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.

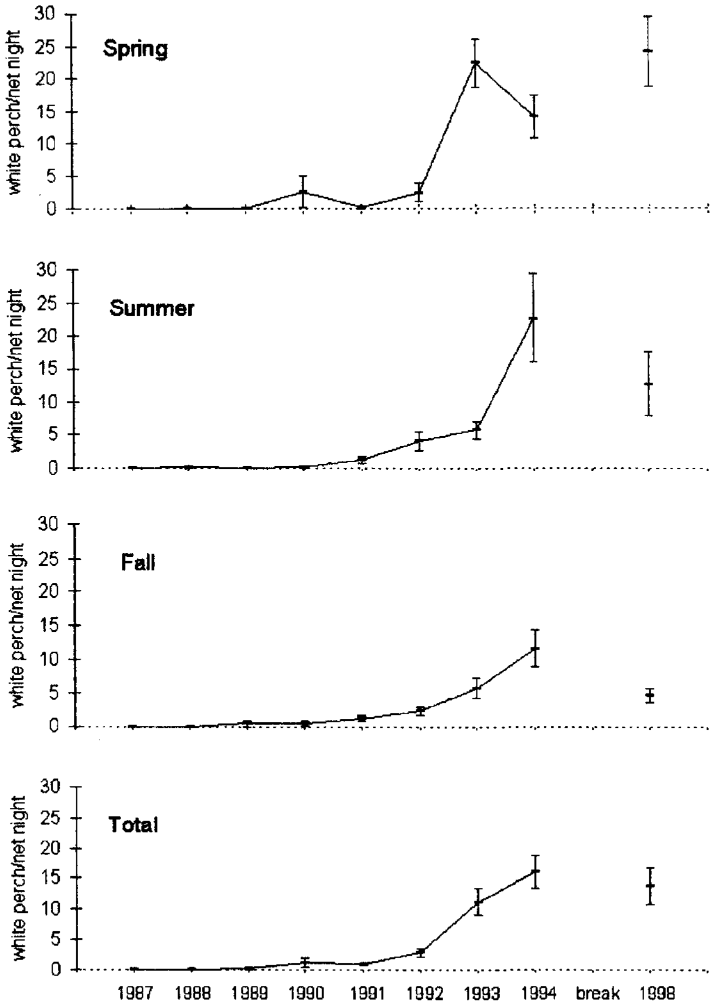

Figure 1. Mean gill-net catch of white perch per net night ±1 SE, by season and by year in Jordan Lake, North Carolina.

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.