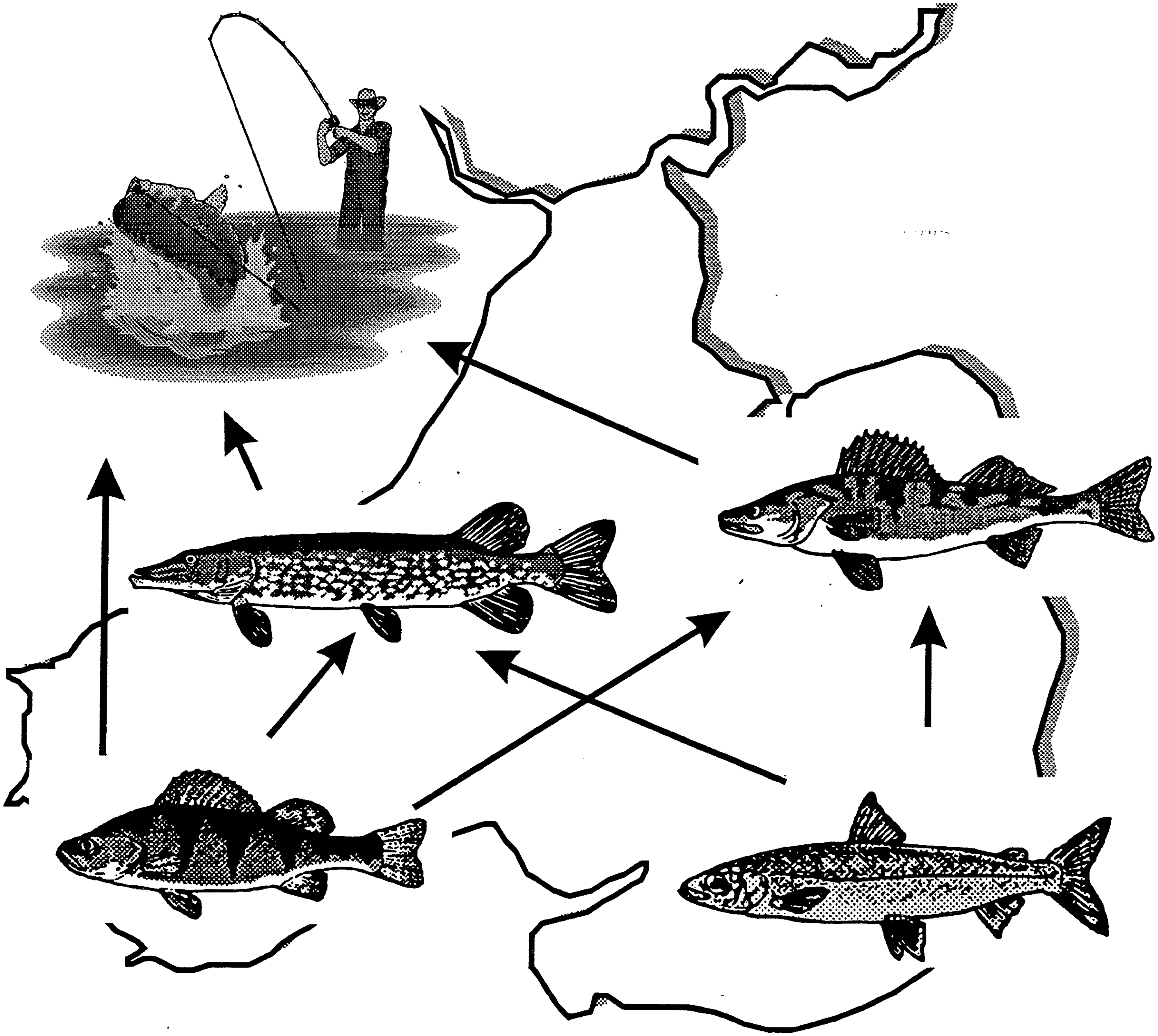
Ecology of Fishes in the Madison Lakes, 1987



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

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ABSTRACT. — The Madison Lakes Project was initiated in 1987. Work in 1987 focused on Lake Mendota, the largest of the four Yahara chain of lakes. At this time, adult predator density in Lake Mendota was low. Population estimates of adult walleye, northern pike, and largemouth bass combined totaled less than 1 fish/acre. About 75% of the walleye population was under 15 inches. A continuous creel survey estimated that 36,399 boat trips and 44,990 shore or ice fishing trips were made on the lake during January-September, 1987. Walleyes comprised 44% (7,182 fish) of the predator catch, and yellow perch comprised 64% (273,194 fish) of the non-predator catch. During winter, catch and harvest rates of walleye were higher during 23:00-07:00 h than daytime rates. There was no difference in day or night catch rates in summer, and there was no night harvest of walleye in summer. Walleye and northern pike populations have been maintained by stocking during the last 10 years; however, natural reproduction has been documented occasionally during this period. In 1987, 20.1 million walleye fry and 647,540 walleye fingerlings were stocked. About 11 million northern pike fry and 23,434 northern pike fingerlings were also stocked. Population estimates for 11-15 inch walleye marked and recaptured in fyke nets were different from independent estimates computed using gill nets to recapture fish marked in fyke nets. Mark-recapture estimates of age-0 walleye and smallmouth bass in fall did not seem to be accurate, possibly due to insufficient mixing of marked and unmarked populations. Spring fyke net length frequencies overestimated relative abundance of walleye >11 inches and largemouth bass > 15 inches and underestimated abundance of walleye < 11 inches, largemouth bass < 15 inches, and northern pike < 26 inches. The reverse was true for walleye sampled with an electroshocker. Electroshocker size selectivity for northern pike and largemouth bass was unclear. Gillnets were effective for sampling adult walleye in summer for diet data and recapture samples. Highest walleye catch rates occurred in depths of 21-30 ft in June, and < 10 ft in July and August. Shoreline seining for young-of-year (YOY) of all species had low catch-per-effort (CPE). Fall electroshocker CPE of age-0 predators was highly variable. The GIFSIM fishery model predicted dramatic improvements in the walleye fishery as a result of the stocking program and special harvest regulations that were established January 1, 1988. By 1992, walleye biomass is predicted to increase by 109% and 73%, respectively. Under the size limit constraints and with the stocking programs of 1987 and 1988, walleye reproductive potential should double by 1992. From predictions of the fishery model combined with a bioenergetics model, maximum planktivore consumption by walleye stocked in 1987-1989 will occur after 1991. Because of time lag, maximum effects of the biomanipulation project will likely be realized after 1991.

INTRODUCTION

Biomanipulation theory predicts that: 1) as the biomass of top predator fish 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 (Kitchell et al. 1986, Carpenter et al. 1985, Shapiro and Wright 1984). To apply biomanipulation and study the resultant interactions among trophic levels, WDNR's Bureau of Fisheries Management and UW's Center for Limnology jointly undertook a 5-year research project in 1987 — the Madison Lakes Project (MLP).

This report summarizes MLP's first year, including:

- population data,
- predicted changes in the sport fishery and in the total biomass of prey consumed,
- stocking and harvest regulations to increase walleye, *Stizostedion vitreum vitreum*, and northern pike, *Esox lucius* 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 Lake 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 gamefish are walleye, northern pike, largemouth bass, *Micropterus salmoides*, and smallmouth bass, *Micropterus dolomieui*.

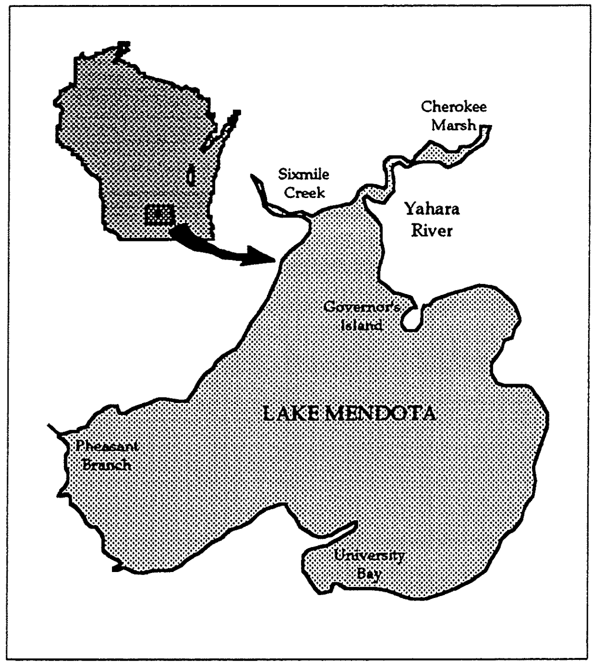

Figure 1. Location of Lake Mendota with associated local landmarks.

METHODS

POPULATION DATA

Fish Sampling

Various methods provided fish sampling data (Table 1). Fykenetting began on 17 March 1987 and continued for 5 weeks, followed by electrofishing for 17 nights. For 1 week/month, May-August, experimental gillnets were used, and at 20 sites/month June-September seining samples were taken. In early September, electrofishing ensued for another 18 nights.

The UW-Madison's Center for Limnology analyzed the stomach contents collected from electroshock- and gillnet-sampled predators. 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.

Fykenetting occurred daily 17 March - 24 April 1987, sampling 48 sites altogether. Fykenets 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. Sampling began at northern pike spawning areas (Cherokee Marsh, Sixmile Creek, Pheasant Branch Creek, and University Bay). Then, as northern pike catch-per-effort (CPE) declined, sampling targeted walleye along Lake Mendota's rocky shorelines.

Data collected from daily adult predator sampling included sex, reproductive condition, weight, total length, and pre-existing marks. Researchers scale-aged 10 fish/sex/inch-group — taking scales from the left nape of northern pike and hybrid muskellunge, *Esox lucius x Esox masquinongy*, and from behind the left pectoral fin of largemouth bass, smallmouth bass, and walleye. For age estimate comparisons, the second dorsal spine was also removed from scale-sampled walleye >20 inches. For estimating population, validating age and growth, and determining exploitation rates, researchers inserted yellow Floy T-bar tags — with 55-mm collars and 20-mm leaders — under left dorsal fins. However, because of stress to the fish, only the larger ones were tagged: largemouth bass >8 inches; smallmouth bass >9 inches; walleye >11 inches; and northern pike, hybrid muskellunge, longnose gar, *Lepisosteus osseus*, bowfin, *Amia calva*, and channel catfish, *Ictalurus punctatus*, >12 inches. Tagged fish had left ventral fins clipped to monitor tag loss — and walleye <11 inches, although untagged, also had left ventral fins clipped, to enable a mark-recapture population estimates.

Data collected from weekly non-predator sampling indicated size structure and abundance. Researchers recorded the weight and total length of 20 fish/species/net, scale-aging 10 fish/inch-group — except for yellow perch, for which researchers scale-aged 10 fish/sex/inch-group because the sexes were distinguishable. The remaining fish were counted. Electrofishing enabled us to continue tagging and to recapture fish tagged in fykenetting, to mark and recapture walleye <11 inches, and to gather walleye <12 inches for stomach content analysis. Three-person crews electrofished after sunset 15 April - 4 June. They used a standard WDNR electrofishing boat, set at 300 volts and 2.5 amps

Table 1. Common and scientific names and abbreviations for species mentioned in this report, and sampled in Lake Mendota during 1987. Predators are those species that were considered to be important predators on planktivorous fish or piscivorous species for which background population data were needed. Non-predator species include all other species sampled.

Common name	Scientific name	Abbreviation
PREDATORS		
Northern pike	*Esox lucius*	NPIKE
Hybrid musky	*E. lucius x E. masquinongy*	HMUSK
Largemouth bass	*Micropterus salmoides*	LMBAS
Smallmouth bass	*M. dolomieu*	SMBAS
Walleye	*Stizostedion vitreum*	WALLE
Channel catfish	*Ictalurus punctatus*	CHCAT
Longnose gar	*Lepisosteus osseus*	LNGAR
Bowfin	*Amia calva*	BOWFN
NON-PREDATORS		
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 promelas*	BLUNT
Creek chub	*Semotilus atromaculatus*	CCHUB
Spottail shiner	*Notropis hudsonius*	SPOTT
Bigmouth buffalo	*Ictiobus cyprinellus*	BBUFF
Whiter sucker	*Catostomus commersoni*	WHSUC
Black bullhead	*Ameiurus melas*	BLBUL
Brown bullhead	*Ameiurus nebulosus*	BRBUL
Yellow bullhead	*Ameiurus natans*	YBULL
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* sp.	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

(mean) DC, with a 20% duty cycle and 60 pulses/second. On all but two sampling dates two people netted fish; thus, CPE data are catch/two-netter hour or mile. Shocking was divided into stations. 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-min topographic maps (published in 1983). We used a cartometer to develop a standardized shoreline mileage numbering scheme. 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. Predators were handled as during fykenetting, except that sampling for stomach content analysis was added. Non-predator species were only collected to complete scale-length group subsamples.

The three-person crews began electro-shocking again on 8 September. Autumn electro- shocking had several objectives: to gather CPE data for comparison with previous surveys of the lake; to develop a database for relating autumn electroshocking CPE to predator density; to collect autumn predator diet data; to 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*. Predators tagged in autumn did not receive a finclip. This allowed us to distinguish fish marked in autumn from fish marked in spring for spring-to-spring population estimates. Tag loss rate computed for finclipped fish was applied to recaptures of autumn-tagged fish for autumn estimates.

Gillnetting -- With the help of WDNR's Bureau of Research, experimental gillnets were fished May through August. Gillnet sampling was used 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.

Seven nets were set on the bottom at each of ten lake sectors at dusk each day and were lifted the following morning. One day was sampled in May (19) and four days each in June (8-11), July (13-16), and August (10-13) (Table 2). All nets were constructed of five panels of differing mesh size, each panel either 10 or 25 ft long. Mesh stretch measure was 1-3 inches (0.5-inch increments) or 4-8 inches (1-inch increments). Nets were either 3 or 6 ft high; 3-ft nets were set in the shallowest water sampled. Because of low walleye density and expected low capture probability, net locations were not randomly determined. Rather, to maximize catch, nets were placed in "classical" walleye habitat: reefs and drop offs steeper than 8 ft of depth per 100 ft of horizontal distance.

In each sector, May-June, two 100-ft nets and one 125-ft net were set in a line starting at the 15-ft depth contour. After a net was set, the next net in the sequence was placed starting at the next deeper multiple of 5-ft depth contour. Mesh size was randomized with respect to depth. We set two complements of net in this arrangement at each sector. The seventh net was 125 ft long and was placed in deeper water between the two shallow sequences.

