EFFECTS OF AN EPISODIC REMOVAL SCHEME ON A WALLEYE, *Stizostedion vitreum vitreum*, POPULATION

by
David M. Reid ©

Lakehead University
Thunder Bay, Ontario

May 1985

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

EFFECTS OF AN EPISODIC REMOVAL SCHEME ON A WALLEYE, *Stizostedion vitreum vitreum*, POPULATION

by

DAVID M. REID

A thesis submitted to the Department of Biology in partial
fulfillment of the requirements for the
Degree of Master of Science
Lakehead University
Thunder Bay, Ontario

Abstract

A pulse fishing scheme, applied over a three year period (1980 to 1982), deliberately removed 3226 walleye from Henderson Lake, Ontario, causing the stock to collapse. The objective of the removal was not only to seek out characteristics which could have served as a predictor of the collapse, but also to test the applicability of pulse fishing as a management alternative for walleye.

Several indices failed to serve as indicators of the population collapse. At high densities of walleye the Schumacher-Eschmeyer population estimate (using trap nets) apparently only estimated the brood stock abundance. Not only did it incorrectly indicate the walleye population to be relatively stable after two years of intensive removal, because of younger fish being recruited to the gear, it also failed to forewarn of the impending collapse of the stock in the third year.

Catch per unit effort data proved a poor index of fish abundance for northern pike and white sucker. Walleye abundance was significantly correlated to walleye catches from four and six-foot trap nets. Catches in both eight-foot trap and gill nets were very poorly correlated to fish densities, although these gears were used at reduced effort levels. Evidently vulnerability to gill nets of the remaining walleye may change as a result of reductions in food abundance causing more predator movement to seek prey. Changes in fish condition with changes in population abundance could also influence gill net capture rates. Condition of most walleye age-classes and both walleye and northern pike fecundity showed a time lag in response to fishing, not increasing significantly until 1984, 3 years after stock collapse.

Walleye growth rates increased only for younger age classes (II - V). Both mean age and the mean age to maturity decreased with exploitation.

Annual production estimates appeared to serve as a good indicator of walleye response to fishing. They originally ranged between 1.92 to 3.07 kg/ha/yr before exploitation, quickly fell to negative values following the second year of exploitation, and only increased to 0.41 kg/ha/yr by 1984, two years after exploitation ceased.

The most promising predictors of the walleye population collapse were length at age increases, Abrosov's mean age to mean age at maturity index (0.5 critical value), annual production estimates and possibly Petersen population estimates.

Northern pike and white sucker numbers have not increased since walleye exploitation began. They appeared not to be filling any vacated walleye niche, at least over the short term.

Due to an unfortunate succession of abiotic factors unfavourable to production of strong year-classes, walleye recruitment was very poor. This demonstrates that any implementation of an episodic removal scheme must take into account such possibilities. Further research in this area should clarify the exact sequence of removal and recovery necessary to successfully implement this scheme for the management of walleye.

Acknowledgements

I would like to thank my academic advisor Dr. W. T. Momot for his help and support throughout my thesis. I want to thank the members of my committtee Dr. M. Lankester, Dr. A. E. Macdonald, Dr. L. Johnson and especially Dr. P. J. Colby for their constructive criticisms and suggestions. I thank the Walleye Research unit, Ontario Ministry of Natural Resources, Thunder Bay, for equipment use, financial assistance and help in data interpretation.

My heartiest appreciation is extended to Mr. D. Baccante for his plentiful assistance and to Mr. K. Roberts for help during fecundity collections in 1983. Special thanks to Ms. B. J. Ritchie for enduring my countless questions.

My technicians Ms. J. Pessendorfer, Ms. J. Miller and Ms. S. McIver (who also helped with several figures in this thesis) have my gratitude for putting up with me and doing a great job. As well I wish to thank my other co-workers in the field Mr. G. Morgan, Ms. S. Bell and Mr. K. Trimble.

I am grateful to Dr. W. McCallum for allowing me use of his printer and Dr. J. Ryder for the loan of his monitor. Special thanks to Mrs. L. Tamasi who had the unenviable task of typing all of my tables.

To all the graduate students at Lakehead thank you for your friendship and all the good times, "So long and thanks for all the fish."

Last but far from least for her love, support and assistance I thank my wife, Mayda, who saw me through these past two years.

This project was funded by the Canadian Sportsman Show in 1983 and 1984 and by the Department of Fisheries and Oceans in 1982.

to my parents

Table of Contents

List of Tables

List of Tables

List of Tables

List of Tables

Page

List of Tables

List of Tables

List of Tables

List of Figures

List of Figures Page

List of Figures

Page

List of Figures

Pag

List of Figures

List of Figures

Page

List of Appendices

Pag

Appendix I

Appendix II

Appendix III

Appendix IV

Appendix V

Appendix VI

Introduction

Walleye (Stizostedion vitreum vitreum Mitchill) is the most sought after game fish in Northern Ontario (Ontario Ministry of Natural Resources 1980). Approximately 150 million dollars is spent annually on angling in North Ontario, with most of it spent on the capture of walleye (Ontario Ministry of Natural Resources 1980).

While the available quantity is finite, the recreational fishing demand for walleye is ever increasing. There have been many ideas on how to maximize the benefit from this limited resource but new alternatives need to be investigated. One possible strategy is the pulse fishing method. Pulse fishing could reduce the burden of large enforcement costs while reducing the psychological and social costs to anglers caused by other management schemes based on quotas which restrict yields, use patterns or effort levels.

The present study's objectives were to evaluate the applicability of an episodic or "pulse"-type angling fishery for walleye. In pulse fishing, instead of setting quotas, the fish in a lake would be intensively fished under normal regulations, until fishing quality fell below some acceptable level. The lake would then be closed to harvest and when the fish stock had recovered fishing would resume. As one lake recovers, another is opened to fishing, so the program is established on a rotational basis among a set of several lakes. Such a management scheme not only requires less enforcement, but necessitates less knowledge about the intrinsic characteristics of individual walleye stocks than other management strategies.

Not all lakes, of course, are suitable for application of such a technique. However, a variety of management strategies are necessary if one is to supply a variety of fishing experiences for all types of fishermen found in any fishing public (McFadden 1969). The great number of water bodies in this area of Ontario, makes the tailoring of individual management programs for each lake an impossible task, yet many of the lakes might be well suited to a pulse management scheme. Smaller, road accessable, semi-isolated lakes might be managed through pulse fishing to cater to the "meat"-type fisherman. Since these lakes do not produce any trophy sized fish (Nunan 1982; Mosindy 1980; Sandhu 1979), they are especially suitable for this purpose.

We intentionally overexploited the walleye stock in Henderson Lake to determine the applicability of this management strategy for walleye. We especially wished to investigate the effects of such a strategy on the fish community as a whole and so monitored the other fish species in this boreal-percid lake. As well we recorded the compensatory reactions of walleye, the target species, to overexploitation. We hoped to test or develop a number of useful indices that would help other fishery managers to recognize and hopefully avoid catastrophic collapses in walleye populations from overfishing. This would be particularly useful where intensive studies are not economically feasible.

Materials and Methods

Study Area

Henderson Lake (151 ha), is located approximately 128 km north-west of Thunder Bay, Ontario (latitude 48 49’, longitude 90 18’, Fig. 1). It is one of five research lakes in the Savanne Lake area that were designated as provincial fish sanctuaries and closed to public fishing in 1969.

The fish fauna of Henderson Lake consists of nine major species: walleye, *Stizostedion vitreum vitreum* (Mitchill); northern pike, *Esox lucius* (Linnaeus); white sucker, *Catostomus commersoni* (Lacepede); burbot, *Lota lota* (Linnaeus); yellow perch, *Perca flavescens* (Mitchill); mimic shiner, *Notropis volucellus* (Cope); blacknose shiner, *Notropis heterolepis* (Eigenmann and Eigenmann); Iowa darter, *Etheostoma exile* (Girard); and ninespine stickleback, *Pungitius pungitius* (Linnaeus). Since the study began the ninespine stickleback population has shown a drastic decrease in numbers, with only a single specimen captured in 1983 and none in 1984. An incidental northern redbelly dace, *Chrosomus eos* (Cope) was captured by use of a dipnet on May 9, 1984.

The lake has a maximum depth of 5.25 m (2.5 m mean depth), with a varied gravel, boulder and sand littoral zone and a mainly mud bottom. The lake is divided into two natural basins (Fig. 2) by the northernmost island, with the north basin being much shallower due to a central mud reef. There is seldom a thermal gradient greater than one or two degrees celsius as wave action frequently mixes the water

Figure 1. Map showing the location of Henderson Lake, Ontario.

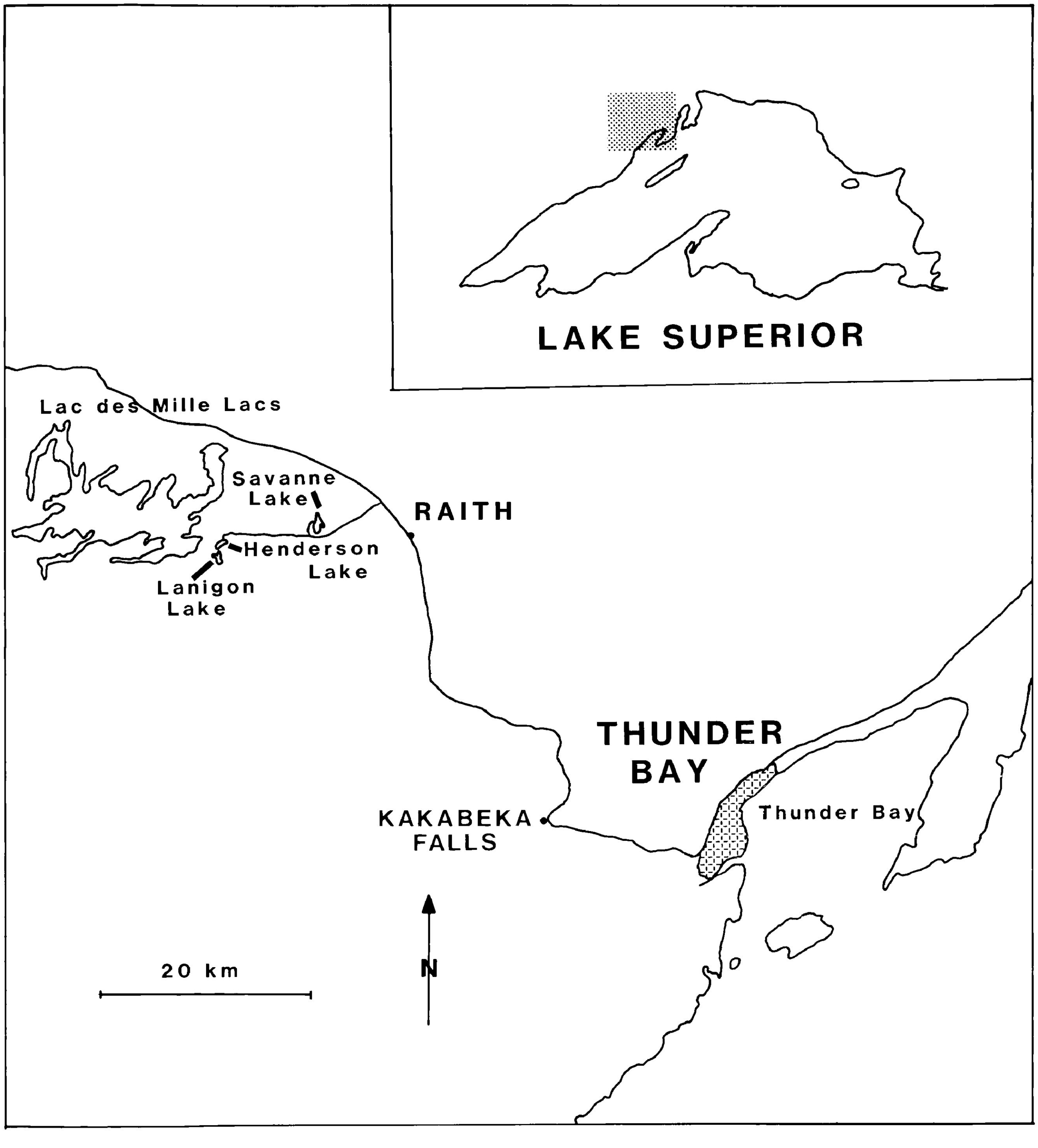

LAKE SUPERIOR
Lac des Mille Lacs
Savanne Lake
RAITH
Henderson Lake
Lanigon Lake
THUNDER BAY
KAKABEKA FALLS
Thunder Bay
20 km
N

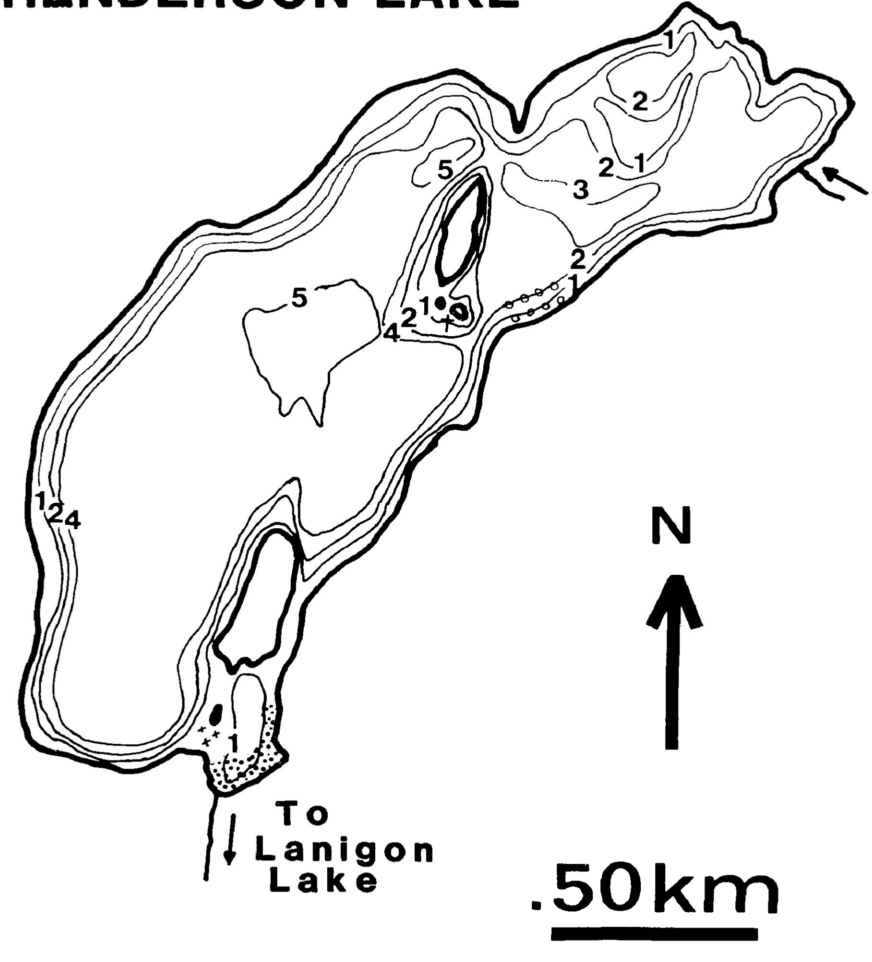
Figure 2. Map showing the contours of Henderson Lake, and spawning grounds.

† walleye spawning area

░ northern pike spawning area

⠿ white sucker spawning area

HENDERSON LAKE



column. The physical and chemical characteristics of the lake have been described by Nunan (1982) and Ritchie (1985), with additional chemical testing done on August 26, 1984 (Table 1).

An intensive study to determine the effects that overfishing the walleye of Henderson Lake would have on the boreal percid community was initiated in 1979 (Nunan 1982). The 1979 field season consisted of a mark and recapture population estimate and the collection of initial age and growth data. Population estimates of walleye, northern pike, and white sucker have been conducted each year since 1979. In 1980 the large scale removal of walleye was begun. During three field seasons (1980 to 1982) a total of 3226 walleye were removed (Nunan 1982). Concurrent monitoring of the population dynamics of walleye, northern pike and perch provided fundamental baseline data (Nunan 1982; Ritchie 1985).

Population Estimates

Spring mark and recapture population estimates were conducted on Henderson Lake for walleye, northern pike and white suckers from 1982 to 1984. Standard 1.22 m (four foot), 1.83 m (six foot), and 2.44 m (eight foot) trap nets (Sandhu 1979) were used to live-trap fish for mark and release.

Two 1.22 m, three 1.83 m and one 2.44 m nets were employed from May 13 to June 24 for the 1982 estimate, for a total of 132 sets. From May 15 to July 6, 1983, seven nets were used, five 1.83 m and two 2.44 m for a total of 208 sets. From May 2 to June 6, 1984, three 1.83 m and two 2.44 m nets, totalling 124 sets, were used. Nets were placed at various traditional locations around the lake and

Table 1. Physical and chemical characteristics of Henderson Lake, Ontario. (Chemical analysis done on August 26, 1984.)

Latitude	48°49' N	Potential yield^3 (kg ha^{-1} yr^{-1})		Sodium (Na)	0.97-1.1 mg/ℓ
Longitude	90°18' W	-Angling		Potassium (K)	0.52-0.54 mg/ℓ
Area	150.9 ha	Walleye	1.45-1.56	Calcium (Ca)	5.5 mg/ℓ
Mean depth	2.5 m	Northern pike	1.14-1.22	Magnesium (Mg)	1.9 mg/ℓ
Maximum depth	5.25 m	-Commercial		Nitrogen (free ammonia)	0.02-0.03 mg/ℓ
Morphoedaphic index^1	13.7^2-16.0	Walleye	0.91-0.96	Nitrogen (total kjeldahl)	0.49-0.52 mg/ℓ
Secchi disk	2.0-3.5m	Northern pike	0.45-0.96	(nitrite)	0.001 mg/ℓ
Hardness ($CaCO_3$)	22 mg/ℓ	pH	7.6	(nitrate)	0.01 mg/ℓ
Alkalinity ($CaCO_3$)	18.5 mg/ℓ	Colour	21-23 hazen units	Total phosphorus (as P)	0.017-0.020 mg/
Iron (Fe)	0.25 mg/ℓ	Turbidity	1.6-2.4 fermazin units	Dissolved reactive phosphorus (as P)	0.001 mg/ℓ
Chloride (Cl)	0.1 mg/ℓ	Conductivity	47 μMHOS/cm		
				Total dissolved solids	40.06

---

[1] Ryder 1965

[2] Nunan 1982

[3] Ontario Ministry of Natural Resources 1982

were moved as catch per unit effort decreased substantially, or when the ratio of marked to unmarked fish was high. A total of 14, 15 and 11 sites were used in 1982, 1983 and 1984 respectively (Fig. 3).

Trap nets were checked daily in most cases, with an approximate 24 hour set time. Fish were weighed to the nearest 20 grams using Jim tube-type spring scales. Total length was recorded for all fish to the nearest millimeter, and fork lengths were also measured in 1983 and 1984. The species, sex and maturity (by extrusion of gonad products, if possible), and any previous clips were recorded. Walleye were marked by a different dorsal spine clip each year (Table 2). The soft membrane was cut on either side of the selected spine with a knife, and the spine cut off as close to it's base as possible with nail snippers. Northern pike and white suckers were marked by cutting the tip of a fin with pruning shears which would leave an identifiable ridge when regenerated (Laird and Stott 1978). A second clip was used for all three species in 1982 and 1983 to indicate the frequency of multiple recaptured fish to aid in trap net placement decisions (Table 2). In 1984, however, to reduce the effects of stress caused by marking, only a single clip for each species was utilized. Other fish incidentially captured in the trap nets (burbot and yellow perch), were released unmarked after being measured and weighed. All fish were released on the side of the boat opposite the trap entrance.

Scale samples were retained from approximately 5 to 10 northern pike and white sucker, of both sexes when possible, in each 5 cm total length interval during the spring population estimate. The key scale area as used by Nunan (1982) was retained, i.e. an area on the left side of the fish just dorsal to the lateral line, above the

Figure 3. Map of spring population estimate trap net locations, 1982 to 1984. Numbers represent sequential numbering of trap nets per year and bracketed numbers the size of trap nets, eg. 6' is a six-foot trap net.

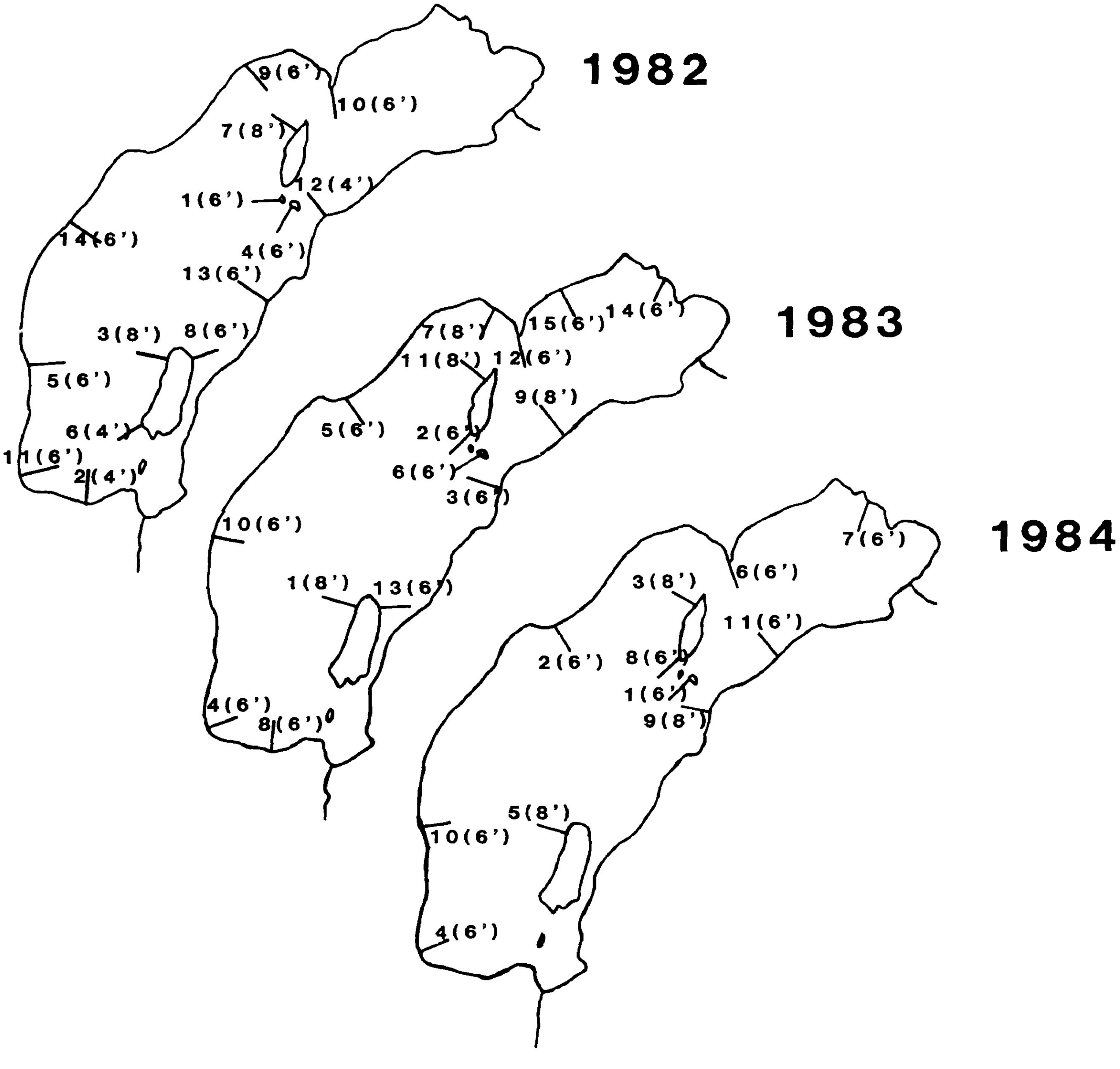

1982
9(6')
10(6')
7(8')
12(4')
1(6')
4(6')
14(6')
13(6')
3(8')
8(6')
5(6')
6(4')
11(6')
2(4')
1983
7(8')
15(6')
14(6')
11(8')
12(6')
9(8')
5(6')
2(6')
6(6')
3(6')
10(6')
1(8')
13(6')
4(6')
8(6')
1984
7(6')
6(6')
3(8')
11(6')
2(6')
8(6')
1(6')
9(8')
5(8')
10(6')
4(6')

Table 2. Fin clips used for population estimates (1979 to 1984) for walleye, northern pike and white sucker.

	Initial Clip		Second Clip
Walleye			
1979	3rd	dorsal spine	—
1980	5th	dorsal spine	—
1981	6th	dorsal spine	7th dorsal spine
1982	9th	dorsal spine	anal fin
1983	2nd	dorsal spine	left pectoral
1984	4th	dorsal spine	—
Northern Pike			
1979	LP	left pectoral	—
1980	RV	right ventral (pelvic)	—
1981	RP	right pectoral	anal
1982	LV	left ventral	right pectoral
1983	LP	left pectoral	lower caudal
1984	RV	right ventral	—
White Sucker			
1979	LP	left pectoral	—
1980	RV	right ventral	—
1981	RP	right pectoral	—
1982	LV	left ventral	anal
1983	RV	right ventral	left pectoral
1984	RP	right pectoral	—

region of the pelvic fin.

Duration of set, water temperature (surface, middle and bottom), secchi depth and wind (direction and velocity) were recorded when lifting each trap net. All walleye and northern pike that died in the trap nets furnished aging material (opercles and cleithra), were internally sexed (Olynyk 1980) and provided stomach contents for a food habitat study. Cleithra and opercles were cleaned of any tissue with the use of warm water and a toothbrush and stored with other aging material in scale envelopes. Any fish not captured within the house of the trap net were not included in the catch per unit effort calculations. Any live fish gilled inside the house entrance were untangled and left within the entrance, and live fish caught in the net lead were released without processing. Trap nets were fished for ten consecutive days and then closed off for four days during the population estimates. Closure of nets appeared to assist the dispersal of marked fish throughout the lake, since a higher percentage of unmarked fish were usually caught when nets were reopened.

Population estimates were calculated using the Schumacher-Eschmeyer method (Schumacher and Eschmeyer 1943; Ricker 1975) each day following the inspection of trap nets. When the variance of the confidence limits was less than ten percent, estimates ceased.

Age and Growth

In 1982, both dorsal spines and opercular bones were examined to provide an estimate of the age distribution of walleye. The opercles were obtained from trap killed walleye and those sacrificed immediately following the population estimate. A ten percent stratified subsample, by length, of walleye was aged in 1982 (Ketchen 1950). During the 1983 and 1984 population estimates all walleye captured were aged. The age distribution of walleye in Henderson Lake for 1983 and 1984 was determined solely by aging dorsal spines removed during the population estimates. Dorsal spines are easy to collect and provide the best agreement in age between people (Campbell and Babaluk 1979). If the age of any fish was uncertain it was not included in subsequent calculations. Fish that were aged were separated into 5 cm length intervals and the percentage of each age per length interval was calculated. The number of individuals of any age group found in a particular size group in the subsample is assumed to be proportional to the number of individuals of that age group and size in the actual population (Ketchen 1950). Multiplying the population estimate by the length frequencies of the catch provided an estimate of numbers of fish in each age class within the total population.

Walleye spines were placed in scale envelopes and allowed to air-dry. The spines cleaned of any fin remnants, were dipped in xylene and set in Lepages® epoxy until hardened. Spines were cut into 0.5 mm cross-sections using an Isomet 11-1180 low speed saw and then mounted on glass microscope slides with Diatex, a synthetic mounting medium (Campbell and Babaluk 1979). Spines were examined with a Wild M5 dissecting microscope and annuli assigned by using established criteria (Campbell and Babaluk 1979; Erickson 1979, 1983; Olson 1980). The edge of each dorsal spine collected in the spring was assigned the current year's annulus, as walleye annuli are not fully formed until late May or even mid-June (Smith 1977; Glenn 1969; Forney 1966; Schmulbach 1959; Carlander 1945; Beakman 1943).

The northern pike age distributions were determined by the aging of scales collected during the population estimates in 1982 and 1983, and from cleithral bones collected immediately following the 1984 population estimate. Scale impressions were made by rolling scales between two plastic acetate slides (Smith 1954). The slides were read with the aid of a microfiche projector (Vantage Com IV, 33 X). Ages were determined by counting annuli using established guidelines (Frost and Kipling 1959; Wainio 1966; Casselman 1967). Following the 1984 population estimate the left cleithra was removed (Casselman 1980) from an approximate ten percent stratified subsample of sacrificed pike. The sacrificed pike were chosen to supply a 5 to 10 fish sample in each 5 cm length interval for each sex. When possible pike were externally sexed to prevent the taking of samples of a sex for which the length category was already filled (Casselman 1974a). Northern pike samples were collected concurrently during walleye and white sucker population estimates which require a longer time to complete.

Ages were determined from cleithra by counting the number of annuli (Casselman 1980,1978,1974b). Since the current year's annulus of both scales and cleithra had not been laid down from spring caught pike the edge of the aging structure was considered to be the last annulus. Subsamples were aged for each 5 cm length interval, and the aging results extrapolated to the entire population (Ketchen 1950).

Northern pike lengths were backcalculated in all years by the use of the cleithral bone. However, in 1982 the small cleithra sample size (50 specimens) was supplemented with additional data from 70 scales collected during the population estimate. Annuli on cleithra were determined by use of a lighted magnifying glass and a Wild M5 dissecting microscope. The distances from the origin to each annulus were measured directly with vernier calipers to the nearest 0.1 mm (Casselman 1974b, 1980). To backcalculate lengths from scales, distances from annuli to the origin were marked on bristleboard strips held up to the image of the scale projected by a microfiche projector. Measurements were taken from the origin to the anterior most position of each annulus. The distances along the strips were then measured to the nearest millimeter with the aid of a ruler.

Walleye backcalculated lengths were estimated by use of the opercular bone, the annuli being determined by conventional criteria (LeCren 1947; Bardach 1955; Campbell and Babaluk 1979). Cleaned opercular bones were observed beneath a Wild M5 dissecting microscope and the distance from the origin to a perpendicular line through each annulus was marked on a strip of bristolboard. These distances were then measured with vernier calipers to the nearest 0.1 millimeter and recorded.

Regression analysis of body length to aging structure length generated a correction factor, allowing the backcalculating of lengths at each age (Bagenal and Tesch 1978; Everhart et. al. 1975; Ricker 1975).

Lengths were backcalculated by direct proportion. For calculation of total lengths at each age the following formula was used:

$$ln - a = \frac{Sn}{S} (l - a)$$ (Bagenal and Tesch 1978)

ln = length of fish when annulus "n" was formed,

l = length of fish when aging structure was obtained,

Sn = distance of annulus "n" from origin (at fish length ln),

S = total length of aging structure (origin to edge),

a = intercept of regression of aging structure length with total length.

Opercular bone and dorsal spine ages of 107 walleye, and similarily both cleithral bone and scale ages for 95 northern pike were determined to serve as a comparison between aging structures, and as an important validation of aging methods for each species (Beamish and McFarlane 1983).

Fecundity

In the fall of each year female walleye and northern pike were collected for fecundity estimates. In 1982, ovaries were obtained from fish captured as part of the removal scheme using a variety of trap and gill nets, for a total of 39 mature female walleye and 17 pike ovaries. In 1983 fecundity samples were obtained on September 24 and 25. Four overnight sets of standard monofilament gill nets and two 24 hour sets of a 1.22 m (four foot) hoop net provided a sample of 17 walleye and 20 northern pike ovaries. In 1984 collections occured on October 2, 3 and 4 and six overnight standard gill net sets yielded a total of 10 walleye and 28 pike ovaries. Pike were externally sexed in 1984 in an attempt to reduce male mortality (Casselman 1974a).

After measuring the fish for weight and length, aging structures were retained, previous clips noted, stomach contents preserved, and ovaries removed. The ovaries of both walleye and pike were first weighed with a triple beam balance in the field then wrapped in cheese cloth and preserved in a ten percent solution of formalin (Serns 1982). Samples were packed so as to allow separation of the left and right ovary in later analysis.

Fecundity estimates were determined by the gravimetric method (Bagenal and Braun 1978) for both walleye (Serns 1982; Wolfert 1969) and northern pike (Kipling and Frost 1969). The ovaries were dried in the lab with paper towels and re-weighed with a Mettler AE160 balance to the nearest 0.001 g. The ovary membrane and as much artery material as possible were peeled away from walleye ovaries and the eggs re-weighed to the nearest 0.001 g. Northern pike ovaries were prepared in a similar fashion, but because the eggs adhered they had to be scraped off the ovary wall. The eggs of each pike ovary (left and right) were retained in separate weighing boats to prevent mixing. Walleye eggs could be held in the same weighing boat as the ovary remained intact and separation of left and right ovaries presented no problem. A subsample of eggs not less than five percent of the weight of both ovaries was retained in a vial of ten percent formalin solution. Wolfert (1969) found the anterior part of the right ovary the best area for walleye egg subsamples but Serns (1982) and Eschmeyer (1950) felt the medial section of the right ovary to be superior. Kipling and Frost (1969) found no significant differences in egg counts estimated from subsamples in any region of either ovary for pike. Egg samples were taken from the anterior, middle and posterior regions of the left ovary for both walleye and northern pike in 1982. These samples allowed comparisons of the number of eggs per gram in the different regions of the ovary. The subsamples were removed from the left ovary in order to maintain continuity with earlier work (Nunan 1982). Subsamples of eggs were removed from the medial portion of the left ovary for both walleye and pike in 1983 and 1984.

The eggs within each subsample were counted with the use of a Wild M5 dissecting microscope at 6X power. Eggs were gently teased apart by dissecting needles and counted on a dark background. Northern pike eggs were only counted if it appeared they were developing and would mature the following year, as smaller immature eggs are reabsorbed (Carbine 1944). All walleye eggs were counted in each subsample. The total number of eggs in each ovary was then calculated by direct proportion by weight. Variations in fecundity with length, weight and age were determined between years by covariance analysis (Snedecor 1956; Sokal and Rohlf 1981).

Feeding

Following the 1983 population estimates both walleye and northern pike were gill netted from July 15 to August 19 (76 sets) to provide age and feeding data. Two standard monofilament gill net gangs of eight 15.24 m (50 feet) panels consisting of 2.54 cm (1 in), 3.81 cm (1.5 in), 5.08 cm (2 in), 6.35 cm (2.5 in), 7.62 cm (3 in), 8.89 cm (3.5 in), 10.16 cm (4 in), 11.43 cm (4.5 in) sized mesh were used.

Initially a 4 hour set time was used but in August set times were reduced to 3 and later 2 hours to reduce net mortalities. Nets were fished during daylight and sufficient walleye and northern pike were retained to supply an approximate ten percent stratified subsample of the population.

Any live fish retained were sacrificed by cervical dislocation and all net mortalities were also processed. A ten percent formalin solution was injected into the digestive tract of all walleye and northern pike retained via the oesophagus by a hypodermic needle to preserve stomach contents for later processing. Samples of both the left opercular bone and dorsal spine (second or third) from each walleye and both cleithra and scale samples of each northern pike were retained.

The body cavity of each fish was opened to determine sex, maturity and if food was present in the digestive tract. Stomachs with food were severed anteriorly and placed along with any food items located in the mouth cavity into a Whirl Pac bag with a ten percent formalin solution for later study.

In 1984, after the population estimate, food habit samples were collected from northern pike as the fish were sacrificed for aging material.

Following the population estimates in 1984, a stomach pump system (Crossman and Hamilton 1978) was employed. This non-destructive sampling technique was adopted to mitigate walleye mortality while allowing feeding studies to continue. The method, originally developed for muskellunge and largemouth bass, worked better with walleye than northern pike and seemed more appropriate than other reported techniques (Giles 1980; Jernejcic 1969; Seaburg

1957; Foster 1977; Baker and Fraser 1976; Light et. al. 1983).

Trap nets captured fish for stomach pumping. Food items and their relative abundance in the stomachs of fish captured in trap and gill nets have essentially the same composition of diet and changes in diet for both gears (Johnson 1977). Trap nets (one 1.83 m and one 2.44 m) were lifted each morning and walleye and pike anaesthetized in a tricane methanesulfonate bath (MS-222, approximately 6.0 mg/litre of water). Northern pike regurgitation required a steady, gentle stroking of the fish belly while on the B.A.R.F. board (Crossman and Hamilton 1978) and the employment of hook removers to remove large food items. On several occasions large white sucker and pike prey proved exceedingly difficult to remove from pike stomachs. Two pike which died during processing were later examined and found to have food remaining in their stomachs, demonstrating the technique was not totally effective. Walleye responded much better than northern pike, easily regurgitating their food and recovering much sooner from the anaesthetic. Regurgitation was facilitated because they had fed on smaller prey items. While ten pike are known to have died from the procedure all the walleye appeared to survive. Stomachs of walleye and northern pike caught incidentially in small mesh gill nets set for yellow perch were also pumped. Stomach pumped fish captured in gill nets recovered much more slowly than those captured from trap nets.

A number of YOY northern pike were captured in 1983 and 1984 with the use of a bag seine 18.29 m (60 feet) in length and 1.83 m (6 feet) in height. These specimens were also inspected for any stomach contents and any samples were included in the feeding analysis.

Stomach samples were further processed in the lab according to specified techniques (Windell and Bowen 1978; Hyslop 1980; Hynes

1950). Stomach contents were removed from Whirl Pac bags and blotted dry with paper towels. Species and quantities of contents were noted and when possible total lengths of prey fish were determined or estimated. Food habits were determined by the frequency of occurence (Windell and Bowen 1978; Hyslop 1980) and volumeteric method. The latter ascertained by water displacement in various sized graduated cylinders (Windell and Bowen 1978; Hyslop 1980). Many items could not be identified to species, but if possible were at least classified as either fish or invertebrate remains. Any incidental matter such as grass, stones or sticks was not measured or used in subsequent calculations. Frequency of occurence and volumes of food items were calculated both by month and by size classes for walleye and northern pike.

Condition Factors

Condition factors (K) (LeCren 1951; Bagenal and Tesch 1978) were calculated for spring captured walleye, northern pike and white suckers (1982 to 1984), using the formula:

$$K = \frac{(\text{Weight})}{(\text{T.L.})^3} \times 100{,}000 \text{ (Bagenal and Tesch 1978)}$$

T.L. = total length in millimeters

Weight = total weight in grams

Condition factors were compared between years by 5 cm length interval and age-class to mitigate the effects of larger fish possessing disproportionately larger K values (Bagenal and Tesch 1978; Sandhu 1979; Van Engel 1940). Comparisons were done using the Kruskal-Wallis non-parametric test (Sokal and Rohlf 1981).

Removals

In 1982 any walleye dying during the spring population estimate, summer gill netting for perch (Ritchie 1985), and during fall walleye exploitation, were removed. From August 30 until November 4, a Ministry of Natural Resources field crew using a combination of trap and gill net gear, assisted in the removal during the final year of intense walleye exploitation. For each fall trap mortality (both walleye and northern pike) the fish were sexed, gonad maturity determined, stomach contents, aging structures and ovaries retained. All surviving walleye were used for Ministry stocking programs in other water bodies and any live pike were released back into Henderson Lake.

Trap net gear used in 1982 consisted of 1.22 m (four foot, 10 sets), 1.83 m (six foot, 22 sets), 2.44 m (eight foot, 19 sets), and 3.66 m (twelve foot, 8 sets) standard Ministry trap nets (Sandhu 1979). The gill net gear used consisted of nylon nets of lengths 15.24 m (40 ft, 1 set), 121.92 m (400 ft, 10 sets), 182.88 m (600 ft, 21 sets) and a 182.88 m (600 ft, 42 sets) monofilament gill net. Each net had a staggered gang ranging from 3.81 cm (1.5 in) to 12.70 cm (5.0 in) in mesh size.

In 1983 the large scale removal program for walleye was terminated because of the decrease in the walleye population. Small numbers of walleye and northern pike were removed as trap mortalities during the population estimates, for feeding studies from July 15 to August 19 and fecundity samples on September 24 and 25.

Removal of walleye in 1984 was restricted to fecundity samples on October 3,4 and 5, and as trap mortalities from perch gill nets. Northern pike were removed as: incidental trap mortalities from the population estimate and perch gill nets; for aging structures immediately following the population estimate; as mortalities from stomach pumping; and during ovary collection.

Mean Age and Mean Age to Maturity

Weighted mean ages by year for both walleye and northern pike were calculated from the age-frequency distribution. This distribution was determined from the spring trap net catch of fish using the Schumacher-Eschmeyer population estimate.

Mean age to maturity estimates were calculated using Lysack's (1980) correction of Abrosov's (1969) formula.

Production

Annual production estimates (spring to spring) were determined for both walleye and northern pike using the methods of Ricker (1975). Gonadal products were also included in production estimates. Survival rates were determined from the age-frequency distribution, which was calculated using the Schmacher-Eschmeyer (not partitioned by size-class) population estimate.

Lanigon Lake

During the 1984 spring population estimate, white suckers were noted in the outflow stream from Henderson (Fig. 2) to Lanigon Lake. These suckers appeared to be spawning in the stream and seemed to have clear passage from one lake to the other. A former beaver dam had decayed allowing the fish to pass that previously blocked area. In order to determine if any marked fish had been escaping out of Henderson Lake and into Lanigon a series of four gill net sets (four hour duration) were placed in Lanigon Lake between June 4 and July 29. A total of 19 pike, 34 suckers and 22 walleye were captured by gill nets and a further 11 pike and 21 walleye by angling. No marked fish were encountered.

The inflow to Henderson was also investigated but a number of tiered beaver dams preclude the possibility of any fish movement from upstream.

Statistical Analysis

All statisical analysis was performed with the aid of the Statistical Package for the Social Sciences (SPSS) computer programs (Nie et al. 1975), using a VAX 11-780 computer system.

RESULTS

Population Estimates

Schumacher-Eschmeyer mark and recapture population estimates (Schumacher and Eschmeyer 1943; Ricker 1975) of walleye, northern pike and white sucker (1979, 1980 and 1981), vulnerable to the gear, were revised from an earlier report (Nunan 1982)(Table 3).

Walleye Schumacher-Eschmeyer population estimates reflect a fairly stable pre-exploitation population, as the 1979 estimate is only 16 percent below that of 1980. The 1981 estimate, which followed the first year of intense exploitation (removal of 84 percent of the estimated walleye), deviated by only 11 percent from the 1979 and 26 percent from the 1980 estimate. Following the 1981 population estimate, a further 94 percent of estimated walleye numbers were removed, yet in 1982, 945 walleye were still estimated to be present. The first sign of a population collapse came in 1983, when only 345 fish were estimated to be present, after three years of intense harvest. In 1983 intense exploitation ceased, however, 28 percent of the estimated population was removed for age and feeding studies. Walleye numbers declined further in 1984 to an estimated low of 152 fish.

Walleye population estimates also were calculated from 1980 to 1984 using the Petersen method (Table 4) (Everhart et al. 1975; Ricker 1975). Petersen estimates were determined from the number of sacrificed fish possessing the current year's spring fin clip, the total number of fish exploited that year, and the total number of fish marked that spring. These estimates exceeded the

Table 3. Mark and recapture population estimates (N) and confidence limits (C.L.) using the Schumacher-Eschmeyer method (Schumacher and Eschmeyer 1943) for walleye, northern pike and white sucker in Henderson Lake 1979 to 1984.

		N	95% C.L.
	Walleye		
1979	May 17 - June 22	1336	1122 - 1652
1980	May 1 - May 25	1588	1310 - 2016
1981	May 21 - June 27	1183	1008 - 1431
1982	May 13 - June 24	945	750 - 1276
1983	May 12 - July 1	375	334 - 428
1984	May 3 - June 6	152	133 - 177
	Northern Pike		
1979	May 17 - June 22	1963	1705 - 2313
1980	May 1 - May 25	2285	2020 - 2631
1981	May 21 - June 27	1104	938 - 1342
1982	May 13 - June 24	1064	938 - 1383
1983	May 12 - June 27	817	768 - 872
1984	May 3 - May 24	1171	1073 - 1289
	White Sucker		
1979	May 17 - June 22	1454	1172 - 1914
1980	May 1 - May 25	1058	683 - 2356
1981	May 21 - June 27	1281	902 - 2208
1982	May 13 - June 24	748	497 - 1517
1983	May 12 - June 26	976	840 - 1165
1984	May 3 - June 6	1146	1027 - 1296

Table 4. Population estimates of walleye (*Stizostedion vitreum vitreum*), for Henderson Lake (1980 to 1984) using the Petersen method (Ricker 1975; Everhart et al. 1975).

	N^1	95% C.L.^{2}
1980	$\frac{(561)(1332)}{(276)} = 2707$	± 203
1981	$\frac{(417)(1115)}{(215)} = 2163$	± 181
1982	$\frac{(210)(779)}{(137)} = 1194$	± 107
1983	$\frac{(199)(105)}{(67)} = 312$	± 37
1984	$\frac{(121)(42)}{(30)} = 169$	± 28

[1] $$N = \frac{MC}{R}$$

[2] $$V(N) = N^2 \frac{(N-M)(N-C)}{MC(N-1)}$$

$$N \pm 1.96\sqrt{V(N)}$$

Schumacher-Eschmeyer estimates by 70, 83, 26 and 11 percent in 1980, 1981, 1982 and 1984 respectively, but were 17 percent lower in 1983.

Population estimates were also calculated for each 50 mm size-class for walleye (1980 to 1984), to alleviate the effects of trap net length selectivity (Latta 1959). Walleye display increased susceptibility to trap net capture as their size increases (Fig. 4). Northern pike (Fig. 5) and white sucker (Fig. 6) also show similar trends. Latta (1959) suggested the use of a Petersen-type estimate by size-class, to alleviate this problem. However, since removals in this current study took place later in the field season, growth of individual fish prevented use of his method within size-classes. Schumacher-Eschmeyer estimates were therefore calculated for walleye in each 50 mm interval from the spring catch data for 1980 to 1984 (Table 5). Estimates by length-class were 10, 8, 4, 1, and 2 percent greater for 1980, 1981, 1982, 1983 and 1984 respectively, than those calculated by the Schumacher-Eschmeyer method without partitioning fish by size. Size-class estimates were 35, 41, 17 and 8 percent less than Petersen estimates for 1980, 1981, 1982 and 1984 respectively, and 22 percent greater than the 1983 Petersen estimate.

Northern pike Schumacher-Eschmeyer population estimates (Table 3), show a general downward trend during the study from a 1980 high of 2285 fish to a low of 817 in 1983. The 1984 estimate has, however, shown a 43 percent increase in numbers from the 1983 low.

The white sucker population has demonstrated relative stability, with numbers ranging from a high in 1981 of 1281 fish to 748 in 1982 (Table 3). The confidence limits of white sucker population estimates were more variable than those of either walleye or northern pike.

Figure 4. The percentage of recapture of marked fish, plotted against length (mm) for each size-class of walleye in Henderson Lake (1982 to 1984).

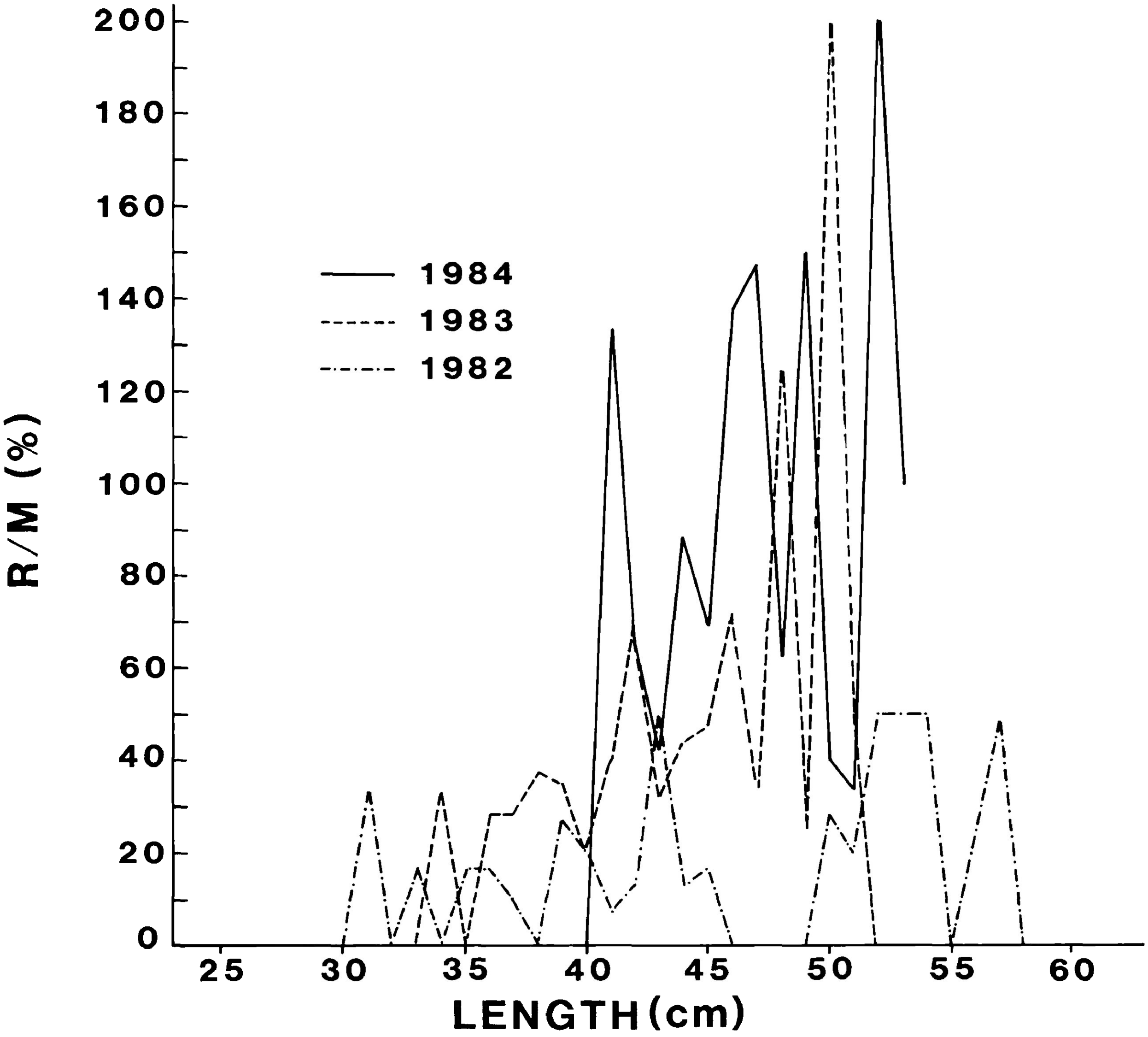

200
180
160
140
120
100
80
60
40
20
0
R/M (%)
25
30
35
40
45
50
55
60
LENGTH (cm)
1984
1983
1982

Figure 5. The percentage of recapture of marked fish plotted against length (mm) for each size-class of northern pike in Henderson Lake (1982 to 1984).

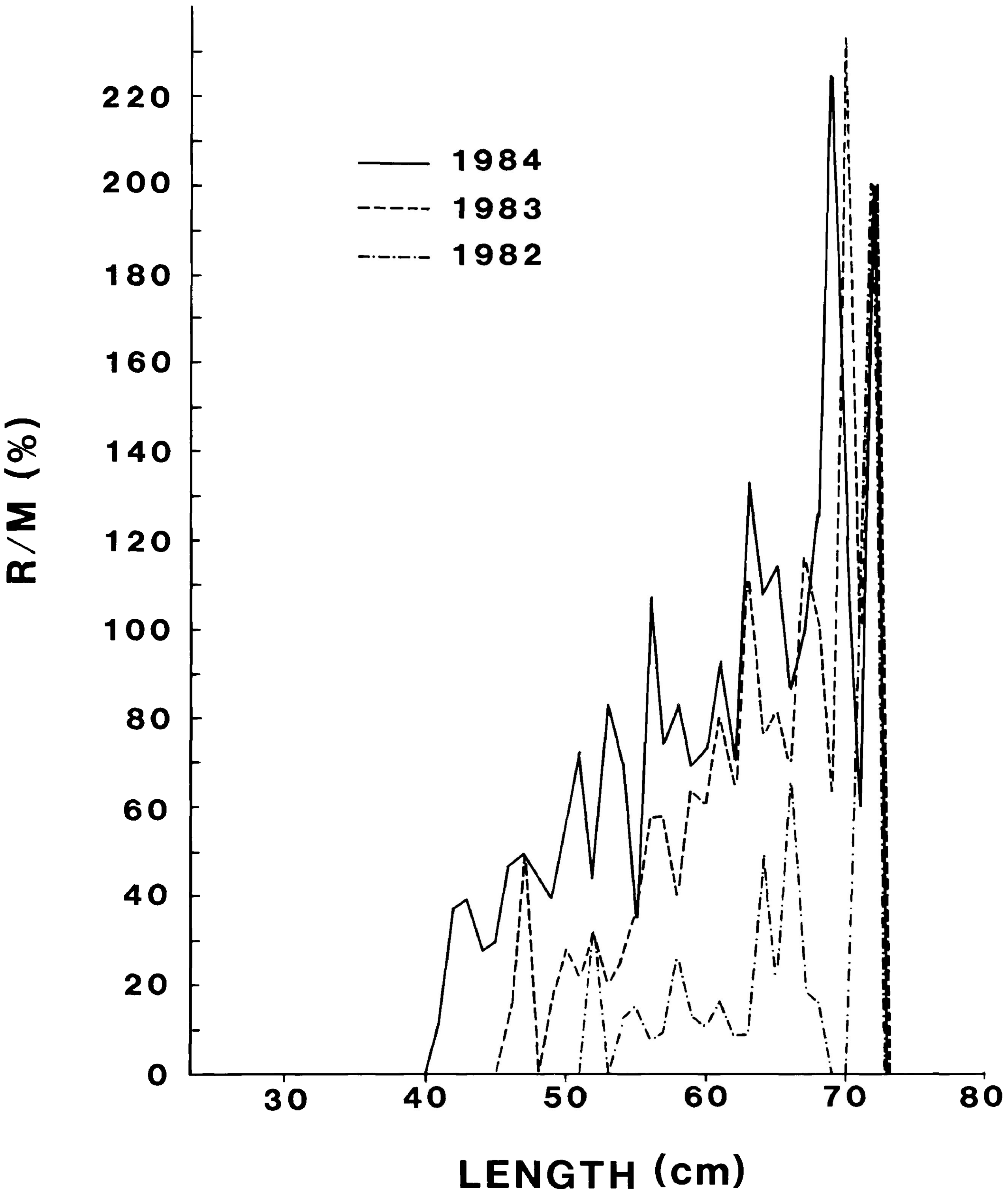

R/M (%)
220
200
180
160
140
120
100
80
60
40
20
0
1984
1983
1982
30
40
50
60
70
80
LENGTH (cm)

Figure 6. The percentage of recapture of marked fish plotted against length (mm) for each size-class of white sucker in Henderson Lake (1982 to 1984).

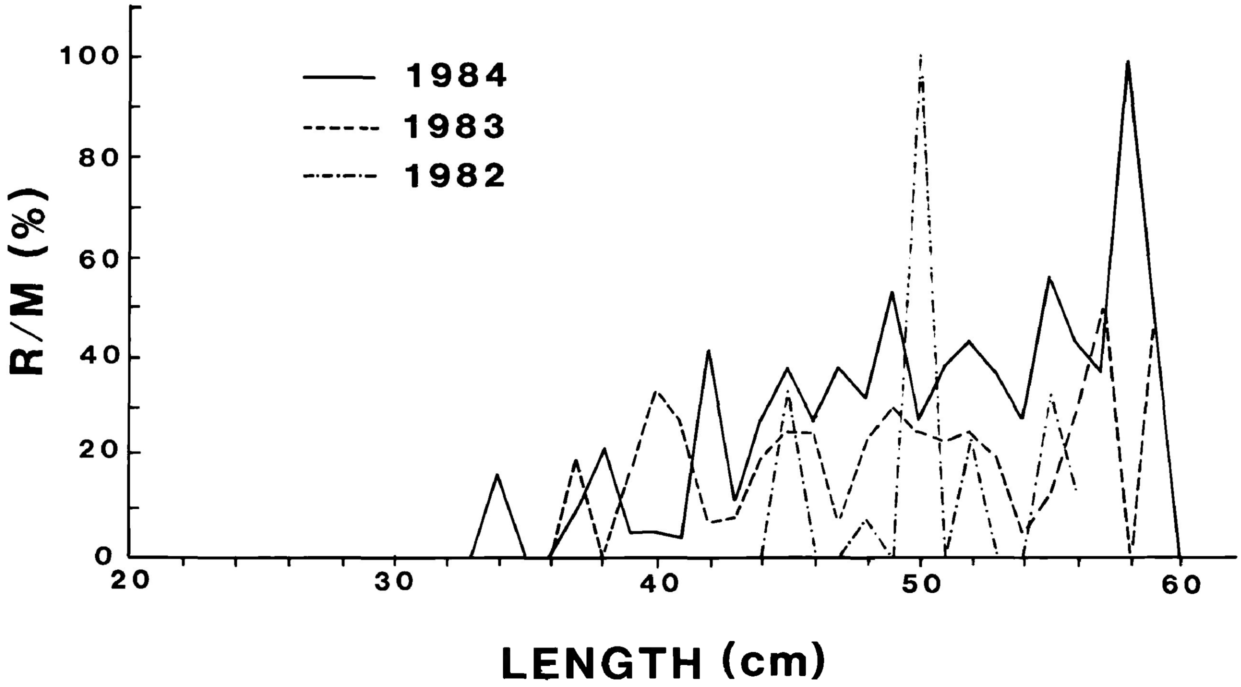

1984
1983
1982
R/M (%)
100
80
60
40
20
0
20
30
40
50
60
LENGTH (cm)

Table 5. Population estimates (N) and confidence limits (C.L.), using the Schumacher-Eschmeyer method (Schumacher and Eschmeyer 1943) by size class of walleye in Henderson Lake from 1980 to 1984.

Year	Size Class (mm)	N	95% C.L.	Total Estimate	
				N	95% C.L.
1980	0 - 399	797	589 - 1195	1753	(1336 - 2555)
	400 - 449	502	382 - 731		
	450 - 499	240	190 - 328		
	500 - 549	168	130 - 234		
	500+	46	35 - 67		
1981	0 - 399	627	485 - 890	1278	(1011 - 1747)
	400 - 449	464	382 - 591		
	450 - 499	124	100 - 165		
	500+	62	45 - 101		
1982	0 - 399	550	347 - 1323	986	(657 - 2059)
	400 - 449	230	164 - 387		
	450 - 499	159	112 - 271		
	500+	47	34 - 77		
1983	0 - 399	125	104 - 157	380	(316 - 476)
	400 - 449	188	155 - 238		
	450+	67	57 - 81		
1984	0 - 449	74	60 - 96	155	(128 - 195)
	450 - 499	68	58 - 82		
	500+	13	11 - 17		

Age and Growth

Length and Age Frequencies

Length frequencies for walleye (Fig. 7), northern pike (Fig. 8), and white sucker (Fig. 9) were calculated from the total number of fish of each length obtained in spring trap net catches, excluding any recaptured fish.

The bimodal walleye length-frequency histogram of 1979 (Fig. 7) transformed to unimodality by 1983. Larger walleye were easily removed from the population by exploitation, while low recruitment of younger fish in later years resulted in the compressed 1984 curve. The age-class structure is positioned above the 1982, 1983 and 1984 frequency histograms. While younger age-classes were displaying increased growth, larger individuals from older age-classes were rapidly eradicated by the removal scheme. The end result was a substantial overlap in the size range among remaining year-classes in succeeding years.

In contrast, the length-frequency histograms for northern pike (Fig. 8) remained stable over the entire study period. The flattened 1979 curve is an artifact resulting from recording only the lengths of a certain number of pike in each interval, the mode is, however, still evident. By sequentially examining curves one observes progressive reduction in the number of large pike (Fig. 8). Increased capture and handling of these larger fish, may have resulted in a higher mortality rate. Correspondingly the recruitment of smaller sized pike increased in 1984. The age-class length ranges (shown

Figure 7. Length-frequency histograms for walleye from Henderson Lake. ($\hat{N}$ = population estimate; n = sample size; lines above curves represent the length ranges of age-classes) The 1979 to 1981 data from Nunan (1982).

