AN ABSTRACT OF THE THESIS OF

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in Biological Sciences presented on June 18, 2001

Title: Biology of nonindigenous white perch and yellow bass in an oxbow of the Missouri River

Abstract approved: David Seldes

I investigated population dynamics, age and growth, reproduction, and feeding habits of nonindigenous white perch (*Morone americana*) and yellow bass (*Morone mississippiensis*) in Browning Oxbow of the Missouri River. I collected 367 white perch and 371 yellow bass from April 1998 to May 1999; trap nets yielded higher catch per unit effort than gill nets or seining. Total catch per unit effort did not vary seasonally. White perch collections were predominantly stock (13.0 to 19.9 cm TL) and quality (20.0 to 24.9 cm TL) length fish, with mean relative weights (W_r) of 113 and 93, respectively. Yellow bass were predominantly quality (18.0 to 22.9 cm TL) lengths, with a mean W_r of 100. Male/female sex ratios for white perch and yellow bass were significantly different from 1:1, with more females than males for both species. Populations of white perch and yellow bass were mainly age-2 and age-3 individuals, and I caught more older females than males for both species. Growth rates were highest in the first two years, and decreased thereafter. White perch and yellow bass successfully reproduced in the oxbow in April and May, as evidenced by gonadosomatic index values and presence of young-of-the-year (YOY). Most age-1 male and age-2 female white perch and yellow bass were sexually mature, and males ripened earlier in spring than did females. Fecundity estimates were high for both species, suggesting that white perch and yellow bass might quickly overpopulate this small impoundment, and that stunting could result. Diet of YOY was mainly zooplankton, and adult white perch and yellow bass fed primarily on aquatic insects and fishes. White perch fed heavily on dipterans in spring and summer, but switched to feed on fish in fall and winter. Yellow bass fed heavily on dipterans in spring, summer, and fall, and switched to feed on fish in winter. The nature of white perch and yellow bass diets raises the possibility for competition with indigenous fishes.

BIOLOGY OF NONINDIGENOUS WHITE PERCH AND YELLOW BASS IN AN OXBOW OF THE MISSOURI RIVER

A Thesis

Presented to

The Department of Biological Sciences

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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August 2001

Approved by the Department Chair

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ACKNOWLEDGMENTS

I thank my wife (B. Stein) and family for their constant support and encouragement throughout the duration of my thesis. I also thank my committee chair (D. Edds) for advice and assistance in developing, initiating, and completing this research. I thank my committee members, T. Mosher, R. Schultz, and S. Crupper, and the following people for helpful discussions: K. Tjelmeland, C. Johnson, V. Travnichek, and J. Schwartz. I thank the Kansas Department of Wildlife and Parks and the Missouri Department of Conservation for collecting permits, and A. Stuerke, C. Stuerke, M. Combes, B. Stein, K. Edds, and K. Shaw for assistance in the field. Funding was provided by an Emporia State University Faculty Research and Creativity grant and by the Emporia State University Department of Biological Sciences.

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INTRODUCTION

Many investigators have shown that nonindigenous fishes severely threaten native species through competition, predation, hybridization, and alteration of food webs (e.g., Busack and Gall 1981; Moyle et al. 1986; Krueger and May 1991). The invasion of white perch (*Morone americana*) into the Great Lakes and its introduction into Nebraska reservoirs has led to various problems inherent to the spread of nonindigenous species (Hergenrader and Bliss 1971; Todd 1986; Schaeffer and Margraf 1987; Parrish and Margraf 1990). Driscoll and Miranda (1999) found that yellow bass (*Morone mississippiensis*) harm native species through predation of fish eggs. Recent invasion of white perch and yellow bass in the Missouri River drainage of Kansas and Missouri (Stein and Edds 2000) warrants investigation of the biology of these species outside their native range.

Although three species of the genus *Morone*, white perch, white bass (*M. chrysops*), and striped bass (*M. saxatilis*) sometimes co-occur, yellow bass and white perch have not previously been found in sympatry (Lee et al. 1980; Tomelleri and Eberle 1990; Page and Burr 1991; Fuller et al. 1999). Documentation is lacking concerning the biology of these two species in sympatry, or in Missouri River oxbows. The purpose of this study was to document population dynamics, reproduction, seasonal feeding, and age and growth of white perch and yellow bass in Browning Oxbow, an oxbow lake of the Missouri River on the Missouri/Kansas border (Figure 1).

Invasion and Introduction of White Perch

White perch are endemic to saltwater, freshwater, and estuarine ecosystems of the Atlantic Coast (Mansueti 1961), but have invaded and been introduced into the north central and midwestern United States. In their native range, white perch are important to sport and commercial fisheries because of their flavorful taste (Jenkins and Burkhead 1993). However, the species is a nuisance when introduced into freshwater systems because it can overpopulate, resulting in stunted fish (Hergenrader 1980; Boileau 1985). White perch are anadromous in their native range, and can produce 20,000 to 388,736 ova per female (Sheri and Power 1968; Taub 1969; Bur 1986; Carlander 1997).

White perch were first captured in the Great Lakes during the 1950s (Larsen 1954); its invasion was facilitated by shipping canal construction (Jenkins and Burkhead 1993). Rapid expansion of white perch in the Great Lakes led to numerous studies that described problems caused by its invasion. Elrod et al. (1981) found that white perch and yellow perch (*Perca flavescens*) in Lake Ontario consumed similar foods, and suggested that competition was possible between young-of-the-year (YOY) of these species. Parrish and Margraf (1990) demonstrated diet overlap between white perch and yellow perch in Lake Erie, and concluded that invasion of white perch had negatively affected yellow perch populations. White perch affected other native fishes in the Great Lakes through predation. Schaeffer and Margraf (1987) showed that white perch fed extensively on the eggs of walleye (*Stizostedion vitreum*) and white bass from May through June; during these months, fish eggs made up 100% of the white perch diet. White perch also negatively affect native fishes through predation on larval fish. White perch switch to piscivory and are considered efficient predators of other fishes when they reach 200 mm total length (TL) (Elrod et al. 1981). Schaeffer and Margraf (1986) found that a large portion of the white perch diet in Lake Erie consisted of YOY gizzard shad (*Dorsosoma cepedianum*). Madenjian et al. (2000) suggested that invasion of white perch into Lake Erie has severely affected white bass populations, possibly through predation on eggs or juveniles.

In 1964, the Nebraska Game and Parks Commission (NGPC) stocked white perch into highly saline lakes of the Sandhills region of Nebraska to examine its effectiveness as a sport fish (Hergenrader and Bliss 1971). White perch were inadvertently stocked into Wagon Train Reservoir in southeastern Nebraska during the same year (Hergenrader and Bliss 1971). White perch became the dominant fish in this 146-hectare reservoir within five years, destroying a native population of black bullhead (*Ameiurus melas*) (Hergenrader 1980). White perch quickly overpopulated the impoundment, resulting in decreased growth rates, and continued to dominate the fishery until NGPC eliminated the species by renovating the lake (Hergenrader 1980).

White perch dispersed from Wagon Train Reservoir into its tributaries, and in 1974 were captured in Lake Waconda near Union, Nebraska (Hergenrader 1980). The species also was collected in the Missouri River, bordering Nebraska and Missouri, in 1971, 1973, and 1974 (Pflieger 1997). Once in the Missouri River, white perch dispersed into parts of western Missouri and eastern Kansas. Missouri Department of Conservation (MDC) personnel first captured white perch in 1992 in Lake Contrary, Buchanon County, and in 1995 they collected it in scour holes along the Missouri River in Carroll and Howard counties (Pflieger 1997). In 1995, Kansas Department of Wildlife and Parks (KDWP) personnel collected white perch in Browning Oxbow in Doniphan County (K. Tjelmeland, KDWP, pers. comm.).

Introduction and Expansion of Yellow Bass

The yellow bass is indigenous to the Mississippi River drainage, and its native range extends from Minnesota to Louisiana (Burgess 1980). Yellow bass are important as sport fish and extensive research has been conducted on populations in Iowa (Harlan et al. 1987). The distribution of yellow bass has been extended through inadvertent stocking and subsequent dispersal. Iowa Department of Natural Resources (IDNR) personnel have found yellow bass in many lakes in southwest Iowa, including Rathbun Reservoir (Appanoose County) and Lake Icaria (Adams County) (J. Schwartz, IDNR, pers. comm.). Yellow bass apparently gained access to the Missouri River from these drainages, and were first collected in Browning Oxbow in 1998 (Stein and Edds 2000).

Yellow bass negatively affect native species through predation, hybridization, and overpopulation (Bulkley 1970; Driscol and Miranda 1999). A single adult yellow bass can produce up to 280,000 ova, and this high fecundity can lead to overpopulation and stunted growth (Bulkley 1970). Driscoll and Miranda (1999) demonstrated that 30% of the yellow bass diet in a Mississippi River oxbow was comprised of fish eggs. Fries and Harvey (1989) found that yellow bass co-occur with white bass and striped bass in some Texas reservoirs, and concluded that hybridization could deplete pure stocks of white bass.

MATERIALS AND METHODS

Study Area

Browning Oxbow (Figure 1) is located 1.6 kilometers west of St. Joseph, Missouri, and 0.8 km north of Elwood, Kansas (N 39° 45.7', W 94 ° 54.1'). The oxbow is a shallow, 40-hectare floodplain lake with a maximum depth of 3 meters. The oxbow was formed after a large flood in 1952, and the U.S. Army Corps of Engineers built a levee to ensure that it did not rejoin the river. Browning Oxbow is isolated from the Missouri River, but a head gate on the levee can be used to raise or lower the lake level; the water level also fluctuates according to discharge from the river due to subsurface flow. The oxbow provides a recreational fishery managed by the KDWP and MDC.

Collection of Fishes

I collected white perch and yellow bass monthly from April 1998 to May 1999 (Appendix 1) with two experimental gill nets (38.1 m x 1.8 m, with 12.7, 25.4, 38.1, 63.5, and 88.9 mm mesh), six trap nets (1.8 m x 1.2 m frame and 12.7 mm mesh with 13.7 lead lines), one bag seine (7.7 m x 1.8 m x 6.4 mm mesh with 1.8 x 1.8 m bag), and one straight seine (4.6 m x 1.8 m x 3.2 mm mesh). Trap nets and gill nets were set at eight stations (Figure 1) between 1600 and 1800 hours, and retrieved the following morning between 0800 and 1130 hours. Shoreline seining was conducted with each seine at eight stations (Figure 1). In addition to the regular monthly sample, I conducted a 24-hour sample on 9-10 July 1998 to determine diel activity and feeding patterns of both species; four trap nets, one gill net, and the two seines were used to collect white perch and yellow bass every four hours.

I preserved white perch and yellow bass in 10% formalin, and slit the abdomen of fishes > 150 mm TL to facilitate preservation of viscera. After specimens had been in formalin for at least 7 d, I transferred them to 45% isopropyl alcohol for storage and laboratory analysis.

Population Dynamics

I determined catch per unit of effort (CPUE) as the number of white perch and yellow bass collected per trap net night, per gill net night, and per seine haul. I determined relative stock density (RSD) for both species (Gablehouse 1984), and calculated relative weight (W_r) from standard weight equations given by Bister et al. (2000). I utilized least squares regression to determine weight-length relationships for both species. Following Anderson and Nuemann (1996), length and weight data were log-tranformed to fit the standard weight-length equation $\log_{10}(W) = a' + b * \log_{10}(L)$, where W is weight (g) and L is length (mm). I determined annual mortality rates (A) for white perch and yellow bass as $S = (1 - A) = e^2$ (Van den Avyle and Hayward 1999), where S is the finite survival rate, A is the finite mortality rate, e is the base of natural logarithms, and Z is the instantaneous mortality rate (descending slope of a catch curve).

Age and Growth

I collected scale samples from 335 adult white perch and 363 adult yellow bass; YOY were not included in growth analysis. I collected scales from above the lateral line just below the first and second dorsal fin (Mansueti 1960; Mosher 1976; DeVries and Frie 1996). I placed four scales between two glass slides, and used a microprojector to count annuli (DeVries and Frie 1996). I determined growth of white perch and yellow bass by back calculation of scale samples with the Fraser-Lee method: $L_i = \frac{L_c - a}{S_c}(S_i + a)$ (Carlander 1982), where L_i is the back-calculated fish length when the *i*th increment was formed; $L_c - a / S_c$ is the slope of a two point regression line; L_c is the length of fish at capture; a is the intercept parameter; S_c is the scale radius at capture; and S_i is the scale radius at the *i*th increment. I used age-frequency analysis to examine year class strength for white perch and yellow bass (Anderson and Neumann 1996).

I collected 20 sagittal otoliths from each putative age class to verify scale interpretations. Following Maceina (1988), I marked the focus with a pencil and ground the ventral surface to the mark with a Dremel tool. I attached the ground end to a glass microscope slide with thermoplastic cement, and polished the otolith with the Dremel tool and 800 grain sand paper until annuli were visible. I then counted annuli under a compound microscope.

Gonads

I positively identified sexes of 249 white perch (86 males, 163 female) and 302 yellow bass (105 males, 197 females), and used percent gonadosomatic index (%GSI = mass of gonads/mass of fish * 100) (Strange 1996) to determine reproductive season. During summer (June through August), some gonads were too small to identify; only those fishes that could be clearly identified were included in GSI and age at maturity analyses.

Maturity of white perch and yellow bass was determined by observation of gonads; fish were considered ripe if sperm or ova were easily extracted when pressure was applied to the abdomen. Fish collected in fall, winter, and spring were considered mature if gonads were large and possessed developing gametes. Mature ovaries were distinguished from immature in fall, winter, and spring by their large size, presence of ova, a pink color (versus yellow), and large ovarian arteries. Mature testes were identified from immature by their white color (versus yellow) and larger size. A total of 204 white perch (71 male, 133 female) and 273 yellow bass (99 male, 174 female) were analyzed for age at maturity. White perch and yellow bass collected in summer were excluded because sex identification was not possible for all fish.

I determined fecundity for 10 white perch (159 to 280 mm TL), and 10 yellow bass (166 to 308 mm TL). I utilized individuals with the highest GSI values because they represented fish that were closest to spawning. I weighed gonads to the nearest 0.001 g, and determined fecundity by subsampling 0.1 g each from the anterior, middle, and posterior sections of each ovary. Mature ova were counted under a dissecting microscope, and were easily distinguished from immature ova by their larger size. I used least squares regression to examine fecundity-length and fecundity-weight relationships (Taub 1969).

Stomach Contents

I dissected stomachs from 367 white perch and 371 yellow bass. Using a dissecting microscope, I counted each food item, identified it to the lowest practical taxonomic unit, and visually estimated percent volume (Larimore 1957). I used percent number (%N), percent volume (%V), and percent frequency of occurrence (%FO) to calculate the index of relative importance of foods: IRI = (% N + % V) x (% FO) (Pinkas et al. 1971). Percent volume provides an indication of nutritional value for the prey type consumed, and has been utilized extensively to describe the diet of fishes (Bowen 1996). However, %V is biased for larger prey items and overlooks smaller organisms. Percent number quantifies the amount a certain prey item contributes to diet, and is useful in determining importance of a particular item. Percent number calculations are biased towards small prey items that may appear more readily in fish diets. Percent frequency of occurrence describes how often a prey item is consumed by each fish, but can be biased if a fish inadvertently consumes organisms during normal feeding (Bowen 1996). Each of these diet indices provides useful information in describing diets of fishes, but all are biased in some way. The index of relative importance combines the three diet indices into a single calculation and includes the advantages (and disadvantages) of each (Pinkas et al. 1971; Gilliland and Clady 1984; Bigg and Perez 1985; Carrasson et al. 1992; Bowen 1996).

