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# Composition of Age-0 Fish Assemblages in the Apalachicola River, River Styx, and Battle Bend, Florida

Open-File Report 2009-1145

U.S. Department of the Interior
U.S. Geological Survey

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**U.S. Department of the Interior**
KEN SALAZAR, Secretary

**U.S. Geological Survey**
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U.S. Geological Survey, Reston, Virginia: 2009

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Detailed Geographic Information System (GIS) data for the St. Johns River Water Management District are available on the District's spatial data web site (*http://sjr.state.fl.us/gisdevelopment/docs/themes.html*). Due to the way certain land-use codes were combined in this study, and differences in coding between years of available data, some differences exist between codes used for land-use and land-cover categories. For example, some of the percentages provided on figure 4 reflect a different overall pattern than would be evident from a broad landscape-scale area of coverage. Readers of this report and land-use and land-coverage data users are encouraged to utilize the original GIS sources for any in-depth applications requiring detailed spatial data.

Suggested citation:
Walsh, S.J., Buttermore, E.N., Burgess, O.T., and Pine, W.E., III, 2009, Composition of Age-0 Fish Assemblages in the Apalachicola River, River Styx, and Battle Bend, Florida: U.S. Geological Survey Open-File Report 2009-1145, 28 p.

# Contents



# Figures

## Tables



# Conversion Factors

| Multiply | By | To obtain |
|---|---|---|
| millimeter (mm) | 0.03937 | inch (in.) |
| centimeter (cm) | 0.3937 | inch (in.) |
| kilometer (km) | 0.6214 | mile (mi) |

## Acronyms and other abbreviations

*C/f* catch per unit effort
FPC Floodplain Pulse Concept
GPS global positioning system
PVC polyvinyl chloride
SE standard error
UF University of Florida
µm micrometer

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = (1.8 × °C) + 32

# Composition of Age-0 Fish Assemblages in the Apalachicola River, River Styx, and Battle Bend, Florida

Stephen J. Walsh[1], Elissa N. Buttermore[2], O. Towns Burgess[2], and William E. Pine III[2]

## Abstract

Light traps were used to sample the age-0 year class of fish communities in the Apalachicola River and associated floodplain water bodies of River Styx and Battle Bend, Florida, in 2006-2007. A total of 629 light traps were deployed during the spring and early summer months (341 between March 15 and June 6, 2006; 288 between March 9 and July 3, 2007). For combined years, 13.8 percent of traps were empty and a total of 20,813 age-0 fish were captured representing at least 40 taxa of 29 genera and 16 families. Trap catches were dominated by relatively few species, with the most abundant groups represented by cyprinids, centrarchids, percids, and catostomids. Six taxa accounted for about 80 percent of all fish collected: *Micropterus* spp. (28.9 percent), *Notropis texanus* (28.9 percent), *Lepomis macrochirus* (7.9 percent), *Carpiodes cyprinus* (6.2 percent), Cyprinidae sp. (4.6 percent), and *Minytrema melanops* (4.2 percent). Based on chronological appearance in light traps and catch-per-unit effort, including data from previous years of sampling, peak spawning periods for most species occurred between early March and mid-June. A complementary telemetry study of pre-reproductive adults of select target species (*Micropterus* spp., *Lepomis* spp., and *M. melanops*) revealed distinct patterns of habitat use, with some individual fish exclusively utilizing mainstem river habitat or floodplain habitat during spawning and post-spawning periods, and other individuals migrating between habitats. A comparison of light-trap catches between a pre-enhancement, high-water year (2003) and post-enhancement, low-water year (2007) for the oxbow at Battle Bend revealed some difference in community composition, with slightly greater values of diversity and evenness indices in 2007. Two dominant species, *Lepomis macrochirus* and *Micropterus salmoides*, were substantially greater in relative abundance among all age-0 fish collected in 2007 in comparison to 2003. Excavation of sediments at the mouth of Battle Bend improved river-floodplain connectivity during low flows such as occurred in 2007 and likely provided greater access and availability of fish spawning and nursery habitats.

## Introduction

Large rivers are extremely complex, dynamic, spatially and temporally variable ecosystems (Johnson and others, 1995). The role of floodplains in the ecology of large rivers is extensively documented in the literature. The Floodplain Pulse Concept (FPC; Junk and others, 1989) is commonly used to explain large-river structure and function. The most important natural hydrologic feature of large floodplain rivers is considered to be the annual flood pulse, which extends a river onto its floodplain. The FPC emphasizes connectivity of the river channel and floodplain through annual flood pulses that influ-

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ence how physical and biological processes interact. The main tenet of the FPC is that floodplains are highly productive areas that provide critical habitats and energy sources required to sustain river communities (Bayley, 1995). Aquatic organisms exist in dynamic equilibrium with physical features of the annual cycle, especially the timing, duration, magnitude, and rate of rise and fall of water levels. Disruptions to the flood pulse may interfere with community or population dynamics by altering reproduction, survivorship, and trophic webs.

Tropical rivers have the largest floodplains and the best documented aquatic-terrestrial linkages (Welcomme, 1979, 1985; Goulding, 1980; Lowe-McConnell, 1987). Rivers of the temperate zone are among the most substantially altered in the world, and have also received substantial study (Dodge, 1989; Bravard and others, 1992; Sparks and others, 1998; Galat and Zweimüller, 2001; Grift, 2001). Rivers with the most extensive forested floodplains in the United States are located primarily in the Midwest (Mississippi River basin), and in the southeastern Coastal Plain (Gulf of Mexico coast and Atlantic Slope). Floodplains of these systems are known to provide food, cover, spawning, and nursery habitats for fishes and other aquatic organisms during periods of inundation (Larson and others, 1981; Wharton and others, 1981, 1982; Crance, 1988; Leitman and others, 1991; Hackney and Adams, 1992; Sparks, 1995; Galat and others, 1998; Light and others, 1998; Matthews, 1998). Natural resource managers in the southeastern United States are concerned with how changes in water levels associated with regulated flows affect the ecology of floodplain-dependent aquatic communities. In particular, there is interest in determining how hydrologic alterations and reservoir release operations influence fish spawning, recruitment, survival, and sustainability.

The focus area of this study was the Apalachicola River, Florida—a large alluvial river of the southeastern Coastal Plain with an extensive forested floodplain (fig. 1). The Apalachicola River and its floodplain have been affected by changes in the landscape and decades of regulated flows, primarily as a result of increased urbanization and agriculture in Georgia. Adverse ecological effects stem from altered flows from upriver reservoir operations, changes in sediment transport, navigational dredging, spoil disposal, and geomorphic modifications to the channel. A major consequence of these changes is that conditions that normally govern river-floodplain connectivity are compromised at low river flows. The floodplain is thought to provide important habitat to fishes and other aquatic organisms, yet few empirical data are available to document how physical and hydrologic changes have affected these biological communities. Light and others (1998) suggested that floodplain habitats may be used by as many as 80 percent (91 species) of freshwater fishes in the Apalachicola drainage. Based on other large floodplain rivers, it is likely that disconnection and prolonged isolation of floodplain habitats from the river channel interrupts natural processes that affect the ecology of many species. Such physical habitat changes may alter spawning, recruitment, movements, growth, and other aspects of the ecology of species that utilize the floodplain temporally and spatially. As demands for water resources continually increase in the Apalachicola-Chattahoochee-Flint basin, there is a growing need to assess floodplain utilization by fishes during spawning and nursery periods.

This investigation builds on previous studies of fish recruitment and habitat associations in the Apalachicola River and floodplain water bodies. The objectives of the study were the following:

1. To document spawning of fishes in the Apalachicola River mainstem and floodplain. Emphasis was to determine spatial and temporal peak distributions of larval fishes in the context of associating these patterns with hydrologic conditions and seasonal inundation of the floodplain.

2. To relate larval production and abundance with adult fish movement patterns and spawning among floodplain and main channel habitats. A corollary of this objective was to assess, to the extent possible, a habitat enhancement project that consisted of reconnecting the mouth of an artificial oxbow (Battle Bend) with the river channel during low-flow conditions. Due to scheduling of the habitat enhancement project, a natural floodplain system (River Styx) was used as a proxy during the first year of the study (2006) for evaluating adult movement patterns and determining peak abundances of larval fishes. Similar sampling was conducted in Battle Bend in 2007 following excavation of sand and debris at the mouth of the oxbow.

This study developed as a collaborative effort with investigators from the University of Florida (UF), and was designed to complement a simultaneous investigation of movement patterns of pre- and post-reproductive adults of four target fish species/guilds: black basses (*Micropterus* spp.), particularly largemouth bass (*M. salmoides*), sunfishes (*Lepomis* spp.), particularly redear sunfish (*L. microlophus*), spotted sucker (*Minytrema melanops*), and channel catfish (*Ictalurus punctatus*). The movement study conducted by UF researchers consisted of tracking adult fishes that had been implanted with sonic or radio telemetry tags over the course of two spawning and post-spawning seasons in 2006-2007. The results of the tracking study in combination with selected components of this study are provided in a separate summary report (Pine and others, 2008). Concurrent with the tracking study, larval fish communities were sampled to explore for possible correlates between movement patterns of adult fishes and the appearance, peak timing, and abundance of age-zero (herein, “age-0”) cohorts of the target species. As a consequence of sampling for the target species, data were obtained on the entire community of age-0 fishes within the study area. This report summarizes community data for the concurrent telemetry/larval recruitment investigation, as well as retrospective (2002-2004) community data for the study area, including chronological appearance and peak abundance of age-0 cohorts.

## Study Area

The Apalachicola River is formed by the confluence of the Chattahoochee and Flint rivers at the borders of Florida, Georgia, and Alabama; collectively, the system is referred to as the Apalachicola-Chattahoochee-Flint basin (fig. 1). The Apalachicola River is the largest river that discharges into the coastal waters of Florida (Nordlie, 1990). Large annual fluctuations in flow of the Apalachicola River dictate the character and function of the forested floodplain system (Elder and others, 1988). The river forms a vast meandering and braided system with an extensive network of tributaries and distributaries that extend laterally onto the forested floodplain, especially in the middle and lower reaches. Light and others (1998) summarized the historical, physical, and biological data for the Apalachicola River floodplain, and characterized the diverse aquatic habitats and connectivity between the main channel and floodplain under different flow conditions. Light and others (2006) summarized the extent of habitat modifications as a function of channel morphology changes and water-level declines since construction of Jim Woodruff Lock and Dam at the Florida-Georgia border. Livingston (2008) provided a general overview of environmental and ecological issues pertaining to the Apalachicola River.

The study area is in the non-tidal lower reach of the Apalachicola River as described by Light and others (1998), in the region around Battle Bend and River Styx. Battle Bend is an oxbow lake on the eastern shoreline of the Apalachicola River near river mile 28.5 (river kilometer 45.9) that was formed as a backwater habitat in 1969 when the U.S. Army Corps of Engineers excavated a cut to bypass a meander in the river. Subsequent to its formation as a backwater lake, the mouth of Battle Bend became filled with sand and debris, and was disconnected during low flows. In 2006, the Florida Fish and Wildlife Conservation Commission contracted a project to remove depositional sediments to restore connectivity of the former river channel to the current river channel during low flows.

River Styx is a large tributary system that flows into the Apalachicola River near river mile 35.5 (river kilometer 56.9). A series of perennial to intermittently flowing streams connect the Apalachicola River and River Styx depending on flows in the main channel (fig. 2). The largest of these are Swift Slough and Moccasin Slough; the smaller connecting streams are Hog, Grayson, and Everett Sloughs. Information on depths, elevations, and connecting flows was provided by Light and others (1998). River Styx was selected as an unaltered control site for larval fish recruitment and adult fish movement studies in 2006-2007 for comparison to post-enhancement sampling in Battle Bend.

During 2006, light traps were set throughout River Styx and in the Apalachicola River at various sites between river miles 35.0 and 40.5, downstream of the mouth of River Styx (30.08590°N, 85.13700°W) to just upstream of the head of Swift Slough (30.12146°N, 85.13144°W). In 2007, light trap collections were made in the same areas of River Styx and the surrounding mainstem channel as in 2006. In addition, collections were made in 2007 throughout the Battle Bend oxbow and in the river channel between river miles 28.5 and 29.0, downstream of the mouth of Battle Bend (30.01396°N, 85.09751°W) to near the upstream segment of the former river channel (30.01992°N, 85.10279°W).

# Methods

Light traps are efficient for collecting small fishes in a broad range of habitats (Doherty, 1987; Secor and others, 1992; Kissick, 1993; Ponton, 1994; Knight and Bain, 1996; Hernandez and Lindquist, 1999; Hickford and Schiel, 1999). Niles and Hartman (2007) determined that light traps were more effective than benthic sleds or activity traps for determining species presence and relative abundance in a navigable river. A custom-designed floating light trap based on a modification of the quatrefoil trap described by Floyd and others (1984) and Kissick (1993) was used to collect larval, postlarval, and juvenile fishes (fig. 3). The top and base of each trap consisted of flat, opaque polyvinyl chloride (PVC) panels (30 cm × 30 cm × 6.4 mm thick). Sides (funnels) of the trap consisted of eight clear, flat plexiglass panels (15 cm wide × 30 cm high) mounted diagonally from the trap corners with ~5 mm vertical slots through which fish could pass. Traps were soaked for a minimum of 12 hours between about 1800-0800 ± 4 hours using a battery-operated submersible light. Each night of light-trap sampling consisted of deploying a series of 8 to 18 traps, divided about evenly between sites in the river and the floodplain. Fish and invertebrates were retrieved using a collection bag (350-µm mesh) affixed to an open PVC ring at the trap bottom. The contents of each trap were fixed in 4-percent buffered formalin (Lavenberg and others, 1984) and returned to the laboratory.

In the laboratory, specimens were transferred through solutions of 30- and 50-percent ethanol, with final storage in 70-percent ethanol. Larval and postlarval fish were separated from other aquatic organisms and identified to the lowest practicable taxonomic category. Sources used as aids in taxonomic identifications were Lippson and Moran (1974), Hogue and others (1976), Hardy (1978), Jones and others (1978), Auer (1982), McGowan (1984), Conrow and Zale (1985), Scheidegger (1990), Wallus and others (1990), Kay and others (1994), and Simon and Wallus (2003, 2006a,b). The total length (TL, in millimeters) of each fish was measured with an ocular micrometer or ruler, or a random subsample of 30 specimens was measured when the number of individuals of the same taxon from a single trap exceeded that count.

