ABSTRACT

WONG, RUSSELL KERN. White Perch Expansion and Life History Within a Southern Reservoir. (Under the direction of Richard L. Noble).

Concern has been raised regarding the effects of invasive fishes, among them white perch Morone americana, in a variety of freshwater systems. Previous research on white perch as an invasive species has examined landlocked white perch in ponds, lakes and reservoirs throughout much of its geographic range. However, research has been lacking regarding the role of invasive white perch in southern reservoirs. A long-term data set of the Jordan Lake fish community indexed via gill nets was evaluated to assess the expansion of white perch in Jordan Lake, as well as concurrent declines in other fishes found in Jordan Lake from 1987 through 1998. White perch catch rates increased from zero fish per net night in 1987 to 16.1 fish per net night in 1994, surpassing catch rates for all other fish captured in gill nets. White perch were found to live to age 7 in Jordan Lake where they shift food habits seasonally from zooplankton and diptera larvae in the spring to young shad in the fall. Relative weights and mean calculated total lengths at annulus formation suggest that the Jordan Lake white perch population is in good condition, comparable to other landlocked white perch populations in North Carolina and surpassing white perch populations found in their native estuarine environs throughout the eastern seaboard. Young white perch were found to prefer cover-free primary points featuring hard sand and clay substrates, minimizing the likelihood that Jordan Lake white perch will impact centrarchids as has been suggested by research in other freshwater systems outside of the southeastern United States.

White Perch Expansion and Life History Within a Southern Reservoir

by

Russell Kern Wong

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Department of Zoology

Raleigh

2002

APPROVED BY:

Dr. James A. Rice

Dr. Kenneth H. Pollock

Dr. Richard L. Noble
Chair of Advisory Committee

BIOGRAPHY

I was born, Russell Kern Wong, to Philip and Elaine Wong in Augusta, Georgia, April 25, 1962. I grew up in Augusta, graduating from Westside High School in 1980 before attending Augusta College and transferring to the University of Georgia. In Athens, I took nary a fisheries science class, focusing instead on English, journalism and education. Graduating in 1985, I began work as a middle school English teacher at Savannah Country Day School where I also learned the rare joys and privileges of working with the debate team, sponsoring the middle school newspaper, and coaching the middle school football team. A subsequent stint as a newspaper reporter with *The Augusta Chronicle-Herald* was interrupted by my marriage and a move to North Carolina where I worked as an editor and assistant director of communications for the N.C. Bar Association. Exchanging my coats and ties for shorts and sneakers, I went back to school in the mid 1990s, taking undergraduate coursework in chemistry, zoology, and fisheries and wildlife science at North Carolina State University before Rich Noble took me on as a graduate student working on one of the components of the Jordan Lake project.

ACKNOWLEDGMENTS

This work was a component of reservoir fish community dynamics studies in Jordan Lake conducted through Federal Aid in Sport Fish Restoration Project F-30, Studies 1, 3, and 4. The project was administered by the Division of Boating and Inland Fisheries of the N.C. Wildlife Resources Commission, which provided invaluable support in the data collection and data analysis components of the study. I want to thank in particular Scott Van Horn and Shari Bryant of the N.C. Wildlife Resources Commission for assisting in the data collection and sharing the previously collected data in the long-term gill net sampling of Jordan Lake. Students, staff and faculty of N.C. State University's Department of Zoology provided valuable assistance and guidance throughout the project. They are too numerous to name, but that fails to diminish their contributions to this work. I especially would like to acknowledge my graduate advisor and committee chair, Rich Noble, who may not be able to squeeze water out of a rock, but certainly can approximate an analogous academic miracle if he can coax me to complete my thesis. The same is true for Randy Jackson, Jim Rice and Ken Pollock who were also very encouraging and helpful throughout the process. I am most grateful to my wife Lydia for her support and patience lo these many years. My close-knit family has always been just a phone call away. Kamala and Tasha provided input also, but most of it came in the form of dog hair shed on my books and papers. Finally, Guy Sodano has seen me through some of the best — and some of the worst — times of my life. Some things you never forget. Nor should you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

The Department of Zoology at N.C. State University and the Division of Boating and Inland Fisheries of the N.C. Wildlife Resources Commission collaborated on a 12-year investigation of reservoir fish community dynamics on B. Everett Jordan Reservoir, North Carolina, from 1987-1998. During routine monitoring of the Jordan Lake fish community through gill net sampling of adult fish and shoreline electrofishing samples of juvenile fish, principal investigators detected a pronounced increase in white perch density. Concurrent decreases in abundance of adult white crappie, bluegill and flat bullheads drew attention to the white perch proliferation.

The current study began in 1996 after a literature search documented successful white perch invasions in a variety of inland habitats, including the Great Lakes (Christie 1972; Busch et al. 1977; Hurley and Christie 1977; Boileau 1985), Nebraska reservoirs (Hergenrader and Bliss 1971; Zuerlein 1981), New York lakes (Dence 1952; Clady 1976), Massachusetts ponds (Mosher 1976), and North Carolina reservoirs (Jackson et al. 1995). In addition, negative effects of white perch on native fish communities had been suggested by Zuerlein (1981), who documented declines in black bullhead and suppression of bluegill with increasing abundance of white perch in Nebraska reservoirs, and Hurley and Christie (1977), who linked declining centrarchid populations in Lake Ontario with increasing populations of white perch and alewife.

White perch had been documented as being able to spawn at age 2 or 3 in their typical coastal habitat (Mansueti 1961), using a variety of spawning substrates (Zuerlein 1981), and initiating spawning at temperatures lower than most southern species (11^{0}C) (Jenkins and Burkhead 1994). In inland waters, white perch are opportunistic generalists, feeding on zooplankton, diptera larvae and fish (Schaffer and Margraf 1986), so they pose potential competitive or predatory risks to centrarchids which typically spawn later than white perch (Jenkins and Burkhead 1994). Although white perch inland populations include those landlocked in reservoirs, studies of white perch populations in southern reservoirs were conspicuously absent in the literature. The long-term study of the Jordan Lake fish community afforded an opportunity to examine white perch life history in a new research setting.

Chapter 1 reprints the published results of a study documenting white perch invasion of Jordan Lake (Wong et al. 1999). This study uses a long-term data set from gill net sampling conducted three times annually with nine nets distributed over three reservoir sub-basins. The study examines catch rates and effects of location, season and year on adult white perch catch between 1987-1998. Chapter 2 assesses age structure, growth, relative weights and food habits of Jordan Lake white perch in context with other North Carolina white perch populations as well as others from the Southeast. Chapter 3 presents long-term, shoreline electrofishing data from a Jordan Lake embayment, Little Beaver Creek, to document the establishment and expansion of young white perch within the embayment's littoral fish community. Data from an additional embayment, Bush Creek, are included to assess spatial differences in abundance. Shoreline electrofishing catch rates are examined to identify preferred habitat of littoral-dwelling age-0 white perch.

References

Boileau, M.G. 1985. The expansion of white perch, Morone americana, in the lower great lakes. Fisheries 10(1):6-10.

Busch, W.D.N., D.H. Davies, and S.J. Nepszy. 1977. Establishment of the white perch, Morone americana, in Lake Erie. J. Fish. Res. Board Can. 34:1039-1041.

Christie, W.J. 1972. Lake Ontario: effects of exploitation, introductions, and eutrophication on the salmonid community. J. Fish. Res. Board Can. 29:913-929.

Clady, M.D. 1976. Change in abundance of inshore fishes in Oneida Lake, 1916 to 1970. N. Y. Fish and Game J. 23(1):73-81.

Dence, W.A. 1952. Establishment of white perch, Morone americana, in central New York. Copeia 3:200-201.

Hergenrader, G.L., and Q.P. Bliss. 1971. The white perch in Nebraska. Transactions of the American Fisheries Society 100(4):734-738.

Hurley, D.A. and W.J. Christie. 1977. Depreciation of the warmwater fish community in the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Can. 34:1849-1860.

Jackson, J.R., R.L. Noble, and E.R. Irwin. 1995. Largemouth bass recruitment in Jordan Lake. Final Report, Federal Aid in Sport Fish Restoration Project F-30-3, N.C. Wildlife Resources Commission, Raleigh. 100 pp.

Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater fishes of Virginia. AFS, Bethesda, Md.

Mansueti, R.J. 1961. Movements, reproduction and mortality of the white perch, Roccus americanus, in the Patuxent Estuary, Maryland. Chesapeake Sci. 2:142-205.

Mosher, T.D. 1976. Comparison of freshwater pond and estuarine populations of the white perch, Morone americana (Gmelin), in the Parker River, Massachusetts. M.S. Thesis, Univ. Mass. 77 pp.

Schaeffer, J.S. and Margraf. 1986. Population characteristics of the invading white perch (Morone americana) in western Lake Erie. J. Great Lakes Res. 12:127-131.

Wong, R.K., R.L. Noble, J.R. Jackson, and S. Van Horn. 1999. White Perch Invasion of B. Everett Jordan Reservoir, North Carolina. Proc. Annu. Conf. Southeast Assoc. Fish & Wildl. Agencies 53:162-169.

Zuerlein, G. 1981. The white perch, Morone americana (Gmelin) in Nebraska. Nebraska Technical Series No. 8, Nebraska Game and Parks Commission, Lincoln. 108 pp.

Chapter 1

White Perch Invasion of

B. Everett Jordan Reservoir, North Carolina

White Perch Invasion of B. Everett Jordan Reservoir, North Carolina

Russell K. Wong, *Department of Zoology, Campus Box 7617, North Carolina State University, Raleigh, NC 27695–7617*

Richard L. Noble, *Department of Zoology, Campus Box 7617, North Carolina State University, Raleigh, NC 27695–7617*

James R. Jackson, *Department of Zoology, Campus Box 7617, North Carolina State University, Raleigh, NC 27695–7617*

Scott Van Horn, *N.C. Wildlife Resources Commission, Falls Lake Office, 1142 I-85 Service Rd., Creedmoor, NC 27522*

Abstract: From 1987 to 1998, gill netting was conducted annually in Jordan Lake, North Carolina, usually 3 times per year with 9 nets distributed over 3 reservoir sub-basins. White perch *(Morone americana)* began appearing in gill-net samples in 1988. By 1993 they were the second-most abundant species (11.2/net night), following black crappie *(Pomoxis nigromaculatus)* (21.2/net night). White perch catch rates in 1994 (16.1/net night) exceeded rates for other fish captured in gill nets. White perch continued to constitute a large percentage (21.1%) of the gill-net catch from 1995–1998. Analysis of variance of log-transformed white perch catch data detected significant year effects (P=0.0001). No significant season or sub-basin effects were detected. Neither interaction between sub-basin and year nor interaction between sub-basin and season was significant. The 3-way interaction between year, sub-basin, and season was not significant. Interaction between season and year was significant (P=0.0001). Concurrent with increasing white perch abundance during the 12-year study were decreases in abundance of white crappie *(Pomoxis annularis)*, bluegill *(Lepomis macrochirus)*, and flat bullheads *(Ameiurus platycephalus)*. However, this period also corresponded to early succession of the reservoir which was impounded in 1981.

Proc. Annu. Conf. Southeast. Assoc. Fish & Wildl. Agencies 53:162–169

The white perch is a semi-anadromous species native to riverine and estuarine habitats of the mid-Atlantic and New England regions (Jenkins and Burkhead 1993). They have also established populations in inland lakes and reservoirs through introduction or invasion (Carlander 1997). White perch opportunistically prey on zooplankton, benthic macroinvertebrates, and fish depending on season, age, and available food, enabling them to adapt to a variety of habitats (Stanley and Danie 1983). As a result of their opportunistic feeding strategies, and because they are fecund broadcast spawners with no strong preference for substrate type, white perch populations have become successfully established in a variety of inland habitats, including the Great Lakes (Christie 1972, Busch et al. 1977, Hurley and Christie 1977, Boileau 1985), Nebraska reservoirs (Hergenrader and Bliss 1971, Zuerlein 1981), New York lakes (Dence 1952, Clady 1976), Massachusetts ponds (Mosher 1976), and North Carolina reservoirs (Jackson et al. 1995).

White perch spawning is reported to initiate at 10–15 C (Mansueti 1964), making juvenile white perch potential competitive risks to centrarchids and ictalurids, which typically spawn at warmer temperatures (Jackson et al. 1995). Zuerlein (1981) documented declines in black bullhead *(Ameiurus melas)* and suppression of bluegill with increasing abundance of white perch in Nebraska reservoirs. Similarly, Hurley and Christie (1977) reported that declines in centrarchid populations in Lake Ontario coincided with explosions in populations of white perch and alewife *(Alosa pseudoharengus).*

The objectives of this paper are to present long-term gill net data from a North Carolina reservoir documenting establishment and expansion of white perch, and to assess possible responses in the centrarchid and ictalurid populations.

This work, a component of reservoir fish community dynamics studies in Jordan Lake, was conducted through Federal Aid in Sport Fish Restoration Project F-30, Studies 1, 3, and 4. The project was administered by the Division of Boating and Inland Fisheries of the North Carolina Wildlife Resources Commission which provided invaluable support in the data collection and data analysis components of the study. Special thanks to S. Bryant of the North Carolina Wildlife Resources Commission for assisting in the data collection, and to Dr. K. Pollock of the North Carolina State University statistics department for assisting in the statistical analysis.

Methods

B. Everett Jordan Reservoir (Jordan Lake) is a 5,720-ha, flood-control reservoir in North Carolina's Piedmont region. It was impounded in 1981 on the Haw River below its confluence with the New Hope River. Jordan Lake's other designated uses are water supply, recreation, and fish and wildlife habitat. Jordan Lake has a mean depth of 5 m and experiences annual water-level fluctuations of ± 2m. The reservoir is turbid and eutrophic, with a secchi disk visibility of 0.5 m, and chlorophyll-a concentration of 26 μg/liter (N.C. Dep. Nat. Resour. and Community Devel. 1989).

