Predatory Effects of Northern Pike and Largemouth Bass: Bioenergetic Modeling and Ten Years of Fish Community Sampling

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ABSTRACT

Bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and common carp (*Cyprinus carpio*) were sampled in fall 1992 to 2001 in Pelican Lake, Nebraska using electrofishing, gill netting, and trap netting to evaluate the effects of northern pike and largemouth bass on the introductions of bluegill and perch and the potential effects of northern pike on common carp recruitment throughout a 10-year period. The number of yellow perch per gill net remained low even after over 59,000 adult perch were stocked in 1994. However, the number of bluegill collected per hour of night electrofishing increased from <20 prior to 1997 (when 102,800 25-50 mm bluegills were stocked) and has typically been >40 since then. The mean number of common carp collected per gill net remained low in all years and protection of northern pike ≥710 mm with a maximum length limit may have aided in controlling carp recruitment. Bioenergetic modeling revealed that the 2001 northern pike population consumed between 49,000 and 77,000 yellow perch, suggesting that these predators can substantially reduce perch abundance.

INTRODUCTION

The introduction of warmwater and coolwater fish species into lakes and impoundments is a common practice. Smith and Reeves (1986) reported that 29 states primarily in the Midwest and Southeast stock bluegill (*Lepomis macrochirus*), whereas the yellow perch (*Perca flavescens*) is commonly stocked in the Midwest to provide angling opportunities and prey for larger predators (Conover 1986). However, success of these introductions may depend in part on predator abundance. To provide quality angling opportunities for these panfish, a sufficient predator population is needed to control the reproductive potential and avoid overabundant, slow growing panfish. However, an overabundance of predators may reduce panfish abundance to levels not acceptable to anglers.

Northern pike (*Esox lucius*) and largemouth bass (*Micropterus salmoides*) can exert substantial influences on fish community structure. Northern pike may reduce abundance and size structure of yellow perch through predation (Margenau 1995, Paukert and Willis In press) but are less likely to affect bluegill (Beyerle and Williams 1968, Paukert and Willis In press). Anderson and Shupp (1986) suggested that stocking northern pike into Horseshoe Lake,

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Minnesota resulted in the collapse of the yellow perch population. Consumption estimates suggested that northern pike in Windermere, England consumed 50% of the annual production of Eurasian perch (*Perca fluviatilis*) (Johnson 1966). In Nebraska sandhill lakes, size structure and abundance of yellow perch was reduced when northern pike were present, whereas bluegill size structure and relative abundance remained unchanged (Paukert and Willis In press). Largemouth bass may also influence bluegill and yellow perch populations. High abundance of small (< 30 cm total length [TL]) largemouth bass typically is associated with increased proportions of larger bluegill and yellow perch in small impoundments in the midwestern U.S. (Guy and Willis 1990, 1991) and in Nebraska sandhill lakes (Paukert et al. 2002).

Northern pike consumption of common carp (*Cyprinus carpio*) may be influenced by time of year and size of both the pike and the carp. Smaller common carp (<110 mm TL) were vulnerable to northern pike up to 316 mm TL in a laboratory experiment (Mauck and Coble 1971). In a field study at Lake Thompson, South Dakota, larger (>600 mm TL) northern pike consumed common carp up to 300 mm TL during the winter months, whereas smaller pike consumed carp in summer and rarely in fall (Sammons et al. 1994). Because common carp can negatively affect aquatic plant abundance (e.g., Crivelli 1983, Paukert and Willis 2000), waterfowl managers are interested in the utility of northern pike as a carp predator.

The primary objectives of this study were to evaluate the effects of northern pike and largemouth bass on the introductions of yellow perch and bluegill populations throughout a 10-year period in Pelican Lake, Nebraska, and to assess the potential effects of northern pike on common carp recruitment.

STUDY SITE AND BACKGROUND

Pelican Lake is a shallow (mean depth=1.6 m), 332-ha natural lake on Valentine National Wildlife Refuge in northcentral Nebraska. In recent years, submersed and emergent vegetation has been interspersed throughout the lake and has occupied up to 40% of the lake surface. Secchi disk transparency was only 38 cm (Paukert and Willis 2000).

The fish community consists of northern pike, largemouth bass, bluegill, yellow perch, common carp, and black bullhead (*Ameiurus melas*). The lake is known for its quality bluegill population, but still receives only moderate fishing effort. Exploitation estimates for bluegill were <6% for each of three years (Paukert et al. In press). Pelican Lake was chemically renovated in 1979 but common carp were collected from the lake in 1980, suggesting that a complete kill did not occur (USFWS 2001).

