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Seasonal Variation in Fish Assemblages Within the Estuarine Portions of the Myakka and Peace Rivers, Southwest Florida

CHARLES F. IDELBERGER AND MARIN F. D. GREENWOOD

Juvenile and small adult fish were sampled monthly from 1996 to 2002 in the estuarine portions of the Myakka and Peace rivers, at the northern end of Charlotte Harbor (a relatively pristine estuarine system in southwest Florida). We provide a detailed description of the fish faunas in these areas, including seasonal assemblage structure. Seasonal cycles in assemblage structure were evident. Nearshore (to ~5 m) fish assemblages sampled by seine were separated into three main seasonal groups by cluster analysis (January–April, May–September, September–January). The ichthyofauna collected from deeper (≥1.8 m) areas by otter trawl formed two seasonal groups (June–October and November–March). Small schooling taxa such as *Anchoa mitchilli*, *Menidia* spp. and *Eucinostomus* spp. dominated seine catches, and variations in their abundances contributed greatly to dissimilarities between seasons, as did seasonal recruitment of young-of-the-year (YOY) estuary-dependent species such as *Mugil cephalus*, *Lagodon rhomboides*, *Leiostomus xanthurus*, and *Bairdiella chrysoura*. Estuarine residents (e.g., *A. mitchilli* and *Trinectes maculatus*) and YOY estuary-dependent species (e.g., *Cynoscion arenarius* and *Menticirrhus americanus*) were important in defining seasonal dissimilarities in fish assemblages from the trawled areas. Correlations between biotic patterns and environmental factors (water temperature, salinity, dissolved oxygen, precipitation, and river discharge) were relatively low, perhaps reflecting the euryhaline nature of the fish present and their intrinsic spawning periods. The present study provides a detailed description of temporal ichthyofaunal patterns in the estuarine portions of two tidal rivers in southwest Florida and provides a baseline with which future fish populations in this area can be compared.

Temperate and subtropical estuaries are widely recognized as productive areas that serve as habitat for many fish species (e.g., Blaber and Blaber, 1980; Boesch and Turner, 1984; Comp and Seaman, 1985). The fish assemblages in these systems are typically dynamic, reflecting the changing suite of environmental conditions to which they are exposed on short-term or seasonal bases (Tremain and Adams, 1995; Able and Fahay, 1998). Low-salinity portions of estuaries, including brackish riverine areas, are of particular importance as nurseries for juvenile stages of many fishes (Lewis and Estevez, 1988; Peebles and Flannery, 1992). Benefits such as plentiful food resources, shelter, and limited predation pressure outweigh potential disadvantages such as fluctuating environmental conditions (Day et al., 1989).

The Myakka and Peace rivers and the adjacent bay system (Charlotte Harbor) remain one of the least developed areas in Florida (Comp and Seaman, 1985; Estevez, 1998). However, current and projected levels of human activity in this area and its watershed have heightened interest in maintaining the biological health of the system (Hammett, 1990; Estevez, 1998). As a result of increasing human population in southwest Florida, freshwater withdrawals from groundwater sources are reaching limits of sustainability, and rivers are increasingly being targeted as water supplies (Flannery et al., 2002). It is therefore of importance to examine the nature of the biological communities, including fishes, in order to establish baselines against which future observations can be compared (Tsou and Matheson, 2002). Information regarding the fish fauna in the estuarine portions of the Myakka and Peace rivers has been limited to unpublished or short-term data collected at few sites (Wang and Raney, 1971; Texas Instruments, Inc., 1978; Estevez, 1991). Peebles (2002) presented an analysis of fish and invertebrate data collected from numerous sites in the Peace River and Shell Creek during April 1997–May 1999. Other studies, including those by Wang and Raney (1971), Fraser (1997), and Poulakis et al. (2003), provided species accounts for the fish fauna in nonriverine areas of the Charlotte Harbor estuarine system. Poulakis et al. (2004) presented a detailed list of fish species records and a bibliography of ichthyological research in Charlotte Harbor, including the study area.

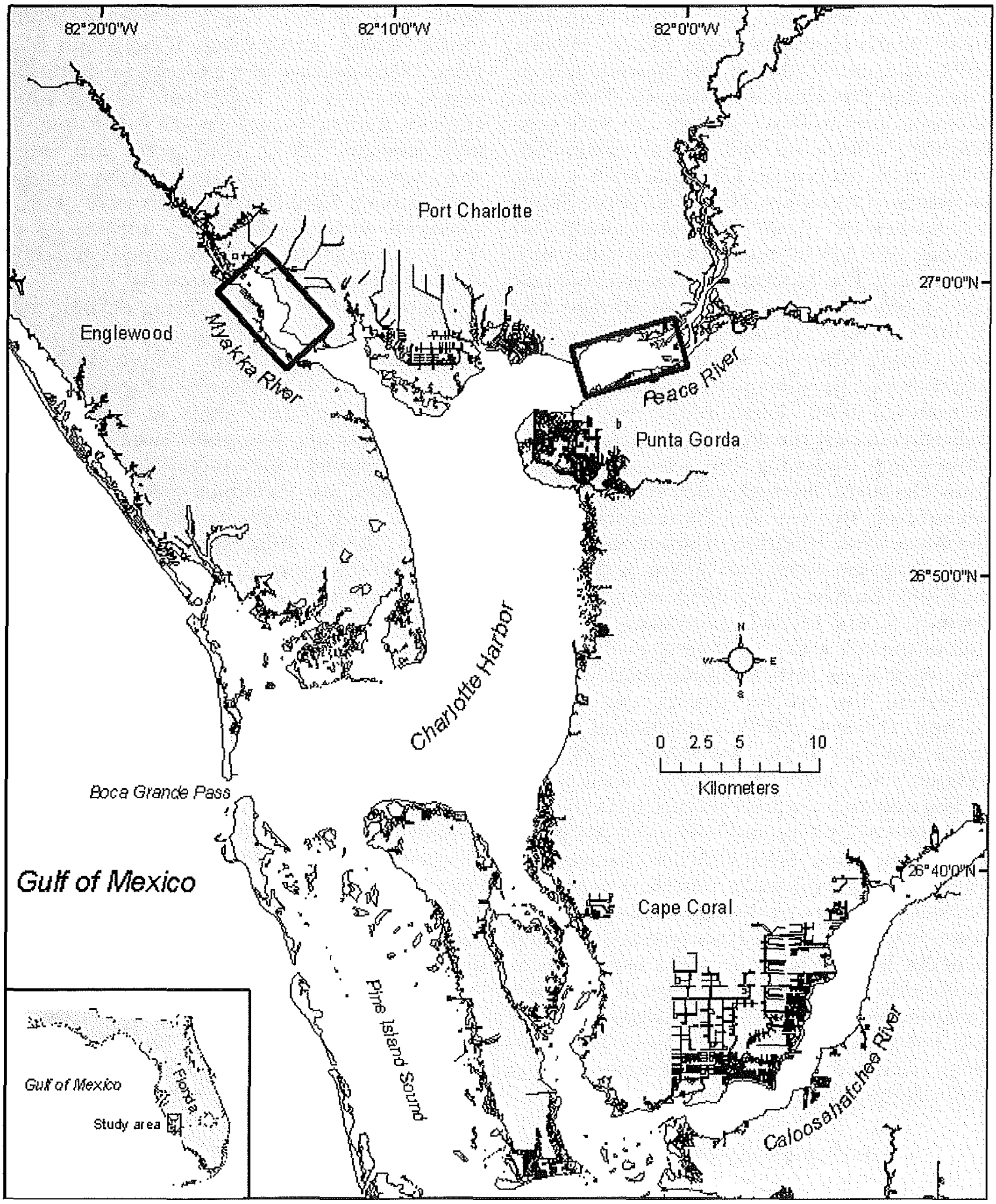

Fig. 1. Charlotte Harbor, Florida, with study areas in Myakka and Peace rivers denoted by rectangles.

The objectives of the present study were to address the lack of knowledge concerning the ichthyofauna in the estuarine sections of the Peace and Myakka rivers by using a long-term dataset to investigate seasonal patterns in the structure of the fish assemblages, and to test for relationships between these assemblage structures and various environmental factors.

