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Effects of Mechanical Harvesting of Eurasian Watermilfoil on Angling for Bluegills in Fish Lake, Wisconsin

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Abstract.—We examined changes in angling effort, catch and catch rates, and fishing and natural mortality of bluegills *Lepomis macrochirus* associated with mechanical plant harvesting in a lake heavily infested with Eurasian watermilfoil *Myriophyllum spicatum.* In August 1994, 18% of the total plant biomass was removed in a radial pattern of 2-m-wide channels in Fish Lake, Dane County, Wisconsin. After the vegetation removal, winter angler hours increased significantly, whereas summer angler hours did not. The number of boat trips in summer increased significantly, but the number of shore trips did not. Catch rates and total catch of bluegills did not change significantly, but the size structure of harvested bluegills increased. Catches of bluegills by shore anglers decreased in summer, whereas catches of bluegills by boat anglers increased. Natural mortality declined for bluegills of ages 4–6, but fishing mortality more than doubled for bluegills of the same ages. We conclude that removal of Eurasian watermilfoil may increase winter angler effort, decrease natural mortality of bluegills, and increase fishing mortality of bluegills. We also conclude that removing vegetation may improve the quality of the bluegill fishery, as evidenced by the increase in the number of larger bluegills harvested. However, this study lacked the replication and controls needed to separate the effects of plant harvesting from those of other biotic and abiotic factors.

Dense aquatic vegetation can reduce access to a fishery for anglers, while offering cover to large fish targeted by anglers, thereby reducing vulnerability of the fish to angling harvest. Shore angler effort may increase when vegetation biomass is reduced (Mitzner 1978) because reduction of aquatic plant coverage increases the fishable shoreline of impoundments (Berry et al. 1974). For example, angling effort declined by 85% and catch rates of largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus* increased in autumn when hydrilla *Hydrilla verticillata* invaded Orange Lake, Florida (Colle et al. 1987). Although overall catch rates may increase with increased vegetative cover, catch of large fish may decline because refuge provided by dense aquatic plants reduces the vulnerability of large fish to angling (Maceina and Reeves 1996). For example, catch rates of largemouth bass increased with increasing plant cover in reservoirs dominated by Eurasian watermilfoil *Myriophyllum spicatum*—though strong recruitment may have also influenced catch rates (Maceina and Reeves 1996; Wrenn et al. 1996).

Severe plant infestation can reduce sport fish production; however, vegetation should be controlled, not eradicated (Swingle 1946; Strange et al. 1975). Eradication can be detrimental to centrarchids (Judd and Taub 1973); vegetation density, the pattern of cutting, and the amount of vegetation removed may also influence centrarchid populations. As reported, clear-cutting large areas and removing more than half the vegetation decreased bluegill growth, whereas cutting narrow channels and removing 20–40% of the vegetation increased bluegill feeding and growth rates (Trebitz and Nibbelink 1996). Bluegills grew better when narrow (2 m wide) channels were cut, and only 20% of Eurasian watermilfoil was removed from several lakes (Olson et al. 1998), whereas production of harvestable size largemouth bass was greatest when hydrilla coverage was only 10–20% of lake surface area (Moxely and Langford 1982).

Few studies have attempted to describe changes

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in angling effort and catch rates or the interplay of fishing and natural mortality of bluegills when channels are used to increase vegetated edge habitat and reduce total plant biomass. Therefore, we sought to determine whether angling effort, catch rates, and fishing and natural mortality of bluegills changed when 18% of the biomass of Eurasian watermilfoil was removed from a heavily vegetated lake in southern Wisconsin. We expected angling effort, catch rates, and fishing mortality of bluegills to increase, as in other systems. We compared angling attributes for bluegills in years before (1992–1994) and after (1995–1996) removal of Eurasian watermilfoil to determine the effect of reduced vegetation on fishery dynamics.

