Biological Sciences

Fishes of the Lemon Bay estuary and a comparison of fish community structure to nearby estuaries along Florida's Gulf coast

Charles F. Idelberger[(1)], Philip W. Stevens[(2)], and Eric Weather[(2)]

[(1)]Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Charlotte Harbor Field Laboratory, 585 Prineville Street, Port Charlotte, Florida 33954
[(2)]Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue Southeast, Saint Petersburg, Florida 33701

Abstract Lemon Bay is a narrow, shallow estuary in southwest Florida. Although its fish fauna has been studied intermittently since the 1880s, no detailed inventory has been available. We sampled fish and selected macroinvertebrates in the bay and lower portions of its tributaries from June 2009 through April 2010 using seines and trawls. One hundred three fish and six invertebrate taxa were collected. Pinfish *Lagodon rhomboides*, spot *Leiostomus xanthurus*, bay anchovy *Anchoa mitchilli*, mojarras *Eucinostomus* spp., silver perch *Bairdiella chrysoura*, and scaled sardine *Harengula jaguana* were among the most abundant species. To place our information into a broader ecological context, we compared the Lemon Bay fish assemblages with those of nearby estuaries. Multivariate analyses revealed that fish assemblages of Lemon and Sarasota bays differed from those of lower Charlotte Harbor and lower Tampa Bay at similarities of 68–75%, depending on collection gear. These differences were attributed to greater abundances of small-bodied fishes in Lemon and Sarasota bays than in the other much larger estuaries. Factors such as water circulation patterns, length of shoreline relative to area of open water, and proximity of Gulf passes to juvenile habitat may differ sufficiently between the small and large estuaries to affect fish assemblages.

Keywords Estuarine fishes, Lemon Bay, southwest Florida

Introduction

Estuaries in southwest Florida support productive biological systems with diverse and valuable fish populations (Comp and Seaman 1985). If these systems and their fish communities are to be protected, it is important to have accurate and detailed information on the fish fauna of the estuaries (Able and Fahay 1998, Franco et al. 2008). The ecological integrity of many estuaries worldwide is being increasingly taxed by impacts of human population growth such as habitat destruction, altered freshwater inflow, excess nutrient input, and introduction of nonnative organisms (Kennish 2002). Estuarine fish populations can also be negatively affected by overfishing and by natural events such as, in southwest Florida, hurricanes, cold kills, and toxic algal (red tide) blooms (Hammett 1990, Flaherty and Landsberg 2011). As a starting point for tracking changes in a region's ichthyofauna, a basic species inventory is needed.

Corresponding author: Philip Stevens, philip.stevens@MyFWC.com

A southwest Florida estuary for which the fish fauna has not been thoroughly described is Lemon Bay. Henshall (1891) first investigated the fish fauna of southwest Florida, including Lemon Bay, in 1889. Subsequently, marine research has been conducted at facilities adjacent to Lemon Bay (Bass Biological Laboratory 1931–1944, Cape Haze Marine Laboratory 1955–1960). Wang and Raney (1971) sampled fish by trawl at four sites in Lemon Bay during April 1968. A comprehensive species inventory of fish in this estuary, however, has been unavailable. We sampled fish in Lemon Bay from June 2009 through April 2010 to develop such an inventory and to describe the fish fauna.

To place our information into a broader ecological context, we also compared species compositions and relative abundances of fish assemblages in Lemon Bay with those of several similar nearby polyhaline estuarine areas (lower Charlotte Harbor, Sarasota Bay, and lower Tampa Bay). Fish assemblages in all these estuaries might be expected to share similarities due to the influence of shared regional factors, including climatic variations and variations in recruitment of transient species from common offshore spawning sites. Such similarities have been demonstrated among proximate European estuaries, where fish assemblages were shown to be functionally similar to one another and to exhibit a shared seasonal pattern in diversity (Franco et al. 2008, Selleslagh et al. 2009, Cardoso et al. 2011). Differences between neighboring estuaries in characteristics such as watershed land use (e.g. agricultural vs. urban), connectivity to open ocean waters, freshwater input, and composition and quality of aquatic habitat, can nevertheless result in estuary-specific differences in the fish assemblages (Paperno et al. 2001, Franco et al. 2008). Identifying interbay differences in fish assemblages would help resource managers in evaluating the relative value of an area as fish habitat.

Materials and Methods

Study site. Lemon Bay is a long (21 km), narrow (<2 km), shallow estuary on the coast of southwest Florida (FDNR 1992) (Figures 1 and 2). It is located behind a series of barrier islands where the town of Englewood Beach and several smaller coastal communities are situated and is connected to the Gulf of Mexico by Stump and Gasparilla passes. Fresh water enters the estuary from several small tributaries on the mainland that pass through the urban areas of Englewood and Venice. Historically, the Lemon Bay estuarine system consisted of a series of shallow linear lagoons. In the early 1960s these embayments were connected and joined with Charlotte Harbor to the south and Sarasota Bay to the north as part of the Intracoastal Waterway (Antonini et al. 1998, FDEP 2005). The study area included the estuarine waters of Lemon Bay from the Boca Grande Causeway north to Alligator Creek, and the lower (1 km) portions of the six major tributaries (Alligator, Forked, Gottfried, Ainger, Oyster, and Buck creeks).

The climate in the Lemon Bay area is subtropical, with rainy summers and a fall to spring dry season (Hammett 1990, FDNR 1992). Occasional events such as freezes, tropical cyclones, and blooms of toxic phytoplankton (red tides) affect the ecosystem (Hammett 1990, Flaherty and Landsberg 2011). Mangroves dominate the shorelines of the estuary, although small stretches have been seawalled where the Intracoastal Waterway passes close to shore. Seagrasses, principally shoal grass *Halodule wrightii*, turtle grass *Thalassia testudinum*, and manatee grass *Syringodium filiforme*, are common throughout the shallow waters of Lemon Bay and are present to some degree in the relatively shallow (<2 m) tributaries (FDNR 1992).

