Increasing the Efficiency of Florida's Freshwater Fisheries Long-term Monitoring Program

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Abstract: In an effort to evaluate the Florida Fish and Wildlife Conservation Commission (FWC)'s long-term fisheries monitoring program for inland water bodies, we conducted a power analysis utilizing fish data from electrofishing, mini-fyke net, and gill net samples. We resampled data and simulated the effects of different combinations of gear and sample size for collecting presence–absence information. Our objective was to determine whether the use of either mini-fyke nets or gill nets could be eliminated or reduced in the monitoring program. Thirty fyke net/gill net gear combinations were evaluated to determine how many samples were needed to collect at least 80% of the known species when combined with FWC's standard 25 fall electrofishing samples. The best option (i.e., the gear combination that would require the least amount of sampling effort to achieve our target detection) included an additional 16 mini-fyke net sets and three field days for a crew of two. Because some recreationally important species, in particular white catfish (*Ameiurus catus*) and channel catfish (*Ictalurus punctatus*), would not be well represented in the monitoring program without gill nets, it is recommended that all three gears be used in lakes where these fisheries occur. Using a simple resampling and simulation procedure, we demonstrate how fisheries managers can make informed decisions for improving the efficiency of a monitoring program.

Key words: power analysis, electrofishing, gill net, fyke net, lakes

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Fisheries monitoring programs are often criticized for poor sampling design, lack of clear objectives, and low power, each of which can have costly consequences (Legg and Nagy 2006). It is important that agencies evaluate their monitoring program to ensure that the sampling protocol is statistically powerful, while minimizing cost and manpower requirements (Gibbs et al. 1998). One way to do that is through the use of power analyses, which can be used to evaluate trade-offs between sampling effort, logistical constraints, and power to detect trends for monitoring programs (Gibbs et al. 1998, Legg and Nagy 2006).

In 2006, the Florida Fish and Wildlife Conservation Commission (FWC) initiated a long-term monitoring program for inland lakes and reservoirs, which includes collecting data on the fish community, sport fishery, habitat, and water quality in these systems. Each year, fish are collected with a variety of gear types from approximately 30 lakes in order to track temporal trends in sport fisheries and the fish community. Three main types of gear are used to collect fish community information: boat electrofishing to sample the nearshore, littoral areas with depths ≤1.8 m, gill nets to sample the offshore, pelagic zone with depths ≥2 m, and mini-fyke nets to sample the shallow-water regions with depths <0.75 m; all using standardized FWC protocols (Bonvechio 2009). Combined, these data are used to obtain a snapshot view of the fish community with the long-term goal of tracking temporal shifts in the distribution and percent composition of species in these systems.

Previous power analyses focused solely on shads (*Dorosoma* spp.) collected with gill nets (Bonvechio et al. 2009) and community characteristics, including diversity and richness, for mini-fyke net catches (FWC, unpublished data). Based on these results, FWC set the initial sample sizes at 20 gill net sets and 30 mini-fyke net sets. However, variation in catch rates was high, with average coefficients of variation of 217% and 574% for individual species collected by gill net and mini-fyke net, respectively (FWC, unpublished data). Thus, it was determined that tracking trends in species relative abundance was not a realistic long-term objective for these gear types. Furthermore, decreased funding and manpower constraints prompted FWC to investigate ways to reduce costs while still providing meaningful information about the species present in

Table 1. Descriptors for Long-term Monitoring (LTM) lakes included in this study. Trophic classification is based on the Carlson and Simpson (1996) classification schema using water chemistry data collected by Florida Lakewatch. Size of presence-absence datasets used in the resampling procedure, including number of fall electrofishing transects (EF), winter gill net sets (GN), and summer mini-fyke net sets (MF) for each lake.

Lake	County	Size (ha)	Trophic classification	EF	GN	MF
Alligator	Osceola	1417	Mesotrophic	145	40	58
Crescent	Putnam	6462	Eutrophic	139	40	90
Deer Point	Bay	1480	Mesotrophic	137	40	60
Harris	Lake	6691	Eutrophic	211	40	130
Tarpon	Pinellas	1026	Eutrophic	140	40	57
Weohyakapka	Polk	3021	Eutrophic	144	40	59

these systems. Although the LTM program has various objectives, this study focused on the detection of species, with particular emphasis on species of conservation concern and exotic species.