Methods

Study site.—Fish Lake, Dane County, Wisconsin, is a 101-ha mesotrophic-eutrophic seepage lake, with a maximum depth of 19.5 m and a mean depth of 6.6 m, located 50 km northwest of Madison, Wisconsin (Unmuth et al. 1999). Fish Lake has a diverse fish fauna, but largemouth bass and bluegill are the predominant predator and prey species. Eurasian watermilfoil has dominated the littoral zone since the 1970s, forming a contiguous ring around the lake's perimeter at depths ranging from 1.5 to 4.5 m (Lillie 1996) and covering about 40% of the total lake bottom (Budd et al. 1995; Lillie 1996). Coontail *Ceratophyllum demersum* has formed a dense band at the deep-water edge of the Eurasian watermilfoil bed, and a mixture of native species grow inshore in shallow water (Unmuth et al. 1998).

Bioenergetics modeling suggested that selective removal of 20–40% of the vegetation biomass would optimize growth of bluegills and largemouth bass in Fish Lake (Trebitz 1995; Trebitz and Nibbelink 1996). In August 1994, after 2 years of collecting baseline data, 262 channels, 2 m wide, were cut in a radial pattern through the Eurasian watermilfoil beds of Fish Lake by using a mechanical plant harvester modified to cut plants close to the bottom (Unmuth et al. 1998). Total plant biomass was initially reduced 18% by cutting 36,200 m of vegetated edge habitat. Mean biomass of Eurasian watermilfoil was also reduced 50% from 1992 to 1993–1995 by an attack from the watermilfoil weevil *Eurahrychiopsis lecontei* (Lillie 1996). By 1996, Eurasian watermilfoil biomass had recovered to pretreatment levels, but remnants of 170 channels, totaling 7,700 m in length, remained (Unmuth et al. 1998).

Creel survey.—A creel survey was conducted to determine how reducing the vegetation affected angling effort and catch rates of bluegills. Sport fishery effort and catch rates were determined from a 20 h/week year-round creel survey. The creel survey design was access-access (Pollock et al. 1994) in summer (May–November) and roving-access in winter (January–April). The survey was made primarily during daylight hours, and three nonoverlapping sample shifts (early, midday, late) were stratified by month and day type (weekday and weekend). Shift length was defined as fishing day length divided by three and thus varied among months. All weekend days and three randomly selected weekdays were sampled in summer 1992–1996 and in winter 1992–1995. Clerks observed anglers from a road along the west shore of the lake and interviewed anglers as they completed their trips. Instantaneous counts of ice anglers were completed at three randomly selected times per shift.

Angling effort (number of hours in summer and winter, number of trips in summer) and variance were estimated for summer surveys from angler interviews and for winter surveys from instantaneous angler counts (Hayne 1991; Pollock et al. 1994). For summer surveys, we estimated shore and boat trips by averaging the number of started and completed trips and then expanded the results to the entire month and day type stratum. For winter surveys, we estimated angler hours from instantaneous angler counts, which were first converted to angler hours by multiplying by fishing day length, and then expanded these to the entire month and day type stratum (Newman et al. 1997). Variance of effort in winter was calculated with formulas for two-stage surveys (Cochran 1977). Approximate 95% confidence intervals for estimated hours of winter effort, and for numbers of shore and boat angling trips, were calculated as the estimate $\pm$ 1.96 SE, where the SE is the square root of the variance of the estimator. Winter hours and summer trips before and after vegetation removal were compared with *t*-tests (Zar 1999). Vegetation was removed in August 1994. Because most angling in summer is done before August, summer effort was compared between pretreatment years 1992–1994 and posttreatment years 1995–1996, whereas winter effort was compared between pretreatment years 1992–1993 and posttreatment years 1994–1995.

