 6-h sets of the gill net. For Stations 1, 2, and 3, abundant catches in September were followed by relatively low numbers of fishes. Stations 1 and 3 had the highest catches. Rarefaction curves for the gill net data from Stations 1 to 3 show that Station 1 had the highest richness followed closely by Stations 2 and 3

Table 11. Species collected in 6-h sets of multi-mesh gill nets at each station in September, January, April, and July. Sets were made only at night.

Species	September			January			April				July				Total
	1	2	3	1	2	3	1	2	3	4	1	2	3	4	
Brevoortia smithi	351	96	205	---	32	150	---	2	8	---	---	---	---	---	844
Leiostomus xanthurus	110	53	135	---	19	4	8	4	6	---	3	---	1	---	343
Dorosoma cepedianum	14	48	39	20	6	32	---	---	---	---	33	5	---	---	197
Mugil cephalus	1	3	42	1	6	---	1	---	---	---	4	---	---	---	58
Elops saurus	2	7	12	---	---	---	---	---	---	---	---	---	5	---	26
Lepisosteus osseus	---	5	---	---	1	1	1	---	3	1	2	---	---	---	14
Ameiurus catus	1	---	---	4	1	1	1	---	---	1	---	---	---	1	10
Ictalurus punctatus	---	---	6	---	---	---	---	---	2	---	---	---	1	---	9
Lepisosteus platyrhincus	---	1	---	5	--	---	---	---	1	1	---	---	---	---	8
Bagre marinus	3	1	---	---	---	---	---	---	---	---	---	2	---	---	6
Caranx hippos	---	---	3	1	---	---	---	1	---	---	---	---	---	---	5
Lepomis microlophus	---	---	---	---	---	---	2	---	---	---	---	---	1	---	3
Bairdiella chrysoura	---	1	---	---	---	---	---	---	---	---	2	---	---	---	3
Ameiurus nebulosus	---	---	---	---	1	---	---	---	1	1	---	---	---	---	3
Micropogonias undulatus	---	---	1	---	---	1	---	--	1	---	---	---	---	---	3
Sciaenops ocellatus	---	---	2	---	---	---	1	---	---	---	---	---	---	---	3
Micropterus salmoides	---	---	---	---	---	---	1	1	---	---	---	---	---	---	2
Mugil curema	---	---	2	---	---	---	---	---	---	---	---	---	---	---	2
Esox americanus	---	---	---	---	1	1	---	---	---	---	---	---	---	---	2
Ariopsis felis	---	1	---	---	---	---	1	---	---	---	---	---	---	---	2
Dasyatis sabina	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1
Lagodon rhomboides	---	---	1	---	---	---	---	---	---	---	---	---	---	---	1
Lepomis gulosus	---	---	---	---	---	---	---	---	---	1	---	---	---	---	1
Lepomis punctatus	---	---	1	---	---	---	---	---	---	---	---	---	---	---	1
Cynoscion regalis	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1
Total Individuals	**482**	**216**	**449**	**31**	**67**	**190**	**16**	**10**	**22**	**5**	**44**	**7**	**8**	**1**	**1,548**
Total Species	**7**	**10**	**12**	**5**	**8**	**7**	**8**	**6**	**7**	**5**	**5**	**2**	**4**	**1**	**25**

