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Comparison of exploited and unexploited yellow perch *Perca flavescens* (Mitchill) populations in Nebraska Sandhill lakes

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Abstract Exploitation can have a pronounced effect on fish populations. Yellow perch, *Perca flavescens* (Mitchill), populations in Nebraska Sandhill lakes were sampled in 1998 and 1999. Three of the 29 lakes containing yellow perch have been closed to fishing for at least 10 years. Unexploited yellow perch populations had fast growth rates, but age structure was similar to exploited populations. For unexploited lakes combined, mortality and condition were not different from exploited lakes. However, one unexploited lake, Marsh Lake, had the fastest growth, highest proportion of older fish and highest condition of all populations sampled. This lake had low interspecific competition and high invertebrate abundance, which likely resulted in fast growth and high condition. However, size structure and growth were also related to lake productivity. Although exploitation may affect yellow perch populations, other factors (food availability, predators and lake productivity) also play an important role in structuring these populations. Regardless, these results indicate the potential of yellow perch in Nebraska Sandhill lakes given no exploitation.

KEYWORDS: exploitation, Nebraska, *Perca flavescens*, productivity, yellow perch.

Introduction

Exploitation can substantially alter fish population characteristics. Unexploited populations typically have a high proportion of larger, older fish (Goedde & Coble 1981), which also may be in lower body condition (Van Den Avyle & Hayward 1999). Population size structure and abundance may be diminished soon after a lake is open to angling (Redmond 1974; Goedde & Coble 1981), which has been attributed to high harvest of naïve fish. In the absence of exploitation, growth and mortality are regulated by density-dependent (Ricker 1975) and abiotic (e.g. temperature) factors. Unexploited populations can provide valuable insights for biologists regarding potential size and age structure for that species.

Although exploitation may reduce the number of larger fish, predator–prey interactions, food availability and lake productivity also play important roles in structuring fish communities. For example, the proportion of larger yellow perch (i.e. proportional stock density, PSD; Anderson 1976) increased with increased abundance of largemouth bass, *Micropterus salmoides* (Lacépède), the primary predator of yellow

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perch in small South Dakota impoundments (Guy & Willis 1991). In addition, high invertebrate abundance and an increased proportion of larger invertebrates were correlated with growth and condition of yellow perch in South Dakota and Nebraska natural lakes (Lott, Willis & Lucchesi 1996; Paukert & Willis 2000). Increased fish yield and production were also linked to increased lake productivity (Hays & Anthony 1964; Hanson & Leggett 1982). The objective of this study was to determine the effects of sport angler exploitation on yellow perch populations in Nebraska Sandhill lakes. The relationship between exploitation and yellow perch size structure, abundance, condition and growth were specifically investigated. It was hypothesized that unexploited lakes would have a higher proportion of larger and older fish and lower adult mortality than exploited populations. It was also hypothesized that growth and condition of yellow perch would not be different in exploited and unexploited populations because there is little evidence to suggest that growth and condition is density-dependent (as suggested by Van Den Avyle & Hayward 1999) in Nebraska Sandhill lakes (Paukert & Willis 2000). In addition, the influence of other factors (i.e. food availability, predator abundance and lake productivity) on yellow perch population characteristics were examined.

Materials and methods

Thirty natural lakes in the Sandhill region of north-central Nebraska were sampled for yellow perch in 1998 and 1999. Of these 30 lakes, 29 contained yellow perch. These lakes are dependent on groundwater and surface water drainage, with many having flowing springs and seepages. Lakes varied in surface area from 15 to 907 ha, were shallow (maximum depth 1.5–4.0 m) and almost entirely littoral (mean depth 1.0–2.9 m). Submergent vegetation coverage ranged from 4 to 97% (mean 48%). Secchi disk transparency was highly variable (14–258 cm), with total alkalinity ranging from 85 to 447 mg L^{-1}, total phosphorus from 0.01 to 1.79 mg L^{-1} and total dissolved solids from 107 to 559 $\mu S\ cm^{-1}$ (Paukert & Willis 2000). Three lakes were closed to fishing: one (Marsh Lake) was on a National Wildlife Refuge, whereas two (Round and Lackaff lakes) were on a private ranch. The exploited and unexploited lakes had similar physical and chemical characteristics, with the unexploited lakes ranging from 1.0 to 1.8 m in mean depth and 8–83% submergent vegetation coverage. The largest (Marsh Lake at 907 ha) and one of the smallest (Round Lake at 17 ha) were two of the three unexploited lakes.

