Fishery Dynamics of Macrophyte-dominated Banks Lake National Wildlife Refuge, Georgia

Steven J. Herrington, *The Nature Conservancy, Northwest Florida Program, P.O. Box 393, Bristol, FL 32321*

Karen J. Herrington, *U.S. Fish and Wildlife Service, 1601 Balboa Ave., Panama City, FL 32405*

Holly B. Herod, *U.S. Fish and Wildlife Service, Stockton Fish and Wildlife Office, 4001 N. Wilson Way, Stockton, CA 95205*

Donald Harrison, *Georgia Department of Natural Resources, P.O. Box 2089, Waycross, GA 31502*

Abstract: Banks Lake National Wildlife Refuge is a 1,640-ha refuge consisting of 405 ha open water (Banks Lake) and 1,235 ha of cypress swamp, marsh, and uplands located in southern Georgia. Fishes from Banks Lake, a system with problematic densities of both indigenous and nonindigenous aquatic vegetation, were collected during eight sampling periods in open water habitats from 1992 through 2003 to evaluate assemblage and sportfish dynamics. Stability and persistence analyses indicated that the fish assemblage was stable and persistent over time, though catch per unit effort of assemblage members was low in most years sampled. The bluegill population appeared stunted and was characterized by low relative weights (W_r) and proportional stock densities (PSD), while the largemouth bass population had low W_r and medium to high PSDs throughout the sample period. Length, weight, and structural indices for these fishes were characteristic of populations in a system with excessive vegetation. An experimental drawdown to control aquatic vegetation during winter 1993–94 resulted in a short-term increase in largemouth bass W_r and shift in bluegill size-distributions. Low system productivity and high concentrations of aquatic vegetation likely drive the population dynamics of the Banks Lake fish assemblage, thus future drawdowns or other vegetation-control actions may be an effective technique for improving its fishery.

Key words: Banks Lake National Wildlife Refuge, aquatic vegetation, fishery assemblage, stunting

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Located in Lanier County near Lakeland, Georgia, Banks Lake National Wildlife Refuge (BLNWR) comprises 1,640 ha, and drains into the Alapaha River (Suwannee River drainage). The refuge contains a variety of habitat types, including 1,235 ha of marsh, cypress swamp and uplands, and 405 ha of open water (referred to as Banks Lake). The refuge is a popular fishing area and averages approximately 20,000 fishing visits and several fishing tournaments each year, with anglers primarily targeting largemouth bass (*Micropterus salmoides)* and bluegill (*Lepomis mac-*

rochirus). Banks Lake has typically had excessive coverage of aquatic vegetation and over the past 20 years experienced a dramatic increase in nonindigenous aquatic vegetation (NAV) densities, primarily water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata;* L. Jenkins, USFWS, personal communication). To manage problematic aquatic vegetation, the lake is periodically drawn down to expose the vegetation to the killing effects of cold winter temperatures.

Unlike moderate amounts (<30%) of aquatic vegetation coverage which can provide structure and food resources for fishes (Wiley et al. 1984, Moxley and Langford 1985, Maceina 1996), excessive coverage (>40%) has been found to change prey assemblages, reduce growth rates, alter foraging behaviors, shift population size-structures, and reduce relative condition of warm-water sportfishes (Borawa et al. 1979, Colle and Shireman 1980, Shireman et al. 1985, Bettoli et al. 1992, Miranda and Pugh 1997). For example, Savino and Stein (1982) noted decreased efficiency in prey capture of largemouth bass with increasing habitat complexity. Similar increases in habitat complexity resulting from excessive NAV have been found to reduce feeding efficiency and growth rates of largemouth bass (Bettoli et. al 1992, Brown and Maceina 2002).

Although Banks Lake is a popular fishing area, little is known about its fish assemblage or the possible effects of excessive aquatic vegetation on the sport fishery. In 1992, the U.S. Fish and Wildlife Service (USFWS) and the Georgia Department of Natural Resources initiated an ongoing survey to identify trends in the fishery population dynamics of Banks Lake. Our objective was to summarize changes in the fish composition in Banks Lake from 1992 to 2003. Specifically, we examined temporal trends of the fish assemblage through measures of stability and persistence and catch per unit effort (CPUE). We also examined trends in sportfish populations using length-frequency distributions, proportional stock densities (PSDs), and relative weights over the 12-year study period.