STUDY AREA

The Myakka and Peace rivers are major tributaries of Charlotte Harbor, a relatively large (~700 km^2; Hammett, 1990), shallow estuary on the southwest coast of Florida (Fig. 1). The area is subtropical, with air temperatures averaging 16 °C in winter (December–January) and 27 °C in summer (July–August; Hammett, 1990). Yearly rainfall averages 134 cm (Taylor, 1974) and up to 70% of this typically falls as convection precipitation in summer. Occasional freezes and tropical cyclones can have considerable effects on the system (Hammett, 1990). Both rivers enter Charlotte Harbor near its northern terminus. The Peace River drains a watershed of ~6,090 km^2 and discharges an average of 3,415 $m^3 \cdot min^{-1}$ of fresh water into the estuary. The Myakka River's watershed covers ~1,560 km^2 and provides an average flow of 1,070 $m^3 \cdot min^{-1}$ (Hammett, 1990). Flow rates vary considerably on a seasonal basis, coinciding with precipitation patterns (Taylor, 1974; Hammett, 1990). Fresh water may extend downstream past the river mouths during and immediately following the wet season (i.e., June–October). Brackish water may extend upstream from the river mouths at least 50 km in the Peace River (Charlotte Harbor National Estuary Program, 1999) and 30 km in the Myakka River (Estevez et al., 1990) after extended periods of low rainfall, particularly near the end of the dry season of November–May. Varying degrees of vertical stratification are observed in the estuary during the warmer months (Estevez, 1998), contributing to seasonal hypoxia in the underlying water mass (Fraser, 1997) that may affect the study area.

The estuarine portions of both rivers are shallow (generally <3 m) and have a very low grade (Hammett, 1990). Shorelines are characterized by mangroves (principally *Rhizophora mangle* and *Avicennia germinans*), saltmarshes (dominated by *Spartina alterniflora* and *Juncus roemerianus*), and seawalls. Bottom substrate varies from sand to mud, with a few isolated patches of seagrasses (*Ruppia maritima* and *Halodule wrightii*) in shallow areas. Residential development lines portions of both rivers and is particularly dense at the mouth of the Peace River.

MATERIALS AND METHODS

Sampling methods.—The study area was sampled monthly from February 1996 through December 2002. Shallow (≤1.8 m) habitats close (≤5 m) to shore were sampled with a 21.3-m nylon bag seine (1.8-m depth, 3.2-mm mesh, 1.8-m × 1.8-m center bag). The seine was set by boat in a semicircle with both ends on the shoreline and hauled ashore. Deeper areas (≥1.8 m) were sampled with a 6.1-m otter trawl (38-mm mesh, with 3.2-mm mesh liner), towed for 5 min at ~0.6 $m \cdot sec^{-1}$, giving a typical tow length of ~180 m. Use of both seines and trawls allowed us to sample much of the estuarine fish fauna. Gear of these types and sizes most efficiently sample small fishes (Comp and Seaman, 1985) and are less effective in capturing larger, more mobile individuals such as adult clupeids, carangids, and elopids (see Kupschus and Tremain, 2001). Four seine and three trawl samples were collected monthly in each river estuary. Sampling locations were chosen randomly each month from a universe of all 0.1 × 0.1 nm sites that contained shoreline (seines) or suitable depth (trawls).

Samples were collected during daytime and processed in the field. All specimens were sorted to lowest practical taxon, enumerated, and up to 40 randomly selected individuals were measured (standard length in millimeters) from each sample. Extremely large collections were subsampled with a modified Motoda box splitter after less abundant species had been removed and processed (Winner and McMichael, 1997). Representative samples of most species were retained for quality control inspection, with the remaining fish being returned to the water. Species that could not be identified in the field were retained for laboratory identification. *Brevoortia* spp. and *Menidia* spp. were identified to genus due to the possibility of hybridization (Rogers and Van Den Avyle, 1983; Middaugh et al., 1986). *Eucinostomus* spp. <40 mm standard length were identified to genus, because species in this area cannot be reliably distinguished at small size (Tsou and Matheson, 2002). Nomenclature follows that of Robins et al. (1991).

Detailed physical data were recorded at each sampling site, including date, location (global positioning satellite coordinates), depth, and bottom and shoreline descriptors (e.g., substrate and vegetation type). Immediately following sample collection, a Hydrolab® water quality instrument was used to obtain hydrological measurements, including temperature (°C), salinity (‰), and dissolved oxygen ($mg \cdot liter^{-1}$). These variables were measured at the water surface and at 1.0-m depth intervals to the bottom.

Data analysis.—Hydrological data collected in the Myakka and Peace rivers were compared as follows: the null hypothesis that there was no significant difference in mean monthly values for temperature, salinity, or dissolved oxygen between the rivers was tested using t-tests; and the correlation of each of these variables between rivers was tested using Pearson correlation analysis.

Data from seine and trawl collections were both treated in the same manner but analyzed separately because of inherent differences in gear characteristics (Kjelson and Johnson, 1978; Allen et al., 1992). Monthly means of sample abundance indices (fish·100 m^{-2}) for each taxon were transformed ($\ln[x + 1]$) to reduce the influence of highly abundant species. All statistical procedures were performed with PRIMER (Plymouth Routines in Multivariate Ecological Research; Clarke and Warwick, 1994) version 5.2.2 software. A concise account of the same techniques used in a similar context is available in Tsou and Matheson (2002).

Bray–Curtis similarity matrices (Bray and Curtis, 1957) were calculated and used to perform a two-way analysis of similarity (ANOSIM; Clarke and Green, 1988) of seine and trawl data in order to assess whether any differences in fish assemblages existed between years or rivers for each month individually. Fish assemblage structure did not differ greatly between rivers; 67% of the monthly ANOSIM global R values were <0.25, indicating very similar faunas (Clarke and Gorley, 2001). Data from both rivers were therefore pooled for subsequent analyses, with the exception of BIO-ENV, which required river-specific environmental data. Remaining analyses used data averaged by year and month. Agglomerative hierarchical clustering with group-average linking (Kaufman and Rousseeuw, 1990) and nonmetric multidimensional scaling (MDS; Clarke and Warwick, 1994) were used to group months containing similar fish assemblages. Similarity percentage analysis (SIMPER; Clarke and Warwick, 1994) identified taxa representative of similarities within, and dissimilarities between, seasonal groups determined from cluster analysis. The PRIMER RELATE routine (Clarke and Warwick, 1994) was used to verify the presence of annual cycles in the fish assemblages (see Tsou and Matheson, 2002). This was achieved by creating a distance matrix wherein the distance between samples collected was based on the number of months between them (e.g., distance between January and February = distance between January and December = 1). The distance matrix was then related to the monthly biotic Bray–Curtis similarity matrix used in earlier analyses by calculating the Spearman rank correlation (ρ) between all the elements of the matrices; a permutation test randomly paired elements of the two matrices 999 times to investigate the null hypothesis that there was no relationship between the matrices (i.e., $\rho = 0$).

Patterns in the fish assemblages and environmental conditions were compared using the BIO-ENV routine (Clarke and Ainsworth, 1993). Environmental variables (water temperature, salinity, dissolved oxygen, precipitation, and river discharge), averaged by month of sampling, were used to form matrices based on normalized Euclidean distance; this was undertaken for every combination of transformed ($\ln[x + 1]$) variables (i.e., 31 matrices in total for each river). These matrices were compared to biotic matrices described above by computing Spearman rank correlation coefficients. To investigate how closely the observed biotic patterns matched typical environmental conditions, the analyses were repeated using environmental data averaged over all years; thus, the environmental matrices consisted of data that were repeated seven times, covering the 7 yr from 1996 through 2002. Precipitation data were obtained from the Southwest Florida Water Management District (SWFWMD) Web site (http://www.swfwmd.state.fl.us/data/wmdbweb.rnfpage.htm. The sums of mean daily precipitation (in millimeters) for the month of sampling at Myakka River State Park Nova (Site 194), North Port Water Treatment Plant (Site 334), and Venice NWS (Site 349) were used for the Myakka River. Data from Horse Creek (Site 418), Joshua Creek (Site 416), and Shell Creek (Site 420) were used for the Peace River. River discharge data were obtained from the U.S. Geological Survey Web site (http://water.usgs.gov/data.html). Monthly means of cumulative daily river discharge at Big Slough Canal near Myakka City (Station 02299410) and the Myakka River near Sarasota (Station 02298830) were used for the Myakka River. Data from Horse Creek near Arcadia (Station 02297310), Joshua Creek at Nocatee (Station 02297100), Shell Creek near Punta Gorda (Station 02298202), and the Peace River at Arcadia (Station 02296750) were used for the Peace River. Differences and correlations between monthly mean values of daily precipitation in the Myakka and Peace river watersheds were tested using t-tests and Pearson correlation analysis, respectively; the Pearson correlation between mean daily discharges of each river was also examined.

