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A BIOLOGICAL ANALYSIS OF THE YELLOW PERCH POPULATION IN THE LES CHENEAUX ISLANDS, LAKE HURON[1]

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A thesis submitted in partial fulfillment
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ABSTRACT

The yellow perch (_Perca_ _flavescens_) fishery in the Les Cheneaux Islands, which supports the tourism-based economy of the area, was reputed by local residents to have declined. Complaints about the fishery prompted this study. The purpose was to estimate catch, mortality, exploitation, and growth statistics from a creel census and tagging study. These estimates were compared to estimates from previous years and were applied in a fishery simulation model to predict changes in the fishery produced by 7- to 8-inch minimum size limits (MSL). From the creel census, the best estimate for yellow perch catch in 1986 was approximately 438,000 fish. For an estimated 142,000 trips, anglers fished slightly over 400,000 total hours. The summer fishery accounted for 89% of the total perch catch. Counts of boats made from an airplane were on average 2.5 times greater than counts made from the ground, and were used to construct best estimates of catch and effort. Estimates of growth, age structure, and mortality rate for perch were constant over time, indicating that the population has remained stable since sampling began in 1969. In addition, creel census estimates provided little indication of trends in perch catch. Simulation of the perch fishery predicted that yields (in weight) would only increase slightly (2-3%) under 7- and 8-inch MSL's relative to the 1986 fishery.

Number of older perch (age 5+) was predicted to increase substantially (7-54%). Commercial fishing in 1986 accounted for only a small proportion of the predicted total catch in numbers (4%) and yield (6%). Relative importance of the commercial fishery was predicted to increase with increasing MSL, but catch in numbers and yield would still comprise less than 10% of the total.

INTRODUCTION

Yellow perch, *Perca flavescens*, is an important species to both the commercial and sport fisheries of Lake Huron. In 1986 yellow perch ranked first in numbers caught, with sportfishermen taking an estimating catch of over 3 million (Rakoczy and Rogers 1987). Many small coastal towns along Lake Huron rely on tourism generated by this popular sport fishery for yellow perch.

Overfishing, which results in a decrease in numbers and size of perch caught by anglers, can severely affect the local economy by discouraging tourism. Unfortunately, localized populations of yellow perch in the Great Lakes are readily susceptible to overfishing by commercial fishermen (Hile and Jobes 1941; El-Zarka 1959; Eshenroder 1977; Wells 1977; Wells and Jorgenson 1983). Surprisingly, overfishing of Great Lakes perch has never been attributed to sportfishing, though annual yields for the sport fishery may be many times greater than for the commercial fishery (Weber 1986; Diana et al. 1987; Keller et al. 1987).

Public perception of overfishing also can be detrimental to tourism. Public perception that a fish population is being overfished is in itself sufficient to discourage anglers, though the quality of a fishery may have changed little. Under these circumstances, regulatory agencies are often called upon to improve the quality of the fishery with hopes of improving tourism.

Although problems such as overfishing of Great Lakes yellow perch are relatively common, regulatory agencies often lack adequate information for making sound management decisions. Seldom have recent studies on Great Lakes yellow perch completely analyzed both the status of the population and the impact of the fishery upon it (Weber 1985, 1986). Furthermore, long-term data necessary for assessing trends in the perch population and catch are often scant or nonexistent.

In recent years, residents of the Les Cheneaux Islands have consistently complained that the yellow perch population has declined and that tourism is suffering as a result of this decline. Anglers attribute the apparent decline in their catch to commercial fishing by Native Americans, to increased predation by introduced species of fish such as brown trout (Salmo trutta) and chinook salmon (Oncorhynchus tshawytscha), and to heavy angling pressure during the spawning period. Despite angler complaints, evaluation of the rather uneven data available suggested that the perch population and catch have remained relatively stable since the first assessment in 1969 (Michigan Department of Natural Resources interoffice communication from J. R. Ryckman and J. C. Schneider to W. C. Latta, December 1, 1983). However, more complete data on the perch population and on exploitation of that population were necessary to test results from previous analyses. Therefore, a cooperative study between the Michigan Department of Natural Resources (MDNR) and The University of Michigan was organized to gather information on the perch fishery and to determine its importance to the local economy of the Les Cheneaux Island area.

Specifically, this thesis covers the evaluation of the yellow perch fishery in the Les Cheneaux Islands. A creel census and tagging study were conducted to estimate catch, mortality, exploitation, and growth statistics. These estimates were:

1. Compared to estimates obtained from previous studies to determine whether declining trends in the population and catch had actually occurred;
2. Utilized in a fishery simulation model to predict changes in the fishery under different regulations; and
3. Used to assess the impact of the Native American fishery on the perch population and sport catch.

The findings from this study were then used to determine an optimal strategy to manage this yellow perch fishery.

METHODS

The Les Cheneaux Islands are located along the northern shoreline of Lake Huron approximately 23 km northeast of the Straits of Mackinac (Figure 1). The bays and channels of the Les Cheneaux Islands cover approximately 5,000 acres of water and contain a variety of aquatic habitats, including shallow (0-2 m) bays densely populated with submergent and emergent aquatic macrophytes, deeper (2-8 m) channels and open bays, and deep (8-20 m) outer bays and rocky shoals. Over 70% of the original shoreline has been disrupted by development in the resort communities of Cedarville and Hessel (Jaworski and Raphael 1978). Still, most of the aquatic habitat continues to retain its oligotrophic character.

Little information on the Les Cheneaux yellow perch fishery prior to 1979 is available. Spot censuses were conducted prior to sampling in 1969, but no estimates of annual catch are present in the literature. However, resort owners stated that yellow perch have attracted vacationing anglers to the area since the 1920s. Since then the perch fishery has supported as many as 50 resorts. In 1986 the number of resorts in the area was about one-half that figure. Still, tourism generated primarily by the yellow perch fishery was estimated to increase local income by approximately 2-4 million dollars (Diana et al. 1987).

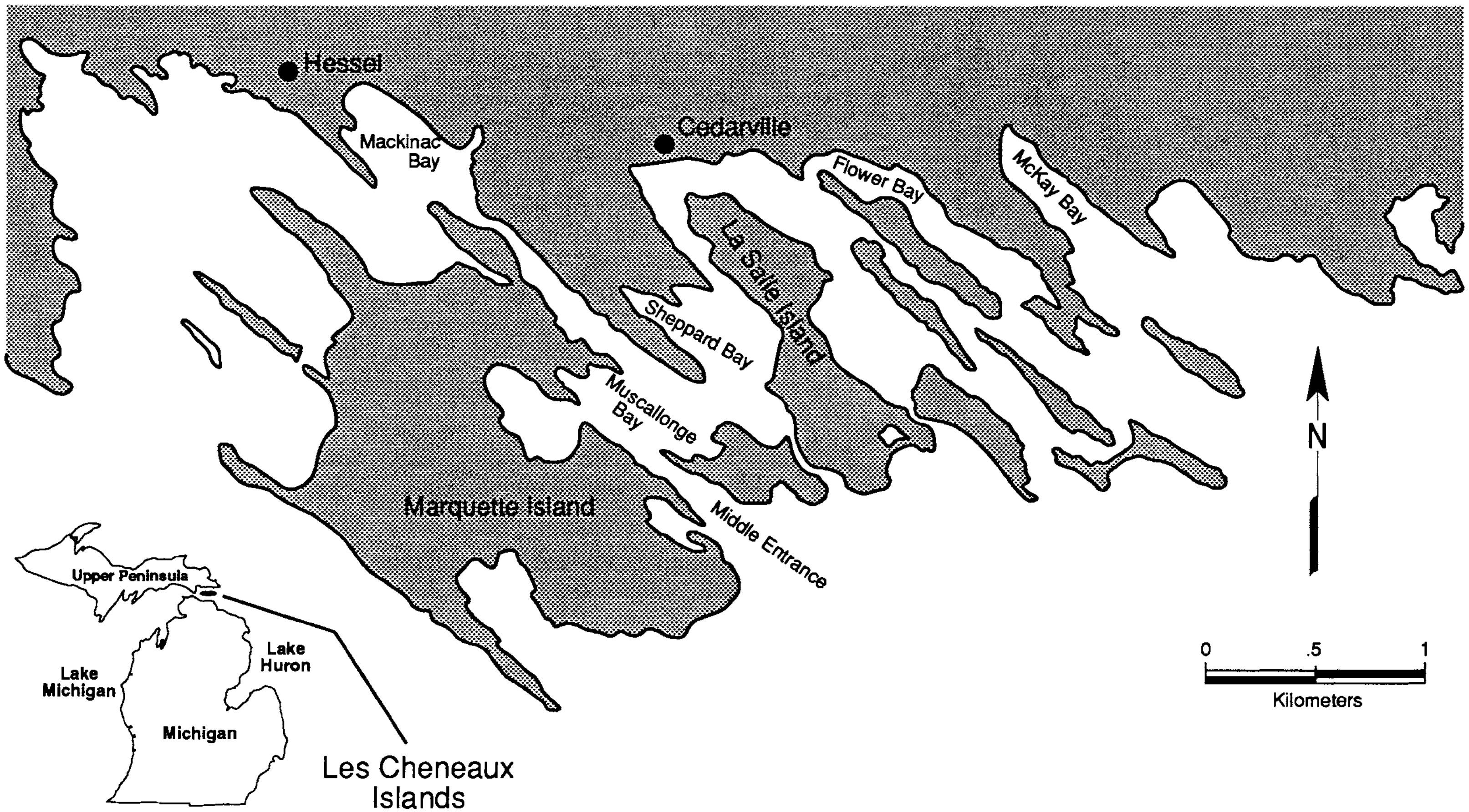

Figure 1. The Les Cheneaux Islands area of northern Lake Huron.

Creel Census

A creel census was conducted in the Les Cheneaux Islands from 11 January through 25 October 1986 (for detailed methods, see Ryckman and Lockwood 1985). The census clerk interviewed anglers 5 days per week on a random schedule with 8-hour shifts. The weekly schedule always included weekends and holidays. Census shifts were arranged so that on any given day, either morning or evening, anglers were randomly sampled. Anglers were interviewed at the end of a fishing trip to determine catch (species, number, and size), hours fished, species sought, gear, and residence. Anglers were also asked if they would prefer to catch seven 7.5-inch perch or five 9-inch perch, and if they would support regulations to produce larger, but fewer, perch in the catch.

Periodic counts of anglers were made throughout the census period to estimate angler effort in the Les Cheneaux Islands. From 11 January through 14 April the census clerk made counts of shanties and open-ice anglers from various access points. Biweekly counts of shanty use by anglers were made to determine percent of shanties occupied, which were stratified by month and location. From 23 April through 25 October 1986, the census clerk made similar periodic counts of fishing boats, pier anglers, and shore anglers. Counts were randomly scheduled and made twice daily. From 19 May through 7 November 1986, counts of fishing boats were also made from an airplane five times a week, weather permitting.

Total effort and total catch were estimated by strata (weekday and weekend, and month) for each category of angling (shanty, open ice, boat, shore, and pier). Angler hours, mean catch per hour (CPH), and their variances were calculated as outlined by Ryckman (1981). CPH was multiplied by total angler hours for each stratum to calculate total catch by stratum. Total catch and total angler hours were summed across strata to give an annual estimate for total catch and total effort for each category of angling. These estimates were summed for all categories of angling to give overall estimates of total catch and total effort.

While interviewing fishermen, the clerk also measured total length for a representative sample of five yellow perch from the angler's creel. From these samples, length frequency of yellow perch in the catch was estimated.

Yellow Perch Tagging

Data used in estimating exploitation rates, distribution, and population size were collected from a tagging experiment conducted by fisheries personnel from District 4 of the Michigan Department of Natural Resources. During the last 2 weeks of April, trap nets were set in Mackinac, Sheppard, and Flower bays (Figure 1) to collect spawning yellow perch. Yellow perch 7.0 inches and longer were measured, sexed, and then tagged using serially numbered Floy FD-68B anchor tags. The T-bar anchor end of the tag was inserted between interneural bones of the dorsal fin. Stebo (1972) showed that mortality of yellow perch tagged using this method was not significantly greater than for untagged fish in the Ottawa River, Ontario. Tag colors were orange in 1985 and yellow in 1986, however, tag numbers overlapped. Scale samples were collected from five fish per inch group per sex to determine growth rate.

In 1985 and 1986, 4,969 and 6,680 yellow perch were tagged, respectively. Tag returns were collected and recorded at local bait stores and resorts. Several measures were taken to encourage returns. Flyers describing the tagging study, and providing information regarding return of tags, were posted at resorts and local bait and tackle stores. Local newspapers published accounts of the project. Chippewa tribal fishermen were also asked for their cooperation in returning tags from yellow perch taken in their assessment nets. Also, in 1985, a $1.00 reward was offered for each tag returned, and a lottery for $500.00 in prizes was held following the summer fishery. In 1986 the $1.00 reward was dropped and a lottery for ten $100.00 prizes was held. Census clerks also recorded tag returns while interviewing anglers.

All tagged fish and tag returns were recorded on computer file by District 4 employees, and all entries were rechecked against the original tag-return sheets. Sex, length, date tagged and recaptured, and tagging and recapture location were entered for each tagged perch.

To analyze the distribution of tag returns, return entries were sorted by tagging and return site. Numbers of returns by site for each tagging location were then plotted on a map and distributions of tag returns were assessed visually.

Population Estimates

Population estimates were made using both single and multiple census techniques. Single census techniques included two applications of the Petersen estimate (Ricker 1975):

$$N = (M \cdot n)/m$$

where N = estimated size of population at time of marking

M = number of fish marked

n = catch or sample taken for census

m = number of recaptured marked fish in a sample.

Variance for the simple Petersen estimate was calculated as:

$$V(N) = [M^2 \cdot n \cdot (n-m)]/m^3.$$

The first application of the Petersen estimate compared the April 1986 trap net catch of untagged yellow perch to perch tagged in 1985. The second application compared number of tagged to untagged yellow perch observed by the census clerk in the June 1986 sport catch. Individual estimates were calculated under assumptions of either negligible or 1-inch annual growth. Stebo (1972) found that Floy FD-67 anchor tags on yellow perch were retained well in his study of less than a year. Therefore, negligible tag loss was also assumed when estimating population size.

Multiple census techniques used for population estimation included mean of Petersen estimates (Ricker 1975) and regression estimation (Paloheimo 1963). The 1986 recaptures of yellow perch tagged in 1985 and 1986, and 1986 creel census catch estimates were used in both of these population estimators.

Mean of Petersen estimates took the average of simple Petersen estimates ($N_i = M_i \cdot n_i/m_i$) over a total of i periods (s):

$$N = \sum(N_i - N)^2/(s-1).$$

Variance for N was calculated as:

$$V(N) = \sum(N_i - N)^2/[(s-1) \cdot (s-2)] \text{ or } V(N) = \sum V(N_i)/(s-1)^2$$

where $V(N_i)$ is variance for the simple Petersen estimate for the i^{th} period. Similar values for variance estimates calculated from these two equations indicated that assumptions underlying this estimator had been met. Advantages of using mean of Petersen estimates stem from the fact that individual estimates of population, made for each period, permit calculation of error based on observed variability, and can reveal trends indicating departure from assumptions underlying this estimator (Ricker 1975).