Fish communities primarily consisted of bluegill, *Lepomis macrochirus* (Rafinesque) (22 lakes), largemouth bass (22 lakes) and black bullhead, *Ameiurus melas* (Rafinesque) (25 lakes). Northern pike, *Esox lucius* L., was found in 16 lakes whereas common carp, *Cyprinus carpio* L., was collected in nine lakes. However, all three unexploited lakes contained no largemouth bass, Round Lake contained a low abundance of northern pike. All unexploited lakes contained black bullhead.

Yellow perch were sampled at randomly selected locations with overnight sets of double-throated trap (i.e. modified fyke) nets with 16-mm bar measure mesh, 1.1- by 1.5-m frames and 22-m leads. Total sampling effort was 10 trap net nights in lakes < 50 ha and 20 trap net nights in lakes ≥ 50 ha. Yellow perch catch-per-unit-effort (CPUE) was expressed in two different ways: The number of fish greater than or equal to 13 cm and the number of fish greater than or equal to 30 cm per trap net night. This gave on estimate of overall abundance (i.e., 13 cm and longer fish) and larger-sized fish (i.e., 30 cm and longer fish).

Yellow perch scales were taken from 10 individuals per centimetre length group for age and growth analyses. These fish were weighed (nearest g) and measured for total length (TL, nearest mm). All additional fish collected were tallied by centimetre length group by species. Growth was assessed using the time (in years) to reach 25 cm derived from the von Bertalanffy growth model (Ricker 1975). Yellow perch condition was quantified using relative weight (W_r), defined as the weight of an individual fish/standard weight for a yellow perch of that length × 100 (Wege & Anderson 1978). The standard weight equation for yellow perch was computed by Willis, Guy & Murphy (1991). Because calculation of mean W_r across all fish lengths may mask length-related trends in condition (Murphy, Willis & Springer 1991), the mean W_r for four length categories suggested by Gabelhouse (1984) was calculated: stock (S – 13 cm) to quality (Q – 20 cm), quality to preferred (P – 25 cm), preferred to memorable (M – 30 cm), and memorable to trophy length (T – 38 cm). Yellow perch size structure was quantified using PSD (the number of quality length and longer fish/number of stock length and longer fish × 100) (Anderson 1976) and relative stock density of memorable-length and longer fish (RSD-M; the number of memorable-length and longer fish/number of stock length and longer fish × 100) (Wege & Anderson 1978).

Wilcoxon rank sum tests were used to compare yellow perch population characteristics (e.g. CPUE, size structure, condition, total annual mortality) between exploited and unexploited populations. A Kolmogorov–Smirnov two sample test was used to compare age distribution between exploited and unexploited populations. For this analysis, the mean relative frequency (for each class: exploited and unexploited) for each age group was used. Stepwise multiple regression was used to determine the influence of physicochemical measurements (i.e. total alkalinity, total phosphorus, chlorophyll *a*, total dissolved solids, Secchi depth, lake size and mean lake depth) on PSD, W_r for each length group, time to reach 25 cm, and L_∞. All analyses were performed in SAS (SAS Institute 1996) with an α level of 0.05.

Results

Catch-per-unit-effort of 13-cm and longer fish ranged from 0 to 121 in exploited populations and from 16 to 52 in unexploited populations, but was not different ($Z = 1.73$, $P = 0.08$) (Table 1). However, CPUE of 30-cm and longer yellow perch was higher in unexploited populations (mean = 5.6) compared with exploited populations (mean = 0.2; $Z = 2.29$, $P = 0.02$) (Table 1).