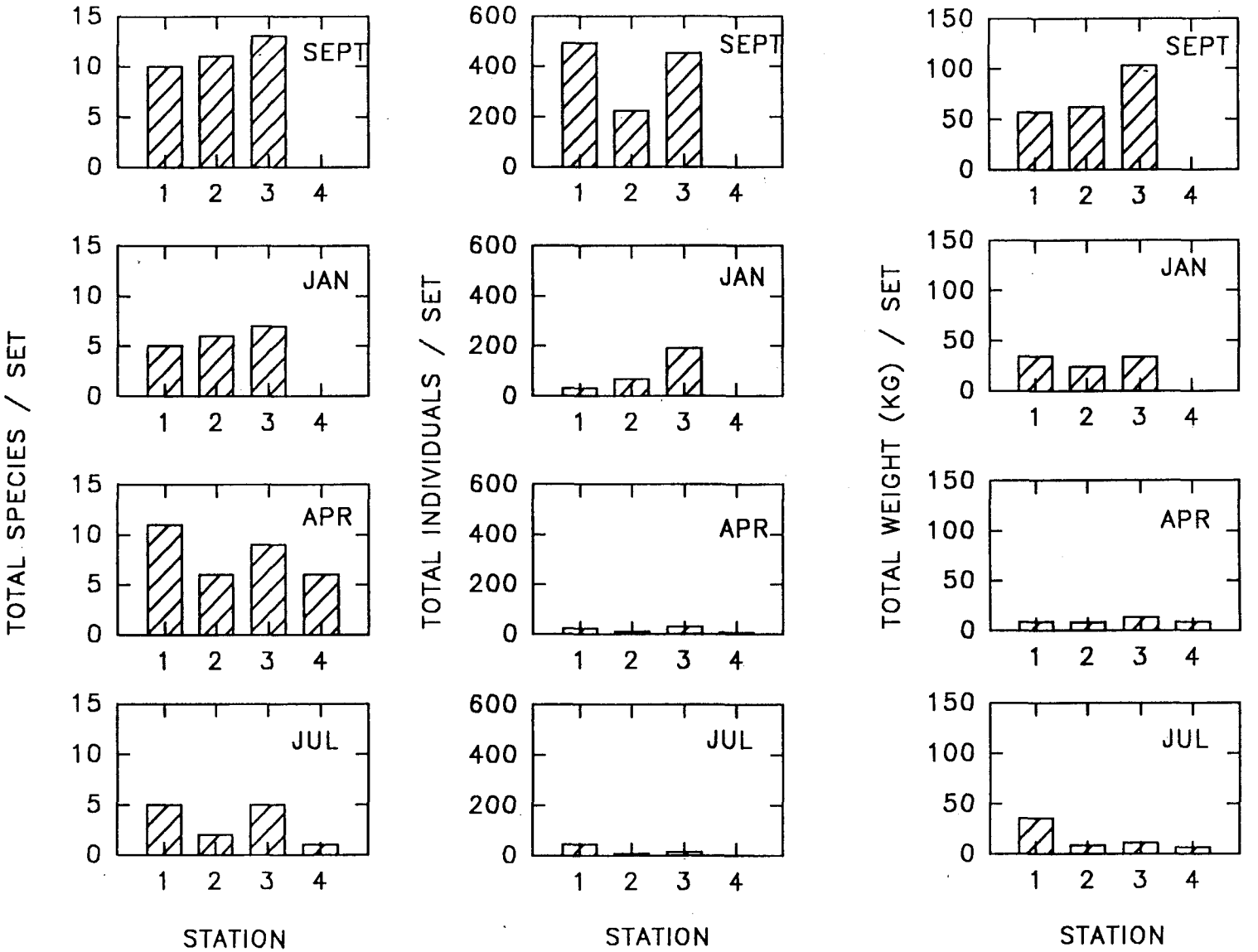

Figure 27. Total number of species, number of individuals, and weights of fishes collected in 6-h gill net sets at each station.

(**Figure 28**). The catch consisted of motile marine, estuarine, and freshwater species mostly from seven dominant families: Sciaenidae (6 species), Centrarchidae (4 species), Ictaluridae (3 species), Ariidae (2 species), Clupeidae (2 species), Lepisosteidae (2 species), and Mugilidae (2 species). Clupeids represented 68%, sciaenids 23%, and mugilids 4% of the catch by numbers.

3.4.2 Major Species

Brevoortia smithi, a pelagic schooling species, was most abundant in September, common in January, less common in April, and absent in July. This species uses the lower St. Johns River estuary in fall and winter as adults, and leaves the river in spring and summer. *Dorosoma cepedianum* is a mid-water clupeid of freshwater origin most numerous in gill net collections during September and January. *Leiostomus xanthurus*, a bottom dwelling species, was also most abundant in September and found in greatly reduced numbers in January and April.