Jordan Lake's main storage basin, the New Hope arm of the lake, is effectively divided by causeways into 3 distinct sub-basins where state roads cross the lake (Jackson et al. 1991). The 3 sub-basins within the New Hope arm of Jordan Lake are connected only by narrow openings at the causeway bridges.

Adult fish were sampled in the 3 sub-basins from 1987–1998 with 9 experimental multi-filament gill nets, 45.7 m by 2.4 m, consisting of 6 equal-length panels with

Table 1. Annual mean gill-net catches per net night, Jordan Lake, 1987–1998.

Common name	Scientific name	1987[a]	1988[a]	1989[b]	1990[a]	1991[b]	1992[a]	1993[a]	1994[a]	1995[c]	1996[d]	1997[e]	1998[a]
Bowfin	*Amia calva*	0.4	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.4
Gizzard shad	*Dorosoma cepedianum*	1.3	3.2	2.3	9.0	40.9	20.8	6.4	10.6	24.1	3.4	25.8	5.2
Common carp	*Cyprinus carpio*	11.1	8.3	6.8	7.3	10.3	6.6	6.2	3.9	4.5	9.6	6.8	4.7
Suckers	*Catostomidae*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
White catfish	*Ameiurus catus*	5.3	2.6	4.2	2.9	5.7	3.2	2.7	5.3	4.3	8.7	7.3	4.6
Brown bullhead	*Ameiurus nebulosus*	1.3	0.6	0.3	0.1	0.2	0.5	0.9	0.1	0.0	0.0	0.1	0.2
Flat bullhead	*Ameiurus platycephalus*	1.4	0.9	0.8	0.9	1.1	0.7	1.1	1.1	1.5	0.7	0.2	0.1
Channel catfish	*Ictalurus punctatus*	3.9	3.4	5.5	5.2	4.5	4.5	6.0	9.0	6.9	15.9	11.3	6.3
White perch	*Morone americana*	0.0	0.1	0.2	1.1	0.9	2.9	11.2	16.1	18.0	5.9	11.6	13.7
White bass	*Morone chrysops*	0.3	0.0	0.0	0.0	0.3	0.3	0.7	0.1	0.5	0.3	0.5	0.6
Striped bass	*Morone saxatilis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Striped bass hybrid	*Morone chrysops* × *M. saxatilis*	2.6	4.4	1.4	2.8	1.5	1.8	1.5	3.3	8.4	1.1	1.4	0.4
Pumpkinseed	*Lepomis gibbosus*	1.1	0.7	0.4	0.0	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.0
Warmouth	*Lepomis gulosus*	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Bluegill	*Lepomis macrochirus*	3.7	2.4	1.3	1.2	0.5	0.2	0.2	0.0	0.4	0.2	0.1	0.0
Largemouth bass	*Micropterus salmoides*	0.3	0.4	0.2	0.2	0.5	0.2	0.9	0.3	0.6	0.1	0.6	0.4
White crappie	*Pomoxis annularis*	3.3	1.2	0.6	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.1
Black crappie	*Pomoxis nigromaculatus*	11.6	10.3	8.6	11.2	9.7	10.3	21.2	11.8	10.8	7.7	8.2	8.7
Yellow perch	*Perca flavescens*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0

a. 27 net nights, 3 seasons.
b. 26 net nights, 3 seasons,
c. 11 net nights, 2 seasons,
d. 9 net nights, 1 season.
e. 18 net nights, 2 seasons.

bar meshes of 25.4, 38.1, 50.8, 63.5, 76.2, and 88.9 mm. The gill nets were fished seasonally—spring, summer, and fall—at fixed stations. Three nets were fished in each lake sub-basin—uplake, midlake, and downlake—so that a total of 27 nets were fished in a full year of sampling. Nets were set perpendicular to shore beginning at depths >2.4 m and fished overnight. Fish were identified to species, weighed to the nearest gram, and measured for total length to the nearest millimeter.

Annual effort across all sub-basins and seasons represented 27 net nights. Exceptions were 1989 and 1991 when 26 gill nets were fished in 3 seasons, 1995 when 11 nets were fished—9 in spring and 2 in fall, 1996, when 9 nets were fished in spring, and 1997 when 18 nets were fished in 2 seasons—9 each in spring and fall. All years were included in a catch-per-unit-effort (CPUE) summary table, but data from 1995, 1996, and 1997 were excluded from the analysis of variance (ANOVA) of catch data in order to analyze only those data resulting from equal effort across sub-basins and seasons.

Catch data were log-transformed and analyzed by split-split-plot analysis of variance to account for repeated measures, where gill net locations were nested within sub-basins and treated as replicates, and where sub-basins were nested within the lake and seasons were nested within years (Maceina et al. 1994, Steel et al. 1997). Because 2 missing data points made the ANOVA unbalanced, type III instead of type I sums of squares were used to compute mean square errors (Steel et al. 1997). Alpha was set at 0.05.

The test for sub-basin effects used the type III mean square for net location by sub-basin as its error term (Error A). Tests for seasonal effects and season by sub-basin interaction used type III mean square for net location by sub-basin by season as its error term (Error B). In the main plot, tests for year effects, year by sub-basin interaction, year by season interaction, and year by sub-basin by season interaction used the mean square error term from the full model (Error C). Because sub-basin and season effects were not significant, and because interaction of sub-basin and season was not significant, catch data were averaged across sub-basins and seasons and tabulated as annual catch per net night (Table 1).

Results

No white perch were caught in 1987 (Table 1). Over the next 4 years, white perch accounted for <3% of the total annual catch, but by 1992, 5.5% of the total gill net catch was composed of white perch. In subsequent years percentages of white perch in the gill net catches increased dramatically, peaking in 1994 at 26% and again in 1998 at 30%.

Catch-effort data (Fig. 1) correspond with percent-abundance data. White perch catch per net night increased from 2.9 in 1992 to 16.1 in 1994. The 1992 white perch catch rate was sixth highest among 14 species captured that year. The 1994 white perch CPUE was highest among 12 species captured. White perch CPUE in 1998, 13.7 white perch per net night, again represented the highest catch rate among 14 species captured.

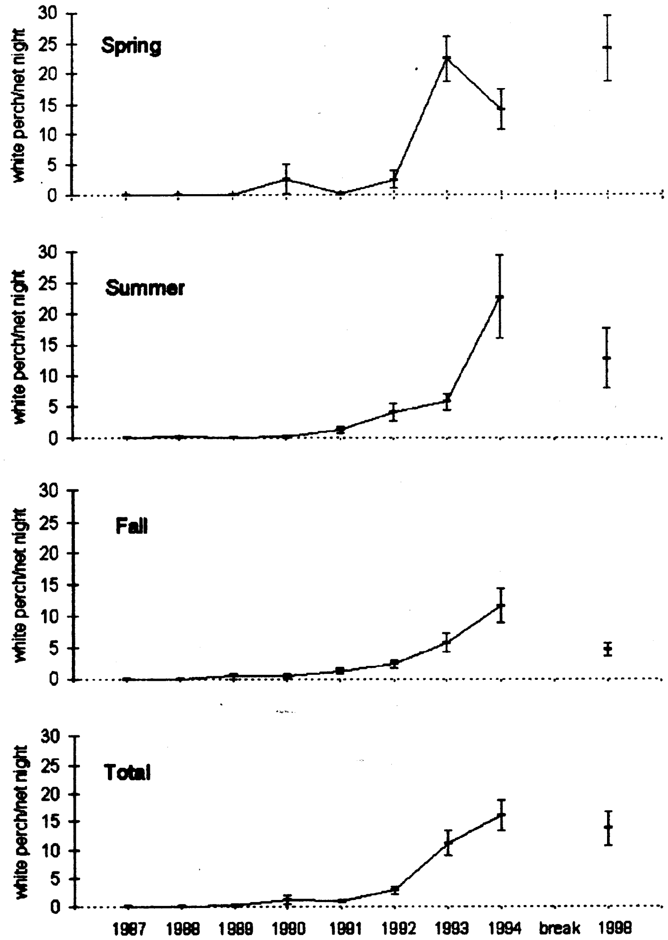

Figure 1. Mean gill-net catch of white perch per net night ±1 SE, by season and by year in Jordan Lake, North Carolina.

Annual increases in lakewide white perch catches were highly significant (P=0.0001). White perch catch did not differ significantly between sub-basins (P=0.4697) or between seasons (P=0.1647). Neither interaction between sub-basin and year (P=0.8094) nor between sub-basin and season (P=0.0908) were significant. The 3-way interaction between year, sub-basin, and season was not significant (P=0.8364). Interaction between season and year was significant (P=0.0001).

Catches of most other species, whether stable or erratic, showed no obvious trends over the 12-year study period (Table 1). Naturally reproducing white bass

(Morone chrysops) were consistently low in abundance. Striped bass hybrids *(M. chrysops* x *M. saxatilis)* and striped bass *(M. saxatilis),* maintained by stocking, were low relative to white perch after 1991.

Declines in catch rates of several species coincided with increases in the white perch population (Table 1). Brown bullhead catches were variable through the first 7 years of the study, peaking at 1.3 fish per net night prior to establishment of white perch, but were rare or absent from gill-net samples following 1993. Catch rates for flat bullheads fluctuated after white perch appeared in gill-net surveys. From the period 1987–1990, an average of 1 flat bullhead and 0.6 white perch were captured per net night. From 1991–95, when white perch catch increased sharply from 0.9 to 18 fish per net night, flat bullhead catch averaged 1.1 fish per net night, peaking in 1995 at 1.5 fish per net night. Catch rates for flat bullheads declined thereafter, falling to 0.7, 0.2, and 0.1 fish per net night in 1996, 1997, and 1998 respectively. Annual variation in catch rates was significant for flat bullheads (P=0.0368), but not for brown bullheads (P=0.2199).

Other declines concurrent with the white perch invasion of Jordan Lake were seen in catch rates of white crappie and bluegill. Average catch rates for 1987–1990 were 1.3 white crappie per net night, and 2.2 bluegill per net night. After white perch catches increased in the early 1990s, catch rates for white crappie in 1995–1998 fell to 0.025 fish per net night. Catch rates in 1995–1998 also declined sharply for bluegill, 0.175 fish per net night. Significant annual variability occurred for both white crappie (P=0.0355) and bluegill (P=0.0012).

Discussion

Our study reveals correlation between the expansion of the white perch population and declines in centrarchid and ictalurid catches in Jordan Lake similar to those reported from Nebraska (Hergenrader and Bliss 1971, Zuerlein 1981) and Lake Ontario (Christie 1972, Hurley and Christie 1977). Zuerlein (1981) hypothesized that increases in white perch, accompanied by a simultaneous decrease in black bullheads, and the long-term suppression of bluegill in Wagon Train Reservoir may have resulted from competition for food, primarily benthic invertebrates. It has also been suggested that white perch consumption of bluegill eggs may in part suppress bluegill populations (Snow et al. 1970). Hurley and Christie (1977) associated centrarchid declines with white perch proliferation, resulting from eutrophication in the Bay of Quinte, Lake Ontario.

However, attempts to correlate population fluctuations between fish species warrant caution in the absence of data that directly address possible mechanisms (Carlander 1955). If food is limited, intratrophic competition between white perch and other fishes may negatively affect established species (Parrish and Margraf 1990). But analyzing direct competition on the same trophic level fails to recognize that predator-prey interaction occurs at several trophic levels (Noble 1986).

Linking the declining numbers of white crappie with the increasing numbers of white perch in Jordan Lake must take into account that crappie year classes tend to exhibit cyclic fluctuations that can result in misleading trends in short-term data sets (Maceina and Stimpert 1998). Furthermore, declines in white crappie catches in Jordan Lake began prior to the expansion of the white perch population. Catches of black crappie, the dominant species of crappie in the lake, have not declined concurrent with increases in white perch (Jackson et al. 1995).

The decrease in catch of flat bullheads in Jordan Lake lags behind the appearance and spread of white perch. This inverse, albeit delayed, relationship is similar to the fish community dynamics observed in Wagon Train Reservoir in Nebraska following the white perch invasion (Zuerlein 1981). However, time-series analyses of other reservoirs suggest that bullhead abundance in reservoirs can reach high levels immediately following impoundment, but decline rapidly thereafter (Hashagen 1973, Timmons et al. 1977). In those studies, rapid declines in bullhead numbers from initial peaks documented in Merle Collins Reservoir and West Point Reservoir occurred in <5 years post-impoundment. Jordan Lake was impounded in 1981, and no gill-net catch data for bullheads were available for the years immediately following impoundment. However, declines in bullhead catches documented in our study took place >5 years after impoundment, which would be inconsistent with the almost immediate declines observed in those earlier studies. In light of the timing of declining bullhead catches in Jordan Lake, and similar results from older reservoirs in Nebraska (Zuerlein 1981), the role of white perch in the decrease of bullheads documented in our study cannot be discounted.

Further research is needed to elaborate trophic interactions within reservoir fish communities before the impacts of introduced or invading species such as white perch can be understood fully. However, our results, combined with earlier reports from Nebraska reservoirs (Hergenrader and Bliss 1971, Zuerlein 1981) and Lake Ontario (Christie 1972, Hurley and Christie 1977) suggest that white perch, once established, can disrupt reservoir fish populations. White perch reach sizes in their native, estuarine habitats that can support important recreational and commercial fisheries (Stanley and Danie 1983), but reservoir populations tend to stunt (Zuerlein 1981, R. K. Wong, unpubl. data) making them unlikely to reach sizes attractive to recreational anglers. Their role in reservoir fish communities therefore warrants additional study.