Geographic coordinates were recorded with a geographic positioning system (GPS) for each trap location, and the following physicochemical properties were measured when each trap was set and again when retrieved: water depth, Secchi depth, temperature, dissolved oxygen, pH, specific conductance, and turbidity.

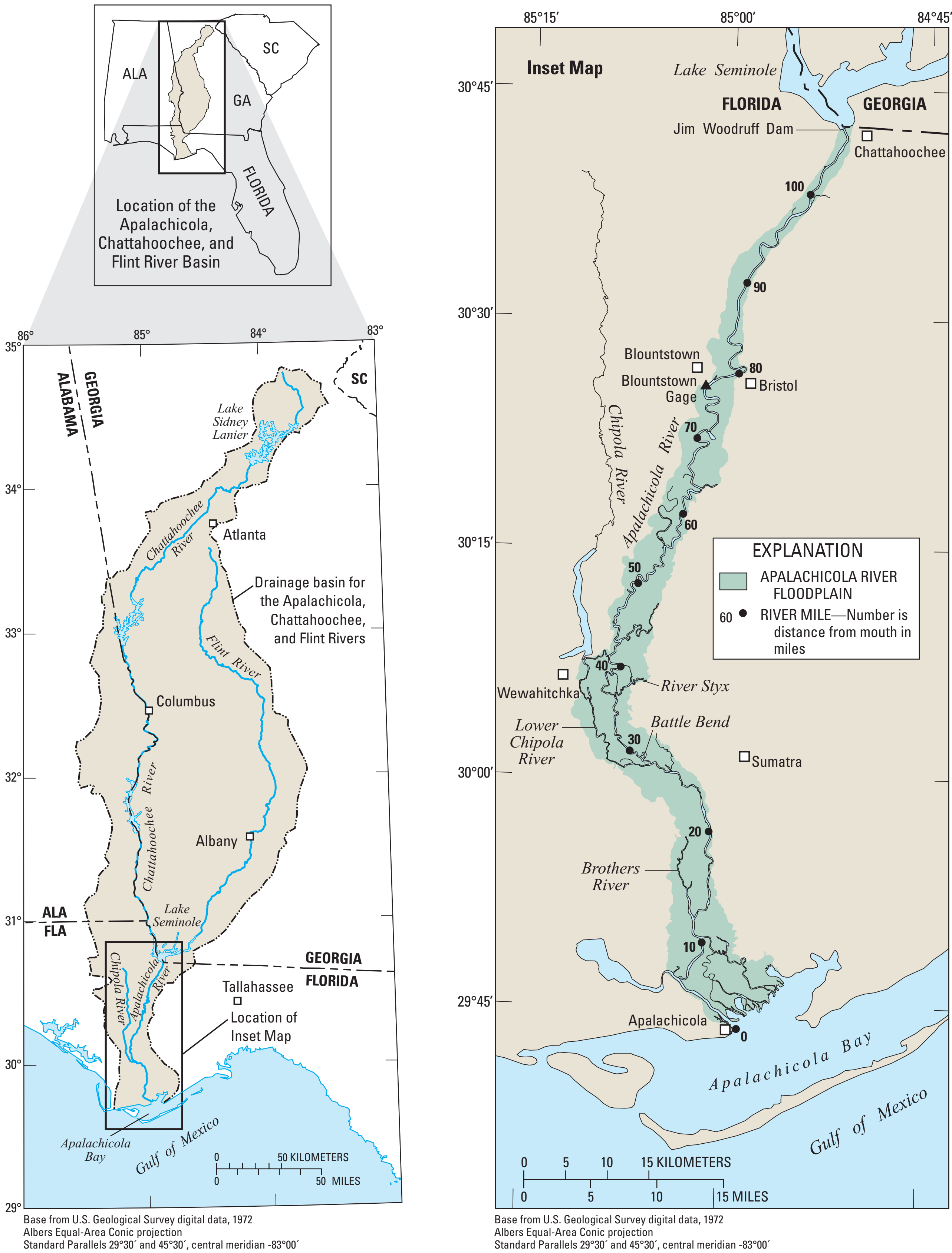
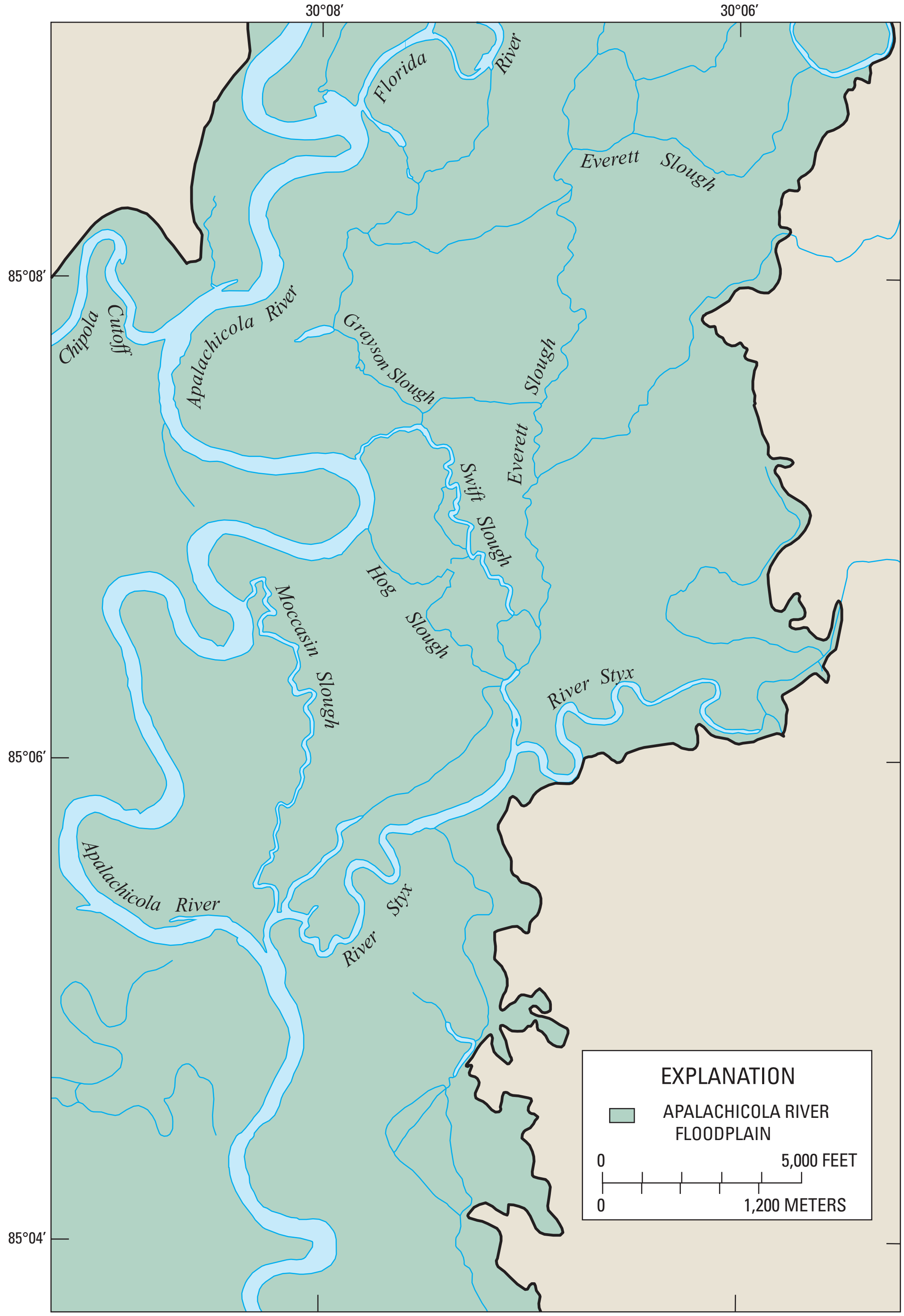



**Figure 1.** Apalachicola, Chattahoochee, and Flint River basin (left) and Apalachicola River floodplain (right).




Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

**Figure 2.** Apalachicola River, River Styx, and associated sloughs.

**Figure 3**. Light trap used to collect age-0 fishes in the Apalachicola River and floodplain. Luminescent chemical sticks were used in 2002-2004; a battery-operated white light was used in 2006-2007.

Light traps were deployed weekly from March 15 to June 6, 2006, in the Apalachicola River channel and River Styx, and biweekly from March 9 to July 3, 2007, in these two systems plus Battle Bend. River Styx was selected as a proxy floodplain system for sampling in 2006 due to delays in habitat enhancement (channel-mouth dredging) of the Battle Bend oxbow. The River Styx and Battle Bend sites are referred to herein as the “floodplain,” whereas the Apalachicola River is referred to as the “river channel” or “mainstem.” Light trapping of age-0 fishes similar to that conducted in this study was previously done in various areas of the Apalachicola River and floodplain during the years 2002-2004 to document temporal and spatial occurrence of spawning (Walsh and others, 2006). The previous work included sampling in River Styx and Battle Bend, and those data are included herein for selected comparisons with data obtained in this study.

Kwak and Peterson (2007) recommend providing specific equations used in reporting community indices of species diversity, evenness, and dominance, because there are many variants and occasional inconsistent use of terminology. The Shannon-Wiener index ($H'$), a Type I index sensitive to the abundances of rare species in a community (Shannon and Weaver, 1949; Krebs, 1999), was calculated using the logarithmic base *e* as:

$$H' = -\sum_{i=1}^{s} (p_i)(\log_e p_i) \,, \qquad (1)$$

where

$s$ is number of species,

$p_i$ is proportion of the total sample represented by the *i*th species.

Based on the Shannon-Wiener index of diversity, evenness (Pielou, 1966), a measure of equitability in relative abundance among taxa, was calculated as:

$$J' = \frac{H'}{H'_{\max}} \,, \qquad (2)$$

where

$H'_{max}$ is $\log_e s$ = maximum possible diversity.

Simpson’s index of diversity ($1 - \hat{D}$), a Type II index that is influenced to a greater extent by abundant species (Simpson, 1949; Clarke and Warwick, 2001; Kwak and Peterson, 2007), was calculated as:

$$1 - \hat{D} = 1 - \sum_{i=1}^{s} \left[ \frac{n_i(n_i - 1)}{N(N-1)} \right], \qquad (3)$$

where

$n_i$ is number of individuals of species *i* in the sample,

$N$ is total number of individuals in the sample = $\sum n_i$ ,

$s$ is number of species in the sample.

Bray-Curtis similarity (1-*B*) (Bray and Curtis, 1957) was calculated as:

$$B = \frac{\sum_{i=1}^{n} \left| X_{ij} - X_{ik} \right|}{\sum_{i=1}^{n} (X_{ij} + X_{ik})} \,, \qquad (4)$$

where

$B$ is Bray-Curtis measure of dissimilarity,

$X_{ij}$, $X_{ik}$ are number of individuals in species *i* in each sample (*j*, *k*),

$n$ is number of species in samples.

Diversity metrics were computed with Primer-E© (ver. 6.1.6) software (Clarke and Warwick, 2001; Clarke and Gorley, 2006) on raw numbers of fishes collected by year in each water body. Relative abundance (percent composition) data were upward collapsed by distributing numbers of fish identified only to genus or family level to those identified to species in their relative proportions based on site and year, with a few exceptions (cyprinids and *Lepomis* sp. were considered to be unique taxa from others identified to species). Diversity indices were assumed to under-represent age-0 assemblages due to phototaxic response differences among individual species and because some species exhibit a negative or no behavioral response to light.

Catch-per-unit effort (*C/f*) is reported as numbers of fish per trap (or means among traps per sampling event), because trap collections were considered to represent approximately the same effort; that is, dusk-to-dawn sampling periods of similar duration.

# Results

## Surface-Water Discharge

Discharge data were obtained from the National Water Information System (*http://waterdata.usgs.gov/fl/nwis/rt/*) for a gage on the Apalachicola River near Blountstown, operated by the U.S. Army Corps of Engineers. Discharge in the Apalachicola River during 2002-2007 was highly variable (fig. 4). Except for 2003, mean monthly discharge during the peak periods of light-trap sampling (March-June) were below average for the period of record (fig. 5); 2002 and 2006-2007 experienced substantial drought conditions throughout late spring, summer, and early fall months. Because no light trapping was conducted during 2005, hydrologic data for that year were omitted.

## Age-0 Fish Assemblage Composition

### 2006-2007 Sampling Period

A total of 629 light traps were deployed in the Apalachicola River, River Styx, and Battle Bend during spring and early summer months between March 15, 2006, and July 3, 2007 (table 1). Of these, 87 (13.8 percent) were empty. During both years, the number of empty traps was much greater in the river channel than in floodplain water bodies. For samples pooled by water body and year, the following percentages of traps were empty: Apalachicola River, 20.7 percent (2006; n = 169) and 19.4 percent (2007; n = 144); River Styx, 5.2 percent (2006; n = 172) and 9.7 percent (2007; n = 72), and; Battle Bend, 11.1 percent (2007; n = 72).

A total of 20,813 fish were collected by light traps during this time period—12,560 in the Apalachicola River and River Styx in 2006, and 8,253 in the Apalachicola River, River Styx, and Battle Bend in 2007 (table 1). Nearly all specimens were age-0 fish, although a few subadult and adult specimens of slim-bodied species were also collected (mainly cyprinids, *Labidesthes sicculus*, and *Anchoa mitchilli*); regardless of size, all specimens collected in light-trap samples were included in summaries and analyses presented here. Samples for each water body and year were binomially distributed, because few traps contained large catches and many traps contained small catches. Two traps, in particular, skewed samples for each year: 695 yolk-sac and post-yolk sac larvae of *Carpiodes cyprinus* were captured in a single trap placed downstream of a sandbar in the Apalachicola River on March 3, 2006, and 4,012 postlarval *Micropterus* (presumably a single clutch of *M. salmoides*) were captured in a single trap placed in an upstream section of River Styx on April 9, 2007.