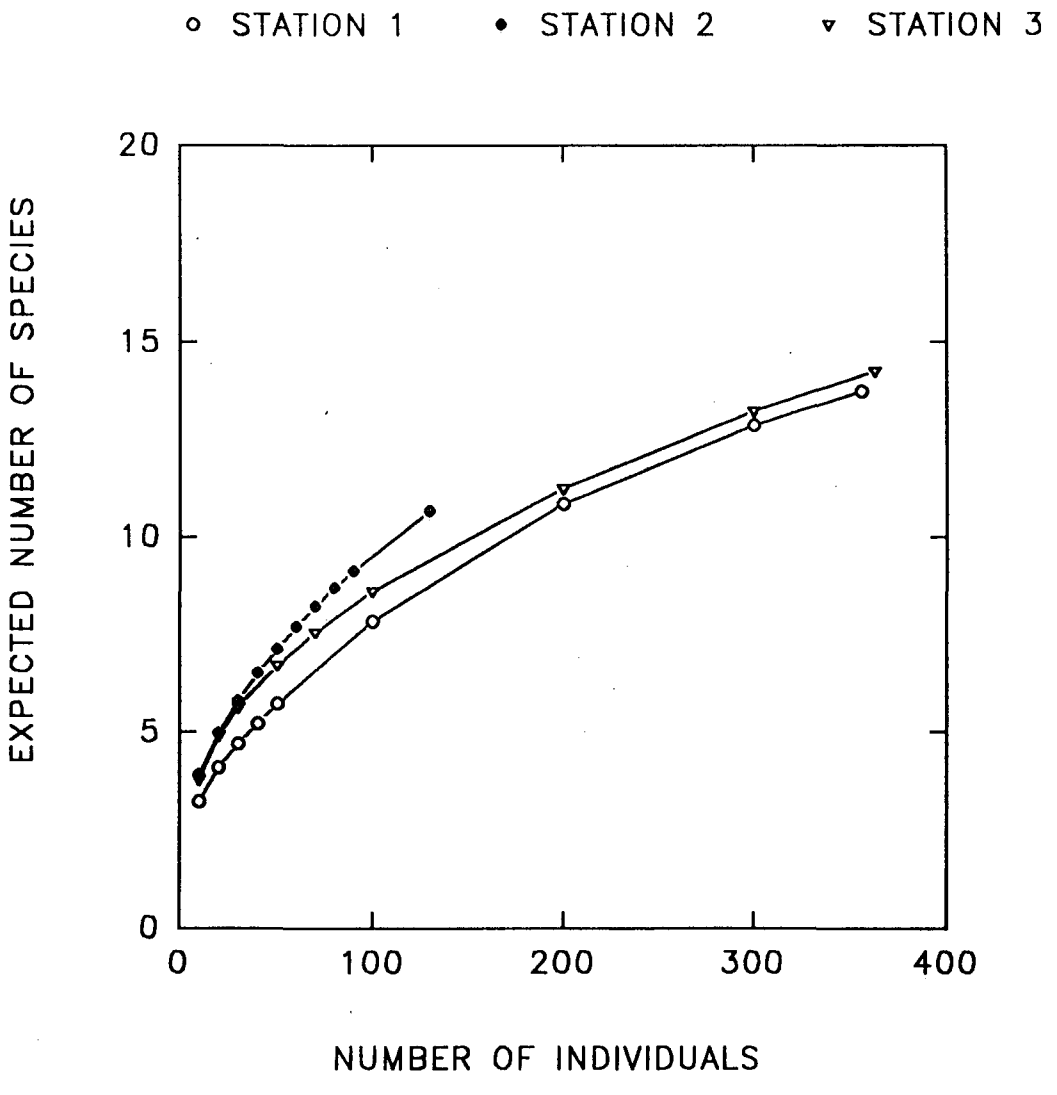

Figure 28. Rarefaction plots of expected number of species $E(S_n)$ per increasing sample size for gill net data from Stations 1, 2, and 3.