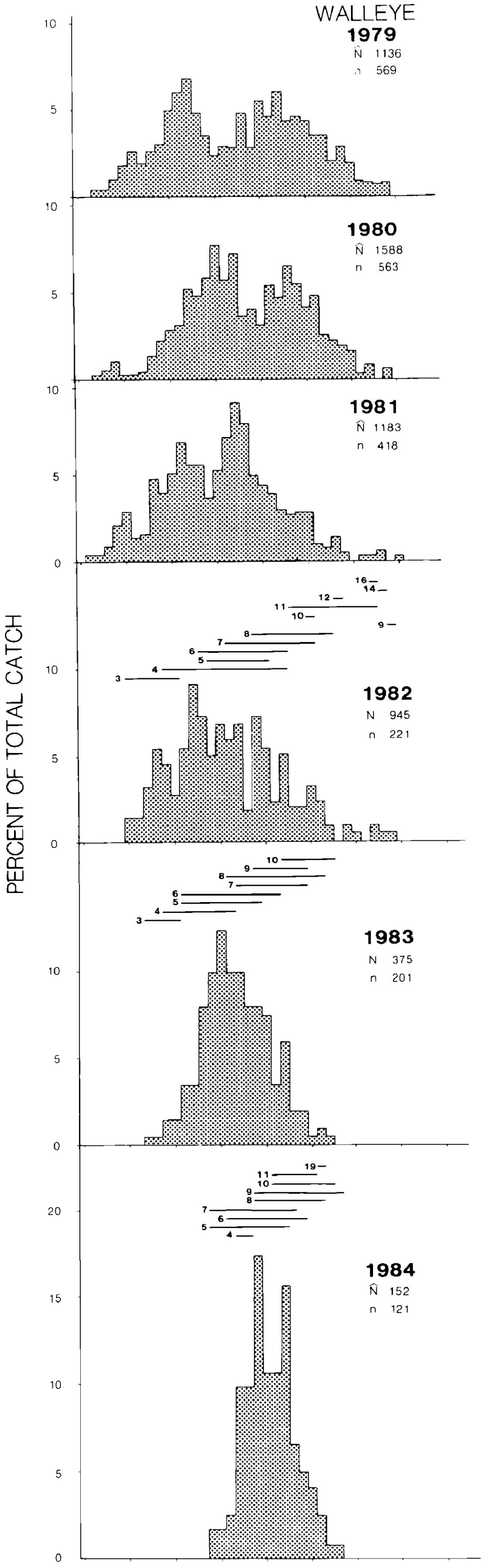
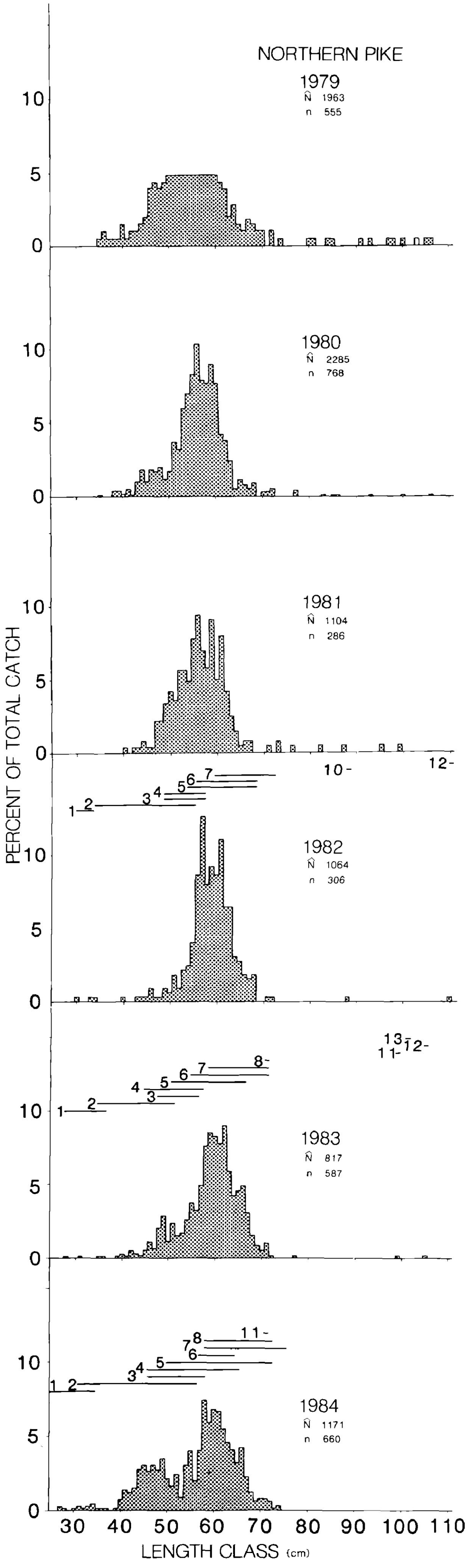

WALLEYE
1979
N̂ 1136
n 569
1980
N̂ 1588
n 563
1981
N̂ 1183
n 418
16
14
12
11
10
9
8
7
6
5
4
3
1982
N 945
n 221
10
9
8
7
6
5
4
3
1983
N 375
n 201
19
11
10
9
8
7
6
5
4
1984
N̂ 152
n 121
0
5
10
15
20
25
30
35
40
45
50
55
60
65
PERCENT OF TOTAL CATCH
TOTAL LENGTH (cm)

Figure 8. Length-frequency histograms for northern pike from Henderson Lake. ($\hat{N}$ = population estimate; n = sample size; lines above graphs represent length ranges of age-classes) The 1979 to 1981 data from Nunan (1982).


NORTHERN PIKE
1979
N̂ 1963
n 555
1980
N̂ 2285
n 768
1981
N̂ 1104
n 286
1 2 3 4 5 6 7 10- 12-
1982
N̂ 1064
n 306
1 2 3 4 5 6 7 8- 11- 12- 13-
1983
N̂ 817
n 587
1 2 3 4 5 6 7 8 11-
1984
N̂ 1171
n 660
PERCENT OF TOTAL CATCH
0
5
10
30
40
50
60
70
80
90
100
110
LENGTH CLASS (cm)

above the 1982, 1983 and 1984 frequency histograms), remained relatively stable (Fig. 8).

White sucker length-frequency histograms were determined from 1982 to 1984 (Fig. 9). Similar modes were found in each of the three years, however, a second peak appears within the 400 to 420 mm length range in 1983 and 1984. The larger sample size in 1983 and 1984 provided a greater range of lengths for use in the construction of size-frequency distributions.

A comparison of length-frequency histograms of fish captured by different fishing gear permitted an assessment of size selectivity. Gill nets tended to capture slightly larger walleye (Fig. 10).

Gill nets tended to capture slightly smaller northern pike than did trapnets in 1983 (Fig. 11). Smaller pike were encountered in greater numbers in 1984 in trap nets than 1983, probably as a result of the increased abundance of two year-olds. Gill nets selected smaller white suckers than did trap nets (Fig. 12).

Trap and gill net length-frequency data was collected at different times during the summer. Any secular changes in behaviour between small and large fish might be misinterpreted as a result of the gear itself rather than reflecting actual changes in fish behaviour.

Walleye age-frequency data was expressed as both percent (Fig. 13) and actual number of fish (Fig. 14). The effects of early reduction and subsequent eradication of older age-classes are clearly shown with the modal age-class varying from age 4 to 6. With poor recruitment of younger walleye in recent years, no 2 or 3 year-olds and only a few 4 year-olds were captured in 1984.

Older, larger pike became infrequent after 1982 (Fig. 15) the

Figure 9. Length-frequency histograms for white sucker from Henderson Lake. ($\hat{N}$ = population estimate; n = sample size)

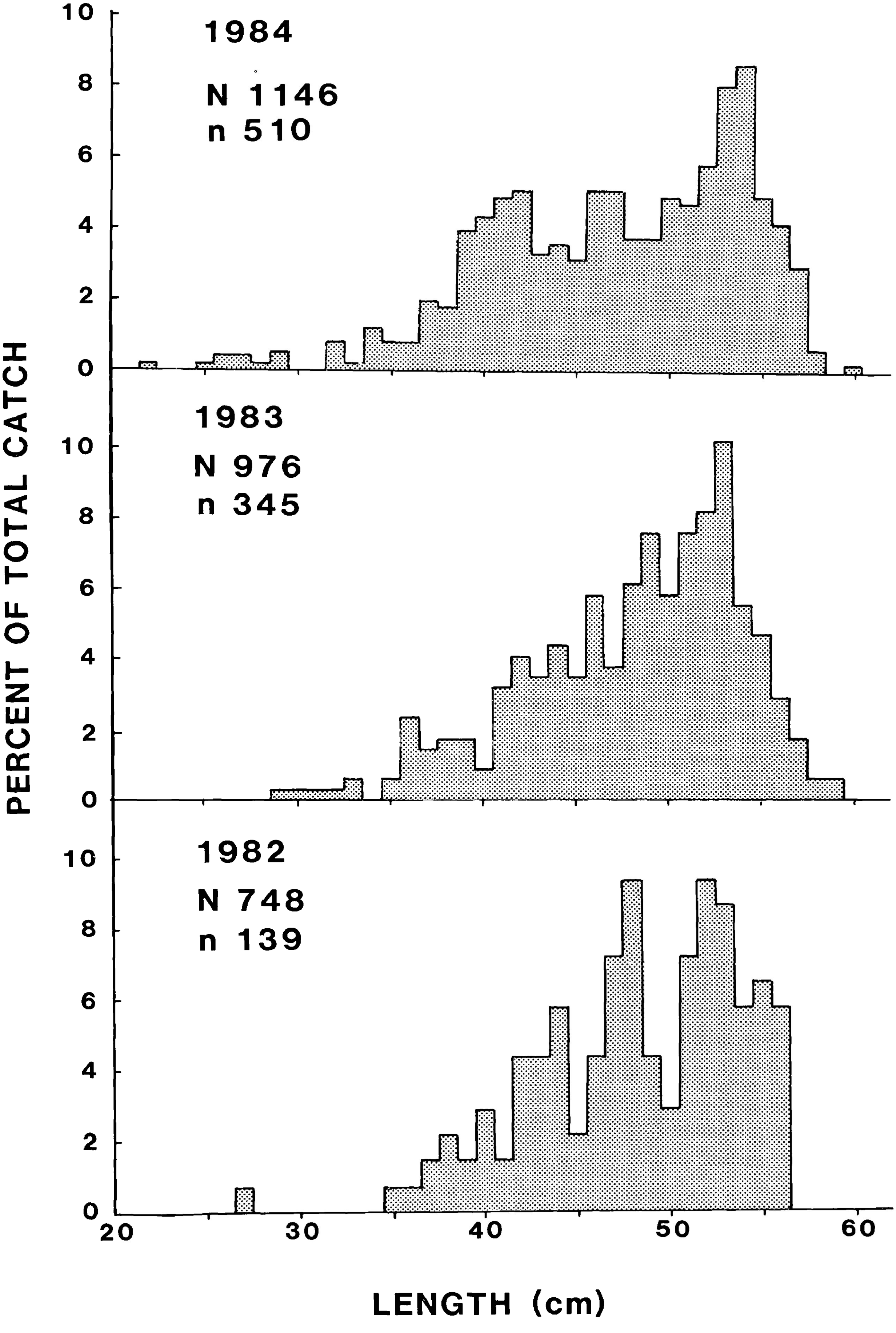
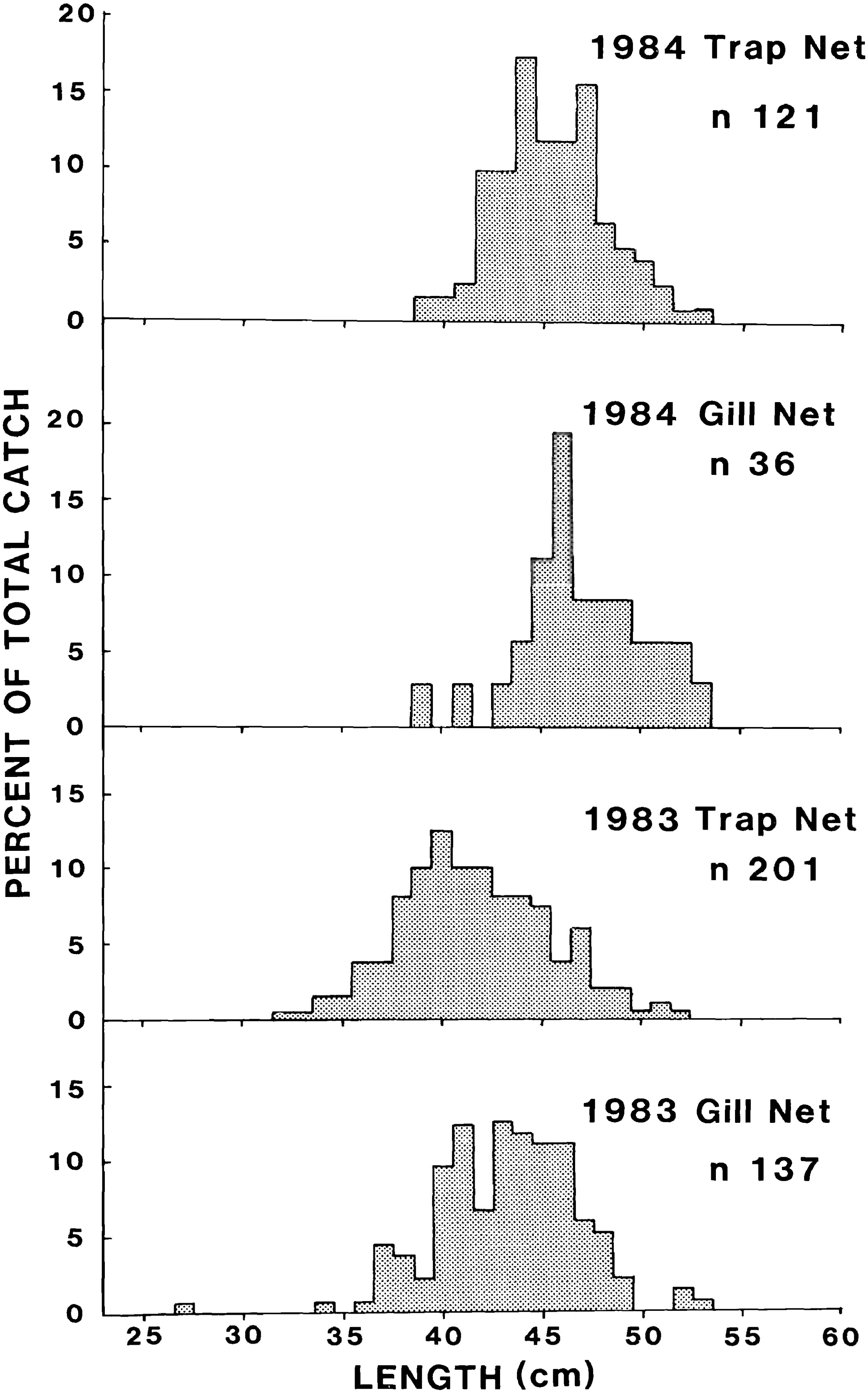

PERCENT OF TOTAL CATCH
1984
N 1146
n 510
1983
N 976
n 345
1982
N 748
n 139
0
2
4
6
8
10
20
30
40
50
60
LENGTH (cm)

Figure 10. Comparisons of walleye length-frequency catch curves between trap and gill net gear, Henderson Lake, 1983 and 1984.



20
15
10
5
0
1984 Trap Net
n 121
20
15
10
5
0
1984 Gill Net
n 36
15
10
5
0
1983 Trap Net
n 201
15
10
5
0
1983 Gill Net
n 137
PERCENT OF TOTAL CATCH
25
30
35
40
45
50
55
60
LENGTH (cm)

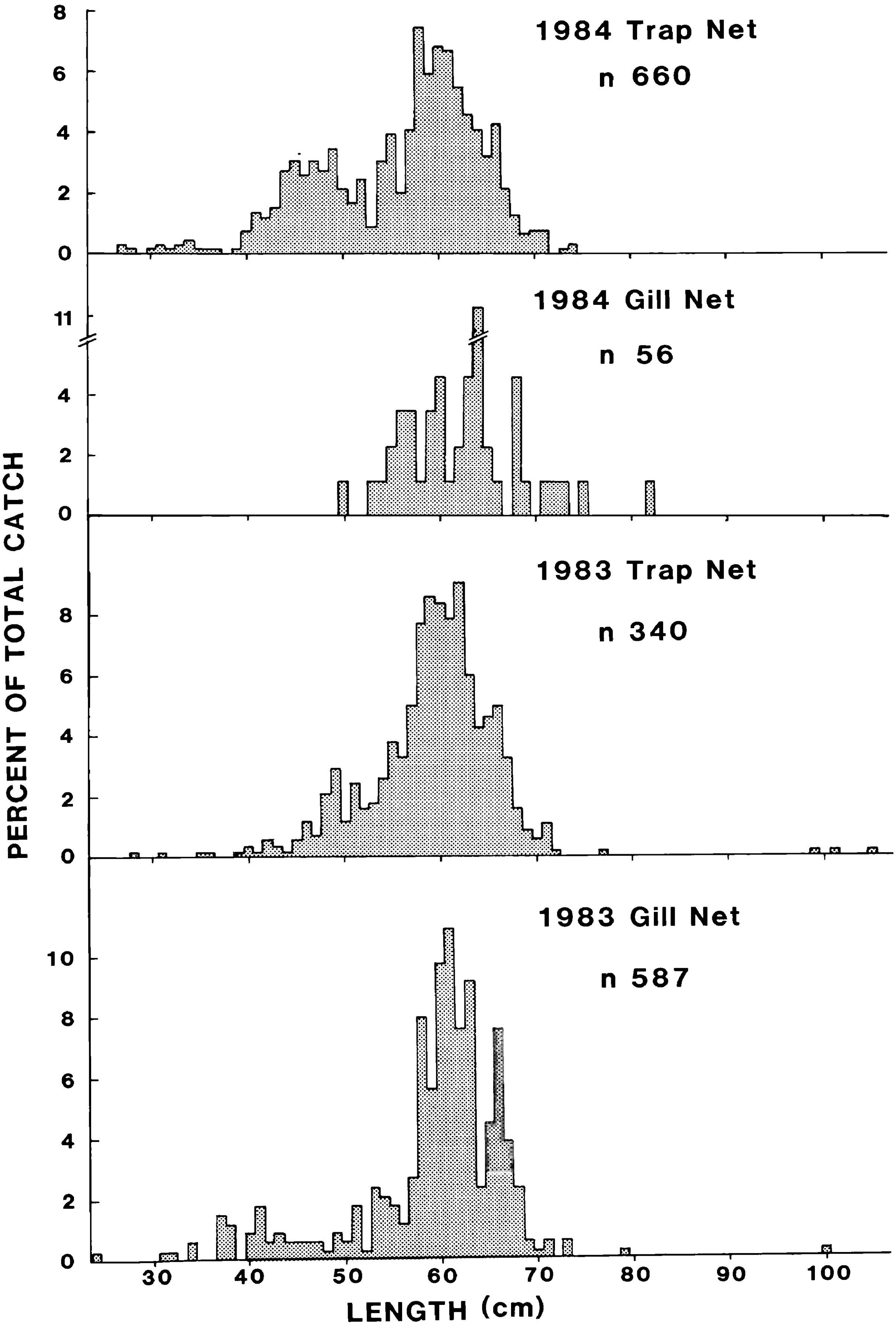

1984 Trap Net
n 660
1984 Gill Net
n 56
1983 Trap Net
n 340
1983 Gill Net
n 587
PERCENT OF TOTAL CATCH
LENGTH (cm)
0
2
4
6
8
11
10
30
40
50
60
70
80
90
100

Figure 12. Comparison of white sucker length-frequency catch curve between trap and gill net gear, Henderson Lake, 1983.

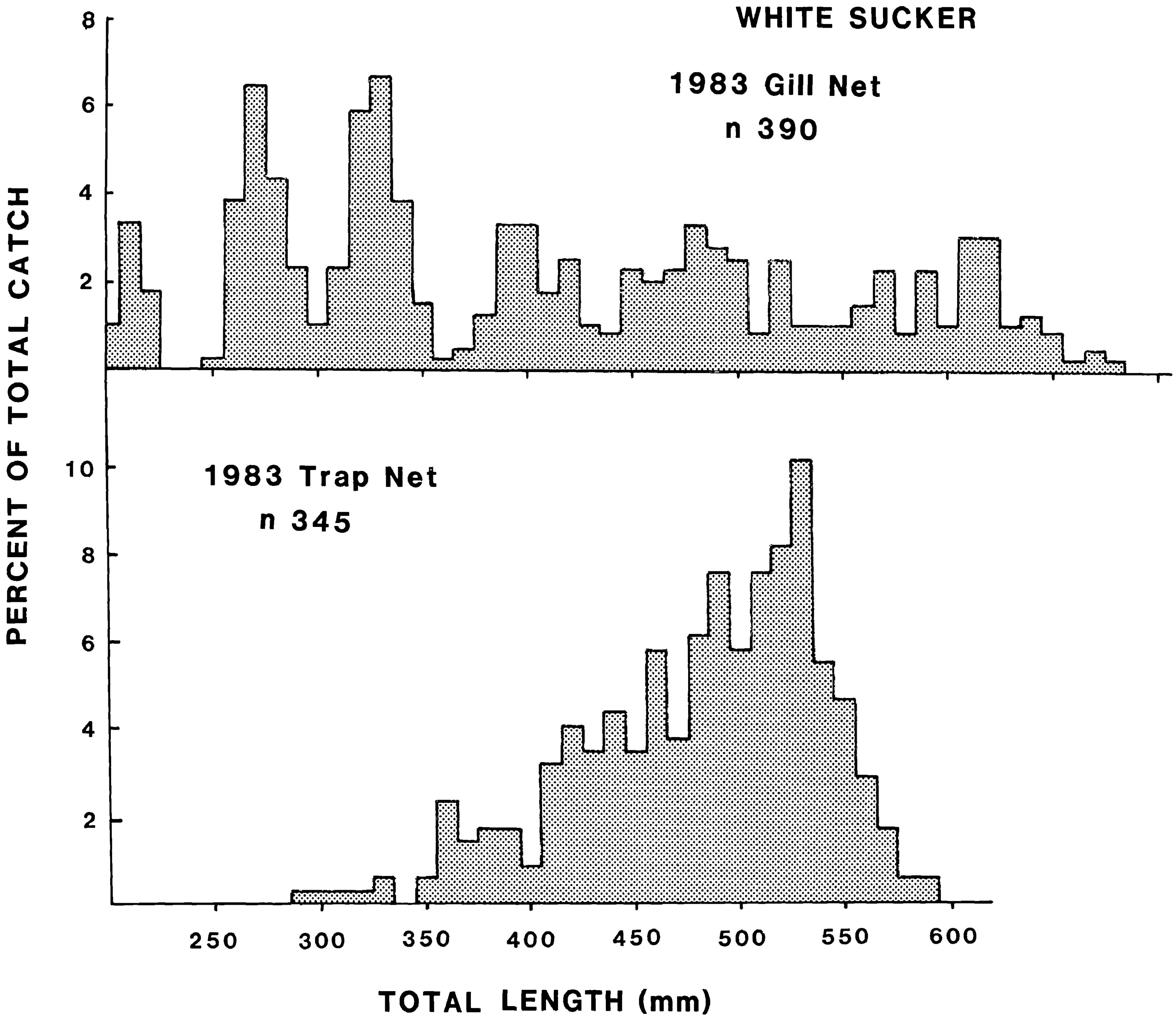

WHITE SUCKER
1983 Gill Net
n 390
1983 Trap Net
n 345
PERCENT OF TOTAL CATCH
8
6
4
2
10
8
6
4
2
250
300
350
400
450
500
550
600
TOTAL LENGTH (mm)

Figure 13. Age-classes by percentage of catch for walleye 1979 to 1984 for Henderson Lake. ($\hat{N}$ = population estimate; n = sample size) The 1979 to 1981 aging data is from Nunan (1982).

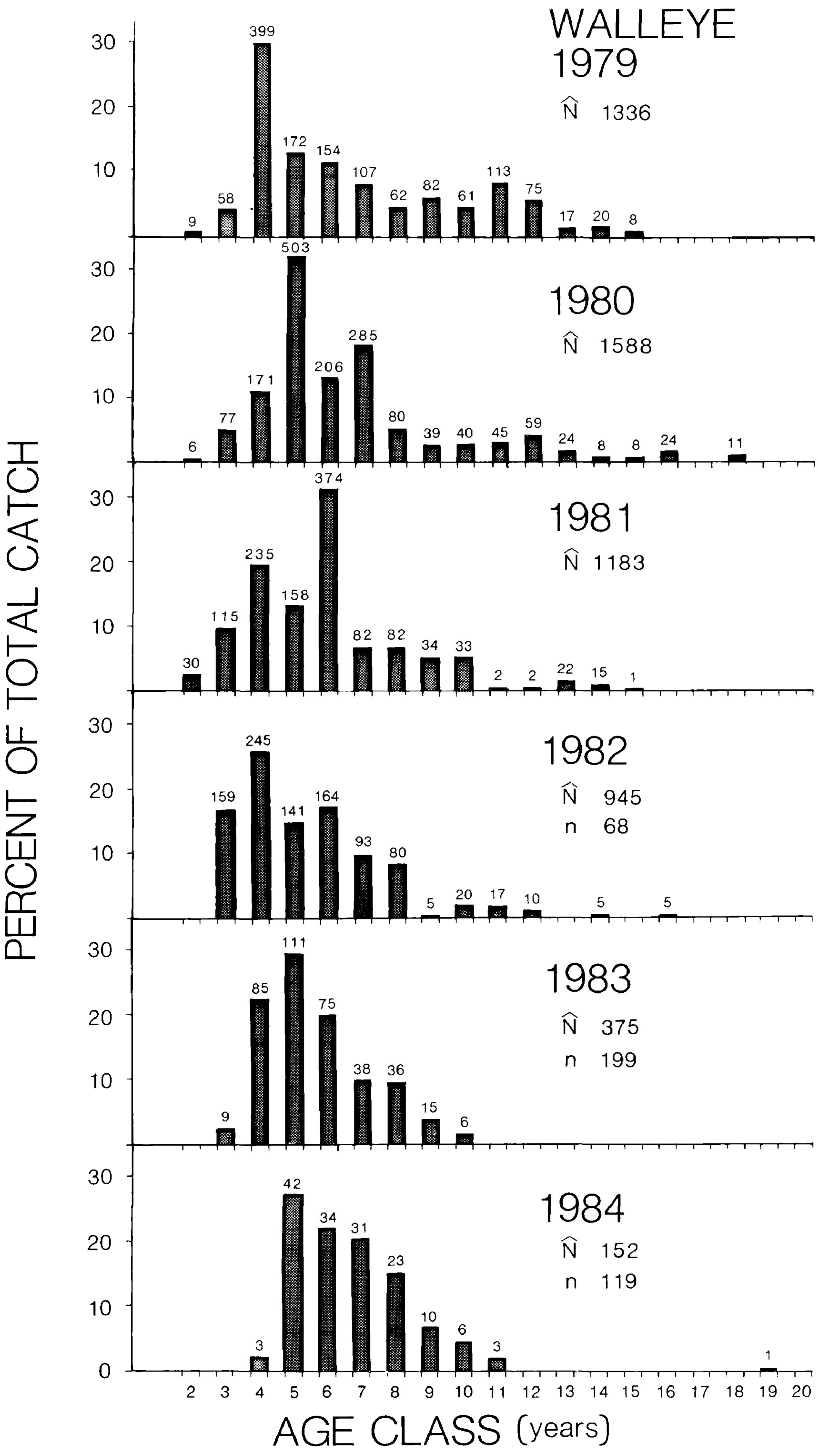
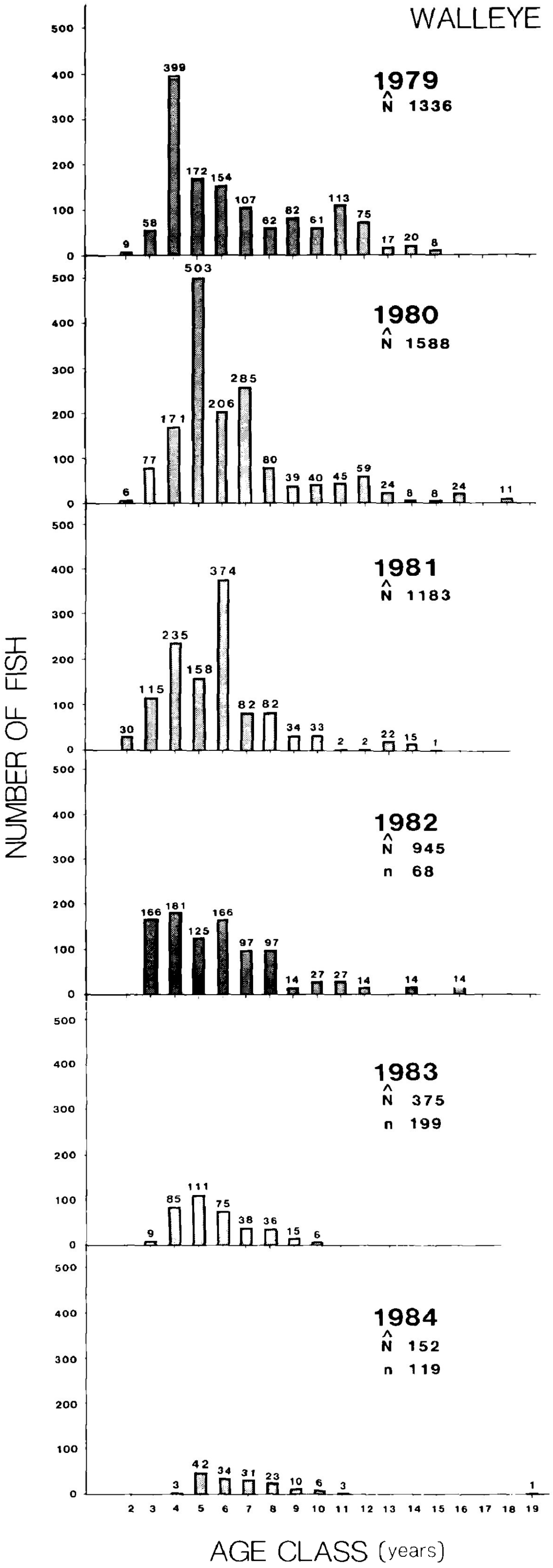

WALLEYE
1979
N̂ 1336
9
58
399
172
154
107
62
82
61
113
75
17
20
8
1980
N̂ 1588
6
77
171
503
206
285
80
39
40
45
59
24
8
8
24
11
1981
N̂ 1183
30
115
235
158
374
82
82
34
33
2
2
22
15
1
1982
N̂ 945
n 68
159
245
141
164
93
80
5
20
17
10
5
5
1983
N̂ 375
n 199
9
85
111
75
38
36
15
6
1984
N̂ 152
n 119
3
42
34
31
23
10
6
3
1
0
10
20
30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
PERCENT OF TOTAL CATCH
AGE CLASS (years)

Figure 14. Age-class by walleye numbers for Henderson Lake, 1979 to 1984. ($\hat{N}$ = population estimate; n = sample size) The 1979 to 1981 aging data is from Nunan (1982).


WALLEYE
NUMBER OF FISH
0
100
200
300
400
500
1979
N̂ 1336
9
58
399
172
154
107
62
82
61
113
75
17
20
8
1980
N̂ 1588
6
77
171
503
206
285
80
39
40
45
59
24
8
8
24
11
1981
N̂ 1183
30
115
235
158
374
82
82
34
33
2
2
22
15
1
1982
N̂ 945
n 68
166
181
125
166
97
97
14
27
27
14
14
14
1983
N̂ 375
n 199
9
85
111
75
38
36
15
6
1984
N̂ 152
n 119
3
42
34
31
23
10
6
3
1
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
AGE CLASS (years)

dominant year-class ranging between age 5 to 7. However, in 1983 and 1984, with an increase in recruitment, younger pike became prominent.

Growth Response

For each age-class mean lengths were compared between years for both walleye (Fig. 16; Appendix II, Table 1), and northern pike (Fig. 17; Appendix II, Table 2). Age-class lengths were compared between years 1982 to 1984 by the Kruskal-Wallis (K-W) non-parametric test (Sokal and Rohlf 1981). Individual length at age data was not available for 1979 to 1981 fish, however, the availability of means, sample sizes and standard deviations of lengths at age (Nunan 1982) allowed comparisons, using the student-t test (Sokal and Rohlf 1981). This necessitated the assumption of normality in all samples, and comparisons of standard deviations to assure equality between years. Since all standard deviations were not equal (determined by an F-test (Sokal and Rolf 1981)), not all of the comparisons between years were possible.

Age 5 walleye were significantly greater in length in 1984 than in 1982 and 1983 (K-W test, $P<0.01$) and both 1982 and 1984 age 6 fish were significantly larger than 1983 walleye (K-W test, $P<0.01$)(Fig. 16). Age 4 walleye in 1984 just failed to be significantly greater in mean length than 1982 and 1983 age 4 walleye (K-W test, $P>0.05$). Student-t tests showed a significant increase in length in 1981 age 2 walleye from both 1980 ($t = 4.96$, d.f. = 29,$P<0.01$) and 1979 ($t = 6.52$,d.f. = 30,$P<0.01$). Unfortunately no age 2 fish were caught after 1981. Both 1982 ($t = 6.79$,d.f. = 28,$P<0.01$) and 1983 ($t = 7.03$,d.f. =

Figure 15. Age-class frequency bar graph for northern pike from Henderson Lake, 1979 to 1984. ($\hat{N}$ = population estimate; n = sample size)

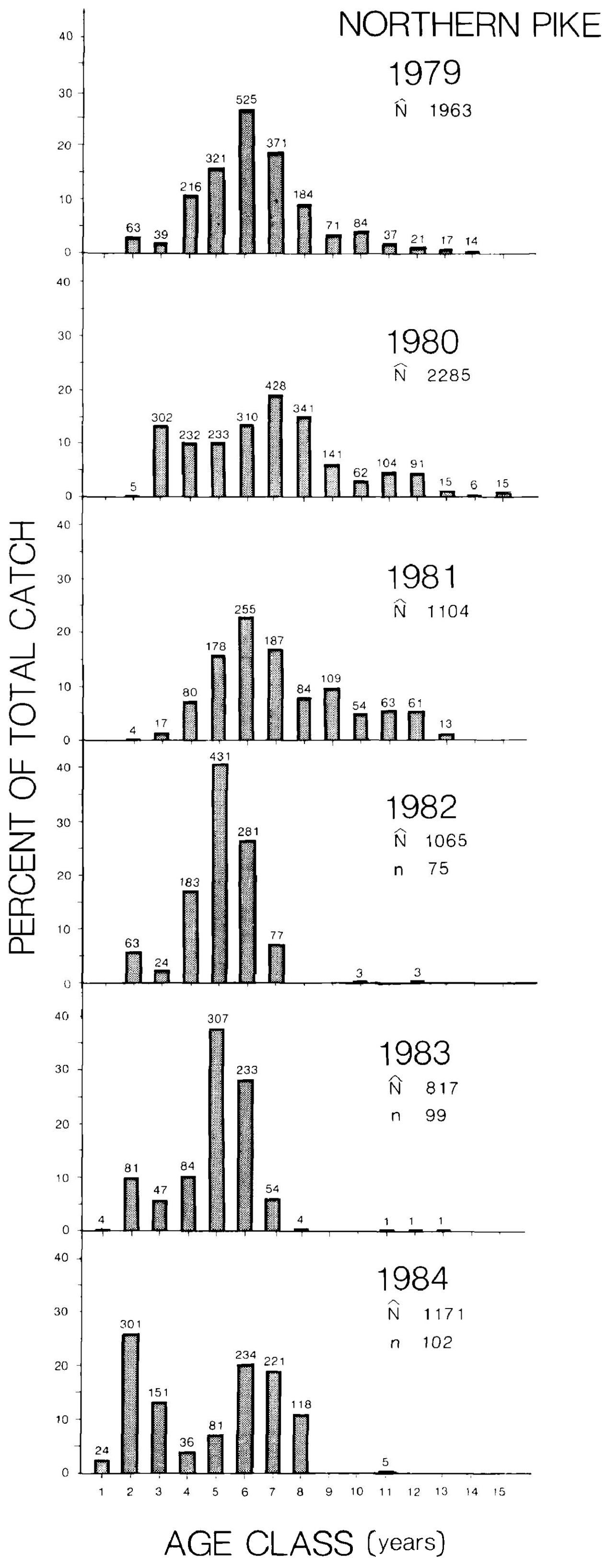
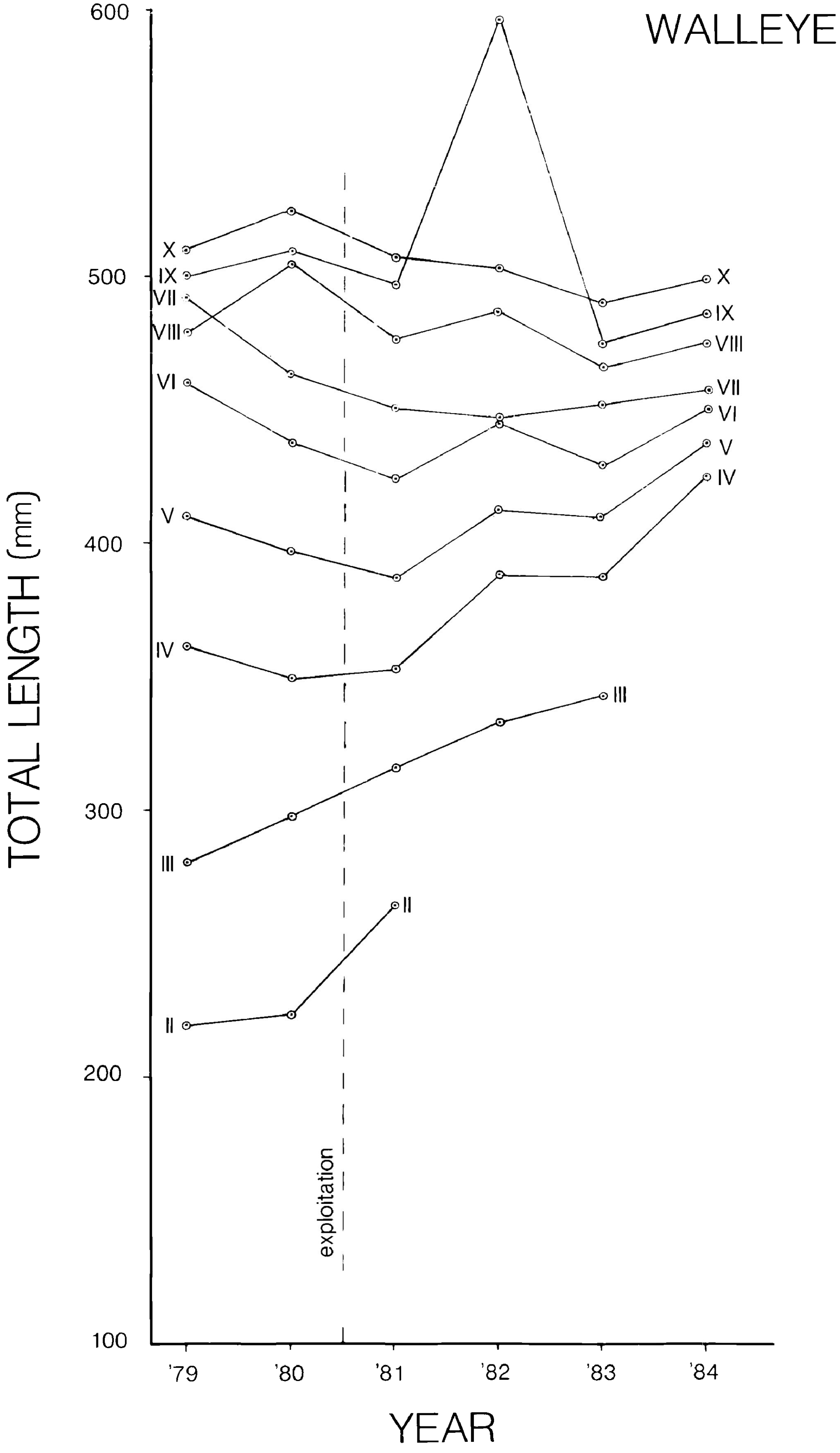

NORTHERN PIKE
PERCENT OF TOTAL CATCH
AGE CLASS (years)
1979
N̂ 1963
63 39 216 321 525 371 184 71 84 37 21 17 14
1980
N̂ 2285
5 302 232 233 310 428 341 141 62 104 91 15 6 15
1981
N̂ 1104
4 17 80 178 255 187 84 109 54 63 61 13
1982
N̂ 1065
n 75
63 24 183 431 281 77 3 3
1983
N̂ 817
n 99
4 81 47 84 307 233 54 4 1 1 1
1984
N̂ 1171
n 102
24 301 151 36 81 234 221 118 5
0
10
20
30
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Figure 16. Mean length (mm) per year by age-class for walleye from Henderson Lake, 1979 to 1984. The 1979 to 1981 lengths are from Nunan (1982).


WALLEYE
TOTAL LENGTH (mm)
600
500
400
300
200
100
YEAR
'79
'80
'81
'82
'83
'84
exploitation
X
IX
VII
VIII
VI
V
IV
III
II
X
IX
VIII
VII
VI
V
IV
III
II

21,P<0.01) age 3 walleye were significantly larger in length than 1980 (pre-exploitation) fish. Age 4 walleye from 1982 were significantly larger than those of 1980 (t = 4.28,d.f. = 33,P<0.01), in 1983 larger than in 1981 (t = 9.23,d.f. = 83,P<0.01) and the 1984 fish were the largest of any year but a significantly different standard deviation did not allow for comparison with other years. Age 5 walleye were the last age group to demonstrate significant increases in growth, the only significant comparison possible was that between 1979 and 1984, which showed a significant increase of length in 1984 (t = 4.37,d.f. = 31,P<0.01). Probably as a result of smaller sample sizes, age 6 and older walleye showed considerably more fluctuation in mean lengths per year than younger age-classes. Several ages appear to decrease in mean length over the study period (Fig. 16), but only the age 7 wallleye from 1979 to 1984 were significantly smaller (t = 3.52,d.f. = 29,P<0.01). The youngest age-classes of walleye have displayed the most significant increases in growth following exploitation.

Northern pike lengths at each age were not significantly different between 1982 to 1984 (K-W tests, P>0.05)(Fig. 17). Means lengths from 1979 age 2 pike were significantly smaller than in 1982 (t = 4.56,d.f. = 16,P<0.01). The size of age 3 fish increased from 1979 to 1982 (t = 8.93,d.f. = 17,P<0.01) and from 1979 to 1984 (t = 7.75,d.f. = 18,P<0.01). Between 1981 and 1982 a significant increase in age 4 (t = 3.96,d.f. = 13,P<0.01) and age 5 fish (t = 5.06,d.f. = 32,P<0.01) was evident. Age 6 pike demonstrated significant increases between 1981 and 1982 (t = 5.50,d.f. = 36,P<0.01), 1980 and 1981 (t = 2.39,d.f. = 31,P<0.05) and a significant decrease between 1982 and 1984 (t = 2.39,d.f. = 26,P<0.05). The 1982 (t = 2.89,d.f. = 18, P<0.01), 1983 (t = 4.30,d.f. = 19,P<0.01) and 1984 (t = 4.85,d.f. =

26,P<0.01) lengths of age 7 pike were significantly greater than those in 1981. A significant increase in 1984 lengths from 1981 (t = 3.69,d.f. = 15,P<0.01) was seen in age 8 fish. No comparisons of fish older than age 8 were possible due to small sample sizes.

More significant increases in pike growth are seen between 1981 and 1982 than any other years (Fig. 17). Because this period marks the transition between persons aging the northern pike (i.e. Nunan 1979 to 1981, Reid 1982 to 1984), differences may be due to the criteria employed by each reader. Re-aging of a number of cleithra from 1980 and 1981, by the current author, reduced age by at least one year for each size of fish previously aged. Northern pike age data (1979 to 1981, fig. 15) has not, however been changed from earlier presentation (Nunan 1982).

Length-Weight Relationships

Length-weight, least-square regressions were computed for walleye (Table 6), northern pike (Table 7) and white sucker (Table 8) for each spring (1982 to 1984) using both log-log and untransformed data, from spring trap net records. Covariant analysis (Sokal and Rohlf 1981;Snedecor 1956) compared log length-log weight regressions between sexes in the same year, and determined between year variation of length-weight curves (sexes combined). Not all covariance comparisons were possible as the assumption of equality of variances was not always met.

Sample sizes of sexed walleye (by extrusion of gonad products) from 1982 and 1983 spring trap netting were small as most fish had already spawned. There were no significant differences between sexes

Figure 17. Mean length (mm) per year by age-class for northern pike from Henderson Lake, 1979 to 1984. The 1979 to 1981 lengths are from Nunan (1982). Vertical dotted line represents the initiation of walleye exploitation. Roman numerals represent age-classes.

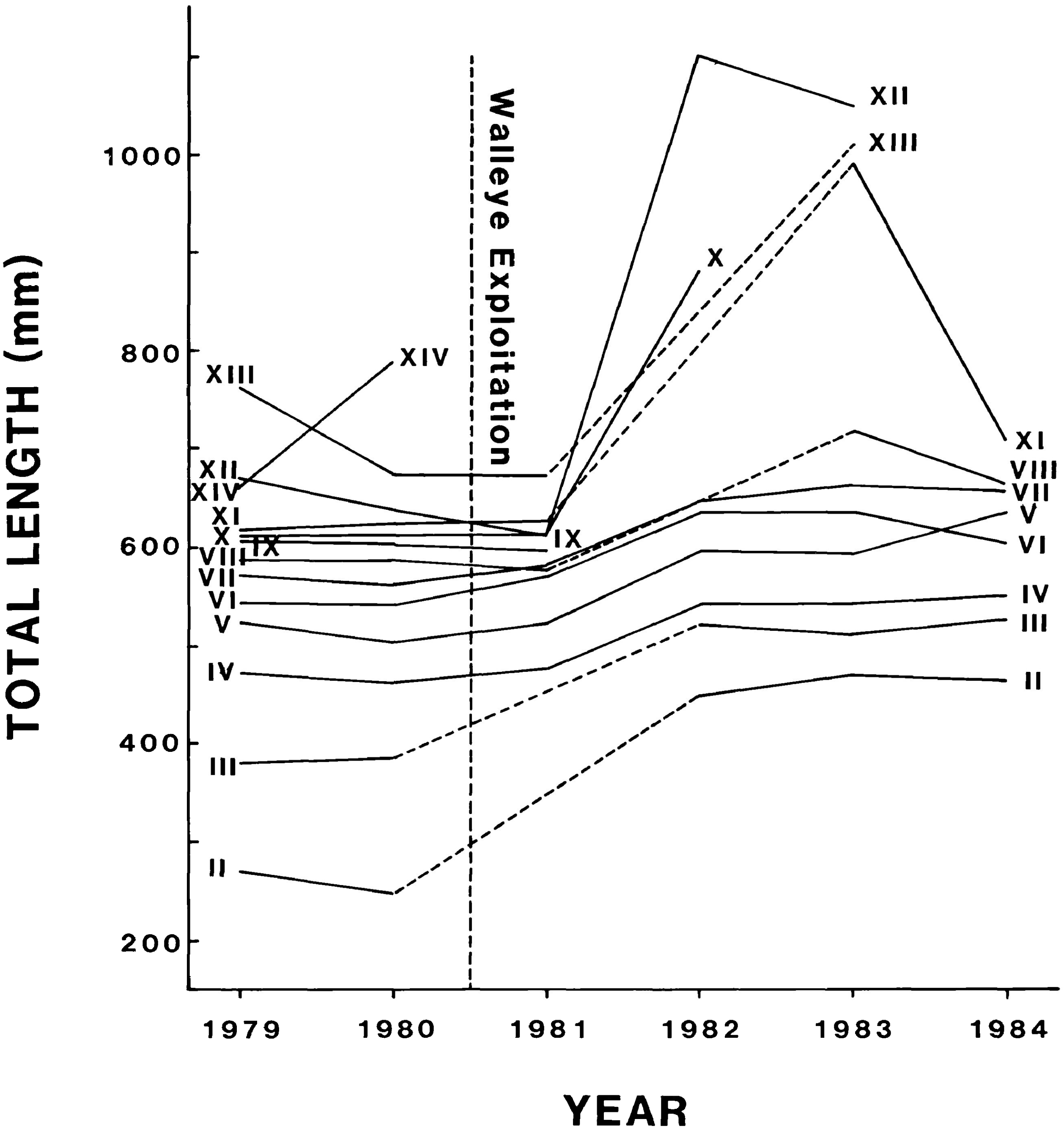

TOTAL LENGTH (mm)
YEAR
1000
800
600
400
200
1979
1980
1981
1982
1983
1984
Walleye Exploitation
XIII
XIV
XII
XIV
XI
X
IX
VIII
VII
VI
V
IV
III
II
IX
X
XII
XIII
XI
VIII
VII
V
VI
IV
III
II

Table 6. Length-weight regressions (log-log and untransformed) for walleye, 1982 to 1984, from spring trap nets in Henderson Lake. (weight in grams, total length in millimeters, logs to the base 10).

1982			
		weight = -1369.6078 + 4.9867 length	r = 0.92 (17)
		log weight = -4.7046 + 2.8760 log length	r = 0.97 (17)
		weight = -1869.3644 + 6.2378 length	r = 0.98 (4)
		log weight = -5.4040 + 3.1403 log length	r = 0.997 (4)
	sexes combined	weight = -1550.8784 + 5.4451 length	r = 0.96 (220)
		log weight = -5.2784 + 3.0925 log length	r = 0.98 (220)
1983			
		weight = -1423.5649 + 4.7646 length	r = 0.91 (22)
		log weight = -6.4344 + 3.5002 log length	r = 0.91 (22)
		weight = -2283.7363 + 6.8394 length	r = 0.80 (4)
		log weight = -7.2963 + 3.8414 log length	r = 0.80 (4)
	sexes combined	weight = -1353.6688 + 4.8862 length	r = 0.91 (202)
		log weight = -4.7026 + 2.8725 log length	r = 0.91 (202)
1984			
		weight = -1860.4179 + 6.1734 length	r = 0.92 (66)
		log weight = -5.1562 + 3.0580 log length	r = 0.92 (66)
		weight = -3212.7908 + 9.1972 length	r = 0.93 (31)
		log weight = -7.3959 + 3.9048 log length	r = 0.93 (31)
	sexes combined	weight = -2228.3142 + 7.0027 length	r = 0.91 (121)
		log weight = -5.7047 + 3.2651 log length	r = 0.92 (121)

Table 7. Length-weight regressions (log-log and untransformed) for northern pike, 1982 to 1984, from spring trap nets in Henderson Lake. (weight in grams, total length in millimeters, logs to the base 10).

1982			
		weight = -1468.9005 + 4.6928 length	r = 0.83 (150)
		log weight = -4.0530 + 2.5852 log length	r = 0.89 (150)
		weight = -1542.2398 + 4.9392 length	r = 0.98 (9)
		log weight = -5.2238 + 3.0194 log length	r = 0.996 (9)
	sexes combined	weight = -3206.1480 + 7.6589 length	r = 0.85 (323)
		log weight = -4.6945 + 2.8144 log length	r = 0.93 (323)
1983			
		weight = -1855.2706 + 5.1067 length	r = 0.88 (189)
		log weight = -4.7193 + 2.8066 log length	r = 0.91 (189)
		weight = -1350.00 + 4.2802 length	r = 0.80 (16)
		log weight = -4.6012 + 2.7636 log length	r = 0.87 (16)
	sexes combined	weight = -3190.3452 + 7.4293 length	r = 0.79 (585)
		log weight = -5.0796 + 2.9364 log length	r = 0.94 (585)
1984			
		weight = -1636.2931 + 4.9388 length	r = 0.94 (369)
		log weight = -4.3229 + 2.6781 log length	r = 0.97 (369)
		weight = -1736.3902 + 5.2134 length	r = 0.92 (73)
		log weight = -3.9029 + 2.5312 log length	r = 0.95 (73)
	sexes combined	weight = -1796.6680 + 5.2917 length	r = 0.87 (754)
		log weight = -4.6766 + 2.8054 log length	r = 0.98 (754)

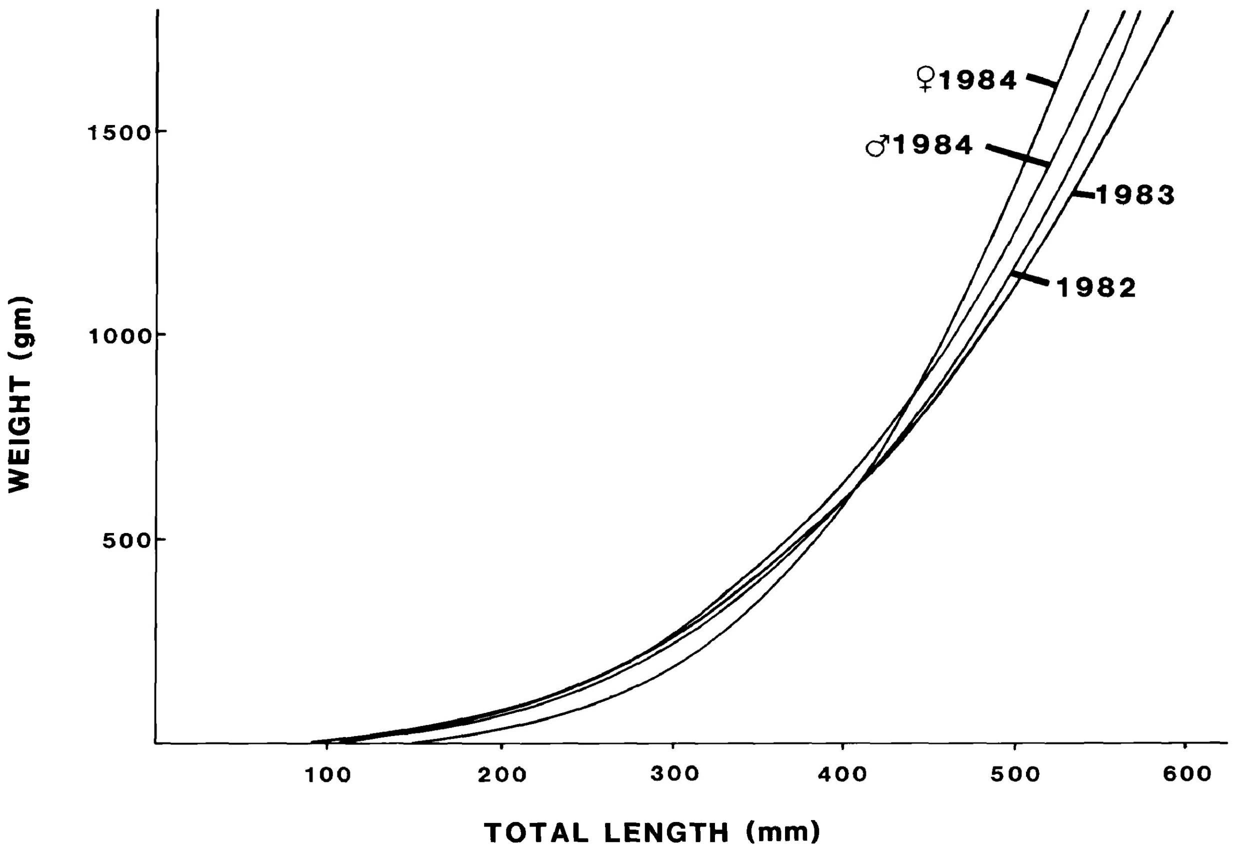
Table 8. Length-weight regressions (log-log and untransformed) for white sucker, 1982 to 1984, from spring trap nets in Henderson Lake. (weight in grams, total length in millimeters, logs to the base 10).

1982			
		weight = -2166.9382 + 7.4198 length	r = 0.99 (16)
		log weight = -5.5493 + 3.2439 log length	r = 0.99 (16)
	♀	weight = -2372.5570 + 8.2509 length	r = 0.92 (22)
		log weight = -5.1580 + 3.1035 log length	r = 0.98 (22)
	sexes combined	weight = -3056.4177 + 9.5661 length	r = 0.95 (139)
		log weight = -5.4917 + 3.2275 log length	r = 0.97 (139)
1983			
		weight = -1815.5786 + 6.4191 length	r = 0.96 (43)
		log weight = -4.9055 + 2.9858 log length	r = 0.98 (43)
		weight = -3147.8506 + 9.5974 length	r = 0.93 (197)
		log weight = -5.1696 + 3.1026 log length	r = 0.95 (197)
	sexes combined	weight = -2339.6482 + 7.9418 length	r = 0.92 (349)
		log weight = -5.3546 + 3.1679 log length	r = 0.98 (349)
1984			
		weight = -1871.0057 + 6.6686 length	r = 0.95 (98)
		log weight = -4.5334 + 2.8556 log length	r = 0.96 (98)
		weight = -2981.1845 + 9.4170 length	r = 0.96 (335)
		log weight = -4.9656 + 3.0332 log length	r = 0.97 (335)
	sexes combined	weight = -2672.4128 + 8.7509 length	r = 0.96 (506)
		log weight = -5.3675 + 3.1790 log length	r = 0.98 (506)

for either slopes (1982,$F = 0.526$,d.f. = 1,17,$P>0.05$;1983,$F = 0.00$,d.f. = 1,22,$P>0.05$) or intercepts (1982,$F = 0.00$,d.f. = 1,18,$P>0.05$;1983,$F = 2.00$,d.f. = 1,23,$P>0.05$) of 1982 and 1983 walleye. There were, however, only four confirmed females captured in each 1982 and 1983 sample. In 1984, with a larger sample size (31 females, 66 males), both slope ($F = 6.81$,d.f. = 1,93,$P<0.025$) and intercepts ($F = 7.00$,d.f. = 1,94,$P<0.01$) were signficantly different between sexes. Sexual differences in growth rate is common in walleye (Schainost 1983; Paxton et al. 1981; Wolfert and Miller 1978; Smith 1977; Lewis 1970; Priegel 1969a; Rawson 1957; Eschmeyer 1950; Stroud 1949; Carlander 1945). Small sample size may explain the absence of sexual dimorphism in the length-weight relationship between 1982 and 1983. The only between year comparison (sexes combined) possible (due to inequality of variances) was 1982 to 1984. Non-significant differences in variance ($F = 1.00$,d.f. = 218,119,$P>0.05$) and slope ($F = 1.52$,d.f. = 1,337,$P>0.05$) were noted, however, intercepts were significantly different ($F = 68.00$,d.f. = 1,338,$P<0.01$). Larger fish decreased in weight with length in 1983 compared to 1982 (Fig. 18), as was also revealed by the reduced condition factor (see condition factor). Both the 1982 and 1983 curves were below that for 1984 (Fig. 18).

Covariance comparisons of length-weight regressions between sexes of northern pike for each year were not possible for log regressions due to inequality of variances. However, 1982 male-female length-weight regressions of untransformed data revealed no significant differences in variances ($F = 1.86$,d.f. = 148,7,$P>0.05$), slopes ($F = 0.15$,d.f. = 1,155,$P>0.05$) or intercepts ($F = 1.44$,d.f. = 1,156,$P>0.05$). Sample sizes were, however, small for 1982 (150

Figure 18. Plot of length-weight regressions (determined by $\log_{10}$-$\log_{10}$ plots) for walleye 1982, 1983 and 1984 (male and female), for Henderson Lake.



♀1984
♂1984
1983
1982
WEIGHT (gm)
1500
1000
500
100
200
300
400
500
600
TOTAL LENGTH (mm)

Figure 19. Plot of length-weight regressions (determined by $\log_{10}$-$\log_{10}$ plots) for northern pike 1982, 1983 and 1984 for Henderson Lake.

