THE DYNAMICS OF A POLYPHAGOUS LAKE TROUT, *Salvelinus namaycush* (WALBAUM), POPULATION IN A NORTHWESTERN ONTARIO LAKE

BY

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ABSTRACT

Tagging studies, index gill netting and an experimental winter fishery were used to investigate the dynamics of a polyphagous lake trout (Salvelinus namaycush) population in Squeers Lake of northwestern Ontario. The density and standing crop of mature lake trout in Squeers Lake is higher than reported for other lake trout populations. Lake trout in Squeers Lake exhibit a bimodal length distribution with a wide range in length at age, suggesting recruitment of juveniles into the adult population is regulated. Observed depth distribution of lake trout indicates adults may limit young juveniles to deep water. Exploitation in the 1970's may have produced several strong year classes, but recruitment into the adult population did not occur.

The slow growth of lake trout in Squeers Lake appears to result from the lack of available pelagic forage fishes. Thermal regimes limit foraging activity to Mysis relicta and Pontoporeia hoyi during the summer months resulting in suboptimal growth.

In Squeers Lake, scales underestimate the age of lake trout; the magnitude of the error increases with age. In slow growing polyphagous populations, age should be assessed using otoliths. The wide range in size of fish at a given age suggests the choice of aging tissue should be based on age rather than length.

The Ricker Yield model indicates Squeers Lake can withstand the removal of four to eight times the allowable yield of lake

trout recommended by the Morphoedaphic Index. This model accurately reflected actual yield of the 1986 winter fishery.

The lottery system is useful for experimental management projects because it allows strict control and monitoring of effort and harvest. Anglers thought the lottery system was an unacceptable method for managing lake trout populations. Rotational pulse fishing appears to be a simple and acceptable system for managing polyphagous lake trout populations.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICIES

INTRODUCTION

Lake trout, *Salvelinus namaycush* (Walbaum), inhabit deep oligotrophic lakes of the Precambrian Shield. They are adapted to cold water temperatures, slow rates of organic turnover resulting from low nutrients, and short growing seasons characteristic of these lakes (Ryder and Johnson 1972). Lake trout are long-lived, slow-growing, late in maturing and have a low fecundity. Although these characteristics enable lake trout populations to maintain a high level of stability, they also affect the ability of lake trout populations to respond to exploitation, and to changing limnological and environmental conditions.

Ontario lake trout populations are slowly being reduced through both habitat destruction and overexploitation. By 1976 lake trout had become extinct in 70 of the 2000 known lake trout lakes in Ontario (Martin and Olver 1976). Declines in northern Ontario lake trout populations became evident in the early 1970's (Ryder and Johnson 1972). With the establishment of logging roads, inland lakes become accessible to anglers as the route expands to each lake. Fishermen exploit and deplete these newly accessible lake trout stocks.

In 1978, development of the Burchell Lake logging road, 100 km west of Thunder Bay, Ontario provided access to Squeers Lake and five other small lake trout lakes in the area (Figs. 1 and 2). Conservation Officers reported an increase in fishing pressure and harvest of lake trout in all of the lakes. By February 1979, angling effort on Squeers Lake quadrupled, and

Fig. 1. Map showing location of Squeers Lake in relation to Thunder Bay, Ontario.