Excluding specimens identified only to family level and *Micropterus* sp. (assignable to either *M. salmoides* or *M. punctulatus*), about 40 distinct taxa representing at least 29 genera and 16 families were collected by light traps in 2006-2007 (table 2). Unidentified cyprinids likely included one or more additional species, especially in collections from the river channel, and were thus treated as a single taxon in the computation of diversity metrics and other analyses. *Lepomis* sp. were counted as distinct because most or all probably represented *L. punctatus* or *L. microlophus*, and the larvae of neither species could be definitively identified. Six taxa individually comprised greater than 5 percent of the total composition of light-trap catches for 2006-2007: *Notropis texanus* (28.9 percent), *Micropterus* spp. (28.9 percent, which includes both *M. salmoides* and a few specimens provisionally identified as *M. punctulatus*), *Lepomis macrochirus* (7.9 percent), *Carpiodes cyprinus* (6.2 percent), Cyprinidae sp. (4.6 percent), and *Minytrema melanops* (4.2 percent). Three taxa, based on small numbers, were collected in the Apalachicola River channel but not taken in the floodplain water bodies: *Anquilla rostrata* (n = 1), *Strongylura marina* (n = 3) and *Opsopoeodus emiliae* (n = 6). Conversely, based on small numbers, eight taxa were collected in the floodplain but not from the river channel: *Lepisosteus osseus* (n = 3), *Cyprinus carpio* (n = 69), *Notropis chalybeus* (n = 3), *N. maculatus* (n = 4), *Ictalurus punctatus* (n = 4), *Erimyzon sucetta* (n = 3), *Fundulus* sp. (n = 2), and *Elassoma okefenokee* (n = 2). For all age-0 fish collected in 2006-2007, species of four families dominated samples in percent composition and catch-per-unit effort (*C/f*, the mean number of fish per trap for the total sampling period): centrarchids (38 percent; 12.7 *C/f*), cyprinids (37 percent; 12.3 *C/f*), catostomids (11 percent; 3.7 *C/f*), and percids (7 percent; 2.4 *C/f*). The high relative abundance of centrarchids was due in part to the aforementioned single-trap catch of a large number of *Micropterus* sp. in River Styx in 2007, and for cyprinids due to the large numbers of *Notropis texanus* taken in the River Styx in 2006 and a large number of unidentified cyprinids taken in the river channel in 2006. Tables 3-5 provide relative abundances by family and summaries for all years of effort in the Apalachicola River channel (throughout a more extensive portion of the middle reach, as described in Walsh and others, 2006), and for River Styx and Battle Bend.

Traps placed in River Styx captured greater numbers of individuals than the other two sites (tables 3-5). For the 2006-2007 study period, catch-per-unit effort was lowest in the Apalachicola River and intermediate in Battle Bend. For the following water bodies and years shown, the mean numbers of all fish ($C/f \pm$ 1SE) were: Apalachicola River, 22.3 ± 5.7 (2006) and 7.0 ± 1.4 (2007); River Styx, 51.1 ± 7.3 (2006) and 76.4 ± 55.5 (2007); and Battle Bend, 24.3 ± 3.7 (2007). In 2006, catch rates decreased over time with decreasing discharge and increasing water temperature, although a few weekly samples from March to May had low catch rates in comparison to preceding or subsequent weeks (fig. 6). Such a trend was not evident for 2007 based on non-transformed data, in part because traps were set biweekly and catch rates were much lower than in 2006 (fig. 7).

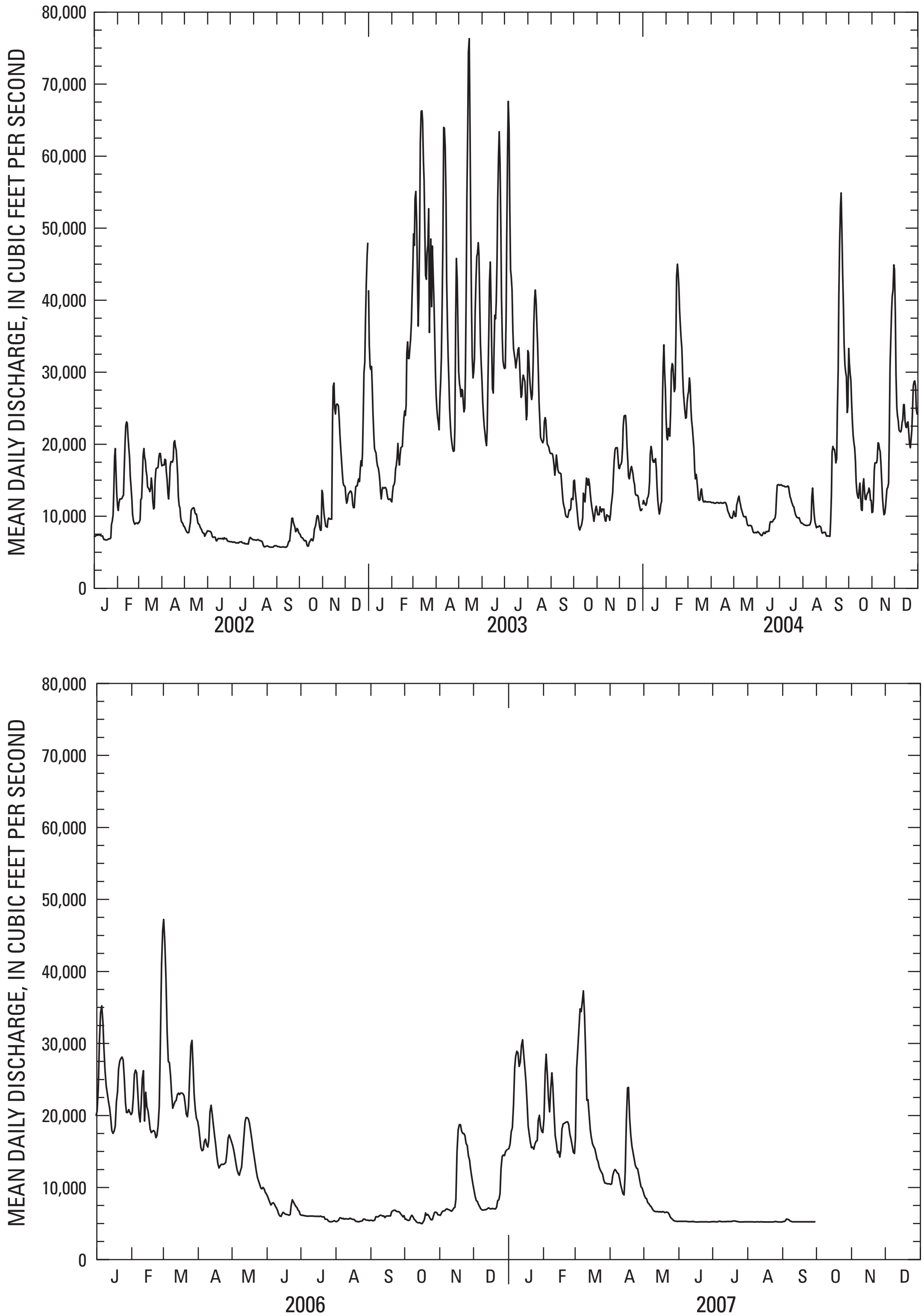



**Figure 4**. Annual discharge in the Apalachicola River at Blountstown during years of age-0 fish sampling.

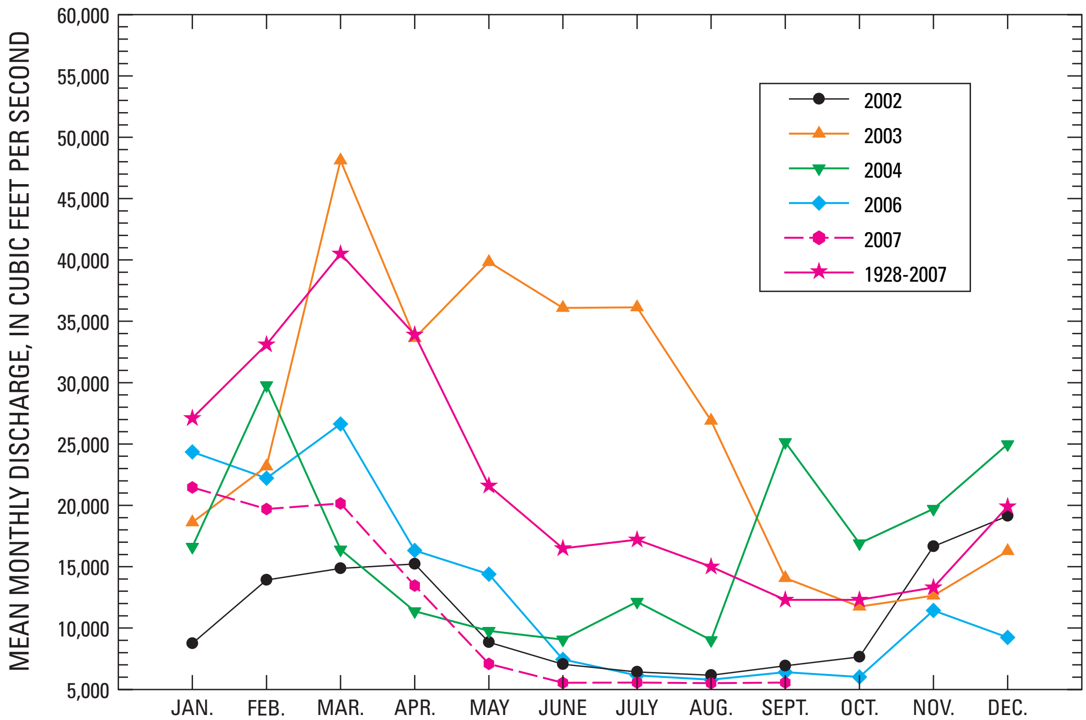



**Figure 5.** Mean monthly discharge in the Apalachicola River at Blountstown during years of age-0 fish sampling.

**Table 1.** Light-trap collections of age-0 fishes made in the Apalachicola River and floodplain habitats, 2006-2007.

| Data category | 2006 | | 2007 | | |
|---|---|---|---|---|---|
| | Apalachicola River | River Styx | Apalachicola River | River Styx | Battle Bend |
| Dates sampled | 15 March-6 June | 15 March-6 June | 9 March-3 July | 9 March-3 July | 10 March-2 July |
| Total number of traps | 169 | 172 | 144 | 72 | 72 |
| Number of empty traps | 35 | 9 | 28 | 7 | 8 |
| Percent empty traps | 20.7 | 5.2 | 19.4 | 9.7 | 11.1 |
| Total number of fish | 3,763 | 8,797 | 1,005 | 5,497 | 1,751 |

**Table 2.** Number and percent composition by taxon of age-0 fishes collected by light traps in the Apalachicola River, River Styx, and Battle Bend in 2006-2007.

[LPIL, lowest practicable identification level; n, number of specimens; %, percent composition by year; families arranged in approximate ascending phylogenetic sequence and species listed alphabetically within each family]

| Family | Taxon | Apalachicola River | | | | River Styx | | | | Battle Bend | | All sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | | 2007 | | 2006 | | 2007 | | 2007 | | 2006 | | 2007 | | 2006-2007 | |
| | | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| Lepisosteidae | *Lepisosteus oculatus* | 2 | 0.05 | 3 | 0.30 | 2 | 0.02 | | | | | 4 | 0.03 | 3 | 0.04 | 7 | 0.03 |
| | *Lepisosteus osseus* | | | | | 3 | 0.03 | | | | | 3 | 0.02 | | | 3 | 0.01 |
| Anguillidae | *Anguilla rostrata* | | | 1 | 0.10 | | | | | | | | | 1 | 0.01 | 1 | <0.01 |
| Engraulidae | *Anchoa mitchilli* | | | 56 | 5.57 | | | 3 | 0.05 | | | | | 59 | 0.71 | 59 | 0.28 |
| Clupeidae | Clupeidae LPIL | 4 | 0.11 | | | 1 | 0.01 | | | 1 | 0.06 | 5 | 0.04 | 1 | 0.01 | 6 | 0.03 |
| | *Dorosoma cepedianum* | 1 | 0.03 | | | 3 | 0.03 | | | 1 | 0.06 | 4 | 0.03 | 1 | 0.01 | 5 | 0.02 |
| | *Dorosoma petenense* | 2 | 0.05 | 40 | 3.98 | 6 | 0.07 | 16 | 0.29 | 108 | 6.17 | 8 | 0.06 | 164 | 1.99 | 172 | 0.83 |
| Cyprinidae | Cyprinidae LPIL | 784 | 20.83 | 16 | 1.59 | 137 | 1.56 | 21 | 0.38 | 8 | 0.46 | 921 | 7.33 | 45 | 0.55 | 966 | 4.64 |
| | *Cyprinella venusta* | 10 | 0.27 | 131 | 13.03 | 5 | 0.06 | 14 | 0.25 | 77 | 4.40 | 15 | 0.12 | 222 | 2.69 | 237 | 1.14 |
| | *Cyprinus carpio* | | | | | 2 | 0.02 | | | 67 | 3.83 | 2 | 0.02 | 67 | 0.81 | 69 | 0.33 |
| | *Notemigonus crysoleucas* | 3 | 0.08 | 1 | 0.10 | 312 | 3.55 | 42 | 0.76 | 93 | 5.31 | 315 | 2.51 | 136 | 1.65 | 451 | 2.17 |
| | *Notropis chalybaeus* | | | | | 3 | 0.03 | | | | | 3 | 0.02 | | | 3 | 0.01 |
| | *Notropis maculatus* | | | | | | | | | 4 | 0.23 | | | 4 | 0.05 | 4 | 0.02 |
| | *Notropis texanus* | 696 | 18.50 | 123 | 12.24 | 3,985 | 45.30 | 528 | 9.61 | 686 | 39.18 | 4,681 | 37.27 | 1,337 | 16.20 | 6,018 | 28.91 |
| | *Opsopoeodus emiliae* | 6 | 0.16 | | | | | | | | | 6 | 0.05 | | | 6 | 0.03 |
| Catostomidae | Catostomidae LPIL | 1 | 0.03 | 3 | 0.30 | | | 5 | 0.09 | 11 | 0.63 | 1 | 0.01 | 19 | 0.23 | 20 | 0.10 |
| | *Carpiodes cyprinus* | 1,156 | 30.72 | 20 | 1.99 | 6 | 0.07 | 2 | 0.04 | 107 | 6.11 | 1,162 | 9.25 | 129 | 1.56 | 1,291 | 6.20 |
| | *Erimyzon sucetta* | | | | | 2 | 0.02 | 1 | 0.02 | | | 2 | 0.02 | 1 | 0.01 | 3 | 0.01 |
| | *Minytrema melanops* | 424 | 11.27 | 125 | 12.44 | 283 | 3.22 | 31 | 0.56 | 3 | 0.17 | 707 | 5.63 | 159 | 1.93 | 866 | 4.16 |
| | *Moxostoma* sp. | 133 | 3.53 | 3 | 0.30 | 4 | 0.05 | 1 | 0.02 | | | 137 | 1.09 | 4 | 0.05 | 141 | 0.68 |
| Ictaluridae | *Ictalurus punctatus* | | | | | 2 | 0.02 | 2 | 0.04 | | | 2 | 0.02 | 2 | 0.02 | 4 | 0.02 |
| | *Noturus gyrinus* | | | 1 | 0.10 | 1 | 0.01 | | | | | 1 | 0.01 | 1 | 0.01 | 2 | 0.01 |
| | *Noturus leptacanthus* | 11 | 0.29 | 9 | 0.90 | 9 | 0.10 | 4 | 0.07 | 1 | 0.06 | 20 | 0.16 | 14 | 0.17 | 34 | 0.16 |
| Aphredoderidae | *Aphredoderus sayanus* | 14 | 0.37 | 2 | 0.20 | 405 | 4.60 | 3 | 0.05 | | | 419 | 3.34 | 5 | 0.06 | 424 | 2.04 |
| Atherinopsidae | *Labidesthes sicculus* | 6 | 0.16 | 12 | 1.19 | 157 | 1.78 | 99 | 1.80 | 33 | 1.88 | 163 | 1.30 | 144 | 1.74 | 307 | 1.48 |
| Belonidae | *Strongylura marina* | 2 | 0.05 | 1 | 0.10 | | | | | | | 2 | 0.02 | 1 | 0.01 | 3 | 0.01 |