RESULTS

Hydrological variables.—Hydrological conditions in the estuarine portions of the Myakka and Peace rivers were similar during the study period. No significant differences between locations were apparent for any of the variables (all t-tests: $P > 0.05$), and strong correlations between the same variables in both systems existed (Pearson $r = 0.86$ [temperature], 0.80 [sa-

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TABLE 1. Phylogenetic listing of taxa collected during 1996–2002, with catch totals by river and gear.

		Myakka River		Peace River		
Family	Taxon	Seines	Trawls	Seines	Trawls	Total catch
Dasyatidae	*Dasyatis sabina*	4	125	18	125	272
	Dasyatis say	0	4	0	1	5
	Gymnura micrura	0	1	0	1	2
Myliobatidae	*Rhinoptera bonasus*	0	2	1	1	4
Lepisosteidae	*Lepisosteus osseus*	3	2	1	1	7
	Lepisosteus platyrhynchus	1	0	6	0	7
Elopidae	*Elops saurus*	8	1	18	0	27
	Megalops atlanticus	0	0	0	1	1
Albulidae	*Albula vulpes*	1	0	0	0	1
Ophichthidae	*Myrophis punctatus*	0	1	0	1	2
Clupeidae	*Brevoortia* spp.	1,189	0	125	0	1,314
	Dorosoma petenense	2	4	43	0	49
	Harengula jaguana	412	4	91	0	507
	Opisthonema oglinum	353	1	213	1	568
Engraulidae	*Anchoa hepsetus*	2,216	4	832	5	3,057
	Anchoa mitchilli	349,729	21,081	119,925	15,343	506,078
Synodontidae	*Synodus foetens*	14	6	30	12	62
Cyprinidae	*Notemigonus crysoleucas*	0	0	1	0	1
	Notropis maculatus	0	0	1	0	1
Ictaluridae	*Ameiurus catus*	0	1	0	24	25
	Ictalurus punctatus	0	5	0	19	24
Ariidae	*Arius felis*	8	1,526	1	310	1,845
	Bagre marinus	0	353	1	68	422
Batrachoididae	*Opsanus beta*	0	1	0	12	13
Gobiesocidae	*Gobiesox strumosus*	27	9	20	10	66
Belonidae	*Strongylura marina*	2	0	0	0	2
	Strongylura notata	164	0	65	0	229
	Strongylura timucu	60	0	34	0	94
Cyprinodontidae	*Adinia xenica*	126	0	314	0	440
	Cyprinodon variegatus	75	0	502	0	577
	Floridichthys carpio	2	0	3	0	5
	Fundulus confluentus	59	0	25	0	84
	Fundulus grandis	175	0	583	0	758
	Fundulus majalis	1,233	0	1,271	0	2,504
	Fundulus seminolis	0	0	42	0	42
	Jordanella floridae	1	0	1	0	2
	Lucania goodei	0	0	1	0	1
	Lucania parva	517	0	1,910	0	2,427
Poeciliidae	*Gambusia holbrooki*	2,037	0	365	0	2,402
	Heterandria formosa	0	0	24	0	24
	Poecilia latipinna	682	0	81	0	763
Atherinidae	*Membras martinica*	1,472	0	1,461	0	2,933
	Menidia spp.	11,742	3	14,952	0	26,697
Syngnathidae	*Hippocampus erectus*	0	4	0	4	8
	Syngnathus floridae	1	0	0	0	1
	Syngnathus louisianae	3	12	13	11	39
	Syngnathus scovelli	102	33	109	31	275
Triglidae	*Prionotus scitulus*	3	20	7	44	74
	Prionotus tribulus	6	65	20	276	367
Centropomidae	*Centropomus undecimalis*	7	0	16	0	23
Serranidae	*Diplectrum formosum*	4	0	0	0	4
Centrarchidae	*Lepomis gulosus*	25	0	0	0	25
	Lepomis macrochirus	17	1	9	0	27
	Lepomis microlophus	1	0	0	0	1
	Micropterus salmoides	0	0	2	0	2

TABLE 1. Continued.

		Myakka River		Peace River		
Family	Taxon	Seines	Trawls	Seines	Trawls	Total catch
Carangidae	*Caranx hippos*	0	0	4	0	4
	Chloroscombrus chrysurus	1	31	0	18	50
	Hemicaranx amblyrhynchus	0	0	0	2	2
	Oligoplites saurus	274	0	174	2	450
	Trachinotus falcatus	0	0	5	0	5
Lutjanidae	*Lutjanus griseus*	18	5	3	7	33
	Lutjanus synagris	1	0	1	2	4
Gerreidae	*Diapterus auratus*	1	0	2	0	3
	Diapterus plumieri	477	25	457	21	980
	Eucinostomus gula	2,150	209	470	19	2,848
	Eucinostomus harengulus	3,191	57	3,117	260	6,625
	Eucinostomus spp.	3,578	112	5,778	514	9,982
Haemulidae	*Orthopristis chrysoptera*	2	10	2	6	20
Sparidae	*Archosargus probatocephalus*	33	8	15	10	66
	Diplodus holbrooki	0	0	0	2	2
	Lagodon rhomboides	754	263	1,101	223	2,341
Sciaenidae	*Bairdiella chrysoura*	834	331	1,222	430	2,817
	Cynoscion arenarius	831	3,343	1,087	5,376	10,637
	Cynoscion nebulosus	236	25	201	13	475
	Leiostomus xanthurus	4,853	130	806	86	5,875
	Menticirrhus americanus	180	1,586	619	1,569	3,954
	Menticirrhus saxatilis	1	1	0	0	2
	Sciaenops ocellatus	454	11	697	13	1,175
Ephippidae	*Chaetodipterus faber*	0	24	3	46	73
Mugilidae	*Mugil cephalus*	2,406	0	2,356	0	4,762
	Mugil curema	37	0	10	0	47
	Mugil gyrans	193	0	251	0	444
Blenniidae	*Chasmodes saburrae*	9	0	5	3	17
	Lupinoblennius nicholsi	2	0	0	0	2
Gobiidae	*Bathygobius soporator*	26	1	40	2	69
	Gobionellus oceanicus	0	0	0	1	1
	Gobiosoma bosc	221	3	192	7	423
	Gobiosoma robustum	102	20	39	0	161
	Lophogobius cyprinoides	31	0	2	0	33
	Microgobius gulosus	917	402	465	67	1,851
	Microgobius thalassinus	2	70	0	80	152
Stromateidae	*Peprilus alepidotus*	0	0	0	1	1
Bothidae	*Paralichthys albigutta*	0	3	2	1	6
Soleidae	*Achirus lineatus*	30	9	35	11	85
	Symphurus plagiusa	44	101	57	202	404
	Trinectes maculatus	419	1,897	416	5,539	8,271
Balistidae	*Monacanthus hispidus*	0	0	0	1	1
Ostraciidae	*Lactophrys quadricornis*	0	1	0	0	1
Tetraodontidae	*Chilomycterus schoepfi*	1	6	0	4	11
	Sphoeroides nephelus	4	4	17	5	30
	Total	394,796	31,957	162,788	30,844	620,385
	Number of samples	336	247	339	252	1,174