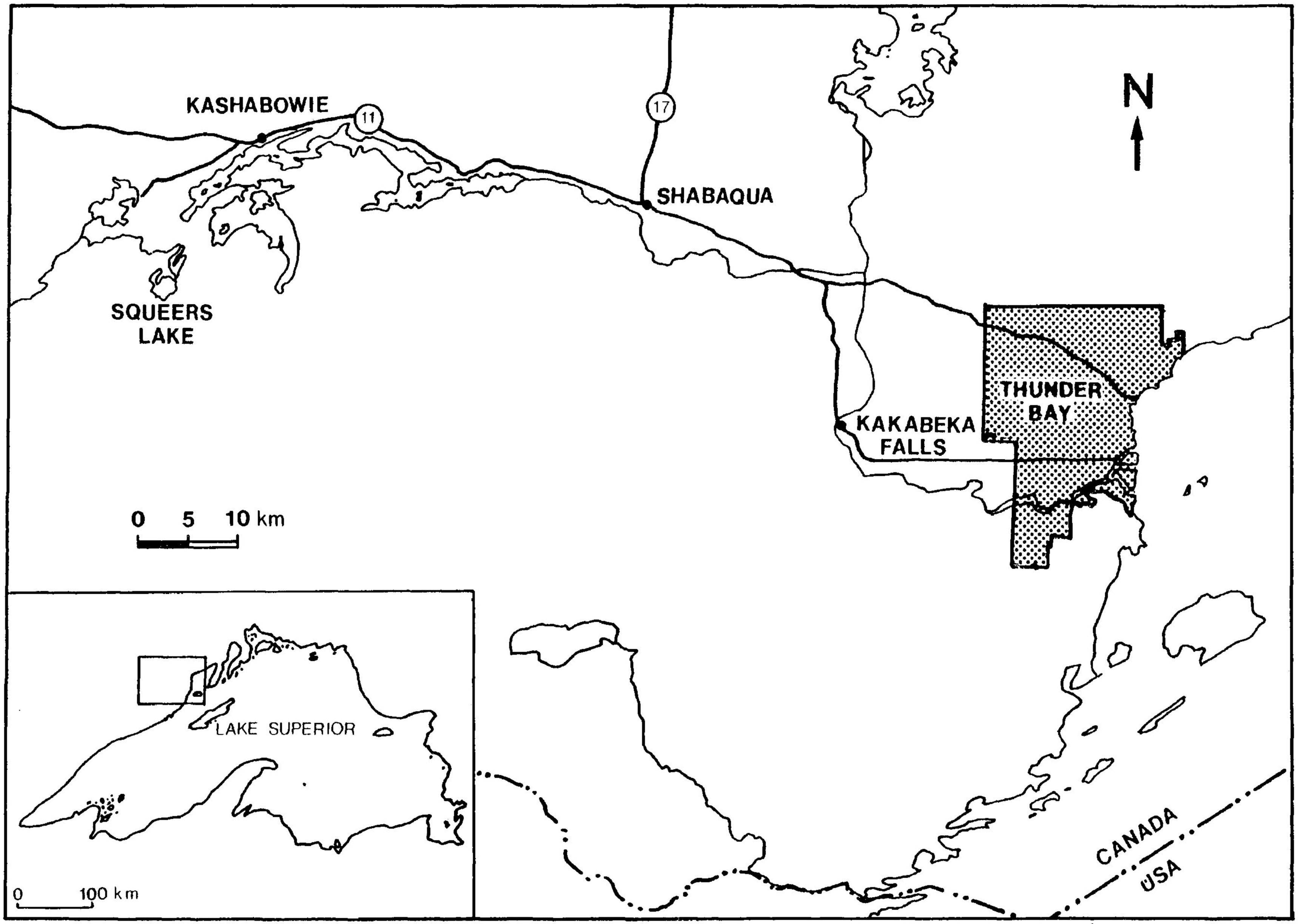
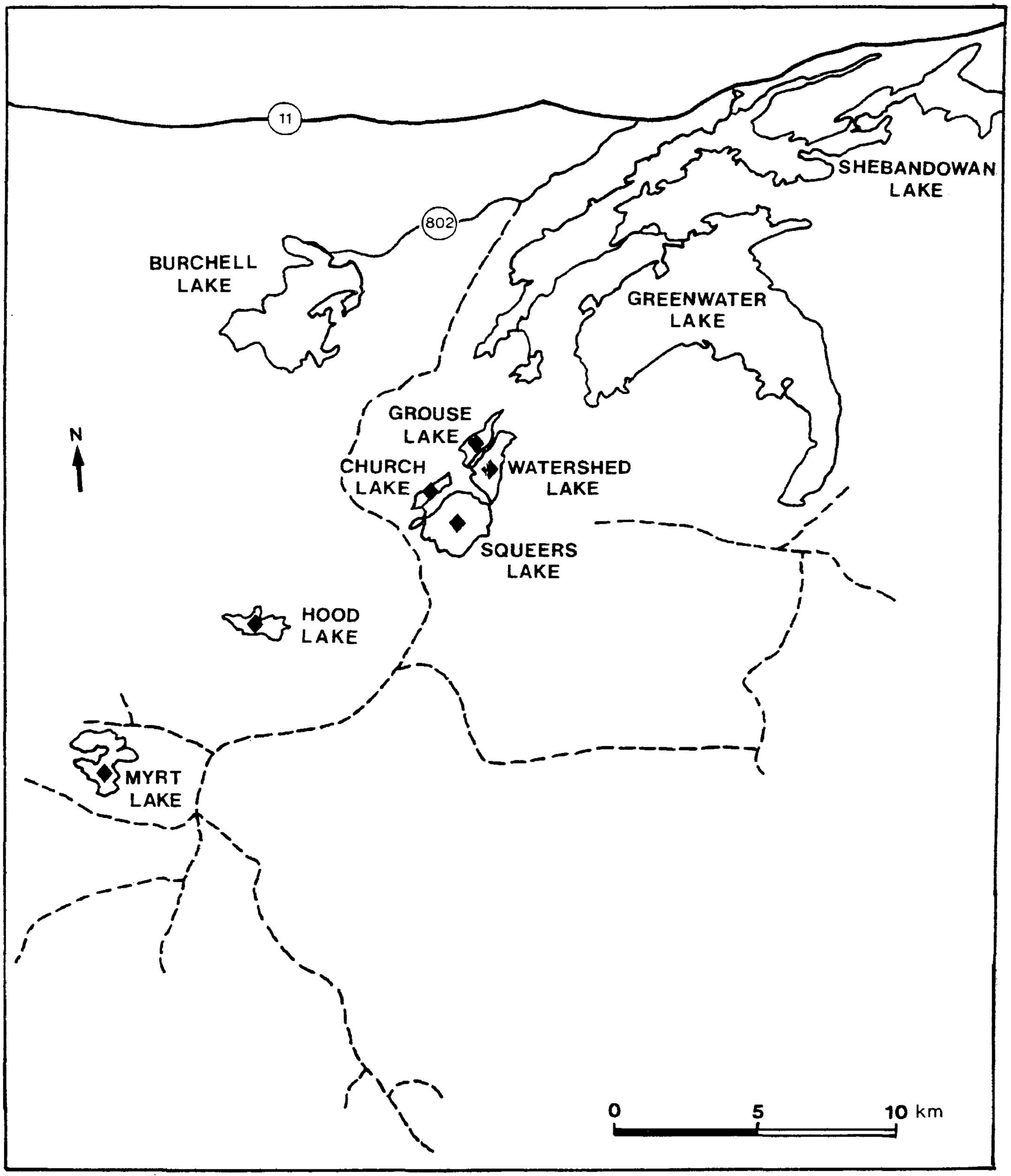

KASHABOWIE
11
17
N
SHABAQUA
SQUEERS
LAKE
THUNDER
BAY
KAKABEKA
FALLS
0 5 10 km
LAKE SUPERIOR
0 100 km
CANADA
USA

Fig. 2. Location of the Burchell Lake logging road in relation to Squeers Lake, Ontario, and five other lakes closed to angling in 1979 (diamond symbols represent closed lakes).



11
802
SHEBANDOWAN LAKE
BURCHELL LAKE
GREENWATER LAKE
GROUSE LAKE
CHURCH LAKE
WATERSHED LAKE
SQUEERS LAKE
HOOD LAKE
MYRT LAKE
N
0
5
10 km

harvest on one weekend equalled the yearly allowable yield as predicted by the morphoedaphic index (.5 kg ha^{-1}, Ryan and Ball 1985; Table 1). In response to increased concern over declining lake trout populations in the Thunder Bay area, all six lakes were declared fish sanctuaries on February 1, 1979. In 1981, five of the lakes were reopened with a restricted summer season. Squeers Lake remained closed to public fishing and was designated a provincial fisheries assessment unit lake: established to obtain long term population data for management of lake trout populations in northwestern Ontario. In conjunction with Quetico-Mille Lacs Fisheries Assessment Unit (QMLFAU), data on the population structure of lake trout in Squeers Lake were collected between 1984 and 1986. Additional data collected by QMLFAU in 1982 and 1983 were also analyzed and incorporated into this study (Ryan and Ball 1985). Squeers Lake was temporarily reopened for experimental exploitation and a predetermined number of anglers were chosen by lottery in 1985 and 1986 (Ryan and Howell 1985; Dubois 1986). The lottery system was used to control angling pressure to avoid overharvest; to design an experimental management program over a number of years to monitor the effects of exploitation and determine an empirical estimate of sustainable lake trout harvest; to obtain accurate catch per unit effort and angler profile data; and to encourage public involvement and increase public awareness about lake trout management in small lakes.

Aside from classic studies by Martin (1952,1954,1957,1966, 1970) on southern Ontario lakes and Johnson (1973,1976,1983) and

Table 1. Angler effort and harvest prior to the closure of Squeers Lake, Ontario, 1970-1978.

