Ecological Investigation of the Invasive White Perch in Kaw Lake, Oklahoma

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Following an unintentional introduction of white perch (*Morone americana*) into Kaw Reservoir, Oklahoma, questions were raised about the potential impacts this new species may have on resident sport fish populations. White perch, white crappie (*Pomoxis annularis*), and white bass (*Morone chrysops*) were collected from 2001 through 2004 using a variety of sampling techniques. White perch catch rates were low with all sampling methods. White crappie and white bass catch rates have remained within or exceeded historical ranges. White perch growth rates were slow, especially for fish reaching age-2+, and a sectioned otolith viewing method was more effective than a whole view method. White crappie mean length-at-age for age-1, age-2, and age-3 fish was significantly less during this study than historical samples prior to white perch introduction. Little diet overlap between the white perch and the other two target species was observed. Moderate diet overlap (0.544) was observed between white perch and white bass less than 200 mm total length. It appears that the current white perch population in Kaw Reservoir has not negatively affected the white crappie or white bass populations.

The Nebraska Game and Parks Division introduced the white perch (*Morone americana*) into some of its state-managed lakes in 1964 in an effort to increase sportfishing opportunities (Zuerlein 1981). Introductions in Kansas shortly followed, and additionally through unintentional introductions, the white perch has emigrated from a series of reservoirs through Nebraska and Kansas to Oklahoma waters via the Arkansas River system. White perch were detected in gill-net samples of Kaw Reservoir in 2000 (Bill Wentroth, Oklahoma Department of Wildlife Conservation, personal communication), and also in Lake Keystone in 2004. Understanding competition and trophic interactions between white perch and native fish species might allow ODWC to better predict impacts on other Arkansas River impoundments.

The white perch is native to the northern Atlantic coast of the United States, where it inhabits both marine and freshwater environments (Alsop and Forney 1962; Marcy and Richards 1974). In both marine and freshwater environments it is considered to be a game fish. The range of the white perch has expanded westward and southward, including the Great Lakes. This dramatic range expansion in the past fifty years is attributed to developments of canal systems in the great lakes region, stocking efforts of fish and wildlife agencies, and private stockings (Prout et al 1990; Zuerlein 1981).

Stocking of the white perch into inland waters tends to produce stunted populations due to rapid overpopulation (Zuerlein 1981). Stunted populations are characterized by large quantities of slow-growing, small individuals where few fish reach age-5 or exceed 300 mm total length (Busch et al 1977; Zuerlein 1981). Although growth rates for white perch can be higher in introduced populations, small body size limits its appeal as a popular target fish for anglers.

The introduction of exotic species into a reservoir community can lead to competition with resident fish populations. Two species commonly affected by the invasion of white perch are white bass (*Morone chrysops*) and yellow perch (*Perca flavescens*) (Parrish and Margraf 1990; Prout et al 1990; Madenjian et al 2000). White bass and yellow perch population declines are often linked to the expansion of invasive white perch populations. Food habit studies have shown that white perch compete directly with white bass and yellow perch throughout juvenile and adult life stages (Webster 1942; Zuerlein 1981; Parrish and Margraf 1990; Prout et al 1990; Madenjian et al 2000). In addition, the likelihood of competition with white crappie (*Pomoxis annularis*) is high due to similarity of prey items between species. White perch and white crappie both utilize *Daphnia* spp., *Cyclopoida* spp., and chironomids as major food sources, especially during their first year of life (Marcy 1954; Mathur and Robbins 1971; Elrod et al 1981; Zuerlein 1981; O'Brien et al 1984; Bath and O'Connor 1985; Hurley 1992; Parrish and Margraf1990; Prout et al 1990). White perch also prey upon the eggs of other fish species (eg. walleye *Stizostedion vitreum*), which could negatively impact populations (Schaeffer and Margraf 1987).

Because the white perch is likely to continue to expand its range and invade new water bodies, there is a need to better understand the potential effects on existing fish communities. Examining the effects of white perch introductions in Kaw Reservoir, Oklahoma could lead to improved management strategies.

METHODS

Relative Abundance

A variety of techniques were used to sample three target species. Spring samples were collected using both day and night boat electrofishing in 2002 and 2003. Experimental gill nets were employed during Summer in 2002 and 2003. Fall 2003 and 2004 sampling included gill netting and trap netting; results were compared to ODWC historical fall sampling data. All three target species (white perch, white crappie, and white bass) were collected in the fall of 2002, but highly turbid water in the fall of 2003 prevented adequate samples.