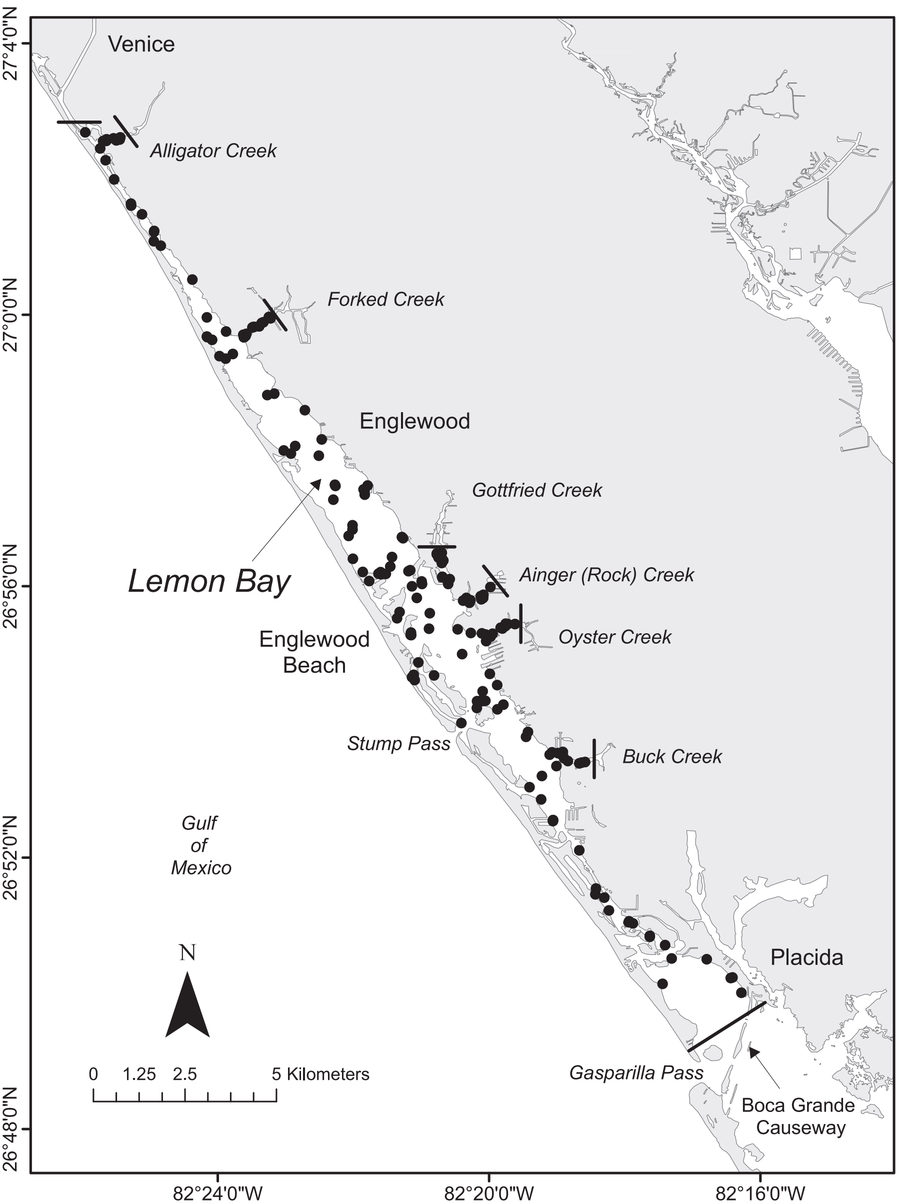

Figure 1. Lemon Bay estuary, with sites sampled during the study period (June 2009–April 2010). Solid vectors denote boundaries of study area.

The Lemon Bay estuary has undergone considerable urbanization since the 1950s, and "significant artificial alterations have been made to the natural shorelines and drainage patterns of the Lemon Bay area through dredging and filling" (FDNR 1992). It has been estimated that about 70% of the historic wetlands and 55% of the mangroves in the watershed remain (Conservancy of Southwest Florida 2011). Overall water quality in this system (e.g. chlorophyll *a*, fecal coliform,

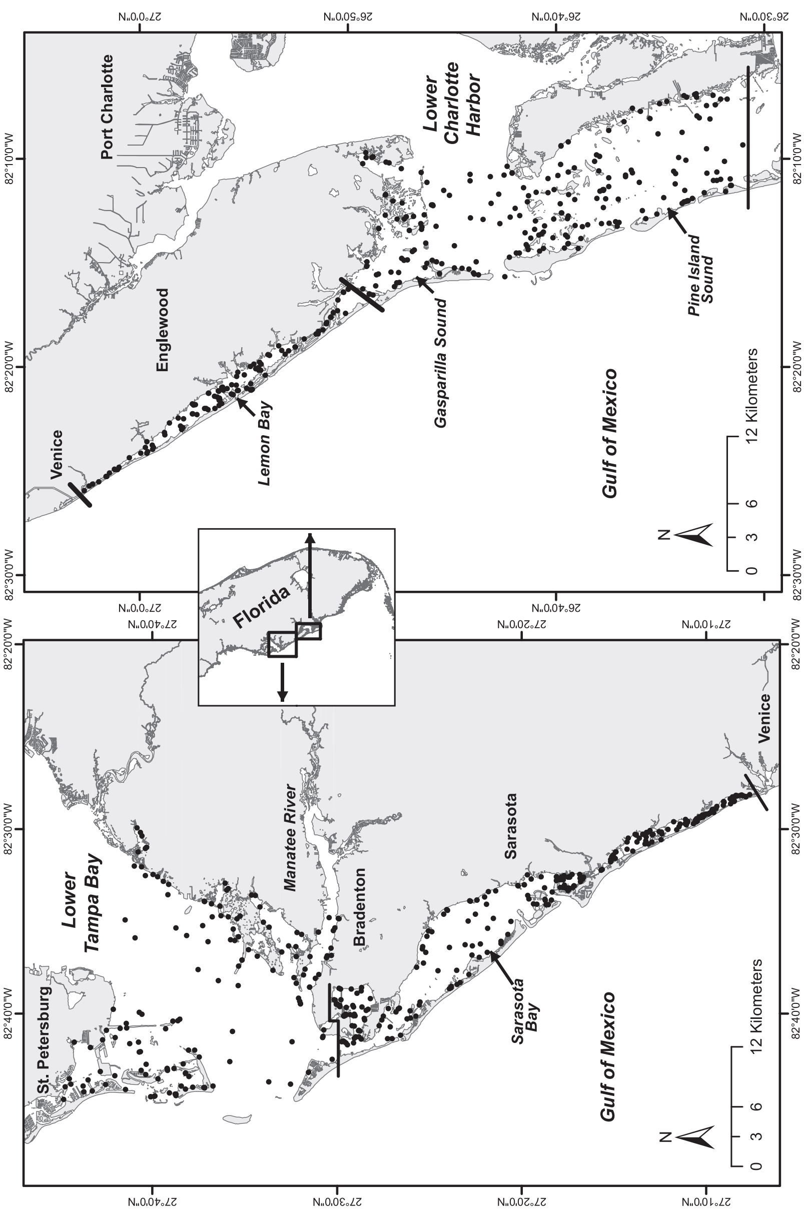

Figure 2. Lemon Bay and nearby estuaries on the coasts of central and southwest Florida (Lower Tampa Bay, Sarasota Bay, and Lower Charlotte Harbor), with sites sampled during the study period (June 2009–April 2010). Solid vectors denote boundaries of study areas.

dissolved oxygen) has been categorized as fair to below average, with the poorest quality in the upper bay and at the creek mouths (FDEP 2005, FDEP 2007).