Using the regression estimator (Paloheimo 1963), population size was estimated as:

$$N = M \cdot \sum n_i / \sum m_i.$$

Variance for β ($\sum m_i / \sum n_i$) was calculated as:

$$V(\beta) = \sigma_{x \cdot y^2} / \sum n_i, \text{ where}$$

$$\sigma_{x \cdot y^2} = [\sum m_i^2 - (\sum m_i)^2] / [\sum n_i \cdot (s-1)].$$

From $V(\beta)$, confidence intervals were calculated as:

$$(M \cdot \sum n_i) / [\sum m_i \pm |t_{\alpha/2}| \{V(\beta) \cdot (\sum n_i)^2\}^{1/2}].$$

Advantages of using the regression estimator are that it weighs each estimate of β_i according to how it varies with β, and it is a robust estimator with respect to underlying assumptions (Paloheimo 1963).

Several modifications were made to determine n_i from catch estimates. First, since only perch ≥7 inches were tagged, catch estimates had to be modified from catch for all sizes to catch for perch ≥7 inches. Therefore, percentage of perch ≥7 inches was calculated from sport catch length frequency, and total catch was then multiplied by this percentage.

Further alteration of catch estimates was necessary to account for seasonal growth. Only perch in the catch which were ≥7 inches at time of tagging were to be included in estimates of n_i. Although no data were available to approximate seasonal patterns in growth, Jobes' (1952) observations on seasonal growth of Lake Erie yellow perch appeared reasonable for application to perch in the Les Cheneaux Islands. Thus, annual growth, which totaled about 1 inch, was added by monthly increment (using Jobes' data) to the initial minimum size of 7 inches, and only the percentage of perch which exceeded this minimum size were included in the estimate of n_i for each month.

Absence of catch estimates for 1985 required that multiple census population estimates, based upon 1985 tagged perch, be constructed using 1986 returns. Therefore, M and n_i had to be adjusted in order to estimate abundance from 1985 tagged fish captured in 1986. To estimate M as of January 1986, number of perch tagged was multiplied by survival rate (s) where: $s = m + n - m \cdot n$. Exploitation (m) for April-December 1985 was estimated from percent of tags returned for that period. Conditional natural mortality (n) was also estimated for that period under the assumption that expectation of death from natural causes remained constant throughout the year. In addition, minimum size for perch included in monthly n_i estimates was set at 8 inches and seasonal growth during summer was calculated as before.

Growth and Age Structure

From 1969 to the present, scale samples were collected by MDNR (Alpena Great Lakes Fisheries Station and District 4) during their fall assessment of the fish population in the Les Cheneaux Islands. Yellow perch and other species of fish were netted using graded-mesh gill nets. Aging of many of the scales was checked to verify that aging done by technicians in Alpena and Newberry had been consistent. All scales were impressed on cellulose acetate slides and examined under a microfiche projector at 44 times magnification.

To analyze for annual variations in growth of Les Cheneaux yellow perch, mean length-at-age for 1969-86 collections was calculated for each age and year. Then, a 95% confidence interval for each mean length was constructed using the pooled estimate for variance of the population (s^2). This pooled variance was derived from a two-way analysis of variance (ANOVA) which tested the effect of year and age on length. The mean square error (MSE) from the ANOVA is the best estimate for s^2 (Neter et al. 1985). Variance of the mean ($s_x{}^2$) was then calculated for each mean length by dividing s^2 by sample size for each age and year. Values for standard error of the mean (s_x) were multiplied by $t_{0.05,\ n-1}$ (Remington and Schork 1985), where n was sample size at each age, to obtain 95% confidence intervals for each mean length. All statistical analyses were performed on the Michigan Terminal System using MIDAS (Fox and Guire 1976).

Length-age data were also analyzed to determine whether year class strength had a noticeable effect on growth rate. Annual growth was calculated for ages 2-7 by subtracting the mean length at age t-1 from that at age t for the following year. For example, mean length of age-2 perch in 1971 was subtracted from mean length of age-3 perch in 1972 to calculate growth for 3 year olds in 1972. Average growth for 1969-86 was calculated by age, and then summed for ages 2-5 and ages 2-6. Growth was also summed for ages 2-5 and ages 2-6 for each year and year class of perch. All of these values were subtracted from 1969-86 average growth to calculate deviation from the mean. Deviations for years and year classes were not normally distributed. Therefore, a non-parametric procedure, the Wilcoxon sum rank test (Remington and Schork 1985), was applied to test the hypothesis that average deviation of growth between year classes and years was not significantly different.

Catch per unit effort (CPUE) for assessment nettings was analyzed to search for trends in CPUE at each age and for the presence of exceptionally strong year classes. Annual CPUE was calculated by age. Values of CPUE were not normally distributed for all ages, so comparisons of mean CPUE for different periods were made using the Wilcoxon sign rank test.

To test for the presence of exceptionally strong year classes, percentage of total catch at each age was calculated for each assessment from 1969 to 1986. Percentages for total catch at each age were then averaged over all assessments, and standard deviations were calculated by age. Deviation from the mean was calculated by age and year. Ages having a deviation greater than one standard deviation were considered exceptional. The repeated appearance of an exceptional year class over consecutive years was considered to indicate a strong year class of yellow perch.

Finally, mean lengths of perch netted in the fall were compared with back-calculated mean length-at-ages to determine whether fall length-age data could be used in constructing a von Bertalanffy growth model. Assuming negligible growth occurred between time of capture in the fall and time of annulus formation, then fall lengths for each age and back-calculated length-at-age should not produce significantly different von Bertalanffy growth parameters. To test this hypothesis, two von Bertalanffy growth coefficients (k and L_∞) calculated from fall length-age data and back-calculated length-at-age, were compared.

Scale samples from 1971, 1980, and 1986 were used in back calculations. For each year, five scale samples per age were taken at random using the ages originally determined by the fisheries technicians. For ages 6 and older, all available scale samples were used. The scale samples were aged and distance from focus to each annulus and to scale margin was measured. Perch length was regressed upon length of the scale radius using MIDAS. The intercept of this regression approximates length of yellow perch at time of scale formation (Carlander 1977), and equals the intercept (a) in the Fraser-Lee modification of the direct proportion back-calculation procedure:

$$L_i = a + [(L_c - a) \cdot S_i]/S_c$$

where L_c = length of fish at capture; S_c = length of scale at capture; S_i = length of scale at age i; and L_i = length of fish at age i (Bagenal 1978). A FORTRAN program, utilizing the Fraser-Lee modification, back-calculated length-at-age for each age and then used a weighted average to compute mean length-at-age for each year's sample of perch. To compare mean lengths of fall fish with back-calculated mean length-at-ages, Ford-Walford plots were constructed using the Least Squares Method (Walford 1946). Slope of the Ford-Walford plot is related to Ford's growth coefficient k [slope = exp (-K)], and intercept equals $L_\infty \cdot (1-k)$, where L_∞ is asymptotic length of the fish. For 1971, 1980, and 1986, differences in these growth parameters for Ford-Walford plots, generated from fall length-age data and back-calculated length-at-age, were tested for using an analysis of covariance based on a 5% level of significance (Neter et al. 1985).

Mortality and Exploitation

Total instantaneous mortality rate (Z) was estimated using the Least Squares Method to fit a straight line to the descending limb of a catch curve (Ricker 1975; Everhart and Youngs 1981). Catch curves were derived from spring tagging and fall assessment catch data. To determine total catch by age, all yellow perch taken during fall assessment gill netting were scale sampled and aged. For the spring tagging study, subsamples of five perch per sex, per inch group, were collected for scale analysis.

From the aged scales, percentages of perch at each age for each inch group were determined. These percentages were then multiplied by total catch for each inch group to give total catch by age within an inch group. Total catch by age per inch group was then summed across inch groups to give total catch at each age. Perch older than the first age class which had declined to 10 fish were not included in the catch curve (Everhart and Youngs 1981). A one-way analysis of covariance was used to test for significant differences between Z values calculated from spring and fall catch data. Similar values for Z would permit pooling of fall and spring catch data to estimate Z.

Instantaneous rate of fishing mortality (F) was estimated using the relationship:

$$Z/A = F/u$$

where (A) is actual total mortality rate and (u) is rate of exploitation (Ricker 1975). This relationship holds for Ricker (1975) Type-II fisheries where fishing and natural mortality were assumed to operate concurrently. Actual mortality rate is $(1 - e^{-Z})$, and rate of exploitation was estimated from the percentage of tagged yellow perch returned within a year after tagging. The estimate for instantaneous rate of fishing mortality was subtracted from instantaneous total mortality rate to calculate instantaneous rate of natural mortality (M): $M = Z - F$.

Hooking Mortality

Les Cheneaux yellow perch anglers were asked to participate in a study to estimate hooking mortality for yellow perch. Anglers volunteered to utilize various angling techniques (bobber fishing, tight-line fishing, and vertical jigging) and baits (minnows, earthworms, and leeches) to catch yellow perch. All sizes of perch caught were kept and were placed in wire live baskets, which were submerged alongside their boats. Transport of perch from fishing site to the boat launch was in 20-liter plastic buckets and length of time for transport was less than 20 minutes. Perch were rapidly measured, their overall condition noted, and were placed into 1,000-liter live cages. Dead yellow perch were culled and measured last. Live cages were totally submerged in a well-oxygenated, partially shaded location, and the water temperature was measured daily. After 24 hours, condition of the yellow perch was checked again, and they were returned to the participating angler or released.

Fishery Simulation

The dynamic pool model is one of the most commonly used estimation procedures for stock assessment (Tyler and Gallucci 1980). Unlike the surplus production model, the dynamic pool model explicitly incorporates growth and mortality rates into its calculation for yield. Though its consideration of biological parameters makes the dynamic pool approach intuitively more appealing to biologists, parameters utilized in this model are sometimes difficult to estimate.

The Beverton and Holt (1957) approach to the dynamic pool model is often used for stock assessment. In their approach to yield modeling, Beverton and Holt made several simplifying assumptions. These assumptions included using constant rates of natural and fishing mortality which were immediately applied to cohorts of fish at their respective ages (knife-edge recruitment), using the von Bertalanffy growth curve to represent growth in length, and taking the simple cube of the von Bertalanffy parameters to convert them from length to weight. A modified version of the Beverton and Holt approach, the multiple-cohort population simulator (Clark and Huang 1985), was used to assess yellow perch stock in the Les Cheneaux Islands. Modifications over Beverton and Holt's model included:

1. Using instantaneous rates of natural (M) and fishing (F) mortality calculated by age;
2. Using separate F values for different fishing gears;
3. Using gradual recruitment of a cohort into fishing gears;
4. Using length-weight coefficients to convert von Bertalanffy parameters from growth in length to growth in weight; and
5. Using the Baranov catch function to compute catch by age.

These modifications for this fishery yield model were suggested by Tyler and Gallucci (1980), and were described in greater detail by Clark and Huang (1985).

The multiple cohort population simulator was used to simulate catch, yield, and population size for the perch fishery under 0-, 7-, and 8-inch minimum size limits (MSL). The 1986 fishery (0-inch MSL) provided much of the baseline data that the model is based on. In order to simulate the fishery under different MSL's, instantaneous rates of mortality for sportfishing had to be estimated by age. F values estimated from angler tag returns were assigned to ages greater than 4, which were fully exploited. To estimate F values for ages 1-3, which were not yet fully exploited by the sport fishery, F values were adjusted by trial and error until age frequency of predicted catch was similar to that of observed sport catch (as calculated from length-frequency data).

F values were also adjusted for ages of perch protected under 7-inch and 8-inch MSL's. Percentages of age-3 perch greater than 7 inches in total length were estimated from age frequency for the 1986 sport catch. This percentage was then multiplied by the F value for that age. The same procedure was performed for age-4 perch greater than 8 inches in total length.

The effect of hooking mortality on protected ages of perch was also included in the simulation. To represent the effect that hooking of sublegal fish had on yield under any MSL, hooking mortality rate was multiplied by F values calculated under no MSL, and these values were added to natural mortality rates for sublegal ages.

Simulations were also run to show the effect of commercial fishing on sportfishing. F values for the commercial fishery were calculated by age. To calculate F values by age, 1986 fall assessment data were used to estimate age frequency for commercial catch from length frequency for 1986 (yellow) tags returned by Native American netters. Since a majority of commercial netting was done in May, length-at-age t for fall fish was assigned to age t+1 for netted fish. This correction was necessary to adjust for the fact that commercially netted fish were assumed to be one year older with no appreciable growth. Age frequency for perch tagged in 1986 was also estimated. At each age, percentage of tagged fish returned by commercial netters was calculated to give an estimation of exploitation by age. F values were then calculated using these exploitation rates.

For all simulations, recruitment was held constant at 1,000 perch entering the fishery annually. Growth, natural mortality, and fishing intensity were assumed to remain constant in spite of regulations or changes in density of perch. Calculations were made on an annual basis, beginning in October and extending through September.

RESULTS

Creel Census

In 1986 yellow perch comprised 85% of the total estimated sport catch in the Les Cheneaux Islands (Table 1). Rock bass (*Ambloplites rupestris*) and cisco (*Coregonus artedii*) were second and third in total numbers caught. The best estimate (made using airplane counts) for total catch of yellow perch was about 438,000 fish (Table 2). Perch catch peaked in June (Figure 2). Total angler hours were estimated at slightly over 400,000 (Table 2). Using ground counts, total yellow perch catch and total angler hours were estimated at 213,000 and 184,000, respectively. The estimates for total catch in 1980 and 1986 were similar, however, the estimate for angler effort was significantly lower in 1980 (Table 2). Therefore, catch per angler hour of yellow perch was significantly higher in 1980 than in 1986.

Yellow perch catch during winter (49,283) represented only 11% of the total for 1986 (Figure 2). Yellow perch comprised 95% of total catch in winter, with remainder of the catch comprised mostly of cisco and northern pike (Table 1). Total effort for the winter fishery (33,499 hours) represented 8% of the yearly total. Effort for shanty anglers comprised the greatest proportion (63%) of this estimate. Effort for the winter fishery was similar in

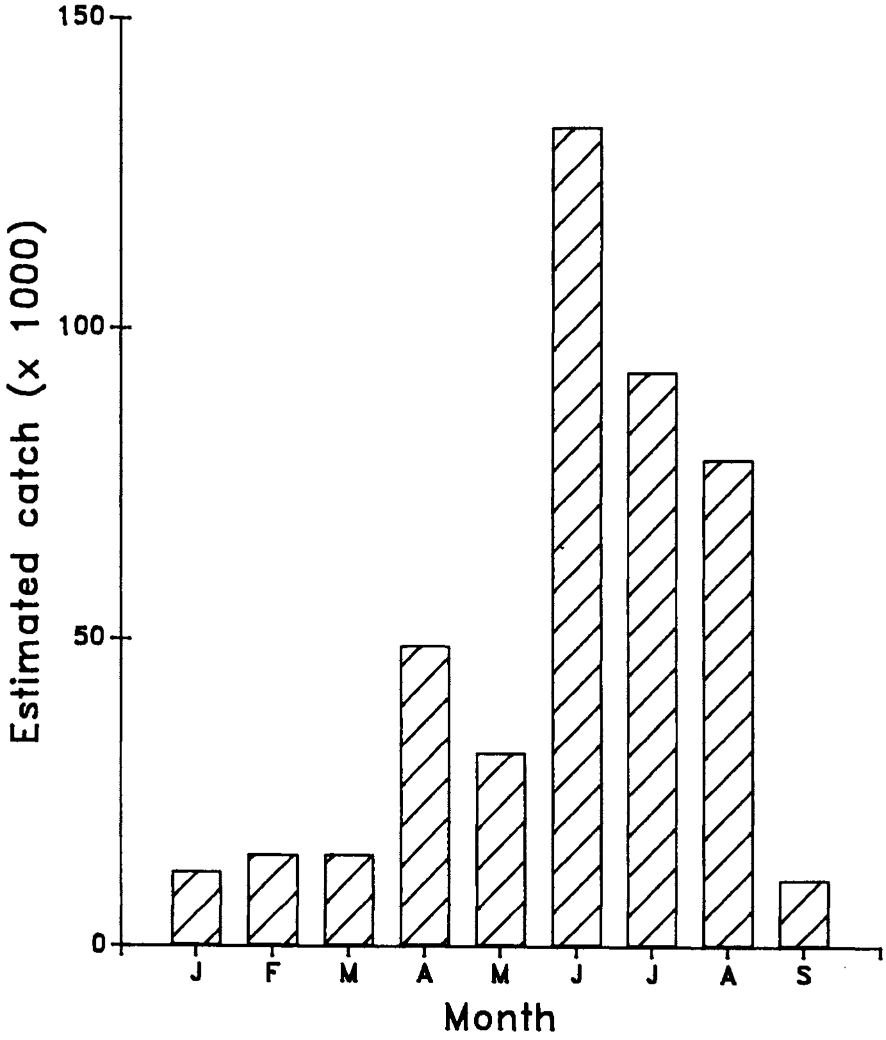

Figure 2. Best estimates for monthly catch of yellow perch from January 1986 through September 1986 for anglers in the Les Cheneaux Islands.

