Evaluation of Walleye Introductions into Lakes Burton and Seed

by

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FINAL REPORT

State: Georgia Project Number: F-25

Project Title: Northern Region Fisheries Investigations

Study XXV Title: **Evaluation of Walleye Introductions into Lakes Burton and Seed**

Period Covered: July 1, 1990 to December 31, 1997

Study Objective: To establish and maintain a walleye population and fishery by stocking and to document any measurable impact of these introductions on both forage and game species. To compare the effects of stocking on forage abundance at two different population densities of yellow perch.

Abstract

Over 12 million walleye fry were introduced into Lake Burton in 1990 and 1991 to supplement limited natural reproduction in the existing low density population. One million walleye fry and 41,373 walleye fingerlings, ranging from 50 mm to 179 mm total length (TL), were introduced into Lake Seed from 1990 to 1995 in order to establish a walleye population and fishery. Fry stockings were not successful in Lake Burton. Limiting factors implicated in this unsuccessful effort included high latent mortality immediately after stocking due to poor water quality in the hauling media, insufficient food availability shortly after stocking, and predation. Walleye introductions were moderately successful in Lake Seed. Survival from all fry and fingerling stockings was documented in fall gill net samples. The primary factor which hindered stocking success in Lake Seed was two dramatic flood events in 1994 and 1995, which displaced significant numbers of stocked walleye into the neighboring downstream reservoir (Lake Rabun).

As a result, a moderate-density walleye population and minor fishery was subsequently established in Lake Rabun.

Although survival and recruitment was documented from all walleye stockings into Lake Seed, introductions of small fingerlings (50 mm TL) accounted for a majority of returns in annual fall gill net samples. As a result of walleye stockings in Lake Seed, a small fishery was established, and successful natural reproduction was documented in 1996. Spawning activity was observed in the headwaters of Lake Seed located in the Lake Burton tailrace and on main channel points with a rubble-gravel substrate.

In both reservoirs, walleye initially consumed yellow perch almost exclusively. Illegal introductions of blueback herring into the system, however, altered walleye diet composition during the study period and subsequently thwarted efforts to enhance the yellow perch size structure to a more desirable state for anglers. As a result of this dietary shift coupled with limited expansion of the walleye population, the total density and biomass of yellow perch experienced negligible changes after walleye stocking. In addition, the annual length and age distributions of yellow perch remained similar over time. Annual fluctuations in the survival rate of yellow perch were weakly correlated with walleye catch data.

Introduction

Fisheries managers frequently choose to stock walleye (*Stizostedion vitreum)* in coolwater systems in order to diversify sport fisheries and increase predation on underutilized forage species (Laarman 1978; Cobly et al. 1979). At least twelve lakes across north Georgia were stocked with low densities of walleye fry and small fingerlings during the 1960s, from which self-sustaining fisheries developed in only three reservoirs. One of the three successful reservoirs was Lake Burton, which received approximately 6.5 million walleye from 1960 to 1969 (Table 1). During the late 1970s and early 1980s, the Lake Burton walleye population supported a popular fishery that yielded a relatively high success rate of 0.38 fish/hr (Fatora and England 1982). By 1985, however, the population declined significantly, resulting in a dramatically decreased angling success rate of 0.04 walleye/hr (unpublished data). Studies conducted in 1987 and 1988 indicated that natural reproduction was inhibited as a result of decreasing walleye spawning habitat (Rabern 1989). The availability of walleye spawning habitat was strongly associated with the amount of winter rainfall and the lake elevation during the spawning season.

Laarman (1978) defined three types of walleye stocking. *Introductory stockings* are conducted in waters where walleye are absent; *maintenance stockings* are made in waters where natural reproduction is inhibited; and *supplemental stockings* are conducted in waters with self-sustaining walleye populations. In response to declining reproductive success in Lake Burton, a maintenance stocking of walleye fry was recommended as an effort to rebuild the population. Because walleye were virtually non-existent in Lake

Table 1. Walleye stocking history of Lake Burton, Georgia.

Year	Fry	Fingerlings	Size Range (mm TL)	Total	No./ha
1960	180,000		< 25	180,000	160
1961	280,000	32,700	25-75	312,700	278
1962	455,000	4,768	25-100	459,768	409
1963	3,420,000		< 25	3,420,000	3,045
1964	500,000	3,000	25-100	503,000	448
1965	0			0	0
1966	150,000		< 25	150,000	134
1967	500,000		< 25	500,000	445
1968	800,000		< 25	800,000	712
1969	225,000		< 25	225,000	200
Subtotal	*6,510,000*	*40,468*		*6,550,468*	*5,831*
1990	4,521,000		< 25	4,521,000	4,026
1991	8,062,370		< 25	8,062,370	7,179
Subtotal	*12,583,370*			*12,583,370*	*11,205*
Total	19,093,370	40,468		19,133,838	17,036

Seed, introductory stockings of walleye fry and fingerlings were made to establish a walleye population and fishery and to provide increased predatory pressure on the stunted yellow perch population. From 1990 to 1996, a study was implemented to measure the success of these introductions. Specific objectives of this study were: 1) to establish a self-sustaining walleye fishery in Lake Seed; 2) to increase the broodstock population in Lake Burton; 3) to enhance the population structure of yellow perch, and 4) to determine the most appropriate stocking size.

Description of Study Area

Lake Burton is a 1,123 hectare (ha) impoundment located near the headwaters of the Tallulah River in the northeast Georgia mountains (Figure 1). The reservoir was impounded in 1919 to provide storage capacity for the five downstream hydropower reservoirs in the Tallulah River system and secondarily to provide hydroelectric peaking power. Lake Burton extends 5.9 river kilometers (km) and has a maximum depth of 38 meters (m). The reservoir fluctuates annually between 2.5 and 6.0 m during the winter drawdown. Lake Burton is characterized as a coolwater, monomictic, oligotrophic reservoir. The basin morphology consists of steep-sided slopes and a bottom that is relatively devoid of structure and aquatic macrophytes. The 38.5 km of shoreline contain a very high density of single-family dwellings and associated boat houses, estimated at 1 house or boat dock per 100 m. Due to relatively low natural productivity, Lake Burton

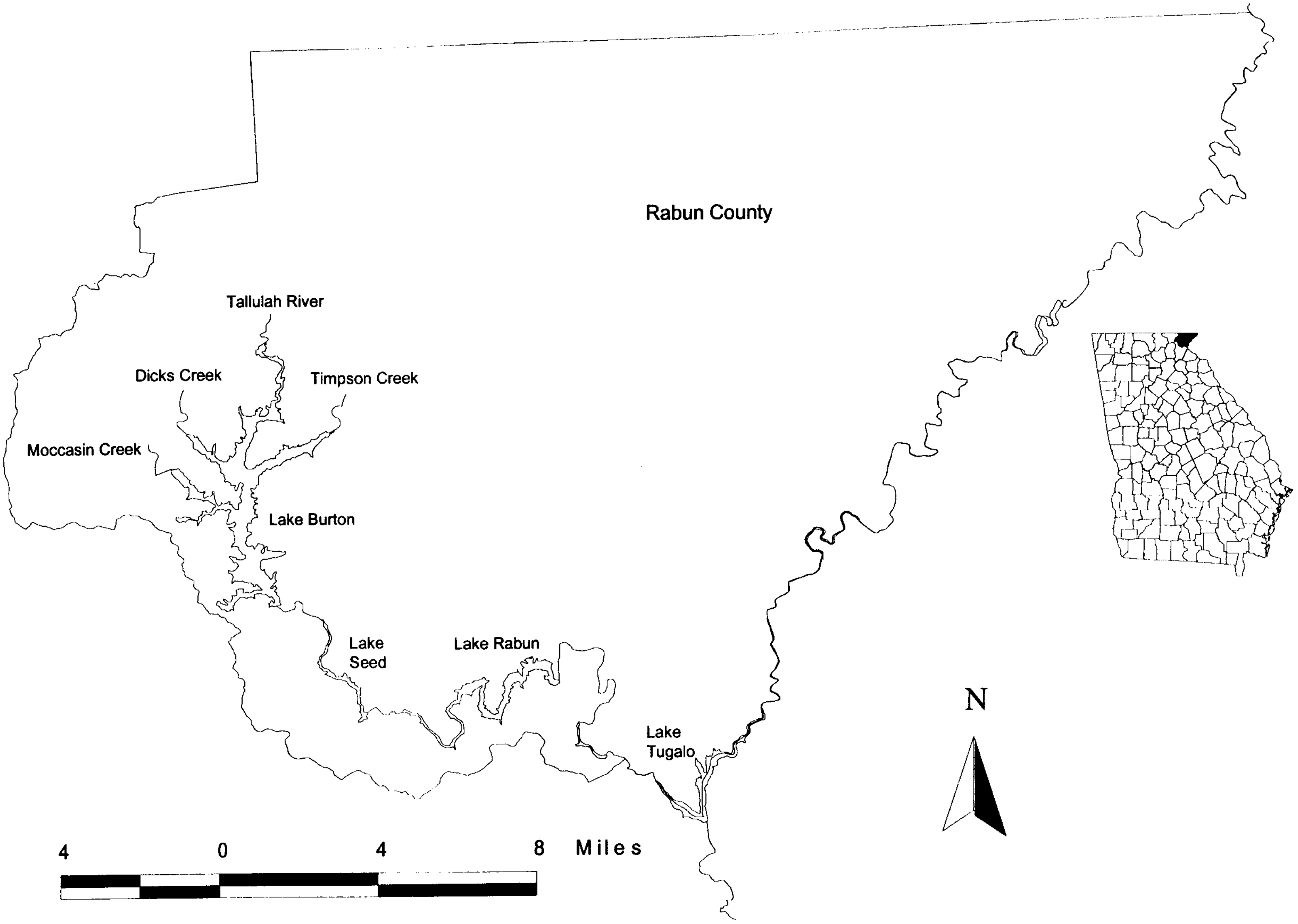

Figure 1. Map of the Tallulah River reservoir system in Rabun County, Georgia.

supports a low fish biomass. Intensive predator fish stocking efforts during the 1950s and 1960s contributed to the existing predator heavy fish community, which is composed of spotted bass (*Micropterus punctulatus)*, largemouth bass (*Micropterus salmoides*), chain pickerel (*Esox niger*), white bass (*Morone chrysops*), walleye (*Stizostedion vitreum*), and black crappie (*Pomoxis nigromaculatus*) (Rabern 1989). The forage base primarily consists of bluegill (*Lepomis macrochirus*), and yellow perch (*Perca flavescens*). Blueback herring (*Alosa aestivalis*) were illegally introduced during the study period and subsequently experienced rapid population expansion. The fishery of Lake Burton strongly reflects its community structure. In most years, approximately 75% of the directed effort is targeted at black bass, of which spotted bass dominate the creel (unpublished data). The remaining fishing effort and harvest are directed at bluegill, black crappie, yellow perch, and channel catfish (*Ictalurus punctatus).* Negligible effort is directed at walleye.

Lake Seed, the second reservoir in the Tallulah River system, is formed by the tailwaters of Lake Burton and spans 97 ha (Figure 1). Lake Seed was impounded in 1926 for the purpose of generating hydroelectric power. The morphology of Lake Seed is characterized by its narrow, run-of-the-river shape, steep-sided shoreline, and relatively shallow bottom. The upper one-third of the reservoir is moderately infested with aquatic vegetation, primarily parrotfeather (*Myriophyllum brasiliense).* The shoreline of Lake Seed also contains a high density of single family dwellings. The lake extends 2.8 km and has a maximum depth of 18 m. The lake is oligotrophic, but it does not stratify due its small volume and rapid exchange rate. The water column, therefore, remains relatively isothermal throughout the year.

Due to low natural productivity, Lake Seed supports a low fish biomass. The fish community is dominated by yellow perch, bluegill, largemouth bass, spotted bass, chain pickerel, and white catfish *(Ictalurus catus*). Blueback herring from Lake Burton successfully immigrated to Lake Seed during the study period and became well established. In contrast to Lake Burton, the principle fishery of Lake Seed is sunfish, of which bluegill is the dominant species. Yellow perch and largemouth bass also rank high in importance for Lake Seed anglers.

Methods

Walleye Stocking

Four to seven day-old walleye fry were obtained from the Ohio Department of Natural Resources and from the Pennsylvania Fish and Boat Commission in 1990 and 1991 for stocking into lakes Burton and Seed. Between 100,000 and 160,000 walleye fry were placed into plastic bags with approximately 4 liters (L) of water. Bags were injected with approximately 25 L of oxygen, sealed, and placed in styrofoam coolers with ice as needed to maintain water temperatures. Walleye fry were flown by state aircraft for approximately 5 hours to the nearest airport to Lake Burton. Fry boxes were then trucked approximately 1 hour to Lake Burton and Lake Seed for stocking. Upon arrival at the reservoir, fry boxes were loaded into boats and transported to open water sites at the lower, middle, and upper sections of the reservoir. At each stocking site, fry were tempered by adding 0.5 to 1.0 L of reservoir water to each bag every 2 to 5 minutes for 30 minutes. On Lake Seed in 1990, severe weather forced fisheries personnel to temper walleye fry for less than 10 minutes before releasing all fry at one open water site. Water chemistry, including temperature, dissolved oxygen, total hardness, and pH, was measured in each container and at each stocking site. In fry stocking activities from 1993 to 1995, water chemistry in the holding containers was measured every five minutes to monitor the rate of change and to assess the potential physiological effects of tempering. Walleye fry stocking rates were based only on the availability of fry from outside state agencies and ranged from 4,647 to 7,179 fry/ha.

From 1992 to 1995, walleye fingerlings were stocked into Lake Seed. Funds were provided by the Georgia Power Company to obtain fingerlings from a private walleye producer in Minnesota. Small fingerlings, averaging 50 mm TL, were stocked in 1992, and increasingly larger fingerlings, ranging from 125 to 179 mm TL, were stocked in subsequent years (Table 2). Fingerling walleye were transported from upstate Minnesota in hauling trucks outfitted with liquid oxygen at a loading density between 0.06 to 0.12 kg/L (0.5 to 1.0 lb/gal) for approximately 26 to 30 hours before reaching Lake Seed. Upon arrival, reservoir water was added to the hauling box using a small gasoline water pump at a near continuous basis for 60 to 75 minutes.

In 1993 and 1994, post-stocking mortality was estimated by holding 30 walleye in a 1.27m x 1m x 1m (1.27 m^3) cage covered with 23 mm^2 mesh netting for 10 and 13 days, respectively. Test fish experienced all the hauling, tempering, and handling stresses of other stocked walleye. To provide a food supply during captivity, small golden shiners (38 mm TL) were also stocked into the holding cage at the beginning of the evaluation

Table 2. Walleye stocking history of Lake Seed, Georgia.

Year	Fry	Fingerlings	Mean Total Length (mm)	Total	No./ha
1961	50,000		<25	50,000	515
1962	160,000		<25	160,000	1,649
1963	180,000		<25	180,000	1,856
Subtotal	*390,000*			*390,000*	*4,020*
1990	450,750		<25	450,750	4,647
1991	588,000		<25	588,000	6,062
1992		12,000	50	12,000	124
1993		11,000	125	11,000	113
1994		12,000	179	12,000	124
1995		6,373	173	6,373	66
Subtotal	*1,038,750*	*41,373*		*1,080,123*	*11,136*
Total	1,428,750	41,373		1,470,123	15,156

period. Walleye mortality and forage availability were monitored daily. Post-stocking mortality was expressed as the percent mortality in the sample.

In 1995, a multiple cage experiment was designed to measure post-stocking mortality of walleye fingerlings tempered for various lengths of time. Treatments consisted of three tempering intervals - 10 minutes, 30 minutes, and 60 minutes. Three equally sized holding cages (1.27 m^3) were each divided into three equally sized compartments for a total of nine compartments. As walleye were tempered, a random sample of 30 fish was collected at 10 minutes, 30 minutes, and 60 minutes. With the 30 fish sample from each treatment, ten fish were stocked into a randomly assigned compartment in each cage and held for seven days (Figure 2). Twenty-two small golden shiners were added to each compartment at the beginning of the holding period and were replenished as needed. Holding cages were submerged approximately 3 m below the surface within the protected and shaded enclosure of a boat house. Walleye mortality and forage availabilty were monitored daily during the captivity period. Mean mortality rates were calculated for each treatment, and treatments were compared statistically by one-way analysis of variance (ANOVA; Sokal and Rohlf 1981). Significance levels for all statistical analyses were set at $p = 0.05$.