As recommended by Wallace (1981), I used mean %V to calculate Shoener's index of diet overlap between white perch and yellow bass: $C_{xy} = 1 - 0.5\ (\sum|P_{xi} - P_{yi}|)$ (Schoener 1971), where C_{xy} = Schoener overlap index between species *x* and *y*; P_{xi} = the proportion of food type *i* for species *x;* and P_{yi} = the proportion of food type *i* for species *y*. Shoener values range from 0 to 1. Inferential statistics have not been validated for overlap comparisons between species (Wallace 1981), but values less than 0.30 suggest very little overlap, values larger than 0.75 suggest considerable overlap, and values greater than 0.90 suggest nearly complete overlap (Pianka and Pianka 1976).

I calculated diet breadth of foods consumed by white perch and yellow bass collected from Browning Oxbow: $B = 1/\Sigma\ (\ P_i^2\ )$ (Levins 1968), where P_i^2 = the proportion of food type *i*. Breadth values range from 1 to *n*, where *n* is the number of food groups. A score of 1 describes a diet that is specialized with only one food group, and a value of *n* depicts a generalized diet of many types of prey items (Hurlbert 1978).

I used mean %V to compare diets of age-0, age-1, and age-2 and older white perch and yellow bass, as well as seasonal feeding for both species. Seasons were determined by equinox and solstice (Appendix 1). Age-0 white perch and yellow bass were not included in seasonal feeding analyses because diets have been found to differ among age groups (Bulkley 1970; Bath and O'Connor 1985; Driscoll and Miranda 2000). I analyzed stomachs from 335 white perch and 363 yellow to determine seasonal feeding.

Statistical Analyses

I used one-way analysis of variance to test for differences in: 1. catch rates among seasons and gear types; 2. mean GSI values among months; 3. number of ova in different sections of ovaries; 4. diet breadth among seasons for each species; 5. mean %V of prey consumed among fish of age 0, 1, and 2 and older; 6. mean %V among prey items within seasons; and 7. mean % empty stomachs among seasons. Percentage data were arcsine square root transformed before performing anova (Zar 1996). If anova was significant, I used a Tukey multiple comparisons test to determine where differences occurred (Zar 1996). I used a two-way anova to test for differences in growth between sexes and among ages, and I tested for interaction between age and sex. I used chi-square goodness of fit to test the hypothesis that male/female sex ratios for white perch and yellow bass were 1:1. All statistical analyses were performed with Jump Statistical Discovery Software (SAS Institute Inc., 1999).

RESULTS

Population Dynamics

I collected 367 white perch and 371 yellow bass throughout the 14-month period, including 32 and 8 YOY identifiable as white perch and yellow bass, respectively (Table 1). I also captured 445 *Morone* sp. that could not be positively identified to species due to their small size; unless otherwise stated, these fish are not included in the following analyses. Total CPUE for white perch and yellow bass did not vary significantly among seasons ($F = 0.40$, $df = 3$, $P = 0.81$; $F = 0.28$, $df = 3$, $P = 0.89$, respectively). However, the greatest number of white perch and yellow bass were generally collected in spring and summer; I collected only 12 white perch and 33 yellow bass in winter (Table 1). The CPUE among gear types was significantly different for both species ($F = 11.28$, $df = 2$, $P = 0.002$; $F = 8.91$, $df = 2$, $P = 0.004$, respectively), with trap nets yielding the highest catch (Table 2). Only 18 white perch and 22 yellow bass were captured in gill nets throughout the study.

The white perch population in Browning Oxbow was dominated by stock- and quality-length fish, and W_r values were high for various length categories (Table 3). A plot of W_r across seasons showed very little yearly variation for white perch or yellow bass. Relative stock density for quality lengths (RSD-Q) was 51 and relative stock density for preferred-lengths (RSD-P) was 9. The weight-length relationship of white perch was $\text{Log } W = -5.17 + 3.12 \text{ Log } L$ ($r^2 = 0.96$). Sex ratios for white perch were significantly different from 1:1 ($X^2 = 281.3$, df = 1, $P = 0.0001$), with 163 females and 86 males. Annual mortality for the white perch population in Browning Oxbow was 45%.

The yellow bass population was dominated by quality-length fish, and W_r values were high for all length categories (Table 3). Relative stock density was 74, RSD-P was 8, and relative stock density for memorable lengths (RSD-M) was 2. The weight-length relationship for yellow bass was $\text{Log } W = -5.44 + 3.24 \text{ Log } L$ ($r^2 = 0.97$). Sex ratios for yellow bass were significantly different from 1:1 ($X^2 = 492.7$, df = 1, $P = 0.0001$), with 197 females and 105 males. Annual mortality for the yellow bass population was 31%.

Age and Growth

Otolith readings from each age class matched scale readings, suggesting there were no discrepancies in scale data. White perch collections in 1998 were dominated by age-2 individuals, suggesting a strong 1996 year class (Figure 2). In 1999, the majority of white perch were age-4 or the 1995 cohort, possibly due to overwinter mortality in the 1996 year class (Figure 3). The oldest white perch collected was age-7. Yellow bass collections were predominantly age-2 and age-3 in 1998 (Figure 2), and age-3 and age-4 in 1999 (Figure 3), suggesting strong 1995 and 1996 cohorts. The oldest yellow bass collected was age-8. I collected more older females than males for both species (Figures 4, 5).

Body-scale regressions for white perch and yellow bass were: $TL = 13.49 + 1.19$ radius ($r^2 = 0.86$) and $TL = 27.26 + 1.04$ radius ($r^2 = 0.87$), respectively. A significant difference was noted in growth among age groups for white perch ($F = 285.8$, $df = 6$, $P = 0.0001$), and yellow bass ($F = 428.5$, $df = 7$, $P = 0.0001$). Growth was rapid in the first two years of life, but decreased thereafter (Table 4). White perch and yellow bass growth did not differ between sexes ($F = 2.03$, $df = 1$, $P = 0.16$; $F = 0.42$, $df = 1$, $P = 0.55$, respectively). There was no significant interaction between age and sex did not differ for white perch ($F = 0.67$, $df = 6$, $P = 0.66$) or yellow bass ($F = 0.41$, $df = 7$, $P = 0.80$).

Reproductive Biology

The first YOY *Morone* sp. appeared in June 1998 and in May 1999. Mean GSI values for male and female white perch peaked in April each year (Figure 6,

Appendix 2). Water temperatures were 14 and 17 C in these sample periods, respectively. The peak in April 1998 was significant for males ($F = 13.56$, $df = 10$, $P = 0.0001$) and females ($F = 33.37$, $df = 12$, $P = 0.0001$), compared to other months. Mean GSI values for females decreased from 9.9 in April 1998 to 2.4 in May 1998, suggesting the spawn occurred during this period. Ovaries were small from June through August, with mean GSI values < 1.0. Mean GSI values increased from August until a slight drop in February 1999, but increased to 7.5 in April (Figure 6), dropping to 4.9 in May 1999. I did not collect any females in January 1999. Male mean GSI values in 1998 were highest in April (8.4) and dropped to 2.4 in May 1998. Testes were quiescent from June through August, with mean GSI values < 1.0. Male mean GSI values increased from 1.0 in September 1998 to 3.6 in October. Three of eight adult white perch males captured in October were ripe; these fish released milt when pressure was applied to the abdomen. Male mean GSI values continued to increase until a peak of 5.1 in April 1999 (Figure 6). I did not collect any white perch males in December 1998, January 1999, or May 1999.

Yellow bass male and female mean GSI values peaked in April each year (Figure 7, Appendix 2); these values were significantly higher than those in other months ($F = 15.55$, $df = 12$ $P = 0.0001$; $F = 36.45$, $df = 12$, $P = 0.0001$). I did not collect any male or female yellow bass in January 1999. Female mean GSI values in 1998 dropped from 11.0 in April to 3.6 in May, suggesting that spawning occurred at this time. Ovaries were small from June through August 1998, and mean GSI values were less than 1.0. Female mean GSI values steadily increased from September 1998 (1.6) until the peak in April 1999 (8.0), then dropped to 5.1 in May 1999. Mean GSI values for males decreased from 6.8 in April 1998 to 2.4 in May 1998. Testes were small and quiescent from June through September 1998, with GSI values less than 1.0. Mean GSI values increased from 0.3 in September 1998 until the peak of 5.7 in April 1999, before dropping to 3.4 in May 1999 (Figure 7).

White perch and yellow bass in Browning Oxbow matured at an early age. Ninety-one percent (10/11) of age-1 male white perch and 43% (3/7) of age-1 females were sexually mature (Table 5). Mature age-1 males had a mean TL of 132 mm (25 SD), and one immature age-1 male was 103 in TL. Mature age-1 females had a mean TL of 124 mm (38 SD), whereas immature females averaged 114 mm (15 SD) TL. Of 16 age-2 males, all were sexually mature, and 85% (23/27) of age-2 females were mature (Table 5). Mature age-2 females averaged 182 mm (18 SD) TL, whereas immature age-2 females had a mean TL of 179 mm (29 SD). All (16/16) male age-2 white perch were mature; mean TL was 163 mm (31 SD). The remaining age groups (age-3 to age-8) of male and female white perch were sexually mature.

Eight of nine (89%) age-1 male yellow bass were sexually mature, and 12% (1/8) of age-1 females were mature. Mature age-1 males averaged 122 mm (24 SD) TL, and one immature male was 113 mm TL. The one mature age-1 female was 125 mm TL, whereas seven immature age-1 females averaged 112 mm (22 SD). Most age-2 female yellow bass were sexually mature (43/46 = 93%), averaging 187 mm TL (20 SD). Immature age-2 females had a mean TL of 148 mm (9 SD). All (42/42) age-2 male yellow bass were mature; mean TL was 172 mm (19 SD). The remaining age groups (age-3 to age-8) of male and female yellow bass were sexually mature.

Fecundity estimates from anterior, middle, and posterior sections of ovaries were not significantly different for white perch ($F = 0.10$, $df = 2$, $P = 0.91$) or yellow bass ($F = 0.06$, $df = 2$, $P = 0.94$). White perch fecundity estimates ranged from 33,401 to 166,162 ova per female (Table 6). Fecundity was only weakly related to TL ($r^2 = 0.45$), and less related to mass ($r^2 = 0.27$) (Figures 8, 9). Yellow bass fecundity estimates ranged from 26,520 to 186,206 ova per female (Table 6). Fecundity was moderately related to fish length ($r^2 = 0.70$), and less related to fish mass ($r^2 = 0.67$) (Figures 10, 11).

Seasonal Feeding and Diet Overlap

Of 123 white perch and 158 yellow bass collected in spring (Table 1), 62 white perch (50%) and 97 yellow bass (61%) had food in their stomach. For both species, mean %N, mean %V, mean %FO, and IRI values were high for dipterans (Chironomidae, Tipulidae, and Ceratopogonidae) in the spring months (Tables 7, 8). Dipteran mean %V was greater than that for all other prey items for both white perch and yellow bass in spring ($P < 0.05$; Tables 7, 8). Zooplankton (Copepoda, Cladocera, and *Leptodora* sp.) had a mean %V of 10 for white perch, and 1 for yellow bass. Hemipterans (Corixidae) comprised 6% of white perch diet and 20% of yellow bass diet in spring. Fish (white crappie, *Pomoxis annularis*, bluegill, *Lepomis machrochirus*, and gizzard shad, *Dorosoma cepedianum*) and fish eggs were consumed by both species in spring, but these prey items yielded relatively small %V, %N, %FO, and IRI values (Table 7). Diet overlap between white perch and yellow bass for spring was 0.82, indicating considerable overlap, and food niche breadth values were 2.3 for both white perch and yellow bass.

Of 140 white perch and 106 yellow bass collected in summer, 72 white perch (51%) and 67 yellow bass (63%) contained food. Dipterans constituted high mean %N, mean %V, mean %FO, and IRI values for white perch and yellow bass in summer (Tables 7, 8). Mean %V of dipterans was greater than that for all other prey items in summer for both white perch and yellow bass ($P < 0.05$; Tables 7, 8).

White perch and yellow bass also consumed hemipterans, zooplankton, and fish in summer, but these foods did not yield large diet metrics. Overlap between white perch and yellow bass for summer was 0.91, indicating nearly complete overlap, and breadth values were 1.7 for white perch and 2.2 for yellow bass.

Fifty percent of white perch (30/60) and 38% of yellow bass (25/66) collected in fall contained prey items in their stomach. Fish yielded the highest %V for white perch in fall (Table 7), and was significantly different from all other prey items ($P < 0.05$; Table 7). For yellow bass, no single prey item dominated the %N, %V, %FO, or IRI values in fall, and no significant difference was found in mean %V among prey items ($p > 0.05$; Table 8). Overlap between white perch and yellow bass in fall was 0.57. Breadth values were 2.7 for white perch and 3.2 for yellow bass.

I collected only 12 white perch and 33 yellow bass in winter. Seventy-five percent (9/12) of white perch and 64% (21/33) of yellow bass contained prey items. Fish constituted the great majority of white perch and yellow bass diets by %N, %V, %FO, and IRI in winter (Tables 7, 8). Mean %V for fish was significantly higher than all other prey items for both white perch and yellow bass ($P < 0.05$; Tables 7, 8). Overlap was 0.80, indicating considerable overlap, and breadth values were 1.5 for white perch and 1.8 for yellow bass in winter. Food niche breadth values did not differ among seasons for white perch or yellow bass

(F = 0.99, df = 3, P = 0.45; F = 3.23, df = 3, P = 0.06, respectively). No significant differences occurred in the percentage of empty stomachs for white perch (F = 0.27, df = 3, P = 0.89) and yellow bass (F = 0.23, df = 3, P = 0.91) among seasons.

Diets Among Life Stages

Zooplankton and dipterans dominated age-0 white perch diet, with mean %V of 50 and 45, respectively; diet of age-0 yellow bass was dominated by zooplankton, with a mean %V of 79 (Table 9). Mean %V for zooplankton was significantly higher for age-0 white perch and yellow bass than for other age classes ($P < 0.05$). The diet of age-1 white perch consisted primarily of dipterans, with a mean %V of 60; dipterans, zooplankton, and hemipterans comprised the great majority of age-1 yellow bass diet (Table 9). Age-2 and older white perch and yellow bass consumed large amounts of dipterans and fish (Table 9). Age-2 and older white perch ate a greater mean %V of fish compared to other age groups ($P < 0.05$), but no difference was noted in mean %V of fish consumed by age-0, age-1, and age-2 and older yellow bass ($p > 0.05$).

Diel Feeding Activity

Diel sampling showed that white perch, yellow bass, and YOY *Morone* sp. were most active during the 2400 hour sample period (Figure 12); I collected 25 white perch, 13 yellow bass, and 181 *Morone* sp. during this sample. White perch feeding was highest at 2000, 2400, and 0400 hours, and yellow bass peak feeding occurred during the 2400 and 0400 sample periods (Figure 13). All 25 white perch and 13 yellow bass collected during the 2400 hour period, and the two white perch and three yellow bass collected at 0400 contained food items in their stomach.