We present the results of a power analysis performed by resampling historical fisheries data from multiple gears, with the aim of improving the efficiency of Florida's Freshwater Fisheries Long-term Monitoring (LTM) Program. We selected six LTM program lakes, for which at least two years of data and at least 40 samples had been collected for each gear type with established standard sampling protocols (Table 1, Bonvechio 2009). Using these data, we (1) determined the most efficient combination of gear and sample size for collecting presence-absence data given a range of sampling targets, specifically to collect 80%–90% of known species in the lake and (2) identified which species would be least likely detected, based on the outcome of that analysis.

Methods

Field Data

Electrofishing transects were sampled each fall (September–December) from 2006 through 2011. Samples were collected from randomly-selected sites along the shoreline where water depth was 1.8 m or less, and sites were sampled for 10 min (electrofishing pedal time) using two netters. All fishes were collected, identified to species, and enumerated. The number of transects sampled each year on a given lake ranged from 15 to 90 during 2006–2008, but a standard 25 samples was collected each year beginning in 2009 (Bonvechio et al. 2009). Over the entire study period, the number of transects sampled per lake ranged from 137 to 211 (Table 1).

Although FWC's standard protocol for experimental gill-net sampling was implemented in 2009, due to manpower constraints sampling was only performed on a subset of lakes each year. Thus, for each of the six study lakes, only two years of data, representing a total of 40 sites per lake, were available for inclusion in this study (Table 1). The pelagic zone (≥2 m in depth) was divided into 300- or 600-m grids depending on lake size, and 20 locations were randomly sampled each winter (December to March). Each location was sampled during daytime hours using a single sinking net (84 m × 1.8 m) that contained 11 7.6-m panels with stretch mesh sizes of 19.1 mm, 25.4 mm, 31.8 mm, 38.1 mm, 50.8 mm, 63.5 mm, 76.2 mm, 88.9 mm, 101.6 mm, 114.3 mm, and 127 mm. Nets were deployed with the direction of the wind, and not oriented towards any particular structure or shoreline. To minimize the effects of net saturation, nets were retrieved after approximately 2 h of fishing time. All fish in the net were then identified to species and enumerated.

As with gill nets, FWC's standard protocol for mini-fyke-net sampling was implemented in 2009, but sampling was only performed on a subset of lakes each year. In all, two to three years of data, representing a total of 58 to 130 sites for each of the six study lakes, were included in the analysis (Table 1). Each mini-fyke net consisted of three 0.6- by 0.6-m (0.37-m^2) metal frames, two 0.6- by 0.6- by 0.6-m (0.23-m^3) chambers, and a 0.9-m conical cod end. A 4.6- by 0.6-m lead with float and lead lines extended 0.6 m into the first chamber. The second chamber consisted of a funnel with a 5.1-cm excluder ring elevated 15.2 cm from the bottom. The entire net, including the lead line, was composed of 3-mm nylon mesh. For most years, each lake was split into three equal sections, and 10 sample sites were randomly selected from within each section for a total of 30 sample sites; however, in one year, 50 sites were randomly selected from all possible locations in Lake Harris as part of a different study. Nets were deployed such that the lead extended to shore or to the edge of dense vegetation or structure. All nets were fished overnight, i.e., set during afternoon (1200 to 1600 hours) and retrieved the following morning (0800 to 1100 hours). For all samples, fish were identified to species, counted, and weighed. If a net was found to be "unfished" due to the capture of a large predator or damage to the net, that particular data point was omitted from the dataset.