Walleye Sampling

The relative abundance and age composition of walleye in lakes Burton and Seed were measured from spring electrofishing and fall gill netting samples. In addition, fall gill net sampling was conducted in Lake Rabun, which is immediately downstream of

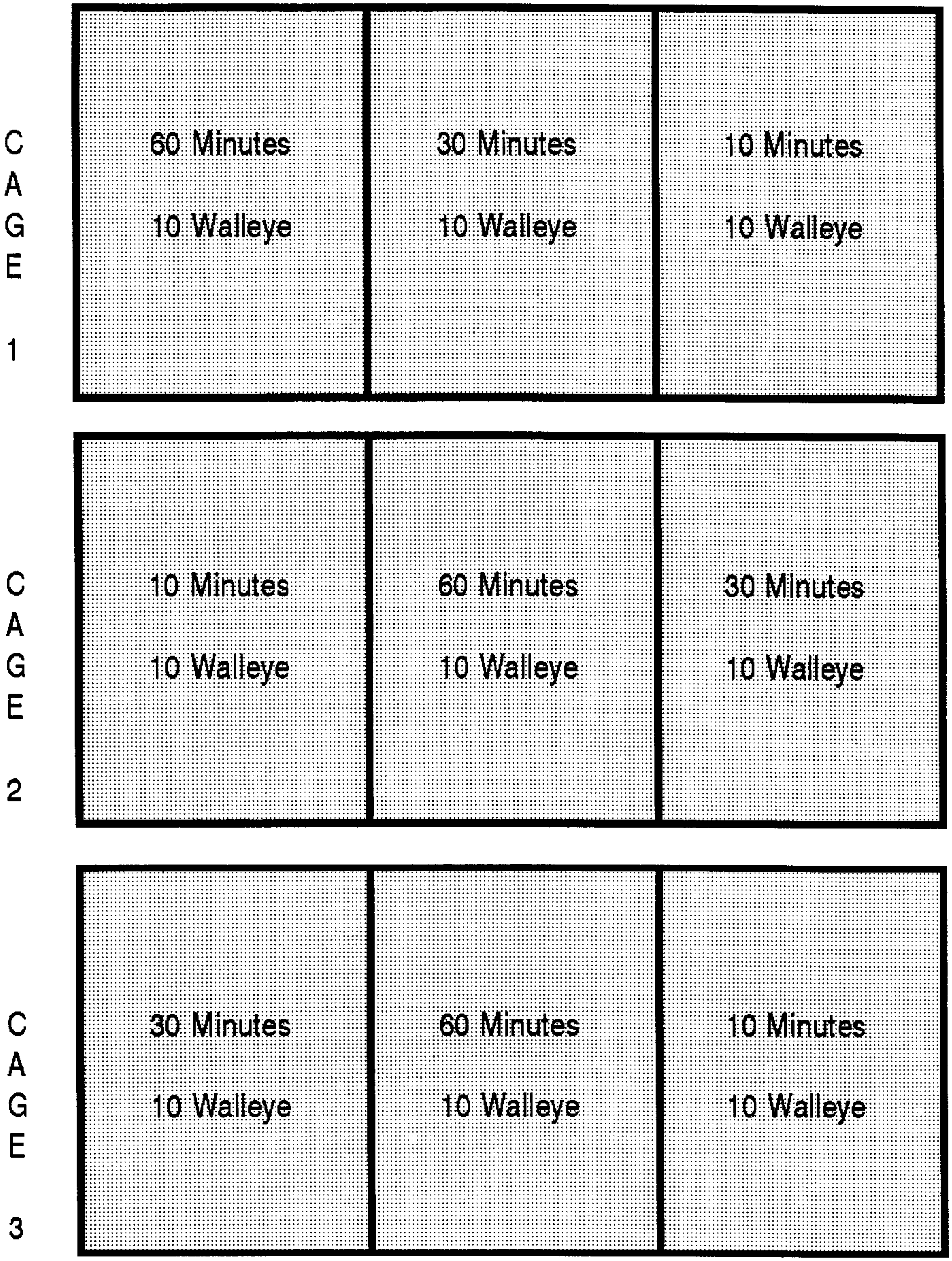

Figure 2. Experimental design for evaluating post-stocking mortality of walleye fingerlings in Lake Seed, Georgia using three different acclimation periods.

Lake Seed, to assess walleye displacement that occurred during the study. All walleye collected by both electrofishing and gill netting were individually weighed (g) and measured for total length (mm). A scale sample was collected from each walleye from an area below the lateral line and behind the pectoral fin. Age and growth determinations were made using the Fraser-Lee back-calculation method (Carlander 1981) and a correction factor of 25 mm (Priegel 1964).

Weekly electrofishing for walleye was conducted during March between 2000 and 2400 hours in the four major tributaries of Lake Burton (Figure 3) and in the headwaters of Lake Seed (Figure 4). Previous research identified the four major tributaries as the primary walleye spawning areas in Lake Burton (Rabern 1989), but no historical data relevant to walleye spawning areas were available for Lake Seed. During this study, electrofishing was conducted with a boat-mounted, Smith-Root Type V Electrofisher using pulsed DC operated at 1,000 volts and 3 amperes. Because of the large size of the Tallulah River, a two-pass sample was conducted at the headwaters of Lake Burton and Lake Seed, but only one pass was used to sample the three smaller tributaries of Lake Burton. Sampling effort was consistent for each station during the study period, but effort varied between stations due to differences in stream length. When boat access was not possible due to low lake levels, supplemental walleye counts were made at night using a 400,000 candle power spotlight. Walleye collected in electrofishing samples were fin-clipped at a unique location to identify the individual's home tributary. For example, all walleye collected in the Tallulah River were fin-clipped along the ventral lobe of the caudal fin. For each lake, the total number of captures and recaptures was recorded

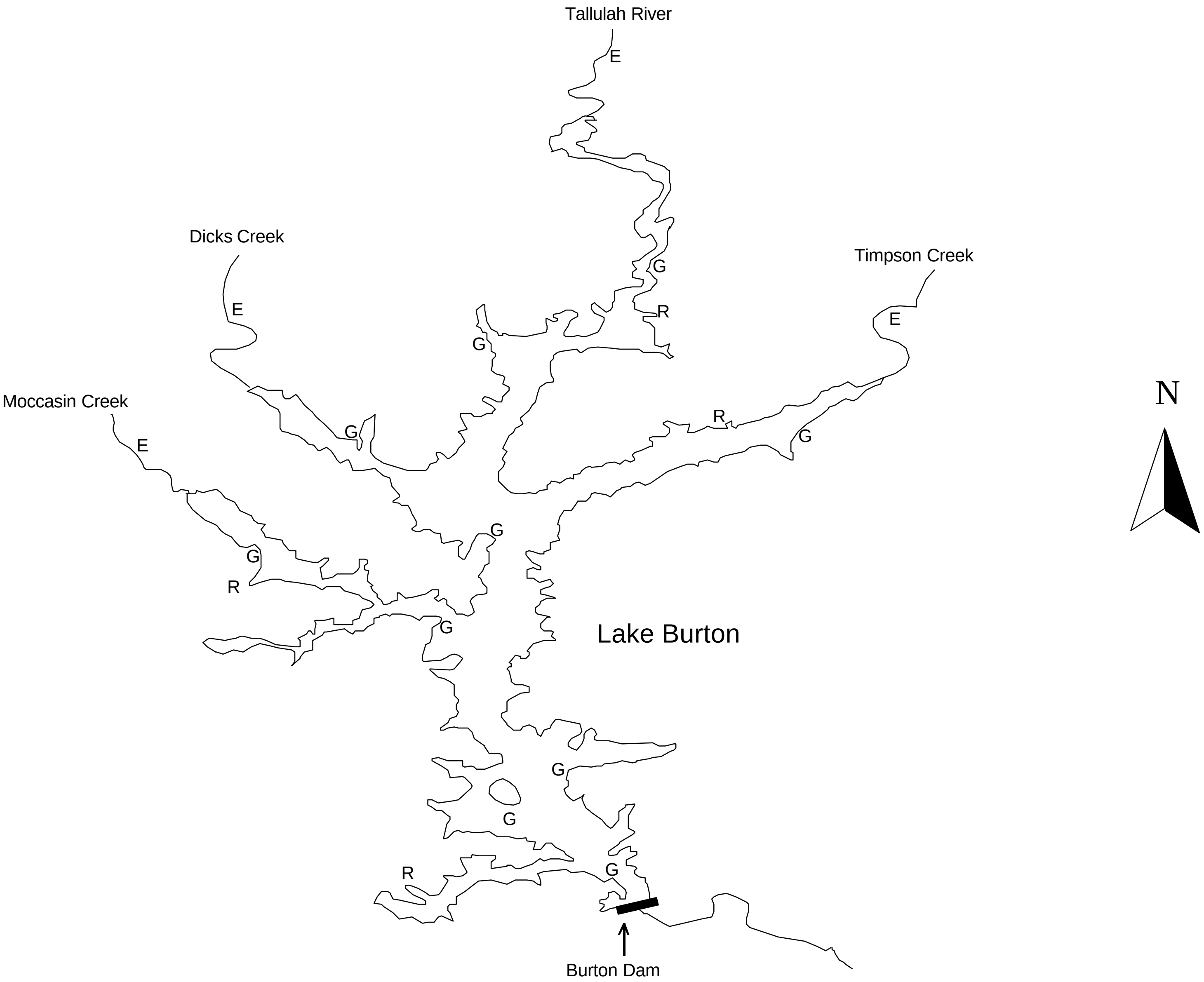

Figure 3. Electrofishing (E), gill netting (G), and cove rotenone (R) sampling stations on Lake Burton, Georgia.

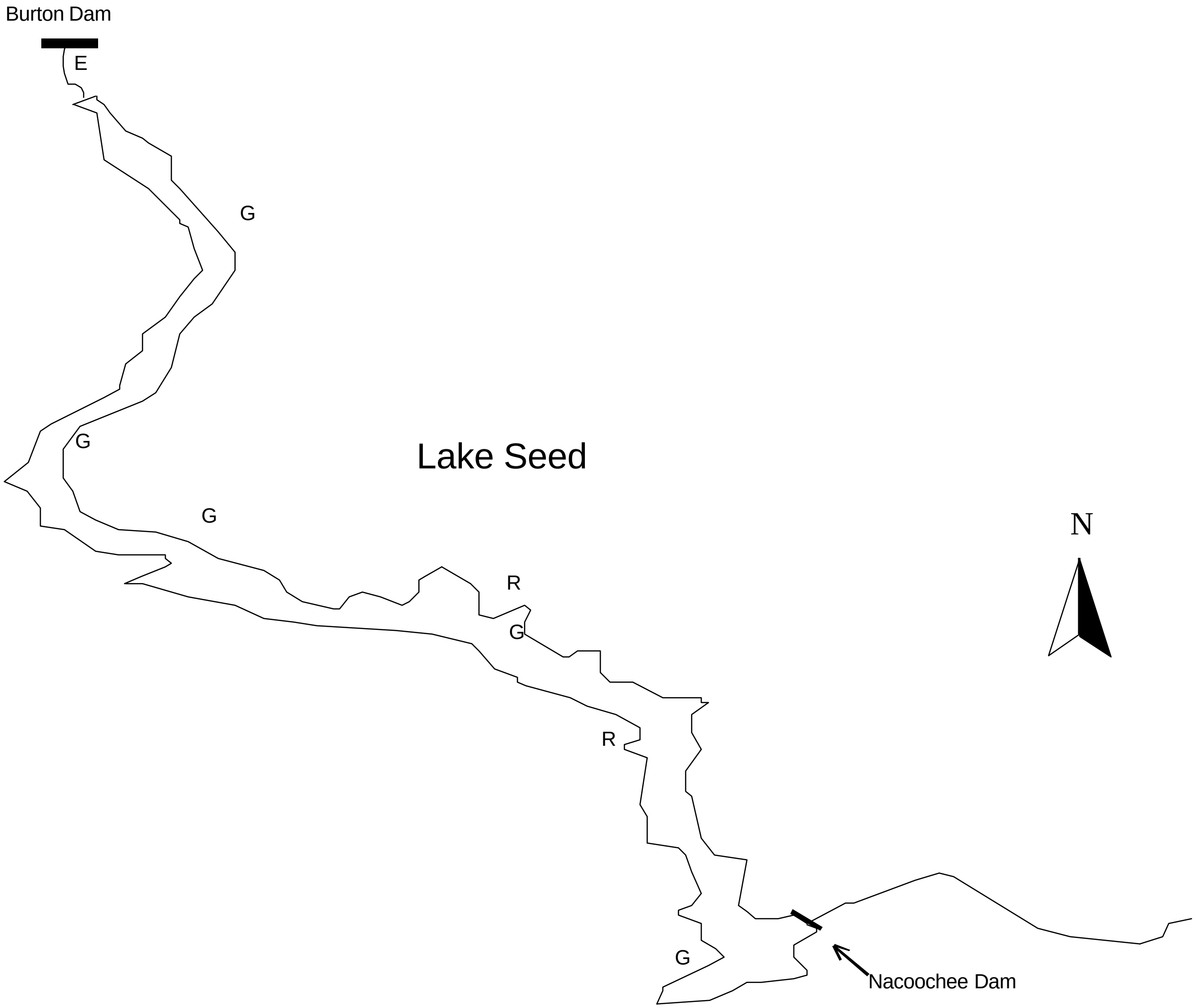

Figure 4. Electrofishing (E), gill netting (G), and cove rotenone (R) sampling stations on Lake Seed, Georgia.

during weekly sampling to derive a population estimate using the Schnabel multiple recapture method (Ricker 1975). In addition, the sex and state of sexual maturity (e.g. flowing or spent) of each walleye were noted. Total abundance was expressed as the number of walleye collected during March, excluding recaptures.

To explore potential spawning activity in other areas of Lake Seed, gill nets were set in the main body of the reservoir where gravel and/or rubble substrates existed. Experimental gill nets consisted of five 12.1 m long x 2.4 m deep panels with increasingly larger bar mesh sizes of 19 mm, 25 mm, 38 mm, 51 mm, and 64 mm, respectively. Nets were set perpendicular to the shoreline at dusk and retrieved the following morning. Each net set constituted one net-night of effort. Walleye abundance from gill net sampling was expressed as the total number of walleye collected during March.

To assess survival of stocked walleye and to provide an estimate of walleye abundance for each lake, gill nets were set annually during November and December from 1989 to 1996 at randomly selected stations (Figures 3 and 4). Experimental gill nets used in fall sampling were the same as those used in spring sampling on Lake Seed. Catch data from November and December samples were pooled, and total abundance from gill net sampling was expressed as the number of walleye collected per net-night of effort. Because negligible natural reproduction and recruitment occurred in Lake Burton (unpublished data), all walleye collected from the 1990 and 1991 year-classes were assumed to originate from stocking. Walleye reproduction was not known to occur in Lake Seed; therefore, all walleye collected from the 1990 to 1995 year-classes were also assumed to originate from stocking.

Food habit information was obtained from walleye by excising stomach contents with appropriately sized PVC tubes and identifying the contents to the lowest possible taxon. The frequency of occurrence of identifiable food items was quantified to document forage utilization.

Yellow Perch and Other Forage Collections

To document shifts in species composition, total fish biomass, and density in lakes Burton and Seed, as well as to document changes in the population dynamics of yellow perch which may have occurred as a result of walleye stocking, cove rotenone sampling was conducted in selected years before and after walleye introductions (Figures 3 and 4). On Lake Burton, three coves measuring 0.51, 0.53, and 1.12 ha were sampled during late August in 1991, 1993, and 1994 and compared to pre-stocking data collected from these same coves during late August in 1987 and 1988. On Lake Seed, two coves measuring 0.57 and 0.65 ha were sampled during early September in 1989 and annually during early September from 1991 to 1995. Between the times of 2100 hours and 0600 hours prior to sampling, a 4.8 mm bar mesh block net was stretched across the mouth of the study cove to prevent fish migration to and from the study area. A pre-determined quantity of 5% emulsifiable rotenone was dispensed from a diluting tank through a weighted, perforated hose to achieve a concentration of 1 mg/L in the water column.