Table 1. Percent composition of species in the catch for anglers in the Les Cheneaux Islands from catch estimates for the 1986 creel census.

	Percent of total catch		
Species	Winter fishery	Summer fishery	Combined
Yellow perch	95	85	85
Cisco	3	3	3
Northern pike	1	2	2
Menominee	---	1	1
Rock bass	---	4	4
Pumpkinseed	---	2	2
Smallmouth bass	---	1	1
Chinook salmon	---	1	1
Other	1	1	1

Table 2. Yellow perch catch, catch per angler hour (CPH), and total angler hours and trips from creel census estimates from 1979-81 and 1986 in the Les Cheneaux Islands. (Two standard errors in parentheses.)

Season and year	Catch	Catch per hour	Total angler Hours	Total angler Trips
Winter				
1980[1]	109,145	3.44	31,752	7,687
	(24,826)	(1.01)	(5,857)	(1,497)
1981	50,718	1.86	27,281	6,221
	(6,776)	(0.25)	(386)	(452)
1986	49,283	1.47	33,499	8,646
	(6,196)	(0.24)	(3,607)	(889)
Summer				
1979	83,818	0.96	87,526	22,137
	(35,822)	(0.44)	(14,464)	(3,657)
1980	91,929	2.27	40,506	12,302
	(11,270)	(0.33)	(3,282)	(1,090)
1986[2]	164,047	1.02	150,287	54,195
	(28,147)	(0.22)	(17,102)	(5,659)
1986[3]	389,444	1.04	372,781	133,871
	(68,401)	(0.22)	(46,128)	(15,466)
Combined				
1980	201,074	2.78	72,285	19,989
	(27,264)	(0.46)	(6,714)	(1,852)
1986[2]	213,330	1.16	183,786	62,841
	(28,821)	(0.19)	(17,478)	(5,728)
1986[3]	438,727	1.08	406,280	142,517
	(68,402)	(0.21)	(46,261)	(15,491)

[1] Estimates for 1979-81 taken from Ryckman and Lockwood (1985).

[2] Estimates based on counts of boats from shore.

[3] Estimates based on counts of boats from airplane.

1980, 1981, and 1986 (Table 2). Perch catches during the winter of 1981 and 1986 were also similar. However, yellow perch catch during winter 1980 was substantially better than in 1981 and 1986. Therefore, catch per angler hour was also significantly greater in 1980 (Table 2).

During the open-water fishery, airplane counts of fishing boats were on average 2.52 (±0.225) times greater than counts made from different vantage points on the ground. This surprisingly large difference between air and ground counts was attributed to the large percentage of boats hidden in the myriad of islands and bays, or located too far offshore to be seen by the creel clerk counting from vantage points along shore. Consequently, estimates of total catch and total angler hours were based on both ground and air counts. Estimates calculated using air count data were believed to be more accurate, while estimates utilizing ground counts were valuable for comparison with estimates from previous surveys, which used only ground counts. The pilot was unable to accurately count pier and shore anglers, therefore, catch-and-effort estimates made for pier and shore anglers were based on ground counts.

The majority (89%) of yellow perch catch was made during summer (Figure 2). The best estimate for total summer catch was about 390,000 yellow perch. Species of lower frequency during the summer fishery included rock bass, cisco, northern pike (Esox lucius), menominee (Prosopium cylindraceum), and pumpkinseed (Lepomis gibbosus)

(Table 1). Angler hours for summer totaled 373,000, of which 97.8% was by boat anglers, 1.6% by shore anglers, and 0.6% by pier anglers. The estimate of yellow perch catch based on ground counts was about 164,000 fish; this was significantly greater than comparable estimates for summer 1979 and 1980 (Table 2). In fact, the 1986 estimate was 39% higher than the 1979-80 average. Similarly, the estimate for angler effort during summer 1986 was also significantly greater than estimates for 1979 and 1980 (Table 2). Total catch and total angler hours were significantly greater for the 1986 summer fishery, however, resultant catch per angler hour was similar to that for summer 1979, and both these rates were significantly below catch per angler hour for 1980 (Table 2).

An analysis of angler residence from 2,530 interviews showed major differences in demography of anglers participating in winter and summer fisheries (Figure 3). A majority (77%) of winter fishing effort was by local anglers (Mackinac and Chippewa counties), and combined efforts for residents of the Lower Peninsula and out-of-state anglers constituted a substantially smaller proportion of the total effort (Figure 3). However, for the summer fishery, anglers residing in the Lower Peninsula contributed the largest proportion to total angling effort, out-of-state anglers were second, and Upper Peninsula residents contributed the smallest portion to total effort. Overall, local anglers constituted 21% of the angling effort, out-of-state anglers

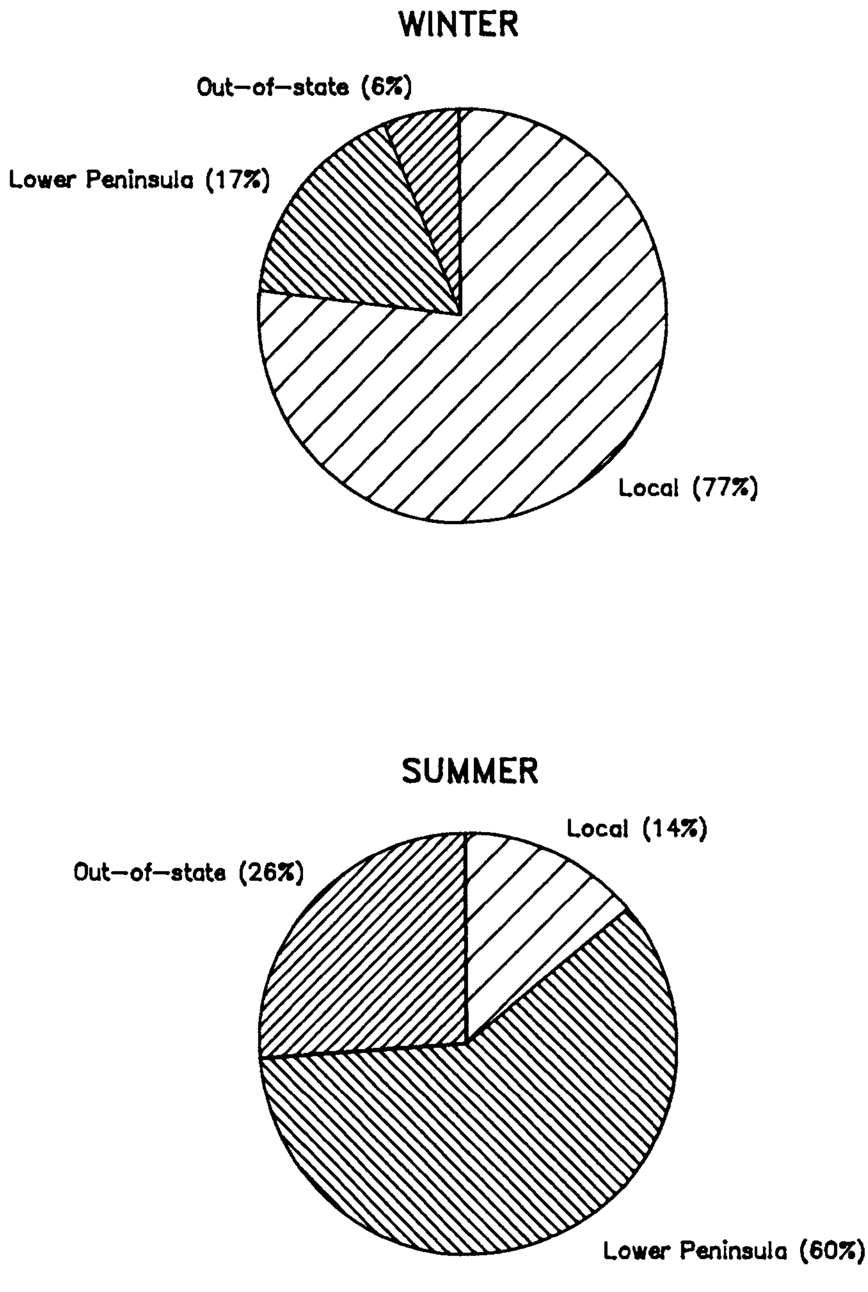

Figure 3. Residence of anglers interviewed by the creel census clerk for the 1986 winter and summer fisheries in the Les Cheneaux Islands.

contributed 22%, and anglers residing in the Lower Peninsula contributed the majority of effort (51%).

Most anglers (68%) fishing in the Les Cheneaux Islands stated that they were fishing for yellow perch. The percentage of anglers targeting yellow perch varied over the fishing season with 95% of winter anglers and 61% of summer anglers fishing for perch. During summer, anglers also fished for pike (15%), cisco (12%), and salmonids (4%).

A majority of anglers stated that they would prefer to catch five 9-inch perch over seven 7.5-inch perch (Figure 4). Anglers during winter, who were predominately local residents, often preferred the many small-perch option, while summer anglers, predominately tourists, were more inclined to select the few large-perch option. Likewise, a majority of anglers interviewed supported restrictive regulations on the fishery, which would produce larger, but fewer perch (Figure 5). Once again, response varied with fishing season.

Distribution

Perch tended to remain close to where they were tagged and formed fairly discrete stocks. A majority of perch tagged in Mackinac Bay were recaptured by anglers in Hessel Bay and adjoining bays on the west side of the islands (Figure 6). Similarly, perch tagged in Flower Bay tended to remain on the east side of the islands (Figure 7). Returns for perch tagged in Sheppard Bay indicated that these fish

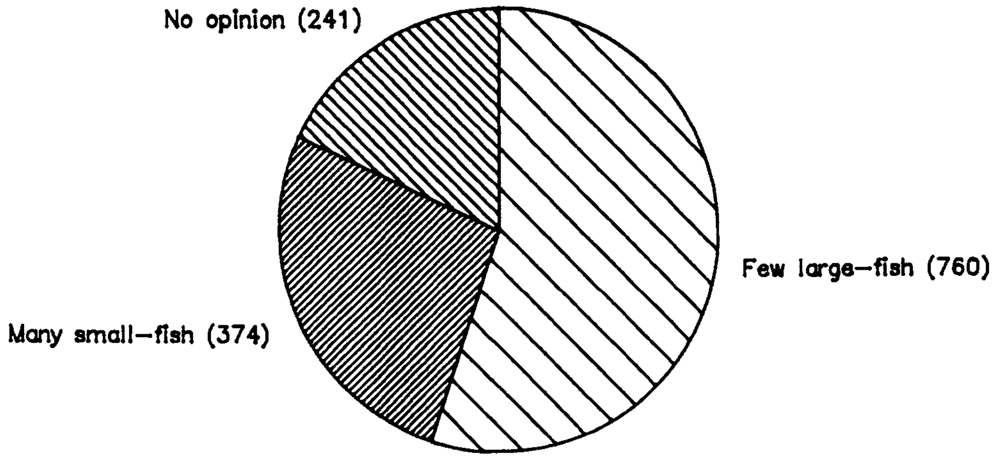

Figure 4. Response of Les Cheneaux perch anglers interviewed during the 1986 creel census to a question concerning catch preference for yellow perch.

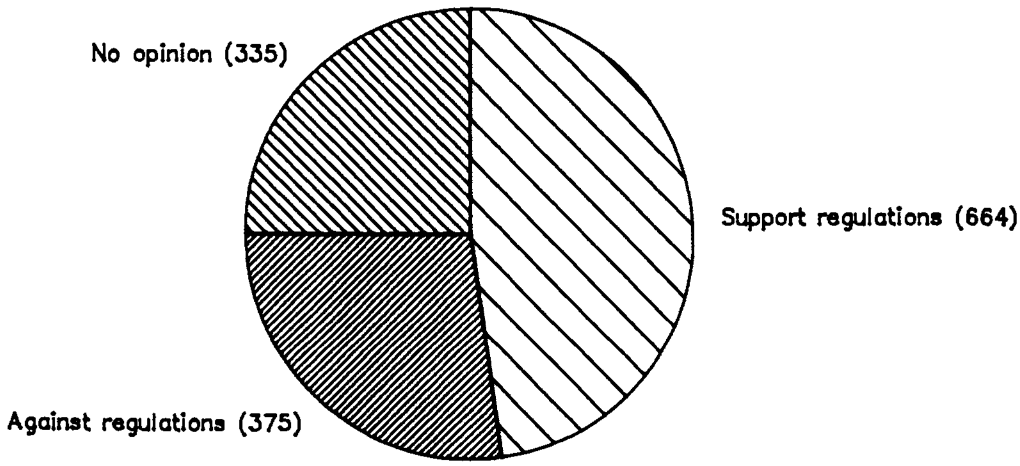

Figure 5. Response of Les Cheneaux perch anglers interviewed during the 1986 creel census to a question concerning their desire to support fishing regulations on the yellow perch fishery.