Temperature -- Dissolved oxygen profiles (R. Lathrop, Wis. Dep. Nat. Res., pers. comm.) were used to monitor the development of the thermocline and guide net placement July-August. After the thermocline was established, the same sequence of nets was set starting at the 6-ft depth contour and running out to the 30-ft contour, which was the maximum depth with dissolved oxygen >1 ppm. Nets that would have been placed deeper than 30 ft were placed arbitrarily in water <30 ft deep. In August, some 50-ft nets were suspended above the thermocline (Table 2) to develop techniques for sampling pelagic walleye. The bottom of each suspended net was 26 ft below the surface in water >30 ft deep.

Stomachs from dead predators were preserved in 10% formalin, and a stomach pump was used to remove stomach contents from live fish. All predators were measured and weighed. We measured 20 fish of other species/net/mesh size, and counted the remaining fish.

Table 2. Length (feet) of experimental gillnet (1-8 inch stretch mesh; 3-6 ft. high) set on bottom, reef, and pelagic habitat in Lake Mendota during May-August, 1987. Pelagic sets were nets suspended on the top of the thermocline (only set in August). Days is the number of days gillnets were fished per month.

		Bottom sets		Reef Sets		Pelagic sets		Total
Month	Days	Length	Depth Range	Length	Depth Range	Length	Depth Range	Length of net
May	1	450	15-45	325	16-42	0	-	775
June	4	4,575	15-60	1,625	13-58	0	-	6,200
July	4	4,550	6-46	1,650	10-35	0	-	6,200
August	4	2,000	6-56	200	14-53	600	30-60	2,800
Total	13	11,575	6-60	3,800	10-58	600	30-60	15,975

Seining -- Monthly shoreline seining surveys were conducted June-September to estimate year-class strength, relative abundance, and size structure of the littoral zone fish community. Twenty sites that were comparable to seine sites used in previous surveys were sampled. Sites included various substrate types and macrophyte densities. Seine hauls were made with a 25-ft bag seine with 1/8-inch mesh pulled perpendicular to shore starting from a 1-m depth. Average area seined was 105.3 m^2. Twenty fish/species were measured from each haul, and any additional fish were counted.

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. shifts and two 3-7 a.m. shifts were sampled per month to estimate the same parameters during nighttime hours.

During the ice-fishing season (January-February), 22 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 (March-December), 13 access points were sampled; 10 were boat ramps and 3 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 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 percentage 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 >20 fish/non-predator species/day.

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 gear for recaptures to minimize bias due to gear selectivity. This was impossible for the spring estimate of walleye >11 inches. Although many large walleye were caught during fykenetting, few were caught during electroshocking, so the last 7 days of the fykenetting period were used as the recapture run. This fykenet recapture estimate was compared to an estimate using gillnets for recaptures. All autumn estimates were based on electroshocking recaptures.

In spring, all predators that were tagged received a permanent finclip. Also in spring, walleye <11 inches were given a permanent left ventral finclip in case a mark-recapture estimate could not be obtained from spring sampling only. After obtaining the spring small walleye estimate, we did not use permanent finclips on any untagged fish to avoid confounding tag loss rate estimates. No other small predators were marked in spring.

Fish tagged in the autumn were not finclipped so they could be distinguished from fish marked in the spring when spring-to-spring estimates and annual mortality estimates were done. Recaptures for all but the autumn large predator estimate were finclipped fish; thus, tag loss rate was not required for population estimates. Walleye, largemouth and smallmouth bass, and northern pike that were too small to tag during autumn electrofishing were given a temporary top-of-tail caudal finclip. Subsequent runs during autumn electrofishing provided the recapture sample.

Whenever the number of recaptures was sufficient, we made 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.

Marking and recapture effort was not randomized with respect to location because of multiple objectives for fykenetting and electrofishing sampling. To maximize catch, fykenets were placed in the tributary inlets and shorelines we considered to be good spawning habitat. To develop electrofishing index stations, we shocked the entire lake shoreline at least twice in spring and again in autumn. Because marking effort with both gear types was widely distributed around the lake, mixing of marked and unmarked fish should have been good. Thus, bias in estimates from non-random sampling should be minimal.

We conducted mark-recapture experiments in spring and autumn by making 2.5 complete laps of the lake shoreline with an electroshocker. This required 17-18 nights of sampling. We released marked fish at the end of each transect. Most estimates were computed using Chapman's modification of the Petersen formula. Chapman's modified Schnabel estimate was also used on small walleye in spring and autumn, and on small smallmouth bass in autumn. Confidence limits (95%) were computed by considering recaptures, R, as a Poisson variable. Values for R from Ricker (1975) were substituted in formulae to obtain confidence limits.

Because we were able to make separate population estimates by size class, 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 that included recaptured fish found in fykenets and the boomshocker. 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 Cherokee Marsh and Sixmile Creek. Northern pike fingerlings were scattered in the littoral zone. We stocked walleye fry at least 0.25 mi from shore. About 50% of the fry were stocked in areas of high zooplankton density, determined by systematic plankton tows made around the lake (R. Lathrop, Wis. Dep. Nat. Res., pers. comm.). To avoid possible concentrations of fry-eating predators near zooplankton, the remaining walleye fry were stocked in other areas of the lake, at least 0.25 mi from shore. Walleye fingerlings were stocked 8 June - 9 July, and on 26 September. Fish were scattered throughout the littoral zone, in areas with macrophytes.

We used a Miller high speed ichthyoplankton sampler on 7 May to determine if naturally produced walleye fry existed. We made eight 5- to 20-min hauls during the day, and nine 10-min hauls that night. In all, four hauls were made at 0.5 m, five hauls at 1.0 m, four hauls at 2.0 and 3.0 m, and three hauls at 5.0 m – for a total volume sampled of 662 m^3.

The potential production of native walleye fry was determined to study the importance of stocking (fry or fingerlings) to maintaining Lake Mendota's walleye population and to examine reasons for the near lack of observed natural reproduction over the previous 10 years. The biomass of female walleye was computed from length-class population estimates and length-weight regressions. The biomass of eggs produced was then estimated assuming a maturity schedule of: 0% for age-3 and younger, 58% for age-4, and 100% for age-5 and older (Forney 1976, Wolfert 1969) and an average fecundity of 64,400 eggs/kg of mature female biomass (Serns 1982, 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 1 January 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

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 and natural mortality are conditional mortality rates occurring in each simulation period.

Population Statistic	Simulation Period	Sex	Age-class (years)							
			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	11.0	13.0	10.0	11.0	10.0	12.0	19.0
	Mar 2-May 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May 2-Nov 15		0.0	22.0	18.0	20.0	12.0	13.0	15.0	4.0
	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	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
	Mar 2-May 1		5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0
	May 2-Nov 15		14.0	14.0	12.0	12.0	12.0	12.0	12.0	12.0
	Nov 16-Dec 31		3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0

improving 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 walleye from 5 to 3 fish/day and created a minimum length limit of 15 inches. The bag limit on northern pike was reduced from 5 to 1 fish/day, and the minimum length limit became 32 inches. 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 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 1 January - 1 March and covered the legal ice-fishing season. The closed season, 2 March - 6 May, was period 2 in our simulations. Period 3 was 7 May - 15 November and was the openwater season before the late-autumn decline in fishing pressure. Period 4 was 16 November - 31 December, 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 experiments and scale samples, respectively. The proportion of annual growth increment occurring in each period was greatest in period 3 (Table 3). The model used sex-specific length-weight regressions (weight in g; total length in mm) to convert lengths to weights for biomass and yield estimates:

Males: Wet weight = 0.0000023 * Length (3.230)
$R^2 = 96.9$, N = 238, $P < 0.0001$

Females: Wet weight = 0.0000022 * Length (3.250)
$R^2 = 85.8$, N = 204, $P < 0.0001$.

Exploitation rates by age-class 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 openwater-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 walleye 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 vs. 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.

To simplify interpretation of model predictions, we modeled a constant annual recruitment, resulting only from stocking. We used a value of 8,000 yearlings/year, based on the mark-recapture population estimate of YOY walleye 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 walleye. Estimates of these different levels were made by inputing the population structure derived from GIFSIM into a bioenergetics model (Hewett and Johnson 1987) The bioenergetics model estimates the biomass of food consumed by a predator from observed growth, physiological constants, and the thermal history of the predator. In addition to GIFSIM population structure, the bioenergetics model requires data on: thermal history of walleye 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.

Thermal history was most critical in summer because Lake Mendota is thermally stratified May-August (Lathrop et al. 1989) and a range of temperatures are available to the fish. We used walleye catch in experimental gillnets stratified across habitat types and depths to determine depth distribution and, hence, temperatures experienced by the fish. Nets were fished a total of 13 days May-August 1987. Prey selection was determined from analysis of stomach contents from walleye 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/gram wet weight) of walleye and yellow perch were obtained from Hewett and Johnson (1987).

RESULTS AND DISCUSSION

POPULATION DATA

Fish Sampling

Fykenetting. -- Walleye dominated fykenet catch. A total of 1,431 walleye were caught in fykenets 17 March - 23 April (713 net-days) and 831 were tagged. Average total walleye catch/net-day was 2.0, or about 2.7 times higher than the 0.73/net-day observed for the second most numerous species in fykenets, northern pike. We captured 520 northern pike and tagged 399 of them. We also caught 209 largemouth bass (174 tagged), 176 bowfin (145 tagged), 106 channel catfish (93 tagged), 93 smallmouth bass (90 tagged), 20 hybrid muskellunge (17 tagged), and 14 longnose gar (13 tagged). Predators sampled in fykenets provided the majority of the scale samples used to estimate growth (Table 4). We were able to determine growth by sex only for walleye, northern pike, and yellow perch, because sexes were not easily distinguishable for other species. The need to validate ages based on scales has recently been re-emphasized (Carlander 1987, Beamish and McFarlane 1983). Future recaptures of tagged fish and completion of aging spine sections should provide validation of the aging techniques used here.

Spring length-weight relationships for predators (Table 5) were computed from fish sampled in fykenets. Separate regressions were made for each sex, and by reproductive condition for females, whenever possible. Regression equations developed for females before and after spawning will be useful for estimating proportions of body weight that is lost as eggs, a quantity of interest in bioenergetics modeling. The coefficient of determination (R^2) was always >90%, and usually >95% for all regressions.

Fykenets set during the spring spawning run are size-selective (Ricker 1975), and size distributions of fish in fykenets are biased. We discuss the

Table 4. Age (from scales) and growth of some fishes in Lake Mendota. Fish were aged separately by sex whenever possible (F, M, and U are female, male, and unknown respectively). Scales were collected during fyke netting from March 17 to April 23, 1987. Some centrarchid scales were also collected during electrofishing from April 15 to June 4, 1987.

Species	Sex	Age	Mean Length (inches)	Standard Error	N	Mean Weight (grams)	Standard Error	N
Walleye	F	1	-	-	0	-	-	0
		2	-	-	0	-	-	0
		3	13.2	-	1	396	-	1
		4	16.4	0.3	4	647	45	3
		5	20.9	0.5	6	1,507	107	6
		6	22.4	0.6	6	2,202	174	6
		7	23.7	0.4	8	2,445	52	8
		8	24.4	0.4	11	2,796	132	11
		9	25.7	0.5	14	3,326	209	13
		10	27.3	0.3	21	3,938	157	21
		11	28.2	0.2	2	3,870	156	2
Walleye	M	1	-	-	0	-	-	0
		2	12.1	0.2	19	272	15	18
		3	13.9	0.2	23	417	23	22
		4	15.8	0.3	12	605	42	11
		5	16.5	0.2	13	729	39	12
		6	18.6	0.4	7	949	72	6
		7	20.4	0.4	12	1,399	39	11
		8	21.8	0.4	13	1,756	143	13
		9	21.7	0.2	6	1,720	78	6
		10	23.0	0.6	4	2,006	121	4

Table 4. (continued)

Species	Sex	Age	Mean Length (inches)	Standard Error	N	Mean Weight (grams)	Standard Error	N
Walleye	U	1	7.5	0.2	38	71	3	26
		2	11.3	0.2	37	214	12	34
		3	14.1	0.2	22	418	25	21
		4	15.5	0.9	13	665	57	13
		5	18.9	0.3	8	1,020	17	5
		6	19.6	0.6	8	1,237	180	8
		7	20.8	0.3	4	1,574	232	4
		8	25.3	-	1	2.381	-	1
		9	26.9	0.6	2	4,026	171	2
Northern pike	F	1	14.5	-	1	310	-	1
		2	17.9	0.5	16	629	58	15
		3	23.7	0.4	36	1,465	106	26
		4	29.9	0.5	33	2,884	214	22
		5	33.7	0.4	22	4,410	201	15
		6	37.5	1.9	3	5,613	908	3
		7	39.1	1.1	2	6,011	458	2
		8	40.7	0.4	2	7,314	401	2
Northern pike	M	1	11.0	0.3	5	122	8	4
		2	17.8	0.3	57	574	36	50
		3	22.3	0.3	44	1,091	48	40
		4	25.0	0.4	13	1,528	92	11
		5	27.6	0.3	9	2,130	121	5
		6	29.0	-	1	2,155	-	1
		7	-	-	0	-	-	0
		8	30.1	-	1	-	-	0
Northern pike	U	1	11.7	0.4	20	147	17	19
		2	18.4	0.7	20	683	106	17
		3	22.6	0.9	7	1,215	170	7
		4	26.9	3.1	3	1,947	728	3
Hybrid musky	M	1	9.6	-	1	60	-	1
		2	17.2	0.6	5	399	74	4
		3	20.0	0.5	5	690	78	3
		4	-	-	0	-	-	0
		5	-	-	0	-	-	0
		6	33.8	0.5	9	3,444	206	4
		7	38.5	-	1	6,804	-	1
Largemouth bass	U	1	5.4	0.2	20	38	3	7
		2	9.2	0.1	14	199	10	11
		3	11.6	0.4	13	380	45	12
		4	13.4	0.2	23	623	33	21
		5	16.0	0.2	22	1,093	58	16
		6	16.8	0.5	6	1,375	138	4
		7	18.3	0.1	8	1,820	104	5
		8	18.8	0.3	4	1,985	-	1
		9	20.1	0.2	4	2,523	144	2
		10	20.1	0.1	2	2,438	114	2
		11	21.0	-	1	2,608	-	1
		12	22.0	-	1	3,515	-	1