Dead fish were collected for two days and sorted by species into 20 mm size groups. The number of fish in each group was counted and bulk weighed (kg). Weights of fish collected on the second day were calculated from the average of the first day weight for fish in the same size group. If a first day weight was not available for a species size group, then the second day weight was measured and recorded. Data were summarized by cove, as described by Surber (1959), into fingerling, intermediate, and harvestable size groups for each species. Total biomass (kg/ha) and density (fish/ha) estimates were calculated as the unweighted mean from all cove samples for each lake.

Scale samples were collected from 20 yellow perch per 20 mm size group in all sample years on both reservoirs. An age-at-length key was derived for each sample year to determine the age distribution. Catch curve analysis was used to estimate the annual survival rate of yellow perch (Robson and Chapman 1961). In addition to age frequency analysis, total biomass and density of yellow perch were statistically compared for significant differences over time and were also tested for linear relationships with walleye catch data.

Creel Surveys

A four month creel survey was designed to measure sport fishing effort and harvest during the peak spring fishing season in years prior to and following walleye stocking. Non-uniform probability, roving, daytime creel surveys were conducted from mid-February to June in 1989 and 1993 on Lake Burton and in 1990, 1994, and 1996 on Lake Seed. Sampling periods were divided into eight, two-week intervals. Each 14-day period included six randomly selected weekdays, four weekend days, and four off days. Morning or evening periods were randomly selected based on assigned probabilities of expected fishing pressure patterns. In general, evening periods were assigned a higher probability than morning periods. For data expansion purposes, an instantaneous count of anglers was made daily at a randomly selected time. Creel survey data included the number and weight of each species harvested, the number and species of fish released, the hours fished, the species sought, and the fishing method. All *Lepomis* sunfish, crappie (*Pomoxis* spp.), and catfish (*Ictalurus* spp.) were grouped into separate categories. Individual lengths and weights of walleye and black bass were recorded, except for the 1994 survey of Lake Seed. Estimates of total harvest, effort, and success were calculated using an in-house creel expansion program. Sample means were tested for significant differences between years.

Results

Walleye Stocking Success in Lake Burton

Abundance

A total of 1,450 walleye was collected from Lake Burton during the eight-year sampling period (1989 to 1996). Of the total sample, 1,255 walleye (86.6%) were collected by spring electrofishing during the annual spawning migration into tributary streams, 181 walleye (12.5%) were collected by fall gill netting, 14 (0.9%) walleye were documented in creel surveys, and no walleye were collected in summer cove rotenone studies. The mean catch of adult walleye for March collected by electrofishing during the spring migration was 179 fish (SE = 18.1 fish). Annual walleye samples from March electrofishing peaked in 1987 (412 fish) and again in 1994 (250 fish), but declined to its lowest level the following year (105 fish; Figure 5). Results from March electrofishing

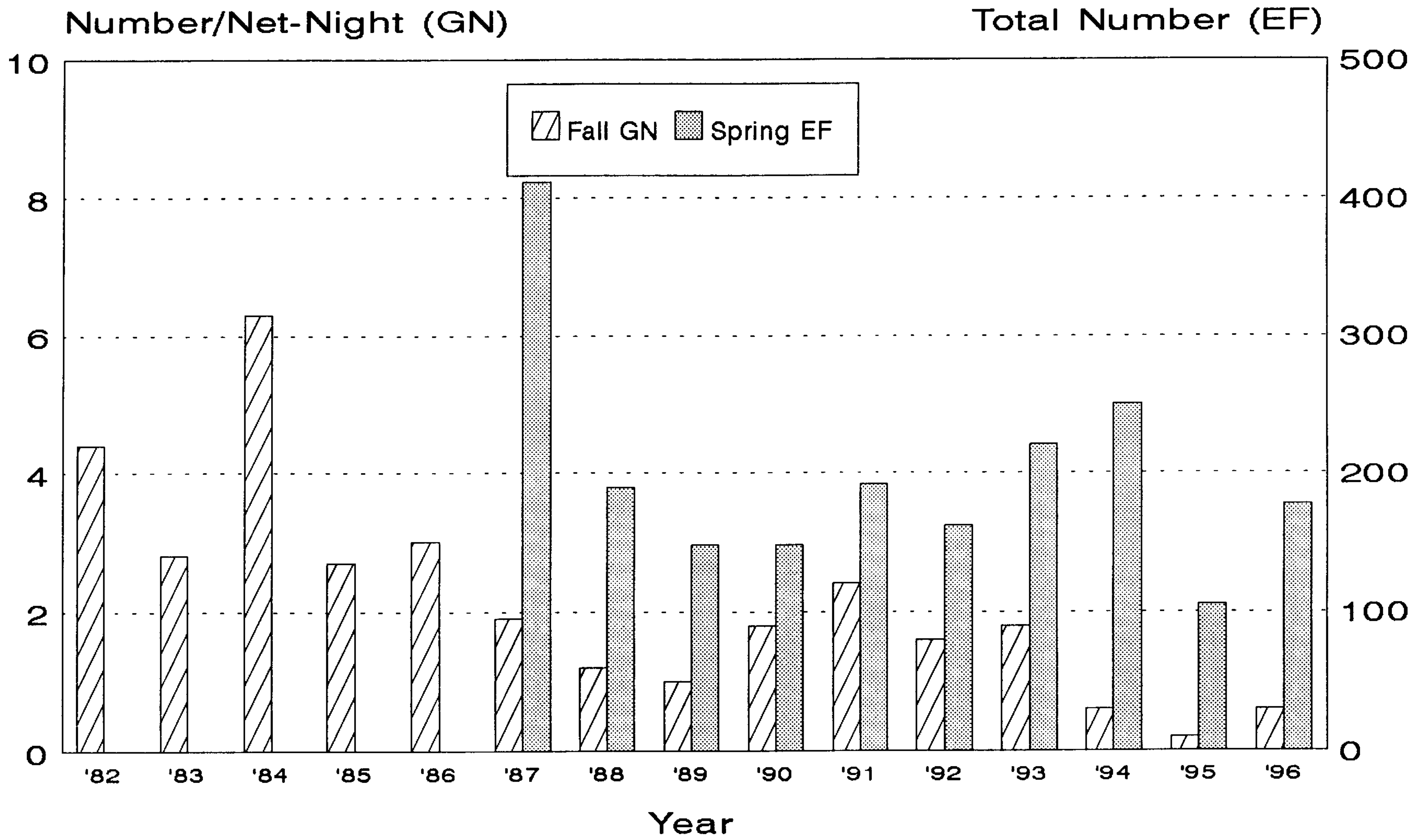

Figure 5. Walleye catch data from Lake Burton, Georgia collected by fall gill netting (GN) from 1982 to 1996 and spring electrofishing (EF) from 1987 to 1996.

indicated a significant linear increase in walleye abundance from 1990 to 1994 ($r = 0.88$; $p = 0.0489$) followed by a a sharp, but statistically insignificant decline from 1994 to 1996 ($r = -0.50$; $p = 0.66$).

Because of the tendency of male walleye to loiter in the spawning grounds throughout the spawning period and the tendency of females to briefly visit the spawning grounds just once in order to disperse eggs, 90.4% (SE = 2.7%) of the total collection was male fish. As a result, only males were recaptured during the study period. Schnabel population estimates of male walleye from multiple mark-recapture samples indicated an overall decline in the broodstock population from 1991 to 1996 (Figure 6). One-way ANOVA indicated a significant difference in the male walleye population size among years ($p < 0.01$). Results from a Tukey's Multiple Range test revealed that population size was significantly lower in 1995 and 1996 compared to 1990 to 1994 ($p < 0.05$).

Gill net catches reflected a similar pattern of abundance as the spring electrofishing data in years following walleye stocking, with the exception of 1994 (Figure 5). An unpaired t-test of log (X)-transformed gill net catch data indicated a significant difference between pre- and post-stocking walleye density ($p = 0.03$). The post-stocking density (1.3 walleye/net-night) was less than one half of the pre-stocking density (2.9 walleye/net-night). Post-stocking biomass (2.1 kg/net-night) was also lower than the pre-stocking biomass (3.4 kg/net-night); however, the difference was not statistically significant ($p = 0.14$). Linear regression analysis of total walleye density versus time indicated a low negative correlation coefficient ($r = -0.21$, $p = 0.08$).

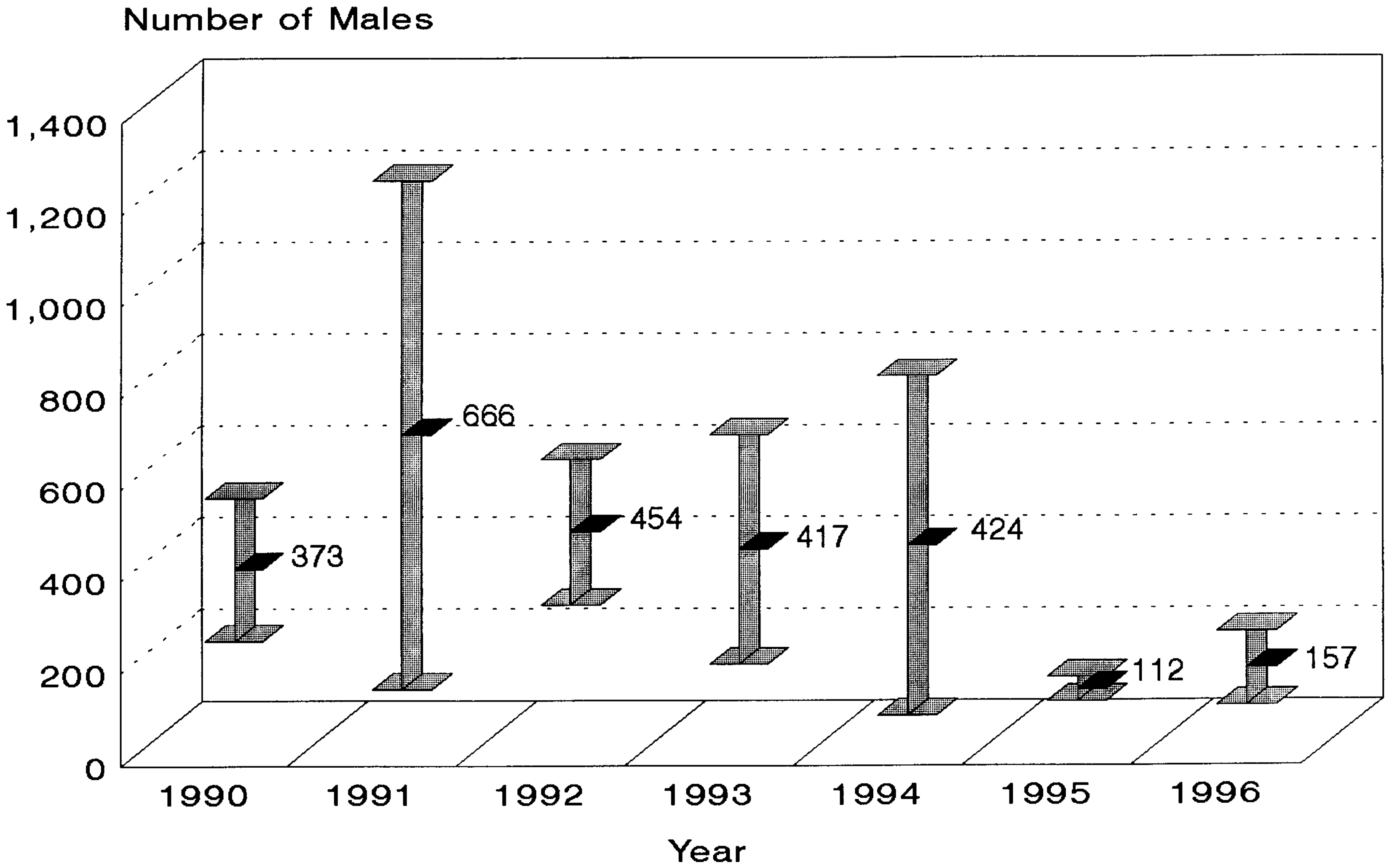

Figure 6. Schnabel population estimates and 95% confidence intervals for male walleye from Lake Burton, Georgia collected by electrofishing during March spawning migrations up tributary streams from 1990 to 1996.

Age Structure

Age and growth data for Lake Burton walleye are presented in Table 3. The age structure of adult walleye in annual spring electrofishing samples demonstrated a normal distribution pattern. Although there was considerable variation from year to year, the average age of the population increased from 1990 to 1996 (Table 4). These findings were a result of strong year-classes produced in 1985 and 1988, which dominated the population through 1994. The 1990 year-class, which was assumed to originate from fry stocking, provided minor contributions to the annual catch in 1993 (1.3%) and 1994 (2.0%), but provided significant proportional contributions in 1995 (24.5%) and 1996 (34.7%) (Figure 7).

The 1990 and 1991 year-classes in Lake Burton, which were stocked as fry, were represented in low numbers in both electrofishing and gill netting samples. Similar to spring electrofishing data, fall gill net samples also demonstrated a progressively aging walleye population (Table 5). From 1989 to 1993 the mean age of the population was age 5, but increased sharply from 1994 to 1996 as the dominant year-classes moved out of the population. Based on results of fall gill netting, the 1990 year-class provided minor contributions to the declining annual catch in 1991 (2.0%), 1993 (10.5%), and 1994 (9.1%) (Figure 7). These percentages, however, converted to only one fish in 1991 and four fish in 1993. The 1991 year-class was also represented by only one fish in 1992 and 1996.

Table 3. Pooled mean back-calculated length (mm) at annulus of walleye collected in Lake Burton, Georgia from 1987 to 1996. Standard errors are listed in parentheses.

		Age Group							
Year-Class	N	I	II	III	IV	V	VI	VII	VIII
1982	1	228	334	415	478	530	567	596	628
1983	3	247 (27.7)	359 (66.6)	414 (63.7)	471 (56.0)	515 (48.5)	547 (49.0)	574 (51.1)	
1984	6	241 (23.7)	372 (33.3)	441 (24.9)	481 (25.1)	507 (29.0)	530 (30.2)	544 (42.4)	560 (45.3)
1985	11	248 (31.3)	382 (41.1)	457 (48.0)	488 (50.7)	512 (53.3)	554 (42.7)	588 (58.4)	616 (75.2)
1986	12	239 (40.8)	373 (42.9)	445 (47.8)	487 (55.4)	538 (39.1)	556 (41.7)	578 (46.8)	610 (46.0)
1987	18	265 (41.6)	402 (59.6)	467 (56.8)	513 (42.5)	534 (42.9)	559 (42.1)	579 (46.6)	587 (55.0)
1988	12	261 (18.1)	420 (27.9)	473 (28.2)	503 (34.4)	527 (34.4)	547 (38.9)	562 (46.6)	574 (50.2)
1989	10	255 (20.0)	406 (25.9)	459 (21.1)	481 (21.0)	493 (19.3)	501 (18.4)	520 (2.1)	
1990	7	264 (37.6)	404 (30.8)	457 (9.6)	483 (3.8)	496 (5.0)	505		
1991	5	273 (19.0)	410 (12.6)	464 (19.7)	485 (24.9)	506 (33.9)			
1992	2	282 (7.1)	406 (11.3)	443 (21.9)	483				
1993	1	254	380						
Mean Total Length (Std. Error)	88	255 (4.4)	387 (7.2)	449 (5.9)	487 (3.5)	516 (5.0)	541 (7.9)	568 (8.8)	596 (10.8)

Table 4. Age distribution, mean age, and mean length (mm) of walleye collected by electrofishing during March spawning migrations up tributary streams of Lake Burton, Georgia from 1990 to 1996.

		% of Total by Age Class								
Year	N	II	III	IV	V	VI	VII	VIII+	Mean Age	Mean Length (mm)
1990	116		7.8	25.0	56.9	8.6	1.7		4.7	485
1991	165			0.6	11.5	41.8	29.7	16.4	6.5	493
1992	141		1.4	41.1	34.0	15.6	6.4	1.5	4.9	505
1993	231		1.3	10.4	38.5	32.5	12.1	5.2	5.6	507
1994	250		0.8	2.0	24.0	37.6	30.0	5.6	6.1	509
1995	49	2.0	4.1	8.2	24.5	36.7	16.3	8.2	5.7	518
1996	75			4.0	16.0	34.7	33.3	12.0	6.3	523

Table 5. Age distribution, mean age, and mean length (mm) of walleye collected by fall gill netting on Lake Burton, Georgia from 1989 to 1996.