DISCUSSION

White perch and yellow bass populations in Browning Oxbow were dominated by stock and quality sized individuals, suggesting that they possibly contribute to angler catch. Mean W_r values for all length categories suggest that both species were in good condition, with relative weight values ranging from 93 to 113. Annual mortality rates were high for white perch (45%) and moderate for yellow bass (31%), suggesting that older individuals may be susceptible to angling; I collected very few white perch or yellow bass that were older than age-5.

White perch and yellow bass can be captured in a variety of habitats (Pflieger 1997), and various sampling devices have shown to be efficient for collecting them. Collection of white perch in estuaries and large tidal rivers is effective with the use of trawls, gill nets, and seines (Bath and O'Connor 1985; Rudershausen and Loesch 2000). Collection of yellow bass in freshwater impoundments is successful with gill nets, seines, trap nets, and electrofishing (Bulkley 1970; Van Den Avyle et al. 1983). Trap nets were most effective in collecting white perch and yellow bass in Browning Oxbow. The higher CPUE for both species in trap nets versus gill nets and seines could have been due to limited open water habitat, and the fact that Browning Oxbow is shallow, with a maximum depth of 3 m. Male/female sex ratios were skewed from a 1:1 ratio, and females dominated the catch of both species. Mansueti (1961) collected more female white perch than males during spring in non-spawning areas, but he found that males outnumbered females in spawning habitats. It is possible that fewer males were collected in Browning Oxbow because they occupied different habitats than females.

Although scale readings matched otolith readings, annuli from otoliths were easier to read than scales, especially for older white perch and yellow bass ($\geq$ age-5). The first three annuli were easily read on scales, but remaining annuli were hard to distinguish due to crowding on outer scale margins. Taub (1966) and Mosher (1976) described similar results for annuli from white perch $\geq$ age-5. Otolith annuli from older fish were not as crowded at the margin.

Age frequency diagrams for white perch and yellow bass collected in Browning Oxbow are not typical because few age-0 were positively identified, and age-1 individuals may have been underrepresented due to sample gear bias. The white perch and yellow bass populations were predominantly age-2, age-3, or age-4 individuals. Because KDWP fisheries biologists had not collected white perch or yellow bass in Browning Oxbow prior to 1995 (K. Tjelmeland, KDWP, pers. comm.), it seems likely that both species gained access to the oxbow during massive flooding of the Missouri River in 1993. High numbers of age-2 and age-3 white perch and yellow bass suggests a population explosion characteristic of invading species (Dence 1952).

I collected more older female white perch and yellow bass than males in Browning Oxbow. Previous studies have produced conflicting results. Females lived longer than males in the Patuxent River Estuary, Maryland, and in the James and York rivers, Virginia (Mansueti 1961; St. Pierre and Davis 1972). However, Mosher (1976) showed that male white perch collected from a Massachusetts pond lived longer than females, and the oldest male was age-10. No previously published studies on yellow bass have compared longevity of males and females.

Growth of white perch and yellow bass was rapid in the first two years of life, but slowed considerably after age-2. Similar results have been reported elsewhere for both species. Marcy and Richards (1974), Mosher (1976), and

Busch and Heinrich (1982) showed that highest growth for white perch occurred in the first two years of life, and decreased thereafter, in the Lower Connecticut River, Connecticut, Parker River Estuary, Massachusetts, and Lake Ontario. Growth of yellow bass was highest for age-1 and age-2 fish collected from Clear Lake, Iowa, and Lake Poygan, Wisconsin, and declined thereafter (Carlander et al. 1953; Priegel 1975). Growth of white perch from Browning Oxbow was higher for all age groups compared to white perch collected from the Delaware River, Delaware, Parker River Estuary, Massachusetts, and Lake Ontario (Wallace 1971; Mosher 1976; Busch and Heinrich 1982; Carlander 1997), but similar to that in the lower Connecticut River, Connecticut (Marcy and Richards 1974). Growth of yellow bass in Browning Oxbow was high compared to that of yellow bass in Clear Lake, Iowa (Carlander et al. 1953; Buchholz 1960; Skillman 1965; Carlander 1997), but similar to that in Lake Poygan, Wisconsin (Priegel 1975).

Male growth rate did not differ from that of females for white perch or yellow bass in Browning Oxbow. Male and female white perch showed no difference in growth in the lower Connecticut River (Marcy and Richards 1974), but female white perch collected from the Parker River Estuary, Massachusetts (Mosher 1976), Delaware River, Delaware (Wallace 1971), and Lake Ontario (Busch and Heinrich 1982) exhibited higher growth rates than males. Growth of female yellow bass was not different from that of males in Lake Poygon, Wisconsin (Priegel 1975), but female yellow bass collected from Clear Lake, Iowa, and Watts Bar Reservoir, Tennessee, exhibited higher growth rates than males (Lewis and Carlander 1947; James 1979).

Spawning of white perch and yellow bass occurred in Browning Oxbow from April into May of 1998 and 1999, and water temperatures ranged from 14 to 17 C on these sample dates. Mean GSI values and presence of ripe white perch and yellow bass suggested that spawning occurred in April and May of each year. Appearance of YOY in June 1998 and May 1999 verified that spawning occurs in this population. Spawning of white perch and yellow bass in Browning Oxbow may occur along the southern shore, which is composed of rock substrate (riprap), typical spawning habitat for other populations (Mansueti 1961; Mosher 1976; Carlander 1997).

White perch and yellow bass spawning seasons are related to an increase in water temperature in spring, and dates vary depending on location of populations. White perch reproduction takes place from late May into June at water temperatures from 11 to 15 C in the Bay of Quinte, Lake Ontario (Sheri and Power 1968). In the Chesapeake Bay, reproduction occurs from March into April (Dovel 1971; Carlander 1997). Yellow bass reproduce in Arkansas from April to May, and in Clear Lake, Iowa, from May into June (Ridenhour 1958; Buchholz 1960; Atchison 1967; Bulkley 1970; Carlander 1997).

Male white perch matured earlier in the season than did females, as shown by mean GSI values. Three of eight adult males were releasing gametes in the fall. Mansueti (1961) showed that white perch in the Patuxent Estuary, Maryland, were capable of releasing sperm in fall, and that males ripened earlier in spring than females. Male yellow bass in Browning Oxbow matured earlier in spring than females, as shown by higher GSI values, but I did not collect any in fall that released gametes. Jackson and Sullivan (1995) showed that both male and female white perch exhibit a peak in hormone development and GSI levels in fall and spring.

Male white perch and yellow bass matured at a younger age and smaller size than did females. Most male white perch (91%) and yellow bass (87%) were mature at age-1, and all were mature by age-2; most female white perch and yellow bass took two to three years to mature. In Lake Ontario and Lake Erie, most male white perch also mature at age-1, and all mature by age-2 (Sheri and Power 1968; Bur 1986). Mansueti (1961), Sheri and Power (1968), and Bur (1986) reported that female white perch took two to four years to reach sexual maturity in Lake Ontario, Lake Erie, and the Patuxent Estuary. Atchison (1967) and Priegel (1975) reported that female yellow bass took two to four years to mature in Clear Lake, Iowa, and Lake Poygan, Wisconsin, respectively.

Fecundity estimates for both white perch and yellow bass were high, suggesting that these populations have the potential to populate quickly. Previous studies found both white perch and yellow bass are highly fecund, and quick overpopulation can lead to stunting. Sheri and Power (1968) reported white perch fecundities from 5,100 to 247,681 ova per female. Bur (1986) observed maximum white perch fecundity to be 388,736. Hergenrader (1980) documented the introduction and dispersal of white perch in Nebraska, and reported that high fecundity rates led to quick overpopulation. He observed stunting in white perch growth, with few fish reaching harvestable size. Bulkley (1970) estimated average yellow bass fecundity in Clear Lake, Iowa, at 203,800. Fecundity estimates of white perch and yellow bass from Browning Oxbow were more related to fish length than mass. Other investigators have shown that these relationships vary among populations. In white perch collected from the Parker River Estuary, Massachusetts, Mosher (1976) found fecundity more related to mass ($r = 0.973$) than to length ($r = 0.866$). Sheri and Power (1968) reported that white perch fecundity in Lake Ontario was more related to length ($r = 0.82$) than mass ($r = 0.00005$). No previously published analysis has examined these relationships for yellow bass.

Diets of white perch and yellow bass collected in Browning Oxbow consisted mainly of dipterans, hemipterans, and fish. Previous feeding studies of white perch and yellow bass have shown these species to be quite adaptable, with varying diets, likely influenced by prey availability in different habitats. Weisberg and Janicki (1990) found that white perch collected from the Susquhanna River, Maryland, fed heavily on caddisflies, and Mosher (1976) showed that white perch diet in a Massachusetts pond was dominated by dipterans. Fishes were frequently consumed by white perch in 18 Maine lakes (Warner 1974). Mosher (1976) and Bath and O'Connor (1985) found that white perch in the Parker River Estuary, Massachusetts, and the Hudson River Estuary, New York, respectively, had eaten mainly amphipods, isopods, and fish. Collier (1959) showed that yellow bass collected from North Twin Lake, Iowa, consumed large numbers of dipterans, and Welker (1963) and Kraus (1963) found that yellow bass fed heavily on dipterans in Clear Lake, Iowa. Yellow bass collected from an oxbow of the Mississippi River fed primarily on dipterans, fish eggs, and fish (Driscoll and Miranda 1999).

Diets of white perch and yellow bass were similar throughout the seasons. Dipterans dominated mean %N, mean %V, mean %FO, and IRI values in spring, summer, and fall. However, both species switched to feed on fish in winter. Elrod et al. (1982) found that adult white perch (>200 mm TL) consumed dipterans in spring and summer, but ate fish in fall. Bulkley (1970) showed that yellow bass in Clear Lake, Iowa, ate large numbers and amounts of dipterans in the summer, but shifted to feed heavily on fish in the fall.

Diets of white perch and yellow bass overlapped considerably in spring, with both eating primarily dipterans. Although overlap was high, minor differences were noticed, in that white perch consumed more zooplankton, and yellow bass ate more hemipterans. Diet overlap was nearly complete during summer, as a result of consumption of mainly dipterans by both species. Fall diet overlap was much lower, and white perch ate a greater mean %V of fish than did yellow bass. Yellow bass consumed a larger mean %V of hemipterans and zooplankton than did white perch. Winter diet overlap (0.80) was similar to that in spring. Both species ate mainly fish, although white perch consumed more dipterans, and yellow bass ate more hemipterans.

Diet breadth values show that white perch and yellow bass were specialized feeders in spring, summer, and winter. Breadth values were low in spring and summer because both species fed predominantly on dipterans, and breadth values were low in winter because white perch and yellow bass fed heavily on fish. Fall breadth values were higher, indicating more generalized food use.

White perch and yellow bass in Browning Oxbow exhibited differences in diet among life stages. Young-of-the-year of both species fed heavily on zooplankton, whereas age-1 and older individuals fed mainly on aquatic insects or fish. Young-of-the-year white perch < 110 mm SL collected from the Hudson River Estuary, New York, fed primarily on zooplankton, whereas adults (> 110 mm SL) ate mainly on amphipods, isopods, and aquatic insects (Bath and O'Connor 1985). Rundershausen and Loesch (2000) showed that YOY white perch collected in the James River, Virginia, fed primarily on zooplankton. Diet of YOY yellow bass in Clear Lake, Iowa, was dominated by zooplankton, and adults ate mainly aquatic insects (Welker 1963; Kraus 1963; Bulkley 1970). Likewise, Van den Avyle et al. (1983) showed that young yellow bass collected from Watts Bar Reservoir, Tennessee, consumed large amounts of zooplankton.

White perch and yellow bass were most active at night during the July diel sample, and the number of stomachs with food peaked at 2400 hours. Kraus (1963) collected the largest number of yellow bass between 2000 and 2400 hours in Clear Lake, Iowa, and found that peak feeding occurred during the 2400 hour sample. Likewise, Ridenhour (1960) found that yellow bass feeding occurred at night in Clear Lake, Iowa. No diel feeding studies of white perch have been published previously.

The nature of white perch and yellow bass diets in Browning Oxbow possibility affects indigenous fishes. Early feeding on zooplankton, and the switch to insects and fish suggest that these fishes could compete with native sport fishes, including bluegill, white bass, largemouth bass (*Micropterus salmoides*), and white crappie. Predation on fish eggs and juveniles likely affects native fish populations (e.g., Schaeffer and Margraf 1987; Driscoll and Miranda 1999), and in

Browning Oxbow white perch and yellow bass ate large amounts of fish in winter. Predation by white perch and yellow bass could decimate native fish populations in Browning Oxbow. Future research should be directed toward understanding trophic relationships between white perch, yellow bass, and native species to determine if competition or predation lead to species declines.

Range expansion of white perch and yellow bass in Kansas and Missouri may threaten native fishes, just as the invasion of white perch into the Great Lakes led to population declines of yellow perch and white bass (Parrish and Margraf 1994; Prout et al. 1990; Madenjian et al. 2000). Boileau (1985) suggested that white perch may reduce abundance of walleye (*Stizostedion vitreum*) and various centrarchids in the Great Lakes possibly due to predation. White perch and yellow bass have been shown to hybridize with white bass (Todd 1986; Fries and Harvey 1989). Hybridization and subsequent backcrossing could lead to introgression with native white bass (Tseng et al. 2000). Research should be conducted to determine if hybridization and introgression are occurring between white perch, yellow bass, and white bass in Browning Oxbow. Range expansion of white perch and yellow bass could cause other problems for aquatic resources. White perch can quickly overpopulate, leading to stunted populations (Dence 1952; Hergenrader and Bliss 1971; Hergenrader 1980), and the need to renovate lakes. White perch has recently been accidentally introduced into Wilson and Cheney reservoirs in Kansas. Individuals have apparently escaped the confines of Cheney Reservoir, and are now widespread downstream in the Ninnescah River (K. Mitchell, KDWP, pers. comm.), raising the potential for adverse ecological effects on native aquatic communities inherent to introduction and spread of nonindigenous fishes (e.g., Taylor et al. 1984; Li and Moyle 1999).

Literature Cited

Anderson, R.O., and R.F. Neumann. 1996. Length, weight, and associated structural indices. Pp. 447-481. *In* Murphy, B.R., and D.W. Willis, eds. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Atchison, G.J. 1967. Contributions to the life history of the yellow bass, *Roccus mississippiensis*, (Jordan and Eigenmann), in Clear Lake, Iowa. M.S. thesis, Iowa State University. Ames, Iowa.

Bath, D.W., and J.M. O'Connor. 1985. Food preferences of white perch in the Hudson River Estuary. New York Fish and Game Journal 32:63-70.

Bigg, M.A., and M.A. Perez. 1985. Modified volume: A frequency-volume method to assess marine mammal food habits. Pp. 277-283. *In* Beddington, J.R., R.J.H. Beverton, and D.M. Lavigne, eds. Marine mammals and fisheries. George Allen and Unwin, London, United Kingdom.

Bister, T.J., D.W. Willis, M.L. Brown, S.M. Jordan, R.M. Neuman, M.C. Quist, and C.S. Guy. 2000. Proposed standard weight (W_s) 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.

