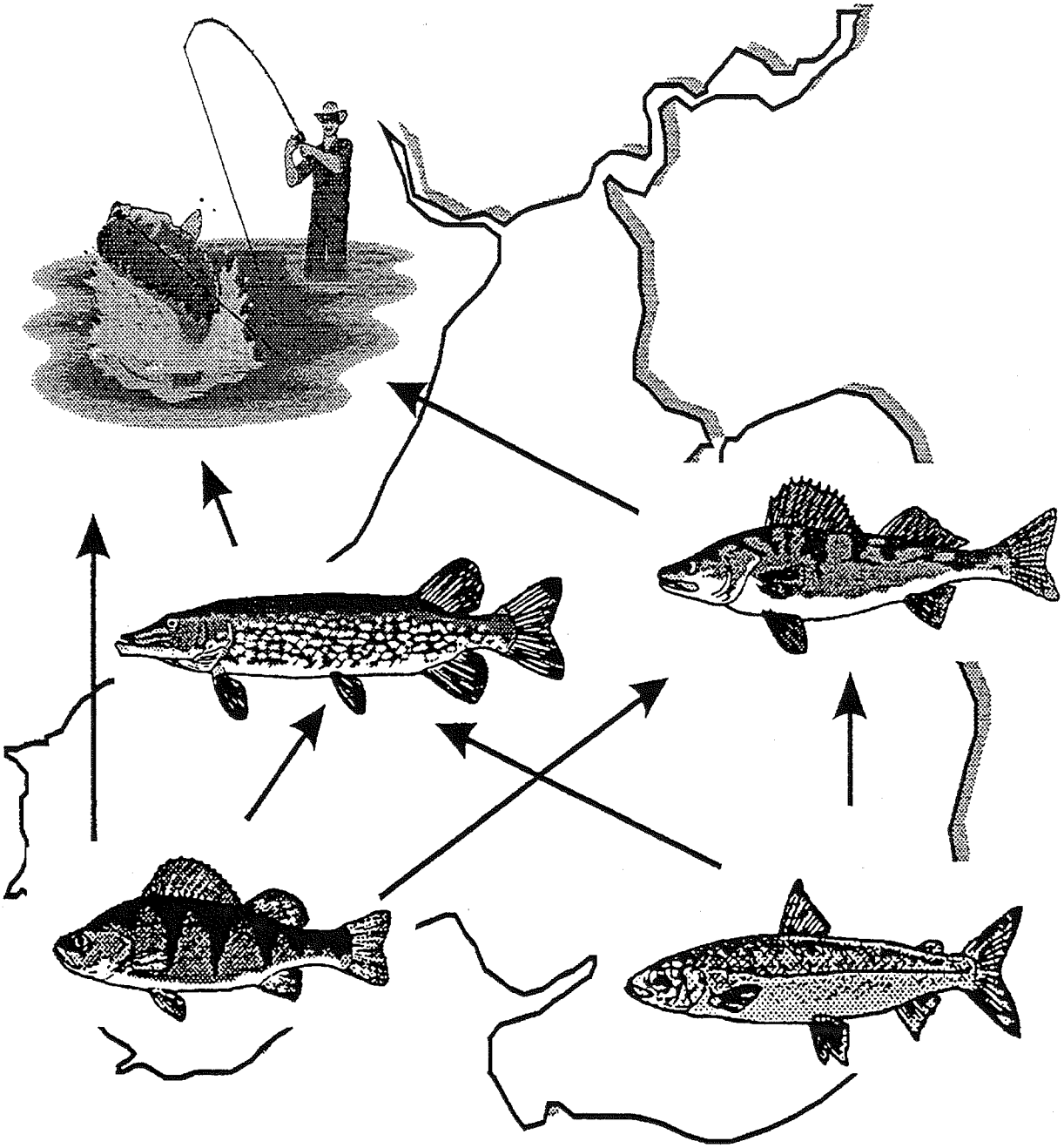
Ecology of Fishes in the Madison Lakes, 1988-1989



Fisheries Management Report No. 148
Bureau of Fisheries Management
Wisconsin Department of Natural Resources
December 1995

WISCONSIN
DEPT. OF NATURAL RESOURCES

ECOLOGY OF FISHES IN THE MADISON LAKES, 1988-1989

by Brett M. Johnson, R. Scot Stewart, and Stephen J. Gilbert

Fisheries Management Report No. 148
Department of Natural Resources
Madison, Wisconsin
December, 1995

CONTENTS

1 Introduction

2 Study Area

2 Methods
- Fish Sampling 2
- Creel Survey 7
- Stocking 8
- Harvest Regulations 8

11 Results/Discussion
- Fish Sampling 11
- Creel Survey 38
- Stocking 48
- Harvest Regulations 53

57 Management Recommendations

59 Summary

61 Literature Cited

Wisconsin Department of Natural Resources
Fisheries Management Report No. 148
December, 1995

Ecology of Fishes in the Madison Lakes, 1988-1989

BRETT M. JOHNSON, R. SCOT STEWART, AND STEVE J. GILBERT

Wisconsin Department of Natural Resources
Bureau of Fisheries Management
Madison Area Headquarters
2801 Coho Street, Suite 101
Madison, WI 53713

ABSTRACT. -- The Madison Lakes Project began in 1987. Work during 1988 and 1989 focused on Lake Mendota and studied the affects of a massive predator stocking on the lake ecosystem. In 1988 and 1989, the walleye population ≥11 inches was estimated at 1.7 and 1.1 fish/acre respectively. Northern pike ≥13 inches increased to 1.3 fish/acre by 1989, and largemouth bass were estimated at 0.6 fish/acre in 1989. A continuous creel survey estimated a slight decrease in fishing pressure in 1988, compared to 1987 (271,160 h vs. 287,176 h). However, pressure increased to 547,073 h in 1989 due to excellent perch fishing throughout the year. Fishing pressure directed at walleye doubled each year from 1987-1989. Total catch of all predators except hybrid muskie increased each year of the study period. Exploitation rates of legal-sized walleye and largemouth bass increased despite new size limits. The 15-inch minimum size limit for walleye is not sufficient to protect females to maturity. Angler response to showcase management was rapid and intense, suggesting that adequate regulations must be in place prior to showcasing a fishery improvement project. Neither spring fyke nets or electrofishing alone adequately assessed walleye population size structure. However, spring fyke nets did assess northern pike size structure well. Both spring fyke nets and spring electrofishing assessed largemouth bass size structure. Fyke nets set for predators in spring also provided good size structure data for non-predator species, but had high variability in CPE. Mini-fyke nets appear useful for assessing year-class-strength of predators and non-predator species and can be used in more habitat types than seines. A purse seine was successful for collecting larval walleyes. Population estimates for walleyes using gill nets for recapture during summer were thought to be most accurate. A population estimate of 860,000 adult yellow perch was obtained in 1988. Survival to autumn of walleye fingerlings in 1988 was similar to 1987, but overwinter survival was poor probably due to smaller size. During summer, walleye and northern pike inhabited water <10 ft; largemouth bass were shallower than these species and smallmouth bass were deeper. Walleye diet consisted mostly of YOY panfish; northern pike ate a higher percentage of yellow perch. Tag loss rate of 1.8-inch T-bar tags was half the loss rate of 3-inch tags used in 1987. Prey consumption by walleye or northern pike alone was greater in 1989 than for all predators combined in 1987. Despite the greater numbers of walleyes stocked, northern pike prey consumption was greater in 1989 because of excellent survival and growth. Combining GIFSIM and bioenergetics modeling provided the means to predict and evaluate ecological effects of changes in gamefish harvest regulation, exploitation rates, or stocking regime.

INTRODUCTION

Biomanipulation theory predicts that: 1) as the biomass of top predators increases, more planktivorous fish are consumed; 2) as the biomass of planktivorous fish decreases, zooplankton multiply; and 3) the zooplankton then consume more phytoplankton, improving water clarity (Carpenter et al. 1985, Kitchell et al. 1986, Shapiro and Wright 1984). To apply biomanipulation and study the resultant interactions among trophic levels, WDNR and UW's Center for Limnology jointly began a 7-year research project in 1987 - the Madison Lakes Project (MLP).

This report summarizes MLP's work during 1988 and 1989, the second and third years of the project including:

- population data,
- predicted changes in the sport fishery and total biomass of prey consumed,
- stocking and harvest regulations to increase walleye, *Stizostedion vitreum*, and northern pike, *Esox lucious,* biomass,
- fisheries monitoring to test predictions, and
- evaluations of population estimates, abundance indices, stocking techniques, and harvest regulations.

STUDY AREA

Most of Lake Mendota is in the city of Madison, central Dane County, southern Wisconsin (Fig. 1). First in a chain of four natural lakes on the Yahara River, 9,730-acre Mendota is also the largest. About 70% of the lake is >20 ft deep, and its maximum depth is 82 ft. Lake Mendota supports a diverse cool- and warmwater fishery, dominated by yellow perch, *Perca flavescens*, cisco, *Coregonus artedii*, and bluegill, *Lepomis macrochirus*. Common gamefishes are walleye, northern pike, largemouth bass, *Micropterus salmoides*, and smallmouth bass, *Micropterus dolomieu*.

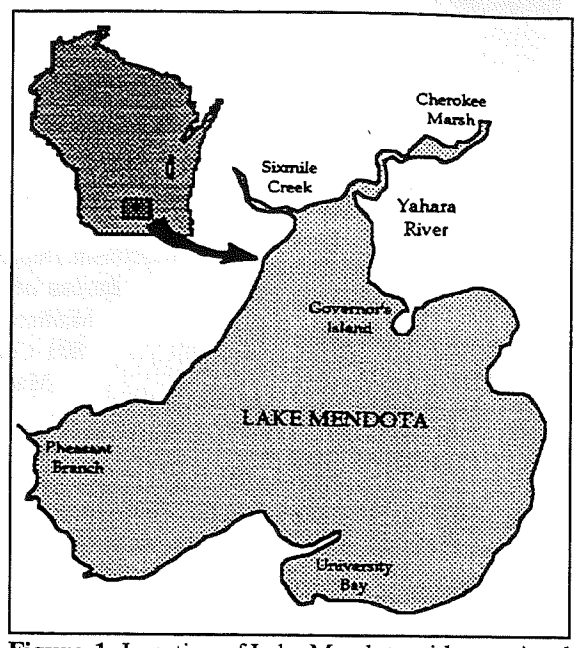


Figure 1. Location of Lake Mendota with associated local landmarks.

METHODS

POPULATION DATA

Fish Sampling

Various methods were used to gather fish population data during 1988-1989 (Table 1). Fyke nets were fished for about four weeks each year, starting at ice-out. When fyke net catch declined we electrofished for about 18 nights each spring. Experimental gill nets were fished for two weeks in June, and for one week per month during July and August, each year. Mini-fyke nets were fished at about 20 sites per month during July through September, 1988, and during July and August, 1989. Ten mini-fyke net sites were also seined in 1989. Starting in mid-September, we electrofished again for about 14 nights.

The UW-Madison's Center for Limnology analyzed the stomach contents collected from predators sampled during electrofishing and gill netting. Stomach samples were obtained by gastric lavage (Gilbert and Johnson In Press) on large predators during electrofishing and were excised from predators sampled in gill nets. Large predator stomach contents and whole small predators were preserved in 10% formalin. When possible, invertebrate contents were identified to family; fish contents, to species. Based on these data, researchers estimated dietary proportion by weight of each prey taxa. Backbone-length:weight regression formulae estimated the wet weights of digested fish (Wahl 1982, Knight et al. 1984, Carlander 1969, 1977).

Fyke Netting -- Fyke netting occurred daily from March 24 to May 6, 1988, but was only directed at predators during March 24-April 15, 1988, and for yellow perch thereafter. In 1989 we fished fyke nets from March 30 to April 28, 1989. Fyke nets had 1.25-inch stretch mesh, 3- by 6-ft frames, and 3-ft diameter hoops. They were 28 ft long plus the lead length - most had 50-ft leads; a few, 25-ft leads. We set nets in 43 locations in 1988 (Fig. 2) and 31 locations in 1989 (Fig. 3). Initially, we concentrated effort around traditional northern pike spawning sites (Cherokee Marsh, Six Mile Creek, Pheasant Branch Creek, and University Bay). Then, as northern pike catch-per-effort (CPE) declined, sampling targeted sites that had high walleye CPE in 1987.

Data collected from daily adult predator sampling included, sex, reproductive condition, weight, total length, and pre-existing marks. Female predators were only weighed during fyke netting if they were gravid, because we wanted estimates of annual growth increments to include the weight of eggs elaborated. Researchers scale-aged at least 10 fish/sex/inch-group from all predators in spring, and from walleye, bass, and pike <13 inches in autumn to identify YOY. Scales were taken behind the pectoral fin on bass and walleye, and from the nape on esocids. For age estimate comparisons, the second dorsal spine was removed from 10 walleyes/sex/inch-group in 1988.

In 1988 and 1989, predators were individually marked for age validation. To minimize tagging stress, only largemouth bass >8 inches, smallmouth bass >9 inches, walleye >11 inches; and northern pike, hybrid muskie, *Esox lucius x Esox masquinongy*, and channel catfish, *Ictaluris punctatus*, >12 inches were tagged. Longnose gar, *Lepisosteus osseus*, and bowfin, *Amia calva*, were examined for marks given in 1987, but were not tagged or clipped. Tags were inserted under the spinous dorsal fin on the right side of the fish in

Table 1. Common and scientific names, and abbreviations for species mentioned in this report, and sampled in Lake Mendota during 1988-1989.

Common name	Scientific name	Abbreviation
PISCIVORES		
Northern pike	*Esox lucius*	NPIKE
Hybrid muskie	*E. lucius X E. masquinongy*	HMUSK
Largemouth bass	*Micropterus salmoides*	LMBAS
Smallmouth bass	*M. dolomieu*	SMBAS
Walleye	*Stizostedion vitreum*	WALLE
Channel catfish	*Ameirus punctatus*	CHCAT
Longnose gar	*Lepisosteus osseus*	LNGAR
Bowfin	*Amia calva*	BOWFN
NON-PISCIVORES		
Lake sturgeon	*Acipenser fulvescens*	LSTUR
Cisco	*Coregonus artedii*	CISCO
Carp	*Cyprinus carpio*	CCARP
Golden shiner	*Notemigonus crysoleucas*	GSHIN
Unknown shiner	*Cyprinid*	UNSHI
Bluntnose minnow	*Pimephales notatus*	BLUNT
Creek chub	*Semotilus atromaculatus*	CCHUB
Spottail shiner	*Notropis hudsonius*	SPOTT
Unknown redhorse	*Moxostoma spp.*	REDHO
Bigmouth Buffalo	*Ictiobus cyprinellus*	BBUFF
White sucker	*Catostomus commersoni*	WHSUC
Black bullhead	*Ameirus melas*	BLBUL
Brown bullhead	*Ameirus nebulosus*	BRBUL
Yellow bullhead	*Ameirus natalis*	YBULL
Unknown bullhead	*Ameirus spp.*	UNBUL
Brook silverside	*Labidesthes sicculus*	SILVR
Bluegill	*Lepomis macrochirus*	BGILL
Pumpkinseed	*Lepomis gibbosus*	PUMPK
Rock bass	*Ambloplites rupestris*	ROCKB
Green sunfish	*Lepomis cyanellus*	GREEN
Black crappie	*Pomoxis nigromaculatus*	BLCRP
White crappie	*Pomoxis annularis*	WHCRP
Crappie species	*Pomoxis spp.*	UNCRP
Unknown centrarchid	*Centrarchid*	CENTR
White bass	*Morone chrysops*	WBASS
Yellow bass	*Morone mississippiensis*	YBASS
Yellow perch	*Perca flavescens*	PERCH
Logperch	*Percina caprodes*	LOGPR
Iowa darter	*Etheostoma exile*	IODAR
Johnny darter	*Etheostoma nigrum*	JODAR
Freshwater drum	*Aplodinotus grunniens*	FDRUM
Unknown species	---	UNKNO

1988 and on the left side in 1989. A different fin clip was used to identify tag loss in each year: the entire right ventral fin in 1988 and half of the left pectoral in 1989.

In 1988, researchers began using T-bar tags, available from Hallprint Pty, Ltd., Australia (phone 1-800-537-1614). These tags have a clear plastic sheath to protect the printing from abrasion and periphyton growth, and were easier to read on recaptured fish. The new tags were shorter overall (1.75 inches) and have a shorter leader (0.75 inches) than the Floy tags used in 1987. The new tags stay tight to the body, which should reduce injury and tag loss due to whipping and drag. Walleyes and bass were tagged under the spinous dorsal fin in 1988-1989, as opposed to under the soft dorsal in 1987. Most fish were tagged during spring fyke netting, although some fish, especially bass, were also tagged during spring

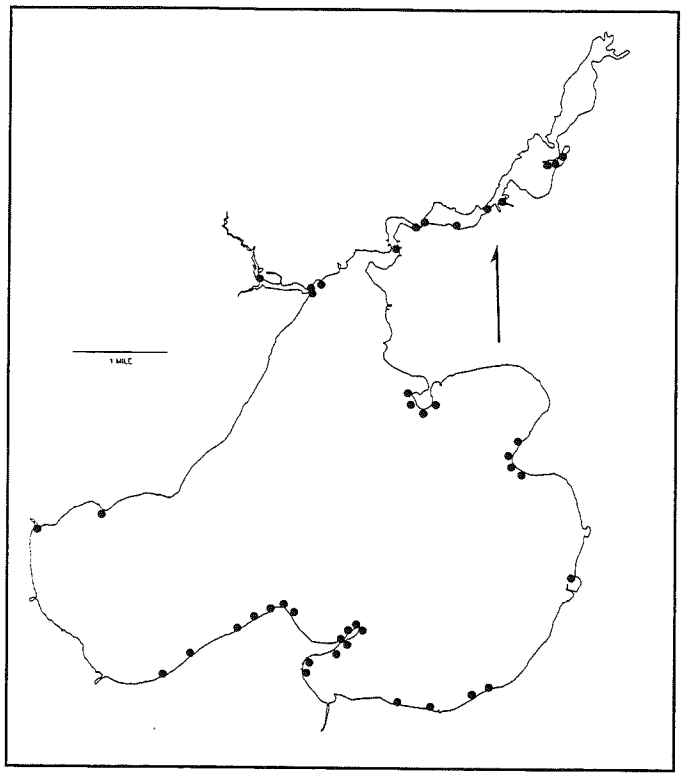


Figure 2. Locations of fyke nets set in Lake Mendota and Cherokee Marsh during March 24 to May 6, 1988.

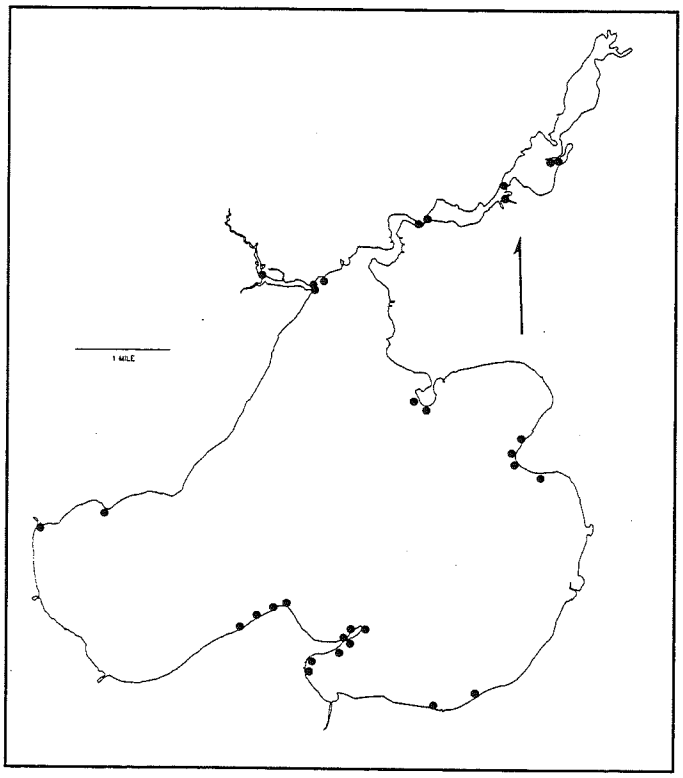


Figure 3. Locations of fyke nets set in Lake Mendota and Cherokee Marsh during March 24 to April 15, 1989.

electrofishing. We computed tag loss rate during three periods: after about six months using autumn electrofishing for recaptures, after one year using spring fyke nets for recaptures, and after 18 months using autumn electrofishing.

Data collected from weekly non-predator sampling provided size structure, abundance, and age and growth information (Table 1). In 1988, we sampled non-predators in all fyke nets fished that day. In 1989, we randomly selected six nets to sample for non-predators. Researchers recorded the weight and total length of 20 fish/species/net and scale-aged 10 fish/species/inch-group, except for yellow perch, for which researchers scale-aged 10 fish/sex/inch-group because sexes were distinguishable. The remaining fish were counted.

Electrofishing -- Electrofishing was used to tag additional bass (because of low bass CPE in fyke nets), to recapture fish tagged in fyke netting, to mark and recapture walleyes <11 inches, and to gather fish for stomach analysis. Three-person crews electrofished after sunset from May 10-June 2, 1988, and from May 9-June 15, 1989. A standard WDNR electrofishing boat was used, set at 300 volts and 2.5 amps (mean) DC, with a 20 % duty cycle and 60 pulses per second. On all sampling dates two people netted fish; thus, CPE data are catch/two-netter hour or mile. Shocking was divided into stations (Fig. 4). For each station, we recorded the actual starting and ending time and the generator's meter times. Starting and ending points of each station were plotted on 7.5 minute topographic maps (published in 1983). We used a cartometer to develop a standardized shoreline mileage numbering scheme (Table 2). Starting at the Yahara River outlet at Tenney Park and measuring counterclockwise, we numbered the shoreline according to the number of miles from the outlet. We then determined the length of shoreline shocked for each station using these maps.

We used the 3-person electroshocker again during September 20 to November 14, 1988 and September 11 to October 31, 1989. Autumn electrofishing had several objectives: to gather CPE data for comparison with previous surveys of the lake; develop a database relating autumn electroshocker CPE to predator density; collect autumn predator diet data; make mark-recapture population estimates of YOY predators; and to determine year-class strength of yellow perch, yellow bass, *Morone mississippiensis*, and white bass, *Morone chrysops*. We scale-sampled predators assumed to be <3 years old so age-specific CPE could be computed.

Predators were handled as they were during fyke netting, except a sample of walleyes ≤12 inches was collected for stomach analysis. In spring, non-predator species were only collected to complete subsamples for scale length groups. Predators too small to tag were given a temporary fin clip (bottom of tail, BT, in spring and top of tail, TT, in autumn) to make mark-recapture population estimates.

Table 2. Standard electrofishing transects shocked during September-November 1988-1989, on Lake Mendota. Transects correspond to those pictured in Figure 4. Starting and ending mileage is the distance along the shore from the Tenney Park boat ramp to the endpoints of the transect.

Transect	Starting Mileage	Starting Location	Ending Mileage	Ending Location	Length (miles)
A	0.0	Tenney Park boat ramp	1.5	Maple Bluff flagpole	1.5
B	1.5	Maple Bluff flagpole	2.7	Warner Park boat ramp	1.2
C	2.7	Warner Park boat ramp	4.7	Governor's Island-west	2.0
D	9.2	Six Mile lakeside	10.3	Governor Nelson boat ramp	1.1
E	10.3	Governor Nelson boat ramp	12.1	Hammacher's dock (Fox Bluff)	1.8
F	12.1	Hammacher's dock (Fox Bluff)	13.0	Mendota County Park boat ramp	0.9
G	13.0	Mendota County Park boat ramp	13.9	Hatch Cover boat ramp	0.9
H	13.9	Hatch Cover boat ramp	14.6	Marshall Park mouth-south	0.7
I	14.6	Marshall Park mouth-south	15.7	Spring Harbor mouth-south	1.1
J	15.7	Spring Harbor mouth-south	17.3	Tent Colony access	1.6
K	17.3	Tent Colony access	19.0	Picnic Point-white sign	1.7
L	20.4	Willows Beach	21.2	Limnology Lab	0.8
M	21.4	Red Gym-UW campus	22.2	James Madison Park-west	0.8
N	22.2	James Madison Park-west	23.7	Tenney Park boat ramp	1.5

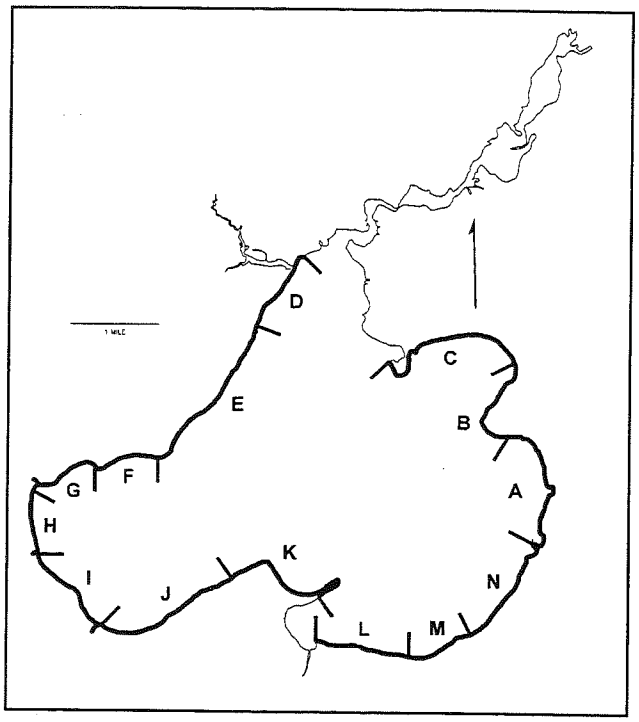


Figure 4. Locations of standard electrofishing transacts on Lake Mendota. Starting and stopping points are described in Table 2.

Recently there has been concern about potential injury to electroshocked fishes. Given that we have been electrofishing over 30 nights/year on Mendota, we were concerned whether differential mortality occurred between fish tagged in fyke nets versus fish tagged during electrofishing. To examine this question, we compared the recapture rate after one year, of fish tagged in each gear that were subsequently recaptured. In this analysis we assumed tag loss rate was constant between sampling gears.

Gill Netting -- With assistance from DNR Bureau of Research, experimental gill nets were fished during June through August, 1988-1989. Gill nets were used to recapture predators (and yellow perch in 1988) for population estimates of fish marked in fyke nets, to determine walleye depth distribution and thermal history, and to collect midsummer walleye diet data. These data were required for bioenergetics modeling of predator consumption.

Gill nets were set on the bottom (except during August 1988) at about 18 locations at dusk each day, and were lifted the following morning. All nets were constructed of five panels of differing mesh size, each panel either 10 or 25 ft long. Meshes measured 1-3 inches (0.5-inch increments, stretch) or 4-8 inches (1-inch increments, stretch). Nets were either 3 or 6 ft high; 3-ft nets were set only in water 6-9.9 ft deep. Sampling design differed in 1988 and 1989. During June 6-9, 1988, we used 1-3 inch stretch mesh nets to examine a sample of yellow perch fin-clipped during fyke netting for recaptures. In subsequent sampling periods in 1988 we used a combination of 1-3, 2.5-4.5, and 4-8 inch stretch mesh nets to sample predators. Sampling locations were stratified by depth and habitat in 1988, but as in 1987, sites within strata were not selected randomly. In July, nets were set perpendicular to the depth contour; in June and August nets were set parallel to the contours. In August, 1988, 4,875 ft of net was set suspended above the thermocline to sample pelagic walleyes. The bottom of each suspended net was 26 ft below the surface in water >30 ft deep.

In 1989, all nets had five 2.5-4.5 inch stretch mesh panels, and were 125 ft long. Nets set in water shallower than 10 ft were 3 ft high; all others were 6 ft high. Sampling locations were selected randomly from four strata: 1) reef sets, 2) inshore sets, 6-9.9 ft deep, 3) mid-depth sets, 10-29.9 ft deep, and 4) deep sets, >30 ft deep.

Temperature-dissolved oxygen profiles were used to monitor the development of the thermocline and guide net placement during July and August. After the thermocline was established nets were set out to the 30-ft contour, or to the maximum depth with dissolved oxygen >2 ppm.

Depth distributions of predator populations were determined from 1989 gill net sampling. We assumed catch/100 ft of gill net (CPE) in a given depth stratum was proportional to the number of fish per unit surface area in that stratum. We then multiplied CPE in the stratum by the proportion of the lake's surface area in that depth stratum to obtain a product assumed to be proportional to total abundance in the stratum. The proportion of the predator population inhabiting each depth stratum was computed from the products for all strata. In 1988, stomachs from dead predators were preserved in 10% formalin, and a stomach pump was used to remove contents from live fish, which were then released. In 1989, dead predators were packed in dry ice in the field, and kept frozen until stomachs could be removed. All predators were measured and weighed.

Mini-fyke Netting and Seining -- Mini-fyke nets were fished at about 20 sites/month during July through September, 1988, and in July and August, 1989, to estimate year-class strength, relative abundance, and size structure of fishes in the littoral zone. Nets were constructed with 3/16-inch stretch mesh, 2-ft diameter hoops, 2- by 3-ft frames, and 25-ft leads. Sites were comparable to seine sites used in previous surveys

(Fig. 5), and included a variety of substrate types and macrophyte densities. To exclude turtles and large predators from mini-fyke nets, some nets had 2- by 2-inch mesh at the entrance to the net. Thus, mini-fyke net data are most accurate for YOY fishes, and should not be used to make inferences about larger fish. In July and August, 1989, we also seined 10 randomly selected mini-fyke net sites on the same day to compare catches between gears. Seine hauls were made with a 25-ft bag seine with 1/8-inch stretch mesh pulled perpendicular to shore starting from a depth of 1 m. Average area seined was about 100 m^2. Twenty fish/species were measured from each haul, and any additional fish were counted.