Total catch was estimated by multiplying angler effort by catch rate, using the ratio-of-means estimator for catch rate (Jones et al. 1995). This allowed us to account for the situations when the clerk was unable to interview, but could count, all anglers completing their trips. Although the ratio of means estimator of catch rate was used to estimate total catch, the bluegill catch rates were also estimated by using the mean-of-ratios estimator, which provides a better measure of angler success or satisfaction (Hayne 1991; Jones et al. 1995). Approximate 95% confidence intervals for catch rates were constructed as the estimate ± SE. Total catch and catch rates before and after vegetation removal were compared with *t*-tests (Zar 1999). As with angling effort, summer catch and catch rates were compared between pretreatment years 1992–1994 and posttreatment years 1995–1996, whereas winter catch and catch rate were compared between pretreatment years 1992–1993 and posttreatment years 1994–1995.

Length distributions of bluegills harvested in summer and winter were compared to assess the effects of angler harvest on the population size structure in Fish Lake. Lengths of bluegills were compiled from those observed during completed-trip interviews of anglers. Length distributions were tallied by 10-mm length-classes for each year and were compared between pretreatment (1992–1994) and posttreatment (1995–1996) years by using the Kolmogorov-Smirnov test for differences in frequency distributions (Zar 1999).

Mortality.—Instantaneous fishing and natural mortality rates were estimated to determine their relative importance on total annual mortality of bluegills before and after vegetation removal. Annual exploitation rates were estimated from the total number of marked fish harvested, as estimated from the creel survey, divided by the number of fish marked during population sampling. Instantaneous rates of fishing mortality for bluegills of ages 4–6, the predominant age-classes in the population, were estimated as $F = uZ/A$, where F is the instantaneous rate of fishing mortality and u is the rate of exploitation (Ricker 1975). Total instantaneous mortality (Z) and annual mortality rate (A) were estimated as $Z = -\log_e(S)$ and $A = 1 - S$, where S is the annual survival rate, previously described by Unmuth et al. (1999). Briefly, the annual survival rate was estimated from the ratio of estimated numbers present in a cohort in adjacent years before (1992–1993) and after (1995–1996) vegetation removal. Estimated numbers present at each age in each year were taken from the overall mark–recapture estimate of abundance, divided into each age-class by use of the population age frequency. The age frequency of the population was derived from the subsample of

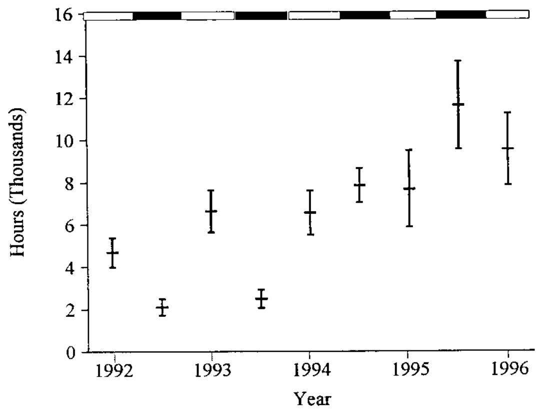

FIGURE 1.—Angling hours on Fish Lake, Wisconsin, 1992–1996. Bar at top of figure indicates summer (white) and winter (shaded) seasons.

ages present, expanded to the entire sample of bluegills through the use of an age-length key. Instantaneous natural mortality (M) was estimated by subtracting instantaneous fishing mortality (F) from instantaneous total mortality (Z). Point estimates of instantaneous natural and fishing mortality rates were qualitatively compared for bluegills before and after vegetation removal, to show how fishing and natural mortality changed.

Results

Total angling effort increased in winter, but not in summer, after vegetation was removed from Fish Lake (Figure 1). Angler hours in winter increased significantly, from an average of 2,300 h/winter during 1992–1993, before vegetation was removed, to 9,754 h/winter during 1994–1995, after vegetation was removed ($t = -5.61$; df = 3; $P = 0.03$). In contrast, angler hours in summer did not change significantly, averaging 5,972 h/summer during 1992–1994, before vegetation was removed, and 8,631 h/summer during 1995–1996, after vegetation was removed ($t = -0.86$; df = 4; $P = 0.45$).