4.0 DISCUSSION

4.1 GEAR EVALUATION

4.1.1 Trawl

Small otter trawls have been used extensively to sample estuarine nekton, and despite acknowledged limitations, consistent results have been obtained by independent workers (i.e., Livingston, 1975; Heck and Orth, 1980; Mulligan and Snelson, 1983). Taylor (1953) suggested that several repetitive tows of short duration would provide better estimates of species richness than fewer tows of longer duration. Roessler (1965) and Livingston (1976) confirmed that seven 2-min tows were adequate to sample at least 90% of the species caught by trawling in Biscayne Bay and Apalachee Bay, respectively. By examining species accumulation throughout the course of the study, we found that 90% of the trawlable species in the lower St. Johns River could be sampled with between 7 and 10 tows. The analysis of species accumulation should be undertaken at the start of individual sampling programs beginning with at least 10 2-min tows. This ensures that the assemblage is being adequately sampled, a necessity if community analyses are to be performed on the data.

If trawl-collected data are to be used in statistical analyses involving hypothesis testing, the data are subject to considerable variability. Our analysis of power and sample sizes required to detect changes in response variables indicate that a large number of samples are required to detect even a gross percentage change in mean abundance or mean weight of fishes per tow; the mean number of species per tow was a more sensitive measure of response variables. However, the factorial ANOVA to test for main effects of season, location, and time (day or night) was largely uninterpretable due to the significant interactions found for each variable.

In summary, for community-level analyses using pattern recognition techniques such as cluster analysis and ordination, 7 to 10 2-min tows will adequately sample species present in demersal habitats of the lower St. Johns River. If sensitive statistical tests are desired (e.g., monitoring differences in mean species or individuals between control and impact areas), sampling by trawl might require unfeasibly large numbers of samples.

4.1.2 Seine

Seines are one of the most widely used sampling devices for shoreline fishes in estuarine waters. Studies show that capture efficiencies of seines will vary with substrate and other variables associated with the sampling locations (Weinstein and Davis, 1980; Wiley and Tsai, 1983; Parsely et al., 1989; and Allen et al., 1992). Our seining was certainly subject to bias associated with the vegetated

substrate encountered in our study area. Summary coefficient of variability estimates (derived from the mean square error term of the three-way analysis of variance on untransformed variables) for the seine were 33% for number of species, 85% for number of individuals, and 51% for mean weight per haul. These variability estimates along with the results of power analyses suggest that data collected by seining should only be used for community composition and general trends but not for statistically detecting differences in abundance, weight, or species. The seine collections did complement the electroshocker samples by providing more of the smaller species such as *Lucania parva* and *Menidia beryllina*. Smaller discrete samplers such as Wegener rings (Wegener et al., 1973), throw traps (Kushlan, 1981), or pop nets (Kilgore et al., 1989) may prove better for sampling the littoral areas in conjunction with electroshocker. Smaller samplers would allow easier replication, which helps account for the expected variation, particularly in densely vegetated areas such as Hallowes Cove (Station 3).

4.1.3 Electroshocker

Hendricks et al. (1980) considered the electroshocker to be the most applicable sampling apparatus available to researchers conducting bioassessments in lotic systems. These authors believed electroshocking was much less selective than other gear, especially in areas where obstructions or snags precluded net sampling. Electroshockers are reportedly size-selective with larger fish being more susceptible to capture than small ones (Wiley and Tsai, 1983). Electroshockers are also considered to be more effective at night than during the day, presumably since fish are more easily approached. In our study, electroshocking captured many more fish during night sampling, however, the rarefaction curves showed that, with the exception of Station 1, the expected number of species caught was not appreciably greater at night than during the day. Electroshocking is subject to several biases including water conductivity, fish behavior and avoidance, and expertise or personal bias of field personnel in choosing microhabitat sampling location and in dipnetting stunned fishes. In streams, electroshockers have proven to be better than seines for estimating fish population sizes by the removal method (Wiley and Tsai, 1983). We found that the variability associated with electroshocking was lower (coefficient of variability was 12% for species, 38% for numbers of individuals, and 30% for weight) than seine or trawl in the lower St. Johns River; however, the day-night effect was not included in the calculations. Electroshocking provides a very good method of sampling the nearshore areas of the lower St. Johns River where obstructions and lack of a beach make seining difficult.