Table 4. (continued)

Species	Sex	Age	Mean Length (inches)	Standard Error	N	Mean Weight (grams)	Standard Error	N
Smallmouth bass	U	1	4.4	0.1	12	-	-	0
		2	8.3	0.2	23	-	-	0
		3	12.0	0.2	21	438	35	15
		4	14.0	0.2	26	687	37	25
		5	15.7	0.3	6	1,180	152	3
		6	17.5	0.1	7	1,563	52	7
		7	18.2	0.3	2	1,842	143	2
Yellow perch	M	1	-	-	0	-	-	0
		2	6.3	0.1	25	49	4	25
		3	8.0	0.1	6	100	8	6
		4	8.8	0.2	10	146	8	10
		5	8.9	-	1	140	-	1
Black crappie	U	1	3.8	0.1	19	37	7	5
		2	6.3	0.1	27	59	4	24
		3	7.8	0.2	5	123	14	4
		4	9.0	0.1	15	187	7	15
		5	10.1	0.2	10	315	12	9
		6	10.6	0.1	6	353	10	6
		7	11.2	0.2	2	-	13	2
White crappie	U	1	4.2	-	1	-	-	0
		2	6.8	0.1	3	67	7	2
		3	8.7	0.1	6	136	10	6
		4	9.4	0.1	9	189	9	9
		5	10.5	0.2	10	240	18	9
		6	11.6	0.3	5	346	22	5
		7	12.8	0.3	5	496	45	4
White bass	U	1	5.5	0.3	8	29	5	7
		2	10.3	0.7	3	261	59	2
		3	12.1	0.2	34	354	17	34
		4	14.9	0.6	4	611	128	3
Yellow bass	U	1	4.8	0.2	10	32	2	2
		2	7.1	0.1	5	72	6	4
		3	8.7	0.1	14	150	6	11
		4	9.8	0.5	6	260	72	4
		5	10.0	0.2	2	250	6	2
Bluegill	U	1	2.1	0.1	16	-	-	0
		2	4.6	0.1	21	24	4	10
		3	5.9	0.2	9	60	2	2
		4	6.9	0.1	11	113	14	3
		5	7.9	0.1	11	201	8	7
		6	8.8	0.1	6	251	11	6
		7	9.2	-	1	304	-	1
Rock bass	U	1	-	-	0	-	-	0
		2	-	-	0	-	-	0
		3	5.5	0.3	3	57	12	3
		4	6.4	0.2	15	87	7	13
		5	7.7	0.1	10	154	11	9
		6	8.4	0.3	5	216	16	5
		7	9.8	-	1	380	-	1

Table 4. (continued)

Species	Sex	Age	Mean Length (inches)	Standard Error	N	Mean Weight (grams)	Standard Error	N
Pumpkinseed	U	1	-	-	0	-	-	0
		2	5.0	0.1	7	65	7	5
		3	5.8	0.2	6	70	9	6
		4	6.4	0.2	7			

extent of this bias later; however, some general characterizations of population size structure were possible.The size distribution of walleye caught in fykenets appeared tri-modal, with modes of 7, 12, and 27 inches (Fig. 2). These modes correspond to 1986, 1985, and 1977 year-classes. Few fish in the 14- to 24-inch range were caught in fykenets. No fish >29 inches were caught. Size distributions of walleye, northern pike, and hybrid muskellunge (Fig.3) indicate the importance of fingerling stockings to Lake Mendota's predator populations over the last 10 years. Northern pike in fykenets ranged from 9 to 41 inches. The only distinct mode was 23 inches, which corresponds to the 1984 year-class. Small numbers of northern pike fingerlings (2,274-10,260) were stocked each year since 1981; none were stocked before 1981. Earlier year-classes would have been larger than 38 inches and appear to be under represented in fykenet catches. Four year-classes of hybrid muskellunge were caught in fykenets — 1980, 1981, 1985, 1986 — but these are the only years in the last 20 years when hybrids were stocked. It is encouraging that all stockings were represented in fykenets, even though only 1,500-10,000 fingerlings were stocked each year.

The size range of largemouth bass in fykenets was 5-22 inches, with a mode of 13 inches (Fig. 4). The modal length of smallmouth bass in fykenets was also 13 inches, and the size range was 10-18 inches. Based on electrofishing and gillnetting,

Table 5. Spring (fish collected in fyke nets) and fall (electrofishing) length- weight regressions for gamefishes in Lake Mendota, during March to November, 1987. F=female; M=males; A=females, males, and unknowns combined; U=unknown sex (in spring, usually immature fish). WT is wet weight in grams, MM is total length in millimeters.

Season	Species	Sex	Equation	R^2	N
Spring	Walleye	F[1]	Log_{10} WT = 3.168 (Log_{10} MM) - 5.400	96.5	41
(March 17 -	Walleye	A[1]	Log_{10} WT = 3.337 (Log_{10} MM) - 5.907	98.8	1001
April 23)	Walleye	M,U	Log_{10} WT = 3.314 (Log_{10} MM) - 5.850	98.6	959
	Npike	F[1]	Log_{10} WT = 3.200 (Log_{10} MM) - 5.771	97.6	19
	Npike	F[2]	Log_{10} WT = 3.210 (Log_{10} MM) - 5.843	98.4	25
	Npike	M	Log_{10} WT = 3.043 (Log_{10} MM) - 5.345	95.1	180
	LMbass	M,U	Log_{10} WT = 3.258 (Log_{10} MM) - 5.463	98.6	175
	SMbass	M,U	Log_{10} WT = 3.284 (Log_{10} MM) - 5.536	90.5	78
Fall	Walleye	A	Log_{10} WT = 3.163 (Log_{10} MM) - 5.499	96.3	629
(Sept. 8 -	Npike	A	Log_{10} WT = 3.089 (Log_{10} MM) - 5.511	97.8	77
Nov. 4)	LMbass	A	Log_{10} WT = 3.260 (Log_{10} MM) - 5.443	98.6	112
	SMbass	A	Log_{10} WT = 2.986 (Log_{10} MM) - 4.823	96.9	112
Spring	Walleye	F	Log_{10} WT = 3.249 (Log_{10} MM) - 5.649	85.8	204
through	Walleye	M	Log_{10} WT = 3.232 (Log_{10} MM) - 5.632	96.9	238
Fall	Walleye	U	Log_{10} WT = 3.221 (Log_{10} MM) - 5.631	97.4	1351
(March 17 - Nov. 4)	Walleye	A	Log_{10} WT = 3.298 (Log_{10} MM) - 5.808	98.8	1795

[1] Weighed before fish spawned.

[2] Weighed after fish spawned.

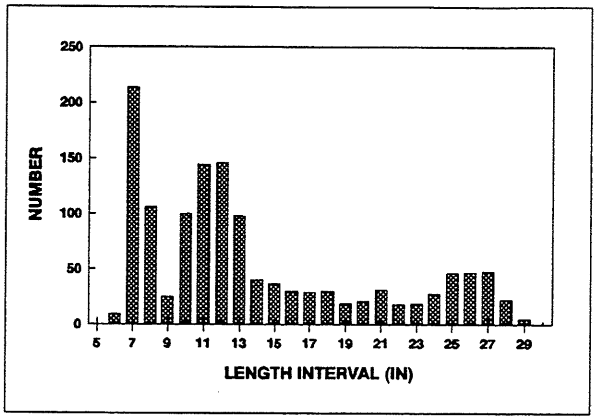

Figure 2. Length-frequency of walleyes sampled in fyke nets during March 17 - April 23, 1987, in Lake Mendota.

estimates are that smallmouth bass <10 inches are probably equally or more abundant than largemouth bass <10 inches. Thus, small smallmouth bass do not appear to be as vulnerable to fykenets as small largemouth bass. Also, fewer than half as many smallmouth bass of all sizes were caught in fykenets. Population estimates of smallmouth bass could not be made. Assuming equal vulnerability to angling, creel catch estimates and information from experienced bass anglers suggest that smallmouth bass are more numerous than our sampling indicates, possibly more numerous than largemouth bass.

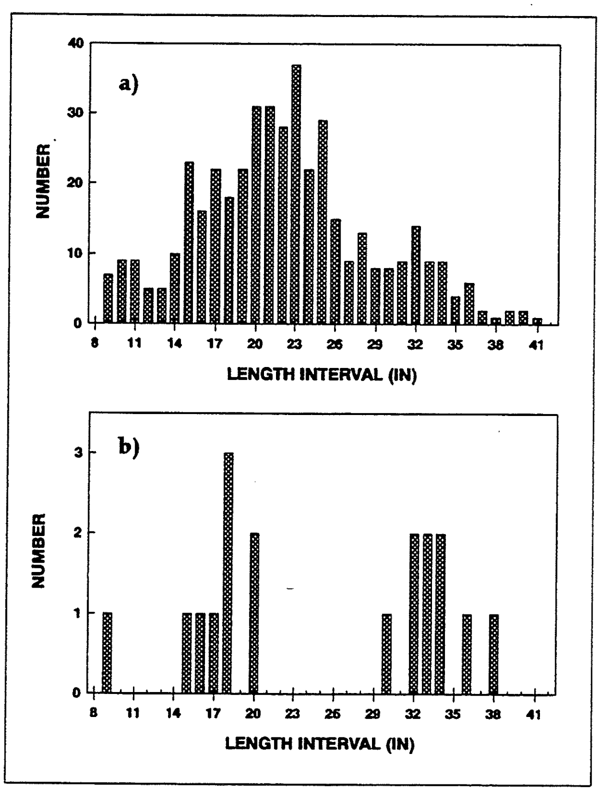

Figure 3. Length-frequency of a) northern pike (upper panel) and b) hybrid muskellunge (lower panel) sampled in fyke nets during March 17 - April 23, 1987, in Lake Mendota.

We recorded data on non-predator species caught in fykenets 1 day/week, 17 March - 23 April. A total of 15 species were sampled on at least 2 of the 5 days when data were gathered (Table 6). Yellow perch, bluegill, black crappie, *Pomoxis nigromaculatus*, and white bass, in that order, were the most abundant non-predator species in fykenets. Average catch/net-day of each species over the entire netting period was >3.0 fish/net-day.

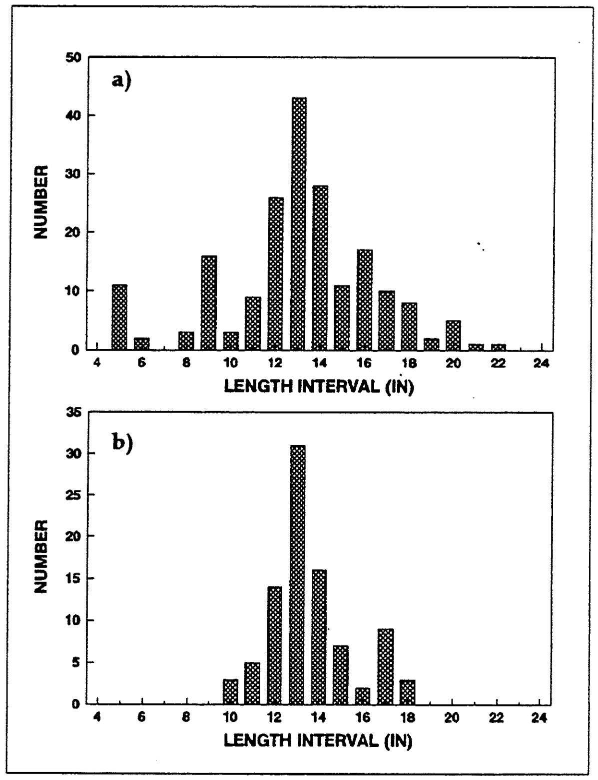

Figure 4. Length-frequency of a) largemouth bass (upper panel) and b) smallmouth bass (lower panel) sampled in fyke nets during March 17 - April 23, 1987, in Lake Mendota.

Yellow perch catch increased through the netting period, presumably due to the onset of spawning near the end of the netting period. Bluegill and black crappie catch declined 17 March - 23 April, and no temporal trend was evident for other species. The coefficient of variation (CV) in non-predator catch/net-day was >50% for all but two species, freshwater drum, *Aplodinotus grunniens* and golden shiner, *Notemigonus crysoleucas*. CV of catch of the four most abundant species was >80%, and was 162% for yellow perch.

Table 6. Total number of non-predator fish caught in fyke nets, number caught per net, and coefficient of variation (CV) in Lake Mendota, on five dates in 1987. Species are listed in decending order of abundance in fyke nets.