Literature Cited

Boileau, M. G. 1985. The expansion of white perch, *Morone americana,* in the lower great lakes. Fisheries 10(1):6–10.

Busch, W. D. N., D. H. Davies, and S. J. Nepszy. 1977. Establishment of the white perch, *Morone americana,* in Lake Erie. J. Fish. Res. Board Can. 34:1039–1041.

Carlander, K. D. 1955. The standing crop of fish in lakes. J. Fish. Res. Board Canada 12(4):543–570.

———. 1997. Handbook of freshwater fishery biology, vol. 3. Iowa State University Press, Ames. 397pp.

Christie, W. J. 1972. Lake Ontario: effects of exploitation, introductions, and eutrophication on the salmonid community. J. Fish. Res. Board Can. 29:913–929.

Clady, M. D. 1976. Change in abundance of inshore fishes in Oneida Lake, 1916 to 1970. N. Y. Fish and Game J. 23(1):73–81.

Dence, W. A. 1952. Establishment of white perch, *Morone americana,* in central New York. Copeia 3:200–201.

Hashagen, K. A. 1973. Population structure changes and yields of fishes during the initial eight years of impoundment of a warmwater reservoir. Calif. Fish and Game 59(4):221–244.

Hergenrader, G. L. and Q. P. Bliss. 1971. The white perch in Nebraska. Trans. Am. Fish. Soc. 100(4):734–738.

Hurley, D. A. and W. J. Christie. 1977. Depreciation of the warmwater fish community in the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Can. 34:1849–1860.

Jackson, J. R., R. L. Noble, and E. R. Irwin. 1995. Largemouth bass recruitment in Jordan Lake. Final Rep. Fed. Aid in Sport Fish Restor. Proj. F-30–3. N.C. Wildl. Resour. Comm., Raleigh. 100pp.

———, J. A. Rice, R. L. Noble, and S. C. Mozley. 1991. Mechanisms of reservoir fish community dynamics. Final Rep. Fed. Aid in Sport Fish Restor. Proj. F-30–1. N.C. Agric. Res. Serv., N.C. State Univ., Raleigh. 104pp.

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. Am. Fish. Soc., Bethesda, Md. 1080pp.

Maceina, M. J. and M. R. Stimpert. 1998. Relations between reservoir hydrology and crappie recruitment in Alabama. North Am. J. Fish. Manage. 18:104–113.

———, P. W. Bettoli, and D. R. DeVries. 1994. Use of a split-plot analysis of variance design for repeated-measures fishery data. Fisheries 19(3):14–20.

Mansueti, R. 1964. Eggs, larvae, and young of the white perch, *Roccus americanus,* with comments on its ecology in the estuary. Chesapeake Sci. 5(1–2):3–45.

Mosher, T. D. 1976. Comparison of freshwater pond and estuarine populations of the white perch, *Morone americana* (Gmelin), in the Parker River, Massachusetts. M.S. Thesis, Univ. Mass. 77pp.

Noble, R. L. 1986. Management of reservoir fish communities by influencing species interactions. Pages 137–143 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 80's. South. Div., Am. Fish. Soc. Bethesda, Md.

North Carolina Department of Natural Resources and Community Development. 1989. 1988 North Carolina lakes monitoring report 89–04, Raleigh, N.C. 256pp.

Parrish, D. L. and F. J. Margraf. 1990. Interactions between white perch *(Morone americana)* and yellow perch *(Perca flavescens)* in Lake Erie as determined from feeding and growth. Can. J. Fish. Aquat. Sci. 47:1779–1787.

Snow, H., A. Ensign, and J. Klingbiel. 1970. The bluegill, its life history, ecology and management. Wis. Conserv. Dep. Publ. 230:1–14.

Stanley, J. G. and D. S. Danie. 1983. White perch. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic). U.S. Fish and Wildl. Serv., Washington, D.C. 14pp.

Steel, R. G. D., J. H. Torrie, and D. A. Dickey. 1997. Principles and procedures of statistics: a biometrical approach, 3rd ed. McGraw-Hill Book Co., New York, N.Y. 666pp.

Timmons, T. J., W. L. Shelton, and W. D. Davies. 1977. Initial fish population changes following impoundment of West Point Reservoir, Alabama-Georgia. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31:312–317.

Chapter 2

Growth, Condition and Diet of White Perch (*Morone americana*)

in B. Everett Jordan Reservoir

Abstract. - Gill netting was conducted on B. Everett Jordan Reservoir (Jordan Lake), North Carolina, from 1987-1998 with nine nets distributed over three reservoir sub-basins. An earlier study documenting the expansion of white perch (Morone americana) in Jordan Lake concluded that additional studies were warranted to assess adult white perch age structure, growth, relative weights and food habits. To this end, 356 white perch were extracted from the 1998 gill net samples and examined in a laboratory. White perch were found to live to age 7 in Jordan Lake where they shift food habits seasonally from zooplankton and diptera larva in the spring to young shad in the fall. Relative weights and mean calculated total lengths at annulus formation suggest that the Jordan Lake white perch population is in good condition, marked by rapid first- and second-year growth (83 and 126 mm at annulus formation, respectively) surpassing that of white perch populations throughout the eastern seaboard including the Roanoke River.

INTRODUCTION

The white perch is a semi-anadromous species native to riverine and estuarine habitats of the mid-Atlantic and New England regions (Jenkins and Burkhead 1993). They have also established populations in inland lakes and reservoirs through introduction or invasion (Carlander 1997). White perch opportunistically prey on zooplankton, benthic macroinvertebrates, and fish depending on season, age, and available food, enabling them to adapt to a variety of habitats (Stanley and Danie 1983). As a result of their opportunistic feeding strategies, and because they are fecund broadcast spawners with no strong preference for spawning substrate type, white perch populations have become successfully established in a variety of inland habitats, including the Great Lakes (Christie 1972; Busch et al. 1977; Hurley and Christie 1977; Boileau 1985), Nebraska reservoirs (Hergenrader and Bliss 1971; Zuerlein 1981), New York lakes (Dence 1952; Clady 1976), Massachusetts ponds (Mosher 1976), and North Carolina reservoirs (Jackson et al. 1995; Wong et al. 1999).

White perch spawning is reported to initiate at 10-15^0 C (Mansueti 1964), making juvenile white perch potential competitive risks to centrarchids and ictalurids, which typically spawn at warmer temperatures (Jackson et al. 1995). Zuerlein (1981) documented declines in black bullhead (Ameiurus melas) and suppression of bluegill with increasing abundance of white perch in Nebraska reservoirs. Similarly, Hurley and Christie (1977) reported that declines in centrarchid populations in Lake Ontario coincided with explosions in populations of white perch and alewife (Alosa pseudoharengus).

Wong et al. (1999) described the establishment of white perch in Jordan Lake, North Carolina, and concurrent changes in the fish community. The objectives of this paper are to assess age structure, growth, relative weights and food habits of Jordan Lake white perch in context with other North Carolina white perch populations as well as others from the Southeast.

METHODS

B. Everett Jordan Reservoir (Jordan Lake) is a 5,720-hectare, flood-control reservoir in North Carolina's piedmont region. It was impounded in 1981 on the Haw River below its confluence with the New Hope River. Jordan Lake's other designated uses are water supply, recreation, and fish and wildlife habitat. Jordan Lake has a mean depth of five meters and experiences annual water-level fluctuations of two meters. The reservoir is turbid and eutrophic, with a mean secchi disk visibility of 0.5 m, and mean chlorophyll-a concentration of 26 μg/L (NCNRCD 1989).

Jordan Lake's main storage basin, the New Hope arm of the lake, is effectively divided by causeways into three distinct sub-basins where state roads cross the lake (Jackson et al. 1991). The three sub-basins within the New Hope arm of Jordan Lake are connected only by narrow openings at the causeway bridges.

White perch first appeared in Jordan Lake samples in 1987 (Wong et al. 1999). Their abundance, as indicated by gillnet catches, rapidly increased to form a substantial part of the littoral community.

Adult white perch were sampled in the three sub-basins in 1998 with nine experimental multi-filament gill nets, 45.7 m by 2.4 m, consisting of six, equal-length panels with bar meshes of 25.4, 38.1, 50.8, 63.5, 76.2, and 88.9 mm. The gill nets were fished seasonally – spring, summer, and fall – at fixed stations. Three nets were fished in each lake sub-basin – uplake, midlake, and downlake – so that a total of 27 nets were fished in a full year of sampling (Figure 1). Nets were set perpendicular to shore beginning at depths >2.4 m and fished overnight.

Young-of-year and juvenile white perch were sampled via nighttime shoreline electrofishing from Little Beaver Creek, a 64-ha embayment contiguous with the furthest downlake sub-basin of the New Hope arm, and Bush Creek, a 31-ha embayment in the midlake sub-basin of the New Hope arm (Figure 2).

Nighttime electrofishing samples were collected every third week from 1987-1994 in Little Beaver Creek and monthly from July to November in 1997-1998 from both Little Beaver and Bush Creeks at five sites using a 260-volt, straight DC delivered by a hand-held, triangular anode fitted with a 6-mm bar mesh net. Electrofishing was conducted from a 4.2-m, flat-bottomed boat poled along the shoreline. Depths of up to about 0.7 m were sampled, but shallower depths of about 0.2 m or less were more typically sampled.

All fish, excluding shad, were collected to obtain a minimum sample size of 75 fish per site representative of the littoral species composition. Total electrofishing times for each site were recorded for calculating species-specific catch per unit effort (CPUE),

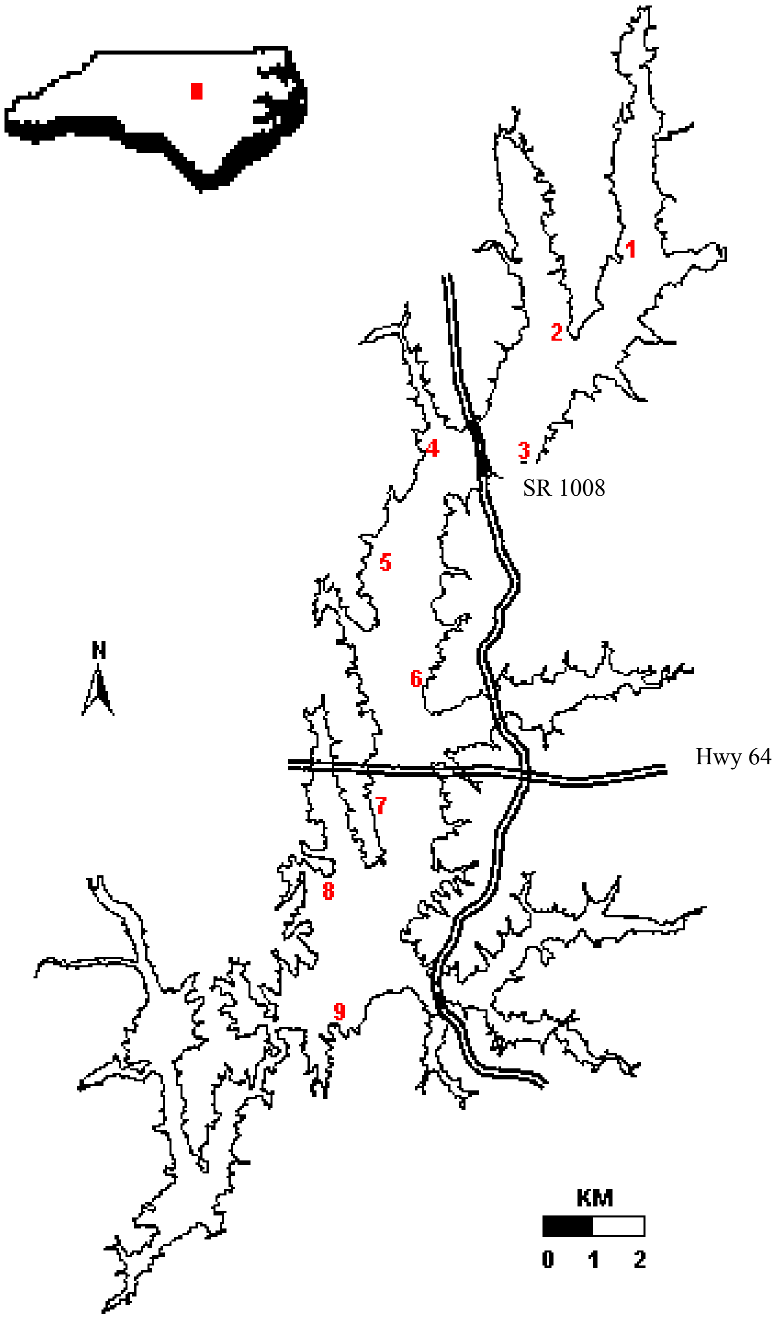

Figure 1. Nine gill net sites located on B. Everett Jordan Reservoir, Chatham County, North Carolina.