Study Site

Historically, Banks Lake was a shallow, natural depression lake with extensive pond cypress (*Taxodium ascendens)* stands. In the 1820s, a low dam was constructed on a small tributary downstream of the depression to operate a gristmill and cotton gin. Its size increased in 1848 when the dam was elevated, raising the water to its current full pool level (58 m msl). Banks Lake is a blackwater, semi-acidic (pH 5.5) system with low total alkalinity (50 mg/L) and hardness (12 mg/L). Managers conducted lake drawdowns during the winters of 1993 and 2001 to control aquatic vegetation densities.

Methods

Sampling Protocol

Banks Lake was sampled for fishes on eight occasions from 1992 through 2003 during winter months using standard boat electrofishing protocols (Reynolds 1996).

All habitats sampled were considered open water and consisted of the littoral zone around the main open water depression in the center of the lake. Pulsed DC current from a 7.5 GPP generator (Smith Root, Inc.) yielded consistent power (approximately 5 kW) though water conductivity was low (20–30 µS) during the study period. Seven fixed stations were sampled during each time period. During most years, seven stations were electrofished for 60 minutes. However, in 1995, 1997, and 2003, only four, six, and three stations were sampled for the required 60 minutes, respectively. All fishes collected were enumerated and released near the vicinity of capture. Fishes from a representative sample at each sampling station were measured for total length (TL; nearest mm) and weighed (nearest g).

Fish Assemblage Data Analysis

Fish assemblage data were assessed for stability and persistence at all sites over the 12-year study period. Stability is a community metric based on abundance data that express constancy of numbers of individuals within species over time (Connell and Sousa 1983). Persistence is a metric describing continued presence of a species over time (Meffe and Minckley 1987). An assemblage member was included in stability analyses if it was considered dominant, which we defined as those contributing at least 1% of the total collection and occurring in at least 50% of samples through the entire study period (sensu Grossman et al. 1990). Assemblage stability was assessed using both Horn's Index of Similarity (Horn 1966) and the coefficient of variation (Grossman et al. 1990). Horn's Index of Similarity was used to quantify temporal differences in abundances of dominant species by combining all sites and species for all adjacent sampling year combinations, with values ranging from 0 (no similarity) to 1 (complete similarity). The mean of this index was calculated across all adjacent sampling periods to assess assemblage stability.

We used the coefficient of variation (CV) to quantify variability in abundances of dominant species within sites (intra-site) and among years (inter-annual; Grossman et al. 1990). Intra-site CV values were calculated for each year based on standardized abundances of dominant species at each site (mean number per 60 min. electrofishing) and then averaged across years for each dominant species. Inter-annual CV values were calculated across years based on yearly mean abundance for each dominant species. Mean intra-site and inter-annual CV values were calculated across dominant species to represent stability of the entire assemblage and compared using a *t*-test. If there were large changes in dominant species across the sample period, we would predict that the inter-annual CVs would be significantly higher than intra-site CVs (Gido et al. 2000). An assemblage may be considered stable if mean inter-annual CVs do not differ from intra-site CVs. If inter-annual CVs were higher than intra-site CVs, stability was classified according to the following scales: highly stable (0% to <25%), moderately stable (25% to <50%), moderately fluctuating (50% to <75%), and highly fluctuating (≥75%).

Total and dominant fish assemblage persistence was assessed using a modification of an index of faunal turnover (Meffe and Minckley 1987). Turnover (T) between adjacent sample periods was measured by:

$$T = (C + E)/(S_1 + S_2),$$

where C and E are the number of species colonizations or extinctions, respectively, and S_1 and S_2 are total numbers of species in each sample. The T value ranges from 0 (no turnover) to 1 (complete turnover). A mean assemblage turnover rate ($\bar{T}$) was calculated for all adjacent periods, and the Index of Persistence (PR) was calculated as $1 - \bar{T}$. The PR value ranges from 0 (no persistence) to 1 (complete persistence), with assemblages with PR > 0.6 considered persistent (Meffe and Minckley 1987).