Species	Date	Total Number	Number of Nets	Catch Per Net	Mean Catch Per Net	CV (%)
Yellow perch	03/26/87	10	20	0.500		
	04/01/87	8	20	0.400		
	04/09/87	135	24	5.625	40.04	162.26
	04/16/87	831	20	41.550		
	04/23/87	2890	19	152.105		
Bluegill	03/26/87	457	20	22.850		
	04/01/87	136	20	6.800		
	04/09/87	159	24	6.625	8.89	90.56
	04/16/87	125	20	6.250		
	04/23/87	37	19	1.947		
Black crappie	03/26/87	246	20	12.300		
	04/01/87	107	20	5.350		
	04/09/87	100	24	4.167	5.22	80.82
	04/16/87	27	20	1.350		
	04/23/87	55	19	2.895		
White bass	03/26/87	65	20	3.250		
	04/01/87	38	20	1.900		
	04/09/87	49	24	2.042	4.47	83.73
	04/16/87	218	20	10.900		
	04/23/87	80	19	4.211		
Black bullhead	03/26/87	163	20	8.150		
	04/01/87	8	20	0.400		
	04/09/87	77	24	3.208	2.61	126.92
	04/16/87	16	20	0.800		
	04/23/87	9	19	0.474		
White sucker	03/26/87	29	20	1.450		
	04/01/87	15	20	0.750		
	04/09/87	10	24	0.417	1.32	56.11
	04/16/87	41	20	2.050		
	04/23/87	33	19	1.737		
Yellow bullhead	03/26/87	53	20	2.650		
	04/01/87	12	20	0.600		
	04/09/87	35	24	1.458	1.07	92.52
	04/16/87	7	20	0.350		
	04/23/87	6	19	0.316		
Brown bullhead	03/26/87	16	20	0.800		
	04/01/87	1	20	0.050		
	04/09/87	44	24	1.833	0.90	82.16
	04/16/87	29	20	1.450		
	04/23/87	7	19	0.368		
Rock bass	03/26/87	9	20	0.450		
	04/01/87	7	20	0.350		
	04/09/87	35	24	1.458	0.78	72.48
	04/16/87	21	20	1.050		
	04/23/87	6	19	0.316		

Table 6. (continued)

Species	Date	Total Number	Number of Nets	Catch Per Net	Mean Catch Per Net	CV (%)
White crappie	03/26/87	24	20	1.200		
	04/01/87	18	20	0.900		
	04/09/87	20	24	0.833	0.75	51.24
	04/16/87	3	20	0.150		
	04/23/87	13	19	0.684		
Common carp	03/26/87	16	20	0.800		
	04/01/87	38	20	1.900		
	04/09/87	4	24	0.167	0.73	116.20
	04/16/87	1	20	0.050		
Pumpkinseed	03/26/87	19	20	0.950		
	04/01/87	6	20	0.300		
	04/09/87	6	24	0.250	0.50	78.63
	04/16/87	18	20	0.900		
	04/23/87	2	19	0.105		
Freshwater drum	03/26/87	10	20	0.500		
	04/01/87	13	20	0.650		
	04/09/87	6	24	0.250	0.46	33.79
	04/16/87	8	20	0.400		
	04/23/87	7	19	0.368		
Yellow bass	03/26/87	4	20	0.200		
	04/01/87	31	20	1.550		
	04/09/87	2	24	0.083	0.43	147.21
	04/16/87	3	20	0.150		
	04/23/87	2	19	0.105		
Golden shiner	03/26/87	12	20	0.600		
	04/01/87	18	20	0.900	0.75	28.28

The high temporal variation in average catch/net-day probably precludes the use of spring fykenets set for predators as an index of absolute non-predator abundance in Lake Mendota. We will need to compare several years of spring fykenet data with information from other gear and the creel survey to determine if spring fykenets will be useful for evaluating relative abundance of non-predator species in the community.

The size structure of non-predator species in spring fykenets was far less variable than CPE, both through time and among regions of the lake. Primary and secondary modal lengths, estimated from length-frequency histograms, were consistent or within 1 inch for the four most abundant species sampled 1-23 April. CV of mean and modal lengths among 10 regions of the lake was <10% for three of the four most abundant non-predator species. The most variable was the modal length of black crappie, with a 20.3% CV (Table 7). Thus, spring fykenets do provide a consistent estimate of non-predator size structure, which does not vary greatly either through time or by location.

Although fykenets tend to capture larger fish, they may sample the population available to anglers. We could compare non-predator lengths in fykenets to mean lengths observed during the creel survey over several years to examine this relationship.

Seining.-- Shoreline seining was used to obtain information on non-predator populations during summer. June-July seine hauls yielded mostly bluntnose minnows (30%), yellow perch (15%), unidentified centrarchids (15%), and bluegill (13%) (Table 8). Mean length of all species but bluntnose minnow declined during June-July, possibly reflecting recruitment of YOY to the seine in July. August-September seine hauls contained mostly — brook silverside, *Labidesthes sicculus*, 36%; bluegill, 30%; pumpkinseed, *Lepomis gibbosus*, 14%; and yellow perch, 8%. During August-September, mean length

Table 7. Mean and modal lengths (inches) of the four most abundant non-predator species sampled in fyke nets in Lake Mendota during spring of 1987. Lake shoreline (including Cherokee Marsh) was divided into ten segments or regions. Region location is reported as shoreline mileage with 0.0 located at Tenney Locks. N is number of fish measured. Dash signifies that fewer than 3 fish were caught in the region. CV is coefficient of variation.

	Yellow perch			Bluegill			Black crappie			White bass		
Shoreline mileage	Mean length	Modal length	N	Mean length	Modal length	N	Mean length	Modal length	N	Mean length	Modal length	N
1.75-2.20	8.5	8.7	22	-	-	-	9.2	8.9	4	11.0	12.1	6
4.40-6.20	9.1	9.0	93	7.2	7.9	4	-	-	-	11.8	11.1	6
9.20-9.45	7.8	6.6	79	6.7	7.6	87	8.4	9.1	92	11.3	11.2	111
10.70-12.10	8.6	9.1	7	7.4	7.1	10	9.0	8.9	21	11.3	10.6	18
12.80-13.80	8.1	8.7	94	6.6	6.7	83	7.5	6.5	82	12.1	11.3	16
15.30-17.80	8.6	8.7	147	6.3	6.3	65	8.2	9.2	24	11.8	12.4	7
18.80-20.40	8.6	8.8	51	7.0	7.5	178	8.7	8.9	107	12.2	13.4	6
20.80-22.20	8.3	8.7	47	6.4	6.1	57	7.6	5.1	13	-	-	-
23.00-23.70	8.6	7.3	12	-	-	-	-	-	-	-	-	-
23.90-26.40	8.3	8.8	76	6.4	7.3	109	7.4	6.5	99	10.1	11.1	99
Mean	8.4	8.4		6.8	7.1		8.2	7.9		11.4	11.6	
Std. Dev.	0.4	0.8		0.4	0.6		0.7	1.6		0.7	0.9	
CV (%)	4.2	9.6		6.0	9.1		8.4	20.3		6.0	7.9	

Table 8. Catch (N), catch per haul, and length of species sampled in a 25-ft bag seine (1/8 inch mesh) used at 20 sites around Lake Mendota during June and July, 1987.

Date	Species	N	Catch Per Haul	Total Length (inches) Minimum	Maximum	Mean	Std Dev
6/26/87	Bluntnose minnow	75	3.75	0.6	2.7	1.9	0.41
	Unident. centrarchid	33	1.65	0.6	1.4	1.0	0.17
	Yellow perch	25	1.25	1.4	7.8	4.8	1.75
	Bluegill	15	0.75	1.8	7.0	2.9	1.44
	Unidentified fish	11	0.52	0.4	0.7	0.5	0.11
	Unidentified crappie	8	0.40	0.7	1.1	0.8	0.12
	Largemouth bass	4	0.20	0.9	2.2	1.4	0.58
	Pumpkinseed	3	0.15	3.4	5.9	0.9	1.26
	White sucker	3	0.15	1.2	1.5	1.4	0.14
	White bass	2	0.10	0.9	1.8	1.3	0.64
	Spottail shiner	2	0.10	1.1	1.2	1.1	0.11
	Walleye	2	0.55	2.4	3.3	2.8	0.67
	Yellow bass	1	0.05	5.1	5.1	5.1	-
7/21/87	Bluegill	20	1.00	0.7	5.7	1.5	1.49
	Yellow perch	15	0.75	2.2	5.9	2.6	0.93
	Unidentified crappie	9	0.45	1.2	1.9	1.5	0.27
	Unident. centrarchid	8	0.40	0.6	0.9	0.7	0.11
	Bluntnose minnow	6	0.30	2.0	2.7	2.4	0.24
	Largemouth bass	6	0.30	1.8	4.1	2.7	0.83
	Brook silverside	5	0.25	0.9	1.1	1.0	0.09
	White bass	4	0.20	2.3	2.4	2.3	0.07
	Yellow bass	2	0.10	2.1	4.1	3.1	1.45
	Smallmouth bass	2	0.10	2.1	2.2	2.1	0.08
	Unidentified shiner	1	0.05	2.3	2.3	2.3	-
	Common carp	1	0.05	2.2	2.2	2.2	-
	Yellow bullhead	1	0.05	1.3	1.3	1.3	-
	Rock bass	1	0.05	6.4	6.4	6.4	-
	Black crappie	1	0.05	1.5	1.5	1.5	-
	Johnny darter	1	0.05	1.4	1.4	1.4	-
	Logperch	1	0.05	2.4	2.4	2.4	-

of all these species increased (Table 9) suggesting that growth affected mean length in seine hauls more than recruitment in this period.

Because seine capture efficiencies vary greatly among species (Lyons 1986), CPE data alone cannot be used to estimate absolute or relative abundance of littoral species. Rather, it seems seine hauls might be more useful for comparing abundance of individual species through years. However, average catch/haul was low for all dates and species, with only a single species exceeding 2 fish/haul on any date. A more productive gear for assessing relative abundance of littoral zone fish should be examined. Mini-fykenets and purse seines will be evaluated in 1988 and 1989.

Table 9. Catch (N), catch per haul, and length of species sampled in a 25-ft bag seine (1/8 inch mesh) used at 20 sites (August) and 11 sites (September) around Lake Mendota during 1987.

			Catch	Total Length (inches)			
Date	Species	N	Per Haul	Minimum	Maximum	Mean	Std Dev
8/19/87	Bluegill	71	3.55	0.9	4.3	1.6	0.40
	Brook silverside	26	1.30	0.6	2.9	2.3	0.40
	Pumpkinseed	25	1.25	1.4	2.3	1.8	0.20
	Yellow perch	21	1.05	2.8	3.4	3.0	0.14
	Black crappie	13	0.65	1.9	3.0	2.4	0.35
	Largemouth bass	3	0.15	2.6	4.1	3.5	0.74
	Yellow bass	2	0.10	7.2	9.0	8.1	1.28
	Green sunfish	2	0.10	1.6	1.7	1.6	0.06
	Common carp	1	0.05	3.7	3.7	3.7	-
	Rock bass	1	0.05	3.8	3.8	3.8	-
	Smallmouth bass	1	0.05	3.7	3.7	3.7	-
	White crappie	1	0.05	2.3	2.3	2.3	-
	Logperch	1	0.05	2.6	2.6	2.6	-
9/23/87	Brook silverside	77	7.00	1.9	3.2	2.7	0.43
	Pumpkinseed	16	1.45	1.7	2.4	2.1	0.21
	Bluegill	15	1.36	1.3	2.0	1.7	0.20
	Logperch	2	0.18	3.2	3.3	3.2	0.08
	Smallmouth bass	1	0.09	3.8	3.8	3.8	-
	Largemouth bass	1	0.09	3.8	3.8	3.8	-
	Yellow perch	1	0.09	3.7	3.7	3.7	-
	Northern pike	1	0.09	10.1	10.1	10.1	-
	Common carp	1	0.09	4.8	4.8	4.8	-

Gillnetting. -- We used gillnetting to sample predators for food habits and distribution during summer. The catch rate of walleye in experimental gillnets set May-August was low. We caught a total of 48 walleye (Table 10) in 15,975 ft of gillnet, which was 0.30 walleye/100 ft of net/day. Low catch rates were expected given the low density of walleye in the lake. We would expect an even lower catch rate if net locations were selected at random. Random sampling will be necessary to determine the horizontal distribution of walleye. If these data are required, random sampling should be conducted in the future when walleye density is higher.

Walleye catch rate in May was highest (4.0 fish/100 ft) in the 11-20 ft depth range, and June catch rate was highest (0.394) in the 21-30 ft depth range. No nets were set shallower than 11 ft during May-June. July-August catch rate was greatest in bottom sets in water 6-10 ft deep. No fish were caught in water >31 ft deep July-August, presumably because there was <2.0 ppm dissolved oxygen below 31 ft beginning on 6 July 1987 (R. Lathrop, Wis Dep. Nat. Res., unpubl. data).

Although gillnets were the only method available of obtaining midsummer walleye growth and diet data required for bioenergetics modeling, this gear caused high mortality. Most of the walleye caught died (81%); delayed mortality of released fish is unknown. More walleye (34%) were caught in 2.5-inch mesh than any other mesh size. Equal proportions (13%) of walleye were caught in 2-, 4-, and 7-inch mesh nets, and <10% were caught in each other mesh size. Other studies (Wis. Dep. Nat. Res. 1984, Hamley and Regier 1973) have found that 2.5-

Table 10. Number of feet of experimental gillnet set, number of walleyes caught, and walleyes caught per 100 feet of gillnet per day, set in six depth intervals during May to August, 1987, in Lake Mendota.

Dates set		Depth (ft)	Feet of gillnet	Walleyes caught	Catch per 100 feet of net
May 19		0-10	0	-	-
		11-20	75	3	4.000
		21-30	131	0	0.000
		31-40	377	1	0.265
		41-50	192	0	0.000
		51+	0	-	-
	Total	All	775	4	0.516
June 8-11		0-10	0	-	-
		11-20	1,169	2	0.171
		21-30	1,521	6	0.394
		31-40	1,304	5	0.383
		41-50	1,742	1	0.057
		51+	464	0	0.000
	Total	All	6,200	14	0.226
July 13-16		0-10	1,405	12	0.854
		11-20	2,952	10	0.339
		21-30	1,599	1	0.062
		31-40	217	0	0.000
		41-50	27	0	0.000
		51+	0	-	-
	Total	All	6,200	23	0.371
August 10-13		0-10	683	5	0.732
		11-20	229	0	0.000
		21-30	1,270	2	0.157
		31-40	428	0	0.000
		41-50	156	0	0.000
		51+	34	0	0.000
	Total	All	2,800	7	0.250
May-August		All	15,975	48	0.300

inch mesh nets were effective for sampling walleye <14 inches total length and yet had relatively broad size selectivity. Future gillnetting on Lake Mendota should include 2.5-inch mesh nets. July-August sampling in water 6-10 ft deep appears to be most productive.

Electrofishing. -- Spring electrofishing was more efficient than fykenetting for sampling all tagging-sized predators except northern pike. On 17 trips, comprising 51 worker-days of electrofishing in spring, 377 walleye, 192 largemouth bass, and 53 smallmouth bass large enough to tag were caught. Catch/worker-day was lower for fykenetting, which required 195 worker-days to tag 831 walleye, 174 largemouth bass, and 90 smallmouth bass. However, spring electrofishing tended to sample fewer large predators than fykenetting. Although tagging was not a major objective of autumn shocking, this sampling required more worker-days for sampling tagging-sized predators than either spring shocking or fykenetting.

CPE of tagging-sized walleye, largemouth bass, and smallmouth bass declined between spring and autumn shocking, but CPE of all sizes of northern pike was higher in the autumn. More small predators were caught in autumn (Table 11), most likely because of YOY recruitment. CPE in autumn electrofishing, has been used to estimate abundance of YOY predators, especially walleye, in northern

Table 11. Spring (April 15-June 4) and fall (September 8-October 19) catch per effort of predators sampled during electrofishing on Lake Mendota in 1987. Length class is range of total length (inches) and usually corresponds to length classes that were used in population estimates.