4.1.4 Gill Net

Because of the time required to replicate gill net sets, we did not conduct variability analyses on this gear. Nevertheless, the gill net is a valuable collecting tool for documenting the occurrence and movements of the fast moving pelagic species.

4.2 FISH ASSEMBLAGES

During this study we found that fishes from littoral, demersal, and pelagic habitats in the lower St. Johns River formed fairly distinct assemblages. A total of 77 species of marine, estuarine, and freshwater fishes were collected from the three habitats with four gear types. The littoral habitat produced the most species (57), followed by demersal (39), and pelagic (23). The coexistence of such a diverse group of fishes is undoubtedly mediated by physical and biological factors yet to be identified.

The littoral habitat was characterized by the presence of moderate to dense stands of tapegrass (*Vallisneria americana*), and other submerged macrophytes. These plants provide food, shelter, and substrate for fishes inhabiting the nearshore areas. The littoral zone fish assemblage, as described by electroshocking and seining, was composed of freshwater and estuarine residents interspersed with seasonally appearing euryhaline marine species. The freshwater group was best represented in this habitat, including centrarchids (*Micropterus salmoides, Lepomis* spp.), *Menidia beryllina*, and *Erimyzon sucetta*. Also present were euryhaline marine species (e.g., *Sciaenops ocellatus*, *Lutjanus griseus*, *Mugil cephalus*, and *Eucinostomus harengulus*).

The demersal habitat sampled by trawling is inhabited primarily by the young of euryhaline marine species. Abundance fluctuations within our study area of these species were most likely related to ingress and egress of developing juveniles, particularly *Micropogonias undulatus*, *Leiostomus xanthurus*, and *Paralichthys lethostigma*. Their occurrence is based on the somewhat predictable spawning season of the oceanic adult populations and much less on changes in riverine physical and chemical variables on the postlarvae or juveniles. The demersal zone in low salinity areas is considered environmentally stable even if the mean measured salinity is very low. The species composition and abundance of fishes collected in the trawls were similar to what we found here earlier (Snyder and Burgess, in prep.). We have documented that members of this assemblage extend at least 100 km from the river's mouth, where salinities never exceed 1 ppt (Snyder and Burgess, in prep.). Euryhaline freshwater species occurring in this habitat were mostly ictalurid catfishes (*Ameiurus catus, Ameiurus nebulosus*).

The pelagic environment was sampled with multi-mesh gill net which mostly collected schooling varieties of fish. Two seasonally abundant species, the marine *Brevoortia smithi* and freshwater *Dorosoma cepedianum*, possibly migrate in response to salinity or reproductive activities.

Interstation differences in numbers of fish collected, numbers of species, and assemblage composition were slight. At the scale of our investigation (kilometers), Station 3 (Hallowes Cove) appeared slightly different in terms of the assemblage composition. At the outset of the project, Station 3 was chosen as an unimpacted reference site due to lack of human alterations such as those observed

at Stations 1 and 2. The three sites are similar due to their relatively stable oligohaline salinity regimes. If these three sites were examined on a broader spatial scale (10 s of km) they would undoubtedly cluster together. Station 3 is dissimilar because of differences in microhabitat complexity, greater extent of submerged aquatic vegetation, and the sheltered nature of the site (it is not located directly adjacent to the deeper channel). The other two stations are similar in their microhabitat complexity (submerged aquatic vegetation), extent of human influence, and proximity to the deeper channel. Whether the similarities or dissimilarities are the result of degraded conditions is unknown. Human activity has certainly altered the topography of Doctors Inlet and Julington Creek (and Red Bay), but these sites probably never appeared similar to Hallowes Cove in terms of submerged aquatic vegetation and flow regimes. Therefore, Station 3 would not be a suitable "reference site" in a classical impact analysis.