		% of Total by Age Class									
Year	N	I	II	III	IV	V	VI	VII	VIII+	Mean Age	Mean Length (mm)
1989	14		7.1	14.3	21.4	21.4	14.3	21.4		4.9	560
1990	31				71.0	19.4	9.6			5.1	489
1991	49	2.0		8.2	24.5	30.6	20.4	14.3		5.0	536
1992	30	3.3			23.3	36.7	16.7	20.0		5.2	525
1993	38			10.5	23.7	42.1	15.8	5.3	2.6	4.9	521
1994	11				9.1	36.4	27.3	27.3		5.7	538
1995	5						20.0	20.0	60.0	7.4	550
1996	11					9.1		45.5	45.5	7.3	565

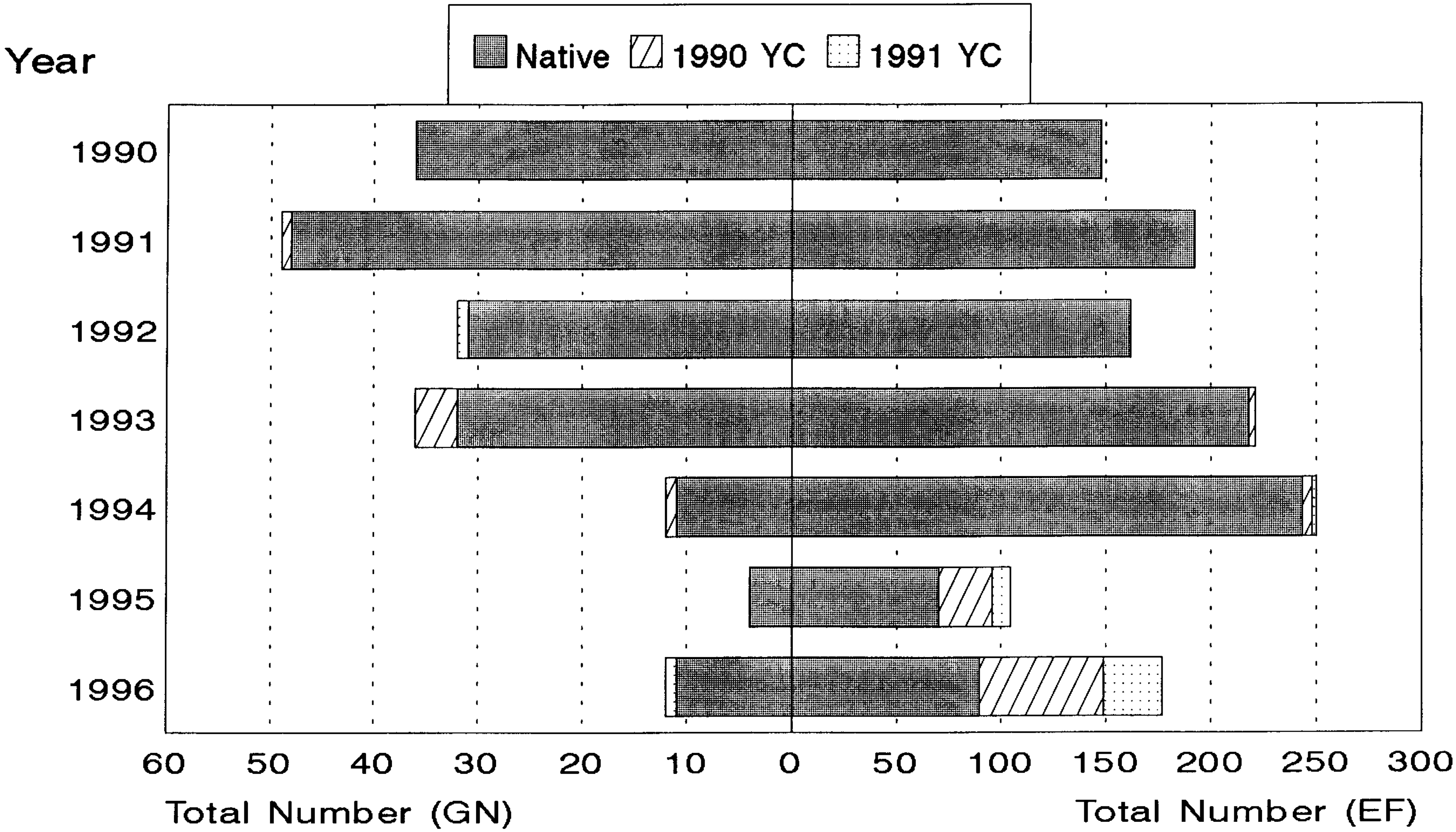

Figure 7. Relative abundance of native and stocked walleye year-classes (YC) in fall gill netting (GN) and spring electrofishing (EF) samples from 1990 to 1996 in Lake Burton, Georgia.

Food Habits

Yellow perch was the dominant prey of walleye for most of the study period. In 1990, approximately 40,000 threadfin shad (*Dorosoma petenense*) were stocked into Lake Burton and an additional 20,000 were stocked in 1991. As a result of these stockings, a strong threadfin shad population was established. By 1993, the food habits of several pelagic predators, including walleye, shifted to threadfin shad. In fall gill net samples for 1993, all food items in walleye stomachs were threadfin shad. After a moderate winter kill in 1993, the frequency of threadfin shad in walleye stomachs declined to 50% in the 1994 gill net sample. After a total winter kill of threadfin shad in 1994, walleye reverted back to a diet of predominantly yellow perch supplemented with crayfish.

Walleye Stocking Success in Lake Seed

Abundance

A total of 139 walleye was collected during the study period. Of the total, 79 (56.8%) were collected in fall gill nets, 54 (38.8%) were collected by spring electrofishing and gill netting, three (2.2%) were documented in creel surveys, and three (2.2%) were collected in summer cove rotenone studies. An additional 16 walleye were collected in supplemental gill net sampling during November 1997. In spring samples, catches of adult fish were low when compared to Lake Burton during the same period. Because of low sample sizes and lack of recaptures, no population estimates were calculated from March electrofishing data.

Walleye abundance estimates based on fall gill netting indicated widely fluctuating population densities from year to year and a relatively low population density throughout the study period (Figure 8). One-way ANOVA of log (X+1)-transformed catch data from fall gill netting detected no significant differences in walleye density ($p = 0.06$) and biomass ($p = 0.64$) among years. Mean walleye density in 1989, prior to stocking, was 0.8 fish/net- night, whereas the mean post-stocking density from 1990 to 1996 was only 1.1 fish/net-night. Supplemental gill net sampling in 1997, however, yielded a catch rate of 4.0 walleye/net-night.

Age and Size Distribution

With the influx of young walleye into the existing low-density, older age population, the length frequency distributions from spring and fall samples demonstrated a gradual shift over time toward smaller fish (Tables 6 and 7). The mean length of the fall population declined from 542 mm prior to stocking to 411 mm in 1993 and 471 mm in 1996.

Despite small sample sizes, age analysis indicated survival from all year-classes of stocked walleye. All introduced year-classes were collected in gill nets within two years of stocking, and the 1992 and 1994 year-classes were represented in all samples that followed stocking. The age distribution of the spawning stock was not impacted by walleye introductions until 1994, when fry stocked in 1991 were first detected in spring samples (Table 8). In 1995, sexually mature males were collected at age 2, and some spawning of age 2 females was also detected. In 1995, age 2 fish from the 1993 fingerling stocking accounted for 43.5% of the sample. It appeared, however, that males were fully

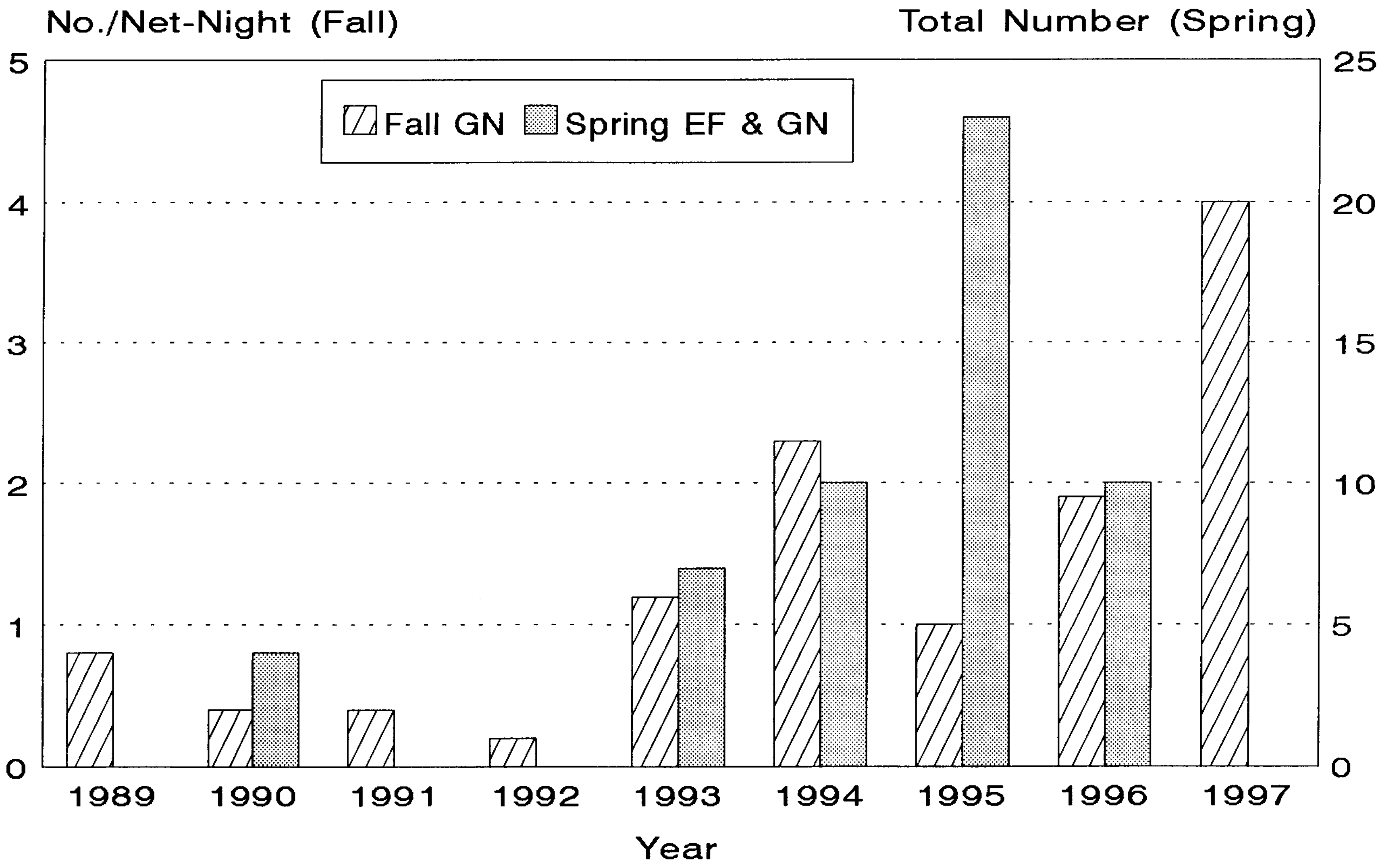

Figure 8. Walleye catch data from Lake Seed, Georgia collected by fall gill netting (GN) from 1989 to 1997 and spring electrofishing (EF) and gill netting from 1989 to 1996.

Table 6. Length frequency distribution of walleye collected in gill nets during November and December on Lake Seed from 1989 to 1996.

	% of Total							
Length Group (cm)	1989	1990	1991	1992	1993	1994	1995	1996
< 16								
18						13.0		
20						8.7		
22								
24								
26								15.8
28						4.4	10.0	
30		33.3						5.3
32								
34					25.0			
36					33.3			
38					8.3			
40		33.3						
42						4.4		5.3
44						8.7		5.3
46						17.4	10.0	5.3
48		33.3	25.0			4.4		
50					16.7	17.4	10.0	5.3
52	40.0			50.0		4.4	20.0	21.0
54	20.0		25.0		8.3	13.0	10.0	15.8
56	20.0						10.0	5.3
58			25.0		8.3		20.0	
60	20.0							5.3
62			25.0				10.0	5.3
64						4.4		5.3
66				50.0				
Mean Total Length (mm)	542	571	548	586	411	418	516	471
(Standard Error)	(14.3)	(18.0)	(30.8)	(69.0)	(25.6)	(29.0)	(30.6)	(28.0)

Table 7. Length frequency distribution of walleye collected by electrofishing and gill netting during the March spawning period on Lake Seed from 1990 to 1996.

	% of Total						
Length Group (cm)	1990	1991	1992	1993	1994	1995	1996
< 38							
40						4.8	
42							
44						14.3	50.0
46						4.8	
48						4.8	
50					20.0	19.0	
52				14.3	20.0	14.3	
54				57.1	30.0	14.3	
56	25.0					9.5	
58	25.0			14.3			50.0
60	25.0						
62					10.0	4.8	
64					20.0		
66	25.0			14.3		4.8	
68							
70						4.8	
Mean Total Length (mm)	605			556	545	518	512
(Standard Error)	(19.4)			(20.3)	(23.6)	(15.7)	(68.0)

Table 8. Age distribution of walleye collected by electrofishing and gill netting in March on Lake Seed, Georgia from 1990 to 1996.

		% of Total by Age Class								
Year	N	I	II	III	IV	V	VI	VII	VIII+	Mean Age
1990	4					25.0	50.0	25.0		6.0
1991[a]										
1992[a]										
1993	7					33.3	50.0	16.7		5.8
1994	10			25.0	25.0	25.0	12.5	12.5		4.6
1995	23		43.5	21.7	21.7	13.1				3.0
1996	10			50.0		50.0				4.0

[a] No walleye were collected.

recruited to the spawning stock at age 3 and females at age 4. The mean age of the spawning stock prior to stocking was 5.9 years, but declined to a mean of 3.9 years after recruitment of stocked walleye to the broodfish population.

Based on walleye scale samples from Lake Seed, all stocked year-classes were also represented in fall gill net samples (Table 9). Mean age of the fall walleye population prior to the establishment of stocked walleye was 5.1 years, but declined to an average age of 2.6 years from 1993 to 1997. The 1992 year-class accounted for the majority of all stocked walleye collected in fall gill nets from 1993 to 1996 (Figure 9). The 1990 fry stocking contributed the least to fall gill net samples. Contributions of various stocked year-classes remained similar, even when walleye collected from Lake Rabun (where they were displaced by flood events in 1994 and 1995) were considered in the analysis.

Table 9. Age distribution of walleye collected by fall gill netting on Lake Seed, Georgia from 1989 to 1997.