Angling regulations for all species except northern pike have remained constant throughout the 10-year study. Panfish (bluegill and yellow perch in aggregate) are open year round with no length limit and a daily bag limit of 30 fish. Largemouth bass is open year round with a bag limit of four and a minimum length limit of 381 mm with only one of those over 533 mm. Northern pike regulations have been altered in an attempt to protect larger fish that may control common carp recruitment though predation on small carp. Since 1993, there has been a 710 mm maximum length limit with a bag limit of three fish. A 558 to 660 harvest (i.e., open length limit) slot (with a bag limit of three) was in effect prior to 1993 (USFWS 2001).

Several fish stockings occurred from 1992 to 2001 on Pelican Lake. The only stocking of largemouth bass occurred in June 1992 when 136,000 small fingerlings (<38 mm) were stocked. A total of 6,510 adult (i.e., sexually mature) northern pike was stocked in March 1994, and 102,800 25 to 50 mm bluegill were stocked in September and October 1996. In an effort to increase yellow perch angling opportunities, 1,100 adult and juvenile yellow perch were transplanted from other lakes in April 1992, 5,653 in April 1993, 59,981 in April 1994, and 2,000 in April 1995.

METHODS

The fish community was sampled during September or October of each year 1992-2001. Largemouth bass and bluegill were collected at eight-15 min nighttime electrofishing stations with pulsed-DC current. Northern pike, yellow perch, and common carp were collected with seven experimental gill nets (38 m by 1.8 m, with 7.5 m panels of 19 mm, 25 mm, 51 mm, and 76 mm bar measure monofilament mesh) that were set overnight. In addition, 12 trap (i.e., modified fyke) nets (single throat, 1.1 x 1.5 m frames, 15.2 m leads, 13 mm mesh) were set overnight each year. The same sites (i.e., fixed sites) were used each year for each gear.

Relative abundance of fish (i.e., catch per unit effort, CPUE) was assessed using the mean number of all sizes of fish collected per hour of electrofishing (for largemouth bass and bluegill) and the mean number of all sizes of fish collected per overnight gill net set (for northern pike, yellow perch, and common carp). Size structure was assessed using proportional stock density (PSD-the percentage of stock-length fish that also exceeded quality length [Anderson and Neumann 1996]), and 95% confidence intervals were calculated (Gustafson 1988). Stock length is 80 mm for bluegill, 130 mm for yellow perch, 200 mm for largemouth bass, and 350 mm for northern pike; quality length is 150 mm for bluegill, 200 mm for yellow perch, 300 mm for largemouth bass, and 530 mm for northern pike (Anderson and Neumann 1996). Because lengths of individual fish were not recorded by gear, size structure indices were calculated using all gears combined. However, equal effort of all gears during all years was conducted.

Bioenergetic modeling. To further evaluate the effects of predators on other fish species in Pelican Lake, we used bioenergetic modeling to determine the consumption of fish by largemouth bass and northern pike (Hanson et al. 1997). Food habits of largemouth bass and northern pike were assessed on 20-25 April, 19-27 June, 1-4 August, and 21-24 September, 2001. Fish were either collected by electrofishing or short-term (i.e., 1-3 h) gill net sets. Stomach contents were extracted with an acrylic tube (Light et al. 1983) and summarized as percent of diet taxa by weight. Caloric values of prey items were estimated using the literature for macroinvertebrates (Cummins and Wuychuck 1971) and fish (Kitchell et al. 1974, Craig 1977, Rice et al. 1983, Bevelheimer et al. 1985, Bryan et al. 1996). Simulations were run on two length groups of largemouth bass and northern pike. Length groups for largemouth bass were <300 mm and ≥300 mm and were based primarily on sample sizes as diets for both length groups were similar. Northern pike length groups were <710 mm and ≥710 mm, the maximum length limit for pike. Because we did not estimate growth throughout the 2001 season, we assumed no growth (i.e., starting weight equals ending weight) for our initial simulation. Therefore, these bioenergetic estimates were considered minimum ration.

However, we did estimate probable consumption based on annual growth of largemouth bass from Pelican Lake in 1998 and 11 northern pike populations in the sandhills in 1998 and 1999 (Paukert and Willis 2000). Because we believe that fish did grow to some degree (therefore above the minimum ration) but not their entire annual growth increment during the study period (20 April to 24 September), actual consumption likely was within the range of our minimum and probable consumption estimates.