Sportfish Dynamics

Relative weights (W_r), a measure of fish condition, were calculated for bluegill and largemouth bass according to the formula:

$$W_r = (W/W_s) \times 100$$

where W is weight of the individual and W_s is the length-specific standard weight predicted by a length-weight regression constructed to represent the species (Wege and Anderson 1978). Standard weights were calculated according to *a'* and *b* values provided in Anderson and Neumann (1996). Values at or above 100 usually indicate healthy fish in good condition, while values below 100 suggest poor condition potentially related to problematic feeding conditions (Anderson and Neumann 1996).

Proportional stock densities (PSDs; Anderson 1976) were calculated for bluegill and largemouth bass per sample year according to the formula:

$$PSD = \frac{\text{number of fish} \geq \text{minimum quality length}}{\text{number of fish} \geq \text{minimum stock length}} \times 100,$$

where bluegill PSDs were calculated using designations of stock (80 mm) and quality (150 mm) TL, and largemouth bass PSDs were calculated using stock (200 mm) and quality (300 mm) TL (Gabelhouse 1994). Relative weights, PSDs, and length-frequency histograms were calculated for bluegill and largemouth bass during all sample years except 2003 due to insufficient sample sizes. All statistical analyses were conducted using SPSS version 11.5 (SPSS 2002) and considered significant at the $P \leq 0.05$ level.

Results

Fish assemblage structure

Sampling from 1992 to 2003 produced 5,789 fishes, representing 22 identified species from 12 families (Table 1). Florida gar (*Lepisosteus platyrhincus*), bowfin (*Amia calva*), golden shiner (*Notemigonus crysoleucas*), lake chubsucker (*Erimyzon succeta)*, chain pickerel (*Esox niger*), black crappie (*Pomoxis nigromaculatus)*, warmouth (*Lepomis gulosus*), bluegill, and largemouth bass were the dominant species collected. Other species were captured only sporadically over the study period. Therefore, collection data for these species were considered unrepresentative of this portion of the assemblage and were only used in the total fish assemblage persistence analysis.

Table 1. Fishes[a] collected from Banks Lake, Georgia, from 1992–2003. Dominant species are denoted by [D].

Family	Scientific name	Common name
Lepisosteidae	*Lepisosteus platyrhincus*	Florida gar[D]
Amiidae	*Amia calva*	bowfin[D]
Cyprinidae	*Notemigonus crysoleucas*	golden shiner[D]
Catostomidae	*Erimyzon sucetta*	lake chubsucker[D]
Ictaluridae	*Ameiurus natalis*	yellow bullhead
	Ameiurus nebulosus	brown bullhead
Esocidae	*Esox niger*	chain pickerel[D]
	Esox americanus	redfin pickerel
Aphredoderidae	*Aphredoderus sayanus*	pirate perch
Fundulidae	*Fundulus chrysotus*	golden topminnow
	Fundulus lineolatus	lined topminnow
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish
Atherinopsidae	*Labidesthes sicculus*	brook silverside
Centrarchidae	*Centrarchus macropterus*	flier
	Enneacanthus gloriosus	bluespotted sunfish
	Lepomis gulosus	warmouth[D]
	Lepomis macrochirus	bluegill[D]
	Lepomis marginatus	dollar sunfish
	Lepomis microlophus	redear sunfish
	Lepomis punctatus	spotted sunfish
	Micropterus salmoides	largemouth bass[D]
	Pomoxis nigromaculatus	black crappie[D]

a. Some individuals from the families Ictaluridae, Fundulidae, and Percidae were not identified to species.

Total fish assemblage CPUE varied by year and was highest in 1995 (Table 2). Mean Horn's Index of Similarity for all adjacent sample periods was 0.879 (range = 0.789–0.937), indicating that the fish assemblage was similar (i.e., stable) in terms of constancy of dominant species and their abundances during the duration of the study. Mean assemblage CV across years (inter-annual; 99.1 ± 53.2%) was not significantly different than mean assemblage CV within sites (intra-site; 86.7 ± 25.1%), suggesting the dominant fish assemblage may be stable. Persistence of both the total fish (PR = 0.79) and dominant fish assemblages (PR = 0.98) were high, indicating high persistence during the study period.