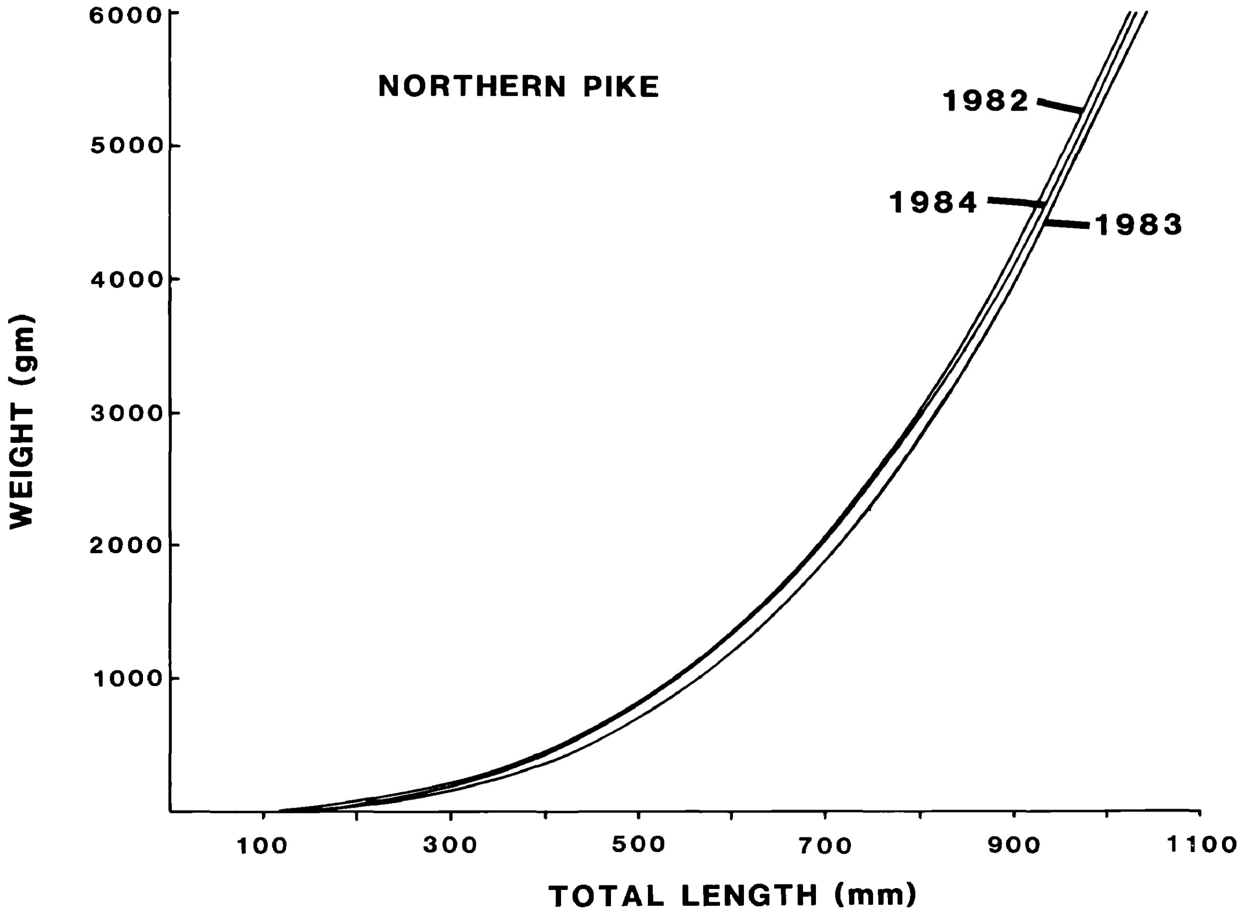

NORTHERN PIKE
1982
1984
1983
WEIGHT (gm)
6000
5000
4000
3000
2000
1000
100
300
500
700
900
1100
TOTAL LENGTH (mm)

Figure 20. Plot of length-weight regressions (determined by $\log_{10}$-$\log_{10}$ plots) for white sucker 1982, 1983 (male and female) and 1984 (male and female) for Henderson Lake.

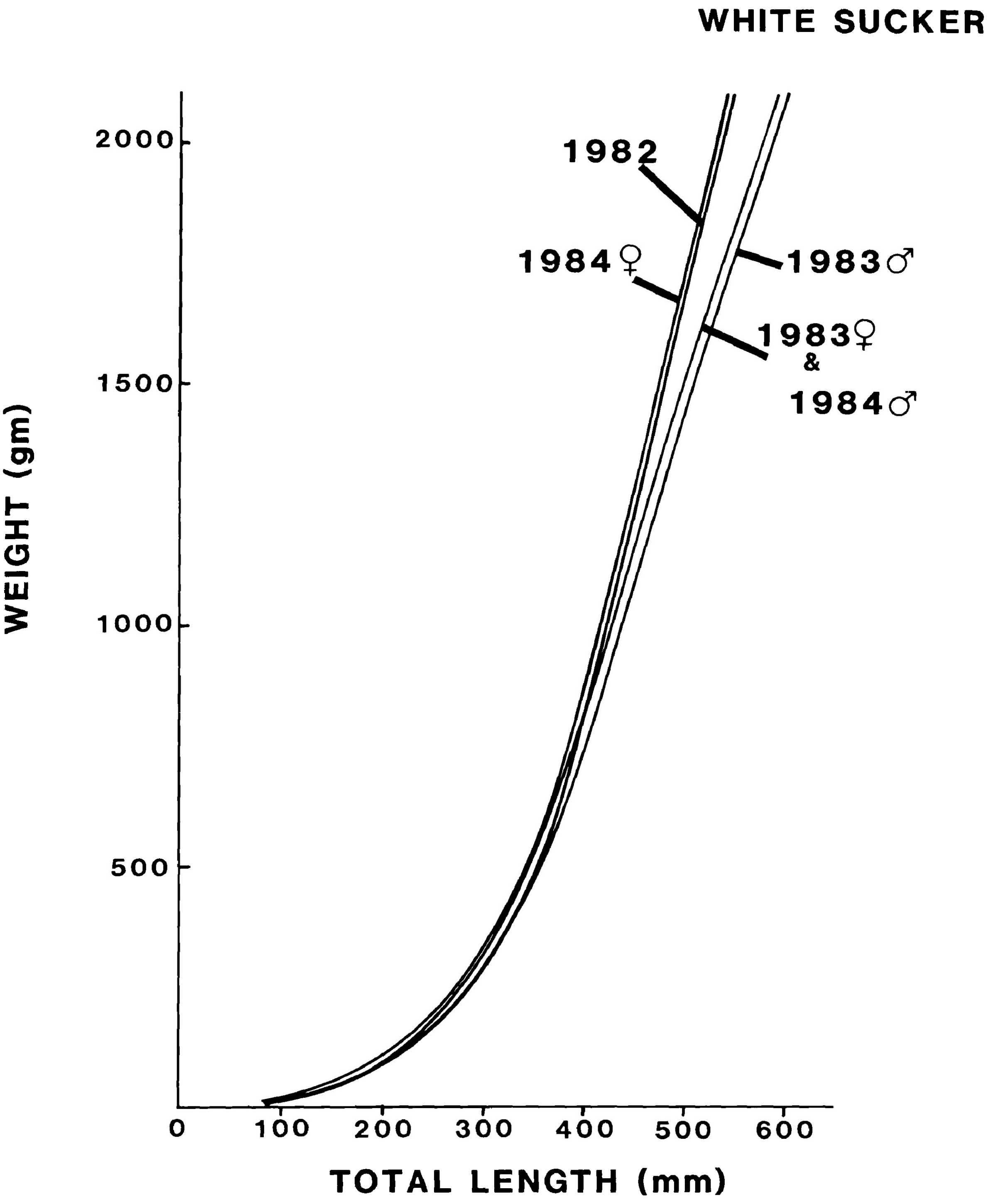

WHITE SUCKER
WEIGHT (gm)
2000
1500
1000
500
0
100
200
300
400
500
600
TOTAL LENGTH (mm)
1982
1984♀
1983♂
1983♀
&
1984♂

Table 9. Log-log and untransformed, least square regressions for walleye total length (mm) to opercular length (mm) from Henderson Lake, 1982 to 1984.

1982		
	total length = 95.6918 + 14.7176 opercle length	r = 0.95 (195)
	log total length = 1.5979 + 0.7641 log opercle length	r = 0.96 (195)
	intercept = 39.62 mm	
1983		
	total length = 117.7000 + 14.0200 opercle length	r = 0.90 (104)
	log total length = 1.6388 + 0.7380 log opercle length	r = 0.91 (104)
	intercept = 43.53 mm	
1984		
	total length = 164.8050 + 11.8905 opercle length	r = 0.91 (40)
	log total length = 1.7568 + 0.6497 log opercle length	r = 0.92 (40)
	intercept = 57.12	

Table 10. Log-log and untransformed, least square regressions for northern pike total length (mm) to cleithral length (mm) and scale length (mm) from Henderson Lake, 1982 to 1984.

1982		
	total length = 6.4728 + 10.8566 cleithra length	r = 0.98 (52)
	log total length = 0.9800 + 1.0350 log cleithra length	r = 0.99 (52)
	intercept = 9.55 mm	
	total length = 64.0002 + 23.4075 scale length	r = 0.83 (70)
	log total length = 1.7120 + 0.7824 log scale length	r = 0.90 (70)
	intercept = 51.53 mm	
1983		
	total length = 57.6661 + 9.7530 cleithra length	r = 0.95 (175)
	log total length = 1.2170 + 0.8942 log cleithra length	r = 0.93 (175)
	intercept = 16.48 mm	
1984		
	total length = 6.6512 + 10.6744 cleithra length	r = 0.99 (120)
	log total length = 1.0754 + 0.9752 log cleithra length	r = 0.99 (120)
	intercept = 11.90 mm	

coefficients equal to, and intercepts more acceptable than those from untransformed data. Since untransformed regressions were highly significant lengths were backcalculated by direct proportion.

Lengths at each age were calculated both by sex and sexes combined for each age-class. Data from 1982, 1983 and 1984 was combined by year-class, to increase sample size, for both walleye (Appendix III, Table 1, 2 and 3) and northern pike (Appendix III, Table 4, 5 and 6).

Walleye mean length at each age fluctuates by year-class but no definite indication of Lee's phenomenon (ie. length at age from younger year-classes indicating greater length than those from older year-classes) is evident for either sex. Comparisons between backcalculated total lengths and empirical data (Fig. 21, 22 and 23) show a general increase in length at age of younger fish between 1982 to 1984 compared to mean backcalculated lengths at ages (Appendix III, Tables 1, 2 and 3). Older fish are generally close to mean backcalculated lengths at age. Averaged backcalculated walleye lengths at age from 1979 to 1981 (Nunan 1982) and 1982 to 1984 (current study) show quite good agreement for sexes combined and only slight differences for males and females (Fig. 21, 22, 23).

Northern pike backcalculated lengths at age generally tended to increase in recent year-classes in both sexes, indicating the presence of Lee's phenomenon. Empirical lengths at age (1982 to 1984) were generally greater than those determined from backcalculated lengths at age for both sexes (Fig. 24, 25 and 26). Lee's phenomenon could account for this discrepancy between calculated and actual lengths at age. The 1982-1984 backcalculated data more closely agrees with the empirical data for both sexes than the 1980-1981 data (Nunan

Figure 21. Plot of backcalculated and empirical (1982 to 1984) lengths at age for walleye, combined sexes, from Henderson Lake.

——— backcalculated data, 1979 to 1981 (Nunan 1982).

– – ▵ – – backcalculated data, 1982 to 1984 (present study).

○ × □ empirical data.

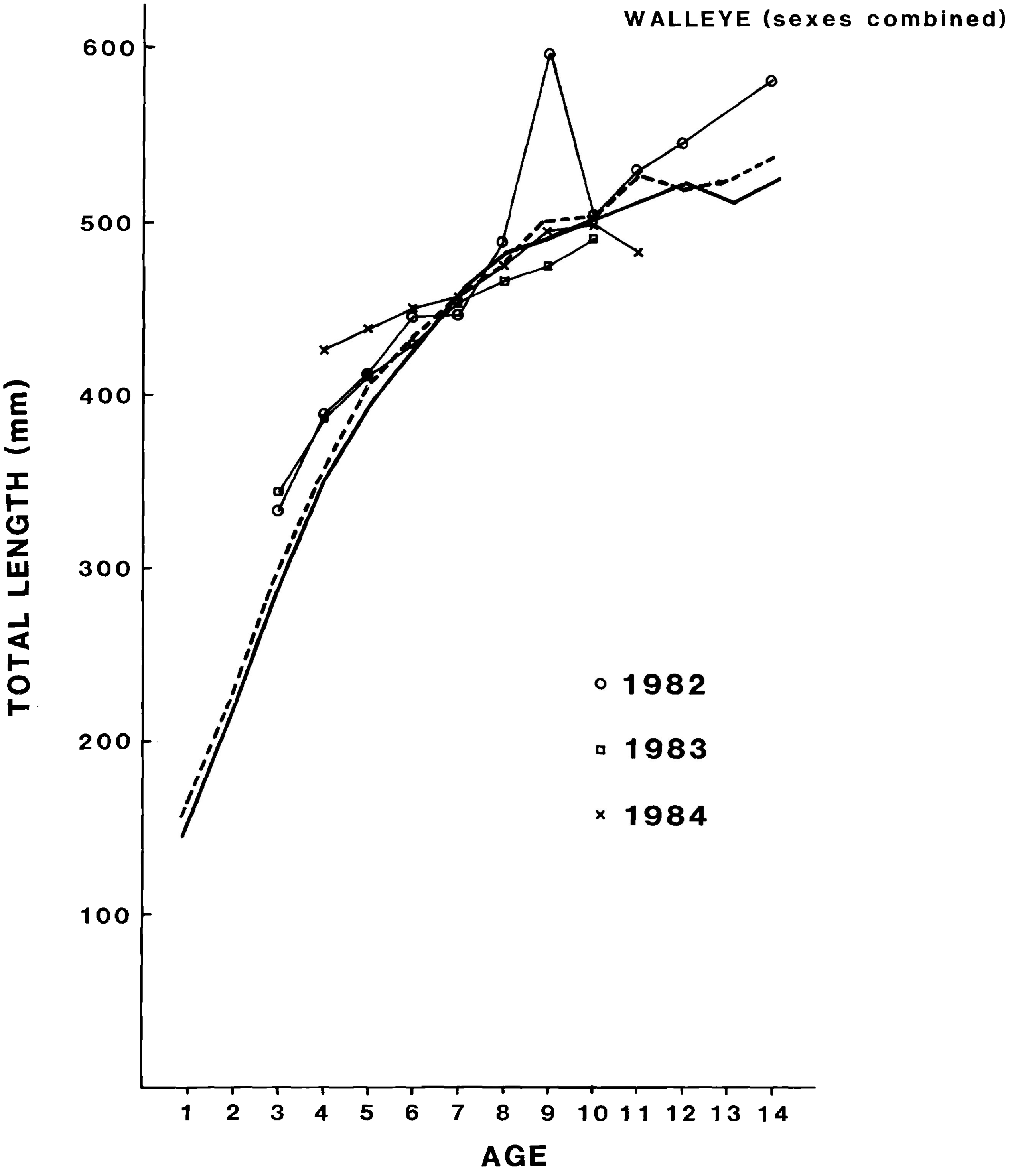

WALLEYE (sexes combined)
TOTAL LENGTH (mm)
600
500
400
300
200
100
AGE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
○ 1982
□ 1983
× 1984

Figure 22. Plot of backcalculated and empirical (1982 to 1984) lengths at age for male walleye from Henderson Lake.

——— backcalculated data, 1979 to 1982 (Nunan 1982).
- - - - - - backcalculated data, 1982 to 1984 (present study).
○ × □ empirical data.

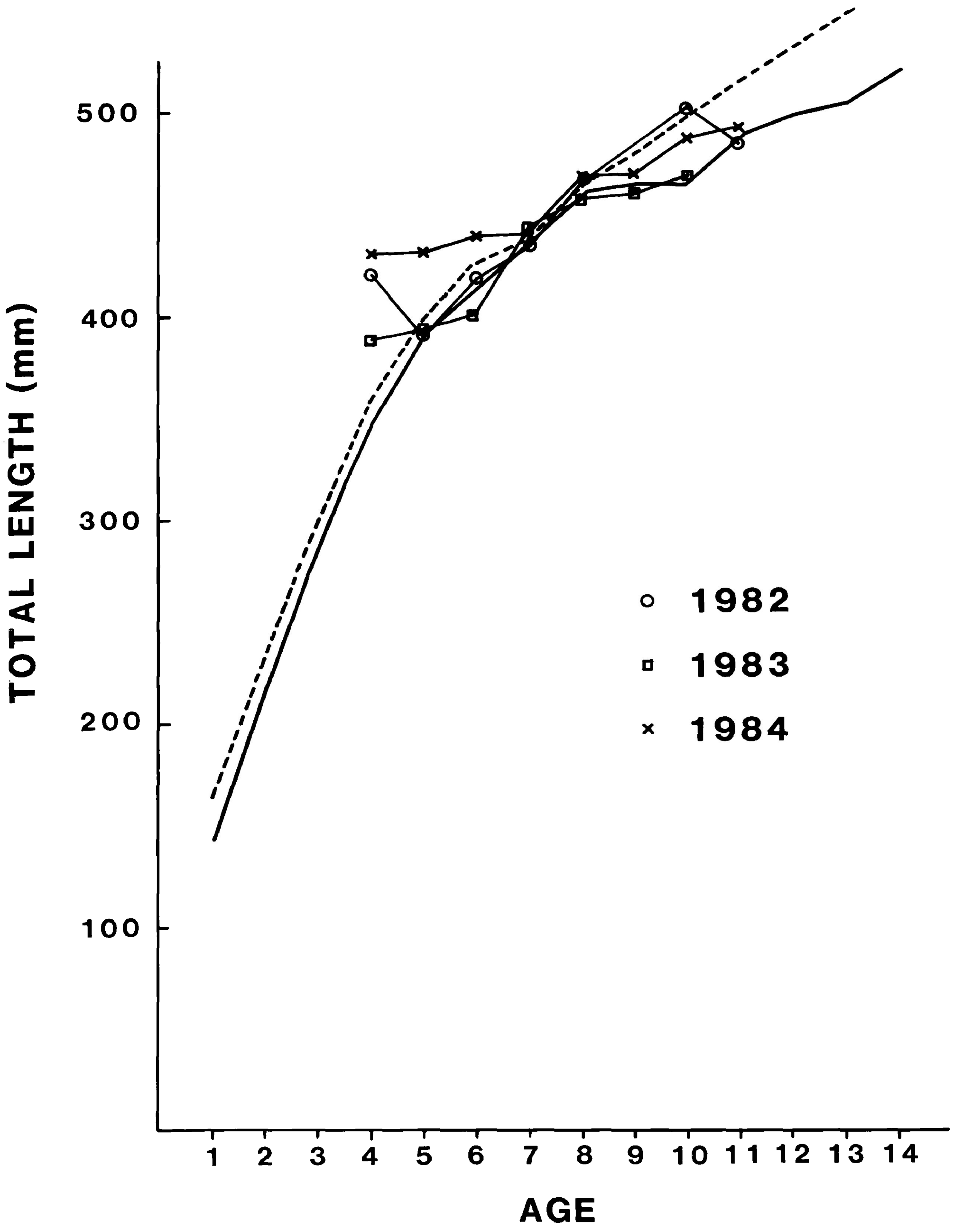
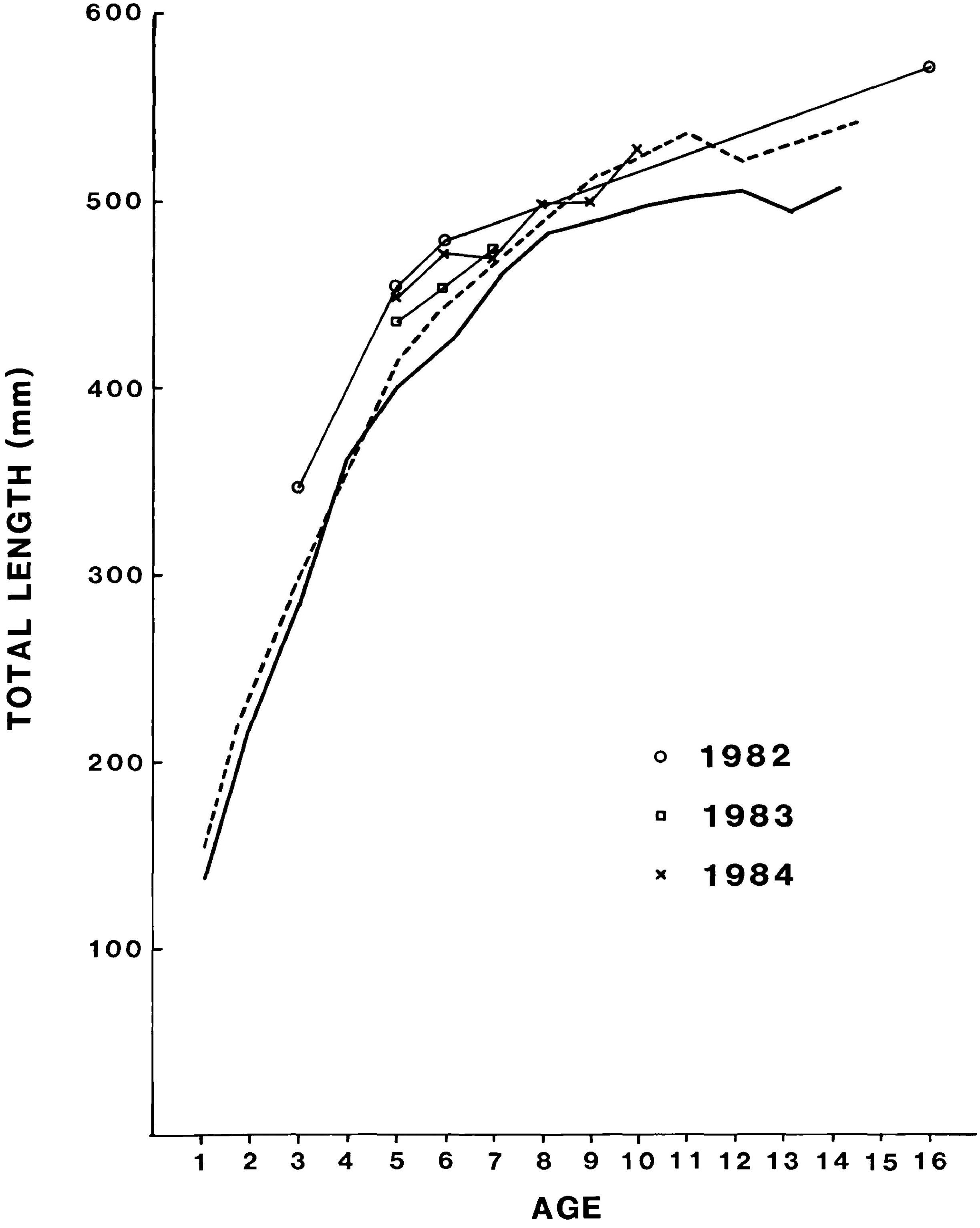

TOTAL LENGTH (mm)
500
400
300
200
100
AGE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
○ 1982
□ 1983
× 1984

Figure 23. Plot of backcalculated and empirical (1982 to 1984) lengths at age for female walleye from Henderson Lake.

——— backcalculated data, 1979 to 1981 (Nunan 1982).

------ backcalculated data, 1982 to 1984 (present study).

○ × □ empirical data.



600
500
400
300
200
100
TOTAL LENGTH (mm)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
AGE
○ 1982
□ 1983
× 1984

Figure 24. Plots of backcalculated and empirical (1982 to 1984) lengths at age for northern pike, sexes combined, from Henderson Lake.

———— backcalculated data, 1979 to 1981, (Nunan 1982).

--▲--▲--▲ backcalculated data, 1982 to 1984 (present study).

○ × □ empirical data.

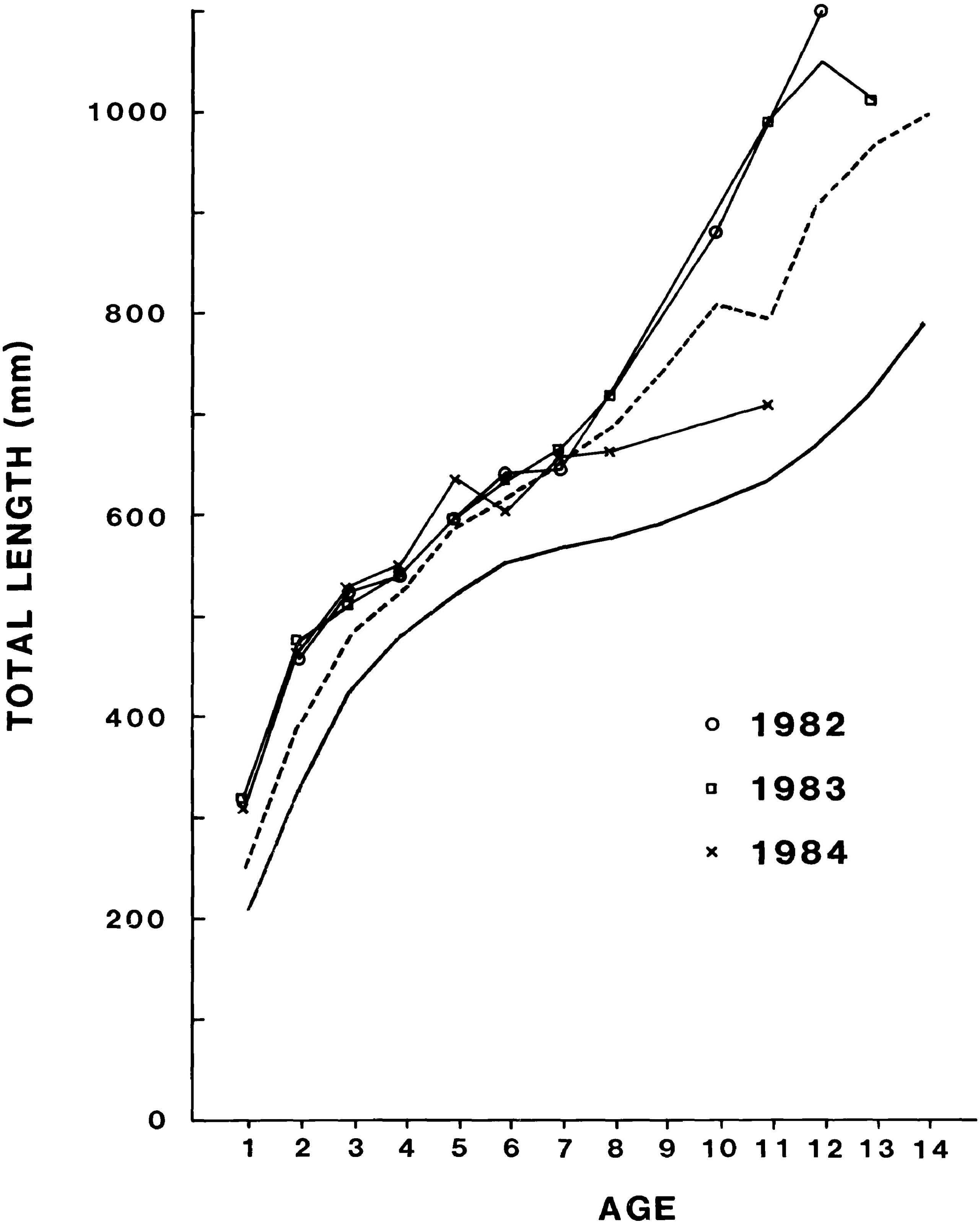

TOTAL LENGTH (mm)
0
200
400
600
800
1000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
AGE
○ 1982
□ 1983
× 1984

Figure 25. Plots of backcalculated and empirical (1982 to 1984) lengths at age for male northern pike from Henderson Lake.

——— backcalculated data, 1979 to 1981 (Nunan 1982).

------- backcalculated data, 1982 to 1984 (present study).

○ × □ empirical data.

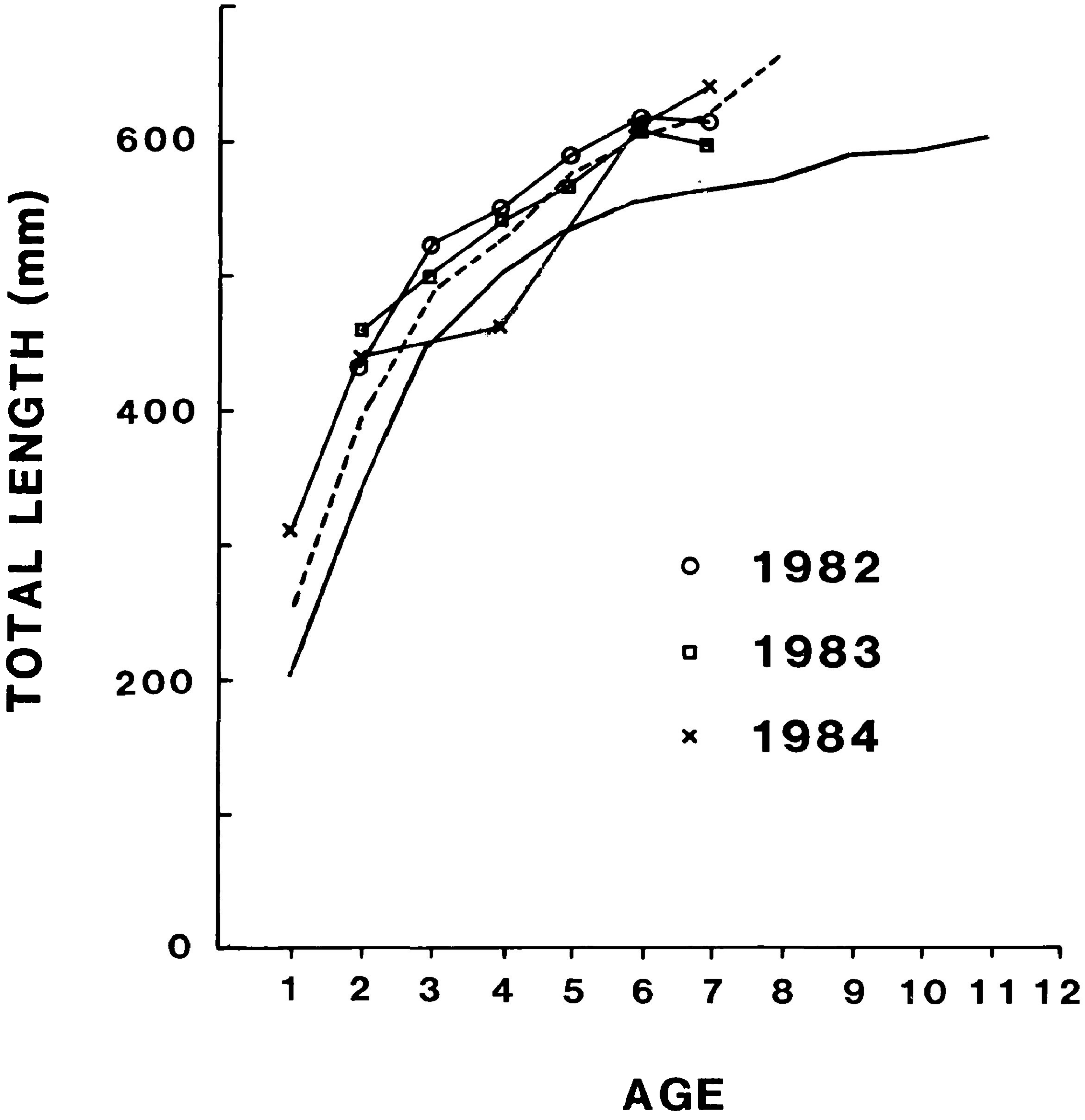
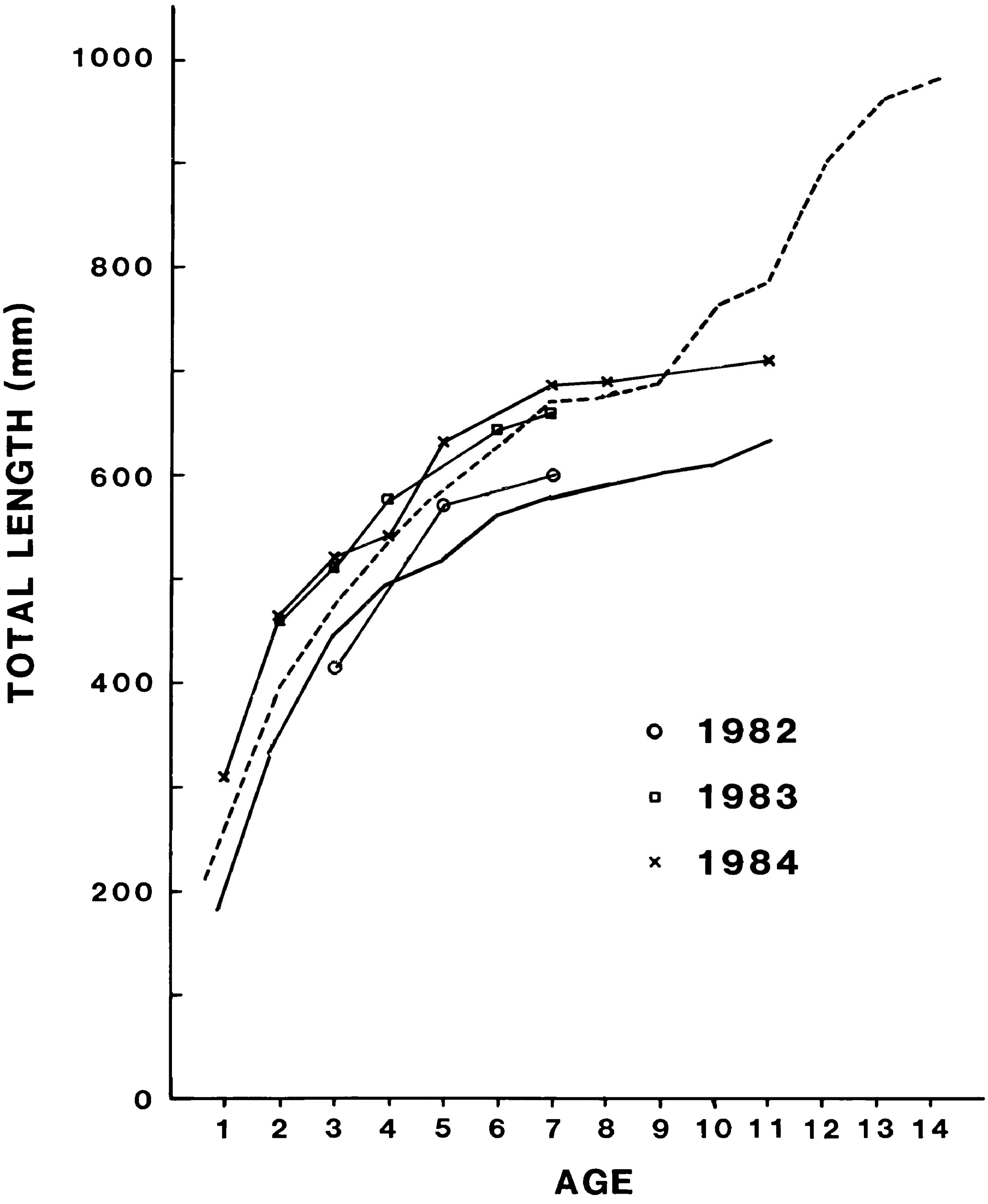

TOTAL LENGTH (mm)
600
400
200
0
1
2
3
4
5
6
7
8
9
10
11
12
AGE
○ 1982
□ 1983
× 1984

Figure 26. Plots of backcalculated and empirical (1982 to 1984) lengths at age for female northern pike from Henderson Lake.

——— backcalculated data, 1979 to 1981 (Nunan 1982).

------ backcalculated data, 1982 to 1984 (present study).

○ × □ empirical data.



TOTAL LENGTH (mm)
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
AGE
○ 1982
□ 1983
× 1984

1982). Large differences between backcalculated mean lengths at age, especially of older fish, possibly reflects the different criteria employed in assessing age within each of the study periods.

Dorsal spines and opercles closely agree for walleye ages, despite greater variability in older individuals (Fig. 27). Northern pike scale and cleithra ages are closely correlated, however scales tend to over-age younger fish and under-age older fish compared to cleithra (Fig. 28). Mosindy (1980) found scales over-estimated ages of older fish relative to cleithra in nearby Savanne Lake.

Fecundity

No significant difference in the estimated number of eggs per gram were found for any region of the ovary, for either walleye (K-W,$\chi^2 = 0.13, P>0.05$) or northern pike (K-W,$\chi^2 = 0.06, P>0.05$), in 1982.

Due to the decline in the walleye population, fewer ovaries were collected in 1983 and 1984 than in 1982. A total of 39, 17 and 10 mature females were obtained in 1982, 1983 and 1984 respectively (Appendix IV, Tables 1, 2 and 3). Mean fecundity of walleye caught each year increased from 1982 to 1984 (Table 11), however, this undoubtedly reflects the lower number of small sized fish (lower fecundity) recruited to the population in later years. Mean fecundities by age-class (Table 12) increased for most ages from 1982 to 1984, however, fewer older age-classes in 1983 and 1984 were sampled than in 1982.

Various least-square regressions (log-log and untransformed) were performed with data from mature females. Correlation coefficients of transformed log plots (Table 13) between fecundity; length, weight

Figure 27. Comparisons between opercle and dorsal spine age for walleye collected in Henderson Lake, 1983 and 1984. Numbers represent multiple data points.

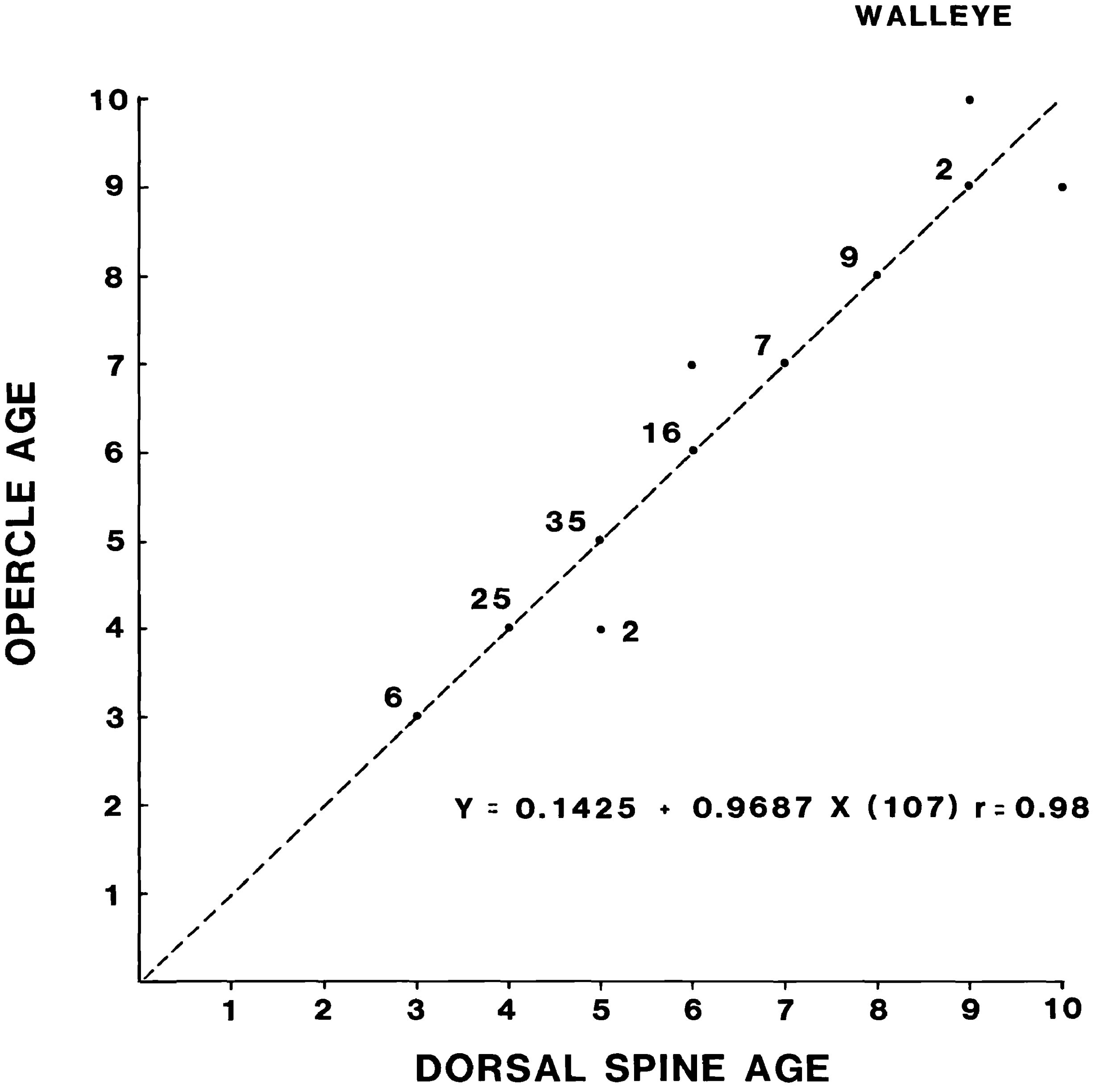

WALLEYE
10
9
8
7
6
5
4
3
2
1
OPERCLE AGE
2
9
7
16
35
25
2
6
Y = 0.1425 + 0.9687 X (107) r = 0.98
1
2
3
4
5
6
7
8
9
10
DORSAL SPINE AGE

Figure 28. Comparison between scale and cleithra ages for northern pike collected in Henderson Lake, 1983 and 1984. Numbers represent multiple data points.

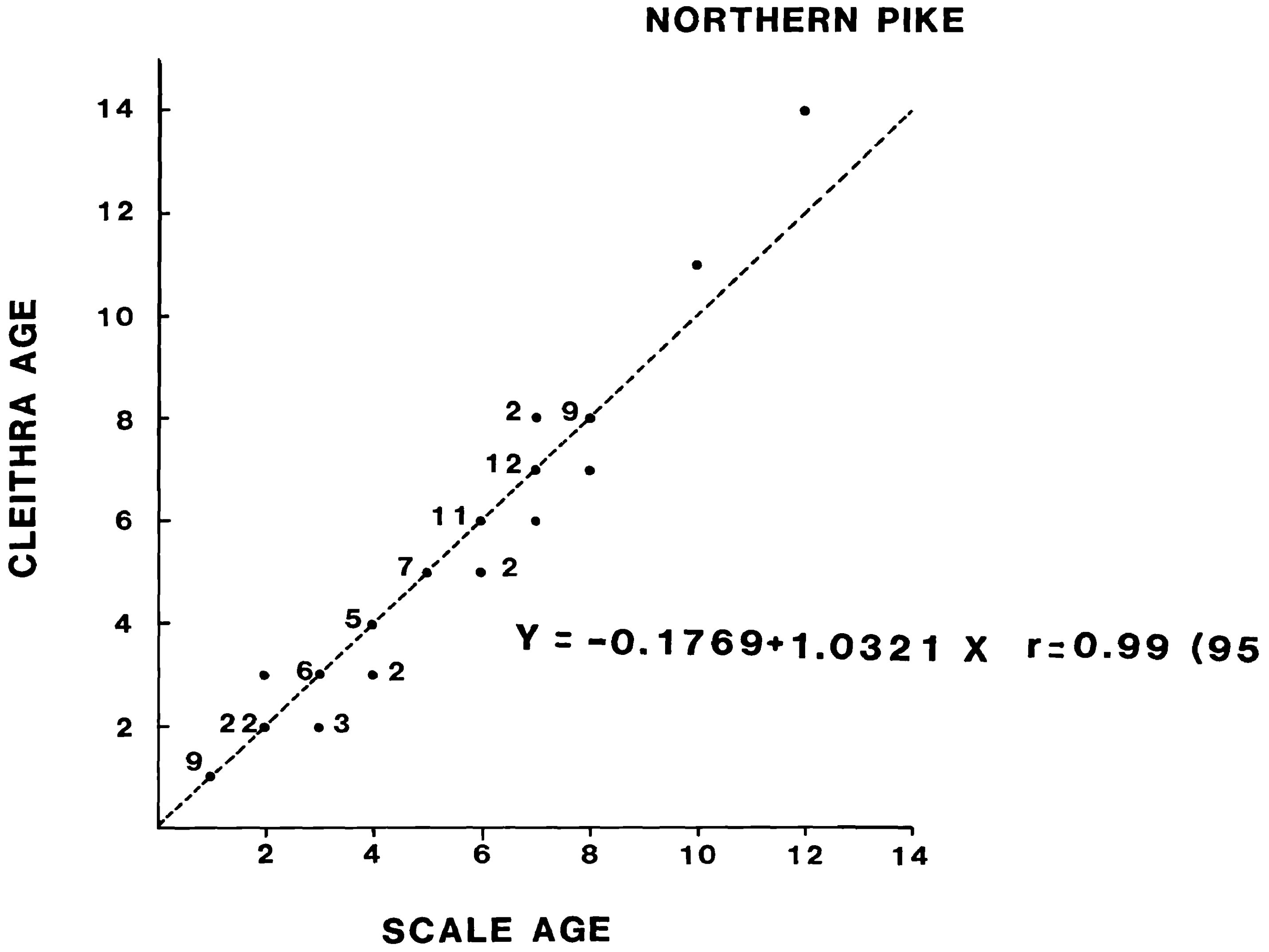

NORTHERN PIKE
CLEITHRA AGE
SCALE AGE
14
12
10
8
6
4
2
2
4
6
8
10
12
14
9
2 2
6
3
5
2
7
2
1 1
1 2
2
9
Y = -0.1769+1.0321 X r=0.99 (95

Table 11. Mean egg number, weight (gm), length (mm), age, gonado-somatic index and eggs per gram for walleye from Henderson Lake, 1982 to 1984.

	1982		1983		1984	
egg number	55,317	(15,754.62)[1]	61,737	(12,530.66)	83,943	(19,912.76)
total weight	1161	(350.74)	1214.71	(248.76)	1520	(347.77)
length	475	(45.74)	467.18	(21.77)	497	(33.90)
age	6.00	(1.78)	5.29	(1.45)	6.70	(1.77)
gonado-somatic index (GSI)	0.0224	(0.0102)	0.0198	(0.0046)	0.0404	(0.0045)
eggs gm^{-1}	48.94	(11.19)	50.92	(3.49)	55.35	(6.12)
sample size	39		17		10	

---

[1] Standard deviation

Table 12. Mean, range and standard deviations of fecundity by age-class for walleye from Henderson Lake, 1982 to 1984.

Year	N	Age	Mean Egg No.	Range	SD
1982	8	4	40,751	28,297 - 74,576	15,004
	9	5	53,631	32,327 - 74,180	12,458
	10	6	52,439	37,219 - 63,706	9,802
	7	7	64,008	44,828 - 86,511	12,864
	1	8	66,628	66,628	—
	2	9	80,964	69,228 - 92,699	16,597
	2	11	73,838	70,885 - 76,791	4,176
	39				
1983	5	4	54,043	42,622 - 58,957	6,614
	8	5	56,535	52,667 - 62,025	3,673
	1	6	72,983	72,983	—
	1	7	81,643	81,643	—
	1	8	88,498	88,498	—
	1	9	83,907	83,907	—
	17				
1984	1	4	52,197	52,197	—
	2	5	71,844	71,813 - 71,875	44
	2	6	75,257	66,476 - 84,038	12,418
	1	7	109,208	109,208	—
	2	8	105,568	95,674 - 115,463	13,993
	2	9	86,344	76,804 - 95,883	13,491
	10				

Table 13. Regression equations ($\log_{10}$ - $\log_{10}$) for various parameters of fall captured mature female walleyes from Henderson Lake, 1982 to 1984.

Fecundity with Weight		
1982	Log fec. = 2.50179 + 0.72998 log weight	r = 0.76 (39)
1983	Log fec. = 1.85541 + 0.95142 log weight	r = 0.93 (17)
1984	Log fec. = 1.84964 + 0.96566 log weight	r = 0.89 (10)
Fecundity with Length		
1982	Log fec. = -1.50430 + 2.32864 log length	r = 0.74 (39)
1983	Log fec. = -5.11846 + 3.70966 log length	r = 0.89 (17)
1984	Log fec. = -2.58742 + 2.78284 log length	r = 0.78 (10)
Fecundity with Age		
1982	Log fec. = 4.18914 + 0.70316 log age	r = 0.64 (39)
1983	Log fec. = 4.30488 + 0.67240 log age	r = 0.86 (17)
1984	Log fec. = 4.37438 + 0.66318 log age	r = 0.75 (10)
Fecundity with GSI (gonado-somatic index)		
1982	Log fec. = 4.89505 + 0.10002 log GSI	r = 0.18 (39)
1983	Log fec. = 5.91590 + 0.66151 log GSI	r = 0.77 (17)
1984	Log fec. = 7.57628 + 1.90786 log GSI	r = 0.87 (10)
Weight with Length		
1982	Log wt. = -5.24771 + 3.10019 log length	r = 0.95 (39)
1983	Log wt. = -7.45632 + 3.94642 log length	r = 0.97 (17)
1984	Log wt. = -5.16975 + 3.09512 log length	r = 0.94 (10)
Weight with Age		
1982	Log wt. = 2.38392 + 0.86814 log age	r = 0.77 (39)
1983	Log wt. = 2.55998 + 0.72723 log age	r = 0.94 (17)
1984	Log wt. = 2.75358 + 0.51545 log age	r = 0.64 (10)
Length with Age		
1982	Log len. = 2.46411 + 0.27682 log age	r = 0.80 (39)
1983	Log len. = 2.54973 + 0.16787 log age	r = 0.89 (17)
1984	Log len. = 2.58449 + 0.13628 log age	r = 0.56 (10)

Table 14. Regression equations for various parameters of fall captured mature female walleye from Henderson Lake, 1982 to 1984.

Fecundity with Weight

1982	fec. = 14334.066 + 35.303 weight	r = 0.79 (39)
1983	fec. = 4893.048 + 46.796 weight	r = 0.93 (17)
1984	fec. = 7398.351 + 50.358 weight	r = 0.88 (10)

Fecundity with Length

1982	fec. = -67051.862 + 257.535 length	r = 0.75 (39)
1983	fec. = -175522.505 + 507.858 length	r = 0.88 (17)
1984	fec. = -141434.271 + 453.841 length	r = 0.77 (10)

Fecundity with Age

1982	fec. = 21777.949 + 5589.833 age	r = 0.63 (39)
1983	fec. = 20922.105 + 7709.458 age	r = 0.89 (17)
1984	fec. = 32951.737 + 7610.651 age	r = 0.68 (10)

Fecundity with GSI (gonado-somatic index)

1982	fec. = 51062.843 + 190120.274 GSI	r = 0.12 (39)
1983	fec. = 17794.362 + 2214801.436 GSI	r = 0.82 (17)
1984	fec. = -71235.241 + 3842134.399 GSI	r = 0.86 (10)

Weight with Length

1982	weight = -2318.989 + 7.32371 length	r = 0.96 (39)
1983	weight = -3908.941 + 10.96726 length	r = 0.96 (17)
1984	weight = -3223.297 + 9.552 length	r = 0.93 (10)

Weight with Age

1982	weight = 203.397 + 159.583 age	r = 0.81 (39)
1983	weight = 342.105 + 164.825 age	r = 0.96 (17)
1984	weight = 820.196 + 104.448 age	r = 0.53 (10)

Length with Age

1982	length = 347.804 + 21.225 age	r = 0.82 (39)
1983	length = 396.105 + 13.425 age	r = 0.89 (17)
1984	length = 437.039 + 8.890 age	r = 0.46 (10)

and age, were little better than for untransformed data (Table 14). Walleye fecundity had the highest correlation coefficients with weight, however, the two variables may be auto-correlated (Olynyk 1982; Healey 1978a). Fecundity was more precisely correlated to length, than age, but both were highly significant ($P<0.01$). Fecundity and gonado-somatic index (LeCren 1951), were significantly correlated in 1983 and 1984 but not in 1982.

Covariance analysis (Sokal and Rohlf 1981; Snedecor 1956) of between year log fecundity-log length (base 10) indicated a significant increase in intercepts (indicating significant increases in fecundity), for 1984 walleye compared to 1982 (intercepts,$F = 8.29$,d.f. = 1,46,$P<0.01$;slope,$F = 0.697$,d.f. = 1,45,$P>0.05$;variances,$F = 2.79$,d.f. = 37,8,$P>0.05$). Assumptions of the covariance method (equality of variances) precluded comparison of the 1983 length-fecundity regression to those of 1982 and 1984, however, the regression line for 1983 does lie between those of 1982 and 1984 (Fig. 29). This apparently indicates that the 1983 fecundity for walleye is not greatly different from either that of 1982 or 1984.

General trends in fecundity by length-class (Fig. 30) and age-class (Fig. 31), conclusively illustrate the increased fecundity in all walleye age-classes and most size-classes. Larger walleyes (600 mm) appear to show a decrease in fecundity in 1984 from 1983, however, only one walleye over 520 mm was caught in 1984 (560 mm), so this extrapolation may be invalid.

A total of 18, 21 (one sample misplaced) and 29 ovary samples were collected for northern pike in the fall of 1982, 1983 and 1984 respectively (Appendix IV, Tables 4, 5 and 6). Mean fecundities of pike increased from 1982 to 1984 despite decreases in the mean age

Figure 29. Relationships between length and fecundity (determined by Log_{10}-log_{10} plots) for Henderson Lake walleye, 1982 to 1984.

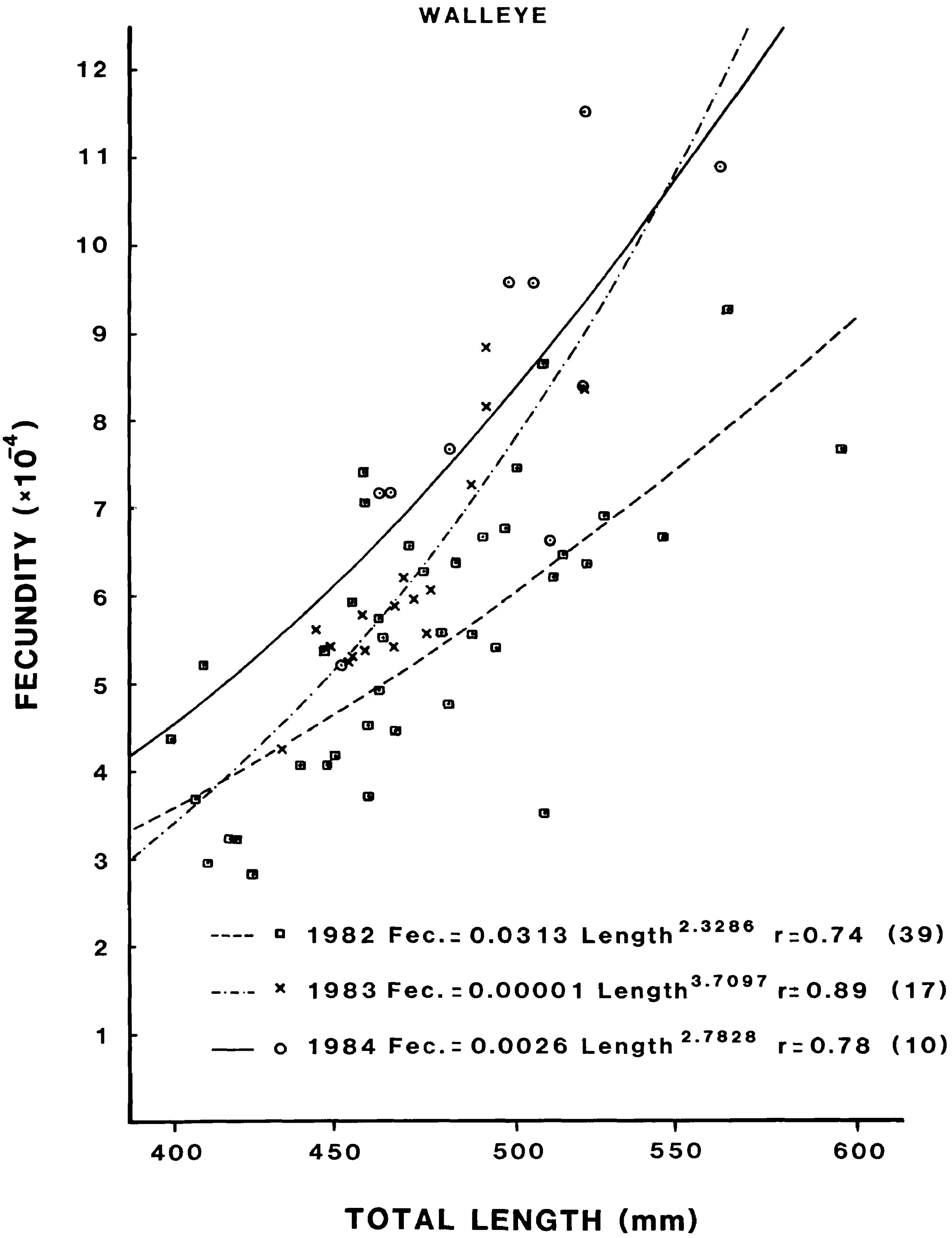

WALLEYE
FECUNDITY (×10⁻⁴)
TOTAL LENGTH (mm)
12
11
10
9
8
7
6
5
4
3
2
1
400
450
500
550
600
---- □ 1982 Fec.= 0.0313 Length^2.3286 r=0.74 (39)
-·-·- × 1983 Fec.=0.00001 Length^3.7097 r=0.89 (17)
—— o 1984 Fec.= 0.0026 Length^2.7828 r=0.78 (10)

Figure 30. Plots of fecundity by size-class by year of walleye from Henderson Lake, 1979 to 1984. Numbers represent size of fish in millimeters.

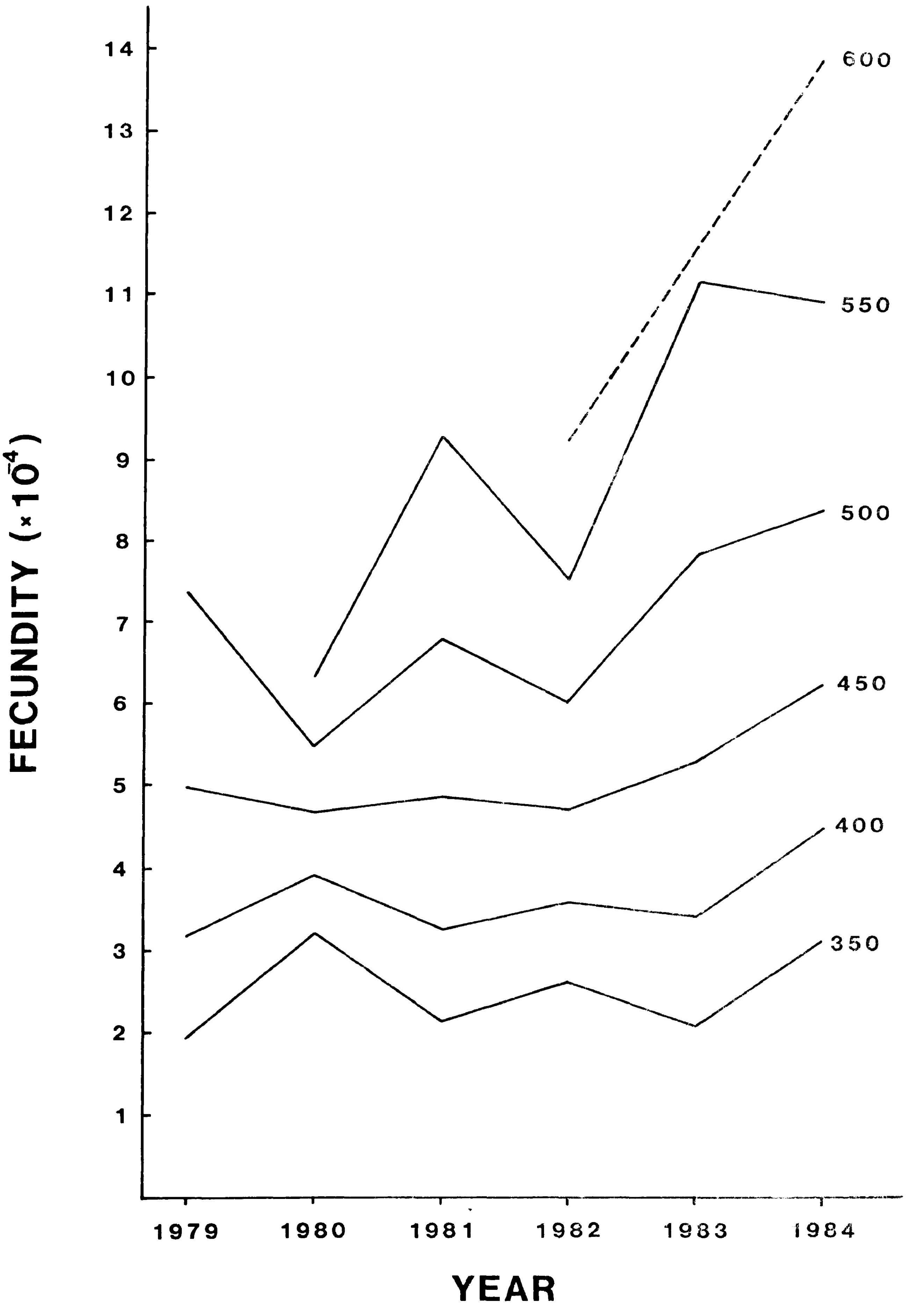
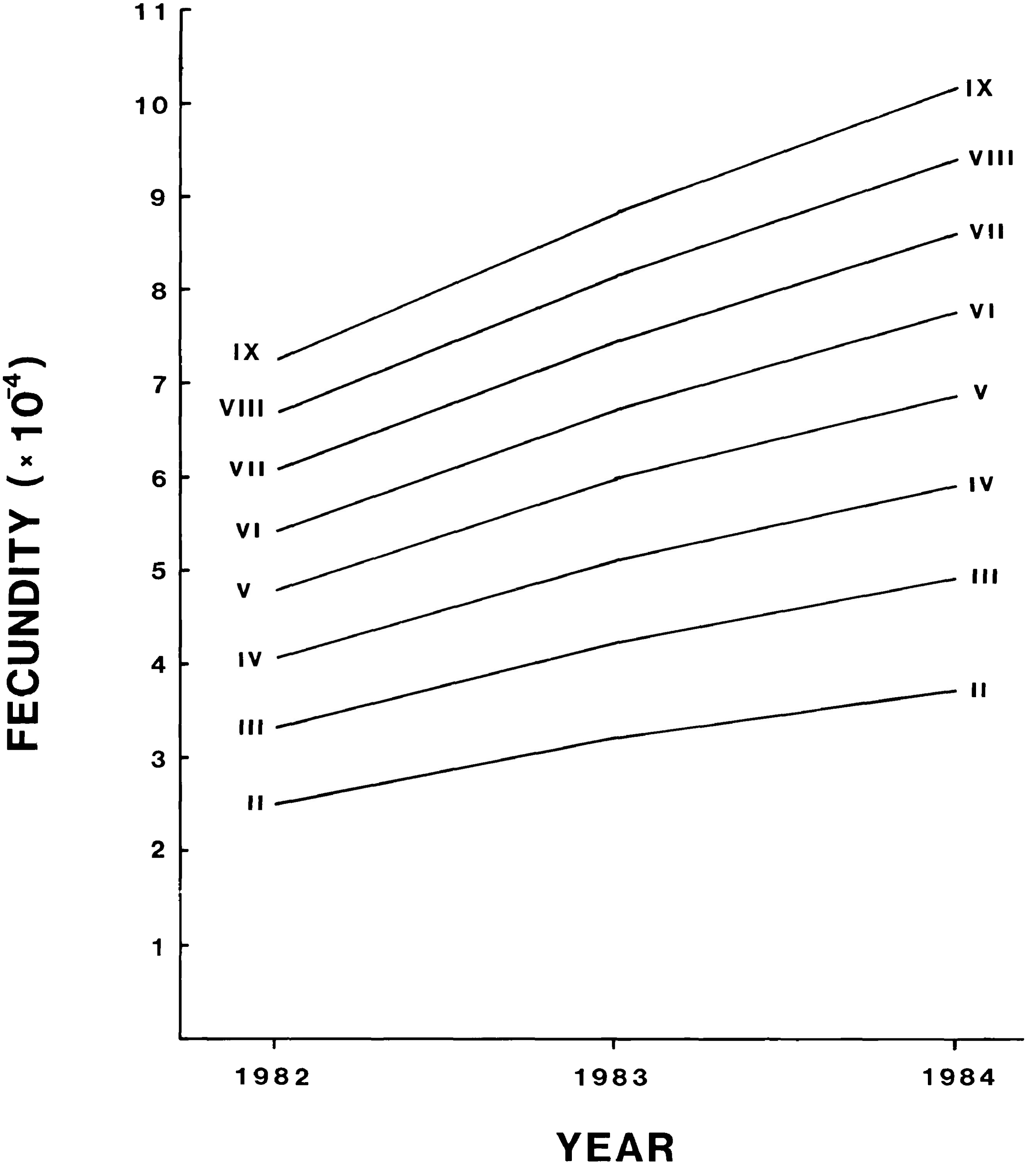

FECUNDITY (×10⁻⁴)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
600
550
500
450
400
350
1979
1980
1981
1982
1983
1984
YEAR

Figure 31. Plots of fecundity by age-class by year of walleye from Henderson Lake, 1979 to 1984. Roman numerals represent age-class of fish in years.