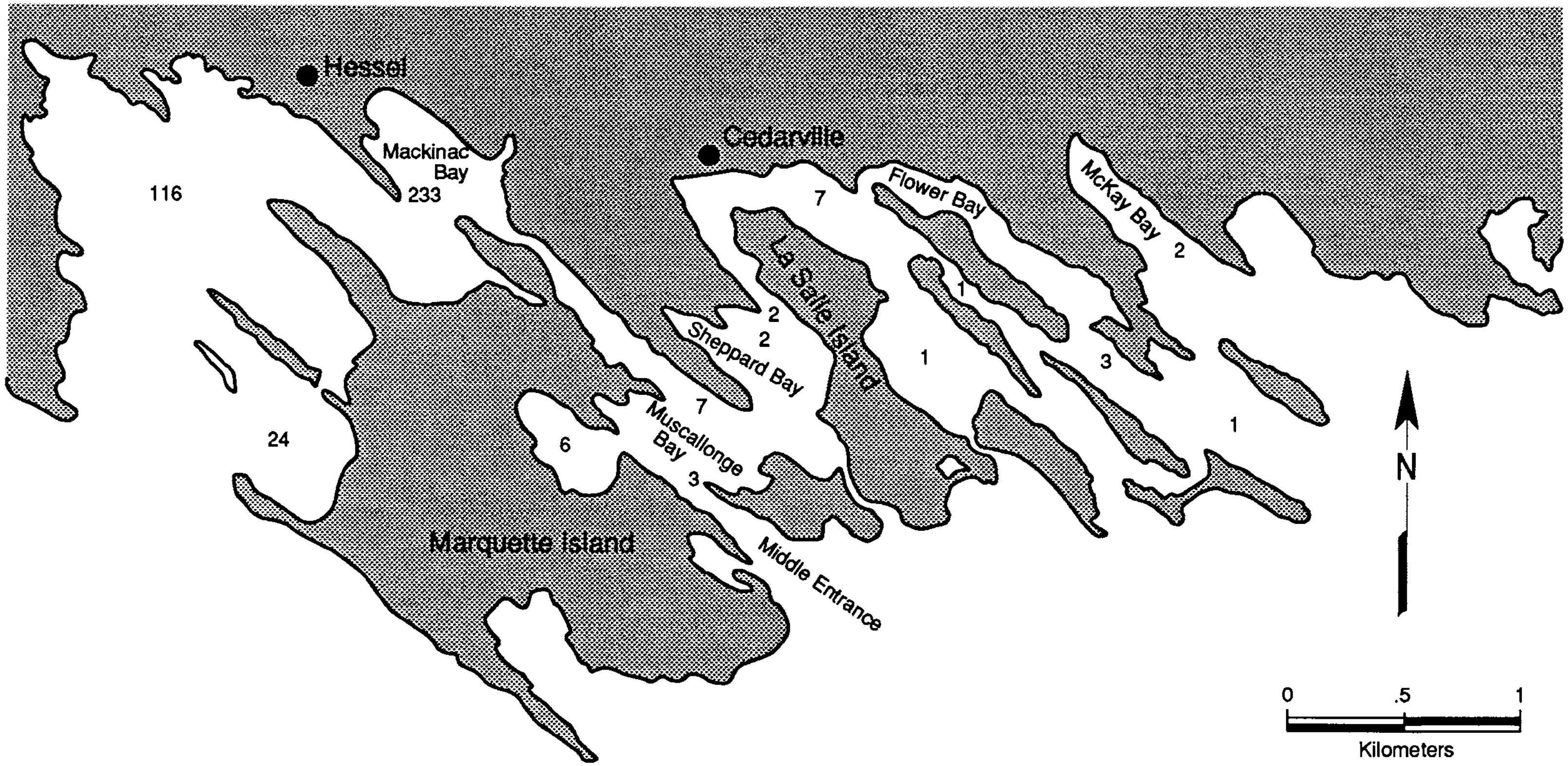

Figure 6. Distribution of tag returns, April 1985 through April 1986, of yellow perch tagged in Mackinac Bay, April 1985.

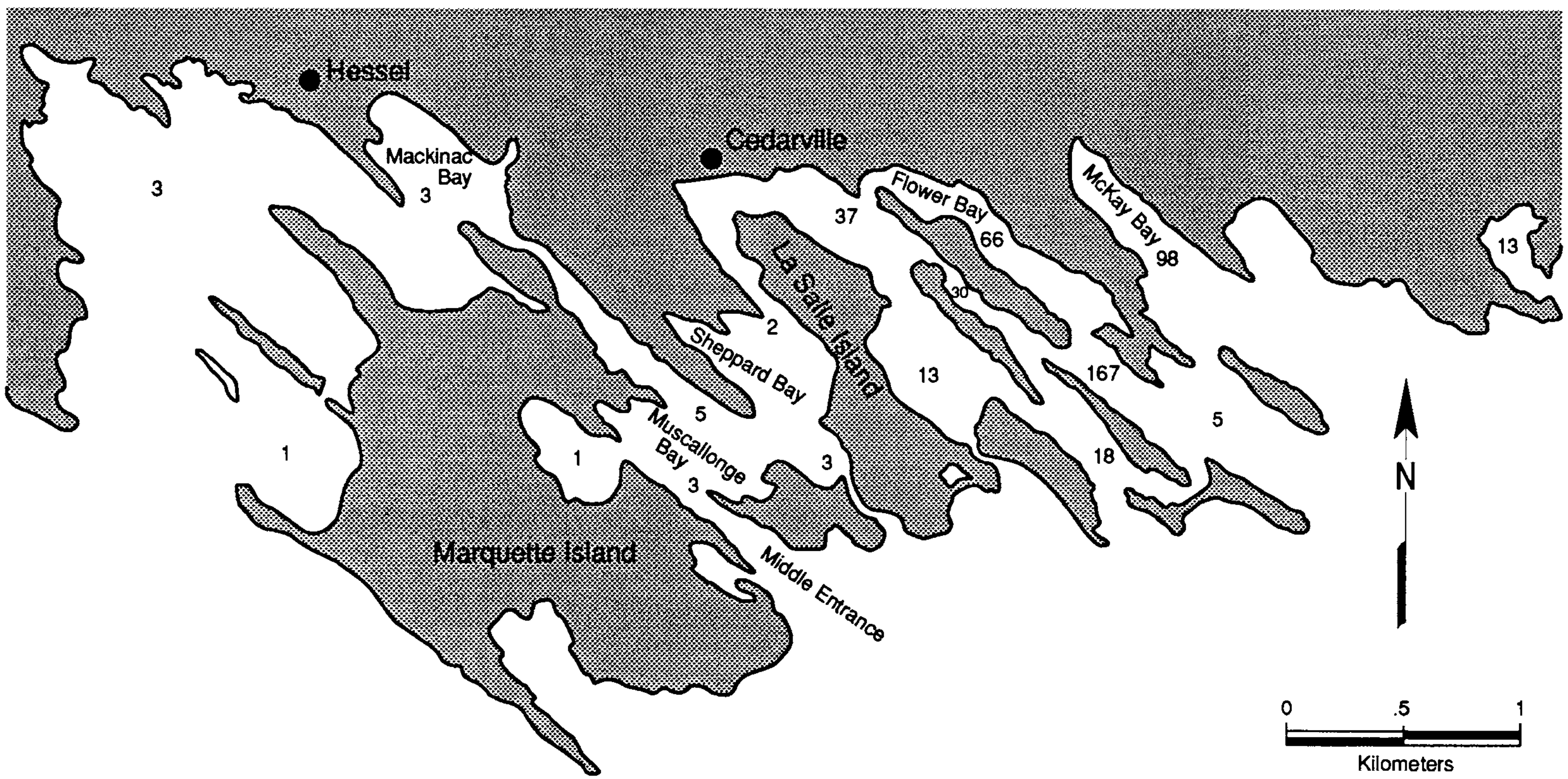

Figure 7. Distribution of tag returns, April 1985 through April 1986, of yellow perch tagged in Flower Bay, April 1985.

ranged over a wider area than perch tagged in Mackinac or Flower bays (Figure 8). Even among fish tagged in Sheppard Bay, a substantially greater percentage of these perch were located in adjacent Muscallonge Bay and Middle Entrance than other areas. Returns for 1986 tagged perch demonstrate similar distributions.

A large percentage (96%) of the 253 perch tagged in 1985 and recaptured in 1986 tagging study trap nets were caught in the same bay where the fish had been tagged. This suggests that perch may home to spawning bays. Homing of yellow perch to spawning bays further supports the idea that discrete stocks may exist within the Les Cheneaux Island area.

Population Estimates

Angler returns for orange tags from April 1985 to April 1986 totaled 1,401. A large percentage of recaptures were made during the summer (Figure 9). Returns for yellow tags from April 1986 to April 1987 totaled 1,126, and the seasonal distribution of returns was quite similar to 1985. Thus, annual return rates for 1985 and 1986 were 28% and 17%, respectively.

The two applications of the Petersen estimate made using tag return results gave very different estimates for population size of yellow perch. The population of perch ≥7 inches was estimated at approximately 80,000 fish using ratio of perch tagged in 1985 to untagged perch captured in

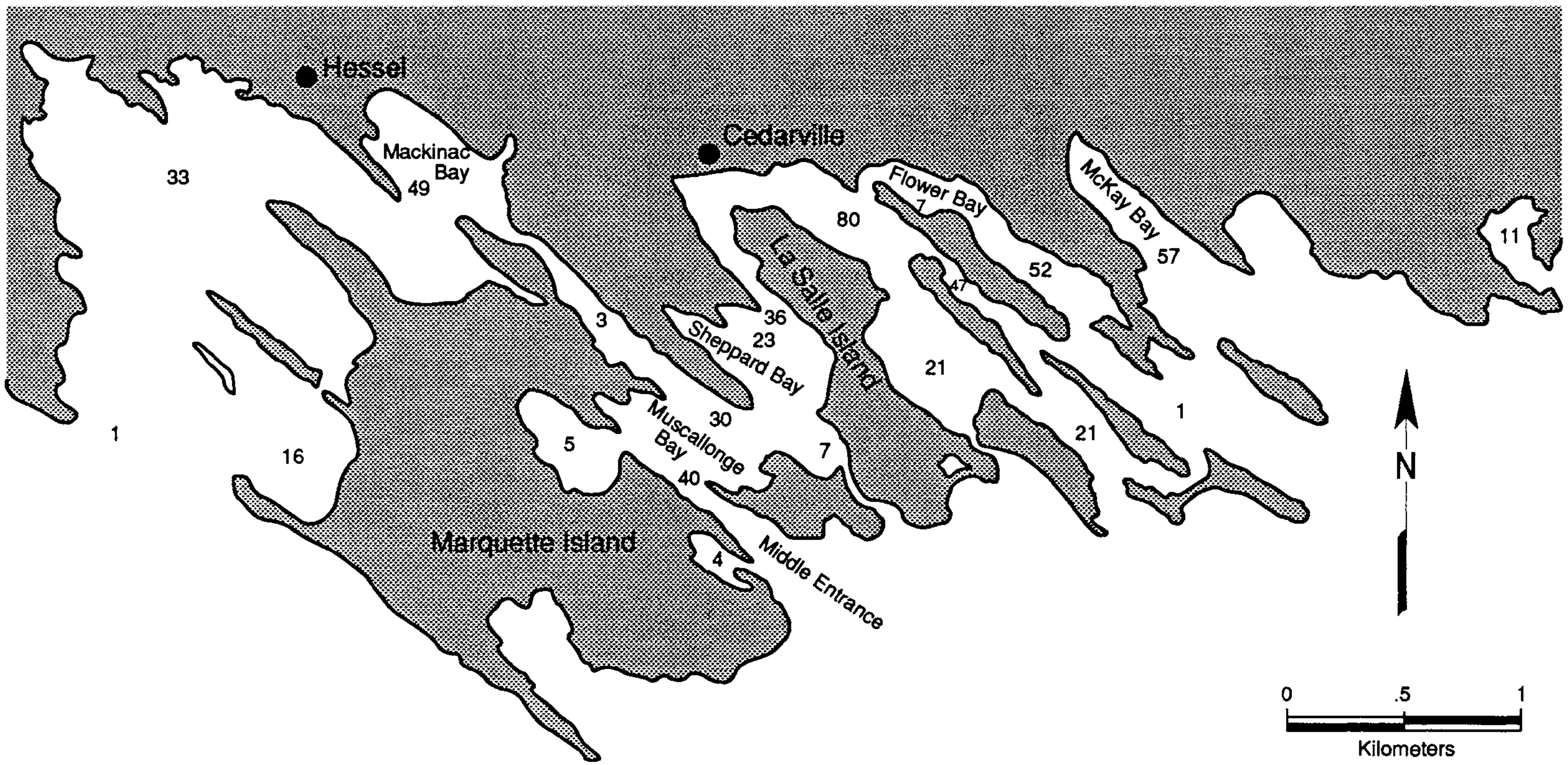

Figure 8. Distribution of tag returns, April 1985 through April 1986, of yellow perch tagged in Sheppard Bay, April 1985.

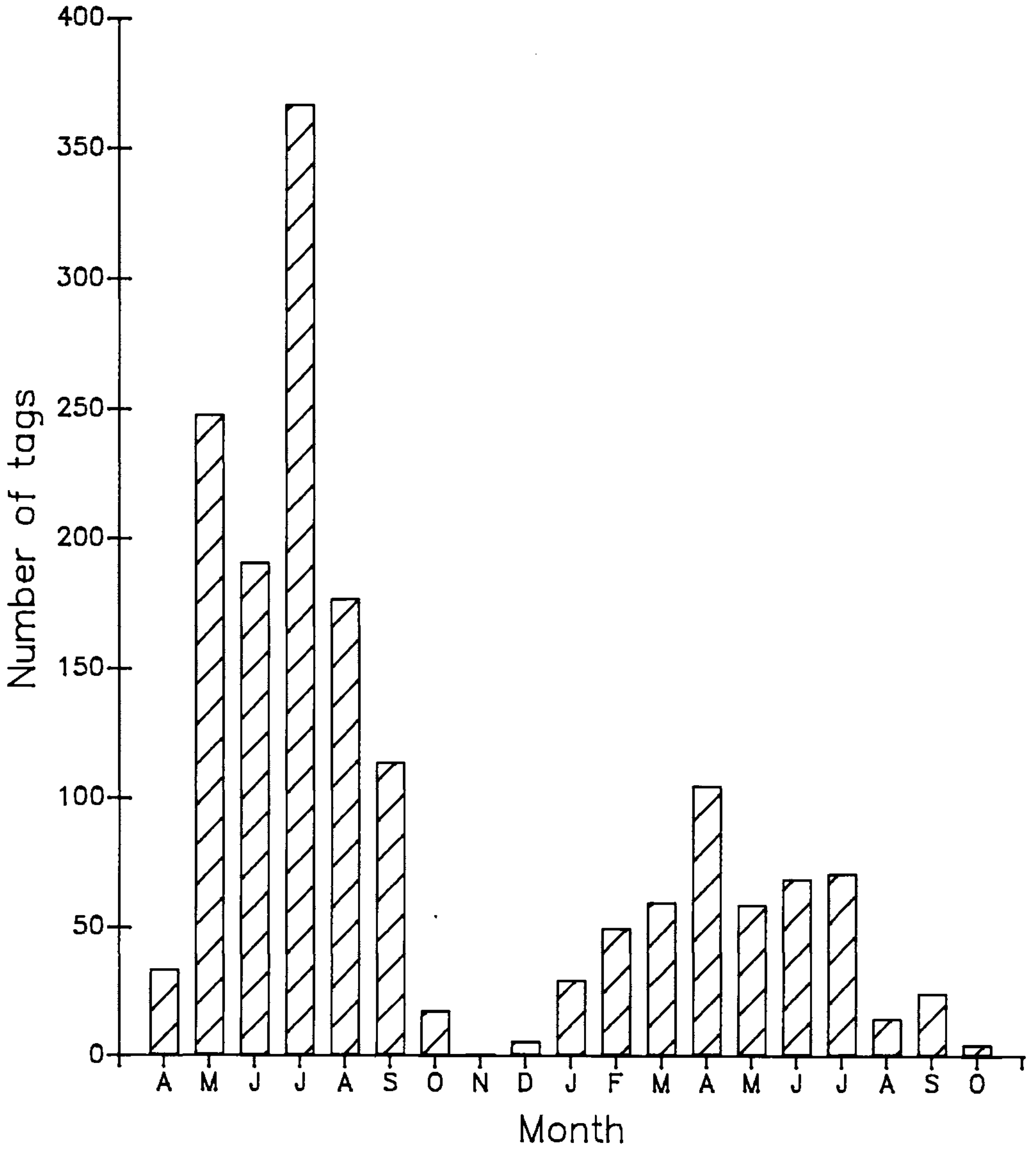

Figure 9. Number of tags returned by anglers each month April 1985 through October 1986, for yellow perch tagged in 1985 (orange tags) in the Les Cheneaux Islands.

the 1986 trap nets. This estimate appears extremely low, considering that catch of perch ≥7 inches was estimated at approximately 360,000 fish in 1986.