Size structure varied among exploited and unexploited populations, with an exploited population (Alkali Lake) having the highest PSD (96), but Marsh Lake, an unexploited population, had the highest RSD-M (31) (Table 1). Yellow perch PSD was not different between exploited and unexploited populations ($Z = -0.84$, $P = 0.40$). However, the proportion of memorable length (30 cm) and longer fish (RSD-M) was highest in unexploited populations ($Z = 2.26$, $P = 0.02$). Proportional stock density across all populations increased with increased total alkalinity and total phosphorus and decreased

Table 1. Yellow perch population characteristics in three unexploited populations in Nebraska Sandhill lakes

	Lackaff West	Marsh Lake	Round Lake	Exploited Lakes*
Abundance				
CPUE 13 cm	15.8 (3.4)	51.9 (9.6)	25.7 (6.5)	17.9 (5.5)
CPUE 30 cm	0.3 (0.1)	16.1 (2.7)	0.4 (0.3)	0.2 (0.1)
Size structure				
PSD	18 (5)	71 (3)	11 (4)	46 (5)
RSD-M	2 (2)	31 (3)	2 (2)	1 (1)
Growth				
L_∞	312	365	336	306 (8)
Time to reach 25 cm (years)	4.8	3.5	4.3	5.8 (0.5)
Mortality				
Total annual (%)	47.5	N/A	52.3	38.6 (4.2)

*Paukert & Willis (2000); N/A: Not applicable.

with mean lake depth ($r^2 = 0.54$, $P = 0.002$). Shallow lakes with higher levels of total phosphorus and total alkalinity typically had a higher proportion of large fish (high PSD).

Maximum age was 12 for unexploited populations and 11 for exploited populations. Age structure for exploited and unexploited populations were not different (KSa $= 0.71$, $P = 0.70$) (Fig. 1). However, median age for Marsh Lake was 6, whereas median age for Lackwaff West Lake was 3 and Round Lake 2. In addition, maximum age was 8 for Lackaff West Lake and 7 for Round Lake. Although Round Lake and Lackaff West Lake were unexploited, only 6.4 and 5.5% of these populations, respectively, were older than

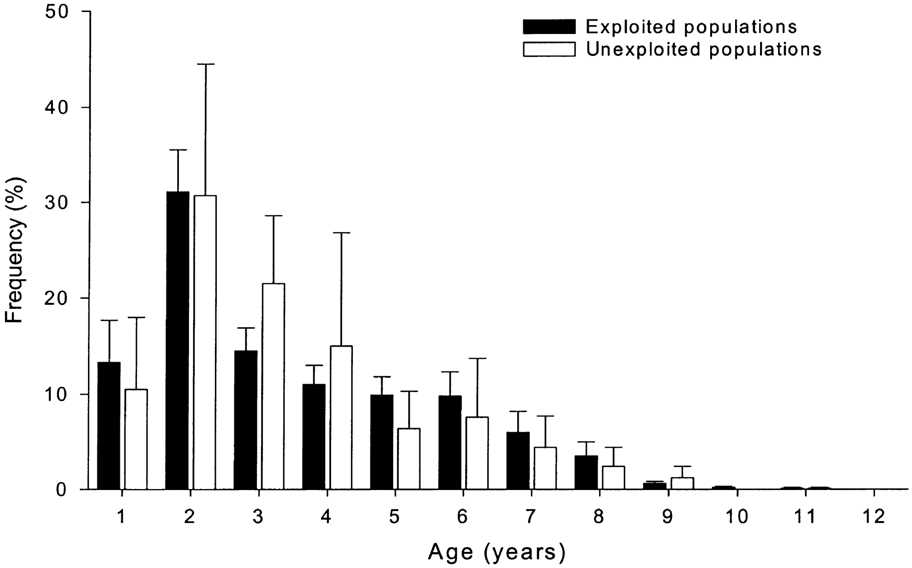

Figure 1. Age structure of exploited and unexploited yellow perch populations in Nebraska Sandhill lakes sampled in 1998 and 1999. Values for each age group represent the mean relative frequency with error bars representing ±1 SE.