Simulations

For each treatment, we randomly selected (with replacement) 25 electrofishing transects using Proc Surveyselect (SAS 2008). This was considered a set "parameter" based on historical use of this gear and previous work which determined this sample size to be adequate for describing the fish community (Bonvechio et al. 2009). We then randomly selected (with replacement) sample sizes of 0 to 32 mini-fyke net sets and 0 to 20 gill net sets by groups of eight for mini-fyke net sets and groups of four for gill net sets in each possible combination (e.g., 8 mini-fyke net samples and 4 gill net samples; 8 mini-fyke net samples and 8 gill net samples; and so forth). We chose four as our sample size increment for gill nets because this represents the typical number of gill nets that can be set and processed in one day by a single crew. Due to the overnight soak time, two days are required to set, retrieve, and process samples for up to eight mini-fyke net sets. If sampling is conducted on consecutive days, another eight mini-fyke net sets could be set on the same day the previous set of nets was retrieved; thus, every additional eight nets constitutes one more day of sampling. For each of the 30 different gear-sample size combinations, we resampled the datasets 10,000 times and calculated the average number of species collected with all gears combined from the resampled data. We then determined which of the gear-sample size combination(s) would most efficiently collect 80%–90% of the species known to exist in the lake. In other words, we determined what gear-sample size combination would require the least amount of effort to collect, on average, at least 80% of the species in the lake. For each of these combinations, we also calculated individual detection probabilities to determine what species would most likely not be represented under the proposed sampling regime. By resampling the observed data, we were able to investigate potential sample sizes using known species assemblages for each lake given a range of sampling targets (for a general overview of resampling techniques, see Efron 1982).

Results

A total of 39–52 species was collected per lake and 73 species over all gear types, lakes, and years (Appendix 1). Of these, 18 were sport fishes, 6 were invasive species, and 1 a species of special concern. Based on our simulations, it was determined that in addition to electrofishing, on average 2–3, 2–5, and ≥4 field crew days would be necessary to collect 80%, 85% and 90% of the species in these lakes, respectively (Table 2, Figure 1). The 90% target was not considered a viable option given the large amount of additional effort required to reach that target. In fact, three of the six lakes examined would require more samples than were included in this study in order to reach the 90% target (Appendix 1). Furthermore, the 80% target was the only option that would favor the use of a single additional gear type, and in these instances the preferred gear was the mini-fyke net which tended to collect more unique species than did the gill nets. The only imperiled freshwater fish species collected with any gear was the Lake Eustis pupfish (*Cyprinodon variegatus hubbsi*) which was collected in both electrofishing and mini-fyke net samples but not in gill net samples. With results from all six lakes considered, we estimated a sample size of at least 16 mini-fyke net sets, in addition to the standard 25 electrofishing transects, would be sufficient to reach the 80% target.

Table 2. Number of field days and gear types needed to satisfy targets of 80%, 85%, and 90% species detection, based on 10,000 resamples. Results reflect the minimum effort requirements of mini-fyke nets sets (MF) or combination of mini-fyke and gill net sets (Both) in addition to the standard 25 electrofishing transects sampled each fall. Blank cells (–) indicate that the 90% target could not be reached with the gears and sample sizes included in this study.

	80% Target		85% Target		90% Target	
Lake	Field days	Gear types	Field days	Gear types	Field days	Gear types
Alligator	3	MF or Both	4	MF	7	Both
Crescent	3	MF	5	MF or Both	–	–
Deer Point	2	MF	4	MF or Both	–	–
Harris	2	MF	3	MF	5	MF or Both
Tarpon	3	MF	5	MF or Both	–	–
Weohyakapka	2	MF	2	MF	4	MF

Although gill net samples did not add much to the overall species richness value (Figures 1 and 2), the elimination of this gear type would negatively affect the detection of four main species, which support important recreational fisheries in some systems: channel catfish (*Ictalurus punctatus*), striped bass (*Morone saxatilis*), striped bass hybrid (*Morone saxatilis* × *M. chrysops*), and white catfish (*Ameiurus catus*) (Appendix 1). Even with four additional gill net sets, detection of the two catfish species was low in some lakes (as small as 5%). However, with eight gill net sets, detection levels exceeded 52% for both species in all lakes. *Morone* spp. were collected in only two of our study lakes, but the combination of 16 mini-fyke net sets and additional gill net sets greatly improved the detection of these species as well. For example, detection of striped bass at Crescent Lake increased from 16% without gill nets to 50% and 57% with the addition of four and eight gill net sets, respectively. Detection of hybrid striped bass increased from 71% to more than 97% in Lake Harris when data for as few as four gill net sets were included with the mini-fyke net and electrofishing samples.