The Petersen estimate, which compared tagged to untagged perch actually observed in the June sport catch, gave a more realistic estimate of population size. Assuming negligible growth in May, the population of perch ≥7 inches was estimated at about 524,000. This population estimate was considered the most accurate of the estimates because it was relatively precise (coefficient of variation (CV) = 19%), and assumptions underlying it did not appear to be violated. If perch were assumed to grow 0.2 inch in May, this estimate was reduced to 351,000 fish.

The four estimates of population size derived from mean of Petersen estimates or regression estimators were not significantly different ($p > 0.05$). Using mean of the Petersen estimates, population size (perch ≥7 inches), estimated from 1986 returns of 1985 tagged perch, was about 900,000 fish. This estimate increased to 1,600,000 fish when 1986 returns of 1986 tagged fish were used. Coefficient of variation for both estimates was approximately 25%. Regression estimates of population size, derived from 1986 returns of 1985 and 1986 tagged perch, were 1,000,000 and 1,800,000 perch ≥7 inches, respectively. These population estimates were similar to mean of the Petersen estimates, however, they were less precise (CV = 26% and 42%).

Growth and Age Structure

Analysis of scale samples collected from 1969 to 1986 revealed large discrepancies in ages previously assigned to yellow perch by fisheries technicians. Aging of 1985 and 1986 samples differed substantially from aging done for 1969-84 samples. Scales for 1986 perch were re-aged, while scales from 1985 and 1981-82 (which were not available) were omitted from the growth analysis.

Overall, growth of yellow perch in the early 1970s was better than the 1969-86 average (Figures 10 and 11). Age-4 and age-5 perch were significantly larger in 1969-74 than in 1975-86 ($p < 0.05$). Age-3 perch also showed better than average size in the early 1970s, but they were about average in 1969-70. Although average size was smaller in 1975-86, perch growth for individual years during this period was equal to or better than in 1969-74. Unlike 1969-74, perch did not show better than average growth for more than two consecutive years during this period.

Growth of age-3 and older yellow perch declined sharply by 1975 (Figures 10 and 11). Size began to decline for younger perch prior to 1975. Size of age-3 perch started to decline in 1973 and continued to decline through 1975. Size of age-2 perch appeared to decline slightly from 1972 through 1975, however, mean lengths for age-2 perch during this decline were not significantly different from years prior to it ($p < 0.05$).

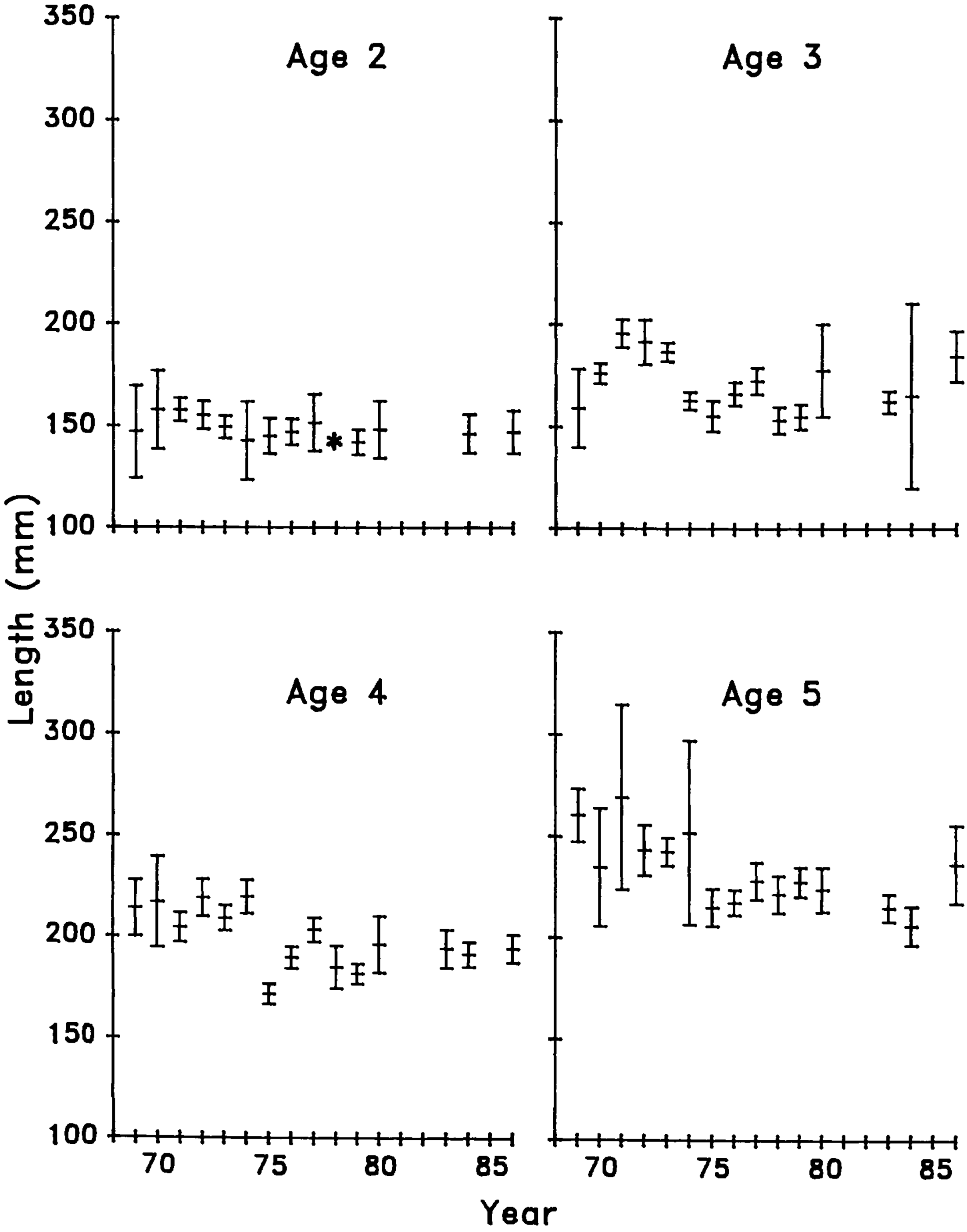

Figure 10. Mean length (with 95% confidence intervals) for ages 2- to 5-male yellow perch collected during 1969-86 fall assessments in the Les Cheneaux Islands. Length-at-age derived from samples containing only one fish is indicated with an asterisk (*).

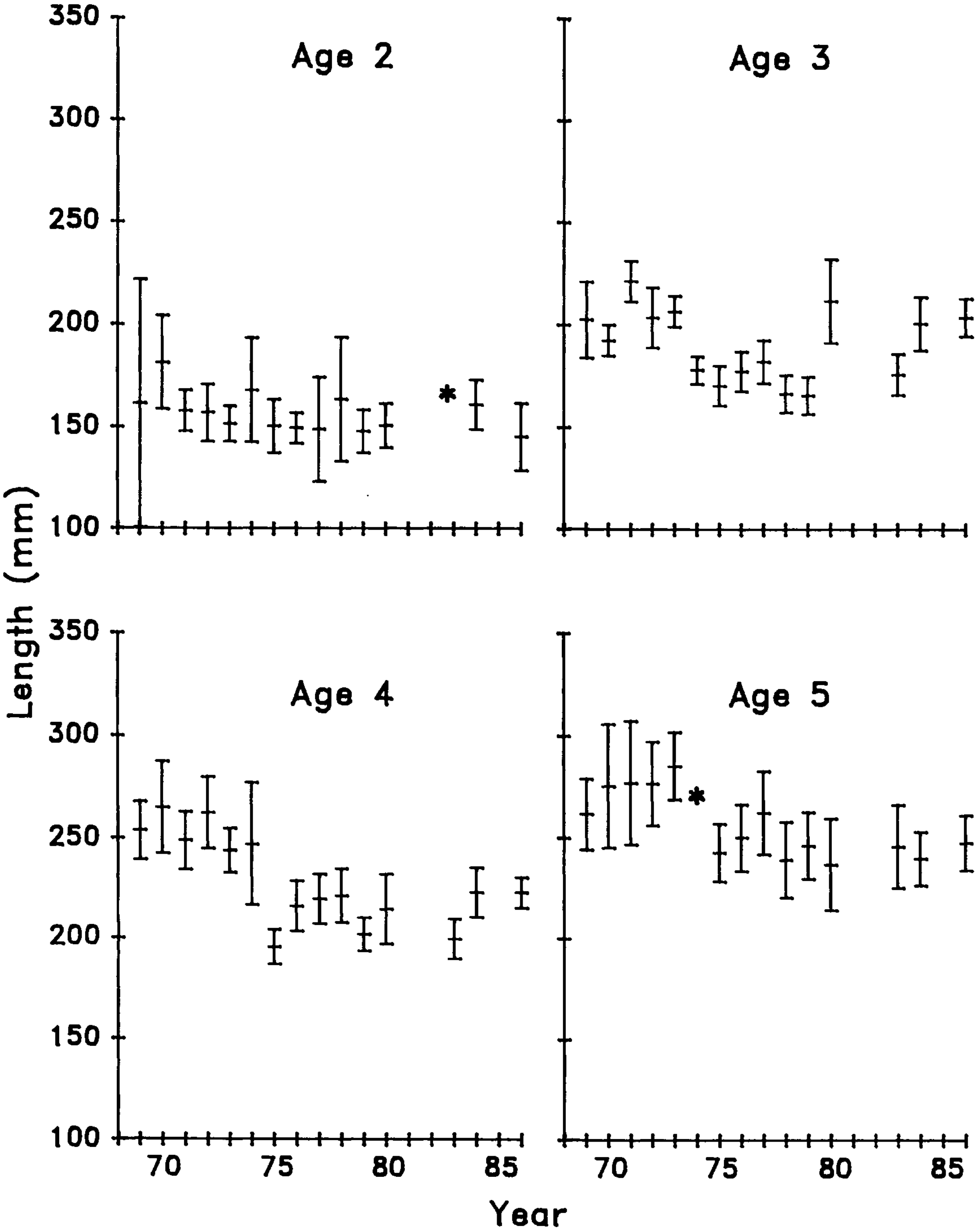

Figure 11. Mean length (with 95% confidence intervals) for ages 2- to 5-female yellow perch collected during 1969-86 fall assessments in the Les Cheneaux Islands. Length-at-age derived from samples containing only one fish is indicated with an asterisk (*).

From 1975 to 1986, average size of perch showed no trend. However, sizes of age-3 and age-4 perch were highly variable, and on occasion, mean length-at-age was significantly different for consecutive years (Figures 10 and 11). Sizes of age-5 perch in 1975-86 also varied, but variation among mean lengths was not as great as for age-3 and age-4 perch. Size of age-2 perch varied least. No significant differences were present between mean lengths for age-2 perch ($p > 0.05$).

Female perch grew significantly faster than males, ($p < 0.05$) for ages 2-7 (Figure 12). Sexual differences in mean size increased with increasing age, but were insignificant at age 8+, due to high variability and small sample sizes. Also, size among individual female perch, ages 2-7, was significantly more variable than for males (F-test, $p < 0.001$).

Overall, growth of yellow perch showed greater deviation among years than among year classes (Table 3). Deviation of yearly growth from the 1969-86 average was significantly greater than deviation of year classes from that average for both age-2 to age-5 females ($p = 0.01$) and age-2 to age-6 males ($p = 0.03$). The difference between deviation for growth for years and year classes was marginally significant for age-2 to age-5 males ($p = 0.06$) and insignificant for age-2 to age-6 female perch ($p = 0.13$). Average deviation for growth between year classes was not significantly different between sexes ($p > 0.85$).

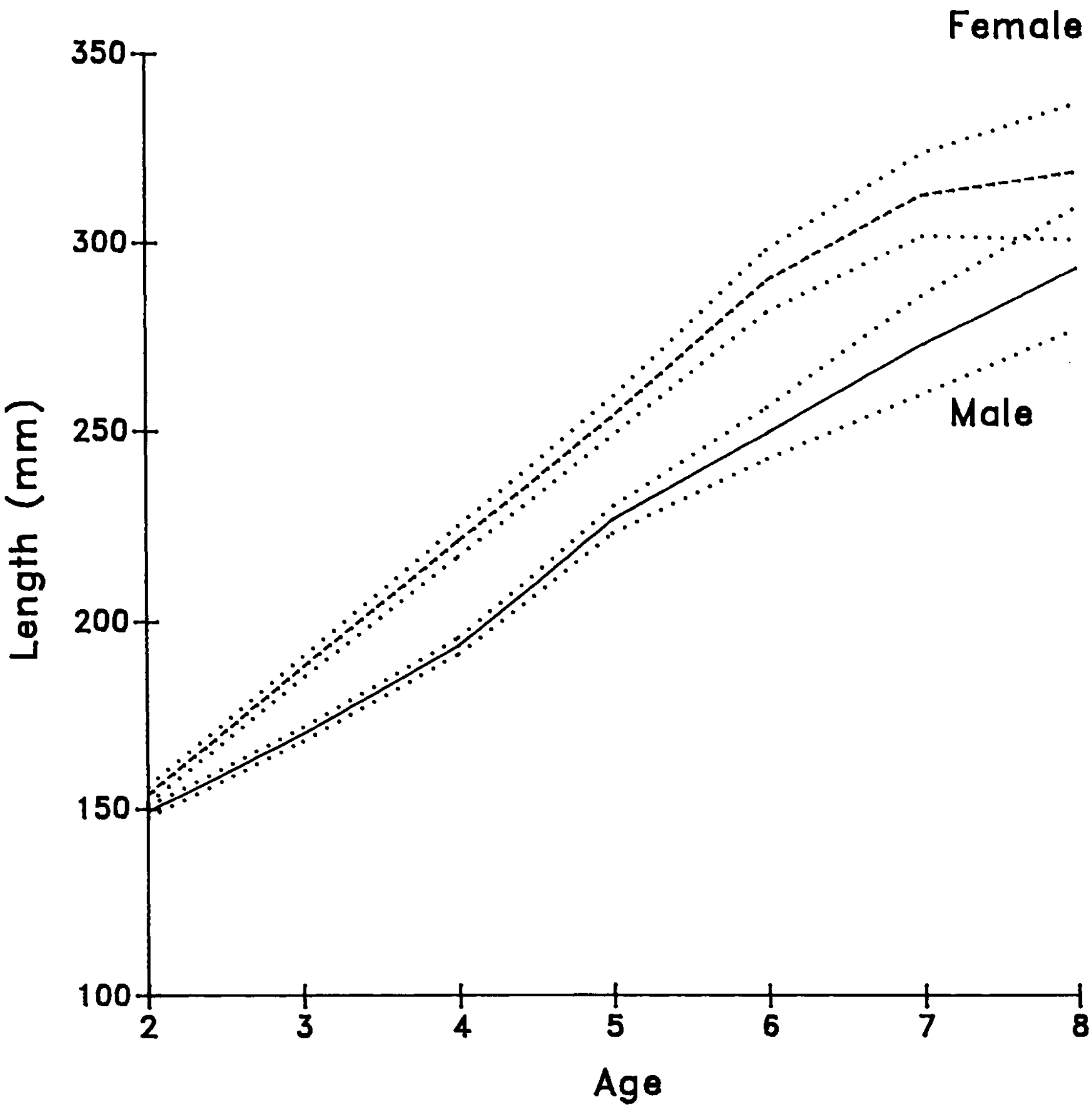

Figure 12. Mean growth (with 95% confidence intervals) for male and female yellow perch collected during 1969-86 fall assessments in the Les Cheneaux Islands.