Year	Number of days checked	Mean number of anglers	Number fish per angler	CPUE	Harvest	
					kg/day	kg/ha
Jan - Mar, 1970	11	6.9	2.08 (n=2) [1]	0.300	7.18	
Jan - Apr, 1971	11	4.1	-			
Jan - Feb, 1972	4	12.7	1.16 (n=2) [1]	0.290	7.50	0.0195
Jan - Mar, 1973	9	9.6	1.79 (n=9) [1]	0.334	8.60	0.0224
Jan - Mar, 1974	9	8.3	1.44 (n=2) [1]	0.250	6.00	0.0156
Feb 13 - 15, 1978	3	43.3	2.99 (n=1) [1]		23.40	0.5489

[1] number of days angler catches were counted

Healey (1978b) on Arctic lakes, comprehensive studies on the dynamics of lake trout populations are limited. Many aspects of the species life history and its response to exploitation are unknown. Lake trout in northern Ontario have not been intensively investigated and may possess quite different characteristics than Arctic or southern Ontario populations.

In Thunder Bay district, cisco, Coregonus artedii Lesueur, and other coregonines occur in 53 percent of all lake trout lakes (OMNR unpub.data, 1963-1984), but are absent from Squeers Lake. Lack of adequate sized, available forage fishes forces lake trout to feed on small fishes, benthic invertebrates and plankton. These lake trout are often inadequately referred to as benthivorous or planktivorous, and for the purpose of this study will be referred to as polyphagous. Past studies on southern Ontario lakes and Arctic lakes have focussed on the dynamics of piscivorous lake trout populations. Apart from one experiment by Martin (1970) which examined the effects of planting polyphagous lake trout in a lake dominated by piscivores, the population characteristics of polyphagous lake trout populations and their response to exploitation have been virtually ignored.

The present study examined the dynamics of a polyphagous lake trout population in Squeers Lake, northwestern Ontario. Population size, age composition, growth, fecundity, maturity, and feeding behaviour were examined. In addition, the initial two years of the experimental fishery were examined to assess the possible effects of exploitation on a polyphagous lake trout population.

STUDY AREA

Squeers lake is located 100 kilometres west of Thunder Bay (48 31'N, 90 33'W; Fig 1). It is an oligotrophic lake with a small eutrophic side basin connected to the main lake by a small shallow channel. Lake trout inhabit only the main basin. The surface area of the lake is 384.4 hectares. The main basin is dimictic and has a maximum depth of 33.5 m (11.5 m mean depth; Ryan and Ball 1985; Table 2, Fig. 3). The substrate of the littoral zone in the main basin is comprised mainly of rubble (8-25 cm), and aquatic macrophytes are scarce. Thermal stratification is evident by mid-June and hypolimnetic oxygen depletion occurs by late summer before fall turnover (Appendix 2). A detailed description of physical and limnological characteristics can be found in Laine (unpub).

Lake trout, _Salvelinus namaycush_ (Walbaum) and northern pike, _Esox lucius_ (Linnaeus) are the principal game fish species which inhabit the lake. The remaining fish fauna of Squeers lake consists of 11 species: redbelly dace, _Chrosomus eos_ Cope; lake chub, _Couesius plumbeus_ (Agassiz); blacknose shiner, _Notropis heterolepis_ Eigenmann and Eigenmann; longnose dace, _Rhinichthys cataractae_ (Valenciennes); white sucker, _Catostomus commersoni_ (Lacepede); burbot, _Lota lota_ (Linnaeus); nine spine stickleback, _Pungitius pungitius_ (Linnaeus); yellow perch, _Perca flavescens_ (Mitchill); Iowa darter, _Etheostoma exile_ (Girard); slimy

Fig. 3. Bathymetric map of Squeers Lake, Ontario, showing depth contours in metres.

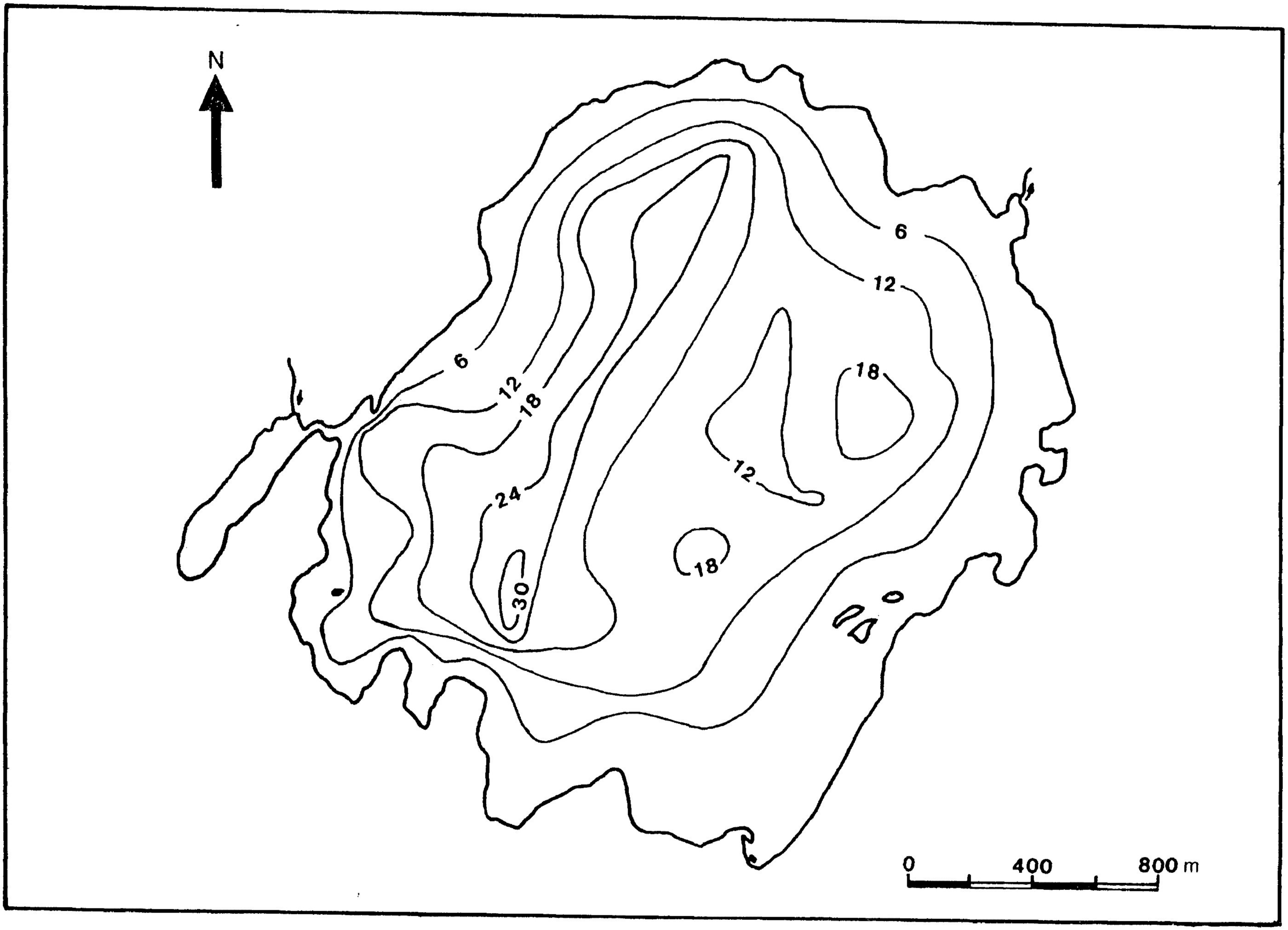

N
6
12
18
24
30
12
18
6
12
18
0
400
800 m

Table 2. Limnological characteristics of Squeers Lake, Ont.