Discussion

Biologists have traditionally favored the use of abundance and species composition data for tracking temporal trends in fish community structure. However, in some cases, the inherent variation associated with catch techniques, both within and across years, may limit our ability to perform meaningful analyses given funding and manpower restrictions that often influence how many samples can be collected. In a large-scale monitoring program, presence-absence surveys can be a cost-effective alternative to collecting relative abundance data (Pollock 2006). Methods have been developed that can help managers choose cost-effective monitoring regimes, even when data are not available or when the degree of temporal variation in the data (e.g., from year-to-year) is unknown. In a review of 512 published studies, Gibbs et al. (1998)

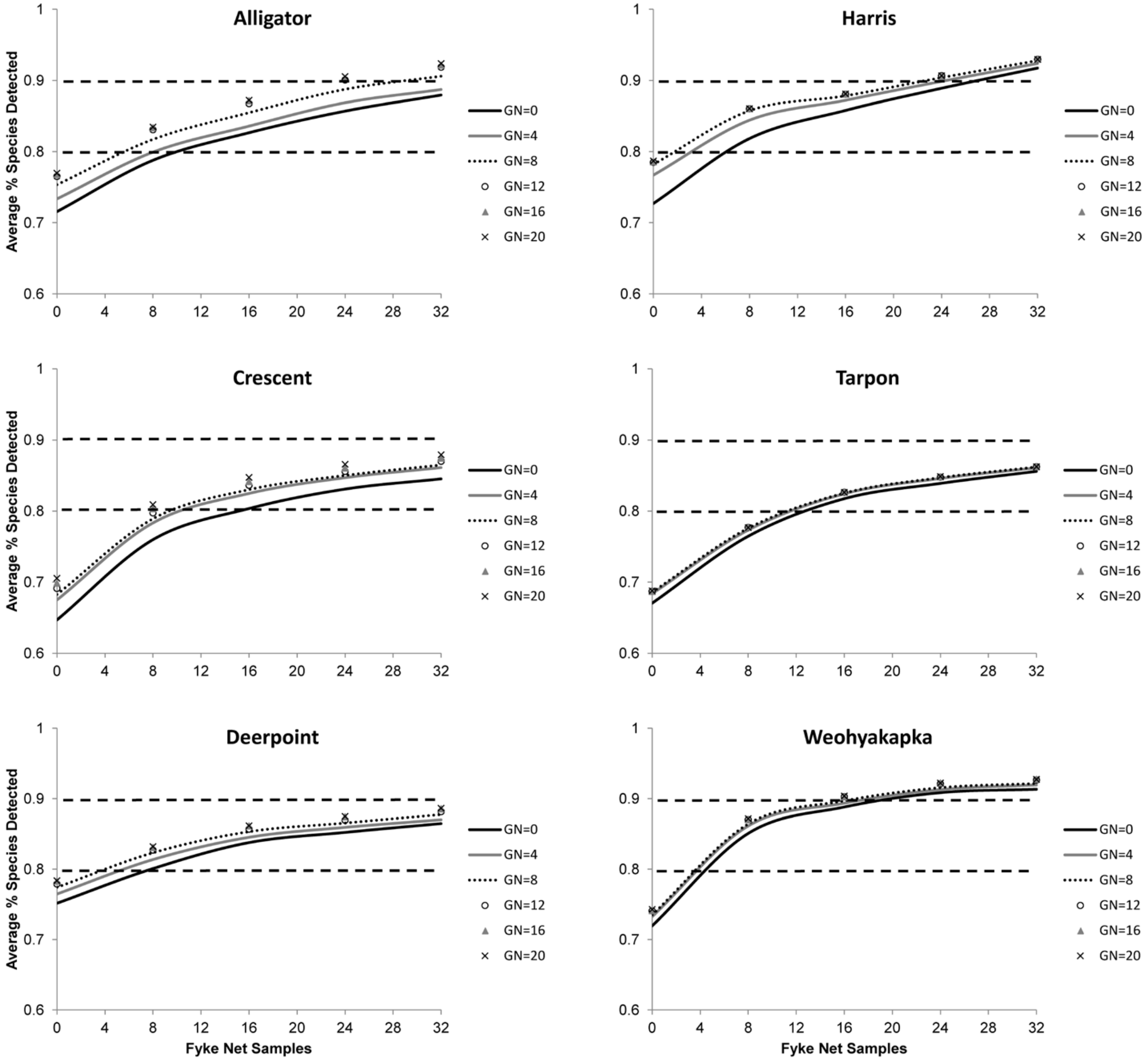

Figure 1. Average percent (%) of known species detected in the resamples for different levels of gill net (GN) and mini-fyke net effort. For each combination of gear type and sample size, results include species collected in 25 electrofishing samples.