Bowen, S.H. 1996. Quantitative description of the diet. Pp. 513-529. *In* Murphy, B.R., and D.W. Willis, eds. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Buchholz, M.M. 1960. Ecological relationships associated with decreasing growth rate of Clear Lake yellow bass. Ph.D. thesis, Iowa State University of Science and Technology. Ames, Iowa.

Bulkley, R.V. 1970. Changes in yellow bass reproduction associated with environmental conditions. Iowa Journal of Science 45:137-180.

Bur, M.T. 1986. Maturity and fecundity of the white perch, *Morone americana,* in western Lake Erie. Ohio Journal of Science 86:205-207.

Burgess, G.H. 1980. *Morone mississippiensis* Jordan and Eigenmann, yellow bass. Pp. 575 *In* Lee D.S. et al., eds. Atlas of North American freshwater fishes. N.C. State Museum of Natural History, Raleigh, I-x + 854 pp.

Busack, C.A., and G.A.E. Gall. 1981. Introgressive hybridization in populations of Paiute cutthroat trout (*Salmo clarki seleniris*). Canadian Journal of Fisheries and Aquatic Sciences 38:939-951.

Busch, W.D.N., and J.W. Heinrich. 1982. Growth and maturity of white perch in Lake Ontario. New York Fish and Game Journal 29:206-208.

Carlander, K.D. 1982. Standard intercepts for calculating length from scale measurements for some centrarchid and percid fishes. Transactions of the American Fisheries Society 111:332-336.

Carlander, K.D. 1997. Handbook of freshwater fishery biology. 3rd edition. Iowa State University Press, Ames, Iowa.

Carlander, K.D., W.M. Lewis, G.E. Ruhr, and R.E. Cleary. 1953. Abundance, growth, and condition of yellow bass, *Morone interrupta* Gill, in Clear Lake, Iowa, 1941 to 1951. Transactions of the American Fisheries Society 82:91-103.

Carrasson, M., C. Stefanescu, and J.E. Cartes. 1992. Diets and bathymetric distributions of two bathyal sharks of the Catlan deep sea (western Mediterranean). Marine Ecology Progress Series 82:21-30.

Collier, J.E. 1959. Changes in fish populations and food habits of yellow bass in North Twin Lake, 1956-1959. Proceedings of the Iowa Academy of Science 77:518-522.

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

DeVries, D.R., and R.V. Frie. 1996. Determination of age and growth. Pp. 483-508. *In* Murphy, B.R., and D.W. Willis, eds. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Dovel, W.L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. University of Maryland Natural Resources Institute Special Report 4:1-71.

Driscoll, M.P., and L.E. Miranda. 1999. Diet ecology of yellow bass, *Morone mississippiensis*, in an oxbow of the Mississippi River. Journal of Freshwater Ecology 14:477-486.

Elrod, J.J., W.D.N. Busch, B.L. Griswold, C.P. Shneider, and D.R. Wolfert. 1981. Food of white perch, rock bass, and yellow perch in eastern Lake Ontario. New York Fish and Game Journal 28:191-201.

Fries, L.T., and W.D. Harvey. 1989. Natural hybridization of white bass with yellow bass in Texas. Transactions of the American Fisheries Society 118:87-89.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, Maryland.

Gablehouse, D.W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Gilliland, E.R., and M.D. Clady. 1984. Diet overlap of striped bass x white bass hybrids and largemouth bass in Sooner Lake, Oklahoma. Proceedings of the Annual Conference of the Southeastern Fish and Wildlife Agencies 35:317-330.

Harlan, J.R., E.B. Speaker, and J. Mayhew. 1987. Iowa fish and fishing. Iowa Department of Natural Resources. Ames, Iowa.

Hergenrader, G.L. 1980. Current distribution and dispersal of white perch (*Morone americana*) in Nebraska and adjacent waters. American Midland Naturalist 103:404-407.

Hergenrader, G.L., and Q.P. Bliss. 1971. The white perch in Nebraska. Transactions of the American Fisheries Society 100:737-738.

Hurlbert, S.H. 1978. The measurement of niche overlap and some relatives. Ecology 59:67-77.

Jackson, L.F., and C.V. Sullivan. 1995. Reproduction of white perch: the annual gametogenic cycle. Transactions of the American Fisheries Society 124:563-577.

James, B.T. 1979. Feeding, growth, and competitive interrelationships of *Morone chrysops* (Rafineque) and *Morone mississippiensis* (Jordan and Eigenmann) in Watts Bar Reservoir, Tennessee. M.S. thesis, Tennessee Technological University, Cookeville, Tennessee.

Jenkins, R.E., and N.M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Kraus, R. 1963. Food habits of the yellow bass, *Roccus mississippiensis*, Clear Lake, Iowa, summer 1962. Journal of the Iowa Academy of Science 70:209-215.

Krueger, C.C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48 (Supplement 1):66-79.

Larimore, W.R. 1957. Ecological life history of warmouth (Centrarchidae). Illinois Natural History Survey Bulletin 27:1-83.

Larsen, A. 1954. First record of the white perch (*Morone americana*) in Lake Erie. Copeia 1954:154.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980 et seq. Atlas of North American freshwater fishes. N.C. State Museum of Natural History, Raleigh. *I-x* + 854 pp.

Levins, R. 1968. Evolution of changing environments: some theoretical explorations. Princeton University Press, Princeton, New Jersey.

Lewis, W.M., and K.D. Carlander. 1947. Growth of the yellow bass, *Morone interrupta* Gill, in Clear Lake, Iowa. Iowa State College Journal of Science 22:185-195.

Li, H.W., and P.B. Moyle. 1999. Management of introduced fishes. Pp. 345-375 *In* Kohler, C.C., and W.A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Maceina, M.J. 1988. Simple grinding procedure to section otoliths. North American Journal of Fisheries Management 8:141-143.

Madenjian, C.P., R.L. Knight, M.T. Bur, and J.L. Forney. 2000. Reduction in recruitment of white bass in Lake Erie after invasion of white perch. Transactions of the American Fisheries Society 129:1340-1353.

Mansueti, R.J. 1960. Selection of body site for scale samples in the white perch, *Roccus americanus*. Chesapeake Science 1:103-109.

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

Marcy, B.C., and F.P. Richards. 1974. Age and growth of white perch, *Morone americana*, in the Lower Connecticut River. Transactions of the American Fisheries Society 103:117-120.

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, University of Massachusetts, Amherst, Massachusetts.

Moyle, P.B., H.W. Li, and B.A. Barton. 1986. The Frankenstein effect: impact of introduced fishes on native fishes in North America. Pp. 415-426. *In* The role of fish culture in fisheries management, R.H. Stroud, ed. American Fisheries Society, Bethesda, Maryland.

Page, L.M., and B.M. Burr. 1991. A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Co., New York.

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. Canadian Journal of Fisheries and Aquatic Sciences 47:1779-1787.

Parrish, D.L., and F.J. Margraf. 1994. Spatial and temporal patterns of food use by white perch and yellow perch in Lake Erie. Journal of Freshwater Ecology 9:29-35.

Pflieger, W.L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City.

Pianka, E.R., and H.D. Pianka. 1976. Comparative ecology of twelve species of nocturnal lizards (Gekkonidae) in the Western Australian desert. Copeia 1976:125-142.

Pinkas, L., M.S. Oliphant, and I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. California Fish and Game 152:1-105.

Priegel, G.R. 1975. Age and growth of yellow bass in Lake Poygan, Wisconsin. Transactions of the American Fisheries Society 104:513-515.

Prout, M.W., E.L. Mills, and J.L. Forney. 1990. Diet, growth, and potential competitive interactions between age-0 white perch and yellow perch in Onieda Lake, New York. Transactions of the American Fisheries Society 119:966-975.

Ridenhour, W.E. 1958. Ecology of young game fishes of Clear Lake, Iowa. Ph.D. thesis. Iowa State University of Science and Technology, Ames, Iowa.

Rudershausen, P.J., and J.G. Loesch. 2000. Feeding habits of young-of-year striped bass, *Morone saxatilis*, and white perch, *Morone americana*, in lower James River, VA. Virginia Journal of Science 51:23-37.

SAS Institute Inc. 1999. JMP Statistics and Graphics Guide. Version 3. SAS Institute Inc., Cary, North Carolina.

Schaeffer, J.S., and F.J. Margraf. 1986. Food of white perch (*Morone americana*) in Lake Erie. Ohio Journal of Science 86:26-29.

Schaeffer, J.S., and F.J. Margraf. 1987. Predation on fish eggs by white perch, *Morone americana*, in western Lake Erie. Environmental Biology of Fishes 18:77-80.

Schoener, T.W. 1971. Theory of feeding strategies. Annual Review of Ecology and Systematics 2:369-404.

Sheri, A.N., and G. Power. 1968. Reproduction of white perch, *Roccus americanus*, in the Bay of Quinte, Lake Ontario. Journal of the Fisheries Research Board of Canada 25:2225-2231.

Skillman, R. A. 1965. Increased growth of yellow bass in Clear Lake, Iowa, 1959-1964. Ph.D. thesis. Iowa State University of Science and Technology, Ames, Iowa.

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

Stein, J.E., and D.R. Edds. 2000. White perch and yellow bass range extensions into Kansas. Prairie Naturalist 32(4): In press.

Strange, R.J. 1996. Field examination of fishes. Pp. 433-446. *In* Murphy, B.R., and D.W. Willis, eds. Fisheries techniques, 2nd edition, American Fisheries Society, Bethesda, Maryland.

Taub, S.H. 1966. Some aspects of life history of white perch, *Roccus americanus* (Gmelin), in Quabbin Reservoir, Massachusetts. M.S. thesis. University of Massachusetts, Amherst, Massachusetts.

Taub, S.H. 1969. Fecundity of the white perch. Progressive Fish-Culturist 31:166-168.

Taylor, J.N., W.R. Courtenay, Jr., and J.A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pp. 322-373. *In* Courtenay, W.R., Jr., and J.R. Stauffer, Jr. eds. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore, Maryland.

Todd, T.N. 1986. Occurrence of white bass-white perch hybridization in Lake Erie. Copeia 1986:196-199.

Tomelleri, J., and M. Eberle. 1990. Fishes of the central United States. University Press of Kansas, Lawrence.

Tseng, C.W., J.E. Stein, C.R. McFall, D. Edds, and S.S. Crupper. 2000. Molecular differentiation of white perch and yellow bass. Transactions of the Kansas Academy of Science 103:168-172.

Van den Avyle, M.J., B.J. Higginbotham, B.T. James, and F.J. Bulow. 1983. Habitat preferences and food habits of young-of-the-year striped bass, white bass, and yellow bass in Watts Bar Reservoir, Tennessee. North American Journal of Fisheries Management 3:163-170.

Van den Avyle, M.J., and R.S. Hayward. 1999. Dynamics of exploited fish populations. Pp. 127-166. *In* Kohler, C.C., and W.A. Hubert, eds. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Wallace, D.C. 1971. Age, growth, year-class strength and survival rates of the white perch, *Morone americana* (Gmelin), in the Delaware River in the vicinity of Artificial Island. Chesapeake Science 12:205-218.

Wallace, R.K., Jr. 1981. An assessment of diet overlap indexes. Transactions of the American Fisheries Society 110:72-76.

Warner, K. 1974. Utilization of fish as spring food by white perch and yellow perch in Maine lakes. Progressive Fish Culturist 36:96-98.

Weisberg, S.B., and A.J. Janicki. 1990. Summer feeding of white perch, channel catfish, and yellow perch in the Susquehanna River, Maryland. Journal of Freshwater Ecology 5:391-405.

Welker, B.D. 1963. Summer food habits of yellow bass and black bullheads in Clear Lake. Proceedings of the Iowa Academy of Sciences 67:286-295.

Zar, H.J. 1996. Biostatistical analysis. 3rd edition. Prentice Hall, Upper Saddle River, New Jersey.

Table 1. Seasonal catch of white perch and yellow bass in Browning Oxbow from April 1998 to May 1999.

Species	Spring	Summer	Fall	Winter	Total
White perch	123	157	75	12	367
Yellow bass	158	106	74	33	371
Morone sp.	0	394	51	0	445
Total	281	657	200	45	1183

Table 2. Seasonal mean CPUE (SD) of white perch and yellow bass for gear types employed in Browning Oxbow from April 1998 to May 1999. Different letters denote significant differences ($P < 0.05$).

	White perch n = 367			Yellow bass n = 371		
Sample season	Trap net	Gill net	Seine	Trap net	Gill net	Seine
Spring 98	3.9 (2.9)	1.8 (2.5)	0.5 (-)	1.9 (2.1)	0.0 (-)	0.6 (-)
Summer 98	7.0 (19.0)	0.4 (0.5)	0.5 (-)	3.7 (7.3)	0.3 (-)	0.1 (2.5)
Fall 98	2.7 (2.0)	0.0 (-)	0.0 (-)	3.9 (4.1)	0.7 (0.5)	0.0 (-)
Winter 98/99	1.0 (0.5)	0.7 (-)	0.0 (-)	3.0 (2.0)	2.0 (0.8)	0.0 (-)
Spring 99	4.1 (3.5)	1.3 (3.0)	0.0 (-)	7.2 (8.9)	1.2 (0.6)	0.0 (-)
Mean combined	3.7^{a}	0.8^{b}	0.2^{b}	3.9^{a}	0.8^{b}	0.2^{b}
Standard Error	(0.9)	(0.4)	(0.1)	(1.7)	(0.4)	(0.1)

Table 3. Catch of length categories, with relative weight (W_r) for white perch and yellow bass collected in Browning Oxbow from April 1998 to May 1999.

Length category	Total Length (cm)	Number	Mean W_r (SD)
		White perch	
Sub-stock	< 13.0	80	
Stock	13.0-19.9	152	113 (15.2)
Quality	20.0-24.9	128	93 (9.4)
Preferred	25.0-29.9	7	98 (11.3)
Memorable	30.0-37.9	0	- -
Trophy	38.0+	0	- -
		Yellow bass	
Sub-stock	<10.0	8	
Stock	10.0-17.9	97	99 (11.5)
Quality	18.0-22.9	231	100 (11.5)
Preferred	23.0-27.9	29	102 (9.4)
Memorable	28.0-32.9	6	110 (9.1)
Trophy	33.0+	0	- -

Table 4. Back-calculated mean total lengths (mm) of 335 white perch and 363 yellow bass collected in Browning Oxbow from April 1998 to May 1999.

White perch

		Length at age						
n	Age-group	1	2	3	4	5	6	7
46	1	92						
112	2	73	151					
101	3	81	173					
65	4	86	181	221	234			
3	5	88	183	240	255	260		
0	6							
8	7	95	190	243	251	254	266	272
Mean		82	168	219	238	260	266	272
SD		13.7	24.0	20.4	16.9	6.0	7.5	7.0
Mean Increment		82	86	51	20	22	6	6

Yellow bass

		Length at age							
n	Age-group	1	2	3	4	5	6	7	8
17	1	101							
174	2	86	162						
131	3	89	172	203					
24	4	98	184	215	231				
7	5	98	189	219	245	256			
2	6	100	203	219	249	266	275		
4	7	98	197	222	240	250	261	273	
4	8	106	196	232	250	264	276	285	290
Mean		88	169	207	237	258	275	284	290
SD		24.0	45.0	18.7	18.5	12.3	9.5	5.3	14.0
Mean Increment		88	81	38	30	21	17	9	6

Table 5. Age and size at maturity for white perch and yellow bass collected in Browning Oxbow from April 1998 to May 1999. Numbers in parentheses are standard deviations.