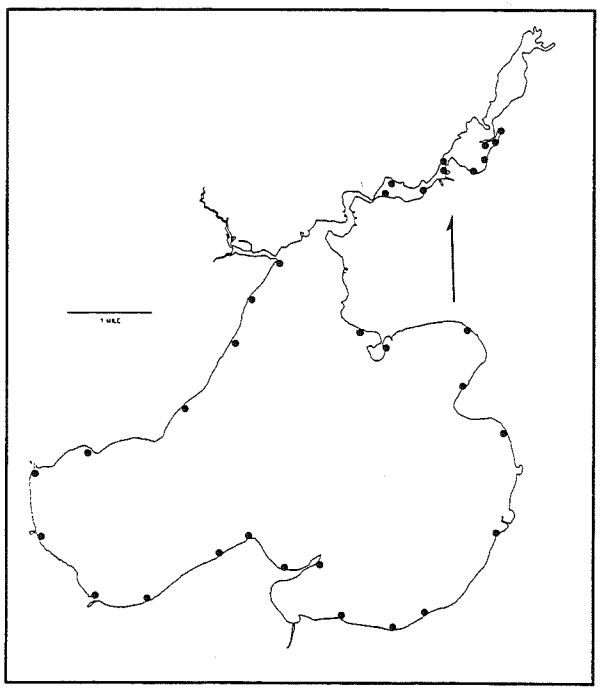


Figure 5. Locations of mini-fyke nets set in Lake Mendota (summer 1988, 1989) and Cherokee Marsh (summer 1988). Most lake sites correspond to sites seined during previous surveys.

Creel Survey

Fishing pressure, catch rates, harvest, and exploitation rates were estimated from a randomized, access-point creel survey. The schedule was stratified into weekday and weekend/holiday day types. Shifts were selected randomly and were either 7 a.m. - 3 p.m. or 3-11 p.m. In addition, two 11 p.m. - 3 a.m. and two 3-7 a.m. shifts were sampled per month to estimate the same parameters during night hours.

During the ice-fishing season (late December-February), 23 access points around Lake Mendota and upstream to the Highway 113 bridge were sampled. The creel clerk counted the number of anglers starting and completing trips during the scheduled stop at each access point. During openwater (May-December), 13 access points were sampled; 9 were boat ramps and 4 were popular shore-fishing sites. At each of these sites, an instantaneous count of shore anglers was made upon arrival at the site, and continuous counts of boat anglers starting and completing trips at public and private access points were made.

Boat occupants and ice-fishing anglers were only interviewed if they were completing a trip. Both complete-trip and incomplete-trip interviews were conducted with shore anglers. Number caught and number kept of each species, and percent of time seeking a particular species were recorded. All predators possessed by anglers were measured, weighed, and inspected for finclips and tags. We measured a random sample of at least 20 fish/non-predator species/day. During summer 1988, and in winter 1989, all yellow perch that were measured were examined for finclips.

POPULATION ESTIMATES

The different marks used for different sizes of fish and times of year allowed calculation of several different population estimates. Whenever possible we used one gear for marking and another for recapturing to minimize bias due to gear selectivity. Exceptions to this were estimates for walleye computed using the last week of spring fyke netting period as the recapture run, and estimates of small predators using exclusively electrofishing. Fyke net estimates were compared to estimates using gill nets for recaptures; no alternative estimate was available for small predator abundance.

In spring, all predators that were tagged received a permanent finclip. Also in spring, walleyes <11 inches were given a temporary fin clip (bottom of tail, BT). Other predators that were too small to tag were marked in spring. Mark-recapture estimates of yellow perch were performed in 1988. Yellow perch were caught in fyke nets during April 21-May 6, 1988 and marked with a complete left ventral fin clip. Marked fish were released at three different sites around the lake. Experimental gill nets composed of 1-4 inch stretch mesh and set for 12 days during June 6-July 21 were used to obtain the recapture sample. Because few female perch were marked, estimates for males and females combined were determined by dividing the estimated number of males by the percentage of males in the gill net catch. Estimates were corrected for growth occurring between marking and recapture, and Chapman's modification of the Petersen formula was used (Ricker 1975).

In autumn, walleye, largemouth and smallmouth bass, and northern pike that were assumed to be <age-

3 were given a different temporary fin clip (top of tail, TT). Subsequent electrofishing runs during autumn and the following spring provided recapture samples.

Whenever the number of recaptures was statistically sufficient, we made separate estimates by size intervals. Sizes of fish judged to be of equal vulnerability were grouped together if necessary. Because fish could not be sexed after the spawning period, estimates by sex could not be made.

We conducted electrofishing mark-recapture estimates in spring and autumn by making about 2.5 laps of the lake's shoreline with an electroshocker. This required about 15 nights of sampling for each estimate. We released marked fish at the end of each transect. Whenever possible, we used randomly selected recapture transacts that were shocked on the last night of electrofishing for each seasonal estimate. Recapture effort was also randomized in estimates using gill nets for recapture samples. Most estimates were computed using Chapman's modification of the Petersen formula. Confidence limits (95%) were computed by considering recaptures, R, as a Poison distributed variable. Values for R from Ricker (1975, Appendix II) were substituted in formulae to obtain confidence limits.

Because we were able to make separate population estimates by size classes, we could evaluate the magnitude of size selectivity shown by typical sampling gear. To do this, we computed the relative length-frequency histograms for the walleye, northern pike, and largemouth bass populations. This was done by taking the population estimates partitioned into size classes and applying the relative length-frequency (within these size classes) of marked and unmarked fish measured during the marking and recapture runs to obtain absolute size structure within the size class. We then obtained relative size structure for the population by computing percentages in length intervals for the entire population. This size distribution was then compared to the size distribution found in fyke nets and the boomshocker, which included recaptured fish. Admittedly, the relative size structure within size classes could be biased, but only to the extent that the gear is selective for different sizes within a size class. And, because size classes were chosen based on our judgement that vulnerability to the gear was equal for all sizes of fish within a size class, bias should be minimized.

INCREASING PREDATOR BIOMASS

Stocking

To obtain the immediate increase in predator biomass required for the biomanipulation, large numbers of both northern pike and walleye fry and fingerlings were stocked. Northern pike fry were stocked in emergent vegetation at University Bay, Cherokee Marsh, and Six Mile Creek. Northern pike fingerlings were scattered in the littoral zone. We stocked walleye fry at least 0.25 mi from shore at several locations around the lake to avoid possible concentrations of fry-eating predators, and to increase the likelihood that some fry would find sufficient zooplankton densities. Fingerling walleye were scattered throughout the littoral zone, in areas with macrophytes.

The potential production of native walleye fry was determined to study the importance of stocking (fry or fingerlings) for maintaining Mendota's walleye population, and to examine reasons for inconsistent natural reproduction observed over the previous 10 years. The biomass of female walleyes was estimated using the GIFSIM model assuming a 15-inch size limit, 1988 exploitation rates, and a 3% average survival rate of stocked fingerlings. We assumed a 50:50 sex ratio in the population. The biomass of eggs produced was then estimated assuming a maturity schedule of: 0% for age-3 and younger, 8% for age-4, 32% for age-5, and 100% for age-6 and older (Priegel 1969) and an average fecundity of 64,400 eggs/kg of mature female biomass (Serns 1982a; Forney 1976; Priegel 1969; Wolfert 1969). An egg to fry survival rate from Oneida Lake, New York of 0.00065 (Forney 1976) was used to predict potential fry production.

Harvest Regulations

Special harvest regulations were adopted for Lake Mendota, including tributaries upstream to the first bridge, beginning on January 1, 1988. The objectives of these regulations were to protect the age-classes of predators with the highest consumption rate of planktivores, improve the fishery by increasing size structure and biomass of walleye and northern pike populations, and increase the reproductive potential of walleye and northern pike populations. The regulations reduced the bag limit on walleyes from five to three fish per day, and created a minimum size limit of 15 inches The bag limit on northern pike was reduced from five to one fish per day, and the minimum size limit became 32 inches A statewide minimum size limit of 14 inches for largemouth and smallmouth bass was established on January 1, 1989. We used a computer model designed for inland fisheries to evaluate the proposed regulations.

Forecasting Changes -- The Generalized Inland Fishery Simulator (GIFSIM; Taylor 1981) was used to predict changes in walleye population structure and

reproductive potential resulting from various harvest regulations and stocking scenarios. GIFSIM is an age-structured computer model that allows the user to input age- and sex-specific population parameters. It also allows these parameters to vary throughout the year. Growth and survival functions can vary stochastically, and density-dependent effects on growth and survival can be modeled.

We modeled four periods/year that corresponded to the periods when fishing statistics changed. Period 1 was January 1 to March 1 and covered the legal ice-fishing season. The closed season, March 2-May 6, was period 2 in our simulations. May 7 to November 15 was period 3, and was the open water season before the late autumn decline in fishing pressure; and period 4 was November 16-December 31, a period when fishing pressure was low while ice formed on the lake.

All population inputs were sex-specific. Initial number/age-class and average length at age were estimated from mark-recapture estimates and scale samples, respectively. The proportion of annual growth increment occurring in each period was greatest in period 3 (Table 3,4). The model used sex-specific length-weight regressions (weight in g; length (TL) in mm) to convert lengths to weights for biomass and yield estimates:

$$\text{males: Wet weight} = 0.0000023*\text{Length}^{3.23000}$$
$$R^2 = 96.9;\ N = 238;\ P < 0.0001$$
$$\text{females: Wet weight} = 0.0000022*\text{Length}^{3.25000}$$
$$R^2 = 85.8;\ N = 204;\ P < 0.0001.$$

Exploitation rates by age-class (Table 3,4) were determined by dividing harvest of an age-class by mark-recapture population estimates for that age-class. Harvest was computed separately for ice-fishing (period 1) and open water fishing (period 3) seasons, from creel survey data. No harvest occurred during periods 2 and 4. Mortality of fish caught and released was not estimated; however, other studies have shown that hooking mortality of walleyes is low (Fletcher 1987; Payer et al. 1987). We used a value of 15% for hooking mortality.

Natural mortality could not be measured because population data were collected in one season. A catch curve of age versus catch was not appropriate because year-class strength depended on stocking, which was highly variable. We used data from Colby et al. (1979) for natural mortality rate of walleye.

To simplify interpretation of model predictions, we modeled a constant annual recruitment, resulting only from stocking. We used a value of 8,000 yearlings per year, based on the mark-recapture population estimate of YOY walleyes made in autumn 1987.

To examine the relative importance of stocking and various harvest regulations on walleye population structure, we made four types of simulations: 1) no stocking and no new harvest regulations, 2) stocking only, 3) harvest regulations only, and 4) stocking plus harvest restrictions. Harvest restrictions were minimum size limits ranging from 13 to 20 inches.

Changes in the walleye population structure resulting from various management scenarios would result in different levels of prey biomass consumed by walleyes. A bioenergetics model for walleye (Hewett and Johnson 1987) was used to estimate prey consumed under these different scenarios. The bioenergetics model estimates the biomass of food consumed by a predator from observed growth, physiological functions, and the thermal history of the predator. Predicted population structure derived from GIFSIM simulations was input to the bioenergetics model. In addition to GIFSIM population structure and mortality rates, the bioenergetics model requires data on: thermal history of walleyes in Lake Mendota because temperature affects consumption required for a given amount of growth, prey selection data to make species-specific estimates of biomass consumed, and energy content of walleye and their prey because model calculations are performed in energy units.

We used the bioenergetics model to evaluate the importance of walleye thermal history on model predictions of prey consumption. Estimating the thermal history, or the water temperatures experienced by the fish, could be a costly and time-consuming undertaking, depending on how accurately it needs to be determined. One would expect this parameter to be most important in summer, when a range of temperatures are available, and consumption rate is high. We used the model to determine how much error in annual consumption estimates can be caused by errors in thermal history, and to determine the most critical time of year for estimating thermal history. To do this, we created three thermal histories from 1988 Mendota temperature profiles: minimum temperatures, maximum temperatures, and temperatures nearest the optimum temperature for consumption. Total consumption predicted with these temperature inputs was then compared to determine the range of possible values. We used walleye catch per effort in experimental gill nets stratified across habitat types and depths to determine temperatures actually experienced by the fish. Nets were fished for 4 days/month from June through August, 1988 and 1989.

We used default values in the WALLEYE.BIO file from Hewett and Johnson (1987) for all energetics parameters. Each model cohort corresponded to an age-class, with cohort 1 being age-1 walleyes. Each

Table 3. Walleye population statistics input to GIFSIM (Taylor 1981) model used to predict the effects of various stocking and harvest regulation scenarios on the walleye population and fishery in Lake Mendota, Wisconsin. Growth pattern is the proportion of the annual growth increment occurring during each simulation period. Values for fishing mortality (measured in 1988) and natural mortality are conditional mortality rates occurring in each simulation period.

Population Statistic	Simulation Period	Sex	Age-class 1	2	3	4	5	6	7	8
Mean Length at Age (in)	Jan 1-Dec 31	Male	7.5	11.7	13.9	15.8	16.5	18.6	20.4	21.8
		Female	7.5	11.7	14.1	16.4	20.9	22.4	23.7	24.4
Growth Pattern	Jan 1-Mar 1	M+F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mar 2-May 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May 2-Nov 15		95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
	Nov 16-Dec 31		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fishing Mortality	Jan 1-Mar 1	M+F	0.0	4.0	10.0	10.0	11.0	14.0	0.0	10.0
	Mar 2-May 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May 2-Nov 15		1.0	7.0	13.0	24.0	28.0	41.0	13.0	6.0
	Nov 16-Dec 31		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Mortality	Jan 1-Mar 1	M+F	4.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
	Mar 2-May 1		4.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
	May 2-Nov 15		11.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
	Nov 16-Dec 31		3.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0

Table 4. Walleye population statistics input to GIFSIM (Taylor 1981) model used to predict the effects of various stocking and harvest regulation scenarios on the walleye population and fishery in Lake Mendota, Wisconsin. Growth pattern is the proportion of the annual growth increment occurring during each simulation period. Values for fishing mortality (measured in 1989) and natural mortality are conditional mortality rates occurring in each simulation period.

Population Statistic	Simulation Period	Sex	Age-class 1	2	3	4	5	6	7	8
Mean Length at Age (in)	Jan 1-Dec 31	Male	7.5	11.7	13.9	15.8	16.5	18.6	20.4	21.8
		Female	7.5	11.7	14.1	16.4	20.9	22.4	23.7	24.4
Growth Pattern	Jan 1-Mar 1	M+F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mar 2-May 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May 2-Nov 15		95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
	Nov 16-Dec 31		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fishing Mortality	Jan 1-Mar 1	M+F	0.0	4.0	10.0	3.0	11.0	18.0	13.0	0.0
	Mar 2-May 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May 2-Nov 15		1.0	7.0	13.0	49.0	52.0	63.0	52.0	35.0
	Nov 16-Dec 31		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Mortality	Jan 1-Mar 1	M+F	4.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
	Mar 2-May 1		4.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
	May 2-Nov 15		11.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
	Nov 16-Dec 31		3.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0

cohort was modeled for one year starting on April 15. Initial population size was the number of walleyes in the age-class in 1991, projected from GIFSIM (Taylor 1981) simulations of stocking and harvest regulations called for in the Mendota Project. The mortality rate for these simulations was the average total annual rate computed from 1987 exploitation rate and a natural mortality rate from Colby et al. (1979). Starting and ending walleye weight was derived from scale aging data obtained in spring, 1988. All species data inputs are identical for the three thermal histories simulated, except P-value. P-values for each cohort of each .BIO file were determined using the P-fit option of the bioenergetics model so that simulated growth matched observed annual growth increments.

Prey selection was determined from analysis of stomach contents from walleyes collected throughout the year. Average proportion of each prey in the diet during winter, spring, summer, and autumn were input to the bioenergetics model. Energy content (1.0 kcal/g wet weight) of walleyes and yellow perch were obtained from Hewett and Johnson (1987).

We also used the bioenergetics model to investigate how changes in the seasonal pattern of fishing mortality affects predicted consumption of all age-4 walleyes in Mendota. Here, the model was used to evaluate the utility of fishing regulations (season length) as a tool to mediate walleye prey consumption. Using literature data for annual natural mortality rate (17%, Colby et al. 1979) and the annual exploitation rate observed in a creel survey in 1988 (32%), we simulated five harvest schedules assuming annual fishing mortality occurred: at a constant rate throughout the year, only in May, only in July, only in September, or only in January-February. These simulations were run using the optimum temperatures; all other inputs were identical to those used in evaluating the importance of thermal history, above.

Unless otherwise noted, results of simulations with GIFSIM and the bioenergetics model are presented at equilibrium conditions.

RESULTS AND DISCUSSION

POPULATION DATA

Fish Sampling

Fyke netting -- To capture yellow perch for a population estimate, fyke nets were fished later into spring in 1988 (March 24-May 6) than in 1987 or 1989. However, about 91% of the total predator catch occurred before the yellow perch spawning run began (April 21). Interestingly, about half of all the smallmouth bass caught in fyke nets in 1988 were captured after April 20, and the highest smallmouth CPE occurred on the last day of fyke netting (May 6). Because smallmouth bass have proven very difficult to sample with early fyke nets, and electrofishing, it may be worthwhile to try fyke netting in May to sample this species. Predators sampled in fyke nets provided the majority of scale samples used to estimate growth (Table 5). We were able to determine growth by sex for walleye, northern pike, and yellow perch because sexes were easily distinguishable. Future recaptures of tagged fish should provide validation of the aging techniques used here.

To compare 1988 predator CPE (catch-per-net-day) to other years when fyke netting ended as perch spawning began, CPE is reported for the period March 24-April 20, 1988 (357 net-days). In 1989, fyke nets were fished during March 30-April 28 for a total of 398 net-days. As in 1987, walleye catch/net-day during this period was about 2 times higher than the second most numerous species in fyke nets, northern pike (Table 6).

Northern pike CPE increased substantially in 1989, but walleye still dominated the catch. Largemouth and smallmouth bass CPE has remained constant since 1987. Fyke nets set during the spring spawning run are size-selective (Ricker 1975) and size distributions of fish in fyke nets are biased. Comparing the length-frequency of fish caught in the gear with that of the population estimated from mark-recapture experiments, we can quantify this bias.

The size distribution of walleyes caught in fyke nets were similar in 1988 and in 1989. There were modes of 14, 20-21, and 26 inches (Fig. 6).
In 1989 there was a mode at 10 inches, but not in 1988. Fyke nets caught few walleyes <10 inches in either year. No walleyes >30 inches were caught. Fyke nets set during the spawning run in 1988 and 1989 greatly underestimated the relative abundance of walleyes <11.0 inches (Fig. 6). Walleyes 11-24 inches TL were overestimated in fyke nets by 50-100%, and walleyes >24 inches TL were overestimated by 200-300%.

Northern pike up to 43 inches were sampled in fyke nets (Fig. 7). In 1988, there was a slight mode at 13 inches but the size distribution between 13-28 inches was quite flat (Fig. 7). In 1989, the size distribution was dominated by 13-24 inch fish (Fig. 7), presumably as more fish from fingerling stocking in 1987 recruited to the gear. Because the fyke net catch alone was used to generate the population length-frequency, gear selectivity cannot be evaluated for pike. However, the rapid growth rate and early age at maturity of pike may decrease the selectivity of the gear. Recaptures during fyke netting do not appear to have biased the estimated length-frequency, as the close agreement between gear and population size structure indicates (Fig. 7).

Table 5. Growth of some Lake Mendota fishes, aged from scales. Fish were aged separately by sex whenever possible (F, M, and U are female, male, and unknown respectively). Stratified samples of 10 scales per inch and sex were collected during fyke netting from March 24 to April 28, 1988, and during fyke netting from March 30 to April 28, 1989. Some centrarchid scales were also collected during electrofishing from May 9 to June 1, 1989. Mean size at age is not corrected for population length-frequency.

Year	Species	Sex	Age	Mean length (in.)	Std err	N	Mean weight (g)	Std err	N
1988	WALLEYE	F	1	-	-	0	-	-	0
			2	-	-	0	-	-	0
			3	16.1	-	1	612	-	1
			4	17.2	-	1	732	-	1
			5	22.2	1.1	3	2,041	441	3
			6	21.6	0.6	7	1,720	122	6
			7	23.5	0.4	10	2,307	204	8
			8	25.1	0.3	18	2,851	179	16
			9	27.3	0.3	14	3,834	183	12
			10	27.6	0.4	13	4,075	212	11
			11	28.4	0.3	8	4,125	218	6
			12	29.6	0.6	2	4,437	215	2
	WALLEYE	M	1	-	-	0	-	-	0
			2	11.9	0.1	17	242	8	17
			3	14.3	0.2	30	436	20	29
			4	16.0	0.3	11	629	36	11
			5	17.3	0.2	12	802	37	12
			6	18.7	0.2	15	1,034	34	15
			7	19.9	0.3	8	1,276	67	8
			8	21.2	0.1	14	1,476	38	14
			9	22.6	0.2	8	1,875	95	8
			10	22.4	0.2	2	1,758	142	2
	WALLEYE	U	1	7.8	0.2	26	67	5	26
			2	11.6	0.2	38	233	13	36
			3	15.0	0.2	29	516	26	28
			4	16.0	0.2	6	737	97	6
	NORTHERN PIKE	F	1	13.6	0.3	8	202	25	7
			2	20.2	0.4	68	978	60	67
			3	25.5	0.4	27	1,940	95	27
			4	29.0	0.3	26	2,710	144	26
			5	31.6	0.6	20	3,590	288	20
			6	37.1	0.4	8	5,670	384	8
			7	36.9	1.4	3	4,876	401	3
	NORTHERN PIKE	M	1	13.4	0.2	30	224	17	30
			2	19.0	0.3	59	675	34	59
			3	22.9	0.3	25	1,200	58	24
			4	24.9	0.2	11	1,502	46	11
			5	26.3	0.3	9	1,792	64	9
			6	28.1	0.2	5	2,115	38	5
			7	28.3	0.8	2	1,816	344	2
	NORTHERN PIKE	U	1	11.7	0.4	20	147	17	19
			2	17.0	0.3	24	462	168	23
	HYBRID MUSKIE	U	1	-	-	0	-	-	0
			2	-	-	0	-	-	0
			3	22.4	1.1	3	1,030	175	3
			4	27.5	0.0	2	1,928	116	2
			5	32.0	0.6	2	3,402	0	2
			6	36.3	-	1	4,593	-	1
			7	43.2	1.3	6	7,201	618	3

Year	Species	Sex	Age	Mean length (in.)	Std err	N	Mean weight (g)	Std err	N
1988	LARGEMOUTH BASS	U	1	5.4	0.2	13	34	3	13
			2	8.8	0.3	33	174	14	32
			3	12.2	0.2	25	475	28	25
			4	14.3	0.3	21	802	52	21
			5	15.8	0.2	12	1,166	74	12
			6	17.2	0.3	4	1,680	81	4
			7	18.6	0.1	4	2,006	71	4
			8	18.9	0.4	3	1,994	146	3
			9	20.4	0.2	2	2,608	227	2
			10	22.0	-	1	3,572	-	1
	SMALLMOUTH BASS	U	1	4.5	0.1	13	19	2	12
			2	7.8	0.2	34	114	9	32
			3	10.4	0.3	22	293	28	19
			4	14.1	0.5	7	749	86	7
			5	16.1	0.2	8	1,144	74	7
			6	17.1	0.2	2	1,517	71	2
			7	18.2	-	1	1,928	-	1
	YELLOW PERCH	U	1	5.1	0.2	14	-	-	0
			2	6.7	0.1	9	-	-	0
	YELLOW PERCH	M	1	-	-	0	-	-	0
			2	-	-	0	-	-	0
			3	7.7	0.1	13	-	-	0
			4	9.0	0.1	12	-	-	0
			5	9.1	0.2	5	-	-	0
1989	WALLEYE	F	1	-	-	0	-	-	0
			2	-	-	0	-	-	0
			3	16.9	-	1	765	-	1
			4	19.4	0.4	15	1,276	70	15
			5	21.3	0.2	18	1,717	56	18
			6	22.9	0.3	13	2,172	95	13
			7	25.0	0.2	18	3,155	174	13
			8	26.3	0.3	14	3,589	123	12
			9	27.8	0.2	15	4,260	80	14
			10	28.7	0.4	6	4,784	256	5
			11	28.9	-	1	4,738	-	1
	WALLEYE	M	1	-	-	0	-	-	0
			2	11.8	0.2	5	293	26	5
			3	13.7	0.1	23	389	14	23
			4	16.1	0.2	22	624	28	22
			5	17.9	0.7	30	964	45	28
			6	20.6	0.3	13	1,404	77	13
			7	22.1	0.2	14	1,709	47	14
			8	23.3	0.2	4	2,034	72	4
			9	23.3	-	1	2,041	-	1
	WALLEYE	U	1	6.7	0.2	26	55	7	8
			2	10.3	0.2	43	185	13	32
			3	14.5	0.2	43	480	26	42
			4	17.8	0.2	27	896	46	26
			5	20.6	0.3	13	1,424	54	13
			6	21.9	0.6	4	1,864	192	4

Year	Species	Sex	Age	Mean length (in.)	Std err	N	Mean weight (g)	Std err	N
1989	NORTHERN PIKE	F	1	-	-	0	-	-	0
			2	18.1	0.3	27	643	42	22
			3	21.4	0.3	45	1,070	48	40
			4	24.7	0.3	16	1,657	97	11
			5	26.6	0.3	18	2,240	129	13
			6	30.0	0.4	34	2,950	146	27
			7	31.7	0.5	16	3,758	282	10
			8	35.1	0.6	15	5,084	284	12
			9	37.3	0.5	6	5,732	852	3
			10	40.2	1.5	4	6,933	425	3
	NORTHERN PIKE	M	1	-	-	0	-	-	0
			2	14.8	0.3	62	339	20	62
			3	19.2	0.3	28	698	46	27
			4	21.5	0.3	20	973	44	18
			5	23.8	0.2	24	1,315	35	24
			7	25.7	0.3	13	1,636	66	13
			8	27.5	0.4	10	1,937	156	9
	NORTHERN PIKE	U	1	11.8	0.3	18	154	12	16
			2	17.0	0.3	38	487	33	37
			3	21.4	0.3	46	978	40	44
			4	23.8	0.5	9	1,273	90	9
			5	26.3	0.3	6	1,871	104	6
			7	30.8	1.4	3	2,893	343	3
			8	32.2	1.0	3	3,281	464	3
	HYBRID MUSKIE	U	3	26.0	0.8	3	1,720	139	3
			4	28.4	1.3	4	2,510	453	4
			5	33.2	-	1	3,802	-	1
			6	-	-	0	-	-	0
			7	-	-	0	-	-	0
			8	38.7	0.6	3	5,977	310	3
			9	45.7	-	1	9,988	-	1
	LARGEMOUTH BASS	U	1	5.4	0.2	4	37	8	2
			2	8.8	0.3	24	203	29	14
			3	10.9	0.3	32	380	35	29
			4	14.0	0.3	18	799	53	18
			5	15.3	0.4	12	1,113	77	10
			8	17.0	0.2	15	1,490	77	14
			7	18.0	0.2	7	1,909	68	6
			8	18.7	-	1	1,871	-	1
			9	20.4	-	1	2,608	-	1
	SMALLMOUTH BASS	U	2	8.2	-	1	122	-	1
			3	11.3	0.4	16	403	48	16
			4	13.5	0.5	10	772	98	9
			5	17.1	0.7	2	1,404	212	2
			6	18.4	0.3	2	1,999	184	2
			7	17.7	-	1	1,701	-	1
			9	18.7	-	1	2,098	-	1
	BLACK CRAPPIE	U	1	4.1	0.2	10	-	-	0
			2	6.9	0.1	23	-	-	0
			3	9.0	0.2	13	202	-	1
			4	10.3	0.2	18	339	30	9
			5	11.1	0.3	10	376	23	10
			8	11.4	1.0	3	469	80	3

Year	Species	Sex	Age	Mean length (in.)	Std err	N	Mean weight (g)	Std err	N
1989	WHITE CRAPPIE	U	1	-	-	0	-	-	0
			2	5.2	0.5	13	-	-	0
			3	8.0	0.2	8	-	-	0
			4	9.0	0.2	8	178	6	2
			5	10.7	0.1	2	280	-	1
			6	11.9	0.2	9	380	29	8
			7	13.7	-	1	709	-	1
	BLUEGILL	U	1	-	-	0	-	-	0
			2	5.1	0.2	26	-	-	0
			3	7.2	0.1	22	-	-	0
			4	8.3	0.1	4	-	-	0
			5	8.7	0.2	6	325	17	2
			8	9.4	0.2	9	322	12	7
			7	9.4	0.1	3	329	4	2

Table 6. Spring catch/fyke net/day of predators sampled in Lake Mendota, 1987-1989.

Year	Walleye	Northern pike	Largemouth bass	Smallmouth bass
1987	2.0	0.7	0.3	0.1
1988	4.5	2.3	0.3	0.1
1989	7.4	5.5	0.4	0.1

The largest smallmouth bass caught in fyke nets was 18 inches (Fig. 8). Population estimates of smallmouth bass could not be made so we cannot assess gear selectivity. Smallmouth bass CPE in fyke nets set in March and April was about one third of that for largemouth bass, yet creel survey and gill netting suggest that smallmouth bass are more abundant than largemouth. We need to investigate new methods to assess Mendota's smallmouth bass population; work in 1988 suggested that fyke netting in May could be an effective method for sampling smallmouth bass.

Largemouth bass up to 22 inches were sampled in fyke nets, but a greater proportion of the catch consisted of fish >16 inches in 1988 than in 1989 (Fig. 9). However, the abundance of largemouth >8 inches increased threefold in 1989, primarily due to recruitment of 8-10 inch bass, and this reduced the proportion of 16-inch and larger bass in the catch. Differences between estimated population size structure and that from fyke nets were not large and were inconsistent between years (Fig. 9). Also, the size structure of largemouth bass in fyke nets was similar to sizes in spring electrofishing in 1988 and 1989, as well as in 1987 (Johnson et al. 1991). From these three years it appears that either gear may provide an acceptable estimate of population size structure.

In order of decreasing overall CPE, yellow perch, bluegill, and black crappie, *Pomoxis nigromaculatus*, were the most abundant non-predator species in fyke nets. Average catch per net-day of each species over the entire netting period was greater in 1989 than in 1988.