FECUNDITY (×10⁻⁴)
11
10
9
8
7
6
5
4
3
2
1
1982
1983
1984
YEAR
IX
VIII
VII
VI
V
IV
III
II
IX
VIII
VII
VI
V
IV
III
II

Table 15. Mean egg number, weight (gm), length (mm), age, gonado-somatic index and eggs per gram for northern pike from Henderson Lake, 1982 to 1984.

	1982		1983		1984	
egg number	30,714	(9,489.84)[1]	34,768	(17,080.32)	39,961	(14,474.39)
weight	1693	(502.85)	1870	(1,430.97)	1766	(633.85)
length	639	(37.38)	638	(104.55)	642	(64.35)
age	5.33	(1.19)	4.90	(2.83)	3.68	(1.94)
gonado-somatic index (GSI)	0.0229	(0.0109)	0.0113	(0.0035)	0.0207	(0.0049)
egg gm^{-1}	18.40	(4.36)	19.82	(4.34)	22.77	(4.00)
sample size	18		20		28	

[1] Standard deviation

Table 16. Mean, range and standard deviations of fecundity by age-class for northern pike from Henderson Lake, 1982 to 1984.

Year	N	Age	Mean Egg No.	Range	SD
1982	1	3	24,596	24,596	—
	4	4	28,932	21,546 - 43,263	9944.3
	4	5	27,598	20,128 - 35,846	6480.9
	6	6	28,786	21,228 - 43,983	8542.4
	3	7	43,206	34,963 - 52,785	8985.7
	18				
1983	1	1	14,895	14,895	—
	3	2	27,412	22,060 - 31,920	4983.8
	3	3	18,705	14,105 - 26,105	6,471
	2	4	30,582	29,174 - 31,989	1,991
	2	5	42,470	36,699 - 48,242	8,162
	6	6	38,135	24,592 - 49,341	10,263
	2	7	38,495	29,631 - 47,359	12,536
	1	14	90,215	90,215	—
	20				
1984	11	2	29,585	17,320 - 37,121	5,946
	7	3	43,781	24,084 - 62,407	12,607
	2	4	35,961	30,483 - 41,439	7,747
	5	6	47,458	24,629 - 63,010	16,185
	2	7	57,978	41,948 - 74,007	22,669
	1	8	61,851	61,851	—
	28				

(Table 15). Mean fecundities by age-class for northern pike (Table 16) also showed increases for most ages from 1982 to 1984.

Northern pike fecundity was best correlated to weight and secondarily to length, with non-logarithmic plots providing higher correlation coefficients than log regressions (Table 17 and 18). Age was less closely correlated to fecundity than either length or weight, with the 1982 age-fecundity relationship not significant at the 0.05 level. The fecundity-gonado-somatic index regression was not significant in 1982 and 1983 ($P>0.05$) but was so in 1984. The length-fecundity relationship (Fig. 32) showed fecundity increased in 1984 especially in fish of the 700 mm range compared to 1982 and 1983.

Covariance analysis of northern pike length-fecundity regressions between years revealed the 1982 and 1983 lines were not significantly different for either variances ($F = 1.35$,d.f. = 16,18,$P>0.05$), slopes ($F = 0.032$,d.f. = 1,34,$P>0.05$) or intercepts ($F = 3.48$,d.f. = 1,35, $P>0.05$). Significant differences of intercepts between 1984 and both 1982 ($F = 15.61$,d.f. = 1,43,$P<0.01$) and 1983 ($F = 4.84$,d.f. = 1,45,$P<0.05$) were detected while slopes (1982,$F = 0.47$,d.f. = 1,42,$P>0.05$;1983,$F = 3.00$,d.f. = 1,44,$P >0.05$) and variances (1982,$F = 1.11$,d.f. =16,26,$P>0.05$;1983,$F = 1.22$,d.f. = 26,18,$P>0.05$) showed no significant differences. Trends of significant increases in northern pike fecundity in 1984 are seen by both age-class (Fig. 33) and in larger size-classes ie. greater than 500 mm (Fig. 34).

Feeding Analysis

There was a severe reduction in numbers of ninespine stickleback eaten by both walleye (Appendix V, Tables 1 to 6) and northern pike

Table 17. Regression equations ($\log_{10}$ $\log_{10}$) for various parameters of fall captured mature female northern pike from Henderson Lake, 1982 to 1984.

Fecundity with Weight		
1982	log fec. = 1.97465 + 0.77582 log weight	r = 0.63 (18)
1983	log fec. = 1.83500 + 0.82888 log weight	r = 0.85 (20)
1984	log fec. = 1.44821 + 0.96989 log weight	r = 0.88 (28)
Fecundity with Length		
1982	log fec. = -3.87483 + 2.97496 log length	r = 0.58 (18)
1983	log fec. = -2.90420 + 2.64368 log length	r = 0.86 (20)
1984	log fec. = -4.11475 + 3.09753 log length	r = 0.85 (28)
Fecundity with Age		
1982	log fec. = 4.13163 + 0.47189 log age	r = 0.39 (18)
1983	log fec. = 4.14755 + 0.56372 log age	r = 0.75 (20)
1984	log fec. = 4.34949 + 0.43993 log age	r = 0.61 (28)
Fecundity with GSI (gonado-somatic index)		
1982	log fec. = 4.48698 + 0.01042 log GSI	r = 0.02 (18)
1983	log fec. = 5.74187 + 0.63031 log GSI	r = 0.50 (20)
1984	log fec. = 6.35547 + 1.04913 log GSI	r = 0.75 (28)
Weight with Length		
1982	log wt. = -8.03235 + 4.01022 log length	r = 0.96 (18)
1983	log wt. = -5.45785 + 3.09669 log length	r = 0.99 (20)
1984	log wt. = -5.71381 + 3.18590 log length	r = 0.96 (28)
Weight with Age		
1982	log wt. = 2.86652 + 0.48773 log age	r = 0.50 (18)
1983	log wt. = 2.84246 + 0.59571 log age	r = 0.77 (20)
1984	log wt. = 2.98341 + 0.46907 log age	r = 0.71 (28)
Length with Age		
1982	log len. = 2.69392 + 0.15494 log age	r = 0.66 (18)
1983	log len. = 2.67358 + 0.20330 log age	r = 0.83 (20)
1984	log len. = 2.72845 + 0.15010 log age	r = 0.75 (28)

Table 18. Regression equations for various parameters of fall captured mature female northern pike from Henderson Lake, 1982 to 1984.

Fecundity with Weight		
1982	fec. = 9276.10424 + 12.66215 weight	r = 0.67 (18)
1983	fec. = 15035.20416 + 10.55246 weight	r = 0.88 (20)
1984	fec. = 3412.54655 + 20.69496 weight	r = 0.91 (28)
Fecundity with Length		
1982	fec. = -71694.82006 + 160.26393 length	r = 0.63 (18)
1983	fec. = -62003.43395 + 151.67983 length	r = 0.93 (20)
1984	fec. = -85978.00624 + 196.24360 length	r = 0.87 (28)
Fecundity with Age		
1982	fec. = 12236.94444 + 3464.41667 age	r = 0.43 (18)
1983	fec. = 9442.51120 + 5168.52833 age	r = 0.86 (20)
1984	fec. = 22950.68975 + 4624.24939 age	r = 0.62 (28)
Fecundity with GSI (gonado-somatic index)		
1982	fec. = 30574.35336 + 6087.37482 GSI	r = 0.01 (18)
1983	fec. = 22377.29474 + 1101041.61888 GSI	r = 0.23 (20)
1984	fec. = -3568.72062 + 2104296.04223 GSI	r = 0.72 (28)
Weight with Length		
1982	wt. = -6480.71633 + 12.79151 length	r = 0.95 (18)
1983	wt. = -6399.93798 + 12.96229 length	r = 0.95 (20)
1984	wt. = -4257.29843 + 9.38585 length	r = 0.95 (28)
Weight with Age		
1982	wt. = 561.57407 + 212.15278 age	r = 0.50 (18)
1983	wt. = -273.83070 + 437.51647 age	r = 0.86 (20)
1984	wt. = 906.12977 + 233.77055 age	r = 0.72 (28)
Length with Age		
1982	len. = 524.11111 + 21.54167 age	r = 0.68 (18)
1983	len. = 470.95455 + 34.09091 age	r = 0.92 (20)
1984	len. = 550.21546 + 24.88318 age	r = 0.75 (28)

Figure 32. Regression relationship, using untransformed data, between length and fecundity for Henderson Lake northern pike, 1982 to 1984.

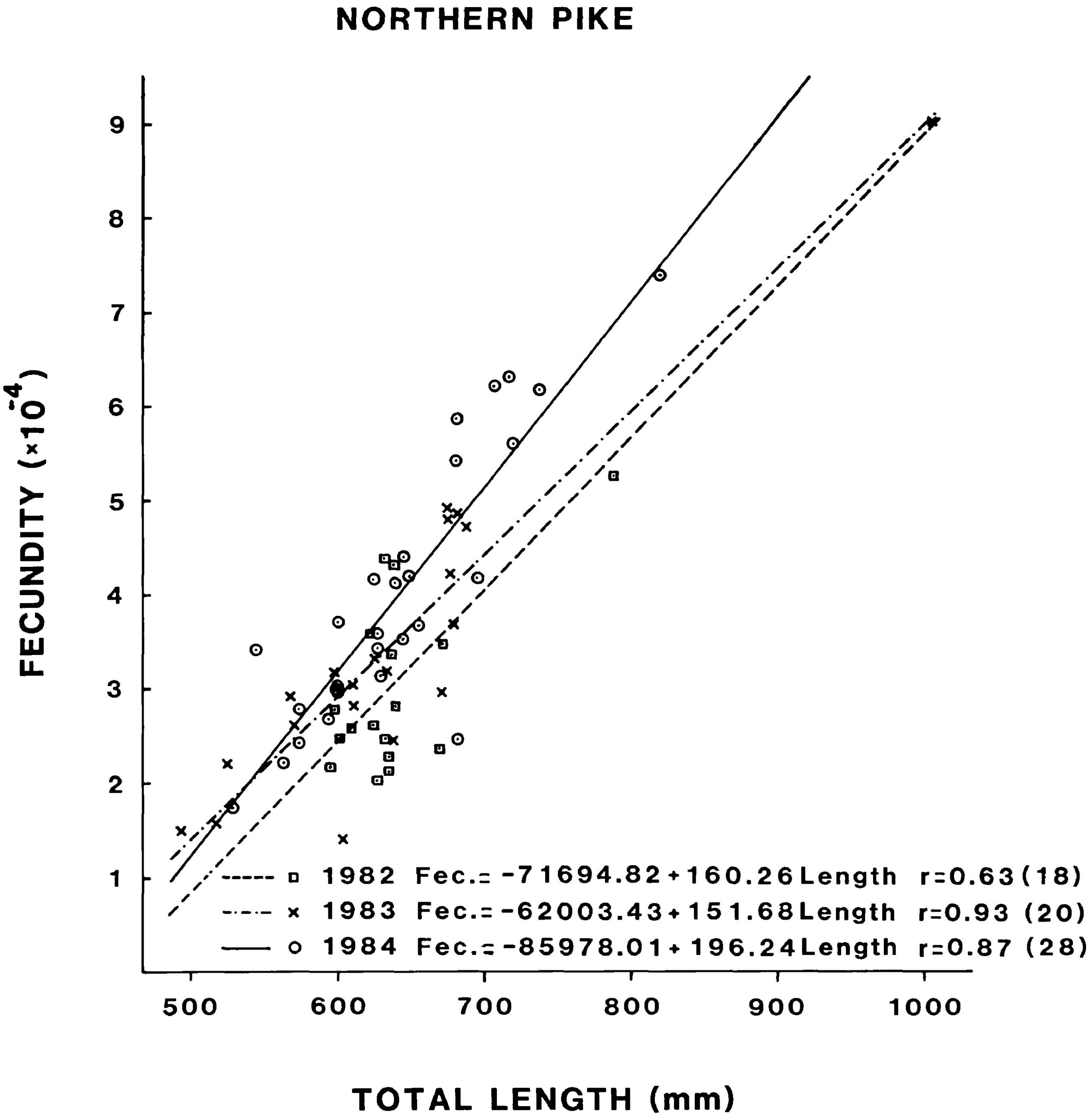

NORTHERN PIKE
FECUNDITY (×10⁻⁴)
9
8
7
6
5
4
3
2
1
500
600
700
800
900
1000
TOTAL LENGTH (mm)
----- □ 1982 Fec.= -71694.82 + 160.26 Length r=0.63 (18)
-·-·- × 1983 Fec.= -62003.43 + 151.68 Length r=0.93 (20)
—— ○ 1984 Fec.= -85978.01 + 196.24 Length r=0.87 (28)

Figure 33. Plots of fecundity by age-class by year of northern pike from Henderson Lake, 1980 to 1984. Roman numerals represent age-class of fish in years.

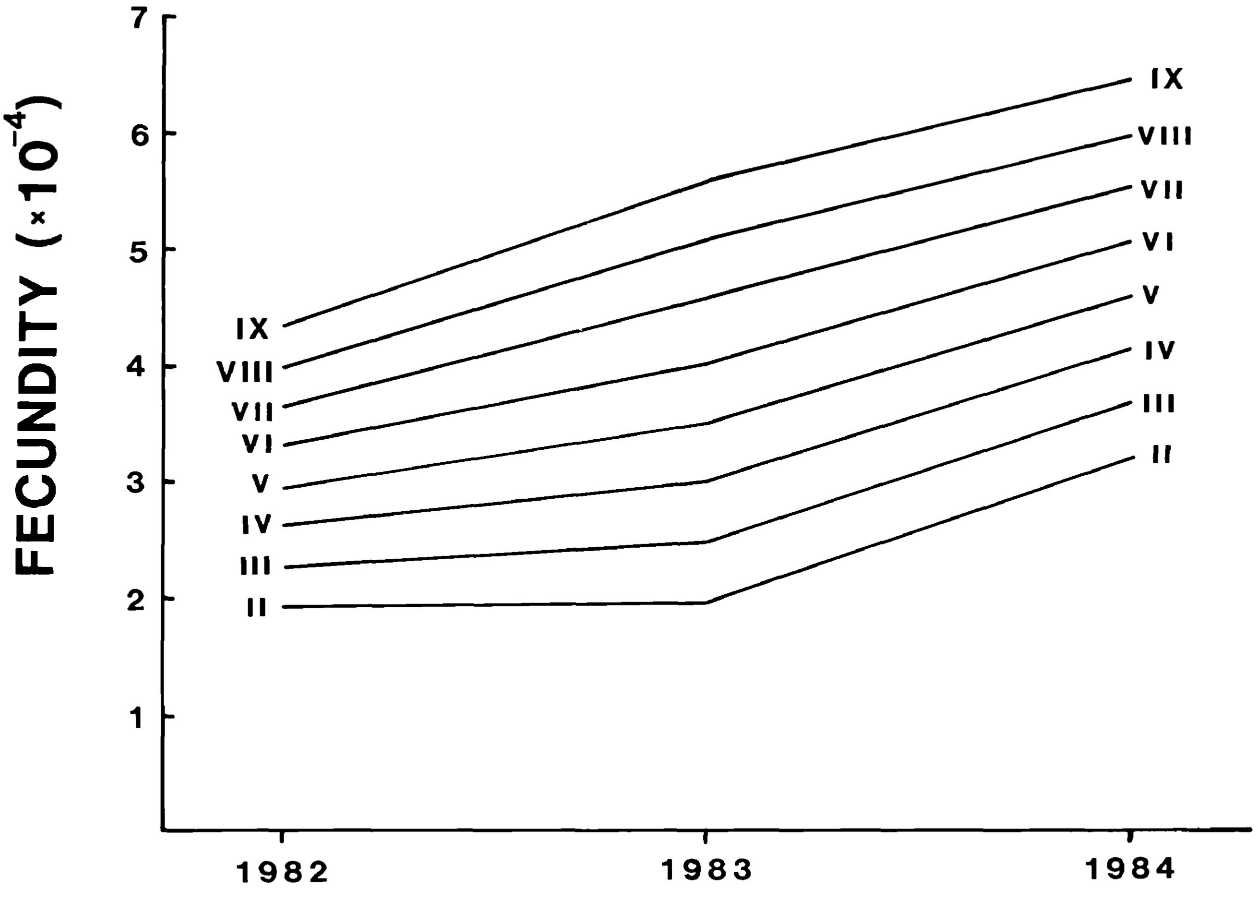
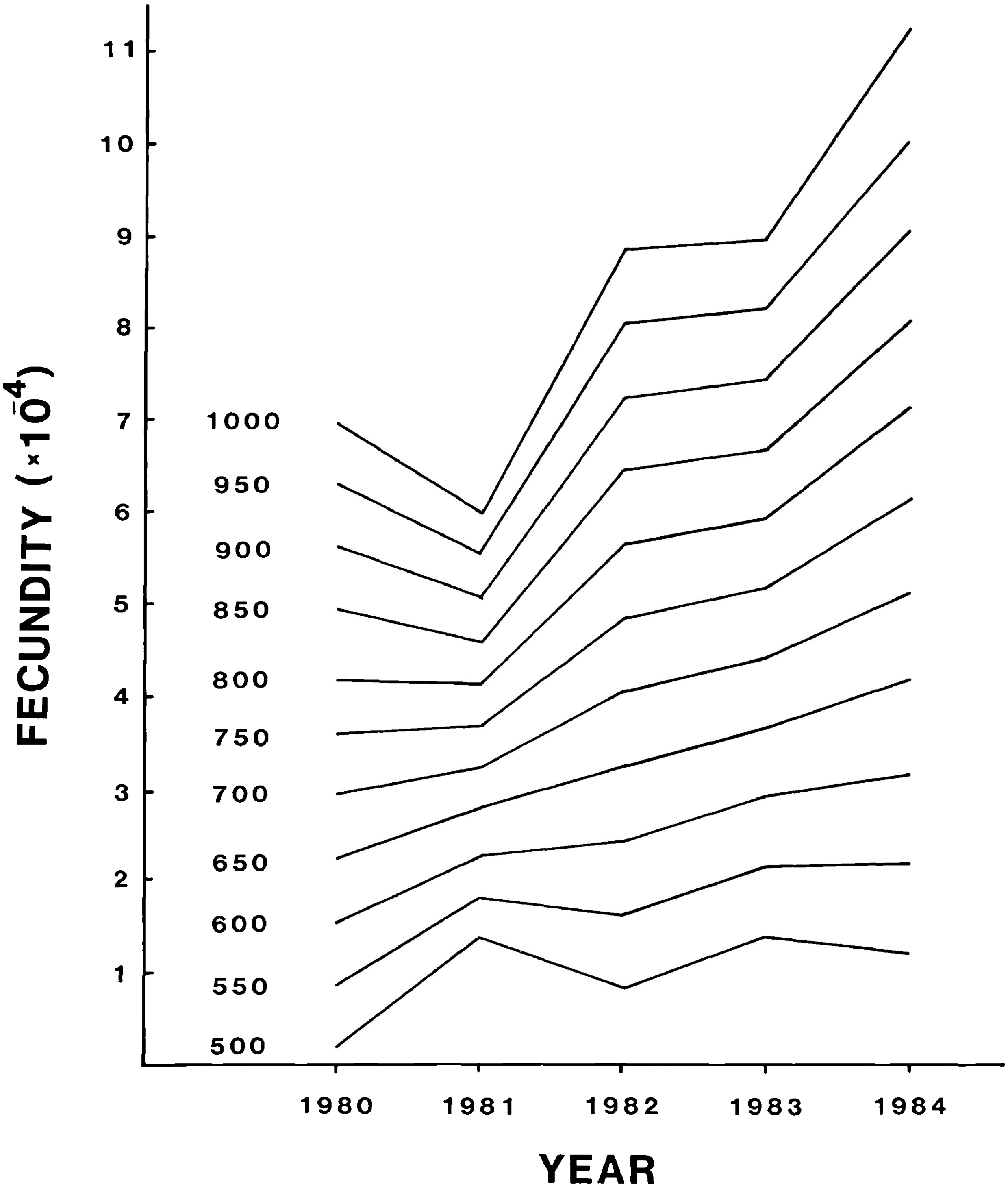

FECUNDITY $(\times 10^{-4})$
7
6
5
4
3
2
1
1982
1983
1984
IX
VIII
VII
VI
V
IV
III
II
IX
VIII
VII
VI
V
IV
III
II

Figure 34. Plots of fecundity by size-class by year of northern pike from Henderson Lake, 1980 to 1984. Numbers represent size of fish in millimeters.


FECUNDITY (×10⁻⁴)
11
10
9
8
7
6
5
4
3
2
1
1000
950
900
850
800
750
700
650
600
550
500
1980
1981
1982
1983
1984
YEAR

(Appendix V, Tables 7 to 12) in 1982, followed by their total absence in stomach samples from 1983 and 1984. Instead, yellow perch became the predominant prey for both predators, thus replacing the position held by the ninespine stickleback before 1982 (Nunan 1982). Yellow perch being the most common walleye prey also yielded the highest volume of food (Fig. 35). Some white suckers and northern pike were found in walleye stomachs in 1982, but none were encountered in 1983 or 1984. A sample of four small walleye collected in the fall of 1984 (total length 170 to 190 mm) revealed that the blacknose shiner may be important in the diet of small walleye. Young walleye proved quite elusive, preventing the collection of larger samples. Monthly prey selectivity by walleye remained rather constant (Fig. 36), eg. perch was the major prey in almost every month sampled from 1982 to 1984. Leeches and crayfish (Orconectes virilis) were the most common invertebrates in the walleye diet. However, the ratio of invertebrate volume to fish volume was 0.049:1, reflecting their relative insignificance to larger walleye.

Northern pike have a much more diverse diet than walleye. The invertebrate to fish volume ratio is lower in pike than in walleye (0.043:1), however, the presence of 19 suckers and 8 pike prey in 25 of the pike examined accounted for a large proportion of the total volume. If these 25 stomach volumes are excluded the ratio increases to 0.153:1, and the invertebrate portion of the diet becomes much more significant. Odonata nymphs and crayfish are the most common invertebrates in the diet of pike, especially for larger sized pike. Small pike appear to depend more on perch, Iowa darters and shiners for food (Fig. 37). Large pike (500 mm +), rely less on perch and more on white sucker, northern pike, odonata larvae, and crayfish as prey. There is no discernable trend in monthly volume and

Figure 35. Percentage composition by frequency and volume of food items by size-class, for Henderson Lake walleye, 1982 to 1984.

- ░ Yellow Perch (YP)
- ▦ Iowa Darter (D)
- ▒ Blacknose Shiner (BN)
  Notropis spp. (NO)
- ◇ White Sucker (S)
- ▓ Northern Pike (P)
- ░ Ninespine Stickleback (ST
- ○ Unidentified Fish (F)
- □ Crayfish (C)
- ▧ Hexagenia (X)
- ✚ Unidentified Matter (M)
- ▨ Unidentified Invertebrate (I)
- ▦ Hirudinea (L)
- ▫ Trichoptera (T)
- ▧ Odonata (O)
- ▤ Heptagenia (HP)

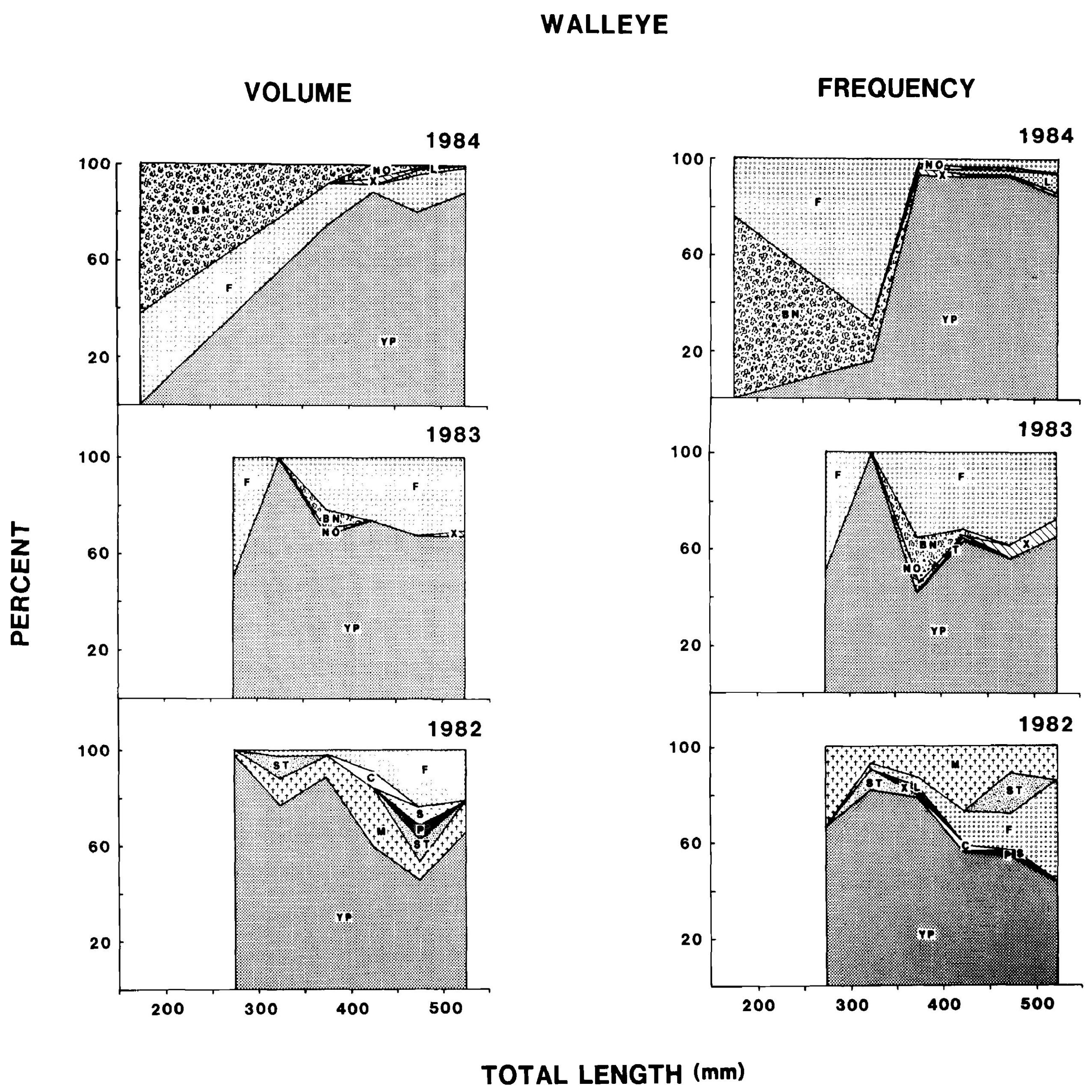
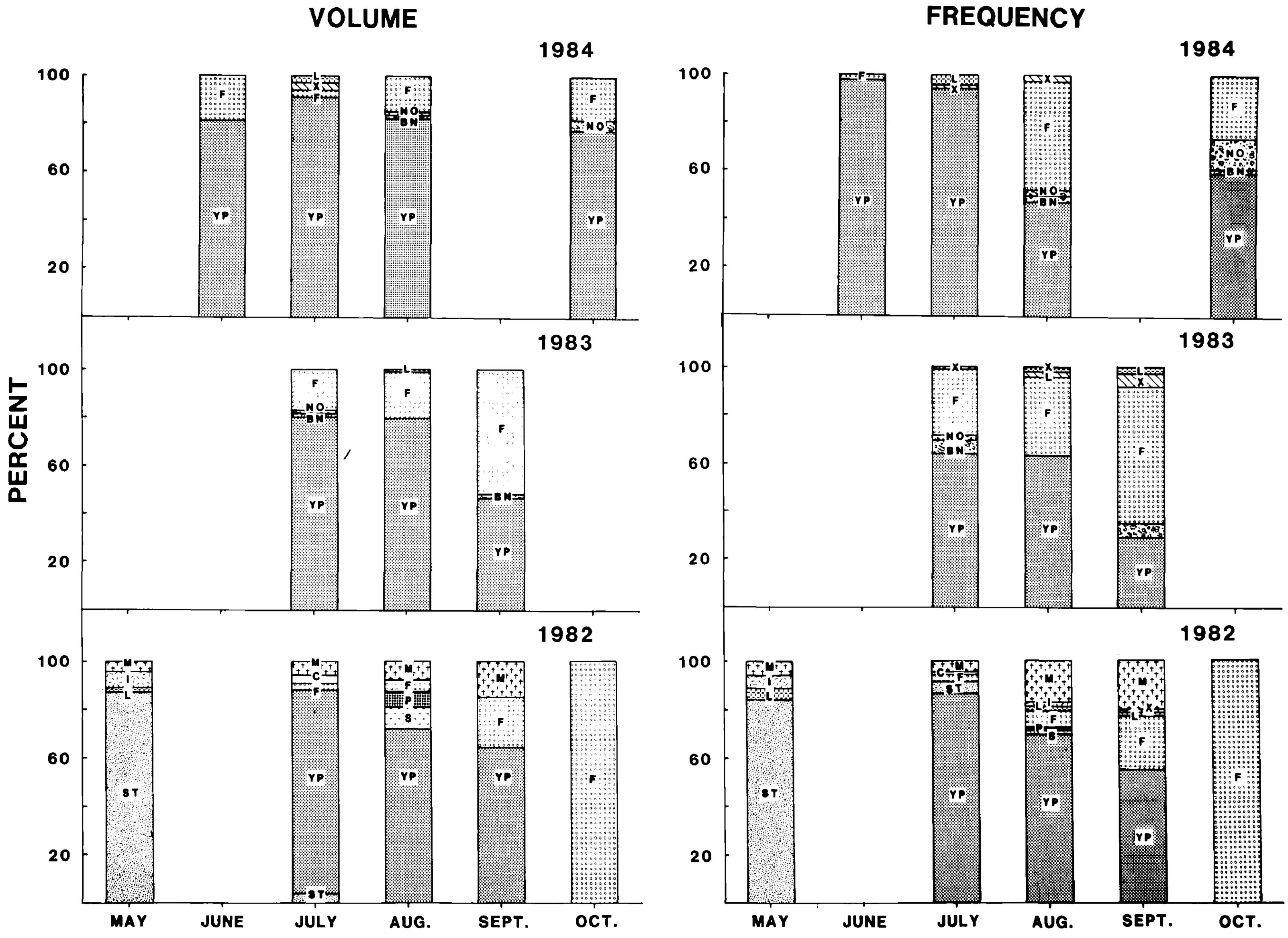

WALLEYE
VOLUME
FREQUENCY
1984
1983
1982
PERCENT
100
60
20
TOTAL LENGTH (mm)
200
300
400
500
BN
F
YP
NO
X
L
ST
C
S
P
M
T

Figure 36. Percentage composition by frequency and volume of food items by month, for Henderson Lake walleye, 1982 to 1984.

- ░ Yellow Perch (YP)
- ▦ Iowa Darter (D)
- ▒ Blacknose Shiner (BN)
  Notropis spp. (NO)
- ◇ White Sucker (S)
- ▓ Northern Pike (P)
- ⁘ Ninespine Stickleback (ST)
- ○ Unidentified Fish (F)
- □ Crayfish (C)
- ▧ Hexagenia (X)
- ✚ Unidentified Matter (M)
- ⁄ Unidentified Invertebrate (I)
- ▦ Hirudinea (L)
- ▫ Trichoptera (T)
- ▧ Odonata (O)
- ▤ Heptagenia (HP)

WALLEYE



VOLUME
FREQUENCY
PERCENT
1984
1983
1982
100
60
20
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
YP
F
L
X
NO
BN
ST
M
I
C
P
S

frequencies of prey items (Fig. 38), with perch, sucker and pike varying in a random fashion. Although volume analysis emphasizes the importance of suckers and pike as prey, frequency of occurence data indicates that white sucker are only present in 7.6 percent, and pike in 3.2 percent of those pike stomachs containing food. Since perch are found in 60.2 percent of stomachs containing food they are a much more important part of the diet for the majority of the northern pike population, especially for smaller pike.

The length-frequency of perch selected by walleye in 1983 (Fig. 39) and northern pike (Fig. 40) in 1983 and 1984 was about the same. However in 1984, walleye increasingly fed on smaller perch (young of the year). This increase in YOY perch predation reflects the production of the very strong 1984 year-class (K. Trimble pers. com.).

Comparisons of mean length of perch prey to predator length reveals that walleye, regardless of size, feed on similar sized perch (Fig 41). Northern pike show a slight tendency to feed on larger perch at larger sizes, with the variance of prey length increasing with predator size (Fig. 42).

Condition Factors

Mean walleye condition factors (K) significantly increased from 1982 and 1983 to 1984 (Table 19) (K-W,$\chi^2 = 73.9$,d.f. = 543,$P<0.01$). This increase possibly reflects the lower numbers of smaller walleye present in 1984, as condition increases with fish size (Bagenal and Tesch 1978). Comparisons of condition among various age-classes (Fig. 43) reveals that for most mid-age-classes (5 to 9), the 1984 condition significantly increased (Table 20), from that in both 1982

Figure 37. Percentage composition by frequency and volume of food items by size-class, for Henderson Lake northern pike, 1982 to 1984.

- ░ Yellow Perch (YP)
- ▦ Iowa Darter (D)
- ▒ Blacknose Shiner (BN)
Notropis spp. (NO)
- ◇ White Sucker (S)
- ▓ Northern Pike (P)
- ░ Ninespine Stickleback (ST)
- ○ Unidentified Fish (F)
- ☐ Crayfish (C)
- ▧ Hexagenia (X)
- ✚ Unidentified Matter (M)
- ▒ Unidentified Invertebrate (I
- ▦ Hirudinea (L)
- ▫ Trichoptera (T)
- ▧ Odonata (O)
- ☰ Heptagenia (HP)

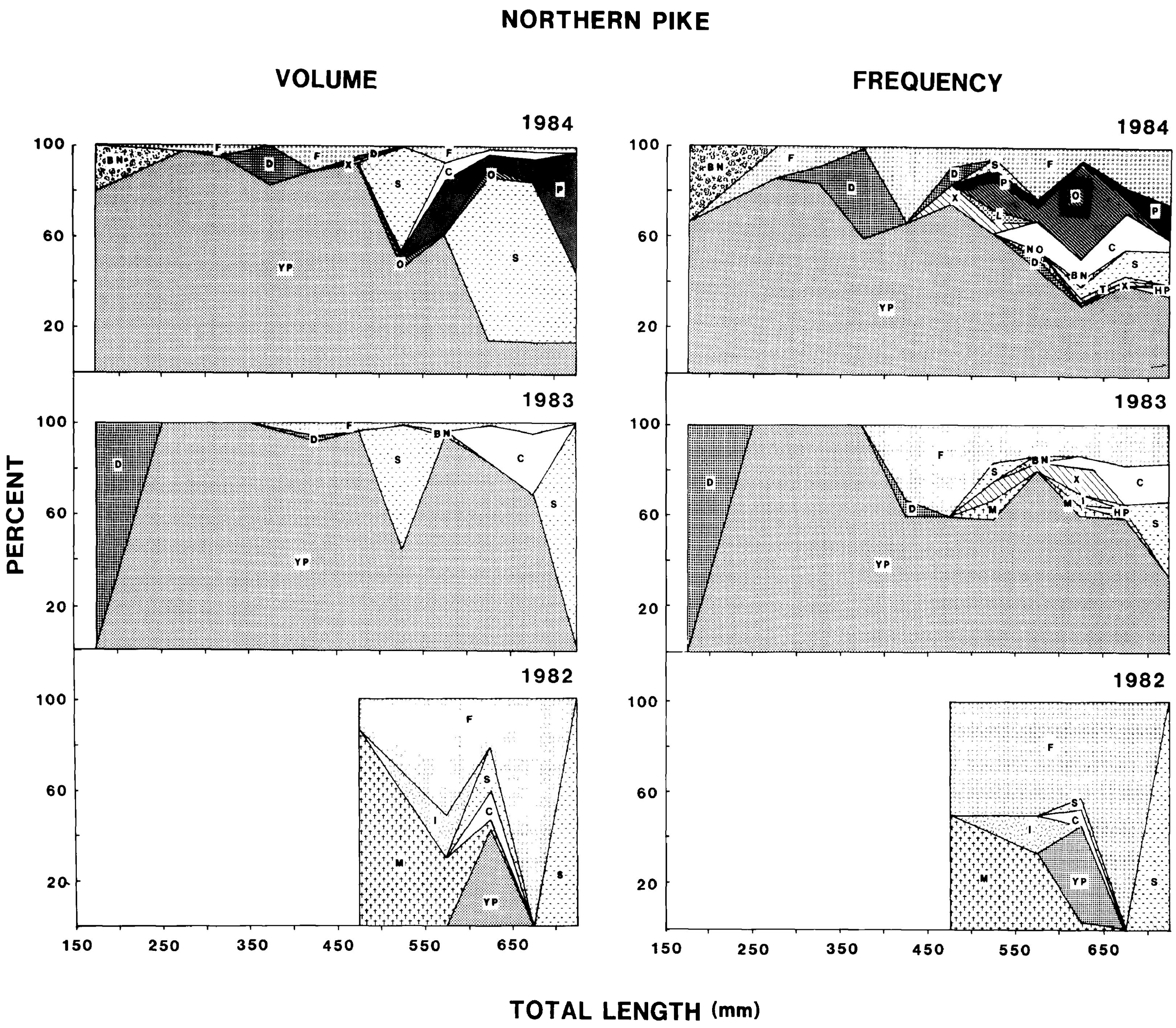
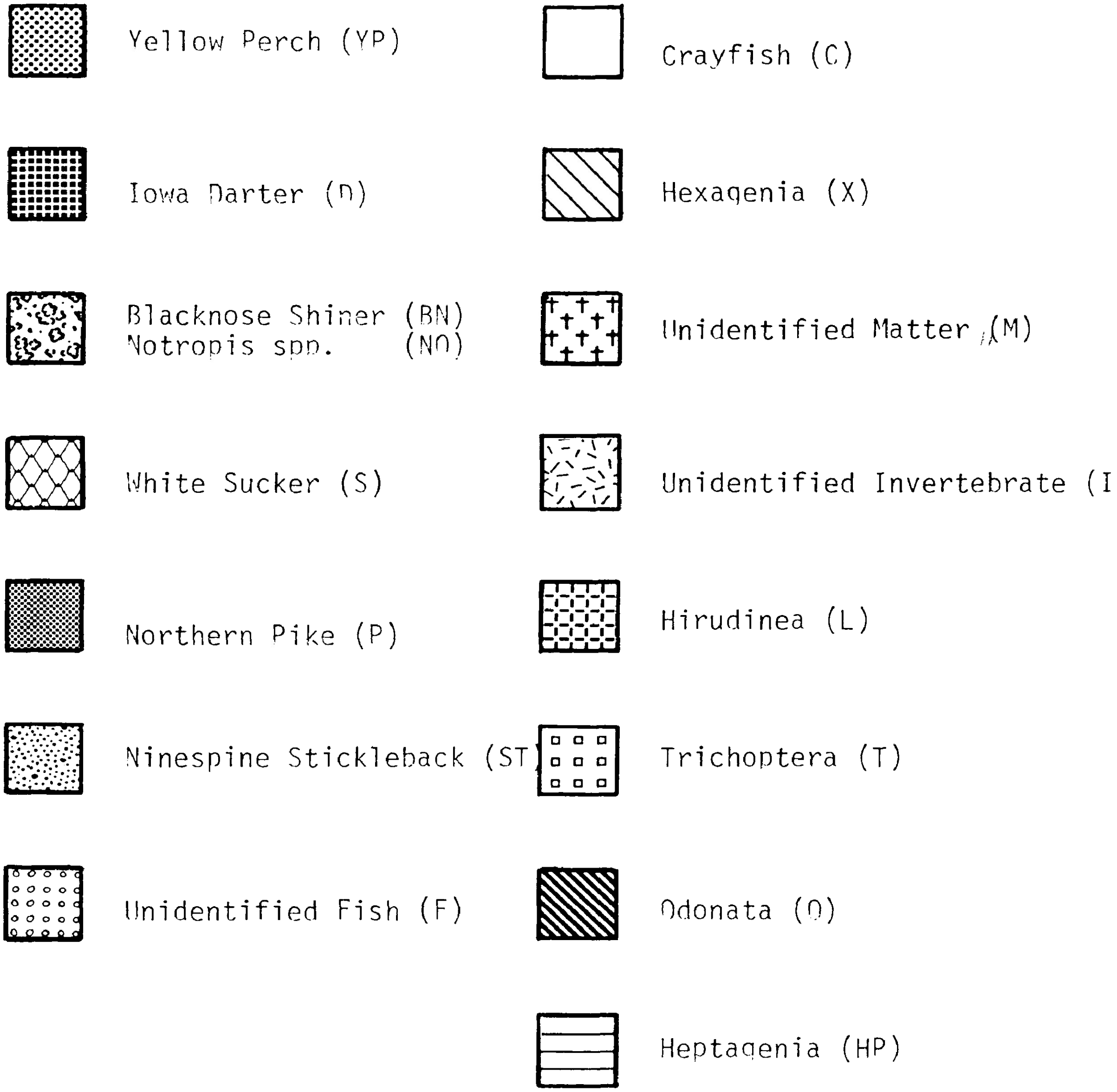

NORTHERN PIKE
VOLUME
FREQUENCY
1984
1983
1982
PERCENT
100
60
20
150
250
350
450
550
650
TOTAL LENGTH (mm)
YP
D
F
BN
X
S
C
O
P
L
NO
T
HP
M
I

Figure 38. Percentage composition by frequency and volume of food items by month, for Henderson Lake northern pike, 1982 to 1984.



NORTHERN PIKE

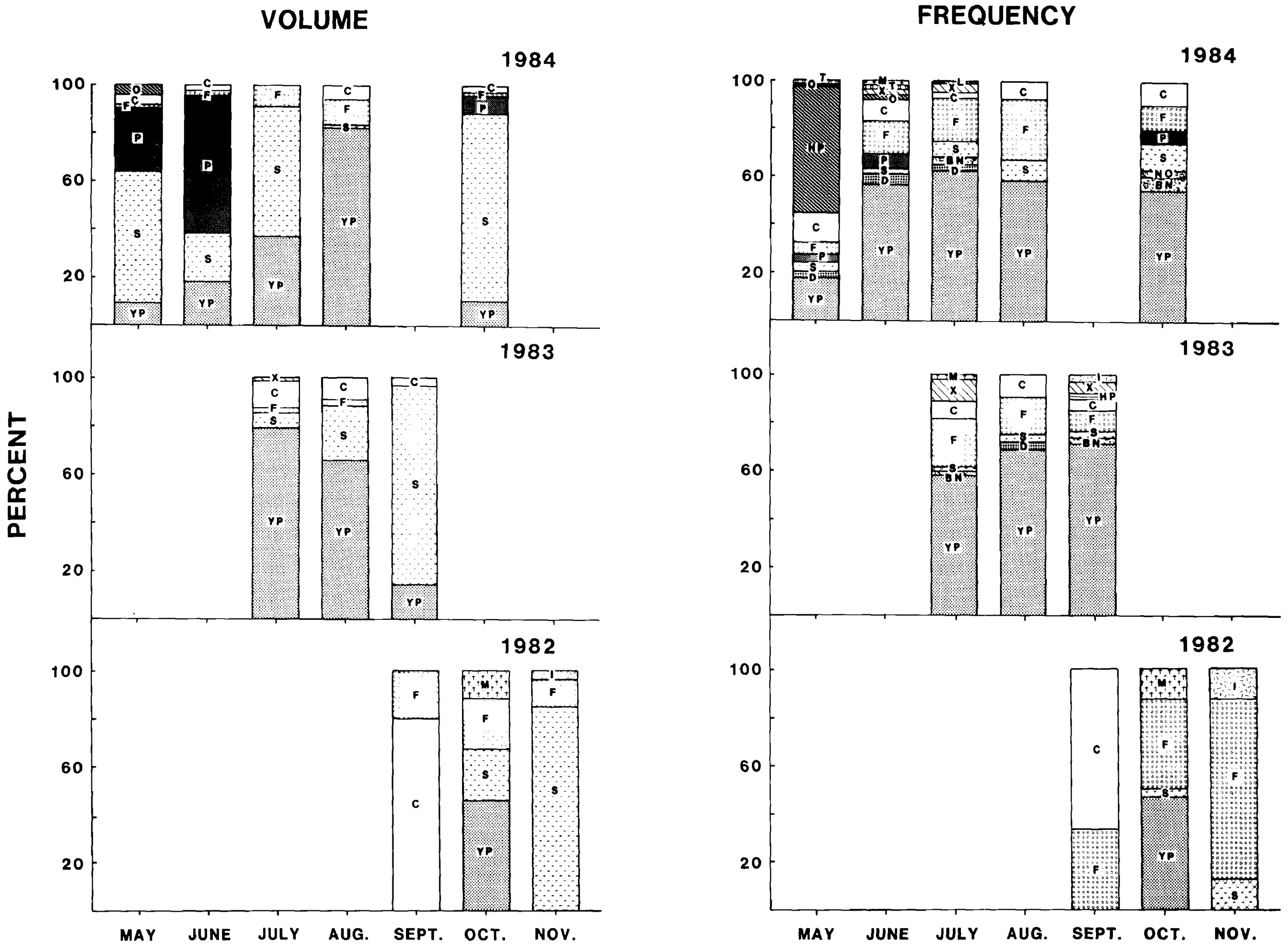
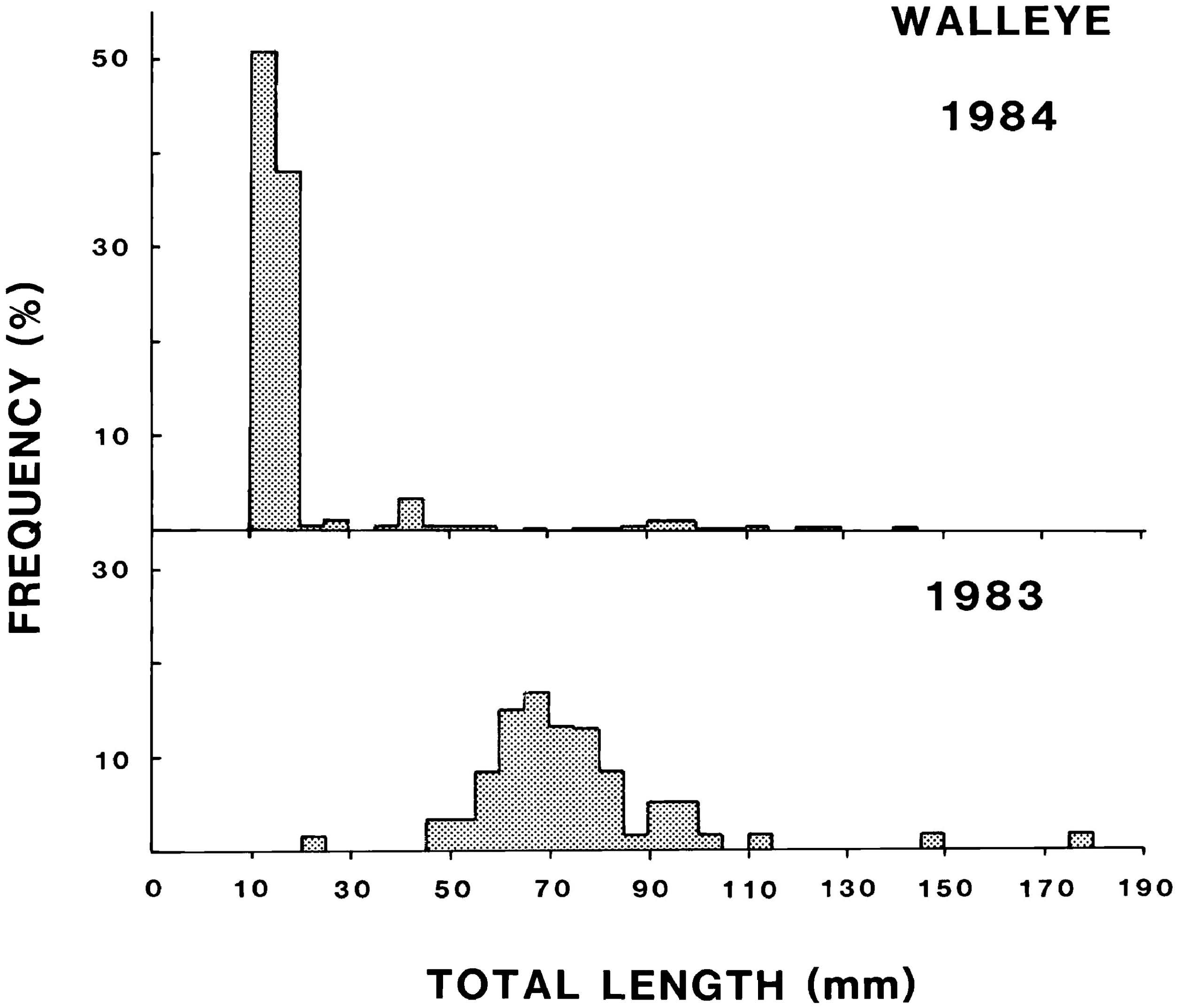


Figure 39. Length-frequency distribution for perch removed from walleye stomachs from Henderson Lake, 1983 and 1984.


WALLEYE
1984
1983
50
30
10
30
10
FREQUENCY (%)
0
10
30
50
70
90
110
130
150
170
190
TOTAL LENGTH (mm)

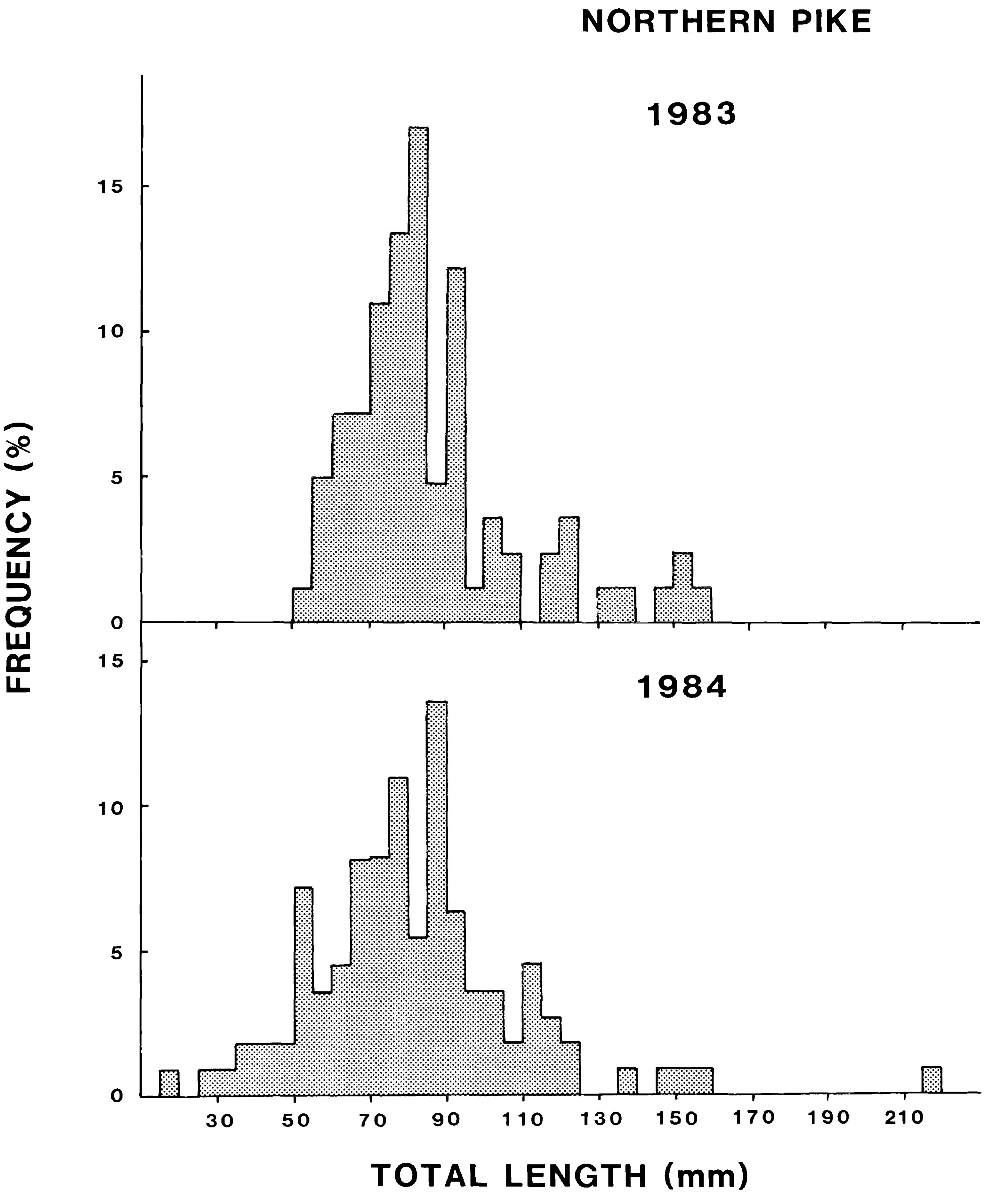

NORTHERN PIKE
1983
1984
FREQUENCY (%)
0
5
10
15
30
50
70
90
110
130
150
170
190
210
TOTAL LENGTH (mm)

Figure 41. Mean total lengths of perch prey by total length-class of walleye predators in Henderson Lake, 1983 and 1984.

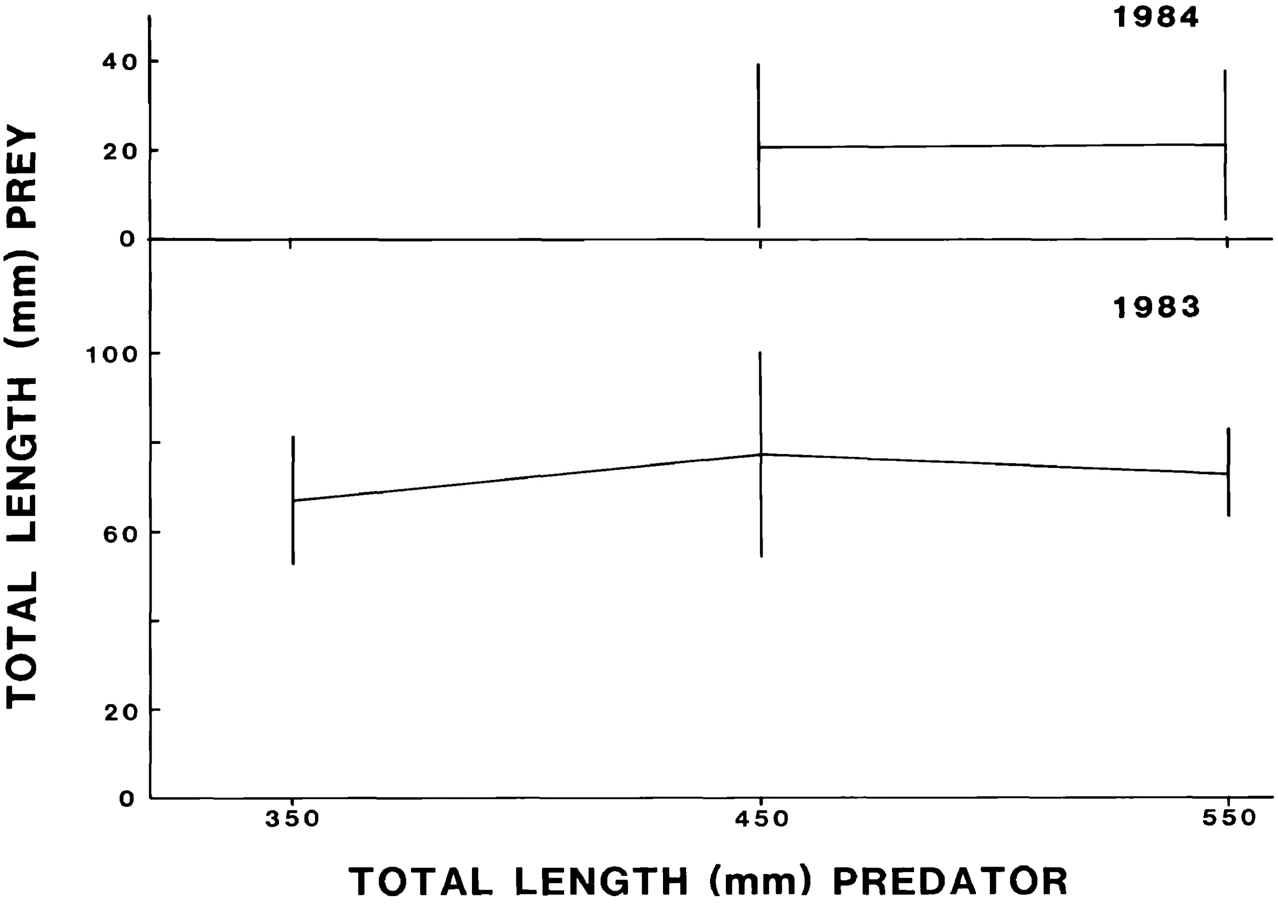

1984
40
20
0
1983
100
60
20
0
350
450
550
TOTAL LENGTH (mm) PREY
TOTAL LENGTH (mm) PREDATOR

Figure 42. Mean total lengths of perch by total length-class of northern pike predators, 1983 to 1984.