To estimate the northern pike population, we conducted a Schnabel multiple mark-recapture population estimate from 20 to 24 March 2001. Northern pike were collected with modified fyke nets and a left pectoral fin was clipped and recaptures were recorded. Lengths and weights were recorded for the first 100 fish sampled to estimate size structure and biomass.

Statistical analyses. Because the same sites were used each year, a repeated-measures analysis of variance was used to determine if mean CPUE differed among years for each species. We specifically wanted to evaluate whether mean CPUE differed before and after stocking events and therefore used linear orthogonal contrasts to determine if CPUE differed prior to and after stockings. To determine if PSD differed among years for each species, we used a likelihood ratio chi-square test (i.e., G-test). All analyses were conducted using SAS (SAS Institute 1996).

RESULTS

Fish populations exhibited variable CPUE over the 10-year study, with mixed results following stockings (Figure 1). Northern pike mean CPUE remained relatively constant throughout the 10 year study (F=0.15, df=1,16, P=0.71), although 651 adult northern pike were stocked in 1994. Largemouth bass CPUE peaked in 1997 (F=13.87, df=9,17, P<0.001); however, stocking of 136,000 fry in 1992 apparently did not increase CPUE at least four years after stockings. In contrast, bluegill CPUE was significant higher following fall stocking of 102,800 25-50 mm bluegill in 1996 (F=94.97, df=1, 30, P<0.001). Mean CPUE increased from 7.5/hour (SE=1.0) in 1992 to 1996 to 61.2/hour (SE=7.0) in 1997-2001 (Table 1). Yellow perch CPUE fluctuated throughout the study, ranging from a low of 0.4 perch per gill net in 1995 (one year after 59,981 adult and juvenile yellow perch were stocked) to a high of 11.0 in 1997. Yellow perch CPUE did increase slightly after stocking (1996-2001; mean=5.6/gill net SE=1.0) compared to 1992-1995 (mean=3.1 SE=0.8)(F=5.79, df=1,29, P=0.02).

Size structure for all species was highly variable throughout the 10-year study (Figure 2). Northern pike PSD remained high for the duration, with a low of only 61 in 1996 (x^2=38.37, df=9, P<0.001). Largemouth bass PSD varied from 20 in 1992 to 95 in 2001 (x^2=57.36, df=9, P<0.001). Bluegill PSD peaked in 1993, but was typically below 50 (x^2=220.98, df=8, P<0.001). No stock-length bluegill were collected in 1994. Yellow perch PSD fluctuated in a similar trend to yellow perch CPUE (x^2=58.71, df=9, P<0.001). Yellow perch PSD ranged from 10 to 51, but remained higher during 1993 to 1995 when 67,634 adult and juvenile perch were stocked.

Common carp mean CPUE remained <1.0 per gill net in all years except 1995 (2.4; SE=1.2) and 2001 (4.7; SE=1.4)(F=5.90, df=9,60, P<0.0001). Only one common carp (mean CPUE=0.14) was collected in 1992-1994, 1996, 1998, and 2000, with no carp collected in 1999. All common carp collected in 1995 were between 400 and 500 mm; all carp collected in 2001 were <280 mm.

Bioenergetics modeling. Both small (< 300 mm) largemouth bass and large (≥300 mm) bass primarily consumed yellow perch across all seasons (Table 1). Mean percent by weight of yellow perch across all lengths of largemouth bass and all seasons ranged from 62% to 100%. The remaining diets contained primarily macroinvertebrates. Rarely did largemouth bass consume bluegills, with the highest percentage only 16% for large largemouth bass in August. In fact, no bluegills were consumed by small largemouth bass in April, June, and August, or by large largemouth bass in April.

Northern pike also primarily consumed yellow perch throughout the study (Table 2). Yellow perch were consumed by all sizes of northern pike during all seasons, typically constituting over 60% of the diet by weight. However, northern pike ≥710 mm apparently switched from yellow perch to common carp by September. Bluegills composed up to 31% of the diet by weight, although no bluegills were consumed by small northern pike in April and June or by large northern pike in April and August.