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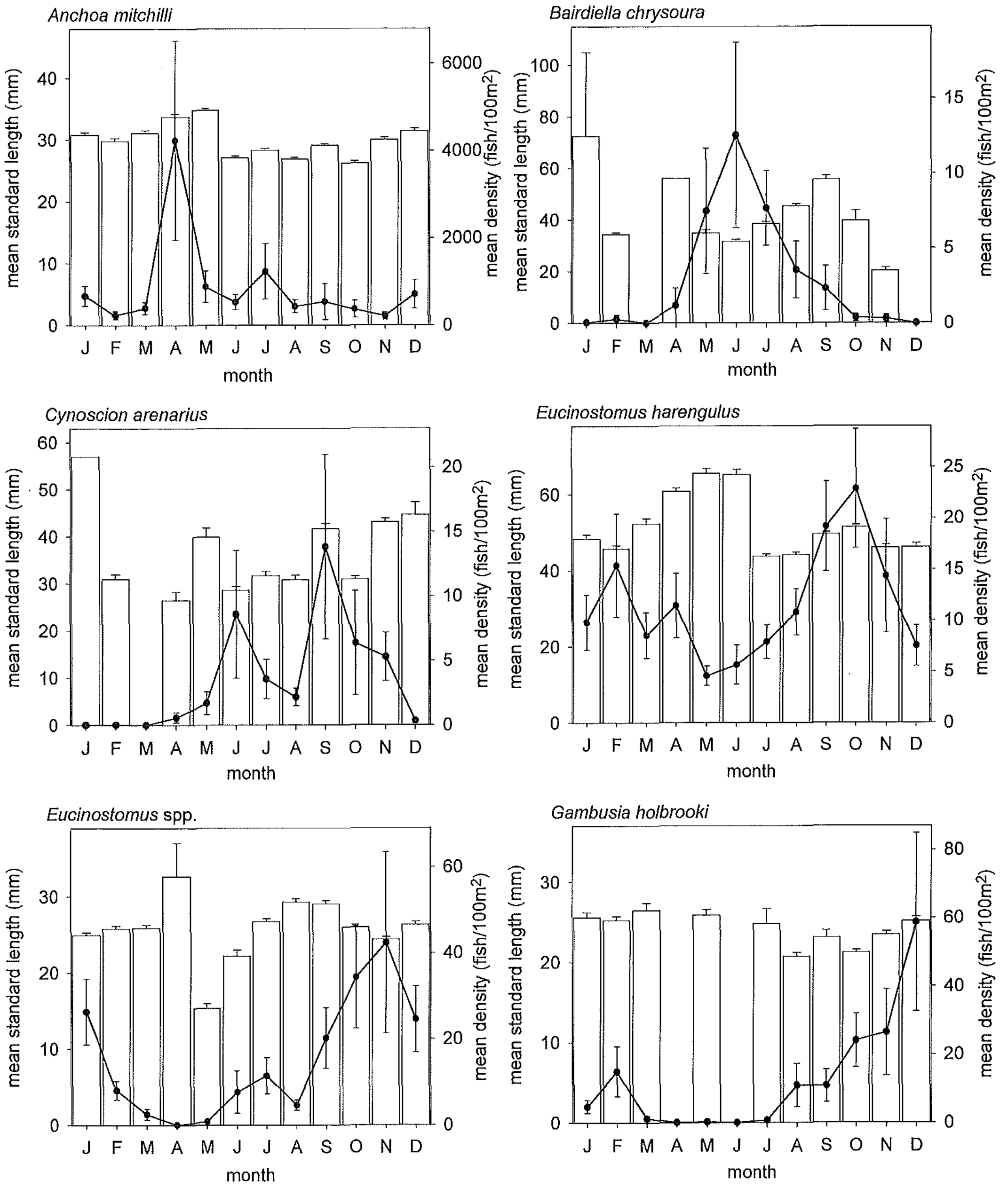

Fig. 2. Monthly length-frequency (bar) and mean abundance (line) plots ± SE for the most abundant taxa collected in Myakka and Peace river seine samples. Data from 1996 to 2002 were pooled.

linity], 0.68 [dissolved oxygen]; all $P < 0.05$). The range of mean monthly water temperatures was 14.4–31.8 C in the Myakka River and 14.1–32.9 C in the Peace River. Monthly mean temperature (rivers and years combined) was lowest in January (17.9 C) and February (20.1 C) and highest in July (30.7 C) and August (30.3 C). Monthly mean salinity ranged from 0.2 to 29.9‰ in the Myakka River, and 0.0 to 27.4‰ in the Peace River. Salinity (rivers and years combined) was highest in May (19.0‰) and June (20.5‰) and lowest from August to November (5.3 to 6.7‰), coincident with the beginning and end of the wet season. Monthly mean dissolved oxygen values ranged from 3.0 to 9.6 mg·liter^{-1} in the Myakka River, and 3.5 to 9.7 mg·liter^{-1} in the Peace River. Dissolved oxygen levels (rivers and years combined) were

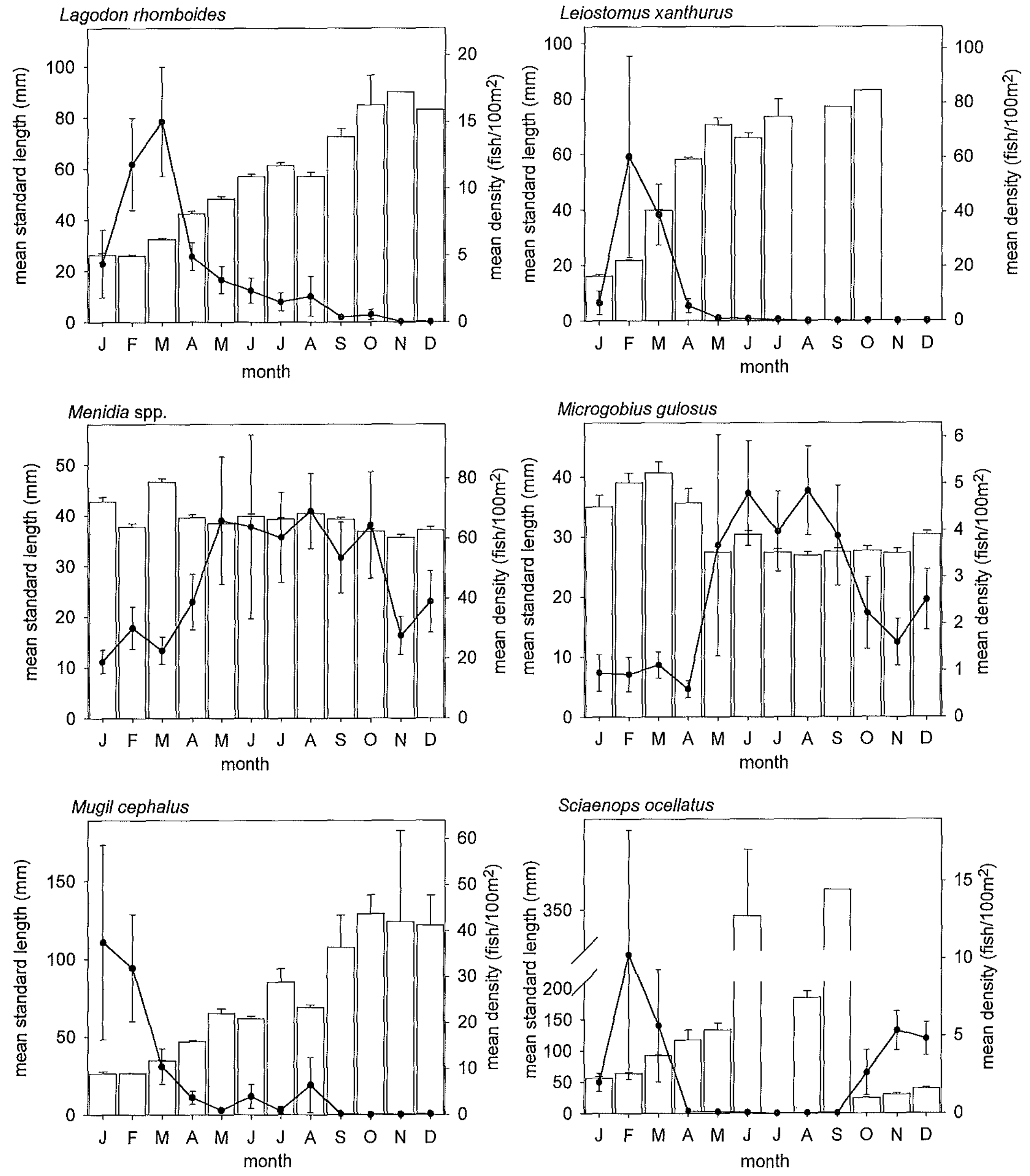

Fig. 2. Continued.