Age	Sex	No. mature	Mature TL-mm (SD)	Immature TL-mm (SD)	Mature Mass (g)	Immature Mass (g)
			White perch			
0		0/32	79 (22)		10 (12)	
1	Male	10/11	132 (25)	103 -	33 (21)	14
	Female	3/7	124 (38)	114 (15)	44 (28)	21 (8)
2	Male	16/16	163 (31)		69 (39)	
	Female	23/27	182 (18)	179 (29)	93 (35)	81 (37)
3	Male	26/26	209 (23)		136 (47)	
	Female	40/40	197 (25)		146 (62)	
4	Male	18/18	235 (14)		193 (33)	
	Female	48/48	240 (18)		213 (55)	
5	Male					
	Female	3/3	260 (6)		272 (38)	
7	Male					
	Female	8/8	331 (42)		275 (7)	
			Yellow bass			
0		0/8	62 (15)		8 (7)	
1	Male	8/9	122 (23)	113 -	25 (16)	16 -
	Female	1/8	125 (-)	112 (22)	23 -	20 (14)
2	Male	42/42	172 (19)	- -	79 (30)	- -
	Female	43/46	187 (19)	148 (9)	92 (30)	48 (14)
3	Male	43/43	202 (20)		119 (41)	
	Female	83/83	209 (16)		135 (35)	
4	Male	4/4	227 (13)		180 (39)	
	Female	21/21	235 (21)		204 (62)	
5	Male					
	Female	7/7	260 (24)		280 (81)	
6	Male					
	Female	2/2	275 (9)		337 (14)	
7	Male					
	Female	4/4	278 (12)		356 (47)	
8	Male	1/1	390 -		324 -	
	Female	3/3	305 (2)		486 (30)	

Table 6. Fecundity estimates for 10 white perch and 10 yellow bass collected from Browning Oxbow during April 1998 and April 1999.

Total Length(mm)	Body Mass (g)	Gonad Mass Right	Gonad Mass Left	No. of ova per 0.3g Right	No. of ova per 0.3g Left	Estimated Total
White perch						
159	57	3.3	4.5	2805	2484	68,115
169	76	4.7	4.4	1120	1081	33,401
221	157	4.3	4.0	1444	1272	37,657
225	160	3.7	3.9	2577	2874	69,145
226	165	6.1	6.2	1846	1668	72,007
227	100	8.0	9.0	2038	2375	125,597
241	189	13.7	10.5	1931	2228	166,162
254	248	7.8	7.1	2088	1817	97,290
280	367	9.3	20.0	1090	1293	119,990
282	340	10.2	8.4	2241	1747	125,110
Yellow bass						
166	97	3.1	4.4	1140	1005	26,520
173	186	5.2	6.3	2805	2484	100,784
205	132	4.4	3.2	2130	1995	52,520
246	234	11.6	10.5	1416	1557	109,247
256	280	9.0	9.9	2727	2973	179,919
256	296	13.5	12.7	837	777	70,558
258	280	9.4	7.6	2133	1761	111,446
260	282	5.3	11.9	2319	2112	124,745
302	483	21.2	22.6	1305	1086	174,032
308	444	15.6	15.4	1878	1725	186,206

Table 7. Seasonal mean percent number (%N), mean percent volume (%V), mean percent frequency of occurrence (%FO), and index of relative importance (IRI) of prey items consumed by 335 white perch collected in Browning Oxbow from April 1998 to May 1999. Different letters denote a significant difference ($p < 0.05$) in %V within each season; tr indicates values < 1.0.

Food Item	%N	%V	%FO	IRI
		Spring 1998/1999 n = 123		
Diptera	50	65[a]	82	9458
Hemiptera	3	6[b]	25	225
Zooplankton	35	10[b]	18	804
Fish	tr	14[b]	18	247
Fish eggs	11	3[b]	4	51
Other	1	2[b]	9	26
		Summer 1998 n = 139		
Diptera	83	75[a]	85	13434
Hemiptera	4	7[b]	29	255
Zooplankton	tr	tr[b]	1	tr
Fish	2	12[b]	19	259
Other	10	5[b]	4	59
		Fall 1998 n = 61		
Diptera	63	27[b]	56	5014
Hemiptera	2	5[b]	18	132
Zooplankton	12	3[b]	15	227
Fish	22	54[a]	68	5159
Other	1	10[b]	9	97
		Winter 1998/1999 n = 12		
Diptera	2	21[a]	5	175
Hemiptera	tr	tr[a]	tr	tr
Zooplankton	tr	8[a]	5	9
Fish	98	67[b]	100	16490

Table 8. Seasonal mean percent number (%N), mean percent volume (%V), mean percent frequency of occurrence (%FO), and index of relative importance (IRI) of prey items consumed by 363 yellow bass collected in Browning Oxbow from April 1998 to May 1999. Different letters denote a significant difference ($p < 0.05$) in %V within each season; tr indicates values < 1.0.

Food Item	%N	%V	%FO	IRI
		Spring 1998/1999 n = 158		
Diptera	74	63^a	80	10936
Hemiptera	11	20^b	30	903
Zooplankton	13	1^b	6	79
Fish	tr	12^b	10	123
Fish eggs	2	4^b	1	6
Other	tr	tr^b	tr	tr
		Summer 1998 n = 106		
Diptera	97	79^a	91	16040
Hemiptera	2	4^b	34	202
Zooplankton	tr	2^b	9	18
Fish	tr	12^b	14	175
Other	tr	3^b	2	7
		Fall 1998 n = 66		
Diptera	38	21^a	47	2781
Hemiptera	13	24^a	13	1161
Zooplankton	28	13^a	16	637
Fish	19	21^a	28	1118
Other	2	18^a	18	375
		Winter 1998/1999 n = 33		
Diptera	14	5^a	21	398
Hemiptera	20	14^a	16	546
Zooplankton	32	8^a	5	209
Fish	33	74^b	79	8437

Table 9. Mean percent volume of prey items consumed by age-0, age-1, and age-2 and older white perch and yellow bass collected in Browning Oxbow from April 1998 to May 1999. Different letters indicate significant differences ($p < 0.05$) among age groups for each fish species.

	White perch			Yellow bass		
Prey Item	Age-0	Age-1	Age-2+	Age-0	Age-1	Age-2+
Diptera	45	60	67	21	41	60
Hemiptera	2	11	5	0	26	17
Zooplankton	50[a]	19[b]	6[b]	79[a]	31[b]	7[b]
Fish	1[a]	6[a]	22[b]	0	2	14
Other	2	4	0	0	0	2
n	32	33	141	8	14	196
Niche breadth	2.2	2.4	1.9	1.5	3.0	2.4

Figure 1. Study area at Browning Oxbow, Kansas/Missouri, including location of monthly shoreline seining (S), trap net (TN), and gill net (GN) stations.

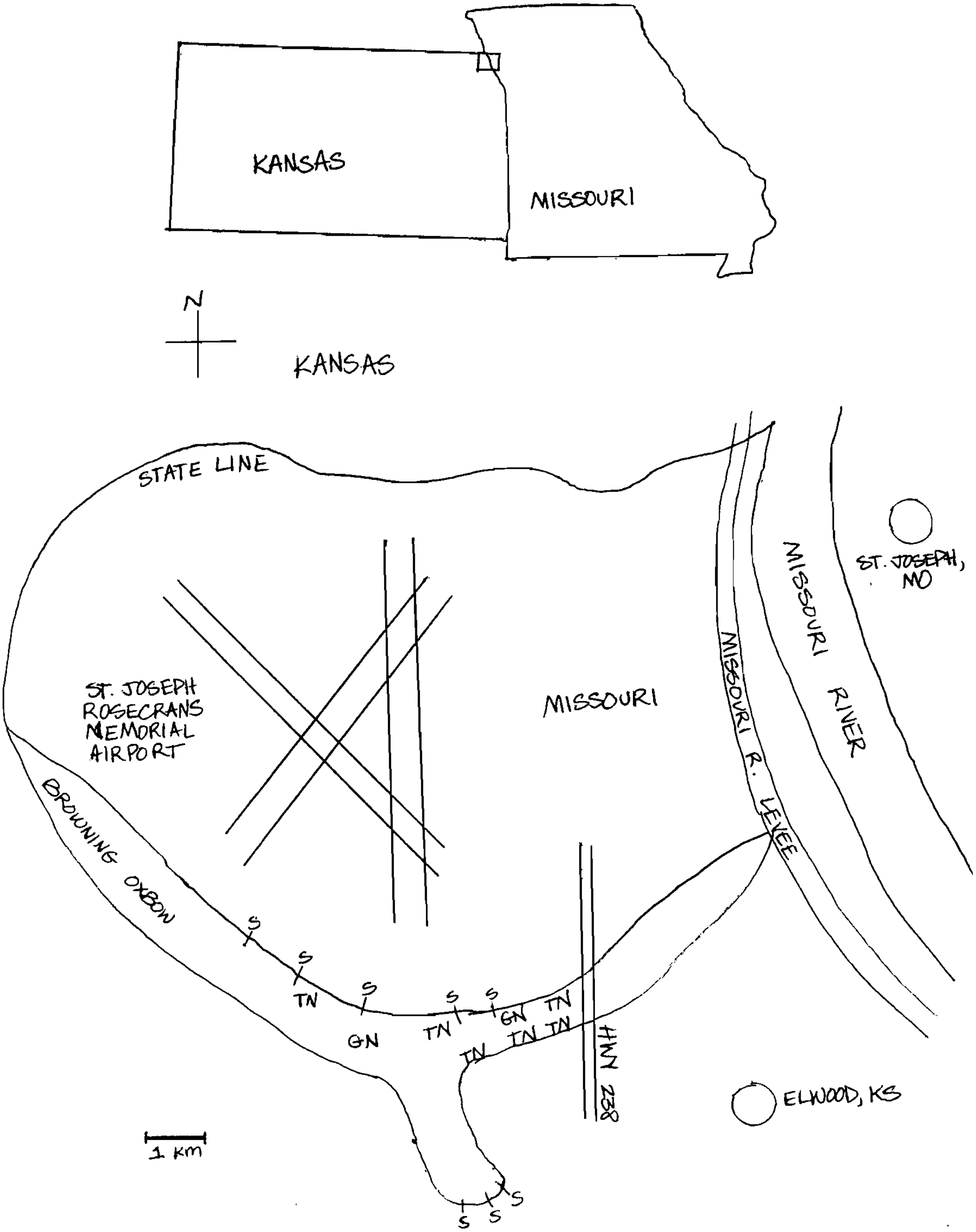

KANSAS
MISSOURI
N
KANSAS
STATE LINE
ST. JOSEPH ROSECRANS MEMORIAL AIRPORT
MISSOURI
MISSOURI R. LEVEE
MISSOURI RIVER
ST. JOSEPH, MO
BROWNING OXBOW
S
TN
GN
HWY 238
ELWOOD, KS
1 km

Figure 2. Age-frequency diagram for white perch and yellow bass collected in Browning Oxbow from April 1998 to December 1998.