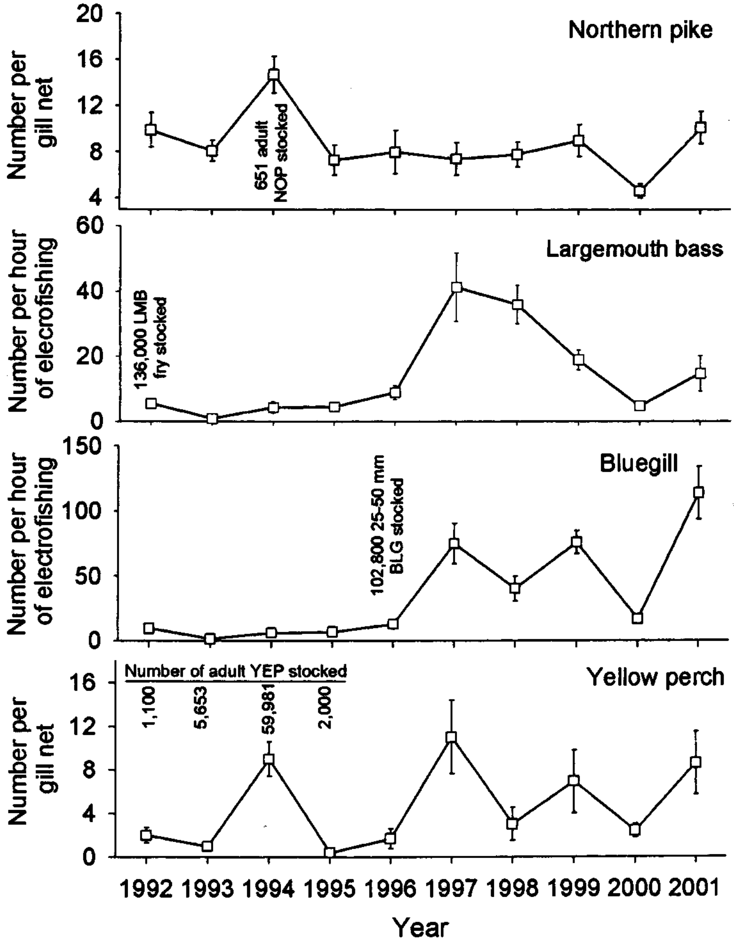

Figure 1. Mean relative abundance (number per gill net or number per hour of electrofishing) for northern pike, largemouth bass, bluegill, and yellow perch collected during fall, 1992-2001 in Pelican Lake, Nebraska. Error bars represent ± one standard error.

Consumption estimates based on bioenergetic modeling revealed that an individual largemouth bass <300 mm with no annual growth (i.e., minimum ration) consumed 467 g of yellow perch, whereas larger largemouth bass consumed 823 g of yellow perch. Few bluegills were consumed by largemouth bass, summing to only 132 g for both a large and small largemouth bass combined (Table 3). Northern pike consumed considerably more prey biomass of all species. Consumption of yellow perch was 1,552 g for a small northern pike and 1,573 g for a large northern pike at minimum ration, whereas probable consumption was estimated at 2,555 g and 2,008 g, respectively. Large northern pike did consume common carp, but only an estimated 467 g at minimum ration and just in September. Per capita consumption of yellow perch by a large and small northern pike combined was about 2.5 times more biomass than a large and small largemouth bass combined. A similar trend was evident for bluegill consumption, with northern pike consuming six to seven times more biomass than largemouth bass (Table 3).

Table 1. Percent by weight of diet items consumed by largemouth bass (LMB) in Pelican Lake, Nebraska, April-September, 2001. Only diet items found in the stomach for each month are presented. N=number of fish collected.

Month	Taxon consumed	Mean proportion by weight (SE)
LMB <300 mm		
April, N=1	Yellow perch	1.0(-)
June, N=4	Yellow perch	1.0(-)
August, N=9	Yellow perch	0.89(0.14)
	Odonata	0.11(0.11)
September, N=31	Yellow perch	0.94(0.08)
	Bluegill	0.02(0.01)
	Decapoda	0.04(0.03)
LMB ≥300 mm		
April, N=49	Yellow perch	0.81(0.07)
	Odonata	0.04(0.03)
	Hirudinea	0.10(0.04)
	Ephemeroptera	0.03(0.02)
	Anura	0.02(0.02)
June, N=45	Yellow perch	0.62(0.07)
	Bluegill	0.13(0.04)
	Odonata	0.06(0.03)
	Diptera	0.05(0.03)
	Trichoptera	0.05(0.03)
	Hemiptera	0.02(0.02)
	Decapoda	0.07(0.04)
August, N=46	Yellow perch	0.80(0.07)
	Bluegill	0.16(0.04)
	Odonata	0.04(0.03)
September, N=43	Yellow perch	0.83(0.06)
	Bluegill	0.08(0.03)
	Decapoda	0.02(0.01)
	Hirudinea	0.02(0.02)
	Anura	0.05(0.05)