Sample collection. We sampled Lemon Bay and its major tributaries from June 2009 through April 2010 as part of the Florida Fish and Wildlife Conservation Commission's Fisheries-Independent Monitoring (FIM) program, which uses standardized procedures and protocols to collect data on fish and selected macroinvertebrates in estuarine systems throughout Florida. A stratified-random sampling design and use of multiple types of sampling gear enabled collection of fish and macroinvertebrates from a variety of habitats and in a range of sizes and life history stages. The resulting data can be used to examine patterns of spatial and temporal abundance.

Three types of sampling gear were used: 1) a 21.3-m, 3.2-mm stretched-mesh, center-bag seine was used to collect small-bodied fish (typically <80 mm standard length) in shallow (<1.8 m) areas; 2) a 6.1-m otter trawl with a 3.2-mm mesh cod-end liner was used to collect small-bodied fish in deeper (1.8–7.6 m) areas; and 3) a 183-m haul seine with 38-mm stretched mesh was used to collect large-bodied fish (typically >100 mm standard length). Seine samples in the Lemon Bay tributaries (river seines) were collected in areas to a depth of 1.8 m by deploying the 21.3-m seine from the stern of a boat in a shallow arc along the shore and hauling it directly to shore, encompassing an area of ~68 m^2. Samples in Lemon Bay proper (bay seines) were collected by deploying the 21.3-m seine in areas to a depth of 1.5 m along shorelines and on offshore flats, sampling an area of 140 m^2. The 6.1-m trawl was used in areas 1.8 to 7.6 m deep and towed for 5 min at ~0.6 m/s, giving a typical tow distance of 180 m and an approximate area sampled of 720 m^2. The 183-m haul seine was deployed by boat in a standardized rectangular shape in areas to a depth of 2.5 m and hauled to shore, enclosing an area of 4,120 m^2 (see Paperno et al. 2001 for a more detailed description of sampling techniques). During the study period (June 2009–April 2010), 180 samples were collected (Figure 1). Thirty samples (twelve 21.3-m river seines, ten 21.3-m bay seines, four 6.1-m bay trawls, and four 183-m haul seines) were collected during each bimonthly sampling event.

Concurrently with each net deployment, physicochemical parameters including temperature (°C), salinity (psu), and dissolved oxygen (mg/l) were profiled with a water quality datasonde (measurements taken at 0.2 m from the surface, every meter thereafter, and at 0.2 m from the bottom). A variety of qualitative habitat assessments were also made, such as characteristics of the shoreline (e.g. vegetation type and distance of inundation), substrate (e.g. sediment type, quantity and type of submerged aquatic vegetation), and bycatch (total volume and composition). All sampling was conducted during the day.

Fish and selected macroinvertebrates were identified to the lowest practical taxonomic level (nomenclature follows Page et al. 2013 and WoRMS 2012). Selected macroinvertebrates (i.e. those of commercial or recreational importance, such as pink shrimp *Farfantepenaeus duorarum*, spiny lobster *Panulirus argus*, portunus crabs *Portunus* spp., blue crab *Callinectes sapidus*, and stone crab *Menippe* spp., are included in the terms "fish" and "fish assemblage" throughout this paper. When large numbers (>1,000) of fish of a single taxon were captured, the total number was estimated by fractional expansion of subsampled portions of the total catch split with a modified Motoda box splitter (Winner and McMichael 1997).

Due to hybridization of local species (Dahlberg 1970, Duggins et al. 1986) menhaden *Brevoortia* spp. and silversides *Menidia* spp. were treated as single taxonomic groups. Due to the extreme difficulty of distinguishing between species at small size, mojarras of the genus *Eucinostomus* (<40 mm SL), gobies of the genus *Gobiosoma* (<20 mm SL), and small *Strongylura marina* and *S. timucu* (<100 mm SL) were also treated as single taxonomic groups.

Data analysis. We compared Lemon Bay fish assemblages with those of nearby estuarine systems using univariate (ANOVA) and nonparametric multivariate analyses with PRIMER v6 software (PRIMER-E Ltd., UK) (Plymouth Routines in Multivariate Ecological Research, Clarke and Warwick 2001). Data used in the analysis included those from Lemon Bay, lower Charlotte Harbor, Sarasota Bay, and lower Tampa Bay. Together these water bodies represent the entire chain of polyhaline bays behind the barrier island complex from Charlotte Harbor north through Tampa Bay (Figure 2). Comparisons used FIM program collections during the same time period and months, and included the same gear types and techniques, as those collected in Lemon Bay. Data collected with each gear type were treated separately; data from Lemon Bay tributaries were not included in the interbay analysis. Abundance was standardized to number/sample for seine samples. Trawl sample abundance was standardized to number/100 m^2 to account for varying tow distances.

Total fish densities were compared between estuaries using ANOVA. Total fish densities were ln-transformed to improve normality and better satisfy the assumptions of the statistical test. Comparisons were deemed significant at $p < 0.05$. Significant differences were analyzed further using Tukey's HSD test.

To compare the fish assemblage structure of Lemon Bay with those of nearby estuarine systems, a one-way analysis of similarity (ANOSIM, Clarke and Warwick 2001) was performed for each type of gear, with estuarine system as the factor of interest. Before ANOSIM was performed, Bray-Curtis similarity matrices were calculated for data averaged by estuary and sampling event (month-year) to include an appropriate level of variability in the statistical test. Nonmetric multidimensional scaling (MDS, Clarke and Warwick 2001) and hierarchical agglomerative cluster analysis (CLUSTER, Clarke and Warwick 2001) were used to graphically depict relative differences in fish assemblages among the estuarine systems. Before performing MDS and CLUSTER, Bray-Curtis similarity matrices were calculated for data averaged by estuarine system in an effort to allow for better visual interpretation of the factor of interest. Similarity percentage analysis (SIMPER, Clarke and Warwick 2001) was used to identify species representative of dissimilarities between groups determined from MDS and CLUSTER. Species that contributed >2% to the total average dissimilarity between groups were considered distinguishing. All abundances were square-root transformed prior to analysis to reduce the influence of highly abundant taxa.

Results

Climatic conditions during the latter part of our study period were atypical. A severe freeze occurred in January 2010, and minimum air temperatures remained below freezing for two weeks; fish kills of predominately subtropical species resulted (Adams et al. 2012). Precipitation did not differ appreciably from the typical yearly pattern.