Environmental factors affecting the distribution of fishes in this segment of the river are not fully understood. Salinity is undoubtedly the most important physical factor and ontogenetic patterns the most important biological factor determining species distribution throughout the lower St. Johns River. To evaluate the importance of salinity, we must view the river on a broader geographical scale. Salinity acts as the initial sift in determining which species inhabit the lower river. In general, the species inhabiting this portion of the river were members of four basic ecohalinity groups: 1) marine invaders with limited brackish water tolerance; 2) euryhaline marine species with wide tolerances for low salinities; 3) euryhaline freshwater species with the ability to accept a limited range of brackish water; and 4) freshwater species essentially restricted to pure freshwater situations. In our study area, the marine invaders were poorly represented but seasonally present, mostly at Station 1. The freshwater group was better represented but confined to the littoral area, especially at Hallowes Cove (Station 3).

Ontogenetic cycles are the most important biological factor affecting distribution, especially since the dominant ecohalinity group is marine derived. Although we do not have length data, from earlier studies and casual observations we know that young of the year are the most important age group for most of the numerically dominant species. The ichthyofaunal composition of the lower St. Johns River, then, is greatly influenced by life history events not directly occurring in the estuary including reproductive success offshore, larval survival during inshore movement, and timing of these events. This is especially true for the demersal component of the ichthyofauna. The importance of other biological factors such as predation or competition for resources is unknown.

Since, by definition, most of the species that utilize the lower river as a nursery are preadapted to low salinity regimes, once these mostly-young fishes arrive in the river their distributions are likely to be influenced by seasonal and short-term water flow patterns, water temperature, and dissolved oxygen. The former is most important in the river's mainstem, the latter two in the nearshore shallows. Therefore while salinity is of overwhelming importance, short-term

fluctuations in flow temperature and/or salinity can have marked affect on ichthyofaunal composition at any given instant. This is especially true in shallows where the water temperatures and dissolved oxygen can vary substantially by season; in addition, wind-driven upwellings of saline water can drastically affect the largely stenohaline freshwater littoral assemblage.

Weinstein (1985) proposed that there were three distinct ecological facies within an estuary: 1) deep water of the channels and slopes near the head of the estuary; 2) shallow areas including marshes and associated habitats over oyster reefs, seagrass meadows, mudflats, etc.; and 3) deeper waters of higher salinity in the lower reach of an estuary. The second and third ecological facies agree with our study's shoreline and demersal zones. Weinstein (1985) believed that spatial and temporal partitioning of the estuary by species was an adaptation allowing maximum productivity of individual populations. The observed patterns of abundance and distribution are probably dependent upon a combination of biotic and environmental influences.

Investigations of oligohaline waters in other areas have reported species composition and proportions of freshwater, euryhaline/marine, and marine species similar to those we found in the lower St. Johns River. In an oligohaline portion of Old Fort Bayou, Mississippi, Peterson and Ross (1991) collected 38 fish species using seines. Of those collected, 19 were freshwater species and 19 were species of estuarine/marine origin. The assemblage was dominated by *Gambusia affinis*, *Lucania parva*, and *Anchoa mitchilli*. Our seine hauls produced 53 species, numerically dominated by *L. parva*, *A. mitchilli*, and *Menidia beryllina*. Of the 53 species collected, 23 were freshwater species, and 30 species were of estuarine/marine origin. Hastings et al. (1987) sampled the ichthyofauna of oligohaline Lake Maurepas, Louisiana where they collected 32 species by trawl, 34 species by multi-mesh gill net, and 41 species by rotenone, for a total of 67 species. The collections included 33 species of freshwater origin and 34 species of estuarine/marine origin. Their trawl catches were numerically dominated by *A. mitchilli*, *Ictalurus punctatus*, *I. furcatus*, and *Micropogonias undulatus*. The most numerous fishes in our trawl catches were *A. mitchilli*, *M. undulatus*, and *L. xanthurus*. The St. Johns River trawl collections included 29 estuarine/marine species and 10 freshwater species.