		Spring			Fall		
Species	Length class (in.)	Number caught	Number per mile	Number per hour	Number caught	Number per mile	Number per hour
Walleye	0.0-8.9	522	12.34	14.50	1755	34.82	40.91
	9.0-14.9	440	10.40	12.22	234	4.64	5.45
	15.0-23.9	44	1.04	1.22	25	0.50	0.58
	24.0+	10	0.24	0.28	3	0.06	0.07
	All sizes	1016	24.02	28.22	2017	40.02	47.01
Smallmouth bass	0.0-8.9	37	0.87	1.03	309	6.13	7.20
	9.0-15.9	53	1.25	1.47	11	0.22	0.26
	16.0+	0	0.00	0.00	0	0.00	0.00
	All sizes	90	2.12	2.50	320	6.35	7.46
Largemouth bass	0.0-7.9	11	0.26	0.31	178	3.53	4.15
	8.0-15.9	170	4.02	4.72	40	0.79	0.93
	16.0+	22	0.52	0.61	10	0.20	0.23
	All sizes	203	4.80	5.64	228	4.52	5.31
Northern pike	0.0-11.9	1	0.02	0.03	66	1.31	1.54
	12.0-23.9	11	0.26	0.31	16	0.32	0.37
	24.0+	11	0.26	0.31	20	0.40	0.47
	All sizes	23	0.54	0.65	102	2.03	2.38

lakes (Serns Index). We wanted to know if a similar index could be developed for predators in southern Wisconsin lakes. CPE was calculated for YOY and yearling walleye, smallmouth bass (Table 12), largemouth bass, and YOY northern pike (Table 13) sampled in autumn electrofishing. There was no temporal trend in CPE for any species (correlation $p > 0.05$) Only yearling largemouth bass CPE was correlated ($p = 0.038$) with location (shoreline mile number).

Variability in CPE among all transects and dates was high. The smallest CV in CPE was 72% for YOY walleye (Table 14). Based on this variability, 13 nights would be required to estimate YOY walleye CPE to within 40% with 95% confidence limits. However, variability between repeated runs of the same transect was lower. Average CV from repeated transects indicated that CPE at those transects could be estimated to within 40% in 7 nights for YOY walleye and 6 nights for YOY smallmouth bass. Further, certain transects had quite low intra-transect variability. Thus, by choosing index stations, variability in CPE can be greatly reduced. 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.

YOY walleye CPE in autumn electrofishing varied dramatically during 1977-87. Walleye fingerlings were caught in 5 of the 9 years in which sampling occurred (Fig. 5), but walleye fingerlings had been stocked in only 3 of these years. It is encouraging that natural reproduction is possible in Lake Mendota, but we should investigate why it has occurred so rarely and determine what can be done to foster natural reproduction in the future.

Tag loss rate based on fish sampled in autumn electrofishing was high. We computed tag loss for fish finclipped and tagged with Floy T-bar tags in spring electrofishing and fykenets and recaptured during autumn electrofishing. Tag loss rate was highest for walleye. We recaptured 15 walleye in autumn shocking, and 7 (47%) of these fish had lost tags. Thirty percent of recaptured largemouth bass had lost tags, and 25% of the northern pike lost tags.

Tag loss was probably worsened by the large tags we used (overall length about 3 inches) and because we tagged most fish below the soft dorsal fin where tag whipping during swimming might be a problem. In 1988, we used a new brand of T-bar tags, available from Hallprint Pty, Ltd., Australia. These new tags are shorter overall (1.75 inches) and have a shorter leader (0.75 inches), so tags stay tight to the body, reducing whipping.

Table 12. Number of fish caught, number caught per mile of shoreline shocked, and number caught per hour shocked for young-of-year (YOY) walleye (<9.0 inches TL), yearling walleye (9.0-12.9 inches TL), YOY smallmouth bass (<6.0 inches TL), and yearling smallmouth bass (6.0-9.9 inches TL), sampled in Lake Mendota during fall, 1987. Length intervals for ages are approximate (based on 1987 scale- derived ages and length-frequency histograms) to allow for comparisons with previous years. Average catch-per-effort, sample standard deviation (std. dev.), and standard error (std. error) are given below each column. Gen. hours is the time spent shocking.

Date	Water Temp.	Miles Shocked	Gen. Hours	YOY walleye			Yearling walleye			YOY smallmouth			Yearling smallmouth		
				Number	No./Mi	No./Hr	Number	No./Mi	No./Hr	Number	No./Mi	No./Hr	Number	No./Mi	No./Hr
09/08/87	71	2.9	2.6	62	21.38	23.85	9	3.10	3.46	2	10.69	0.77	14	4.83	5.38
09/09/87	72	2.6	1.8	10	3.85	5.56	8	3.08	4.44	0	0.00	0.00	0	0.00	0.00
09/15/87	72	3.2	2.2	27	8.44	12.27	2	0.63	0.91	14	4.38	6.36	24	7.50	10.91
09/16/87	69	3.5	2.6	43	12.29	16.54	6	1.71	2.31	6	1.71	2.31	7	2.00	2.69
09/21/87	65	3.6	4.2	195	54.17	46.43	24	6.67	5.71	3	0.83	0.71	2	0.56	0.48
09/22/87	64	3.7	3.4	61	16.49	17.94	11	2.97	3.24	15	4.05	4.41	7	1.89	2.06
09/23/87	65	3.4	2.7	83	24.41	30.74	4	1.18	1.48	12	3.53	4.44	10	2.94	3.70
09/24/87	64	4.7	4.9	151	32.13	30.82	27	5.74	5.51	34	7.23	6.94	37	7.87	7.55
09/28/87	63	4.2	3.0	82	19.52	27.33	15	3.57	5.00	4	0.95	1.33	6	1.43	2.00
09/29/87	63	0.9	0.9	39	43.33	43.33	11	12.22	12.22	2	2.22	2.22	0	0.00	0.00
09/30/87	64	3.1	2.9	117	37.74	40.34	21	6.77	7.24	1	0.32	0.34	0	0.00	0.00
10/01/87	--	0.9	0.6	8	8.89	13.33	0	0.00	0.00	2	2.22	3.33	0	0.00	0.00
10/07/87	58	2.4	2.3	114	47.50	49.57	5	2.08	2.17	11	4.58	4.78	4	1.67	1.74
10/12/87	57	3.0	2.8	255	85.00	91.07	19	6.33	6.79	47	15.67	16.79	14	4.67	5.00
10/13/87	56	1.5	1.3	38	25.33	29.23	6	4.00	4.62	0	0.00	0.00	0	0.00	0.00
10/19/87	54	6.8	4.9	472	69.41	96.33	5	0.74	1.02	33	4.85	6.73	4	0.59	0.82
Mean				109.81	31.87	35.92	10.81	3.80	4.13	11.63	3.33	3.84	8.06	2.25	2.65
Std. Dev.				118.11	23.07	25.91	8.13	3.14	3.06	14.26	3.90	4.21	10.22	2.64	3.17
Std. Err.				29.53	5.77	6.48	2.03	0.79	0.76	3.57	0.97	1.05	2.56	0.66	0.79

Table 13. Number of fish caught, number caught per mile of shoreline shocked, and number caught per hour shocked for young-of-year (YOY) northern pike (<14.0 inches TL), YOY largemouth bass (<7.0 inches TL), and fingerling largemouth bass (7.0-9.9 inches TL), sampled in Lake Mendota during fall, 1987. Length intervals for ages are approximate (based on 1987 scale- derived ages and length-frequency histograms) to allow for comparisons with previous years. Average catch-per-effort, sample standard deviation (std. dev.), and standard error (std. error) are given below each column. Gen. hours is the time spent shocking.

Date	Water Temp.	Miles Shocked	Gen. Hours	YOY Northern pike			YOY Largemouth bass			Yearling Largemouth bass		
				Number	No./Mi	No./Hr	Number	No./Mi	No./Hr	Number	No./Mi	No./Hr
09/08/87	71	2.9	2.6	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
09/09/87	72	2.6	1.8	0	0.00	0.00	1	0.38	0.56	0	0.00	0.00
09/15/87	72	3.2	2.2	0	0.00	0.00	4	1.25	1.82	0	0.00	0.00
09/16/87	69	3.5	2.6	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
09/21/87	65	3.6	4.2	10	2.78	2.38	8	2.22	1.90	2	0.56	0.48
09/22/87	64	3.7	3.4	4	1.08	1.18	11	2.97	3.24	2	0.54	0.59
09/23/87	65	3.4	2.7	2	0.59	0.74	29	8.53	10.74	5	1.47	1.85
09/24/87	64	4.7	4.9	8	1.70	1.63	29	6.17	5.92	0	0.00	0.00
09/28/87	63	4.2	3.0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
09/29/87	63	0.9	0.9	3	3.33	3.33	3	3.33	3.33	3	3.33	3.33
09/30/87	64	3.1	2.9	20	6.45	6.90	8	2.58	2.76	1	0.32	0.34
10/01/87	--	0.9	0.6	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
10/07/87	58	2.4	2.3	11	4.58	4.78	35	14.58	15.22	1	0.42	0.43
10/12/87	57	3.0	2.8	4	1.33	1.43	24	8.00	8.57	3	1.00	1.07
10/13/87	56	1.5	1.3	2	1.33	1.54	6	4.00	4.62	1	0.67	0.77
10/19/87	54	6.8	4.9	8	1.18	1.63	14	2.06	2.86	1	0.15	0.20
Mean				4.50	1.52	1.60	10.75	3.51	3.85	1.19	0.53	0.57
Std. Dev.				5.62	1.89	1.97	11.95	4.04	4.36	1.47	0.86	0.90
Std. Err.				1.41	0.47	0.49	2.99	1.01	1.09	0.37	0.22	0.22

Table 14. Coefficient of variation (C.V. = [standard deviation/mean] *100%) of catch per mile of shoreline shocked (CPE) of age-0 and age-1+ walleye, smallmouth bass, and largemouth bass, and age-0 northern pike during fall 1987, in Lake Mendota. Length intervals for ages are approximate based on 1987 scale-derived ages and length-frequency histograms. Nights for ±40% error in CPE is the number of nights of electrofishing required to estimate catch-per-mile with 95% condifence limits that are ±40% of the mean. Standard deviation pertains to the average of C.V.'s within transects that were shocked three times, N is the number of C.V.'s that were averaged.

			All nights and transects			Repeated transects			
Species	Age	Size Interval (inches)	C.V. (%)	No. of Nights	Nights for ±40% error in CPE	Average C.V. (%)	Standard Deviation	N	Nights for ±40% error in CPE
Walleye	0	< 9.0	72.4	16	13	52.7	9.00	6	7
Walleye	1+	9.0-12.9	82.7	16	17				
SMbass	0	< 6.0	117.2	16	34	50.7	42.1	6	6
SMbass	1+	6.0-9.9	117.4	16	34				
LMbass	0	< 7.0	115.1	16	33	77.0	31.7	4	15
LMbass	1+	7.0-9.9	163.2	16	66				
Npike	0	<14.0	124.3	16	39				

Walleye, largemouth bass, and smallmouth bass were also tagged under the spinous dorsal fin. Tag loss rate should be lower with these new tags. The new tags also have a clear plastic sheath to protect the printing and thus should be much easier to read on recaptured fish.

Creel Survey

Walleye and yellow perch were the most numerous fish in the sport catch in 1987. Walleye comprised 43.7% (7,182 fish) of the predator catch January-September. Smallmouth bass comprised 35.2% of the predator catch, and about three times as many smallmouth bass as largemouth bass were caught (Table 15). Northern pike were the fourth most numerous predator in the creel, with 1,132 caught. Catch-and-release of predators was considerable. Only about 20% of the walleye and largemouth bass caught were harvested, and 12% of the smallmouth bass were harvested. Anglers harvested 54% of the northern pike they caught in 1987. There has been no change in the relative importance of these four predators to the fishery since 1981-82. The same rank of these four species was observed in

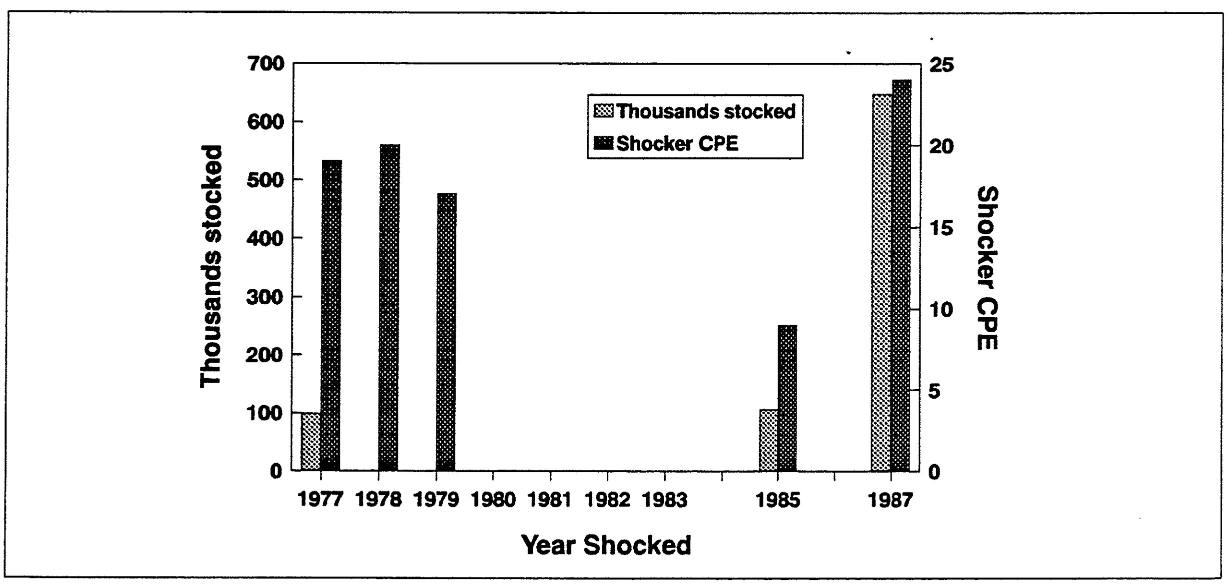

Figure 5. Numbers of walleyes stocked and young-of-year walleye catch-per-hour in fall boomshocking. No boomshocking was conducted in 1984 and 1986. (57,662 walleye fingerlings were stocked in 1986).

Table 15. Total catch, harvest, and mean length (inches) of harvested fish estimated from a creel survey on Lake Mendota during two periods in 1987.