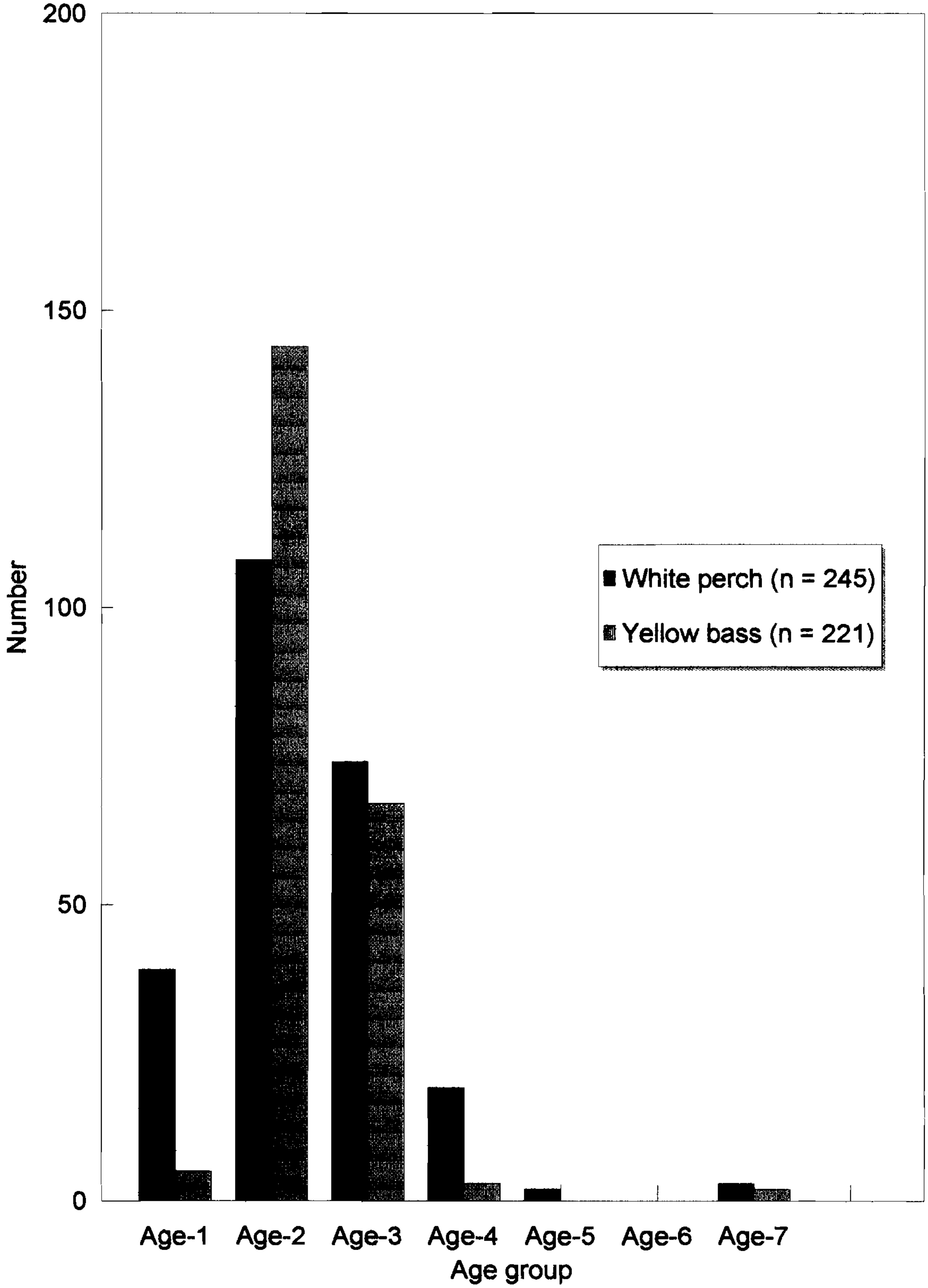
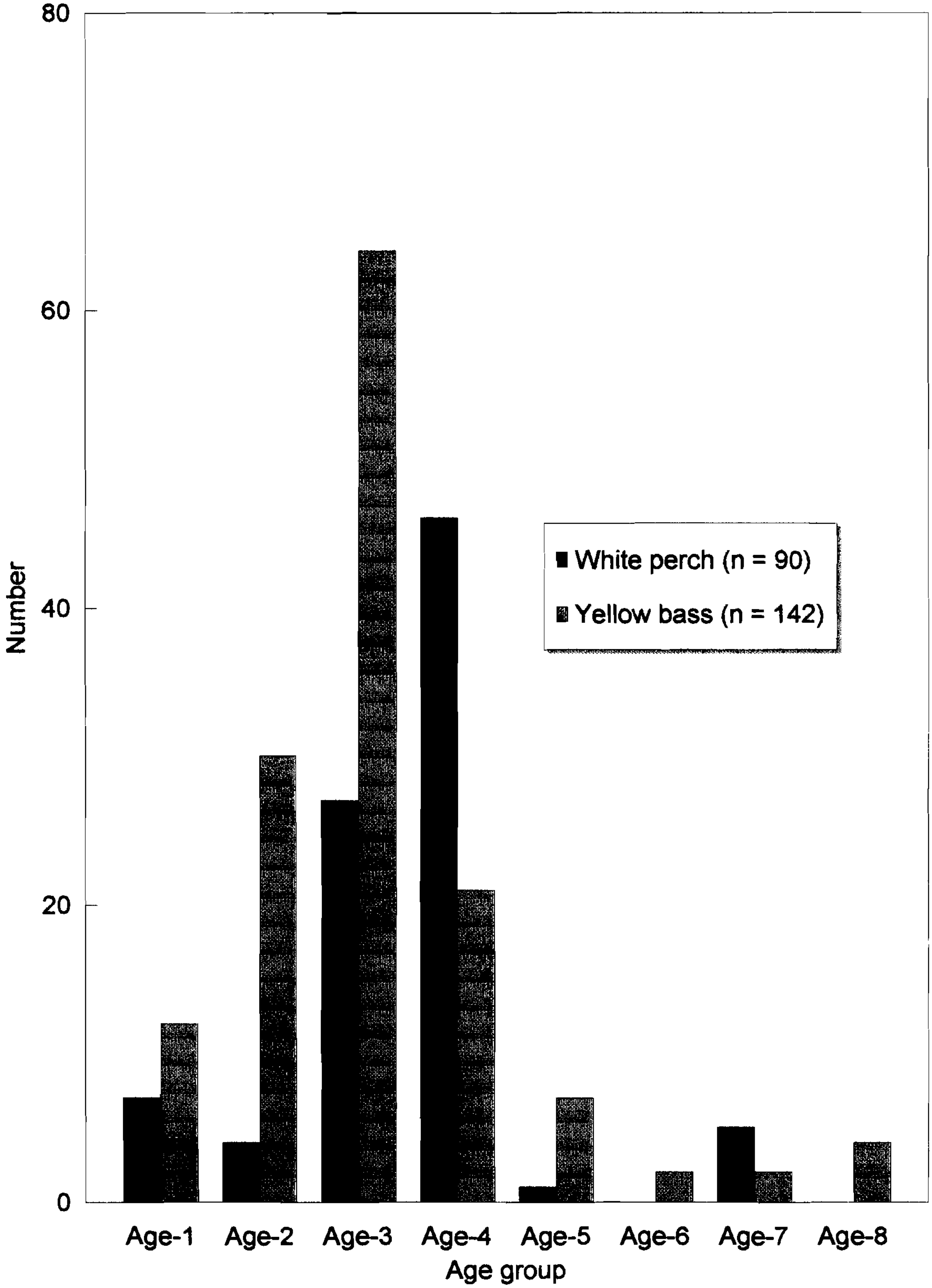
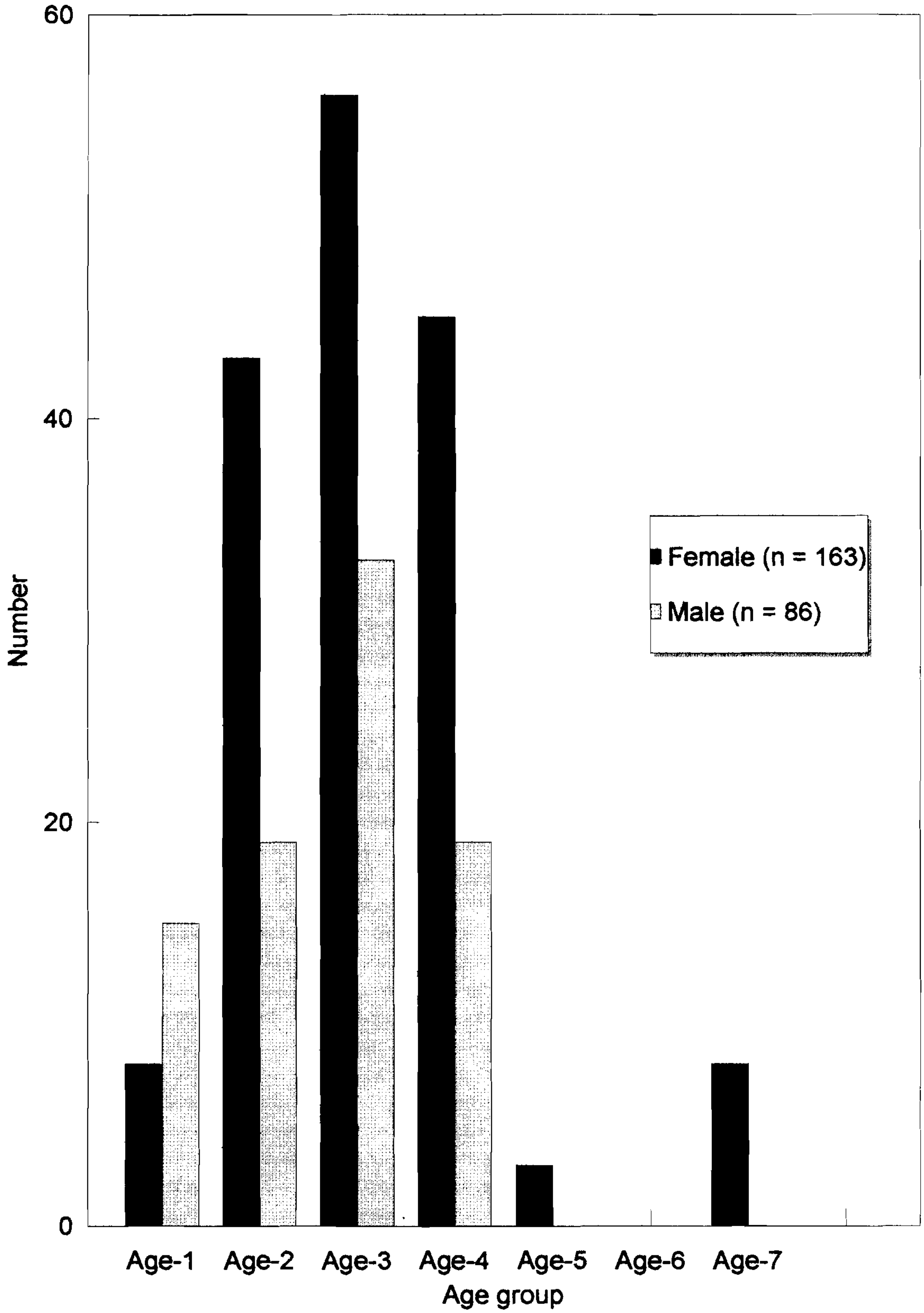

200
150
100
50
0
Number
White perch (n = 245)
Yellow bass (n = 221)
Age-1
Age-2
Age-3
Age-4
Age-5
Age-6
Age-7
Age group

Figure 3. Age-frequency diagram for white perch and yellow bass collected in Browning Oxbow from January 1999 to May 1999.



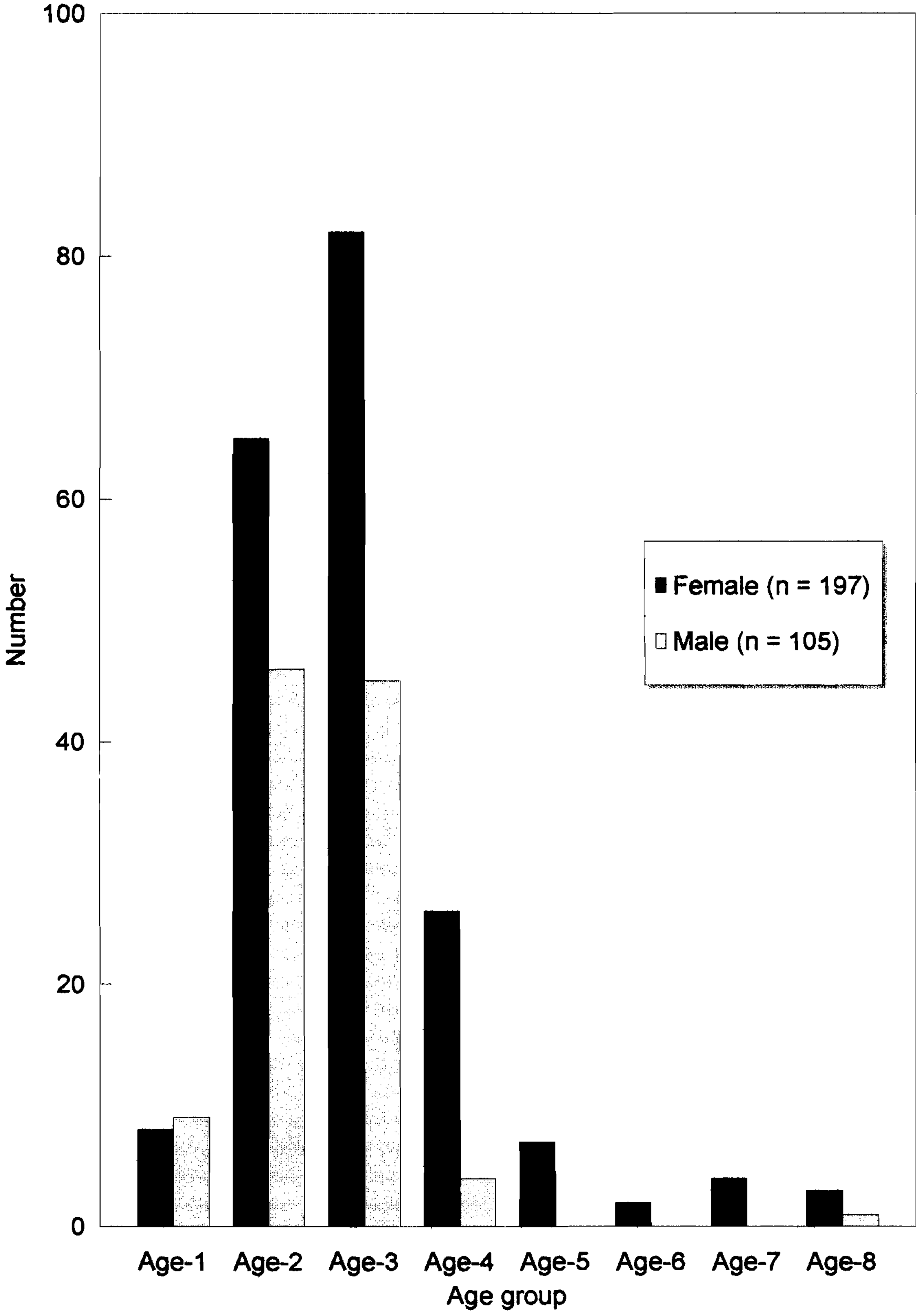
80
60
40
20
0
Number
White perch (n = 90)
Yellow bass (n = 142)
Age-1
Age-2
Age-3
Age-4
Age-5
Age-6
Age-7
Age-8
Age group

Figure 4. Age-frequency diagram for sexed white perch collected in Browning Oxbow from April 1998 to May 1999.



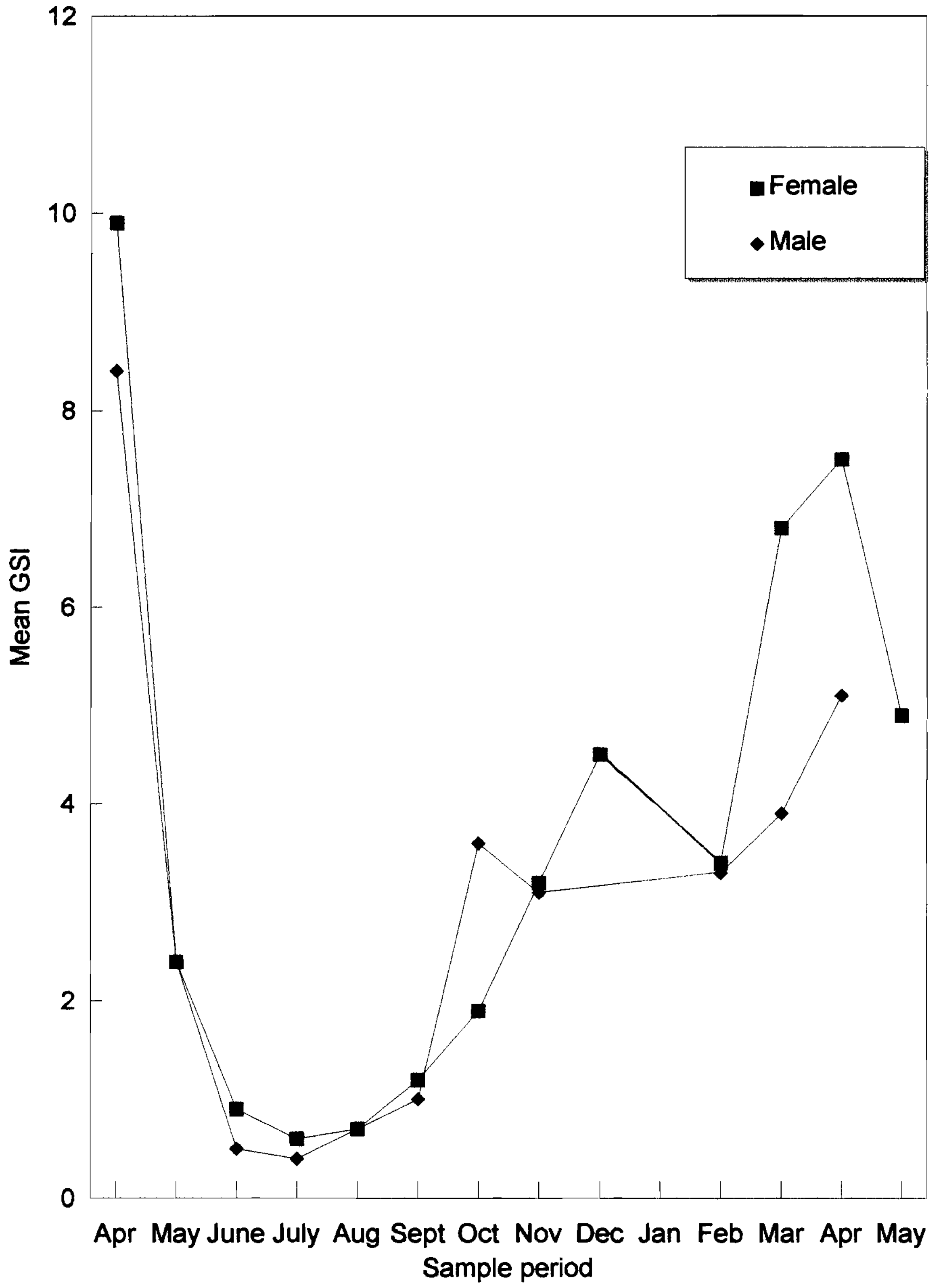
60
40
20
0
Number
Female (n = 163)
Male (n = 86)
Age-1
Age-2
Age-3
Age-4
Age-5
Age-6
Age-7
Age group

Figure 5. Age-frequency diagram for sexed yellow bass collected in Browning Oxbow from April 1998 to May 1999.