highest during January (8.2 mg·liter^{-1}) and February (7.9 mg·liter^{-1}) and lowest from August to November (4.7 to 5.3 mg·liter^{-1}). Hypoxic bottom conditions (dissolved oxygen levels of 1.2–2.6 mg·liter^{-1} at individual sites) were observed in the lower Peace River during each summer season. Mean daily precipitation in each month did not differ between river basins (t-test: $P > 0.05$); values were significantly correlated (Pearson $r = 0.83$, $P < 0.001$). The time series included several major deviations from long-term precipitation means (SWFWMD, 2003): June 1996–March 1997 and 2000 were unusually dry periods; November 1997–March 1998 and much of 2002 were uncharacteristically wet. Mean daily river discharge in each month was also significantly correlated between rivers (Pearson $r = 0.93$, $P < 0.001$).

Ichthyofaunal description.—A total of 1,174 samples containing 620,385 fish (99 taxa, 39 families) were collected (Table 1). Families with the most species represented were Cyprinodontidae (10), Sciaenidae (7), Gobiidae (7), and Carangidae (5). *Anchoa mitchilli* was the most abundant species collected (81.6% of total catch), followed by *Menidia* spp. (4.2%), *Cynoscion arenarius* (1.7%), *Eucinostomus* spp. (1.6%), *Trinectes maculatus* (1.3%), *Eucinostomus harengulus* (1.1%), *Leiostomus xanthurus* (0.9%), and *Mugil cephalus* (0.8%). Thirty-two species were relatively rare (fewer than 10 individuals taken). Catches in the Myakka and Peace rivers were qualitatively similar—78 taxa were common to both systems. Those that were not taken in both rivers were not abundant or not frequently collected. Although the total catch in the Myakka River ($n = 426,753$) was larger than that taken in the Peace River ($n = 193,632$), the difference was due principally to larger numbers of *A. mitchilli* collected in the Myakka River (Table 1), including two unusually large seine samples, one containing 117,248 and the other 45,568 individuals.

Monthly variations in abundance and size of individual taxa collected in the study area were apparent. Periods of highest abundance often coincided with periods of lowest mean length and reflected peak recruitment periods of young-of-the-year (YOY) of that taxon in the study area (Figs. 2, 3; see Livingston, 1976). Recruitment of *L. xanthurus, Lagodon rhomboides,* and *M. cephalus* to the study area took place in winter. *Anchoa hepsetus* and *Brevoortia* spp. recruited in spring. Maximum recruitment of *A. mitchilli, Bairdiella chrysoura, C. arenarius,* the mojarras (*E. gula, E. harengulus,* and *Eucinostomus* spp.), *Membras martinica, Menidia* spp., *Menticirrhus americanus,* and *Microgobius gulosus* occurred in spring and summer. *Arius felis, Bagre marinus,* and *T. maculatus* recruited mainly in summer; *Gambusia holbrooki* recruited mainly in fall; and *Sciaenops ocellatus* recruited in fall and winter.

Temporal variation in fish assemblages.—Annual cycles in fish assemblage structure were apparent as circular progressions of consecutive monthly samples in MDS plots (Figs. 4, 5), although the degree of definition of the annual cycles varied between years and was generally less well-defined for the trawl data than for the seine data. Results of the RELATE analyses indicated significant correlations between these assemblage patterns and monthly distance matrices in all cases (Figs. 4, 5).

Three main seasonal faunal groups were identified by cluster analysis of the seine data. They consisted of samples collected principally from January to April, samples collected from May to September, and samples collected from September to January. Similarities among and dissimilarities between the faunal compositions of these seasonal groups were examined by SIMPER analyses. The abundant estuarine resident taxa *A. mitchilli, Menidia* spp., and *E. harengulus* were found to be characteristic in each of these groups. Variations in abundance of these species helped to distinguish the seasonal assemblages from one another: *A. mitchilli* were most abundant during January–April, *Menidia* spp. were most abundant during May–September, and *E. harengulus* were most abundant during September–January. The January–April period was also typified by high abundances of *L. rhomboides, L. xanthurus,* and *M. cephalus.* Highest abundances of *A. hepsetus, B. chrysoura, C. arenarius, E. gula, Fundulus majalis, M. martinica,* and *M. gulosus* characterized the May to September fish assemblage. The September–January assemblage was characterized by highest abundances of *E. harengulus, Eucinostomus* spp., *Fundulus grandis, G. holbrooki,* and *S. ocellatus.*

Trawl samples did not cluster as distinctly as seine samples did: only two large seasonal groups were obvious, consisting of samples collected from June to October and samples collected from November to March (Fig. 7). When these groups were examined using SIMPER, both were characterized by four main species: *A. mitchilli, T. maculatus, C. arenarius,* and *M. americanus.* Differences in abundance of these species were most important in differentiating the two seasonal assemblages, with *A. mitchilli* the only species being more abundant from November to March. Highest abundances of *A. felis, B. chrysoura, B. marinus, E. harengulus, Eucinostomus* spp., and *M. gulosus* from June to October and lowest abundances of *Dasyatis sabina, L. rhomboides,* and *Prionotus tribulus* from November to March also distinguished the two main seasonal assemblages.

Temporal biotic–environmental relationships.—Correlations between temporal biotic and environmental matrices were relatively low for the environmental factors we examined ($\rho \leq 0.297$) and differed little when monthly mean environmental conditions from 1996 to 2002 were pooled ($\rho \leq 0.305$; Table 2). Temperature and river discharge, either singly or in combination, were the environmental variables that most often best matched the fish assemblage.

DISCUSSION

The estuarine portions of the Myakka and Peace rivers are proximate, physically similar,