Year	N	% of Total by Age Class									Mean Age
		0	I	II	III	IV	V	VI	VII	VIII+	
1989	5				20.0	60.0	20.0				4.0
1990	4						25.0	50.0		25.0	6.5
1991	4				25.0		25.0	25.0	25.0		5.2
1992	2			50.0						50.0	5.0
1993	12		58.3	25.0		8.3		8.4			1.9
1994	23	21.6	4.4	65.2			4.4			4.4	2.0
1995	10			10.0	10.0	70.0	10.0				3.8
1996	19			21.0	21.0	42.1	15.9				3.5
1997	16		37.5	37.5	12.5	12.5					2.0

Growth

One-way ANOVA indicated that the mean back-calculated length of walleye at ages 1 and 2 was significantly different among year-classes ($p < 0.01$; Table 10), but length differences in older age classes were not significant ($p > 0.05$), primarily due to the wide size variation. First year growth of native fish (1996 and pre-1990 year-classes) and 1990 fry averaged 240 mm, whereas subsequent fry and fingerling stockings averaged 167 mm after their first growing season. A two-tailed t-test indicated that the difference between these two means was significant ($p < 0.01$). Tukey’s Multiple Range test further indicated that the 1990 year-class (fry) experienced significantly faster growth through age 2 ($p < 0.05$) than all subsequent stocked year-classes. Fry stocked during the first year of

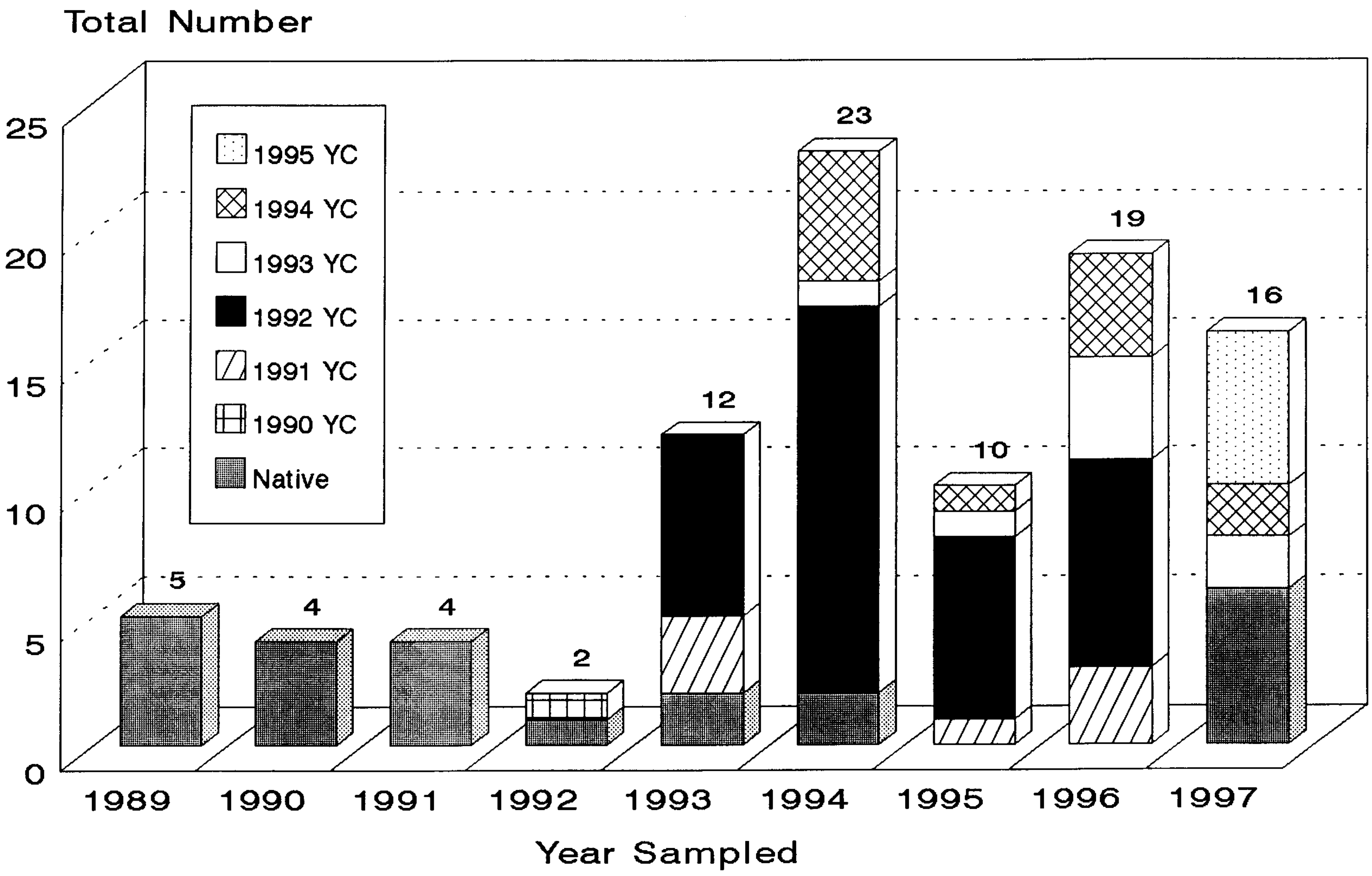

Figure 9. Relative abundance of native and stocked walleye year-classes (YC) in fall gill net samples from 1989 to 1997 in Lake Seed, Georgia.

Table 10. Pooled mean back-calculated length at annulus (mm) of walleye collected in Lake Seed, Georgia from 1989 to 1996. Standard errors are listed in parentheses.

		Age Group				
Year-Class	(stock size)	I	II	III	IV	V
Pre-1990	(native)	250* (11.5)	403* (10.9)	473 (9.0)	512 (7.9)	543* (6.0)
1990	(fry)	271* (6.0)	422* (10.8)	515 (30.0)	581 (20.2)	634 (36.0)
1991	(fry)	177 (21.1)	368 (20.9)	508 (16.7)	554 (15.1)	601 (5.4)
1992	(50mm)	135* (5.4)	330 (10.7)	456 (16.2)	510 (17.2)	
1993	(125mm)	151* (11.1)	319 (8.3)	453 (13.5)	520 (31.3)	
1994	(179mm)	174 (22.5)	270 (4.0)			
1995	(173mm)	196 (12.2)	323 (34.9)			
1996	(native)	230 (7.0)				
Mean Total Length (Std. Error)		198 (17.0)	348 (20.0)	481 (13.0)	535 (13.9)	593 (26.6)

* Significantly different ($p < 0.05$) from the mean total length.

the study achieved a mean total length of 271 mm during their first growing season. Subsequent year-classes never achieved this accelerated growth rate. The 1992 year-class, which was stocked as 50 mm fingerlings in July, grew an additional 85 mm during their first growing season. Subsequent year-classes, which were stocked as advanced fingerlings in late October or early November, failed to add additional growth in the first growing season after stocking. Stocked fingerlings never achieved the mean length at annulus of fry in any year during the study period. In some cases, mean length of adults stocked as fingerlings was at least one growing season behind that of adults stocked as fry.

Food Habits

Dietary shifts were documented during the study period, which reflected changes in the species composition of the forage community over time. Initially, yellow perch was the dominant food item in walleye stomachs, based on fall gill net samples. As blueback herring emigrated from Lake Burton into Lake Seed in 1994 and experienced rapid population expansion in subsequent years, they became the dominant food item for walleye. In supplemental gill net sampling in 1997, only 10% of the walleye stomachs contained yellow perch whereas 90% contained young-of-year blueback herring.

Creel Survey Results from Lake Burton

Based on expanded creel estimates, 10,561 fish were harvested during spring 1989 and 10,043 during spring 1993 (Table 11). Black bass dominated the spring fishery in both 1989 and 1993, accounting for an average of 80.8% of the total effort (Table 12), 41.8% of the total number harvested, and 65.8% of the total weight harvested (Table 11). Sunfish, primarily bluegill, ranked second in importance and were followed by black crappie, yellow perch, and catfish (white catfish, channel catfish, and brown bullhead). The length frequencies of largemouth bass and spotted bass from the two creel surveys were normally distributed around quality-size fish (Tables 13 and 14), based on the Gablehouse classification system (Gablehouse 1984).

Table 11. Daytime sport fish harvest statistics from February 15 to June 6, 1989 and 1993 on Lake Burton, Georgia.

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	Numbers Harvested (% of Total)				Weight (kg) Harvested (% of Total)				Mean Weight (kg)	
Species	1989		1993		1989		1993		1989	1993
Black Bass[a]	3,981	(37.7)	4,623	(46.0)	2,505	(59.1)	2,719	(72.6)	0.63	0.59
Walleye	63	(0.7)	0		42	(1.0)	0		0.67	0.00
Crappie	1,598	(15.1)	1,751	(17.4)	477	(11.2)	458	(12.2)	0.30	0.26
Sunfish[b]	3,399	(32.2)	2,746	(27.3)	708	(16.7)	400	(10.7)	0.21	0.15
Yellow Perch	976	(9.2)	726	(7.2)	207	(4.9)	72	(1.9)	0.21	0.10
Catfish[c]	183	(1.7)	41	(0.5)	124	(2.9)	21	(0.6)	0.68	0.51
Other [d]	361	(3.4)	156	(1.6)	179	(4.2)	73	(2.0)	0.50	0.47
Total	10,561		10,043		4,242		3,743		0.40	0.37
(Standard Error)	(2,074)		(1,482)		(761)		(696)			

[a] Includes largemouth and spotted bass.

[b] Includes bluegill, redear sunfish, and redbreast sunfish.

[c] Includes white catfish, channel catfish, and brown bullhead.

[d] “Other” includes chain pickerel, white bass, and rainbow trout.

Table 12. Daytime harvest rate (fish/hr), catch rate (fish/hr), and directed effort (hr) by anglers on Lake Burton, Georgia from February 15 to June 6, 1989 and 1993.

	Harvest Rate		Catch Rate		Directed Effort (% of Total)			
Species	1989	1993	1989	1993	1989		1993	
Black Bass [a]	0.178	0.226	0.297	0.370	11,539	(85.1)	15,451	(76.4)
Walleye [b]	0.003	0.000	0.004	0.000	53	(0.4)	0	
Crappie	0.071	0.086	0.073	0.094	797	(5.9)	1,580	(7.8)
Sunfish [c]	0.152	0.135	0.179	0.206	760	(5.6)	2,136	(10.6)
Yellow Perch	0.044	0.036	0.056	0.062	46	(0.3)	449	(2.2)
Catfish [d]	0.008	0.002	0.013	0.002	164	(1.2)	172	(0.8)
Other [e]	0.016	0.008	0.027	0.020	203	(1.5)	440	(2.2)
Total	0.471	0.492	0.649	0.754	13,562		20,229	
(Standard Error)	(0.055)	(0.070)	(0.060)	(0.093)	(2,705)		(2,622)	

[a] Includes largemouth and spotted bass.
[b] Fourteen walleye were documented during the 1989 survey period and no walleye were seen in the 1993 survey.
[c] Includes bluegill, redear sunfish, and redbreast sunfish.
[d] Includes white catfish, channel catfish, and brown bullhead.
[e] "Other" includes chain pickerel, white bass, and rainbow trout.

Table 13. Gablehouse (1984) length frequency classification of largemouth bass from creel surveys on Lake Burton, Georgia in 1989 and 1993.

		Total Number		% of Total	
Category	Size Range (mm)	1989	1993	1989	1993
Pre-Stock	< 189	0	0	0.0	0.0
Stock	190 - 309	52	12	23.2	12.5
Quality	310 - 369	95	43	42.3	44.7
Preferred	370 - 509	66	33	29.3	34.5
Memorable	510 - 629	10	7	4.7	7.3
Trophy	> 630	1	1	0.5	1.0
Total		224	96	100.0	100.0

Table 14. Gablehouse (1984) length frequency classification of spotted bass from creel surveys on Lake Burton, Georgia in 1989 and 1993.

		Total Number		% of Total	
Category	Size Range (mm)	1989	1993	1989	1993
Pre-Stock	< 169	0	0	0.0	0.0
Stock	170 - 269	39	21	8.7	6.0
Quality	270 - 349	236	202	53.1	57.6
Preferred	350 - 429	123	99	27.7	28.4
Memorable	430 - 509	45	28	10.1	8.0
Trophy	> 510	2	0	0.4	0.0
Total		445	350	100.0	100.0

Pre-stocking creel results in 1989 estimated the walleye harvest at 0.003 fish/hour, and total directed effort for walleye was only 53 hours during the four month period (Table 12). In 1989, only fourteen walleye were directly observed in the Lake Burton creel survey, which resulted in an expanded estimate of 63 fish. By 1993, however, the walleye fishery and incidental catch were non-existant.

Creel Survey Results from Lake Seed

From the creel data collected on Lake Seed, the estimated total harvest during spring was 7,631 fish in 1990, 7,185 fish in 1994, and 4,565 fish in 1996 (Table 15). Anglers on Lake Seed primarily targeted black bass, which accounted for 44.3% of the mean total effort (Table 16). Harvest of black bass, however, was relatively low and only accounted for an average of 3.5% of the total harvested weight. The low harvest rate was not associated with an unacceptable size distribution but was strongly related to low catch rates, which averaged 0.10 fish/hr during the four month period. The length frequencies of largemouth bass and spotted bass from creel surveys were normally distributed around Quality and Preferred size groups (Tables 17 and 18).

Sunfish dominated the harvest in both numbers (53.0%) and weight (41.8%). Sunfish, however, ranked second in relative importance to anglers, accounting for 30.1% of the total directed effort. Anglers targeting sunfish and yellow perch experienced high catch rates of 1.10 fish/hr and 0.87 fish/hr, respectively. Yellow perch ranked third in relative importance to anglers, accounting for 11.6% of the total directed effort, and ranked second in importance to the harvest, accounting for 35.2% of the mean total

Table 15. Daytime sport fish harvest statistics from February 28 to June 3, 1990, 1994, and 1996 on Lake Seed, Georgia.

	Numbers Harvested (% of Total)						Weight (kg) Harvested (% of Total)						Mean Weight (kg)		
Species	1990		1994		1996		1990		1994		1996		1990	1994	1996
Black Bass [a]	274	(3.6)	161	(2.2)	210	(4.6)	165	(12.6)	149	(14.0)	164	(19.0)	0.60	0.93	0.78
Walleye	0		0		23	(0.5)	0		0		5	(0.5)	-	-	0.22
Rainbow Trout	335	(4.4)	259	(3.6)	263	(5.8)	206	(15.8)	116	(10.8)	203	(23.6)	0.61	0.45	0.77
Sunfish [b]	3,551	(46.5)	4,103	(57.1)	2,527	(55.4)	443	(34.0)	544	(51.0)	347	(40.3)	0.12	0.13	0.14
Yellow Perch	2,802	(36.7)	2,603	(36.2)	1,494	(32.7)	279	(21.4)	258	(24.2)	107	(12.4)	0.10	0.10	0.07
Other [c]	668	(8.8)	59	(0.9)	48	(1.0)	211	(16.2)	0		36	(4.2)	0.32	-	0.75
Total	7,631		7,185		4,565		1,304		1,067		862		0.17	0.15	0.19
(Standard Error)	(1,978)		(1,329)		(925)		(195)		(197)		(164)				

[a] Includes largemouth and spotted bass.
[b] Includes bluegill, redear sunfish, and redbreast sunfish.
[c] "Other" includes chain pickerel, crappie, and catfish.

Table 16. Daytime harvest rate (fish/hr), catch rate (fish/hr), and directed effort (hr) by anglers on Lake Seed, Georgia from February 28 to July 3, 1990, 1994, and 1996.

	Harvest Rate			Catch Rate			Directed Effort (% of Total)					
Species	1990	1994	1996	1990	1994	1996	1990		1994		1996	
Black Bass [a]	0.038	0.029	0.044	0.123	0.048	0.126	1,112	(55.5)	1,086	(33.7)	2,023	(43.7)
Walleye [b]	0.000	0.000	0.005	0.000	0.000	0.014	0		5	(0.2)	43	(0.9)
Rainbow Trout	0.088	0.057	0.056	0.144	0.073	0.059	105	(5.2)	506	(15.7)	663	(14.3)
Sunfish [c]	0.491	0.744	0.536	0.861	1.258	1.195	492	(24.5)	1,221	(37.8)	1,292	(27.9)
Yellow Perch	0.387	0.472	0.317	0.570	1.153	0.878	235	(11.7)	408	(12.6)	489	(10.6)
Other [d]	0.051	0.000	0.010	0.084	0.000	0.014	61	(3.1)	0		123	(2.6)
Total	1.054	1.303	0.968	1.781	2.532	2.286	2,005		3,226		4,633	
(Standard Error)	(0.204)	(0.200)	(0.107)	(0.329)	(0.256)	(0.265)	(320)		(578)		(628)	

[a] Includes largemouth and spotted bass.

[b] No walleye were documented in the 1990 and 1994 creel surveys. Seventeen walleye were documented during the 1996 creel survey and over 50 walleye were caught and reported by anglers.

[c] Includes bluegill, redear sunfish, and redbreast sunfish.

[d] “Other” includes chain pickerel, crappie, and catfish.

Table 17. Gablehouse (1984) length frequency classification of largemouth bass from creel surveys on Lake Seed, Georgia in 1990 and 1996. Individual lengths of largemouth bass were not measured in 1994.

		Total Number		% of Total	
Category	Size Range (mm)	1990	1996	1990	1996
Pre-Stock	< 189	0	0	3.8	0.0
Stock	190 - 309	7	0	26.9	0.0
Quality	310 - 369	11	2	42.3	11.8
Preferred	370 - 509	5	15	19.2	88.2
Memorable	510 - 629	2	0	7.8	0.0
Trophy	> 630	0	0	0.0	0.0
Total		26	17	100.0	100.0

Table 18. Gablehouse (1984) length frequency classification of spotted bass from creel surveys on Lake Seed, Georgia in 1990 and 1996. Individual lengths of spotted bass were not measured in 1994.