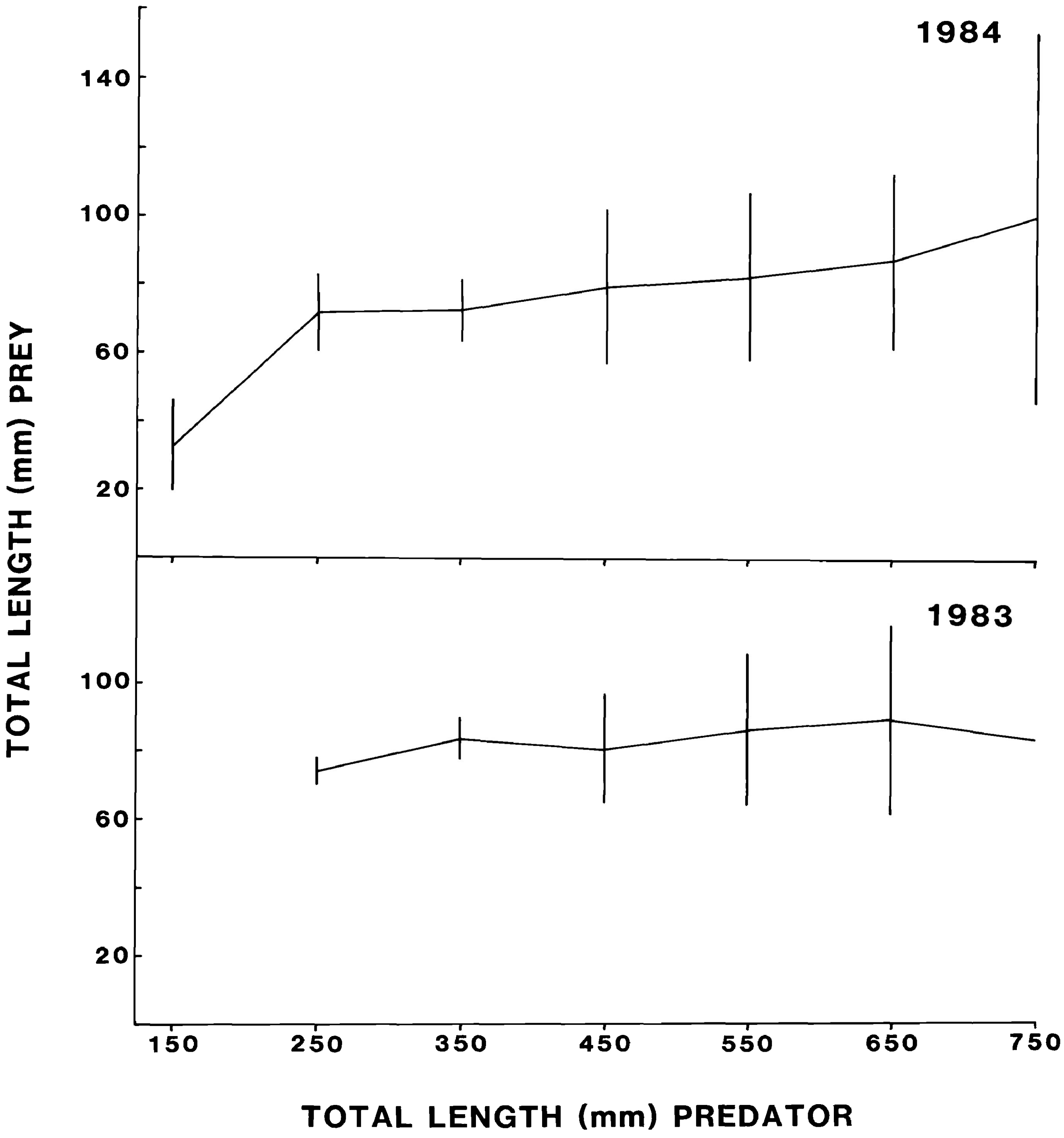

1984
140
100
60
20
1983
100
60
20
150
250
350
450
550
650
750
TOTAL LENGTH (mm) PREY
TOTAL LENGTH (mm) PREDATOR

Table 19. Mean condition factors, lengths and weights for walleye from Henderson Lake, 1982 to 1984.

	1982	1983	1984
Mean condition factor	0.922	0.924	1.005
Minimum	0.700	0.574	0.790
Maximum	1.336	1.183	1.227
Variance	0.006	0.010	0.007
Standard deviation	0.080	0.100	0.085
Mean length	413.714	421.243	457.702
Minimum	304.000	329.000	329.000
Maximum	650.000	520.000	530.000
Variance	3848.722	1343.538	767.844
Standard deviation	62.038	36.654	27.710
Mean weight	701.818	704.609	976.860
Minimum	225.000	303.000	550.000
Maximum	2550.000	1404.000	1650.000
Variance	122673.620	38692.110	45335.055
Standard deviation	350.248	196.703	212.920

Figure 43. Mean condition factor (K) by age-class for Henderson Lake walleye, 1982 to 1984. Roman numerals represent age-class of fish in years.

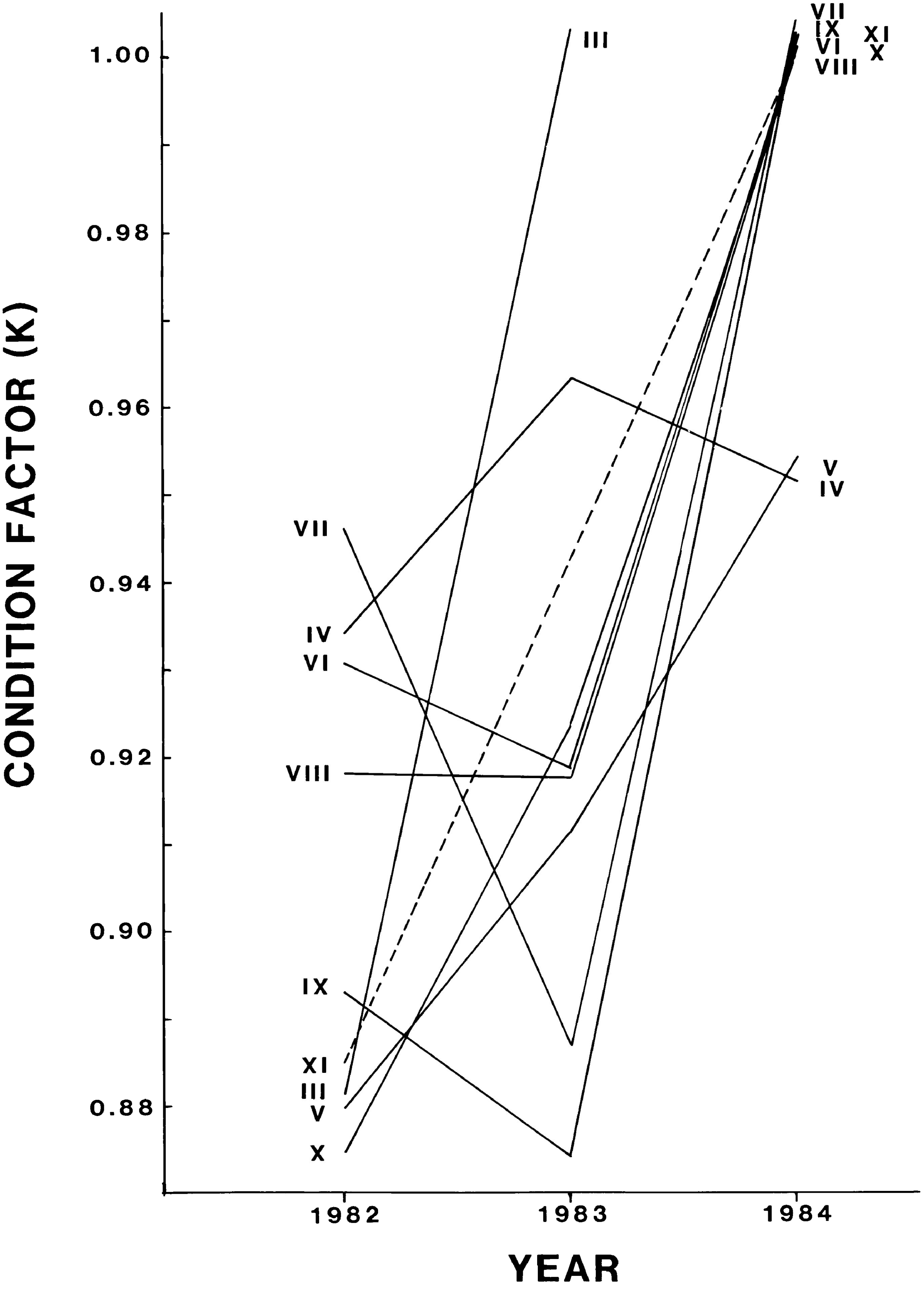

CONDITION FACTOR (K)
1.00
0.98
0.96
0.94
0.92
0.90
0.88
YEAR
1982
1983
1984
III
VII
IX
XI
VI
X
VIII
V
IV
VII
IV
VI
VIII
IX
XI
III
V
X

Table 20. Mean condition factors ($\overline{K}$) for Henderson Lake walleye, by age-class, 1982 to 1984.

Age	Year	$\overline{K}$[1]	S.D.[2]	Cases
3	1982	0.8813	0.0580	12
3	1983	1.0329 *	0.1183	5
4	1982	0.9343	0.1205	13
4	1983	0.9633	0.0790	45
4	1984	0.9514	0.0559	2
5	1982	0.8799	0.0858	9
5	1983	0.9112	0.0963	59
5	1984	0.9543 *	0.0640	33
6	1982	0.9308	0.0456	12
6	1983	0.9186	0.0990	40
6	1984	1.0215 **	0.0907	26
7	1982	0.9462	0.0647	7
7	1983	0.8868	0.0947	21
7	1984	1.0443 **	0.0702	24
8	1982	0.9180	0.0588	7
8	1983	0.9175	0.1287	19
8	1984	1.0209 *	0.1060	18
9	1982	0.8930	0.0000	1
9	1983	0.8741	0.1058	8
9	1984	1.0269[3]*	0.0891	8
10	1982	0.8739	0.0269	2
10	1983	0.9238	0.0647	3
10	1984	1.0153	0.0401	5
11	1982	0.8847	0.0116	2
11	1984	1.0189	0.0846	2
12	1982	0.9776	0.0000	1
14	1982	0.8370	0.0000	1
16	1982	0.9484	0.0000	1
19	1984	0.9517	0.0000	1

---

[1] $\overline{K}$ = Mean K value

[2] S.D. = Standard deviation

[3] From 1983 only

* $P<0.05$

** $P<0.01$

Figure 44. Mean condition factor (K) by size-class for Henderson Lake walleye, 1982 to 1984. Numbers represent size-class range of fish in millimeters.

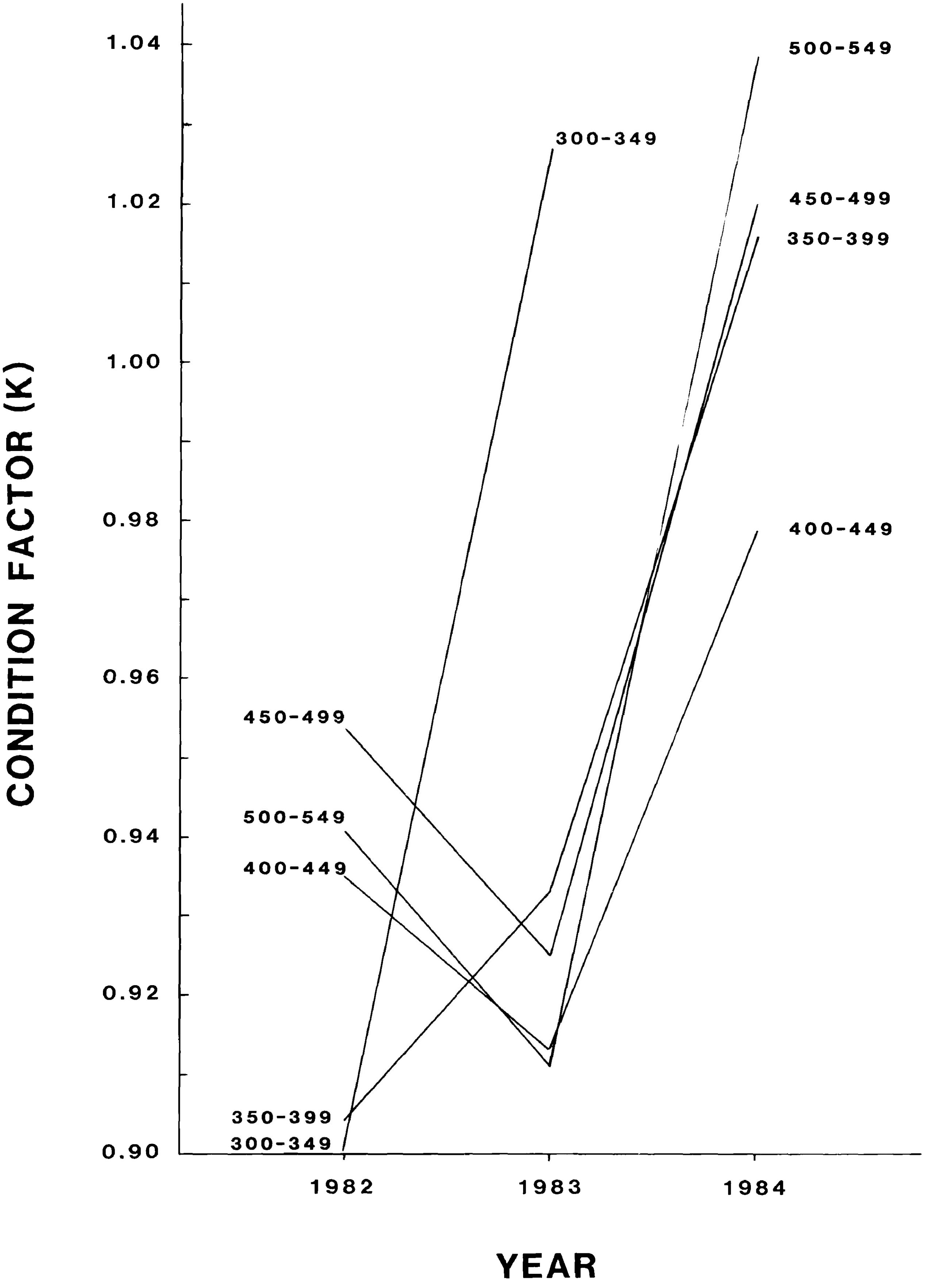
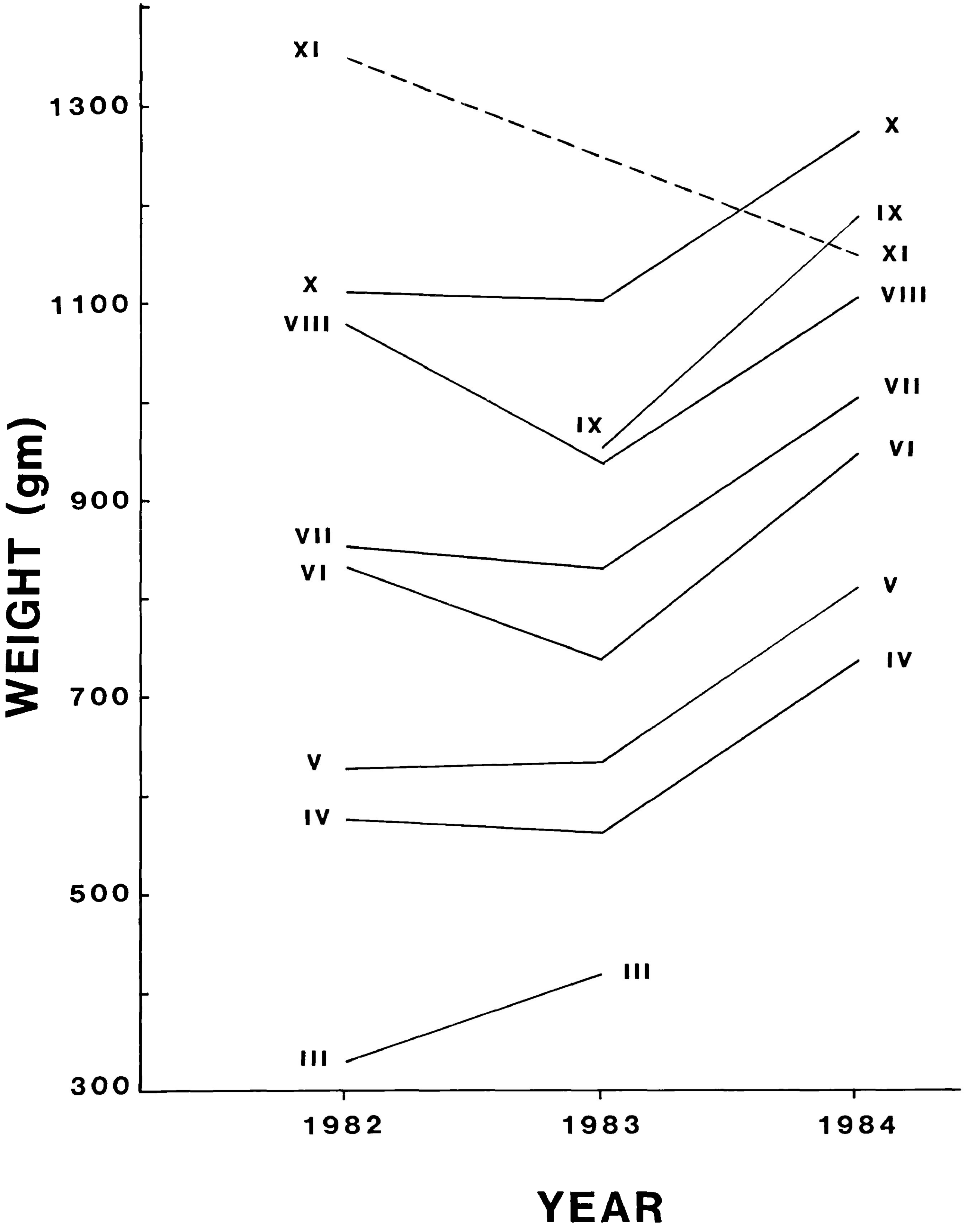

CONDITION FACTOR (K)
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
YEAR
1982
1983
1984
300-349
500-549
450-499
350-399
400-449
450-499
500-549
400-449
350-399
300-349

Figure 45. Mean weight (gm) changes by age-class for Henderson Lake walleye, 1982 to 1984. Roman numerals represent age-class of fish in years.



WEIGHT (gm)
1300
1100
900
700
500
300
1982
1983
1984
YEAR
XI
X
VIII
IX
VII
VI
V
IV
III
X
IX
XI
VIII
VII
VI
V
IV
III

Table 22. Mean weight (gm) for Henderson Lake walleye by age-class, 1982 to 1984.

Age	Year	Mean Weight	S.D.[1]	Cases
3	1982	327.08	43.25	12
3	1983	417.20 **	48.85	5
4	1982	575.00	268.68	13
4	1983	563.44	90.10	45
4	1984	737.50 *	17.68	2
5	1982	627.78	125.90	9
5	1983	634.44	116.92	59
5	1984	811.36 **	122.81	33
6	1982	831.25	165.53	12
6	1983	739.76	154.93	40
6	1984	949.04 **	181.86	26
7	1982	853.57	152.36	7
7	1983	830.24	146.74	21
7	1984	1005.21 **	149.27	24
8	1982	1078.57	227.96	7
8	1983	939.37	203.65	19
8	1984	1106.94	199.04	18
9	1982	1900.00	0.00	1
9	1983	945.12	199.79	8
9	1984	1187.50	223.21	8
10	1982	1112.50	53.03	2
10	1983	1103.67	262.37	3
10	1984	1275.00	204.63	5
11	1982	1350.00	459.62	2
11	1984	1150.00	141.42	2
12	1982	1600.00	0.00	1
14	1982	1650.00	0.00	1
16	1982	1775.00	0.00	1
19	1984	1300.00	0.00	1

[1] S.D. = Standard deviation

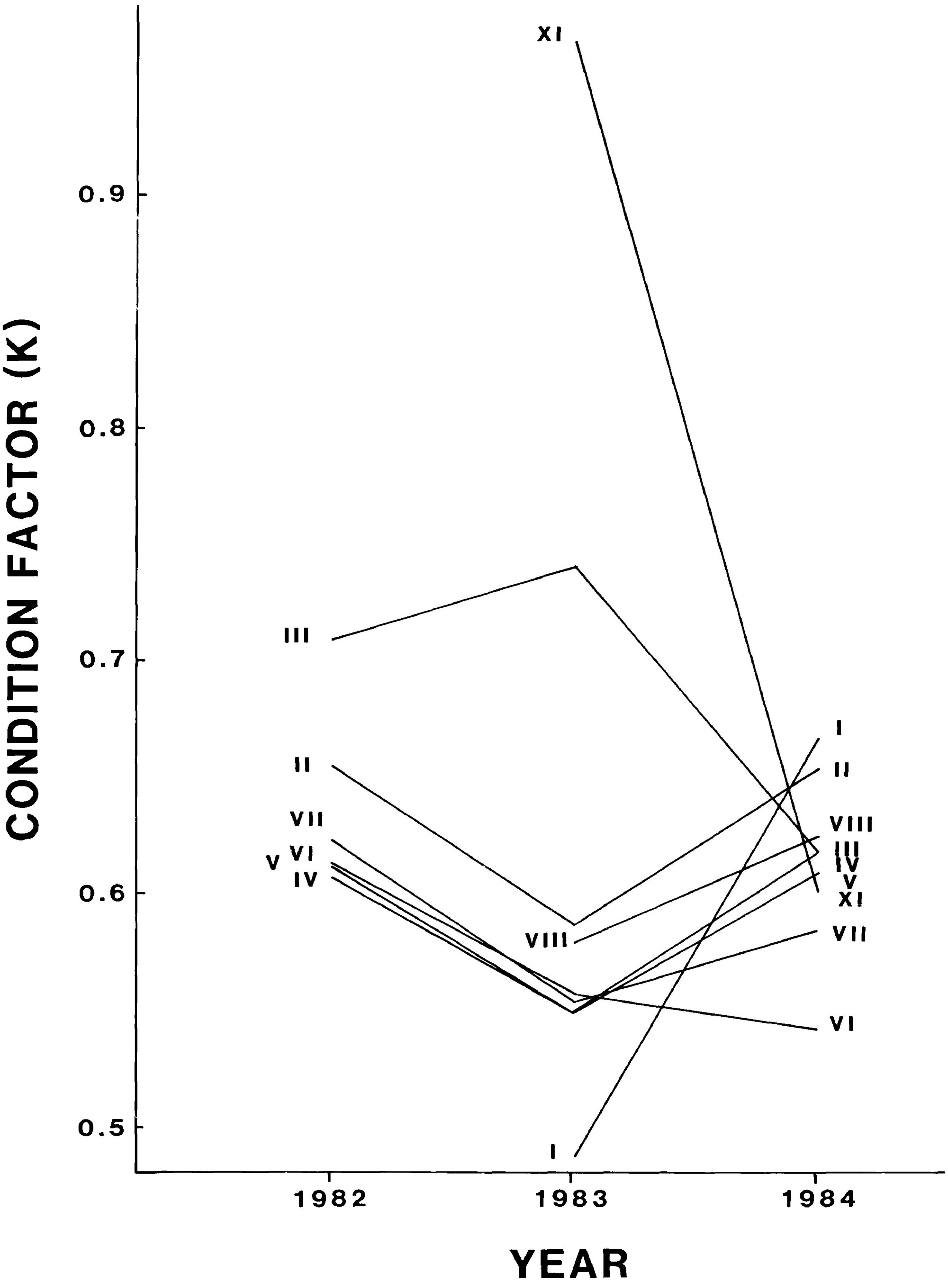
* $P<0.05$

** $P<0.01$

Table 23. Mean condition factors, lengths and weights for northern pike from Henderson Lake, 1982 to 1984.

	1982	1983	1984
Mean condition factor	0.623	0.560	0.621
Minimum	0.262	0.182	0.278
Maximum	1.338	1.378	1.412
Variance	0.007	0.007	0.006
Standard deviation	0.081	0.083	0.080
Mean length	592.146	595.706	559.958
Minimum	306.000	280.000	251.000
Maximum	1100.000	1051.000	1110.000
Variance	3775.640	4894.920	9316.888
Standard deviation	61.446	69.964	96.524
Mean weight	1329.009	1235.321	1166.471
Minimum	175.000	40.000	100.000
Maximum	9000.000	9999.000	9999.000
Variance	306440.941	432688.078	343252.257
Standard deviation	553.571	657.790	585.877

Figure 46. Mean condition factor (K) changes by age-class for Henderson Lake northern pike, 1982 to 1984. Roman numerals represent age-class of fish in years.



CONDITION FACTOR (K)
0.9
0.8
0.7
0.6
0.5
1982
1983
1984
YEAR
XI
III
II
VII
VI
V
IV
VIII
I
I
II
VIII
III
IV
V
XI
VII
VI

Table 24. Mean condition factors ($\bar{K}$), by age-class for Henderson Lake northern pike, 1982 to 1984.

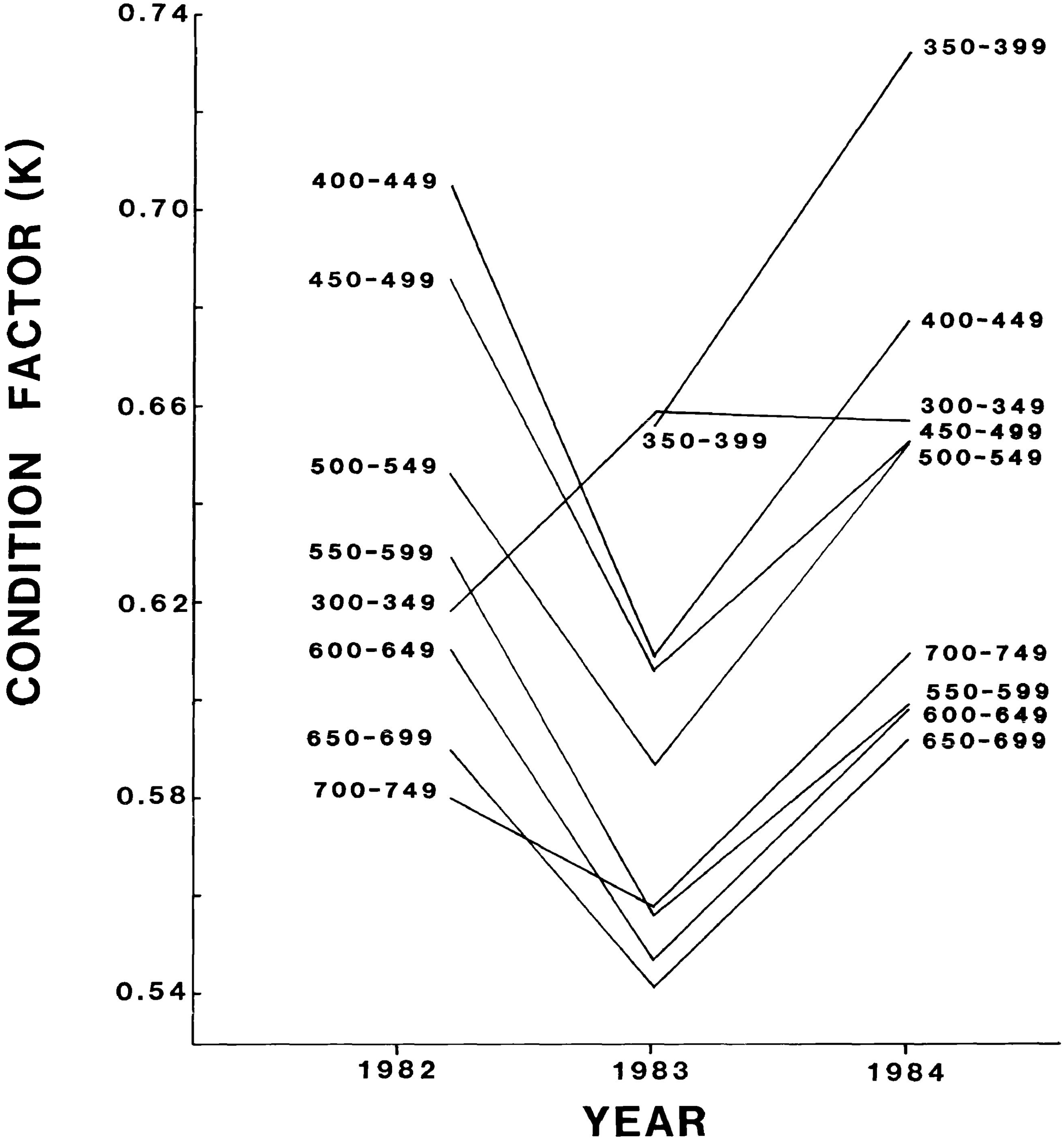
Age	Year	K[1]	S.D.[2]	Cases
1	1983	0.4864	0.2643	3
1	1984	0.6673	0.0866	24
2	1982	0.6547	0.0533	9
2	1983	0.5869 **	0.0695	22
2	1984	0.6537	0.0800	13
3	1982	0.7087	0.2163	11
3	1983	0.7403	0.3389	10
3	1984	0.6188	0.0340	4
4	1982	0.6062	0.0420	7
4	1983	0.5499	0.0578	10
4	1984	0.6185	0.0086	2
5	1982	0.6205	0.0756	21
5	1983	0.5488 **	0.0536	21
5	1984	0.6082	0.0000	1
6	1982	0.6137 **	0.0464	19
6	1983	0.5566	0.0585	20
6	1984	0.5407	0.0047	2
7	1982	0.6213	0.0688	5
7	1983	0.5523	0.0384	6
7	1984	0.5822	0.0590	5
8	1983	0.5798	0.0000	1
8	1984	0.6240	0.0000	1
10	1983	0.6827	0.0000	1
11	1983	0.9629	0.0000	1
11	1984	0.6007	0.0000	1
12	1982	0.6762	0.0000	1
12	1983	0.6374	0.0000	1
13	1983	0.9619	0.0000	1

[1] $\bar{K}$ = Mean K value

[2] S.D. = Standard deviation

** $P<0.01$

Figure 47. Mean condition factor (K) changes by size-class for Henderson Lake northern pike, 1982 to 1984. Numbers represent size-class range of fish in millimeters.



CONDITION FACTOR (K)
0.74
0.70
0.66
0.62
0.58
0.54
400-449
450-499
500-549
550-599
300-349
600-649
650-699
700-749
350-399
350-399
400-449
300-349
450-499
500-549
700-749
550-599
600-649
650-699
1982
1983
1984
YEAR

Table 25. Mean condition factors ($\bar{K}$), by size-class, for Henderson Lake northern pike, 1982 to 1984.

Size-Class (mm)	Year	$\bar{K}$[1]	S.D.[2]	Cases
250-299	1983	0.1822	0.0000	1
250-299	1984	0.6613	0.0853	12
300-349	1982	0.6183	0.1138	3
300-349	1983	0.6592	0.0000	1
300-349	1984	0.6574	0.1214	21
350-399	1983	0.6564	0.1113	3
350-399	1984	0.7328	0.0851	7
400-449	1982	0.7053	0.0530	3
400-449	1983	0.6092 *	0.0589	9
400-449	1984	0.6778	0.0566	49
450-499	1982	0.6861	0.2133	9
450-499	1983	0.6063[3]**	0.1807	43
450-499	1984	0.6536	0.0567	110
500-549	1982	0.6468	0.1656	26
500-549	1983	0.5871	0.1052	53
500-549	1984	0.6539 **	0.1140	73
550-599	1982	0.6299 **	0.0660	132
550-599	1983	0.5566 **	0.0514	161
550-599	1984	0.5999 **	0.0518	160
600-649	1982	0.6105	0.0474	115
600-649	1983	0.5474 **	0.0512	206
600-649	1984	0.5988	0.0549	204
650-699	1982	0.5901	0.0433	26
650-699	1983	0.5417 **	0.0568	87
650-699	1984	0.5926	0.1101	85
700-749	1982	0.5804	0.0473	2
700-749	1983	0.5582	0.0606	10
700-749	1984	0.6106	0.0677	21
750-799	1983	0.6099	0.0000	1
750-799	1984	0.6400	0.0000	1
1000-1049	1983	0.9619	0.0000	1

---

[1] $\bar{K}$ = Mean K value

[2] S.D. = Standard deviation

[3] From 1984 only

* $P<0.05$

Figure 48. Mean weight (gm) changes by age-class for Henderson Lake northern pike, 1982 to 1984. Roman numerals represent age-class of fish in years.

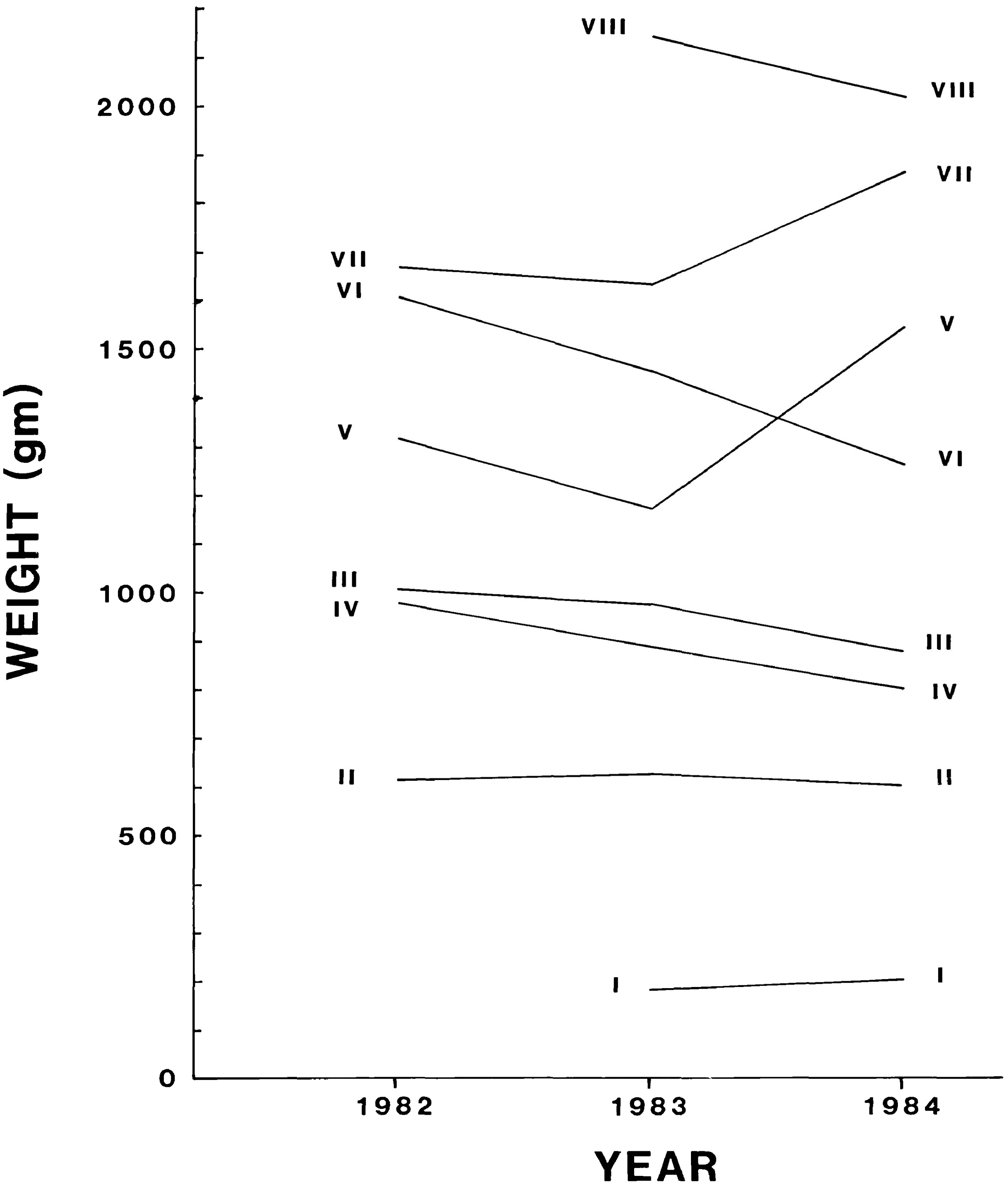

WEIGHT (gm)
2000
1500
1000
500
0
1982
1983
1984
YEAR
VIII
VIII
VII
VII
VI
VI
V
V
III
IV
III
IV
II
II
I
I

Table 26. Mean weight (gm), by age-class, for Henderson Lake northern pike, 1982 to 1984.

Age	Year	Mean Weight	S.D.[1]	Cases
1	1983	182.67	131.15	3
1	1984	205.83	69.24	24
2	1982	613.89	197.29	9
2	1983	627.45	150.48	22
2	1984	609.62	227.20	13
3	1982	1009.09	270.48	11
3	1983	975.20	387.95	10
3	1984	881.25	238.38	4
4	1982	978.57	159.71	7
4	1983	887.10	139.72	10
4	1984	800.00	282.84	2
5	1982	1319.05	220.78	21
5	1983	1172.76	249.48	21
5	1984	1550.00	0.00	1
6	1982	1605.53	281.06	19
6	1983	1458.50	360.66	20
6	1984	1262.50	123.74	2
7	1982	1670.00	251.50	5
7	1983	1632.00	257.50	6
7	1984	1870.00	549.54	5
8	1983	2146.00	0.00	1
8	1984	2050.00	0.00	1
10	1982	4700.00	0.00	1
11	1983	9400.00	0.00	1
11	1984	2150.00	0.00	1
12	1982	9000.00	0.00	1
12	1983	7400.00	0.00	1
13	1983	9999.00	0.00	1

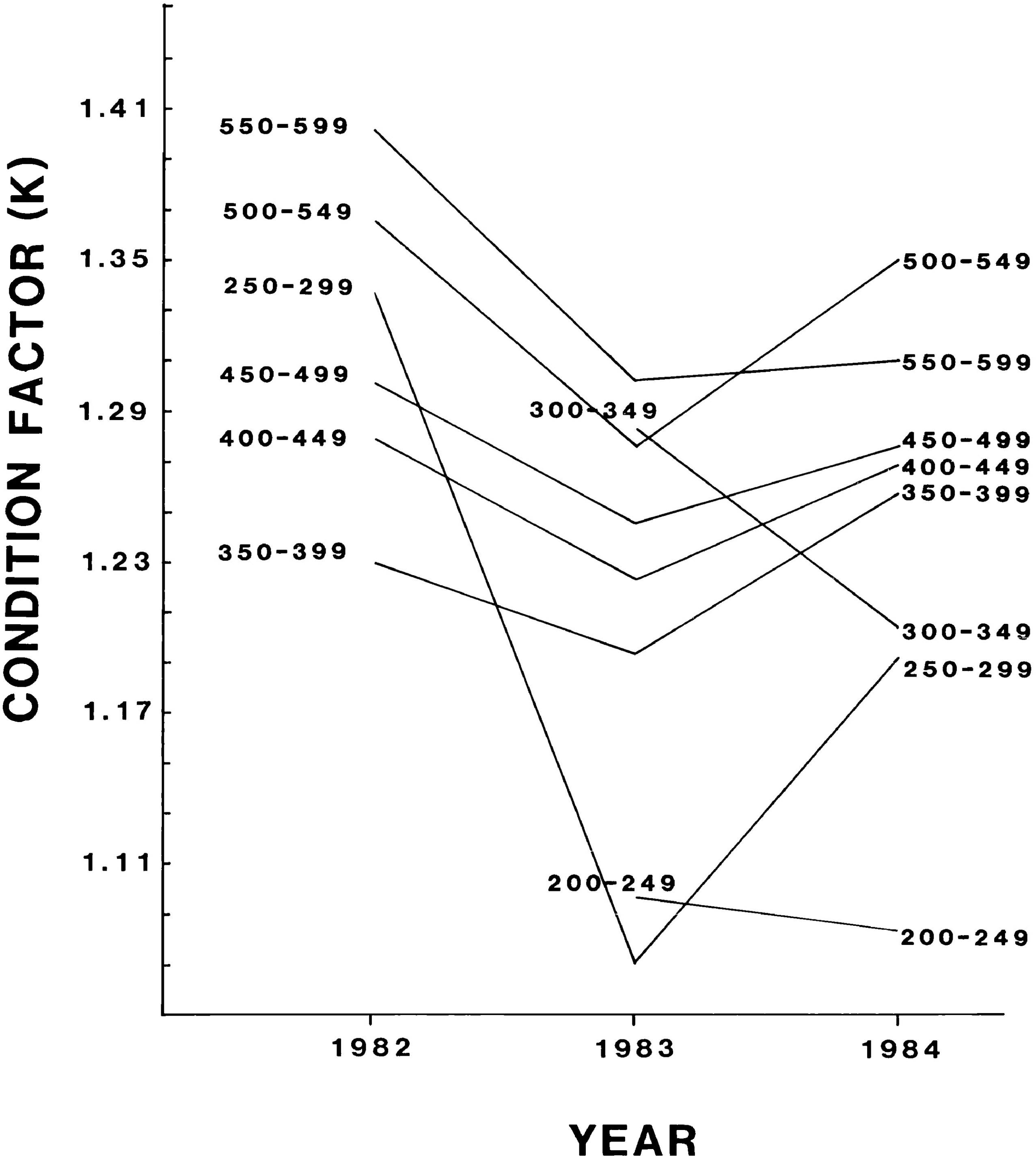
---

[1] S.D. = Standard deviation

Table 27. Mean condition factors, lengths and weights for white sucker from Henderson Lake, 1982 to 1984.

	1982	1983	1984
Mean condition factor	1.322	1.252	1.298
Minimum	0.967	0.519	0.921
Maximum	1.761	2.244	1.670
Variance	0.016	0.018	0.015
Standard deviation	0.128	0.133	0.124
Mean Length	487.971	482.344	487.204
Minimum	274.000	170.000	226.000
Maximum	690.000	595.000	609.000
Variance	3316.260	4294.726	4384.820
Standard deviation	57.587	65.534	66.218
Mean weight	1611.547	1491.052	1512.302
Miminum	275.000	51.000	125.000
Maximum	3200.000	4025.000	2900.000
Variance	333418.424	320325.210	366290.184
Standard deviation	577.424	565.973	605.219

Figure 49. Mean condition factor (K) changes by size-class for Henderson Lake white sucker, 1982 to 1984. Numbers represent size-class range of fish in millimeters.


CONDITION FACTOR (K)
1.41
1.35
1.29
1.23
1.17
1.11
1982
1983
1984
YEAR
550-599
500-549
250-299
450-499
400-449
350-399
300-349
200-249
500-549
550-599
450-499
400-449
350-399
300-349
250-299
200-249

Catch Per Unit Effort

Catch per unit effort (CPUE) was determined for each year of the Henderson Lake study (1979 to 1984). The CPUE was set as the number of fish captured per hour of set time for each gear type. CPUE was calculated for each gear type namely: four, six and eight-foot trap nets, and gill nets. The mean CPUE of each type of gear was calculated by species (walleye, northern pike and white sucker). As well, a combined CPUE was calculated for all species. Least-square regressions were calculated for mean CPUE (independent variable) and Schumacher-Eschmeyer population estimates (dependent variable), to determine if CPUE was a suitable indicator of population abundance.

Walleye population estimates were significantly correlated with CPUE from six-foot trap nets (Fig. 50; $r = 0.95$, d.f. $= 5$, $p<0.01$) and four-foot trap nets (Table 29; $r = 0.96$, d.f. $= 4$, $p<0.05$). However, eight-foot trap and gill netted walleye CPUE's were not significantly correlated to population estimates at even the 0.05 level. Sample sizes of gill net data were generally smaller than those from other gear types.

Northern pike CPUE data was not significantly correlated ($P<0.05$) to the estimated population abundance for any of the gear types (Fig. 51; Table 29). White sucker data also displayed no significant correlations (Fig. 52; Table 29). Regressions of the CPUE for all species to the total population estimates (all species summed per year), showed no significance at the 0.05 level for any of the gear in use (Fig. 53; Table 29).

Figure 50. Regression of Schumacher-Eschmeyer population estimates of walleye with catch per unit effort (from six-foot trap nets) per year for Henderson Lake, 1979 to 1984.

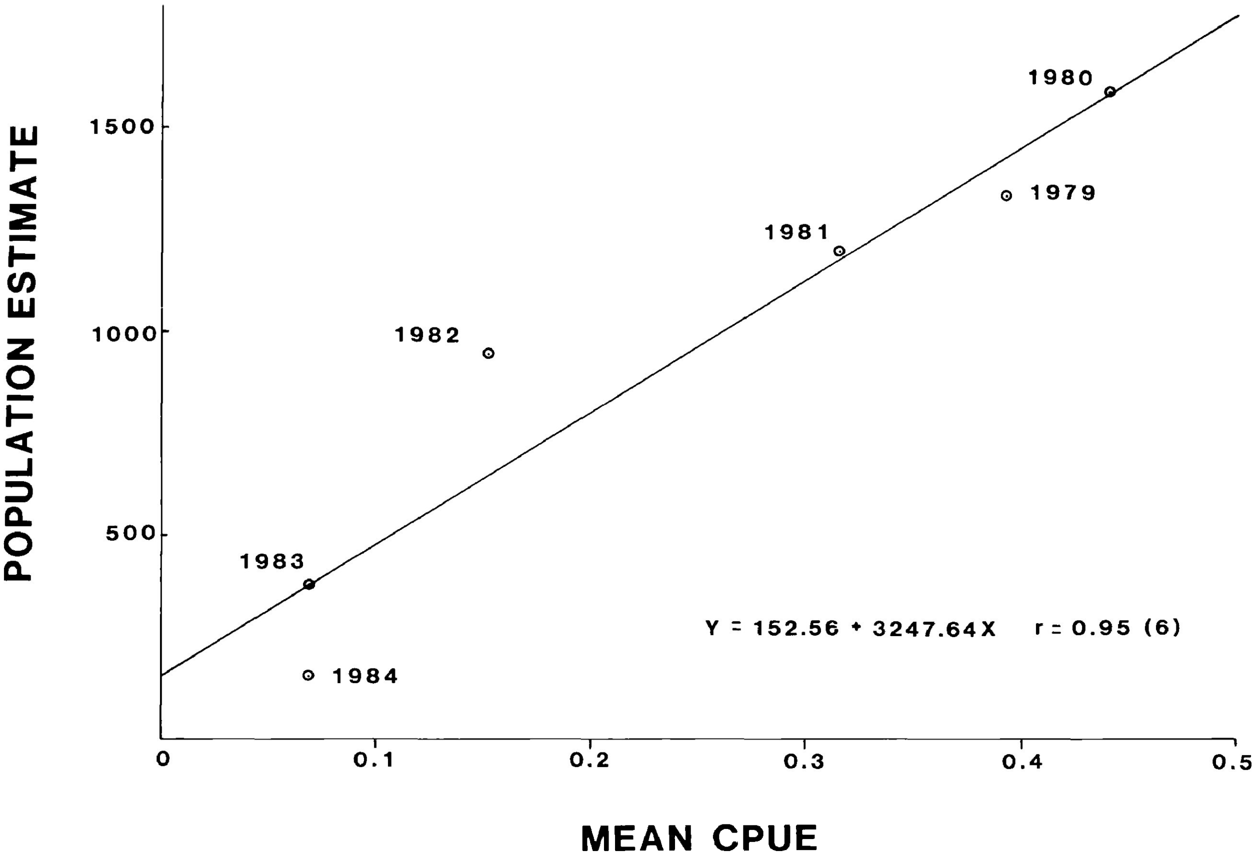

POPULATION ESTIMATE
1500
1000
500
0
0.1
0.2
0.3
0.4
0.5
MEAN CPUE
1980
1979
1981
1982
1983
1984
Y = 152.56 + 3247.64X r = 0.95 (6)

Table 29. Linear regressions of catch-per-unit effort (CUE) with population estimates (Schumacher-Eschmeyer method) by year (1979 to 1984), by gear type, for Henderson Lake walleye, northern pike, white sucker and all species combined.

Four-foot trap nets:			
walleye	$Y^{1} = 834.14 + 3411.10\,x^{2}$	$r = 0.96$ (4)[3]	*
	$Y(P)^{4} = 1094.53 + 7284.31\,x$	$r = 0.88$ (3)	
northern pike	$Y^{1} = 763.81 + 8983.57\,x$	$r = 0.74$ (4)	
white sucker	$Y = 825.20 + 8137.82\,x$	$r = 0.68$ (4)	
combined	$Y = 1506.41 + 10913.64\,x$	$r = 0.81$ (4)	
Six-foot trap nets:			
walleye	$Y = 152.56 + 3247.64\,x$	$r = 0.95$ (6)	**
	$Y(P) = -92.11 + 6712.89\,x$	$r = 0.98$ (5)	**
northern pike	$Y = 780.97 + 2058.58\,x$	$r = 0.28$ (6)	
white sucker	$Y = 853.07 + 2068.28\,x$	$r = 0.71$ (6)	
combined	$Y = 541.83 + 4424.57\,x$	$r = 0.79$ (6)	
Eight-foot trap nets:			
walleye	$Y = 702.87 + 921.78\,x$	$r = 0.48$ (6)	
	$Y(P) = -177.28 + 11482.36\,x$	$r = 0.74$ (5)	
northern pike	$Y = 1230.84 + 850.57\,x$	$r = 0.16$ (6)	
white sucker	$Y = 985.97 + 1341.64\,x$	$r = 0.28$ (6)	
combined	$Y = 2491.21 + 1766.06\,x$	$r = 0.51$ (6)	
Gill net:			
walleye	$Y = 568.07 + 380.78\,x$	$r = 0.59$ (5)	
	$Y(P) = 800.81 + 689.81\,x$	$r = 0.56$ (5)	
northern pike	$Y = 1324.60 - 46.14\,x$	$r = -0.04$ (5)	
white sucker	$Y = 866.82 + 113.55\,x$	$r = 0.44$ (5)	
combined	$Y = 2826.82 + 151.70\,x$	$r = 0.25$ (5)	

---

[1] Y = Number of fish estimated in population (Schumacher-Eschmeyer method)

[2] x = Catch-per-unit effort (fish per hour of set)

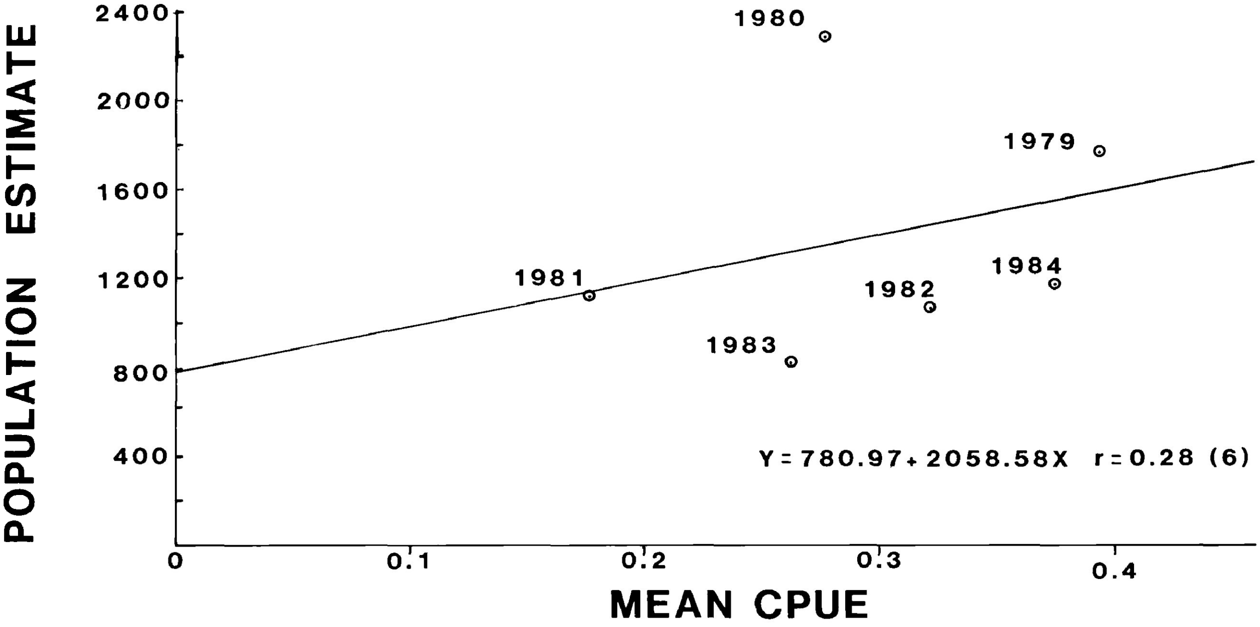
[3] Sample size

[4] Y = Number of fish estimated in population (Petersen method)

* $P < 0.05$

** $P < 0.01$

Figure 51. Regression of Schumacher-Eschmeyer population estimates with catch per unit effort (from six-foot trap nets) per year for northern pike from Henderson Lake, 1979 to 1984.


POPULATION ESTIMATE
2400
2000
1600
1200
800
400
0
0.1
0.2
0.3
0.4
MEAN CPUE
1980
1979
1981
1982
1984
1983
Y = 780.97 + 2058.58X r = 0.28 (6)

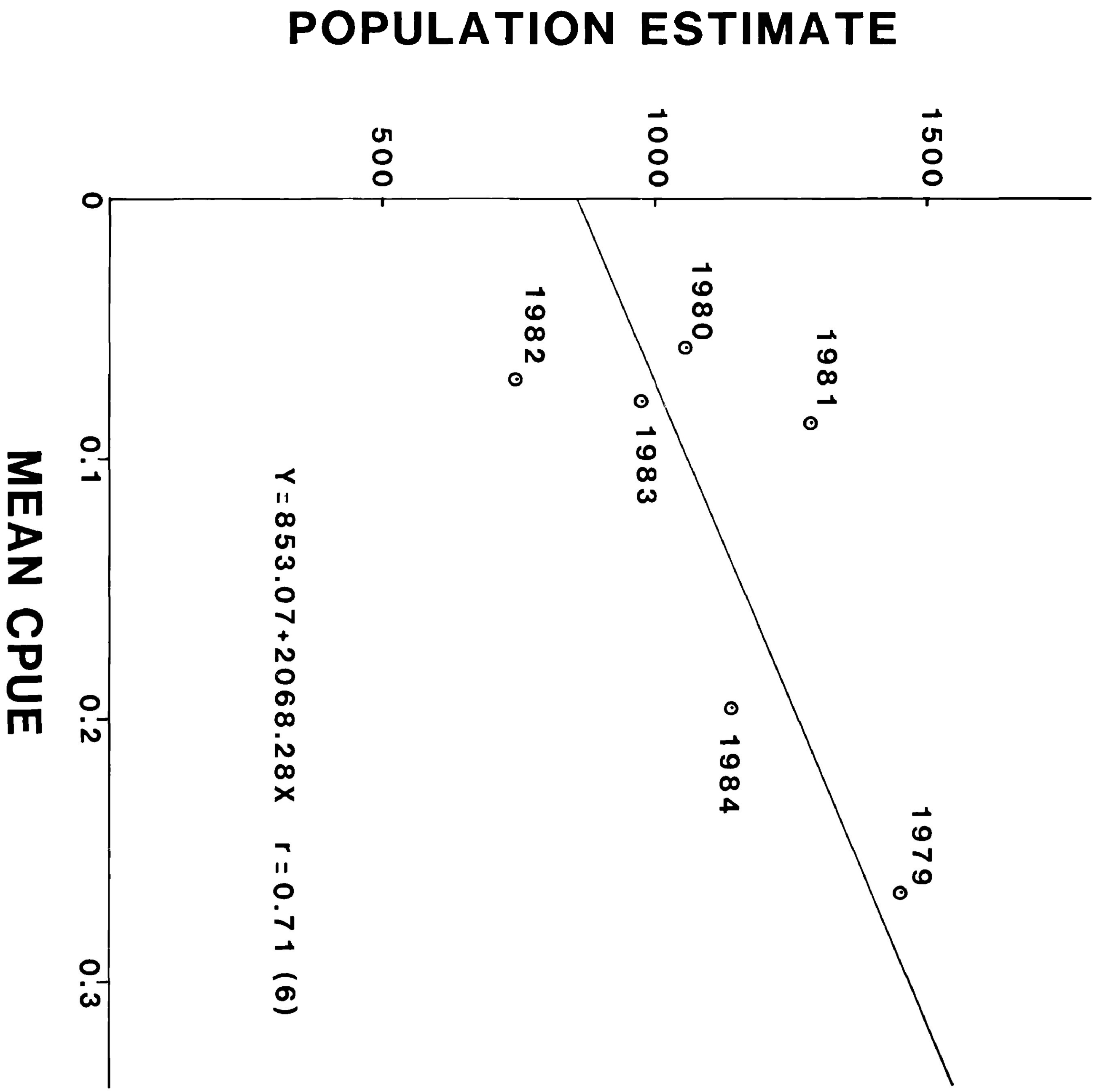
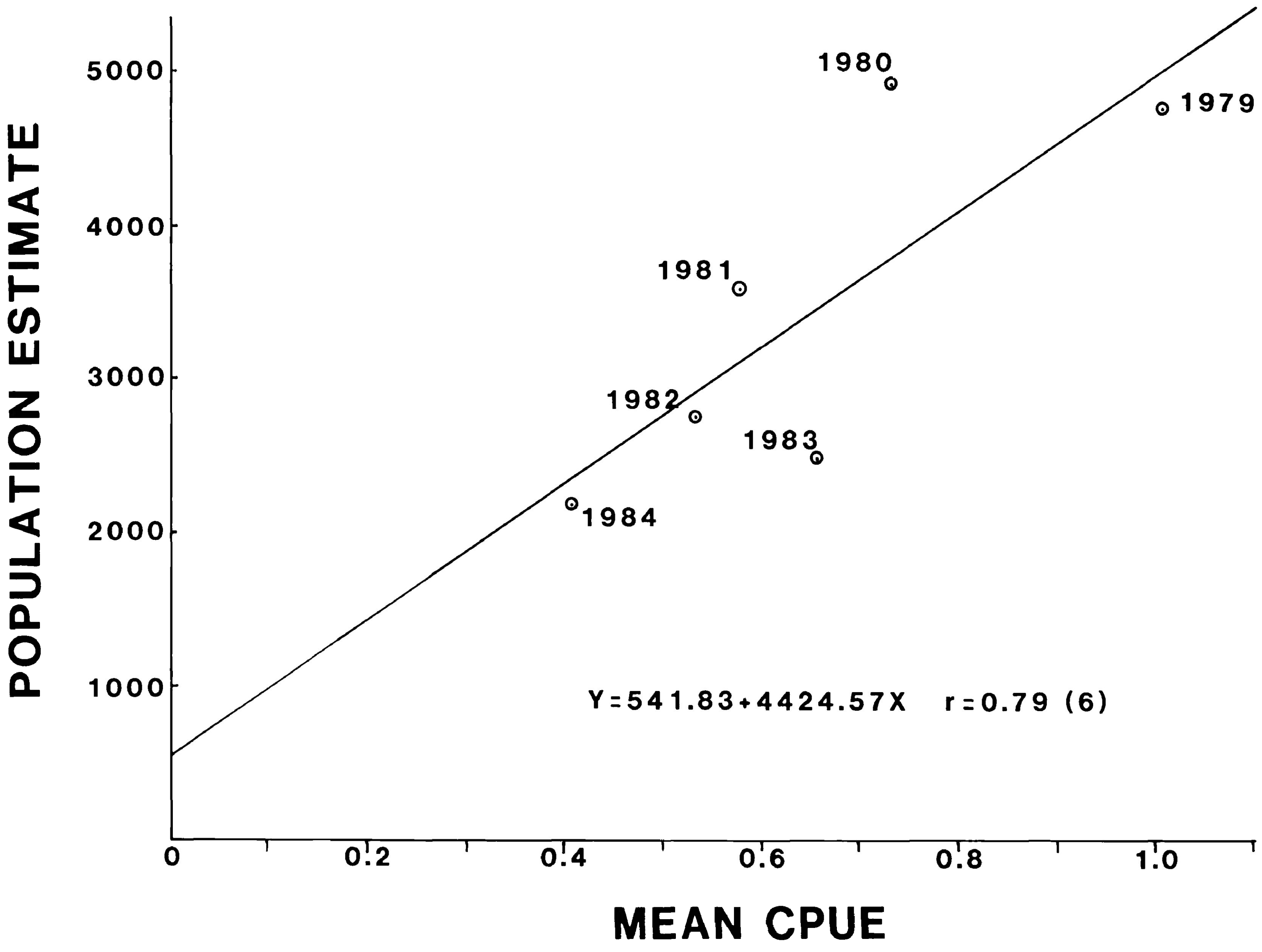

POPULATION ESTIMATE
500
1000
1500
0
0.1
0.2
0.3
MEAN CPUE
1979
1980
1981
1982
1983
1984
Y=853.07+2068.28X r=0.71 (6)

Figure 53. Regression of Schumacher-Eschmeyer population estimates with catch per unit effort (from six-foot trap nets) per year for walleye, northern pike and white sucker combined, from Henderson Lake, 1979 to 1984.


POPULATION ESTIMATE
5000
4000
3000
2000
1000
0
0.2
0.4
0.6
0.8
1.0
MEAN CPUE
1980
1979
1981
1982
1983
1984
Y=541.83+4424.57X r=0.79 (6)

Removals

A total of 779 walleye and 163 northern pike were removed from Henderson Lake in 1982 (Table 30). One of the walleye captured from either a gill or trap net escaped back into the lake. During the entire 1982 field season only dead northern pike were removed.

In 1983 there was no large scale removal of walleye. A total of 106 walleye and 181 northern pike were removed as mortalities and for age and feeding studies and 66 white sucker died from either netting or handling (Table 30).

Removals in 1984 consisted of 46 walleye, 167 northern pike and 2 white sucker (mortalities) (Table 30). Over the study period, walleye removals ranged from 5.69 kg/ha in 1981 to 0.32 in 1984 (Table 31). In 1982 the biomass removed was more than that estimated to be present in the spring. This anomaly could be the result of an increase in biomass production over the summer, increased recruitment, or as a result of an inaccurate spring estimate. Northern pike harvest varied from 2.12 kg/ha in 1981 to the current low of 1.27 in 1984 (Table 31).