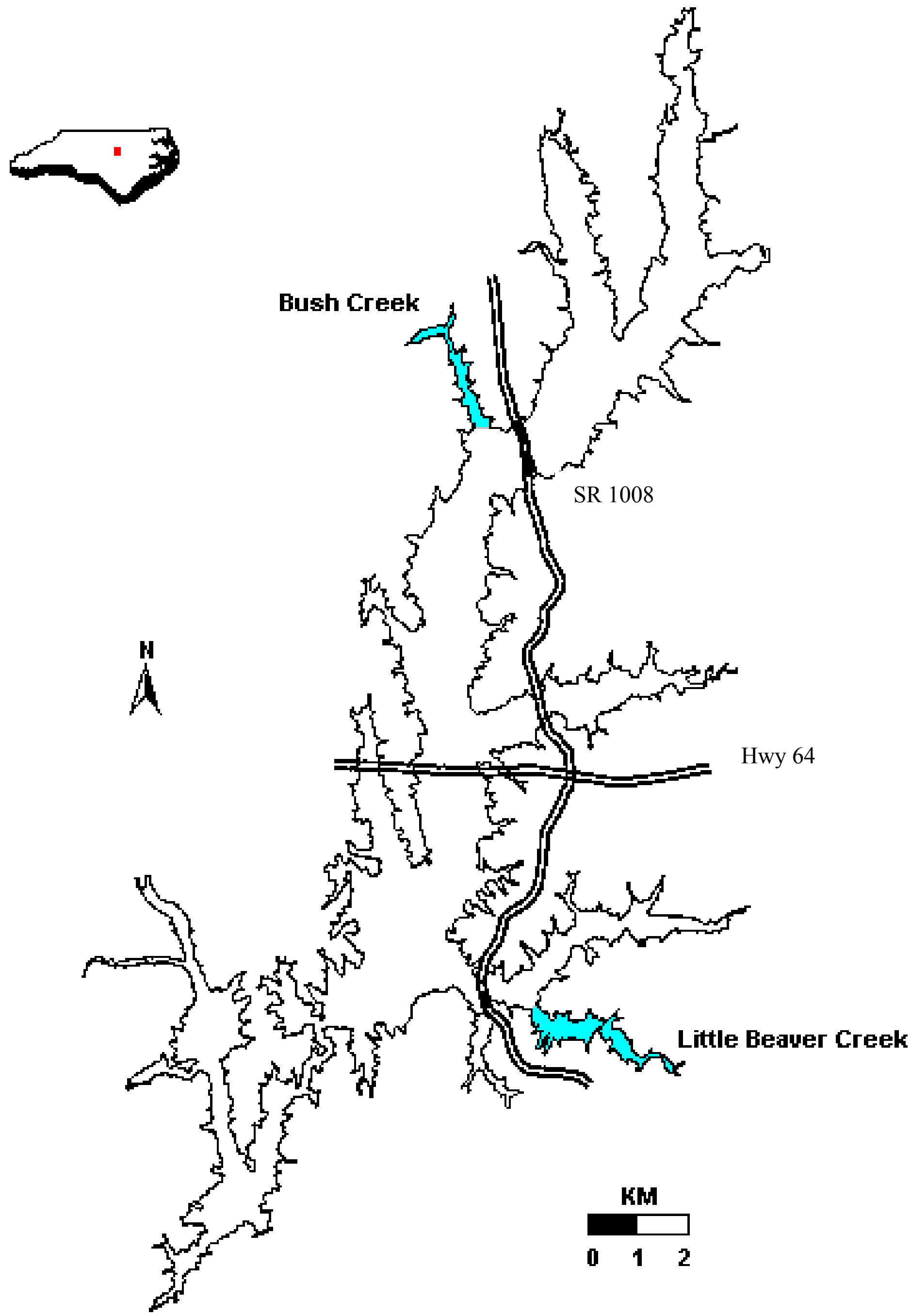

Figure 2. Juvenile white perch were sampled via nighttime shoreline electrofishing from Little Beaver Creek and Bush Creek, B. Everett Jordan Lake, Chatham County, North Carolina.

and mean catch rates calculated as catch per 20 minutes, the average time spent sampling each site.

White perch extracted via gill nets and electrofishing samples were preserved on ice and taken to a lab where they were weighed to the nearest gram and measured for total length to the nearest millimeter. The fish were then dissected to determine sex and to remove saggital otoliths and stomachs. Otoliths were cleaned, dried and submerged in glycerin to clarify the annuli for aging (Maceina and Betsill 1987). Thirty otolith pairs initially were examined independently by two separate readers without reference to fish size. Left and right otoliths were selected randomly by readers. One reader aged otoliths using the whole otolith aging technique; the other by sectioning and polishing the otolith (Taubert and Coble 1977). All otoliths were subsequently aged using the whole otolith technique.

Lengths at age were calculated by recording mean total lengths of white perch of the same cohort in the latest fall and earliest spring sample. The difference in a cohort's mean total length was divided by the number of days between the fall and spring sample to determine an estimate of daily change in length of a white perch cohort. This daily estimate was multiplied by the number of days falling between the fall sample and January 1, and the product was added to the mean fall total length to estimate length at age for a given cohort. This was repeated for all cohorts.

Stomachs were preserved in alcohol and analyzed later by sorting and counting food items using a dissecting microscope. Stomach contents were classified in general prey categories — zooplankton, fish eggs, dipteran larvae, terrestrial insects and fish.

Summary data were calculated for white perch based on juveniles and mature fish — respectively, those age 2-3, and those older than age 3 (Mansueti 1961). Diet data were presented by change in percent occurrence across seasons.

Relative weights of individual fish were calculated using the standard weight equation of Bister et al. (2000). The 1998 data were compared with data from previous years (1987-1998). Based on total catches for 1998, catch curves were developed and a logistic regression line fitted by the least squares method.

RESULTS

The 1998 gill net samples captured 356 white perch during spring, summer and fall samples conducted in uplake, midlake and downlake locations. Effort from each seasonal sample represented nine gill nets fished overnight in sets of three in each lake region. White perch total lengths ranged from 152-326 mm, representing age 2 to age 7 fish.

Readers aging otoliths using the whole otolith technique and the sectioning and polishing technique achieved 97 percent agreement on ages of the 30 initial fish, which ranged in age from 2 to 6. The sole disagreement occurred when a malformed otolith was examined. As a result of the close agreement, and the relatively difficult task of sectioning, the whole otolith aging technique was employed for the balance of the study. The present study found that Jordan Lake white perch reach a maximum age of 7. Age 3 and 4 fish dominated the catch; however, catch curve analysis suggests Jordan Lake white perch exhibit sex-specific selectivity curves (Figure 3). Males appear to recruit

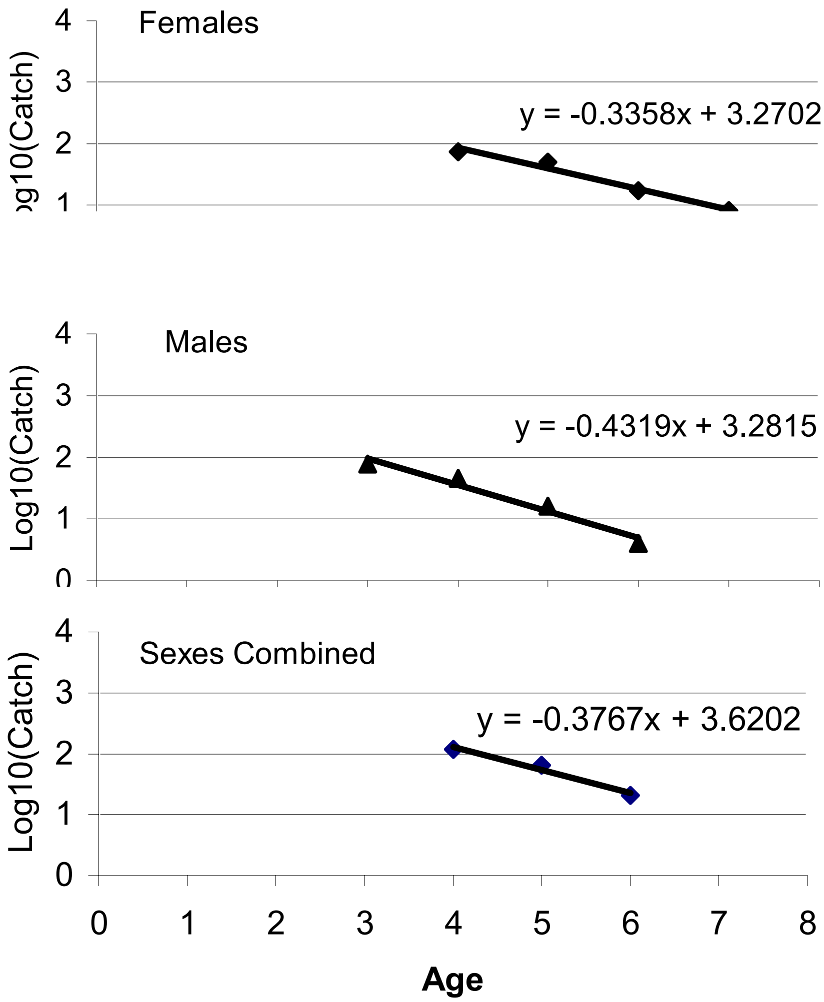

Figure 3. Catch curves for white perch based on 1998 spring, summer and fall gill net samples, B. Everett Jordan Reservoir. Regression lines were fitted by least squares method.

fully into the sampling gear at age 3 but females do not recruit fully into the fishery until age 4.

Males mature earlier than females, with all males having sexually matured by age group 2. All females were sexually mature by age 3, but two of four age 2 females captured in the spring sample were immature.

In general, female white perch live longer and grow faster than male white perch in Jordan Lake, but that difference does not become discernable until white perch exceed age 3 (Figure 4). Combined mean calculated lengths at age for Jordan Lake white perch are 148 mm for age 3 fish, 176 mm for age 4 fish, 211 mm for age 5 fish, 236 mm for age 6 fish, and 253 mm for age 7 fish (Table 1). Calculated lengths at age suggest Jordan Lake white perch experience the greatest incremental increase in length between ages 0 and 1.

Jordan Lake white perch in 1998 had a mean relative weight in spring of 89 (range 60-133), summer mean relative weight of 82 (range 70-96), and fall mean relative weight of 81 (range 60-93). Mean summer and fall relative weights differed significantly from the mean spring relative weight ($\underline{P}<0.05$). Between-season analyses of white perch relative weights in previous years were precluded by missing data sets, so relative weight data were summed by year. No differences between years in relative weights were detected. (Figure 5). Jordan Lake white perch relative weights calculated for 1987-1998 suggest white perch exhibit a seasonal fluctuation, peaking during pre-spawn spring samples (Figure 5).

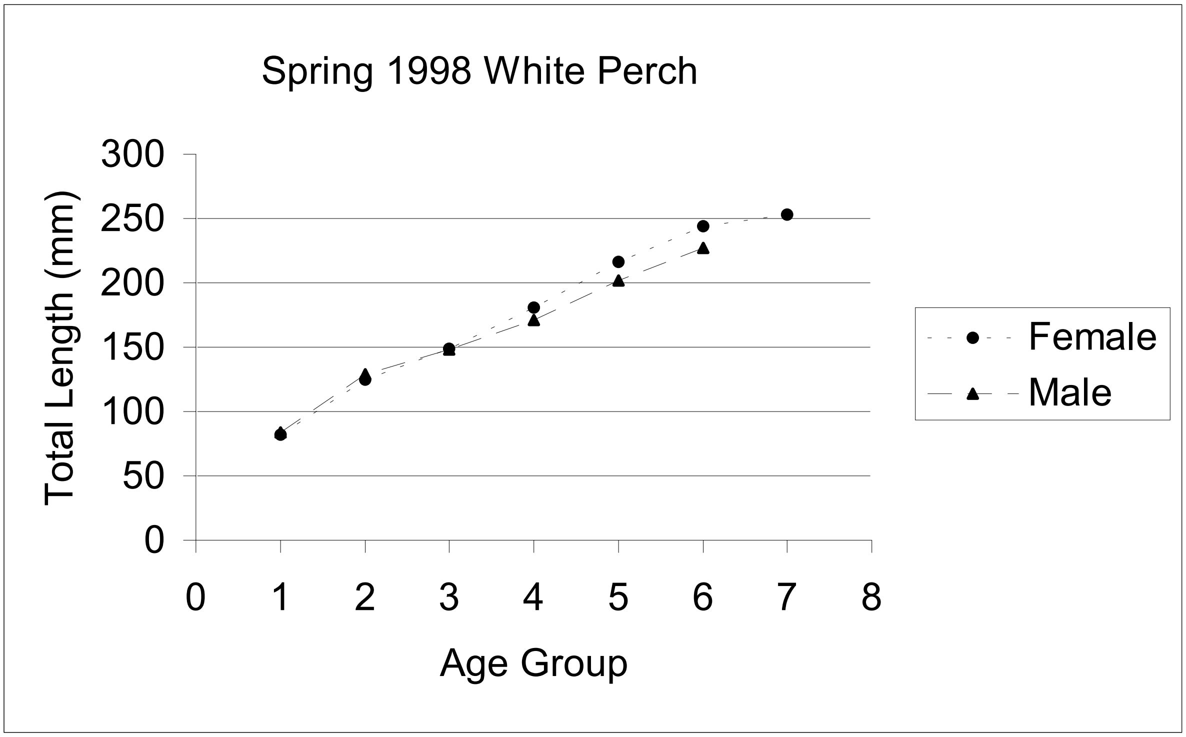

Figure 4. Calculated lengths and increments of growth in length for male and female white perch in Jordan Lake.

Table 1 - Mean calculated total lengths (mm) at annulus formation for white perch along the United States' eastern seaboard.