**Table 2.** Number and percent composition by taxon of age-0 fishes collected by light traps in the Apalachicola River, River Styx, and Battle Bend in 2006-2007.—Continued

[LPIL, lowest practicable identification level; n, number of specimens; %, percent composition by year; families arranged in approximate ascending phylogenetic sequence and species listed alphabetically within each family]

| Family | Taxon | Apalachicola River | | | | River Styx | | | | Battle Bend | | All sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | | 2007 | | 2006 | | 2007 | | 2007 | | 2006 | | 2007 | | 2006-2007 | |
| | | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| Fundulidae | *Fundulus* sp. | | | | | 1 | 0.01 | | | 1 | 0.06 | 1 | 0.01 | 1 | 0.01 | 2 | 0.01 |
| Poeciliidae | *Gambusia holbrooki* | 1 | 0.03 | 7 | 0.70 | 28 | 0.32 | 4 | 0.07 | 17 | 0.97 | 29 | 0.23 | 28 | 0.34 | 57 | 0.27 |
| | *Heterandria formosa* | | | 1 | 0.10 | 1 | 0.01 | 1 | 0.02 | 1 | 0.06 | 1 | 0.01 | 3 | 0.04 | 4 | 0.02 |
| Centrarchidae | *Lepomis auritus* | 1 | 0.03 | 85 | 8.46 | 17 | 0.19 | | | 22 | 1.26 | 18 | 0.14 | 107 | 1.30 | 125 | 0.60 |
| | *Lepomis gulosus* | 1 | 0.03 | 1 | 0.10 | 67 | 0.76 | 10 | 0.18 | 1 | 0.06 | 68 | 0.54 | 12 | 0.15 | 80 | 0.38 |
| | *Lepomis macrochirus* | 42 | 1.12 | 29 | 2.89 | 718 | 8.16 | 575 | 10.46 | 291 | 16.62 | 760 | 6.05 | 895 | 10.84 | 1,655 | 7.95 |
| | *Lepomis* sp. | | | 20 | 1.99 | 4 | 0.05 | 11 | 0.20 | 2 | 0.11 | 4 | 0.03 | 33 | 0.40 | 37 | 0.18 |
| | *Micropterus punctulatus* | 5 | 0.13 | | | 17 | 0.19 | | | | | 22 | 0.18 | | | 22 | 0.11 |
| | *Micropterus salmoides* | 76 | 2.02 | 11 | 1.09 | 429 | 4.88 | 14 | 0.25 | 89 | 5.08 | 505 | 4.02 | 114 | 1.38 | 619 | 2.97 |
| | *Micropterus* sp. | 74 | 1.97 | 184 | 18.31 | 952 | 10.82 | 4,047 | 73.62 | 114 | 6.51 | 1,026 | 8.17 | 4,345 | 52.65 | 5,371 | 25.81 |
| | *Pomoxis nigromaculatus* | 3 | 0.08 | | | 99 | 1.13 | 1 | 0.02 | 1 | 0.06 | 102 | 0.81 | 2 | 0.02 | 104 | 0.50 |
| Percidae | Percidae LPIL | 16 | 0.43 | 2 | 0.20 | 264 | 3.00 | | | | | 280 | 2.23 | 2 | 0.02 | 282 | 1.35 |
| | *Ammocrypta bifascia* | 1 | 0.03 | 2 | 0.20 | | | 1 | 0.02 | | | 1 | 0.01 | 3 | 0.04 | 4 | 0.02 |
| | *Etheostoma fusiforme* | 53 | 1.41 | 35 | 3.48 | 273 | 3.10 | 17 | 0.31 | 4 | 0.23 | 326 | 2.60 | 56 | 0.68 | 382 | 1.84 |
| | *Etheostoma swaini* | 120 | 3.19 | 8 | 0.80 | 464 | 5.27 | 35 | 0.64 | 3 | 0.17 | 584 | 4.65 | 46 | 0.56 | 630 | 3.03 |
| | *Percina nigrofasciata* | 71 | 1.89 | 49 | 4.88 | 105 | 1.19 | 2 | 0.04 | | | 176 | 1.40 | 51 | 0.62 | 227 | 1.09 |
| Elassomatidae | *Elassoma okefenokee* | | | | | 2 | 0.02 | | | | | 2 | 0.02 | | | 2 | 0.01 |
| | *Elassoma zonatum* | 24 | 0.64 | | | 28 | 0.32 | | | 2 | 0.11 | 52 | 0.41 | 2 | 0.02 | 54 | 0.26 |
| Achiridae | *Trinectes maculatus* | 20 | 0.53 | 24 | 2.39 | | | 7 | 0.13 | 3 | 0.17 | 20 | 0.16 | 34 | 0.41 | 54 | 0.26 |
| **Total** | | **3,763** | | **1,005** | | **8,797** | | **5,497** | | **1,751** | | **12,560** | | **8,253** | | **20,813** | |

**Table 3.** Summary by family for age-0 fishes[1] collected by light trap in the Apalachicola River, 2003-2007.

[*C/f*, catch-per-unit effort (mean number of fish per trap); n, number of specimens; %, percent composition by year; families arranged in approximate ascending phylogenetic sequence and species listed alphabetically within each family]

| Family | 2003 | | | 2004 | | | 2006 | | | 2007 | | | All years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | C/f | n | % | C/f | n | % | C/f | n | % | C/f | n | % | C/f |
| Lepisosteidae | | | | 5 | 0.08 | 0.05 | 2 | 0.05 | 0.01 | 3 | 0.30 | 0.02 | 10 | 0.09 | 0.02 |
| Anguillidae | | | | | | | | | | 1 | 0.10 | 0.01 | 1 | 0.01 | <0.01 |
| Engraulidae | | | | 12 | 0.20 | 0.11 | | | | 56 | 5.57 | 0.39 | 68 | 0.64 | 0.16 |
| Clupeidae | | | | 441 | 7.46 | 3.97 | 7 | 0.19 | 0.04 | 40 | 3.98 | 0.28 | 488 | 4.56 | 1.15 |
| Cyprinidae | 1 | 4.54 | 0.50 | 3,682 | 62.28 | 33.17 | 1,499 | 39.84 | 8.87 | 271 | 26.97 | 1.88 | 5,453 | 50.95 | 12.80 |
| Catostomidae | | | | 742 | 12.55 | 6.68 | 1,714 | 45.55 | 10.14 | 151 | 15.02 | 1.05 | 2,607 | 24.36 | 6.12 |
| Ictaluridae | | | | 8 | 0.14 | 0.07 | 11 | 0.29 | 0.07 | 10 | 1.00 | 0.07 | 29 | 0.27 | 0.07 |
| Aphredoderidae | | | | 1 | 0.02 | 0.01 | 14 | 0.37 | 0.08 | 2 | 0.20 | 0.01 | 17 | 0.16 | 0.04 |
| Atherinopsidae | 4 | 18.18 | 2.00 | 29 | 0.49 | 0.26 | 6 | 0.16 | 0.04 | 12 | 1.19 | 0.08 | 51 | 0.48 | 0.12 |
| Belonidae | | | | 2 | 0.03 | 0.02 | 2 | 0.05 | 0.01 | 1 | 0.10 | 0.01 | 5 | 0.05 | 0.01 |
| Fundulidae | | | | 1 | 0.02 | 0.01 | | | | | | | 1 | 0.01 | <0.01 |
| Poeciliidae | | | | 6 | 0.10 | 0.05 | 1 | 0.03 | 0.01 | 8 | 0.80 | 0.06 | 15 | 0.14 | 0.04 |
| Centrarchidae | 17 | 77.27 | 8.50 | 777 | 13.14 | 7.00 | 202 | 5.37 | 1.20 | 330 | 32.84 | 2.29 | 1,326 | 12.39 | 3.11 |
| Percidae | | | | 203 | 3.43 | 1.83 | 261 | 6.94 | 1.54 | 96 | 9.55 | 0.67 | 560 | 5.23 | 1.31 |
| Elassomatidae | | | | | | | 24 | 0.64 | 0.14 | | | | 24 | 0.22 | 0.06 |
| Achiridae | | | | 3 | 0.05 | 0.03 | 20 | 0.53 | 0.12 | 24 | 2.39 | 0.17 | 47 | 0.44 | 0.11 |
| Total n | 22 | | | 5,912 | | | 3,763 | | | 1,005 | | | 10,702 | | |
| Number of traps | 2 | | | 111 | | | 169 | | | 144 | | | 426 | | |
| Number of empty traps | 0 | | | 6 | | | 35 | | | 28 | | | 69 | | |
| Percent empty traps | | 0 | | | 5.4 | | | 20.7 | | | 19.4 | | | 16.2 | |
| **Total *C/f*** | | | **11.00** | | | **53.26** | | | **22.27** | | | **6.98** | | | **25.12** |

[1]Subadults and adults of relatively few specimens of slim-bodied taxa included (for example, engraulids, cyprinids, atherinopsids).

**Table 4**. Summary by family for age-0 fishes[1] collected by light trap in River Styx, 2002-2007.

[*C/f*, catch-per-unit effort (mean number of fish per trap); n, number of specimens; %, percent composition by year; families arranged in approximate ascending phylogenetic sequence and species listed alphabetically within each family]

| Family | 2002 | | | 2003 | | | 2004 | | | 2006 | | | 2007 | | | All years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | C/f | n | % | C/f | n | % | C/f | n | % | C/f | n | % | C/f | n | % | C/f |
| Lepisosteidae | | | | 4 | 0.04 | 0.04 | 1 | 0.09 | 0.06 | 5 | 0.06 | 0.03 | | | | 10 | 0.04 | 0.02 |
| Anguillidae | | | | | | | | | | | | | | | | | | |
| Engraulidae | | | | | | | 5 | 0.45 | 0.28 | | | | 3 | 0.05 | 0.04 | 8 | 0.03 | 0.02 |
| Clupeidae | | | | 9 | 0.09 | 0.09 | 16 | 1.45 | 0.89 | 10 | 0.11 | 0.06 | 16 | 0.29 | 0.22 | 51 | 0.20 | 0.12 |
| Cyprinidae | 76 | 27.44 | 1.38 | 7,778 | 78.30 | 76.25 | 284 | 25.82 | 15.78 | 4,444 | 50.52 | 25.84 | 605 | 11.01 | 8.40 | 13,187 | 51.50 | 31.47 |
| Catostomidae | | | | 63 | 0.63 | 0.62 | 6 | 0.55 | 0.33 | 295 | 3.35 | 1.72 | 40 | 0.73 | 0.56 | 404 | 1.58 | 0.96 |
| Ictaluridae | 2 | 0.72 | 0.04 | 3 | 0.03 | 0.03 | 3 | 0.27 | 0.17 | 12 | 0.14 | 0.07 | 6 | 0.11 | 0.08 | 26 | 0.10 | 0.06 |
| Aphredoderidae | | | | 79 | 0.80 | 0.77 | | | | 405 | 4.60 | 2.35 | 3 | 0.05 | 0.04 | 487 | 1.90 | 1.16 |
| Atherinopsidae | 15 | 5.42 | 0.27 | 68 | 0.68 | 0.67 | 23 | 2.09 | 1.28 | 157 | 1.78 | 0.91 | 99 | 1.80 | 1.38 | 362 | 1.41 | 0.86 |
| Fundulidae | | | | | | | | | | 1 | 0.01 | 0.01 | | | | 1 | 0.00 | 0.00 |
| Poeciliidae | 2 | 0.72 | 0.04 | 64 | 0.64 | 0.63 | 1 | 0.09 | 0.06 | 29 | 0.33 | 0.17 | 5 | 0.09 | 0.07 | 101 | 0.39 | 0.24 |
| Centrarchidae | 179 | 64.62 | 3.25 | 706 | 7.11 | 6.92 | 728 | 66.18 | 40.44 | 2,303 | 26.18 | 13.39 | 4,658 | 84.74 | 64.69 | 8,574 | 33.49 | 20.46 |
| Percidae | | | | 781 | 7.86 | 7.66 | 33 | 3.00 | 1.83 | 1,106 | 12.57 | 6.43 | 55 | 1.00 | 0.76 | 1,975 | 7.71 | 4.71 |
| Elassomatidae | 1 | 0.36 | 0.02 | 371 | 3.73 | 3.64 | | | | 30 | 0.34 | 0.17 | | | | 402 | 1.57 | 0.96 |
| Achiridae | 2 | 0.72 | 0.04 | 8 | 0.08 | 0.08 | | | | | | | 7 | 0.13 | 0.10 | 17 | 0.07 | 0.04 |
| Total n | [2]277 | | | 9,934 | | | 1,100 | | | 8,797 | | | 5,497 | | | 25,605 | | |
| Number of traps | 55 | | | 102 | | | 18 | | | 172 | | | 72 | | | 419 | | |
| Number of empty traps | 27 | | | 15 | | | 1 | | | 9 | | | 7 | | | 59 | | |
| Percent empty traps | | 49.1 | | | 14.7 | | | 5.6 | | | 5.2 | | | 9.7 | | | 14.1 | |
| **Total *C/f*** | | | **5.04** | | | **97.39** | | | **61.11** | | | **51.15** | | | **76.35** | | | **61.11** |

[1]Subadults and adults of relatively few specimens of slim-bodied taxa included (for example, engraulids, cyprinids, atherinopsids).