Table 3. Deviation in growth (mm) from the 1969-84 average for years (A) and year classes (B) of yellow perch collected during fall assessment in the Les Cheneaux Islands.

(A) Deviation from average yearly growth.

Year	Males ages 2-5	Females ages 2-5	Males age 2-6	Females age 2-6
1970	+24	+16	+9	+20
1971	+34	+5	+60	+13
1972	+11	+14	+28	+14
1973	-10	+13	-30	0
1974	+5	-9	-15	---
1975	-68	-100	-39	-140
1976	+17	+29	+44	+35
1977	+18	+22	+12	+41
1978	-52	-24	-63	-57
1979	0	-36	-8	-36
1980	+36	+47	+36	+47
1981	---	---	---	---
1982	---	---	---	---
1983	---	---	---	---
1984	-34	-26	-53	+26
Average deviation*	34	39	40	57

(B) Deviation from average growth for a year class.

Year	Males age 2-5	Females age 2-5	Males age 2-6	Females age 2-6
1968	+12	+16	-8	+3
1969	0	+4	-20	---
1970	+10	+11	+39	---
1971	-23	-14	+4	-8
1972	-16	-1	-22	+18
1973	+1	-21	-10	-54
1974	+17	-11	+9	-8
1975	-3	-3	-3	+30
1976	-12	-12	---	---
Average deviation*	14	13	26	29

* Calculated from the absolute value of deviations for years and year classes.

Likewise, average deviation for growth between years was also not different for males and females ($p > 0.84$).

CPUE for any age from 2-8 (Table 4) was not significantly different between 1969-74 and 1975-86 ($p > 0.07$). CPUE in 1985-86 was extremely small for all ages and, therefore, comparisons were also made between 1969-74 and 1975-84. CPUE for age-5 and age-6 perch was significantly greater in 1975-84 ($p < 0.02$). Differences between CPUE for the two periods were insignificant for all other ages.

With the exception of the 1971 year class, year classes failed to demonstrate greater than average representation within the catch for consecutive years, which indicated a lack of exceptionally strong year classes for this population. For the strong 1971 year class, CPUEs for age-2, -3, and -4 yellow perch were greater than one standard deviation above the mean (Table 5). However, most of the 38 ages which deviated by more than one standard deviation from the average were randomly distributed among different year classes (Table 5). Thus, a large proportion of the differences in relative strength for ages from year to year appeared to be a result of random variation in catch. The insignificant level of variability in year class strength supported the idea of pooling catch data to obtain better estimates for total mortality and age composition. Homogeneous catch data also imply constant recruitment of

Table 4. Number of yellow perch caught per 1,000 feet experimental mesh gill net (CPUE) by age for 1969-86 fall assessment nettings in the Les Cheneaux Islands.

Year	Age 1	2	3	4	5	6	7	8	9	10	Total
1969	---	3.6	5.3	8.6	5.0	3.6	0.7	0.3	---	---	27.1
1970	0.4	5.3	40.9	4.9	3.7	1.7	2.4	1.2	0.8	---	61.3
1971	0.1	31.4	22.2	17.3	2.6	1.1	0.9	0.2	---	---	75.8
1972	0.1	8.8	6.8	6.6	3.6	0.7	1.1	0.3	---	----	28.8
1973	0.3	24.4	26.4	13.6	10.1	2.5	---	0.4	---	---	77.7
1974	---	9.8	65.0	14.9	4.0	1.2	0.4	---	---	---	95.3
1975	0.2	7.5	12.2	23.5	11.8	1.5	0.5	0.7	---	---	57.9
1976	---	13.5	11.2	10.8	8.0	1.5	0.5	---	---	---	45.5
1977	0.2	2.9	11.9	11.4	5.6	2.4	0.8	---	---	---	35.2
1978	---	4.6	33.7	12.4	8.5	5.6	3.8	1.1	0.3	---	70.0
1979	---	16.0	16.3	21.3	9.6	3.2	0.6	---	0.3	---	67.3
1980	1.6	16.2	6.8	11.0	9.2	5.4	0.8	0.3	---	---	51.3
1981	---	---	43.7	19.6	26.2	23.8	9.4	2.7	1.6	---	127.0
1982	0.9	15.2	4.7	11.1	12.5	4.1	1.3	0.5	---	0.3	50.6
1983	---	0.3	19.0	10.8	9.8	6.3	1.3	1.3	0.3	---	49.1
1984	---	17.9	7.6	21.3	13.0	3.7	1.4	---	---	---	64.9
1985	---	1.8	4.5	4.2	3.3	1.1	2.1	---	---	---	17.0
1986	---	3.1	5.1	9.3	2.6	1.6	0.1	0.3	---	---	26.5

Table 5. Percent of total catch by age for yellow perch collected during 1969-86 fall assessments in the Les Cheneaux Islands. Ages deviating by more than one standard deviation above and below the 1969-86 average percent of total catch for each age are indicated by ($^{+}$) and ($^{-}$), respectively.

	Age										
Year	1	2	3	4	5	6	7	8	9	10	Total
1969	---	13.1	19.7	31.7	18.6	13.1^{+}	2.7	1.1	---	---	100
1970	0.7	8.7	66.7^{+}	18.0^{-}	6.0^{-}	2.6	4.0	2.0	1.3^{+}	---	100
1971	0.2	41.3^{+}	29.4	22.9	3.4^{-}	1.4^{-}	1.1	0.3	---	---	100
1972	0.5	31.3^{+}	24.2	23.6	12.9	2.5	4.0	1.0	---	---	100
1973	0.4	31.5^{+}	34.0	17.4	12.9	3.2	---	0.6	---	---	100
1974	---	10.3	68.2^{+}	15.6^{-}	4.2^{-}	1.3^{-}	0.4	---	---	---	100
1975	0.3	13.0	21.0	40.6^{+}	20.5	2.5	0.9	1.2	---	---	100
1976	---	29.7	24.5	23.8	17.6	3.3	1.1	---	---	---	100
1977	0.7	8.3	33.7	32.3	15.9	6.9	2.2	---	---	---	100
1978	---	6.5	48.2^{+}	17.7	12.1	8.0	5.5	1.6	0.4	---	100
1979	---	23.9	24.3	31.4	14.3	4.8	0.8	---	0.5	---	100
1980	3.1^{+}	31.5^{+}	13.3^{-}	21.5	17.9	10.5	1.5	0.7	---	---	100
1981	---	---	34.4	15.5^{-}	20.6	18.7^{+}	7.4^{+}	2.1^{+}	1.3^{+}	---	100
1982	0.6	30.4^{+}	9.5^{-}	22.3	25.1^{+}	8.1	2.5	1.0	---	0.5^{+}	100
1983	---	0.5^{-}	39.0	22.1	20.0	12.7^{+}	2.6	2.6^{+}	0.5	---	100
1984	---	---	27.6	11.7^{-}	32.9^{+}	20.0^{+}	5.7	2.1^{+}	---	---	100
1985	---	10.6	26.5	24.7	19.4	6.5	12.3^{+}	---	---	---	100
1986	---	13.7	22.5	40.7^{+}	11.6^{-}	7.2	2.7	0.6	1.0	---	100

perch into the fishery, which was an underlying assumption in fishery simulation.

No significant differences were found between von Bertalanffy coefficients (k and L_∞) generated from fall length-age data and back-calculated length-at-age ($p > 0.54$). The von Bertalanffy parameters calculated for 1971, 1980, and 1986 from fall length-age data were more consistent when compared to those calculated from back-calculated length-at-age. However, R^2 values indicated that back-calculated mean length-at-age fit the von Bertalanffy model slightly better than mean lengths for fall fish. Pooled length-age data for 1969-86 fit the von Bertalanffy growth model well ($R^2 = 0.99$), and growth parameters generated were reasonable for yellow perch. Therefore, pooled length-age data were used to estimate von Bertalanffy growth parameters used in fishery simulation.

Mortality and Exploitation

Total instantaneous mortality rates and their 95% confidence intervals, calculated from 1986 spring and fall catch data, were 0.97 (±0.75) and 0.86 (±0.32), respectively. Values for Z were not significantly different (F-test, $p = 0.73$). Catch-curve regression for pooled spring and fall catch data resulted in a Z value of 0.97 (±0.66). The Z value calculated from the catch-curve regression of average CPUEs for 1969-85 was 0.80 (±0.17), which was not significantly different from Z calculated from

1986 catch data (F-test, p = 0.39). Therefore, all available catch data from 1969 through 1986 were then pooled to give an overall estimate for Z of 0.80 (±0.17). Actual total mortality calculated from this overall estimate for Z was 55% (±16%) per year.

Rate of exploitation (u) was estimated using 1985 tag returns. Tag returns by anglers for 1986 appeared unreasonably low. Comparison of 1985 and 1986 yellow perch sport catch estimates for May-June showed a twofold increase in catch in 1986, yet return rate in 1986 of yellow tags was only 56% of return rate in 1985 of orange tags for that same period. Relative to catch, return rates by sport anglers were over 3.5 times greater in 1985. Decrease in rate of return was probably a result of the altered reward system and decreased interest in the tagging study after the first year.

The annual return rate of 28% for orange tags was considered the minimum sport angling exploitation rate. Although little published information is available on tag reporting rates, a tagging study on walleyes in the Minnesota waters of Lake of the Woods did show nonreporting by anglers to be slightly less than one-half the number of tags reported (Payer et al. 1987). Under this assumption, nonreporting in this tagging study was estimated at about 14%, which inflates annual exploitation rate by sport anglers to 42%.

Indian assessment netters returned only 23 orange tags in 1985, which represented a 0.5% exploitation rate for commercial fishing. Returns increased to 151 yellow tags in 1986, representing a 2.3% exploitation rate. Overall, rate of exploitation (u) upon the perch population from both sport and commercial fishing was estimated at 43% for 1985. From this estimate of exploitation rate, instantaneous rates of fishing mortality and natural mortality were estimated at 0.63 and 0.17, respectively.

Hooking Mortality

For the hooking mortality study, anglers caught 153 yellow perch varying from 5.0 to 9.5 inches in total length. Mortality ranged from about 20-30% for perch of all sizes (Table 6). Hooking mortality during winter should be considerably less. With lower water temperatures, fish are less susceptible to disease or stress induced mortality from handling or injuries sustained from hooking. Also, the majority of Les Cheneaux winter anglers fish with ice jigs and spoons. Perch taken using this method of fishing were usually hooked in the lip rather than in the gills or esophagus. Although hooking mortality rate was probably lower during winter, the winter fishery takes a relatively small percentage of the total perch catch (Figure 2). Therefore, annual hooking mortality was assumed to remain at about 20% to 30%. Hooking mortality for yellow perch <7 inches was not significantly different from hooking

Table 6. Hooking mortality of yellow perch in the Les Cheneaux Islands with percent mortality of perch at the time anglers reached the boat launch (immediate) and after 24 hours in a live cage (cumulative).

		Immediate		Cumulative	
Species and size	Number caught	Number of deaths	Percent mortality	Number of deaths	Percent mortality
Yellow perch (all sizes)	153	31	20.3	45	29.4
Yellow perch (<7.0 inches)	34	6	17.1	8	23.5

mortality for all sizes of perch (Table 6). Thus, a hooking mortality rate of 25% was used in the fishery simulation.

Fishery Simulation

Simulation of the perch fishery under a 7-inch MSL predicted that, at equilibrium, there would be little change in the anglers' catch in numbers, yield, or older (age 5+) yellow perch compared to the existing fishery under no MSL (Tables 7 and 8). On the other hand, simulation of the perch fishery under the 8-inch MSL predicted a significant decline in number caught, a small increase in yield, and a substantial increase in number of older perch in the catch compared to 1986 catch.

The first year after new regulations were imposed, predicted catch in numbers would decline 12% under the 7-inch MSL and 49% under the 8-inch MSL. As the fishery approached equilibrium, catch in numbers under the 7-inch MSL would remain slightly below 1986 catch, whereas, the severe decrease in catch under the 8-inch MSL would be cut almost in half (Table 7).

Predicted yields in kilograms for perch under both 7- and 8-inch MSL's (equilibrium conditions) demonstrated only a slight increase over yield for 1986. Upon implementation of a 7-inch MSL, yield would decline slightly (6%). However, with time, yield would slowly improve until it was slightly better than yield for 1986 (Table 8). Yield under the 8-inch MSL initially showed a substantial decline

Table 7. Predicted sport fishery catch in number (per 1,000 yearling recruits) under 0-, 7-, and 8-inch minimum size limits (MSL) for 1 year and 6 years (equilibrium conditions) after implementation of a MSL. Percent change in catch under 7- and 8-inch MSL relative to 1986 catch was calculated for all ages and for age-5+ yellow perch.

	Predicted catch				
	0-inch MSL	7-inch MSL		8-inch MSL	
Age	1986	1 yr	6 yrs	1 yr	6 yrs
1	0	0	0	0	0
2	12	0	0	0	0
3	138	91	92	0	0
4	192	192	207	90	108
5	90	90	98	90	140
6	42	42	45	42	65
7	20	20	21	20	32
8	9	9	10	9	14
9	4	4	4	4	7
10+	4	4	4	4	4
Total	511	452	481	259	370
Percent change (all ages)	---	-12	-6	-49	-27
Percent change (age 5+)	---	0	+7	0	+54

Table 8. Predicted sport fishery yield in kilograms (per 1,000 yearling recruits) for yellow perch under 0-, 7-, and 8-inch minimum size limit (MSL) for 1 year and 6 years (equilibrium conditions) after implementation of a MSL. Percent change in yield under 7- and 8-inch MSL relative to 1986 yield was calculated for the perch fishery.

	Predicted yield (kg)				
	0-inch MSL	7-inch MSL		8-inch MSL	
Age	1986	1 yr	6 yrs	1 yr	6 yrs
1	0	0	0	0	0
2	1	0	0	0	0
3	15	9	10	0	0
4	33	33	36	15	19
5	24	24	25	24	36
6	16	16	18	15	24
7	10	10	10	10	14
8	6	6	6	6	9
9	3	3	3	3	5
10+	2	2	4	2	6
Total	110	103	112	75	113
Percent change	---	-6	+2	-32	+3

(33%), but increased rapidly to 3% above 1986 yield (Table 8).

Greatest increase under MSL regulations, relative to the 1986 fishery, was the number of older perch (age 5+) in the catch (Table 7). As for overall catch and yield, increase in number of age-5+ perch under the 7-inch MSL was relatively small (Table 7). This increase was substantially greater under the 8-inch MSL, with number of age-5+ perch in the catch approximately 54% greater than in 1986.

Predicted population size under the 7-inch MSL also demonstrated a relatively small increase compared to 1986, while increase under the 8-inch MSL was considerably greater. Age-3 and older perch in the population would increase relatively little under both MSL regulations (Table 9). Number of older perch increased significantly under higher MSL's, with number of age-5+ perch increasing 8% with a 7-inch MSL and 55% with an 8-inch MSL at equilibrium. Increases for perch over 7 inches and under 7- and 8-inch MSL's were predicted to be 7% and 29%, while those for perch over 8 inches were predicted at 8% and 42%, respectively.