A consistent temporal pattern in CPE of four important non-predator species occurred each year during 1987-1989. Yellow perch and white bass CPE increased through the netting period, while bluegill and black crappie CPE declined during the same period. Increases in yellow perch CPE are presumably due to the onset of spawning near the end of the normal predator netting period. The other three species spawn well after the end of fyke netting and thus pre-spawning behavior may not explain trends in CPE for these fishes. Coefficient of variation in non-predator CPE of the four most abundant species ranged from 37-156% in 1988 and 84-136% in 1989 (Table 7, 8). The highest CV observed each year was for yellow perch.

The size structure of non-predator species in spring fyke nets was far less variable than CPE, both among regions of the lake (Table 9) and through time (Table 8). The CV of mean and modal lengths among 10 regions of the lake in 1988 was 10% or less for two of the three most abundant non-predator species. As was the case in 1987, the modal length of black crappie was the most variable among regions of the lake, with a CV of 50% (Table 9). The CV's for mean and modal

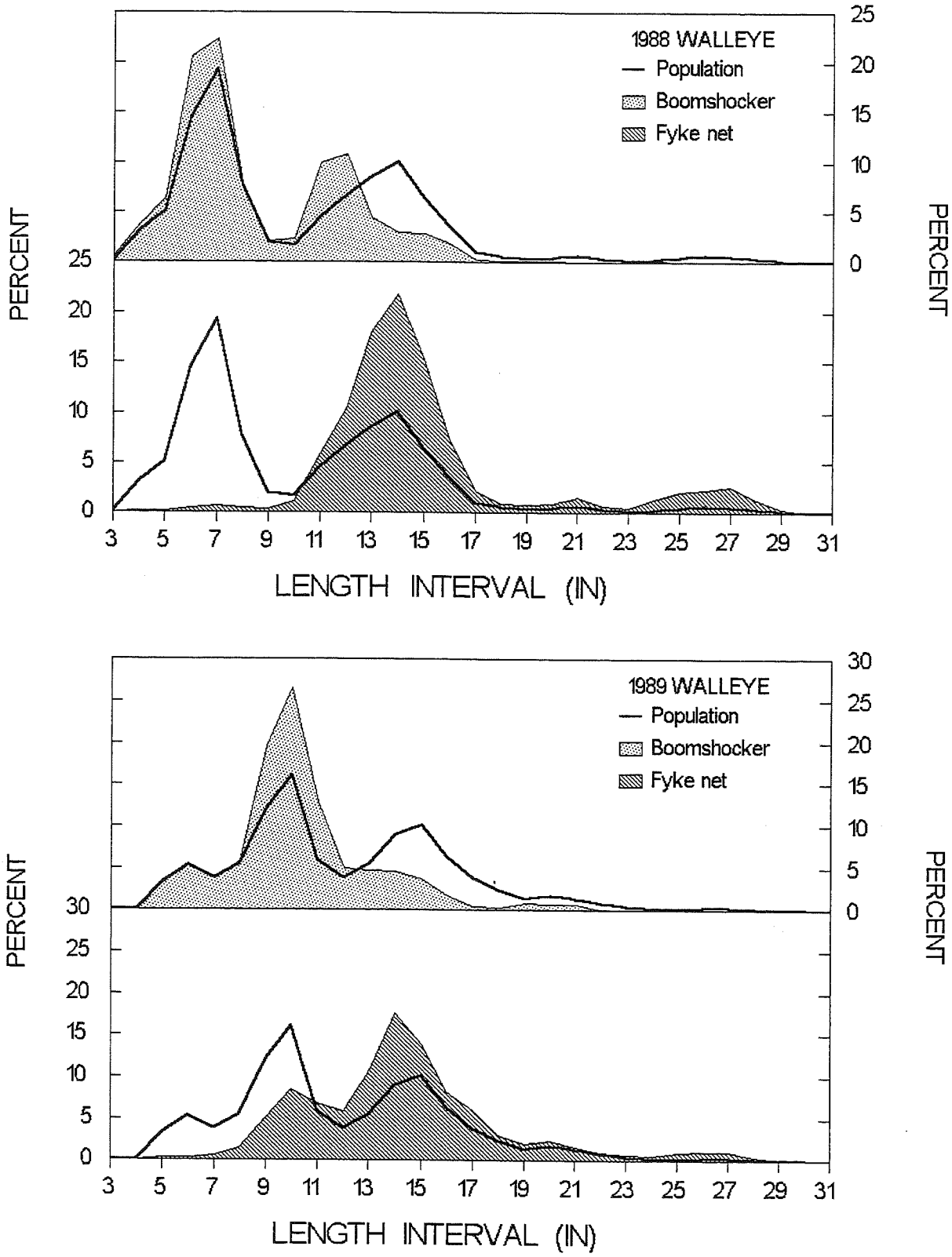


Figure 6. Length-frequency (percent) of the walleye population, estimated from mark-recapture experiments on five size classes (0.0-8.9, 9.0-10.9, 11.0-14.9, 15.0-23.9, and >24.0 inches) marked in fyke nets and spring electrofishing and recaptured in gill nets or shocking, and length-frequency of all walleyes sampled in fyke nets or electrofishing in Lake Mendota. Length-frequency in gear includes recaptures of previously marked fish.

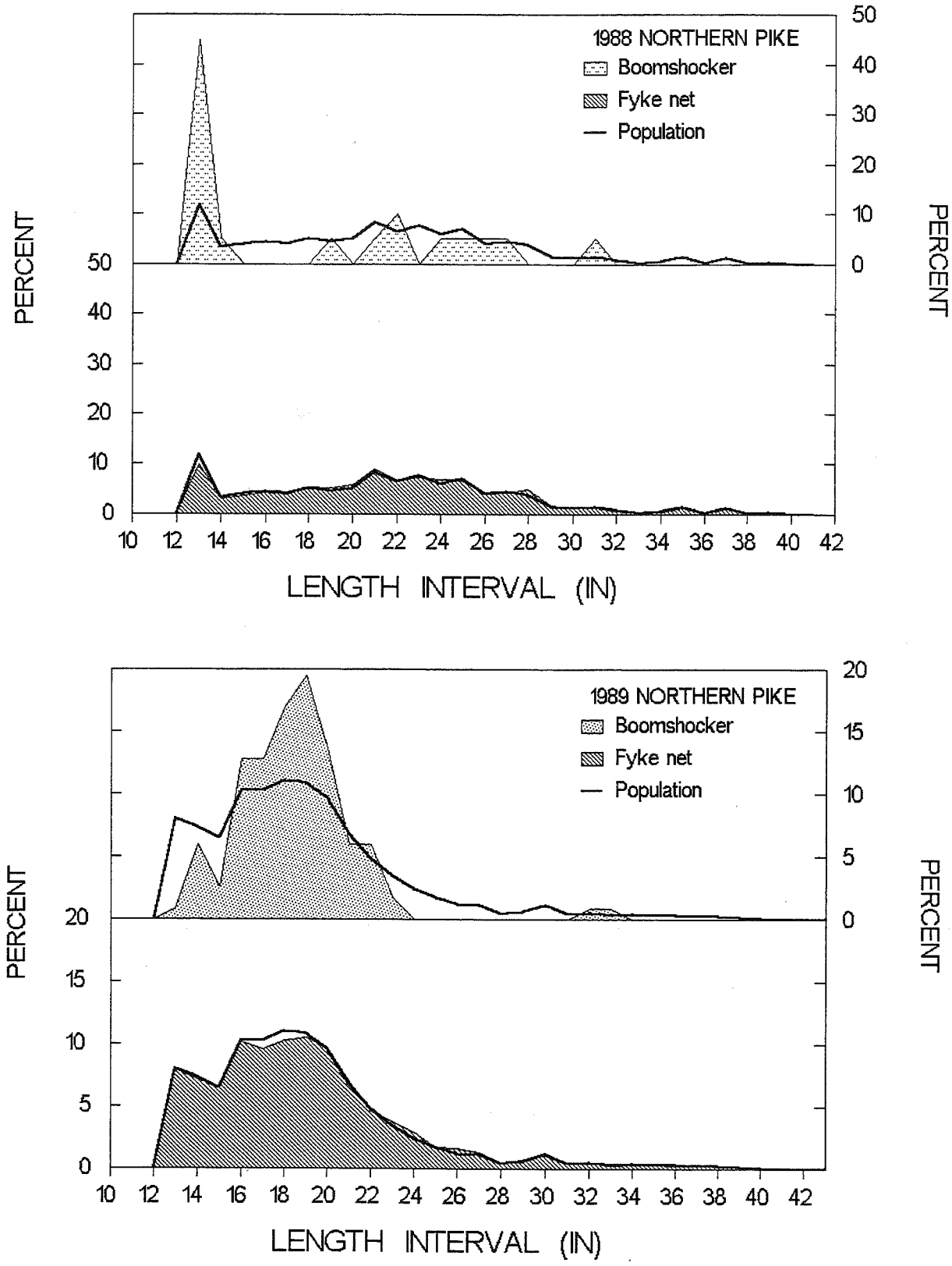
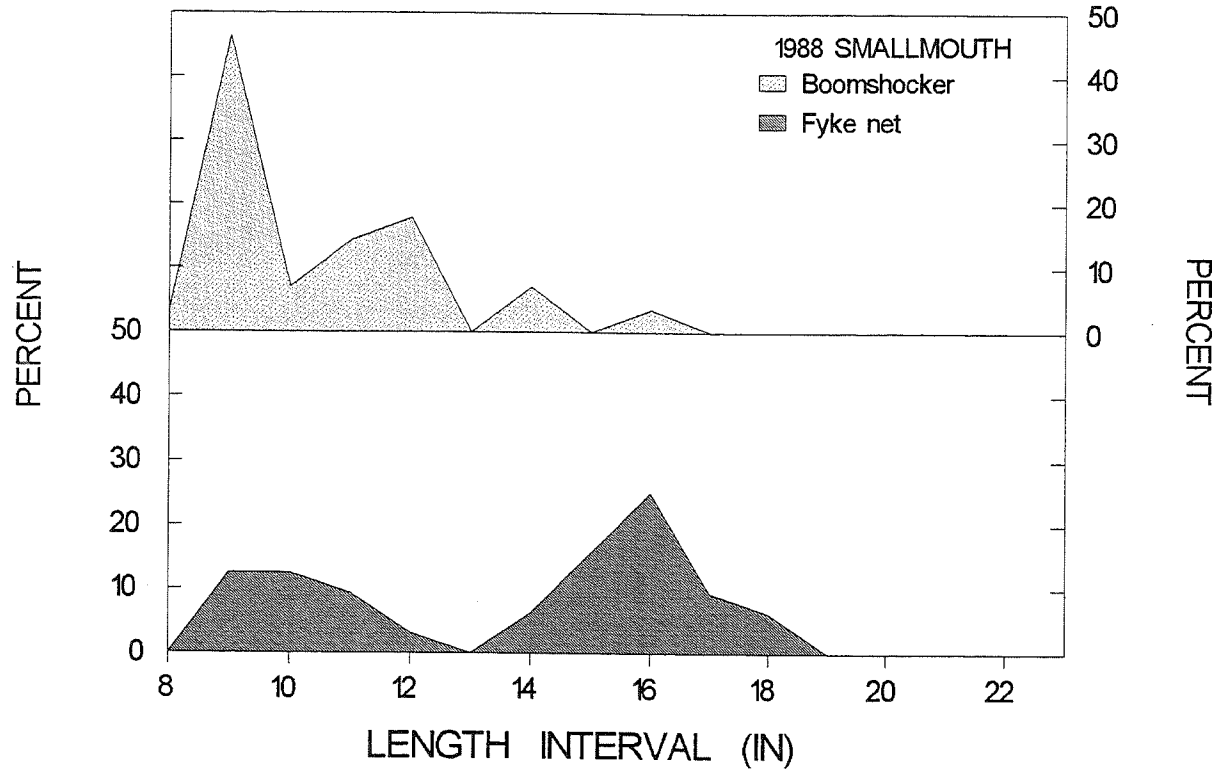


Figure 7. Length-frequency (percent) of the northern pike population, estimated from mark-recapture experiments on northern pike marked in fyke nets and recaptured during gill netting, and length-frequency of all northern pike at least 12.0 inches long, sampled in fyke nets or spring electrofishing in Lake Mendota. Length-frequency in gear includes recaptures of previously marked fish.



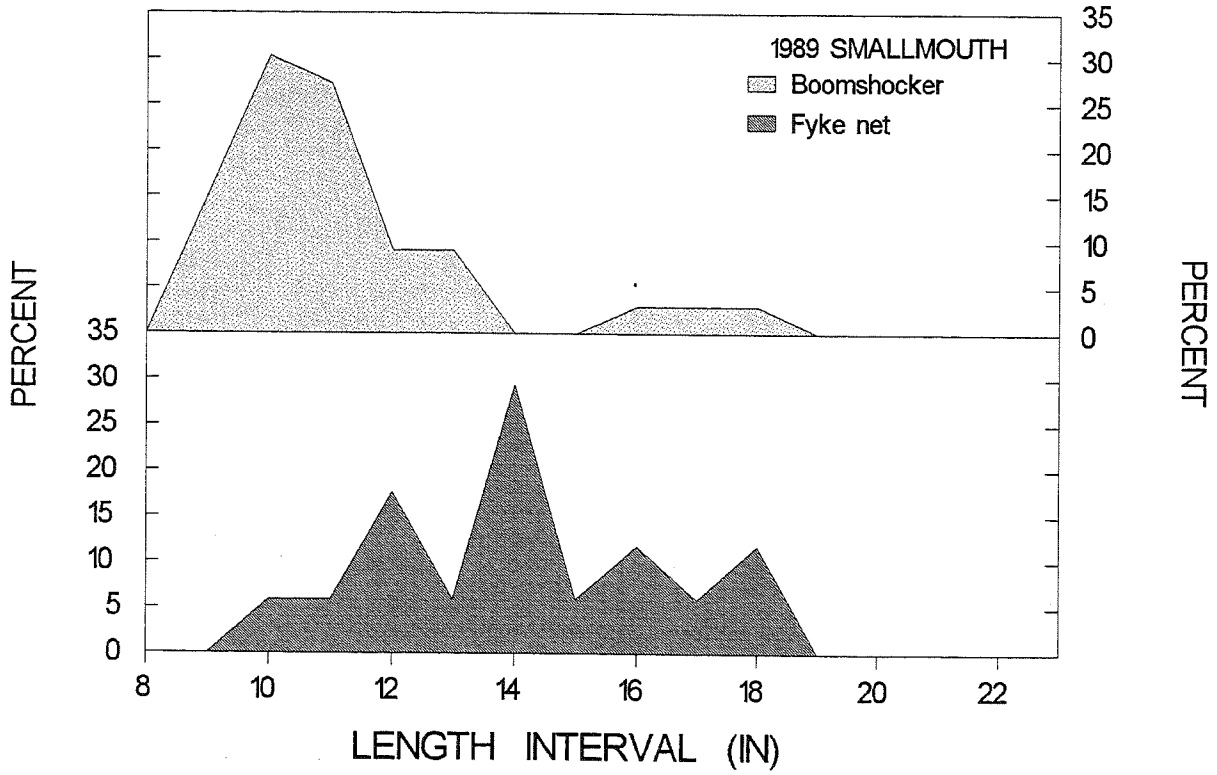


Figure 8. Length-frequency (percent) of the smallmouth bass sampled in fyke nets and spring electrofishing, including recaptures of fish previously marked in fyke nets, in Lake Mendota.

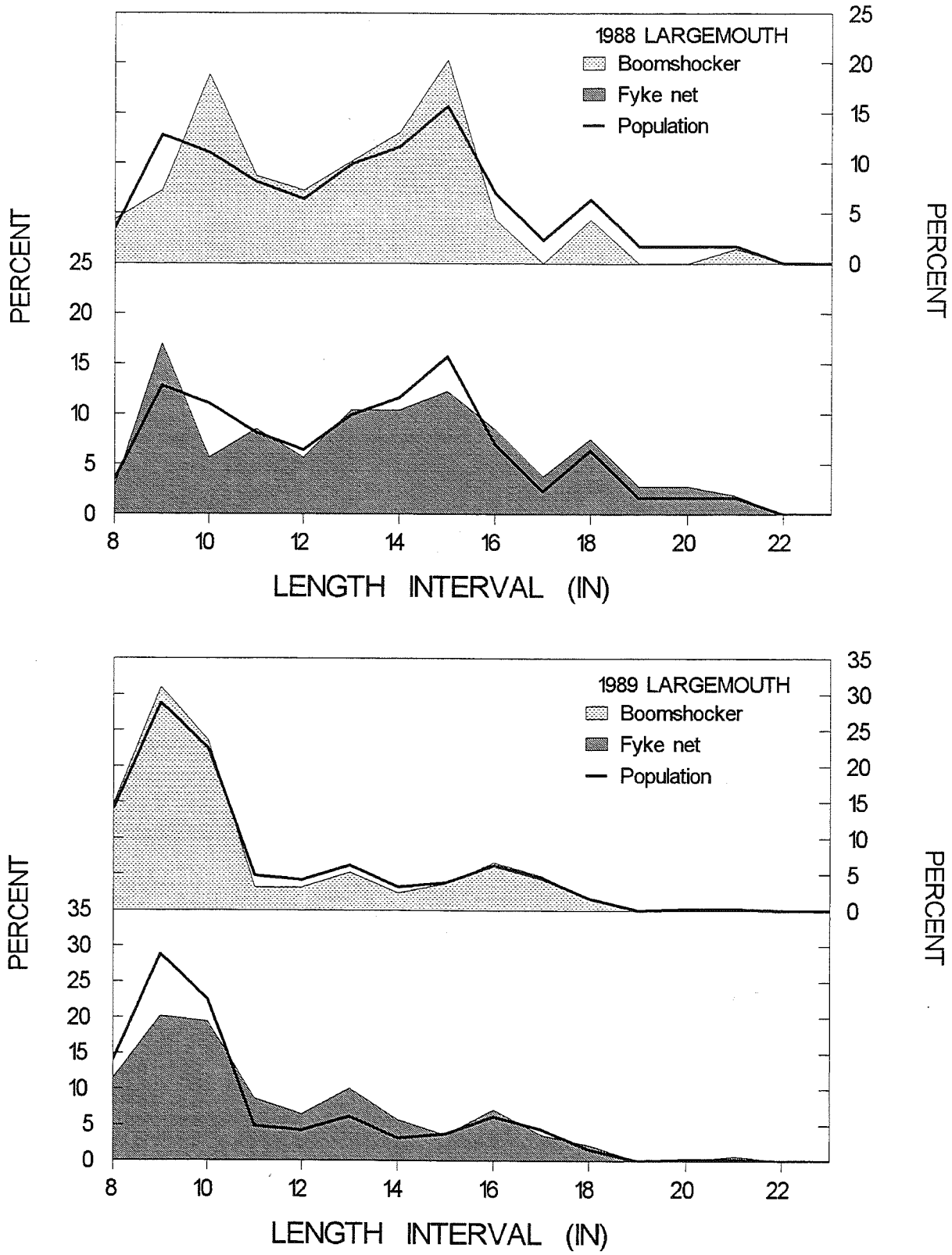


Figure 9. Length-frequency (percent) of the largemouth bass population, estimated from mark-recapture experiments with fish marked in fyke nets and spring electrofishing and recaptured during spring electrofishing, and length-frequency of all largemouth bass at least 8.0 inches long, sampled in fyke nets or spring electrofishing in Lake Mendota, including recaptures of previously marked fish.

Table 7. Total number of non-piscivore fish caught in fyke nets, number caught per net-day, and coefficient of variation (CV) in Lake Mendota, on three dates in 1988. Species are listed in descending order of abundance in fyke nets.

Species	Date	Total number	Net-days	Catch per net-day	Mean catch per net-day	CV (%)
PERCH	04/01/88	8	20	0.40		
	04/07/88	95	19	5.00	26.85	156.0
	04/14/88	977	13	75.15		
BGILL	04/01/88	667	20	33.35		
	04/07/88	347	19	18.26	22.08	45.0
	04/14/88	190	13	14.62		
BLCRP	04/01/88	248	20	12.40		
	04/07/88	182	19	9.58	9.20	37.1
	04/14/88	73	13	5.62		
BLBUL	04/01/88	39	20	1.95		
	04/07/88	152	19	8.00	4.01	86.2
	04/14/88	27	13	2.08		
YBULL	04/01/88	98	20	4.90		
	04/07/88	42	19	2.21	2.86	63.3
	04/14/88	19	13	1.46		
WHSUC	04/01/88	15	20	0.75		
	04/07/88	27	19	1.42	1.16	31.0
	04/14/88	17	13	1.31		
WBASS	04/01/88	9	20	0.45		
	04/07/88	7	19	0.37	1.07	106.9
	04/14/88	31	13	2.38		
WHCRP	04/01/88	31	20	1.55		
	04/07/88	14	19	0.74	0.99	48.6
	04/14/88	9	13	0.69		
BOWFN	04/01/88	32	20	1.60		
	04/07/88	13	19	0.68	0.92	65.9
	04/14/88	6	13	0.46		
FDRUM	04/01/88	14	20	0.70		
	04/07/88	15	19	0.79	0.57	52.3
	04/14/88	3	13	0.23		
PUMPK	04/01/88	16	20	0.80		
	04/07/88	12	19	0.63	0.58	43.2
	04/14/88	4	13	0.31		
GREEN	04/01/88	12	20	0.60		
	04/07/88	2	19	0.11	0.29	95.2
	04/14/88	2	13	0.15		

Species	Date	Total number	Net-days	Catch per net-day	Mean catch per net-day	CV (%)
YBASS	04/01/88	8	20	0.40		
	04/07/88	3	19	0.16	0.21	79.4
	04/14/88	1	13	0.08		
GSHIN	04/01/88	2	20	0.10		
	04/07/88	6	19	0.32	0.14	117.0
	04/14/88	0	13	0.00		
ROCKB	04/01/88	1	20	0.05		
	04/07/88	6	19	0.32	0.17	77.3
	04/14/88	2	13	0.15		
CCARP	04/01/88	3	20	0.15		
	04/07/88	1	19	0.05	0.12	48.3
	04/14/88	2	13	0.15		
CENTR	04/01/88	1	20	0.05		
	04/07/88	2	19	0.11	0.08	37.5
	04/14/88	1	13	0.08		
REDHO	04/01/88	0	20	0.00		
	04/07/88	1	19	0.05	0.02	173.2
	04/14/88	0	13	0.00		

Table 8. Number, catch per effort, and mean length of non-piscivore fish caught in six randomly selected fyke nets set for gamefish in Lake Mendota on four dates in 1989. Coefficient of variation (CV) is standard deviation/mean. Species are listed in descending order of abundance in fyke nets. Lengths are total length in inches. Modal lengths determined from length-frequency histograms with one-inch intervals.

Species	Date	Total number	Daily catch per net-day	Overall mean catch per net-day	CV (%)	Daily mean length	Overall mean length	CV (%)	Daily modal length	Mean modal length	CV (%)
BGILL	04/06/89	2269	378.2	170.4	83.56	6.2	6.0	7.50	5	4.8	10.5
	04/13/89	876	146.0			6.2			5		
	04/20/89	396	66.00			6.2			5		
	04/27/89	550	91.67			5.3			4		
PERCH	04/06/89	8	1.333	87.29	136.0	9.2	9.0	3.05	10	9.2	5.41
	04/13/89	33	5.500			9.0			9		
	04/20/89	523	87.17			9.2			9		
	04/27/89	1531	255.2			8.6			9		
BLCRP	04/06/89	583	97.17	33.88	124.7	6.8	7.1	6.69	6	6.2	8.00
	04/13/89	93	15.50			6.5			6		
	04/20/89	67	11.17			7.4			6		
	04/27/89	70	11.67			7.5			7		
PUMPK	04/06/89	57	9.500	4.222	113.3	4.9	4.8	1.46	4	-	-
	04/13/89	1	0.167			-			-		
	04/20/89	0	0.000			-			-		
	04/27/89	18	3.000			4.8			4		
WHCRP	04/06/89	12	2.000	1.125	60.93	8.1	9.9	19.2	9	9.3	16.4
	04/13/89	6	1.000			8.8			8		
	04/20/89	7	1.167			10.2			11		
	04/27/89	2	0.333			12.4			-		
WBASS	04/06/89	0	0.000	1.111	70.89	-	10.3	19.6	-	-	-
	04/13/89	3	0.500			8.0			-		
	04/20/89	5	0.833			11.5			11		
	04/27/89	12	2.000			11.6			11		

Table 9. Modal and mean lengths (inches) of the four most abundant non-piscivore species sampled in fyke nets in Lake Mendota during spring of 1988. Lake shoreline (including Cherokee Marsh) was divided into ten segments or regions. Region location is presented as shoreline mileage with 0.0 located at Tenney Locks. N is number of fish measured. Modal length was determined from length-frequency histograms with one-inch intervals. Dash signifies that fewer than 3 fish were caught in the region. CV is coefficient of variation.

	Yellow Perch				Bluegill				Black Crappie			
Region	Modal Length	Mean Length	Std. Error	N	Modal Length	Mean Length	Std. Error	N	Modal Length	Mean Length	Std. Error	N
0.0-4.6	8	8.8	0.10	21	5	5.2	0.22	9	9	8.8	1.00	7
7.2-7.6	8	8.5	0.16	10	5	5.8	0.19	30	-	6.7	1.09	9
9.2-9.5	8	8.6	0.22	8	5	5.8	0.11	112	8	8.2	0.24	92
12.8-13.8	-	-	-	-	4	5.2	0.16	42	5	6.1	0.31	33
16.1-17.8	8	8.7	0.18	3	-	-	-	-	3	-	-	-
18.9-19.6	8	8.6	0.15	21	5	6.3	0.16	91	3	4.8	0.51	21
20.8-21.2	-	-	-	-	4	6.3	0.25	46	3	5.3	0.52	31
23.9-26.4	8	8.1	0.09	89	5	5.7	0.11	87	4	6.9	0.24	87
MEAN	8.0	8.6			4.7	5.8			5.0	6.7		
STD. DEV.	0.00	0.24			0.49	0.45			2.5	1.45		
CV (%)	0.0	2.8			10.4	7.8			50.3	21.6		

length of these species were also 10% or less across the four dates sampled in 1989. Thus, spring fyke nets do provide a consistent estimate of non-predator size structure, which does not vary greatly either through time or by location.

The high temporal variation in average catch/net-day may preclude the use of spring fyke nets set for predators as an index of absolute non-predator abundance in Lake Mendota. However, average fyke net CPE of perch and bluegill in the spring do seem to be correlated with that year's summer angler catch (Table 10). No relationship between fyke net CPE and angler catch is apparent for white bass and black crappie. Although fyke nets tend to capture larger fish, they may sample the population available to anglers. Comparing mean lengths of non-predators in fyke nets to mean lengths observed during the creel survey (Table 10), we see that yellow perch size in fyke nets is within $\pm$ 0.5 inch of the size harvested by anglers. A somewhat poorer relationship exists for the other three species examined, with sizes in fyke nets consistently lower than the size of harvested bluegill and black crappie; there was no trend for white bass (Table 10).

Table 10. Total catch from May-October creel survey, mean spring fyke net catch per net-day, mean length of harvested fish, and mean length in spring fyke nets of four species of panfish in Lake Mendota during 1987-1989.

		Catch			Mean length (in.)		
Year	Species	Creel	Fyke nets	Creel/fyke catch	Creel	Fyke nets	difference
1987	PERCH	165,708	40.0	4,143	7.9	8.4	0.5
1988		72,044	26.9	2,678	8.5	8.6	0.1
1989		278,153	87.3	3,186	9.2	9.0	-0.2
1987	BGILL	27,788	8.9	3,122	7.4	6.8	-0.6
1988		38,625	22.1	1,748	7.2	5.8	-1.4
1989		261,017	170.4	1,532	7.1	6.0	-1.1
1987	WHBAS	49,946	4.5	11,099	10.1	11.4	1.3
1988		44,324	1.1	40,294	10.3	11.1	0.8
1989		49,023	1.1	44,566	11.2	10.3	-0.9
1987	BLCRP	21,166	5.2	4,070	9.2	8.2	-1.0
1988		11,856	9.2	1,289	9.6	6.7	-2.9
1989		26,656	33.9	786	8.7	7.1	-1.6

Electrofishing -- The spring electrofishing selected for small walleyes. This gear underestimated the relative abundance of walleyes >12 inches by about 100%, and almost no walleyes >20 inches were caught during spring electrofishing (Fig. 6). It appears that neither spring electrofishing nor fyke netting alone are adequate to estimate the size structure of the walleye population.

In spring 1988, the shocker caught roughly the same sizes of northern pike as did fyke netting, but only fyke netting caught pike >32 inches In 1989, it appeared that shocking was ineffective for pike >23 inches; however, it should be noted that the pike population in 1988 and especially in 1989 was largely composed of fish <30 inches so gear selectivity on larger size classes is difficult to evaluate.

Compared to the fyke net catch, the size distribution of smallmouth bass caught in spring electrofishing in 1988 and 1989 has a shape more like one would expect to see from a population with consistent recruitment (Fig. 8). Because we could not obtain population estimates for smallmouth bass, we cannot determine which gear provides the better estimate of population size structure.

Largemouth bass size structure in electroshocker samples was quite similar to that for the population and for the fyke net samples in 1988-1989 (Fig. 9), as well as in 1987 (Johnson et al. 1991). In 1988, it appears that shocking underestimated the abundance of largemouth bass >16 inches but not in 1989. Both fyke netting and spring electrofishing appear to provide acceptable estimates of population size structure.

In 1987, spring electrofishing was more efficient (in terms of worker-days/fish sampled) than fyke netting for sampling most tagging-sized predators. In 1988 and 1989, when fyke netting effort was half of 1987 effort and more productive netting sites were known, we found that fyke netting was the more efficient sampling method for walleye and northern pike. Spring electrofishing was 2-5 times more efficient than fyke netting for sampling largemouth and smallmouth bass.

We were interested in identifying consistent interseasonal differences in predator CPE that would indicate the most efficient time to sample these fishes. Obviously, comparisons of spring and autumn CPE, particularly of small size classes, are affected by recruitment and growth. Catch-per-effort of small predators was generally higher in autumn than spring, with the largest differences for largemouth bass and walleye. Catch-per-effort of tagging-sized walleye, largemouth bass, smallmouth bass and northern pike was higher in spring than in autumn shocking in 1987 and in 1989, but CPE of large walleye, largemouth bass, and pike was higher in the autumn than spring in 1988 (Table 11).