[2]Low catch rate attributable to large number of empty traps retrieved in February, May, and October (58 percent empty; n = 43; remaining 12 traps all set in July) and overall low richness (11 or fewer taxa).

**Table 5**. Summary by family for age-0 fishes[1] collected by light trap in Battle Bend, 2002-2007.

[*C/f*, catch-per-unit effort (mean number of fish per trap); n, number of specimens; %, percent composition by year; families arranged in approximate ascending phylogenetic sequence and species listed alphabetically within each family]

| Family | 2002 | | | 2003 | | | 2004 | | | 2007 | | | All years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | *C/f* | n | % | *C/f* | n | % | *C/f* | n | % | *C/f* | n | % | *C/f* |
| Lepisosteidae | | | | 3 | 0.15 | 0.05 | | | | | | | 3 | 0.08 | 0.02 |
| Anguillidae | | | | | | | | | | | | | | | |
| Engraulidae | 23 | 11.92 | 3.83 | | | | | | | | | | 23 | 0.58 | 0.15 |
| Clupeidae | | | | 2 | 0.10 | 0.03 | | | | 110 | 6.28 | 1.53 | 112 | 2.80 | 0.75 |
| Cyprinidae | 21 | 10.88 | 3.50 | 1,285 | 63.27 | 20.40 | | | | 935 | 53.40 | 12.99 | 2,241 | 56.04 | 14.94 |
| Catostomidae | | | | 1 | 0.05 | 0.02 | | | | 121 | 6.91 | 1.68 | 122 | 3.05 | 0.81 |
| Ictaluridae | | | | | | | | | | 1 | 0.06 | 0.01 | 1 | 0.03 | 0.01 |
| Aphredoderidae | | | | 1 | 0.05 | 0.02 | 15 | 62.50 | 1.67 | | | | 16 | 0.40 | 0.11 |
| Atherinopsidae | | | | 22 | 1.08 | 0.35 | 1 | 4.17 | 0.11 | 33 | 1.88 | 0.46 | 56 | 1.40 | 0.37 |
| Fundulidae | | | | | | | | | | 1 | 0.06 | 0.01 | 1 | 0.03 | 0.01 |
| Poeciliidae | 1 | 0.52 | 0.17 | 58 | 2.86 | 0.92 | 7 | 29.17 | 0.78 | 18 | 1.03 | 0.25 | 84 | 2.10 | 0.56 |
| Centrarchidae | 148 | 76.68 | 24.67 | 580 | 28.56 | 9.21 | | | | 520 | 29.70 | 7.22 | 1,248 | 31.21 | 8.32 |
| Percidae | | | | 41 | 2.02 | 0.65 | 1 | 4.17 | 0.11 | 7 | 0.40 | 0.10 | 49 | 1.23 | 0.33 |
| Elassomatidae | | | | 29 | 1.43 | 0.46 | | | | 2 | 0.11 | 0.03 | 31 | 0.78 | 0.21 |
| Achiridae | | | | 9 | 0.44 | 0.14 | | | | 3 | 0.17 | 0.04 | 12 | 0.30 | 0.08 |
| Total n | 193 | | | 2,031 | | 32.41 | [2]24 | | 3.22 | 1,751 | | 24.43 | 3,999 | | |
| Number of traps | 6 | | | 63 | | | 9 | | | 72 | | | 150 | | |
| Number of empty traps | 1 | | | 11 | | | 5 | | | 8 | | | 25 | | |
| Percent empty traps | | 16.7 | | | 17.5 | | | 55.6 | | | 11.1 | | | 16.7 | |
| **Total *C/f*** | | | **32.17** | | | **32.24** | | | **2.67** | | | **24.32** | | | **26.66** |

[1]Subadults and adults of relatively few specimens of slim-bodied taxa included (for example, engraulids, cyprinids, atherinopsids).

[2]Low catch rate and large proportion of empty traps due to limited number set in early March.

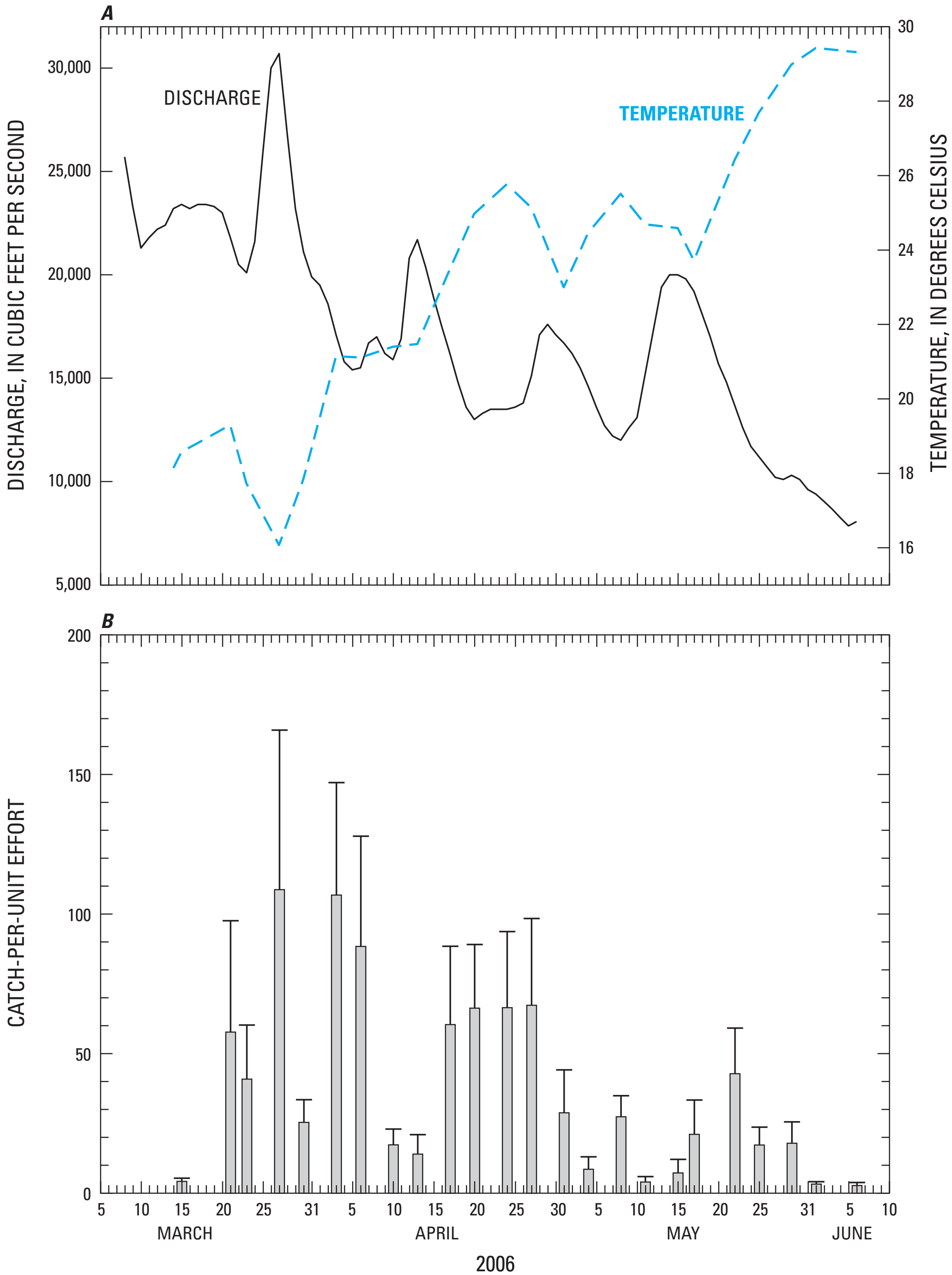



**Figure 6.** (*A*) Continuous discharge at the Blountstown gage (solid black line) and mean water temperature (dashed blue line) on light-trap sampling dates in the Apalachicola River and River Styx in 2006, and (*B*) catch-per-unit effort (*C*/*f*, mean number fish per trap ± 1SE) by date for all age-0 fishes (bottom graph).

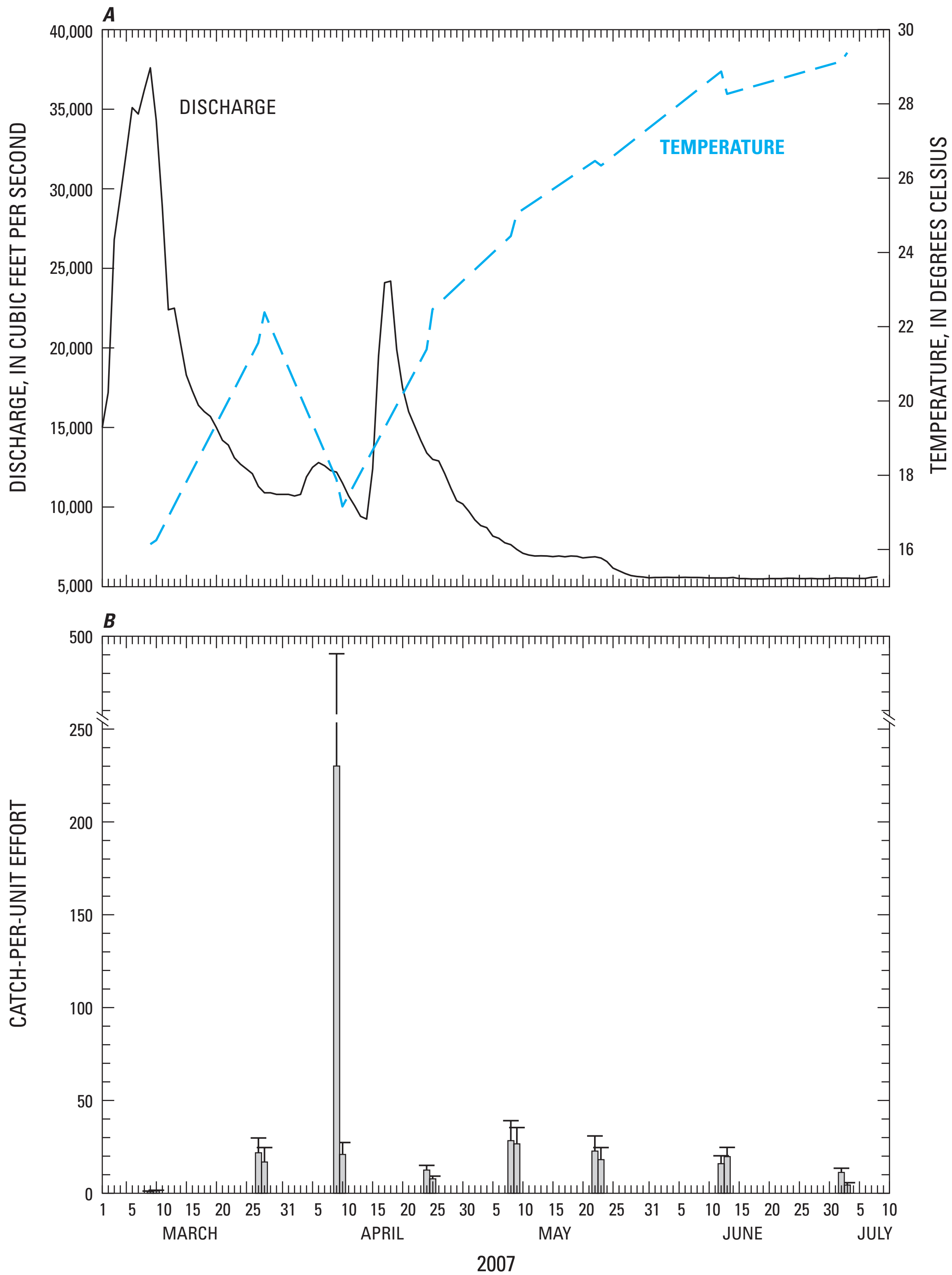



**Figure 7**. (*A*) Continuous discharge at the Blountstown gage (solid black line) and mean water temperature (dashed blue line) on light-trap sampling dates in the Apalachicola River, River Styx, and Battle Bend in 2007, and (*B*) catch-per-unit effort (*C/f*; mean number fish per trap ± 1SE) by date for all age-0 fishes (bottom graph).