A total of 96,647 fishes (103 taxa) and selected invertebrates (6 taxa) were collected in 180 Lemon Bay samples (Table 1). Pinfish *Lagodon rhomboides*, bay anchovy *Anchoa mitchilli*, spot *Leiostomus xanthurus*, and mojarras *Eucinostomus* spp. comprised a large portion (81.4%) of the catch made in shallow areas of Lemon Bay proper with the 21.3-m seine (bay seines). Spot and pinfish were the dominant species in deeper habitats sampled with 6.1-m trawls (composing 72.8% of the catch). Pinfish, silver perch *Bairdiella chrysoura*, and scaled sardine *Harengula jaguana* accounted for 79.4% of the catch made with the 183-m haul seine. Spot and bay anchovy were the most numerous species in the tributaries, composing 55.9% of the tributary catch (river seines). No introduced fish species were represented in our samples. Detailed collection data, including seasonality, size, and density information, are available in Stevens et al. (2010a).

Physicochemical conditions were similar among the bay areas we examined during each sampling event (Figure 3). Mean water temperatures (based on water column–averaged values at each site) ranged from 16° to 31°C during the study period. Mean salinities were relatively high and stable, ranging from 28 to 38 psu. Lower Tampa Bay had slightly lower mean salinities during most sampling events, reflecting the influence of the Manatee River, a large tributary

Table 1. Fish and selected macroinvertebrate taxa collected during Lemon Bay bimonthly sampling, June 2009–April 2010. Values refer to number of individuals collected. Effort, or the total number of hauls, is labeled *E*. Taxa are arranged phylogenetically.

Species	Common Name	River Seine E=72	Bay Seine E=60	Bay Trawl E=24	Bay Haul Seine E=24	Totals E=180
Penaeidae						
Farfantepenaeus duorarum	pink shrimp	108	731	47	.	886
Panuliridae						
Panulirus argus	spiny lobster	.	.	1	.	1
Portunidae						
Portunus spp.	portunus crabs	.	1	47	2	50
Callinectes ornatus	shelligs	.	1	7	2	10
Callinectes sapidus	blue crab	.	7	170	33	210
Xanthidae						
Menippe spp.	stone crabs	1	.	101	.	102
Ginglymostomidae						
Ginglymostoma cirratum	nurse shark	.	.	.	1	1
Dasyatidae						
Dasyatis americana	southern stingray	.	.	2	1	3
Dasyatis sabina	Atlantic stingray	.	.	2	2	4
Elopidae						
Elops spp.	ladyfish	.	.	1	94	95
Ophichthidae						
Myrophis punctatus	speckled worm eel	.	1	.	.	1
Engraulidae						
Anchoa hepsetus	striped anchovy	27	5	23	.	55
Anchoa mitchilli	bay anchovy	7,740	7,382	1	.	15,123
Clupeidae						
Brevoortia spp.	menhadens	2	.	.	.	2
Harengula jaguana	scaled sardine	128	719	2	957	1,806
Opisthonema oglinum	Atlantic thread herring	.	42	.	3	45
Sardinella aurita	Spanish sardine	.	93	.	.	93
Ariidae						
Ariopsis felis	hardhead catfish	.	1	49	103	153
Bagre marinus	gafftopsail catfish	.	.	1	.	1
Synodontidae						
Synodus foetens	inshore lizardfish	18	51	14	25	108
Phycidae						
Urophycis floridana	southern hake	.	11	5		16
Batrachoididae						
Opsanus beta	Gulf toadfish	4	1	5	9	19
Ogcocephalidae						
Ogcocephalus cubifrons	polka-dot batfish	.	.	13	.	13
Mugilidae						
Mugil cephalus	striped mullet	1,734	1,153	.	44	2,931
Mugil curema	white mullet	1	.	.	19	20
Mugil gyrans	whirligig mullet	23	740	.	31	794
Atherinopsidae						
Membras martinica	rough silverside	.	1	.	.	1
Menidia spp.	silversides	964	804	.	.	1,768
Belonidae						
Strongylura marina	Atlantic needlefish	.	.	.	5	5

Table 1. Continued.

Species	Common Name	River Seine E=72	Bay Seine E=60	Bay Trawl E=24	Bay Haul Seine E=24	Totals E=180
Strongylura notata	redfin needlefish	118	21	.	52	191
Strongylura spp.	needlefishes	2	2	.	.	4
Strongylura timucu	timucu	1	1	.	.	2
Hemiramphidae						
Hyporhamphus meeki	false silverstripe halfbeak	.	5	.	3	8
Hyporhamphus unifasciatus	Altantic silverstripe halfbeak	.	1	.	.	1
Fundulidae						
Fundulus similis	longnose killifish	.	9	.	.	9
Lucania parva	rainwater killifish	1,195	3,183	.	.	4,378
Poeciliidae						
Gambusia holbrooki	eastern mosquitofish	1	.	.	.	1
Poecilia latipinna	sailfin molly	.	3	.	.	3
Cyprinodontidae						
Floridichthys carpio	goldspotted killifish	30	38	.	.	68
Syngnathidae						
Hippocampus erectus	lined seahorse	.	.	2	.	2
Hippocampus zosterae	dwarf seahorse	3	14	.	.	17
Syngnathus floridae	dusky pipefish	.	5	.	.	5
Syngnathus louisianae	chain pipefish	.	6	10	.	16
Syngnathus scovelli	Gulf pipefish	6	115	12	.	133
Scorpaenidae						
Scorpaena brasiliensis	barbfish	.	1	4	.	5
Triglidae						
Prionotus scitulus	leopard searobin	2	.	27	1	30
Prionotus tribulus	bighead searobin	.	1	17	.	18
Centropomidae						
Centropomus undecimalis	common snook	17	3	.	115	135
Serranidae						
Centropristis striata	black sea bass	.	1	.	.	1
Diplectrum formosum	sand perch	.	.	4	.	4
Mycteroperca microlepis	gag	.	2	.	4	6
Serraniculus pumilio	pygmy sea bass	.	.	2	.	2
Serranus subligarius	belted sandfish	.	.	11	.	11
Carangidae						
Caranx hippos	crevalle jack	3	3	.	3	9
Oligoplites saurus	leatherjack	5	8	.	3	16
Trachinotus carolinus	Florida pompano	.	.	.	2	2
Trachinotus falcatus	permit	.	.	.	93	93
Lutjanidae						
Lutjanus griseus	gray snapper	17	62	1	53	133
Lutjanus synagris	lane snapper	4	18	11	20	53
Gerreidae						
Diapterus auratus	Irish pompano	1	.	.	4	5
Eucinostomus gula	silver jenny	549	772	222	152	1,695
Eucinostomus harengulus	tidewater mojarra	408	83	5	51	547
Eucinostomus spp.	mojarras	4,348	5,906	188	.	10,442
Eugerres plumieri	striped mojarra	5	.	.	9	14

Table 1. Continued.