The northern pike population in March 2001 was estimated at 3,025 fish (95% confidence interval: 2,520-3,625); density estimates were 9.1 fish/ha (95% confidence interval: 7.6-10.9 fish/ha). Using a mean weight of 1.6 kg per fish, corresponding biomass estimates were 15 kg/ha (95% confidence interval: 12-18 kg/ha). Of the fish measured, 27.5% were at least 710 mm, the maximum length limit for northern pike.

DISCUSSION

Our results suggest that the introduction of over 68,000 adult yellow perch over four years did not provide lasting benefits to anglers. In contrast, stocking over 102,000 fingerling bluegill may have increased bluegill abundance, although we could not distinguish stocked fish from naturally-recruited fish. The lowest CPUE of yellow perch occurred the year following the

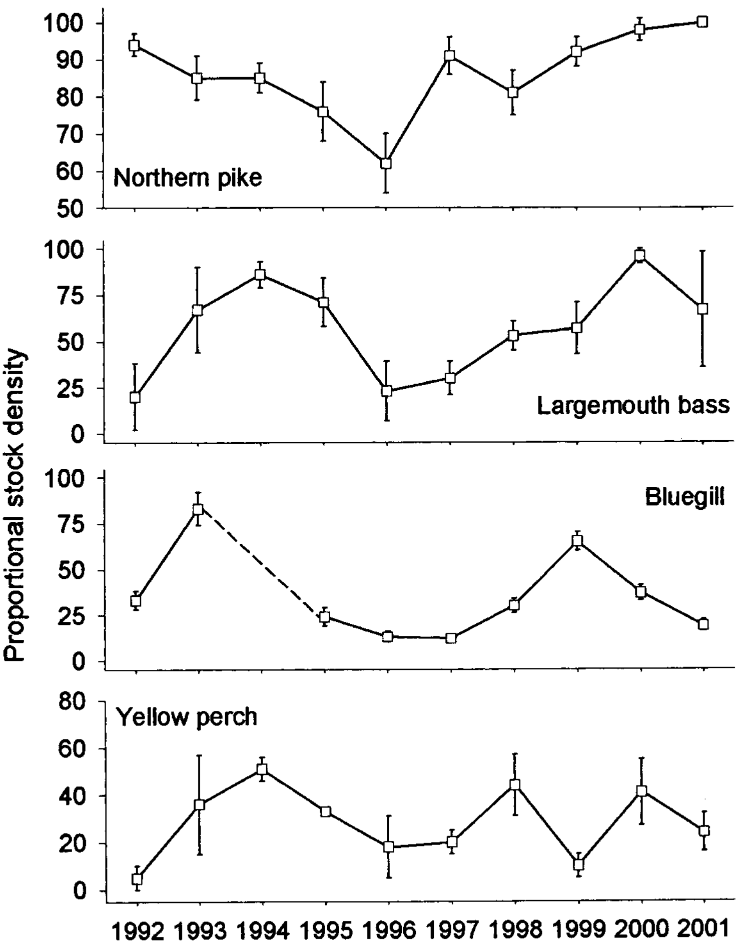

Figure 2. Proportional stock density for northern pike, largemouth bass, bluegill, and yellow perch collected during fall, 1992-2001 in Pelican Lake, Nebraska. No stock-length and longer bluegills were collected in 1994 so proportional stock density could not be computed. Error bars represent 95% confidence intervals.

introduction of over 59,000 adult perch. In contrast, bluegill abundance did increase and remained higher than prior to stocking. However, size structure varied for both bluegill and yellow perch during the study, possibly because of variable natural recruitment. The largemouth bass stocking was apparently unsuccessful; Loska (1982) reported in an extensive literature review that supplemental bass stockings typically will not succeed.