Shore anglers made no more trips to Fish Lake after vegetation was removed than before, whereas boat anglers increased the number of trips to Fish Lake after vegetation removal (Figure 2). The number of shore trips per summer did not change significantly, averaging 2,657 during 1992–1994, before plant removal, and 2,183 during 1995–1996, after plant removal ($t = 0.82$; df = 4; $P = 0.48$). In contrast, the number of boat trips per summer increased significantly, from 863 during 1992–1994 to 1,175 during 1995–1996 ($t = -3.00$; df = 4; $P = 0.05$).

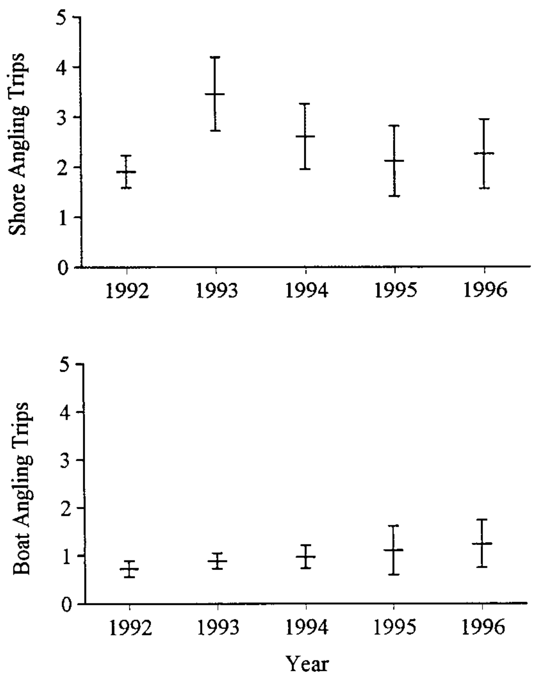

FIGURE 2.—Number of trips (thousands) by shore and boat anglers in summer on Fish Lake, Wisconsin, 1992–1996.

Angling catch rates of bluegill were higher in winter than summer but did not change significantly in summer or winter after the vegetation removal (Figure 3). Angler catch rates of bluegill did not change significantly in summer, averaging 2.8 fish/h during 1992–1994, before plant removal, and 2.0 fish/h during 1995–1996, after plant removal (t = 0.92; df = 4; P = 0.43). Angler catch rates of bluegill also did not change significantly in winter, averaging 4.0 fish/h during 1992–1994 and 3.4 fish/h during 1995–1996 (t = 1.54; df = 3; P = 0.62). Catch rates of bluegill in Fish Lake averaged less than 5.0 fish/h regardless of season during 1992–1996.

Total catch of bluegill was similar in winter and summer and did not change significantly in either season after vegetation was removed (Figure 4). Total catch of bluegill in winter did not change significantly, averaging 31,859 fish/winter during 1992–1994, before plant removal, and 34,810 fish/winter during 1995–1996, after plant removal (t = −0.56; df = 3; P = 0.63). Total catch of bluegill in summer also did not change significantly, averaging 30,720 fish/summer during 1992–1994 and 22,930 fish/summer during 1995–1996 (t = −0.56; df = 4; P = 0.63). Shore-angling catches of bluegill in summer declined from 24,004 fish/summer during 1992–1994 to 8,509 fish/summer during 1995–1996. In contrast, boat-angling catches of bluegill in summer increased from 6,716 fish/summer during 1992–1994 to 14,421 during 1995–1996.

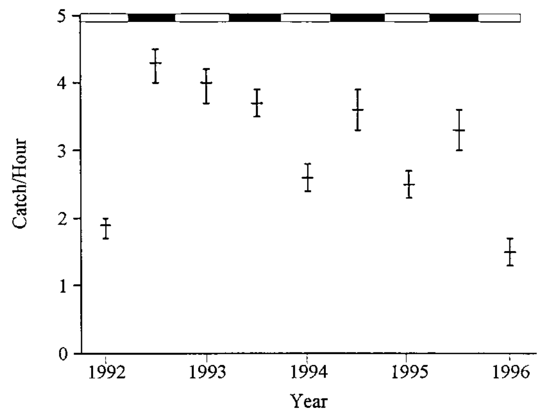

FIGURE 3.—Catch rates of bluegills by anglers on Fish Lake, Wisconsin, 1992–1996. Bar at top of figure indicates summer (white) and winter (shaded) seasons.