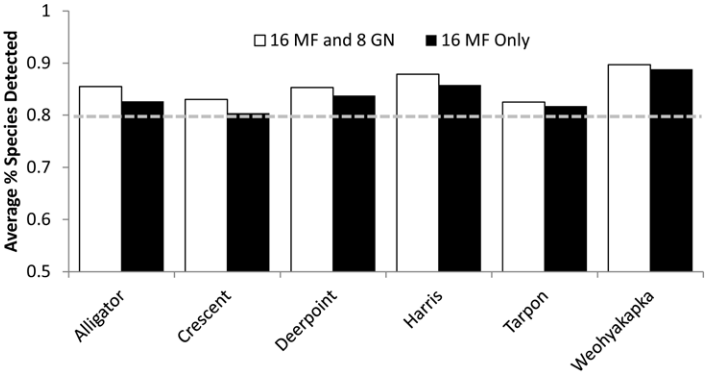

Figure 2. Average percent (%) of known species detected in the resamples from each lake given data for 25 electrofishing samples and one of two sampling options: both gear types with 8 gill net and 16 mini-fyke net sets (white bars); and single gear type with 16 mini-fyke net sets (black bars).

found that temporal variability inherent in counts was the most critical influence on power to detect trends in populations. Based on 30 time series of the count data that extended at least five years, fishes averaged a temporal coefficient of variation (CV) of 71%, which was relatively high compared to other groups of plants and animals (Gibbs et al. 1998). If only a single count is done each year, as originally dictated by FWC's standard sampling protocol, it would take an estimated 20, 70, and 420 samples to detect changes of 50%, 25%, and 10%, respectively, over a 10-year period. Using simulations, Joseph et al. (2006) determined that under budgetary constraints, presence–absence data can outperform count data when abundance or species detection is low. In fact, for large-scale monitoring programs, the proportion of sites at which a species is present can also be used as a surrogate for species abundance, although this applies primarily to cryptic, low-density, or territorial species (MacKenzie 2005).

In this study, we resampled extensive datasets from six lakes to determine whether sampling gears could be reduced while still allowing at least 80% of the known species within the lake to be collected. In addition to standard electrofishing sampling, current protocol dictates sample sizes of 20 gill-net sets (Bonvechio et al. 2012) and 30 mini-fyke net sets (FWC, unpublished data), but our results suggested that for gathering presence–absence information, this effort can be reduced by approximately 50% for each gear type. Our primary variable of interest was the total number of species collected, but a secondary emphasis lies in describing the statewide distribution of key species. For example, shad populations are known to increase with the trophic state of a lake (Bachmann et al. 1996, DiCenzo et al. 1996, Michaletz 1998, Allen et al. 1999, 2000); thus, occurrence of these species in lakes where they were once absent can be an important signal of eutrophication in a system. The spread of invasive species, including brown hoplo (*Hoplosternum littorale*), blue tilapia (*Tilapia aureus*), and sailfin catfishes (*Pterygoplichthys* spp.), is also of interest. Although some of these species had low (<50%) detection rates in some lakes, this may be the result of other factors such as reduced abundance or restricted distribution within the lake rather than the gear type or sample size employed.

Aside from distribution information, presence-absence data may be important for tracking trends in abundance and evaluating species-habitat relationships. The extent of occupancy of a region by a species has been found to be positively correlated with the size of the population for a wide variety of ecological groups (Holt et al. 2002). Thus, in the context of a long-term monitoring program, the potential exists for using presence-absence data as a rough index of abundance to indicate the need for more intensive sampling and directed hypothesis testing. For example, Pascual et al. (2002) used presence-absence information to create distribution maps of native and invasive species and, consequently, to identify research needs and possible management strategies for the protection of native fish assemblages. Presence-absence data can also be used to rank areas according to specified conservation criteria. In New Zealand, sites were ranked according to overall fish species richness and number of rare fish species to identify areas needing protection or conservation (Minns 1987). Newer occupancy models that can account for differences in species detectability through time and space may also be used to assess a sampling regime (Field et al. 2005, MacKenzie 2005) and potentially important habitat-occupancy relationships for individual species or groups.