Addition of the commercial fishery resulted in only small declines for sport catch in numbers of perch. Catch in numbers for commercial netters constituted only a small proportion (4-8%) of total catch under different MSL's (Table 10). As MSL increased, proportion of total catch harvested by the commercial fishery did increase slightly (Table 10). Participation by the commercial fishery in 1986

Table 9. Predicted population size (number per 1,000 yearling recruits) for yellow perch under 0-, 7-, and 8-inch minimum size limit (MSL) for 1 year and 6 years (equilibrium conditions) after implementation of a MSL. Percent change in population size under 7- and 8-inch MSL relative to 1986 population size was calculated for age-3+ and age-5+ perch.

	Population size				
	0-inch MSL	7-inch MSL		8-inch MSL	
Age	1986	1 yr	6 yrs	1 yr	6 yrs
1	1,000	1,000	1,000	1,000	1,000
2	844	844	844	843	843
3	701	709	710	709	709
4	466	496	501	555	562
5	217	217	235	280	338
6	102	102	110	102	158
7	48	48	51	48	74
8	22	22	24	22	35
9	10	10	10	10	16
10+	9	9	10	9	13
Total (age 3+)	1,575	1,613	1,651	1,735	1,905
Percent change (age 3+)	---	+2	+5	+10	+21
Total (age 5+)	408	408	440	471	634
Percent change (age 5+)	---	0	+8	+15	+55

Table 10. Predicted catch in number of yellow perch (per 1,000 yearling recruits) for sport and commercial fisheries in the Les Cheneaux Islands for 1986 and for 7- and 8-inch minimum size limit (equilibrium conditions).

	Predicted catch					
	0-inch MSL		7-inch MSL		8-inch MSL	
Age	Sport-fishery	Commercial fishery	Sport-fishery	Commercial fishery	Sport-fishery	Commercial fishery
1	0	0	0	0	0	0
2	12	0	0	0	0	0
3	138	0	91	0	0	0
4	192	0	207	0	108	0
5	87	9	94	10	136	15
6	38	5	42	5	59	7
7	17	3	18	3	26	4
8	7	2	7	1	10	2
9	3	0	4	1	5	1
10+	2	0	2	1	3	1
Total	496	19	465	21	347	30
Percent of annual total catch	96	4	96	4	92	8

reduced predicted catch for anglers by only about 3%. This reduction in predicted catch would remain constant under the 7-inch MSL, but would increase under the 8-inch MSL to about 6%.

Fishing at a rate similar to that for 1986, the commercial fishery would account for 6% to 10% of predicted total yield (Table 11). Competition from assessment netters reduced predicted sportfishing yield for 1986 (no MSL) by approximately 7%. Yields under 7- and 8-inch MSL's would be reduced by about 7% and 10%, respectively. For this simulation, Indian assessment nets would effectively negate small gains in predicted yield achieved through implementation of 7- and 8-inch MSL's.

For the competing fisheries, effect of the commercial fishery upon catch of age-5+ perch was similar to its effect upon yield. Commercial fishermen would harvest approximately 11% of the total catch in numbers of age-5+ perch under all three MSL's. Therefore, reduction in angler harvest of age-5+ perch as a result of Chippewa assessment netting was predicted to be about 9%.

Table 11. Predicted yield in kilograms of yellow perch (per 1,000 yearling recruits) for sport and commercial fisheries in the Les Cheneaux Islands for 1986 and for 7- and 8-inch minimum size limit (equilibrium conditions).

Age	Predicted yield (kg)					
	0-inch MSL		7-inch MSL		8-inch MSL	
	Sport-fishery	Commercial fishery	Sport-fishery	Commercial fishery	Sport-fishery	Commercial fishery
1	0	0	0	0	0	0
2	1	0	0	0	0	0
3	15	0	10	0	0	0
4	34	0	36	0	19	0
5	23	3	25	3	36	4
6	14	2	15	2	22	3
7	8	1	9	2	12	2
8	4	1	5	1	7	1
9	2	0	2	0	4	1
10+	1	0	2	0	3	0
Total	102	7	104	8	103	11
Percent of annual total yield	94	6	93	7	90	10

DISCUSSION

Analysis of growth, age structure, and mortality suggests that the yellow perch population has remained relatively stable. Growth of yellow perch was significantly greater in 1969-74. However, analysis of length-age data for this period suggests that growth was at a peak then. Growth in 1975-86 was variable, but stable. Age structure for fall assessment catch varied little from 1969-86. Mortality for yellow perch demonstrated no significant trend. The combination of constant growth, age structure, and mortality strongly indicates that the perch population has remained relatively stable since sampling began in 1969.

Length-age and CPUE suggest that growth in early samples was exceptional, and may not represent average growth prior to sampling in 1969. First, although size of age-4 and older perch was greater in 1969-74, size of age-2 and age-3 perch was about average throughout this time (Figures 10 and 11). Also, yearly growth summed for perch was not greater during this period than in 1975-86 (Table 3). However, yearly growth was above average for several consecutive years, which resulted in significantly greater mean sizes for perch in 1969-74. Unlike 1969-74, years of good growth during 1975-86 were interspersed with years of poor growth. Thus, overall size for 1973-76 year classes of yellow perch was about average to slightly below average.

Finally, high densities of age-3 and older perch, along with poor growing conditions, probably resulted in the sharp decline in size for 1975. Fall CPUE data suggested that a strong year class of perch was produced in 1971 (Table 4). Year classes produced in 1969-70 also were slightly larger than average. As a result, greatest CPUEs for age-3 and age-4 perch for 1969-86 fall assessments were recorded in 1974 and 1975, respectively. Large declines in growth for perch age-3 and older coincided with these extraordinary CPUEs, which implies that the decline in growth through 1975 was density related.

Analysis of length-age and CPUE data made it apparent that both density dependent and density independent factors are important in determining growth rate for yellow perch in the Les Cheneaux Islands. An inverse relationship between density and growth in yellow perch has been demonstrated in several studies (Beckman 1950; Bardach 1951; Buck and Thoits 1970; Schneider 1972, 1973, 1979, 1983; Kempinger et al. 1982). Over the past 60 years, density dependent growth has been quite evident for perch in Saginaw Bay. El-Zarka (1959) noted that growth for Saginaw Bay perch in 1949-53 had declined substantially below that reported by Hile and Jobes (1941) for 1929-30. He attributed this decline to a sevenfold increase in density of perch over that period. In 1966, growth for Saginaw Bay perch once again improved in response to a reduction in stock size from increased commercial fishing (Eshenroder 1977). Presently, excellent recruitment and an 8.5-inch MSL on perch for the commercial fishery have once again increased stock size, and perch growth has declined (Weber 1985).

Although density dependent factors appear important in controlling growth, further analysis of fall length-age data indicated that density independent factors may play a greater role in determining growth rate of perch in the Les Cheneaux Islands. Comparisons between yearly growth and growth of year classes showed significantly greater fluctuations for yearly growth (Table 3). These large fluctuations in yearly growth were especially evident for 1975-86, while fluctuations in growth of year classes were substantially less during that period. This would imply that environmental conditions during the growing season had a greater effect on growth than did size of a year class. In addition, analysis of fall assessment CPUE demonstrated insignificant variation between size of most year classes.

One explanation for significant variation in annual growth for Les Cheneaux yellow perch concerns large differences in water temperature during the growing season. Water temperature in the Les Cheneaux Islands is strongly dependent upon wind direction and water temperature in the open lake. Strong offshore winds will push warm surface water offshore. In addition, slow-moving currents flowing through the Les Cheneaux Islands continually replenish bays and channels with colder water from the open lake. Consistent offshore winds and cold temperatures in the open lake can reduce temperatures in the bays and channels substantially below the temperature for optimal perch growth of 24.7 C (Hokanson 1977). Coble (1966) found that growth in adult female yellow perch in Lake Huron was correlated to water temperature at a depth of 6 meters. Le Cren (1958) found that two-thirds of the variation in annual growth for European perch, Perca fluviatilis, in Lake Windemere was accounted for by surface water temperature during the growing season. He believed that the primary effect of temperature on growth was its direct effect on metabolism, rather than its effect on the food source.

Growth rate for Les Cheneaux yellow perch is not exceptional among Great Lakes perch populations, but similar to rates for slower-growing populations (Table 12). Historical growth rates of Lake Erie perch (Jobes 1952) and of Saginaw Bay perch (Hile and Jobes 1941) prior to 1940 were significantly greater than growth rates for Les Cheneaux perch and other Great Lakes populations. Growth rate of perch currently is declining in Lake Erie and Saginaw Bay (Weber 1985; Hayward and Margraf 1987). Growth rates of yellow perch in Green Bay and northern Lake Michigan (Hile and Jobes 1942), areas of a latitude similar to the Les Cheneaux Islands, were not substantially different from growth rate for perch in the Les Cheneaux Islands. Recent studies analyzing growth of yellow perch around Ludington (Brazo et al. 1975) and in the southern

Table 12. Total lengths (mm) at the end of each year of life for yellow perch in different locations throughout the Great Lakes.

Location	Year(s) of study	Sex	Sample size	Age 1	2	3	4	5	6	7	8
Les Cheneaux Island,[1] Lake Huron	1969-86	M	1,559	---	123	149	170	193	227	249	272
		F	1,187	---	145	154	188	221	254	290	312
Lake Erie[2]	1927-37	M	---	91	168	213	239	257	---	---	---
		F	---	94	170	218	249	272	---	---	---
Saginaw Bay,[3] Lake Huron	1929-30	M	203	76	135	196	236	269	292	325	---
		F	600	76	135	206	244	272	292	307	---
Saginaw Bay,[4] Lake Huron	1949-55	M	2,096	66	107	142	170	193	216	236	---
		F	1,305	69	109	150	191	224	256	282	---
Saginaw Bay,[5] Lake Huron	1983	M	671	76	135	160	175	188	208	231	---
		F	724	76	147	173	193	216	241	272	---
Green Bay,[6] Lake Michigan	1932-38	M	165	73	117	154	186	217	246	264	---
		F	587	72	117	162	203	231	266	292	---
Northern Lake Michigan,[6] (Beaver Island)	1937	M+F	509	72	114	152	180	214	247	---	---
Saugatuck,[7] Lake Michigan	1971-79	M	1,604	85	162	207	235	255	267	279	---
		F	2,084	85	167	227	261	288	310	326	---

basin of Lake Michigan (Wells and Jorgenson 1983) show substantially greater growth for perch in those areas.

Age structure of yellow perch in the Les Cheneaux Islands has also undergone little change from 1969 to 1986 (Table 4). Comparison of CPUE for all ages between 1969-74 and 1975-86, periods of substantially different growth, showed no significant differences in CPUE. Furthermore, annual total mortality has remained relatively constant. A significant trend in mortality should produce an inverse trend in growth in density affected populations. Trends in growth would produce changes in age structure. Absence of trends for CPUE, along with relatively constant growth and mortality, strongly support that the perch population has remained relatively stable.

Year class strength of yellow perch has been relatively constant when compared with other Great Lakes perch populations. Variability in recruitment and consecutive years of poor reproductive success have been associated with perch populations in Saginaw Bay (Eshenroder 1977) and Lake Erie (Hartman 1973; Leach and Nepszy 1976; Nepszy 1977; and Spangler et al. 1977) which were subject to severe biological stresses such as overexploitation or cultural eutrophication. Low variability in recruitment and continued production of successful year classes in the Les Cheneaux Islands imply that high exploitation rate is not severely impeding reproductive success.

Several problems inherent in the fall assessment data created difficulties for growth and CPUE analyses. First, yearly growth at each age was estimated from mean lengths, which were calculated from very uneven sample sizes. Uneven sample sizes, in addition to unequal variances, resulted in estimates of pooled variance that were relatively large.

Another problem with the length-age data was absence of young-of-the-year and yearling perch in fall assessment catch. Only nine yearling perch were caught from 1969-86. All other perch netted during fall assessments had three seasons growth and were partially recruited into the sport fishery. Samples of younger perch would have provided useful information for assessing recruitment, growth, and impact of density on growth for unexploited ages.

CPUE from fall assessments was not an extremely reliable estimator of yellow perch density. Assessments were conducted over only a 2-day period, and net hours for 1,000 feet of experimental mesh gill net often totaled less than a 100. Since nets were in the water for such a short period of time, catch of perch was inconsistent.

Mortality rates for yellow perch in the Les Cheneaux Islands were similar to mortality rates estimated for perch elsewhere in the Great Lakes and other large inland waters (Table 13). In several cases, resultant total mortality rate from the intensive sport fishery was similar to total mortality rates for commercially fished populations. From assessment gill net catch in the Les Cheneaux Islands, total

Table 13. Total annual mortality rates for yellow perch in different locations throughout the Great Lakes and other large inland lakes.

Location	Year(s) of study	Total annual mortality rate
Les Cheneaux Islands, Lake Huron	1969-86	0.55
Saginaw Bay, Lake Huron[1]	1960-74	0.61
Saginaw Bay, Lake Huron[2]	1983-84	0.64
Saugatuck, Lake Michigan [3]	1978	0.56
Benton Harbor, Lake Michigan[3]	1979	0.60
Red Lakes, Minnesota[4]	1941-56	0.57

[1]Estimated from catch data for Eshenroder (1977).

[2]Keller et al. (1987).

[3]Rybicki (1985).

[4]Heyerdahl and Smith (1971).

annual mortality of yellow perch was estimated at 55%. Fishing mortality was directly estimated from tag returns at 42% and natural mortality was estimated at about 16% annually. Estimates of total annual mortality for perch in Saginaw Bay, made from commercial trap-net data for 1960-74 (Eshenroder 1977) and 1983-84 (Keller et al. 1987) were similar to the estimate for Les Cheneaux perch. Rybicki (1985) obtained similar estimates of total annual mortality for Lake Michigan perch populations off Benton Harbor and Saugatuck, Michigan. He found a significantly greater mortality for females than males in both populations. Only Lake Erie yellow perch had a total annual mortality rate substantially greater than in the Les Cheneaux Islands (Hartman et al. 1977).

Estimates of mortality rates for yellow perch in the commercially fished Red Lakes in north-central Minnesota showed greatest similarity to those for perch in the Les Cheneaux Islands (Table 13). For Red Lakes perch, Heyerdahl and Smith (1971) estimated total mortality (55%) from commercial gill-net data collected from 1943-55. Annual natural mortality for ages not exploited by the commercial fishery (22%) was directly estimated from experimental gill-net data. Fishing mortality, estimated at 45% annually, was only slightly greater than in the Les Cheneaux Islands, and could almost entirely be attributed to commercial fishing.

Prior to tagging in 1985, exploitation of Les Cheneaux yellow perch was believed to be relatively low (MDNR interoffice communication from J. R. Ryckman and J. C. Schneider to W. C. Latta, December 1, 1983). Returns from the 1985-86 study indicated that exploitation was surprisingly high, especially for a yellow perch sport fishery on the Great Lakes. In fact, tag returns for 1985 (28%) and 1986 (17%) were exceptional, when compared with returns for other perch tagging studies (Mraz 1951; Clady 1977; Weber and Les 1982; Rybicki 1985).

Although some yellow perch traveled a relatively long way from the tagging site (up to 16 km), the majority of perch remained within a limited distance from bays where they spawned. Most tagged perch returned by anglers were taken close enough to their spawning bays that distributions of perch tagged in Mackinac, Sheppard, and Flower bays (Figures 6-8) appeared discrete. Similar results were obtained for other tagging studies on the Great Lakes (Mraz 1951; Rybicki 1985) and on Oneida Lake, New York (Clady 1977).