		Total Number		% of Total	
Category	Size Range (mm)	1990	1996	1990	1996
Pre-Stock	< 169	0	0	0.0	0.0
Stock	170 - 269	1	1	6.2	5.3
Quality	270 - 349	7	6	43.8	31.6
Preferred	350 - 429	6	10	37.5	52.6
Memorable	430 - 509	2	2	12.5	10.5
Trophy	> 510	0	0	0.0	0.0
Total		16	19	100.0	100.0

number harvested and 19.3% of the mean total weight harvested.

Limited population expansion by stocked walleye resulted in the slow development of a fishery. No directed effort for walleye or harvest was measured in the 1990 and 1994 creel surveys (Tables 15 and 16). In 1994 and 1995, occasional catches of small walleye were reported by anglers. By 1996, a minimal amount of harvest and directed effort was measured in the creel survey. The 1996 survey also indicated some catch-and-release of sub-adult walleye. During the 1996 creel survey, three walleye were directly observed (ages 1 and 2) in the creel, which resulted in an expanded estimate of 23 fish. Over 50 walleye were caught and reported by anglers independently from the 1996 survey, but these results were not incorporated into the expanded estimates. Walleye reported by anglers were typically age 1 fish that measured between 250 and 300 mm TL and averaged 200 g in weight.

Abundance of Yellow Perch and Other Forage in Lake Burton

Annual fish biomass estimates from late summer cove rotenone sampling ranged from 62.70 kg/ha prior to walleye fry stocking to 113.59 kg/ha in 1993 (Table 19). One-way ANOVA indicated no significant difference in biomass estimates among years ($p = 0.22$). Bluegill was consistently the dominant species in all samples, accounting for an average of 36.7% of the total biomass. In terms of biomass, yellow perch (16.2%) and largemouth bass (15.8%) ranked second and third, respectively. These three species accounted for 68.7% of the average fish biomass of Lake Burton during the study period.

Table 19. Unweighted mean standing crop estimates (kg/ha) from three late summer cove rotenone samples on Lake Burton, Georgia. Percent of total is listed in parentheses. Species are grouped according to Surber (1959).

	Standing Crop and % Total by Year							
Group/Species	Mean of 1987-88		1991		1993		1994	
Predatory Game Fish								
Largemouth Bass	11.20	(17.9)	10.32	(13.6)	20.32	(17.9)	10.05	(13.9)
Spotted Bass	4.24	(6.8)	1.95	(2.6)	6.42	(5.6)	3.07	(4.3)
Walleye	0.02	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)
White Bass	0.00	(0.0)	0.00	(0.0)	0.47	(0.4)	0.00	(0.0)
Chain Pickerel	2.76	(4.4)	2.27	(3.0)	5.12	(4.5)	2.26	(3.1)
Black Crappie	0.76	(1.2)	1.40	(1.8)	1.77	(1.6)	0.91	(1.3)
White Crappie	0.07	(0.1)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)
Total	19.05	(30.4)	15.94	(21.0)	34.10	(30.0)	16.29	(22.6)
Non-Predatory Game Fish								
Bluegill	17.69	(28.2)	32.69	(43.1)	37.58	(33.1)	30.70	(42.5)
Redbreast Sunfish	3.29	(5.3)	3.37	(4.4)	3.25	(2.9)	1.62	(2.2)
Redear Sunfish	0.95	(1.5)	1.43	(1.9)	3.24	(2.9)	1.42	(2.0)
Green Sunfish	1.71	(2.7)	1.75	(2.3)	0.84	(0.7)	0.81	(1.1)
Warmouth	0.00	(0.0)	0.00	(0.0)	2.03	(1.8)	0.69	(1.0)
Yellow Perch	12.19	(19.4)	11.57	(15.2)	22.71	(20.0)	7.21	(10.0)
Total	35.83	(57.1)	50.81	(66.9)	69.65	(61.4)	42.45	(58.8)

Table 19, continued.

	Standing Crop and % Total by Year							
Group/Species	1987-88		1991		1993		1994	
Non-Predatory Food Fish								
Carp	2.54	(4.0)	0.00	(0.0)	3.10	(2.7)	1.32	(1.8)
Northern Hogsucker	0.29	(0.5)	0.00	(0.0)	0.21	(0.2)	0.00	(0.0)
Brown Bullhead	0.29	(0.5)	0.29	(0.4)	0.14	(0.1)	0.68	(0.9)
Total	3.12	(5.0)	0.29	(0.4)	3.45	(3.0)	2.00	(2.7)
Predatory Food Fish								
Channel Catfish	2.15	(3.4)	7.84	(10.3)	1.18	(1.0)	0.37	(0.5)
White Catfish	2.37	(3.8)	0.43	(0.6)	4.23	(3.7)	5.01	(7.0)
Total	4.52	(7.2)	8.27	(10.9)	5.41	(4.7)	5.38	(7.5)
Forage Fish								
Gizzard Shad	0.02	(0.0)	0.49	(0.7)	0.62	(0.6)	5.90	(8.2)
Threadfin Shad	0.00	(0.0)	0.00	(0.0)	0.08	(0.0)	0.00	(0.0)
Blueback Herring	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.01	(0.0)
Golden Shiner	0.00	(0.0)	T	(0.0)	0.00	(0.0)	0.00	(0.0)
Spottail Shiner	0.00	(0.0)	T	(0.0)	0.00	(0.0)	0.00	(0.0)
Whitefin Shiner	0.16	(0.3)	0.06	(0.1)	0.28	(0.3)	0.15	(0.2)
Total	0.18	(0.3)	0.57	(0.8)	0.98	(0.9)	6.06	(8.4)
Total for All Species	62.70	100.0	75.88	100.0	113.59	100.0	72.18	100.0

T = less than 0.01 kg/ha.

During the study period, minor shifts in species composition were documented. In 1990 and 1991, approximately 60,000 threadfin shad were stocked into Lake Burton. In 1993, threadfin shad were collected in cove rotenone samples. Winter water temperatures in 1993 and 1994 stabilized below 4.5°C for more than two weeks, resulting in the elimination of threadfin shad from Lake Burton. Around 1993, blueback herring were illegally introduced into Lake Burton and were subsequently documented in cove rotenone samples in 1994. Although gizzard shad was the dominant forage species in Lake Burton by weight, its biomass was accounted for by only a few, very large individuals that averaged 320 mm TL.

Because yellow perch was the dominant prey of walleye in Lake Burton, a more detailed analysis of the yellow perch population was conducted. The mean density estimate for yellow perch prior to stocking (1,592 fish/ha) was not significantly different ($p = 0.26$) from the mean post-stocking density (1,736 fish/ha; Table 20). Density estimates for fingerling, intermediate, and harvestable size groups of yellow perch before and after walleye fry stocking were not significantly different ($p > 0.05$). Likewise, the mean total biomass estimate for yellow perch prior to walleye stocking (12.20 kg/ha) was not significantly different ($p = 0.74$) from the mean post-stocking biomass (13.83 kg/ha).

Yellow perch demonstrated slower growth after walleye stocking was initiated, although mean length of age 1 yellow perch prior to walleye stocking (75 mm TL) and after walleye stocking (73 mm TL) was nearly identical. Similar results were observed for age 2 yellow perch, which averaged 120 mm TL before and 111 mm TL after walleye stockings. The mean length of yellow perch at age 3 in post-walleye stocking years

Table 20. Population density (fish/ha) and biomass (kg/ha) estimates for yellow perch collected in late summer cove population surveys of Lake Burton, Georgia. Size groups are according to Surber (1959).

Year	Density				Biomass (kg/ha)
	Fingerling	Intermediate	Harvestable	Total	
Pre-Stocking					
1987 [a]	1,221	235	220	1,676	13.15
1988 [a]	824	584	100	1,508	11.24
Mean	1,022	410	160	1,592	12.20
Standard Error	198.5	174.5	60.0	84.0	0.9
Post-Stocking					
1991	392	535	144	1,071	11.57
1993	2,054	886	328	3,268	22.71
1994	266	556	46	868	7.21
Mean	904	659	173	1,736	13.83
Standard Error	576.1	113.7	82.7	1,002.1	4.6

[a] Data from Rabern (1989).

(135 mm TL), however, was significantly less ($p < 0.01$) than pre-walleye stocking years (160 mm TL). As yellow perch growth rate declined over time, annual survival rate increased significantly ($r = 0.88$, $p = 0.05$; Table 21). No significant correlation was detected between yellow perch survival and walleye catch per unit effort ($r = -0.51$, $p = 0.38$) and male walleye population size ($r = -0.45$, $p = 0.45$).

Table 21. Age frequency and annual survival rate of yellow perch from late summer cove rotenone samples from Lake Burton, Georgia.

		Percent of Total by Age Class						
Year	N	O	I	II	III	IV	V+	Annual Survival Rate
1987[a]	2,322	72.6	21.2	5.4	0.8	0.0	0.0	0.25
1988[a]	3,146	55.2	42.4	2.0	0.4	0.0	0.0	0.32
1991	2,003	38.5	53.1	3.4	2.4	2.0	0.6	0.44
1993	4,858	59.2	22.5	16.2	1.9	0.2	0.0	0.38
1994	1,901	19.8	47.2	32.1	0.6	0.1	0.2	0.52

a Data from Rabern (1989)

Abundance of Yellow Perch and Other Forage in Lake Seed

Annual fish biomass estimates in late summer cove rotenone samples on Lake Seed ranged from 35.68 kg/ha in 1992 to 64.46 kg/ha in 1995 (Table 22). One-way ANOVA indicated no significant difference in the mean total biomass among years ($p = 0.19$). Yellow perch (22.6%), bluegill (22.4%), largemouth bass (15.8%), and redbreast sunfish (8.8%) dominated the mean total fish biomass of Lake Seed and cumulatively accounted for 69.6% of the total. Illegal introductions of blueback herring into Lake Burton and subsequent emigration into Lake Seed led to the establishment of a rapidly expanding population. Blueback herring were collected in cove samples in 1994 (0.10 kg/ha) and 1995 (1.26 kg/ha).

Significant differences were detected between the mean densities of yellow perch fingerlings ($p = 0.05$) and harvestable sizes ($p = 0.02$) in pre-stocking and post-stocking years (Table 23). The density of fingerling yellow perch increased from 81 fish/ha to 276

Table 22. Unweighted mean standing crop estimates (kg/ha) from two late summer cove rotenone samples on Lake Seed, Georgia. Percent of total is listed in parentheses. Species are grouped according to Surber (1959).

	Standing Crop and % Total by Year											
Group/Species	1989		1991		1992		1993		1994		1995	
Predatory Game Fish												
Largemouth Bass	4.72	(9.6)	6.28	(17.0)	9.86	(27.6)	9.83	(18.1)	6.52	(17.1)	6.74	(10.5)
Spotted Bass	1.84	(3.8)	0.53	(1.4)	0.17	(0.5)	1.02	(1.9)	1.98	(5.2)	2.61	(4.0)
Chain Pickerel	3.92	(8.0)	1.25	(3.4)	1.79	(5.0)	2.17	(4.0)	3.85	(10.1)	3.71	(5.8)
Black Crappie	1.21	(2.5)	0.61	(1.7)	0.04	(0.1)	0.61	(1.1)	0.15	(0.4)	0.36	(0.6)
Walleye	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.17	(0.3)
Total	11.68	(23.9)	8.67	(23.5)	11.86	(33.2)	13.63	(25.1)	12.50	(32.8)	13.59	(21.2)
Non-Predatory Game Fish												
Bluegill	9.24	(18.9)	8.20	(22.2)	6.58	(18.5)	13.36	(24.6)	6.83	(17.9)	18.03	(28.0)
Redbreast Sunfish	4.62	(9.4)	5.44	(14.7)	5.32	(14.9)	13.59	(25.0)	5.95	(15.6)	6.13	(9.5)
Redear Sunfish	0.07	(0.1)	0.00	(0.0)	0.04	(0.1)	0.22	(0.4)	0.00	(0.0)	0.95	(1.5)
Green Sunfish	0.00	(0.0)	0.06	(0.1)	0.03	(0.1)	0.02	(0.0)	0.05	(0.1)	0.00	(0.0)
Warmouth	1.77	(3.6)	1.75	(4.8)	0.98	(2.7)	1.50	(2.8)	0.90	(2.3)	1.81	(2.8)
Yellow Perch	17.90	(36.6)	11.56	(31.3)	8.21	(23.0)	9.72	(17.9)	5.63	(14.7)	9.88	(15.3)
Total	33.60	(68.7)	27.01	(73.2)	21.16	(59.3)	38.41	(70.8)	19.36	(50.6)	36.80	(57.1)

Table 22, continued.

	Standing Crop and % Total by Year											
Group/Species	1989		1991		1992		1993		1994		1995	
Non-Predatory Food Fish												
Brown Bullhead	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.05	(0.1)
Total	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.05	(0.1)
Predatory Food Fish												
Channel Catfish	3.65	(7.4)	0.00	(0.0)	0.20	(0.6)	0.97	(1.8)	0.00	(0.0)	0.00	(0.0)
White Catfish	0.00	(0.0)	1.20	(3.2)	0.10	(0.3)	1.26	(2.3)	0.46	(1.2)	4.48	(7.0)
Total	3.65	(7.4)	1.20	(3.2)	0.30	(0.9)	2.23	(4.1)	0.46	(1.2)	4.48	(7.0)
Forage Fish												
Gizzard Shad	0.01	(0.0)	0.00	(0.0)	2.36	(6.6)	0.00	(0.0)	5.80	(15.2)	8.28	(12.8)
Blueback Herring	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.10	(0.2)	1.26	(1.9)
Golden Shiner	0.00	(0.0)	0.01	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)
Whitefin Shiner	0.01	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)	0.00	(0.0)
Total	0.02	(0.0)	0.01	(0.0)	2.36	(6.6)	0.00	(0.0)	5.90	(15.4)	9.54	(14.7)
Total for All Species	48.95	100.0	36.89	100.0	35.68	100.0	54.27	100.0	38.22	100.0	64.46	100.0

Table 23. Population density (fish/ha) and biomass (kg/ha) estimates for yellow perch collected in late summer cove population surveys of Lake Seed, Georgia. Size groups are according to Surber (1959).

Year	Density				Biomass (kg/ha)
	Fingerling	Intermediate	Harvestable	Total	
Pre-Stocking					
1973 [a]	138	508	369	1,015	27.23
1989	24	104	316	444	17.90
Mean	81	306	342	730	22.56
Standard Error	57.0	202.0	26.5	285.5	4.66
Post-Stocking					
1991	256	196	168	620	11.56
1992	218	201	146	565	8.21
1993	836	108	169	1,113	9.73
1994	18	118	126	262	5.63
1995	53	43	324	420	9.88
Mean	276	133	187	596	9.00
Standard Error	147.2	29.6	35.3	143.4	1.00

[a] Data from Hottel (1976).

fish/ha in post-stocking years. The density of harvestable yellow perch decreased from 342 fish/ha to 187 fish/ha after walleye stocking was initiated in Lake Seed. No significant differences were detected in the mean total density ($p = 0.64$) and total biomass ($p = 0.15$) of yellow perch between pre-stocking and post-stocking years.

The abundance of young-of-year yellow perch was highly variable in cove rotenone samples among years, but age 1 abundance was more consistent over time

(Table 24). Yellow perch survival declined annually from 1989 to 1993, but increased again in 1994 and 1995. A linear regression analysis of yellow perch annual survival over time was not significant (r = -0.23, p = 0.66). Variability in yellow perch survival was not correlated to walleye catch rates in fall gill net samples (r = 0.07, p = 0.90).

Mean lengths of yellow perch at ages 1 and 2 were relatively consistent over time, as indicated by the low standard error for these two age classes (Table 25). Differences in mean lengths for age 3 and older yellow perch among years were also not statistically significant (p = 0.10). Annual growth was slow, averaging only 28 mm per year.

Table 24. Age frequency and annual survival rate of yellow perch from late summer cove rotenone samples from Lake Seed, Georgia.

		Age Group						
Year	N	O	I	II	III	IV	V+	Annual Survival Rate
1989	621	3.5	23.3	10.1	54.6	7.2	1.3	0.71
1991	759	37.0	30.9	14.0	10.4	2.4	5.3	0.56
1992	730	38.6	28.1	27.6	1.8	1.4	2.5	0.52
1993	1358	75.4	8.4	8.5	6.9	0.6	0.2	0.33
1994	319	5.6	54.7	15.0	19.5	4.6	0.6	0.62
1995	513	13.3	31.5	24.2	27.2	3.4	0.4	0.64

Table 25. Pooled mean back-calculated length (mm) at annulus of yellow perch from Lake Seed, Georgia collected in late summer cove rotenone samples before and after walleye stocking. Standard errors (SE) are listed in parentheses.