Location	48°31'N 90°33'W
Access	350 metre portage
Surface area	384.4 ha
Mean depth	11.5 m
Maximum depth	33.5 m
Thermal stratification	dimictic
Secchi disc transparancy	5.3 m
Conductivity	42
MEI	2.43

sculpin, _Cottus cognatus_ Richardson; deepwater sculpin, _Myoxcephalus quadricornis_ (Linnaeus);

METHODS

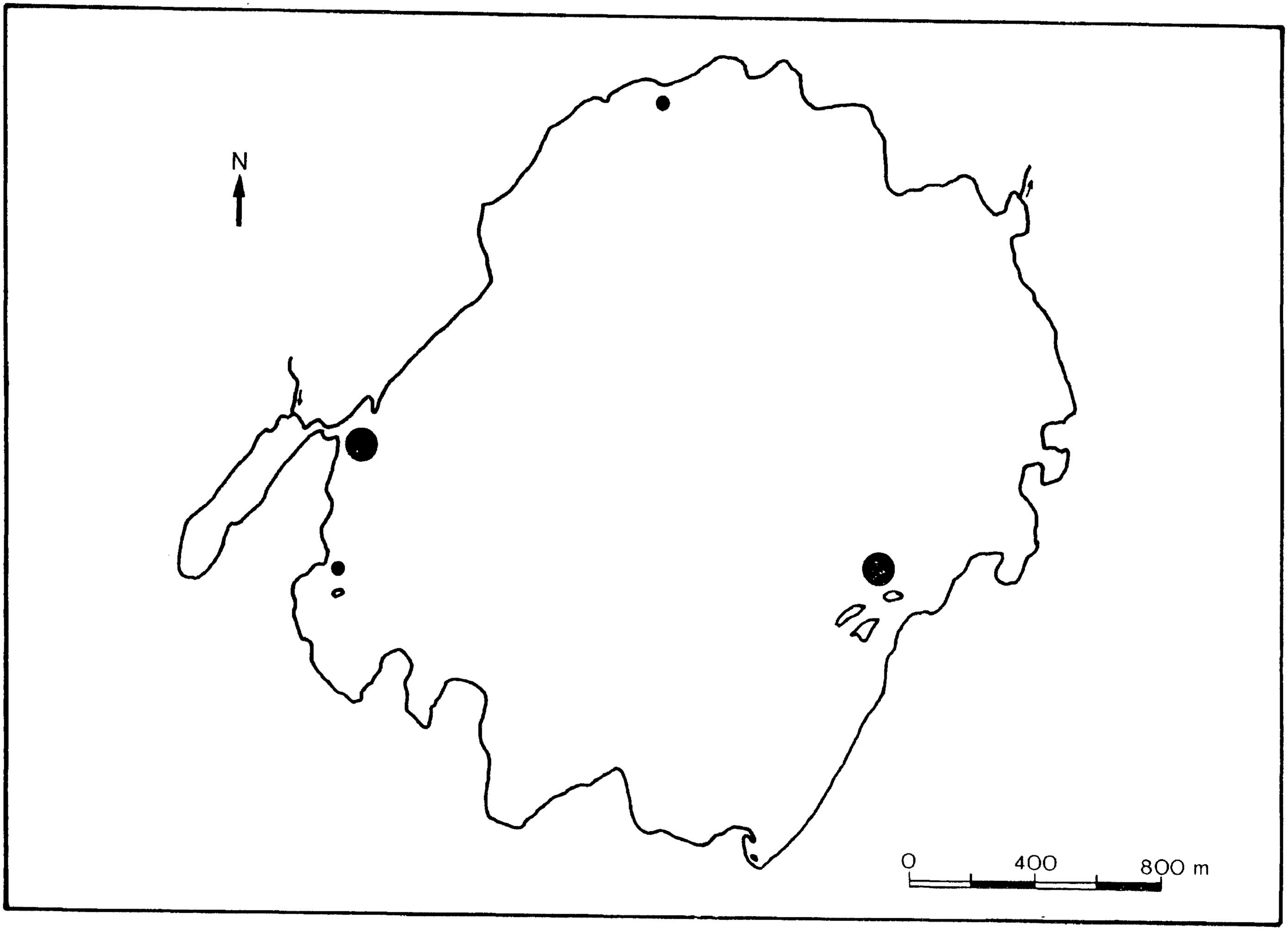
Population Estimates

Population estimates were conducted using single and multiple marking recapture techniques. Fish were marked with numbered disc tags each fall from 1982-1986 and in the springs of 1982, 1984, and 1985. Fish were recaptured in all fall and spring sampling periods, and in the winter fisheries held in March 1985 and 1986.

In the fall of 1982 the perimeter of Squeers Lake was surveyed for suitable gravel substrate and angling was used to locate concentrations of fish to identify lake trout spawning shoals (Fig.4). Then trap nets, gill nets and angling were used on the spawning sites to capture fish. Lake trout were captured between the last week of September and the second week of October depending on the year (Appendix 2).

Gill nets were the primary source of gear used to capture lake trout on the spawning shoals in the fall during the day and night. Monofilament and multifilament nets (3.8 cm - 8.8 cm stretched mesh) comprised of four 15 m long panels were set on spawning shoals at depths ranging from 1 to 4 metres. In 1982 and 1983 nets were set for a maximum of 2 hours and then lifted. Between 1984 and 1986 a motor boat was used to frighten fish into the net, and the net was lifted immediately. The latter method was found to be more efficient, especially for daytime capture. Angling was used to capture lake trout in areas adjacent to the

Fig. 4. Map of Squeers Lake, Ontario, showing the location of lake trout (*Salvelinus namaycush*) spawning shoals (large circles represent primary spawning shoals, small circles represent minor shoals).