Catch per effort in autumn electrofishing has been used to estimate abundance of YOY predators, especially walleyes, in northern Wisconsin lakes (e.g., Serns Index, Serns 1983). We wanted to know if a similar index could be developed for predators in southern Wisconsin lakes. The critical test of the usefulness of CPE indices is to determine if our best estimate of autumn CPE is correlated with abundance of YOY predators. Several years of CPE data and population estimates will be required to test this correlation.

Catch per effort was calculated for small sizes of walleyes, smallmouth bass, largemouth bass, and northern pike (Table 12) sampled in spring and autumn electrofishing. Variability in CPE among all transacts and dates was high, but CPE was generally more variable in spring than in autumn. The smallest variation in CPE was found for walleye, with CV's ranging 43-77% (Table 12).

Water temperature was correlated with sampling date ($P<0.015$; positive correlation in spring and negative in autumn); however, there was no temporal trend in CPE of largemouth bass <10 inches or pike <14 inches (correlation; $P>0.05$). CPE of walleyes <13 inches was correlated with water temperature in autumn 1988 ($R=0.61$, $P=0.034$), and CPE of smallmouth bass <9 inches was correlated with water temperature in autumn 1989 ($R=0.59$, $P=0.028$).

We have relied heavily on spring and autumn electrofishing as a primary sampling method for predator diet data, CPE indices, and mark-recapture population estimates. We found no evidence of higher mortality in electroshocked fish than in fish sampled with fyke nets. Recapture rates of northern pike and walleye tagged by electrofishing were only slightly lower than rates for fish tagged in fyke nets (Table 13). Largemouth bass tagged during electrofishing actually had a higher recapture rate than those tagged in fyke nets (Table 13). Because of small sample size, these rates are for all sizes of fish. We know that each gear tends to sample different sizes of fish, which could bias the comparison of rates between gears. However, there does not appear to be a large difference in sampling gear related mortality between electrofishing and fyke netting.

Gill Netting -- The catch rate of walleyes in experimental gill nets set during June-August 1988 and 1989 should not be compared because sampling design differed between years. In 1988 we selected strata to sample randomly; however, sites within strata were not chosen randomly and not all strata were sampled each month. Data from 1989 provide more reliable insights into walleye abundance and depth/habitat distribution

Table 11. Spring (May 10-June 2, 1988, 36 worker-days; May 9-June 12, 1989, 36 worker-days) and fall (September 20-November 14, 1988, 39 worker-days; September 11-October 31, 1989; 42 worker-days) catch per effort of piscivores sampled during electrofishing on Lake Mendota. Length class is the range of total length (inches) and usually corresponds to length classes that were used in population estimates.

		Spring 1988			Fall 1988		
Species	Length Class	Number Caught	Number Per Mile	Number Per Hour	Number Caught	Number Per Mile	Number Per Hour
WALLE	0.0- 8.9	449	16.09	17.61	742	19.95	23.41
	9.0-14.9	241	8.64	9.45	614	16.51	19.37
	15.0-23.9	41	1.47	1.61	74	1.99	2.33
	24.0+	1	0.04	0.04	3	0.08	0.09
	ALL SIZES	732	26.24	28.71	1433	38.52	45.21
SMBAS	0.0- 8.9	121	4.34	4.74	98	2.63	3.09
	9.0-15.9	27	0.97	1.06	20	0.54	0.63
	16.0+	1	0.04	0.04	0	0.00	0.00
	ALL SIZES	149	5.34	5.84	118	3.17	3.72
LMBAS	0.0- 7.9	35	1.25	1.37	189	5.08	5.96
	8.0-15.9	60	2.15	2.35	167	4.49	5.27
	16.0+	9	0.32	0.35	14	0.38	0.44
	ALL SIZES	104	3.73	4.08	370	9.95	11.67
NPIKE	0.0-11.9	10	0.36	0.39	11	0.30	0.35
	12.0-23.9	23	0.82	0.90	86	2.31	2.71
	24.0+	5	0.18	0.20	8	0.22	0.25
	ALL SIZES	38	1.36	1.49	105	2.82	3.31
		Spring 1989			Fall 1989		
WALLE	0.0- 8.9	144	4.17	5.22	883	14.87	20.35
	9.0-14.9	632	18.32	22.90	1101	18.54	25.37
	15.0-23.9	74	2.14	2.68	88	1.48	2.03
	24.0+	0	0.00	0.00	2	0.03	0.05
	ALL SIZES	850	24.64	30.80	2074	34.92	47.79
SMBAS	0.0- 8.9	14	0.41	0.51	88	1.48	2.03
	9.0-15.9	30	0.87	1.09	41	0.69	0.94
	16.0+	3	0.09	0.11	1	0.02	0.02
	ALL SIZES	47	1.36	1.70	130	2.19	3.00
LMBAS	0.0- 7.9	30	0.87	1.09	236	3.97	5.44
	8.0-15.9	329	9.54	11.92	249	4.19	5.74
	16.0+	52	1.51	1.88	21	0.35	0.48
	ALL SIZES	411	11.91	14.89	506	8.52	11.66
NPIKE	0.0-11.9	3	0.09	0.11	23	0.39	0.53
	12.0-23.9	118	3.42	4.28	156	2.63	3.59
	24.0+	2	0.06	0.07	52	0.88	1.20
	ALL SIZES	123	3.57	4.46	231	3.89	5.32

Table 12. Mean and coefficient of variation (CV = [standard deviation/mean] *100%) of catch per mile of shoreline shocked (CPE) of walleye, smallmouth bass, and largemouth bass, and northern pike during spring and fall 1988, 1989 in Lake Mendota.

		Size	Spring			Fall		
Year	Spp	Interval (Inches)	Mean CPE	CV (%)	No. of Nights	Mean CPE	CV (%)	No. of Nights
1988	WALLE	0.0-8.9	14.7	49.0	12	19.5	53.3	13
	WALLE	9.0-12.9	6.1	71.8	12	14.2	45.9	13
	SMBAS	0.0-5.9	1.0	200.4	12	1.3	119.7	13
	SMBAS	6.0-9.9	3.6	122.4	12	1.5	118.5	13
	LMBAS	0.0-6.9	1.0	132.2	12	2.8	129.6	13
	LMBAS	7.0-9.9	0.3	204.8	12	4.3	149.0	13
	NPIKE	0.0-13.9	0.9	82.9	12	0.5	156.5	13
1989	WALLE	0.0-8.9	3.7	77.1	12	14.7	71.9	14
	WALLE	9.0-12.9	15.7	57.8	12	15.4	43.1	14
	SMBAS	0.0-5.9	0.1	244.2	11	0.6	106.4	14
	SMBAS	6.0-9.9	0.5	131.6	11	1.1	115.0	14
	LMBAS	0.0-6.9	0.6	174.6	11	3.1	80.5	13
	LMBAS	7.0-9.9	5.9	120.9	11	2.2	93.2	13
	NPIKE	0.0-13.9	0.3	212.1	11	0.4	145.4	14

Table 13. Recapture rate of gamefishes tagged in shocking or fyke netting during 1988. Individuals recaptured more than once were counted only once. The "1989 Recaps" is the number of fish that were recaptured in all 1989 Mendota fyke netting and boomshocking, that had been tagged in either shocking (Shock) or fyke netting (Net) in 1988. The "Recap rate" is the percent of fish tagged in each sampling gear in 1988 that were subsequently recaptured in shocking or fyke netting in 1989.

	Tagged in 1988		1989 Recaps of fish tagged in		Recap rate	
Species	Shock	Net	Shock	Net	Shock	Net
Northern pike	10	390	1	48	10%	12%
Hybrid muskie	1	10	0	0	0	0
Smallmouth bass	27	27	0	0	0	0
Largemouth bass	65	90	7	4	11	4
Walleye	195	1298	34	263	17	20
All	298	1815	42	315	14%	17%

because sites were chosen randomly, and all depth/habitat strata were sampled every month. Sampling in 1988 provided predator diet data, and attempted to determine if walleyes inhabited the pelagic regions of the lake, at least in August. The pelagic region of Lake Mendota is a vast area. About 64% of the surface area or 6,300 acres has water deeper than 30 ft However, no walleyes were captured in 4,875 ft of suspended gill net (Table 14). Because this pelagic sampling required about 85% of the total gill netting effort we had available, it prevented us from gathering critical information on predator diets, demersal distribution, and recaptures for population estimates. Thus, pelagic sampling was discontinued.

In 1989, total walleye CPE increased from 0.39 walleyes/100 ft in early June to 1.39/100 ft in August (Table 15), perhaps suggesting that developing anoxia may concentrate walleyes into a shallower, smaller volume of water, making them more readily sampled. June-August CPE of 11-18.9 inch walleye was highest

Table 14. Number of feet of experimental gillnet set, number of walleyes caught, and walleyes caught per 100 feet of gillnet per day, set in five sampling strata during June to August, 1988, in Lake Mendota. Nets were constructed of five panels each of 1.0-3.0, 2.5-4.5, or 4.0-8.0 inch stretch mesh. Only panels of 2.5-5.0 inch stretch mesh are included in the feet of net fished and walleye catch per 100 feet. During June and August nets were set perpendicular to the depth contour; in July nets were set parallel to the depth contour. Nets set in water less than 10 feet deep were 3.0 feet high; the other nets were 6.0 feet high.

			All walleyes		11.0-14.9 inches		15.0-18.9 inches		19.0-23.9 inches		> 23.9 inches	
Dates set	Depth	Feet of gillnet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet
June 26-30	reef	2,250	10	0.44	1	0.04	0	0.00	2	0.09	7	0.31
	6.0- 9.9	320	2	0.63	1	0.31	0	0.00	0	0.00	1	0.31
	10.0-29.9	3,250	84	2.58	35	1.08	34	1.05	5	0.15	10	0.31
	>30.0	3,125	2	0.06	0	0.00	0	0.00	0	0.00	2	0.06
	suspended	0	-	--	-	--	-	--	-	--	-	--
	ALL	8,945	98	1.10	37	0.41	34	0.38	7	0.08	20	0.22
July 18-22	reef	0	-	--	-	--	-	--	-	--	-	--
	6.0- 9.9	0	-	--	-	--	-	--	-	--	-	--
	10.0-29.9	8,625	31	0.36	8	0.09	15	0.17	7	0.08	1	0.01
	>30.0	375	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	suspended	0	-	--	-	--	-	--	0	--	-	--
	ALL	9,000	31	0.34	8	0.09	15	0.17	7	0.08	1	0.01
Aug. 15-19	reef	0	-	--	-	--	-	--	-	--	-	--
	6.0- 9.9	0	-	--	-	--	-	--	-	--	-	--
	10.0-29.9	875	13	1.49	3	0.34	6	0.69	0	0.00	4	0.46
	>30.0	0	-	--	-	--	-	--	-	--	-	--
	suspended	4,875	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	ALL	5,750	13	0.23	3	0.05	6	0.10	0	0.00	4	0.07
June-Aug.	reef	2,250	10	0.44	1	0.04	0	0.00	2	0.09	7	0.31
	6.0- 9.9	320	2	0.63	1	0.31	0	0.00	0	0.00	1	0.31
	10.0-29.9	12,750	128	1.00	46	0.36	55	0.43	12	0.09	15	0.12
	>30.0	3,500	2	0.06	0	0.00	0	0.00	0	0.00	2	0.06
	suspended	4,875	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	ALL	23,695	142	0.60	48	0.20	55	0.23	14	0.06	25	0.11

Table 15. Number of feet of experimental gillnet set, number of walleyes caught, and walleyes caught per 100 feet of gillnet per day, set in four sampling strata during June to August, 1989, in Lake Mendota. Nets were constructed of five 25-ft panels each of 2.5-4.5 inch stretch mesh. Nets set in water less than 10 feet deep were 3.0 feet high; the other nets were 6.0 feet high.

			All walleyes		11.0-14.9 inches		15.0-18.9 inches		19.0-23.9 inches		> 23.9 inches	
Dates set	Depth	Feet of gillnet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet	Number caught	Catch per 100 feet
June 5-8	reef	250	4	1.60	0	0.00	0	0.00	3	1.20	1	0.40
	6.0- 9.9	2,500	15	0.60	5	0.20	7	0.28	3	0.12	0	0.00
	10.0-29.9	1,625	10	0.62	0	0.00	7	0.43	2	0.12	1	0.06
	≥30.0	3,500	2	0.06	0	0.00	2	0.06	0	0.00	0	0.00
	ALL	7,875	31	0.39	5	0.06	16	0.20	8	0.10	2	0.03
June 26-29	reef	500	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	6.0- 9.9	2,875	32	1.11	12	0.42	13	0.45	6	0.21	1	0.03
	10.0-29.9	3,500	5	0.14	0	0.00	3	0.09	1	0.03	1	0.03
	≥30.0	2,000	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	ALL	8,875	37	0.42	12	0.14	16	0.18	7	0.08	2	0.02
July 10-13	reef	500	2	0.40	0	0.00	0	0.00	1	0.20	1	0.20
	6.0- 9.9	3,125	30	0.96	7	0.22	16	0.51	7	0.22	0	0.00
	10.0-29.9	5,250	27	0.51	6	0.11	11	0.21	10	0.19	0	0.00
	≥30.0	250	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	ALL	9,125	59	0.65	13	0.14	27	0.30	18	0.20	1	0.01
Aug. 14-17	reef	500	5	1.00	0	0.00	0	0.00	3	0.60	2	0.40
	6.0- 9.9	2,750	56	2.04	19	0.69	22	0.80	15	0.55	0	0.00
	10.0-29.9	5,625	62	1.10	7	0.12	28	0.50	26	0.46	1	0.02
	≥30.0	0	-	--	-	--	-	--	-	--	-	--
	ALL	8.875	123	1.39	26	0.29	50	0.56	44	0.50	3	0.03
June-Aug.	reef	1,750	11	0.63	0	0.00	0	0.00	7	0.40	4	0.23
	6.0- 9.9	11,250	133	1.18	43	0.38	58	0.52	31	0.28	1	0.01
	10.0-29.9	16,000	104	0.65	13	0.08	49	0.31	39	0.24	3	0.02
	≥30.0	5,750	2	0.03	0	0.00	2	0.03	0	0.00	0	0.00
	ALL	34,750	250	0.72	56	0.16	109	0.31	77	0.22	8	0.02

in the 6-9.9 ft stratum (Table 15). CPE was highest for 15-18.9 inch walleyes (0.31/100 ft; Table 15) followed by 19-23.9 inch walleyes (0.22/100 ft) and 11-14.9 inch walleyes (0.16/100 ft)

The June-August CPE of 19 inch and larger walleyes was highest on reefs (Table 15). Given that reef sets tend to sample large walleyes, are difficult to locate, and that a gill net could conceivably capture a large portion of the fish inhabiting the reef, we suggest diverting some of the sampling effort from reefs to other strata.

Both gill netting, and radio telemetry performed by WDNR Fish Research (Fago 1991), suggest that it is unlikely that any substantial portion of the walleye population is pelagic during summer. Cumulative plots of all radio tracking locations also show walleyes inhabiting depths <30 ft (Fago 1991). During June-August, most of the walleyes in Mendota can be found in water shallower than 10 ft (Fig. 10). The population is most dispersed in early June, before hypolimnetic anoxia begins. After anoxia limits fish to depths above the thermocline, their exact depth distribution has little consequence for thermal histories and bioenergetics modeling because temperatures where >95% of the fish were found varied by less than one degree across depth strata in each period.

Northern pike depth distribution during summer was very similar to that of walleye, with a majority of the population found in the 0-10 ft stratum (Fig. 10). As with walleye, northern pike were dispersed over a greater range of depths in early June, when the largest segment of the population was found in 12-18 ft (Fig. 10).

Smallmouth and largemouth bass depth distributions were dissimilar. Largemouth bass inhabited shallower water than the pike and walleye, and smallmouth bass were found in deeper water than the other predators (Fig. 10). This deeper distribution

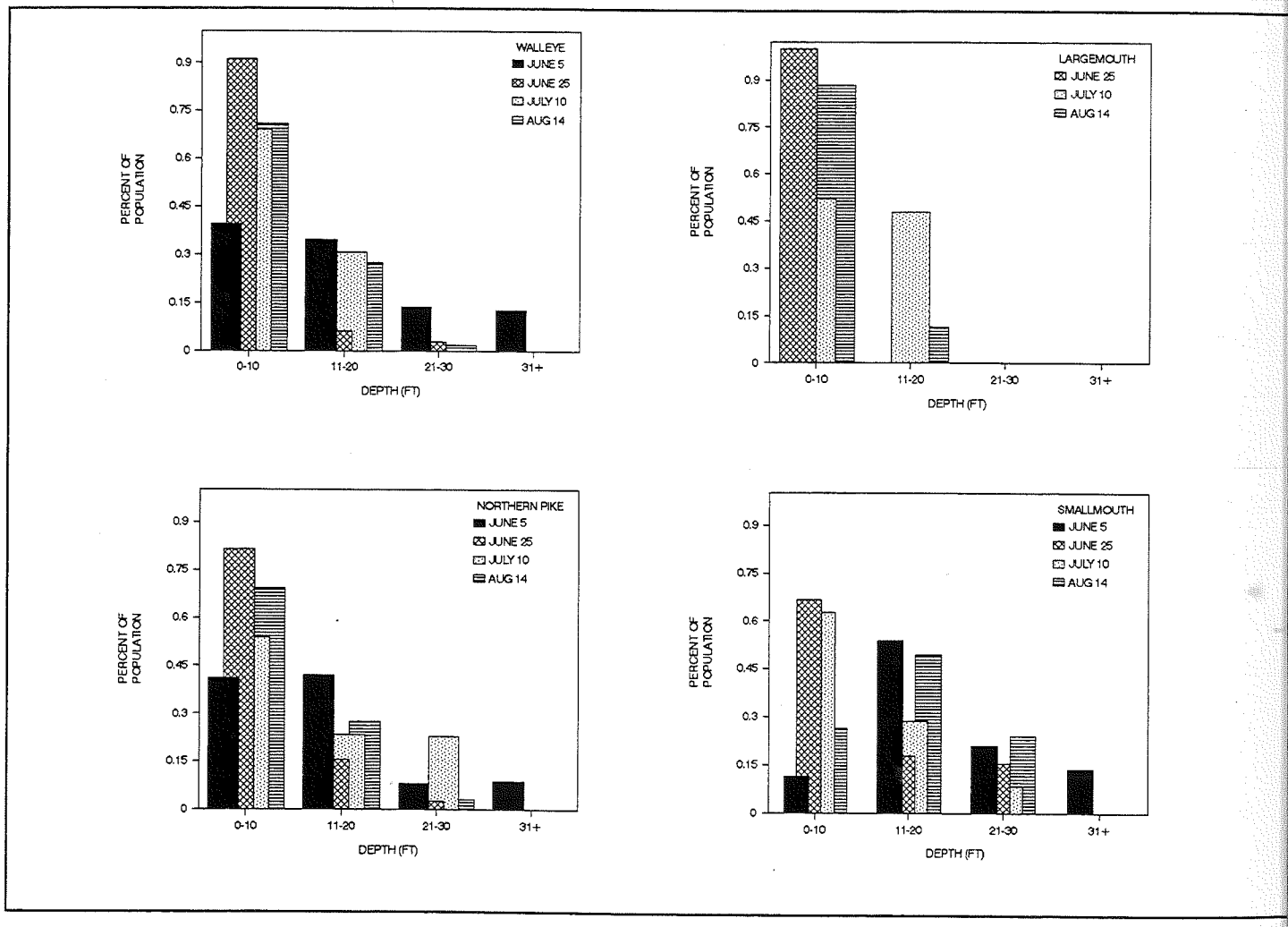


Figure 10. Average depth distribution of predators in Lake Mendota estimated from stratified-random gill net sampling during June-August 1989.

of smallmouth bass could explain the paucity of smallmouth bass in our fyke net and electrofishing sampling.

Tagging and Age Validation -- In 1988, we tagged a total of 2,105 predators. The majority of these fish were walleye (1,491), followed by 405 northern pike, 155 largemouth bass, and 54 smallmouth bass. Similar numbers of large- and smallmouth bass were tagged during fyke netting versus spring electrofishing. We tagged over 50% more predators in 1989 with a similar amount of sampling effort. Most of this increase resulted from a four fold increase in the catch of taggable northern pike (1,558 tagged). These fish were primarily from the 1987 year-class, when 23,000 large pike fingerlings were stocked. The number of walleyes tagged increased to 1,684. We tagged twice as many largemouth bass in 1989 (349) as in 1988, with about two thirds being tagged during electrofishing. Since 1987 we have tagged less than 100 smallmouth bass per year, and only 37 were tagged in 1989. Given these low numbers of tagged smallmouth bass it will be difficult to obtain enough recaptures to validate scale ages.

Average 1988-1989 tag loss rate after six months was highest for walleyes, and was 29 percent (Table 16). None of the nine largemouth bass we recaptured had lost tags. No marked smallmouth bass were recaptured, but only 181 smallmouth bass have been tagged during 1987-1989. Only four percent of 25 recaptured northern pike had lost tags after six months. The table below compares tag loss rate for the 3-inch long tags used in 1987 to tag loss rate for the new 1.8-inch tags used in 1988-1989.

The tag loss rate estimated for northern pike declined with each successive recapture period, which is an unexpected result. This could result from natural variability in the proportion of tagged and untagged (but fin clipped) fish in recapture samples or from unrecognizability of fin clips on fish that had lost tags. Given that pike are soft-rayed fish and they grow very fast, we suspect fin regeneration is causing this decline in estimated tag loss rate by making it difficult to recognize marked fish. Future recapture sampling must quantify the proportion of recaptured, tagged gamefish that have unrecognizable, regenerated finclips. This estimate, combined with tag loss rate, will allow us to expand the number of known recaptures to compute population estimates.

Removal of tags by anglers who caught and released fish was probably not a major source of tag loss. Although the proportion of tagged fish that were under the size limits ranged from 46% for walleye to 97% for northern pike, the number of angler tag returns from released fish has been low. Since 1987, we have received 336 tag returns from anglers and only about 8% (26 fish) of these were from released fish. There have been only 16 tag returns from northern pike that were caught and released. Assuming anglers send us a substantial portion of the tags they remove from released fish, it appears that tag removal by anglers is not contributing a great deal to our measured tag loss rates.

One of the primary functions of our tagging program, aside from its public relations value, is to provide a validation of our aging techniques. Recaptures of individual fish will allow us to compare observed growth increments with those predicted by scale and spine aging. We are developing a long-term database of recapture and scale age data to make this validation, but results are not available for this report.

Table 16. Average tag loss rate for Lake mendota predators with 3-inch and 1.8-inch tags after six months to two years.

	6 Months		1 Year		18 Months		2 Years
Species	3-in	1.8-in	3-in	1.8-in	3-in	1.8-in	3-in
Walleye	47	29	59	13	75	31	90
Largemouth bass	30	0	69	38	--	--	89
Northern pike	25	4	8	2	--	--	8
Smallmouth bass	--	--	100	--	--	--	--

Tag loss rate in 1988 and 1989 was lower than in 1987 when the larger Floy tags were used. After 18 months, tag loss of the shorter tags was less than half of rate estimated for the 3-inch tags. After 2 years about 90% of the recaptured walleyes and largemouth bass had lost 3-inch tags. While we believe tag loss rate is higher with 3-inch tags, we should note that 3-inch tags were only used in the first year of tagging and our tagging technique improved in subsequent years.

Mini-fyke Netting and Seining -- Ranking the relative abundance of non-predator species in mini-fyke net samples, we found that the top four or five ranks consisted of centrarchid species in July-September 1988, but only the top two ranks in 1989. Bluegills were the most abundant species in four out of the five

monthly mini-fyke net samples taken during 1988-89 (Table 17, 18). YOY crappies were the most numerous fish in July 1988, when bluegills were not the dominant species in the sample (Table 17). Generally, more YOY bluegills and YOY crappies were sampled in 1988 than in 1989, and more YOY yellow perch were sampled in 1989 compared with 1988. The catch in mini-fyke nets set in Cherokee Lake in September 1988 were similar to Mendota catches with bluegill and black crappie as the dominant species (Table 19). However, white crappie, *Pomoxis annularis*, white bass, and golden shiner, *Notemigonus crysoleucas*, were sampled in Cherokee Lake but not in Mendota. No YOY walleye or northern pike were caught in Cherokee Lake, and we caught only one largemouth bass there. We do not feel future sampling with mini-fyke nets in Cherokee Lake is justified because this area does not appear to be an important predator nursery area, and non-predator catches were similar to the catch in Mendota.

Young-of-year (YOY) smallmouth and largemouth bass were more abundant in 1988 samples than in 1989, particularly in July. Young-of-year smallmouth were about twice as abundant as YOY largemouth bass in 1988; there were similar numbers of these species in 1989 samples. Young-of-year walleye were caught in all months in 1988, while no YOY walleye were sampled in 1989. Interestingly, fingerling walleye electrofishing CPE was higher in autumn 1988 than in 1989, suggesting that perhaps mini-fyke net CPE is indicative of fingerling walleye abundance. Comparison of mini-fyke CPE and autumn mark-recapture population estimates (computed in spring) will be a better test of this hypothesis. We were pleased that YOY northern pike showed up in our mini-fyke nets and in UW mini-fyke nets in summer, before any fingerlings had been stocked. This suggests that either some stocked pike fry survived, or that there was successful natural reproduction. Mini-fyke nets appear to be useful for assessing year class strength of bass and abundance of YOY walleye, and for evaluating fry survival and/or natural reproduction of pike before fingerlings are stocked in autumn.

We compared mini-fyke net catches with those of a beach seine used at the same sites on the same day to determine the best gear for sampling Mendota's littoral fish community. One might expect the beach seine to be more size-selective than mini-fyke nets because of the potential for gear avoidance; however, we found no consistent differences in mean length of fishes sampled in each gear. The number of species sampled by each gear was similar (Table 20), and both gears shared three of the top five ranked species in July and in August. However, there were large differences in CPE between mini-fyke nets and beach seine hauls made at the same site. For example, the top-ranked species in the seine in July was perch, and no perch were sampled by mini-fyke nets in July. In August, bluntnose minnows, *Pimephales promelas*, ranked third in the seine catch, and yet none were caught in mini-fyke nets. Three species in July (white bass, yellow perch, logperch, *Percina caprodes*) and three species in August (white bass, brook silverside, *Labidesthes sicculus*, and bluntnose minnow) were only caught in the seine. Seven species in July and four species in August were only sampled in mini-fyke nets.

Such differences in relative abundance are not totally unexpected given the typically high variability encountered when sampling small inshore fishes. Coefficients of variation of CPE were very high for both gears (200-300%), making inferences about relative abundance difficult. However, this sampling is still useful for monitoring size structure of potential prey for stocked predators, and for detecting order of magnitude differences in year-class-strength which are not uncommon for many of Mendota's fishes.

Comparing the utility of each gear, the seine can be used in a limited number of habitats, but the mini-fykes can easily be used in areas too densely vegetated or with too irregular a substrate for seining. Sampling efficiency is unknown for both gears so density estimates cannot be computed easily. The seine provides a snapshot of species occurrence and relative abundance whereas the mini-fyke nets can sample over a much longer period of time (about 24-h in our samples). Fish sampled with the seine could be used for diet analysis, but the diet of fish in mini-fyke nets could be biased if fish fed on prey trapped in the net. Because mini-fyke nets can be used in any littoral habitat, we will continue to use this method for assessing growth and year-class-strength of inshore fishes. If diet data are required, we can use the beach seine to obtain these samples.

Table 17. Catch (N), catch/net, and length of fish in mini fyke nets used at 23 sites on Lake Mendota during July through September, 1988. About half of the nets had mesh at the entrance to exclude turtles and large piscivores.

Sampling Period	Species	N	Catch per net	Total length (inches) Minimum	Maximum	Mean	Standard deviation
07/13/88-07/14/88	UNCRP	98	4.90	1.14	1.89	1.54	0.06
	SMBAS	86	4.30	1.38	2.24	1.72	0.18
	LMBAS	41	2.10	1.46	2.56	2.15	0.21
	BGILL	33	1.60	0.94	4.49	1.80	1.06
	WALLE	29	1.40	2.28	5.79	3.20	0.93
	BLUNT	12	0.60	2.01	2.56	2.26	0.17
	CCARP	10	0.50	1.34	2.44	1.81	0.32
	GREEN	6	0.50	2.60	4.80	3.11	0.85
	ROCKB	3	0.15	1.14	4.92	3.02	1.89
	NPIKE	2	0.10	5.56	6.30	5.93	0.53
	BLBUL	2	0.10	6.89	8.90	7.89	1.42
	PUMPK	2	0.10	3.82	6.85	5.33	2.14
	PERCH	1	0.05	2.17	2.17	2.17	----
	FDRUM	1	0.05	6.65	6.65	6.65	----
08/10/88-08/11/88	BGILL	3332	166.60	1.02	7.60	1.65	0.70
	BLCRP	63	3.15	1.77	2.83	2.23	0.21
	PUMPK	56	2.80	1.54	5.87	1.96	0.66
	GREEN	45	2.25	1.26	3.11	1.67	0.48
	SMBAS	28	1.40	2.24	3.46	2.90	0.33
	BLBUL	22	1.10	1.50	3.98	2.91	0.72
	CCARP	11	0.55	2.05	3.46	2.63	0.43
	BLUNT	8	0.40	2.05	2.72	2.32	0.23
	LMBAS	7	0.35	2.05	4.17	3.24	0.64
	WALLE	4	0.20	3.62	5.79	4.53	1.02
	ROCKB	2	0.10	3.23	4.25	3.74	0.72
	PERCH	1	0.05	2.80	2.80	2.80	----
	YBULL	1	0.05	3.03	3.03	3.03	----
	LNGAR	1	0.05	11.57	11.57	11.57	----
09/14/88-09/15/88	BGILL	104	5.20	1.30	7.05	2.44	1.28
	PUMPK	18	0.90	1.81	4.96	3.24	1.19
	ROCKB	15	0.75	2.09	8.74	4.84	2.18
	BLCRP	14	0.70	2.64	6.65	3.77	0.95
	BLUNT	12	0.60	2.17	2.91	2.36	0.22
	WALLE	10	0.50	3.78	14.80	8.25	3.89
	GREEN	6	0.30	1.38	5.35	3.12	1.48
	SMBAS	5	0.25	2.99	4.29	3.63	0.58
	YBULL	5	0.25	5.55	8.35	7.02	1.07
	CENTR	4	0.20	4.37	6.77	5.58	0.99
	LMBAS	2	0.10	4.25	7.56	5.91	2.34
	NPIKE	2	0.10	11.61	16.54	14.07	3.48
	WHSUC	2	0.10	14.02	20.47	17.24	4.57
	SILVR	1	0.05	3.11	3.11	3.11	----

Table 18. Catch (N), catch per net, and length* of fish sampled in mini fyke nets used at 20 sites around Lake Mendota during July and August, 1989. Five nets in July and all nets in September had 2" X 2" mesh at the entrance to the net to exclude turtles and large piscivores.