Species	Common Name	River Seine E=72	Bay Seine E=60	Bay Trawl E=24	Bay Haul Seine E=24	Totals E=180
Haemulidae						
Haemulon aurolineatum	tomtate	.	1	.	.	1
Haemulon plumierii	white grunt	.	6	.	5	11
Orthopristis chrysoptera	pigfish	.	118	95	199	412
Sparidae						
Archosargus probatocephalus	sheepshead	9	60	11	122	202
Diplodus holbrookii	spottail pinfish	.	12	.	8	20
Lagodon rhomboides	pinfish	2,482	25,394	1,489	3,081	32,446
Sciaenidae						
Bairdiella chrysoura	silver perch	1	623	14	1,400	2,038
Cynoscion nebulosus	spotted seatrout	.	55	2	16	73
Leiostomus xanthurus	spot	8,769	6,911	2,083	55	17,818
Menticirrhus americanus	southern kingfish	.	.	3	.	3
Pogonias cromis	black drum	.	.	.	1	1
Sciaenops ocellatus	red drum	10	5	.	2	17
Scaridae						
Nicholsina usta	emerald parrotfish	.	33	4	7	44
Blenniidae						
Chasmodes saburrae	Florida blenny	1	12	2	1	16
Hypleurochilus caudovittatus	zebratail blenny	.	.	10	.	10
Hypsoblennius hentz	feather blenny	.	.	1	.	1
Gobiidae						
Bathygobius soporator	frillfin goby	.	.	3	.	3
Gobiosoma bosc	naked goby	2	.	.	.	2
Gobiosoma longipala	twoscale goby	.	.	2	.	2
Gobiosoma robustum	code goby	9	217	4	.	230
Gobiosoma spp.	gobies	19	82	10	.	111
Microgobius gulosus	clown goby	129	365	3	.	497
Ephippidae						
Chaetodipterus faber	Atlantic spadefish	.	.	1	8	9
Sphyraenidae						
Sphyraena barracuda	great barracuda	9	1	.	10	20
Sphyraena borealis	northern sennet	.	5	.	.	5
Scombridae						
Scomberomorus maculatus	Spanish mackerel	.	.	.	1	1
Paralichthyidae						
Ancylopsetta quadrocellata	ocellated flounder	.	1	3	1	5
Citharichthys macrops	spotted whiff	.	.	10	.	10
Etropus crossotus	fringed flounder	.	.	18	.	18
Paralichthys albigutta	Gulf flounder	.	6	30	17	53
Achiridae						
Achirus lineatus	lined sole	4	5	6	.	15
Trinectes maculatus	hogchoker	.	.	1	.	1
Cynoglossidae						
Symphurus plagiusa	blackcheek tonguefish	.	1	7	2	10
Monocanthidae						
Aluterus schoepfii	orange filefish	1	.	.	.	1
Monacanthus ciliatus	fringed filefish	.	.	4	.	4
Stephanolepis hispidus	planehead filefish	1	41	15	8	65

Table 1. Continued.

Species	Common Name	River Seine E=72	Bay Seine E=60	Bay Trawl E=24	Bay Haul Seine E=24	Totals E=180
Ostraciidae						
Acanthostracion quadricornis	scrawled cowfish	.	3	8	.	11
Tetraodontidae						
Sphoeroides nephelus	southern puffer	.	15	7	2	24
Diodontidae						
Chilomycterus schoepfii	striped burrfish	.	2	54	6	62
Totals		28,911	55,981	4,907	6,848	96,647

that discharges into lower Tampa Bay. Mean dissolved oxygen remained above 5 mg/l, and each bay followed the same trend, with the lowest values in summer and the highest values in winter.

Some patterns were evident in overall mean fish abundances among the bays (Figure 4). The abundances of small-bodied fish sampled with 21.3-m bay seines differed significantly among the bays (ANOVA, $P < 0.001$). Lemon and Sarasota bays had greater abundances than lower Tampa Bay and lower Charlotte Harbor (Tukey's pairwise comparisons, $P < 0.01$). Although the abundance pattern for fish collected with the 6.1-m trawl was similar to that collected with the 21.3-m seine (i.e. greater abundances in Lemon and Sarasota Bays), the differences between estuaries were not significant (ANOVA, $P > 0.05$). There were no obvious trends or significant differences (ANOVA, $P > 0.05$) among the bays in abundances of fish collected with 183-m seines.

Differences in fish assemblages were also apparent among the bay areas, with Lemon and Sarasota bays distinguished from Charlotte Harbor and Tampa Bay. ANOSIM comparisons among the estuaries did not indicate significant assemblage differences ($P > 0.05$). The MDS plots, however, show that the Lemon and Sarasota Bay fish assemblages separated from the Charlotte Harbor and Tampa Bay fish assemblages collected with each gear type at Bray-Curtis similarity percentages ranging from 68 to 75 (Figure 5). Moreover, mean abundances of most of the taxa that distinguished these two groups, for each gear type, were greater in Lemon and Sarasota bays than in Charlotte Harbor and Tampa Bay (SIMPER, Figure 6). All of the 12 distinguishing species collected with 21.3-m bay seines were more abundant in Lemon and Sarasota bays. The bay anchovy, for example, was more than four times more abundant in those two estuaries. Seven of the top 12 distinguishing taxa collected with trawls were more abundant in Lemon and Sarasota bays (i.e. pinfish, silver jenny *Eucinostomus gula*, stone crabs, mojarras, spot, blue crab, and pink shrimp). The majority of the distinguishing species collected with 183-m seines also had greater abundances in Sarasota and Lemon bays (i.e., silver jenny, silver perch, pigfish *Orthopristis chrysoptera,* sheepshead *Archosargus probatocephalus*, common snook *Centropomus undecimalis*, hardhead catfish *Ariopsis felis*, gray snapper *Lutjanus griseus*, and ladyfishes *Elops* spp.).