Electrofishing consisted of pulsed DC current delivered via 5.8 m, aluminum-hulled boat. Each individual unit of effort consisted of one fifteen minute period of shocking. Mean catch rates were calculated as number of fish per hour (mean CPUE of multiple 15-minute units of effort x 4). A variety of rock, gravel, and sand substrate sites in less than 2m of water were sampled.

Trap nets were placed lead first in one to three meters of water leading out to the collection basket in four to six meters of water. Trap nets were constructed from two 183 cm wide by 91.5 cm high steel frames with four 76 cm diameter hoops covered with 12.7 mm square mesh knotless nylon netting material. Each net had a 19.8 m long lead, 91.5 cm in depth constructed of 12.7 mm square mesh knotless nylon netting material. Trap nets were set in the afternoon hours and remained overnight until the following morning. Effort was recorded as total number of hours fished, and mean catch rates were calculated as number of fish per net-night (number of fish per hour x 24 hours). A variety of rock, gravel, and sand substrate sites were sampled.

Floating gill nets were constructed of five 7.6 m long by 1.6 m deep panels of 9.5 mm, 12.7 mm, 15.9 mm, 19.1 mm, and 25.4 mm mesh. Sinking gill nets contained seven panels of similar dimensions with mesh sizes ranging from 12.7 mm to 76.2 mm. Both types of gill nets were set in two to four meters of water, perpendicular to the shoreline, and in areas of sand and gravel substrate. Gill nets were set in the afternoon and fish removed the following day. Effort was recorded as total number of hours fished, and catch rates were calculated as number of fish per net-night (number of fish per hour x 24 hours). Gill net data from the fall 2001 ODWC sample were also included with the gill net data and analysis from this project as this was the first standard sample conducted after white perch were found.

Age and Growth

Sagittal otoliths were collected from white perch to determine age and growth trends. Otoliths were examined in both whole view and cross-sectional view. Whole otoliths were placed in water and observed under 4x magnification of a dissecting microscope. Age calculations for whole otoliths were based upon the number of annuli present (one year per annulus). Sectioned otoliths were broken transversely across the kernel using a foreceps, sanded down to polish rough edges, mounted upright in clay, and viewed underwater with the aid of a mobile fiber optic light source. Annuli appeared as dark lines or rings on the polished surface of the sectioned otolith under 10 x magnifications. Age calculations for sectioned otoliths did not differ from calculations for whole otoliths (eg. one annulus equals one year of growth).

White crappie otoliths were also collected for analysis. Whole otoliths were viewed and aged using the same methods described for white perch whole otoliths. Crappie otoliths collected during the study were pooled for length-at-age analysis (Marcy 1954; Doyle et al 2003) versus a pooled sample of the most recent age data from Kaw Reservoir (1987 to 1992). Data from this study was compared to historical ODWC data using a pooled t-test with equal variances (SAS Institute Inc., Cary, NC) to compare white crappie growth before and after the white perch introduction. Historical white bass age and growth data was not available to use as a pre-white perch introduction baseline, so white bass otoliths were not collected.

Diet Analysis

Stomach samples from all three target species were collected after fish were measured and weighed. To prevent advanced digestion of food items, trap nets were set for no more than three hours before fish were removed to collect stomach contents. Stomachs were removed, and placed in a 10% formalin solution for preservation. In the laboratory, stomach contents were sorted under 4x magnification and grouped into one of four food categories: fish, insects, zooplankton, or fish eggs. Materials were weighed to the nearest 0.01 gram after excess water was blotted with paper toweling. Stomach sample contents were identified and relegated to the four food item categories. The weight of each food item was divided by the total stomach content weight to calculate proportional weight for food items.

Pianka's (1973) index of diet overlap (O) was used to index the similarity of diets between species. Pianka's index is defined as:

$$O = \Sigma p2i\ p1i / (\Sigma p2i \times \Sigma\ p1i) \hat{}0.5$$

Where O is the overlap in food items between species 1 and 2, p1*i* is the weight of food item *i* found in species 1, and p2*i* is the weight of food item *i* in the stomachs of species 2. Food resource overlap values range from 0 to 1, with 0 being no overlap and 1 being complete overlap.