Species	January-February			May-September			Total	
	Catch	Harvest	Mean length	Catch	Harvest	Mean length	Catch	Harvest
Predators								
Walleye	2,744	695	18.2	4,438	727	14.5	7,182	1,422
Smallmouth bass	0	0	-	5,782	677	11.8	5,782	677
Largemouth bass	38	38	12.9	1,753	298	13.9	1,791	336
Northern pike	462	462	29.6	670	154	22.0	1,132	616
Channel catfish	0	0	-	301	214	18.9	301	214
Hybrid musky	38	0	-	197	0	-	235	0
Non-predators								
Yellow perch	107,486	89,765	8.3	165,708	124,692	7.9	273,194	214,457
White bass	17,541	14,250	11.0	49,946	30,010	10.1	67,487	44,350
Bluegill	14,900	14,556	7.6	27,788	19,888	7.4	42,688	34,444
Black crappie	17,582	15,671	9.5	20,166	17,710	9.2	37,748	33,381
White crappie	377	183	9.4	1,072	727	9.3	1,449	910
Pumpkinseed	151	151	5.8	548	300	6.3	699	451
Rock bass	0	0	-	5,723	376	7.7	5,723	376
Yellow bass	194	194	9.8	168	103	-	362	297

a 1981-82 creel survey (C. Brynildson, Wis. Dep. Nat. Res., unpubl. data).

About four times as many yellow perch were caught as any other non-predator species. Yellow perch, white bass, bluegill, and black crappie comprised 98% of the total non-predator catch. The 1981-82 black crappie and white crappie, *Pomoxis annularis* catch was almost twice that of yellow perch. Since 1981-82, bluegill and white bass catch has increased, while crappie, especially white crappie, catch has declined. Catch-and-release for panfish is much lower than for gamefish, with anglers harvesting an average of 75% of the yellow perch, white bass, bluegill, and crappie caught.

Walleye harvest at night was only a small part of the total harvest. The 1981-82 creel survey report speculated that much of the walleye harvest probably occurred between 10 p.m. and 4 a.m.; however, these hours were not sampled. In 1987, >99% of the total fishing effort occurred between the hours of 7 a.m. and 11 p.m. during both ice-fishing and openwater periods (Table 16). May-September, day and night catch rates for walleye were similar; but the January-February catch rate for walleye was about seven times higher at night. The high catch rate at night was offset by low effort and only about 2.5% of the winter walleye harvest was taken at night, in contrast to 1981-82 speculations.

Lake Mendota continues to be a very popular fishing lake. We estimated that a total of 44,990 ice or shore anglers fished the lake January-September — and May-September there were 36,399 boat

Table 16. Creel survey estimates of effort (angler trips), catch rate (per trip in January-February, per angler-hour in May-September), and harvest of walleyes in Lake Mendota, during day (07:00-23:00 h) and night (23:00-07:00 h) hours in 1987. Boat trip effort includes non-fishing boats.

Period	Effort			Catch rate		Harvest		
	Day	Night	Percent Night	Day	Night	Day	Night	Percent Night
January-February	24,107	117	0.50	0.102	0.786	678	17	2.45
May-September	56,808	360	0.63					
Boat trips	36,141	258	0.71	0.018	0.014	727	0	0.00
Shore trips	20,667	102	0.49					

(non-sailboat) trips made on the lake. In all, about 159,000 boaters and anglers used Lake Mendota during the 7-month period in 1987 when data were available.

POPULATION ESTIMATES

We were able to calculate mark-recapture population estimates for five size classes of walleye, and two size classes each of northern pike and largemouth bass (Table 17). Only smallmouth bass <9.0 inches could be enumerated; we did not obtain enough recaptures of smallmouth bass >9.0 inches in any gear to make an estimate. All species of predators in the lake had adult densities of <1.0 fish/acre. Walleye >11.0 inches had the highest density, about 0.5 fish/acre. Adult largemouth bass were more abundant than northern pike. Smallmouth bass catch estimated by the creel survey suggests that smallmouth bass are more abundant than largemouth bass, given equal vulnerabilities to angling.

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 by using the last few days of fykenetting during the walleye spawning run for recaptures, by autumn mark-recapture estimates of YOY walleye and smallmouth bass in a large lake, and by inferring population size structure from size structure in gear.

Walleye mark-recapture estimates using the last few days of the spawning run for recaptures were thought to be biased. Large female walleye usually move onshore only to spawn and the smaller, male walleye usually remain onshore for weeks during the entire spawning run (Colby et al. 1979). Given this tendency, an overestimate of large walleye and an underestimate of small walleye would be expected. Less-biased Petersen estimates using spring fykenetting and electrofishing for marking and summer gillnets for recaptures only partially corroborated this prediction. Estimates of 11.0-14.9-inch walleye were indeed about 35% higher when gillnets were used for recaptures. However, fykenet and gillnet estimates of >24.0-inch walleye were similar. No estimate for 15.0- to 23.9-inch walleye was available using gillnets. 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 size class was exclusively female.

Use of nightly catches in a Schnabel estimate for a large lake electrofishing run overestimates the population. Because one would not expect marked fish to be adequately mixed with the unmarked segment of the population on a nightly basis, using each night as a marking and recapture run for a Schnabel estimate would not be valid and would tend to overestimate population size. We compared mark-recapture population estimates of small predators computed using the Chapman modification of the Petersen and Schnabel formulae. Schnabel estimates were always larger than Petersen estimates computed using the last lap (spring) or the last night (autumn) as the recapture run. It seems that in large lakes, a Petersen estimate where most of the sampling effort was devoted to marking fish and a few randomly selected transects were sampled for recaptures at the end of the survey would be an effective technique.

Petersen population estimates of YOY walleye and smallmouth bass based on autumn electrofishing were much lower than expected. Shoreline electroshocking was probably valid for the shallow shoreline areas sampled. 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 electroshocking. A population estimate made in 1988 showed that estimates based on autumn electrofishing underestimated the actual population in Lake Mendota. The estimate of yearling walleye made in spring 1988 was more than twice the number of YOY fish estimated in the previous autumn. Hauber (1983) suggested that population estimates of age-1+ walleye 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 time to make population estimates of walleye and other predators.

Fisheries workers recognize that most sampling gear is size selective (Ricker 1975). We compared population size structure based on population estimates with size structure in fykenets and electrofishing in spring to estimate the magnitude of this bias. The size structure in the gear includes recaptures because managers will not always have marked fish, and thus would not be able to eliminate recaptures from the sample. Recaptures are a source of bias in this comparison.

Fykenets set during the spawning run underestimated the relative abundance of walleye <10.0 inches by about 50% (Fig. 6). Relative abundance of almost all sizes of northern pike in the fykenet catch was similar to that of the population (Fig. 7). Fykenets underestimated largemouth bass <15.0 inches by about 25% (Fig. 8). Relative abundance of 10.0- to 23.9-inch walleye was slightly overestimated by fykenets (about 25%). Fykenets greatly overestimated the relative abundance of walleye >24.0 inches

Table 17. Mark-recapture population estimates of predators sampled in Lake Mendota during 1987. All tagged fish received a permanent finclip. Chapman's modification of the Petersen and Schnabel estimates were used. Confidence limits were computed using values from Ricker (1975; Appendix II).

		Marking run			Recapture run							
Species	Size Class (inches)	Gear	Time Period	Number Marked	Gear	Time Period	Examined For Marks	No. of Recaps	Modified Petersen Estimate	95% Confidence Limits	Modified Schnabel Estimate	95% Confidence Limits
Walleye	0.0-8.9	Fyke Net and Boomshocker	04/15/87-05/19/87	514	Bshock	05/28/87-06/04/87	118	9	6,128	(3,386-12,257)	11,322	(7,067-18,150)
	9.0-10.9	Fyke Net and Boomshocker	04/15/87-05/19/87	145	Bshock	05/28/87-06/04/87	25	5	633	(299-1,460)	1,578	(830-3,008)
	11.0-14.9	Fyke Net and Boomshocker	03/17/87-04/15/87	296	Fyke Net	04/16/87-04/24/87	165	14	3,287	(2,012-5,667)	-	-
	15.0-23.9	Fyke Net and Boomshocker	03/17/87-04/15/87	225	Fyke Net	04/16/87-04/24/87	30	3	1,752	(715-4,379)	-	-
	24.0+	Fyke Net and Boomshocker	03/17/87-04/15/87	170	Fyke Net	04/16/87-04/24/87	37	11	542	(314-931)	-	-
Walleye	11.0-14.9	Fyke Net and Boomshocker	03/17/87-06/04/87	701	Gillnet	05/19/87 08/14/87	18	2	4,446	(1,626-11,115)	-	-
	15.0-23.9	Fyke Net and Boomshocker	03/17/87-06/04/87	253	Gillnet	05/19/87-08/14/87	10	0	-	-	-	-
	24.0+	Fyke Net and Boomshocker	03/17/87-06/04/87	202	Gillnet	05/19/87-08/14/87	14	4	609	(272-1,522)	-	-
Walleye	0.0-10.9	Boomshocker	09/15/87-10/13/87	1,109	Bshock	10/19/87	491	66	8,151	(6,425-10,304)	22,433	(14,137-30,729)
Northern pike	12.0-23.9	Fyke Net	03/17/87-04/23/87	237	Bshock	04/15/87-06/04/87	11	3	714	(255-1,428)	-	-
	24.0+	Fyke Net	03/17/87-04/23/87	162	Bshock	04/15/87-06/04/87	11	3	489	(175-978)	-	-
Smallmouth bass	0.0-8.9	Boomshocker	09/15/87-10/13/87	245	Bshock	10/19/87	37	4	1,870	(835-4,674)	2,689	(1,571-4,609)
Largemouth bass	8.0-15.9	Fyke Net	03/17/87-04/23/87	130	Bshock	04/15/87-06/04/87	170	10	2,036	(1,155-3,930)	-	-
	16.0+	Fyke Net	03/17/87-04/23/87	44	Bshock	04/15/87-06/04/87	22	3	259	(92-518)	-	-

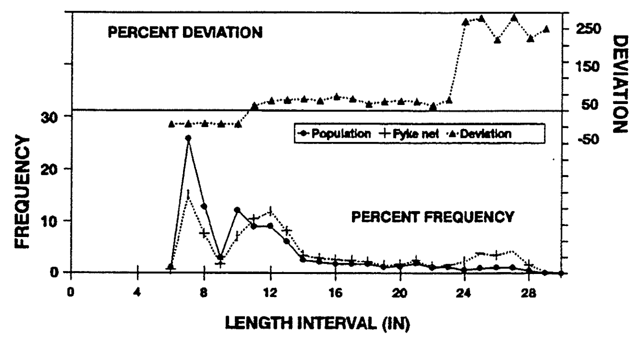

Figure 6. Length frequency (percent) of the walleye population estimated from mark-recapture experiments on five size classes (0.0-8.9, 9.0-10.9, 11.0-14.9, 15.0-23.9, and >24.0 inches) marked and recaptured in fyke nets (March 17-April 23), and length frequency of all walleyes sampled in fyke nets, in Lake Mendota. Length frequency in fyke nets includes recaptures of fish previously marked in fyke nets. Percent deviation is the difference (percent) between the relative frequency in the population and in the fyke net sample, by 1.0 inch length intervals. A positive deviation indicates the gear was selective for fish of that size.

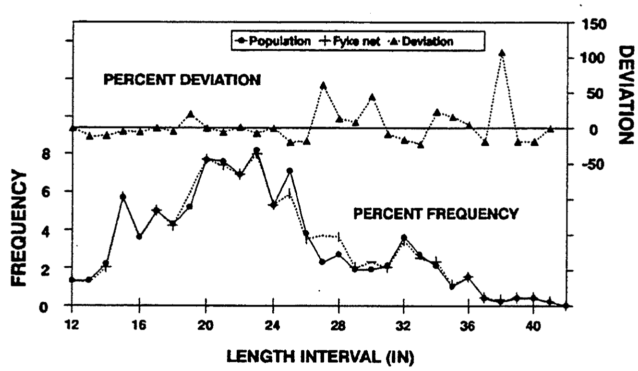

Figure 7. Length frequency (percent) of the northern pike population estimated from mark-recapture experiments on two size classes (12.0-23.9 and >24.0 inches) marked in fyke nets (March 17-April 23) and recaptured by boomshocking (April 15-June 4), and length-frequency of all northern pike at least 12.0 inches sampled in fyke nets, in Lake Mendota. Length-frequency in fyke nets includes recaptures of fish previously marked in fyke nets. Percent deviation is the difference (percent) between the relative frequency in the population and in the fyke net sample, by 1.0 inch length intervals.

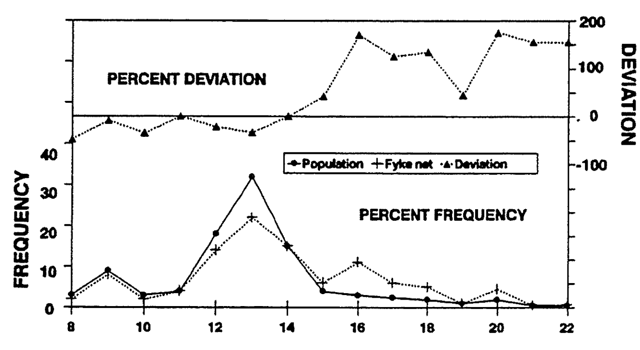

Figure 8. Length frequency (percent) of the largemouth bass population estimated from mark-recapture experiments on two size classes (12.0-23.9 and >24.0 inches) marked in fyke nets (March 17-April 23) and recaptured by boomshocking (April 15-June 4), and length-frequency of all largemouth bass at least 8.0 inches, sampled in fyke nets, in Lake Mendota. Length-frequency in fyke nets includes recaptures of fish previously marked in fyke nets. Percent deviation is the difference (percent) between the relative frequency in the population and in the fyke net sample, by 1.0 inch length intervals.

and largemouth bass >15.0 inches. Electroshocking in spring underestimated the relative abundance of most size classes of walleye by almost 100% (Fig. 9), but largemouth bass size structure in the electroshocking sample was similar to that for the population (Fig. 10). Too few northern pike were sampled with electroshocking for comparison.