100
80
60
40
20
0
Number
Female (n = 197)
Male (n = 105)
Age-1
Age-2
Age-3
Age-4
Age-5
Age-6
Age-7
Age-8
Age group

Figure 6. Monthly mean gonadosomatic index (GSI) values for white perch collected in Browning Oxbow from April 1998 to May 1999; see Appendix 2 for sample sizes.



12
10
8
6
4
2
0
Mean GSI
Female
Male
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Sample period

Figure 7. Monthly mean gonadosomatic index (GSI) values for yellow bass collected in Browning Oxbow from April 1998 to May 1999; see Appendix 2 for sample sizes.

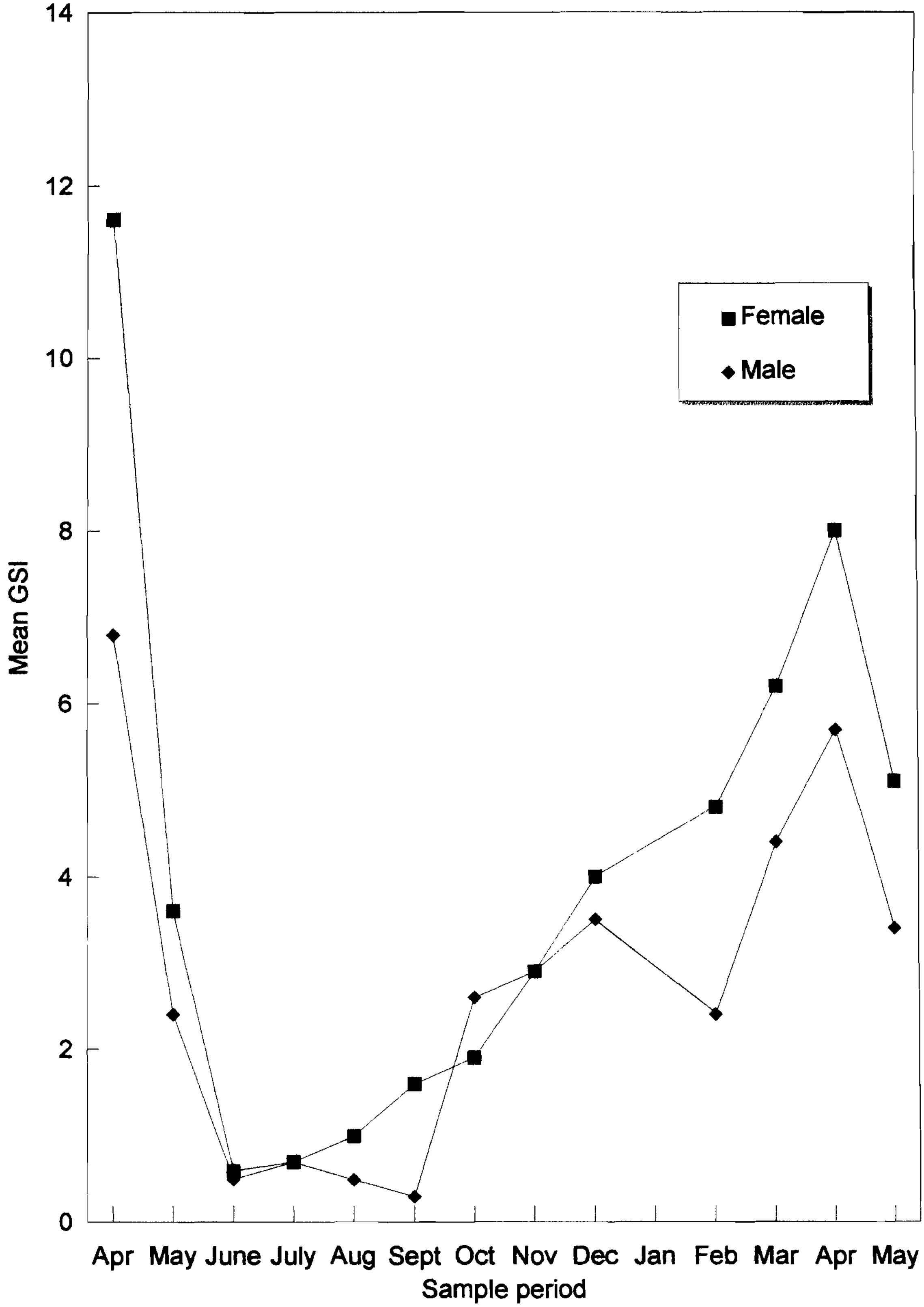
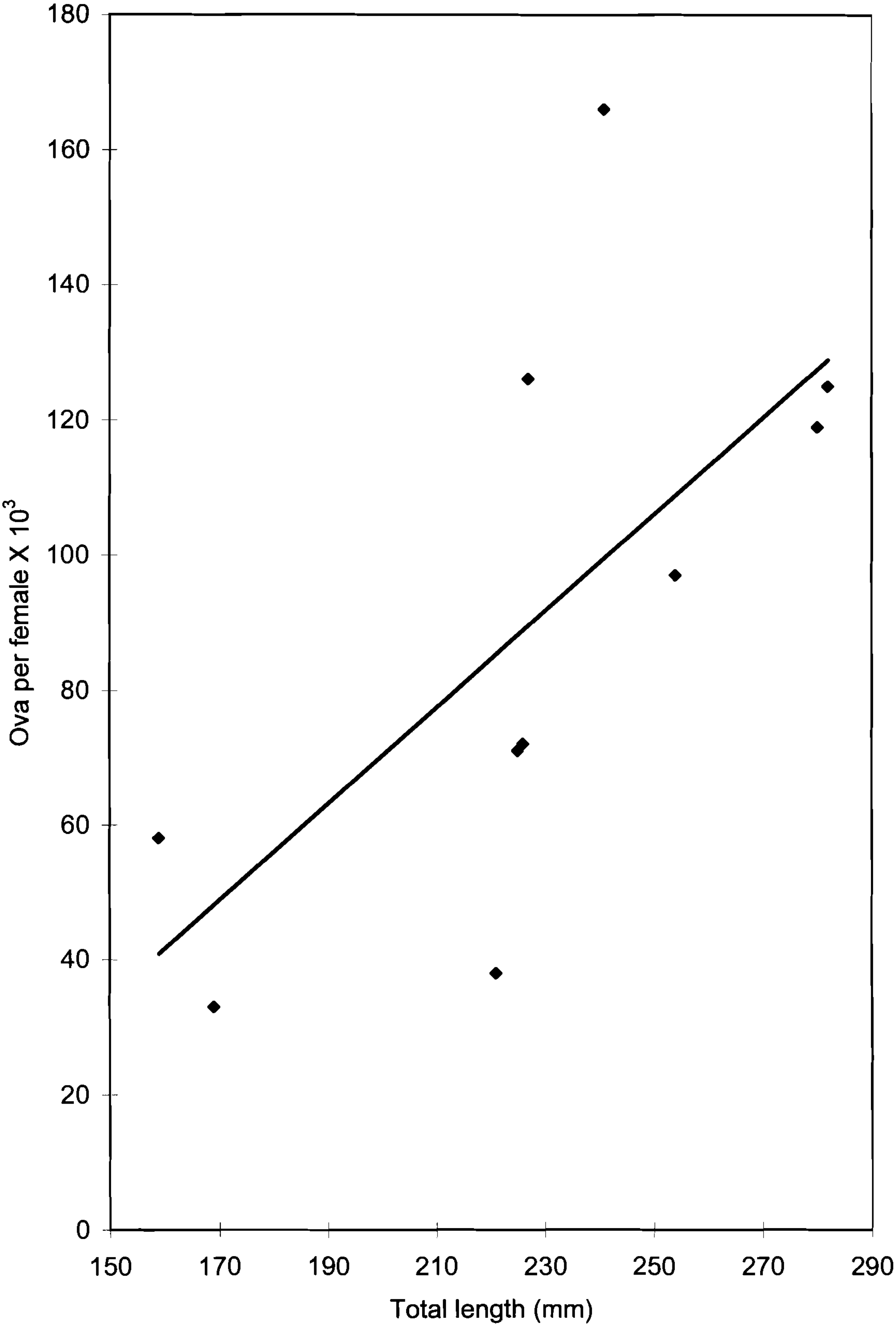
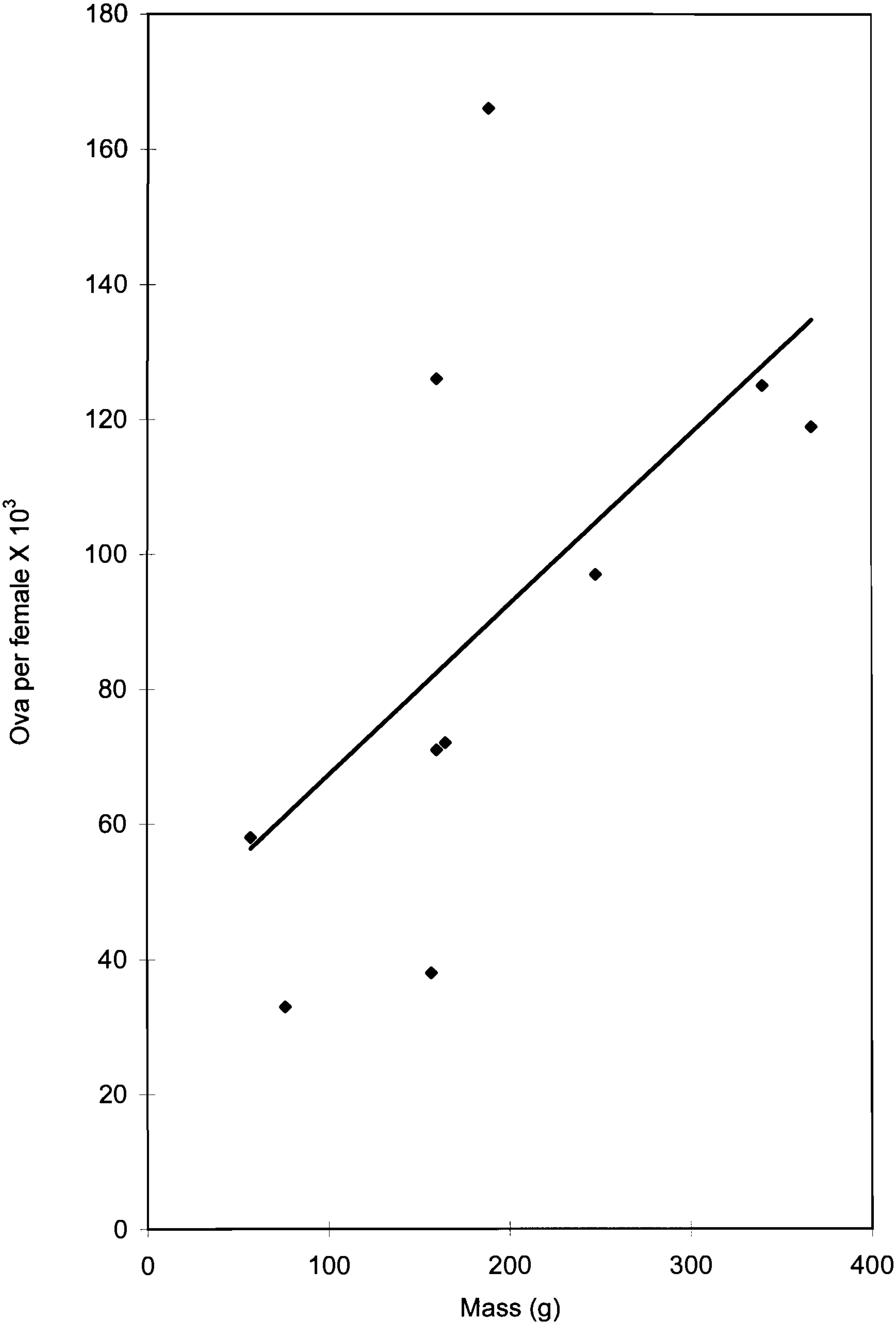

14
12
10
8
6
4
2
0
Mean GSI
Female
Male
Apr May June July Aug Sept Oct Nov Dec Jan Feb Mar Apr May
Sample period

Figure 8. Length-fecundity regression for 10 white perch collected in Browning Oxbow in April 1998 and April 1999 ($r^2 = 0.45$).



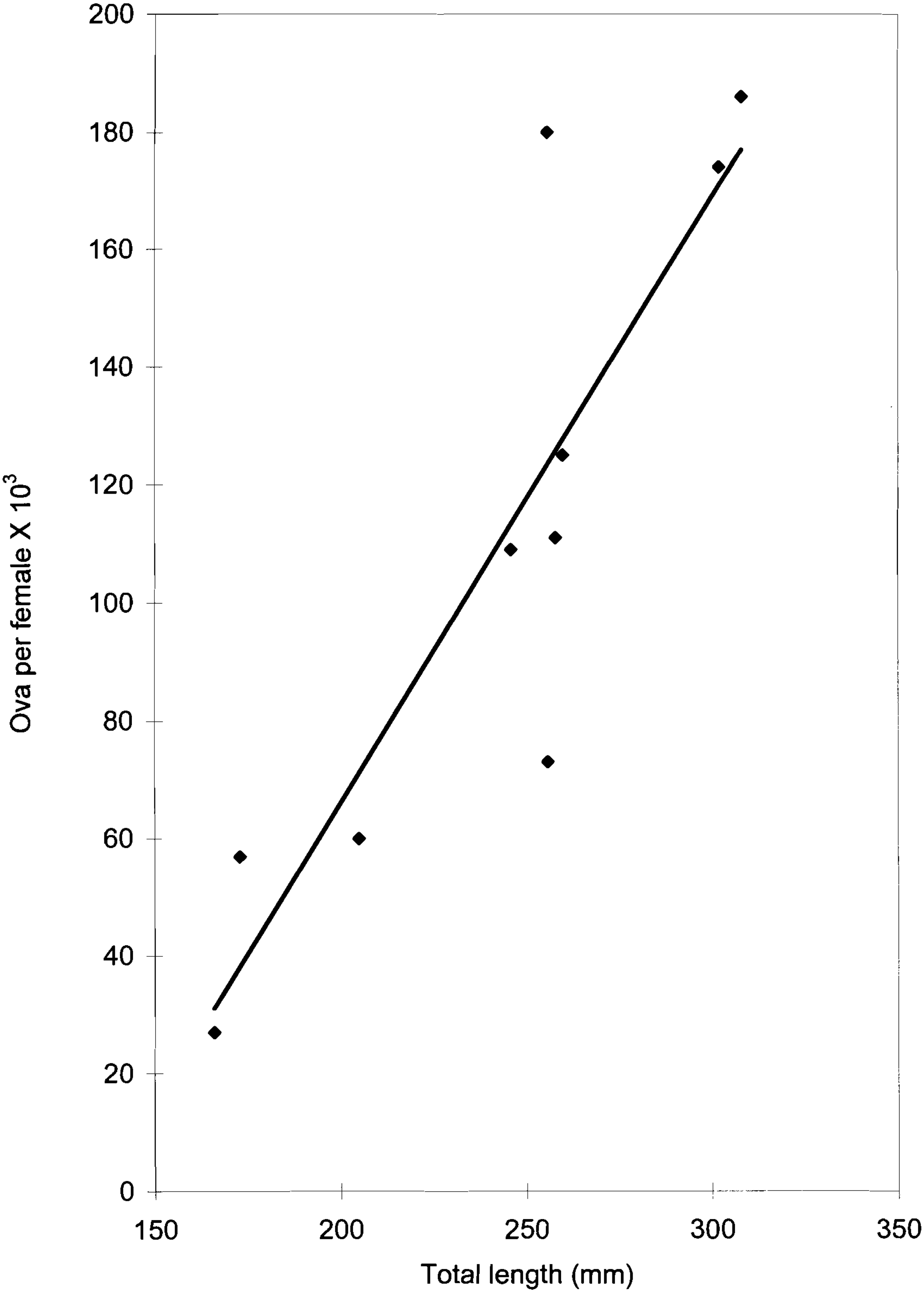
180
160
140
120
100
80
60
40
20
0
150
170
190
210
230
250
270
290
Total length (mm)
Ova per female X 10^3

Figure 9. Mass-fecundity regression for 10 white perch collected in Browning Oxbow in April 1998 and April 1999 ($r^2 = 0.27$).