This study has documented the species composition and structural components of the fish assemblages occupying an oligohaline portion of the St. Johns River. We found the sampling variability of such coarse measures as number of species, number of individuals, and weights to be high. This variability, when considered in conjunction with the results of power analyses, suggests that the use of parametric statistics to test hypotheses regarding changes might be too costly and would not provide easily interpretable results. The use of single indicator species or single measures of diversity also do not appear to provide a clear description of observed data.

Having obtained a better understanding of the structure of the fish assemblage and characteristics of the sampling required to assess the assemblage, the next step is to document the functioning of the assemblage, particularly the trophic structure. Livingston (1980, 1982, 1984, 1988) showed that ecological investigations of fishes in coastal areas should use trophic units (ecological species) rather than taxonomic species as the basic unit of investigation. Several ontogenetic feeding types may be found within one species (Carr and Adams, 1973; Livingston, 1980, 1982) therefore assessments based on the taxonomic species may be misleading. Livingston (1984) found that species assemblages could be divided into ontogenetic feeding units that could be clustered into associations of similar feeding types. He used these associations as indicators of natural or man-induced alterations. Identification of functional feeding groups or guilds tends to provide more realistic biological framework form which to assess degradation of water and has been an important component in the development of the Index of Biological Integrity (Karr, 1991).

5.0 SUMMARY

An intensive ichthyofaunal sampling program was undertaken within a small segment of the lower St. Johns River using four gear types. Littoral, demersal and pelagic habitats were sampled quarterly at three sites. An additional site was sampled during the third and fourth quarters. Groups of common fishes characterized each habitat sampled (littoral, demersal, and pelagic). The littoral assemblage consisted mostly of freshwater species such as largemouth bass, bluegill and redear sunfishes, mosquitofish, and silversides. Marine species tolerant of low salinity were also collected in the nearshore zone. The littoral habitat was favorable to adult and juvenile fishes due to the food and cover provided by submerged aquatic vegetation present at all sampling sites. The demersal (bottom dwelling) fishes collected by trawling included mostly marine species spawned in oceanic waters which utilize the lower river as a nursery area. Atlantic croaker, spot and bay anchovy were the most abundant species collected. The pelagic habitat was characterized by menhaden and gizzard shad, both plankton feeders that migrate up and downstream in response to a variety of environmental factors. Differences among the stations in terms of fish species composition and abundance were slight. The Hallowes Cove site (Station 3) did appear to be somewhat dissimilar to the others, probably due to microhabitat and topography differences rather than degraded conditions related to human activities.

The lower St. Johns River supports a diverse assemblage of marine, estuarine, and freshwater fishes. The coexistence of these groups is mediated by the physical and biological factors yet to be completely identified. With limited temporal resolution we found that the marine component is fairly dynamic (spending only a portion of its life history in the river) while the freshwater and estuarine components are essentially static (i.e., spending their entire life history in the river). There is promise in the utility of community-level data to identify degradation in the system, however, continued analysis of different salinity regimes along the river gradient as well as trophic structure will be required to gain a more realistic assessment of the relationships between water quality and fish community response to alterations in water quality.

At its inception, this program was to produce an Index of Biological Integrity (IBI) for the lower St. Johns River Basin, however, once the initial data were examined it was readily apparent that the IBI would require some major modifications. Although this study did not produce an IBI, we did obtain the following:

- a useful side-by-side comparison of various sampling methodologies;

- an appreciation of the statistical strengths and weaknesses inherent in standard sampling methodologies;
- an understanding that ichthyofaunal monitoring as a tool for measuring environmental health is useful at the community level, not at species levels, at this time (this may not be true for some of the super dominant species if we factored out all outlier species variation); and
- the ability to identify future goals of research and the ways to achieve meaningful results.