Sportfish Dynamics

Relative weights of bluegill (mean = 78.71, SE = 3.83) and largemouth bass (mean = 86.71, SE = 3.20) were low for nearly every year sampled (Fig. 1). Relative weights for bluegill and largemouth bass were highest the first and second year, respectively, after drawdown. Bluegill PSDs (mean = 21.3, SD = 19.2) were poor with exceptionally low values between 1995 and 2001 (mean = 11.2, SD = 5.5), whereas largemouth bass PSDs (mean = 68.0, SD = 16.9) were relatively high throughout the study period (Fig. 2). The size-distributions of bluegill were skewed towards small

Table 2. Catch per unit effort (per hour) for the nine dominant and combined non-dominant species from Banks Lake, Georgia, from 1992–2003.

Species	1992	1994	1995	1996	1997	1999	2001	2003
Florida gar	7	4	11	6	1	7	3	0
Bowfin	1	2	27	3	2	5	0	1
Golden shiner	6	66	15	1	1	5	3	2
Lake chubsucker	8	9	51	15	4	43	9	2
Chain pickerel	3	2	7	8	8	10	9	2
Warmouth	2	2	10	5	5	6	3	7
Bluegill	28	57	170	58	18	33	12	2
Largemouth bass	15	31	35	19	15	13	14	4
Black crappie	1	2	22	1	2	2	0	1
Non-dominant spp.	7	11	8	5	1	4	1	3
Total	78	186	356	121	56	128	54	24

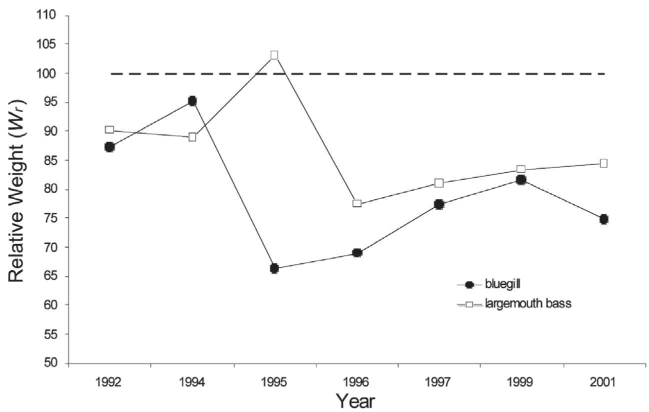

Figure 1. Mean relative weights (W_r) for bluegill and largemouth bass over time from Banks Lake, Georgia, from 1992–2001. A dashed line at 100 has been added as a reference.

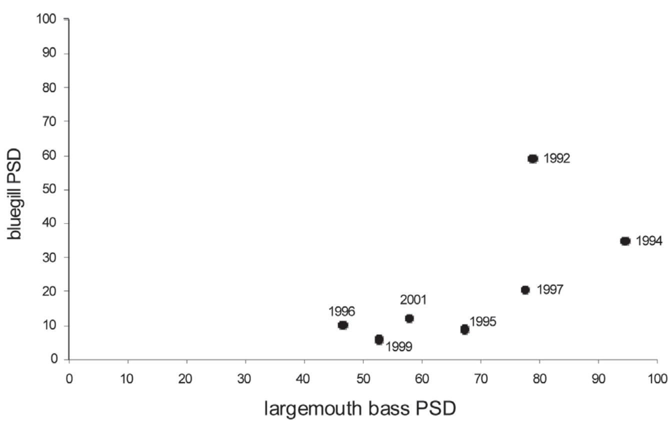

Figure 2. Comparison of bluegill and largemouth bass PSD values from Banks Lake, Georgia, from 1992–2001.