age 4, whereas Marsh Lake had an older age structure with 73.7% of the population exceeding age 4. The time taken for yellow perch to reach 25 cm (i.e. growth) was not different between exploited and unexploited populations ($Z = -1.39$, $P = 0.16$) (Table 1). However, all three unexploited lakes had faster growth than the average for exploited lakes from age 4 (Fig. 2). In younger ages (i.e. < 4), exploited and unexploited populations had very similar growth. Mean theoretical maximum length (L_∞), based on von Bertalanffy growth functions, for exploited populations (306 mm) was not significantly different than unexploited populations (338 mm) ($Z = 1.27$, $P = 0.21$) (Table 1), but no multiple regression model relating L_∞ or time to reach 25 cm to physicochemical variables was significant ($P \geq 0.09$). Neither exploitation nor the physicochemical variables measured had a pronounced effect on maximum size that can be attained in yellow perch populations in Nebraska Sandhill lakes.

Total annual mortality estimates could be derived from 19 yellow perch populations, including two unexploited populations. The remainder of the 29 populations (including Marsh Lake) did not meet the assumptions of the catch curve (e.g. very erratic recruitment or small samples sizes for each age group). Total annual mortality was not different between exploited and unexploited populations ($Z = 0.77$, $P = 0.44$). Total annual mortality rates at Round Lake and Lackaff West Lake were 52.3 and 47.5%, respectively (Table 1), which was higher than exploited populations (mean = 38.6%).

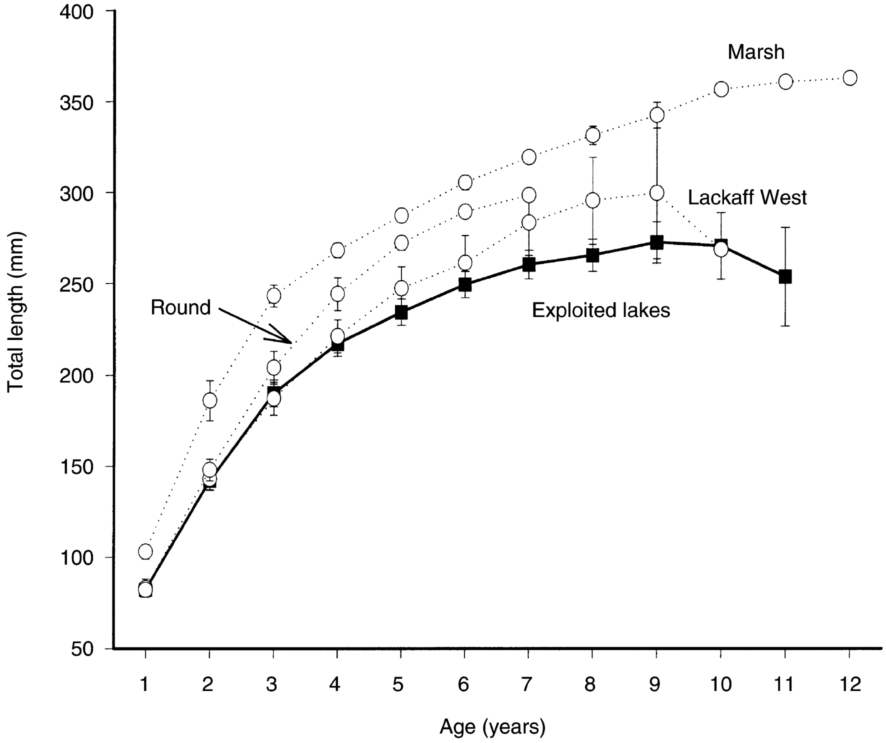

Figure 2. Mean total length at age (mm) for exploited (black squares) and three unexploited (open circles) yellow perch populations in Nebraska Sandhill lakes sampled in 1998 and 1999. Error bars represent ± 1 SE.