Sampling Period	Species	N	Catch per net	Total length (inches) Minimum	Maximum	Mean	Standard deviation
07/25/89-07/26/89	BGILL	471	23.55	0.91	6.77	2.11	1.06
	CENTR	228	11.40	0.59	1.06	0.82	0.10
	PUMPK	64	3.20	2.36	5.70	3.60	1.06
	CCARP	37	1.85	1.33	18.11	2.65	3.21
	ROCKB	34	1.70	0.98	8.31	5.26	2.05
	GREEN	23	1.15	2.17	6.65	3.45	1.29
	BLCRP	11	0.55	1.33	4.72	2.11	1.12
	WALLE	11	0.55	9.76	21.96	12.29	3.34
	BRBUL	11	0.28	1.57	9.44	7.25	2.88
	LMBAS	10	0.50	1.77	2.87	2.32	0.36
	BLBUL	8	0.40	1.81	8.90	5.36	2.62
	PERCH	7	0.35	1.96	2.64	2.31	0.20
	YBULL	7	0.35	7.32	11.89	9.20	1.43
	SMBAS	7	0.35	1.73	7.64	2.76	2.15
	BLUNT	5	0.25	2.17	2.71	2.42	0.20
	GSHIN	3	0.15	2.01	2.56	2.20	0.31
	LOGPR	2	0.10	2.05	2.05	2.05	--
	LNGAR	2	0.10	4.72	18.62	11.67	9.83
	NPIKE	2	0.10	16.61	21.81	19.21	3.67
	WBASS	1	0.05	11.45	11.45	11.45	--
	UNCRP	1	0.05	1.45	1.45	1.45	--
	IODAR	1	0.05	2.08	2.08	2.08	--
08/22/89-08/23/89	BGILL	4993	249.65	0.98	8.27	1.65	0.76
	PUMPK	87	4.35	1.30	6.65	2.23	1.38
	PERCH	30	1.50	2.56	8.07	3.02	0.98
	ROCKB	14	0.70	1.81	7.80	5.25	2.06
	SMBAS	14	0.70	2.13	9.06	3.25	1.71
	GREEN	11	0.55	1.14	5.63	2.70	1.72
	BLUNT	9	0.45	2.24	3.22	2.57	0.33
	BRBUL	7	0.35	6.06	10.35	8.63	1.80
	BLCRP	7	0.35	2.01	2.64	2.36	0.22
	LMBAS	6	0.30	2.17	3.07	2.55	0.36
	YBULL	5	0.25	1.45	9.60	7.22	3.37
	WALLE	4	0.20	9.65	15.04	11.23	2.55
	BLBUL	4	0.20	2.36	8.27	6.67	2.88
	NPIKE	1	0.05	18.62	18.62	18.62	--

* Centrarchids less than 1.0 inches TL were not identified to species; mean lengths are of fish greater than or equal to 1.0 inches TL.

Table 19. Catch (N), catch per net, and length of fish sampled in mini fyke nets used at 10 sites in Cherokee Lake in September, 1988.

Sampling Period	Species	N	Catch per net	Total length (inches) Minimum	Maximum	Mean	Standard deviation
09/16/88	BGILL	507	50.70	1.46	7.36	2.78	1.05
	BLCRP	26	2.60	2.80	10.20	4.76	2.25
	YBULL	19	1.90	6.22	11.10	9.04	1.39
	WHCRP	12	1.20	3.11	10.71	8.13	2.29
	GREEN	12	1.20	1.38	6.02	3.57	1.45
	PUMPK	10	1.00	2.20	5.35	3.96	1.03
	CENTR	7	0.70	5.16	6.73	6.02	0.66
	WALLE	3	0.30	8.86	15.04	11.18	3.36
	WHSUC	3	0.30	14.57	16.65	15.72	1.06
	BLBUL	3	0.30	2.44	9.76	7.22	4.14
	LMBAS	1	0.10	4.17	4.17	4.17	----
	WBASS	1	0.10	11.61	11.61	11.61	----
	GSHIN	1	0.10	2.87	2.87	2.87	----

Table 20. Comparison of catch-per-effort (CPE) and mean length (inches) of fish sampled in mini fyke nets and a 25-ft bag seine at 10 sites on Lake Mendota, in July and August, 1989. Mini fyke net CPE is catch per net-day; seine CPE is catch per 100 square feet sampled. CPE at each site was averaged to obtain mean CPE. Mean lengths are the average of all fish caught at all sites. Std. dev. is standard deviation.

Month	Species	Mini fyke nets No. fish	Mean CPE	N	Std. dev.	Seine No. fish	Mean CPE	N	Std. dev.	Mini fyke nets Mean Length	N	Std. dev.	Seine Mean Length	N	Std. dev.
July	BGILL	163	16.30	10	36.90	36	0.36	10	0.68	2.08	73	1.25	3.08	36	0.83
	CENTR	73	7.30	10	12.10	166	0.42	10	0.93	0.84	45	0.09	0.93	50	0.12
	ROCKB	18	1.80	10	2.53	1	0.01	10	0.02	4.69	18	2.22	1.26	1	--
	CCARP	15	1.50	10	2.95	0	0.00	10	--	2.94	15	4.21	--	0	--
	PUMPK	12	1.20	10	1.40	20	0.21	10	0.35	3.82	12	1.10	5.26	20	0.90
	WALLE	9	0.90	10	1.91	2	0.02	10	0.06	11.20	9	1.00	3.56	2	0.08
	GREEN	7	0.70	10	0.82	0	0.00	10	--	4.08	7	1.35	--	0	--
	SMBAS	5	0.50	10	0.71	4	0.05	10	0.10	1.98	5	0.18	5.39	4	2.28
	BLCRP	5	0.50	10	0.97	0	0.00	10	--	2.12	5	1.46	--	0	--
	LMBAS	4	0.40	10	0.52	3	0.02	10	0.06	2.43	4	0.32	2.45	3	0.14
	YBULL	3	0.40	10	0.84	0	0.00	10	--	9.58	4	1.89	--	0	--
	BLBUL	1	0.30	10	0.68	0	0.00	10	--	4.19	3	4.08	--	0	--
	LNGAR	1	0.10	10	0.32	0	0.00	10	--	4.72	1	--	--	0	--
	NPIKE	1	0.10	10	0.32	0	0.00	10	--	21.80	1	--	--	0	--
	BLUNT	1	0.10	10	0.32	5	0.05	10	0.10	2.32	1	--	2.02	5	0.10
	IODAR	1	0.10	10	0.32	14	0.13	10	0.41	2.09	1	--	1.25	14	0.14
	BRBUL	1	0.10	10	0.32	0	0.00	10	--	9.06	1	--	--	0	--
	WBASS	1	0.00	10	--	4	0.04	10	0.12	--	0	--	1.92	4	0.26
	PERCH	1	0.00	10	--	51	0.48	10	1.29	--	0	--	2.40	51	0.96
	LOGPR	1	0.00	10	--	14	0.20	10	0.21	--	0	--	2.06	19	0.44

Month	Species	Mini fyke nets				Seine				Mini fyke nets			Seine		
		No. fish	Mean CPE	N	Std. dev.	No. fish	Mean CPE	N	Std. dev.	Mean Length	N	Std. dev.	Mean Length	N	Std. dev.
August	BGILL	2197	219.7	10	477.1	144	0.33	10	0.54	1.62	183	0.65	1.53	67	0.73
	PUMPK	47	4.70	10	7.85	2	0.01	10	0.02	1.82	41	1.09	3.58	2	2.90
	ROCKB	11	1.10	10	1.45	1	0.003	10	0.01	4.88	11	2.15	1.73	1	--
	SMBAS	8	0.80	10	1.14	1	0.004	10	0.01	3.46	8	2.29	3.70	1	--
	LMBAS	6	0.60	10	1.58	5	0.01	10	0.04	2.54	6	0.37	2.84	5	0.74
	PERCH	6	0.60	10	1.07	13	0.06	10	0.11	3.05	6	0.25	3.12	13	0.75
	GREEN	4	0.40	10	0.70	0	0.00	10	--	2.78	4	1.98	--	0	--
	BLBUL	4	0.40	10	0.70	0	0.00	10	--	6.67	4	2.88	--	0	--
	BLCRP	3	0.30	10	0.68	1	0.003	10	0.01	2.16	3	0.16	2.24	1	--
	WALLE	3	0.20	10	0.63	0	0.00	10	--	12.70	2	3.34	--	0	--
	NPIKE	1	0.10	10	0.32	1	0.003	10	0.01	18.60	1	--	21.80	1	--
	YBULL	1	0.10	10	0.32	0	0.00	10	--	1.46	1	--	--	0	--
	BLUNT	0	0.00	10	--	11	0.04	10	0.08	--	0	--	2.50	11	0.36
	SILVR	0	0.00	10	--	2	0.01	10	0.02	--	0	--	2.32	2	0.11
	WBASS	0	0.00	10	--	1	0.004	10	0.01	--	0	--	2.44	1	--

* Centrarchids less than 1.0 inches long were not identified to species; thus, mean lengths are of fish greater than or equal to 1.0 inches long.

Predator diets -- Walleye diet data for 1988-1989 are presented in three size classes. The 0-12 inch size class corresponds to walleyes <age-2, 12-15 inches roughly corresponds to ages-2 and -3, and the larger than 15 inch size class was mainly walleyes older than age-4. The largest size class comprised those walleyes vulnerable to anglers. Small walleyes (Fig. 11) consumed mostly small littoral-zone fishes (minnows and darters) in spring of both years, when YOY fishes weren't available. They consumed YOY panfish (centrarchids and perichthyids) in summer 1988, when yellow perch recruitment was poor, and a combination of yellow perch and centrarchid panfish in summer 1989, when there was a moderate perch year class. In autumn of both 1988 and 1989, small walleyes ate mostly YOY panfish, but minnows and darters and silversides were also eaten, perhaps as appropriately sized YOY panfish became scarcer. In autumn 1989, about 20% of the diet of small walleyes was YOY yellow perch.

The diet of 12-15 inch walleyes in each season did not change between years (Fig. 11). Their diet in spring and summer was composed of yellow perch, panfish, and minnows and darters. In autumn the diet was composed mostly of panfish, but with about 15% yellow perch, and 15% YOY black bass. Large walleye diet (Fig. 11) was similar to that for 12-15 inch walleyes, but the larger walleyes consumed a greater proportion of yellow perch in most seasons and years. In 1988, when there appeared to be a large hatch of both black basses, *Micropterus sp.*, about half of the diet of large walleyes in the autumn was composed of basses. However, black bass did not appear in stomachs of large walleyes in 1989, as they did for 12-15 inch walleyes. Cannibalism by walleyes was rarely observed; about 2% of the diet of age-1 walleyes in spring 1989 (Fig. 11), and 5% of the diet of age-4 and older walleyes in summer 1989 (Fig. 11) consisted of young walleyes. However, total biomass of young walleye consumed by age-4 and older walleyes in 1989 was estimated to be about 300 kg, which is a large proportion of total age-0 and age-1 walleye biomass in 1989 (about 1,200 kg). Thus, cannibalism could be an important constraint on walleye recruitment to age-2.

Although we had fewer diet data in 1987 (181 stomachs analyzed), some general differences in walleye diet were apparent. In spring 1987, about 20% of the walleye diet was cisco. Cisco did not appear in walleye guts after spring 1987, presumably because the massive cisco summerkill of 1987 precluded any substantial cisco recruitment in 1988-1989. Perch year-class-strength was moderate in 1987, and about a third of the diet of all sizes of walleyes in that summer was yellow perch. The remainder was centrarchid panfish (about 60%) and minnows and

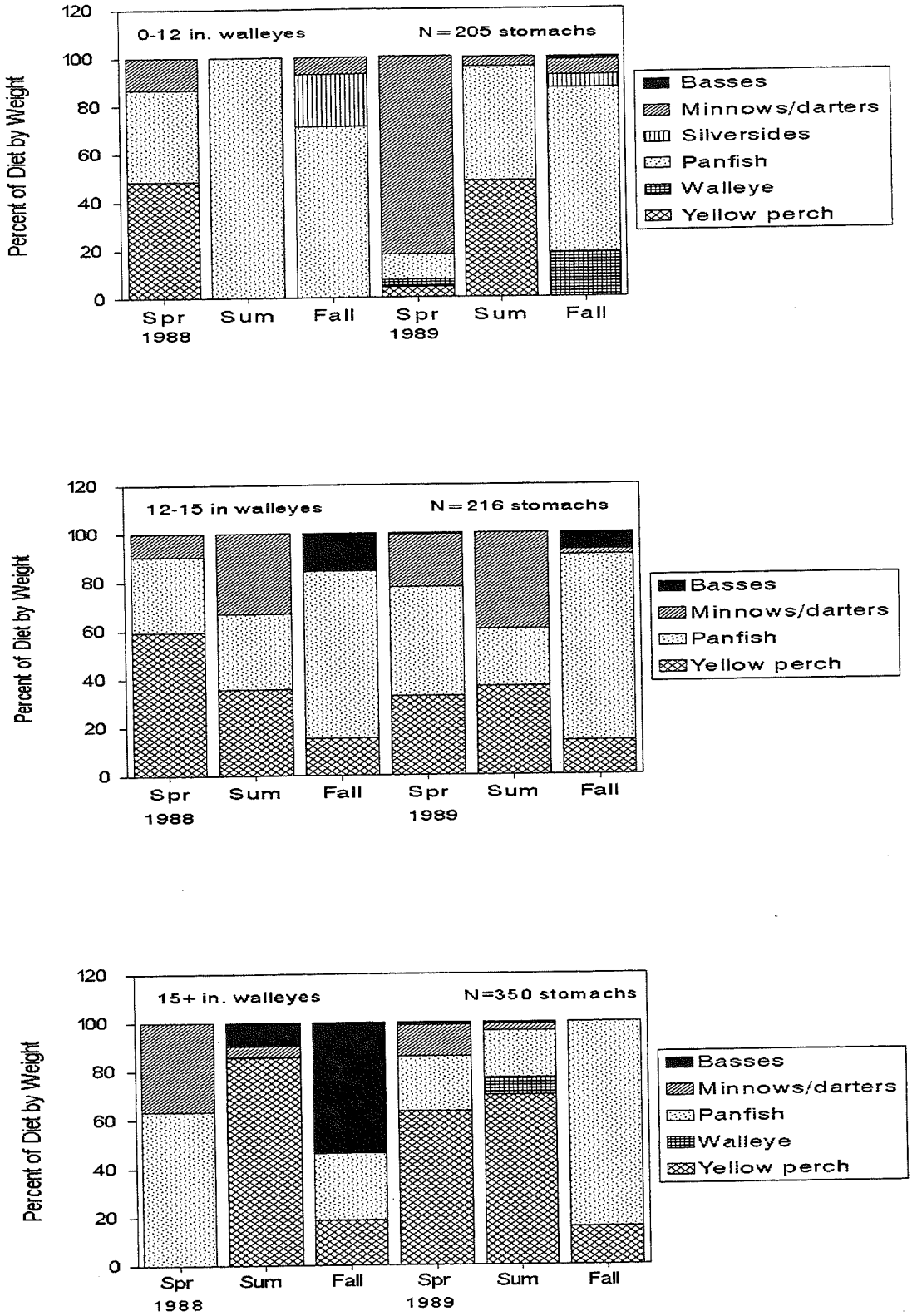


Figure 11. Proportion (by wet weight) of various prey species in the diet of three size classes of walleye in Lake Mendota in 1988, 1989. Stomach samples were obtained from electrofishing in spring and autumn, and gill netting in summer.

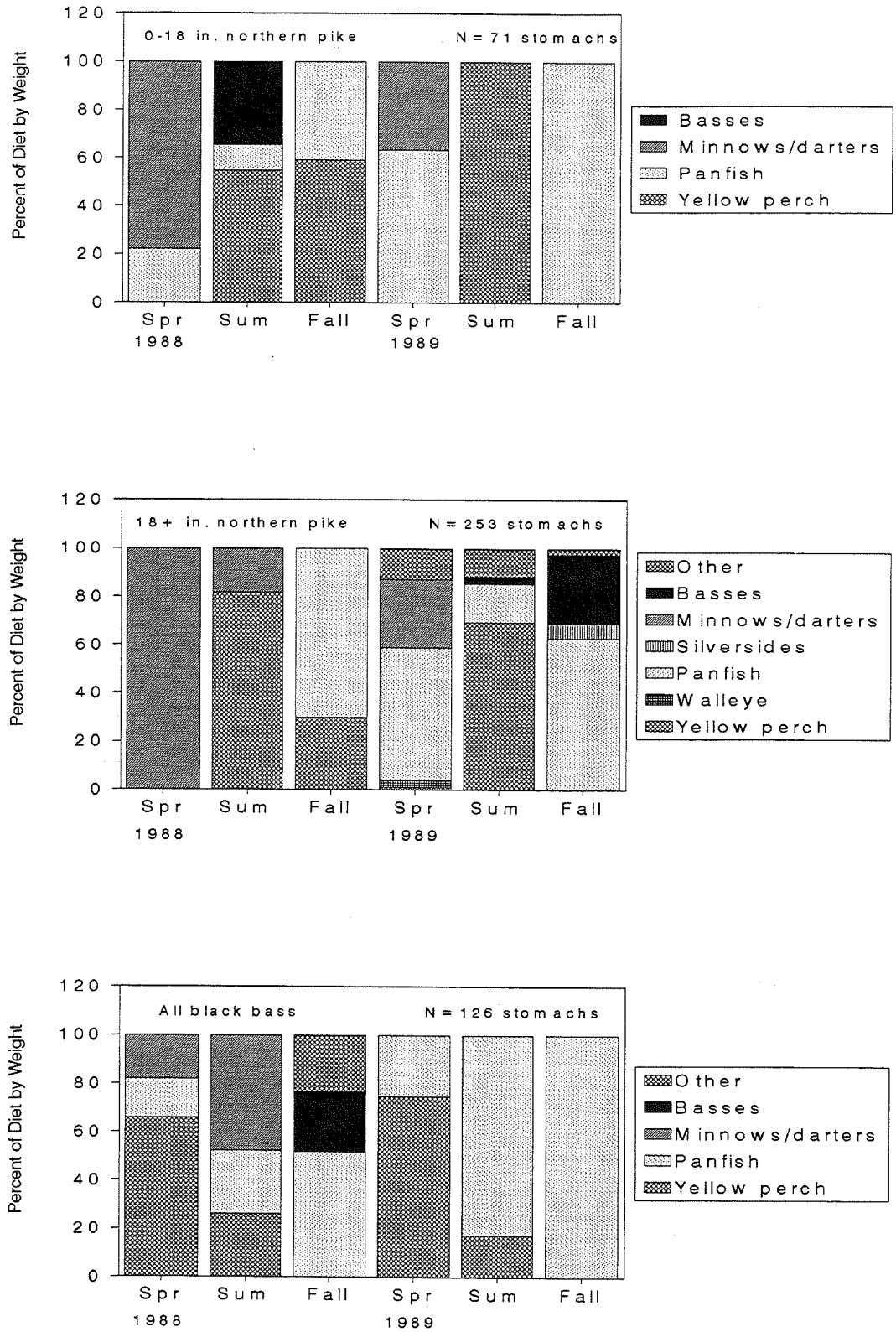


Figure 12. Proportion (by wet weight) of various prey species in the diet of two size classes of northern pike, and all largemouth and smallmouth bass (bottom panel) in Lake Mendota in 1988, 1989. Stomach samples were obtained from electrofishing in spring and autumn, and gill netting in summer.

darters (7%).

Northern pike and bass are probably gape-limited to a lesser degree than walleyes because predator gape is a function of total length. Because northern pike grow faster, a 2 year old pike is as long and thus can probably ingest the same size fish as a 5 year old walleye. Black basses, with a steeper gape:length relationship, should also show a different seasonal pattern of prey choice than the more gape-limited walleye. This suggests that pike and bass diets should be less dependent upon YOY fishes than are walleyes because they can consume a broader range of sizes of prey. In fact, small northern pike (0-18 inches, age-1) consumed more yellow perch (Fig. 12) than same-age walleyes, but pike also relied heavily on small littoral zone fishes in spring when YOY fish of larger species were absent. Age-2 and older pike (>18 inches; Fig. 12) had a similar diet to small pike, but large pike consumed more prey types including freshwater drum, *Aplodinotus grunniens*, bullheads, *Ameiurus sp.*, brook silversides, and walleye.

Recent pike diet differs from that observed in the earlier part of the century. During the spring-summer of 1915 and 1916, Mendota pike consumed 66% yellow perch, 17% largemouth bass, and 17% minnows (Pearse 1918). Thus, at this earlier time pike were consuming more yellow perch and no centrarchid panfish. This is not entirely surprising given that the prey community in Lake Mendota during the early part of the century was dominated by an abundant, slow growing yellow perch population (Pearse and Achtenburg 1920) and the minnow community was much more diverse (Lyons 1989).

Black basses (smallmouth and largemouth bass) consumed a higher proportion of yellow perch in spring than other predator species (Fig. 12). The proportion of yellow perch in their diet in summer was similar in 1988 and 1989, regardless of the different year class strengths of perch observed in the two years. Black basses did not consume any yellow perch in the autumn (Fig. 12), consuming a large proportion of panfish instead.

Creel survey

Walleyes comprised 39% and 48% of the total annual predator catch in 1988 and 1989 respectively (Table 21). Catch rates for anglers seeking walleye increased each year, with the largest increase among shore anglers. Shore anglers fishing for walleye caught 0.08/h in 1987 and in 1989 they caught 0.52/h. Improved walleye catch rates were probably due mostly to increases in the number of catchable-size walleyes (>8 inches) resulting from stocking by the Lake Mendota Fishing Association in 1985 and 1986, and by DNR since 1987.

As in 1987, walleye harvest at night continued to be only a small part of the total harvest, except during 1989 ice fishing when almost 80% (339 fish) of the walleyes harvested through the ice were taken by anglers interviewed between 11 p.m. and 7 a.m. (Table 22). In all periods since 1987, over 98% of the total fishing effort occurred between 7 a.m. and 11 p.m.(Table 22). Walleye catch rate was 2-24 times higher at night except during 1988 ice fishing and 1989 openwater fishing when day and night catch rates were similar (Table 22). Of course, one could argue that most of the fishing effort at night is directed at walleyes, thereby increasing catch rate based on unspecific (seeking any species) hours of effort. Regardless of the cause, the higher walleye catch rate at night is offset by low effort, resulting in low harvest.

Smallmouth bass ranked second in abundance in the predator catch and comprised 36 and 19% of the predators caught (Table 21). Smallmouth bass outnumbered largemouth bass in the catch by a factor of 3.4 in 1988 and 1.6 in 1989. Northern pike were the third most numerous predator in the creel, with 6,847 caught in 1988 and 18,723 caught in 1989 (Table 21).

The composition of the predator catch was the same in 1987 and 1981-1982 (in order of descending rank: walleye, smallmouth bass, largemouth bass, and northern pike; Johnson et al. 1991). Sporadic stocking during the previous 10 years probably kept walleye number one, while adequate natural reproduction of bass (with smallmouth more successful) and declining reproductive success of pike resulting from poor spawning conditions resulted in the relative ranks of these species during this period. However, the composition of the 1988 and 1989 predator catch changed. Northern pike became the third ranked species and largemouth bass were last. The number of largemouth bass caught actually increased since 1987, but the northern pike stocked in 1987 recruited to the fishery by late 1988 and replaced largemouth bass as the third ranked fish in the catch.

The total annual catch of each predator species except hybrid muskellunge has increased each year since 1987 (Table 21). This pattern is not explained by a simple increase in total fishing effort, since total effort was slightly lower in 1988 than in 1987 (Table 22). Although total fishing effort in 1989 was almost twice as high as that measured in 1987 (Table 22), much of this increase in 1989 could be due to the excellent perch fishing during January and most of the summer. There was a considerable redistribution of fishing effort directed at particular species since 1987.

Table 21. Total catch, harvest, and mean length of harvested fish (inches) estimated from an access point creel survey on Lake Mendota during two periods in 1988 and 1989.

	Winter 1988[A]			Summer 1988[B]			1988 Total	
Species	Catch	Harvest	Mean Length	Catch	Harvest	Mean Length	Catch	Harvest
Walleye	2,600	411	18.9	16,714	1,060	16.1	19,314	1,471
Smallmouth bass	0	0	-	17,916	2,041	11.8	17,916	2,041
Largemouth bass	97	97	11.8	5,217	527	11.9	5,314	624
Northern pike	547	95	34.5	6,300	0	-	6,847	95
Channel catfish	0	0	-	467	221	19.4	467	221
Hybrid muskie	95	0	-	66	36	-	161	36
Yellow perch	42,154	42,047	8.2	72,044	53,645	8.5	114,198	95,692
Bluegill	817	763	7.2	38,625	26,440	7.2	39,442	27,203
White bass	605	605	10.3	44,324	27,245	10.3	44,929	27,850
Black crappie	189	189	10.3	11,856	8,609	9.6	12,045	8,798
White crappie	0	0	-	3,039	2,478	10.4	3,039	2,478
Pumpkinseed	0	0	-	706	609	6.3	706	609
Rock bass	0	0	-	4,499	1,788	7.2	4,499	1,788
Yellow bass	0	0	-	0	0	-	0	0
	Winter 1989[C]			Summer 1989[D]			1989 Total	
Walleye	2,023	424	18.0	46,824	3,565	16.1	48,847	3,989
Smallmouth bass	86	0	-	19,519	594	13.6	19,605	594
Largemouth bass	0	0	-	11,912	628	14.0	11,912	628
Northern pike	1,360	0	-	17,363	203	30.5	18,723	203
Channel catfish	0	0	-	2,178	1,687	21.5	2,178	1,687
Hybrid muskie	0	0	-	183	0	-	183	0
Yellow perch	116,457	99,274	9.1	278,153	242,768	9.2	394,610	342,042
Bluegill	23,337	13,042	7.6	261,017	139,380	7.1	284,354	152,422
White bass	156	107	12.0	49,023	33,175	11.2	49,179	33,282
Black crappie	1,895	860	7.7	26,656	11,409	8.7	28,551	12,269
White crappie	184	99	-	7,439	4,654	8.3	7,623	4,753
Pumpkinseed	0	0	-	6,527	3,612	6.0	6,527	3,612
Rock bass	0	0	-	6,562	1,620	7.0	6,562	1,620
Yellow bass	0	0	-	0	0	-	0	0

[A]January 4 - February 29, 1988
[B]May 7 - October 31, 1988
[C]December 24 - March 1, 1989
[D]May 6 - October 31, 1989

Table 22. Creel survey estimates of fishing effort (angler hours), catch rate (walleyes/angler-hour), and harvest (number) of walleyes in Lake Mendota, during day (07:00-23:00 h) and night (23:00-07:00 h) in 1987-1989.

			Effort			Total Catch		Catch Rate		Harvest		
Year	Period	Unit of effort	Day	Night	Percent Night	Day	Night	Day	Night	Day	Night	Percent Night
1987	Jan-Feb	angler hrs	107,383	1,451	1.33	2,677	678	0.025	0.467	678	17	2.45
1987	May-Oct	all angler hrs	179,793	1,109	0.61	5,297	723	0.029	0.652	727	0	0.00
		boat hrs	159,076	1,007	0.63							
		shore hrs	20,717	102	0.49							
1988	Jan-Feb	angler hrs	72,751	566	0.78	2,582	18	0.035	0.032	411	0	0.00
1988	May-Oct	all angler hrs	198,409	1,543	0.77	16,479	235	0.083	0.152	1,010	50	4.72
		boat hrs	176,789	1,327	0.74							
		shore hrs	21,620	216	0.10							
1989	Dec-Mar	angler hrs	90,815	1,603	1.73	1,410	613	0.016	0.382	86	339	79.80
1989	May-Oct	all angler hrs	456,258	4,013	0.87	46,548	275	0.102	0.068	3,563	2	0.001
		boat hrs	410,768	3,618	0.87							
		shore hrs	45,490	395	0.86							

Table 23. Exploitation rates (derived from mark-recapture population estimates of abundance by age, and harvest by age from creel survey) of piscivores in Lake Mendota during 1987-1989. Estimates for largemouth bass and northern pike were not available for 1988. Estimates for smallmouth bass were not obtainable due to their invulnerability to our population assessment methods.

		Exploitation rate by age (%)						
Species	Year	I	II	III	IV	V	VI	VII+
Walleye	1987	0.6	10.2	22.0	27.5	20.0	23.5	22.5
Northern pike		0.0	12.3	19.8	23.9	41.6	52.0	54.4
Largemouth bass		---	0.0	12.6	16.5	27.6	12.2	0.0
Walleye	1988	0.0	0.7	6.3	31.7	36.0	49.7	14.8
Walleye	1989	0.0	6.2	13.4	50.9	57.2	69.7	37.1
Northern pike		0.0	0.0	0.0	0.0	3.8	16.7	22.1
Largemouth bass		---	17.8	8.5	44.8	49.1	35.0	53.1

For example, the hours that anglers fished specifically for walleyes doubled from 1987 to 1988 (51,364 vs. 103,142 h), and doubled again from 1988 to 1989, when anglers spent 204,908 h fishing for walleyes. While angling effort increased during 1987-1989, the residence of anglers remained relatively constant. At this time the Mendota fishery was composed of about 92% Dane County residents, 6% other Wisconsin residents, and about 2% out-of-state anglers.