N
0
400
800 m

shoals in 3 to 5 metres of water during the day and early evening, when lake trout were not on the shallow spawning shoals and gill nets were not successful in capturing large numbers of fish. Trap nets were used intensively in the fall of 1982. Four trap nets (1.8 m deep) were set in four locations adjacent to the spawning shoals and lifted daily. Since trap nets did not capture many fish they were not used in subsequent years. Lake trout caught incidentally in trap nets set for northern pike in the fall of 1984 and 1985 were also tagged. Lake trout were captured by angling around the shoreline in May 1982, 1984 and 1985.

Fish removed from the gear were placed in a 70 litre live tub containing lake water. Fish were anesthetized with MS222 (ethyl m-aminobenzoate methanesulfonate) and then examined for tags, fin clips, wounds or scars (Appendix 3). Fork length was recorded to the nearest millimetre. Sex and state of maturity was determined by the extrusion of gonadal products and classified according to a system used by Quetico- Mille Lacs Fisheries Assessment Unit, OMNR (Appendix 4). If eggs or sperm were not extruded the sex was considered unknown. The weight of five lake trout from every 2 cm length interval was taken using a Jim tube-type spring scale (Appendix 5). All lake trout captured were assigned a serially numbered clear plastic oval disc tag (Appendix 2). To estimate tag loss supplemental marks were administered in each sampling period by clipping or punching fins of all tagged lake trout (Appendix 2).

In the spring and fall tagging programs of 1982, lake trout were retained for varying periods of time in a 1.2 m deep black polypropylene trap net. In the fall of 1983 fish were held for 16 hours in black polypropylene holding nets (1 m in diameter, 1.7 m deep) to assess short term mortality caused by the capture and tagging procedure. All other marked lake trout were released into shallow water and observed until recovery. Any fish which died were sexed internally, and tissues for aging (scales, fin rays, and otoliths), stomachs, and eggs from females were removed. Stomachs and egg samples were preserved in 10 percent and 5 percent formalin respectively, and stored in whirlpacks for future feeding and fecundity analysis.

Petersen estimates, incorporating the Chapman (1951) modification (Ricker 1975), using single recaptures were conducted to estimate the population size in 1982,1983,1984,1985 and 1986. Bailey's Triple Catch estimates (Ricker, 1975) using multiple recaptures were also used to estimate fall 1983,1984 and 1985 population size. Population estimates were calculated for each 5 cm interval by sex and gear type for lake trout between 35 and 50 centimeters in length. Estimates of population size derived from fish captured by angling alone could not be made because ratios of recaptured to marked fish were too low (Appendix 6). Similarly, identification of females on the spawning shoals was difficult and the ratio of recaptured to marked fish was too low to estimate female population size. Population estimates calculated from winter 1985 and 1986 angling had to be adjusted to account for differences in vulnerability of different sized fish. Ketchen's method (cited in Ricker 1975) was used prior to estimating population size to obtain the number of fish "effectively tagged". The number effectively marked was determined by reducing the number marked by the difference between the percent caught (March 1985, 1986) during the recapture period (March 1985, 1986) and the percent marked during the marking period (Fall 1984, 1985) for each length group (Appendix 7). Confidence limits were derived from the poisson frequency distribution (Appendix 11, Ricker 1975).

Length Distributions

In June 1982 and 1984, multifilament and monofilament gill nets of varying mesh sizes (1.25 to 12.5 cm) were set at depths ranging from 1 m to 35 m (Appendix 8). Length distributions derived from June 1982 and 1984 gill netting were used to represent the length distribution of the population. Comparison of male and female length distributions were made using a Student's t test (Sokal and Rohlf, 1981).

Collection of Tissues and Verification of Aging Techniques

Scales, pelvic fin rays and otoliths were removed and assessed from all lake trout captured in June 1982 gill nets. Otoliths were removed and assessed from five lake trout per two cm length class in June 1984. All lake trout were aged using otoliths in March 1985. Five otoliths per sex for each 2 cm length class for fish less than 40 cm, and all otoliths for fish greater than 40 cm were removed and assessed in March 1986. Scales were removed anterior to the dorsal fin above the lateral line, and placed in dry scale envelopes. Impressions of scales were made by rolling scales between two plastic acetate slides with a scale roller. The impressions were viewed with aid of a microfiche projector. Ages were determined by assessing annuli (Cable 1956).

Lake trout ventral rays from each fish were taken with side cutters and placed in dry scale envelopes. Fin rays were prepared by removing excess tissue, dipping in xylene, setting in epoxy, and then cutting into 0.5 mm cross-sections with an 11-1180 Isomet low speed saw. Sections were mounted on glass microscope slides using Diatex (a synthetic mounting medium), and viewed under a compound microscope. Ages were determined by enumerating translucent zones which formed complete annuli around the entire fin ray.

Otoliths were removed from each lake trout using a method later described by Schneidervin and Hubert (1986). Excess tissue was removed and otoliths were placed in dry scale envelopes. In the lab, otoliths was examined under a compound microscope and the nucleus was located and marked with a black marker. The otoliths were placed on a bed of Kleenex and cracked with a razor blade perpendicularly through the nucleus. Each section was held with tweezers over a flame produced by an alcohol lamp until lightly browned. Otoliths were mounted in plasticine and examined under a microscope. Age was determined by counting translucent zones forming complete annuli the otolith.

Ages determined by scales, fin rays and otoliths were compared using Wilcoxin rank sign test (Sokal and Rohlf, 1981).

Ages were verified by sending a subsample of 50 otoliths collected during the winter fishery of 1985 to the Pacific Biological Station in Nanaimo, British Columbia. A similar A Wilcoxin rank-sum test was used to test for significant differences between readers.

Age Composition

The age composition of the population was determined from fish captured in June 1982 and June 1984 gill netting. Aged fish were separated into 2 cm length intervals by sex, and the percentage of each age per length group was calculated. Assuming the proportion of each age per length group was representative of the population, the number of fish captured in gill nets for each 2 cm length interval was multiplied by the percentage of each age per length group. The percentage of age groups for all length classes were added and plotted as a histogram to represent the age composition of the whole population. Male and female age distributions were compared within and between years using a Students t test (Sokal and Rohlf, 1981).

Growth

Growth was assessed by plotting mean length at age of fish captured in June 1982 and 1984 gill netting and March 1985 and 1986 winter fishing. Comparisons of growth between males and females was made using a Mann-Whitney U test (Sokal and Rohlf, 1981).

Growth was described as a funtion of length at age for different aging tissues. Length at otolith age, fin ray age and scale age were compared by Analysis of Covariance (ANCOV, Sokal and Rohlf, 1981).

Walford plots (Walford, 1946 as cited in Ricker 1975) were constructed with size of fish at marking in fall 1984, and length of fish when recaptured in fall 1985, and compared to plots derived from 1986 length at age curves (for lake trout more than 8 years of age). Slopes derived from Walford plots were compared using a Student's t test to verify growth based on length at age, and to assess whether tagging had any effect on lake trout growth (Zar 1984).