RESULTS

Relative Abundance

Catch rates for white perch in Kaw Reservoir varied by sampling technique, and were low in all methods. Spring 2002 electrofishing samples yielded catch rates of 0.00 white perch per hour during daylight sampling (8 units of effort), and 4.67 fish per hour during night sampling (with a standard error of 1.7516) in 6 units of effort. The mean length of seven white perch collected by night electrofishing was 109.9 mm (*SE*).

Summer 2002 gill net mean catch rates for white perch were 17.664 fish per net night (*SE* = 0.425). A total of 59 white perch were collected during summer gill netting in six overnight samples. Summer gill net samples were replaced with summer trap net samples in 2003 and 2004 to obtain diet data in conjunction with catch data.

Fall gill net samples yielded low mean catch rates for white perch following the high initial catch rate of 18.888 fish per net night (SE = 4.248) in 2001 (Fig. 1). Catch rates of white perch never exceeded 5.568 fish per net night after 2001. The gill net mean catch rates for white crappie during the project period were generally high (Fig. 1). The 2002 and 2004 catch rates exceeded the highest historical catch rates for white crappie. The gill net mean catch rates for white bass during the project period were within the normal historical range for Kaw Reservoir (Fig. 1).

Fall 2002 trap net sampling for white perch yielded a mean catch rate of 0.936 (SE = 0.013) fish per net night. This sampling method proved ineffective for white perch

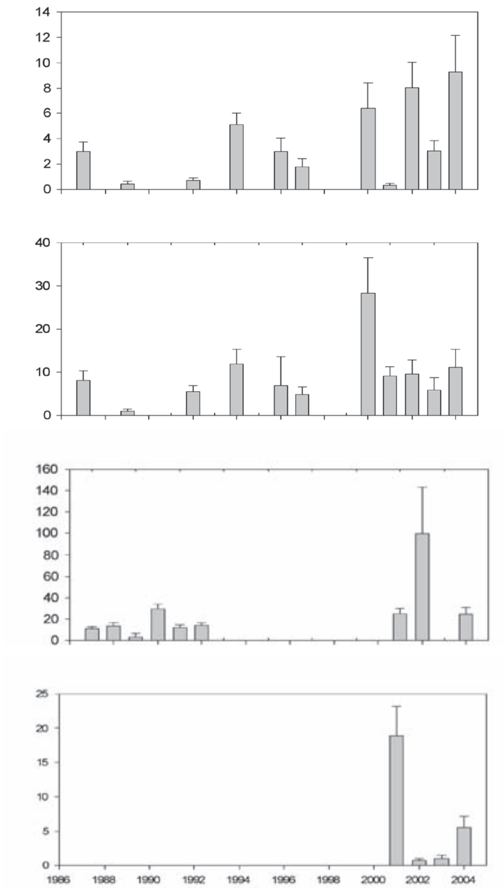

Figure 1. Fall netting mean catch rates (SE = error bars) by sample year (1986-2004) for: (A) White crappie gill net, (B) White bass gill net, (C) White crappie trap net, and (D) White perch gill net.

in 2003 and 2004. White crappie mean catch rates for fall trap netting were generally high (Fig. 1). The 2002 fall trap net catch rate was 99.648 (SE = 1.814) fish per net night, which was higher than historical trap net catch rates (Fig. 1). This is due largely to the fact that age-0 white crappie were very abundant in 2002 trap net samples, as 94% (n = 918) of the white crappie collected in these nets were less than 130 mm in length. Data from fall 2003 were not included in the analysis because rising water levels induced highly turbid conditions. The 2004 fall trap net mean catch rate (x = 24.6 SE = 6.096) was near the upper range of historical data from Kaw.

Age and Growth

The mean length at age for fall sampled white perch is detailed in Table 1. In general, slow growth allows for little separation between year classes. Adult white perch seldom exceeded 200 mm in length. The growth of white perch in Kaw Reservoir appears to slow dramatically after the fish reach age-1 (Table 1). Due to a lack of white perch age and growth studies using length at age determined by otolith ageing, the growth of the Kaw population could not be directly compared to other populations.