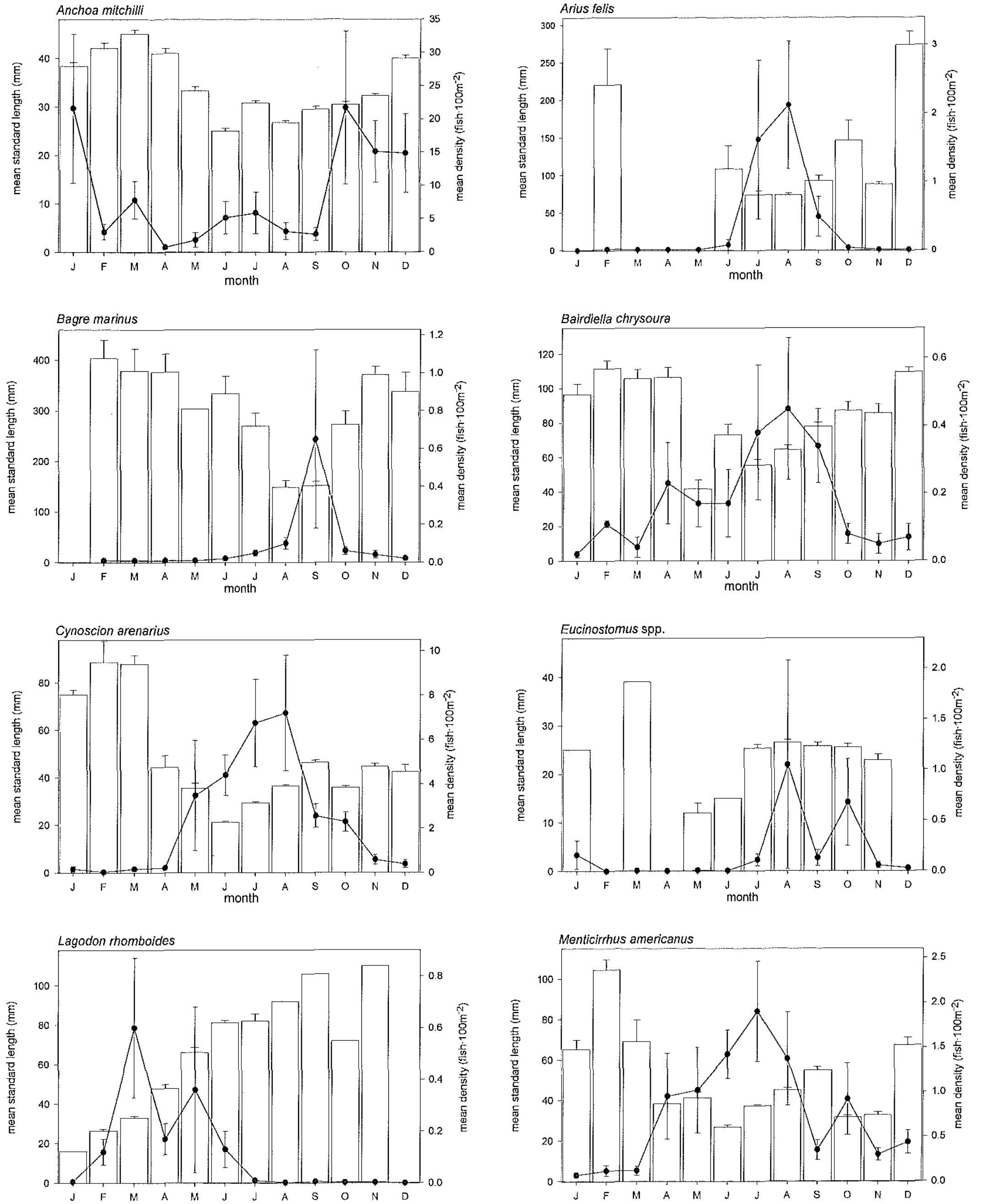

Fig. 3. Monthly length-frequency (bar) and mean abundance (line) plots ± SE for the most abundant taxa collected in Myakka and Peace river trawl samples. Data from 1996 to 2002 were pooled.

and similar in hydrological conditions and fish assemblages. In terms of overall abundance, the fauna in the study area is dominated by a few small-sized schooling taxa, including *A. mitchilli, Menidia* spp., and fishes of the genus *Eucinostomus*. Although species may differ somewhat by location and sampling methods, numerical dominance by relatively few species appears to be characteristic of estuaries throughout Florida (e.g., Comp and Seaman, 1985; Tremain and Adams, 1995; Paperno et al., 2001) and elsewhere (e.g., Henderson,

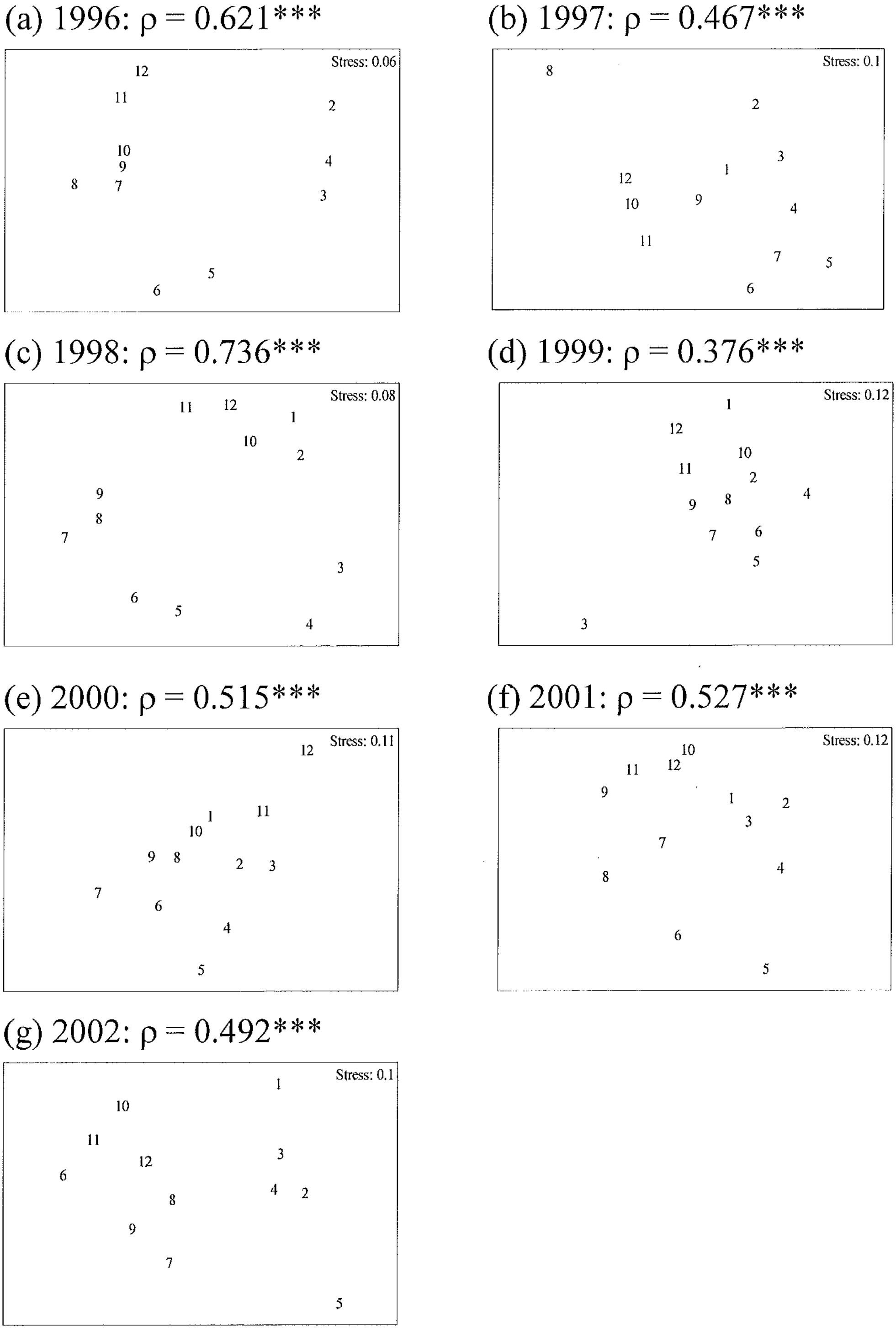

Fig. 4. Multidimensional scaling plots of seine data, 1996 to 2002 (monthly means: 1 = Jan., 2 = Feb., etc.). The degree to which the seasonal progression of fish-assemblage structure approximates a circle indicates regularity of the annual cycles of species succession, with the ρ value from the PRIMER RELATE analysis providing additional evidence of this transition (higher values indicate smoother transition; $*P \leq 0.05$; $***P \leq 0.001$).