The number of walleye removed during the three years of heavy exploitation varied from a high in 1981 of 94.2 percent to 82.4 percent in 1982 of the estimated fish present (Schumacher-Eschmeyer estimate) (Table 32). In the last two years removals were reduced to approximately 30 percent of the estimated population of walleye. Although 84 percent of the walleye were removed in 1980, in 1981 the population was still estimated to be within 75 percent of that in 1980 (1183/1588 = 0.745). Similarily after removing 94 percent of the 1981

Table 30. Number and weight (kg) of walleye, northern pike and white suckers, removed from Henderson Lake, 1982 to 1984.

		1982		1983		1984	
Fish Species	Period of Removal	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)
Walleye	population estimate	16	11.8	2	1.4	1	0.7
	summer gill nets	127	75.2	72	68.2	8	6.1
	fall removals	636[1]	553.0	31	26.3	38[2]	42.0
	Total	779	640.0	105	95.9	47	48.8
Northern pike	population estimate	20	23.5	15	12.8	103	94.2
	summer gill nets	37	31.9	116	126.1	3	3.6
	summer trap nets (stomach pumping)					10	11.6
	fall fecundity	106[3]	158.0	50[4]	77.3	62	96.1
	Total	163	213.3	181	216.2	178	205.5
White sucker (all as mortalities)	population estimate	9	11.0	9	5.1	1	0.5
	summer gill nets			57	9.0	1	1.0
	Total	9	11.0	66	13.1	2	1.5

[1] 228 trap net; 409 gill net

[2] +4 small walleye; 0.23 kg

[3] 6 trap net; 100 gill net

[4] 44 gill net; 6 hoop net

Table 31. Numbers and biomass of walleye and northern pike removed from Henderson Lake, 1980 to 1984.

Species	Year	Number of fish removed	Weight of fish removed (kg)	Weight removed (kg/ha)	Mean weight of individuals removed (kg)	Estimated biomass present from spring estimate (kg/ha)
Walleye	1980	1332[1]	817.85	5.42	0.614	–
	1981	1115[1]	858.55	5.69	0.770	–
	1982	779	640.01	4.24	0.822	4.18
	1983	106	95.85	0.64	0.913	1.69
	1984	47	48.75	0.32	1.06	0.97
Northern pike	1980	226[1]	252.22	1.67	1.116	–
	1981	262[1]	319.64	2.12	1.220	–
	1982	163	213.35	1.41	1.309	9.12
	1983	181	216.14	1.43	1.194	6.42
	1984	178	205.50	1.36	1.154	8.93

[1] Data from Nunan (1982)

Table 32. Walleye removal as a percentage of catchable fish present in Henderson Lake, 1979 to 1984.

Year	Yield		Mean individual weight (kg)	Population estimate (±95% C.L.)	Percent fish removed (±95% C.L.)
	Number	Weight (kg/ha)			
1979	--			1336 (1122-1652)	
1980	1332[1]	5.42	0.614	1588 (1310-2016)	83.9 (66.1-101.7)
1981	1115[1]	5.69	0.770	1183 (1008-1431)	94.2 (77.9-110.6)
1982	779	4.24	0.822	945 (750-1276)	82.4 (61.1-103.9)
1983	105	0.64	0.913	375 (334-428)	28.0 (24.0-31.4)
1984	47	0.32	1.060	152 (133-177)	30.9 (26.6-35.3)

[1] Data from Nunan (1982)

walleye the 1982 population estimate was still within 80 percent of that in 1981 (945/1183 = 0.800). It was not until 82 percent of the 1982 fish had been removed that the 1983 population was calculated to be only 40 percent of the 1982 estimate (375/945 = 0.400).

Exploitation rates (number of marked fish removed over the total number of fish marked) were calculated for each year (1980 to 1984) of walleye removal (Table 33). These actual rates did not agree closely with the estimated exploitation rate (total fish removed over the total estimated population) until after the collapse of the walleye population. Thus only the 1983 and 1984 actual and estimated exploitation rates show close agreement. Exploitation rates calculated from size-class partitioned walleye population estimate (Latta 1959; Table 5) are marginally closer to the actual exploitaiton rates (ie. rates calculated from the number of marked and unmarked fish harvested) than estimates made using the unpartitioned Schumacher-Eschmeyer values (Table 33).

Mean Age and Mean Age to Maturity

Walleye mean age declined for two years following exploitation (1981 and 1982), after which it then steadily increased to 6.7 years in 1984 the exact same value calculated for 1979 (Table 34). The increasing mean age of the catchable walleye population in later years, undoubtedly reflects the poor recruitment of younger walleye.

Sexual maturity is difficult to determine for walleye in the summer (Olynyk 1980). However, to ensure a large sample size, both sex and the state of gonad development was assessed in the summer of 1983. Errors in summer maturity determination for both walleye and

Table 33. Comparison of walleye exploitation rates for Henderson Lake, 1980 to 1984.

	1980	1981	1982	1983	1984
Total number marked removed Total number marked	$\frac{276}{561} = 49\%$	$\frac{215}{417} = 52\%$	$\frac{137}{210} = 65\%$	$\frac{67}{199} = 34\%$	$\frac{30}{121} = 25\%$
Total number removed Total number estimated (Schumacher-Eschmeyer)	$\frac{1332}{1588} = 84\%$	$\frac{1115}{1183} = 94\%$	$\frac{779}{945} = 82\%$	$\frac{105}{375} = 28\%$	$\frac{43}{152} = 28\%$
Total number removed Total number estimated (Latta-type estimate)	$\frac{1332}{1753} = 76\%$	$\frac{1115}{1278} = 87\%$	$\frac{779}{986} = 79\%$	$\frac{105}{380} = 28\%$	$\frac{43}{155} = 28\%$

Table 34. Mean ages of spring captured walleye and northern pike from Henderson Lake, 1979 to 1984.

	Walleye				Northern Pike
	Mean age (years)	Mean age to maturity (years)			Mean age (years)
Year	combined	combined	male	female	combined sexes
1979	6.7	—	—	—	6.4
1980	6.5	5.2[1]	5.2[1]	5.2[1]	6.7
1981	5.8	4.6[1]	4.8[1]	4.4[1]	7.2
1982	4.4	3.9	3.3	4.6	5.0
1983	5.7			—	4.9
1984	6.7	<4	—	—	4.8

[1] Data from Nunan (1982)

northern pike, resulted in several older fish being assessed as immature (Tables 35 and 36). Furthermore mean age to maturity calculations from very small sample sizes of immature fish are not realistic (Olynyk 1980), so walleye mean age to maturities were not calculated for 1983 and 1984. The available walleye mean age to maturity values (1980 to 1982), continued to decrease as exploitation continued (Table 34). In 1984, with the exception of four very small walleye (170-190 mm), all the fish examined were mature.

Northern pike mean age rose from 6.4 years in 1979 to 7.2 in 1981, but has since been decreased to a present low of 4.8 in 1984 (Table 34). This trend is a result of recently increased recruitment of young to the fishing gear. Mean age to maturity calculations were not done for pike due to small sample sizes. In 1982 only one pike older than age 1 (age 5) was assessed as immature. Several males and females were immature at age 6 in 1983, but maturity determinations during the summer months are error prone.

Sex Ratios

Most walleye captured in spring trap nets were males. In 1982, 17 males and 14 females were captured. In 1983, 22 males and 4 females of known sex were caught, while in 1984, 66 males and 31 females were captured. The high number of males present on spawning shoals may reflect behavioural differences between sexes (Eschmeyer 1950), rather than the true ratio in the population.

Fall 1982 walleye samples consisted of 74 males and 61 females for a sex ratio of 1.21 males per female. Thirty one walleye were removed for fecundity samples in 1983 (17 mature females, 13 mature

Table 35. Number of walleye per age by maturity, males and females, from Henderson Lake, 1982 to 1984.

	1982				1983				1984			
	Males		Females		Males		Females		Males		Females	
Age	immature	mature	immature	mature	immature	mature	immature	mature	immature	mature	immature	mature
2	7		5						2		2	
3	4	14	18	1	1	5						
4	2	28	10	12	4	10	1	12		3		2
5		7	1	14		11		21		9		4
6		14		17		9		8		4		2
7		11		12		3		3		4		1
8		1		1		5		3		3		3
9		2		2		1		2		1		2
10		1				2						
11				2								
13		2										
14				2								
TOTAL	13	80	34	63	6	46	2	49	2	24	2	14

Table 36. Number of northern pike per age by maturity, males and females, from Henderson Lake, 1982 to 1984.

	1982				1983				1984			
	Males		Females		Males		Females		Males		Females	
Age	immature	mature	immature	mature	immature	mature	immature	mature	immature	mature	immature	mature
1	1	1	2	1	9	3	5	1	19	1	6	
2		2		2	5	7	7	10	5	10	3	11
3		9		1			2	7		3		6
4		6		3	1	4	2	5				3
5		18		6	1	10		5		2		5
6		11		6	2	18	2	23		7		6
7		5		3		5		8		5		8
8								1		2		8
11												1
14								1				
TOTAL	2	52	2	22	18	47	18	61	24	30	9	48

males and 1 immature male) giving a sex ratio of 0.82 males per female. In 1984, 38 fish were captured, 2 immature males, 24 mature males, 2 immature females and 10 mature females, giving a sex ratio of 2.17 males per female. Although these sex ratios are probably less biased than those provided from spring trap net catches, sample sizes are quite small. Sex ratios from fall gill netting could also be influenced by the differential behaviour of sexes.

Male northern pike predominated in spring trap net catches, with 16.6, 11.8 and 5.1 known males per female being captured in 1982, 1983 and 1984 respectively. Male gonad products were, however, able to be extruded for a longer period after spawning time than those from females. Fall fecundity removal yielded 2 immature males, 25 mature males, 2 immature females and 21 mature females for a sex ratio of 1.17 males per female in 1983. The 1984 ratio was 0.84 from 1 immature male, 25 mature males, 2 immature females and 29 mature females.

Annual Production Estimation

Various problems complicated the estimation of walleye production (Table 37). Some values of Z (the instantaneous rate of mortality), were negative, the result of fewer fish being caught in a certain year-class in one year than in a subsequent year. This resulted from younger age-classes (age 4 to 7) not being fully vulnerable to the gear in one year, compared with the following year. Any negative Z values were assumed as zero in sequential production calculations.

Negative G (instantaneous rate of growth) values were estimated

Table 37. Annual production and biomass estimates for walleye in Henderson Lake, 1979 to 1984. Survival rates (S); total mortality rate (A); instantaneous rate of mortality (Z); instantaneous growth rate (G); weight change factor (K); initial cohort biomass (Wo); mean cohort biomass ($\overline{W}$); annual production (P).

1979 - 1980

Age Class	S	A	Z	G	K=(G-Z)	Wo	$\overline{W}$	P
4 - 5	1.261	-0.261	0^1	0.344	0.344	165.19	196.89	67.73
5 - 6	1.198	-0.198	0^1	0.351	0.351	96.49	115.59	40.57
6 - 7	1.851	-0.851	0^1	0.119	0.119	129.82	137.86	16.41
7 - 8	0.748	0.252	0.291	0.193	-0.098	110.21	104.98	20.26
8 - 9	0.629	0.371	0.464	0.304	-0.160	58.96	54.49	16.56
9 - 10	0.488	0.512	0.718	0.267	-0.451	88.64	71.35	19.05
10 - 11	0.738	0.262	0.304	0.179	-0.125	69.91	65.72	11.76
11 - 12	0.522	0.478	0.650	0.287	-0.363	137.18	115.04	33.02
12 - 13	0.320	0.680	1.139	0.136	-1.003	85.95	54.26	7.38
13 - 14	0.471	0.529	0.754	0.204	-0.550	24.00	18.46	3.77
						Total	934.64	236.51
						Total (kg ha^{-1})	6.19	1.57

Table 37. (Cont'd)

1980 - 1981

Age Class	S	A	Z	G	K=(G-Z)	Wo	$\overline{W}$	P
4 - 5	0.924	0.076	0.079	0.666	0.587	66.52	90.50	60.27
5 - 6	0.744	0.256	0.296	0.551	0.255	293.75	334.60	184.36
6 - 7	0.398	0.602	0.921	0.437	-0.484	164.18	130.15	56.88
7 - 8	0.288	0.712	1.246	0.440	-0.806	270.75	273.28	120.24
8 - 9	0.425	0.575	0.856	0.297	-0.559	99.92	76.54	22.73
9 - 10	0.846	0.154	0.167	0.336	0.169	50.27	54.77	18.40
10 - 11	0.050	0.950	2.996	0.294	-2.702	56.48	19.50	5.73
11 - 12	0.044	0.956	3.124	0.211	-2.913	61.65	20.01	4.22
12 - 13	0.373	0.627	0.986	0.152	-0.834	95.40	64.71	9.84
13 - 14	0.625	0.375	0.470	0.416	-0.054	31.51	30.67	12.76
						Total	1094.73	495.43
						Total (kg ha^{-1})	7.25	3.28

Table 37. (Cont'd)

Age Class	S	A	Z	G	K=(G-Z)	Wo	$\overline{W}$	P
1981 - 1982								
4 - 5	0.600	0.400	0.511	0.137	-0.374	132.78	110.78	15.18
5 - 6	1.038	-0.038	0[1]	0.075	0.075	119.61		—
6 - 7	0.249	0.751	1.392	-0.203	-1.595	378.86	189.33	-38.43
7 - 8	0.976	0.024	0.025	-0.135	-0.160	101.19	93.51	-12.62
8 - 9	0.061	0.939	2.797	0.316	-2.481	120.95	44.67	14.12
9 - 10	0.588	0.412	0.531	-0.344	-0.875	57.15	38.09	-13.10
10 - 11	0.515	0.485	0.663	-0.247	-0.910	59.50	39.07	-9.75
						Total	515.45	-4.45
					Total (kg ha^{-1})		3.42	—
1982 - 1983								
4 - 5	0.453	0.547	0.792	0.173	-0.619	130.83	97.54	16.88
5 - 6	0.532	0.468	0.631	0.110	-0.521	91.37	71.21	7.83
6 - 7	0.232	0.768	1.461	0.029	-1.432	133.82	71.13	2.06
7 - 8	0.387	0.613	0.949	0.103	-0.846	76.91	51.90	5.35
8 - 9	0.188	0.812	1.671	-0.107	1.778	86.24	40.31	-4.31
						Total	332.09	27.81
					Total (kg ha^{-1})		2.20	0.18

Table 37. (Cont'd)

1983 - 1984

Age Class	S	A	Z	G	K=(G-Z)	Wo	$\overline{W}$	P
4 - 5	0.494	0.506	0.705	0.436	-0.269	45.73	40.10	17.48
5 - 6	0.306	0.694	1.184	0.365	-0.819	70.48	48.12	17.56
6 - 7	0.413	0.587	0.884	0.279	-0.605	54.22	40.68	11.35
7 - 8	0.605	0.395	0.503	0.255	-0.248	31.92	28.27	7.21
8 - 9	0.278	0.722	1.280	0.242	-1.038	33.01	20.54	4.97
9 - 10	0.400	0.600	0.916	0.280	-0.636	14.54	10.76	3.01
10 - 11	0.500	0.500	0.693	0.085	-0.608	6.35	4.76	0.40
						Total	193.23	61.98
						Total (kg ha^{-1})	1.28	0.41

---

[1] Z values less than zero were assumed to be zero

during the years of heavy exploitation. The formula for the calculation of growth (log (final mean weight/initial mean weight)), shows that a negative value reflects a net loss in mean weight (calculated from mean length), of a year-class over a year. This resulted from the heavy exploitation of walleye, selectively cropping the larger more susceptible individuals within a year-class, leaving behind smaller fish. Because of negative growth, production in several age-classes was also negative. Any negative production was summed with production estimates from each age-class, and in one year (1981-1982) produced a negative total production value.

Walleye annual production was highest in 1980-1981 (3.28 kg/ha), decreasing rapidly to a negative value by 1981-1982. Since then production has slowly increased to 0.41 kg/ha in 1983-1984. Large increases in walleye growth from 1983 to 1984, resulted in higher production(Table 37).

The highest turnover ratio ($P/\bar{B}$) for walleye occured in 1980-1981, followed by 1983-1984 and then closely by 1979-1980 (Table 38). The 1982-1983 total $P/\bar{B}$ ratio was quite low (0.08) and the ratio was not calculated for 1981-1982 because of the negative annual production.

The proportion of total mortality attributable to fishing and natural mortality was calculated for walleye in the 1983-1984 season (Table 39). An increased susceptibility to fishing mortality at younger ages is evident. Fishing and natural mortality account for 47.5 and 52.5 percent of the 1983-1984 total walleye mortality respectively. The 1979-1980 (pre-exploitation) natural mortality from ages 7 to 11 was 0.35 (1 - 204/312; Fig. 13), and in 1983-1984 was 0.33 (1 - 64/95; Table 39). This seems to indicate that natural

Table 38. Turnover ratios (P/$\bar{B}$) for walleye from Henderson Lake, 1979 to 1984.

	1979-1980			1980-1981			1981-1982			1982-1983			1983-1984		
Age Class	P[1]	$\bar{B}$[2]	P/B	P	$\bar{B}$	P/$\bar{B}$	P	$\bar{B}$	P/$\bar{B}$	P	$\bar{B}$	P/$\bar{B}$	P	$\bar{B}$	P/$\bar{B}$
4 - 5	67.73	229.47	0.30	60.27	93.06	0.65	15.18	112.08	0.14	16.88	100.66	0.17	17.48	40.34	0.43
5 - 6	40.57	130.34	0.31	184.36	336.30	0.55	–	126.72		7.83	72.80	0.11	17.56	50.80	0.35
6 - 7	16.41	200.28	0.08	56.88	132.68	0.43	-34.43	227.88		2.06	82.87	0.02	11.35	41.93	0.27
7 - 8	20.26	105.06	0.19	120.24	195.84	0.61	-12.62	93.72		5.35	54.96	0.10	7.21	28.42	0.25
8 - 9	16.56	54.62	0.30	22.73	78.54	0.29		–		-4.31	50.39		4.97	22.34	0.21
9 - 10	19.05	72.56	0.26	18.40	54.88	0.34							3.01	11.12	0.28
10 - 11	11.76	65.78	0.18										0.40	4.90	0.08
11 - 12	33.02	116.29	0.28												
12 - 13	7.38	58.73	0.13												
Totals	232.74	1033.13	0.23	462.88	891.30	0.52	-38.87	560.40	–	27.81	361.68	0.08	61.98	199.85	0.31

[1] Production estimate (Ricker 1975) in kg yr^{-1}.

[2] Mean biomass calculated as the average spring total weight of walleye between subsequent years.

Table 39. Calculation of natural mortality (M) from total mortality (Z) and fishing mortality (F), for walleye in Henderson Lake, 1983-1984.

	1983	1984			
Age	Number of fish	Number of fish	Z	F	M
3	9	–			
4	85	3	0.66 (6)[1]	0.66 (100.0)[2]	0.0 (0.0)[3]
5	111	42	0.51 (43)	0.34 (67.4)	0.17 (32.6)
6	75	34	0.69 (77)	0.30 (42.9)	0.39 (57.1)
7	38	31	0.59 (44)	0.21 (36.4)	0.38 (63.6)
8	36	23	0.39 (15)	0.21 (53.3)	0.18 (46.7)
9	15	10	0.72 (26)	0.25 (34.6)	0.47 (65.4)
10	6	6	0.60 (9)	0.20 (33.3)	0.40 (66.7)
11		3	0.50 (3)	0.33 (66.7)	0.17 (33.3)
Total	375	152	0.41(223)	0.19 (47.5)	0.22 (52.5)

---

[1] Number of fish that died over the year 1983-1984.

[2] Fishing mortality as a percentage of total mortality.

[3] Natural mortality as a percentage of total mortality.

mortality, at least for ages 7 to 11, has not changed substantially as a result of exploitation.

Northern pike production estimates also generated negative production in one year-class (Table 40). Although fewer older fish were present in 1983-1984, the production from a single age-class (age 6-7) was higher (0.24 kg/ha/yr) than from the entire 1982-1983 value (0.12 kg/ha/yr), generated from four age-classes. Due to the variability in aging before and after 1982, production estimates were not calculated before the 1982-1983 period.

Table 40. Annual production and biomass estimates for northern pike in Henderson Lake, 1982 to 1984. Survival rate (S); total mortality (A); instantaneous rate of mortality (Z); instantaneous growth rate (G); weight change factor (K); initial cohort biomass (Wo); mean cohort biomass ($\overline{W}$); annual production (P).

Age Class	S	A	Z	G	K	Wo	$\overline{W}$	P	$\overline{B}$	P/$\overline{B}$
1982-1983										
6 - 7	0.1922	0.8078	1.6494	0.0408	-1.6086	472.1	234.74	9.58	283.30	0.03
7 - 8	0.0519	0.9481	2.9575	0.2082	-2.7493	134.1	45.66	9.51	71.35	0.13
8 - 9	0	0	0	—	—	—		—		
9 - 10	0	0	0	—	—	—		—		
10 - 11	0.3333	0.6667	1.0986	0.1614	-0.9372	10.7	6.94	1.12	7.15	0.15
11 - 12	0	0	0		—	—		—		
12 - 13	0.3333	0.6667	1.0986	-0.1854	-1.2840	15.7	8.84	-1.64		
						Total	296.18	18.57	302.10	0.06
						Total (kg ha^{-1})	1.96	0.12		
1983-1984										
6 - 7	0.9485	0.0515	0.0529	0.0997	0.0468	357.6	366.10	36.50	354.31	0.10
7 - 8	2.1852	—	—			94.5				
8 - 9	0		—			8.6				
9 - 10	0		—			—				
10 - 11	0		—			—				
11 - 12	0					4.2				
12 - 13	0					4.6				
						Total	366.10	36.50	354.31	0.10
						Total (kg ha^{-1})	2.43	0.24		

Discussion

Populations Estimates

Spring mark and recapture population estimates using trap nets, effectively estimate only that portion of the population completely vulnerable to the gear. Some of the differences in Petersen and Schumacher-Eschmeyer walleye population estimates (Table 3,4), and exploitation rates (Table 33) may be the result of only large sized, sexually mature fish being vulnerable during the spring estimate. In nearby Dexter Lake, Moening (1975) also had difficulty in sampling age 1 to 3 walleye during population estimates. On Lake Manitoba while age 5 and 6 dominated the summer commercial catches, by fall age 2 and 4 fish predominated (Lysack 1981). Therefore differential seasonal vulnerability of walleye, by size, does occur.

Petersen estimates were calculated on walleye removed with both trap and gill nets, whereas Schumacher-Eschmeyer population estimates involved only trapnets. While walleye were not differentially vulnerable by size to gill nets compared to trap nets (Fig. 10) in 1983 and 1984, northern pike (Fig. 11) and white sucker (Fig. 12) were. The failure of gill nets to capture smaller walleye than trap nets may simply reflect the much reduced availability of small walleye in those later years. The removal of smaller walleye (not vulnerable to trap nets) by gill nets, during 1980-1981 (the years of heavy exploitation) may have delayed the dramatic reduction in walleye numbers until the third year of exploitation. The population estimates mainly sampled larger, sexually mature fish, which after spawning return to deep water (Raney and Lachner 1942). Mature and immature fish then mixed and gill net catches now included smaller fish. Since the Petersen population estimate would then include a larger number of unmarked fish, this increased the estimate of the population size.

Gerking (1957) suggested that a pecking order may cause smaller fish to leave preferred areas. In arctic fish populations, similar hypotheses have been presented. Unexploited lake whitefish (Coregonus clupeaformis) appear to employ a behaviour related control over their population size (Healey 1980). Johnson (1976) postulated that the bell shaped catch curve characteristic of arctic charr (Salvelinus alpinus) may be the result of controlled recruitment involving a feedback mechanism which dampened any fluctuations in year-class strength. As a result only recruitment such as is necessary to achieve an equilibrium with mortality is permitted. Adult charr maintain fish within the juvenile mode, in a peripheral position, through some form of suppressive force. When the adults can no longer maintain juveniles within that mode, a number of juveniles undergo rapid growth until they achieve a size admitting them to adult status.

Similarly adult walleye could maintain a social dominance over juveniles in Henderson Lake. While adult walleye do not appear to inhibit the growth rate of young walleye, they may confine juveniles to a less preferred habitat and/or an immature reproductive status. This would result in reduced juvenile vulnerability to trap net capture until sufficient numbers of dominant older adults had been removed. As the harvest of the dominant adults continued the younger fish begin to increasingly frequent areas formerly dominated by the older fish, where their vulnerablility to trap netting increases. By this mechanism walleye continued to be recruited into the fishery until the third year of exploitation. The depletion of the "reservoir" of juvenile recruits when accompanied by the poor survival of new year-classes, due to abiotic conditions, led to a shortage of new recruits and a catastrophic decline in numbers following the third year of exploitation.

Experimental exploitations of white sucker populations have yielded similar results i.e. following an initial heavy removal a higher than expected number of fish occurs in the next year (Olson 1963, Rawson and Elsey 1950). This "filling of the void" in a year's time was attributed to increased recruitment, survival and growth, but similar social interactions to those proposed by Johnson (1976), could also account for such an observed result.

Havey et al. (1981) found that Petersen population estimates brook trout (Salvelinus fontinalis) for were higher than either Schumacher-Eschmeyer or Schnabel estimates but always fell within the 95 percent confidence limits. They recommended Petersen estimates as the best choice, as a waiting period assured even mixing of marked and unmarked fish and there was no problem of "trap-happy" fish. Henderson Lake Petersen walleye estimates in 1980 and 1981 were above the upper 95 percent limit of the Schumacher-Eschmeyer estimate and below the lower limit in 1983 (Table 3,4), indicating poor agreement between methods.

Moenig (1975) found walleye travelled throughout Dexter Lake, Miller (1948) found pike had moved entirely around Square Lake, Alberta (2.5 by 5 kilometers) in 10 days, and Mosindy (1980) observed pike had travelled throughout Savanne Lake in a few days. This indicates that mixing of marked and unmarked fish should not have been a problem in Henderson Lake, however, differential behaviour of sexually mature and immature fish could bias estimated numbers. Latta (1959) stated that size selectivity of a netting gear is probably due to fish behaviour rather than the gear itself, with larger fish being more active.

A virtual walleye population estimate for 1980 was calculated by summing the 1984 estimate (Petersen) together with all walleye removed before that time:

Year	Removals
1980	1332
1981	1115
1982	779
1983	106
1984	169 (estimate)
Total	3501

This quite conservative estimate, does not take into account any natural mortality. In addition this estimate undoubtedly includes fish not vulnerable to the gear in 1980, but an estimate of recruitment is possible from the age-frequency distribution (Fig. 13). The increase in the number of fish caught in a year-class from one spring to the next was calculated for 1981 to 1984 for fish less than age 6 (fully recruited age). It was assumed that walleye recruited from 1980 to 1981 may have become vulnerable to removal during the summer of 1980 and so were not included with the Petersen estimate.

This total of 274 fish added to the 2707 Petersen estimate gives an estimated number of 2981 fish in 1980. The Petersen estimate was therefore much closer to the virtual estimate of 3501 fish than the 1588 fish estimated by the Schmacher-Eschmeyer method of the same year.

The original Schumacher-Eschmeyer population estimate (Schumacher and Eschmeyer 1943) was performed in a 27.52 ha pond and resulted in under-estimates of two species, while over-estimating five other species, some quite significantly. They stated that although the estimate was not very accurate it did give general trends, but nets were apparently quite selective with regard to species, location and time of day.

The Petersen method appeared to generate more useful walleye estimates for Henderson Lake than the Schumacher-Eschmeyer method, for estimating the effects of exploitation. The Petersen estimate was much closer to the virtual walleye estimate when the population was large, and immature fish were plentiful. The multiple mark and recapture method (Schumacher-Eschmeyer) and Petersen only agreed after the population collapse in 1983, as did estimated and actual exploitation rates (Table 33). This agreement could be the result of most of the fish in the population becoming mature, making the entire population vulnerable to trap nets on spawning shoals.

In nearby, lightly exploited, Savanne Lake, estimated (using the Schumacher and Eschmeyer population estimate) and actual exploitation rates have shown close agreement for several years of study (D. Baccante pers. comm.). This suggests that Schumacher-Eschmeyer estimates may not drastically under-estimate walleye numbers in all lakes. Savanne Lake, being more turbid than

Henderson, might have smaller immature walleye frequenting shallower water during the spring, making them more vulnerable to trap nets. The basin morphometry of Savanne Lake is more "bowl" shaped than that of Henderson. This may also influence fish movements. Both or either of these factors might contribute to more accurate spring population estimates in Savanne Lake.

Multiple censuses take less time than Petersen estimates (Havey et al. 1981). However, Petersen estimates gave a better indication of total walleye abundance, while Schumacher-Eschmeyer estimates apparently only measured brood stock size. The more accurate assessment of total walleye abundance given by the Petersen method, yielded a better indication of stock depletion, which would allow for sounder management decisions, for Henderson Lake.

Northern pike numbers have not increased in response to walleye exploitation (Table 3), even though pike are assumed to compete with walleye because of their similar food habits (Moenig 1975; Moyle and Franklin 1953; Johnson 1949). However, just because two species eat the same food is not a just cause for assuming competition (Larkin 1956).

Removal of pike (Forney 1980) and white sucker (Johnson 1977) in two other studies seemingly benefited walleye numbers. However, addition of pike in one study (Carlander 1958) and the removal of white sucker in another lake (Olson 1963) had little effect on the walleye numbers. Removal of coarse fish in Bass Lake, Indiana, increased game fish populations, including walleye (Ricker and Gottschalk 1941). The variable results of these studies show that assuming interactive "competition" between species is not always valid.

In the present study northern pike and white sucker, at least over the short term, are not filling any vacant niche resulting from the removal of a large part of the walleye population. Kennedy (1947) noted that, after a large walleye winter kill in Tathlina Lake, walleye became prevalent again after several years. He felt this demonstrated that competition and predation from older fish of all species must have been negligible. Although a long term response could still occur in Henderson Lake, pike and suckers would have to dramatically increase their numbers to surpass their pre-walleye exploitation level of abundance. Larkin (1956) stated that flexible growth rates combined with high reproductive potential permits fish populations to tide-over unfavourable periods of competition. As walleye show increases in both these responses, in Henderson Lake, they seem, at least over the short term, well equiped to challenge any interspecific competition.

Growth Response

One response of walleye to lower densities, resulting from exploitation, has been a significant increase in the growth rate of younger fish (Fig. 16; Appendix II, Table 1). Various studies record a walleye growth response caused by exploitation (Lysack 1982; Carlander and Payne 1977a; Chevalier 1977; Nepszy 1977; Schupp and Macins 1977; Spangler et al. 1977; Moenig 1975; Parsons 1970; Regier et al. 1969; Wolfert 1969; Kennedy 1948).

In contrast Kempinger and Carline (1977) could not correlate the growth rates of walleye to changes in population density or year-class strength. Possibly the population was not sufficiently reduced for compensatory growth increases to occur.

In several studies the growth response of exploited fish was time delayed (Johnson 1983; Healey 1978b; Johnson 1977). Such a delay seems to have occured in Henderson Lake walleye for several year-classes. A certain time period might be necessary for perch densities to increase to the point where an increase in prey density could then be translated into increased walleye growth.

In addition, the growth response in Henderson Lake walleye was not only time delayed but confined to younger age groups. This makes it's detection much more difficult under normal sampling regimes applied to boreal lake populations. Most likely older fish direct most energy to reproductive potential, rather than somatic growth (Nikolsky 1965). Unfortunately, because of the low susceptibility of young-of-the-year and one year-old walleye to capture, no data are available for the life history period having the greatest potential for compensatory growth.

Mean northern pike lengths at age data (Table 17), determined from larger samples, fluctuated little between 1982 and 1984 (Appendix II, Table 2). Increases in length at age as detected occuring after 1982 may be an artifact caused by a failure to account for a false annulus in the earlier data (Nunan 1982). This false annulus is easily misinterpreted and usually occurs during the first growing season of northern pike (Wainio 1966).

Differential growth between sexes is reported for both walleye (Schainost 1983; Paxton et al. 1981; Lewis 1970; Priegel 1969a; Rawson 1957; Stroud 1949; Carlander 1945) and northern pike (Kipling 1983; Wolfert and Miller 1978; Brown and Clark 1965). However, in a few studies no sexual dimorphism was observed in the growth of pike (Mann

1976; Miller and Kennedy 1948) or walleye (Kennedy 1949).

Female walleye, ages I to XII, in Henderson Lake were greater in mean length than males (Appendix II, Tables 1, 2). However, these differences were not significant at the 0.05 level. Female pike were also larger than males for a given age, but not significantly (Appendix II, Tables 4, 5).

Lee's phenomenon has been documented in both walleye (Wolfert 1977; Forney 1966; Carlander 1945) and northern pike (Mosindy 1980; Wolfert and Miller 1978; Mann 1976; Miller and Kennedy 1948). The lack of Lee's phenomenon in Henderson Lake walleye agrees with other studies (Erickson 1983; Schmulbach 1959), and may simply reflect their relatively slow growth. The differences in backcalculated and empirical length at age (Fig. 21, 22, 23), for younger walleye, seem the result of increased growth at age in response to exploitation, as no long term natural increases in the backcalculated length at age were detected.

The differences between northern pike backcalculated and empirical data (Fig. 24, 25, 26), simply reflect Lee's phenomenon.

Length-weight regressions were determined from spring captured fish and included gonadal products. The significant differences between walleye male and female length-weight relationships, in 1984, may result from the increased egg production by females at the expense of somatic growth.

Henderson Lake walleye possess large slope values compared to other populations with regard to length-weight regression values (Table 41). This large value may simply reflect that weights in the present study included gonadal products. Other studies may have been performed at other times of the year, and possibly did not include

Table 41. Length-weight regressions for walleye from various waters.

Location	Reference	Formula
Henderson Lake, Ontario	Present Study (1984)	$\text{Log } W^1 = -5.7047 + 3.2651 \text{ Log } TL^2$ (sexes combined) $\text{Log } W = -7.3959 + 3.9048 \text{ Log } TL$ (♀) $\text{Log } W = -5.1562 + 3.0580 \text{ Log } TL$ (♂)
Dexter Lake, Ontario	Moenig (1975)	$\text{Log } W = -5.3954 + 3.1867 \text{ Log } TL + 0.0106 Y$ where Y = year of capture (0,1,2)
Savanne Lake, Ontario	Sandhu (1979)	$\text{Log } W = -4.8332 + 2.9153 \text{ Log } TL$ (sexes combined)
Center Hill Reservoir, Tennesse	Muench (1966)	$\text{Log } W = -0.1719 + 3.16 \text{ Log } TL$ (sexes combined) $\text{Log } W = -0.03119 + 2.99 \text{ Log } TL$ (♀) $\text{Log } W = -0.02770 + 3.03 \text{ Log } TL$ (♂)
Lake Meredith, Texas	Kraai and Prentice (1974)	$\text{Log } W = -5.099 + 3.040 \text{ Log } TL$ (♀) $\text{Log } W = -4.584 + 2.845 \text{ Log } TL$ (♂)
Lake Sakakawea, North Dakota	Wahtola, Miller and Owen (1972)	$\text{Log } W = -5.80964 + 3.20447 \text{ Log } TL$ (sexes combined)

[1] W = weight in grams

[2] TL = total length in millimeters

gonad product weights. Significant increases in fecundity of Henderson Lake walleye may have resulted in the high slope values of the female length-weight regression. Northern pike length-weight regression values were ranked below those of most other pike populations (Table 42).

Fecundity

Significant increases were noted in the fecundity of Henderson Lake walleye and northern pike following the over-exploitation of walleye.

Increased fecundity has been related as a response to exploitation in a number of studies (Diana 1983; Healey 1978a; Jensen 1971; Kipling and Frost 1969). However, Healey (1978a) determined that fecundity responses by lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*) were not proportionally related to the rate of exploitation. Fecundity has been related to improved food availability for rainbow trout (*Salmo gairdneri*; Scott 1962), brown trout (*Salmo trutta*; Bagenal 1969), guppies (*Lebistes reticulatus*; Hester 1964), winter flounder (*Pseudopleuronectes americanus*; Tyler and Dunn 1976) and brook trout (*Salvelinus fontinalis*; Vladykov 1956; Wydoski and Cooper 1966). Improved diet has been assumed a factor modifying fecundity of lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*; Healey 1978a), walleye (Colby and Nepszy 1981) and teleosts in general (Wooton 1979). Population density and fecundity have been inversely related (Colby and Nepszy 1981; Bagenal 1973; Jensen 1971; Wolfert 1969; Svardson 1949). Bagenal (1973) suggests that this inverse

Table 42. Length-weight regressions for northern pike from various waters.

Location	Reference	Formula
Henderson Lake, Ontario	Present Study (1984)	Log W[1] = -4.6766 + 2.8054 Log TL[2] (sexes combined) Log W = -3.9029 + 2.5312 Log TL (♀) Log W = -4.3229 + 2.6781 Log TL (♂)
Savanne Lake, Ontario	Mosindy (1980)	Log W = -5.132 + 2.961 Log TL (sexes combined) Log W = -5.447 + 3.074 Log TL (♀) Log W = -5.048 + 2.931 Log TL (♂)
Lake Erie, Ontario	Brown and Clark (1965)	Log W = -4.826 + 2.902 Log TL (♀) Log W = -4.579 + 2.779 Log TL (♂)
Lake Ontario, New York	Wolfert and Miller (1978)	Log W = -5.285 + 3.035 Log TL (sexes combined)

[1] W = weight in grams

[2] TL = total length in millimeters

relationship between fecundity and fish density, helps to prevent large fluctuations in recruitment.

As fecundity increases, egg size may decrease (Scott 1962; Bagenal 1969; Svardson 1949; Mann and Mills 1979). The mean gonado-somatic index for Henderson walleye rose between 1982 to 1984 (Table 11), suggesting an overall increase in gonad size, but in 1982, the year with the largest sample size, it was poorly correlated with fecundity. Whether an increase in walleye fecundity simply results in smaller sized eggs is unknown. This parameter could be tested by measuring a number of walleye eggs each spring at spawning time, to see if egg diameter increases with exploitation.

Northern pike egg number is determined either at the time of previous spawning, or during the summer before the spawning takes place (Kipling and Frost 1969). However, fecundity compensation in Henderson Lake took far longer than one year, for both walleye and northern pike, i.e. not until 1984 (four years following initial exploitation). As a result fecundity was a poor predictor of the imminent collapse of walleye numbers in Henderson Lake. In situations where the reduction in stock abundance is not as rapid, fecundity may however, give some indication of a population's well being.

Fecundity alone cannot lead to an increase in the number of catchable fish. Many other factors will contribute to survival, to recruitment, and recruitment itself has not been related to population fecundity, as determined by brood stock abundance in walleye.

Walleye eggs per kilogram in Henderson Lake favourably compare with other populations even those from more productive waters (Table 43). Northern pike eggs per kilogram, though lower than most other

Table 43. Walleye fecundity comparisons from various waters.

Range/Egg/Kg	Mean Egg Number/Kg	Reference
28,415-32,727	29,700	Norris Reservoir, Tennessee (Smith 1941)
27,900-52,562	47,410	Utah Lake, Utah (Arnold 1960)
29,822-83,286	48,936	Henderson Lake, Ontario (1982)
44,750-56,216	50,921	(Present Study) (1983)
45,068-63,783	55,353	(1984)
	50,000	Lake of the Woods, Minnesota (Carlander 1945)
36,500-72,200	52,000	Lake Meredith, Texas (Kraai and Prentice 1974)
41,191-96,914	61,149	Lake Erie (Eastern Basin) (Wolfert 1969)
57,922-67,797	61,846	Lake Gogebic, Michigan (Eschmeyer 1950)
37,954-143,827	64,715	Center Hill Reservoir, Tennesse (Muench 1966)
48,840-73,700	65,239	Little Cutfoot Sioux Lake, Minnesota (Johnson 1971)
56,314-123,249	82,700	Lake Erie (Western Basin) (Wolfert 1969)
65,778-95,955		Muskegon River, Michigan (Eschmeyer 1950)
63,441-96,116		Lake Winnebego, Wisconsin (Priegel 1970)
28,600-99,000		Wisconsin Waters (Niemuth, Churchill & Wirth 1966)
50,600-110,100		Mississippi River (Nord 1967)

populations, were surprisingly much higher than levels reported from fish in nearby Savanne Lake (Table 44).

Feeding

The dramatic decline and near extinction of ninespine sticklebacks in Henderson Lake, seems unrelated to the removal of walleye, as the collapse was initiated before and continued during the early stages of the removal. Northern pike and walleye easily switched to feeding on perch, with no apparent detrimental effects.

From 1982 to 1984 yellow perch were the predominant prey of walleye (frequency and volume), by both size-class (Fig. 35) and month (Fig. 36). Other studies show a similar use of perch by walleye (Ali et al. 1977; Kelso and Ward 1977; Swenson 1977; Swenson and Smith 1976; Moenig 1975; Parsons 1971; Johnson 1969; Forney 1966; Seaburg and Moyle 1964; Priegel 1963; Raney and Lachner 1942; Eschmeyer 1950).

In certain lakes, perch grow large enough by the end of their first summer, to become unavailable as walleye prey (Parsons 1971; Forney 1966). Henderson Lake perch, however, being stunted (Ritchie 1985) are vulnerable over several years.

Kempinger et al. (1975) described the perch population of Escanaba Lake as displaying the largest annual numerical fluctuation of any species in that lake. Whether the very recent expansion (1984) of perch numbers in Henderson Lake is a result of natural fluctuation, a response to lower walleye predation, or a reduction of interspecific competition resulting from the collapse of the ninespine stickleback population is unknown. Only if the walleye population is

Table 44. Northern pike fecundity comparisons from various waters.

Range-Eggs/Kg	Mean Egg Number/Kg	Reference
7,500-10,540	9,675	Savanne Lake, Ontario (Mosindy 1980)
11,764-36,803	18,402	Henderson Lake, Ontario (1982)
9,890-25,969	19,819	(Present Study) (1983)
14,704-35,822	22,768	(1984)
15,800-39,100	22,500	Lough Glore, Ireland (Healey 1956)
19,600-41,800	28,100	Lough Glore, Ireland (Healey 1956)
22,000-41,000	32,000	Lake Windermere, England (Kipling and Frost 1969)
7,691-97,273	35,200	Houghton Lake, Michigan (Carbine 1944)
19,800-32,000		Various Canadian Waters (Scott and Crossman 1973)

subsequently restored can this matter be clarified.

Swenson and Smith (1976) stated that walleye predation was a major cause of perch mortality during June, August and September and Paxton et al. (1981) noted that absence of a strong predator-prey relationship between walleye and perch in the lake they studied has partially accounted for poor walleye growth in that lake. Both these studies hypothesize a closely balanced relationship between walleye and perch.

Perch abundance has been correlated to abundance of perch in walleye stomachs (Noble 1972), and walleye growth correlated to perch abundance (Forney 1965). The delay of significant increases in growth and condition of Henderson Lake walleye, after exploitation, are perhaps the consequence of a delayed increase in perch abundance or possibly the result of a poor transition from sticklebacks to perch as prey.

Small YOY perch are quite important to the diet of walleye (Mosindy 1980; Priegel 1969b; Forney 1966). The low abundance of YOY perch in the 1983 walleye diet (Fig 39), reflects the poor perch year-class of that year (Ritchie 1985). In contrast the strong YOY year-class of 1984 occured in large numbers in the diet of walleye. Their relative small size and faster digestion rate may have somewhat underestimated their importance in 1984.

In 1983 small perch from the strong 1981 year-class were still abundant (Ritchie 1985). Although Mosindy (1980) found adult perch were not important in the diet of Savanne Lake walleye, extreme stunting of Henderson Lake perch makes them vulnerable to predation over a much longer time frame (Ritchie 1985).

Eschmeyer (1950) and Rawson (1957) found that white suckers were next in importance to perch in the diet of larger walleye in their lakes. However in Henderson Lake, suckers were only present in the diet of walleye before 1983. This may, however, be a consequence of the fact that most of the larger walleye were gone from the population by 1982, as it is the larger walleye that feed on suckers.

Parsons (1971) found walleye to be feeding mostly on perch in June and July and then switching to spottail (*Notropis antherinoides*) and emerald shiners (*Notropis hudsonius*) later in the summer. Nursall (1973) and Knight et al. (1984) determined spottail and emerald shiners were the major food items for walleye, but Swenson (1977) stated *Notropis spp.* electivity, while positive or zero only when YOY perch abundance was low, becomes negative when perch abundance was high. The high prevalence of stunted perch in Henderson Lake makes the utilization of shiners unnecessary for adult walleye, except as an incidental prey item. Parsons (1971) found shiners were the most important walleye food during the winter months while Priegel (1963) noted that walleye did not eat perch in the winter. Knight et al. (1984) found that forage fish abundance decreased as walleye numbers increased. They theorized that as the density of walleye increased, selectivity of food types became reduced. The fish tended to become more opportunistic possibly as a result of intraspecific competition. The walleye of Henderson Lake may display a similar pattern as their numbers increase. In the event that the perch population becomes severely reduced in numbers, as a result of increased predation, most likely the walleye of Henderson Lake will then switch to shiners as a major prey item.

Invertebrates were infrequently found in walleye stomachs, however, walleye digestion is faster than that of pike (Seaburg and

Moyle 1964). Also since walleye tend to eat more perch in bays and shallows than in open areas, perch may have been overestimated (Priegel 1963). As the fish in the 1984 feeding study were captured primarily by trap nets, set close to shore, and because walleye continue to digest food until stomach pumped, the importance of the large hatch of mayfly Hexagenia limbata, which occurs in alternate years (Riklik and Momot 1982), may be underestimated.

Invertebrates are important in the diet of other walleye populations (Mosindy 1980; Swenson 1977; Moenig 1975; Forney 1974; Johnson 1969; Eschmeyer 1950). Their relative absence in Henderson Lake walleye either reflects a sampling bias, or a lower utilization of invertebrate food items because of the greater abundance of yellow perch. Swenson (1977), Forney (1974) and Moenig (1975) found that invertebrates were confined to importance in the spring and early summer. However, in Henderson Lake, small amounts of invertebrates were eaten during most of the months sampled, excluding October (Fig. 36).

Eschmeyer (1950) found invertebrates were more significant in the diets of small walleye, however Johnson (1969) noted fish older than three years were more insectivorous. Raney and Lachner (1942) determined perch and darters were important food items of young walleye. In Henderson Lake, perch prey dominated in all sizes of walleye with the exception of young fish in the 150 to 200 mm range, where blacknose shiners were seasonally important (Fig. 35). Relative prey size and perhaps differences in behaviour between young and adult walleye may render shiners appreciably more vulnerable to young walleye.

Invertebrates appear most susceptible to mid-sized walleye, however, this may only reflect the increased sampling of mid-sized fish.

Larger walleye generally fed almost exclusively on fish, and both pike and sucker prey were eaten by large walleyes in 1982.

The northern pike diet was more diverse than that of walleye, but perch still predominated in both volume and frequency for most months and size-classes (Fig. 37, 38). This dominance of perch in the pike diet is consistent with other studies (Mosindy 1980; Wolfert and Miller 1978; Diana 1979; Nursall 1973; Lawler 1965; Seaburg and Moyle 1964; Frost 1954; Allen 1939).

Mauck and Coble (1971) stated that pike appear to select prey by other methods than abundance, but these other methods were not determined. Hickey (1975) felt, however, that food of pike is related to the abundance of that food. Seaburg and Moyle (1964) felt pike ate mostly a perch diet because they either purposefully sought perch, or they were easier to catch. Wolfert and Miller (1978) and Lawler (1965) found perch the most important food to pike in August and September, while Frost (1954) found this period to extend from May to September. In Henderson Lake perch were quite important in every month.

Mosindy (1980) found few adult perch in Savanne Lake pike and Kipling (1983) stated that if perch are fast growing they soon became unavailable. Adult perch being much larger in Savanne Lake (Ritchie 1985) are far less prevalent in the pike of that lake while adult perch because of slow growth are very abundant in Henderson Lake pike. This may explain why Mosindy (1980) noted mayfly and crayfish prey were seasonally very important to pike in Savanne Lake. While crayfish were generally found in Henderson Lake in all months, and other invertebrates fluctuated from May to September, overall invertebrates were much less utilized by Henderson Lake pike.

Larger prey, such as suckers and trout, are also utilized by pike (Diana 1979; Healy 1956), with suckers being especially vulnerable (Mauck and Coble 1971). Large rare food items may significantly contribute to growth, so that pike feeding regularly on suckers (because of learned behaviour, location in a lake or other factors) would tend to grow faster than those feeding on perch (Diana 1979). Suckers have been utilized by pike greater than 60 cm (Lawler 1965) and 70 cm (Mann 1976). In Henderson Lake northern pike greater than 50 cm showed an increased frequency of suckers in their diet. Increased pike predation on suckers has been reported in July and August (Diana 1979) and December to March (Lawler 1965). In contrast, although a slight increase in larger sucker prey prevalence (by volume and frequency) appears to occur in Henderson Lake from May to October, suckers are used in each month (Fig. 38). Northern pike of Henderson Lake appear not to predate on white suckers until they apparently attain a length of 50 cm and greater. This new source of available food may explain the sudden increased growth rate of female pike starting at the 60 to 70 cm size range (Fig. 26). Male northern pike being shorter lived than females do not appear to reach this critical size necessary to ingest suckers, therefore display no second growth stanza (Fig. 25). This new increased growth stanza for female pike could account for the few large female pike found in this lake (100+ cm).

Large white suckers while travelling in shore at dusk (Johnson 1969; Olson 1963), probably encounter large feeding pike, as pike do not generally appear to feed at night (Diana 1980; Toner and Lawler

1969; Ryder 1977). Suckers ingested by walleye and pike in Henderson Lake were relatively large (>200 mm). Olson (1963) also reported that pike and walleye eat mainly larger suckers. This suggests that larger and smaller suckers are segregated, and possibly it is the inshore-offshore migration of the larger suckers that makes then vulnerable.

Forney (1980) hypothesizes that walleye and yellow perch are closely linked in a feed-back type of relationship. He assumes a high number of walleye adults would control perch abundance as well as reduce their own recruitment through cannibalism. Walleye exploitation would reduce predation on perch causing higher perch abundance, in turn providing better protection for young walleye against cannibalism (Hauber 1983). Eventual increases in walleye numbers would reduce perch abundance resulting in an increase in cannibalism and subsequent control of their own number. Time lags and density independent factors would prevent a completely stable equilibrium.

In Henderson Lake cannibalism was infrequent even at high walleye densities and not noted at all after 1982, possibly as a result of the availability of stunted perch and other forage. The situation, in Henderson Lake, therefore appears far more complex than that of Oneida Lake (Forney 1980). In Henderson Lake walleye seem to have a more diverse food base, and so are not exclusively dependent on perch, making the feed-back relationship less direct than in Oneida Lake.

Northern pike cannibalism has been noted in a number of lakes (Lawler 1965; Mauck and Coble 1971; Healy 1956) and pike can reduce their own numbers (Hunt and Carbine 1951). The increased incidence of pike cannibalism in 1984 reflects the greatly increased prevalence of smaller individuals in that year. Lawler (1965) reported cannibalism only by pike ranging from 15 to 60 cm. However, in Henderson Lake in 1984, only large pike (above 50 cm) cannibalized other pike (Fig. 37). Lengths of the ingested pike fell within the two thirds predator length suggested by Hunt and Carbine (1951).

Johnson (1977) assumed any two predators which had greater than 25 percent of the same food item (by frequency of occurence) in their diets, were potential competitors. Although this would make the northern pike and walleye of Henderson Lake competitors, little evidence of interspecific competition has been uncovered. Possibly the great abundance of forage fish in Henderson Lake supplies sufficient food for both species.

Snow (1978) hypothesized that only at very high pike densities when density dependent mechanisms interceded, was the availability of forage fish an important determinant of pike density. If forage availability is not a controlling factor, than intraspecific density dependent mechanisms may be controlling the Henderson Lake pike population size. Numbers of walleye present would therefore, have little effect on pike density.

Dodson (1970) stated that an environment can maintain two predators that feed on one species of prey as long as they selectively feed on different size ranges of that prey. This appears to be the case in 1984 with walleye feeding on smaller sized perch while pike generally ingested larger individuals, however this was not the case in 1983 (Fig. 39, 40). Frost (1954) also found pike ate few smaller sized perch.

While Parsons (1971) and Mathias and Li (1982) found prey size important to walleye, Mosindy (1980) did not in Savanne Lake. In the present study walleye prey size also varied little with size of the predator (Fig. 41). Although several studies found prey size definitely increased with northern pike size (Johnson 1977; Mann 1976; Lawler 1965; Frost 1954; Allen 1939), the trend for an increase in perch prey size with size of pike was very slight in Henderson Lake. The fact that Henderson Lake perch are stunted, never attaining sizes greater than 21 cm (B. Ritchie pers. comm.), may account for the lack of an increase in prey length. However, the same trend is noted in Savanne Lake even though large yellow perch are abundant (Mosindy 1980). It does seem probable that the faster growth of yellow perch in Savanne Lake may soon make them unavailable as prey (Ritchie 1985). In both lakes, northern pike feed on smaller sized prey and this may be a characteristic of such lakes.

While northern pike are generally more active during the day (Diana 1980; Toner and Lawler 1969; Ryder 1977) walleye tend to feed at night (Lawler 1969; Ali et al. 1977; Ryder 1977; Kelso and Ward 1977). This undoubtedly temporally reduces the potential for competition between the species (Ryder 1977). Since Henderson Lake waters are fairly transparent, walleye may tend to feed at dawn and dusk, as has been demonstrated to occur in other transparent lakes (Eschmeyer 1950). Walleye visual acuity peaks at dusk, while the visual acuity of perch decreases at dusk, thus making perch very vulnerable to walleye predation (Ali et al. 1977). Larger perch being inactive at night, lay on the bottom (Kelso and Ward 1977). As these larger perch prey are unavailable, this may partially explain why walleye ingest more YOY perch.

The manner in which spatial separation or prey abundance inhibits interspecific competition between walleye and northern pike is unknown. Further study may better illuminate this interaction.

Conditon Factor

The walleye of Henderson Lake, as in other lakes, displayed an increase in condition factor following exploitation (Johnson 1977; Moenig 1975). The condition values of Henderson Lake walleye in 1984 favourably compared with that of other populations (Table 45). Food availability seemingly governs walleye condition (Colby et al. 1979). Increases in condition for Henderson Lake are probably related to increases in perch abundance and the decrease in walleye density. If a perch-walleye prey-predator relationship exists, and perch abundance is inverse to that of walleye (Forney 1980), then increased condition could serve as a gross predictor of walleye abundance. Walleye with higher condition values being better fed would be less susceptible to angling (Kempinger et al. 1975). As a result, angling mortality rates would fall off as walleye numbers were reduced, and so possibly result in protection for the dwindling population. Part of the increased condition of walleye in 1984 may be a result of fish being weighed during spawning. These weights would then include gonadal products, whereas 1982 and 1983 weights were generally from spent fish.

Condition factor values have decreased following a return to abundance in both walleye (Johnson 1977) and pike (Kempinger and Carline 1978). Henderson Lake walleye will probably follow a similar trend.

Savel'yeva and Shuvatova (1972) showed that the fittest and

Table 45. Walleye condition factor (K) comparisons from various waters.

	Mean K (sexes combined)	Reference
Excellent[1] (>1.01)	1.11	Mississippi River, Iowa (Van Oosten & Deason 1957)
	1.10 (0.98-1.23)	Lake Erie (Sandusky Bay) (Seward 1967)
	1.03	Canton Reservoir, Oklahoma (Lewis 1970)
	1.01	Dexter Lake, Ontario (Moenig 1975)
	1.00	Henderson Lake (1984), Ontario (Present Study)
Good[1] (0.89-0.97)	0.92	Henderson Lake (1983), Ontario (Present Study)
	0.89 (0.86-0.91)	Red Lake, Minnesota (Smith & Pycha 1961)
	0.88	Savanne Lake, Ontario (Sandhu 1979)
	0.85-0.88	Lake Sakakawea, North Dakota (Wahtola et al. 1972)
	0.86	Wilson Lake, Minnesota (Johnson 1977)
Poor[1] (<0.83)	0.81	Lake Winnebago, Wisconsin (Priegel 1969)

[1] (Carlander 1944 from Carlander 1950)

fattest female pike-perch (Lucioperca lucioperca) produced more viable eggs. Serns (1982) found conditon in the preceding fall affected walleye fecundity, high condition factors being correlated to higher fecundities. As a result of increased perch abundance walleye condition increases in Henderson Lake, could improve and result in production of more numerous and viable eggs.

Henderson Lake white suckers showed much less of an increase in condition factor in 1984 than either northern pike or walleye. This probably reflects the difference in the diet of this species. While pike and walleye ate the plentiful yellow perch, white suckers tend to feed mainly on invertebrates (Olson 1963). Suckers do not utilize perch, but probably compete with the increased numbers of perch for food.

Catch Per Unit Effort

Catch per unit effort efficiently served as a predictor of population abundance in Henderson Lake for walleye captured in four and six foot trap nets (Table 29). However, this significant correlation may be the result of the drastic decrease in walleye numbers. Roff (1983) felt that CPUE data was generally unreliable and should only serve as a gross indicator of major population fluctuations. Kipling and Frost (1970) stated that a significant amount of effort is necessary for CPUE to serve as a reliable index of fish density.

Angling may be even less efficient than commercial gear in determining fish abundance, since it is dependent on changes in fish vulnerability, which is severely altered by changes in forage availability (Forney 1980; Elsey and Thomson 1977; Kempinger et al. 1975). While Kempinger and Carline (1977) found that for most species, population density and CPUE by angling were well correlated, no mention was made of changes in food availability.

Hamley (1975) cautions that not only does selectivity of the same gill net vary between seasons or water bodies but is seriously affected by differences in distribution, behaviour and even condition of the fish. This variability in catchability due to condition may be the reason gill net CPUE in this study was not significantly correlated to walleye abundance. Condition significantly increased as walleye numbers decreased, possibly resulting in walleye becoming increasingly more vulnerable to gill net capture. Also, low food availability may result in fish being more active in seeking a less frequent prey. This perhaps increases their vulnerability to gill nets during those times of low prey availability, as in 1983 (Appendix vi, Table 1). Gill net use did vary over the study however, and part of the lack of a significant relationship may be related to small sample sizes. Eight-foot trap net sample sizes were however larger (Appendix VI, Table 2), yet no significant relationship between CUE and population abundance was found.

Catch per unit effort proved a poor estimator of population abundance in Henderson Lake, using most gear types, except for walleye (using six and four foot trap nets) when the population density rapidly changed.

Removals

A total of 15.35 kg/ha ($\overline{x}$ = 5.12 kg/ha/yr) of walleye was removed from Henderson Lake in three seasons from 1980 to 1982 (Table 32). This level of exploitation amounts to 3.28 to 3.53 the recommended level as calculated by the morphoedaphic index (MEI) (Table 1; Ryder 1965; Ontario Ministry of Natural Resources 1982).

Between 1980 and 1984, the northern pike removed exceeded from 11 to 74 percent of the suggested amount of removal as calculated by the MEI (Table 1, 31). This level of northern pike removal (for aging and feeding studies) could simulate that proportion of the pike population (caught, retained, or dying from hooking and handling) that would be removed as an incidental catch in an intensive walleye angling fishery. Since this level exceeds the recommendation calculated by the MEI, this might help explain the non-response of the pike to walleye removal. However, the years 1977-1978 were a period of drought that lowered water levels, and no doubt severely affected recruitment of younger fish. Northern pike are more vulnerable to angling than walleye (Mosindy 1980; Beyerle 1978), the actual numbers of northern pike removed may then represent the concurrent removal which could result from an intensive walleye angling pulse fishery.

Anglers have been noted to catch smaller fish than those obtained from trap and gill nets in certain lakes (Serns and Kempinger 1981; Elsey and Thomson 1977; Schupp and Macins 1977; Moenig 1975). If true for Henderson Lake, gill nets should have removed more large, brood stock walleye and fewer small individuals. The removal scheme would have then had a greater impact on the population than angling. However, Mosindy (1980) shows that in nearby Savanne Lake, angling and trap nets captured similar sized walleye (Mosindy 1980). The size frequency of the fish removed from Henderson Lake may closely resemble the size range that would be removed in a very intensive, angling fishery on a similar sized lake. Small lakes may cause all size ranges of walleye to be vulnerable to angling, however susceptibility of walleye to different gear by size appears to vary by lake.

Exploitation rates inflicted in the present study on the walleye (25 to 65 percent; Table 33), fall within the upper range of the 3 to 64 percent values reported for various walleye angling fisheries (Schainost 1983; Laarman 1981; Johnson 1977; Kempinger and Carline 1977; Kempinger et al. 1975; Kempinger and Churchill 1972; Forney 1967; Olson 1958).