## All Years

*Taxonomic Composition*—Species richness, diversity, and evenness varied within each water body across all years of study (table 6). A species accumulation curve for all fish collected in the river channel, River Styx, and Battle Bend during 2002-2007 was asymptotic at about 40 to 45 taxa for 6 to 13 cumulative samples (fig. 8). Therefore, diversity metrics were relatively uninformative for the Apalachicola River in 2003, River Styx in 2002, and Battle Bend in 2002 and 2004 due to limited sample sizes. In 2006-2007, species richness at each of the sites was generally lower than total species richness across all years. Among water bodies and across all years, richness was similar between the Apalachicola River channel and River Styx, and lower in Battle Bend. Within each water body, the value of the Shannon-Wiener diversity index was highest in 2006 for River Styx, and highest in 2007 for the Apalachicola River and Battle Bend. River Styx had more species than the other sites, but samples were numerically dominated by relatively few species. Thus, evenness was lowest for River Styx among all years combined, whereas the river channel had the highest evenness, with Battle Bend intermediate between the two.

*Abundance and Dominance*—As percent composition of taxa combined by family, cyprinids, and centrarchids were the most abundant age-0 fish in samples obtained from floodplain habitats, followed to a lesser extent by percids, clupeids, and catostomids (fig. 9). Cyprinids were also dominant in the river channel (including different species than those found in the floodplain), and centrarchids were variable among years, but generally second or third in abundance in mainstem habitats. The most notable difference between the floodplain and the river channel was the greater relative abundance of catostomids in the latter. Similar trends were evident in plots of catch-per-unit effort for individual families across years, and extensive variation occurred within water bodies and among years (fig. 10). Most of the variation is directly attributable to the effects of outliers as a result of one or a few traps that captured unusually large numbers of an individual taxon. For example, for all traps in River Styx, $C/f$ for all centrarchids was greatest in 2007 among years as a result of the single trap that captured 4,012 *Micropterus salmoides*, with a value of 105.8 ± 90.9SE, followed by 2004, which had $C/f$ = 60.7 ± 36.9SE. The large SE value for 2004 also indicated that there may have been outliers in that year; upon reexamination of raw data, it was determined that a single trap captured

**Table 6.** Number of traps, percent empty, and diversity metrics of samples combined by year of age-0 fishes taken by light traps in the Apalachicola River, River Styx, and Battle Bend from 2002-2007.

[$H'$, Shannon-Wiener diversity index; $J'$, Pielou's evenness; *n*, number of traps; N, number of age-0 fish; S, total number of taxa; 1- $\hat{D}$ , Simpson's index of diversity. Taxonomic data were upward collapsed; that is, specimens not identified to species were redistributed in proportion to relative numbers of identified species per water body by year (excluding cyprinids and *Lepomis* sp.).

| Year | Traps | | S | N | $H'$ | 1- $\hat{D}$ | $J'$ |
|---|---|---|---|---|---|---|---|
| | *n* | Percent empty | | | | | |
| **Apalachicola River** | | | | | | | |
| 2003 | 2 | 0 | 4 | 22 | 1.01 | 0.57 | 0.73 |
| 2004 | 111 | 5.4 | 34 | 5,912 | 1.69 | 0.63 | 0.48 |
| 2006 | 169 | 20.7 | 28 | 3,763 | 1.99 | 0.81 | 0.60 |
| 2007 | 144 | 19.4 | 28 | 1,005 | 2.55 | 0.90 | 0.77 |
| All Years | 426 | 16.2 | 39 | 10,702 | 2.31 | 0.84 | 0.63 |
| **River Styx** | | | | | | | |
| 2002 | 55 | 49.1 | 11 | 277 | 1.58 | 0.75 | 0.66 |
| 2003 | 102 | 14.7 | 32 | 9,934 | 1.18 | 0.43 | 0.34 |
| 2004 | 18 | 5.6 | 21 | 1,100 | 1.60 | 0.68 | 0.53 |
| 2006 | 172 | 5.2 | 34 | 8,797 | 1.96 | 0.75 | 0.55 |
| 2007 | 72 | 9.7 | 26 | 5,497 | 1.00 | 0.43 | 0.31 |
| All Years | 419 | 14.1 | 40 | 25,605 | 1.89 | 0.72 | 0.51 |
| **Battle Bend** | | | | | | | |
| 2002 | 6 | 16.7 | 5 | 193 | 1.26 | 0.68 | 0.78 |
| 2003 | 63 | 17.5 | 27 | 2,031 | 1.70 | 0.64 | 0.52 |
| 2004 | 9 | 55.6 | 4 | 24 | 0.92 | 0.54 | 0.66 |
| 2007 | 72 | 11.1 | 25 | 1,751 | 1.99 | 0.79 | 0.62 |
| All Years | 150 | 16.7 | 35 | 3,999 | 2.06 | 0.75 | 0.58 |

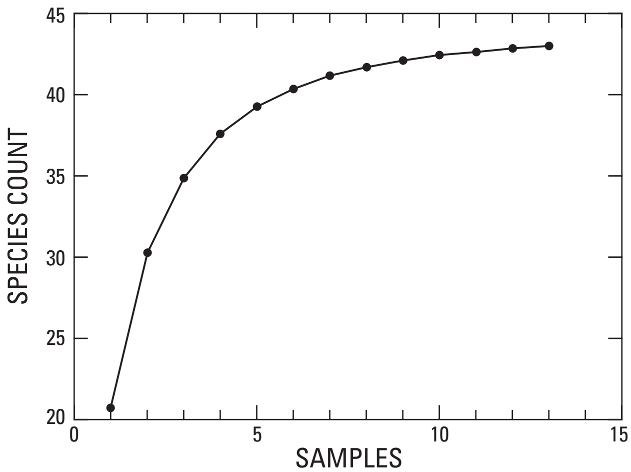



**Figure 8**. Species accumulation curve for all samples of age-0 fish collected in the Apalachicola River, River Styx, and Battle Bend for the years 2002-2007.

448 *Lepomis macrochirus*. When both of these outliers were removed, the *C*/*f* for all centrarchids was much more consistent with other years of sampling in River Styx (that is, $C/f = 24.9 \pm 10.1$SE in 2006, and $15.0 \pm 3.8$SE in 2007). For all taxa, River Styx had the greatest overall catch rates and yielded the most fish (table 4 and fig. 10). The Apalachicola River and Battle Bend sites had comparable overall catch rates, although catch-per-unit effort was much smaller for these sites than River Styx (tables 3 and 5).

*Chronological Appearance*—Prior to 2006, light-trap sampling was done from February to the late summer and early fall months (Walsh and others, 2006). Based on those results, it was determined that greatest spawning activity for most species extended from March through June, although some habitat generalists (for example, *Lepomis macrochirus*) continued to spawn throughout summer months. For the current study, the appearances of age-0 cohorts (as cumulative proportion appearing in traps) of target species (*Micropterus salmoides*, *Minytrema melanops*, *Lepomis* spp.) were summarized in a complementary report (Pine and others, 2008). Walsh and others (2006) summarized data for additional species of centrarchids and combined subordinate taxa of other families.

To summarize data for all years and all taxa of age-0 fish collected in the Apalachicola River and multiple floodplain water bodies, catch-per-unit values were calculated across Julian dates for the most abundant families of fishes and for all taxa combined, disregarding interannual and spatial variability (fig. 11). The resulting plots reveal the range of peaks and temporal extent of appearance of age-0 fish in traps. Temporal variation in some of the peaks is due in part to interspecific differences in the timing of spawning. For example, among centrarchids, *Pomoxis nigromaculatus* spawns relatively early in the spring, whereas *Lepomis macrochirus* has a very protracted spawning period and may exhibit peaks within

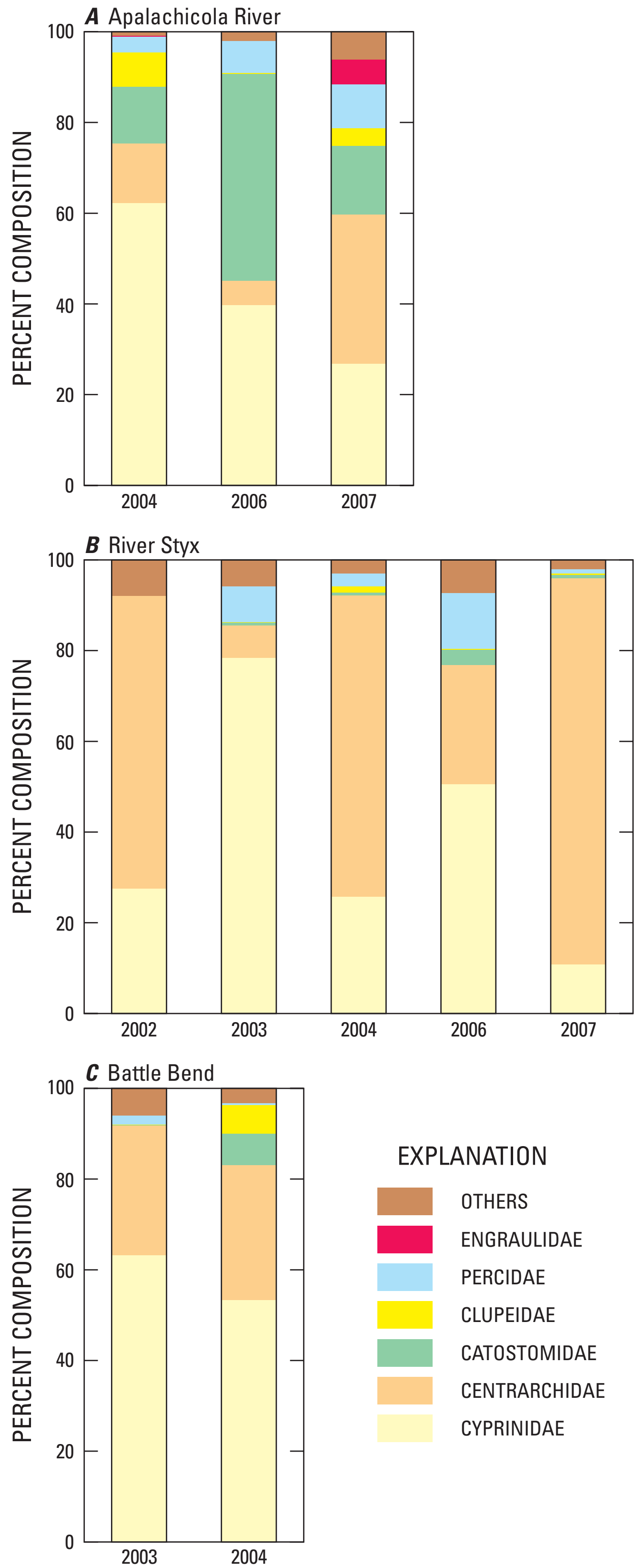



**Figure 9**. Percent composition by year of families representing greatest abundance of age-0 fishes collected by light trap in the Apalachicola River (*A*), River Styx (*B*), and Battle Bend (*C*).

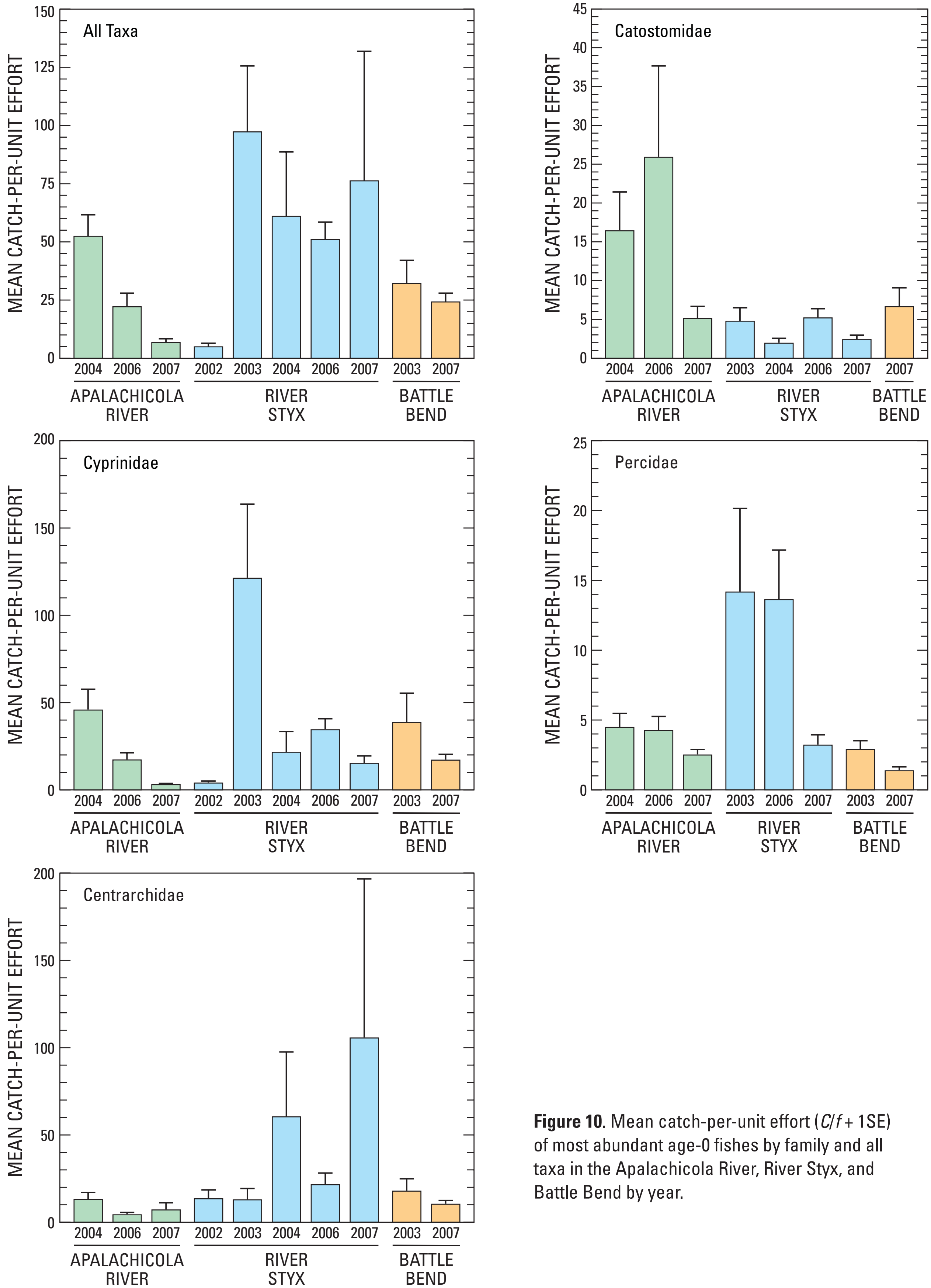



**Figure 10**. Mean catch-per-unit effort (*C*/*f* + 1SE) of most abundant age-0 fishes by family and all taxa in the Apalachicola River, River Styx, and Battle Bend by year.