Survival

Survival was assessed using catch curves derived from 1982 and 1984 gill netting, and tag recaptures on the spawning shoals from one year to the next. Survival was estimated for lake trout fully recruited to the gear (age 5 years and older in June 1982, 1984 and age 7 years and older in March 1985, 1986) from catch curves using the maximum-likelihood indicator developed by Robson and Chapman (1960) in Ricker (1975). Estimates of survival between fall 1984 and 1985 of lake trout greater than 35 cm were calculated from tag recaptures using Ricker's method and Bailey's method (Ricker 1975). In addition, survival between 1984 and 1985 of fish greater than 35 cm was assessed using a tag recapture model proposed by Everhart and Youngs (1975).

Maturity

Lake trout captured in June 1982 and June and August 1984 gill netting were examined for sex and gonad condition. In Squeers Lake, lake trout grow less than 1 cm per year, therefore fish captured in June and August gill netting were combined assuming no growth had occurred between the two periods. Mean length and age at onset of maturity was determined for males, females and sexes combined using the method of Lysack (1980). Empirical estimates of length and age at maturity were also derived from the raw data.

Fecundity

Female lake trout were captured by gill nets in June 1984, August 1984 and September 1985 for fecundity estimates. Ovaries from any mature females which died in the fall during tagging operations were also preserved. Length and weight were recorded for each fish and aging tissues were removed and placed in a dry scale envelope. Ovaries were carefully removed, placed in whirl packs and preserved in 5 percent formalin.

Absolute egg counts were conducted for each ovary. Ovaries were blotted dry with paper towels and weighed with a Mettler

AE160 balance to the nearest 0.01 g. Eggs were scraped from the membranous tissue with a spoon and mature eggs were counted directly. The diameter of 30 eggs from each ovary was measured to the nearest mm with Vernier calipers.

Absolute fecundity was regressed on ovary weight, fork length, round weight and age for each year using the least squares method (Sokal and Rohlf, 1981). Fecundity was only regressed on length with lake trout less than 60 cm because the majority of the spawning population were 36 to 60 cm in length. In addition, only a small number of ovary samples were collected from fish greater than 60 cm. ANCOV was conducted to determine whether there was a difference between 1984 and 1985 fecundity with length, weight and age.

Population fecundity was determined by multiplying the mean number of eggs in every 5 cm length interval for fish greater than 35 cm, by the female population size for each similar 5 cm length group.

<u>Depth Distribution</u>

Depth distribution of lake trout during June was analyzed from fish captured in June 1982 and 1984 gill netting. Depths were divided into 10 m intervals, and the number of fish by 2 cm length classes at each depth was determined. Catch per unit effort by depth intervals was also calculated.

Feeding

Seasonal and size specific feeding habits of lake trout were described by analyzing stomach contents of fish using frequency of occurrence and gravimetric analysis. Stomach samples were collected in June 1984, August 1984, March 1985, May 1985, early September 1985, and in late September, early October 1985. All fish except those captured by angling in March 1985 and May 1985 were captured using gill nets. Angling in May 1985 was primarily along the shoreline and in March 1985 angling was distributed throughout the lake. All gill nets except those set during the fall were set randomly at varying depths throughout the lake. In the fall, lake trout were captured on or near spawning shoals.

Stomachs were removed from all fish, placed in whirl packs and preserved in 10 percent formalin. The mouth and esophagus were checked for regurgitated food items and if present were preserved with the stomach. Length and weight of each fish were recorded, aging tissues were removed and sex was determined.

Wherever sample size permitted, 10 stomachs per 2 cm length interval for each sampling period were analyzed (Appendix 9). In June 1984, 10 stomachs were analyzed per 2 cm length interval over four different depth intervals; 1-10 m, 10-20 m, 20-30 m and greater than 30 m (Appendix 10).

In the lab, stomachs were cut open and all items were removed. Food items lodged in the stomach lining were scraped out with a spoon. Prey items were first classified as insects, crustaceans or fish and were then identified further, to at least order (Scott and Crossman 1973; Merritt and Cummins 1978; Pennak 1953). Rare prey items were combined as other invertebrates. Included in this category were terrestrial beetles such as Ptilidactylidae, Hemipterans, Arachnids, Annelids and Pelycypods. Fish remains included fishes which were severely decomposed and could not be identified.

Seasonal changes in feeding habits of lake trout were observed and compared between sampling periods. Lake trout were grouped into 10 cm size categories to observe changes in diet with fish size by season. Diet of fast growing lake trout (5 cm or greater than the mean length at age) was compared with slow growing lake trout (5 cm or less than the mean length at age) in June and August 1984. Feeding habits by size of fish and depth were analyzed in June 1984.

Experimental Winter Fishery

The experimental fishery held in March 1985 and March 1986 was designed to regulate fishing effort and monitor lake trout harvest. A predetermined number of anglers was chosen by lottery to fish at Squeers Lake. Advertisements regarding the fishery were placed in local Thunder Bay newspapers and broadcasted over the radio and television.

In 1985, the fishery was held for 4 days on 2 consecutive weekends. Anglers were requested to choose a specific fishing day and apply in parties of one or two. The harvest was targeted at 5 to 10 percent of the mature population or 400 fish. Assuming anglers would catch their limit, 35 anglers were invited to fish each of the 4 days. After the first weekend, fishing success was 30 percent lower than expected and 15 percent of anglers did not participate (Appendix 11). The success rate and the no show rate were used to estimate the number of anglers required for the second weekend to catch the outstanding targeted harvest. An additional 97 anglers were chosen from previously unsuccessful applicants (Appendix 11).

In March 1986, fishing effort was doubled. To increase effort and harvest, the 1986 winter fishery was held over ten consecutive days and anglers were asked to apply in parties up to a maximum of four members. A total of 700 anglers were invited to fish over the 10 day period (Appendix 11).

At the lake, anglers checked in at a shelter set up on the ice and were provided with a collector's permit allowing them to fish for the day (Appendix 12). Diaries were given to each angler to monitor fishing effort (Appendix 13). In the diaries anglers were asked to mark down the time they began fishing and the time they stopped fishing, the location they were fishing according to a grid map in the centre of the diary, the number of fish caught and released, and the fishing method used. At the end of the day anglers brought their fish back to the shelter to be sampled. Length, weight, girth, sex and maturity were recorded from each fish. Aging tissues (scales, fin rays, and otoliths) were removed and placed in dry scale envelopes. In March 1985 stomachs were collected for the feeding study.

Catch per unit effort (CPUE) was calculated and compared with winter CPUE's prior to the closure of Squeers Lake, CPUE's of other lake trout lakes in North America, and with the CPUE's obtained from experimental spring angling.