Catch-and-release of predators was considerable. With minimum size limits in effect in 1988-1989, only about 8% of the walleye and 1.2% of the northern pike caught were harvested, compared to 20% and 54% respectively, before size limits on these fish in 1987. Although the frequency of catch-and-release in any given year is affected by the size structure of the population, a similar trend is evident for smallmouth and largemouth bass. In 1987 and 1988, before the statewide 14 inch minimum size limit, anglers kept between 11.4 and 19% of the bass they caught. In 1989, with the size limit in place, 3% of the smallmouth and 5% of the largemouth caught were kept. Average length of bass (smallmouth and largemouth combined) kept in 1988 was 11.8 inches, compared to 13.8 inches during 1989.

Despite the presence of minimum size limits for walleye and pike since 1988, and bass in 1989, increases in effort and catch resulted in increases in predator exploitation rates during 1987-1989 (Table 23). Northern pike are the exception in that exploitation rates were highest in 1987 before the 32-inch size limit. Exploitation was excessive (over 40%) on all pike age-5 and older in 1987 when the total abundance of pike was <0.2 fish/acre. This conflicts with the notion that sport fisheries are self-regulating. In Lake Mendota, it appears that sport fishing can continue to deplete stocks even when stocks are quite low. Walleye and largemouth bass exploitation rates on older age-classes were actually higher after size limits were enacted (Table 23), but size limits for these species were not as restrictive as the 32-inch pike size limit.

We believe the steady increase in the hours that anglers fished for walleye in Lake Mendota since 1987 was the result of at least two basic factors. First, the recent massive stocking of walleyes, in addition to special harvest regulations on walleye in Lake Mendota, probably attracted more walleye anglers to the fishery. Second, the widespread media coverage associated with this project, and the high visibility of this showcase project located within the State's capitol city have focused the attention of the public on this fishery, where walleyes are the dominant gamefish.

Although in principle a very effective strategy for garnering public support, the experience on Lake Mendota has demonstrated some potential pitfalls of showcase management. The response of anglers to actual or perceived improvements in a fishery appears to be rapid and intense. This suggests that managers must anticipate intensified pressure on a rehabilitated resource, and more restrictive harvest regulations may be required to keep pace with the user response, or efforts to improve a resource will result in its degradation.

Given that the average size of bass kept by anglers and shown to the creel clerk in 1989 was less than the minimum size limit, it is obvious that compliance with the regulation was incomplete. Estimated from the length-frequency in the creel survey, about 42% of the smallmouth bass, and 33% of the largemouth bass harvested were under the minimum size limit of 14 inches The average length of these sublegal bass was about 11.8 inches This lack of compliance with the bass size limit was not surprising, given that 1989 was the first year with any minimum size limit on bass.

The walleye and northern pike size limits have been in effect since January 1, 1988. During the 1988 fishing season, no undersized northern pike were observed in the creel. The total catch of pike was 6,847 fish, and the harvest was 95 fish. Based on the size structure of the pike population, we suspect many of the fish caught and released were from the 1987 stocking. These fish would have been about 14-16 inches long, and thus probably too small to be kept by anglers unaware of the size limit. About one fourth (254 fish) of the total walleye harvest was undersized fish. The average size of sublegal walleyes was 13.8 inches and the range was 12.4-14.4 inches We expected compliance with the walleye regulation to be better in 1989 than in the first year of the regulations. While no undersized walleye were observed during the 1989 ice fishing season, openwater anglers kept 392 undersized walleye, or 11% of the total openwater walleye harvest. Sublegal walleyes averaged 12.3 inches, and ranged from 11.4 to 14.5 inches Apparently compliance with the northern pike size limit was better, with only an estimated 68 undersized pike being kept out of a total of 18,723 pike caught during the entire 1989 fishing season. Undersized pike kept by anglers ranged from 28 to 30 inches

Unfortunately, the creel survey would underestimate true compliance because willful violators would not allow the creel clerk to measure their fish. With more undersized gamefish recruiting to the fishery in the next several years, and fishing effort increasing, we must improve compliance with these regulations if the our intensive management efforts are to be successful. We suggest that continued public education and enforcement is needed to improve compliance in the future.

As expected, anglers in 1988 and 1989 kept a much higher proportion (74% and 63% respectively) of the non-predator fish they caught. As was found in 1987 (Johnson et al. 1991), over 98% of the non-predators taken were yellow perch, white bass, bluegill, and black crappie. However, the relative frequency of each species shifted in 1989 such that bluegill became second in abundance and white bass became third. Apparently, a large year-class of bluegills recruited to the fishery by 1989, judging from the increase in harvest from about 30,000 fish/year in 1987 and 1988 to about 152,000 bluegills in 1989. Black crappie remained fourth in abundance in the harvest in all three years, and they comprised about 2-5% of the total in 1988-1989. The harvest of non-predators was dominated by yellow perch in 1988-1989, with yellow perch comprising about 60% of the total. Catch-per-effort in 1989 was about one non-predator per nonspecific hour of fishing which is similar to 1987. In 1988, the year following the cisco dieoff when large zooplankton were extremely abundant, CPE was about 0.6 fish/h.

The creel survey has demonstrated the importance of angling as a structuring force in the lake's food web. Estimates derived from the creel survey will be used to assess the influence of anglers as the true top carnivore in the lake's food web. The interplay between predator harvest and planktivore harvest will be instructive in an ecological sense as differing angling mortality schedules will affect food web dynamics. And in a management sense, potential impacts by anglers will suggest regulation strategies to maximize the effectiveness of the biomanipulation for improving water quality and providing desired population structure of predators and non-predators.

POPULATION ESTIMATES

We were able to calculate mark-recapture population estimates for six size classes of walleyes (Table 24, 25). Northern pike and largemouth bass population estimates were not broken into size classes (Table 26). As in 1987, we did not obtain enough recaptures of smallmouth bass in any gear to make an estimate. In 1988, we obtained a mark-recapture estimate of adult yellow perch. In 1988 walleyes $\geq$11.0 inches had the highest density of all predators, at about 1.7 fish/acre (Table 24), and adult largemouth bass were more abundant than northern pike (Table 26). In 1989, northern pike $\geq$13.0 inches had become the dominant predator numerically at 1.3 fish/acre (Table 26), while the number of walleyes $\geq$11.0 inches actually decreased to 1.1 fish/acre (Table 25), and largemouth bass $\geq$8.0 inches increased to 0.6 fish/acre (Table 26).

Because of the intensive and varied sampling required under this study, we had the opportunity to evaluate the accuracy of some commonly-used population sampling techniques. Validations were made of estimates using the last few days of fyke netting during the walleye spawning run for recaptures, autumn mark-recapture estimates of YOY walleye in a large lake, and inferring population size structure from size structure in sampling gear.

Walleye mark-recapture estimates using the last few days of the spawning run for recaptures were thought to be biased. Large female walleyes usually move onshore only to spawn and the smaller, male walleyes usually remain onshore during the entire spawning run (Colby et al. 1979). Given this tendency, an overestimate of large walleyes and an underestimate of small walleyes would be expected.

Presumably less-biased Petersen estimates using spring fyke netting and electrofishing for marking and summer gill nets for recaptures corroborated this prediction more strongly than in 1987. Estimates of 11.0-14.9 inch walleyes were 1.5-4.3 times higher when gill nets were used for recaptures (Table 24, 25). Estimates for 15.0-23.9 inch walleyes were 2.5-3.9 times higher using gill nets for recaptures versus the last week of fyke netting. Fyke net and gill net estimates of 24.0 inch and larger walleyes were similar, with fyke-net-only estimates 1.3-1.8 times higher (Table 24, 25). These estimates were not sex-specific because fish could not always be sexed in the recapture run, but males dominated the smaller size classes, and the 24.0-inch and greater size class was exclusively females. Estimates of 11.0-inch and larger walleyes using the creel survey (in 1988 and in 1989) to obtain the recapture sample were within 30% of estimates using gill nets for recaptures, but the number of recaptures was much lower using the creel survey, so gill net derived estimates are more precise (Table 24, 25).

Petersen population estimates of YOY walleye based on autumn electrofishing were lower than expected (Table 24, 25). Population estimates made in spring 1988 and 1989 using electrofishing to recapture fish marked the previous autumn showed that estimates based totally on autumn electrofishing may underestimate the actual population in Lake Mendota. Autumn-spring estimates of small walleyes were about twice as high as the number of YOY fish estimated in the previous autumn. Shoreline electrofishing was probably valid for shallow shoreline areas sampled by the electroshocker. However, total numbers in the lake would be underestimated if some fish remained in deeper water and did not mix with the population that was vulnerable to the electroshocker.

Table 24. Petersen (Chapman's modification) mark-recapture population estimates of walleyes in Lake Mendota during 1988. Confidence limits were computed from Ricker (1975; Appendix II). Number of fish marked in each size interval was corrected for growth in estimates using gillnets for recapture. "Last 8 d" refers to the use of the last 8 days of fyke netting as the recapture sample. Estimates in bold are what we consider the most accurate estimate of multiple estimates for each size class and period.

	MARKING RUN			RECAPTURE RUN					
Size class (inches)	Gear	Time period	Number Marked	Gear	Time Period	Examined for marks	No. of recaps	Modified Petersen estimate	95% Confidence Limits
0.0-8.9	**shocker**	**09/15/87-10/19/87**	**1,534**	**shocker**	**05/10/88-06/02/88**	**450**	**32**	**20,978**	**15,017-30,363**
0.0-8.9	shocker	05/10/88-05/18/88	240	shocker	05/23/88-06/02/88	177	2	14,299	5,231-35,748
0.0-10.9	**shocker**	**09/15/87-10/19/87**	**1,539**	**shocker**	**05/10/88-06/02/88**	**482**	**34**	**21,252**	**15,336-30,360**
0.0-10.9	shocker	05/10/88-05/24/88	274	shocker	05/26/88-06/02/88	169	2	15,583	5,701-38,958
11.0-14.9	fyke net	03/24/88-04/15/88	665	last 8 d	04/20/88-05/02/88	91	30	1,976	1,399-2,890
11.0-14.9	fyke net	03/24/88-05/02/88	722	shocker	05/10/88-06/02/88	208	15	9,444	5,857-16,075
11.0-14.9	**fyke net shocker**	**03/24/88-06/02/88**	**887**	**gill net**	**06/06/88 08/18/88**	**77**	**7**	**8,658**	**4,498-18,227**
15.0-18.9	fyke net	03/24/88-04/15/88	336	last 8 d	04/20/88-05/02/88	49	23	702	476-1,080
15.0-18.9	fyke net	03/24/88-05/02/88	355	shocker	05/10/88-06/02/88	39	7	1,780	925-3,747
15.0-18.9	fyke net	03/24/88-05/02/88-	355	shocker gill net	05/10/88-08/18/88	78	8	3,125	1,674-6,392
19.0-23.9	fyke net	03/24/88-04/15/88	49	last 8 d	04/20/88-05/02/88	24	3	312	128-781
15.0-23.9	**fyke net**	**03/24/88-05/02/88**	**422**	**shocker gill net**	**05/10/88-08/18/88**	**93**	**9**	**3,976**	**2,197-7,952**
24.0+	fyke net	03/24/88-04/15/88	127	last 8 d	04/20/88-05/02/88	31	3	1,024	418-2,560
24.0+	**fyke net shocker**	**03/24/88-06/02/88**	**153**	**gill net**	**06/06/88-08/18/88**	**24**	**4**	**770**	**344-1,925**
11.0+	fyke net shocker	03/24/88-06/02/88	1,491	gill net	06/06/88 08/18/88	153	13	16,412	9,861-29,084
11.0+	fyke net shocker	03/24/88-06/02/88	1,491	creel survey	06/01/88 10/31/88	38	4	11,638	5,195-29,094
0.0-8.9	shocker	09/20/88-10/20/88	625	shocker	10/25/88-11/14/88	69	3	10,955	4,471-27,388
9.0-10.9	shocker	09/20/88-10/20/88	384	shocker	10/25/88-11/14/88	26	2	3,465	1,268-8,662

Table 25. Petersen (Chapman's modification) mark-recapture population estimates of Lake Mendota walleyes in 1989. Confidence limits were computed from Ricker (1975; Appendix II). Number of fish marked in each size interval was corrected for growth in estimates using gillnets for recapture. "Last 7 d" refers to the use of the last 7 days of fyke netting as the recapture sample. Estimates in bold are what we consider the most accurate estimate of multiple estimates for each size class and period.

	MARKING RUN			RECAPTURE RUN					
Size class (inches)	Gear	Time period	Number Marked	Gear	Time Period	Examined for marks	No. of recaps	Modified Petersen estimate	95% Confidence Limits
0.0-8.9	**shocker**	**09/20/88-11/14/88**	**671**	**fyke net shocker**	**03/30/89-06/15/89**	**224**	**6**	**21,600**	**10,723-47,250**
0.0-8.9	fyke net shocker	03/30/89-05/23/89	128	shocker	05/25/89-06/15/89	78	2	3,397	1,243-8,492
9.0-10.9	**shocker**	**09/20/88-11/14/88**	**408**	**fyke net shocker**	**03/30/89-06/15/89**	**787**	**27**	**11,510**	**8,027-17,165**
9.0-10.9	fyke net shocker	03/30/89-05/25/89	691	shocker	05/31/89-06/15/89	37	4	5,259	2,348-13,148
11.0-14.9	fyke net	03/30/89-04/20/89	557	last 7 d	04/21/89-04/28/89	417	77	2,990	2,404-3,702
11.0-14.9	fyke net	03/30/89-04/28/89	854	shocker	05/09/89-06/01/89	241	26	7,663	5,147-11,006
11.0-14.9	**fyke net**	**03/30/89-04/20/89**	**854**	**gill net**	**06/06/89 08/17/89**	**89**	**16**	**4,526**	**2,850-7,544**
15.0-18.9	fyke net	03/30/89-04/20/89	462	last 7 d	04/21/89-04/28/89	258	70	1,682	1,342-2,133
15.0-18.9	**fyke net**	**03/30/89-04/28/89**	**592**	**shocker**	**05/09/89-06/01/89**	**55**	**8**	**3,690**	**1,977-7,547**
15.0-18.9	fyke net	03/30/89-04/20/89	592	gill net	06/06/89-08/17/89	92	12	4,242	2,507-7,660
19.0-23.9	fyke net	03/30-89-04/20/89	130	last 7 d	04/21/89-04/28/89	57	17	422	269-697
19.0-23.9	fyke net	03/30/89-04/28/89	162	shocker	05/09/89-06/01/89	19	3	815	333-2,038
19.0-23.9	**fyke net**	**03/30/89-04/20/89**	**162**	**gill net**	**06/06/89-08/17/89**	**63**	**9**	**1,043**	**576-2,086**
24.0+	fyke net	03/30/89-04/20/89	59	last 7 d	04/21/89-04/28/89	49	7	375	195-789
24.0+	**fyke net**	**03/30/89-04/20/89**	**89**	**gill net**	**06/06/89-08/17/89**	**6**	**2**	**210**	**77-525**
11.0+	fyke net	03/30/89-04/20/89	1,698	gill net	06/06/89 08/17/89	250	39	10,661	7,854-14,859
11.0+	fyke net	03/30/89-04/20/89	1,698	creel survey	05/06/89-10/31/89	70	8	13,403	7,180-27,416
0.0-8.9	shocker	09/11/89-10/18/89	753	shocker	10/24/89-10/31/89	84	4	12,818	5,722-32,045
9.0-10.9	shocker	09/11/89-10/24/89	301	shocker	10/31/89	21	4	1,329	593-3,322
11.0-12.9	shocker	09/11/89-10/24/89	469	shocker	10/31/89	41	12	1,518	897-2,742

Table 26. Mark-recapture population estimates of piscivores other than walleyes sampled in Lake Mendota during 1988 and 1989. Chapman's modification of the Petersen estimate was used. Confidence limits were computed using values from Ricker (1975; Appendix II).

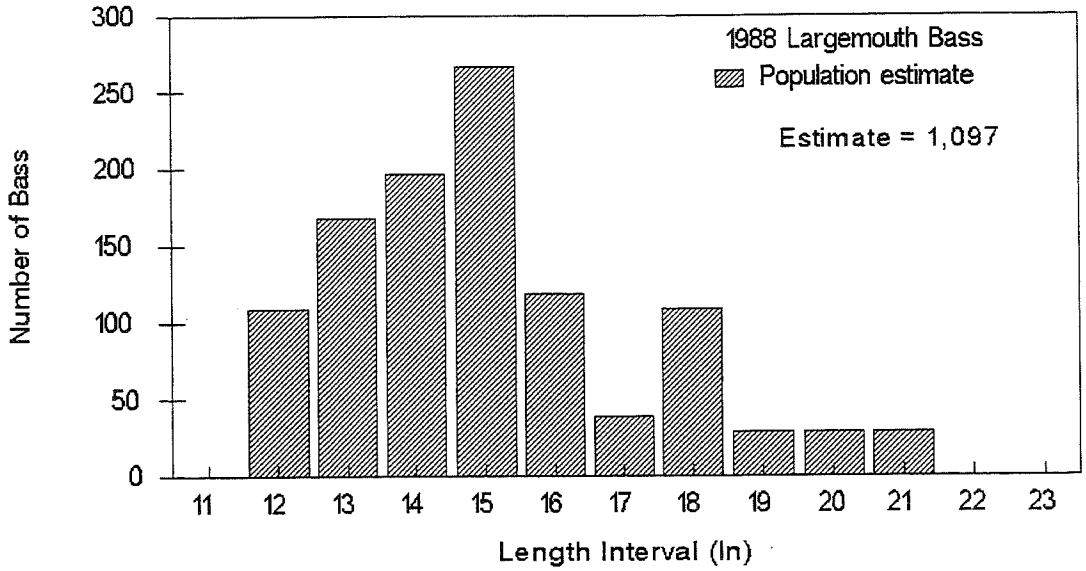
		MARKING RUN			RECAPTURE RUN					
Spp	Size class (inches)	Gear	Time period	Number marked	Gear	Time period	Examined for marks	No. of recaps	Modified Petersen estimate	95% Confidence limits
NPIKE	13.0+	fyke net shocker	03/24/88 06/02/88	405	gill net	06/06/88 08/18/88	32	4	2,680	1,314-6,699
NPIKE	13.0+	fyke net shocker	03/30/89 06/01/89	1467	gill net	06/06/89 08/17/89	177	19	13,065	8,539-20,904
LMBAS	8.0+	fyke net shocker	03/24/88 06/02/88	155	fyke net shocker	03/30/89 06/01/89	184	16	1,698	1,069-2,829
LMBAS	8.0+	fyke net	03/30/89 04/20/89	124	shocker	05/09/89 06/01/89	381	7	5,969	3,101-12,566
LMBAS	10.0+	fyke net	03/30/89 04/20/89	85	shocker	05/09/89 06/01/89	207	7	2,236	1,162-4,707
LMBAS	10.0+	shocker	09/11/89 10/18/89	128	shocker	10/24/89	39	3	1,290	526-3,225

Hauber (1983) suggested that population estimates of age-1+ walleyes are more reliable than age-0+ estimates, especially in lakes with low fingerling density. Comparisons of autumn YOY and spring yearling estimates in several years are needed to determine the best method for making population estimates of walleyes and other predators.

The number of northern pike >13 inches increased from an estimated 2,680 fish in spring 1988 to 13,065 fish in spring 1989 (Table 26). About 90% of the estimated population in 1989 was <24 inches (Fig. 7), suggesting that recruitment from fingerling stocking in 1987 was substantial. Marking northern pike in fyke nets and recapturing in gill nets a few months later appears to be an efficient method for population estimates because of satisfactory numbers of recaptures, and because we require stomach samples from pike in summer which are obtained by gill netting. Low numbers of recaptures in other gear did not allow us to evaluate alternative mark-recapture population estimates.

The population estimate of largemouth bass >8 inches increased from 1,698 in 1988 to 5,969 in 1989 (Table 26). This increase was largely due to an increase in 8-10 inch largemouth bass (Fig. 9). Based on Mendota growth rates, these fish are likely of the 1986 and 1987 year-classes. The estimated number of largemouth bass >12 inches was stable in 1988-1989 (Fig. 13). Size structure was similar in fyke nets and in spring shocking, and neither gear appeared to be strongly size selective when compared to the estimated population length-frequency (Fig. 9). However, average 1988-1989 catch rate of largemouth bass >8 inches was higher in spring shocking than fyke nets (6.2 vs. 1.25 fish/worker-day), so spring shocking is a more efficient means of obtaining largemouth bass population estimates than is fyke netting.

We obtained a mark-recapture population estimate of adult yellow perch in spring 1988. For this estimate we fin clipped 21,896 male perch in fyke nets and captured a sample of 1,914 male perch in gill nets, of which 96 were recaptures (Table 27). This yielded an estimate of 432,296 male perch, and 857,730 male and female perch (Table 27). This estimate was useful to calibrate SONAR and gill net CPE data, and to compute exploitation rates of perch, but it was labor-intensive to obtain. About 54 worker-days of effort were required to mark fish, and this was only possible by relying on considerable volunteer labor. To obtain the recapture samples 48 worker-days of gill netting were needed, but some of this sampling was also used to gather predator information.



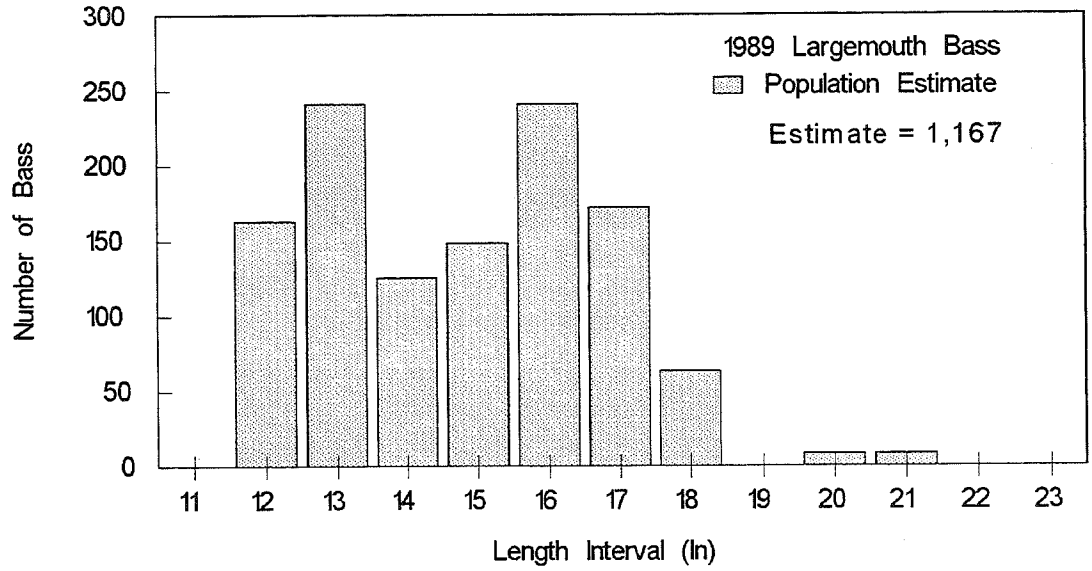


Figure 13. Length-frequency (number) of largemouth bass $\geq$12 inches in Lake Mendota in 1988 and 1989. Estimate is the number of fish >12 inches estimated by Petersen mark-recapture experiments.

Table 27. Mark-recapture population estimates of yellow perch in Lake Mendota in 1988. Yellow perch caught in fyke nets during April 21-May 6 were marked with a fin clip, and recaptured in gill nets in June-July. Because few female perch were marked, estimates for males and females combined were determined by dividing the estimated number of males by the percentage of males in gill nets. Estimates were corrected for growth occurring between marking and recapture samples, and Chapman's modification of the Petersen formula was used.

	Male yellow perch					Males and Females
Size class (inches)	Number marked	Number examined for marks	Number of recaps	Modified Petersen estimate	95% confidence limits	Modified Petersen estimate
7.0-7.9	6,414	138	7	111,461	(57,901-234,654)	221,153
8.0-8.9	11,781	747	42	204,952	(152,473-281,563)	406,651
> 9.0	3,701	1,029	47	79,439	(60,048-107,410)	157,617
> 7.0	21,896	1,914	96	432,296	(354,761-526,793)	857,730

Table 28. Species, dates, number, lake temperature, and location of northern pike and walleye stocked in Lake Mendota during 1988 and 1989. Size of fingerlings is total length (inches). Mean lake temperature was taken at the surface, and it is weighted by number stocked each day.

Species	Year	Dates	Size	Number	Mean temp. (°F)	Location
NPIKE	1988	04/15-05/02	fry	9,923,400	NA	Cherokee Marsh, Six Mile Cr., Univ. Bay in emergent vegetation
NPIKE	1988	08/30	10.0	2,520	71	Scattered in littoral zone at University Bay
WALLE	1988	05/06-05/10	fry	26,865,000	56	Scattered in open water
WALLE	1988	06/05-07/18	2.3	500,986	76	Scattered in littoral zone
NPIKE	1989	04/14-04/18	fry	10,000,000	50	Cherokee Marsh, Univ. Bay in emergent vegetation
NPIKE	1989	08/16-09/28	fgl	22,732	66	Scattered in littoral zone at University Bay
WALLE	1989	05/01-05/18	fry	20,000,000	58	Scattered in open water
WALLE	1989	06/27-07/03	fgl	500,038	79	Scattered in littoral zone
WALLE	1989	09/28-10/12	fgl*	10,000	60	Scattered in littoral zone

* large fingerling, all marked with LV fin clip.

INCREASING PREDATOR BIOMASS

Stocking

As in 1987, we obtained the requested number of fish for all stocking quotas except for the requested 50,000 northern pike fingerlings. In 1988, when statewide production of pike fingerlings was very low, we stocked only 2,520 fingerling pike. Production was better in 1989 and we received 22,732 pike fingerlings (Table 28). In 1988 and in 1989 we stocked 10 million northern pike fry during the last two weeks of April in Six Mile Creek and Cherokee Marsh when water temperatures there were about 50°F.

Survival of stocked northern pike fry and/or natural reproduction was evaluated with mini-fyke nets set at 20 sites in July and August of each year. In 1988, we caught two YOY northern pike in mini-fyke nets set in University Bay, a known pike spawning area. A few YOY pike were also sampled in UW mini-fyke nets in the same area. No YOY pike were sampled in 1989. Survival of the 23,000 pike fingerlings stocked in 1987 appears to have been excellent. Spring fyke net catch of age-1 pike in 1990 will show survival of the similar number of fingerlings stocked in 1989.

Historically, Lake Mendota has had a reproducing northern pike population, but natural recruitment has been poor since 1977 (C. Brynildson, WDNR, unpublished data). Loss of spawning habitat and inadequate spring lake levels are thought to be primarily responsible. An artificial spawning marsh at Six Mile Creek is now complete and we recommended a target spring lake level to Dane County Public Works in 1988 that has improved northern pike spawning conditions (Fig. 14). Given Mendota's historic pike population, improved spawning conditions, a high minimum size limit, and the excellent survival of pike fingerlings stocked so far, we recommend continued stocking of 50,000 northern pike fingerlings per year until natural reproduction can sustain the population.

Over 20 million walleye fry were stocked each year during the first 2-3 weeks of May, when the average lake temperature was 57°F. Food availability, or size and density of prey, is a critical factor determining survival of postlarval walleyes (Li and Mathias 1982). Given that walleye fry stocking date in Mendota is dictated by hatchery production schedules, it is reasonable to assume that walleye fry stocking may not coincide with peak zooplankton availability in Lake Mendota. We evaluated the timing of our fry stocking by comparing stocking dates with zooplankton densities (0-20 m integrated samples; Lars Rudstam, UW-CFL, personal communication).

Zooplankton species composition and abundance have been quite variable in Mendota during 1987-1989, and so have the dates of fry stockings. In 1987, fry were stocked during the last few days of April, about 5 days before peak density of all zooplankters combined (mostly copepods), and almost a month before peak *Daphnia* (mostly *D. galeata*) density (Fig. 15). In 1988, fry were stocked during May 6-10, about 10 days after peak zooplankton density (Fig. 15). And in 1989, 4 million fry were stocked on May 1, about 10 days before zooplankton density peaked, and 16 million were stocked around May 15, which was about 10 days after peak zooplankton density (Fig. 15).

No walleye fry were sampled in a Miller high speed sampler in 1987 (Johnson et al. 1991). In 1988-1989 a purse seine (1-mm mesh, 30 m X 9 m) fished by UW personnel was used to assess walleye fry abundance. In 1988 no larval walleye were caught, but 23 walleyes ranging in size 0.4-0.7 inches TL were caught during May 31 and June 27, 1989 (D. Schael, personal communication). It is encouraging that larval walleyes were present, but we have no means to determine if these fish were stocked or naturally produced. In the next few years, while walleye reproductive potential is high, we should not stock any walleye fry so the abundance of natural fry can be measured. The UW purse seine appears to be a very useful tool for sampling larval walleye.

Clearly, survival of stocked walleye fry is affected by factors other than food availability, such as the pattern of lake warming (Serns 1982b) and predation (Regier et al. 1969). However, given that time of stocking is within the manager's control, and it is important to food availability and subsequent survival of stocked fry in culture systems (Li and Mathias 1982, Hokanson and Lien 1986) and some natural systems (Priegel 1971), efforts should be made to coordinate stockings with zooplankton dynamics.

We stocked about 500,000 fingerling walleyes in 1988 and 1989. The mean length of fingerlings, median stocking date, and average lake temperature at stocking are very similar in 1988 and 1989 (Table 29). Fingerlings were stocked over a longer period of time in 1988 (June 5-July 18) than in 1989 (June 27-July 3). About 90% of the fingerlings stocked in 1988 were reared within the Southern District, while in 1989 about 60% were from Southern District ponds.