Annulus Formation	A* **	B	C	D	E	F	G	H	I
1st	83	74	73	61	64	55	89	87	87
2nd	126	127	113	99	97	87	131	132	132
3rd	148	171	135	124	120	120	160	162	153
4th	176	193	151	144	142	146	181	183	202
5th	211	209	164	159	159	168	210	208	242
6th	236	222	181	172	176	188		232	
7th	253	233	198	186	193	204			
8th		251	209	199	209	218			
9th		264	221	214	220				
10th		273	241	222	229				

A = B. Everett Jordan Reservoir, North Carolina (*present study)
(**includes age 1 and age 2 fish from electrofishing samples)

B = Quabbin Reservoir, Massachusetts

C = Patuxent Estuary, Maryland

D = James River, Virginia

E = York River, Virginia

F = Roanoke River, North Carolina

G = Blewett Falls Reservoir, North Carolina

H = Tillery Reservoir, North Carolina

I = Badin Reservoir, North Carolina

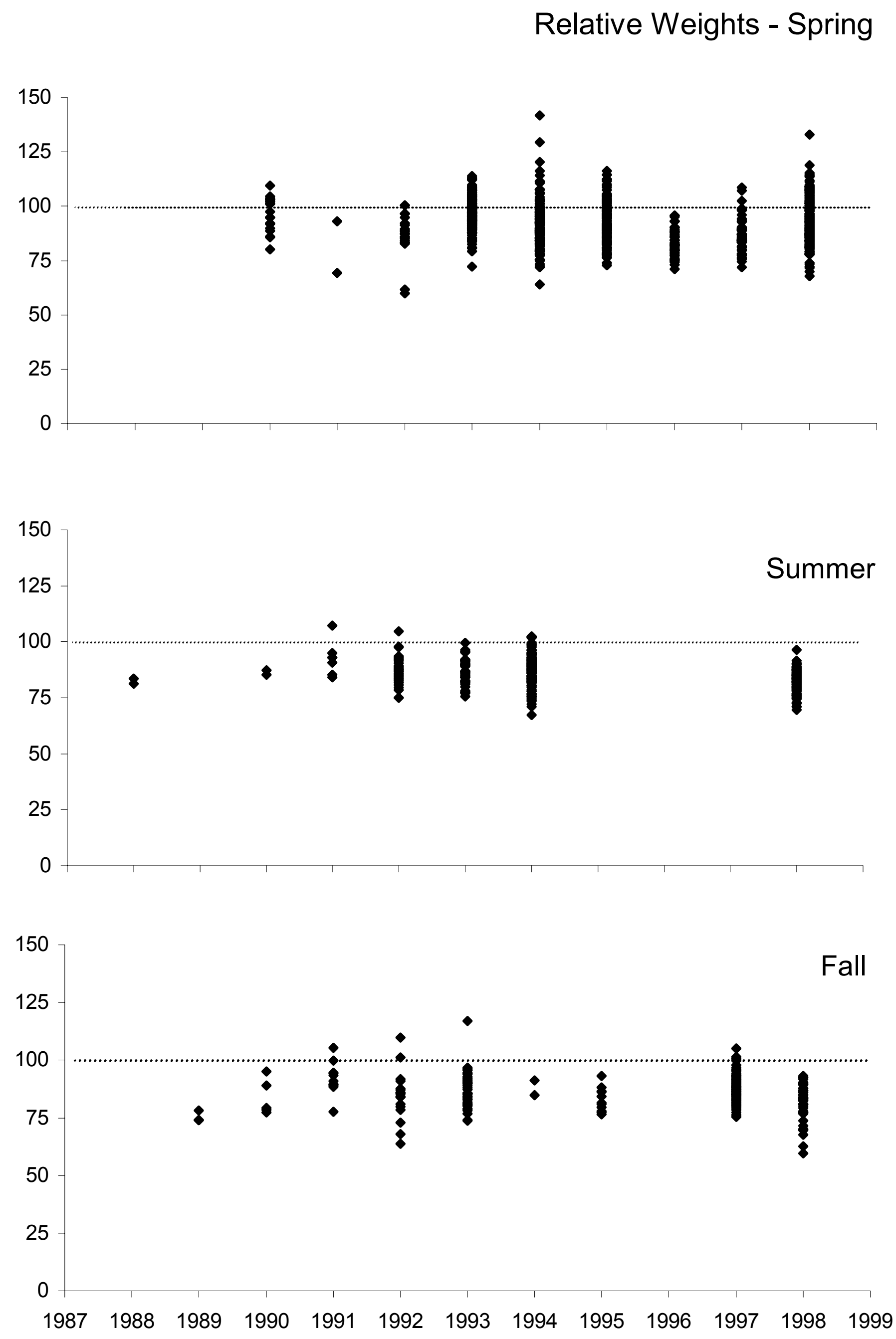

Figure 5. Relative weights of Jordan Lake white perch were consistent over years. The season difference in relative weight can be attributed to the pre-spawn spring sampling period.

Insects generally dominated the stomach contents of Jordan Lake white perch, as represented by frequency of occurrence (Figure 6). Jordan Lake white perch seasonally shift in food utilization. The shift in prey is consistent throughout all ages, but more pronounced in age 4 fish and older (Figure 6). Spring diet analyses of white perch stomachs reveal zooplankton occurred in 19 percent of white perch ages 2-3. Among white perch older than age 3, zooplankton occurred in about 14 percent and diptera larvae in 41 percent of fish collected in the spring. Zooplankton become less important in summer as Jordan Lake white perch begin to shift to mixed insectivory and piscivory. By fall, Jordan Lake white perch have shifted largely to piscivory, selecting YOY shad as their preferred food item. Fish appear in stomachs of 55 percent of white perch older than three and in 38 percent of white perch age 2-3.

DISCUSSION

Jordan Lake white perch are short-lived relative to white perch populations in the northeastern United States (McCaig and Mullan 1960; March 1976), but they have similar life spans as other white perch populations found in North Carolina reservoirs including Blewett Falls, Tillery and Badin (Tatum 1961), as well as the Roanoke River (Conover 1958) (Table 1). Between regions of the United States, white perch populations vary greatly in life span. Some Maine white perch have been reported to reach 16 years old (Cooper 1939). The average life span of Maine white perch is seven years (Cooper 1939) and about four years in Maryland (Mansueti 1961). Previous studies of various North Carolina impoundments report average life spans of slightly more than five years (Tatum 1961). The current study of Jordan Lake white perch has recorded seven-year-old

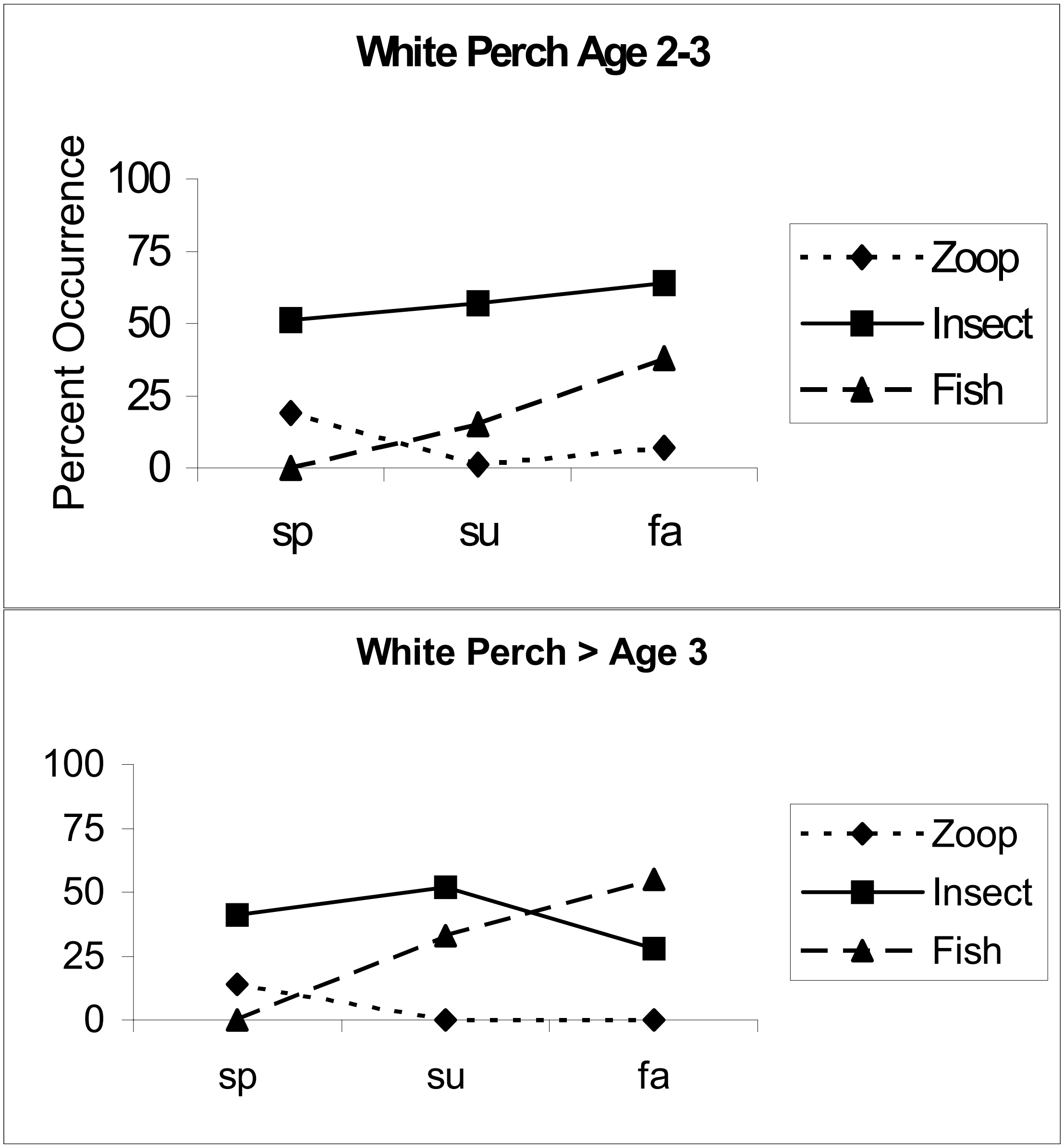

Figure 6. Change in the percent occurrence of zooplankton, insects and fish in white perch diets by season for 1998.

fish, but white perch sampled from their natural environs in the Roanoke River by Conover (1958) have been reported to reach eight years old. Despite the recent and sharp increase in the Jordan Lake white perch population in 1993-1994 (Wong 1999), the age and size structure of the population conforms with those found in other North Carolina waters (Table 1).

In their first year of life, white perch attain larger sizes in the South, but not in later years (Carlander 1997). This holds true for Jordan Lake white perch which were calculated to measure 83 mm at annulus formation, more than 10 mm longer than white perch in Patuxent Estuary, James River, York River and Roanoke River. It should be noted that the length-at-age calculations of the present study assume average overwinter daily growth to be consistent. Differences in overwinter daily growth will bias the length-at-age calculations, but the less the overwinter change in white perch mean length, the less likely it is to be biased. The present study also assumes gill nets and shoreline electrofishing collected representative samples of the Jordan Lake white perch population. Length-at-age calculations for Jordan Lake white perch yielded results suggesting faster growth than perch populations in other inland systems across the country and similar growth rates as those exhibited by white perch in other inland systems in North Carolina (Table 1). While bias in aging and sampling selectivity cannot be ruled out, the Jordan Lake data conformed in part with data from other North Carolina reservoirs supporting white perch populations.

Collectively, it appears North Carolina reservoirs support white perch growth rates surpassing those from other regions (Table 1). At age 5, North Carolina white perch from Badin Lake attained the same length as age 10 Patuxent River perch in Maryland. Age 6 white perch from Lake Tillery exceeded calculated lengths at age for age 10 white perch from the York River, Virginia, and age 5 white perch from Blewett Falls approximated calculated lengths at age for age 9 white perch in the James River, Virginia. Jordan Lake white perch also exhibit growth rates that suggest the fish are not stunting. While white perch reportedly have a tendency to overpopulate and stunt (Cooper 1941; Hergenrader and Bliss 1971; Zuerlein 1981), relative weights of Jordan Lake white perch suggest otherwise (Figure 5).

Mansueti (1961) posits that food supply may be a primary limiting factor when white perch populations stunt. He suggested that white perch growth and population size were negatively correlated. On Jordan Lake, however, catch per unit effort of adult white perch rose sharply, then stabilized in the mid 1990s. Coupled with data suggesting that Jordan Lake white perch are still capable of reaching sizes typical of other North Carolina perch populations, the sustained catch rates suggest Jordan Lake white perch have attained some semblance of an equilibrium. Stroud (1955) and Saila (1957) respectively came to similar conclusions regarding Rhode Island and Massachusetts lakes and reservoirs. They reported that stunting of white perch was atypical on the inland waters they were investigating.

From a dietary standpoint, concerns about white perch stunting in Jordan Lake may have been warranted. White perch are opportunistic feeders, shifting to piscivory when suitably sized prey are available (Carlander 1997). However, Jordan Lake white perch of all age and size classes appear to shift to insectivory and planktivory in the spring (Figure 6). This seasonal shift to less calorically valuable food items has been documented in stunted white perch populations in Maine ponds (Hines 1981), Nebraska reservoirs (Hergenrader 1971), Connecticut lakes (Webster 1942) and Lake Ontario (Haymes 1982).

White perch mouth gape may be limiting their food preferences in spring because preyfish surviving winter may attain sizes too large for white perch to eat (Person et al. 1996). Jackson et al. (1991) observed overlapping spawning seasons of Jordan Lake gizzard and threadfin shad where shad length-frequencies indicated that growth rates of the two species were consistent among years. Because gizzard shad reportedly spawned before threadfin shad (Jackson et al. 1991), they achieved greater mean lengths at age but both species exceeded mean total lengths of 70 mm by October. With age 7 white perch reaching 253 mm lengths at age (Table 1), their spring shift in diet to insects and zooplankton most likely can be attributed to the size of threadfin and gizzard shad surviving over winter.

Jordan Lake white perch do not appear to be stunting at this time, notwithstanding the documented stunting of white perch in these other studies. Mansueti (1961) concluded that food supply and stunting do not necessarily have a cause-and-effect relationship, despite the earlier work of Cooper (1939) on 31 lakes and ponds in Maine. Instead, Mansueti (1961) reported that density-dependent factors such as angler utilization and available habitat warrant additional investigation before stunting can be understood.