	Age Group						
Year-Class	I	II	III	I V	V	VI	VII
Pre-Stocking							
1973 and 1989	73	120	159	185	205	219	232
(SE)	(1.5)	(2.6)	(2.9)	(3.2)	(3.0)	(4.4)	(2.5)
Post-Stocking							
1990	69	120	151	177	183		
	(3.9)	(3.2)	(9.0)	(2.8)	(2.7)		
1991	70	111	138	156			
	(2.5)	(4.3)	(7.5)	(3.3)			
1992	74	110	132				
	(3.8)	(11.5)	(3.1)				
1993	78	116					
	(5.0)	(1.7)					
1994	72						
	(1.3)						
Mean	73	114	140	166	183		
(SE)	(1.6)	(2.3)	(5.6)	(10.5)	(2.7)		

Post-Stocking Mortality in Lake Seed

Water Quality

When walleye were stocked, minor differences were detected between hauling waters and ambient reservoir conditions for most water quality parameters (Figure 10). In most years, the water temperature in hauling waters was lower than reservoir waters by 2 to 5^{o}C, and pH differences ranged from 0.1 to 0.5 units for both fry and fingerlings. In all years except 1990, hauling waters were supersaturated with oxygen upon arrival at the stocking site; therefore, dissolved oxygen concentrations declined steadily through the tempering period. The most dramatic difference in water quality between hauling media and reservoir conditions was in total hardness. Total hardness in lakes Seed and Burton measured 5.0 mg of $CaCO_3$/L . Hauling waters ranged from 175 to 515 mg of $CaCO_3$/L depending on the hatchery origin (i.e. Ohio, Pennsylvania, or Minnesota).

In 1990, poor hauling water quality, namely high water temperature and low dissolved oxygen, resulted in nearly total mortality of walleye fry. Severe weather conditions also forced personnel to release fry before adequately acclimating to reservoir conditions, which probably exacerbated latent mortality. From 1991 to 1994, excellent hauling water quality resulted in negligible mortality. In 1995, however, hauling mortality exceeded 30%. Water quality parameters appeared similar to other years, and no obvious reason for this mortality was determined. One incident of predation was documented during stocking episodes as adult yellow perch fed aggressively on walleye fingerlings (50 mm TL) in 1992.

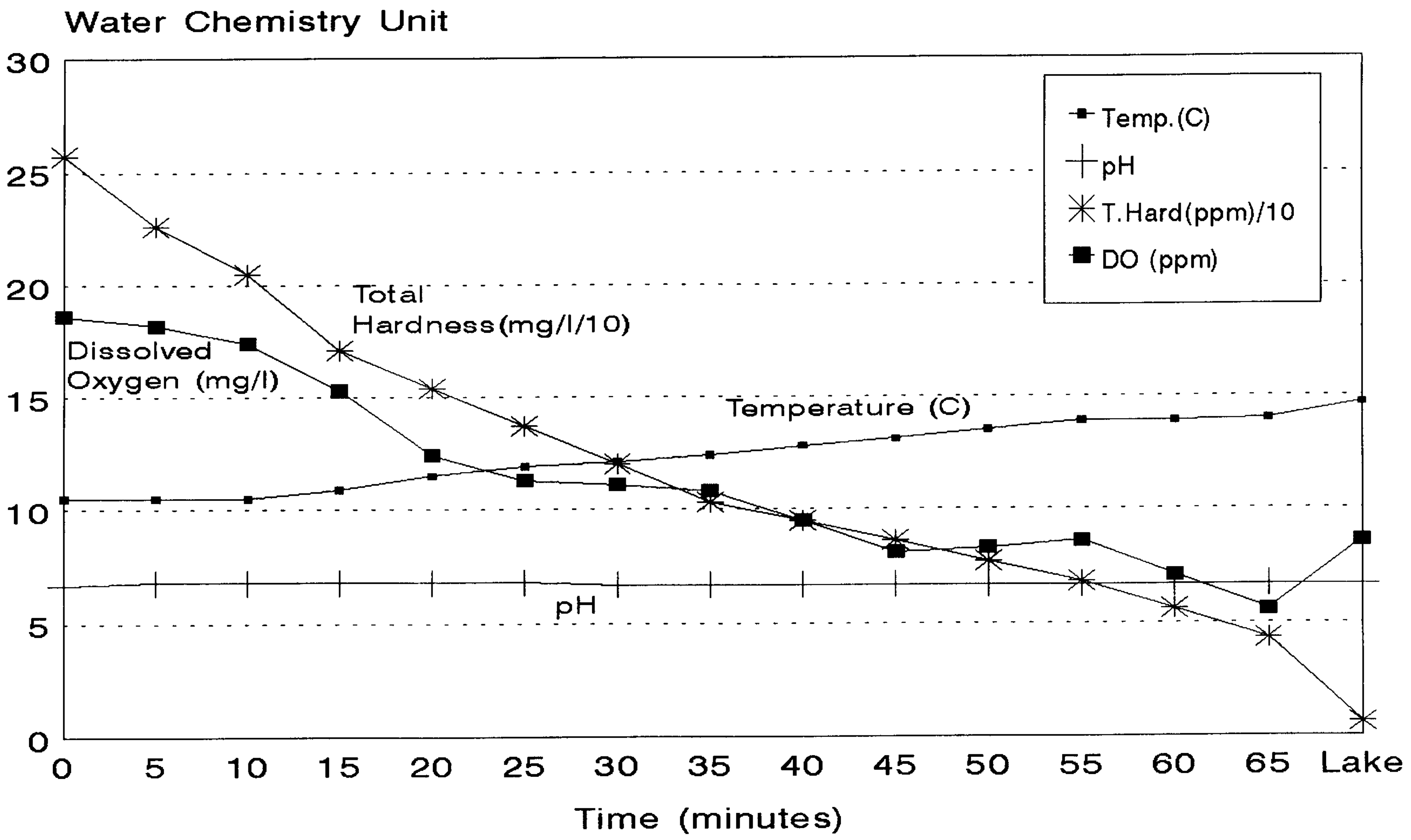

Figure 10. Water chemistry changes of hauling waters during acclimation of walleye fingerlings (173 mm TL) with the receiving waters of Lake Seed, Georgia on October 30, 1995.

Post-Stocking Mortality Study

Of 30 fingerling walleye (125 mm TL) stocked in 1993 into a predator-free enclosure, 100% survived and most were feeding on shiners by the end of the ten-day captivity period. In 1994, however, mortality of walleye fingerlings (179 mm TL) after 13 days of captivity was 34.4%. Nearly 73% of post-stocking mortality occurred within the first four days, and after seven days, mortality ceased. Captive walleye fingerlings consumed all golden shiners that were initially stocked, and feeding was so aggressive that an additional 100 golden shiners were stocked on the seventh day. Moribund fish were necropsied in 1994. Visual observations of dead and dying fish indicated a severe fungal infection of *Saprolegnia* spp. Discussions with the walleye supplier indicated that walleye are susceptible to *Saprolegnia* when confined in high densities for extended periods.

In 1995, the mean mortality rate of walleye tempered for 10 minutes was 13%, for 30 minutes was 20%, and for 60 minutes was 13%. No significant difference in mean total mortality among treatments was detected ($p = 0.63$). As discovered in 1994, moribund fish were infected with *Saprolegnia* spp. Healthy walleye, however, fed aggressively during captivity. By the end of the experiment, all golden shiners had been consumed in every compartment.

Discussion

Walleye Stocking Success

A review of walleye introductions over the past 100 years indicated that walleye stocking success was highly variable over a wide range of geographic locations, stocking densities, and sizes of fish at stocking (Laarman 1978). In a symposium on walleye stocks and stocking, Ellison and Franzin (1992) stated, "From the stocking evaluations reported in the symposium came one overriding lesson: the success of any [walleye] stocking practice remains largely unpredictable." Walleye fry stocking from 1991 to 1992 in Lake Burton was not successful, as indicated by negligible returns to the spawning population and the fall gill net catch. In the six years following stocking, only five walleye from the stocked year-classes were collected in fall gill net samples, and total fall gill net catch declined from a high of 2.4 fish/net-night in 1991 to 0.1 fish/net-night in 1997. In Lake Seed, walleye stocking was moderately successful. As a result of fry and fingerling stockings over six years, the relative abundance of walleye in fall gill net samples increased ten-fold from 1990 (0.4 fish/net-night) to 1997 (4.0 fish/net-night). Single flood events in 1994 and 1995, however, limited population expansion by displacing significant numbers of walleye into the downstream reservoir (Lake Rabun).

Negligible survival in Lake Burton and limited success in Lake Seed resulted in failure to meet most study objectives. No self-sustaining walleye populations or fisheries were established by stocking, and stocked walleye densities were not sufficient to restructure the yellow perch size distribution into a more favorable state for anglers. Study results, however, identified factors that may limit walleye stocking success in Georgia, such as size of fish at stocking, stocking density, hauling stress, and flooding and implicated other possible factors, such as adequate prey availability and predation.

Stocking Size

Laarman (1978) and Ellison and Franzin (1992) indicated that walleye stocking success was partially a function of the size of the fish at stocking. Among walleye stocking evaluations reported by these two researchers, 32% of fry stockings were considered successful, whereas 32% of small fingerling stockings and 50% of advanced fingerling stockings were considered successful. Similar results were observed in a review of the brief stocking history of walleye in Georgia. In twelve Georgia reservoirs stocked with walleye fry during the 1960s, only three reservoirs (25%) developed walleye densities capable of supporting a fishery. After eight years of walleye fry stocking in Lake Nottely, Georgia between 1985 and 1994, only two stockings were considered successful (Wever 1992).

State agencies typically choose to stock walleye fry because of their cost-effectiveness, but fishery managers may prefer to stock small fingerlings (25 to 50 mm TL) or advanced fingerlings (100 to 150 mm TL) in order to enhance survival (Kraai et al. 1983; Kinman 1990). To evaluate the effects of fish size at the time of stocking on stocking success, several investigators have compared the relative stocking success of walleye fry and fingerlings. Koppelman et al. (1992) reported that small fingerlings (38 mm TL) represented the majority of returns from Lake Jacomo (78%) and Longview Lake, Missouri (69%) followed by advanced fingerlings (102 mm TL) and fry, which only represented 5.1% and 11.8% of total returns, respectively. From 1984 to 1988 in West Okoboji Lake, Iowa, advanced fingerlings contributed 70% to 99% of young-of-year densities, whereas small fingerlings accounted for 49% of the young-of-year density in

1989 (McWilliams and Larscheid 1992). Similar stocking successes were achieved with introductions of small fingerlings in Lake Oahe, South Dakota (Fielder 1992) and Collins Pond, Illinois (Heidinger et al. 1985).

In East Okoboji Lake and Spirit Lake, Iowa, fingerling stockings were not as successful as in neighboring West Okoboji Lake, but fry stockings accounted for 37% to 90% of young-of-year walleye densities (McWilliams and Larscheid 1992). In Rathbun Lake, Iowa, fry were more influential in establishing the most abundant year-classes than fingerlings, even though fish stocked as fingerlings dominated the population during some years (Mitzner 1992). In three Iowa rivers that were stocked with fry and fingerling walleye, survival seemed less dependent on the size of the fish stocked than on environmental conditions, mainly water temperature and flow (Paragamian and Kingery 1992).

Returns of walleye fry stocked into Lake Burton in 1990 and 1991 were near zero, whereas stocking success in Lake Seed was more variable. In Lake Seed, the 1990 year-class yielded only three walleye in fall gill net samples over a six-year period. Poor success from the 1990 year-class was likely attributed to low survival of fry immediately after stocking. Approximately 30% of stocked fry in 1990 were dead upon arrival to Lake Seed, probably due to low dissolved oxygen concentrations in the transport media. Secondarily, the 1990 year-class was not sufficiently acclimated to ambient reservoir conditions because severe weather forced a nearly immediate release of all fry at one open water site. It is likely that osmotic shock contributed to significant post-stocking mortality. The 1991 year-class of stocked fry, however, appeared in good condition upon release and subsequently accounted for 9.7% of total returns.

Stockings of advanced fingerlings in Lake Seed provided similar returns as the 1991 fry, accounting for 16.7% (1993) and 8.3% (1994 and 1995) of total returns per year-class, respectively. The single stocking of small fingerlings in 1992 dominated the population throughout the study period, accounting for 54.2% of total returns. Walleye population expansion in Lake Seed was negatively impacted by two flood events, which affected four of the five stocked year-classes. Analysis of supplemental gill net data from Lake Rabun, however, supported the findings from Lake Seed, which clearly identified the 1992 year-class as the most successful in terms of annual and total contributions to walleye abundance (Figure 11).

Walleye Stocking Density

Kraai et al. (1983) recommended high density walleye fry stockings, exceeding 2,000 fry/ha, for Texas reservoirs because such stockings were able to establish a walleye fishery more quickly, especially in reservoirs with limited reproduction or in older reservoirs. In Clear Lake, Iowa, year-class strength was significantly and directly correlated with annual fry stocking rates, which varied from 0 to 6,070 fry/ha (Carlander and Payne 1977). A similar direct relationship between fry stocking density and walleye abundance was reported in Rathbun Lake, Iowa (Mitzner 1990). Annual plantings of 3,782 to 4,903 fry/ha in Lake Nottely, Georgia increased walleye abundance; however, slight variations in annual stocking rates could not account for the high variation in year-class strength (Weaver 1992).

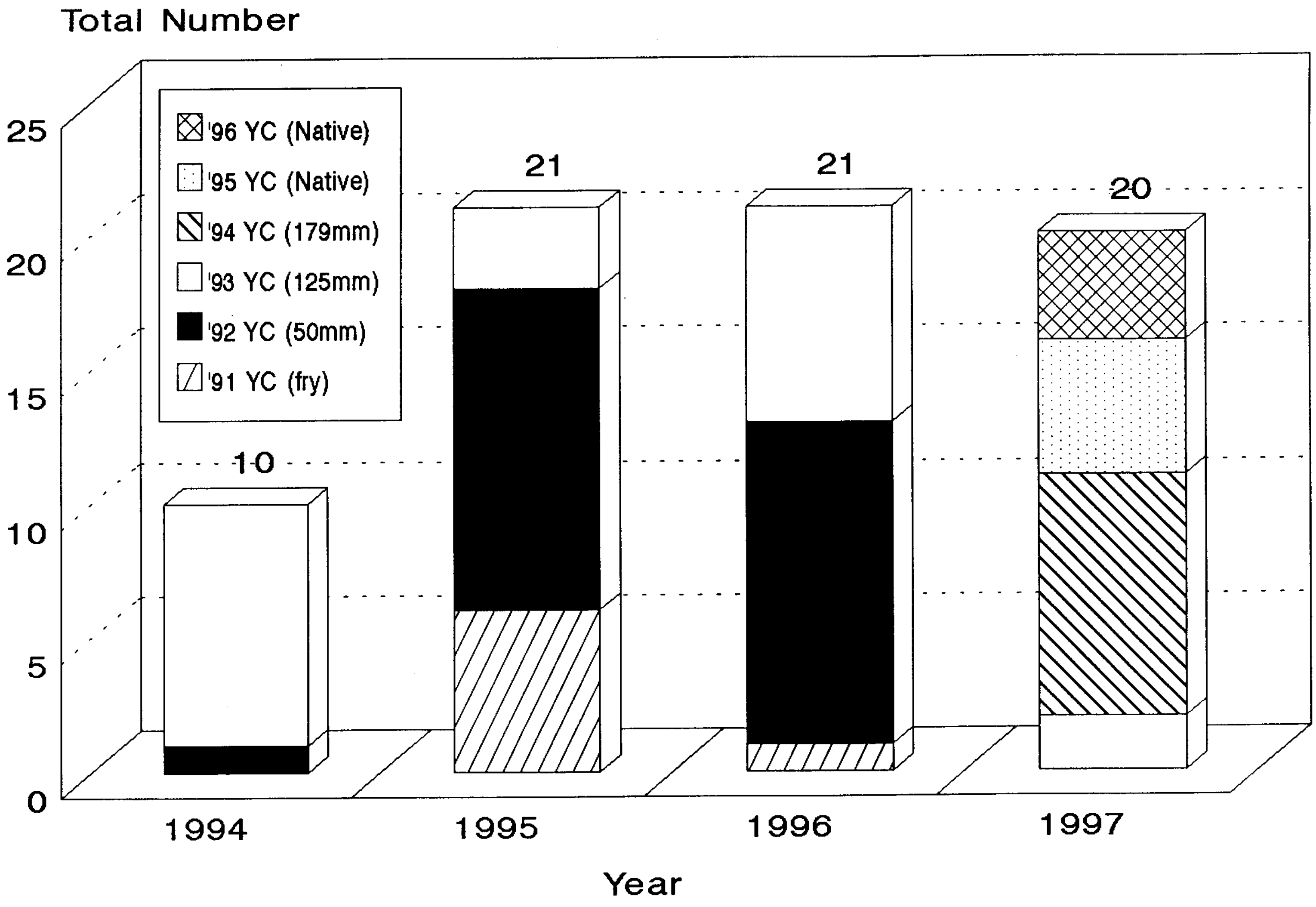

Figure 11. Relative abundance of walleye by year-class (YC) displaced from Lake Seed, Georgia and subsequently collected in Lake Rabun, Georgia by fall gill netting from 1994 to 1997.