As part of a statewide large fingerling stocking evaluation, 5,000 7-inch (SD = 0.7) walleyes were stocked on September 28 and 5,000 6-inch (SD = 0.8) walleyes were stocked on October 12, 1989. About 98% of the fingerlings in each lot were given a permanent fin clip (LV). From autumn electrofishing,

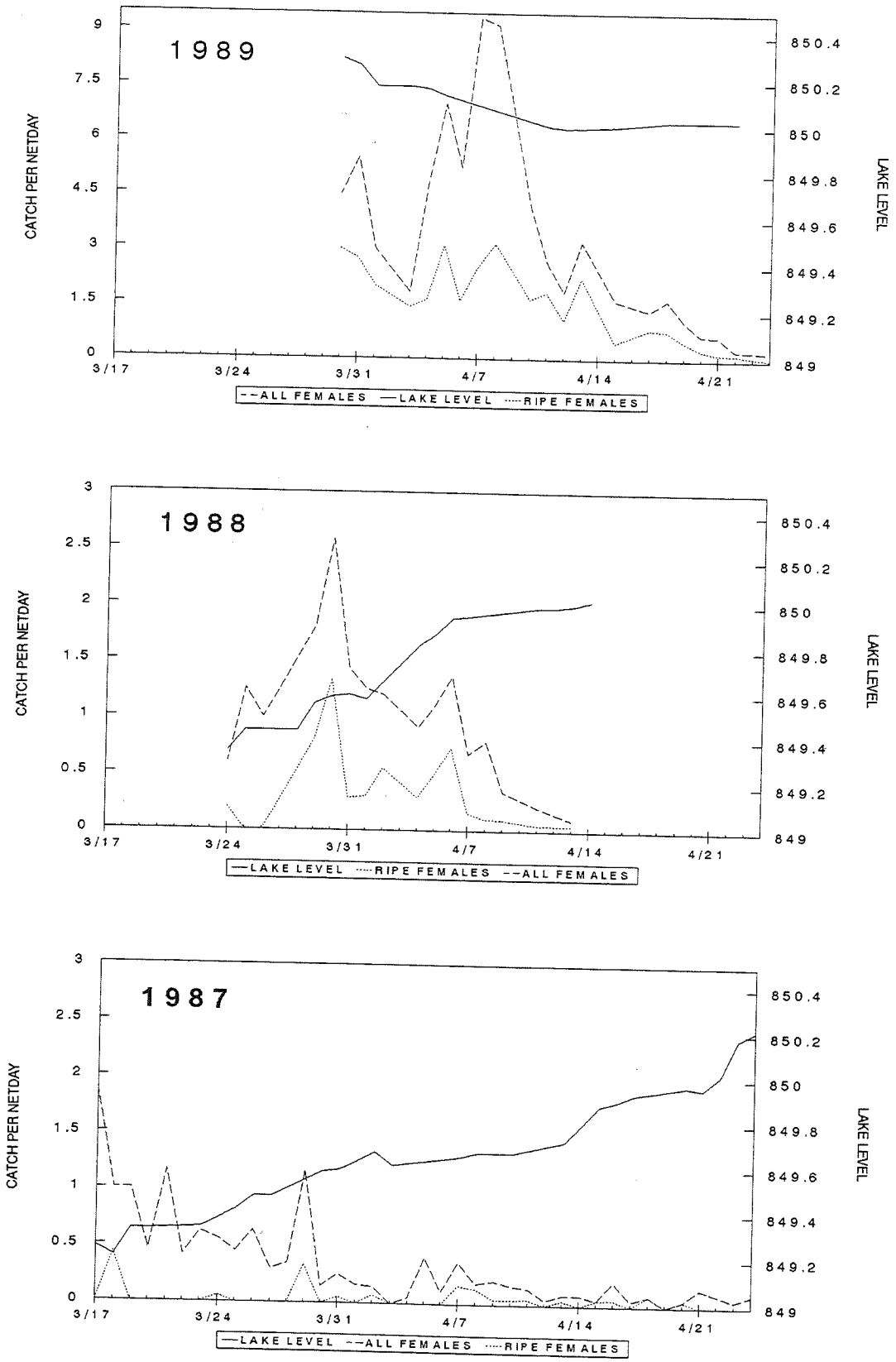


Figure 14. Daily catch-per-fyke net-day of female northern pike in Lake Mendota during the spawning run in 1987-1989 showing corresponding lake levels from a gauging station at Tenney Park.

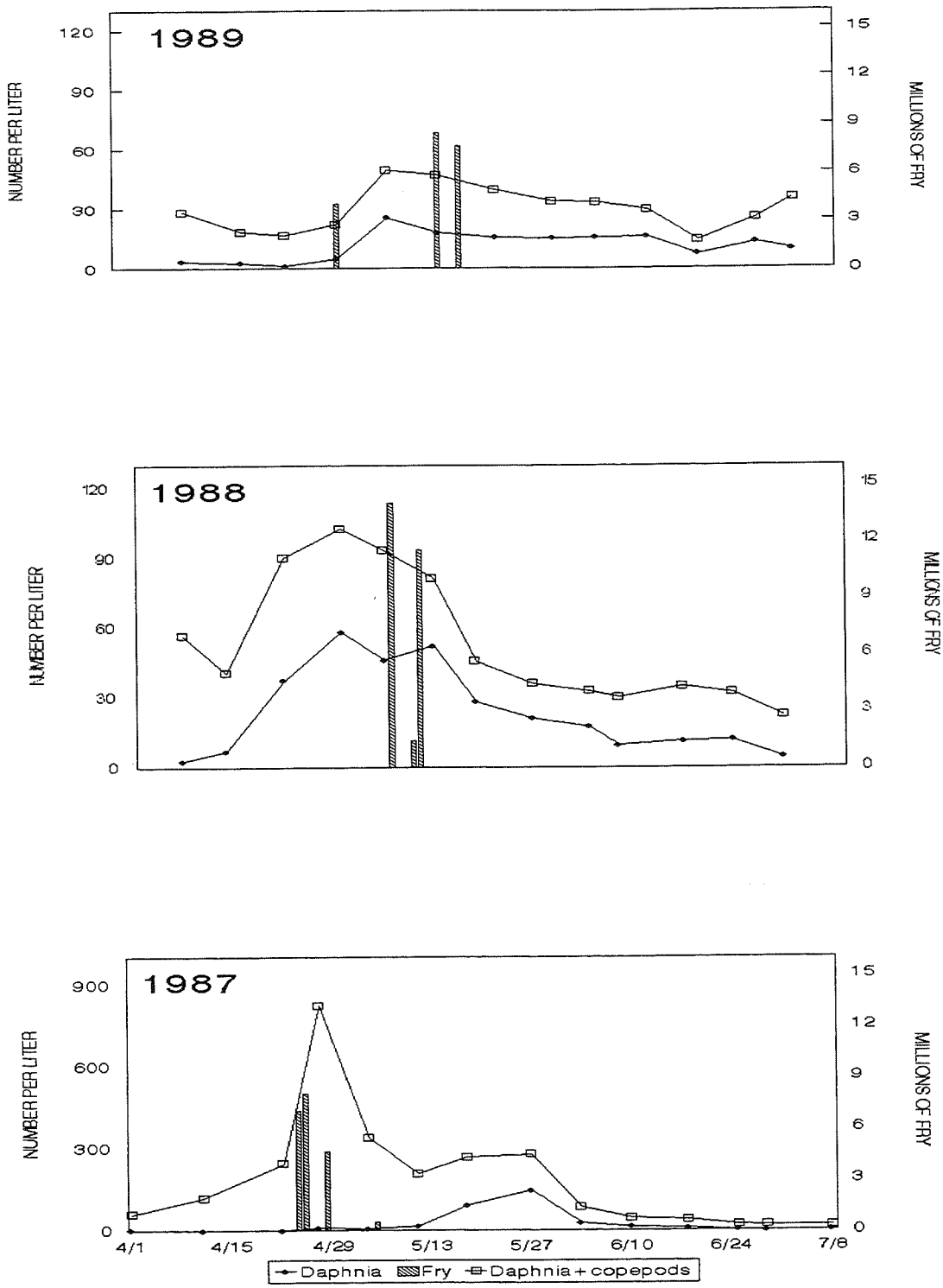


Figure 15. Zooplankton density in Lake Mendota measured by University of Wisconsin-Center for Limnology, and timing of walleye fry stockings, 1987-1989.

Table 29. Mean lake temperature (surface temperature at stocking location), mean difference between transport tank temperature and lake temperature, and mean length of walleye fingerlings stocked in Lake Mendota. Means are weighted by the number of fish stocked each day; median stocking date is date when one half of the quota has been stocked.

	1985	1986	1987	1988	1989
Number stocked	106,200	57,662	647,540	500,986	500,038
Mean lake temperature (°F)	67.0	71.0	78.0	76.0	79.0
Mean difference (°F)	-1.9	-2.8	1.2	2.3	2.2
Mean length (inches)	2.1	3.0	2.3	2.3	2.2
Median stocking date	06/13/85	06/16/86	06/23/87	06/29/88	06/28/89

these fish were stocked at a slightly larger size than the walleyes surviving from stocking as 2-inch fingerlings in June (Fig. 16). We will monitor growth and survival of these fish in spring and autumn electrofishing in 1990.

(Table 25). Length-frequency histograms of fingerlings in autumn show that in 1988 fingerling growth was poorer than in 1987 or 1989 (Fig. 17). Forney (1980) suggests that YOY walleyes in Oneida Lake must attain a minimum size of 175 mm by autumn if they are to survive the winter.

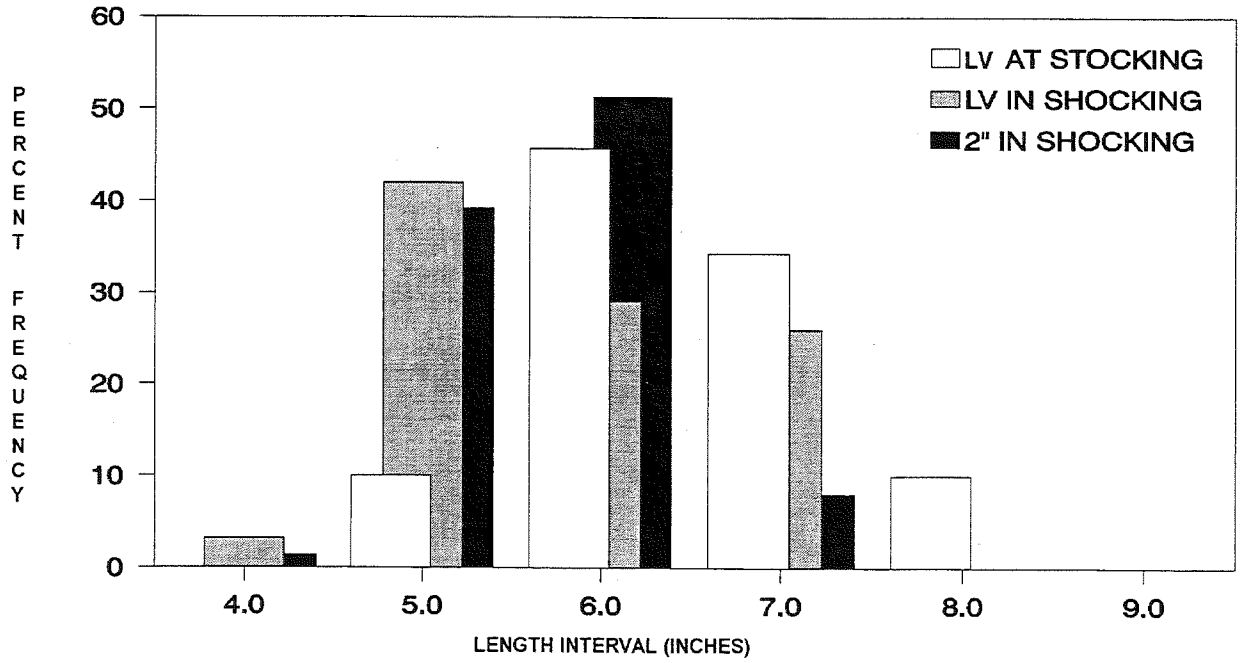


Figure 16. Length-frequency distributions of walleye fingerlings stocked in June (black bars) or on September 28 and October 12 (gray bars) and sampled by electrofishing during October 17-31, 1989. White bars are autumn-stocked walleye fingerlings measured at the time of stocking.

From mark-recapture population estimates it appears that while survival to autumn of fingerlings stocked in 1988 was similar to that in 1987, the overwinter survival of the 1988 year-class was poor

Small size in autumn 1988 may explain the poor overwinter survival of the 1988 year-class.

A new computer modeling technique called individual-based-modeling (IBM) has recently been

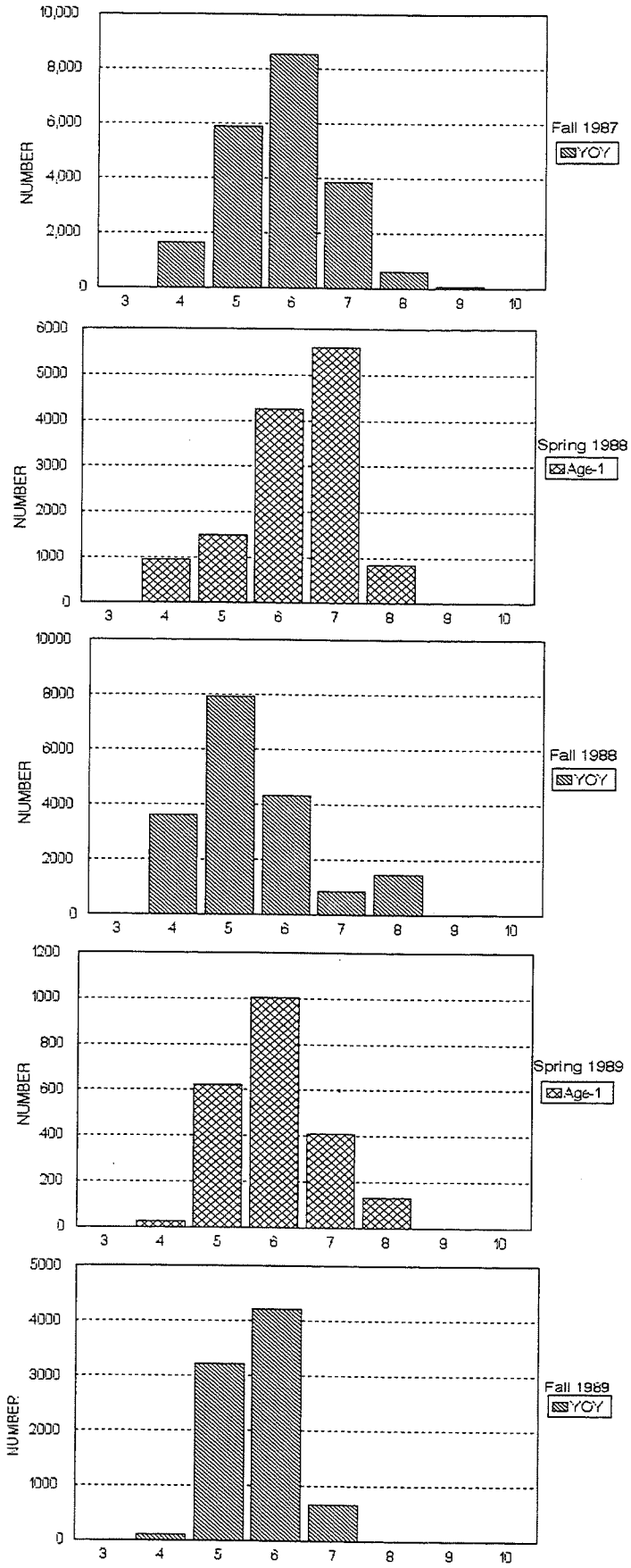


Figure 17. Length-frequency (number) of YOY and yearling walleyes in spring and autumn 1987-1989. Scales taken in autumn and spring were used to separate age-classes. Number of fish was obtained from Petersen mark-recapture experiments during electrofishing surveys.

developed to predict the first year growth and autumn size distributions of predators (e.g., Huston et al. 1988, Adams and DeAngelis 1987). These models use initial size distributions of predators and a sequence of prey size distributions, along with rules governing consumption by predators, to predict growth of individual fish, and thus predictions about end of season size distributions. An IBM has been developed for Lake Mendota walleyes (Madenjian et al. 1991). This model accurately predicted the size distribution of YOY walleyes in Oneida Lake from 1974-75 data and in Lake Mendota from 1989 data. This model should prove very useful for evaluating the effects of various walleye fingerling stocking strategies on autumn size distributions, which appears to be a determinant of overwinter survival.

Currently, Lake Mendota relies on stocking to maintain the walleye population. We know natural reproduction of walleyes has occurred in the recent past, apparently when adult stocks were higher. However, sporadic stocking, variable spawning conditions, and high exploitation have reduced the walleye stock. Calculation of walleye reproductive potential (potential egg production) and an assumed egg to fry survival rate (Forney 1976) suggested the 1987 population of walleyes in Mendota produced about 66,000 fry or about 7 fry per acre. In contrast, over 2,000 fry/acre/year have been stocked during 1987-1989. Even if these calculations underestimate fry production greatly, it is unlikely that when this project began Mendota's walleye population could sustain itself through natural reproduction.

Because another important objective of this study is the re-establishment of a self-sustaining walleye population in Lake Mendota, we predicted changes in reproductive potential resulting from various stocking strategies. Projections with the GIFSIM model indicate that the stocking in 1987-1989 will more than triple walleye reproductive potential by 1994 under a 15 inch size limit (Fig. 18). However, without further stocking, reproductive potential would decline rapidly after this date. To provide an adequate opportunity for natural reproduction, we recommend stocking 250,000 fingerlings/year for three more years (1990-1992). This will prolong the period of maximal reproductive potential to five years. We suggest a five year "window" of high reproductive potential is necessary given the well-known variability in walleye recruitment (Koonce et al. 1977). We recommend discontinuing fry stocking while we look for evidence of natural reproduction using larval fish sampling gear. If we do not see evidence of natural recruitment during this period we must reevaluate our management objectives for walleyes in Lake Mendota.

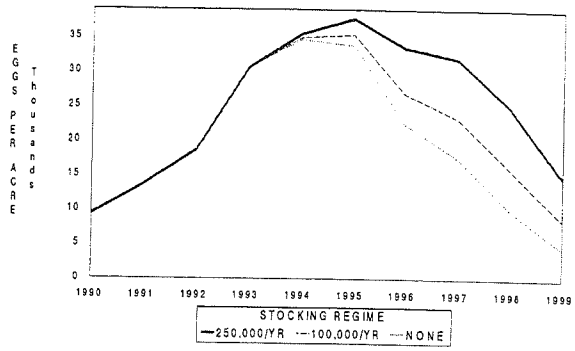


Figure 18. Potential egg production by Lake Mendota walleyes at various stocking regimes. GIFSIM simulations assumed 1988 exploitation rates, a 15-inch size limit, and 3% survival of stocked fingerlings to age-1. Female maturity schedule and egg biomass/fish biomass ratios are given in text.

Harvest regulations

Special harvest regulations for walleye and northern pike went into effect on Lake Mendota on January 1, 1988. Statewide largemouth and smallmouth bass regulations were enacted on January 1, 1989.

With apparently good public response to the regulations on northern pike, and because rehabilitation of the pike population is an important management objective for the lake, we will keep the current pike regulation in place for at least the next few years. However, to further protect Mendota's pike population, we have proposed a rule change to expand the boundaries of the current pike and walleye regulations to include Mendota's tributaries, including Pheasant Branch and Six Mile Creeks, and the Yahara River and Cherokee Marsh.

Given unanticipated increases in exploitation of walleyes >15 inches after the size limit was established, and that female walleyes are not mature until about 17 inches, we proposed to increase the minimum size limit on walleyes to 18 inches. We will maintain the current bag limit of three because most anglers (92%) harvested only one walleye per trip, and 8% of the walleye anglers kept 2 fish/trip. We did not want to needlessly restrict anglers by reducing the bag limit, when size restrictions appear to be the more effective means of controlling harvest.

Given the increasing importance of harvest regulations as a management tool on a statewide basis, and because of the strong background dataset on Mendota's fish populations and fishery, it would seem logical to continue to monitor responses to harvest regulations. Sampling protocols are established that

will provide the necessary data and be complimentary to other sampling objectives.

Data on the effects of a 32-inch limit will be valuable when statewide pike regulations are developed in the near future. If the proposed 18-inch size limit for Mendota walleyes is approved, we should evaluate a size limit more restrictive than the current statewide limit. This evaluation would prove useful if more restrictive regulations are considered on other southern Wisconsin lakes.

Largemouth bass have proven to be much more readily sampled than smallmouth bass. Thus, we will be able to provide a better evaluation of the effects of the statewide size limit on largemouth bass than we will for smallmouth bass. Future monitoring of the effects of all Mendota's harvest regulations should be coordinated with the proposed statewide regulation study to insure data compatibility.

program and special regulations would result in a 3.5-fold increase in walleye biomass if stocking were continued for 10 years. However, simulations allowing for increased exploitation rates in 1988 and 1989, predicted about half the increase in walleye biomass that was predicted in 1987 (Fig. 19).

These simulations assumed that stocking occurs annually and that no natural reproduction occurs. In fact, 1987-1989 stocking rates cannot be maintained because of statewide demand for fingerlings. GIFSIM was useful for evaluating the effects of reduced stocking regimes on the fishery and the reproductive potential of the walleye population.

Projected walleye harvest drops precipitously after 1993 if stocking is discontinued in 1990 (Fig. 20). If stocking is continued during 1990-1992 at either 100,000 fgl/year or 250,000 fgl/year a higher harvest would be maintained; however, without natural

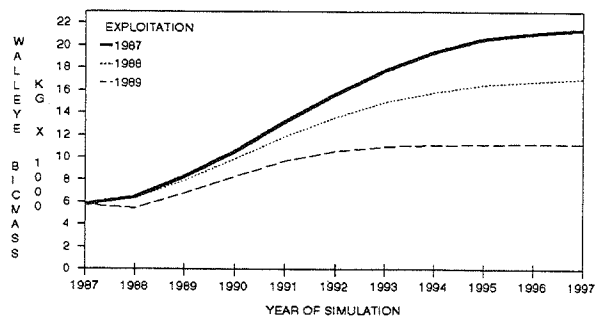


Figure 19. Projected biomass of the Lake Mendota walleye population when subjected to exploitation rates measured in 1987, 1988, or 1989. GIFSIM simulations assumed a 15-inch size limit, annual stocking, and 3% survival of stocked fingerlings to age-1.

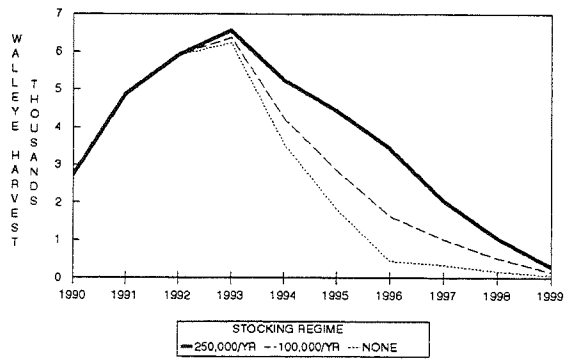


Figure 20. Projected harvest of Lake Mendota walleyes at various stocking regimes. GIFSIM simulations assumed 1988 exploitation rates, a 15-inch size limit, and 3% survival of stocked fingerlings to age-1.

FORECASTING CHANGES

The GIFSIM model allowed us to assess the impacts of changes in exploitation rate on projected walleye biomass. Because 1987-1989 walleye fingerling stocking levels can not be maintained, we used the GIFSIM model to evaluate various stocking scenarios. This model was also useful for evaluating more restrictive harvest regulations that could be implemented to compensate for reduced stocking quotas and increases in exploitation observed in 1988-1989.

Because one objective of the biomanipulation was to establish high walleye biomass, we were concerned about increases in exploitation rate observed in 1988 and 1989. Projections with the GIFSIM model using data gathered in 1987 suggested that the stocking

reproduction projected harvest still decreases to less than 500 fish by 1999 (Fig. 20).

Natural reproduction by walleyes is possible in Lake Mendota, though infrequent (Johnson et al. 1991). One hypothesis to explain sporadic reproduction in Mendota walleyes is that the population is limited by low stock biomass. With the intensive stocking occurring since 1987, adult walleye biomass has been increasing. By stocking 250,000 fgl/year during 1990-1992, potential egg biomass can be maintained at a level 2-3 times higher than the already high 1990 egg biomass for a period of six years (Fig. 18). During this period we will monitor the lake for evidence of natural reproduction. The proposed increase in the minimum size limit from 15 to 18 inches will result in greater than predicted increases in

reproductive potential because females in Lake Mendota do not mature until they reach a length of about 17 inches.

Bioenergetics models provided the means to investigate questions regarding the influence of various factors on consumption by a predator population. With some preliminary knowledge of the system, the importance and sensitivity of each model input can be evaluated. Thus, simulations can be used to design field sampling schemes, with effort allocated based on the sensitivity of each input. We evaluated the importance of thermal history, a costly and time-consuming parameter to estimate. These simulations will be used to help us design future gill netting plans.

The growth of an age-4 walleye takes different trajectories if fish are grown at each temperature regime, and iterations (P-fits) were run to match only the ending weights. Fish at maximum temperatures grew fastest initially, but experienced a midsummer weight loss, and did not approach the other two growth curves until the end of the simulation year. Fish at the minimum temperatures grew slowest at the start, but quickly caught up to fish at near optimum temperatures.

At maximum temperatures, daily consumption declines during July and August, explaining the midsummer growth depression noted above. Apparently, maximum water temperatures exceeded that required for consumption rate to keep pace with respiration rate costs. Fish grown at minimum temperatures maintained high daily consumption during midsummer. Errors in estimating thermal history are most critical during two periods: in early June when the lake is stratified but the hypolimnion is not anoxic and in August when maximum temperatures reduce consumption rate. During these periods, incorrect thermal history can produce at least 50% errors in the daily amount of food consumed. However, a comparison of the total annual consumption of an age-4 walleye grown with each thermal history shows that errors in annual estimates of food consumed are at most only about 15%.

With this in mind, modeling suggests that a prudent strategy for estimating walleye thermal history would be to devote most of the available sampling effort to the early and mid summer periods. And, efforts to estimate thermal history should not be made at the expense of other sampling objectives, such as population estimates and diet sampling.

Because field estimates of consumption itself are not required, this technique allows for a variety of potentially damaging or unpopular management scenarios to be examined without the risk of direct field experimentation. In the simulations of different fishing mortality schedules, we found that although delaying fishing mortality until the end of the growing season affected annual prey consumption by walleyes, gains were not sufficient to justify further complicating angling regulations. Other work with these models has suggested that length limits, where fishing is delayed for greater than one season, would be easier to institute and more effective for increasing predator consumption.

Altering the pattern of fishing mortality can affect total annual consumption of the walleye population. All simulations started on April 15, the assumed "birthday" of the year-class; thus, the case where all fishing mortality occurred only in May had the lowest annual consumption of prey. Here, walleyes are removed by anglers before having the opportunity to consume prey. Alternatively, if all fishing mortality on the age-class is deferred until the end of the simulation year, in January and February, after the end of the growing season, consumption is maximal. Simulations in which fishing occurs only in July or September had intermediate levels of annual consumption. If fishing is assumed to occur at a constant rate throughout the simulation (excluding the closed season in March and April), as was roughly the case in 1988, the total annual consumption is about halfway between May-only and winter-only simulations. Delaying the incidence of fishing mortality on age-4 walleyes through season restrictions could have a large effect on the total biomass of prey consumed by these fish in a year. Because fishing mortality is nearly two times higher than natural mortality, fishing regulations have the potential to mediate the effects of walleye consumption on prey biomass. As much as 37% more prey biomass could be consumed if the annual exploitation was restricted to the end of the year, relative to the situation where harvest occurred at the start of the year (in May). However, there would only be a small increase in annual consumption if fishing was not permitted until after the growing season versus the present situation where there is nearly a constant harvest rate through the year.

When seasonal diet data are translated into estimates of total annual consumption via bioenergetics simulations, we can evaluate predation pressure exerted by predator populations. Total prey biomass consumed by age-2 and older predators increased substantially between 1987 and 1989 (Fig. 21). Between 1987 and 1989, total consumption by walleyes increased 120%. Bass biomass and consumption remained relatively stable during the period. Consumption by northern pike increased by a surprising 780%, overtaking total consumption by the walleye population.

Exploring reasons for inter-species differences in the dynamics of piscivory points out important differences in the utility of each species in

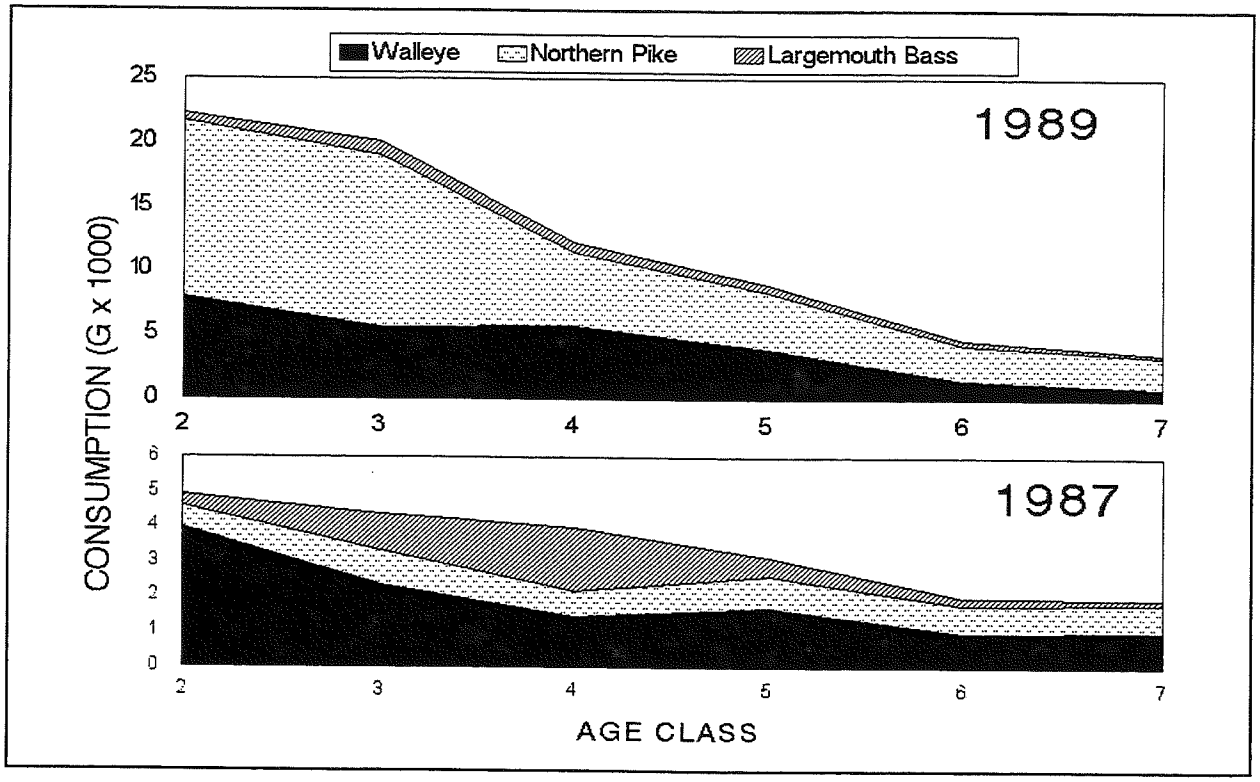


Figure 21. Total prey biomass consumed by six age classes of largemouth bass, northern pike, and walleyes in Lake Mendota in 1987 and 1989. Consumption estimates were computed with a bioenergetics model using observed abundance by age, growth, and thermal history data.