Low food availability appears to make fish more susceptible to angling (Forney 1980,1965; Kempinger and Carline 1977; Johnson 1949). This means that harvest rates will be highest at exactly the same time as the environment becomes less favourable for recruitment of small walleye (Forney 1980). It has been assumed in certain situations, that as walleye are removed perch survival and therefore availability as walleye food increases, reaching a point where walleye angling efficiency may be reduced (Moyle 1949 in Forney 1980). This type of feed-back mechanism, however, is now thought to be less efficient than originally proposed (Forney 1980).

Walleye angling apparently is not sex selective (Schainost 1983; Serns and Kempinger 1981; Olson 1958). If the gear employed in Henderson Lake was biased toward either sex, then the result might be different from that expected from an actual angling fishery.

The use of netting gear, which captures fish throughout the day, might possibly produce a much higher fishing pressure than might result from an angling fishery over three years time. This may occur especially in clear lakes like Henderson where walleye feed mostly at dawn and dusk, compared to Savanne, a dark water lake, where they feed anytime (Mosindy 1980).

Mean Age to Maturity

Walleye growth inversely relates to age at first maturity (Lysack 1982; Colby and Nepszy 1981). A similar trend occurs for northern pike (Frost and Kipling 1967). Exploitation reduces the age to first maturity of a population (Diana 1983; Lysack 1982; Colby and Nepszy 1981; Borisov 1978; Kempinger and Carline 1978; Jensen 1971; Wolfert 1969). Similarly, the mean age to maturity of walleye in Henderson Lake was lowered after initial exploitation (Table 34). Although mean age to maturity estimates were not possible for 1983 and 1984, the 1980 to 1982 values steadily decreased. The abundance of available forage, following exploitation, led to both an increased growth at age and an increase in condition factor. Both factors were essential in the lowering of the age to first maturity.

Male walleye generally mature at an earlier age than females (Colby et al. 1979; Anthony and Jorgensen 1977; Moenig 1975; Priegel 1969a). In Henderson Lake this was not the case in 1980 when they both matured at the same age, or in 1981 when females matured earlier, but was true in 1982 (Table 34).

Male walleye can mature in 2 to 6 years, while females take from

3 to 8 years (Colby et al. 1979). The 1982 mean age to maturity value of 3.9 years, for Henderson Lake, is quite low compared to the 4 to 7.5 values of other lakes (Serns 1982; Lysack 1981; Priegel 1969a; Wolfert 1969; Rawson 1957). Both Lake Nipissing (Anthony and Jorgensen 1977) and Dexter Lake walleye (Moenig 1975) are heavily exploited and age at maturity was similar to that observed in Henderson Lake (namely, 3 and 4 for males and 4 and 5 for females). Scott and Crossman (1973) reported that walleye maturity generally ranges from 2 to 4 years for males and 3 to 6 years for females. The age at maturity for Henderson Lake walleye appears close to the physiological minimum by 1983.

The "critical t-level" index (the difference between mean age and the mean age to maturity), can be used to assess stress on a population from exploitation (Abrosov 1969). Although this technique appeared useful earlier in the present study, subsequent poor recruitment lead to both an increase in the mean age of the population and to such a reduction of younger fish, that mean age to maturity could not be calculated. Hence drastic and rapid overfishing renders the index unusable especially if concurrent with recruitment failure. The critical t-level of 0.5 years (4.4 - 3.9) for Henderson walleye was probably reached in 1982. The decline of the mean age of the walleye population to 4.4 years in 1982, might constitute a critical value for this lake type. As the stock recovers these indices will be monitored in order to establish even more useful trends.

Abrosov's index may however be less useful in an angling fishery, as larger mature fish may possibly be less vulnerable to angling this would yield a biased estimate of the mean age of the population (Colby 1984).

In most lakes northern pike appear mature by age 2 to 4 (Mosindy 1980; Kempinger and Carline 1978; Mann 1976; Casselman 1974a; Toner and Lawler 1969; Frost and Kipling 1967; Healy 1956). In Henderson Lake, however, only one pike older than age 2 was determined as immature in 1982 and 1984. Errors in determining summer maturity of pike in 1983 misassigned older pike to an immature status. Speculation on maturity trends for northern pike was quite difficult because of small samples.

Whether a decrease in the age to first maturity can result in a compensatory increase in walleye numbers is unknown. However, if population fecundity becomes larger, as a consequence of a lowered mean age at maturity, followed by a sequence of climatic conditions favouring recruitment, then a series of larger year-classes may result.

Sex Ratios

The spring sex ratios in Henderson Lake for both walleye and pike favor a higher male abundance. High sex ratios favouring male walleye during spawning, have been observed in many lakes (Sandhu 1979; Smith 1977; Wahtola et al. 1972; Forney 1963; Eschmeyer 1950). The same is true of northern pike (Mosindy 1980; Casselman 1975; Healy 1956; Clark 1950) and reflects male dominance on the spawning grounds.

Casselman (1975) points out the difficulty in obtaining a truely unbiased estimate of the sex ratio of a fish population. It is not known how gear selectivity influences sex ratio. Differential seasonal vulnerability to exploitation by sex has been reported for walleye (Rawson 1957). Casselman (1975) reports that larger female pike became more active in mid-summer, while males are more active in the spring and fall as they ripen. This would lead to different seasonal vulnerability of each sex to gill nets. This may be true for walleye as well. The large percent of males removed in October 1984 might be caused by the increased fall vulnerability of male walleye to gill nets.

This differential fall vulnerability probably did not result in a disproportionate removal of male walleyes during the years of heavy exploitation in Henderson Lake, since the fall 1983 walleye sex ratio was approximately 1:1. Sex reversal suggested to occur in walleye, although unlikely occuring in Henderson Lake, could also change sex ratios (Halnon 1963 in Colby et al. 1979).

Production

Carlander (1977) considered annual production to be the most meaningful measure of a population's response to the environment. Before exploitation Henderson Lake walleye had a relatively high level of production relative to some other lakes (Table 46), although in some studies production was only calculated for older individuals. Total production was even higher than calculated in 1979-1980 for Henderson Lake, as age-classes 4 to 7 had negative mortalities, indicating their incomplete recruitment to the gear (Table 37). Total production was substantially underestimated in each year since as fish less than age 4 were excluded. Kelso and Ward (1977) found the largest contribution to annual walleye production coming from age-class 2.

Table 46. Walleye production (kg ha^{-1} yr^{-1}) and $P/\overline{B}$ comparisons from various waters.

Reference	Year	Age	$\overline{B}$	P	$P/\overline{B}$
Henderson Lake, Ontario	1979-1980	4-14	6.85	1.54	0.23
(Present Study)	1980-1981	4-10	5.91	3.07	0.52
	1981-1982	4-8	3.71	-0.24	—
	1982-1983	4-9	2.40	0.18	0.08
	1983-1984	4-11	1.32	0.41	0.31
Savanne Lake, Ontario	1973-1974	7-16	6.58	1.00	0.15
(Sandhu 1979)	1974-1975	7-14	6.06	1.31	0.22
	1975-1976	8-15	2.64	0.52	0.20
Dexter Lake, Ontario (Moenig 1975)	1967	3-13	7.20	1.78	0.25
West Blue Lake, Manitoba (Kelso and Ward 1977)	1969-1970	1-4	6.1	2.10	0.34
Clear Lake, Iowa	1948-1973	3+	5.7	1.21	0.21
(Carlander and Payne 1977)	1947-1973	1+	7.2	3.08	0.42
Hoover Reservoir, Ohio (Momot et al. 1977)	1967-1973	2+	13.57	2.16	0.16
Oneida Lake, New York	1967	3-8	20.50	3.39	0.16
(Hofmann 1972)	1968	3-8	20.29	7.56	0.37

The very high production rate for Henderson Lake walleye (1979 to 1981) compared to other more southern waters, may lie in their utilization of sticklebacks as the main prey. Examining several preserved sticklebacks (collected in 1980) showed that their main food was zooplankton, whereas perch of this lake feed mainly on insects (Ritchie 1985). As a result, another trophic level appears to have been added to the walleye food web since the stickleback collapse in 1982. This increase in trophic position of the walleye might result in a less efficient funneling of energy through the food web, producing the lowered production and P/B levels seen in 1983-1984, as compared to the years 1979 to 1981. The switch from perch to sticklebacks by the walleye possibly resulted in a less efficient use of available primary productivity. No other boreal lakes for which production estimates are available have this type of food web and may explain the favourable position of Henderson Lake walleye production estimates in comparison to these other waters (Table 46). Continued monitoring of Henderson Lake during an increase in walleye numbers, may establish whether the availability of sticklebacks did cause higher walleye production values. High production levels for Henderson Lake, compared to other waters, may also be a result of the inclusion of gonadal products in annual production calculations.

Kelso and Ward (1977) and Schweigert et al. (1977), have also measured negative production for at least part of the year, especially from September to May.

Reportedly, walleye annual mortality varies from 20 to 80 percent and are mostly in the 40 to 65 percent range (Schainost 1983; Laarman 1981; Carlander and Payne 1977; Kelso and Ward 1977,1972; Schneider et al. 1977; Smith 1977; Moenig 1975; Kempinger and

Churchill 1972; Ryder 1968; Olson 1958). The Henderson Lake data discloses a total annual walleye mortality rate of 60 percent, during the years of the most accurate population estimates (1983 to 1984). Fishing mortaltiy apparently accounted for most of the total mortality of younger age-classes, but natural mortality increased with age (Table 39). This simply reflected the incomplete recruitment of younger age-classes to the gear, producing initial underestimate of age-class numbers. Though Moenig (1975) found older age groups to exibit almost no natural mortality as the result of exploitation, Henderson Lake walleye did not follow this trend. Kempinger and Churchill (1972) and Moenig (1975) felt natural and fishing mortality were inversely related for walleye, however no such evidence was found for Henderson Lake fish.

Walleye display very significant differences in rates of survival between sexes (Schneider et al. 1977), however, due to the small sample sizes of fish of known sex for the present study, such survival rates could not be calculated.

Walleye $P/\overline{B}$ ratios for Henderson Lake, in 1980-1981 and 1983-1984, favourably compare with other populations (Table 46). During the years of heavy walleye removal, production was very low. Moenig (1975) hypothesizes that smaller fish in Dexter Lake increased production and lowered natural mortality so as to compensate for removals of older fish. However, his study, as does the current study, failed to substantiate this assumption. Since in both studies small fish were unavailable, any responses of age 0 to 3 fish could not be monitored. Perhaps the reduction in production levels in the 1981-1982 season resulted from reduced feeding efficiency, as a result of the change by walleye from sticklebacks to perch as their major prey, and is not then related to exploitation. The relative stability of growth rates in older individuals and increases in growth rates of younger fish, appears to demonstrate that the drastic decline in production were at least partly a result of the heavy exploitation. The major reduction in production levels being the result of a drastic reduction in standing biomass rather than great changes in growth rates.

Kipling and Frost (1970) stated that northern pike year-class strength in the preceeding few years determined the amount of production, biomass and food consumption in any subsequent year. The doubling of the production values for pike between 1982-1983 and 1983-1984 reflects the significant contribution that can be made by a single strong year-class (Table 40). Unfortunately as pike do not become totally vulnerable to the gear used until age six, little is known of production and biomass changes at younger ages. Mortality rates though quite high in 1982-1983 became extremely low for the same 6 to 7 age-class in 1983-1984 (Table 40). This meant that pike were not fully recruited to the gear even at age 6 in 1983, resulting in an overestimate of survival. Northern pike annual mortality rates range from 50 to 66 percent (Snow 1978; Toner and Lawler 1969), Henderson rates were higher (Table 40). The $P/\overline{B}$ ratios of 0.061 and 0.103 for Henderson Lake are very much lower than those of Savanne Lake fish (0.276) (Mosindy 1980) and Lake Windermere fish (0.65 to 0.71) (Kipling and Frost 1970). A portion of this discrepancy stems from the inclusion of much younger fish in Savanne (four years-old+) and in Windermere (two years-old+).

Genetics

Pulse fishing, would periodically remove a large fraction of the population. This raises questions about the possible effects of such a scheme in modifying the gene pool of the walleye population. If exploitation selects against those genes which best promote faster growth, then the frequency of genes favouring slower growing fish should increase (Pitcher and Hart 1982).

Colby and Nepszy (1981) state there is no evidence growth, age to maturity, fecundity or longevity is inheritable in walleye. Miller (1957) found little evidence of gene pool alteration, and stated that fish show a remarkable ability to alter their growth and maturity. This ability is not necessarily under genetic control but can be explained as a preadaptation of fish to a wide range of conditions. He further states that upon cessation of exploitation, growth rates and other population characters quickly revert to the pre-exploitation state. This occurs at the individual level and not in future generations. Similarly both thinning out of stunted fish, and transfering them to less crowded environments, has resulted in greatly increased growth responses, indicating that growth is not genetically controlled (Miller 1957).

The heritability of trout growth has been determined to be 0.06. This value is low in comparison to values for characters which have been subjected to selection for genetic improvement in domestic animals (Purdom 1979). In general fish growth itself is not genetically determined in a way that would easily respond to selection. The same seems to be true for genetic control over fecundity and egg size (Purdom 1979).

The literature provides no evidence for pulse fishing significantly altering the walleye gene pool and producing slower growth rates.

Recruitment

Poor recruitment of Henderson Lake walleye has occured since 1982 (Fig. 13). Perhaps the reduction of adult numbers resulted in less reproduction, however most walleye studies demonstrate that year-class strength is not significantly correlated to adult abundance (Sandhu 1979; Kempinger and Carline 1977; Nelson and Walburg 1977; Smith 1977; Kempinger and Churchill 1972; Smith and Krefting 1954). In Escanaba Lake the smallest walleye adult population on record produced the largest year-class (Kempinger et al. 1975), and in Tathlina Lake adequate spawning resulted after the adult population was reduced to a negligible number following winterkill (Kennedy 1947). The size of a year-class also appears independent of the size of previous year-classes (Kempinger and Churchill 1972).

If year-class strength is truly independent of brood stock size, Henderson Lake walleye should be able to produce a strong year-class and so increase their abundance. Unfortunately due to an inability to catch young walleye, any significant increases in walleye year-class abundance can not be monitored until age 3 and 4 when fish become recruited to the netting gear.

Goodyear and Christensen (1984) caution that the lack of an observable relationship between size of spawning stock and the recruits they produce, is not always an indication that recruitment is truly independent of the size of the reproductive stock. They further state that at least some minimal spawning stock might be necessary when the dynamics of a fish population are not well understood. It is possible the brood stock of walleye was reduced below some minimal tolerable level and this may have resulted in poor year-class strength. Poor 1980 and 1981 year-classes did occur however, when the walleye brood stock was still abundant.

Spangler et al. (1977) hypothesize that walleye exploitation increases recruitment variability in both amplitude and frequency. Northern pike show similar post-exploitation fluctuations whenever the population becomes largely dependent on one or two dominant year-classes (Frost and Kipling 1967). Healey (1980) and Henderson et al. (1983) found recruitment of lake whitefish was proportional to the level of exploitation. This suggests that abiotic factors may not be as important to whitefish reproduction as they appear to be for walleye.

Perch abundance seems correlated to walleye year-class strength (Ritchie 1985; Forney 1980, 1976; Koonce et al. 1977; Smith 1977; Maloney and Johnson 1965; Smith and Krefting 1954). Both may simply be determined by the same biotic factors (Smith 1977; Smith and Krefting 1954), yet a fast growth rate in YOY perch often correlates with poor walleye year-classes (Ritchie 1985). Walleye year-class strengths have been influenced by the availability of YOY gizzard shad (Dorosma cepedianum) as food (Momot et al. 1977), therefore yellow perch availability as food undoubtedly may have similar influences.

Cannibalism even at low levels can effect recruitment, but is especially evident when there is intense competition for prey (Forney 1980, 1977, 1976; Chevalier 1973). Walleye YOY are associated with perch throughout the summer (Johnson 1969; Maloney and Johnson 1965; Eschmeyer 1950), so low perch abundance could increase cannibalism leading to establishment of poor year-classes (Forney 1980). The abundance of forage species would appear to lessen competition for prey and therefore cannibalism in Henderson Lake. Johnson (1969) assumed high forage fish numbers would buffer walleye against predation by all species of predators. Alternatively Nelson and Walburg (1977) found relative perch abundance not to be correlated to walleye year-class strength.

Abiotic requirements for production of good year-classes in perch and walleye appear similar, but the actual abundance of perch probably has additional significance, since they serve as prey for walleye. The degree to which walleye abundance is influenced by perch-prey availability, probably depends on the relative availability of alternative food sources in any given lake.

Predation on walleye eggs could effect survival to recruitment. Priegel (1970) and Eschmeyer (1950) found little evidence of predation, but perch (Wolfert et al. 1975; Forney 1965), white suckers (Anthony and Joregensen 1977; Wolfert et al. 1975) and spottail shiners (Wolfert et al. 1975) have been reported to feed on walleye eggs. However, only if walleye and yellow perch reproductive periods greatly overlapped (due to cool water conditions), could perch significantly reduce walleye numbers, and few authors have reported fish predation on walleye eggs as a serious limiting factor (Wolfert et al. 1975).

White suckers were seldom caught in trap nets set on walleye spawning shoals in Henderson Lake, and few perch or other forage fish were ever seen in shallow water during the early spring. Predation on walleye eggs is therefore assumed minimal in the present study.

Temperature can significantly influence year-class strength (Colby et al. 1979; Koonce et al. 1977; Nelson and Walburg 1977; Busch et al. 1975; Wolfert et al. 1975; Kipling and Frost 1970; Johnson 1961; Derback 1947). Derback (1947) reported that walleye stopped spawning when water temperature dropped two degrees celsius, and did not complete spawning. In June he noted walleye reabsorbing eggs. Ova reabsorption is also known to interfere with the development of the next generation of oocytes in walleye, leading to the omission of the following spawning period (W. B. Horning II pers. comm. in Colby et al. 1979).

This drop in spring water temperatures may explain the low abundance of age 3 and 4 walleye in 1984. In the spring of 1980 early warm weather raised water temperatures to 13.5° C by May 2, but subsequently dropped to 10° C on May 4 and 9° C on May 9. Walleye left the shoal areas and spawning activity ceased (D. Baccante pers. comm.). Cool water has also been associated with a poor walleye hatch (Derback 1947). Undoubtedly this temperature drop resulted in a poor 1980 year-class and may have as well influenced the 1981 year-class. As dominant walleye and perch year-classes are often concurrent, it is possible the 1981 walleye spawn was adversely affected by the 1980 cold spell, as the perch year-class was the largest on record in 1981 (Ritchie 1985). Although no reason is known for the apparent poor 1982 year-class, yellow perch failed to produce strong year-classes between 1981 and 1984. The 1984 walleye year-class might be stronger, as water temperatures for the spring of 1984 warmed at an earlier date compared to both 1982 and 1983 (Appendix I), and the 1984 perch year-class in Henderson Lake was very strong.

Other factors which appear to influence year-class strength include water level, limited spawning ground, water flow and wind velocity (Chevalier 1977; Koonce et al. 1977; Nelson and Walburg 1977; Hunt and Carbine 1951). A reduction in walleye numbers may moderate the effects of density dependent processes allowing abiotic factors to strongly influence production of young walleye (Colby et al. 1979; Busch et al. 1975). This trend could explain the occurences of poor recruitment in Henderson Lake.

Savel'yeva and Shuvatova (1972) noted that for Lucioperca lucioperca the quality of fish progeny was dependent on the physiological condition of the spawners. They found correlations between fat in the muscles of females, protein content of the eggs and survival rate of those eggs. If this is true for walleye as well, the improvements in size and fitness of walleye brood stock in Henderson Lake could result in fitter offspring.

Although there has been extremely poor walleye recruitment in Henderson Lake in recent years, there are reasons to be optimistic that the walleye population will eventually re-establish it's previous abundance: year-class strength is seldom correlated to brood stock abundance (although some minimal level may be necessary), and only a few walleye can apparently re-establish themselves in sufficient numbers (Kennedy 1947); high densities of perch are available, providing an abundant food source; cannibalism or predation of walleye has not been noted in the last two years; walleye were observed on traditional spawning shoals at night in early May of 1984, and eyed eggs were found on these shoals several days later. In addition four 1+ walleye were captured in the fall of 1984, indicating that some reproduction has occured. Fecundity and condition factors have increased which will yield more numerous and possibly fitter young. Since yellow perch had a relatively dominant year-class in 1984, perhaps parameters affecting walleye survival may have also been favourable.

Great fluctuations in year-class strengths of walleye are common (Kelso and Ward 1977; Pycha 1961). The current trend of poor walleye reproduction in Henderson Lake is probably only temporary. Macins (1981) felt that on the average, out of five years, one can expect one better than average walleye year-class, one minimal (failure) and the others to provide average year-classes. If this generalization is true, Henderson Lake walleye are at least statistically overdue for an above average year.

Pulse Fishing

Certain overexploited walleye populations, given a certain amount of time to recover, have re-established their previous numbers. As a result of mercury contamination in the early 1970's, fishing pressure was reduced resulting in great increases in Lake Erie walleye abundance (Anonymous 1984; Colby and Nepszy 1981; Shuter and Koonce 1977). When Lake Winnipeg was closed to walleye fishing for two years (1970-1972), walleye numbers increased dramatically (Valiant 1984). A large winterkill in Lake Tathlina in the North-West Territories reduced the concentration of walleye much lower than could have been profitably brought about by a commercial fishery, yet several years later walleye reproduced successfully enough to significantly re-establish themselves (Kennedy 1947).

Adams and Olver (1977) recommended pulse fishing as a compromise between biological and economic considerations. A pulse fishing experimental project was begun on several remote northern Manitoba lakes but was unfortunately terminated before the viability of the technique was determined (Lysack 1979).

Lake whitefish (Healey 1980) and arctic charr (Johnson 1983; 1976) have shown the ability to return to a high level of abundance following severe reduction. Salmonines and corgonines have been traditionally pulse-type fished in Lapland (H. Rundberg pers. comm. in Adams and Olver 1977).

These high arctic lakes do have a low species diversity, therefore it may be argued that they do not provide the same level of fish interactions and competition for any temporarily vacated niche as occurs in the boreal-percid complex (Colby and Olver 1978; Johnson 1949). Walleye and yellow perch tend to show positive correlations to each other however, and no demonstratable relationship has been ascertained between them and northern pike (Smith and Krefting 1954; Present study).

Perhaps the walleye of Henderson Lake were exploited beyond their short term capability to re-establish their former numbers. Further experiments conducted under a range of fishing pressures are necessary in order to establish the most suitable level of exploitation. Replication and use of control lakes would aid in distinguishing unrelated long and short term abiotic and biotic trends from the effects of exploitation. Such a study, conducted on a trial basis, using the public as a controlled harvesting component, would reduce costs, while still allowing a variety of lake types to be tested.

Management Implications

Although the fish of Henderson Lake are being manipulated to determine the feasibility of managing walleye by pulse fishing, the study also serves to document overexploitation. The continued monitoring of the fish species in the lake has supplied data on various indices leading up to the walleye collapse.

Exploitation stress can evoke a population response, if this response can be measured, management decisions could then be based on the weight of such circumstantial evidence (Ontario Ministry of Natural Resources 1983). The relative usefulness, for Henderson Lake walleye, of each population parameter and compensatory mechanism in assessing overexploitation stress, can be assessed by looking at the changes in the various parameters of the Henderson Lake population, namely:

(1). population estimates
(2). growth at age
(3). mean age
(4). mean age at maturity
(5). feeding and competitive interactions
(6). fecundity
(7). condition factor
(8). production
(9). catch per unit effort
(10). sex ratios
(11). variable recruitment

Schumacher-Eschmeyer population estimates were quite misleading as an indicator of the amount of stress on the walleye population. These estimates, by themselves without age data, showed a relatively stable population after two years of intensive harvest and so did not forewarn of the walleye population collapse of 1983. Petersen estimates more realistically measured the effects of exploitation and were therefore, preferable for estimating walleye abundance. Annual Petersen estimates did determine the relative well-being of the walleye stock, however, they might not be very practical for large scale management of many lakes. Although this approach may be useful and yield the most pertinent information for selectively important walleye stocks.

Growth rates responded dramatically to exploitation but only in younger age groups. The sudden acceleration in length at age data in younger walleye provided an early symptom of exploitation stress. The unfortunate inability to capture walleye from younger age-classes throughout the present study limited the usefulness of this response. Gear selectivity for older fish, by traditional sampling gear, might limit it's usefullness unless a strong effort is made for sampling younger fish. Preliminary increases in length at age data for age 2 and 3 walleye in response to exploitation, occured almost immediately after the first large harvest (Fig. 16). Older fish took a much longer time for this response and the magnitude of compensation was much more variable or even non-existent with age. To properly implement the use of growth data from younger fish in the detection of overfishing stress, in Henderson Lake, would have necessitated the accumulation of a certain amount of fundamental initial length at age data for comparison purposes. This data would need to be collected before a lake was subjected to intensive fishing pressure. Although this method would require the collection and accumulation of a long time series of data in order to knowledgebly speculate on acceptible relative increases in length at age, such data are relatively easy to procure. Growth at age of young walleye may therefore have held the promise of an early stress warning in this study. However, changes in growth as a result of density independent factors may result in incorrect interpretation of the causes.

Mean age of the Henderson Lake walleye population showed a decrease with exploitation but later increased as a result of poor recruitment. This initial decrease is characteristic of exploited populations as older fish, being larger, are usually the most susceptible to removal. However, results from angled populations may not follow this trend. The mean age of a population may reach a critical value below which a walleye population will show a drastic reduction in numbers. This value for Henderson Lake was calculated as 4.4 years. The use of mean age values in conjunction with the mean age to maturity, supplies Abrosov's (1969) critical t value. The t value (difference between the mean age and mean age to maturity) decreased from 1.3 (6.5 - 5.2) in 1980 to 0.5 (4.4 - 3.9) in 1982. This 0.5 value leaves very little time for mature fish to spawn before being harvested and may serve to indicate the extreme low value to which a walleye population can be driven before undergoing a collapse. Both the mean age and mean age to maturity values hold promise as a useable indices of fishing stress. However, applicability of such an index to angling situations appears limited (Colby 1984).

Diets of walleye and northern pike changed over the course of the study, but the reasons are not clear. It is possible the walleye harvest may have accelerated the reduction of the ninespine stickleback population, but this seems unlikely. Species interactions both as predator-prey relationships and interspecific competitors seem quite unpredictable and responses are individualistic, and the possibility of relating these to the relative fish densities seem very improbable.

A fecundity response did occur in both walleye and northern pike as a result of walleye exploitation. This increase in the reproductive potential of an individual fish may aid in the ability of the population to re-establish their numbers. However, due to the time-delay in this response (not occuring until 1984, four years after exploitation began), it had no value in serving as a predictor of overexploitation. Fecundity may however, hold more promise as an indicator of exploitation stress for populations subjected to lower removal rates.

Condition factors show a similar response to that of fecundity and the two may possibly be related. Walleye condition factors would not have aided in predicting the rapid walleye collapse.

Production estimates appeared to be a good predictor of the walleye population collapse in Henderson Lake. The lowest values of production occured in the 1981-1982 season as a result of negative growth rates from several age-classes (Table 37). Healey (1975) suggests that using parameters of the fish population itself as an index of productivity is probably the least risky approach to management, and the Henderson Lake data supports this statement. The sudden drastic drop in production of the walleye population in the 1981-1982 period provided an immediate alert and if a drastic reduction in harvest rate could have been implimented it would have averted the collapse of the stock. Unfortunately production data are among the most time consuming and costly data to obtain, so use of this excellent indicator seems economically impractical in most cases.

Trap net catch per unit effort data, was only reliable during great fluctuations in population abundance, and only for walleye. Henderson Lake is quite small yet it took an extreme fishing intensity and a drastic decrease in walleye abundance to achieve a significant trend in CPUE. Gill nets were a poor predictor of fish abundance, even with great changes in walleye numbers. This may be partially the result of small sample sizes in some years, but fish may change their vulnerability to gill net capture over time.

Unbiased estimates of sex ratio, being extremely difficult to obtain, provide no indication of trends in walleye population levels resulting from exploitation.

A reduced amount of recruitment occured in Henderson Lake after exploitation was initiated, but it is assumed to be a result of unfavourable abiotic factors, possibly unrelated to population abundance.

In conclusion, the most promising indicators of exploitation stress on the walleye of Henderson Lake appear to be annual production estimates, growth at age data for younger fish, Abrosov's (1967) index of mean age to mean age at maturity as well as the mean age values and possibly Petersen population estimates.

The continued monitoring of Henderson Lake as walleye numbers increase, may qualify the useful ranges and desirability of employing these indices.

References

Abrosov, V.N. 1969. Determination of commercial turnover in natural bodies of water. Problems of Ichthyology 9:482-489.

Adams, G.F., and C.H. Olver. 1977. Yield properties and structure of boreal percid communities in Ontario. Journal of the Fisheries Research Board of Canada 34:1613-1625.

Ali, M.A., R.A.Ryder, and M. Anctil. 1977. Photoreceptors and visual pigments as related to behavioural responses and preferred habitats of perches (*Perca spp*) and pikeperches (*Stizostedion spp*). Journal of the Fisheries Research Board of Canada 34:1475-1480.

Allen, K.R. 1939. A note on the food of pike (*Esox lucius* Linnaeus) in Windermere. Journal of Animal Ecology 8:72-75.

Anonymous. 1984. Banner year expected of Lake Erie walleye. Sport Fishing Institute Bulletin No. 354, May.

Anthony, D.D., and C.R. Jorgensen. 1977. Factors in the declining contribution of walleye (*Stizostedion vitreum vitreum*) to the fishery of Lake Nippissing, Ontario, 1960-1976. Journal of the Fishery Research Board of Canada 34:1703-1709.

Arnold, B.B. 1960. Life history notes on the walleye, *Stizostedion vitreum vitreum* (Mitchill), in a turbid water, Utah Lake, Utah. Msc. Thesis, Utah State University, Logan, Utah. 114 p.

Bagenal, T.B. 1973. Fish fecundity and its relations with stock and recruitment. Pages 186-198 *in* B.B. Parrish, editor. Conseil International pour l'Exploration de la Mer, volume 164.

Bagenal, T.B. 1969. The relationship between food supply and fecundity in brown trout _Salmo trutta_ Linnaeus. Journal of Fish Biology 1:167-182.

Bagenal, T.B., and E. Braun. 1978. Eggs and early life history. Pages 165-201 _in_ T.B. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3 Blackwell Scientific Publications, London, England. 365 p.

Bagenal, T.B., and F.W. Tesch. 1978. Age and growth. in T.B. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications, London, England. 365 p.

Baker, A.M., and D.F. Fraser. 1976. A method for securing the gut contents of small live fish. Transactions of the American Fisheries Society 105:520-522.

Bardach, J.E. 1955. The opercular bone of the yellow perch, _Perca flavescens_ as a tool for age and growth studies. Copeia 2:107-109.

Beamish, R.J., and G.A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Transactions of the American Fisheries Society 112:735-743.

Beakman, W.C. 1943. Annulus formation on the scales of certain Michigan game fish. Papers of the Michigan Academy of Science, Arts and Letters 28:281-312.

Beyerle, G.B. 1978. Survival, growth and vulnerability to angling of northern pike and walleyes stocked as fingerlings in small lakes with bluegills or minnows. American Fisheries Society Special Publication 11:135-139.

Borisov, V.M. 1978. The selective effect of fishing on the population structure of species with a long life cycle. Journal of Ichthyology 18:896-905.

Brown, E.H. Jr., and C.F. Clark. 1965. Length-weight relationship of northern pike *Esox lucius,* from East Harbour, Ohio. Transactions of the American Fisheries Society 94:404-405.

Busch, W.D.N., R.L.Scholl, and W.L. Hartman. 1975. Environmental factors affecting the strength of walleye (*Stizostedion vitreum vitreum*) year-classes in western Lake Erie, 1969-1970. Journal of the Fisheries Research Board of Canada 32:1733-1743.

Campbell,J.S., and J.A. Babaluk. 1979. Age determination of walleye, *Stizostedion vitreum vitreum* (Mitchell), based on the examination of eight different structures. Fisheries and Marine Services Technical Report No. 849. Department of Fisheries and the Environment. Winnipeg, Manitoba. 23 p.

Carbine, W.F. 1944. Egg production of the northern pike, *Esox lucius* Linnaeus, and the percentage of survival of eggs and young on the spawning grounds. Papers of the Michigan Academy of Science, Arts and Letters 29:123-137.

Carlander, K.D. 1977. Biomass, production, and yields of walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca flavescens*) in North American lakes. Journal of the Fisheries Research Board of Canada 34:1602-1612.

______________. 1958. Disturbance of the predator-prey balance as a management technique. Transactions of the American Fisheries Society 87:34-38.

Carlander, K.D. 1950. Handbook of freshwater fishery biology. Dubuque, Iowa, W.C. Brown Company, 281 p.

______________. 1945. Age, growth, sexual maturity and population fluctuations of the yellow pike-perch Stizostedion vitreum vitreum (Mitchill) with reference to the commericial fisheries, Lake of the Woods, Minnesota. Transactions of the American Fisheries Society 73:90-107.

______________. 1944. Notes on the coefficient of condition, K, of Minnesota fishes. Investigative Report of the Minnesota Bureau of Fisheries No. 41, 40 p.

Carlander, K.D., and P.M. Payne. 1977. Year-class abundance, population and production of walleye (Stizostedion vitreum vitreum) in Clear Lake, Iowa, 1948-1974, with varied fry stocking rates. Journal of the Fisheries Research Board of Canada 34:1792-1799.

Casselman, J.M. 1980. The esocid cleithrum as an indicator calcified structure. Pages 249-272 in J. Dube and Y. Gravel, editors. Proceedings of the 10th Warm Water Workshop, American Fisheries Society, Division du nord-est/Northeast Division, Montebello, Quebec. 285 p.

______________. 1978. Calcified tissue and body growth of northern pike Esox lucius Linnaeus. Ph.D. Thesis, University of Toronto, Toronto, Ontario. 782 p. (2 volumes).

______________. 1975. Sex ratios of northern pike Esox lucius Linnaeus. Transactions of the American Fisheries Society 104:60-64.

Casselman, J.M. 1974a. External sex determination of northern pike, *Esox lucius* Linnaeus. Transactions of the American Fisheries Society 103:343-347.

______________. 1974b. Analysis of hard tissue of pike *Esox lucius* Linnaeus with special reference to age and growth. Pages 13-27 *in* T.B. Bagenal, editor. Aging of fish - Proceedings of an international symposium. Urwin Brothers Limited, England. 234 p.

______________. 1967. Age and growth of northern pike *Esox lucuis* Linnaeus in the upper St. Lawrence River. MSc. Thesis. University of Guelph, Guelph, Ontario. 219 p.

Chevalier, J.R. 1977. Changes in walleye (*Stizostedion vitreum vitreum*) population in Rainy Lake and factors in abundance, 1924-75. Journal of the Fisheries Research Board of Canada 34:1696-1702.

______________. 1973. Cannibalism as a factor in first year survival of walleye in Oneida Lake. Transactions of the American Fisheries Society 102:739-744.

Clark, C.F. 1950. Observations on the spawning habits of the northern pike, *Esox lucius,* in Northwestern Ohio. Copeia 4:285-288.

Colby, P.J. 1984. Appraising the status of fisheries:rehabilitation techniques. *in* V.W. Cairns, P.V. Hodson and J.O. Nriagu, editors. Contaminant effects on fisheries. John Wiley and Sons. New York. 333 p.

Colby, P.J., and S.J. Nepszy. 1981. Variation among stocks of walleye (*Stizostedion vitreum vitreum*): Management implications. Canadian Journal of Fisheries and Aquatic Sciences 38:1814-1831.

Colby, P.J., and C.H. Olver. 1978. Management implications derived from the PERCIS training session. Ontario Ministry of Natural Resources. File report. 51 p.

Colby, P.J., R.E. McNichol, and R.A. Ryder. 1979. Synopsis of the biological data on the walleye, Stizostedion vitreum vitreum (Mitchill 1818). Food and Agricultural Organization Fisheries Synopsis No. 119, Rome, Italy. 139 p.

Crossman, E.J., and J.G. Hamilton. 1978. An apparatus for sampling gut contents of large, living fishes. Environmental Biology of Fishes 3:297-300.

Derback, B. 1947. The adverse effect of cold weather upon the successful reproduction of pickerel, Stizostedion vitreum, at Heming Lake, Manitoba in 1947. The Canadian Fish Culturalist 2:22-23.

Diana, J.S. 1983. Growth, maturation, and production of northern pike in three Michigan lakes. Transactions of the American Fisheries Society 112:38-46.

__________. 1980. Diel activity pattern and swimming speeds of northern pike (Esox lucius) in Lac. Ste. Anne, Alberta. Canadian Journal of Fisheries and Aquatic Sciences 37:1454-1458.

__________. 1979. The feeding pattern and daily ration of a top carnivore; the northern pike. Canadian Journal of Zoology 57:2121-2127.

Dodson, S.I. 1970. Complementary feeding niches sustained by size-selective predation. Limnology and Oceanology 15:131-135.

Elsey, C.A., and R.T. Thompson. 1977. Exploitation of walleye (Stizostedion vitreum vitreum) in Lac des Mille Lacs, Northern Ontario, by commercial and sports fisheries, 1958-1975. Journal of the Fisheries Research Board of Canada 34:1769-1773.

Erickson, C.N. 1983. Age determination of Manitoban walleyes using otoliths, dorsal spines and scales. North American Journal of Fisheries Management 3:176-181.

____________. 1979. Age differences among three hard tissue structures observed in fish populations experiencing various levels of exploitation. MS Report No. 79-77. Manitoba Department of Natural Resources. 31 p.

Eschmeyer, P. 1950. The life history of the walleye in Michigan. Bulletin of the Institute for Fisheries Research No. 3. Michigan Department of Conservation. 99 p.

Everhart, W.H., A.W. Eipper, and W.D. Youngs. 1975. Principles of fishery science. Cornell University Press, Ithaca, New York. 288 p.

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

____________. 1977. Evidence of inter- and intraspecific competition as factors regulating walleye (Stizostedion vitreum vitreum) biomass in Oneida Lake, New York. Journal of the Fisheries Research Board of Canada 34:1812-1820.

____________. 1976. Year-class formation in the walleye (Stizostedion vitreum vitreum) population of Oneida Lake, New York, 1966-1973. Journal of the Fisheries Research Board of Canada 33:783-792.

Forney, J.L. 1974. Interactions between yellow perch abundance, walleye predation and survival of alternate prey in Oneida Lake, New York. Transactions of the American Fisheries Society 103:15-24.

__________. 1967. Estimates of biomass and mortality rates in a walleye population. New York Fish and Game Journal 14:176-192.

__________. 1966. Factors affecting first-year growth of walleyes in Oneida Lake, New York. New York Fish and Game Journal 13:146-167.

__________. 1965. Factors affecting growth and maturity in a walleye population. New York Fish and Game Journal 12:217-232.

__________. 1963. Distribution and movement of marked walleyes in Oneida Lake, New York. Transactions of the American Fisheries Society 92:47-52.

Foster, J.R. 1977. Pulsed gastric lavage: an efficient method of removing the stomach contents of live fish. Progressive Fish Culturalist 39:166-169.

Frost, W.E. 1954. The food of pike Esox lucius (Linnaeus), in Windermere. Journal of Animal Ecology 23:339-360.

Frost, W.E., and C. Kipling. 1967. A study of reproduction, early life, weight-length relationship and growth of pike, Esox lucius Linnaeus, in Windermere. Journal of Animal Ecology 36:651-693.

______________________. 1959. The determination of the age and growth of pike (Esox lucius Linnaeus) from the scales and opercular bone. Journal de Conseil International pour l'Exploration de la Mer 24:314-341.

Gerking, S.D. 1957. Fish behavior as related to stable stream populations. Pages 3-11 in Symposium on evaluation of fish populations in warm-water streams. Ames: Iowa Cooperative Fisheries Research Unit, Iowa State College.

Giles, N. 1980. A stomach sampler for use on live fish. Journal of Fish Biology 16:441-444.

Glenn, C.L. 1969. Seasonal rates of growth within a population of walleye Stizostedion vitreum vitreum (Mitchill) in West Blue Lake, Manitoba, during 1966-1967. MSc. Thesis University of Manitoba, Winnipeg. 63 p.

Goodyear, C.P., and S.W. Christensen. 1984. On the ability to detect the influence of spawning stock on recruitment. North American Journal of Fisheries Management 4:186-193.

Halnon, L.C. 1963. A study of the walleye fishery in Lake Champlain (including a report summarizing ten years of walleye tagging). Vermont Fish and Game Service, Federal Aid Fish and Wildlife Restoration Project. F-1-R-11, Job 1. 41 p.

Hamley, J.M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada 32:1943-1969.

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

Havey, K.A., D.O. Locke, and G.L. Smith. 1981. A comparison of four methods of estimating populations of hatchery-reared brook trout at Tomah Lake, Maine. North American Journal of Fish Management 1:186-192.

Healey, M.C. 1980. Growth and recruitment in experimentally exploited lake whitefish (*Coregonus clupeaformis*) populations. Canadian Journal of Fisheries and Aquatic Sciences 37:255-267.

____________. 1978a. Fecundity changes in exploited populations of lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*). Journal of the Fisheries Research Board of Canada 35:945-950.

____________. 1978b. The dynamics of exploited lake trout populations and implications for management. Journal of Wildlife Management 42:307-327.

____________. 1975. Dynamics of exploited whitefish populations and their management with special reference to the Northwest Territories. Journal of the Fisheries Research Board of Canada 32:427-448.

Healy, A. 1956. Pike (*Esox lucius* Linnaeus) in three Irish lakes. Scientific Proceedings of the Royal Dublin Society 27:51-63.

Henderson, B.A., J.J. Collins, and J.A. Reckahn. 1983. Dynamics of an exploited population of lake whitefish (*Coregonus clupeaformis*) in Lake Huron. Canadian Journal of Fisheries and Aquatic Sciences 40:1556-1567.

Hester, F.J. 1964. Effect of food supply in the female guppy, *Lebistes reticulatus* (Peters). Journal of the Fisheries Research Board of Canada 21:757-764.

Hickey, C.R.H. Jr. 1975. Fish behavior as revealed through stomach content analysis. New York Fish and Game Journal 22:148-155.

Hofmann, P. 1972. Consumption of yellow perch (Perca flavescens) by a walleye (Stizostedion vitreum vitreum) population in Oneida Lake. Ph.D. Thesis, Cornell University, Ithaca, New York, 67 p.

Hunt, P., and W.F. Carbine. 1951. Food of young pike, Esox lucius Linnaeus, and associated fishes in Peterson's ditches, Houghton Lake, Michigan. Transactions of the American Fisheries Society 80:67-83.

Hynes, H.B.N. 1950. The food of fresh-water sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. Journal of Animal Ecology 19:36-58.

Hyslop, E.J. 1980. Stomach contents analysis - a review of methods and their application. Journal of Fish Biology 17:411-429.

Jensen, A.L. 1971. Response of brook trout populations to a fishery. Journal of the Fisheries Research Board of Canada 28:458-460.

Jernejcic, F.A. 1969. Use of emetics to collect stomach contents of walleye and largemouth bass. Transactions of the American Fisheries Society 98:698-702.

Johnson, F.H. 1977. Responses of walleye (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens) populations to removal of white sucker (Catostomus commersoni) from a Minnesota Lake, 1966. Journal of the Fisheries Research Board of Canada 34:1633-1642.

Johnson, F.H. 1971. Numerical abundance, sex ratios and size-age composition of the walleye spawning run at Little Cutfoot Lake Minnesota 1942-1969, with data on fecundity and incidence of Lymphocystis. Investigative Report of the Minnesota Department of Natural Resources No. 315. 9 p.

__________. 1969. Environmental and species associations of the walleye in Lake Winnibigoshish and connecting waters, including observations of food habits and predator-prey relationships. Minnesota Fisheries Investigations 5:5-36.

__________. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Transactions of the American Fisheries Society 90:312-322.

Johnson, L. 1983. Homeostatic characteristics of single species fish stocks in Arctic lakes. Canadian Journal of Fisheries and Aquatic Sciences 40:987-1024.

__________. 1976. Ecology of arctic populations of lake trout Salvelinus namaycush, lake whitefish Coregonus clupeaformis, Arctic char Salvelinus alpinus and associated species in unexploited lakes of the Canadian Northwest Territories. Journal of the Fisheries Research Board of Canada 33:2459-2488.

Johnson, R.E. 1949. Maintenance of natural population balance. Pages 35-42 in Proceedings of the 38th (1948) Convention of the International Association of Game Fish and Conservation Commissioners.

Kelso, J.R.M., and F.J. Ward. 1977. Unexploited percid populations of West Blue Lake, Manitoba, and their interactions. Journal of the Fisheries Research Board of Canada 34:1655-1669.

Kelso, J.R.M., and F.J. Ward. 1972. Vital statistics, biomass and seasonal production of an unexploited walleye (*Stizostedion vitreum vitreum*) population in West Blue Lake, Manitoba. Journal of the Fisheries Research Board of Canada 29:1043-1052.

Kempinger, J.J., and R.F. Carline. 1978. Dynamics of the northern pike population and changes that occurred with a minimum size limit in Escanaba Lake, Wisconsin. American Fisheries Society Special Publication 11:382-389.

____________. 1977. Dynamics of the walleye (*Stizostedion vitreum vitreum*) population in Escanaba Lake, Wisconsin, 1955-72. Journal of the Fisheries Research Board of Canada 34:1800-1811.

Kempinger, J.J., and W.S. Churchill. 1972. Contribution of native and stocked walleye fingerlings to the anglers' catch, Escanaba Lake, Wisconsin. Transactions of the American Fisheries Society 101:644-649.

Kempinger, J.J., W.S. Churchill, G.R. Priegel, and L.M. Christenson. 1975. Estimate of abundance, harvest and exploitation of the fish population of Escanaba Lake, Wisconsin, 1946-69. Technical Bulletin 84. Department of Natural Resources, Madison, Wisconsin. 30 p.

Kennedy, W.A. 1949. Relationship of length, weight and sexual maturity to age in three species of Lake Manitoba fish. Fisheries Research Board of Canada 81:1-5.

____________. 1948. Recent increase in growth rate in two species of Lake Manitoba fish. Canadian Fish Culturalist 3:18-19.

____________. 1947. Some information on the minimum adult stock of fish needed to provide adequate natural spawning. Canadian Fish Culturalist 1:14-15.

Ketchen, K.S. 1950. Stratified subsampling for determining age distribution. Transactions of the American Fisheries Society 79:205-212.

Kipling, C. 1983. Changes in the growth of pike, *Esox lucius*, in Windermere. Journal of Animal Ecology 52:647-657.

Kipling, C., and W.E. Frost. 1970. A study of the mortality, population numbers, year class strengths, production and food consumption of pike, *Esox lucius* Linnaeus, in Windermere from 1944 to 1962. Journal of Animal Ecology 39:115-157.

______________. 1969. Variations in the fecundity of pike, *Esox lucius* Linnaeus, in Windermere. Journal of Fish Biology 1:221-237.

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

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

Kraai, J.E. and J.A. Prentice. 1974. Walleye life history study. Texas Parks and Wildlife Department, Fedral Aid Project F-7-R-22, Job 17a. 28 p.

Laarman, P.W. 1981. Vital statistics of a Michigan fish population, with special emphasis on the effectiveness of stocking 15-cm walleye fingerlings. North American Journal of Fish Management 1:177-185.

Laird, L.M., and B. Stott. 1978. Marking and tagging. Pages 84–100 in T. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications, London, England.

Larkin, P.A. 1956. Interspecific competition and population control in freshwater fish. Journal of the Fisheries Research Board of Canada 13:327–342.

Latta, W.C. 1959. Significance of trap-net selectivity in estimating fish population statistics. Papers of the Michigan Academy of Science, Arts and Letters 44:123–138.

Lawler, G.H. 1969. Activity periods of some fishes in Heming Lake. Journal of the Fisheries Research Board of Canada 26:3266–3267.

____________. 1965. The food of the pike, Esox lucius, in Heming Lake, Manitoba. Journal of the Fisheries Research Board of Canada 22:1357–1377.

LeCren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). Journal of Animal Ecology 20:201–219.

____________. 1947. The determination of the age and growth of the perch (Perca fluviatilis) from the opercular bone. Journal of Animal Ecology 16:188–204.

Lewis, S.A. 1970. Age and growth of walleye Stizostedion vitreum vitreum (Mitchill), in Canton Reservoir, Oklahoma. Proceedings of the Oklahoma Academy of Science 50:84–86.

Light, R.W., P.H. Adler, and D.E. Arnold. 1983. Evaluation of gastric lavage for stomach analysis. North American Journal of Fish Management 3:81–85.

Lysack, W. 1982. 1981 Lake Winnipeg Fish Stock Assessment Program. Manitoba Department of Natural Resources, MS Report No.82-28. 99 p.

________. 1981. 1980 Lake Winnipeg fish stock assessment program. Manitoba Department of Natural Resources, MS Report No.81-20. 67 p.

__________. 1980. 1979 Lake Winnipeg fish stock assessment program. Manitoba Department of Natural Resources, MS Report No.80-30. 118 p.

__________. 1979. Fish stock assessment of lakes in the pulse fishing project. Manitoba Department of Natural Resources, MS Report No.82-5. 387 p.

Macins, V. 1981. Walleye spawning bed rehabilitation. Ontario Ministry of Natural Resources. File Report. 4 p.

Maloney, J.E., and F.H. Johnson. 1965. Life histories and inter-relationships of walleye and yellow perch especially during their first summer in two Minnesota lakes. Transactions of the American Fisheries Society 85:191-202.

Mann, R.H.K. 1976. Observations on the age, growth, reproduction and food of the pike _Esox_ _lucius_ (Linnaeus) in two rivers in southern England. Journal of Fish Biology 8:179-197.

Mann, R.H.K., and C.A. Mills. 1979. Demographic aspects of fish fecundity. Pages 161-177 _in_ P.J. Miller, editor. Fish Phenology; Anabolic Adaptiveness in Teleosts. Symposium of the Zoological Society of London.

Mathias, J.A., and S. Li. 1982. Feeding habits of walleye larvae and juveniles: Comparative laboratory and field studies. Transactions of the American Fisheries Society 111:722-735.

Mauck, W.L., and D.W. Coble. 1971. Vulnerability of some fishes to northern pike (Esox lucius) predation. Journal of the Fisheries Research Board of Canada 28:957-969.

McFadden, J.T. 1969. Trends in freshwater sport fisheries of North America. Transactions of the American Fisheries Society 98:136-150.

Miller, R.B. 1957. Have the genetic patterns of fishes been altered by introductions or by selective fishing? Journal of the Fisheries Research Board of Canada 14:797-806.

__________. 1948. A note on the movement of the pike Esox lucius. Copeia 1948:62.

Miller, R.B., and W.A. Kennedy. 1948. Pike (Esox lucius) from four northern lakes. Journal of the Fisheries Research Board of Canada 7:190-199.

Moenig, J.R. 1975. Dynamics of an experimentally exploited walleye population in Dexter Lake, Ontario. MSc. Thesis. University of Toronto, Toronto, Ontario. 198 p.

Momot, W.T., J. Erickson, and F. Stevenson. 1977. Maintenance of a walleye, Stizostedion vitreum vitreum, fishery in a eutrophic reservoir. Journal of the Fisheries Research Board of Canada 34:1725-1732.

Mosindy, T. 1980. The ecology of northern pike, Esox lucius (Linnaeus) in Savanne Lake, Ontario. MSc. Thesis. Lakehead University, Thunder Bay, Ontario. 159 p.

Moyle, J.B. 1949. Fish population concepts and management of Minnesota lakes for sport fishing. Transactions of the North American Wildlife Conference 14:283-294.

Moyle, J.B., and D.R. Franklin. 1953. Creel census of 23 Minnesota lakes - 1952. Minnesota Department of Conservation, Investigative Report 135. 71 p.

Muench, K.A. 1966. Certain aspects of the life history of the walleye, Stizostedion vitreum vitreum (Mitchill), in Center Hill Reservoir, Tennessee. MSc. Thesis, Tennessee Technological University. 66 p.

Nelson, W.R., and C.H. Walburg. 1977. Population dynamics of yellow perch (Perca flavescens), sauger (Stizostedion canadense) and walleye (Stizostedion vitreum vitreum) in four main stem Missouri River reservoirs. Journal of the Fisheries Research Board of Canada 34:1748-1763.

Nepszy, S.J. 1977. Changes in percid populations and species interactions in Lake Erie. Journal of the Fisheries Research Board of Canada 34:1861-1868.

Nie, N.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner, and D.H. Bent. 1975. Statistical package for the social sciences, 2nd edition. McGraw-Hill Book Company, New York. 675 p.

Niemuth, W., W. Churchill, and T. Wirth. 1966. The walleye, it's life history, ecology and management. Publication of the Wisconsin Conservation Department No. 227. 18 p.

Nikolsky, G.V. 1965. Theory of fish population dynamics as the biological background for rational exploitation and management of fisheriey resources. Nanka Press, Moscow. 328 p.; English edition, Oliver and Boyd, Edenburgh. 323 p.

Noble, R.L. 1972. Distribution of walleye and yellow perch fry in a Bay of Oneida Lake. New York Fish and Game Journal 19:168-177.

Nord, R.C. 1967. A compendium of fishery information on the upper Mississippi River. Contribution to the Upper Mississippi River Conservation Commission. 209 p.

Nunan, C.P. 1982. Initial effects of the exploitation of walleye Stizostedion vitreum vitreum (Mitchill) on the boreal percid community of Henderson Lake, Northwestern Ontario. MSc. Thesis. Lakehead University, Thunder Bay, Ontario. 127 p.

Nursall, J.R. 1973. Some behavioral interactions of spotted shiner Notropis hudsonius, yellow perch Perca flavescens and northern pike Esox lucius Linnaeus. Journal of the Fisheries Research Board of Canada 30:1161-1178.

Olson, D.E. 1980. Comparisons of marks on scales and dorsal spine sections as indicators of walleye age. Section of Fisheries, Investigational Report No.371. Division of Fish and Wildlife, Department of Natural Resources, Minnesota. 17 p.

__________. 1963. Role of the white sucker in Minnesota waters. Proceedings of the Minnesota Academy of Science 31:68-73.

__________. 1958. Statistics of a walleye sport fishery in a Minnesota lake. Transactions of the American Fisheries Society 87:52-72.

Olynyk, J.P.R. 1982. Lake Winnipeg walleye fecundity. Manitoba Department of Natural Resources. MS Report No.82-27. 21 p.

Olynyk, J.P.R. 1980. An analysis of sauger maturity regimes in southern Lake Winnipeg. Manitoba Department of Natural Resources. MS Report No.80-36. 52 p.

Ontario Ministry of Natural Resources. 1983. The identification of overexploitation. SPOF Working Group No.15. Ministry of Natural Resources, Ontario. 84 p.

____________. 1982. Partitioning yields estimated from the morphoedaphic index into individual species yields. SPOF Working Group No. 12. Ministry of Natural Resources, Ontario. 71 p.

____________. 1980. 1980 Surveys of Ontario's resident and non-resident sport fishermen. Ministry of Natural Resources, Ontario. 149 p.

Parsons, J.W. 1971. Selective food preferences of walleyes of the 1959 year class in Lake Erie. Transactions of the American Fisheries Society 100:474-485.

____________. 1970. Walleye fishery of Lake Erie in 1943-62 with emphasis on contributions of the 1942-61 year classes. Journal of the Fisheries Research Board of Canada 27:1475-1489.

Paxton, K.O., R.E. Day, and F. Stevenson. 1981. Limnology and fish populations of Ferguson Reservoir, Ohio, 1971-1975. Ohio Fish and Wildlife Report 8. Division of Wildlife, Ohio Department of Natural Resources. 53 p.

Pitcher, T.J., and P.J.B. Hart. 1982. Fisheries ecology. The AVI Publishing Company Inc., Westport, Connecticut. 414 p.

Priegel, G.R. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Technical Bulletin 45. Department of Natural Resources, Madison, Wisconsin. 105 p.

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

__________. 1969b. Food and growth of young walleyes in Lake Winnebago, Wisconsin. Transactions of the American Fisheries Society 98:121-124.

__________. 1963. Food of walleye and sauger in Lake Winnebago, Wisconsin. Transactions of the American Fisheries Society 92:312-313.

Purdon, C.E. 1979. Genetics of growth and reproduction in teleosts. Pages 207-217 in P.J. Miller, editor. Fish phenology; anabolic adaptiveness in teleosts. Symposium of the Zoological Society of London No. 44.

Pycha, R.L. 1961. Recent changes in the walleye fishery of Northern Green Bay and history of the 1943 year class. Transactions of the American Fisheries Society 90:475-488.

Raney, E.C., and E.A. Lachner. 1942. Studies of the summer food, growth and movements of young yellow pike-perch *Stizostedion vitreum vitreum* in Oneida Lake, New York. Journal of Wildlife Management 6:1-16.

Rawson, D.S. 1957. The life history and ecology of the yellow walleye, *Stizostedion vitreum*, in Lac La Ronge, Saskatchewan. Transactions of the American Fisheries Society 86:15-37.

Rawson, D.S., and C.A. Elsey. 1950. Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. Transactions of the American Fisheries Society 78:13-31.

Regier, H.A., V.C. Applegate, and R.A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Technical Report of the Great Lake Fishery Commission No.15. 101 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No.191. 382 p.

Ricker, W.E., and J. Gottschalk. 1941. An experiment in removing coarse fish from a lake. Transactions of the American Fisheries Society 70:382-390.

Riklik, L., and W.T. Momot. 1982. Production ecology of Hexagenia limbata in Savanne Lake, Ontario. Canadian Journal of Zoology 60:2317-2323.

Ritchie, B.J. 1985. Comparison of the yellow perch, Perca flavescens (Mitchill), populations in Henderson Lake and Savanne Lake, Ontario. MSc. Thesis Lakehead University, Thunder Bay, Ontario. 164 p.

Roff, D. 1983. Analysis of catch effort data: a comparison of three methods. Canadian Journal of Fisheries and Aquatic Sciences 40:1496-1506.

Ryder, R.A. 1977. Effects of ambient light variations on behavior of yearling, subadult and adult walleyes (Stizostedion vitreum vitreum). Journal of the Fisheries Research Board of Canada 34:1481-1491.

__________. 1968. Dynamics and exploitation of mature walleyes Stizostedion vitreum vitreum in the Nipigon Bay region of Lake Superior. Journal of the Fisheries Research Board of Canada 25:1347-1376.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Transactions of the American Fisheries Society 94:214-218.

Sandhu, J.S. 1979. Annual production and population dynamics of a relatively unexploited walleye, Stizostedion vitreum vitreum (Mitchill 1818), population in Savanne Lake, Ontario. MSc. Thesis. Lakehead University, Thunder Bay, Ontario. 139 p.

Savel'yeva, E.A., and T.F. Shuvatova. 1972. Some characteristics of the parent-progeny relationship in the Don Pike-Perch (Lucioperca lucioperca (Linnaeus)). Journal of Ichthyology 12:241-248.

Schainost, S. 1983. Harvest and population dynamics of the walleye in Branched Oak Lake, Nebraska. Nebraska Technical Service Report No.12. Nebraska Game and Parks Commission. 35 p.

Schmulback, J.C. 1959. Growth of walleye in the Des Moines River, Boone County, Iowa. Proceedings of the Iowa Academy of Science. 66:523-533.

Schneider, J.C., P.H. Eschmeyer, and W.R. Crowe. 1977. Longevity, survival, and harvest of tagged walleyes in Lake Gogebic, Michigan. Transactions of the American Fisheries Society 106:566-568.

Schumacher, F.X., and R.W. Eschmeyer. 1943. The estimate of fish populations in lakes or ponds. Journal of Tennessee Academy of Science 18:228-249.

Schupp, D.H., and V. Macins. 1977. Trends in percid yields from Lake of the Woods, 1888-1973. Journal of the Fisheries Research Board of Canada 34:1784-1791.

Schweigert, J.F., F.J. Ward, and J.W. Clayton. 1977. Effects of fry and fingerling introductions on walleye (*Stizostedion vitreum vitreum*) production in West Blue Lake, Manitoba. Journal of the Fisheries Research Board of Canada 34:2142-2150.

Scott, D.P. 1962. Effects of food availability on fecundity of rainbow trout *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 19:715-731.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184. 966 p.

Seaburg, K.G. 1957. A stomach sampler for live fish. The Progressive Fish Culturalist 19:137-139.

Seaburg, K.G., and J.B. Moyle. 1964. Feeding habits, digestion rates and growth of some Minnesota warmwater fishes. Transactions of the American Fisheries Society 93:269-285.

Seward, R. 1967. Lake Erie fish population gill netting survey. Ohio Department of Natural Resources, Federal Aid Fish and Wildlife Restoration Project F-35-R-5, Job 4. 25 p.

Serns, S.L. 1982. Walleye fecundity, potential egg deposition and survival from egg to fall young-of-year in Escanaba Lake, Wisconsin, 1979-1981. North American Journal of Fish Management 4:388-394.