6.0 RECOMMENDATIONS

Ichthyofaunal sampling has proven to be an important mechanism of monitoring the relative health of an aquatic system (i.e., Hocutt and Stauffer, 1980; Fausch et al., 1989; Karr, 1991). Bioassessments using fish are certainly warranted for several reasons. Fishes generally are apex predators in most aquatic situations and as bioconcentrators serve as indicators of environmental health. Fishes are also biopolitically important because they are the most visible component of the estuarine fauna and are captured recreationally and for human consumption. Any long-term monitoring of the lower St. Johns River will require sampling of the estuarine ichthyofauna. The following guidelines for future bioassessment of fishes in the lower St. Johns River Basin were established following the present study. Future bioassessment of fishes in the lower St. Johns River should consider the following recommendations. Many of these recommendations will seem second nature or automatic, but are included to reiterate the importance of basic protocols.

This study, along with earlier studies we performed (Snyder and Burgess, in prep.), suggest that future activities include the following:

(a) **Commitment to continued ichthyofaunal monitoring throughout the entire estuarine segment of the lower St. Johns River (Mayport to Lake George).** Such sampling need not be done all at once (as a mega-project); in fact, it would be better to attempt it as a series of smaller projects over a more prolonged period of time so as to document the year-to-year variation inherent in the physical and biological regimes of the lower river. An approach that allows sampling of sites at varying geographic localities up and down the river would provide the opportunity to document upstream-downstream movements of species, which couldn't be done in the present study because of limited geographic spread of stations. The spatial sampling scale needs to reflect the variability of the system. Such movements of key species is not only the norm for the system, but is also very important when one considers that these species act as carriers/depositors of any pollutants/parasites/diseases found in the river since they consume indigenous organisms and are consumed themselves.

(b) **Such studies require monthly sampling over a minimum of one calendar year.** The more limited quarterly sampling employed in this study, when compared to monthly sampling from earlier work (Snyder and Burgess, in prep.) and other estuarine studies give us only a snapshot when a video is needed. Even bimonthly sampling is too coarse for a dynamic system such as

the St. Johns River where significant changes occur on a weekly basis.

(c) **Such studies absolutely require documentation of species' lengths, as well as total numbers and weights.** Lengths are the only way to document age groups. The different age groups of many dominant euryhaline species often act more like different species than a single species. Measuring the catch allows for cohort analysis of these key species as well as documenting the life stages of all the ichthyofauna.

(d) **Good, consistent documentation of physical and habitat factors taken concurrently with fish sampling is a must.** Gaps in coverage of basic physical parameters (salinity, dissolved oxygen, temperature, color, and turbidity) hinder the accurate consideration of natural vs. man-induced variation. When nearshore sampling is employed, measures of macrophyte cover or density should be required. In many cases sediments should also be collected, especially where areas are thought or known to be contaminated.

(e) **The trophic relationships of the ichthyofaunal community should be investigated by initiating food habit studies.** The value of this approach has been well documented (Carr and Adams, 1972; Livingston, 1980, 1982, 1984). It allows a more realistic and focused look at relationships between species (and size classes) within the community and is a logical second step in the development of a more comprehensive understanding of the estuarine network.

Guidelines for future bioassessments in the lower St. Johns River:

- Broad geographic coverage over lower St. Johns River
- Monthly sampling
- Total numbers and weights of each species at each station/time
- Lengths of 30 individuals of each species at each station/time
- Trawling protocol should use 7 to 10 short duration tows; species accumulation should be analyzed.
- Multi-mesh gill nets should employ replicate sets if statistical analyses are expected.

- Seines were least useful from a variability standpoint, but some inshore collecting required. Alternative sampling methods (Wegener ring, throw traps or drop nets) should be investigated.

- Electrofishing valuable in oligohaline portions of the estuary, unusable in more saline (>15 ppt) portions.

7.0 LITERATURE CITED

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