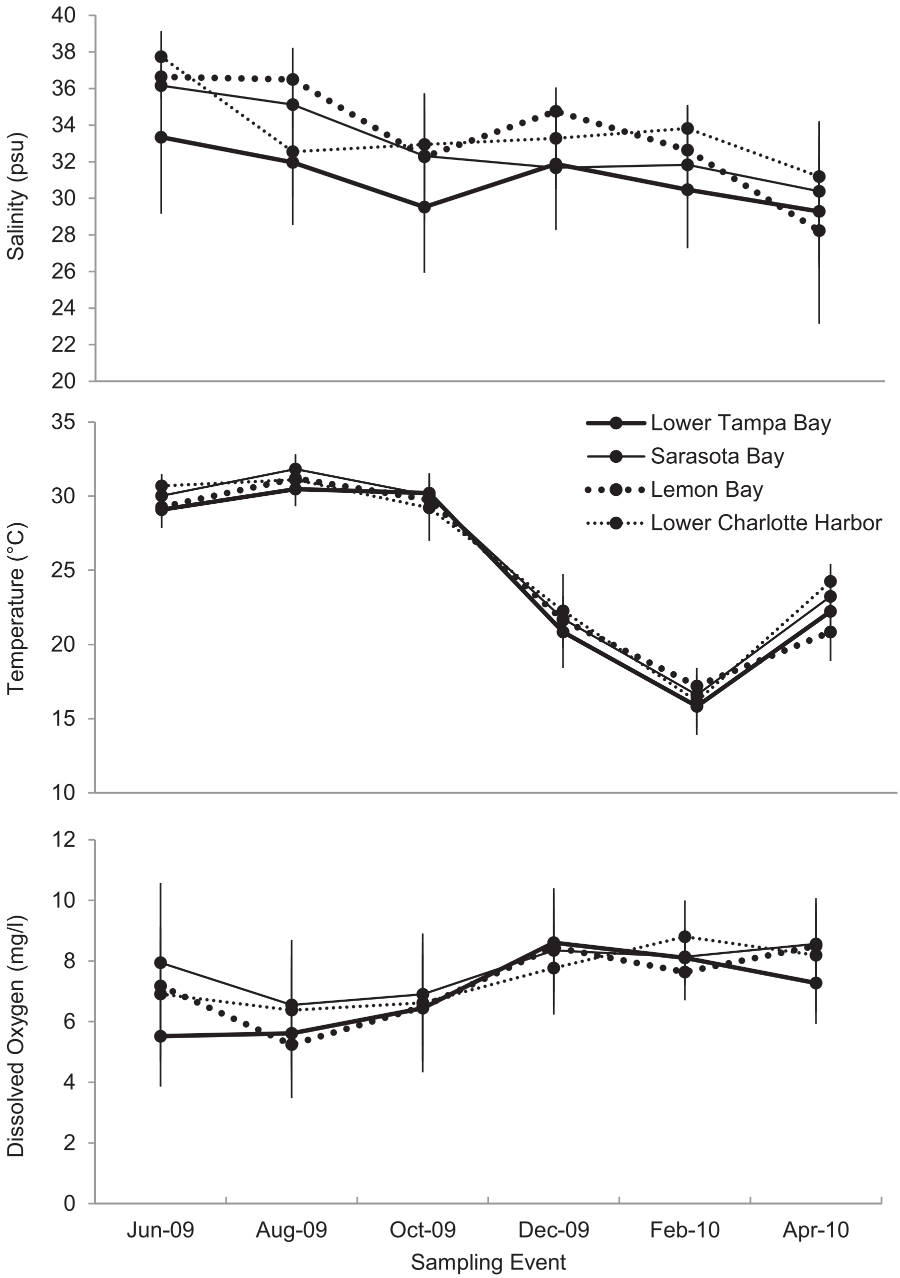

Figure 3. Mean (± standard deviation) water temperature, salinity, and dissolved oxygen taken during the study period (June 2009–April 2010) in Lemon Bay and nearby estuaries on the coasts of central and southwest Florida. Values calculated from water column averages collected during each sample.

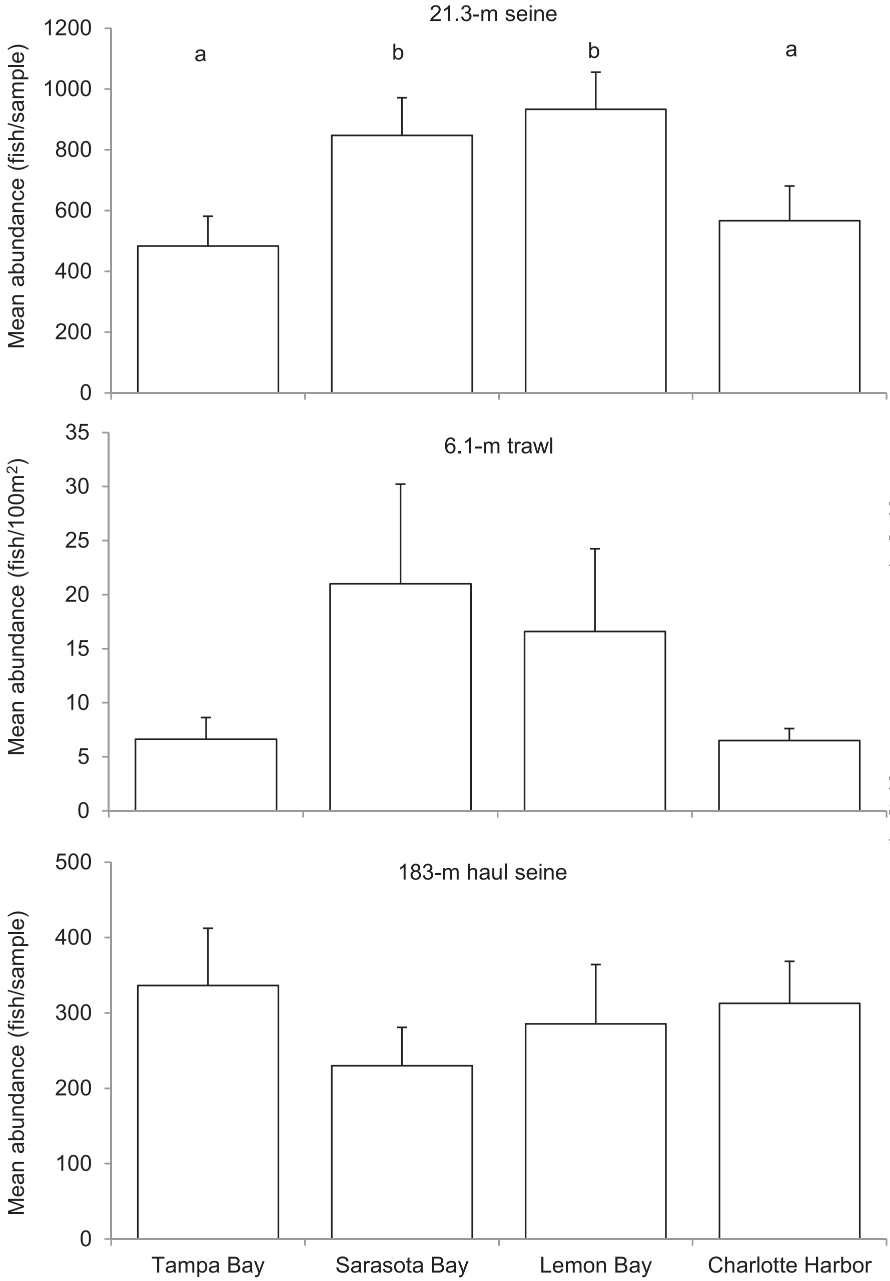

Figure 4. Mean abundance (± standard error) of fish collected in Lemon Bay and nearby estuaries on the coasts of central and southwest Florida. Letters above bars in 21.3-m seine plot represent groups identified as significantly different (ANOVA, $P < 0.001$, Tukey post hoc test, b > a); significant differences ($P < 0.05$) were not found among fish abundances based on 6.1-m trawls or 183-m seine collections.