Serns, S.L. and J.J. Kempinger. 1981. Relationship of angler exploitation to the size, age, and sex of walleyes in Escanaba Lake, Wisconsin. Transactions of the American Fisheries Society 110:216-220.

Shuter, B.J., and J.F. Koonce. 1977. A dynamic model of the western Lake Erie walleye (Stizostedion vitreum vitreum) population. Journal of the Fisheries Research Board of Canada 34:1972-1982.

Smith, C.G. 1941. Egg production of walleyed pike and sauger. Norris Reservoir fish differ from the same species in other localities. Progressive Fish Culturalist 54:32-34.

Smith, L.L Jr. 1977. Walleye (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens) populations and fisheries of the Red Lakes, Minnesota, 1930-75. Journal of the Fisheries Research Board of Canada 34:1774-1783.

Smith, L.L., and R.L. Pycha. 1961. Factors related to commercial production of the walleye in Red Lakes, Minnesota. Transactions of the American Fisheries Society 90:190-217.

Smith, L.L. Jr., and L.W. Krefting. 1954. Fluctuations in production and abundance of commercial species in the Red Lakes, Minnesota, with special reference to changes in the walleye population. Transactions of the American Fisheries Society 83:131-160.

Smith, S.H. 1954. Method of producing plastic impressions of fish scales without using heat. The Progressive Fish Culturalist 16:75-78.

Snedecor, G.W.. 1956. Statistical methods. Applied to experiments in agriculture and biology. The Iowa State College Press, Ames, Iowa. 534 p.

Snow, H.E. 1978. A 15 year study of the harvest, exploitation, and mortality of fishes, in Murphy Flowage, Wisconsin. Technical Bulletin No.103. Department of Natural Resources, Madison, Wisconsin. 22 p.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry, 2nd edition. Freeman and Company, San Francisco. 859 p.

Spangler, G.R., N.R. Payne, J.E. Thorpe, J.M. Byrne, H.A. Regier, and W.J. Christie. 1977. Responses of percids to exploitation. Journal of the Fisheries Research Board of Canada 34:1983-1988.

Stroud, R.H. 1949. Growth of Norris Reservoir walleye during the first twelve years of confinement. Journal of Wildlife Management 13:157-177.

Svardson, G. 1949. Natural selection and egg number in fish. Report of the Institute for Freshwater Research, Drottningholm, Sweden 29:115-122.

Swenson, W.A. 1977. Food consumption of walleye (Stizostedion vitreum vitreum) and sauger (Stizostedion canadense) in relaton to food availability and physical conditions in Lake of the Woods, Minnesota, Shagawa Lake and Western Lake Superior. Journal of the Fisheries Research Board of Canada 34:1643-1654.

Swenson, W.A., and L.L. Smith Jr. 1976. Influence of food competition, predation and cannibalism on walleye (Stizostedion vitreum vitreum) and sauger (Stizostedion canadense) populations in Lake of the Woods, Minnesota. Journal of the Fisheries Research Board of Canada 33:1946-1954.

Toner, E.D., and G.H. Lawler. 1969. Synopsis of biological data on the pike Esox lucius Linnaeus 1758. Food and Agricultural Organization Fisheries Synopsis No. 30.

Tyler, A.V., and R.S. Dunn. 1976. Ration, growth, and measures of somatic and organ condition in relation to meal frequency in winter flounders, Pseudopleuronectes americanus, with hypotheses regarding population homeostasis. Journal of the Fisheries Research Board of Canada 33:63-75.

Valiant, H. 1984. Declining pickerel harvests and Manitoba's search for solutions. Freshwater Country 8:14-15.

Van Engel, W.A. 1940. The rate of growth of the northern pike, Esox lucius Linnaeus, in Wisconsin waters. Copeia 1940:177-188.

Van Oosten, J., and H.J. Deason. 1957. History of Red Lakes fishery, 1917-38, with observations on population status. Special Scientific Report, United States Fish and Wildlife Service, (Fisheries), No. 229. 63 p.

Vladykov, V.D. 1956. Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec lakes. Journal of the Fisheries Research Board of Canada 13:799-841.

Wahtola, C.H. Jr., D.E. Miller, and J.B Owen. 1972. The age and rate of growth of walleye (Stizostedion vitreum) and sauger (Stizostedion canadense) in Lake Sakakawea, North Dakota, 1968-1969. Proceedings of the North Dakota Academy of Science 25:72-83.

Wainio, A.A. 1966. A study of pike (Esox lucius, Linnaeus) in two areas of Lake Huron. MSc. Thesis. University of Toronto, Toronto, Ontario. 72 p.

Windell, J.T., and S.H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. Pages 219-226 in T.B. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No.3. Blackwell Scientific Publications, London, England. 365 p.

Wolfert, D.R. 1977. Age and growth of the walleye in Lake Erie 1963-1968. Transactions of the American Fisheries Society 106:569-577.

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

Wolfert, D.R., and T.J. Miller. 1978. Age, growth, and food of northern pike in eastern Lake Ontario. Transactions of the American Fisheries Society 107:696-702.

Wolfert, D.R., W.N. Busch, and C.T. Baker. 1975. Predation by fish on walleye eggs on a spawning reef in western Lake Erie, 1969-71. The Ohio Journal of Science 75:118-125.

Wooton, R.J. 1979. Energy costs of egg production and environmental determinants of fecundity in teleost fishes. Pages 133-159 in P.J. Miller, editor. Fish Phenology; Anabolic Adaptiveness in Teleosts. Symposium of the Zoolological Society of London.

Wydoski, R., and E.E. Cooper. 1966. Maturation and fecundity of brook trout from infertile streams. Journal of the Fisheries Research Board of Canada 23:623-649.

Appendix I Table 1. Henderson Lake spring water temperatures (°C), 1982 to 1984.

Date	1982	1983	1984
May 1			4
2			
3			6 - 6.5
4			6 - 8
5			7
6			7 - 8
7			7 - 8
8			7
9			6.5 - 7
10			7 - 8
11			
12		9 - 11	
13		9 - 11	
14	9 - 9.5	9 - 10	9.5
15	11	9 - 10	10
16		9 - 10	11 - 12
17	10 - 13.5	10	11 - 12.5
18	11	10 - 11	12 - 13
19			12.5 - 13
20			11.5 - 12.5
21	10.5 - 12		11.5 - 12
22			12 - 13
23		12	12 - 13
24		12	12.5 - 13
25		11	
26		12 - 13	
27		12 - 13	
28		11.5 - 12.5	
29		10 - 12	
30		11.5 - 12	13.5 - 16
31		11.5	14 - 14.5
June 1		13	
2			15.5 - 17
3			17 - 17.5
4			16 - 16.5

Appendix I Table 1. (Cont'd)

Date	1982	1983	1984
June 5			15.5 - 16
6		13 - 14	16 - 16.5
7		12.5 - 13.5	
8		13	
9		12	
10		12 - 13	
11		14	
12		15 - 16	
13		15.5 - 17.5	
14		16 - 18	15.5 - 17
15		16.5 - 18	
16			
17			
18			
19			18 - 20.5
20	16 - 17.5		
21		18.5 - 20	
22	16 - 16.5	18.5 - 21	
23		20 - 25	
24		20.5 - 22.5	
25		21 - 21.5	
26		21.5 - 23	
27		19.5 - 20	18.5
28		20	17.5 - 18
29		20 - 21	18 - 22
30		20	19 - 19.5
July 1		20	21.5

Appendix II Table 1. Mean length standard deviation and sample size per age class from spring caught walleye from Henderson Lake, 1982 to 1984.

Age Class	1982	1983	1984
3	333.25 (15.00)[1] (12)[2]	343.20 (11.01) (5)	
4	388.38 (32.44) (13)	387.24 (15.13) (45)	426.50 (4.95) (2)
5	413.22 (19.21) (9)	410.31 (20.73) (59)	438.85 (19.91) (33) **
6	445.08 (29.34) (12) **	429.90 (22.15) (40)	451.38 (21.34) (26) **
	447.71 (29.50) (7)	452.95 (18.08) (21)	457.50 (22.38) (24)
8	487.86 (33.54) (7)	466.37 (26.28) (19)	475.83 (19.73) (18)
9	597.00 (0.00) (1)	475.88 (17.27) (8)	486.00 (27.94) (8)
10	503.00 (0.00) (2)	490.33 (26.27) (3)	499.60 (21.58) (5)
11	531.00 (63.64) (2)	—	483.50 (33.23) (2)
12	547.00 (0.00) (1)		—
14	582.00 (0.00) (1)		
16	572.00 (0.00) (1)		

---

[1] Standard deviation

[2] Sample size

** P<0.01

Appendix II Table 2. Mean length, standard deviation and sample size per age class for spring caught northern pike, from Henderson Lake, 1982 to 1984.

Age Class	1982	1983	1984
1		320.33 (42.10)[1] (3)[2]	310.92 (26.98) (26)
2	450.78 (58.62) (9)	472.59 (39.81) (22)	465.56 (59.09) (25)
3	523.55 (22.99) (11)	511.70 (22.72) (10)	528.80 (40.91) (10)
4	543.14 (24.64) (7)	544.00 (32.21) (10)	552.67 (96.86) (3)
5	596.67 (36.16) (21)	599.04 (46.34) (24)	636.67 (77.47) (6)
6	637.79 (34.79) (19)	636.10 (46.46) (20)	605.67 (24.44) (9)
	646.20 (52.13) (5)	665.33 (41.77) (6)	659.54 (45.72) (13)
8	—	718.00 (0.00) (1)	665.33 (44.58) (9)
9	—	—	—
10	883.00 (0.00) (1)		
11	—	992.00 (0.00) (1)	710.00 (0.00) (1)
12	1100.00 (0.0) (1)	1051.00 (0.00) (1)	
13		1013.00 (0.00) (1)	

---

[1] Standard deviation

[2] Sample size

APPENDICES

ppendix III Table 1. Mean male back-calculated lengths (mm) at age based on opercular bone measurements of walleye collected from Henderson Lake, 1982 to 1984.

♂	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1980	171.63 (9.31[1];16[2])	256.44 (13.89;16)	317.11 (20.60;9)	396.67 (7.64;3)										
1979	165.90 (15.34;41)	237.98 (14.83;41)	316.32 (22.01;41)	369.83 (17.14;23)	423.56 (9.93;9)									
1978	154.90 (11.74;49)	217.61 (12.06;49)	288.92 (13.59;49)	357.24 (17.33;49)	396.06 (19.30;18)	451.17 (20.49;6)								
1977	161.60 (11.57;20)	219.95 (12.54;20)	281.45 (13.11;20)	346.70 (15.57;20)	390.30 (16.25;20)	416.00 (18.38;13)	451.75 (14.97;4)							
1976	159.57 (12.25;21)	226.86 (11.72;21)	286.76 (12.60;21)	343.43 (14.26;21)	391.00 (14.08;21)	422.24 (13.82;21)	441.71 (12.82;7)	460.67 (11.93;3)						
1975	170.18 (12.11;17)	239.29 (14.97;17)	300.94 (17.86;17)	355.88 (22.14;17)	389.24 (17.32;17)	417.12 (17.28;17)	440.59 (15.99;17)	454.67 (18.52;6)	492.00 (0.00;1)					
1974	147.50 (7.78;2)	212.50 (27.58;2)	270.50 (47.38;2)	320.50 (57.28;2)	361.50 (48.79;2)	388.50 (37.48;2)	418.00 (29.70;2)	441.50 (20.51;2)	469.00 (0.00;1)					
1973	170.50 (12.01;4)	238.50 (3.00;4)	312.25 (20.76;4)	370.50 (13.18;4)	409.75 (12.28;4)	425.50 (10.60;4)	447.00 (14.35;4)	463.75 (16.46;4)	475.75 (18.68;4)	467.00 (8.49;2)				
1972	170.00 (0.00;1)	261.00 (0.00;1)	363.00 (0.00;1)	411.00 (0.00;1)	441.00 (0.00;1)	455.00 (0.00;1)	474.00 (0.00;1)	482.00 (0.00;1)	494.00 (0.00;1)	503.00 (0.00;1)				
1969	162.50 (4.95;2)	221.50 (14.85;2)	275.50 (7.78;2)	340.00 (8.49;2)	401.00 (2.83;2)	433.50 (14.85;2)	461.00 (15.56;2)	478.50 (23.33;2)	490.50 (24.75;2)	503.00 (25.46;2)	513.00 (18.38;2)	520.00 (15.56;2)	528.50 (13.44;2)	
TOTAL	162.35 (13.71;173)	230.27 (18.04;173)	297.90 (22.52;166)	356.42 (21.09;142)	395.53 (20.14;94)	422.33 (20.13;66)	443.49 (17.34;37)	460.39 (18.56;18)	482.11 (17.22;9)	488.60 (23.85;5)	513.00 (18.38;2)	520.00 (15.56;2)	528.50 (13.44;2)	
TOTAL 979 to 1981 Nunan 1982)	146.71 (14.99;104)	220.97 (23.94;104)	291.05 (28.41;96)	346.22 (30.64;80)	390.14 (30.45;65)	417.60 (27.48;52)	441.04 (31.66;28)	456.24 (31.69;25)	463.33 (36.09;15)	464.30 (34.86;10)	471.25 (32.78;8)	488.60 (24.58;5)	495.75 (28.98;4)	515.00 (38.18;2)

Standard deviation

Sample size

ppendix III Table 2. Mean female back-calculated lengths (mm) at age based on opercular bone measurements of walleye collected from Henderson Lake, 1982 to 1984.

♀	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1980	173.00 (16.90[1];7[2])	260.14 (16.54;7)	326.50 (16.26;2)	406.50 (7.78;2)										
1979	163.69 (11.62;36)	237.06 (11.44;36)	317.25 (14.60;36)	377.65 (16.34;17)	423.25 (8.96;4)									
1978	154.85 (13.47;47)	220.47 (14.71;47)	296.89 (17.94;47)	369.89 (23.43;47)	413.43 (15.51;23)									
1977	156.73 (12.08;22)	218.09 (13.65;22)	285.86 (15.59;22)	359.86 (16.25;22)	420.77 (16.21;22)	451.38 (17.73;8)	525.00 (0.00;1)							
1976	157.13 (12.67;24)	221.38 (17.41;24)	278.96 (22.88;24)	337.00 (29.72;24)	395.54 (28.74;24)	440.21 (28.62;24)	453.33 (8.69;6)	484.00 (14.80;3)						
1975	165.53 (11.67;19)	232.42 (18.91;19)	296.00 (26.27;19)	354.00 (30.90;19)	401.00 (27.29;19)	441.95 (25.37;19)	470.26 (24.72;19)	468.00 (13.40;5)	473.00 (26.87;2)					
1974	166.00 (2.00;3)	241.33 (12.74;3)	310.33 (18.77;3)	379.33 (16.29;3)	423.33 (10.97;3)	459.67 (9.61;3)	486.00 (10.15;3)	504.00 (17.35;3)	515.00 (11.31;2)					
1973	168.00 (9.90;2)	231.00 (22.63;2)	295.50 (47.38;2)	374.00 (39.60;2)	432.00 (26.87;2)	465.00 (9.90;2)	488.50 (4.95;2)	511.50 (2.12;2)	526.50 (16.26;2)					
1971	168.50 (16.26;2)	243.00 (2.83;2)	305.00 (21.21;2)	375.00 (8.49;2)	430.00 (8.49;2)	467.50 (9.19;2)	500.50 (4.95;2)	510.00 (5.66;2)	523.00 (9.90;2)	541.50 (13.44;2)	564.50 (23.33;2)			
1968	167.50 (43.13;2)	241.00 (59.40;2)	299.00 (52.33;2)	343.00 (22.63;2)	378.50 (2.12;2)	416.00 (18.38;2)	440.50 (27.58;2)	470.50 (34.56;2)	487.00 (35.36;2)	497.00 (42.43;2)	507.00 (41.01;2)	517.00 (45.25;2)	524.50 (45.96;2)	536.00 (52.33;2)
TOTAL	160.07 (13.71;164)	228.04 (18.48;164)	297.90 (23.31;159)	361.94 (27.48;140)	409.13 (24.25;101)	444.15 (25.54;60)	471.34 (25.48;35)	487.53 (23.04;17)	504.90 (27.75;10)	519.25 (36.34;4)	535.75 (42.94;4)	517.00 (45.25;2)	524.50 (45.96;2)	536.00 (52.33;2)
TOTAL 979 to 1981 Nunan 1982)	146.72 (13.62;129)	218.70 (21.44;128)	288.65 (27.94;121)	354.60 (30.64;94)	399.21 (32.12;66)	432.25 (29.26;59)	454.87 (28.28;31)	474.33 (25.91;18)	483.18 (24.44;11)	491.70 (22.66;10)	498.83 (27.07;6)	501.00 (25.34;5)	486.50 (13.44;2)	499.00 (0.00;1)

Standard deviation

Sample size

Appendix III Table 3. Mean lengths (mm) at age (sexes combined) back calculated from opercular bone measurements from walleye collected from Henderson Lake, 1982 to 1984.

♂ + ♀	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1982	170.00 (0.00[1];1[2])	297.00 (0.00;1)												
1980	171.63 (11.65;24)	258.17 (14.45;24)	320.50 (19.49;12)	403.00 (9.65;6)										
1979	164.73 (13.65;78)	237.37 (13.28;78)	316.65 (18.70;78)	373.15 (17.05;40)	423.46 (9.26;13)									
1978	154.88 (12.55;96)	219.01 (13.43;96)	292.82 (16.29;96)	363.44 (21.40;96)	405.80 (19.16;41)	451.17 (20.49;6)								
1977	159.05 (11.95;42)	218.98 (13.01;42)	283.76 (14.46;42)	353.60 (17.08;42)	406.26 (22.23;42)	429.48 (24.95;21)	466.40 (35.23;5)							
1976	157.89 (12.33;47)	224.13 (14.92;47)	283.15 (18.86;47)	340.47 (23.48;47)	393.43 (22.54;47)	431.89 (24.24;47)	446.14 (12.27;14)	472.33 (17.55;6)						
1975	167.72 (11.94;36)	235.67 (17.28;36)	298.33 (22.52;36)	354.89 (26.76;36)	395.44 (23.57;36)	430.22 (25.01;36)	456.25 (25.63;36)	460.73 (17.08;11)	479.33 (21.94;3)					
1974	158.60 (10.95;5)	229.80 (22.82;5)	294.40 (34.83;5)	355.80 (44.62;5)	398.60 (42.45;5)	431.20 (43.78;5)	458.80 (40.73;5)	479.00 (37.78;5)	499.67 (27.74;3)					
1973	169.67 (10.39;6)	236.00 (11.08;6)	306.67 (27.97;6)	371.67 (20.52;6)	417.17 (19.16;6)	438.67 (22.43;6)	460.83 (24.24;6)	479.67 (27.78;6)	492.67 (30.81;6)	467.00 (8.49;2)				
1972	170.00 (0.00;1)	261.00 (0.00;1)	363.00 (0.00;1)	411.00 (0.00;1)	441.00 (0.00;1)	455.00 (0.00;1)	474.00 (0.00;1)	482.00 (0.00;1)	494.00 (0.00;1)	503.00 (0.00;1)				
1971	168.50 (16.26;2)	243.00 (2.83;2)	305.00 (21.21;2)	375.00 (8.49;2)	430.00 (8.49;2)	467.50 (9.19;2)	500.50 (4.95;2)	510.00 (5.66;2)	523.00 (9.90;2)	541.50 (13.44;2)	564.50 (23.33;2)			
1969	162.50 (4.95;2)	221.50 (14.85;2)	275.50 (7.78;2)	340.00 (8.49;2)	401.00 (2.83;2)	433.50 (14.85;2)	461.00 (15.56;2)	478.50 (23.33;2)	490.50 (24.75;2)	503.00 (25.46;2)	513.00 (18.38;2)	520.00 (15.56;2)	528.50 (13.44;2)	
1968	167.50 (43.13;2)	241.00 (59.40;2)	299.00 (52.33;2)	343.00 (22.63;2)	378.60 (2.12;2)	416.00 (18.38;2)	440.50 (27.58;2)	470.50 (34.65;2)	487.00 (35.36;2)	497.00 (42.43;2)	507.00 (41.01;2)	517.00 (45.25;2)	524.50 (45.96;2)	536.00 (52.33;2)
TOTAL	161.18 (13.69;342)	229.49 (18.65;342)	298.04 (22.87;329)	359.30 (24.70;285)	402.48 (23.24;197)	432.73 (25.18;128)	456.71 (25.65;73)	473.57 (24.73;35)	494.10 (25.56;19)	502.22 (32.26;9)	528.17 (36.22;6)	518.50 (27.68;4)	526.50 (27.74;4)	536.00 (52.33;2)
TOTAL 1979 to 1981 (Nunan 1982)	146.42 (15.92;411)	220.65 (22.97;409)	292.50 (29.44;377)	354.76 (34.26;313)	399.83 (37.78;236)	431.66 (31.33;174)	456.67 (32.25;103)	473.35 (32.71;77)	483.47 (34.84;53)	496.33 (35.38;42)	503.27 (35.51;30)	514.73 (33.48;22)	504.54 (30.86;11)	520.25 (31.48;4)

---

[1] Standard deviation

[2] Sample size

Appendix III Table 4. Mean male back-calculated lengths (mm) at age based on cleithra bone and scale measurements of northern pike collected from Henderson Lake, 1982 to 1984.

♂	1	2	3	4	5	6	7	8	9	10	11
1983	293.29 (38.05[1];21[2])										
1982	257.63 (43.72;27)	431.80 (66.84;15)									
1981	279.35 (25.65;17)	428.27 (43.22;15)	514.33 (26.76;3)								
1980	284.00 (15.56;2)	435.00 (7.07;2)									
1979	269.24 (69.01;17)	390.06 (57.51;17)	492.35 (48.57;17)	522.00 (64.22;7)	619.00 (42.43;2)						
1978	243.68 (65.64;25)	379.28 (45.82;25)	468.80 (35.61;25)	527.68 (31.82;25)	571.58 (31.78;19)	585.43 (19.78;7)					
1977	235.48 (42.94;46)	382.30 (46.36;46)	471.04 (44.42;46)	522.80 (42.66;46)	568.89 (38.62;46)	590.81 (28.48;26)	622.40 (24.44;5)				
1976	259.86 (53.60;22)	409.82 (56.23;22)	485.27 (43.63;22)	530.91 (44.10;22)	568.86 (40.27;22)	599.36 (34.61;22)	609.56 (27.04;9)	653.00 (0.00;1)			
1975	222.86 (55.53;7)	347.43 (53.25;7)	443.43 (54.86;7)	507.43 (44.61;7)	553.71 (33.49;7)	579.57 (28.48;7)	601.29 (23.26;7)	648.00 (0.00;1)			
TOTAL	256.58 (52.53;184)	395.42 (54.95;149)	475.68 (44.64;120)	524.55 (42.01;107)	569.35 (37.64;96)	591.97 (30.10;62)	609.86 (25.28;21)	650.50 (3.54;2)			
TOTAL 1980 to 1981 (Nunan 1982)	205.77 (37.40;52)	342.64 (53.76;52)	440.38 (44.39;52)	493.00 (35.17;50)	522.60 (34.04;47)	545.43 (33.87;37)	555.76 (29.90;25)	564.59 (30.14;17)	577.50 (32.14;12)	579.40 (24.36;5)	588.00 (22.52;3)

[1] Standard deviation

[2] Sample size

Appendix III Table 5. Mean female back-calculated lengths (mm) at age based on cleithra and scale measurements of northern pike from Henderson Lake, 1982 to 1984.

♀	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1983	287.17 (11.79[1];6[2])													
1982	252.62 (41.76;21)	466.20 (49.98;15)												
1981	278.65 (55.71;26)	447.43 (67.08;23)	538.50 (49.44;6)											
1980	256.13 (56.82;15)	383.73 (70.18;15)	490.31 (57.52;13)	551.33 (98.76;3)										
1979	221.64 (41.73;14)	377.43 (48.42;14)	483.71 (67.86;14)	554.38 (68.55;13)	620.20 (96.50;5)									
1978	228.22 (46.22;18)	369.56 (44.72;18)	471.06 (36.12;18)	547.39 (43.63;18)	585.36 (47.10;14)	622.60 (26.37;5)								
1977	232.25 (38.74;44)	366.50 (35.14;44)	462.02 (34.95;44)	527.66 (34.98;44)	578.98 (34.50;44)	621.27 (40.36;37)	654.56 (43.99;9)							
1976	226.86 (39.77;21)	366.62 (30.35;21)	463.81 (30.92;21)	519.57 (35.50;21)	561.33 (40.08;21)	607.95 (40.21;21)	651.29 (50.35;14)	681.38 (46.94;8)						
1975	229.00 (37.88;6)	384.00 (38.46;6)	476.17 (15.22;6)	537.50 (19.56;6)	578.00 (24.90;6)	609.83 (26.38;6)	645.83 (36.05;6)	644.00 (0.00;1)						
1973	261.00 (0.00;1)	344.00 (0.00;1)	401.00 (0.00;1)	478.00 (0.00;1)	507.00 (0.00;1)	529.00 (0.00;1)	579.00 (0.00;1)	600.00 (0.00;1)	644.00 (0.00;1)	693.00 (0.00;1)	710.00 (0.00;1)			
1969	169.00 (0.00;1)	304.00 (0.00;1)	388.00 (0.00;1)	457.00 (0.00;1)	492.00 (0.00;1)	568.00 (0.00;1)	635.00 (0.00;1)	664.00 (0.00;1)	708.00 (0.00;1)	798.00 (0.00;1)	856.00 (0.00;1)	902.00 (0.00;1)	952.00 (0.00;1)	982.00 (0.00;1)
TOTAL	243.43 (48.09;173)	390.84 (59.99;158)	472.35 (45.76;124)	532.73 (44.79;107)	576.37 (44.50;92)	614.41 (39.60;71)	648.32 (44.88;31)	669.00 (46.97;11)	676.00 (45.26;2)	745.50 (74.25;2)	783.00 (103.24;2)	902.00 (0.00;1)	952.00 (0.00;1)	982.00 (0.00;1)
TOTAL 1980 to 1981 (Nunan 1982)	193.46 (43.48;39)	318.82 (65.67;39)	425.90 (57.03;39)	481.87 (45.00;39)	516.56 (47.25;34)	547.89 (47.72;28)	562.81 (51.67;21)	575.38 (58.60;13)	594.89 (60.37;9)	599.57 (61.33;7)	633.67 (10.02;3)			

[1] Standard deviation

[2] Sample size

Appendix III Table 6. Mean lengths at age (sexes combined) back-calculated from cleithra bone and scale measurements from northern pike collected from Henderson Lake, 1982 to 1984.

♂ + ♀	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1983	294.52 (31.53[1];33[2])													
1982	255.49 (43.06;51)	449.00 (60.57;30)												
1981	281.83 (44.96;47)	444.00 (58.63;41)	528.80 (40.91;10)											
1980	275.35 (58.44;23)	412.39 (73.84;23)	490.31 (57.52;13)	551.33 (98.76;3)										
1979	245.97 (60.09;35)	385.69 (50.25;35)	492.09 (55.09;35)	543.05 (67.24;20)	619.86 (80.67;7)									
1978	237.56 (57.15;45)	375.36 (44.20;45)	469.96 (34.64;45)	535.47 (37.78;45)	577.42 (38.95;33)	600.92 (28.86;12)								
1977	237.10 (42.05;96)	379.60 (45.42;96)	471.59 (43.81;96)	530.27 (43.87;96)	577.52 (39.96;96)	608.70 (38.75;63)	643.07 (40.37;14)							
1976	247.55 (48.39;51)	396.73 (51.27;51)	487.69 (47.72;51)	538.12 (48.28;51)	576.88 (46.25;51)	612.67 (41.30;51)	634.96 (46.88;23)	678.22 (44.92;9)						
1975	240.94 (56.46;16)	376.94 (59.29;16)	471.94 (57.42;16)	539.63 (54.37;16)	582.06 (47.56;16)	610.00 (45.47;16)	635.69 (45.03;16)	646.00 (2.83;2)						
1973	261.00 (0.00;1)	344.00 (0.00;1)	401.00 (0.00;1)	478.00 (0.00;1)	507.00 (0.00;1)	529.00 (0.00;1)	579.00 (0.00;1)	600.00 (0.00;1)	644.00 (0.00;1)	693.00 (0.00;1)	710.00 (0.00;1)			
1972	231.00 (0.00;1)	368.00 (0.00;1)	561.00 (0.00;1)	658.00 (0.00;1)	732.00 (0.00;1)	778.00 (0.00;1)	809.00 (0.00;1)	843.00 (0.00;1)	869.00 (0.00;1)	883.00 (0.00;1)				
1969	169.00 (0.00;1)	304.00 (0.00;1)	388.00 (0.00;1)	457.00 (0.00;1)	492.00 (0.00;1)	568.00 (0.00;1)	635.00 (0.00;1)	664.00 (0.00;1)	708.00 (0.00;1)	798.00 (0.00;1)	856.00 (0.00;1)	902.00 (0.00;1)	952.00 (0.00;1)	982.00 (0.00;1)
TOTAL	253.82 (51.24;400)	397.86 (58.65;340)	479.85 (48.23;269)	534.99 (48.21;234)	579.13 (45.73;206)	609.93 (42.21;145)	639.30 (49.22;56)	678.79 (63.06;14)	740.33 (115.93;3)	791.33 (95.18;3)	783.00 (103.24;2)	902.00 (0.00;1)	952.00 (0.00;1)	982.00 (0.00;1)
TOTAL 980 to 1981 Nunan 1982)	208.36 (38.08;215)	335.72 (56.51;213)	425.49 (52.62;212)	482.99 (41.00;198)	519.41 (34.97;178)	546.53 (32.04;146)	562.25 (31.02;112)	576.68 (32.54;72)	592.15 (35.92;47)	603.74 (39.39;27)	621.71 (30.66;21)	646.38 (40.42;8)	712.50 (64.35;2)	782.00 (0.00;1)

[1] Standard deviation

[2] Sample size

Appendix IV Table 1. Fecundity data for walleye collected from Henderson Lake in the fall of 1984.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Oct. 3	498	1775	9	75.6	95,883
3	463	1225	5	45.2	71,875
3	460	1225	5	50.7	71,813
4	510	1475	6	58.8	66,476
4	481	1300	9	49.5	76,804
4	520	1600	6	60.7	84,038
4	505	1500	8	70.7	95,674
5	449	1050	4	34.7	52,197
5	560	2200	7	95.5	109,208
5	520	1850	8	85.2	115,463

Appendix IV Table 2. Fecundity data for walleye collected from Henderson Lake in the fall of 1983.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Sept. 24	455	1050	4	17.2	57,984
24	467	1225	5	20.3	62,025
24	475	1200	5	23.7	60,546
24	465	1075	4	25.3	58,957
24	470	1250	5	25.2	59,753
25	491	1575	8	43.9	88,498
25	487	1400	6	32.6	72,983
25	465	1150	5	20.5	54,223
25	521	1875	9	49.0	83,907
25	451	1100	5	19.9	52,667
25	491	1525	7	45.9	81,643
25	432	900	4	16.1	42,622
25	442	1000	4	18.5	56,216
25	474	1175	5	28.3	55,789
25	446	1050	4	17.8	54,434
25	457	1050	5	15.6	53,985
25	453	1050	5	20.8	53,294

Appendix IV Table 3. Fecundity data for walleye collected from Henderson Lake in the fall of 1982.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Aug. 23	452	1125	5	10.3	59,328
25	461	1075	5	13.8	55,406
23	490	1100	7	11.8	66,741
25	469	925	5	7.0	65,526
25	406	525	4	4.8	36,976
24	455	1050	5	10.0	74,180
23	409	625	5	10.6	52,054
24	399	650	4	6.5	43,923
23	410	750	4	4.5	29,540
Sept. 8	447	900	6	20.9	41,879
16	556	1650	11	37.4	70,885
21	514	1350	7	47.6	64,577
14	562	1950	9	47.8	92,699
22	595	1900	11	57.1	76,791
14	511	1350	6	28.7	62,360
7	508	1575	7	25.5	86,511
7	526	1775	9	30.4	69,228
28	543	1800	8	58.4	66,628
16	521	1500	7	33.1	63,738
10	509	1175	4	7.8	35,041
7	473	1275	6	23.2	62,655
7	444	1000	5	12.9	53,772
15	478	1075	6	28.7	55,947
22	445	925	6	25.4	40,820
30	474	1150	6	48.0	56,271
22	418	700	5	20.2	32,327
7	457	1025	6	13.6	37,219
29	417	750	4	16.1	32,244
22	497	1275	7	37.1	67,556
30	465	1150	7	38.0	44,828
14	457	1000	4	26.1	45,410
30	487	1250	6	41.6	55,571

Appendix IV Table 3 (Cont'd)

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Sept. 30	460	1000	5	35.7	49,420
30	500	1425	4	61.2	74,576
Oct. 1	423	800	4	21.3	28,297
1	437	950	5	19.7	40,664
1	482	1300	6	26.6	63,706
1	480	1200	6	43.2	47,964
1	494	1275	7	44.4	54,103

Appendix IV Table 4. Fecundity data for northern pike collected from Henderson Lake in 1984.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Oct. 3	696	2225	7	39.4	41,948
3	656	1475	6	33.3	36,751
3	737	2800	8	77.6	61,851
3	683	1675	6	15.5	24,629
3	680	2450	6	47.1	54,397
3	601	1375	4	29.2	30,483
3	720	2500	3	41.2	56,022
3	594	1300	2	22.0	26,770
3	600	1400	2	22.0	29,222
3	682	2050	6	55.8	58,502
3	717	2650	6	61.6	63,010
3	820	3800	7	87.1	74,007
3	707	2250	3	45.9	62,407
3	627	1500	2	25.0	34,424
3	627	1500	3	25.0	35,962
3	600	1325	2	27.2	29,856
3	575	1350	2	18.6	27,993
4	644	1625	2	28.8	35,208
4	624	1575	3	44.1	41,710
4	649	1650	3	33.5	42,008
4	601	1500	2	27.8	37,121
4	545	950	2	21.0	34,031
4	564	1125	2	18.5	22,015
4	640	1825	4	40.3	41,439
4	574	1100	3	15.6	24,084
4	646	1775	3	36.2	44,277
5	630	1675	2	24.4	31,470
5	530	1025	2	12.2	17,320

Appendix IV Table 5. Fecundity data for northern pike collected from Henderson Lake in 1983.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Sept. 24	1006	7700	14	55.4	90,215
24	676	1900	6	31.0	49,341
24	677	2125	6	26.8	42,243
24	634	1525	4	17.6	31,989
24	626	1450	6	22.0	33,143
24	526	900	2	12.5	22,060
24	671	2050	7	23.9	29,631
24	569	1225	4	21.0	29,174
24	598	1650	2	15.8	31,920
24	604	1425	3	8.0	14,105
24	676	2075	5	31.1	48,242
24	687	2125	7	27.2	47,359
24	518	925	3	6.0	15,906
24	681	1950	6	26.8	44,984
24	612	1425	6	15.8	30,508
24	572	1225	3	15.1	26,105
25	639	1550	6	13.3	24,592
25	680	1850	5	19.5	36,699
25	495	850	—	3.9	14,895
25	613	1475	2	13.6	28,255

Appendix IV Table 6. Fecundity data for northern pike collected from Henderson Lake in 1982.

Date	Total Length (mm)	Total Weight (gm)	Age	Ovary Weight (gm)	Fecundity
Sept. 14	640	1825	4	27.4	43,263
15	599	1325	3	15.4	24,596
15	623	1525	6	21.8	43,983
16	626	1500	5	17.0	26,241
16	635	1425	6	14.8	21,228
21	677	1875	7	36.6	41,871
22	673	950	7	33.4	34,963
22	635	1700	4	25.3	22,947
22	637	1650	6	27.1	33,584
28	626	1500	5	36.8	35,846
28	598	1325	4	25.2	27,974
29	633	1450	6	31.0	24,784
Oct. 22	596	1300	4	32.5	21,546
22	629	1500	5	45.5	20,128
26	640	1775	5	70.8	28,176
26	670	2000	6	83.6	23,529
Nov. 2	610	1350	6	55.8	25,605
4	755	3500	7	134.9	52,785

Appendix V Table 1. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake walleye, 1982.

	May		July		August		September		October		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens			90.6 (84.5)	90.9 (146)	111.2 (72.3)	85.7 (51)	138.4 (64.5)	81.2 (60)			340.2 (68.0)	81.4 (257)
Etheostoma exile												
Notropis heterolepis												
Notropis spp.												
Catostomus commersoni					12.5 (8.1)	7.1 (1)					12.5 (2.5)	1.7 (1)
Esox lucius					10.0 (6.5)	7.1 (1)					10.0 (2.0)	1.7 (1)
Pungitius pungitius	16.5 (86.8)[1]	100[2] (16)[3]	3.9 (3.6)	27.3 (8)							20.4 (4.1)	6.8 (24)
Unidentified fish			3.2 (3.0)	45.5 (5)	6.8 (4.4)	35.7 (5)	45.3 (21.1)	37.5 (22)	5.6 (100.0)	100.0 (1)	60.9 (12.2)	38.0 (33)
Orconectes virilis			3.4 (3.2)	9.1 (1)							3.4 (0.7)	1.7 (1)
Odonata												
Heptagenia spp.												
Hexagenia spp.							0.1 (0.00)	3.1 (1)			0.1 (0.00)	1.7 (1)
Hirudinea	0.4 (2.1)	100.0 (1)			0.2 (0.1)	7.1 (1)	0.2 (0.00)	3.1 (1)			0.8 (0.2)	5.1 (3)
Trichoptera												
Unidentified invertebrate	1.2 (6.3)	100.0 (1)			0.1 (0.1)	7.1 (1)					1.3 (0.3)	3.4 (2)
Unidentified matter	0.9 (4.7)	100.0 (1)	6.5 (5.7)	81.9 (9)	12.9 (8.4)	92.9 (13)	30.5 (14.2)	78.1 (25)			50.4 (10.1)	81.4 (48)
Number of stomachs with food	1		11		14		32				59	

---

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 2. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake walleye, 1982.

	250-299 mm		300-349 mm		350-399 mm		400-449 mm		450-499 mm		500-549 mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	6.6 (97.1)[1]	100.0[2] (2)[3]	31.2 (76.5)	100.0 (67)	170.0 (88.4)	95.2 (106)	33.0 (59.6)	81.8 (20)	80.5 (45.8)	56.2 (51)	18.9 (65.9)	66.7 (6)	340.2 (68.0)	81.4 (252)
Etheostoma exile														
Notropis heterolepis														
Notropis spp.														
Catostomus commersoni									12.5 (7.1)	6.2 (1)			12.5 (2.5)	1.7 (1)
Esox lucius									10.0 (5.7)	6.2 (1)			10.0 (2.0)	1.7 (1)
Pungitius pungitius			3.7 (9.1)	33.3 (7)	0.2 (0.1)	4.8 (1)			16.5 (9.4)	6.2 (16)			20.4 (4.1)	6.8 (24)
Unidentified fish			1.2 (2.9)	33.3 (2)	4.8 (2.5)	28.6 (6)	5.5 (9.9)	45.5 (5)	43.1 (24.5)	43.8 (14)	6.3 (22.0)	100.0 (6)	60.9 (12.2)	39.0 (33)
Orconectes virilis							3.4 (6.1)	9.1 (1)					3.4 (0.7)	1.7 (1)
Odonata														
Heptagenia spp.														
Hexagenia spp.					0.1 (0.1)	4.8 (1)							0.1 (0.0)	1.7 (1)
Hirudinea					0.4 (0.2)	9.5 (2)			0.4 (0.2)	6.2 (1)			0.8 (0.2)	5.1 (3)
Trichoptera														
Unidentified invertebrate					0.1 (0.1)	4.8 (1)			1.2 (0.7)	6.2 (1)			1.3 (0.3)	3.4 (2)
Unidentified matter	0.2 (2.9)	50.0 (1)	4.7 (11.5)	100.0 (6)	16.8 (8.7)	85.7 (18)	13.5 (24.4)	90.9 (10)	11.7 (6.7)	68.8 (11)	3.5 (12.2)	66.7 (2)	50.4 (10.1)	81.4 (48)
Number of stomachs with food	2		6		21		11		16		3		59	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 3. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake walleye, 1983.

	July		August		September		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	178.4 (79.9)[1]	65.8[2] (69)[3]	118.5 (79.2)	55.0 (43)	76.5 (46.7)	34.8 (11)	373.4 (69.6)	54.3 (123)
Etheostoma exile								
Notropis heterolepis	3.5 (1.6)	2.6 (6)			1.4 (0.9)	4.3 (2)	4.9 (0.9)	2.5 (8)
Notropis spp.	1.6 (0.7)	5.3 (2)					1.6 (0.3)	2.5 (2)
Catostomus commersoni								
Esox lucius								
Pungitius pungitius								
Unidentified fish	39.3 (17.6)	60.5 (30)	29.4 (19.7)	70.0 (23)	84.9 (51.9)	73.9 (21)	153.6 (28.6)	66.7 (74)
Orconectes virilis								
Odonata								
Heptagenia spp.								
Hexagenia spp.	0.5 (0.2)	2.6 (1)	0.2 (0.1)	5.0 (1)	0.6 (0.4)	8.7 (2)	1.3 (0.2)	4.9 (4)
Hirudinea			1.5 (1.0)	5.0 (1)	3.2 (0.2)	4.3 (1)	1.8 (0.3)	2.5 (2)
Trichoptera								
Unidentified invertebrate								
Unidentified matter								
Number of stomachs with food	38		20		23		81	
Number of stomachs examined	48		24		31		103	

---

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 4. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake walleye, 1983.

	0-299 mm		300-349 mm		350-399 mm		400-449 mm		450-499 mm		500-549 mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	0.6 (50.0)[1]	100.0[2] (1)[3]	3.5 (100.0)	100.0 (1)	27.0 (67.5)	33.3 (13)	152.5 (73.5)	57.1 (62)	173.3 (67.1)	56.7 (37)	16.5 (67.1)	50.0 (9)	373.4 (69.6)	54.3 (123)
Etheostoma exile														
Notropis heterolepis					3.5 (8.8)	8.3 (6)	1.4 (0.7)	2.9 (2)					4.9 (0.9)	2.5 (8)
Notropis spp.					0.8 (2.0)	8.3 (1)	0.8 (0.4)	2.9 (1)					1.6 (0.3)	2.5 (2)
Catostomus commersoni														
Esox lucius														
Pungitius pungitius														
Unidentified fish	0.6 (50.0)	100.0 (1)			8.7 (21.8)	66.7 (11)	52.9 (25.5)	65.7 (32)	83.8 (32.5)	66.7 (26)	7.6 (30.9)	100.0 (4)	153.6 (28.6)	66.7 (74)
Orconectes virilis														
Odonata														
Heptagenia spp.														
Hexagenia spp.									0.8 (0.3)	10.0 (3)	0.5 (2.0)	50.0 (1)	1.3 (0.2)	4.9 (4)
Hirudinea							1.5 (0.7)	2.9 (1)	0.3 (0.1)	3.3 (1)			1.8 (0.3)	2.5 (2)
Trichoptera														
Unidentified invertebrate														
Unidentified matter														
Number of stomachs with food					12		35		30				81	
Number of stomachs examined	[illegible]		[illegible]		14		44		40		[illegible]		103	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 5. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake walleye, 1984.

	June		July		August		October		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	19.5 (81.2)[1]	60.0[2] (95)[3]	156.0 (91.0)	81.8 (603)	61.7 (82.3)	50.0 (20)	160.0 (77.4)	56.0 (32)	397.2 (83.3)	64.1 (750)
Etheostoma exile										
Notropis heterolepis					0.7 (0.9)	8.3 (1)	1.3 (0.6)	4.0 (1)	2.0 (0.4)	3.1 (2)
Notropis spp.					0.8 (1.1)	8.3 (1)	9.6 (4.6)	8.0 (7)	10.4 (2.2)	4.7 (8)
Catostomus commersoni										
Esox lucius										
Pungitius pungitius										
Unidentified fish	4.5 (18.8)	40.0 (2)	4.5 (2.6)	9.1 (2)	11.7 (15.6)	58.3 (19)	35.8 (17.3)	56.3 (14)	56.5 (11.8)	39.1 (37)
Orconectes virilis										
Odonata										
Heptagenia spp.										
Hexagenia spp.			4.6 (2.7)	27.3 (10)	0.1 (0.1)	8.3 (1)			4.7 (1.0)	10.9 (11)
Hirudinea			4.3 (2.5)	18.2 (22)					4.3 (0.9)	6.2 (22)
Trichoptera										
Unidentified invertebrate										
Unidentified matter			2.0 (1.2)	4.5 (1)					2.0 (0.4)	1.6 (1)
Number of stomachs with food			22		12		25		64	
Number of stomachs examined	34		76		21		38		169	

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 6. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake walleye, 1984.

	150-199 mm		350-399 mm		400-449 mm		450-499 mm		500-549 mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens			6.5 (74.7)	50.0 (1)	83.5 (88.1)	53.3 (162)	214.2 (80.6)	74.3 (468)	93.0 (88.1)	66.7 (119)	397.2 (83.3)	64.1 (750)
Etheostoma exile												
Notropis heterolepis	1.3 (61.9)[1]	33.3[2] (1)[3]	0.7 (8.0)	50.0 (1)							2.0 (0.4)	3.1 (2)
Notropis spp.					5.8 (6.1)	6.7 (4)	4.6 (1.7)	5.7 (4)			10.4 (2.2)	4.7 (8)
Catostomus commersoni												
Esox lucius												
Pungitius pungitius												
Unidentified fish	0.8 (38.1)	100.0 (3)	1.5 (17.2)	50.0 (4)	2.9 (3.1)	26.7 (4)	40.2 (15.1)	37.1 (18)	11.1 (10.5)	44.4 (8)	56.5 (11.8)	39.1 (37)
Orconectes virilis												
Odonata												
Heptagenia spp.												
Hexagenia spp.					2.6 (2.7)	20.0 (4)	1.6 (0.6)	8.6 (5)	0.5 (0.5)	11.1 (2)	4.7 (1.0)	10.9 (11)
Hirudinea							3.3 (1.2)	8.6 (11)	1.0 (0.9)	11.1 (11)	4.3 (0.9)	6.2 (22)
Trichoptera												
Unidentified invertebrate												
Unidentified matter							2.0 (0.8)	2.9 (1)			2.0 (0.4)	1.6 (1)
Number of stomachs with food	3		2		15		35		9		64	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 7. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake northern pike, 1982.

	September		October		November		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens			41.4 (46.0)	44.4 (15)			41.4 (27.2)	28.6 (15)
Etheostoma exile								
Notropis heterolepis								
Notropis spp.								
Catostomus commersoni			19.0 (21.1)	11.1 (1)	40.0 (84.7)	33.3 (1)	59.0 (38.7)	14.3 (2)
Esox lucius								
Pungitius pungitius								
Unidentified fish	3.0 (20.0)[1]	50.0[2] (1)[3]	19.1 (21.2)	88.9 (12)	5.4 (11.4)	66.7 (6)	27.5 (18.1)	76.6 (18)
Orconectes virilis	12.0 (80.0)	50.0 (2)					12.0 (7.9)	7.1 (2)
Odonata								
Heptagenia spp.								
Hexagenia spp.								
Hirudinea								
Trichoptera								
Unidentified invertebrate					1.8 (3.8)	33.3 (1)	1.8 (1.2)	7.1 (1)
Unidentified matter			10.5 (11.7)	44.4 (4)			10.5 (6.9)	28.6 (4)
Number of stomachs with food	2		9		3		14	

---

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 8. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake northern pike. 1982.

	450-499 mm		500-549 mm		550-599 mm		600-649 mm		650-699 mm		700 + mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens							41.4 (42.2)	50.0 (15)					41.4 (27.2)	28.6 (15)
Etheostoma exile														
Notropis heterolepis														
Notropis spp.														
Catostomus commersoni							19.0 (19.4)	12.5 (1)			40.0 (100.0)	100.0 (1)	59.0 (38.7)	14.3 (2)
Esox lucius														
Pungitius pungitius														
Unidentified fish	0.5 (13.6)[1]	100.0[2] (1)[3]			5.0 (51.5)	100.0 (3)	21.1 (21.5)	75.0 (14)	0.9 (100.0)	100.0 (1)			27.5 (18.1)	78.6 (18)
Orconectes virilis							12.0 (12.2)	12.5 (2)					12.0 (7.9)	7.1 (2)
Odonata														
Heptagenia spp.														
Hexagenia spp.														
Hirudinea														
Trichoptera														
Unidentified invertebrate					1.8(1) 18.6	33.3							1.8 (1.2)	7.1 (1)
Unidentified matter	3.1 (86.4)	100.0 (1)			2.9(2) 29.9	66.7	4.5 (4.6)	12.5 (1)					10.5 (6.9)	28.6 (4)
Number of stomachs with food	1		0		3		8		1				14	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 9. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake northern pike, 1983.

	July		August		September		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	207.8 (79.3)[1]	63.9[2] (40)[3]	130.3 (65.7)	66.7 (22)	138.5 (14.6)	69.6 (32)	476.6 (33.7)	66.3 (94)
Etheostoma exile			0.1 (0.1)	4.2 (1)	0.6 (0.1)	4.3 (1)	0.7 (0.0)	2.4 (2)
Notropis heterolepis	0.9 (0.3)	2.8 (1)					0.9 (0.0)	1.2 (1)
Notropis spp.								
Catostomus commersoni	15.0 (5.7)	2.8 (1)	45.0 (22.7)	4.2 (1)	780.0 (82.1)	4.3 (1)	840.0 (59.4)	3.6 (3)
Esox lucius								
Pungitius pungitius								
Unidentified fish	5.6 (2.1)	38.9 (14)	4.0 (2.0)	20.8 (5)	7.2 (0.8)	17.4 (4)	16.8 (1.2)	27.7 (23)
Orconectes virilis	29.2 (11.1)	13.9 (5)	19.0 (9.6)	12.5 (3)	22.5 (2.4)	8.7 (2)	70.7 (5.2)	12.0 (10)
Odonata								
Heptagenia spp.					0.2 (0.0)	4.3 (1)	0.2 (0.0)	1.2 (1)
Hexagenia spp.	0.7 (0.3)	5.6 (6)			0.7 (0.1)	8.7 (2)	1.4 (0.1)	4.8 (8)
Hirudinea								
Trichoptera								
Unidentified invertebrate					0.4 (0.0)	8.7 (2)	0.4 (0.0)	2.4 (2)
Unidentified matter	2.9 (1.1)	5.6 (2)					2.9 (0.2)	2.4 (2)
Number of stomachs with food	36		24		23		83	
Number of stomachs examined	57		58		51		166	

---

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 10. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake northern pike, 1983.

	0-199 mm		200-299 mm		300-399 mm		400-449 mm		450-499 mm		500-549 mm		550-599 mm		600-649 mm		650-699 mm		700 + mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens			6.0 (100.0)	100.0 (2)	25.2 (100.0)	100.0 (6)	41.1 (91.7)	54.5 (9)	10.5 (96.3)	60.0 (3)	35.7 (43.7)	66.7 (7)	98.1 (94.6)	72.7 (24)	151.1 (82.6)	0.70 (21)	101.9 (68.3)	63.2 (20)	7.0 (0.9)	50.0 (2)	476.6(94) 33.7	66.3
Etheostoma exile	0.1 (100.0)[1]	100.0[2] (1)[3]					0.6 (1.3)	9.1 (1)													0.7(2) 0.0	2.4
Notropis heterolepis													0.9 (0.9)	9.1 (1)							0.9(1) 0.0	1.2
Notropis spp.																						
Catostomus commersoni											45.0 (55.1)	16.7 (1)							795.0 (98.7)	50.0 (2)	840.0(3) 59.4	3.6
Esox lucius																						
Pungitius pungitius																						
Unidentified fish							3.1 (6.9)	45.5 (5)	0.4 (3.7)	40.0 (2)	0.6 (0.7)	33.3 (2)	4.2 (4.0)	36.4 (4)	0.7 (4.0)	15.0 (3)	7.0 (4.7)	31.6 (6)	0.8 (0.1)	25.0 (1)	16.8(23) 1.2	27.7
Orconectes virilis															27.7 (15.1)	5.0 (3)	40.0 (26.8)	31.6 (6)	3.0 (0.3)	25.0 (1)	70.7(10) 5.2	12.0
Odonata																						
Heptagenia spp.																	0.2 (0.1)	5.3 (1)			0.2(1) 0.0	1.2
Hexagenia spp.											0.3 (0.4)	16.7 (1)	0.5 (0.6)	9.1 (1)	0.7 (0.4)	10.0 (6)					1.5(1) 0.1	4.8
Hirudinea																						
Trichoptera																						
Unidentified invertebrate															0.2 (0.1)	5.0 (1)	0.2 (0.1)	5.3 (1)			0.4(2) 0.0	2.4
Unidentified matter											0.1 (0.1)	16.7 (1)			2.8 (1.5)	5.0 (1)					2.9(2) 0.2	2.4
Number of stomachs with food							11				6		11		20		19				83	
Number of stomachs examined	6		4		12		12		10		13		26		48		28		7		166	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix V Table 11. Volume (ml) and frequency of occurrence (%) of food items by month from Henderson Lake northern pike, 1984.

	May		June		July		August		October		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	81.0 (9.5)[1]	37.1[2] (15)[3]	140.7 (18.2)	66.6 (26)	338.3 (37.1)	67.9 (46)	41.8 (82.4)	63.6 (7)	93.8 (10.4)	63.6 (20)	695.6 (20.0)	59.7 (114)
Etheostoma exile	1.5 (0.2)	2.9 (2)	1.5 (0.2)	6.1 (2)	1.0 (0.1)	5.7 (2)					4.0 (0.1)	3.9 (6)
Notropis heterolepis					0.8 (0.1)	3.8 (2)			2.0 (0.2)	9.1 (2)	2.8 (0.1)	2.6 (4)
Notropis spp.									1.0 (0.1)	4.5 (1)	1.0 (0.0)	0.6 (1)
Catostomus commersoni	460.0 (54.2)	8.6 (3)	155.0 (20)	3.0 (1)	535.2 (58.7)	9.4 (5)	0.4 (0.8)	9.1 (1)	700.0 (77.7)	18.2 (4)	1850.6 (53.1)	9.1 (14)
Esox lucius	223.0 (26.3)	8.6 (3)	445.0 (57.4)	9.1 (3)					66.0 (7.3)	9.1 (2)	734.0 (21.1)	5.2 (8)
Pungitius pungitius												
Unidentified fish	12.0 (1.4)	11.4 (4)	14.5 (1.9)	18.2 (6)	32.1 (3.5)	24.5 (13)	5.5 (10.8)	27.3 (3)	13.5 (1.5)	18.2 (4)	77.6 (2.2)	19.5 (30)
Orconectes virilis	28.5 (3.4)	11.4 (10)	13.0 (1.7)	6.1 (4)	1.2 (0.1)	3.8 (2)	3.0 (5.9)	9.1 (1)	25.0 (2.8)	4.5 (4)	70.7 (2.0)	6.5 (21)
Odonata	40.6 (4.8)	22.9 (44)	1.5 (0.2)	3.0 (1)							42.1 (1.2)	5.8 (45)
Heptagenia spp.	0.1 (0.0)	2.9 (1)									0.1 (0.0)	0.6 (1)
Hexagenia spp.			0.5 (0.1)	3.0 (1)	2.0 (0.2)	5.7 (3)					2.5 (0.1)	2.6 (4)
Hirudinea					0.5 (0.1)	1.9 (1)					0.5 (0.0)	0.6 (1)
Trichoptera	2.0 (0.2)	2.9 (2)	2.0 (0.3)	3.0 (1)							4.0 (0.1)	1.3 (3)
Unidentified invertebrate												
Unidentified matter			1.0 (0.1)	3.0 (1)							1.0 (0.0)	0.6 (1)
Number of stomachs with food	35		33		53		11		22		154	
Number of stomachs examined	73		91		148		45		55		412	

---

[1] Percent of volume by month.

[2] Percent of stomachs examined containing food item.

[3] Number of each food item.

Appendix V Table 12. Volume (ml) and frequency of occurrence (%) of food items by size-class from Henderson Lake northern pike, 1984.

	0-199 mm		250-299 mm		300-349 mm		350-399 mm		400-449 mm		450-499 mm		500-549 mm		550-599 mm		600-649 mm		650-699 mm		700 + mm		Total	
	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)	Volume (ml)	Frequency (%)
Perca flavescens	1.1 (57.9)[1]	80.4[2] (4)[3]	20.5 (97.6)	83.3 (6)	34.0 (94.4)	90.0 (10)	7.2 (82.8)	75.0 (3)	12.0 (88.9)	66.7 (2)	39.0 (92.9)	87.5 (9)	69.5 (46.3)	66.7 (13)	80.0 (61.2)	55.6 (14)	144.5 (14.6)	56.1 (28)	155.8 (13.9)	46.4 (18)	132.0 (13.5)	37.5 (7)	695.6 (20.0)	59.7 (114)
Etheostoma exile					0.5 (1.4)	10.0 (1)	1.5 (17.2)	50.0 (2)			0.5 (1.2)	12.5 (1)			1.0 (0.8)	5.6 (1)	0.5 (0.1)	2.4 (1)					4.0 (0.1)	3.9 (6)
Notropis heterolepis	0.8 (42.1)	40.0 (2)															2.0 (0.2)	4.9 (2)					2.8 (0.1)	2.6 (4)
Notropis spp.															1.0 (0.8)	5.6 (1)							1.0 (0.0)	0.6 (1)
Catostomus commersoni													70.0 (46.7)	6.7 (1)			700.0 (71.0)	12.2 (5)	775.2 (69.3)	17.9 (5)	305.0 (31.2)	18.8 (3)	1850.6 (53.1)	9.1 (14)
Esox lucius													5.0 (3.3)	6.7 (1)	30.0 (23.0)	5.6 (1)	60.0 (6.1)	2.4 (1)	123.0 (11.0)	7.2 (2)	516.0 (52.8)	18.8 (3)	734.0 (21.1)	5.2 (8)
Pungitius pungitius																								
Unidentified fish			0.5 (2.4)	16.7 (1)	1.5 (4.2)	10.0 (1)			1.5 (11.1)	33.3 (1)	2.0 (4.8)	12.5 (1)	1.0 (0.6)	6.7 (1)	9.6 (7.3)	38.9 (7)	15.5 (1.6)	12.2 (5)	24.5 (2.2)	28.6 (8)	21.5 (2.2)	31.2 (5)	77.6 (2.2)	19.5 (30)
Orconectes virilis															8.5 (6.5)	16.7 (4)	24.2 (2.5)	9.8 (9)	35.0 (3.1)	7.1 (7)	3.0 (0.3)	6.2 (1)	70.7 (2.0)	6.5 (21)
Odonata															0.6 (0.5)	5.6 (2)	36.0 (3.6)	7.3 (37)	2.0 (0.2)	7.1 (3)			42.1 (1.2)	5.8 (45)
Heptagenia spp.																					0.1 (0.0)	6.2 (1)	0.1 (0.0)	0.6 (1)
Hexagenia spp.											0.5 (1.2)	12.5 (1)	0.5 (0.3)	6.7 (1)			1.0 (0.1)	2.4 (1)	0.5 (0.0)	3.6 (1)			2.5 (0.1)	2.6 (1)
Hirudinea													0.5 (0.3)	6.7 (1)									0.5 (0.0)	0.6 (1)
Trichoptera																	2.0 (0.2)	2.4 (2)	2.0 (0.2)	3.6 (1)			4.0 (0.1)	1.3 (3)
Unidentified invertebrate																								
Unidentified matter																	1.0 (0.1)	2.4 (1)					1.0 (0.1)	0.6 (1)
Numbers of stomachs with food	5		6		10		4		3		8		15		18		41		28		16		154	

---

[1] Percent of volume by size-class.

[2] Percent of stomachs examined containing food type.

[3] Number of each food item.

Appendix VI Table 1. Gill net catch per unit effort and population estimate regression data for Henderson Lake walleye, 1980 to 1984.

Year	mean CPUE		population estimate
1980	2.3296[1]	(32)[2]	1588[3]
1981	0.0476	(1)	1183
1982	0.3855	(51)	945
1983	0.5702	(76)	375
1984	0.3207	(6)	152

[1] mean number of walleye caught per hour of fishing time.

[2] number of gill net sets.

[3] determined by the Schumacher-Eschmeyer method (Schumacher and Eschmeyer 1943).

Appendix VI **Table** 2. Eight-foot trap net catch per unit effort and population estimate data for Henderson Lake walleye, 1980 to 1984.

Year	Mean CPUE	Population estimate
1979	0.8301[1] (11)[2]	1336[3]
1980	0.2336 (46)	1588
1981	0.1475 (21)	1183
1982	0.0825 (46)	945
1983	0.0434 (50)	375
1984	0.1402 (73)	152

[1] mean number of walleye caught per hour of fishing time.

[2] number of trap net sets.

[3] determined by the Schumacher-Eschmeyer method (Schumacher and Eschmeyer 1943).