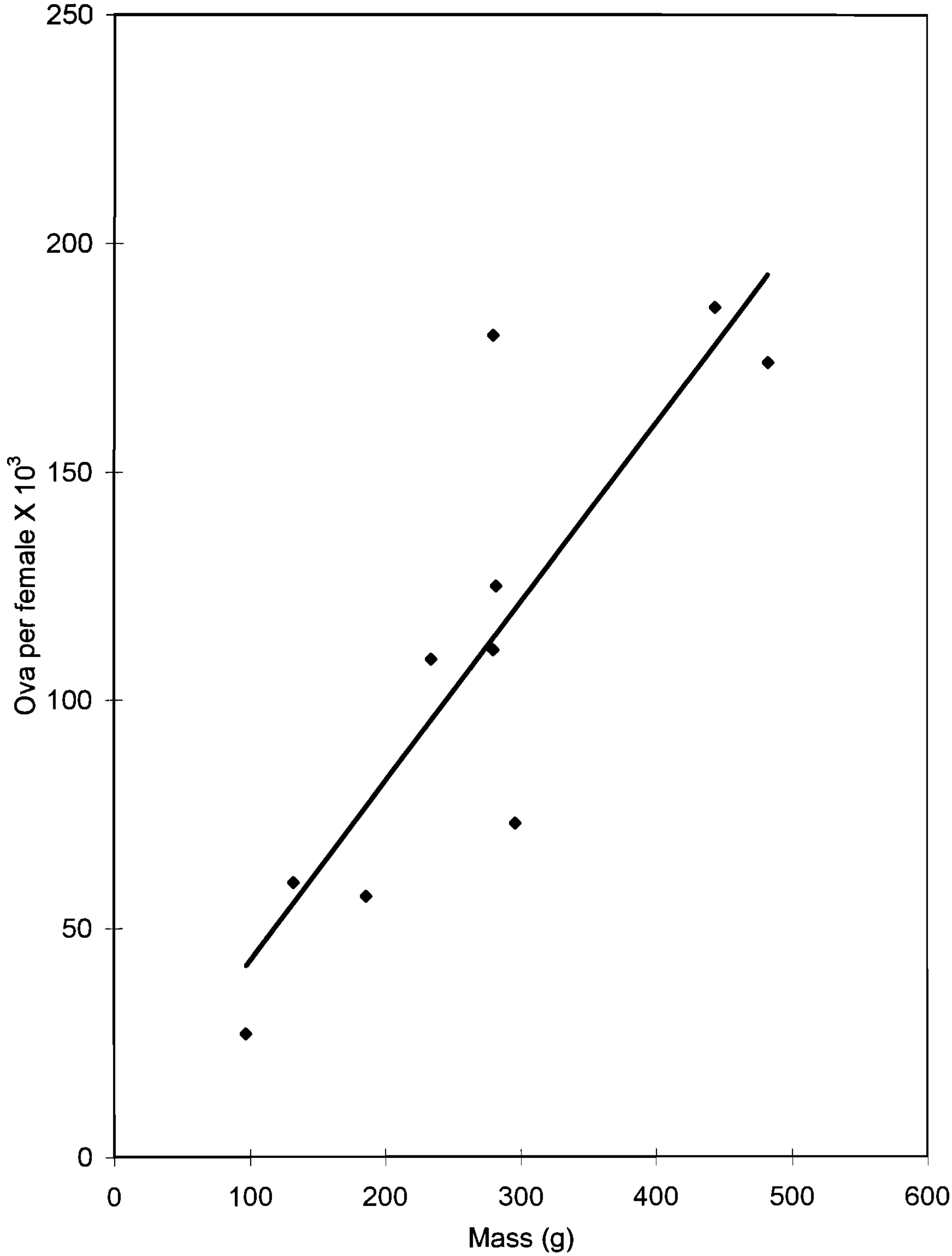
Ova per female X 10^3
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
Mass (g)

Figure 10. Length-fecundity regression for 10 yellow bass collected in Browning Oxbow in April 1998 and April 1999 ($r^2 = 0.70$).



200
180
160
140
120
100
80
60
40
20
0
150
200
250
300
350
Ova per female X 10^3
Total length (mm)

Figure 11. Mass-fecundity regression for 10 yellow bass collected in Browning Oxbow in April 1998 and April 1999 ($r^2 = 0.67$).



250
200
150
100
50
0
Ova per female X 10^3
0
100
200
300
400
500
600
Mass (g)

Figure 12. Number of white perch, yellow bass, and *Morone* sp. collected from Browning Oxbow during diel sample on 9-10 July 1998.

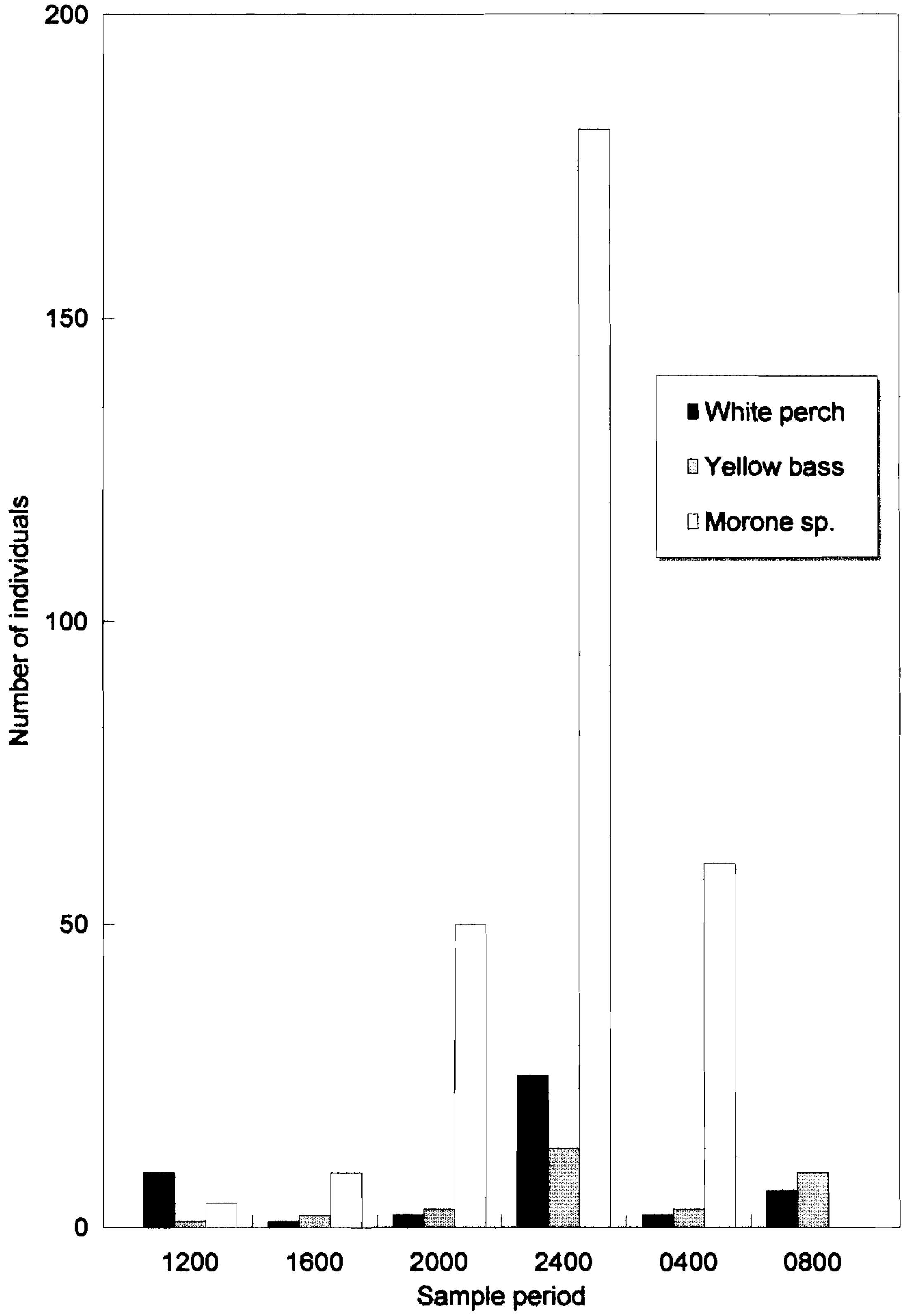
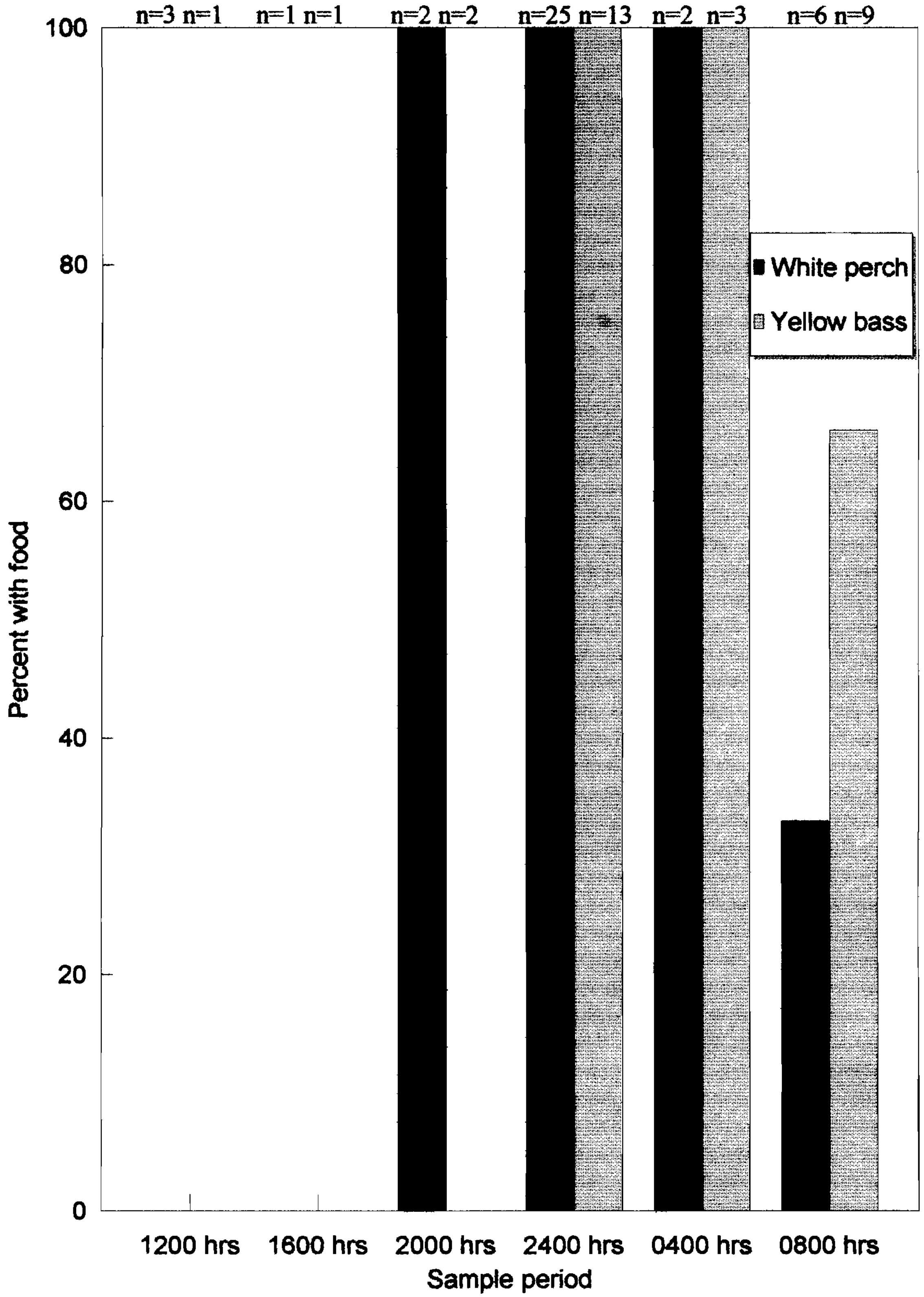

200
150
100
50
0
Number of individuals
White perch
Yellow bass
Morone sp.
1200
1600
2000
2400
0400
0800
Sample period

Figure 13. Percent of white perch and yellow bass stomachs containing food during diel sample on 9-10 July 1998.


n=3 n=1
n=1 n=1
n=2 n=2
n=25 n=13
n=2 n=3
n=6 n=9
100
80
60
40
20
0
Percent with food
White perch
Yellow bass
1200 hrs
1600 hrs
2000 hrs
2400 hrs
0400 hrs
0800 hrs
Sample period

Appendix 1. Monthly sample dates for collections of white perch and yellow bass from Browning Oxbow, 1998-1999.

Collection Date	Date of Equinox or Solstice
Spring 1998	March 21
April 24	
May 26	
Summer 1998	June 22
June 22	
July 22	
August 18	
Fall 1998	September22
September 23	
October 21	
November 22	
Winter 1998-1999	December 22
December 22	
January 30	
February 14	
Spring 1999	March 21
March 22	
April 20	
May 22	

Appendix 2. Number of sexed white perch and yellow bass collected in Browning Oxbow from April 1998 to May 1999.

	White perch		Yellow bass	
Collection Date	Male	Female	Male	Female
April 24	6	14	6	6
May 26	7	9	6	10
June 22	6	5	2	6
July 22	5	17	15	25
August 18	13	21	2	10
September 23	1	5	1	1
October 21	8	23	7	12
November 22	5	10	19	12
December 22	0	5	4	7
January 30	0	0	0	0
February 14	3	3	5	12
March 22	24	39	29	65
April 20	8	11	8	26
May 22	0	1	1	5
Total	86	163	105	197

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8/1/01

Date

Biology of nonindigenous white perch and yellow bass in an oxbow of the Missouri River

Title of Thesis

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August 8, 2001

Date Received