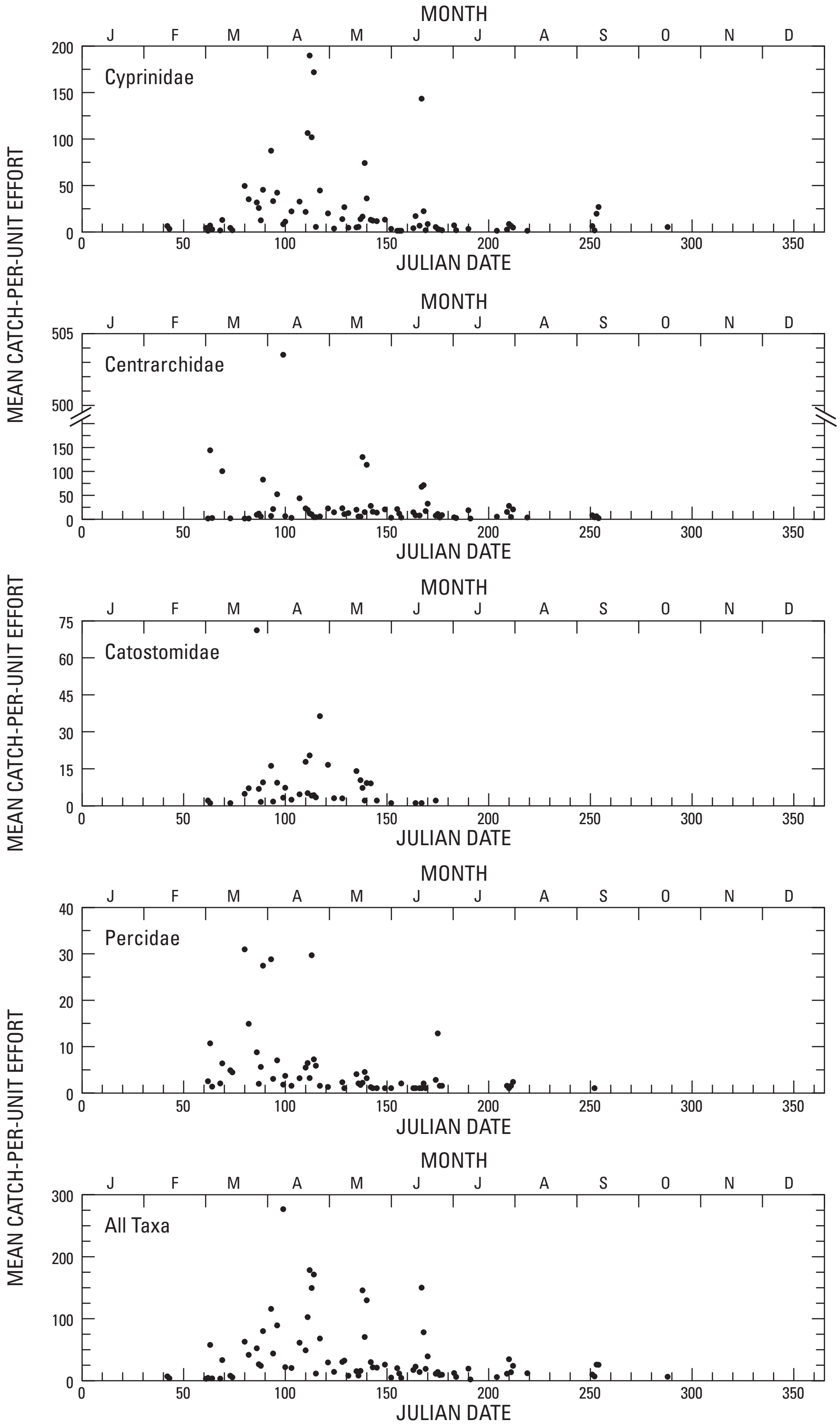



**Figure 11.** Mean catch-per-unit effort (*C/f*) of dominant families and all taxa for combined years (2002-2007) of age-0 fish caught by light traps in the Apalachicola River and multiple floodplain water bodies by Julian date and month. Catch data based on 64,164 fish representing 1,247 traps (empty traps excluded).

specific windows of time based on large catches of one or a few traps. Catostomids appeared to have a relatively narrow window of time in which the age-0 cohorts recruited to light traps in comparison to the other dominant families. The greatest amount of spawning activity, as inferred by recruitment to light traps, was between March and July (approximate Julian dates 60-210, fig. 11). Pine and others (2008) noted that there was probably a minimum 1-2 week period between hatching and recruitment to light traps for the target species. For some taxa, however, recruitment may have occurred in a matter of days or less, as evidenced by the collection of very small yolk-sac larvae.

## Pre- and Post-Enhancement of Battle Bend

In 2006, contractors for the Florida Fish and Wildlife Conservation Commission completed a habitat enhancement project at Battle Bend that consisted of excavating and removing sand and debris at the mouth in order to reestablish connectivity of the oxbow with the main river channel during low flows. An objective of this study was to compare data on the age-0 fish assemblage collected prior to habitat enhancement, with post-enhancement data collected in 2007. Pre-enhancement data included light trap samples that were placed in Battle Bend in 2002, 2003, and 2004. The amount of effort in the first and last of those years was limited to a total of 15 trap nights, and yielded few numbers of species and low overall diversity (table 6). Therefore, it was concluded that the only possible meaningful comparison of pre- and post-enhancement data would be for 2003 and 2007. Hydrologic conditions between these 2 years differed substantially; 2003 was a relatively high-water year and 2007 was a year of extreme drought (fig. 5).

A ranked species-abundance plot based on cumulative percent dominance (*k*-dominance curve) indicated that the samples taken in 2003 and 2007 had similar richness, and that 2007 had greater evenness (lower dominance) of the most abundant taxa (fig. 12*A*). However, a partial dominance curve (fig. 12*B*) revealed that 2007 had greater unevenness than 2003 for a suite of taxa lower in the dominance ranks, only slightly evident in the cumulative plot above the six most abundant taxa. Overall, values for the Shannon-Wiener diversity index, Simpson's index of diversity, and Pielou's evenness were slightly greater in 2007 than in 2003 (table 6), possibly indicating a shift in community characteristics between pre- and post-enhancement conditions. A tabular summary of taxa ranked by percent composition by year indicated notable differences in assemblage composition and relative abundance (table 7). Although the total number of species collected in 2003 and 2007 were comparable (25 and 27 respectively), the species present or absent in samples from each year differed among both low- and high-abundance taxa. Three species were among the top five in abundance in light-trap catches of both years: *Notropis texanus*, *Lepomis macrochirus*, and *Micropterus salmoides* (cumulative percent composition of 74 percent and 67 percent in 2003 and 2007, respectively). Nine species were collected in 2003 but not collected in 2007, all at percent composition values of 0.3 percent or less: *Percina nigrofasciata*, *Elassoma okefenokee*, *Opsopoeodus emiliae*, *Lepisosteus oculatus*, *Centrarchus macropterus*, *Micropterus punctulatus*, *Alosa* sp., *Erimyzon sucetta*, and *Aphredoderus sayanus*. In contrast, six species were collected in 2007 but not in 2003: *Carpiodes cyprinus*, Cyprinidae sp., *Notropis maculatus*, *Minytrema melanops*, *Fundulus* sp., *Dorosoma cepedianum*, and *Noturus leptacanthus*. The Bray-Curtis similarity coefficient between years was 69.2 for samples transformed to presence-absence, and 65.8 when transformed as fourth-root. For species in the mid- to low-range of rank abundance for either year, the most notable differences were for the following species (percent composition, year): *Lepomis auritus* (7.2 percent, 2003; 1.3 percent, 2007), *Lepomis gulosus* (2.7 percent, 2003; <0.1 percent, 2007), *Pomoxis nigromaculatus* (2.4 percent, 2003; <0.1 percent, 2007), *Dorosoma petenense* (<0.1 percent, 2003, 6.2 percent, 2007), and, *Cyprinus carpio* (<0.1 percent, 2003; 3.8 percent, 2007). Among dominant species in both years, the most substantial difference was that *Carpiodes cyprinus* was not collected in 2003, but represented 6.7 percent of the catch in 2007.

# Discussion

A primary objective of this study was to examine age-0 cohort recruitment and abundance in relation to patterns of adult fish movements in mainstem and floodplain habitats of the Apalachicola River in 2006-2007 for targeted species of management interest (*Micropterus* spp., *Minytrema melanops*, *Lepomis* spp., and *Ictalurus punctatus*). Results of the telemetry study and aspects of larval catch data, as cumulative proportions of light traps per week containing age-0 cohorts of the target species over time and in relation to discharge, were summarized in a complementary report (Pine and others, 2008). Discrete movement patterns of tagged reproductive adults of *Micropterus* spp. were characterized by individual fish that utilized mainstem or floodplain habitats only, as well as individuals that moved between both habitats during the spawning season and at other times of the year. Among the target species, *Ictalurus punctatus* appears to be negatively phototaxic and was rarely collected in light traps, hence no conclusions could be drawn regarding age-0 cohorts of this species. Age-0 cohorts of *Micropterus* spp. and *Lepomis* spp. were taken in large numbers in mainstem and floodplain habitats in 2006 and 2007, and appeared with greater frequency in light traps and were collected in greater abundance in both the latter habitat and year. *Minytrema melanops* was also collected in in the mainstem and floodplain but exhibited variation between habitats as well as years. In 2006, proportions of light traps containing *M. melanops* were similar between the Apalachicola River and River Styx, whereas in 2007, *M. melanops* was found in a higher proportion of light traps in the river

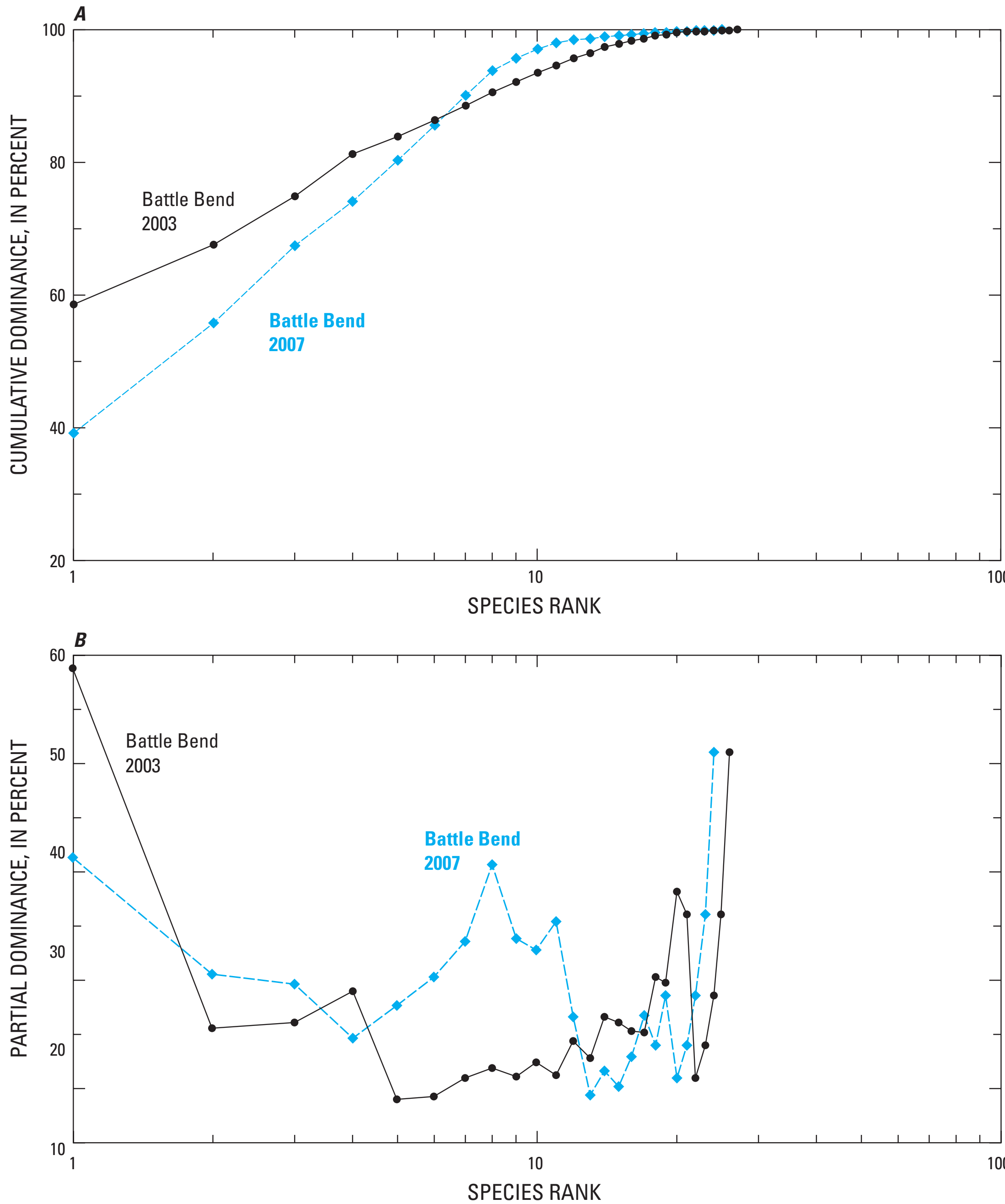



**Figure 12.** (*A*) Cumulative and (*B*) partial ranked species abundance (*k*-dominance) plots of age-0 fishes collected in Battle Bend in 2003 (black line and circles) and 2007 (blue line and diamonds).

channel near River Styx than in the latter water body itself. Also in 2007, *M. melanops* was found in a much higher proportion of light traps in the the Apalachicola River than in Battle Bend, and the total number of age-0 fish collected in the latter was very low (n = 3; table 2). These results suggest that *M. melanops* appears to spawn in floodplain habitats (that is, River Styx) in some if not all years, but in 2007 at least, this species may not have substantially utilized Battle Bend for spawning. A possible explanation for these observations may relate to habitat requirements for successful spawning of *M. melanops* (for example, flow and/or substrate) and differences between floodplain habitats or hydrologic conditions in any given year.