Length and age distributions of lake trout harvested were plotted as histograms, and length distributions were compared with those derived from lake trout captured by June gill netting, spring angling, and fall angling and gill netting. Total harvest was calculated as the lake trout removed by number and weight for each age group. Comparisons of effort and harvest between 1985 and 1986 were made.

Yield and Production

Data collected in winter 1985 and 1986 were used to determine equilibrium yield and production by Ricker's method (Ricker 1975). Yield and production were only calculated for those fish fully recruited to the fishery. In 1985, 8 year olds were fully recruited into the fishery, and in 1986, 6 year olds were fully recruited to the fishery. Therefore, yield and production were estimated for only those fish greater than 8 years of age. A weight change factor between age groups was derived from the antilogarithm of the difference between the instantaneous rate of growth and the instantaneous rates of natural mortality and fishing mortality. Between March 1985 and 1986, fishing mortality was not included in the weight change factor since fishing did not occur during the year. The yield of each age group was determined by multiplying the weight of the stock at each age group by the weight change factor. The yield of each age group was summed to give total yield of fish greater than seven years of age. Production was estimated by multiplying the yield of each age group by the instantaneous rate of growth, and summing the totals.

Yield at varying levels of fishing effort was also determined using a modification of Ricker's yield model. The inherent assumption of the model was that fishing effort was proportional to fishing mortality. Ricker's model was based on a type two fishery, where fishing occurred during the whole year (Ricker 1975). The winter fishery at Squeers Lake was a type 1 fishery since fishing occurred over a very short season. Therefore, when fishing effort was hypothetically increased to predict yields for future winter fisheries, the instantaneous rate of fishing mortality from the previous year's fishery was used to determine the weight change factor. Yield at a given level of fishing effort was determined by multiplying the instantaneous rate of fishing mortality and the weight of the stock for each age class, and summing the totals. Yield derived by Ricker's model was compared with actual yield obtained by anglers during the March 1986 winter fishery.

Questionnaires

Questionnaires were distributed to approximately 90 percent of adult anglers during the March 1985 and 1986 fisheries. The purpose of the questionnaire was to investigate angler attitudes, opinions and ideas about lake trout fishing and management of lake trout populations (Appendix 14). In 1986, the questionnaire was modified to address certain issues more precisely and to reduce its length (Appendix 15). Questions pertained to the angler's fishing experience at Squeers Lake, the qualities an angler seeks on a fishing trip, and the opinions anglers have regarding the status of lake trout populations in northwestern Ontario and the type of management strategies with which they like or dislike.

RESULTS

Characteristics of the Spawning Population

The length distribution of tagged lake trout on spawning shoals remained stable between 1982 and 1986, with the modal length at 39 cm in 1982, and in all other years (1983-1986) at 38 cm (Fig. 5). Lake trout captured on the spawning shoals ranged from 25 cm to 59 cm in length. The mean length in 1982 (39.60 cm) was significantly larger than in 1986 (38.35 cm)($p<.05$; Fig. 5).

Lake trout captured in gill nets were significantly larger than by angling on the spawning shoals in all years ($p<.05$; Fig. 6). Length of lake trout captured in gill nets ranged from 25 cm to 59 cm in length, and the mean length was 38.9 cm in 1986 and 40.2 cm in 1982 (Fig. 6). Lake trout caught by angling ranged from 28 cm to 52 cm in length, and the mean length was 37.2 cm in 1986 and 38.7 cm in 1982 (Fig. 6).

Males were more abundant than females on the spawning shoals (Appendix 16). In 1984 and 1986 lake trout were sexed only if gonadal products were extruded. In 1982, 1983 and 1985 sex and state of maturity were assessed by external characteristics such as extension of vent and extrusion of gonadal products. Ninety two percent of known sex fish were males in 1984 and 1986, however 67 to 72 percent of known sex fish were males and 28 to 33 percent were females in 1982, 1983 and 1985 (Appendix 16).

Of lake trout captured on the main shoals, ninety six percent of lake trout marked in 1982 returned to the same shoal

Fig. 5. Length frequency distribution of all lake trout (*Salvelinus namaycush*) captured on the spawning shoals in Squeers Lake, Ontario, 1982-1986.