White crappie length-at-age analysis showed a decrease in growth between historical data (before white perch) and data from this study (Table 2). Only age classes one through 3 were compared due to a low sample size in the other age classes. The difference is statistically significant ($p < 0.05$) in all three age class comparisons using a t-test with equal variances.

Diet Analysis

Diet analysis was performed on 48 white perch (21 empty stomachs), 141 white crappie (28 empty stomachs), and 69 white bass (20 empty stomachs). Figure 2 illustrates the breakdown of stomach contents by species categories. Because crappie diets are known to shift during normal development and growth, stomach samples were divided into

Table 1. Annual white perch mean total length-at-age from fall samples (gill net and trap net).

Sample year	Age	Mean length (mm)	Standard deviation (sd)	Number (N)
2001	0	106.188	6.036	16
	1	142.000	22.226	5
	2	162.000	0	1
	3	168.000	0	1
	4	205.000	0	1
2002	0	121.667	22.680	3
	1	147.885	10.342	52
	2	145.857	7.966	28
	3	170.000	50.912	2
2003	0	113.000	7.937	3
	1	152.000	0	1
	2	165.000	12.517	4
	3	193.750	16.520	4
2004	0	108.580	6.891	19
	1	154.600	12.747	10
	2	172.200	7.981	5
	3	170.000	0	1

Table 2. White crappie mean length-at-age from 1987 to 1992 (before white perch) and from this study (2002 and 2004 fall samples).

Age	Pooled Sample dates	Mean total Length (mm)	Standard Error (SE)	Number (N)	T Value (p)
Age-1	1987 – 1992	233.72	1.6342	364	7.71
	2002 & 2004	203.86	2.5891	71	(<0.0001)
Age-2	1987 -1992	298.78	1.7385	161	11.83
	2002 & 2004	255.70	3.3677	50	(<0.0001)
Age-3	1987 -1992	328.27	2.8073	44	4.87
	2002 & 2004	291.31	6.4277	21	(<0.0001)

three length categories (Marcy 1954; Mosher 1984). White bass were grouped into two length categories for stomach analysis based on known diet shifts (Bonn 1952; Moser 1968; Olmsted and Kilambi 1969; Hartman 1998).

Insects were the dominant food type found in white perch stomachs during the study (81.1%). Insects were also the dominant food type in white bass less than 200 mm (49.1%). All other length categories showed either fish or zooplankton as the primary food type present in stomach samples (Fig. 2). No egg predation was observed in white perch.

Diet overlap between white perch and white bass less than 200 mm was moderately high for insects as the food type (0.544). Diet