Erickson (1972) found no relationship between fry stocking densities and subsequent walleye abundance in Ohio reservoirs. Li et al. (1996) recommended against high density stockings because their findings indicated that walleye abundance was not directly related to stocking density but was a function of other factors that directly affected survival. In East Okoboji Lake, strong walleye year-classes were not associated with fry stocking densities but with factors that affected fry survival (McWilliams and Larscheid 1992). Laarman (1978) concluded in his review of walleye stocking that environmental and biological conditions governed walleye stocking success more than number and size of fish stocked.

Based on the walleye stocking history of Lake Burton, stocking success of walleye fry appeared to be inversely related to stocking density. The low density stockings in the 1960s, which averaged 648 fry/ha, were more successful at establishing a walleye population than the high density stockings in 1990 and 1991, which averaged 5,602 fry/ha. Comparable and simultaneous walleye fry stockings in Lake Seed from 1990 to 1991 yielded higher returns than experienced in Lake Burton. The high density fry stocking in Lake Seed in 1991 (6,602 fry/ha), however, provided slightly greater returns to the gill net catch than the low density fry stocking in 1990. Based on low returns from year-classes stocked as fry, it was apparent that factors other than stocking density regulated stocking success in lakes Burton and Seed.

In three Iowa rivers, returns of stocked fingerlings was highest when large numbers of fish were stocked (Paragamian and Kingery 1992). In West Okoboji Lake, Iowa, young-of-year abundance was strongly correlated with fingerling stocking rates

(McWilliams and Larscheid 1992). In Lake Cumberland, Kentucky, Kinman (1990) found that walleye year class-strength was more dependent on physical and environmental factors than on fingerling stocking density. Moser (1987) also reported that young-of-year walleye abundance was not related to stocking density in Kansas lakes. Annual stocking densities in Lake Seed were very similar, except for 1995, but the relative frequency of annual returns and total returns for each year-class was highly variable. Results from fingerling stockings, therefore, indicated that factors other than stocking density regulated walleye abundance in Lake Seed.

Prey Availability

The availability of appropriate food items at the time of stocking is frequently reported to affect walleye stocking success in reservoirs (Ellison and Franzin 1992; Koppelman et al. 1992; McWilliams and Larscheid 1992; Peterson and Vanderkooy 1994). Plankton and zooplankton are the principal food items of walleye fry and small fingerlings up to a length of approximately 35 mm TL, at which time they convert to a diet of larval fish such as yellow perch, sunfish, and clupeids (Carlander and Payne 1977; Mathias and Li 1982; Johnson et al. 1988). The availability of appropriately-sized zooplankton was reported to regulate walleye year-class strength in some reservoirs (Crowder et al. 1987). Fox (1989) indicated that the availability of zooplankton immediately after stocking could be critical to the initial success of percids, especially for fry and small fingerlings. In Lake Oahe, South Dakota, low survival of small walleye fingerlings (36 mm TL) was associated with low zooplankton biomass (Fielder 1992). In

Collins Pond, Illinois, high fingerling survival was associated with high zooplankton densities (Heidinger et al. 1985). In Ohio reservoirs, seasonal patterns and availability of reservoir zooplankton and icthyoplankton appeared to influence saugeye (*Stizostedion vitreum* x *S. canadense)* growth and survival (Stahl et al. 1996). Limited zooplankton productivity occurs in oligotrophic reservoirs like Burton and Seed. The relatively low fish biomass in these neighboring impoundments is indicative of low primary and secondary productivity.

In addition to limited zooplankton abundance, interspecific competition for zooplankton has potential adverse effects on the stocking success of walleye fry and fingerlings. In Lake Nipissing, Ontario, Anthony and Jorgensen (1977) reported that competition between yellow perch and walleye contributed to declining walleye abundance. Cramer and Marzolf (1970) reported that competition between gizzard shad and young walleye for zooplankton in Longview Lake, Missouri inhibited the survival of stocked walleye. In Watauga Lake, Tennessee, dietary overlap between alewives and young-of-year walleye was demonstrated (Strange et al. 1985).

Based on published food habits studies, blueback herring and alewives have similar diets (Strange et al. 1985; Guest 1986; Davis 1987). Blueback herring were illegally stocked into Lake Burton and subsequently emigrated into Lake Seed during the study period. Following this introduction, a rapid expansion of the blueback herring population occurred. Because blueback herring and young walleye occupy similar pelagic habitats and feed primarily on large zooplankton, interspecific competition for food is likely to be intense in the low productivity waters of lakes Burton and Seed.

Researchers have recognized the benefits of increased survival when stocking coincides with peak larval fish abundance. Stahl et al. (1996) reported that saugeye survival in Ohio reservoirs was positively related to icthyoplankton density. In Lake Oneida, New York, strong year-classes of walleye were strongly correlated with yellow perch abundance (Forney 1977). Scott (1976) reported that young walleye in Center Hill Lake, Tennessee fed primarily on young *Lepomis*, primarily bluegill and longear sunfish. Cove population studies in lakes Burton and Seed indicated that suitable sizes and densities of prey species, primarily yellow perch and bluegill, are available to walleye fingerlings and adults. Dietary shifts from yellow perch to blueback herring during the study indicated that blueback herring densities were sufficient to support the expanding adult walleye population in Lake Seed. Limited zooplankton abundance and the potential for interspecific competition with blueback herring may negatively impact survival of stocked walleye fry; therefore, fingerling stocking is recommended. Future fingerling walleye stockings should be timed to coincide with peak larval fish abundance.

Predation

In addition to prey availability, predation upon recently stocked walleye is another potential limiting factor to a successful stocking program. Anthony and Jorgensen (1977) indicated that yellow perch predation on young walleye contributed to declining walleye abundance in Lake Nipissing, Ontario. During walleye fingerling stocking in Lake Seed in 1992, yellow perch were observed feeding upon newly stocked walleye fingerlings, which averaged 50 mm TL. Consumption of larval fish up to 25 mm TL by alewife and blueback herring has been documented in several reservoirs (Smith 1970; Kohler and Ney 1980; Guest 1986; and Davis 1987). The availability of alternate prey, such as gizzard shad, enhanced survival of saugeye in Ohio reservoirs (Stahl et al. 1996) and walleye in Oneida Lake, New York (Forney 1974). Because of the relatively small sizes of lakes Burton and Seed, limited zooplankton availability, lack of alternate prey, and high abundance of blueback herring and yellow perch, predation on stocked walleye fry and small fingerlings is potentially significant. Peterson and Vanderkooy (1994) recognized these potentially negative impacts and recommended stocking walleye at open water sites to minimize losses from predation.

Reservoir Storage Ratio

The population density and stocking success of walleye in Kansas reservoirs was directly related to the storage ratio (Willis and Stephen 1987). Reservoirs with low storage ratios, like Lake Seed, produced low densities of walleye, whereas reservoirs with moderate storage ratios yielded high walleye densities. The investigators suggested that the direct loss of fish through reservoir discharges may be the primary reason for these relationships. Jernejec (1986) reported selective migrations of age 1 and age 2 walleye through Tygart Dam, West Virginia. Walleye emigration was associated with high discharge rates during the winter drawdown. Successful passage of walleye through Tygart Dam resulted in the establishment of a walleye fishery in the Tygart Dam tailrace.

Major flood events in 1994 and 1995 in the Tallulah River Valley resulted in the displacement of significant numbers of walleye from Lake Seed downstream into Lake

Rabun. Stocked walleye from the 1991 to 1994 year-classes were subsequently collected in fall gill net samples from Lake Rabun (Figure 11). As a result, a small fishery was established in Lake Rabun, and natural reproduction was documented in 1995 and 1996. Unfortunately, stocking success in Lake Seed was impacted by these events. Without displacement of stocked walleye, population expansion in Lake Seed would potentially have increased dramatically (Figure 12).

Handling Stress

Handling stresses related to capture, transportation, and stocking induce endocrine changes and metabolic disturbances in fish that may have lethal consequences (Mazeaud et al. 1977; Colesante 1980). Stahl et al. (1996) included handling mortality as an influential force that affects the success of walleye stocking. Mitzner (1992) mentioned that the effects of hauling stress on pond-reared walleye fingerlings transported for 300 miles adversely affected walleye survival in Rathbun Lake, Iowa. McWilliams and Larscheid (1992) also suggested that hauling stress may have contributed significantly to post-stocking mortality of walleye in the Okoboji Lakes, Iowa. Paragamian and Kingery (1992) reported that walleye mortality from handling and transportation stress was high and strongly influenced stocking success in three Iowa rivers when water temperatures exceeded 21^{o}C.

Few studies have attempted to quantify mortality associated with handling and transportation stressors. Stahl et al. (1996) reported that post-stocking mortality of saugeye due to hauling stress ranged from 18.9% to 63.5% in Ohio reservoirs, but these

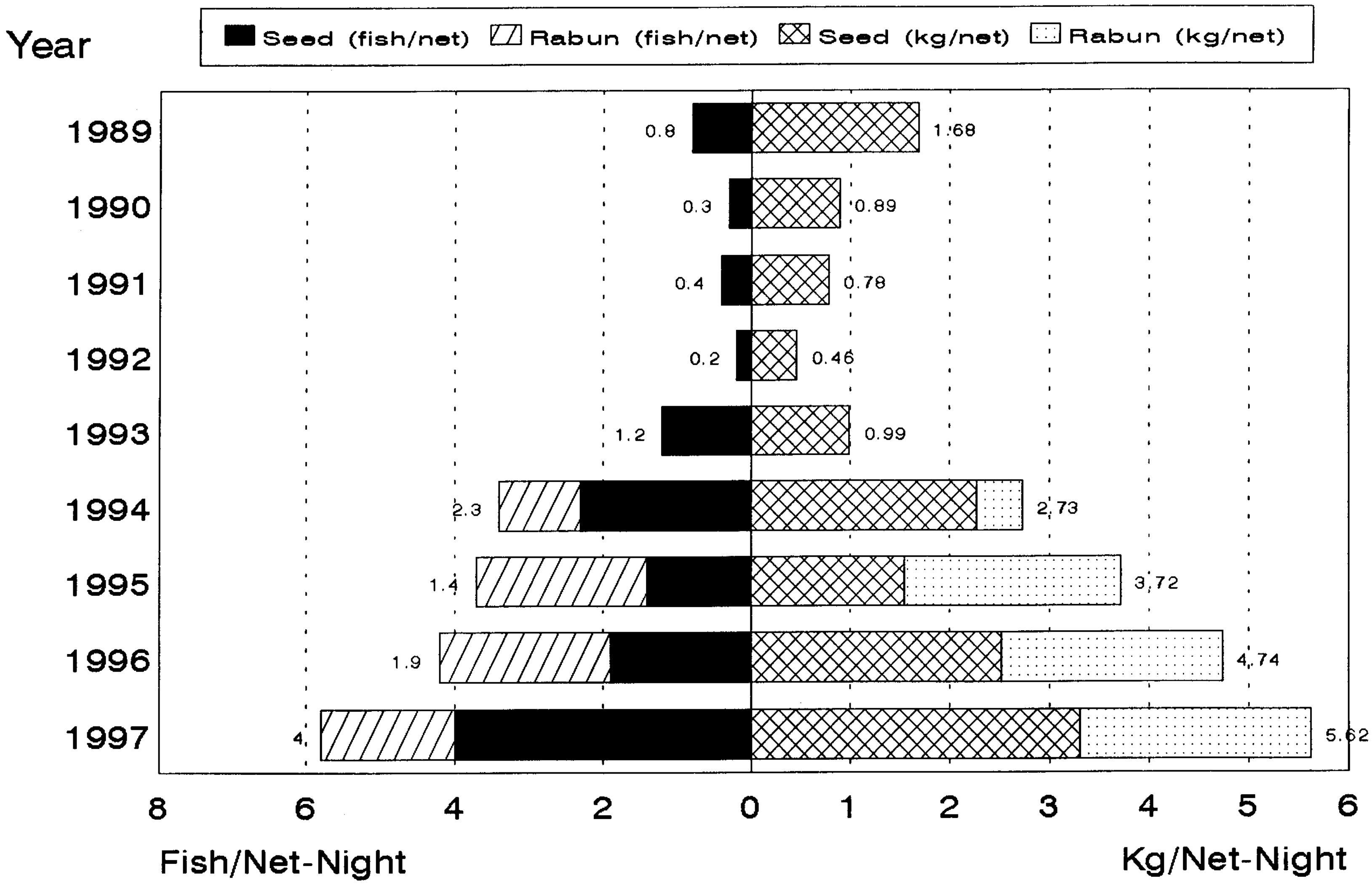

Figure 12. Density (fish/net-night) and biomass (kg/net-night) estimates of stocked walleye from Lake Seed, Georgia and displaced walleye in Lake Rabun, Georgia in fall gill net samples from 1989 to 1997.

investigators believed that hauling mortality did not adequately explain the annual variability in saugeye stocking success. Hurley and Austin (1987) reported that immediate hauling mortality of walleye stocked into Ohio reservoirs ranged from 1% to 5% over a four-year study period. Stress-related, post-stocking mortality in this same study ranged from 17% to 32% after one week in a predator-free enclosure.

Hauling mortality in walleye fingerlings transported for 26 to 30 hours over 1,388 miles from upstate Minnesota to Lake Seed was typically less than 1%. In 1995, however, hauling mortality was approximately 33%. Factors contributing to this high mortality did not include poor water quality but were probably related to overcrowding. Based on cage experiments of advanced walleye fingerlings stocked into Lake Seed, post-stocking mortality over a seven to 13 day period averaged 16.6%. Except for the 1990 Lake Seed fry, it is doubtful that stocking stress limited the development of the Burton and Seed walleye populations.

These results allow for refinement of walleye stocking guidelines. Hauling densities should not exceed 0.03 kg/L (0.25 lbs/gal) and adequate water quality should be maintained during transport. In addition, the use of salt (0.5% NaCl) in the transport media, which has been shown to effectively suppress the stress responses that are associated with acute disturbances (Barton and Zitzow 1995), is recommended. Acclimation periods should range from 10 to 20 minutes for fingerlings and 20 to 30 minutes for fry.

Recommendations

1. To document walleye abundance and natural reproduction in lakes Burton, Seed, and Rabun, continue population monitoring through annual fall gill netting and at least one spring electrofishing sample during the spawning period.
2. Stock small fingerlings (50 mm TL) annually to bi-annually at a rate of 50 to 100 fish/ha in lakes Burton, Seed, and Rabun to control the blueback herring population. Stocking should be curtailed if significant natural reproduction is documented through annual fall gill net surveys.
3. Identify walleye hatchery sources that could supply small fingerlings for Georgia reservoirs when temperatures of receiving waters are less than 21ºC.
4. Ensure that fingerling hauling densities do not exceed 0.03 kg/L (0.25 lb/gal); salt (0.5% NaCl) is added to transport media; fish are tempered for 10 to 20 minutes for fingerlings and 20 to 30 minutes for fry; and open water stocking sites are used to reduce predation.
5. To enhance natural reproduction, construct spawning reefs in lakes Burton and Seed. Evaluate use during spring electrofishing surveys.
6. Assess the effects of blueback herring competition and predation on resident sportfish species in lakes Burton and Seed.

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