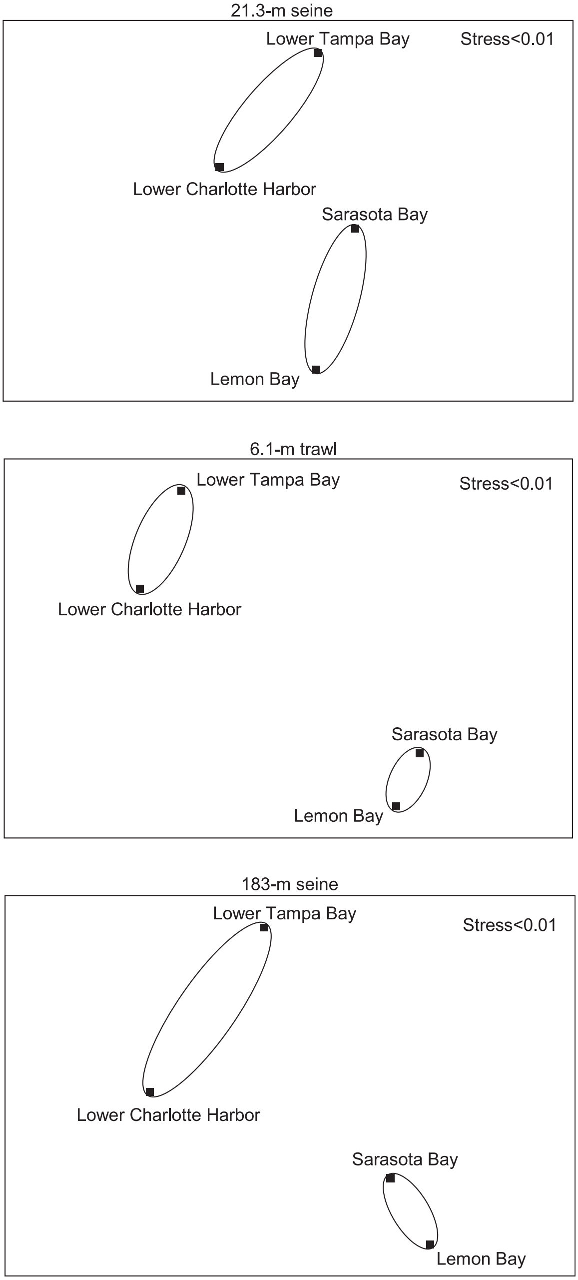

Figure 5. Two-dimensional nonmetric scaling ordination (MDS) of fish assemblages collected in Lemon Bay and nearby estuaries on the coasts of central and southwest Florida during bimonthly sampling (June 2009–April 2010). Ellipses denote groups identified using Bray-Curtis similarity percentages of 68-75 from hierarchical agglomerative cluster analysis.

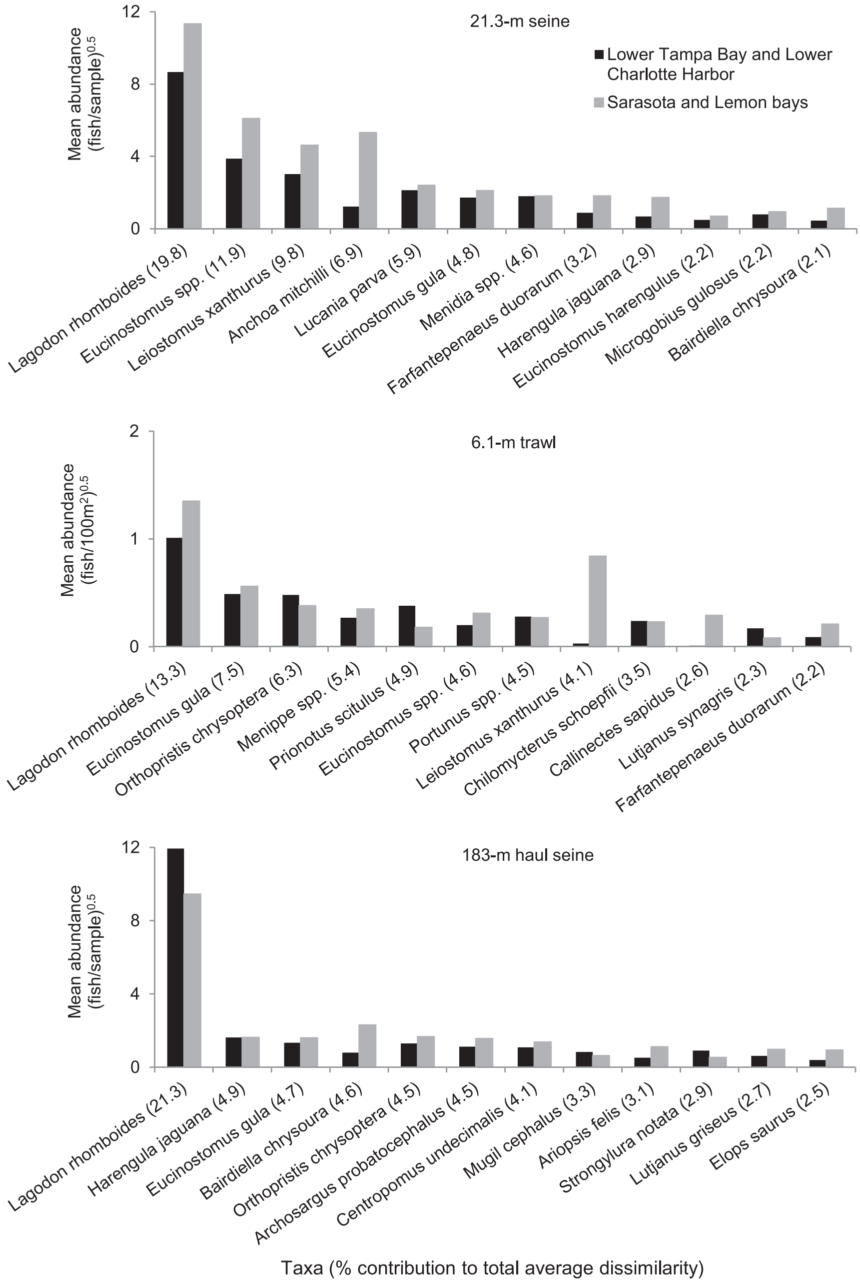

Figure 6. Similarity percentage analysis (SIMPER) showing fishes that distinguished bay groups depicted in MDS ordination. Abundance is the square root of average abundance (fish/sample or fish/100 m^2) as output from SIMPER. Total average dissimilarities between groups ranged from 68.5 to 79.1%. The contribution of each species to the total average dissimilarity is shown in parentheses.