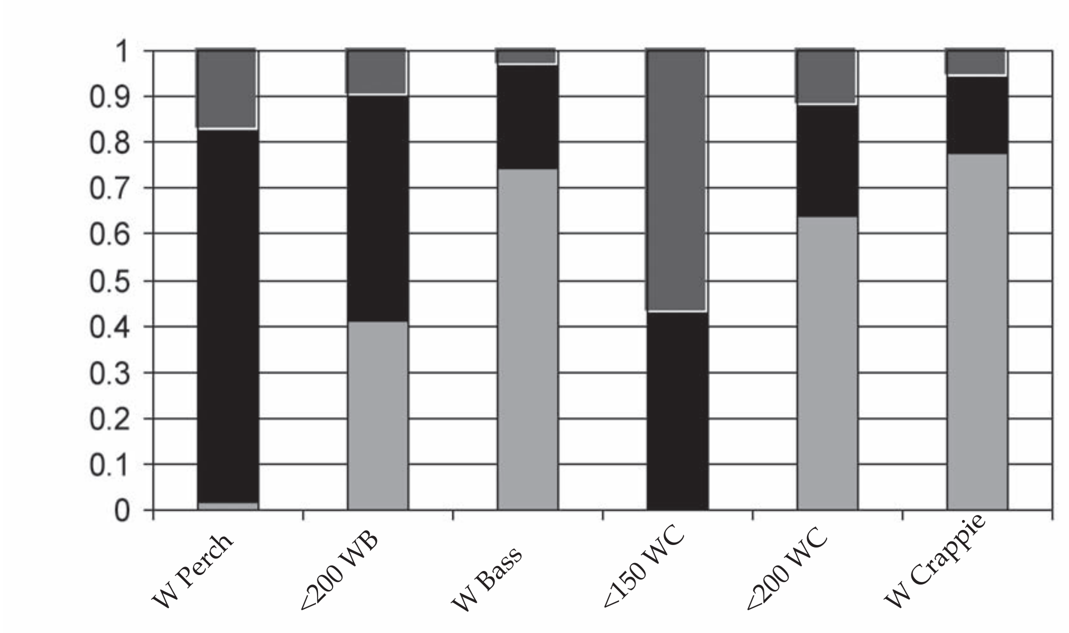

Figure 2. Stomach contents (by weight) of white perch, < 200 mm white bass, all white bass, < 150 mm white crappie, < 200 mm white crappie, and all white crappie. Food item categories are: Zooplankton – diagonal lines, Insects – solid black, and Fish – solid white.

overlap of zooplankton and fish food types between white perch and the other species in all length categories was below 0.5.

DISCUSSION

Electrofishing, particularly during the day, proved to be an ineffective method for collecting white perch. Following poor white perch catch rates in Spring 2003 electrofishing samples conducted in the Arkansas River above Kaw Reservoir, electrofishing was discontinued. It is recommended that future white perch sampling not include electrofishing.

The gill net catch rates for white crappie during the project period were generally high (Fig. 1). The 2002 and 2004 catch rates exceeded the highest historical catch rates for white crappie. The gill net catch rates for white bass during the project period were within the normal historical range for Kaw Reservoir (Fig. 2). In the 4 years since finding white perch in gill net samples, the white crappie and white bass populations have not shown a decline in catch rates.

Results from the white perch sampling on Kaw Reservoir indicate a small population. The white perch population was known for five full years at this point, yet the Kaw Reservoir population does not seem to be following the rapid overpopulation pattern of several Nebraska and Kansas introduced populations. Zuerlein (1981) reported rapid population growth following introduction in Wagon Train, Stagecoach, and Buckley 3F Reservoirs in Nebraska. Although reproduction has been documented through the discovery of various year classes and age and growth data (presented later), the white perch population has not increased annually. White perch were first detected in Lake Erie in 1953; the next reported specimen was collected in 1973 (Busch et. al 1977). Following the second documentation, the white perch population became permanently established in the early 1980's (Parrish and Margraf1990). The Kaw white perch population differs from the Lake Erie population in regards to population growth.

If this trend continues, the Kaw white perch might never become a prominent species.

The white perch population does not seem to be negatively affecting either the white crappie or white bass populations based on results presented here. Catch rates for white crappie and white bass were within historical ranges or higher. To this point, it does not appear that the white perch has competitively excluded either white crappie or white bass. Continued monitoring of population dynamics and interactions between the three species will illustrate the effects of the white perch on the other resident populations.

Aging of the saggital otoliths proved difficult in whole view readings. The better method for accurate ageing of white perch was the sectioned view. Annuli appeared more clearly when a sectioned otolith was viewed under fiber optic light opposed to examination of the whole otolith viewed in water. The sectioned view ageing method is recommended in future white perch studies.

Although relative abundance (mean catch rates) of white crappie has not been negatively affected by white perch, growth rates (mean length at age-1, age-2, and age-3) of white crappie in this study were slower than historical growth rates. It is difficult to directly link the change in white crappie growth to the presence of white perch. Both white perch and juvenile white crappie stomach samples revealed insects comprised part of the total diet, 81.1% and 42.9% respectively. However, Pianka's index showed diet overlap to be minimal (less than 0.5). White crappie growth at Kaw is still satisfactory by ODWC management standards even after observing slower growth in samples from this study. Continued annual trap net sampling is recommended to prevent gaps in white crappie growth data, allowing more accurate trend data with which to monitor future crappie growth, and verify long term patterns.

The highest degree of diet overlap observed was between white perch and white bass less than 200 mm, both of which utilize insects as a large percentage of their diet. However, there have been no measurable changes in the white bass population in regards to quality (percentage of fish larger than 300 mm) or quantity (mean catch rates). With both species competing for insects, the interaction between white perch and juvenile white bass should be the focus of future species interaction monitoring. Continued monitoring of the white perch population will likely reveal if diet overlap will have any negative effects on the white bass fishery in Kaw Reservoir. Results here indicate that the white perch population is not inducing a competitive disadvantage to resident white bass populations.

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