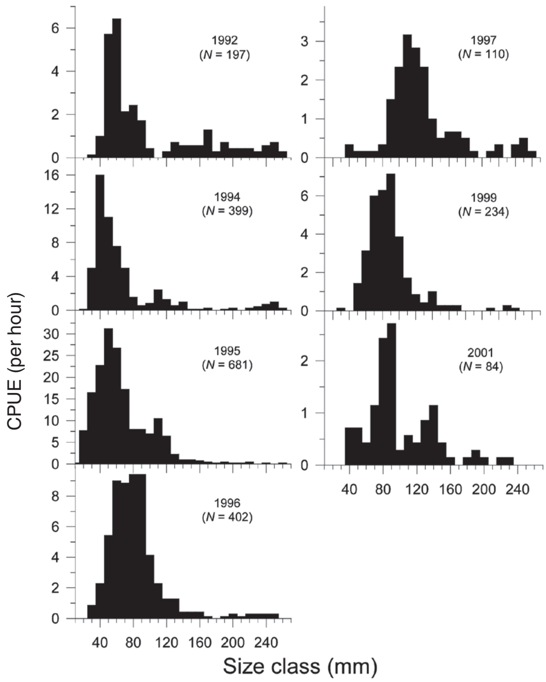

Figure 3. Length-frequency histograms of bluegill collected from Banks Lake, Georgia, from 1992–2001.

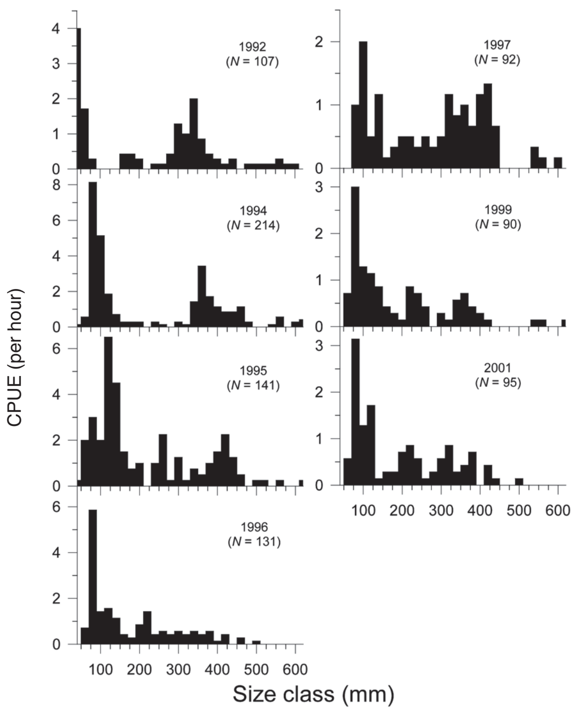

Figure 4. Length-frequency histograms of largemouth bass collected from Banks Lake, Georgia, from 1992–2001.

size-classes with few fish exceeding 152 mm (Fig. 3); whereas largemouth bass size-distributions were less skewed with fish sporadically exceeding 508 mm (Fig. 4).

Discussion

The Banks Lake fish assemblage appeared stable and persistent with little species turnover and changes in species abundances over the 12-year study period. Although this may be the result of adjustment of fish populations to stable environmental conditions of the lake, it should be noted that fluctuations in some species' populations may not have been accurately detected under the methodology of this study. Sampling protocol in this study focused on fishes that are highly susceptible to electrofishing (generally large-bodied species), thus certain small-bodied species were likely more abundant in the lake than represented here.

In addition to sampling bias, low CPUE for the assemblage may have resulted from inefficient sampling due to high densities of aquatic vegetation present throughout most of the study period. Although high densities of fishes may be present in dense aquatic weeds (Wrenn et al. 1996), capture ability by sampling crews was physically hampered by the high vegetation densities during this study (L. Jenkins, USFWS, personal communication). The increase in CPUE for 1994 and 1995 was likely related to improved sampling efficiency resulting from decreased aquatic plant densities after the winter 1993 drawdown, after which aquatic vegetation returned to high density levels for the remainder of the study (L. Jenkins, USFWS, personal commununication). Because high aquatic vegetation densities may hinder assessment efforts, alternative sampling techniques (e.g., passive traps) in conjunction with electrofishing may be useful in further quantifying the entire fish assemblage of Banks Lake. Despite these limitations, the sampling protocol was consistent over the study period, thus trends in abundances over time were likely conservative, supporting the apparent persistence and stability of the fish assemblage observed in this study.

As with electrofishing sampling, high vegetation densities also appeared to affect the Banks Lake sport fishery. Length-frequency histograms indicated that the bluegill population was stunted during most years, with a majority of fish <102 mm and few fish > 152 mm in length. Stunted bluegill populations are common in systems with high vegetation densities and are often stable through time (Schneider 1989), a pattern supported by our observations of the stability of this fish assemblage (of which bluegill was the most common species) and the relative consistency of bluegill size-distributions throughout the study period.