The immediate decline in yellow perch abundance after stocking and the increase in bluegill abundance may be related to selective predation, particularly by northern pike. In Nebraska sandhill lakes, the presence of northern pike was associated with reduced abundance of yellow perch and not bluegills, presumably because of selective predation by northern pike on the more fusiform yellow perch rather than the compressiform bluegill (Paukert and Willis In press). Bioenergetic modeling corroborated these results, as an individual northern pike consumed two to three times more biomass of yellow perch than an individual largemouth bass. Based on these consumption estimates and coupled with our population estimates, the northern pike population in Pelican Lake in 2001 would consume approximately 4,713 kg of

Table 2. Percent by weight of diet items consumed by northern pike (NOP) in Pelican Lake, Nebraska, April-September, 2001. Only diet items found in the stomach for each month are presented. N=number of fish collected.

Month	Taxon consumed	Mean proportion by weight (SE)
NOP <710 mm		
April, N=10	Yellow perch	0.85(0.10)
	Largemouth bass	0.05(0.05)
	Golden shiner	0.10(0.10)
June, N=7	Yellow perch	0.76(0.19)
	Largemouth bass	0.20(0.14)
	Black bullhead	0.04(0.03)
August, N=19	Bluegill	0.22(0.11)
	Yellow perch	0.62(0.15)
	Odonata	0.16(0.11)
September, N=42	Bluegill	0.31(0.09)
	Yellow perch	0.61(0.10)
	Northern pike	0.04(0.04)
	Anura	0.04(0.04)
NOP ≥710 mm		
April, N=9	Yellow perch	1.0(-)
June, N=3	Bluegill	0.31(0.31)
	Yellow perch	0.03(0.02)
	Northern pike	0.33(0.33)
	Odonata	0.33(0.33)
August, N=7	Yellow perch	0.76(0.18)
	Largemouth bass	0.16(0.14)
	Odonata	0.08(0.08)
September, N=21	Bluegill	0.21(0.09)
	Yellow perch	0.06(0.05)
	Common carp	0.73(0.11)

yellow perch and 389 kg of common carp as a minimum ration (i.e., no growth from April to September) and 7,272 kg of perch and 533 kg of carp at probable consumption. Based on the 2001 fish community sampled, mean weight of yellow perch was 0.095 kg and mean weight of the 46 age-0 common carp was 0.407 kg (W. Stancill, unpublished data); therefore, northern pike would consume 49,543 perch and 955 carp to maintain zero growth and 76,565 perch and 1,310 carp at probable growth in 2001. These estimates suggest that northern pike consumption could have reduced the yellow perch population in Pelican Lake even after 59,981 perch were stocked in 1994. However, common carp consumption from April through September 2001 was relatively low.

Factors other than predation may influence the increased bluegill abundance following stocking. Recruitment fluctuations may also influence abundance and size structure of fish populations. Because we did not mark the stocked fish, we were unable to determine if the strong year class produced immediately after stocking was exclusively related to the stocking effort or if these fish were stocked over an existing strong year class. Nonetheless, our circumstantial evidence suggests that further evaluation on the effectiveness of stocking bluegills in sandhill lakes is warranted.

Common carp relative abundance has remained low throughout the 10-year study, suggesting that recruitment has not substantially increased. However, the 2001 samples indicated the highest abundance of small (<280 mm) common carp over the 10-year period. Food habits and bioenergetic

Table 3. Total estimated consumption (g) of an individual small (<710 mm) and large (≥710 mm) northern pike and a small (<300 mm) and large (≥300 mm) largemouth bass for minimum ration (i.e., no growth from April to September) and probable growth (based on estimated annual growth for each species in Sandhill lakes) in Pelican Lake, Nebraska, April to September 2001.

	Northern pike			Largemouth bass		
Taxa consumed	Small	Large	Total	Small	Large	Total
No growth						
Yellow perch	1,552	1,573	3,125	467	823	1,280
Bluegill	281	534	815	2	130	132
Northern pike	15	425	440	0	0	0
Black bullhead	31	0	31	0	0	0
Largemouth bass	170	199	369	0	0	0
Common carp	0	467	467	0	0	0
Probable growth						
Yellow perch	2,555	2,008	4,563	713	1,042	1,755
Bluegill	514	680	1,194	3	165	168
Northern pike	29	528	557	0	0	0
Black bullhead	48	0	48	0	0	0
Largemouth bass	261	263	524	0	0	0
Common carp	0	641	641	0	0	0

modeling revealed that only the larger northern pike during fall consumed common carp, suggesting that protecting these fish to control common carp recruitment may be a viable objective. Although our consumption estimates for common carp were low compared to other fishes, northern pike may primarily prey upon common carp during winter (Sammons et al. 1994), a period we did not sample.

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