Mean W_r by length group ranged from 81 to 94 in exploited populations and from 84 to 92 in unexploited populations (Fig. 3). For all length groups, mean W_r was not different between exploited and unexploited populations ($P \geq 0.46$). However, Marsh Lake was in the highest 10% of W_r values in all length groups. Larger lakes with higher Secchi depth readings had higher mean W_r ($S - Q$; $r^2 = 0.55$, $P = 0.006$); however, no other mean W_r for any length group was significantly related to the physicochemical variables measured ($P \geq 0.06$).

Discussion

Abundance of larger-size fish typically is reduced because of angler harvest (Goedde & Coble 1981; Jennings, Gluesing & Muncy 1986). Even in larger lakes, exploitation can reduce relative abundance of fishes (Keleher 1972). Although no evidence of reduced abundance of moderate-sized yellow perch (i.e. 13–29 cm) in exploited populations was found, decreased abundance of larger (≥ 30 cm) yellow perch was observed, possibly because of angler harvest.

Exploitation may alter size structure of yellow perch in these Sandhill lakes; however, lake productivity was also influential. Other studies concluded that high exploitation altered size structure of fishes in the midwestern United States (Goedde & Coble 1981; Coble 1988; Willis, Neumann & Guy 1994). In Nebraska Sandhill lakes, anglers most likely harvested these larger fish, thus altering size structure toward smaller individuals. However, even with the limited sample of three unexploited lakes in the current study,

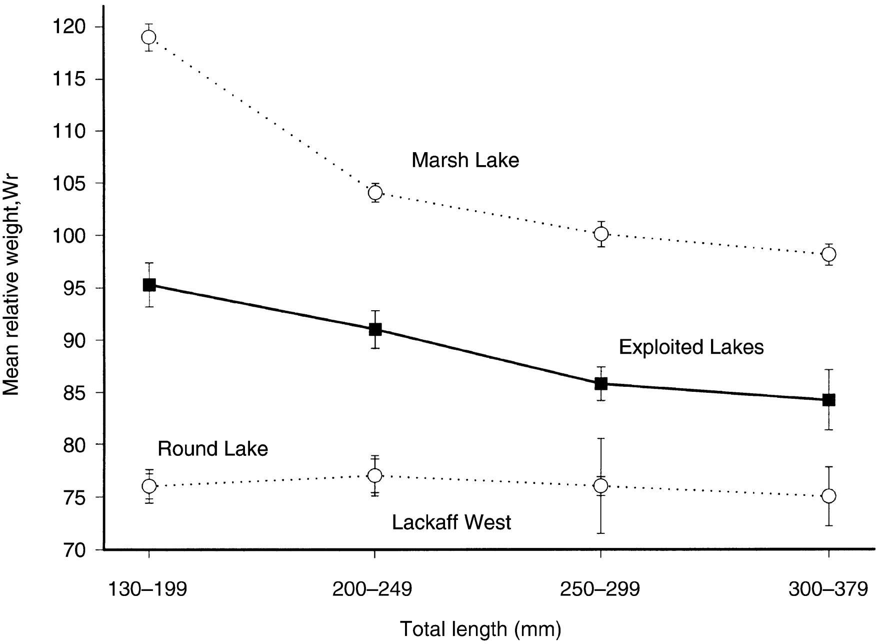

Figure 3. Mean W_r for four length groups of yellow perch sampled from Nebraska Sandhill lakes in 1998 and 1999. The solid line with the black squares represents mean values for exploited populations while the dashed lines with open circles indicate mean values for individual unexploited lakes. Lackaff West and Round lakes have similar values across all length groups. Error bars represent ± 1 SE.

variability in size structure was still found, suggesting that other factors also influence yellow perch size structure. Also PSD increased with increased total alkalinity and phosphorus. Similarly, Jackson & Brown-Peterson (1995) found that bluegill PSD increased with alkalinity. Increased fish yield was also associated with higher productivity (Carlander 1955). However, the unexploited populations in the present study (which had higher RSD-M values) were in the lower 50% for phosphorus levels of all lakes sampled, and total alkalinity values were from 24 to 86% of all lakes sampled, suggesting that, although productivity may alter size structure, exploitation also likely had an effect.