Bluegill and largemouth bass populations exhibited poor relative weights throughout the study. Under circumstances of high vegetation density and stunting, recruitment of young bluegill tends to be high with low natural mortality (Gerking 1962). Combined with low relative productivity characteristic of similar blackwater systems (Freeman and Freeman 1985), bluegill likely experienced high competition for limited food resources, which is supported by the low relative weights observed in this study. Largemouth bass populations also experience poor condition in weedy environments resulting from decreased efficiency in capturing prey and changes in foraging behavior (Savino and Stein 1982, Wiley et al. 1984, Betolli et al. 1992). As such, the short-term increase in relative condition of largemouth bass after the winter 1993 drawdown to control aquatic vegetation probably resulted from increased foraging efficiency under the less-weedy conditions in 1994 and 1995.

These interpretations are further supported by examination of bluegill and bass PSDs. With the exception of 1992 and 1994, mean bluegill PSD was well below 20, while mean largemouth bass PSD was relatively high in every year sampled. This is considered indicative of an unbalanced population for bluegill but potentially balanced (although individuals in relatively poor condition) for largemouth bass (Willis et al. 1993), as supported by these species' length-frequencies during most of the study period. When plotted against each other, the low PSDs of bluegill with medium to high PSDs of largemouth bass may reflect inefficient predation associated with habitat problems (Anderson and Neumann 1996), such as in high densities of aquatic vegetation (Betolli et al. 1992). Although interpretation of these measures or indices alone can be misleading (Willis et al. 1993), the combination of our measures suggest that bluegill and largemouth bass populations appear strongly affected by excessive aquatic vegetation densities in this system.

Managers have historically recognized that aquatic vegetation is problematic at Banks Lake and have employed drawdowns as a technique to manage aquatic vegetation densities and improve the sport fishery. Although long-term aquatic vegetation management and recovery of stunted bluegill populations can be difficult, our results suggest that drawdowns show promise in controlling aquatic vegetation and maximizing the sport fishery. For example, the winter 1993 drawdown decreased aquatic vegetation densities and likely resulted in increased predation pressure on stunted bluegill, as apparent by high largemouth bass relative weights in 1994 and 1995. In addition, bluegill size distributions were less skewed toward small size-classes after the winter 1993 drawdown. This suggests the potential for recovery from stunting, as increasing predation pressure is a technique commonly used by managers to control stunting of bluegill populations. Future drawdowns to decrease densities of aquatic vegetation in Banks Lake may have similar effects of: (1) increasing predation pressure on bluegill by largemouth bass, resulting in (2) increased condition and subsequent growth for largemouth bass, (3) shifting bluegill from a stunted size-distribution due to increased predation on small-sized fish, and (4) increasing condition and subsequent growth of bluegill due to decreased competition for food. Our data was insufficient to determine if similar population responses occurred after the winter 2001 drawdown, though further assessment and modification of this technique may achieve similar results as the winter 1993 drawdown.

BLNWR was established for the protection and conservation of its unique environment and its migratory and resident wildlife. In 1992, the refuge was the site of a celebratory signing of a memorandum of agreement between the USFWS and The Bass Anglers Sportsman Society, Inc., to improve recreational fishing on USFWS lands. BLNWR will continue to require active management to maintain a quality fishery. In addition to continuing experimental drawdowns or similar actions to control problematic aquatic vegetation (e.g., herbicide treatment), we offer the following recommendations for future management of Banks Lake and its fishery. First, install a multi-probe meter to record water quality and quantity. Second, quantify aquatic plant species and densities throughout lake and how fish use these habitats. Third, continue assessments of biodiversity with greater emphasis on relative abundances of all fish species. We also recommend quantifying age, growth, recruitment, and diet of sportfishes, assessing invertebrate and vertebrate prey availability, and conducting creel surveys as part of annual monitoring of sportfish populations and their exploitation. Information attained from these data will further provide insight into the effectiveness of aquatic vegetation control techniques, the ecological dynamics of this system, and afford a better foundation in making management decisions for the fishery of Banks Lake.

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