The role of white perch in southern reservoirs has yet to be elucidated in its entirety, but this study along with other studies of white perch populations in North Carolina reservoirs suggest white perch may not pose an imminent threat to centrarchids and ictalurids as they apparently do in northern inland systems. Nor, it appears, do landlocked white perch populations harm themselves by overpopulating and stunting. On the other hand, specific life history traits of young white perch in southern reservoirs has yet to be examined in great detail. Chapter three of this study attempts to document preferred habitats and food of young white perch, and identify their role within Jordan Lake's littoral community.

Literature Cited

Bister, T.J., D.W. Willis, M.L. Brown, S.M. Jordan, R.M. Neumann, M.C. Quist, and C.S. Guy. 2000. Proposed standard weight equations and standard length categories for 18 warmwater nongame and riverine fish species. North American Journal of Fisheries Management 20:570-574.

Boileau, M.G. 1985. The expansion of white perch, Morone americana, in the lower great lakes. Fisheries 10(1):6-10.

Busch, W.D.N., D.H. Davies, and S.J. Nepszy. 1977. Establishment of the white perch, Morone americana, in Lake Erie. J. Fish. Res. Board Can. 34:1039-1041.

Carlander, K.D. 1997. Handbook of freshwater fishery biology, vol. 3. Iowa State University Press, Ames, Iowa 397 pp.

Christie, W.J. 1972. Lake Ontario: effects of exploitation, introductions, and eutrophication on the salmonid community. J. Fish. Res. Board Can. 29:913-929.

Clady, M.D. 1976. Change in abundance of inshore fishes in Oneida Lake, 1916 to 1970. N. Y. Fish and Game J. 23(1):73-81.

Conover, N.R. 1958. Investigations of the white perch, Morone americana (Gmelin) in Albemarle Sound and the lower Roanoke River, North Carolina. M.S. Thesis, N.C. State College Univ. Mass. 58 pp.

Cooper, G.P. 1939. A biological survey of the waters of York County and the southern part of Cumberland County, Maine. Maine Dept. of Inland Fisheries and Game. Fish Survey Report 1:1-58.

Cooper, G.P. 1941. A biological survey of lakes and ponds of the Androscoggin and Kennebec River drainage system in Maine. Maine Dept. of Inland Fisheries and Game. Fish Survey Report 4:1-238.

Dence, W.A. 1952. Establishment of white perch, Morone americana, in central New York. Copeia 3:200-201.

Hergenrader, G.L., and Q.P. Bliss. 1971. The white perch in Nebraska. Transactions of the American Fisheries Society 100(4):734-738.

Hines, R. 1981. The ecological significance of a stunted white perch population in a eutrophic Maine pond. M.S. Thesis. University of Maine, Orono. 45 pp.

Hurley, D.A. and W.J. Christie. 1977. Depreciation of the warmwater fish community in the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Can. 34:1849-1860.

Jackson, J.R., J.A. Rice, R.L. Noble, and S.C. Mozley. 1991. Mechanisms of reservoir fish community dynamics. North Carolina Agricultural Research Service, N.C. State University, Federal Aid in Sport Fish Restoration, Project F-30-1, Final Report, Raleigh, N.C.

Jackson, J.R., R.L. Noble, and E.R. Irwin. 1995. Largemouth bass recruitment in Jordan Lake. Final Report, Federal Aid in Sport Fish Restoration Project F-30-3, N.C. Wildlife Resources Commission, Raleigh. 100 pp.

Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater fishes of Virginia. AFS, Bethesda, Md.

Maceina, M.J. and R.K. Betsill. 1987. Verification and use of whole otoliths to age white crappie. Pages 267-278 in R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press. Ames.

Mansueti, R.J. 1961. Movements, reproduction and mortality of the white perch, Roccus americanus, in the Patuxent Estuary, Maryland. Chesapeake Sci. 2:142-205.

Mansueti, R.J. 1964. Eggs, larvae, and young of the white perch, Roccus americanus, with comments on its ecology in the estuary. Chesapeake Sci. 5(1-2):3-45.

Marcy, B.C. Jr. 1976. Fishes of the lower Connecticut River and the effects of the Connecticut Yankee Plant. Pages 61-113 in D. Merriman and L.M. Thorpe, editors. The Connecticut River ecological study: the impact of a nuclear power plant. Allen Press. Lawrence, Kansas.

Mosher, T.D. 1976. Comparison of freshwater pond and estuarine populations of the white perch, Morone americana (Gmelin), in the Parker River, Massachusetts. M.S. Thesis, Univ. Mass. 77 pp.

NCNRCD (North Carolina Department of Natural Resources and Community Development). 1989. 1988 North Carolina lakes monitoring report 89-04, Raleigh, N.C.

Person, L., J. Andersson, E. Wahlstrom and P. Eklov. 1996. Size- specific interactions in lake systems: predator gape limitation and prey growth rate and mortality. Ecology 77:900-911.

Saila, S.B., and D. Horton. 1957. Fisheries investigations and management in Rhode Island lakes and ponds. Rhode Island Dept. of Agr. and Conservation. Div. of Fish and Game. Fisheries Publication 3:29-30.

Schaeffer, J.S., and F.J. Margraf. 1986. Population characteristics of the invading white perch (Morone americana) in western Lake Erie. J. Great Lakes Res. 12:127-131.

Stanley, J.G. and D.S. Danie. 1983. White perch. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic). U.S. Fish and Wildlife Service, Washington, D.C. 14 pp.

Tatum, B. 1961. Yadkin and lower Catawba River reservoirs. N.C. Wildlife Resources Commission, Federal Aid Project F5R and F6R Job Completion Report 1:99-158.

Webster, D.A. 1942. Food progression in young white perch, Morone americana (Gmelin), from Bantam Lake, Connecticut. Trans. Amer. Fish. Soc. 72:136-144.

Wong, R.K., R.L. Noble, J.R. Jackson, and S. Van Horn. 1999. White Perch Invasion of B. Everett Jordan Reservoir, North Carolina. Proc. Annu. Conf. Southeast Assoc. Fish & Wildl. Agencies 53:162-169.

Zuerlein, G. 1981. The white perch, Morone americana (Gmelin) in Nebraska. Nebraska Technical Series No. 8, Nebraska Game and Parks Commission, Lincoln. 108 pp.

Chapter 3

Sampling Methods and Sites For

Age 0 White Perch in Southern Reservoirs

Abstract. - From 1988 to 1998, shoreline electrofishing sampling of the littoral fish community was conducted on a tri-weekly basis from June-October in Little Beaver Creek, Jordan Lake, North Carolina. The long-term data series, interrupted in 1995-96, was used primarily as an intensive study of age 0 largemouth bass (*Micropterus salmoides*), but the data also recorded the appearance and increase in abundance of age 0 white perch (*Morone americana*). Catch rates of age 0 white perch standardized to 20 minutes of effort ranged from 0.53 white perch in 1990 to 1.91 white perch in 1993. Catch peaked in 1994, 6.63 per 20 minutes, creating the potential for competition with other littoral species. When shoreline electrofishing resumed in 1997-98, samples were collected again from Little Beaver Creek as well as Bush Creek, along with new sites chosen to collect age 0 white perch from secondary and primary points, within and without these embayments. Catch rates of age 0 white perch on primary points were significantly higher ($P < 0.05$) than those at within-embayment sites. Age 0 white perch appear to prefer cover-free, shallow sloping points that feature hard sand/clay substrates.

Introduction

The white perch is a semi-anadromous species native to riverine and estuarine habitats of the mid-Atlantic and New England (Jenkins and Burkhead 1993). White perch populations have become successfully established in a variety of inland habitats, including the Great Lakes (Christie 1972; Busch et al. 1977; Hurley and Christie 1977; Boileau 1985), Nebraska reservoirs (Hergenrader and Bliss 1971; Zuerlein 1981), New York lakes (Dence 1952; Clady 1976), Massachusetts ponds (Mosher 1976), and North Carolina reservoirs (Jackson et al. 1995).

Potential impacts of white perch on native fish communities have been suggested by several researchers including Zuerlein (1981), who documented declines in black bullhead (Ameiurus melas) and suppression of bluegill (Lepomis macrochirus) with increasing abundance of white perch in Nebraska reservoirs, and Hurley and Christie (1977), who linked declining centrarchid populations in Lake Ontario with increasing populations of white perch and alewife (Alosa pseudoharengus). Because white perch spawning can initiate at temperatures of 10-15^{0} C (Mansueti 1964), age 0 white perch pose potential competitive risks to centrarchids and ictalurids, which typically spawn at warmer temperatures (Jackson et al. 1995).

Habitat-fish relationships in southern reservoirs have been well documented (Miranda et al. 1984; Copeland 1992; Irwin 1994; Irwin et al. 1997). Age 0 white perch have been reported to be littorally oriented (Carlander 1997), but habitat preferences of juvenile white perch in southern reservoirs have not been explored. Reservoir landscape ecology suggests that scale and spatial patterns affect fish behavior and community interactions (Noble et al. 1994). Information concerning the role of white perch in southern reservoirs is lacking.

Objectives of this study are to present long-term, shoreline electrofishing data from an embayment in a North Carolina reservoir to document the establishment and expansion of white perch within the embayment's littoral fish community. Data from an additional embayment are included to assess spatial differences in abundance. Further, shoreline electrofishing catch rates are examined in an attempt to identify preferred shoreline habitat of littoral-dwelling age 0 white perch.

Methods

B. Everett Jordan Reservoir (Jordan Lake) is a 5,720-hectare, flood-control reservoir in North Carolina's piedmont region. It was impounded in 1981 on the Haw River below its confluence with the New Hope River. Jordan Lake's other designated uses are water supply, recreation, and fish and wildlife habitat. Jordan Lake has a mean depth of 5 m and typically exhibits annual water-level fluctuations of ± 2 m. The reservoir is turbid and eutrophic, with a mean secchi disk visibility of 0.5 m, and mean chlorophyll-a concentration of 26 µg/L (NCNRCD 1989).

Jordan Lake's main storage basin, the New Hope arm of the lake, is divided by causeways into three distinct sub-basins where state roads cross the lake (Jackson et al. 1991). The three sub-basins within the New Hope arm of Jordan Lake are connected only by narrow openings at the causeway bridges.

Little Beaver Creek, a 64-ha embayment contiguous with the furthest downlake sub-basin of the New Hope arm, has been a study site for age 0 largemouth bass specifically, and the littoral fish community in general, since 1987 (Fig. 1 and Fig. 2) (Jackson et al. 1991; Jackson et al. 1995). Age 0 white perch, which first appeared in summer electrofishing samples in 1990 (Jackson et al. 1991), continued to comprise a portion of the sample until 1994 when community sampling was temporarily discontinued.

Shoreline electrofishing of littoral fish communities resumed in 1997 and 1998 in Little Beaver Creek as well as being initiated in Bush Creek, a 31-ha embayment in the midlake sub-basin of the New Hope arm (Fig. 3).

From July to November, nighttime electrofishing samples were collected at three-week intervals from 1987-1994 in Little Beaver Creek and monthly from July to November in 1997-1998 from both embayments. Sampling was conducted at five sites using 260-volts DC delivered by a hand-held, triangular anode fitted with a 6-mm bar mesh net. Electrofishing was conducted from a 4.2-m, flat-bottomed boat poled along the shoreline. Depths of about 0.2 m or less were typically sampled in "near shore samples."

Due to low and occasionally non-existent catches of age 0 white perch, additional samples from the same sites were obtained from within both study embayments, but at 0.3 m depths in "off shore samples." During the latter part of the 1998 sample season, external embayment sites were added to include primary points in the sampling regime. Samples were then classified as having from primary points outside of embayments, secondary points within embayments, and non-point sites within embayments.