Age structure for unexploited populations was variable, with Marsh Lake containing a large proportion of older fish, whereas Lackaff and Round lakes had relatively low numbers of older fish. An older age structure is consistent with other reports for unexploited populations (Goedde & Coble 1981; Jennings *et al.* 1986). However, Round and Lackaff West lakes showed age structures that were similar to exploited populations, suggesting that angler exploitation was not the only determinant in age structure.

Lake productivity may have more of an influence on yellow perch growth than angler exploitation. Increased growth was associated with increased productivity, which is consistent with other studies (Tomcko 1997). In addition, exploitation did not influence growth in a Wisconsin lake (Goedde & Coble 1981), but may increase growth by reducing intraspecific competition by removing fish (Backiel & LeCren 1967). However, yellow perch density-dependent growth was not evident in Nebraska Sandhill lakes (Paukert & Willis 2000). Exploitation apparently did not have a pronounced effect on maximum size that can be attained by yellow perch populations in Nebraska Sandhill lakes.

The literature on unexploited yellow perch populations is rare, and only one study suggested that unexploited yellow perch populations had relatively low total annual mortality (Goedde & Coble 1981), but actual values were not computed. In the present study, total annual mortality could not be computed for Marsh Lake, but the age structure suggests that the lake had low total annual mortality of adult fish as well. In addition, Bronte, Selgeby & Swedberg (1993) reported that the exploited Lake Superior yellow perch population had a total annual mortality of 58%, which was similar to Lackaff West and Round lakes.

No difference in mean W_r values for any length group was found between exploited and unexploited yellow perch populations. However, one unexploited lake (Marsh Lake) had higher mean W_r values than the other two (Lackaff West and Round lakes). Condition indices such as W_r can indicate prey availability (Liao, Pierce, Wahl, Rasmussen & Leggett 1995; Marwitz & Hubert 1997; Porath & Peters 1997). Zooplankton and

Table 2. Black bullhead catch-per-unit-effort (CPUE; number of 15 cm and longer fish trap^{-1} net night) and invertebrate abundance in three unexploited Nebraska Sandhill lakes and the mean for 29 Nebraska Sandhill lakes sampled in 1998 and 1999. Standard errors are in parentheses

Lake	Black bullhead CPUE	Zooplankton L^{-1}	Chironomids m^{-2}	Macroinvertebrates m^{-2}
Lackaff West	189 (33)	756 (95)	127 (51)	181 (35)
Marsh	20 (5)	1098 (277)	1815 (702)	3384 (316)
Round	201 (66)	191 (27)	464 (264)	855 (259)
Sandhill mean*	50 (24)	669 (115)	863 (144)	4573 (1805)

*Paukert & Willis (2000).