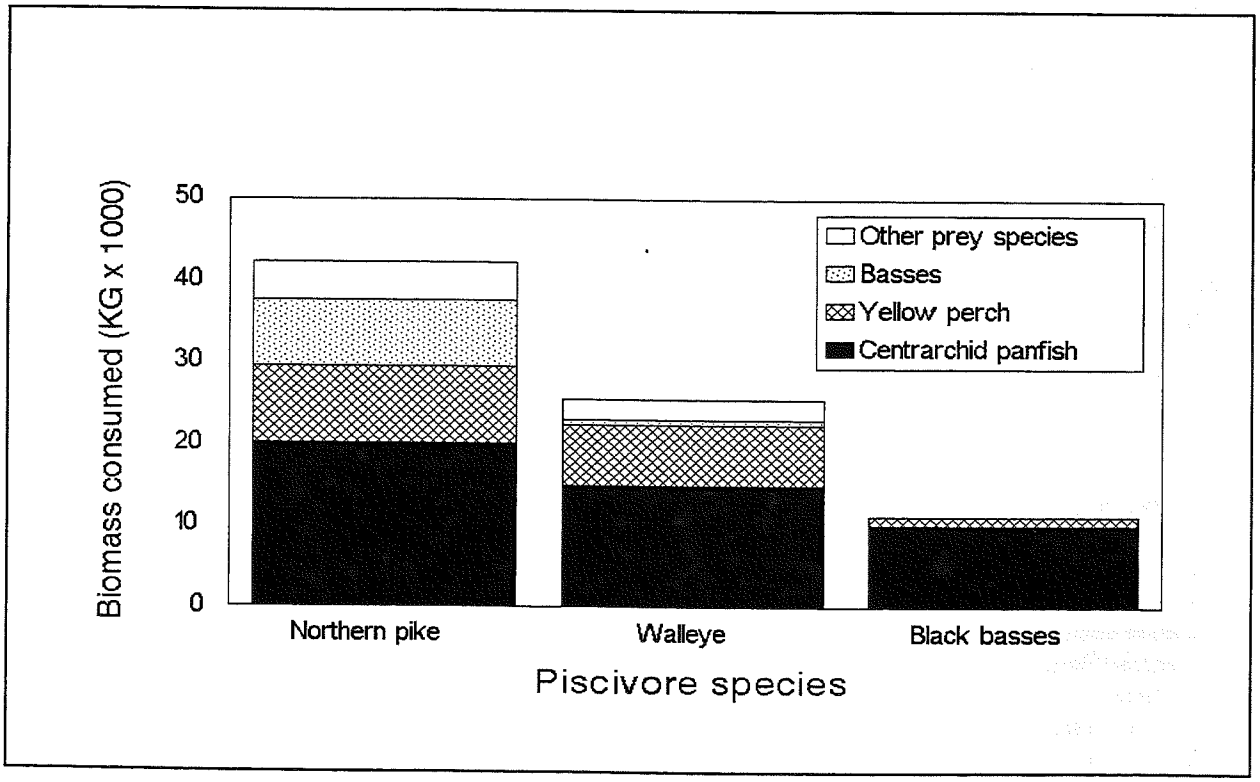


Figure 22. Total biomass of various prey species consumed by predators in Lake Mendota in 1989. Consumption estimates were computed with a bioenergetics model using observed diet, abundance by age, growth, and thermal history data.

biomanipulations. Rapid individual growth of pike relative to other Mendota predators (Table 5), and high survival of stocked fingerlings, suggests a fast-acting predator. Predatory inertia (Stewart et al. 1981) of pike may be low, however effects can be quickly reversed if stocking is discontinued, hooking and/or natural mortality are high, or fishing mortality is not controlled through regulations. Because of their rapid growth, "trophy" harvest regulations may be required if pike are to remain in the lake for a sufficient period of time to maximize consumption. Piscivory by walleye may be slower to develop because of low survival of stocked fingerlings, and a lower individual growth rate. Although usually longer-lived than pike, walleye are highly prized by anglers for food, and thus restrictive harvest regulations may be difficult to institute. Black bass are not raised in hatcheries to any significant extent in Wisconsin, and their growth rate is lower than walleye, making them the least desirable candidate for our biomanipulation.

Prey selection should also be considered when judging utility of predators for biomanipulation experiments. In 1989, when total piscivory was greatest, age-2 and older northern pike consumed a slightly higher biomass of centrarchid panfish and yellow perch than did age-2 and older walleyes (Fig. 22). All predators fed on the dominant planktivores in the lake: mostly centrarchid panfish, followed by yellow perch. However, black bass consumed mostly centrarchids, and walleye ate proportionally less bass and other prey than did northern pike.

Consumption by either the 1989 walleye or northern pike population alone was greater than that consumed by all predators combined in 1987 (Fig. 21). These increases arose primarily from recruitment of fish from the 1986 and 1987 pike, and 1985-1987 walleye year classes. Thus, at present, lakewide piscivory is dominated by a few young age classes of mostly stocked walleye and northern pike. Of course, we expect further increases in estimated predator consumption as 1988, 1989, and later stocked year classes grow and the biomass of populations increase. Increases in northern pike biomass and consumption will continue to outpace that of the walleye population, due to excellent survival of stocked fingerlings, rapid growth rate, and a "trophy" harvest regulation to control fishing mortality.

We believe we can forecast predator biomass and consumption more confidently than we can predict the effects of piscivory on prey populations. Recruitment of predators arises primarily from stocking and not natural reproduction, and stocking quotas are known in advance. Prey recruitment on the other hand, is notoriously variable in Mendota and in other systems. At any given predicted level of predator consumption, a wide range of initial prey year-class-strengths are possible depending on early survival. Thus the importance of predation in controlling planktivore abundance depends on reproductive success of the planktivores.

Still, we can bound the problem by asking under what levels of adult prey biomass and prey recruitment will piscivory be an important force. This question is particularly interesting relative to the yellow perch population because we have seen a decline in adult biomass (Rudstam et al. 1992), and generally poor recruitment since 1985. With burgeoning predator biomass concurrent with declining perch abundance, and the extreme popularity of yellow perch to anglers, we are interested in evaluating the importance of predation to future abundance of this species.

Bioenergetics models allowed us to translate predicted changes in predator population structure (with GIFSIM) resulting from changes in exploitation rate into the expected changes in the biomass of prey consumed by the population. Thus, we were able to assess the impact of observed changes in the fishery on piscivory estimates. Increases in exploitation rate resulted in reductions in the total biomass of prey consumed by walleyes, with the greatest reduction in age-5 and older walleyes (Fig. 23). If exploitation rates observed in 1989 continued, the consumption by walleyes above the minimum size limit would be less than one-fifth that of the sublegal population (Fig. 23). An increase in the minimum size limit to 18 inches would maintain high consumption through age-5 instead of age-4 (Johnson et al. 1991).

The modeling techniques developed here allowed us to evaluate gamefish harvest regulations and stocking regimes relative to both the gamefish population and prey populations. The techniques provide the means to predict how prey populations may respond to changes in the gamefish fishery, and how stocking regime affects the reproductive potential of predator populations. Bioenergetics modeling proved to be a very effective means to focus our field sampling effort by identifying sensitive parameters that must be estimated closely, and eliminating or streamlining sampling for unimportant parameters.

MANAGEMENT RECOMMENDATIONS

We recognize that many of our recommendations or conclusions may not apply to lakes different from Mendota. However, our findings should provide indications of useful practices that managers could test on other waters. Recommendations based on findings from 1988-1989 are:

1. Steps must be taken to improve walleye and northern pike recruitment in the future. Fostering

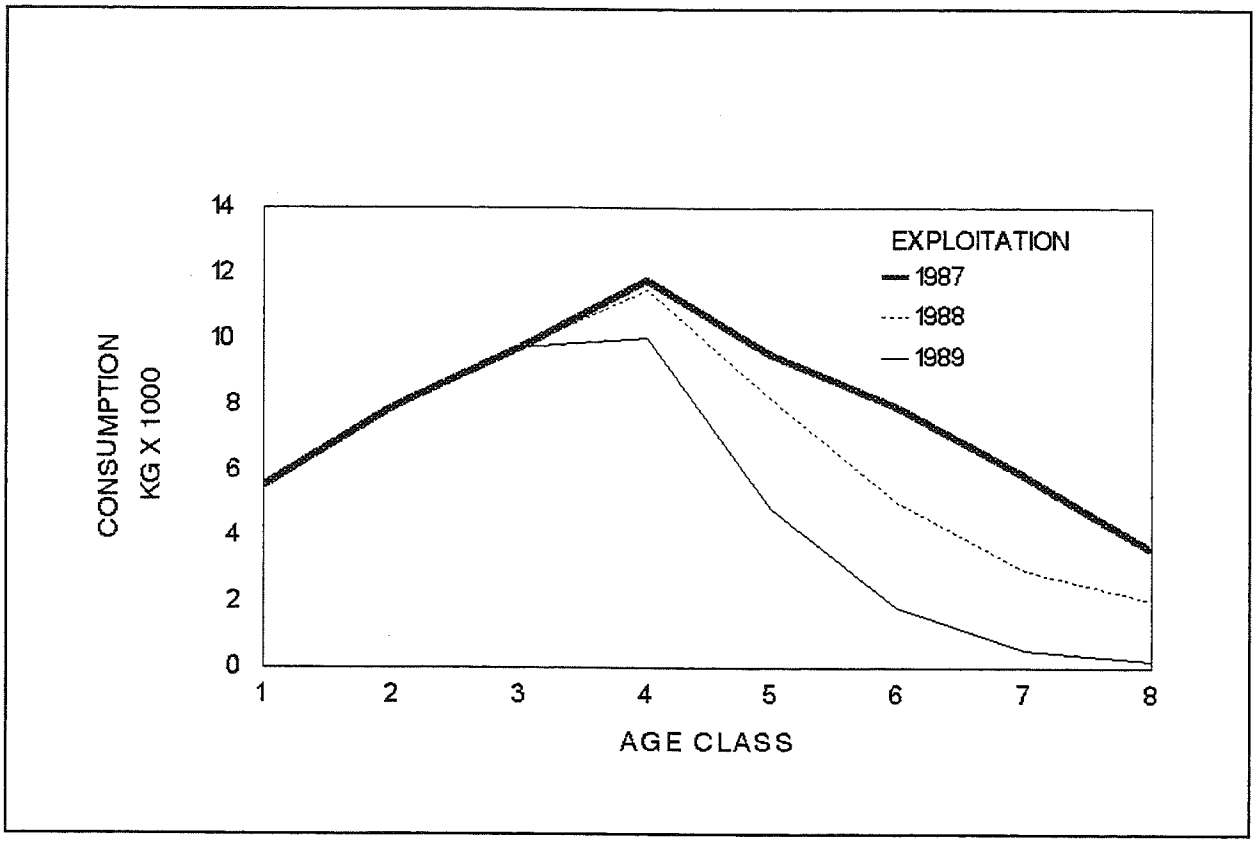


Figure 23. Projected prey consumption of the Lake Mendota walleye population in 1997 when subjected to exploitation rates measured in 1987, 1988, or 1989. GIFSIM simulations assumed a 15-inch size limit, annual stocking, and 3% survival of stocked fingerlings to age-1.

natural reproduction by increasing adult density (thus, reproductive potential) through stocking and harvest restrictions, and improving spawning habitat should be pursued. We should evaluate walleye reproduction while reproductive potential is high, using a purse seine or Miller sampler. Northern pike reproduction should be monitored with mini-fyke nets in summer before fingerlings are stocked. We should evaluate spawning habitat improvement projects at Six Mile Creek, Bible Camp, and the Yahara River above Lake Kegonsa.

2. Stocking should continue to build and sustain walleye and pike populations until the potential for natural reproduction can be assessed. We recommend stocking 250,000 walleye fgl/year in 1990-1992, and 50,000 pike fgl/year when available, until the population can sustain itself.

3. Traditional walleye stocking techniques need to be improved. Factors affecting first year survival of stocked fingerling must be identified. More research is needed to improve survival of stocked fry. Localized rearing and strains would improve timing, availability, and suitability of stocked fish to the Madison lakes.

4. Harvest regulations for walleye, northern pike, and bass should be evaluated because of the extensive dataset available on these fishes in Lake Mendota. The 32-inch limit on pike should continue because the population is rebuilding and public acceptance is good. An 18-inch minimum size limit is needed for walleye to reduce exploitation and to protect a minimum biomass of spawning females. Continued public education and enforcement of harvest regulations is needed because many small bass, pike, and walleye are recruiting to the fishery and compliance with regulations in 1988-1989 was poorer than desired.

5. Abundance indices based on less intensive sampling must be developed. With very few other studies currently available, mark-recapture techniques for large lakes should be refined. Techniques for walleye fingerling abundance estimation are particularly needed. Sampling and estimation techniques should be expanded to the other Yahara lakes. We need to validate ages

based on scales. Future recaptures of tagged fish and aging of spine sections should provide validation of the aging techniques used here.

6. Modeling suggested that maximum effects of the biomanipulation will not occur until 1991-92. Work on the project, particularly in monitoring populations, must continue beyond this date if the experiment is to be evaluated adequately.

7. Continued fisheries management emphasis on the heavily used Yahara lakes is highly recommended because public support for this project has been excellent, and angler expectations are high.

SUMMARY

- Walleyes dominated fyke net catch in 1988 and 1989, although northern pike CPE increased 8-fold since 1987, while largemouth and smallmouth bass CPE was constant.

- In 1987 it appeared that spring fyke nets gave a better representation of walleye population size structure than spring electrofishing. Examining 1988-1989 data it appears that neither spring electrofishing or fyke nets alone adequately assessed walleye population size structure. Fyke nets greatly overestimated the relative abundance of walleyes >11 inches, and electrofishing samples few walleyes >16 inches.

- Fyke nets underestimated the abundance of walleyes <11 inches

- Spring fyke nets and shocking provided similar length-frequencies of largemouth bass in 1987-1989, that were not greatly different from estimated population size structure. It appears that either gear provides a good estimate of largemouth bass size structure in Mendota.

- In 1988 the highest smallmouth CPE was found on the last day of fyke netting (May 6). Fyke nets set in May might be effective for sampling smallmouth bass.

- Spring fyke nets provided a good size representation of all northern pike. Because spring fyke nets tend to sample the spawning population, all sizes of northern pike may be more effectively sampled in fyke nets relative to walleye because of lower age at maturity of both sexes in Mendota. Both fyke nets and the electroshocker appeared to assess largemouth bass size structure adequately.

- In 1988 and 1989, when fyke netting effort was half of 1987 effort and more productive sites were known, fyke nets were the most efficient sampling method for walleye and northern pike.

- In terms of catch per worker-hour, spring electrofishing was 2-5 times more efficient than netting for sampling largemouth and smallmouth bass.

- Fyke nets set for predators in spring provided consistent estimates of non-predator size structure, but non-predator CPE was too variable to use as an index of abundance.

- Examining recapture rates of fish tagged by each gear, we found no evidence that electrofishing caused higher mortality than fyke nets.

- As in 1987, Petersen population estimates of walleyes marked in fyke nets and recaptured during the last week of fyke netting underestimated the number of walleyes <24 inches and overestimated the number of walleyes >24 inches, when compared with less biased estimates obtained using gill nets for recaptures.

- Petersen estimates of walleyes using the creel survey for recaptures were similar to estimates using gill net recaptures, but gill net derived estimates were more precise because of higher numbers of recaptures.

- Northern pike abundance increased from 1,100 fish in 1987 to 13,065 in 1989, as stocked fingerlings recruited to the sampled population. Survival of fingerlings stocked in 1987 appears to have been excellent.

- A mark-recapture estimate of 860,000 adult yellow perch was obtained in 1988.

- Survival to autumn of walleye fingerlings stocked in 1988 was similar to 1987, but overwinter survival of the 1988 year-class was poor.

- Nearly 5,000 ft of suspended gill net caught no walleyes in August 1988. It is unlikely that a significant portion of the walleye population is pelagic in summer. Radio telemetry by WDNR Bureau of Research also supported this conclusion.

- During late June through August most of the walleyes in Mendota were found in water <10 ft deep.

- Northern pike depth distribution in summer was similar to that of walleye.

- Largemouth bass inhabited shallower water than pike or walleye, and smallmouth bass were found in deeper water than the other predators.

- Walleyes <12 inches consumed mostly YOY panfish, but minnows, darters and silversides were eaten when small panfish were scarce. When YOY perch were rare, small walleyes ate YOY bluegills.

- Northern pike <18 inches consumed more yellow perch than same-age walleyes, but pike also consumed minnows, darters and silversides in spring and autumn.

- Large pike diet was similar to small pike, but large pike consumed a higher diversity of species including drum, bullheads, and white bass.

- Although cannibalism and predation on small walleyes was rarely observed, the estimated biomass of small walleyes consumed (from bioenergetics modeling) was a significant proportion of the mortality of the 1989 year class.

- Tag loss rate of 1.8-inch T-bar tags varied through time and by species, but was less than half of that measured for 3-inch tags. Tag removal by anglers who release fish does not contribute greatly to estimated tag loss rate.

- Regeneration of clipped fins on northern pike appeared to be significant. Fin clips on bass and walleye appeared to be permanently recognizable.

- Mini-fyke nets appeared to be to be useful for assessing year-class-strength of predators.

- Mini-fyke net CPE of YOY and yearling fishes was higher than shore seining at the same sites, but fish size and number of species were similar. Mini-fyke nets were useful in more habitats than seining.

- Twenty three larval walleyes were sampled in a UW purse seine in June 1989. We had no means to determine if these fish were stocked or naturally produced. The purse seine appeared to be a useful tool for sampling larval walleyes.

- Catch rates of anglers seeking walleye, and the hours spent fishing for walleye increased in 1988 and again in 1989.

- Exploitation rates on walleye and largemouth increased since 1987, despite new size limits.

- Total catch of all predators except hybrid muskie increased each year.

- Smallmouth bass catch was 1.6-3.4 times higher than largemouth bass catch.

- Most successful walleye anglers (92%) harvested only one walleye per trip; the remainder kept 2 fish per trip.

- Compliance with size limits was poor. About 25-42% of the harvest of bass and walleye consisted of sublegal fish.

- Over 98% of the total annual fishing effort occurred between 7 a.m. and 11 p.m. A higher walleye catch rate at night was offset by low effort, so night harvest of walleyes was low.

- The place of residence of Mendota anglers has remained relatively constant, with 92% Dane County residents, 6% from other Wisconsin counties, and 2% from outside Wisconsin.

- Anglers responded to showcase management. Increased effort and exploitation, especially on walleye point to having adequate harvest restrictions in place before showcasing a fishery improvement project.

- The 15-inch size limit on walleyes was not sufficient to protect female walleyes to maturity, and it is not sufficient for sustaining the fishery either given the increased exploitation rates observed in 1988 and 1989.

- Walleye harvest was predicted to drop precipitously after 1993 if stocking was discontinued after 1989.

- Stocking 250,000 walleye fingerling/year during 1990-1992 would maintain adult walleye biomass at a level 2-3 times higher than 1990 biomass, for a period of six years.

- Without natural reproduction or stocking after 1992, projected harvest would dwindle to less than 500 walleyes by 1999.

- The creel survey showed that we underestimated the magnitude and rapidity of the response in the fishery to our showcase management efforts.

- The time series of creel survey data along with our detailed measurements of population parameters will form a very valuable case study of the dynamics in a fishery as a result of intensive management on a heavily used public resource.

- Variation in depth distribution and thermal history of predators had little consequence for annual consumption estimates, based on gill net sampling and bioenergetics modeling.

- Consumption by either the northern pike or walleye population alone in 1989 was greater than total lakewide piscivory in 1987. Piscivory in 1989 was dominated by recently-stocked year classes.

- Consumption by pike in 1989 was higher than total walleye consumption despite the vastly greater numbers of walleye fingerlings stocked, because of excellent survival and fast growth of pike fingerlings, and a very restrictive size limit.

- Northern pike consumption was predicted to continue to outpace consumption by walleyes.

- Combining GIFSIM and bioenergetics modeling approaches provided the means to evaluate ecological effects of changes in gamefish harvest regulations, exploitation rate, or stocking regime.

- These models can be used to streamline field sampling programs and identify areas requiring greater sampling or analytical attention.

LITERATURE CITED

Adams, S. M. and D. L. DeAngelis. 1987. Indirect effects of early bass-shad interactions on predator population structure and food web dynamics. Pages 103-117 in W.C. Kerfoot and A. Sih, editors. Predation: Direct and indirect impacts on aquatic communities, University Press of New England, Hanover, NH.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames.

Carlander, K. D. 1977. Handbook of freshwater fishery biology. Iowa State University Press, Ames.

Carpenter, S. R., J. F. Kitchell, and J. R. Hodgson. 1985. Cascading trophic interactions and lake productivity. Bioscience 36:634-639.

Colby, P. J., R. E. McNicol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye, *Stizostedion vitreum vitreum* (Mitchell 1818). FAO (Food and Agricultural Organization of the United Nations) Fisheries Synopsis 119.

Fago, D.M. 1991. Lake Mendota summer distribution of predatory fishes. Progress Report, Federal Aid in Fish Restoration Project F-83-R. Wisconsin Department of Natural Resources, Madison.

Fletcher, D. H. 1987. Hooking mortality of walleyes captured in Porcupine Bay, Washington. North American Journal of Fisheries Management 7:594-596.

Forney, J. L. 1976. Year-class formation in the walleye (*Stizostedion vitreum vitreum*) population of Oneida Lake, New York, 1966-73. Journal of the Fisheries Research Board of Canada 33:783-792.

Forney, J. L. 1980. Evolution of a management strategy for the walleye in Oneida Lake, New York. New York Fish and Game Journal 27:105-141.

Gilbert, S. J. and B. M. Johnson. In Press. An efficient, easy to use stomach pump for live fishes. Administrative Report, Wisconsin Department of Natural Resources, Madison.

Hauber, A. B. 1983. Two methods for evaluating fingerling walleye stocking success and natural year-class densities in Seven Island Lake, Wisconsin 1977-1981. North American Journal of Fisheries Management 3:152-155.

Hewett, S. W. and B. L. Johnson. 1987. A generalized bioenergetics model of fish growth for microcomputers. University of Wisconsin Sea Grant Institute, Technical Report WIS-SG-87-245, Madison.

Hokanson, K. E. F. and G. J. Lien. 1986. Effect of diet on growth and survival of larval walleyes. The Progressive Fish Culturist 48:250-258.

Huston, M., D. DeAngelis, and W. Post. 1988. New computer models unify ecological theory. BioScience 38:682-691.

Johnson, B. M., R. S. Stewart, and S. J. Gilbert. 1991. Ecology of fishes in the Madison lakes, 1987. Wisconsin Department of Natural Resources, Fish Management Report 147, Madison.

Kitchell, J. F., H. F. Henderson, E. Grygierek, J. Hrbacek, S. R. Kerr, M. Pedini, T. Petr, J. Shapiro, R. A. Stein, J. Stenson, and T. Zaret. 1986. Management of lakes by food-chain manipulation. FAO Fish. Tech. Pap. UN Food and Agricultural Organization, Rome.

Knight, R. L., F. J. Margraf, and R. F. Carline. 1984. Piscivory by walleyes and yellow perch in western Lake Erie. Transactions of the American Fisheries Society 113:677-693.

Koonce, J. F., T. B. Bagenal, R. F. Carline, K. E. F. Hokanson, and M. Nagiec. 1977. Factors influencing year-class-strength of percids: a summary and a model of temperature effects. Journal of the Fisheries Research Board of Canada 34:1900-1909.

Li, S. and J. A. Mathias. 1982. Causes of high mortality among cultured larval walleyes. Transactions of the American Fisheries Society 111:710-721.

Lyons, J. 1989. Changes in the abundance of small littoral-zone fishes in Lake Mendota, Wisconsin. Canadian Journal of Zoology 67:2910-2916.

Madenjian, C. P., B. M. Johnson, and S. R. Carpenter. 1991. Stocking strategies for fingerling walleye: an individual-based model approach. Ecological Applications 1:280-288.

Payer, R. D., R. B. Pierce, and D. L. Pereira. 1987. Hooking mortality of walleye caught on live and artificial baits. Minnesota Department of Natural Resources, Section of Fisheries Investigational Report 390, Saint Paul.

Pearse, A. S. 1918. On the food of the shore fishes of certain Wisconsin lakes. Bull. U.S. Bur. Fish. 35:245-292.

Pearse, A. S. and H. Achtenburg. 1920. Habits of yellow perch in Wisconsin lakes. Bull. U.S. Bur. Fish. 36:297-362.

Priegel, G. R. 1969. Age and growth of the walleye in Lake Winnebago. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters (1969):121-133.

Priegel, G. R. 1971. Walleye fry stocking in relation to zooplankton densities in southeastern Wisconsin lakes. Informal Research Report, Wisconsin Department of Natural Resources, Madison.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fishery Commission Technical Report 15:1-101.

Reynolds, J. B. 1983. Electrofishing. Pages 147-163 In L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques, American Fisheries Society, Bethesda.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191.

Rudstam, L.G., Y. Allen, B.M. Johnson, C. Luecke, J.R. Post, and M.J.Vanni. 1992. Food web structure of lake Mendota. Pages 232-241 In J.F. Kitchell, editor. Food web management: a case study of Lake Mendota. Springer-Verlag, New York.

Serns, S. L. 1982a. Walleye fecundity, potential egg deposition, and survival from egg to fall YOY in Escanaba Lake, Wisconsin, 1979-1981. North American Journal of Fisheries Management 2:388-394.

Serns, S. L. 1982b. Influence of various factors on density and growth of age-0 walleyes in Escanaba Lake, Wisconsin, 1958-1980. Transactions of the American Fisheries Society 111:299-306.

Serns, S.L. 1983. Relationship between electrofishing catch per unit effort and density of walleye yearlings. North American Journal of Fisheries Management 3:451-452.

Shapiro, J. and D. I. Wright. 1984. Lake restoration by biomanipulation. Freshwater Biology 14:371-383.

Stewart, D. J., J. F. Kitchell, and L. B. Crowder. 1981. Forage fishes and their salmonid predators in Lake Michigan. Transactions of the American Fisheries Society 110:751-763.

Taylor, M. W. 1981. A generalized inland fishery simulator for management biologists. North American Journal of Fisheries Management 1:60-72.

Wahl, D. H. 1982. Daily ration, feeding periodicity, and prey selection of sauger (*Stizostedion canadense*) in the Ohio River. M. S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg.

Wolfert, D. R. 1969. Maturity and fecundity of walleyes from the eastern and western basins of Lake Erie. Journal of the Fisheries Research Board of Canada 26:1877-1888.

ACKNOWLEDGMENTS

The skill, diligence, and dedication of technicians Ron Schwerdtfegger and Pat Cramer is gratefully acknowledged. We thank the numerous DNR and UW employees that volunteered their time to help with fish sampling in 1987. Without their help, much of this work would have been impossible. We are also grateful to the Southern District Operations Crew for their hard work and dedication during spring netting for northern pike eggs, and during walleye rearing and stocking. Bill Jaeger generously provided most of the field gear used in the first year of this study. We applaud the commitment to improving fishing in the Madison Area shown by a legion of local anglers represented by such clubs as the Yahara Fisherman's Club, Capital City Muskies Inc., Four Lakes Bassmasters, Madison B.A.S.S., Dane County Conservation League, Lake Mendota Fishing Association, and the Madison Fishing Expo. Mike Michaels, Charlie Grimm, Norm Hess, Bob Sabroff, and Marv Contney deserve special thanks for their help with the fin-clipping of 23,000 perch in May 1988 and the other members of the Yahara Fisherman's Club that helped is greatly appreciated. We appreciate the cooperation of Ken Koscic in altering spring lake levels. This project was funded in part by the Federal Aid in Sport Fish Restoration Act under project F-95-P and the Wisconsin Department of Natural Resources.

ABOUT THE AUTHORS

Brett Johnson is currently an Assistant Professor with the Department of Fishery and Wildlife Biology at Colorado State University. During 1987-1992, he worked as the fisheries biologist in charge of the Madison Lakes Project with the Wisconsin Department of Natural Resources. Brett received B.S. and Ph.D. degrees from the University of Wisconsin-Madison and a M.S. degree in Zoology from the Ohio State University.

Scot Stewart is the Area Fisheries Supervisor for the Madison Area with the Wisconsin Department of Natural Resources. His responsibilities include managing lakes and streams in the four county area around Madison and supervising fisheries biologists and technicians also stationed in the Madison Area. Scot received a B.S. in Fisheries Biology from the University of Minnesota and an M.S. in Fisheries Management from the Ohio State University.

Steve Gilbert is currently a fisheries biologist with the Wisconsin Department of Natural Resources in Woodruff. He previously worked as a project technician on the Madison Lakes Project. Steve received a B.S. degree from the University of Wisconsin-Stevens Point.