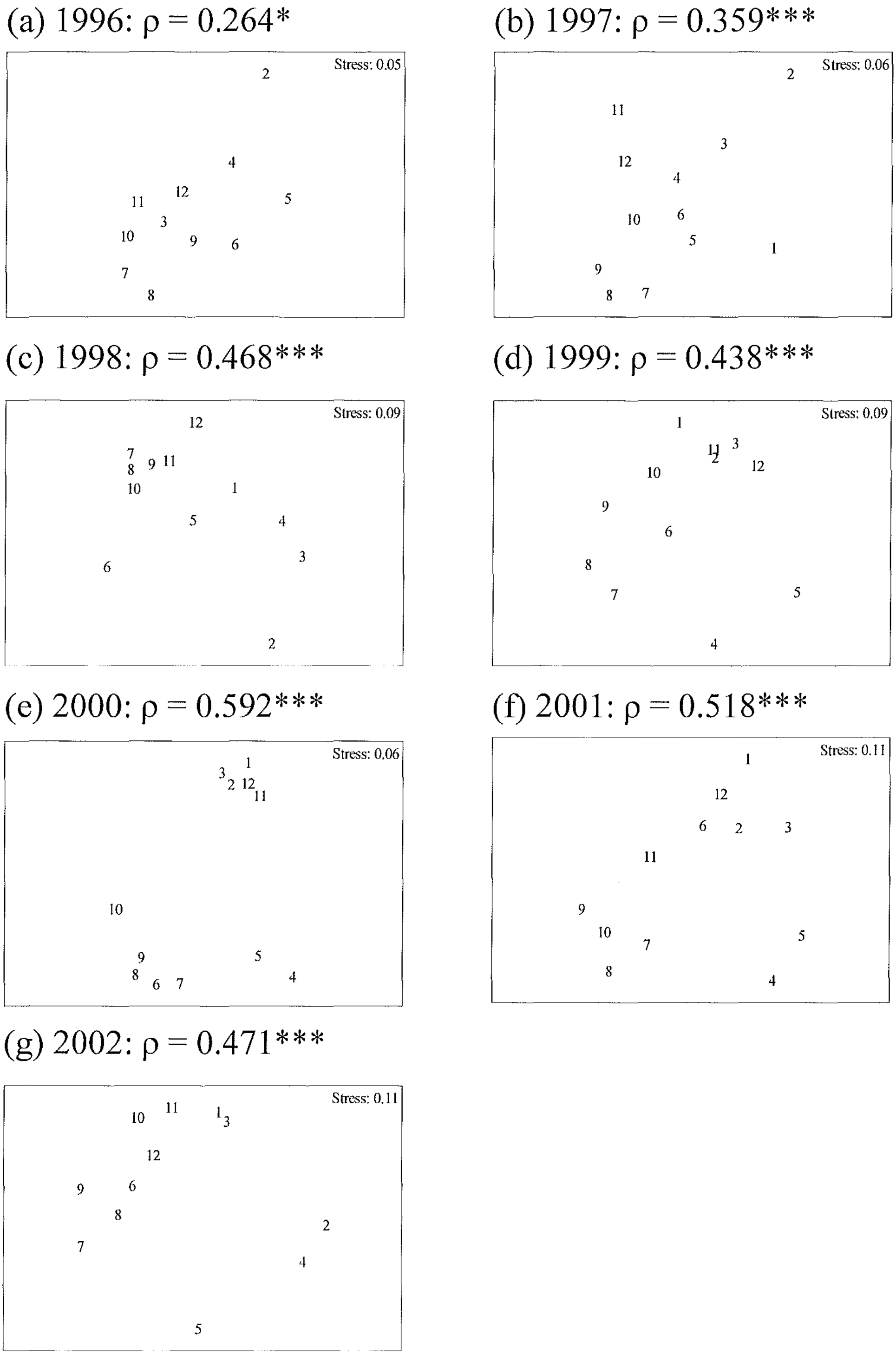

Fig. 5. Multidimensional scaling plots of trawl data, 1996 to 2002 (monthly means: 1 = Jan., 2 = Feb., etc.). The degree to which the seasonal progression of fish-assemblage structure approximates a circle indicates regularity of the annual cycles of species succession, with the ρ value from the PRIMER RELATE analysis providing additional evidence of this transition (higher values indicate smoother transition; $^{*}P \leq 0.05$; $^{***}P \leq 0.001$).

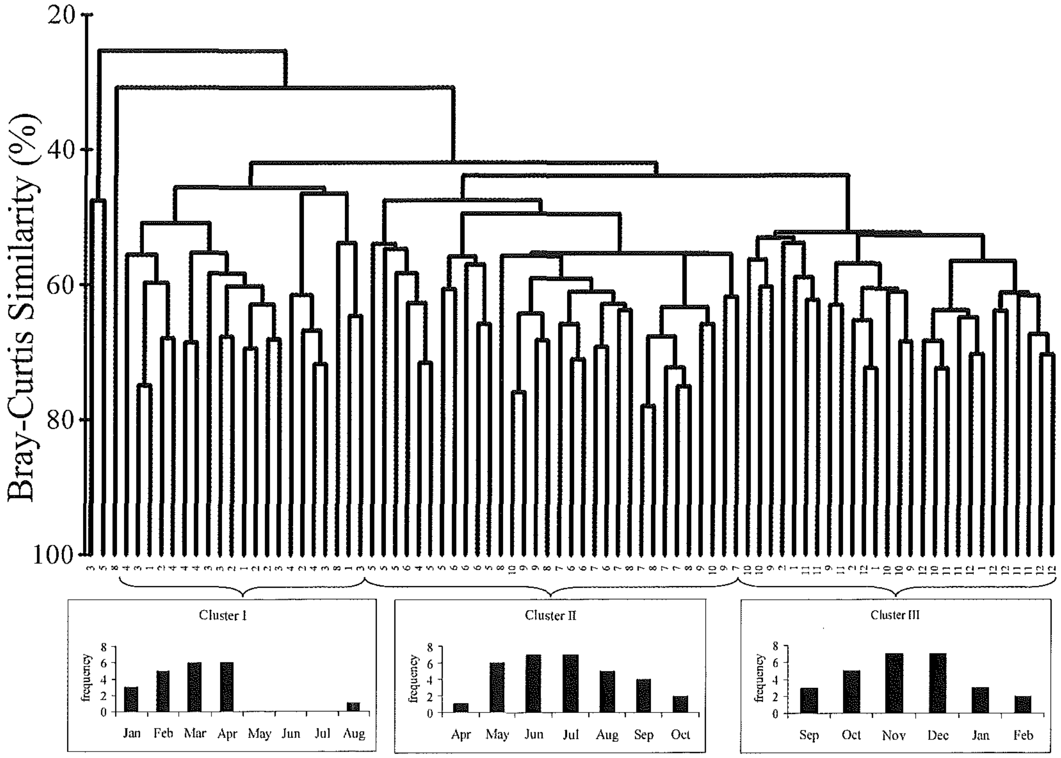

Fig. 6. Dendrogram of monthly seine data (1 = Jan., 2 = Feb., etc.). Frequency plots are included to highlight number of months composing Cluster I (January–April), Cluster II (May–September), and Cluster III (September–January).

1989; Tzeng and Wang, 1992; Jackson and Jones, 1999). This pattern is likely to be attributable to the relatively low number of species that are capable of tolerating major fluctuations in physical conditions that are typical of estuaries (Day et al., 1989).

Seasonal fluctuations in abundance of some resident species, principally *A. mitchilli* and *Menidia* spp., were important in defining seasonal fish assemblages in the Myakka and Peace rivers. Although YOY of these species were collected throughout most of the year, reflecting their protracted spawning periods (Peebles and Flannery, 1992; Peebles, 2002), peak spawning occurred during the warmer months. Influxes of YOY of estuary-dependent species (those species that use the estuary during a part of their lives; e.g., *C. arenarius, L. rhomboides,* and *M. americanus*) from areas of higher salinity also helped define the seasonal assemblages. Peak abundances of these species were usually short-lived, with numbers soon decreasing because of mortality and emigration. Temporary occupation of lower-salinity portions of Florida west coast estuaries by juveniles of many fish species has been well documented (Lewis et al., 1985; Lewis and Estevez, 1988; Peebles and Flannery, 1992), and constitutes a critical link in the life cycles of these fishes.