Discussion

The list of taxa collected in Lemon Bay was consistent with a comprehensive list of fishes reported for the adjacent Charlotte Harbor estuarine system (Poulakis et al. 2004) and with results of studies examining habitat use of fish in Charlotte Harbor (Poulakis et al. 2003, Idelberger and Greenwood 2005, Greenwood et al. 2006, Greenwood et al. 2007, Stevens et al. 2010b). It is noteworthy that nonnative species were not collected in Lemon Bay during the study period. High rainfall that occurs during summer would likely have increased the probability of collecting nonnative freshwater and euryhaline fishes such as cichlids, which tend to move downstream with high freshwater flows (Adams and Wolfe 2007). These species, however, may have been present farther upstream in the tributaries. Similar studies in larger bay systems to the north (Paperno et al. 2008, Greenwood 2012) and south (Stevens et al. 2008a, Stevens et al. 2008b, Champeau et al. 2009, Stevens et al. 2010c, Idelberger et al. 2011) have reported established populations of nonnative fishes.

The tributaries of Lemon Bay were found to be a juvenile habitat for many fish species. Juvenile spot, bay anchovy, striped mullet *Mugil cephalus*, red drum *Sciaenops ocellatus*, and common snook were at least twice as abundant in the tributaries than in Lemon Bay proper (fish density estimates are included in Stevens et al. 2010a). These fishes spawn either in the ocean or in the estuary downstream of their juvenile habitats, and early life history stages (larvae to juveniles) must swim or be transported upstream. Shallow-water refuge, high levels of productivity, and the salinity gradient in the tributaries likely provide physicochemical conditions that are favorable for juveniles of these species. Since these early life stages often use selective tidal stream transport and olfactory navigation to travel to nursery grounds (e.g. Schultz et al. 2003), maintenance and timing of freshwater inflows within the range expected under natural conditions are important for ensuring optimal access to these habitats.

The fish assemblages of Lemon and Sarasota bays appeared to differ from those of lower Tampa Bay and lower Charlotte Harbor. In particular, there were significant differences among the estuaries in total fish abundances of the small-bodied fishes collected with 21.3-m bay seines (ANOVA, Tukey's HSD test). Although ANOSIM did not detect differences in fish assemblage structure among the estuaries (perhaps due to relatively low sample size), the additional multivariate analyses (MDS, CLUSTER followed by SIMPER) seemed to corroborate the findings of the univariate tests. Fish assemblages collected with the 21.3-m bay seine differed and all the distinguishing species were more abundant in Lemon and Sarasota bays than in lower Charlotte Harbor and lower Tampa Bay. Although total fish abundances did not differ significantly for collections made with the other types of sampling gear, the multivariate analyses indicated a similar trend: the distinguishing species, as determined by SIMPER, were generally more abundant in Lemon and Sarasota bays than in lower Charlotte Harbor and lower Tampa Bay.

The differences in fish abundance and community structure among the bay systems we examined may be related to differences in their overall size. The same types of sampling gear and techniques were used in all systems, and physical and biological factors (e.g. water conditions, sediment types, submerged vegetation) appeared to be similar. The most striking difference is the geomorphologies of the bays; Lemon and Sarasota bays are considerably smaller and narrower than Charlotte Harbor and Tampa Bay. Factors such as current and water circulation patterns, water depth, the length of shoreline relative to area of open water, and proximity of Gulf passes to juvenile habitat may differ sufficiently between the small and large bays to affect fish recruitment patterns. For example, the differences in fish assemblages we found between the small and large estuaries were most pronounced for the small fishes collected with 21.3-m seines, with larger numbers of juveniles of many Gulf-spawning species (e.g. pinfish and spot) found in the smaller bays. If larval supplies entering Gulf passes are roughly similar, then the densities of juveniles occupying relatively small bays could be higher than those of larger bays where settlement may occur across a much broader area. Also, narrow bay systems present more shoreline, with its associated shallow seagrass flats, in proximity to the Gulf passes. Shallow shorelines and seagrass beds have been shown to be important habitat for juveniles of many fish species (Bell and Pollard 1989, Arrivillaga and Baltz 1999, Travers and Potter 2002, Acosta et al. 2007). Proximity of suitable habitat to Gulf passes has been found to be an important factor in determining settlement densities of ocean-spawning species (Hannan and Williams 1998, Brown et al. 2005).

While proximity to inlet habitat may have had a positive effect on recruitment or survival of offshore-spawning fishes, conditions in the smaller bays also seemed to favor many small resident estuarine species, including bay anchovy and rainwater killifish *Lucania parva*. These results illustrate that the factors accounting for the greater abundances of fishes in the smaller bay systems are more numerous and complex than inlet dynamics and bay geomorphology alone. It is possible that Lemon and Sarasota bays have greater fish production than that of lower Charlotte Harbor and Tampa Bay (i.e. the resident estuarine species have greater reproductive output, growth, and survivorship). Increases in fish production can be caused by increases in nutrient loads into a receiving body (Deegan and Peterson 1992), with smaller water bodies possibly more sensitive to such changes. The increased production can be viewed as a benefit initially, so long as the receiving body does not reach a tipping point. A tipping point can occur when nutrient loads reach a threshold where conditions can change suddenly and become difficult to reverse (Caddy 2000, Hagy et al. 2004). These sudden changes often take the form of excessive algal blooms with cascading effects (e.g. seagrass losses from shading by algae, fish kills resulting from low dissolved oxygen). Comparative studies across proximate estuaries that include estuarine fauna, as was conducted here, may be of interest to resource managers modeling the effects of nutrient loading into estuaries.

Our year-long survey indicated that the Lemon Bay estuary supports a fish fauna that is similar to those of other bay systems in southwest Florida. More extensive sampling would likely collect additional species that are less common or more difficult to collect. Overall fish abundances were greater in Lemon Bay and nearby Sarasota Bay than in the larger bay systems. The factors accounting for these differences are uncertain, but may be related to general differences in the overall size of these bays.

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