The size structure of bluegills harvested by anglers increased after vegetation was removed from Fish Lake (Figure 5). Most bluegills harvested by anglers ranged from 150 to 170 mm in length before and after vegetation removal, but harvest of fish 180–200 mm long increased significantly after vegetation was removed (D = 0.144; N_1 = 6,668; N_2 = 17,170; P < 0.01).

Instantaneous total mortality of bluegill declined after vegetation was removed, mainly through a decline in natural mortality (Figure 6). After vegetation removal, instantaneous natural

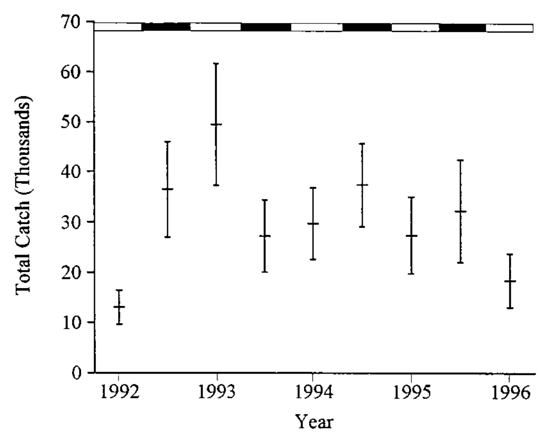

FIGURE 4.—Catch of bluegills by anglers on Fish Lake, Wisconsin, 1992–1996. Bar at top of figure illustrates summer (white) and winter (shaded) seasons.

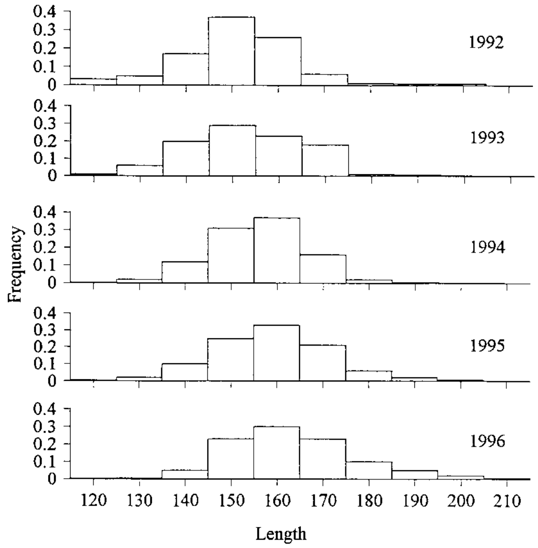

FIGURE 5.—Lengths (mm) of bluegills harvested by anglers from Fish Lake, Wisconsin, 1992–1996.

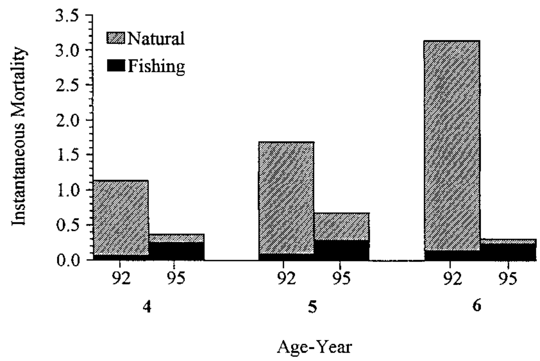

FIGURE 6.—Instantaneous natural and fishing mortality on three age-classes of bluegills before (92 = 1992–1993) and after (95 = 1995–1996) vegetation removal in Fish Lake, Wisconsin.

mortality decreased 60–91% for bluegills of ages 4–6, whereas instantaneous fishing mortality more than doubled, thereby accounting for most of the total instantaneous mortality on bluegills of ages 4–6.