Well-defined fish assemblages occurred from May/June to September/October in both the seine- and trawl-sampled areas of the Myakka and Peace rivers, coincident with the summer wet season. Recruitment of the majority of estuarine-dependent fish species (e.g., *B. chrysoura, C. arenarius,* and *M. americanus*) into these areas during this period may be timed to take advantage of such factors as abundant food resources and shelter (in the form of enhanced turbidity and access to complex shoreline habitats) associated with increased river discharge. Another group of estuarine-dependent species (e.g., *M. cephalus, L. rhomboides,* and *L. xanthurus*) displayed a pattern of fall spawning and winter recruitment into the estuaries. Benefits of this strategy might include lowered food requirements associated with decreased metabolic rate and reduced predation pressure if predators have emigrated from the estuary or decreased feeding (Miller et al., 1984). Seasonal variation in estuarine fish assemblages is strongly influenced by biological

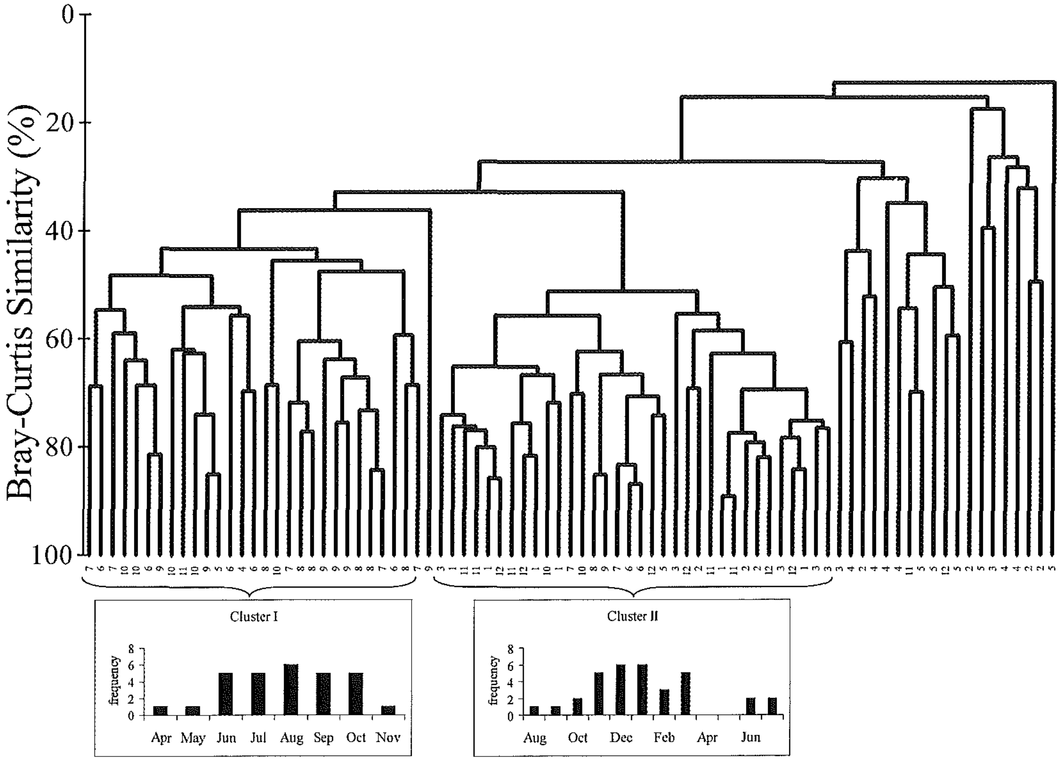

Fig. 7. Dendrogram of monthly trawl data (1 = Jan., 2 = Feb., etc.). Frequency plots are included to highlight number of months composing Cluster I (June–October) and Cluster II (November–March).

factors, including the spawning and recruitment patterns of the individual species within or outside the estuary (Comp and Seaman, 1985; Maes et al., 1998; Tsou and Matheson, 2002). Spawning patterns of each species likely evolved primarily to coincide with the optimal period for survival and development of offspring, with reproductive seasonality triggered by such factors as changing photoperiod (see Bye, 1990) or endogenous rhythms (Connaughton and Taylor, 1996). Not surprisingly, changes in fish-assemblage structure in our study area occurred during the main periods of seasonal transition (April–May and September–October).

Table 2. Results of matching of biotic and environmental data from the Myakka and Peace rivers, conducted with the PRIMER BIO-ENV routine (Clarke and Ainsworth, 1993).[a]

River	Gear	Actual env. data	'96–'02 Env. data
Myakka	seine	$0.257^{\mathrm{temp,disch}}$	0.239^{disch}
	trawl	$0.242^{\mathrm{sal,temp}}$	0.277^{temp}
Peace	seine	$0.297^{\mathrm{sal,temp,rain}}$	$0.305^{\mathrm{temp,disch}}$
	trawl	$0.246^{\mathrm{temp,disch}}$	$0.258^{\mathrm{temp,disch}}$

[a] Results were separated by river and gear, as well as by environmental (env.) data used (actual = mean data for month of sampling; '96–'02 = mean data for month of sampling, all years pooled). Values are Spearman rank correlation coefficients (ρ), with superscripts indicating best combination of environmental data correlating with biotic data: sal, salinity; temp, temperature; disch, river discharge; rain, precipitation.

Temporal fish assemblage patterns were weakly related to environmental factors in both the Myakka and Peace rivers. Tsou and Matheson (2002) noted a similarly low association between environmental factors and nekton assemblages in the estuarine portion of the Suwannee River, with temperature and river discharge best matching the biotic data ($\rho = 0.28$), as in the present study. They cited as possible reasons for the low correlation: (a) delay in biotic response to environmental change, (b) lack of in situ river discharge data, (c) high degree of noise in biotic and environmental data, (d) environmental fluctuations being well within the biota's normal range. Nonlinear relationships between fish abundances and freshwater inflow, such as highest abundance at intermediate flow, may also hinder our ability to determine the relationships between biotic and environmental conditions. Low associations of fish assemblages with environmental factors have been demonstrated in other estuaries in northwest Florida (Subrahmanyam and Drake, 1975; Livingston et al., 1976) and elsewhere (e.g., Maes et al., 1998; Jackson and Jones, 1999). Because many estuarine-dependent fishes are able to tolerate a wide range of hydrological conditions during juvenile stages, the direct influence of factors such as temperature, salinity, and dissolved oxygen level may not strongly affect assemblage composition except under extreme conditions (Livingston et al., 1976; Claridge et al., 1986). Potter et al. (1986), for example, showed that the annual cyclical change in the fish assemblages of the Severn Estuary (U.K.) from 1972 to 1977 was related principally to the recruitment patterns of the numerically dominant species, with salinity being related to changes only in extremely wet or dry years.

Although the effects of environmental alterations on fish populations in estuarine areas are difficult to predict given the natural variability in environmental and biotic conditions, anthropogenic changes have the potential to affect these seasonal assemblages. Peebles (2002, p. 69) states that for the Peace River estuary there is "no time of year when the potential for impacting economically or ecologically important species is absent" because of the different taxa spawning throughout the year. Alterations such as freshwater withdrawal may affect some species directly by presenting them with a suboptimal suite of hydrological conditions or by affecting the transport and retention of eggs and larvae. Abundances of many fish and invertebrate species in southwest Florida tidal rivers have been observed to decrease during low-flow periods (Flannery et al., 2002). Increased water withdrawals from the Peace River are planned to occur principally during periods of high flow (Charlotte Harbor National Estuary Program, 1999), which would overlap the period of highest fish recruitment, diversity, and use of its estuarine area. Alterations to the natural environment may indirectly affect fisheries by causing permanent physical changes to habitat or by altering nutrient supplies that influence the timing, quality, and quantity of specific fish food resources. For example, reduced freshwater inflow may result in a decrease in downstream abundance of mysids, an important food for juvenile *Centropomus undecimalis, S. ocellatus,* and *Cynoscion* spp. (Peebles, 2002). Indirect effects of upstream movement of the salt wedge caused by increased water withdrawal could include a succession of vegetation from saltmarsh to mangrove-dominated habitat (Harris et al., 1983). Any species reliant on marsh may be adversely affected by the reduction in this habitat; one such species is the blue crab, *Callinectes sapidus* (Durako et al., 1985).

In summary, the estuarine portions of the Myakka and Peace rivers are home to similar, diverse fish faunas. These areas have distinctive seasonal assemblages that are defined primarily by recruitment of YOY resident and estuarine-dependent species to and from these nursery areas. The seasonally defined fish assemblages we observed were relatively stable over the 7-yr study period. Based on the characteristically predictable nature of temporal recruitment patterns of estuarine fishes in this and other areas (Livingston et al., 1976; Tremain and Adams, 1995; Maes et al., 1998), these assemblages would be expected to remain stable over the long term, barring environmental alteration.

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