A large percentage (96%) of the 253 recaptures of 1985 tagged perch in 1986 tagging study trap nets occurred in the same bay where the fish had been tagged, which suggests that perch may home to spawning bays. Results from other tagging studies conducted on large inland lakes also support the idea of yellow perch homing to spawning sites (Clady 1977); Weber and Les 1982). Homing implies that separate spawning stocks of yellow perch may exist within the Les Cheneaux Islands.

The best estimate of population size for perch >7 inches was between 400,000 and 900,000 fish. Despite exceptional tag return rates, coefficient of variation for population estimates ranged from slightly less than 8% to over 42%. Estimates from mean of Petersen estimates were relatively more precise than regression estimates. Still, difficulties in meeting underlying assumptions resulted in imprecise population estimates for this estimator, also.

Several problems with using mean of Petersen estimates and regression estimators to determine population size for this tagging study were evident. Although mean of Petersen estimates were most precise, this estimator relies on the assumption of random mixing. Values for variance estimated from observed variance for each replicate of N_i and from a variance estimator dependent upon assumptions underlying the model were substantially different. Furthermore, observed distribution for tag returns implied that the assumption of random mixing was violated. Likewise, trends for the value of m_i/n_i (Figure 13) suggested that relative catchability of perch changed over time. Large variance for m_i/n_i significantly increased size of confidence limits for estimates made from both mean of Petersen estimates and regression estimators. A decreasing trend for values of m_i/n_i can indicate immigration into a population, which will result in serious overestimation of population size (Paloheimo 1963).

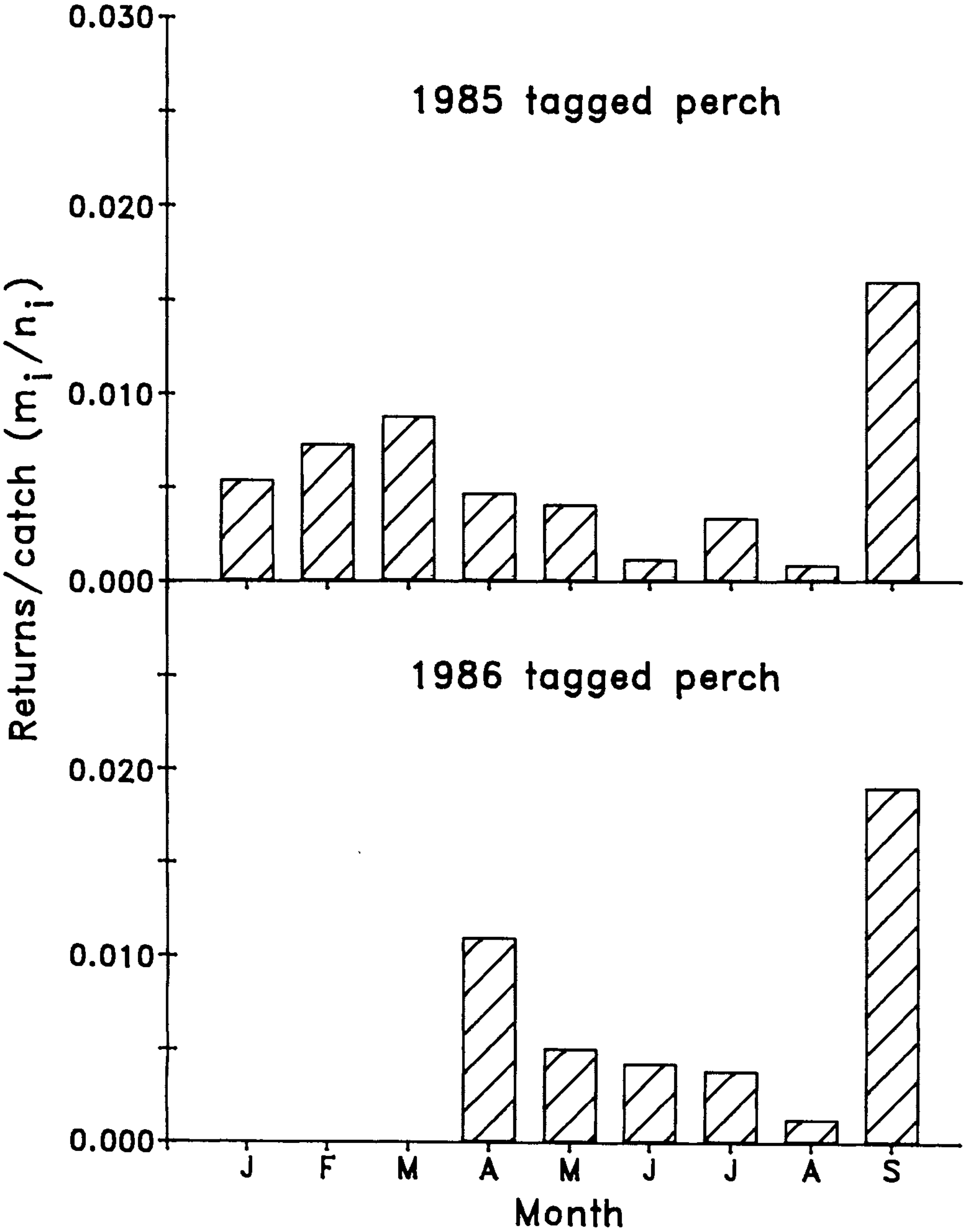

Figure 13. Percent of yellow perch tagged in 1985 (upper) or 1986 (lower) in the total estimated catch (m_i/n_i) for 1986 in the Les Cheneaux Islands.

For this tagging study, fluctuations in tag return rate with respect to estimated catch (m_i/n_i) were probably a result of factors other than varying catchability. A large proportion of variability for m_i/n_i appeared attributable to incomplete tag returns. Analysis of m_i/n_i provided evidence that non-reporting of tags was a significant problem. First, (m_i/n_i) for 1985 tagged perch in May-June 1985 was about 3.5 times greater than for 1986 tags during the same period in 1986. Decreased return rate in 1986 probably was in part due to alteration of the reward system in 1986. Further evidence of incomplete returns was the continual decline in m_i/n_i for April-August 1986 (Figure 13). Fishermen appeared to lose interest in the tagging study as summer progressed. Finally, m_i/n_i for both 1985 and 1986 tags was disproportionately high in September 1986, which was probably due to the prize lottery held near the end of the month. Extremely high return rates in September suggest that tags accumulated over summer were returned just prior to the lottery. Since catch data were not available for most of 1985, m_i/n_i could not be calculated for 1985. Initial interest in the new study and a $1.00 reward for each tag returned should have resulted in greater and more consistent values for m_i/n_i in 1985.

Equilibrium yield for perch was predicted to only increase slightly under a 7- to 8-inch MSL (Table 8). Under these MSL's, fishermen would experience a moderate decline in numbers of perch creeled. However, numbers of larger perch (age 5+) and overall stock density would increase substantially (Table 9).

Lowest predicted yield under no MSL was only 3% less than maximum predicted yield under the 8-inch MSL for equilibrium conditions. Minimal variation among yields for different MSL's has been found for many other fisheries (Ricker 1975; Hartman et al. 1980). Ricker (1975) found this condition for bluegills in Muskellunge Lake. Hartman et al. (1980) predicted only minor changes for yield as minimum age of exploitation increased for yellow perch in the western basin of Lake Erie. Ricker (1975) concluded that stability for yields under different MSL's has a number of implications which can apply to the perch fishery in the Les Cheneaux Islands. First, considerable leeway is allowed for errors in data used to compute MSL's for maximum yield. Second, it is not important to determine the exact optimum MSL for maximum yield. Third, if a particular MSL was best so as to obtain optimal recruitment, then present MSL may be adjusted considerably to meet this requirement without sacrificing yield. Fourth, if either individual size of fish caught or CPUE are important considerations for the fishery, either of these goals can be favored by a MSL without sacrificing a considerable loss in yield.

Schneider (MDNR Fisheries Division Interoffice Communication to John Schrouder, November 15, 1985) also simulated the yellow perch fishery under 0-, 7-, and 8-inch MSL's. In his simulation of the perch fishery, Schneider used catch data from 1969-82, length frequency data from the 1979-81 creel census, and an exploitation estimate from preliminary tag returns for the 1985 tagging study. Overall, changes in catch, yield, and population size under the 7- and 8-inch MSL's were greater for his simulation of the fishery (Table 14). Schneider's predicted decline in equilibrium catch in numbers, and increase in yield and catch of older perch for the 7-inch MSL were over double that for the present study. For the two simulations, difference between predicted catch and yield under the 8-inch MSL was not as great, however, Schneider's fishery simulation still predicted a significantly greater increase for overall yield and catch of age-5+ perch.

For 7- and 8-inch MSL's, increased gains in yield and catch of older perch for Schneider's fishery simulation over the present simulation were largely attributable to different length frequencies used in estimating F values for ages protected by the MSL. Schneider used length frequencies from the 1979-81 sport catch, from which it was estimated that over 45% and 80% of the catch were less than 7 and 8 inches, respectively. For length frequencies from 1986 sport catch, used in the present simulation, estimated percentages of perch catch less than 7 inches (17%) and 8 inches (65%) were substantially smaller. Thus, implementation of a 7- or 8-inch MSL in Schneider's fishery simulation resulted in the protection of a much larger proportion of the perch catch.

Table 14. Predicted percent change in catch in numbers and yield of yellow perch under 7- and 8-inch minimum size limits (equilibrium conditions) relative to no MSL for the present study and Schneider's study.

	Predicted percent change			
	7-inch MSL		8-inch MSL	
Harvest	This study	Schneider	This study	Schneider
Number	-6	-20	-27	-30
Weight	+1	+7	+3	+11
Number of age 5+	+7	+36	+54	+93

Reanalysis of Schneider's simulation demonstrated that the greater rate of instantaneous fishing mortality assigned to fully recruited ages of perch in his study did not result in increased yield and catch of older perch for MSL's. For fully recruited ages of perch, F values used in Schneider's fishery simulation and in the simulation for this study were 0.70 and 0.59, respectively. If the fishery is simulated using these F values, while all other variables are held constant, then net gain in yield under the 8-inch MSL becomes slightly greater (3%) for the simulation in this study. Actually, as fishing mortality increased for ages not protected under MSL's, yield decreased slightly.

Accuracy of predictions for the fishery depends on assumptions that growth, natural mortality, recruitment, and overall fishing intensity do not change significantly with implementation of a MSL. Analyses of available data suggest that these parameters, except possibly growth, should remain relatively constant. Analysis of fall CPUEs indicated relatively constant recruitment and total mortality. Constant total mortality, which is predominantly a function of fishing mortality, would imply that fishing intensity has been relatively constant, despite annual variation in the quality of the fishery.

Growth must also remain constant after addition of a MSL for predictions in catch and yield to be accurate. Since implementation of a MSL often results in a substantial increase in stock density, this assumption implies that growth of perch is density independent, or that population size is substantially below carrying capacity. Although growth of perch in the Les Cheneaux Islands appears to be strongly influenced by density independent factors, effects of density upon growth were apparent in the data and deserve consideration. Increasing numbers of age-3 and age-4 perch through addition of a MSL could further increase fluctuations in growth from year to year. For example, the collapse of growth in 1975 implied that a combination of exceptionally strong year classes and poor growing conditions can drastically reduce annual growth. However, strong year classes of perch did grow well other years. Therefore, increasing stock density of perch through MSL's may further slow growth during years with poor growing conditions, which would result in decreased overall growth for perch.

Native American commercial fishermen presently have a relatively small impact on the Les Cheneaux yellow perch fishery. Commercial catch in 1985-86 represented only a small fraction of total catch. Catch in numbers and yield for the commercial fishery in 1986 comprised less than 5% and 10% of respective totals for the fishery (Tables 10 and 11). Importance of commercial fishing with respect to the sport fishery in the Les Cheneaux Islands is small, and is similar to the situation presently found for the perch fishery in Saginaw Bay (Keller et al. 1987). Commercial fishing pressure in the Les Cheneaux Islands and Saginaw Bay is only a fraction of that imposed by commercial perch fishermen elsewhere in the Great Lakes (Hartman et al. 1980; Keller et al. 1987; Rakoczy and Rogers 1987).

Relative importance of the Native American commercial fishery was predicted to increase with increasing MSL (Tables 10 and 11). As perch catch for sport fishermen declined with increasing MSL, catch for commercial fishermen increased, though commercial fishing effort remained constant. The commercial fishery, which seldom exploited yellow perch less than 8.0 inches total length, benefited from restrictions on sport catch of smaller perch. Still, commercial catch in numbers and yield under a 8-inch MSL remained at less than 10% of the respective totals.

Native American commercial fishermen, fishing at their 1986 rate, would effectively nullify small gains in yield realized under 7- and 8-inch MSL's. The presence of this commercial fishery also reduces the predicted increase in catch of larger perch (age 5+) by almost half. Predicted declines in catch and yield were estimated under the assumption that mortality of yellow perch smaller than 8 inches is negligible for 2-3/4-inch mesh gill net. Substantial mortality for perch less than 8 inches would further reduce gains in catch and yield for the fishery under MSL's. Simulation for the competing fisheries demonstrates that, even at a relatively low intensity of fishing, the commercial fishery must be given consideration when determining a management strategy for perch in the Les Cheneaux Islands.

Management Recommendations

A 7-inch MSL on perch was implemented in the Les Cheneaux Islands as of 1 October 1986. Catch data collected during the 1987 creel census have not yet been analyzed, so predictions for catch in numbers and yield under the 7-inch MSL cannot be verified. However, the 7-inch MSL appears to be fully accepted by local residents. Of 50 local resort owners, businessmen, and anglers attending a presentation on the 1986 yellow perch study in March 1987, 49 voted in favor of retaining the 7-inch MSL. Response to increasing the MSL to 8 inches was not nearly as favorable. Therefore, the proposed 1 October 1987 implementation of an 8-inch MSL was cancelled. The 7-inch MSL will continue until its impact on the fishery can be evaluated.

Implementation of further regulations on the perch fishery will depend on success of the 7-inch MSL, attitudes of local businessmen and anglers, continued good growth of perch, and the future of commercial fishing operations. Results from questions on catch preference posed in both creel and economic censuses clearly established that anglers consider size of perch in their catch most important (Diana et al. 1987). On the other hand, local businessmen vehemently oppose the 8-inch MSL, insisting that its implementation would substantially reduce business.

However, anglers have indicated in the 1986 economic survey that their participation in the fishery would not decrease regardless of regulations (Diana et al. 1987).

Growth must continue to be monitored under the 7-inch MSL. With the predicted increase in stock density for perch under the 7-inch MSL, good growth must continue for this regulation to produce significant increases in catch of larger perch. Consistently poorer growth than that found prior to 1986 would imply a density dependent response to increased stock size. Significantly slower growth would more than likely nullify any increases achieved under this MSL.

If gains under different regulations are to be more accurately assessed, length frequency of the sport catch should also be monitored. Predicted increases under regulations rely heavily upon proportion of catch estimated to be protected under that regulation. For MSL's this is determined from length-frequency data. Analyses of length frequency from 1979-81 and 1986 creel censuses suggest that size of perch in the catch varies from year to year, possibly depending on size of the year class being recruited into the fishery. Therefore, average trends for length frequency must be assessed if increases in yield under MSL's are to be accurately predicted.

Finally, catch for the Native American commercial fishery for perch must be monitored. Simulations demonstrated that presence of a commercial fishery, even at relatively low rates of exploitation, can substantially reduce gains achieved under regulations. If rates of fishing for the commercial fishery should increase, catch in numbers and yield under a regulation should be reevaluated.

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