Every gear type has inherent biases due to multiple factors including fish behavior and where and how the gear is fished (e.g., Hubert 1996). Thus, it was not surprising that eliminating any one gear type from the sampling protocol would negatively impact the detection of some species. With the elimination of gill nets from the sampling protocol, we reached our 80% target in every lake, given a sample size of 16 mini-fyke net sets. However, this resulted in a significant loss in detection of potentially important recreational species, in particular channel catfish (*Ictalurus punctatus*) and white catfish (*Ameiurus catus*). Therefore, in systems where these fisheries exist, the added effort to employ both types of gear, in addition to the standard electrofishing sampling, which is conducted each fall may be warranted. In these instances, we suggest the use of 8 gill net sets combined with 16 mini-fyke net sets which would detect these species more than 52% of the time, on average, in each of the six lakes. This technique can be used to evaluate the detectability of different species with multiple combinations of gear type and sample size. Depending on specific objectives, managers can evaluate species-specific trade-offs.

Legg and Nagy (2006) provided a summarized list of recommendations for a monitoring program. In addition to statistical considerations, they also emphasized the need for the periodic evaluation of monitoring programs, so that methodology and sampling requirements can be adjusted when needed. In an era of budget cuts and downsizing for many state agencies, standardized sampling programs, which can be expensive and time-consuming, are often the first to be reduced due to demands on agencies' workforce and resources. Excluding travel, the current FWC protocol of fishing 30 mini-fyke net sets and 20 gillnet sets requires 160 man-hours, or US$2600, per lake. Following this analysis and with the suggested reduction in data requirements, we estimate an effort savings of 70% for the single gear option and 50% savings for the combination gear option, thus providing substantial cost savings or freeing up funds to allow additional lakes to be sampled. We were able to use previously-collected data to inform this decisionmaking process through relatively simple resampling and simulation techniques. Given specified objectives, similar analyses can be performed by resource managers in other states facing similar challenges with their long-term monitoring programs.

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Appendix 1. Species collected in the six study lakes, with their average detection probabilities for the two sampling options, which includes 25 fall electrofishing transects (EF) and the addition of: (a) one gear type; 16 mini-fyke net sets (EF & MF) or (b) both gear types; 16 mini-fyke net and 8 gill net sets (EF & Both). Number of lakes (*n*) in which the species was known to occur and species status [species of special concern (C), invasive (I), sport fish (S)] are also provided.