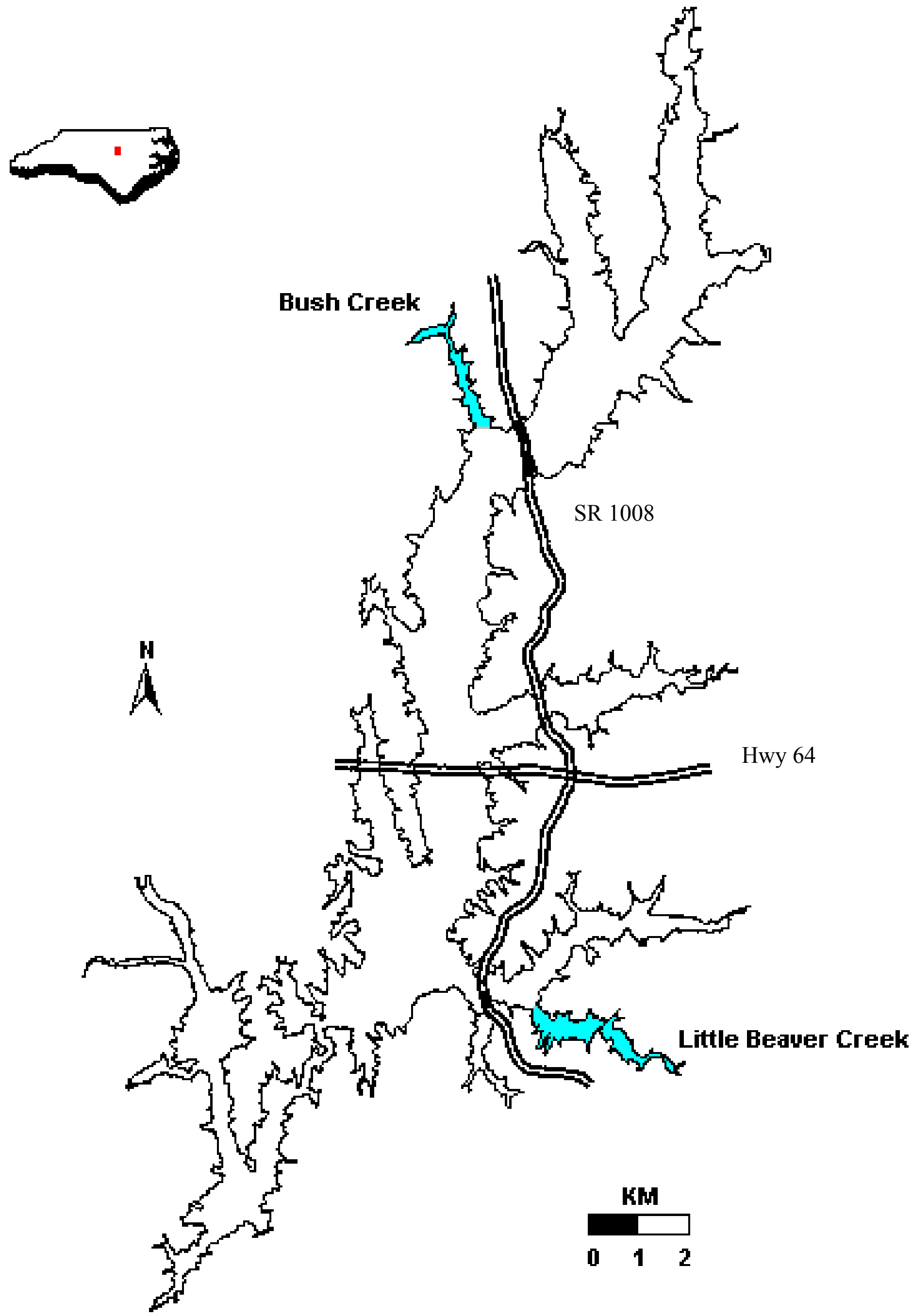

Figure 1. Age 0 white perch were studied in Bush Creek and Little Beaver Creek in Jordan Lake, Chatham County, North Carolina.

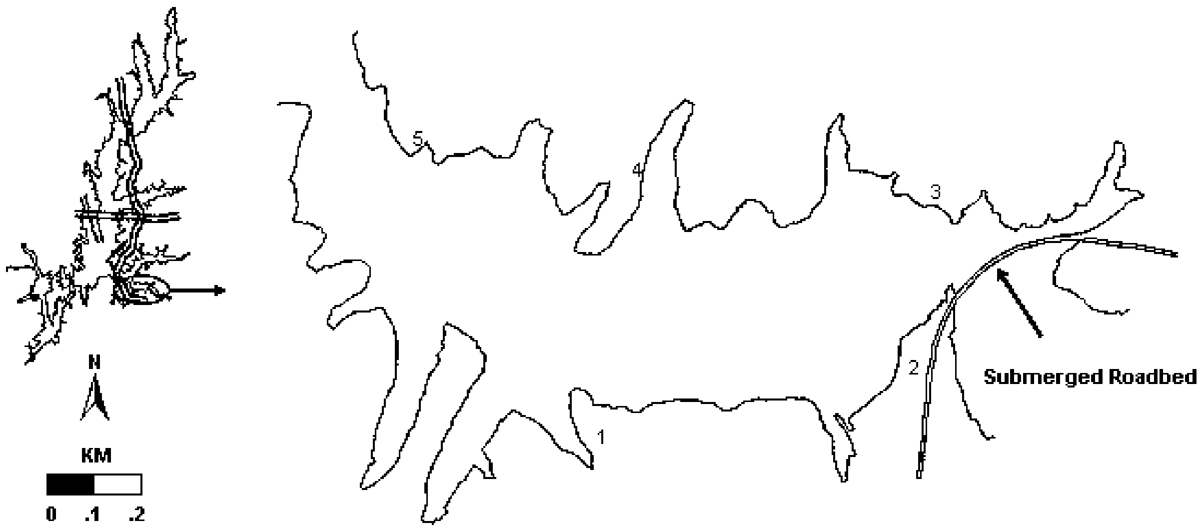

Figure 2. Age 0 white perch were sampled in the Little Beaver Creek embayment of Jordan Lake through shoreline electrofishing at five sites featuring secondary points. A primary point site was located on the main body of the lake outside of the embayment.

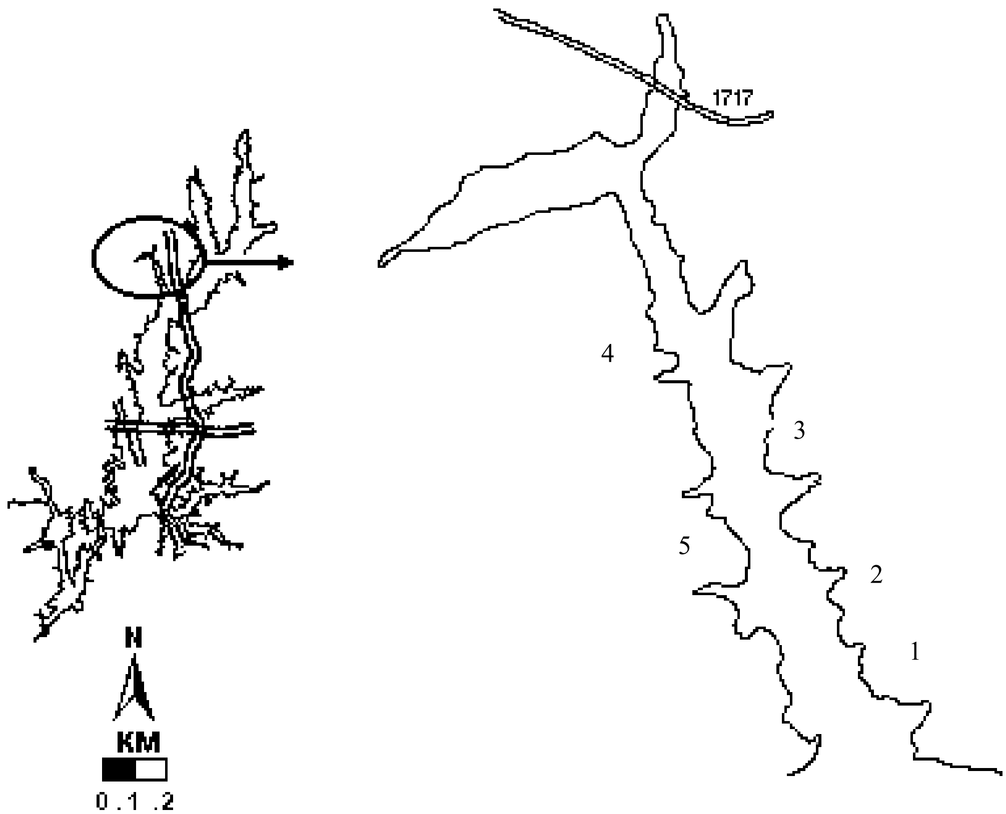

Figure 3. Age 0 white perch were also sampled in the Bush Creek embayment of Jordan Lake through shoreline electrofishing at five sites featuring secondary points. A primary point site was located on the main body of the lake outside of the embayment.

All fish, excluding shad, were collected at random to obtain a minimum sample size of 75 fish per site representative of the littoral species composition. Total electrofishing times for each site were recorded for calculating species-specific catch per unit effort (CPUE) and mean catch rates calculated as catch per 20 minutes, the average time spent sampling each site.

Age 0 white perch catch data were log transformed and analyzed via analysis of variance (ANOVA). Differences in CPUE between depths and among sites were tested. For electrofishing samples conducted in <0.2m depths, catch was tested among sites and dates via ANOVA.

Sites were characterized as featuring secondary points or primary points inside or outside of each embayment and Friedman's test was used to assess consistency of ranks of high and low catch sites. Outside of Little Beaver Creek, site 7 featured a primary point devoid of cover with a mixed sand and clay substrate. Sites 5 and 6 each included a secondary point with little cover and mixed sand and clay substrates. Sites 1, 2, and 3 each included a secondary point, but site 1 had cobble on its point, site 2 had a combination of standing timber and cobble on its point, and site 3 featured woody debris along the shoreline. Sites 4 was located within a cove with woody debris.

Site 7 for Bush Creek featured a primary point devoid of cover but having a mixed sand and clay substrate. Sites 1 and 6 each included a secondary point with little cover and mixed sand and clay substrates. Sites 2, 3, 4 and 5 each included a secondary point, but sites 2 and 3 featured some woody debris and a steeper slope, while sites 4 and

5 each had cobble on their points. The majority of sites 6 and 7 consisted of a flat point; sites 1, 2, 3, 4 and 5 consisted of coves and points.

Results

Shoreline electrofishing of depths <20cm successfully sampled age 0 white perch in Little Beaver Creek, where, over the period 1990-1993, mean CPUE ranged from 0.53 white perch per 20 minutes in 1990 to 1.91 white perch per 20 minutes in 1993. Catch rates increased sharply in 1994 (6.63 wp/20 min), at which time sampling was discontinued for two years. In 1997 when Little Beaver Creek sampling resumed, catch rates for age 0 white perch dropped to 0.27 fish per 20 minutes and zero in 1998. Concurrent shoreline electrofishing conducted in Bush Creek in 1997 and 1998 yielded higher catches than Little Beaver Creek, 1.2 age 0 white perch per 20 minutes of effort in 1997 and 0.3 age 0 white perch per 20 minutes of effort in 1998.

Shoreline electrofishing the five sites in 1998 at 30 cm depths yielded similar low catch rates in Bush Creek, an overall mean of 1.1 fish/20 minutes. Little Beaver Creek, which produced no fish at the shallow depth, yielded an average catch of 0.4 fish/20 minutes at the 30 cm sampling depth.

Accessory sample sites were added in 1998 for the 30-cm electrofishing regimen to include one additional secondary point within each embayment and one primary point outside of each embayment. Sampling was extended through November. Analysis of 30-cm sites was undertaken to evaluate spatial differences among the five regular within-bay sites. Catch rates were highest at Little Beaver site 5 (2.75 fish/20 minutes) and at Bush Creek site 1 (3.0 fish/20 minutes). However, there were no significant differences in catch rates among sites within either embayment. Within each embayment, accessory sites on secondary points produced higher catch rates than the five regular sites, but the difference was not significant. Accessory sites on primary points outside of each embayment produced the highest catch rates of age 0 white perch, 15.25 fish/20 minutes outside of Little Beaver Creek and 13.0 fish/20 minutes outside of Bush Creek. Within- and without-embayment catch rates differed significantly ($\underline{P} < 0.05$), but catch rates were not significantly different between the two outside embayment sites.

Friedman's method for randomized blocks suggests that age 0 white perch appear to prefer cover-free, shallow sloping points that feature hard sand and clay substrates ($\underline{P} < 0.05$). In the Little Beaver Creek area, the primary point site 7 outside of the embayment ranked highest in catch for all months it was sampled, August-November (Table 1). The secondary point site 6 ranked second in September and October, tied for second in August, and ranked third in November.

The primary point site 7 outside of Bush Creek ranked highest in catch each month for August through November, and tied for highest catch in July with the secondary point site 6 within the embayment (Table 2). Secondary point site 6 in Bush Creek ranked second highest in catch in August, October and November. It tied the primary point for highest catch in July, and tied for fourth in September.

Discussion

Juvenile white perch are susceptible to shoreline electrofishing (Carlander 1997), but employing trawls is the preferred sampling method for white perch in their natural

LB Creek 1998	Location	9-Aug	7-Sept	13-Oct	22-Nov
Site 1	2^0 Point, Mixed Cover	1 (4.5)	0 (2.5)	1 (3.5)	0 (2.5)
Site 2	2^0 Point, Mixed Cover	1 (4.5)	0 (2.5)	0 (1.5)	0 (2.5)
Site 3	2^0 Point, Mixed Cover	0 (1.5)	0 (2.5)	0 (1.5)	0 (2.5)
Site 4	2^0 Point, Mixed Cover	0 (1.5)	0 (2.5)	1 (3.5)	0 (2.5)
Site 5	2^0 Point, Mixed Cover	1 (4.5)	1 (5)	2 (5)	7 (6)
Site 6	2^0 Point, No Cover	1 (4.5)	3 (6)	5 (6)	3 (5)
Site 7	1^0 Point, No Cover	10 (7)	5 (7)	13 (7)	33 (7)

Table 1. Catch and rank in parentheses of YOY white perch sampled via <.3m shoreline electrofishing in Little Beaver Creek, 1998. Catch ranks are significant at $P<0.05$.

Bush Cr 1998	Location	18-July	11-Aug	10-Sept	16-Oct	28-Nov
Site 1	2^0 Point, Little Cover	1 (3.5)	2 (5.5)	13 (6)	1 (5.5)	1 (5.5)
Site 2	2^0 Point, Mixed Cover	2 (6)	0 (2)	0 (2.5)	0 (2.5)	0 (2.5)
Site 3	2^0 Point, Mixed Cover	1 (3.5)	0 (2)	1 (5)	0 (2.5)	0 (2.5)
Site 4	2^0 Point, Mixed Cover	0 (1.5)	1 (4)	0 (2.5)	0 (2.5)	0 (2.5)
Site 5	2^0 Point, Mixed Cover	0 (1.5)	0 (2)	0 (2.5)	0 (2.5)	0 (2.5)
Site 6	2^0 Point, No Cover	2 (6)	2 (5.5)	0 (2.5)	1 (5.5)	1 (5.5)
Site 7	1^0 Point, No Cover	2 (6)	12 (7)	22 (7)	29 (7)	10 (7)

Table 2. Catch and rank in parentheses of YOY white perch sampled via <.3m shoreline electrofishing in Bush Creek, 1998. Catch ranks are significant at $P<0.05$.

estuarine environments (Mansueti 1964; St. Pierre and Davis 1972; Mosher 1976). Shallow southern reservoirs such as Jordan Lake, however, are characterized by subsurface obstructions that preclude trawls from being used to sample fish other than in surface waters.