Floodplain habitats in the Apalachicola River support a rich assemblage, as evidenced by light-trap catches of age-0 fishes during this study as well as in previous years (Walsh and others, 2006). Not unexpectedly, catches in 2006-2007 were dominated by relatively few species of cyprinids, centrarchids, percids, and catostomids (table 2

**Table 7.** Rank abundance (n and percent composition) by species of age-0 fishes collected in Battle Bend in 2003 and 2007.

[n, number of specimens; percent, percent composition by year]

| Species | 2003 | | Species | 2007 | |
|---|---|---|---|---|---|
| | n | Percent | | n | Percent |
| *Notropis texanus* | 1,191 | 58.64 | *Notropis texanus* | 686 | 39.18 |
| *Micropterus salmoides* | 182 | 8.96 | *Lepomis macrochirus* | 291 | 16.62 |
| *Lepomis auritus* | 147 | 7.24 | *Micropterus salmoides* | 203 | 11.59 |
| *Lepomis macrochirus* | 130 | 6.40 | *Carpiodes cyprinus* | 118 | 6.74 |
| *Lepomis gulosus* | 55 | 2.71 | *Dorosoma petenense* | 109 | 6.23 |
| *Pomoxis nigromaculatus* | 48 | 2.36 | *Notemigonus crysoleucas* | 93 | 5.31 |
| *Gambusia holbrooki* | 46 | 2.26 | *Cyprinella venusta* | 77 | 4.40 |
| *Cyprinella venusta* | 41 | 2.02 | *Cyprinus carpio* | 67 | 3.83 |
| *Notemigonus crysoleucas* | 32 | 1.58 | *Labidesthes sicculus* | 33 | 1.88 |
| *Etheostoma fusiforme* | 29 | 1.43 | *Lepomis auritus* | 22 | 1.26 |
| *Labidesthes sicculus* | 22 | 1.08 | *Gambusia holbrooki* | 17 | 0.97 |
| *Elassoma zonatum* | 22 | 1.08 | *Cyprinidae* sp. | 8 | 0.46 |
| *Lepomis* sp. | 16 | 0.79 | *Etheostoma fusiforme* | 4 | 0.23 |
| *Cyprinus carpio* | 16 | 0.79 | *Notropis maculatus* | 4 | 0.23 |
| *Heterandria formosa* | 12 | 0.59 | *Etheostoma swaini* | 3 | 0.17 |
| *Trinectes maculatus* | 9 | 0.44 | *Trinectes maculatus* | 3 | 0.17 |
| *Percina nigrofasciata* | 7 | 0.34 | *Minytrema melanops* | 3 | 0.17 |
| *Elassoma okefenokee* | 7 | 0.34 | *Lepomis* sp. | 2 | 0.11 |
| *Etheostoma swaini* | 5 | 0.25 | *Elassoma zonatum* | 2 | 0.11 |
| *Opsopoeodus emiliae* | 5 | 0.25 | *Fundulus* sp. | 1 | 0.06 |
| *Lepisosteus oculatus* | 3 | 0.15 | *Heterandria formosa* | 1 | 0.06 |
| *Centrarchus macropterus* | 1 | 0.05 | *Lepomis gulosus* | 1 | 0.06 |
| *Micropterus punctulatus* | 1 | 0.05 | *Pomoxis nigromaculatus* | 1 | 0.06 |
| *Alosa* sp. | 1 | 0.05 | *Dorosoma cepedianum* | 1 | 0.06 |
| *Dorosoma petenense* | 1 | 0.05 | *Noturus leptacanthus* | 1 | 0.06 |
| *Erimyzon sucetta* | 1 | 0.05 | | | |
| *Aphredoderus sayanus* | 1 | 0.05 | | | |

and fig. 9). For all light trap samples in 2006-2007, the following species accounted for 80.8 percent of all individuals collected: *Notropis texanus* (28.9 percent), *Micropterus* spp. (28.9 percent), *Lepomis macrochirus* (7.9 percent), *Carpiodes cyprinus* (6.2 percent), Cyprinidae sp. (4.6 percent), and *Minytrema melanops* (4.2 percent). Some differences between mainstem and floodplain catches of these dominant species were apparent. The catostomids *C. cyprinus* and *M. melanops* constituted a greater proportion of fish collected in light traps set in the river. Percent composition of *L. macrochirus* was generally similar between years in the Apalachicola River and in River Styx, and this species made up a substantial portion of the catch (16.6 percent) in Battle Bend in 2007, thus showing an overall greater relative abundance in lentic floodplain habitats. Percent composition of *Notropis texanus* was quite variable between years within each water body. Likewise, *Micropterus* spp. abundance was variable within and between sites and years (especially due to skewed catches in River Styx in 2007); like *L. macrochirus* and *N. texanus*, the spatial occurrence and catch rates of *Micropterus* spp. in both mainstem and floodplain water bodies indicate that these taxa are habitat generalists, as noted by Kinsolving and Bain (1993) and others.

Despite the dominance of relatively few species in all light trap catches during this study, including both habitat generalists and apparent fluvial specialists (for example, *C. cyprinus*), the richness of taxa represented by age-0 cohorts in floodplain water bodies attests to the importance of these habitats in providing spawning and nursery areas for a broad suite of species. Similar results have been reported in many other studies; that is, that floodplain communities may be dominated by relatively few species, but that diverse assemblages are characteristic of floodplain habitats and that spawning and recruitment of age-0 cohorts are intricately linked to the hydrologic cycle (for example, Guillory, 1979; Holland, 1986; Finger and Stewart, 1987; Scheidegger, 1990; Baker and others, 1991; Killgore and Baker, 1996; Knight and Bain, 1996; Winemiller and others, 2000; Miranda, 2005).

Water managers in the Apalachicola-Chattahoochee-Flint basin are challenged with identifying critical flows required to sustain aquatic biological communities while balancing other resource needs. Light and others (1998) and Walsh and others (2006) reported that as many as 80 percent of about 91 freshwater fishes in the Apalachicola River may use floodplain habitats during some aspect of their life history. For fishes that use floodplain habitats, information about spawning times and recruitment periods for the most vulnerable life-history stage, the age-0 cohort, is necessary to evaluate how changes in the timing, magnitude, and duration of hydrologic pulses may influence population dynamics. Specifically, these changes may affect spawning success, survivorship, year-class strength, and the resiliency of species and communities to intra- and inter-annual variation. The chronological appearance of age-0 fish in river and floodplain water bodies of the Apalachicola River provides but just one aspect to consider in assessing how hydrologic conditions influence aquatic communities. Nevertheless, understanding the chronology is a necessary step in identifying resource needs using a holistic approach. Thus, data on the chronological appearance and relative abundance of age-0 fish obtained in this study and in prior years is useful for determining the relative timing in which floodplain conditions are optimal for maximizing the success of year-class recruitment. However, these data were collected over a limited time period and under extreme hydrologic conditions (including the low-water years of 2006-2007) and show no clear trends for the species targeted as part of the simultaneous adult-movement investigation (Pine and others, 2008). This finding suggests that data collection over multiple years, under differing hydrologic conditions, would be informative to better evaluate how variable flows and habitat conditions affect fishes that utilize the floodplain. Based on multiple years of study, it is evident that families represented by the most abundant species utilize both floodplain and river habitats as spawning and nursery areas for an extended period of time throughout the spring and summer, with peak recruitment of age-0 cohorts from early March through mid-June (fig. 11).

Temporal shifts in the appearance and relative abundance of individual taxa in this study were concordant with trends observed in other studies. Gallagher (1979) collected ichthyoplankton representing 10 families from March to September in the lower Mississippi River, with peak abundances from late May through early July. Floyd and others (1984) documented larval fish in a Kentucky stream from March through July; there was spatial and temporal overlap among taxa, and individual species were taken as larvae for periods of 3 to 12 weeks. In the upper Mississippi River, Holland (1986) found that fish eggs and larvae appeared from April to August, with seasonal shifts in dominant taxa and peak abundances that varied with discharge and temperature. Finger and Stewart (1987) found that age-0 abundance varied between 2 years with different flooding regimes in a lowland hardwood wetland in Missouri, although they did not quantify temporal appearance of larvae. Scheidegger (1990) found that the chronological appearance of larvae of different families was consistent over a 2-year period in the Cahaba and Tallapoosa Rivers in Alabama, and the following general sequence was observed: percids, catostomids, centrarchids, cyprinids, clupeids, poeciliids, fundulids, and atherinopsids. In the Tallahatchie River, Mississippi, larvae of early spawners (for example, *Dorosoma cepedianum*, *Pomoxis* spp., *Etheostoma* spp., *Percina* spp.) were dominant from spring to mid-summer, and late spawners (centrarchids, *Notropis* spp., *Cyprinella venusta*) were present on the floodplain from May through October (Turner and others, 1994). Killgore and Baker (1996) collected ichthyoplankton in the floodplain of the Cache River, Arkansas, from March through early June, and found the greatest abundance of dominant taxa (percids, aphredoderids, cyprinids, centrarchids) in late spring (April to early May), corresponding to water temperatures of 18-22 °C. The aforementioned studies specifically chronicle the timing and abundance of larval fish in large rivers and/or their floodplains in conjunction with hydrologic fluctuations (backwater indundation), habitat use, or both. An extensive body of literature documents the exploitation of floodplain habitats by cohorts other than age-0 fish (and/or age-0 fish at postlarval stages). These studies address adult spawning, resource use, assemblage characteristics, interannual variation, and other factors associated with hydrologic conditions, especially the annual flood pulse or altered flow regimes. Examples of these studies for rivers in the United States include Beecher and others (1977), Guillory (1979), Ross and Baker (1983), Schlosser (1985), Sheaffer and Nickum (1986), Kwak (1988), Baker and others (1991), Winemiller and others (2000), Rutherford and others (2001), Koel and Sparks (2002), Barko and others (2004), and Koel (2004).

In the present study, the appearance of age-0 fish of different taxonomic groups was similar to that reported by Gallagher (1979) and Scheidegger (1990), although the range of dates when cyprinids and centrarchids were most abundant varied depending on species. These two groups were dominant in spring to early-summer samples as in the study by Turner and others (1994), thus corroborating protracted spawning in floodplain habitats. In the present study, backwater habitats were identified as especially important nursery areas for centrarchids (fig. 9).

Ross and Baker (1983) recognized two groups of fish species based on response to flooding: quiescent and exploitative. Flood-exploitative species opportunistically capitalize on resources made available when the floodplain is inundated. Such species are typically habitat generalists that may delay reproduction in order to feed in productive floodplain habitats and acquire energy stores for spawning. In the Mississippi stream studied by Ross and Baker (1983), two of the dominant taxa that exhibit these characteristics were also floodplain-dominant species in the present study: *Lepomis macrochirus* and *Notropis texanus*. As noted by Ross and Baker (1983), flood-exploitative species often have breeding seasons that extend well beyond the time of spring flooding. Results from the present study confirm that the Apalachicola River floodplain assemblage includes a guild of dominant species exhibiting this pattern of spawning phenology. The concept of flood-exploitative fishes proposed by Ross and Baker (1983) illustrates the importance of how reproductive patterns of individual species determine responses to hydrologic conditions. Fractional spawners (fishes that produce multiple clutches in a single season) are less likely to be adversely affected by disruptions in timing and/or duration of flooding than batch-spawning species with reproductive cycles that are tightly synchronized to hydrologic pulses (Welcomme, 1985).

In rivers at temperate latitudes, water temperature is generally considered to promote the reproductive activity of adult fishes, and may also influence critical resources for early life-history stages. Walsh and others (2006) plotted mean water temperature for light traps containing representatives of individual fish families for samples in the Apalachicola River and floodplain, and found relatively narrow temperature ranges by family for the appearance of age-0 fishes. The activity of dominant freshwater groups was observed over ascending temperatures to infer the chronology of the appearance of the age-0 cohort in the following order: Catostomidae, Percidae, Cyprinidae, and Centrarchidae. Esocids and aphredoderids appeared at low temperatures (early spawners) and poeciliids and ictalurids appeared at high temperatures (late spawners). Water temperatures during the peak spawning period from mid-March through April 2006 in River Styx ranged from about 16-26 °C (fig. 6).

Habitat enhancement at Battle Bend improved connectivity between the oxbow (old river channel) and the current river channel during low-flow conditions. River flows were relatively low during the spring and summer months of 2006 and 2007. Consequently, ingress and/or egress of pre-reproductive adults between the mainstem and backwater habitat should have been improved relative to pre-enhancement, low-water years. It is notable that percent composition of age-0 individuals of two of the dominant species, *Lepomis macrochirus* and *Micropterus salmoides*, was much greater in 2007 in comparison to 2003 (table 7). Moreover, the appearance of *Carpiodes cyprinus* in Battle Bend in 2007 suggests that the habitat enhancement may have provided more river-like nursery refugia.

## Acknowledgments

We especially thank Charlie Mesing of the Florida Fish and Wildlife Conservation Commission (FFWCC) for guidance and support throughout the project. This work could not have been completed without the dedicated efforts of Edward Camp, Drew Dutterer, Jared Flowers, Colin Hutton, Kevin Johnson, Michal Jones, and Darren Pecora of the University of Florida. Additional assistance in the field and laboratory was provided by Sherry Bostick of the U.S. Geological Survey (USGS), and Matthew Glicco of Sante Fe College. Howard Jelks and Walter Courtenay (USGS) provided helpful comments on an earlier draft of the report.

This study was conducted as part of the USGS-FFWCC Joint Funding Agreement 07E0FL207217 (USGS) and 06196 (FFWCC).

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Walsh and others—**Composition of Age-0 Fish Assemblages in the Apalachicola River, River Styx, and Battle Bend, Florida—Open-File Report 2009-1145**