Common name	Scientific name	Status	EF Only	EF & MF	EF & Both	*n*
American eel	*Anguilla rostrata*		0.56	0.61	0.61	3
American shad	*Alosa sapidissima*	S	0.59	0.60	0.75	1
Atlantic needlefish	*Strongylura marina*		0.92	0.97	0.98	5
Banded topminnow	*Fundulus cingulatus*		0.42	0.42	0.43	1
Bay anchovy	*Anchoa mitchilli*		0.90	0.90	0.89	1
Black acara	*Cichlasoma bimaculatum*	I	0.00	0.46	0.46	1
Black crappie	*Pomoxis nigromaculatus*	S	0.94	0.97	0.99	6
Blue tilapia	*Tilapia aureus*	I	0.94	0.94	0.94	5
Blueback herring	*Alosa aestivalis*		0.99	0.99	0.99	1
Bluefin killifish	*Lucania goodei*		0.71	1.00	1.00	6
Bluegill	*Lepomis macrochirus*	S	1.00	1.00	1.00	6
Bluespotted sunfish	*Enneacanthus gloriosus*		0.44	0.95	0.95	4
Bowfin	*Amia calva*		0.99	0.99	1.00	6
Brook silverside	*Labidesthes sicculus*		0.97	0.98	0.98	6
Brown bullhead	*Ameiurus nebulosus*	S	0.86	0.90	0.92	7
Brown hoplo	*Hoplosternum littorale*	I	0.18	0.64	0.64	6
Chain pickerel	*Esox niger*		0.80	0.80	0.81	5
Channel catfish	*Ictalurus punctatus*	S	0.60	0.75	0.92	5
Clown goby	*Microgobius gulosus*		0.59	0.81	0.82	1
Coastal shiner	*Notropis petersoni*		0.56	0.84	0.83	3
Common snook	*Centropomus undecimalis*	S	0.72	0.72	0.71	1
Dollar sunfish	*Lepomis marginatus*		0.72	0.88	0.88	6
Eastern mosquitofish	*Gambusia holbrooki*		0.83	1.00	1.00	6
Flagfish	*Jordanella floridae*		0.04	0.53	0.54	4
Flier	*Centrarchus macropterus*	S	0.43	0.51	0.50	1
Florida gar	*Lepisosteus platyrhincus*		0.83	0.90	0.90	6
Gizzard shad	*Dorosoma cepedianum*		0.88	0.88	0.99	6
Golden shiner	*Notemigonus crysoleucas*		1.00	1.00	1.00	6
Golden topminnow	*Fundulus chrysotus*		0.52	0.73	0.73	6
Grass carp	*Ctenopharyngodon idella*	I	0.92	0.92	0.91	1
Hogchoker	*Trinectes maculatus*		0.56	0.58	0.58	2
Hybrid striped bass	*Morone saxatilis x M. chrysops*	S	0.26	0.61	0.76	2
Inland silverside	*Menidia beryllina*		0.96	0.97	0.97	5
Ladyfish	*Elops saurus*		0.59	0.74	0.87	1
Lake chubsucker	*Erimyzon sucetta*		0.88	0.88	0.88	6
Lake Eustis pupfish	*Cyprinodon variegatus hubbsi*	C	0.62	0.93	0.93	1
Largemouth bass	*Micropterus salmoides*	S	1.00	1.00	1.00	6
Least killifish	*Heterandria formosa*		0.24	0.89	0.89	6
Lined topminnow	*Fundulus lineolatus*		0.98	1.00	1.00	2
Longear sunfish	*Lepomis megalotis*	S	0.17	0.16	0.18	1
Longnose gar	*Lepisosteus osseus*		0.54	0.70	0.80	5
Menhaden	*Brevoortia* spp.		1.00	1.00	1.00	1
Naked goby	*Gobiosoma bosc*		1.00	1.00	1.00	1
Pirate perch	*Aphredoderus sayanus*		0.17	0.17	0.17	1
Pugnose minnow	*Opsopoeodus emiliae*		0.63	0.71	0.71	5
Pygmy killifish	*Leptolucania ommata*		0.00	0.38	0.38	1
Pygmy sunfish	*Elassoma* spp.		0.60	0.61	0.59	1
Red drum	*Sciaenops ocellatus*	S	0.30	0.30	0.31	1
Redbreast sunfish	*Lepomis auritus*	S	0.67	0.83	0.83	4
Redear sunfish	*Lepomis microlophus*	S	1.00	1.00	1.00	6
Redfin pickerel	*Esox americanus americanus*		0.36	0.51	0.51	3
Russetfin topminnow	*Fundulus escambiae*		1.00	1.00	1.00	1
Sailfin catfish	*Pterygoplichthys* spp.	I	0.69	0.88	0.88	4
Sailfin molly	*Poecilia latipinna*		0.49	0.87	0.87	5
Seminole killifish	*Fundulus seminolis*		0.99	1.00	1.00	6
Southern flounder	*Paralichthys lethostigma*		0.60	0.60	0.61	1
Spotfin mojarra	*Eucinostomus argenteus*		0.94	0.94	0.95	1
Spotted gar	*Lepisosteus oculatus*		1.00	1.00	1.00	1
Spotted sucker	*Minytrema melanops*		0.99	0.99	1.00	1
Spotted sunfish	*Lepomis punctatus*	S	0.76	0.88	0.88	6
Striped bass	*Morone saxatilis*	S	0.16	0.17	0.57	1
Striped mojarra	*Eugerres plumieri*		0.42	0.42	0.43	1
Striped mullet	*Mugil cephalus*		1.00	1.00	1.00	1
Swamp darter	*Etheostoma fusiforme*		0.48	0.82	0.83	6
Tadpole madtom	*Noturus gyrinus*		0.00	0.48	0.48	5
Taillight shiner	*Notropis maculatus*		0.50	0.58	0.58	6
Threadfin shad	*Dorosoma petenense*		0.99	0.99	0.99	6
Walking catfish	*Clarias batrachus*	I	0.17	0.16	0.16	1
Warmouth	*Lepomis gulosus*	S	0.97	1.00	1.00	6
Weed shiner	*Notropis texanus*		0.98	0.99	0.99	1
White catfish	*Ameiurus catus*	S	0.54	0.69	0.86	6
White mullet	*Mugil curema*		0.99	0.99	0.99	1
Yellow bullhead	*Ameiurus natalis*	S	0.71	0.78	0.81	6