Catch rates for age 0 white perch significantly varied between point and non-point sites in both Bush Creek and Little Beaver Creek. Lowest catch rates were found at non-point sites that had cover as well as irregular substrates and contours. Hurley and Christie (1977) found that white perch competed with smallmouth and largemouth in Lake Ontario. My shoreline samples, taken in context with the work of Copeland (1992), Phillips (1994) and Irwin (1994) to identify littoral habitats and micro-habitats preferred by young of year largemouth bass, suggest age 0 white perch and largemouth bass spatially segregate in southern reservoirs and thus pose minimal competitive risks to each other. Highest catch rates young of year white perch in Jordan Lake came from primary point sites outside of two of the embayments that Phillips (1994) identified as largemouth bass nursery areas. Irwin (1994) identified age 0 largemouth bass micro-habitats as sites within embayments featuring combinations of slope characteristics and gravel substratum. None of the within-bay sample sites produced higher catch rates of age 0 white perch than the primary point sites outside of the embayments (Table 1 and Table 2).

Consistently high rankings of CPUE suggest age 0 white perch habitat is characterized by cover-free, shallow sloping points featuring hard sand and clay substrates. These results, coupled with those of largemouth bass site fidelity and microhabitat studies (Copeland 1992; Irwin 1994), suggest that potential competition between age 0 white perch and age 0 largemouth bass is limited by minimal habitat overlap. Age 0 white perch habitat preference, inferred from high catch rates on primary points free of structure, appears to mitigate potential competition between white perch and other littoral-dwelling game fishes for which embayments are important nursery areas in southern impoundments.

While this study supports previous findings regarding the littoral orientation of age 0 white perch, it fails to identify a sampling method adequate for estimating mortality and creating catch curves when trawling is not a viable option. Examination of mean monthly catch of age 0 white perch from 1990-94 (Fig. 4) suggests white perch recruit fully into the sampling gear in August. If age 0 white perch distribution is consistent over time, continuous post-August samples should reveal an exponential decline. For years 1990-94, this holds true (Fig. 4). In light of previous studies on preferred habitat of age 0 largemouth bass in Jordan Lake, the present study suggests the potential for competition may be low because of limited spatial overlap between white perch and largemouth bass.

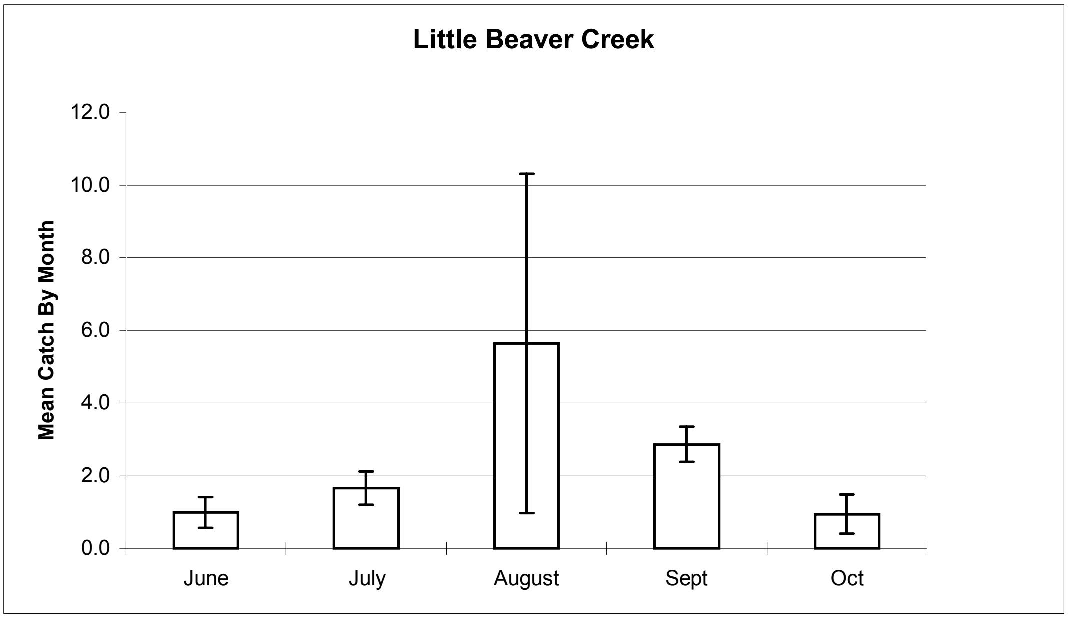

Figure 4 . Mean monthly catch of age-0 white perch, ± 1 SE, across sites and years per 20 minutes of electrofishing <20-cm depths in Jordan Lake, North Carolina, 1990-1994.

Literature Cited

Boileau, M.G. 1985. The expansion of white perch, Morone americana, in the lower great lakes. Fisheries 10(1):6-10.

Busch, W.D.N., D.H. Davies, and S.J. Nepszy. 1977. Establishment of the white perch, Morone americana, in Lake Erie. J. Fish. Res. Board Can. 34:1039-1041.

Carlander, K.D. 1997. Handbook of freshwater fishery biology, vol. 3. Iowa State University Press, Ames, Iowa 397 pp.

Christie, W.J. 1972. Lake Ontario: effects of exploitation, introductions, and eutrophication on the salmonid community. J. Fish. Res. Board Can. 29:913-929.

Clady, M.D. 1976. Change in abundance of inshore fishes in Oneida Lake, 1916 to 1970. N. Y. Fish and Game J. 23(1):73-81.

Copeland, J.R. 1992. Evidence for site fidelity in young-of-year largemouth bass. Implications for reservoir fisheries management. Master's thesis. North Carolina State University, Raleigh.

Dence, W.A. 1952. Establishment of white perch, Morone americana, in central New York. Copeia 3:200-201.

Hergenrader, G.L., and Q.P. Bliss. 1971. The white perch in Nebraska. Transactions of the American Fisheries Society 100(4):734-738.

Hurley, D.A. and W.J. Christie. 1977. Depreciation of the warmwater fish community in the Bay of Quinte, Lake Ontario. J. Fish. Res. Board Can. 34:1849-1860.

Irwin, E.R. 1994. Habitat mediation of young largemouth bass population dynamics. Ph.D. dissertation. North Carolina State University, Raleigh.

Irwin, E.R., R.L. Noble, and J.R. Jackson. 1997. Distribution of age-0 largemouth bass in relation to shoreline landscape features. North American Journal of Fisheries Management 17:882-893.

Jackson, J.R., J.A. Rice, R.L. Noble, and S.C. Mozley. 1991. Mechanisms of reservoir fish community dynamics. North Carolina Agricultural Research Service, N.C. State University, Federal Aid in Sport Fish Restoration, Project F-30-1, Final Report, Raleigh, N.C.

Jackson, J.R., R.L. Noble, and E.R. Irwin. 1995. Largemouth bass recruitment in Jordan Lake. Final Report, Federal Aid in Sport Fish Restoration Project F-30-3, N.C. Wildlife Resources Commission, Raleigh. 100 pp.

Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater fishes of Virginia. AFS, Bethesda, Md.

Mansueti, R.J. 1961. Movements, reproduction and mortality of the white perch, Roccus americanus, in the Patuxent Estuary, Maryland. Chesapeake Sci. 2:142-205.

Mansueti, R.J. 1964. Eggs, larvae, and young of the white perch, Roccus americanus, with comments on its ecology in the estuary. Chesapeake Sci. 5(1-2):3-45.

Miranda, L.E., W.L. Shelton, and T.D. Bryce. 1984. Effects of water level manipulation on abundance, mortality, and growth of young-of-year largemouth bass in West Point Reservoir, Alabama-Georgia. North American Journal of Fisheries Management 4:314-320.

Mosher, T.D. 1976. Comparison of freshwater pond and estuarine populations of the white perch, Morone americana (Gmelin), in the Parker River, Massachusetts. M.S. Thesis, Univ. Mass. 77 pp.

Noble, R.L., J.R. Jackson, E.R. Irwin, J.M. Phillips, and T.N. Churchill. 1994. Reservoirs as landscapes: implications for fish stocking programs. Proc. Annu. Conf. Southeast Assoc. Fish & Wildl. Agencies 48:281-288.

NCNRCD (North Carolina Department of Natural Resources and Community Development). 1989. 1988 North Carolina lakes monitoring report 89-04, Raleigh, N.C.

St. Pierre, R.A., and J. Davis. 1972. Age, growth and mortality of the white perch, Morone americana, in the James and York rivers, Virginia. Chesapeake Sci. 13:272-281.

Zuerlein, G. 1981. The white perch, Morone americana (Gmelin) in Nebraska. Nebraska Technical Series No. 8, Nebraska Game and Parks Commission, Lincoln. 108 pp.

Chapter 4

Summary and Conclusions

This study examines white perch expansion and life history within a southern reservoir and possible effects of white perch on other reservoir species. The documented expansion of the white perch population in Jordan Lake is unquestioned and cause for some concern, in light of the simultaneous declines observed in largemouth bass and ictalurid catches similar to those reported from other inland systems. The size, age structure and condition of Jordan Lake white perch, however, suggests the population is healthy and similar to those found in other North Carolina systems including the naturally occurring population of white perch in the Roanoke River and Albemarle Sound where recreational and commercial fisheries exist for white perch. Littoral habitat preference of juvenile white perch suggests that white perch expansion in southern reservoirs has greatest potential for impact within the moronid community, rather than between moronids and centrarchids as had been suggested by previous studies.

Interaction between white perch and both gizzard and threadfin shad in Jordan Lake most likely manifests itself as predator-prey relationship rather than a competitive relationship. Jordan Lake shad typically feed on detritus, with the exception of a brief period in spring when they prey on zooplankton, White perch also prey most heavily on zooplankton in spring, coinciding with the zooplankton density peak in the early part of the growing season. Throughout spring and fall, adult white perch prey on insects and shad fry. Their inability to continue utilizing shad as prey in the spring suggests white perch mouth gape limitations force white perch of all size classes to revert to insectivory and planktivory.

The long-term data set of adult fishes captured in Jordan Lake through seasonal gill net sampling afforded a unique opportunity to examine post-impoundment fluctuations of the Jordan Lake fish community. The most pronounced change in the fish community was the sudden and rapid increase in white perch catches during the early 1990s. Simultaneous decreases in catches of other fishes were a cause for concern. A cause-and-effect relationship between white perch expansion and other fishes' declines could not be established, however, because cyclic and naturally occurring population fluctuations may have contributed to declines in catches of Jordan Lake white crappie and flat bullheads independent of the white perch expansion.

Still, the timing of the decline in Jordan Lake flat bullhead catches suggests white perch may bear some measure of responsibility for diminished ictalurid catches. As opportunists, white perch feed on dipteran larvae throughout the year. Their ability to feed on benthos-dwelling aquatic insects suggests white perch may compete with flat bullheads for diptera, assuming that particular food source is limiting. To the extent white perch are able to shift seasonally to piscivory when young-of-year shad are available, white perch may have a seasonal predatory advantage over flat bullheads in Jordan Lake.

Size, age structure and condition of Jordan Lake white perch were similar to those found in other North Carolina systems. Notwithstanding out-of-state reports of white perch overpopulating and stunting, Jordan Lake white perch attained lengths during first-year growth exceeding lengths reported from white perch populations found in the James River, York River and Roanoke River. Relative weights of Jordan Lake white perch suggest the population is in relatively good condition as well. As opportunistic predators of zooplankton, diptera larvae and young shad, Jordan Lake white perch age 2 and older shift seasonally from zooplankton and diptera larvae in the spring to diptera larvae and age-0 shad in the fall. White perch younger than age 2 remain primarily planktivorous and insectivorous throughout the year.

Sampling for juvenile white perch in a shallow, obstruction-filled reservoir such as Jordan Lake proved challenging because the preferred sampling method of trawling was precluded by the shallow water and woody debris. While young white perch were susceptible to nighttime shoreline electrofishing, the sampling method proved adequate only for conducting diet analyses and characterizing habitat preferences. It proved inadequate for estimating mortality and creating catch curves. Sufficient age 0 and age 1 white perch were captured to identify shallow primary and secondary points as preferred habitats of juvenile white perch in Jordan Lake. In light of previous studies on preferred habitat of age 0 largemouth bass in Jordan Lake, the current study suggests the potential for white perch-largemouth bass competition may be mitigated by limited spatial overlap.

The 2002 decision of the N.C. Wildlife Resources Commission to eliminate stocking of striped bass hybrids and begin stocking only striped bass in Jordan Lake provides a new research opportunity. The current study suggests juvenile white perch and largemouth bass in Jordan Lake spatially segregate themselves, respectively without and within embayments. But juvenile white perch catch rates were highest at sandy primary points located outside of embayments, where juvenile striped bass hybrids were captured as well. If habitat preferences overlap for moronids, as they appear to in Jordan Lake, the potential exists for competition for habitat and food if they are limiting factors. This potential competition most likely would manifest between age 0 white perch and striped bass, which share spatial overlap discussed previously as well as a dietary overlap consisting of zooplankton and diptera larvae.

White perch in reservoir settings are not subject to recreational and commercial fishing pressures exerted on naturally occurring estuarine populations of white perch, and so managers of the Jordan Lake fishery should be encouraged by the overall health of the white perch population. However, to ensure the future health of Jordan Lake white perch and to minimize the potential for competition between white perch and striped bass, fishery managers should encourage the development of a recreational fishery for white perch.