Apparently spring fykenets give a better representation of walleye population size structure than spring electrofishing, but greatly overestimate the relative abundance of large walleye. Spring fykenets provided a good size representation of all northern pike. Because spring fykenets tend to sample the spawning population, all sizes of northern pike may be more effectively sampled in fykenets relative to walleye because of lower age at maturity of both sexes in Lake Mendota. The electroshocker appeared to represent largemouth bass sizes in the population better than fykenets.

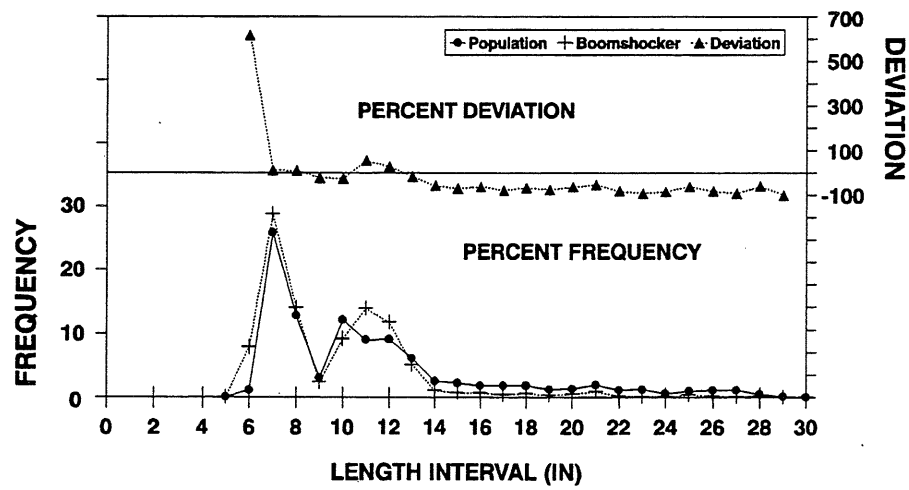

Figure 9. Length frequency (percent) of the walleye population estimated from mark-recapture experiments on five size classes (0.0-8.9, 9.0-10.9, 11.0-14.9, 15.0-23.9, and >24.0 inches) marked and recaptured in fyke nets (March 17-April 23), and length frequency of all walleyes sampled by boomshocking (April 15-June 4; includes recaptures of fish previously marked during fyke netting and boomshocking), in Lake Mendota. Percent deviation is the difference (percent) between the relative frequency in the population and in the fyke net sample, by 1.0 inch length intervals.

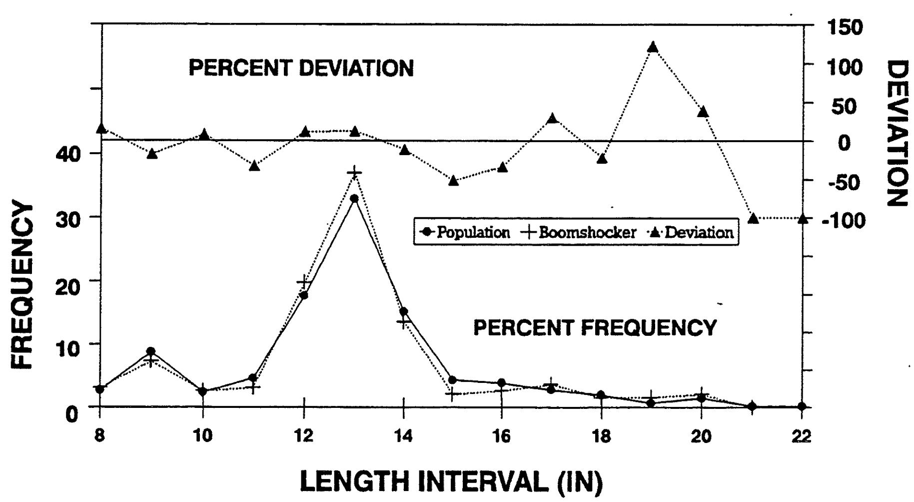

Figure 10. Length frequency (percent) of the largemouth bass population estimated from mark-recapture experiments on two size classes (12.0-23.9, and >24.0 inches) marked in fyke nets (March 17-April 23), and recaptured by boomshocking (April 15-June 4), and length-frequency of all largemouth bass at least 8.0 inches, sampled by boomshocking, including recaptures of fish previously marked during fyke netting and boomshocking, in Lake Mendota. Percent deviation is the difference (percent) between the relative frequency in the population and in the fyke net sample, by 1.0 inch length intervals.

INCREASING PREDATOR BIOMASS

Stocking

We obtained the requested number of fish for all stocking quotas except northern pike fingerlings, of which only 47% of the requested 50,000 northern pike were stocked in September (Table 18). We stocked 10.8-million northern pike fry 14-20 April, when water temperatures in Sixmile Creek and Cherokee Marsh were about 60 F.

Survival of stocked and naturally reproduction northern pike was evaluated by autumn electrofishing in areas where fry were stocked. This was done on 8-9 September, before any northern pike fingerlings were stocked. No YOY northern pike were observed in the 5.5 miles of shoreline shocked. Historically, Lake Mendota has had a reproducing northern pike population, but natural recruitment has been poor since 1977 (C. Brynildson, unpubl. data). Loss of spawning habitat and inadequate spring water levels are thought to be primarily responsible. Current management efforts include development of an artificial spawning marsh and adjusting spring water levels to improve northern pike recruitment.

More than 20-million walleye fry were stocked 24 April - 5 May, when the lake temperature was about 49 F. Preliminary calculations suggested that the density of stocked fry would be about 1 fry/ 100 m^3. This was determined by assuming all stocked fry remained in the top 5 m of the lake, and had 10% survival >12 days. Only 662 m^3 of the lake were sampled with the Miller sampler, so the expected catch was 7 stocked fry plus additional natural reproduction. However, no walleye fry were captured with the Miller sampler, suggesting that survival of stocked fry and production of native fry was probably much lower than 10%..

Walleye fingerlings (68,572) raised by the Lake Mendota Fishing Association (LMFA) helped us to exceed the quota of 500,000 fish. The Association stocked 22,776 of their fingerlings (4.0 inches total length) on 26 September, while the remaining 624,414 walleye fingerlings were stocked 8 June - 9 July. With the unusually warm summer in 1987, the average lake surface temperature was 78° F when walleye fingerlings were stocked. Fortunately, the average difference between the temperature in the transport truck and the lake was <2 F (Table 19). Nonetheless, handling stress increases with temperature (at least for esocids; Stein et al. 1984) and high temperatures during stocking may have reduced fingerling survival. In 1985 and 1986 average lake temperature when walleye fingerlings were stocked was only 67 F and 71 F, respectively, and the first year survival of the 1986 year-class was 9% based on spring 1987 population estimate.

Currently, Lake Mendota relies on stocking to maintain the walleye population. Calculation of walleye reproductive potential suggested the 1987 population of walleye in Lake Mendota would only produce about 75,000 fry or about 8 fry/acre. In contrast, >2,000 fry/acre were stocked. Even if these calculations underestimate fry production greatly, it is unlikely the current walleye population can sustain itself. Another important objective of this study is the re-establishment of a self-sustaining walleye population in Lake Mendota.

Table 18. Species, dates, number, lake temperature, and location of northern pike and walleye stocked in Lake Mendota during 1987. Size of fingerlings is total length (inches). Average lake temperature was taken at the surface.

Species	Dates	Size	Number	Average Lake Temp. (F)	Location
Northern pike	04/14-04/20	fry	10,760,000	59	Cherokee Marsh and Sixmile Creek in emergent vegetation
Northern pike	09/09-09/11	9.8	23,434	71	Scattered in littoral zone
Walleye	04/24-05/05	fry	20,100,000	48	Scattered in open water
Walleye	06/08-07/09	2.0	624,764	78	Scattered in littoral zone
Walleye	09/26	4.0	22,776	65	Scattered in littoral zone

Table 19. Mean lake temperature (surface temperature at stocking location, weighted by number of fish stocked), 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
Number stocked	106,200	57,662	647,540
Mean lake temperature (F)	67	71	78
Mean difference (F)	-1.9	-2.8	1.2
Mean length (inches)	2.1	3.0	2.3
Median stocking date	06/13/85	06/16/86	06/23/87

Projections with the GIFSIM model indicate that reproductive potential would double by 1992 under a 15-inch size limit and a modest recruitment of 8,000 yearlings/year from stocking in 1987 and 1988. To predict future native walleye recruitment, and to assess the need for further stocking, we should continue to model reproductive potential as changes in biomass and abundance resulting from the stocking and harvest regulations are measured.

Harvest Regulations

Because harvest regulations went into effect in the second year of the study, no results are available for this report. However, predictions of the effects of the regulations are presented in the next section.

FORECASTING CHANGES

The GIFSIM model predicted dramatic changes in walleye population structure and characteristics of the walleye fishery resulting from the management plan of stocking and harvest restrictions. Because simulations are based on 1987 population parameters such as exploitation rate and growth and these rates are rarely constant in any population, quantitative predictions should be viewed with caution. We feel the modeling exercise is most useful for examining relative differences in the population and the fishery that can result from various management strategies.

Simulations suggested that after a stable age distribution is reached in nine years maximum yield would occur under a 15-inch minimum size limit (Fig. 11). However, differences in yield between the 13-inch and 18-inch size limits were small. Model runs did not allow for possible compensatory decreases in growth as density increases, so the 15-inch size limit was chosen over the 18-inch limit to guard against such growth declines. Average weight of harvested fish increased from 1.3 lb under no size limit to 4.4 lb with a 20-inch size limit. The 15-inch limit allows for a doubling in the average weight of harvested fish and an increase in total yield, but avoids some potential loss of yield under larger minimum size limits should compensatory changes occur. Public acceptance of the 15-inch size limit was also very good. However, the 15-inch size limit does not protect female walleye to spawning size.

The model predicted a 74% increase (25,217 vs. 14,513 walleye) in abundance of age 1-11 walleye by 1992 under a 15-inch minimum size limit and the stocking program. The model also showed that population biomass would increase by 109% (23,091 vs. 11,029 lb), and the age structure of the population would include more age-classes. By 1992, the predicted number of age 2-6 walleye increased by a factor of between 3.7 (age 2) and 7.4 (age 4).

Bioenergetics models allowed us to translate predicted changes in predator population structure resulting from regulations and stocking, into the expected changes in the biomass of prey consumed by the population. We evaluated proposed regulations based on potential effects on prey populations as well as effects on the walleye population. As the size limit is increased, there is an increase in the total biomass of prey consumed by walleye and an increase in the age-class at which maximum consumption occurs (Fig. 12). Under a 15-inch size limit, maximum consumption occurs in age-class 4, which is the age at which most of the fish have reached harvestable size. A stocking program alone increases the biomass of prey consumed by 100% over the consumption computed for the existing Lake Mendota walleye population in 1987 (Fig. 13). With a 15-inch size limit, another 50% increase in prey consumed would be expected. We also examined effects of the 15-inch size limit occurring within the relatively short time frame of the current project, before a stable age distribution is achieved by modeling consumption by the 1987, 1988, and 1989 stocked year-classes. The biomass of prey con-

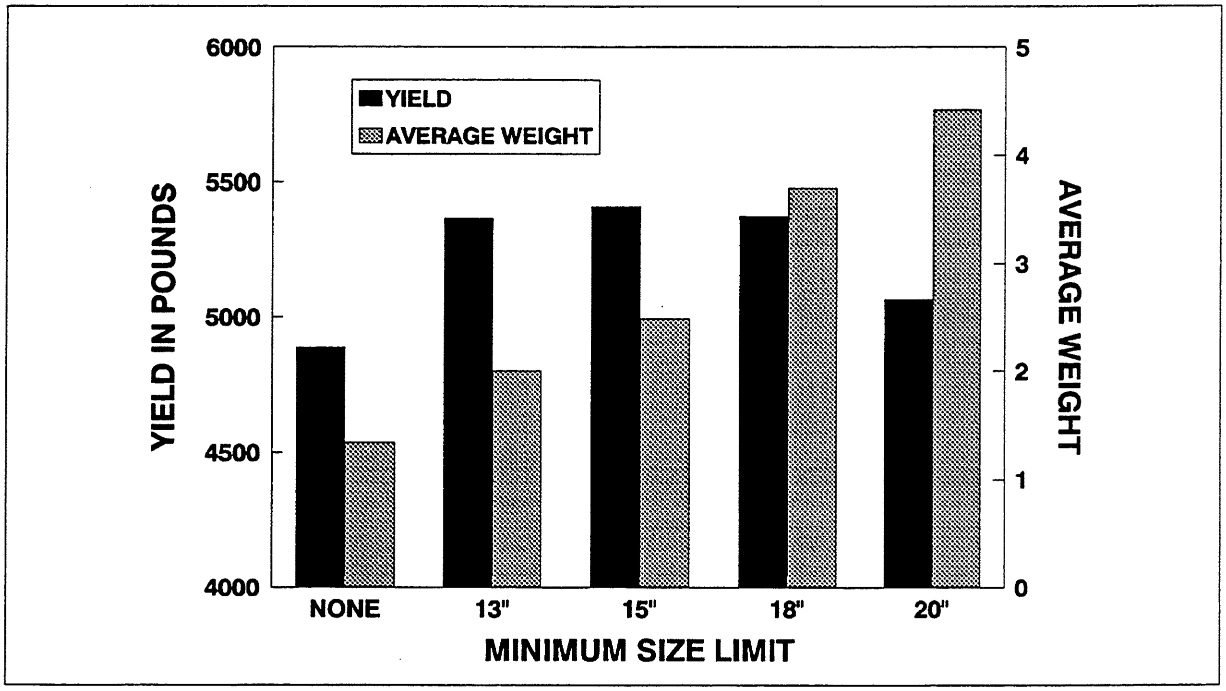

Figure 11. Predicted yield (in pounds) and average weight (pounds) of harvested walleyes in Lake Mendota after a stable age distribution is reached, in nine years, with various minimum size limits. Simulations were performed with the GIFSIM computer model (Taylor 1981) using population parameters measured in 1987, and an assumed recruitment of 8,000 yearlings per year.