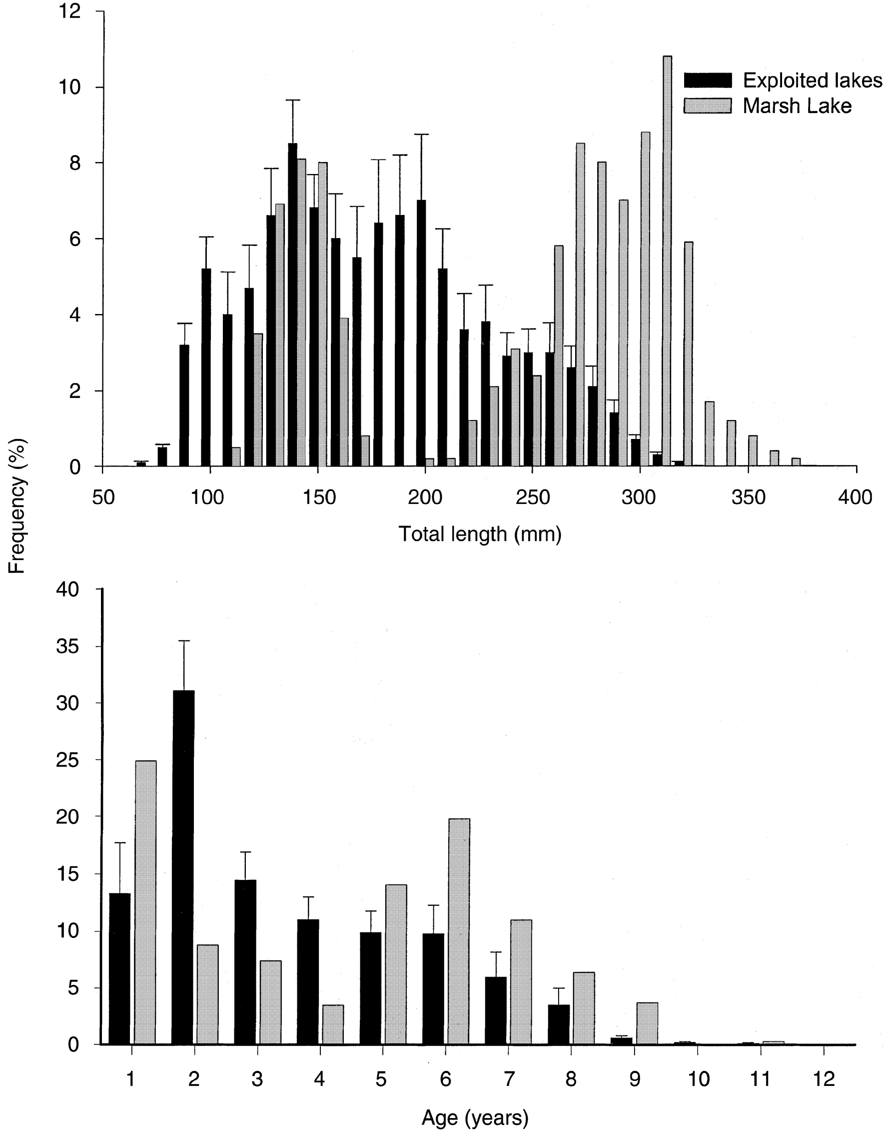

Figure 4. Size and age structure for yellow perch sampled from Marsh Lake, Nebraska and for all exploited yellow perch populations sampled in Nebraska Sandhill Lakes in 1998 and 1999. Values for each age group of exploited populations represent the mean relative frequency with error bars representing ± 1 SE.

macroinvertebrates appear to be the primary prey of yellow perch (Lott *et al.* 1996; Paukert & Willis 2000). Marsh Lake, which had the highest W_r values of the unexploited lakes, had higher zooplankton and macroinvertebrate abundance compared with Lackaff West and Round lakes, the other two unexploited lakes (Table 2). In addition, high black bullhead relative abundance in Round and Lackaff West lakes (which had lower mean W_r values; Table 2) may increase competition for food resources, thus reducing condition.

Of the three unexploited yellow perch populations, one (Marsh Lake) demonstrated a high proportion of older fish (i.e. 74% of yellow perch sampled were older than age 4), and the highest proportion of memorable-length (30 cm) and longer yellow perch of all populations sampled (Fig. 4), as well as high mean W_r values (upper 10% of all lakes sampled) and the second highest L_∞ of all populations sampled. However, the other two unexploited populations had yellow perch population characteristics that were more similar to exploited populations, suggesting that other factors (i.e. prey availability and lake productivity) may also play an important role in structuring these perch populations. In addition, predator–prey interactions likely influence yellow perch populations. Increased yellow perch size structure was positively related to largemouth bass (the primary predator in these Sandhill lakes) relative abundance (Paukert & Willis 2000) as it was in small South Dakota impoundments (Guy & Willis 1991). Regardless, Marsh Lake exhibited the potential for yellow perch populations in Nebraska Sandhill lakes given the appropriate productivity, no exploitation, low interspecific competition and abundant food resources.

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