Discussion

We expected angling effort to increase year-round, not just in winter, after vegetation was removed from Fish Lake. Anglers fished 69 angler-hours/ha before vegetation removal, which was similar to the average of 70 angler-hours/ha among other Wisconsin lakes during 1980–1993 (Beard et al. 1997). When vegetation was removed from Fish Lake, only winter angler effort increased, to an average of 94 h/ha. The increased winter angling effort suggests that anglers had better access to the channels in winter than in summer. Unlike most other aquatic vegetation found in Wisconsin waters, Eurasian watermilfoil is an evergreen perennial that can survive northern winters (Engel 1985). During winter, anglers on Fish Lake may have increased their effort within the Eurasian watermilfoil beds because they could position themselves directly over the narrow channels. Warmer air temperatures or lower snowfall probably did not cause winter angling effort to increase on Fish Lake, because winter air temperatures were lowest in 1994, the first winter that effort increased, and snowfall was greatest in the years after vegetation removal, when winter angling effort increased (National Oceanic and Atmospheric Administration 1991–1996).

Most summer anglers fished from shore where channels were virtually inaccessible. During vegetation removal, we had avoided cutting inshore areas so that native vegetation would be left intact. Channels were therefore inaccessible to shore anglers, who had little motivation to respond to habitat changes further from shore. Shore anglers may perceive dense vegetation as bothersome and thus favor plant reductions closer to shore (Henderson 1996). In addition, Fish Lake shore angling access was limited because more than 90% of the shoreline is privately owned; this limited shoreline access may have moderated any drastic increases in summer angling effort. Boat angling trips increased after vegetation removal and was associated with an increase in bluegill catches by boat anglers. Boat angling was similarly increased in Red Haw Lake, Iowa, when vegetation was reduced by half (Mitzner 1978).

Contrary to our expectations, angler catch rates of bluegill did not increase after vegetation was removed from Fish Lake. The pattern of vegetation removal did not increase access for shore anglers to bluegills, because the channels were not cut close enough to shore. Increased ice angling access to bluegills during the winter should have stimulated an increase in catch rates. Yet, increased bluegill catch rates may have been negated because of significant increases in winter angling effort. Catch rates declined with increased angling effort when vegetation was eradicated in Red Haw Lake, Iowa (Mitzner 1978), though this effort was estimated only during spring and summer months. The increased winter angler effort we found in Fish

Lake may not have been great enough to cause a significant decrease in winter angling catch rates of bluegill.

Natural mortality of age-4 to age-6 bluegills declined after vegetation was removed, whereas fishing mortality increased. Reduced natural mortality probably resulted in more large fish being available for anglers to harvest, so fishing mortality of bluegill increased, as we expected, and the quality of the bluegill fishery improved, as evidenced by the increase in length frequency of harvested fish in the last year of the study.

Removal of vegetation in channels may be a useful fishery management tool to increase angling opportunities. Vegetation removal in Fish Lake was associated with increased winter angling effort. We recommend creating channels in swaths wider than 2 m, and closer to shore, to attract additional summer anglers. Fish Lake anglers complained of the difficulty of finding channels, and many channels were hard to distinguish from the lake surface because vegetation at the channel edges arched over the actual channel.

Natural variation in vegetation density may have contributed to changes in winter angling effort, natural mortality of bluegill, and fishing mortality of bluegill in Fish Lake. Lack of replication and control in our study make it impossible to distinguish observed changes to vegetation reduction or other environmental changes. For example, plant biomass in Fish Lake fluctuated from year to year from natural causes not associated with cutting, which also could have influenced changes in angling effort and catch rates. Natural variation inherent in fish populations may also have influenced mortality rates and bluegill population size structure. Evaluating angling dynamics, before and after plant removal, over a longer time period would be valuable; here, we expected to detect only large changes in angling effort, catch, and catch rates because of the short duration of our study. We recommend that future vegetation manipulation experiments include documentation of changes in angler effort, catch rates, and mortality rates in both treatment and control lakes to separate the effects of vegetation removal from the natural variations inherent in lake communities.

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