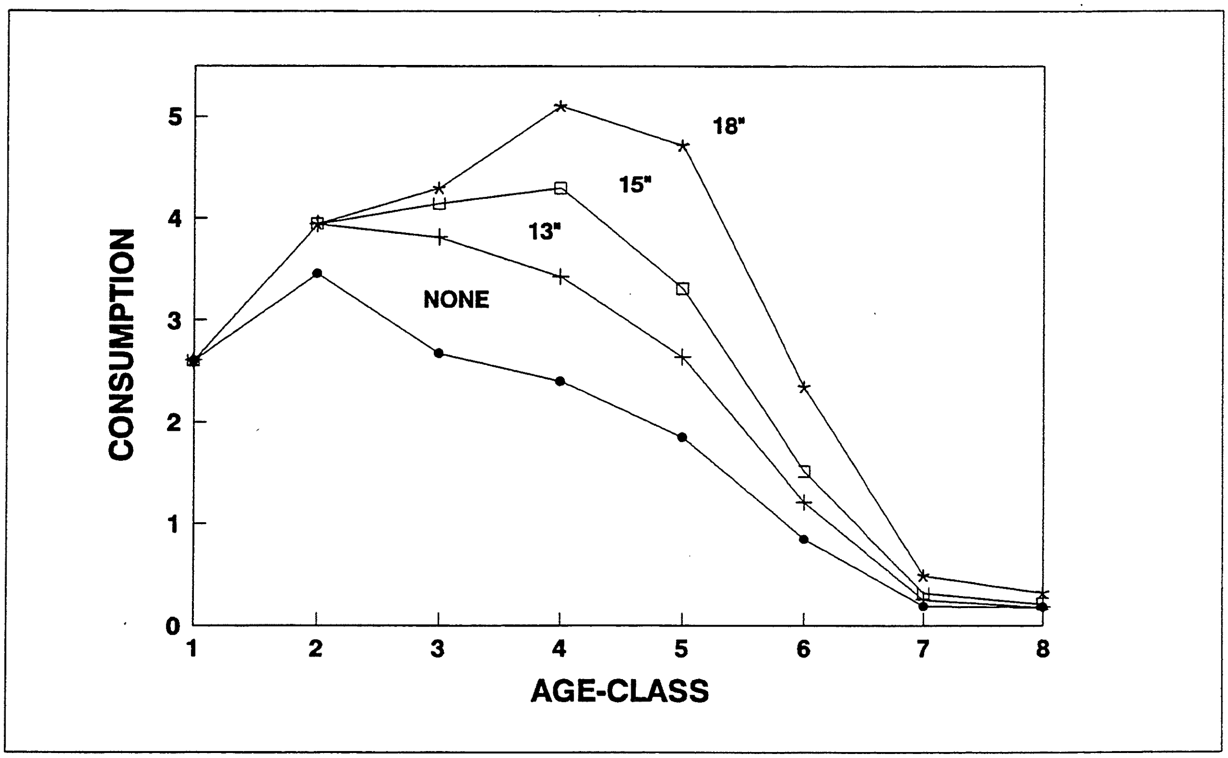

Figure 12. Predicted biomass (pounds x 1,000) of yellow perch consumed by eight age-classes of walleyes in Lake Mendota in 1992, under various minimum size limits. Walleye population parameters, diet, growth, and thermal history data were measured in 1987. Predictions were generated using the GIFSIM model to predict population structure resulting from a size limit and a bioenergetics model to estimate consumption by that population.

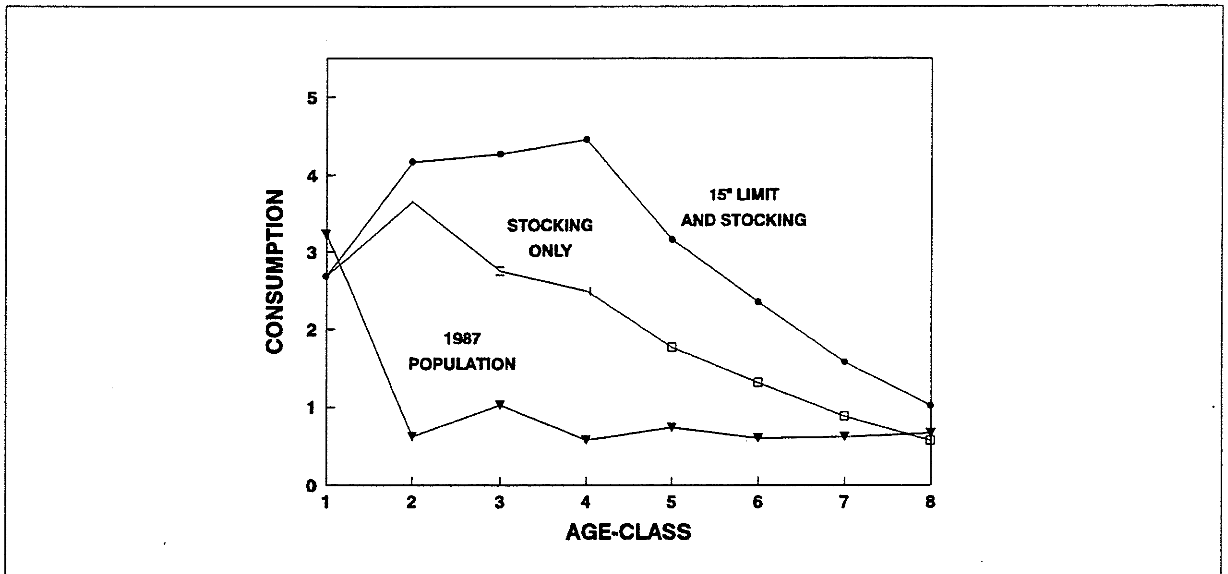

Figure 13. Predicted biomass (pounds x 1,000) of yellow perch consumed by eight age-classes of walleyes in Lake Mendota in 1) year 1987 with no size limits, and sporadic stocking, 2) year 1992 with 8,000 yearling recruits per year, and 3) year 1992 with 8,000 yearlings per year and a 15-inch minimum size limit. Walleye population parameters, diet, growth, and thermal history data were measured in 1987. Predictions were generated using the GIFSIM model to predict population structure resulting from a size limit and a bioenergetics model to estimate consumption by that population.

sumed by each year-class is maximum when the year-class reaches age 4, the age at which most of the year-class becomes vulnerable to the fishery (Fig. 14). Consumption declines rapidly beyond this age, presumably due to fishing mortality.

Total prey consumed by 1987-89 year-classes indicates that the maximum effect of the stocking program and regulations will occur in 1991 (Fig. 15). Responses of zooplankton populations to the reductions in planktivore populations would be expected to lag several years behind the year of maximal planktivore reduction. Similar bioenergetics modeling results (Luecke et al. 1989) indicated that yellow perch have their greatest impact on Daphnia

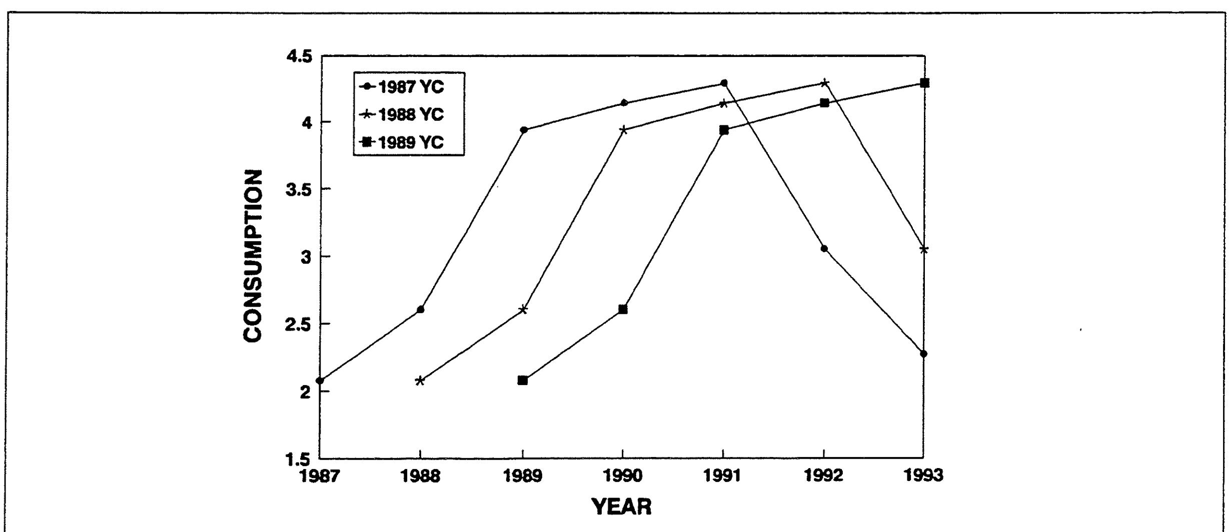

Figure 14. Biomass of prey (pounds x 1,000) consumed by 1987, 1988, and 1989 year-classes (YC) of stocked walleyes in Lake Mendota, under a 15-inch minimum size limit. Stocking was assumed to produce 8,000 yearling recruits per year. Predictions were generated with a bioenergetics model using population parameters, diet, growth, and thermal history measured in 1987.

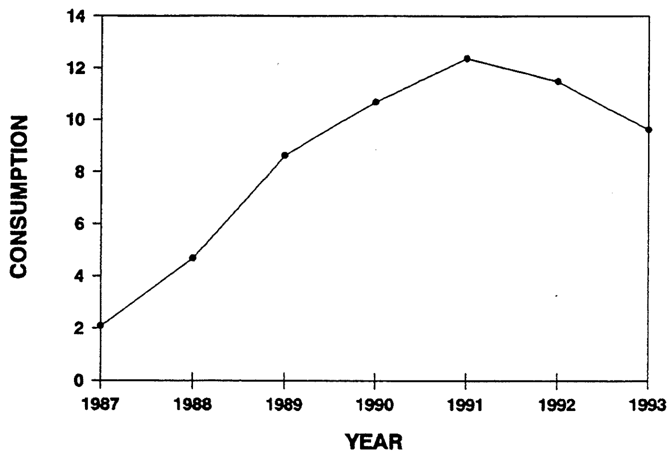

Figure 15. Total biomass of prey (pounds x 1,000) consumed by stocked walleyes (only by walleyes stocked in Lake Mendota during 1987-1989). Predictions were generated using the GIFSIM model to predict population structure under a 15-inch minimum size limit, and a bioenergetics model to compute consumption by that population. Models used walleye population parameters, diet, growth, and thermal history data measured in 1987.

populations in their third year of life. Thus, biomanipulation's effects cannot be fully evaluated until 5 to 6 years after the start of the stocking program (1991-92). The modeling techniques developed here allowed us to evaluate gamefish harvest regulations relative to both gamefish and prey populations. The techniques provide the means to predict how prey populations respond to regulations for gamefish. Potential applications include predictions of the effects of angling on trophic structure and the benefits of gamefish harvest restrictions for stunted panfish populations and manipulating prey community composition.

MANAGEMENT RECOMMENDATIONS

Recommendations for future work based on our 1987 findings are:

1. Mark-recapture techniques for large lakes must be refined. Very few other studies are currently available.Intensive sampling throughout the year is providing the opportunity to develop the most efficient sampling schemes for monitoring fish populations in Lake Mendota and other lakes. Abundance indices based on less intensive sampling are being developed.

2. Sampling and estimation techniques should be expanded to the other Yahara lakes and study findings should be used to develop a management plan for these lakes.

3. Predictions of the benefits of Lake Mendota's special harvest regulations should be tested and refined as more data become available. An evaluation of the 15-inch walleye size limit is particularly important, given the current proposal to extend the regulation statewide.

4. Increasing adult density (thus, reproductive potential) through stocking and harvest restrictions and improving spawning habitat should be pursued. The importance of stocking to maintain Lake Mendota's predator populations over the last 10 years has been clearly demonstrated. Although natural reproduction has occurred in the past, steps must be taken to foster natural reproduction in the future.

5. Work on the Madison Lakes Project, particularly in monitoring populations, must continue beyond 1991-92 – when our modeling suggests that the maximum effects of the biomanipulation will occur – if the experiment is to be evaluated adequately. This study provides the opportunity to evaluate a new computer modeling technique as a predictive tool. By combining traditional single-species fishery models with

bioenergetics models, we have developed the means to examine possible effects of gamefish harvest regulations on prey populations.

6. 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

- Adult gamefish density was low.
- Natural reproduction of walleye is possible, but has been infrequent.
- Gamefish populations, especially walleye, have been sustained mostly by stocking.
- There has been little change in the relative abundance of gamefish in angler catch since the last creel survey in 1981-82.
- Walleye and yellow perch dominated angler catch of gamefish and panfish in 1987.
- About 99% of the fishing pressure in 1987 occurred between 7 a.m. and 11 p.m.
- Walleye harvest between 11 p.m. and 7 a.m. was minimal.
- Spring fykenets represented walleye and northern pike size structure better than spring electrofishing, but greatly overestimated relative abundance of walleye >24 inches.
- Spring shocking sampled all sizes of largemouth bass better than fykenets.
- Smallmouth bass were not adequately sampled by fykenets or boomshocking.
- All stockings of hybrid muskellunge, though small in number, were represented in spring fykenets.
- Variation in panfish CPE was too high to use spring fykenets to index abundance. Size structure of panfish in fykenets was much less variable.
- Summer seining produced low CPE for all species. Alternative gear is needed to estimate year class strength.
- Highest CPE of walleye in gillnets was found in 2.5-inch mesh nets.
- July-August gillnet catch was greatest in 6-10 ft. of water.
- Spring shocking was more efficient for capturing 11- to 18-inch walleye than fykenets.
- Fykenets were much better for sampling walleye >18 inches than shocking.
- Catch-per-worker-day of tagging-sized gamefish was lowest in autumn shocking.
- Tag loss rate of 3-inch Floy tags placed under the soft dorsal fin was high.
- Schnabel population estimates do not appear to be valid in large lakes where shocking is used to mark and recapture.
- Petersen estimates of fingerling gamefish where most shocking effort is devoted to marking with random recapture runs is recommended.
- Marking larger gamefish in fykenets and spring shocking, and recapturing them in summer gillnets appears to be most effective.
- Autumn mark-recapture methods underestimated YOY walleye abundance greatly.
- A 15-inch minimum size limit maximizes yield and protects walleye during the period when their consumption is maximal.
- A 15-inch size limit does not protect female walleye to spawning age.
- Size limits can be very effective for manipulating the biomass of prey consumed by predator populations.

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"The biomanipulation project on Lake Mendota is teaching us much about the relationships between trophic levels in lakes and is supporting the need to consider complete systems instead of single species. This project is also providing us new information regarding large lake sampling, stocking success, the effects of length and bag limit regulations, and the response of anglers to more intensively managed fish populations."