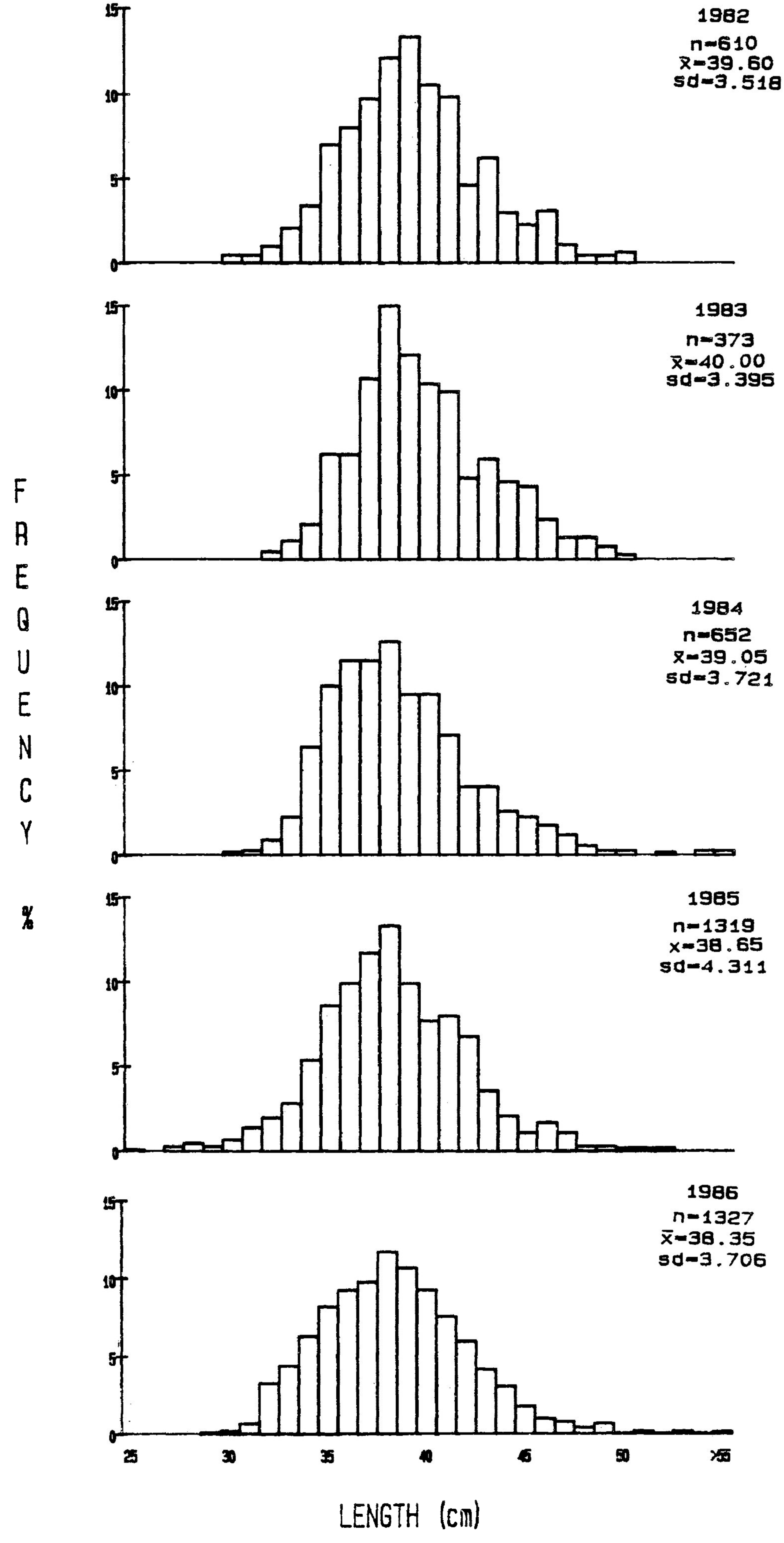
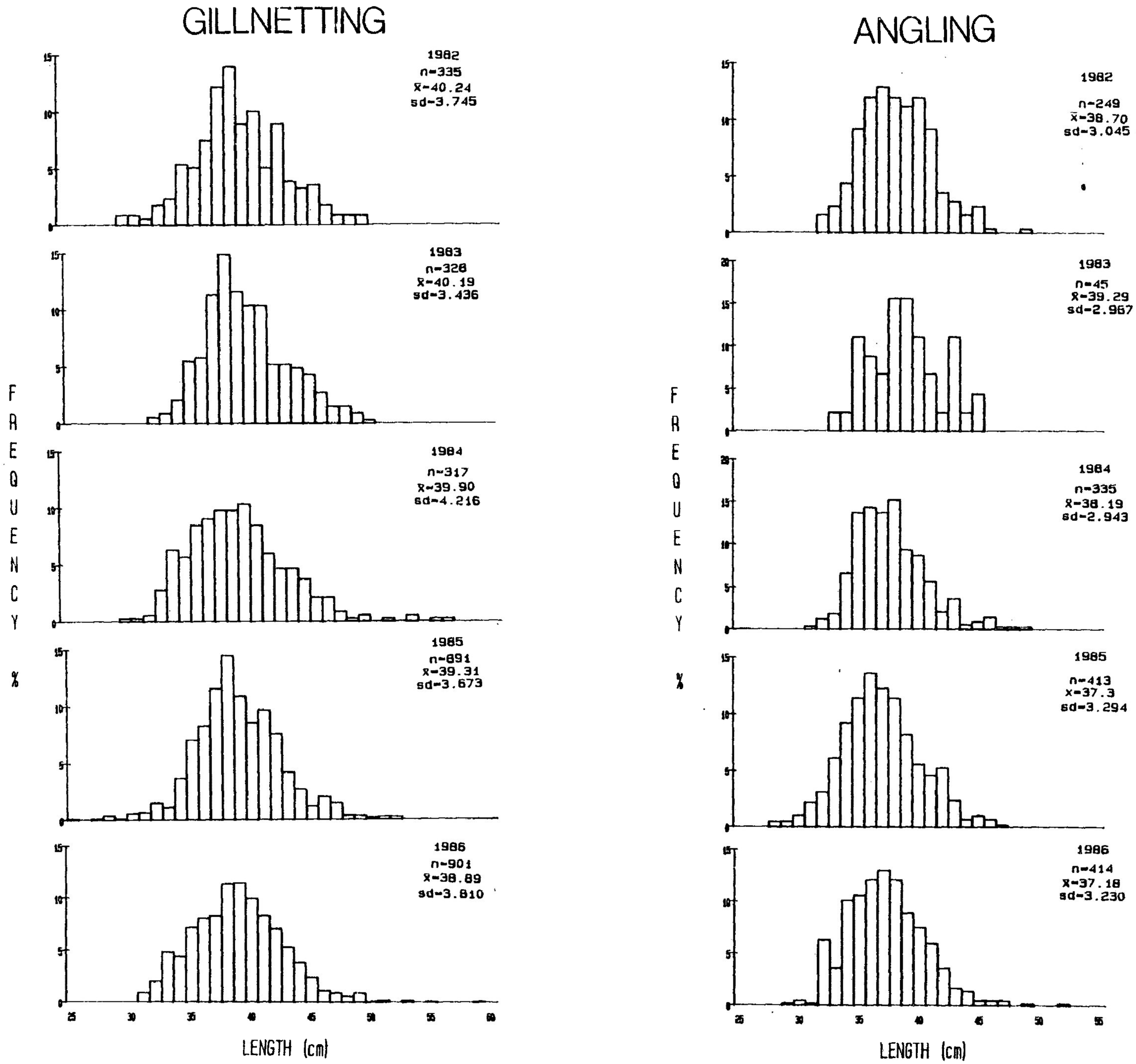

1982
n=610
x̄=39.60
sd=3.518
1983
n=373
x̄=40.00
sd=3.395
1984
n=652
x̄=39.05
sd=3.721
1985
n=1319
x=38.65
sd=4.311
1986
n=1327
x̄=38.35
sd=3.706
FREQUENCY %
0
5
10
15
25
30
35
40
45
50
>55
LENGTH (cm)

Fig. 6. Comparison of length frequency distributions of lake trout (*Salvelinus namaycush*) captured by gill netting and angling on spawning shoals in Squeers Lake, Ontario, 1982-1986.


GILLNETTING
1982
n=335
x̄=40.24
sd=3.745
1983
n=328
x̄=40.19
sd=3.436
1984
n=317
x̄=39.90
sd=4.216
1985
n=891
x̄=39.31
sd=3.673
1986
n=901
x̄=38.89
sd=3.810
FREQUENCY
%
LENGTH (cm)
ANGLING
1982
n=249
x̄=38.70
sd=3.045
1983
n=45
x̄=39.29
sd=2.967
1984
n=335
x̄=38.19
sd=2.943
1985
n=413
x̄=37.3
sd=3.294
1986
n=414
x̄=37.18
sd=3.230
FREQUENCY
%
LENGTH (cm)

in 1983 and 1984. All fish captured on small shoals moved to one of the main shoals during spawning.

Population Size

Yearly Petersen estimates determined population size of lake trout greater than 36 cm in length between 1982 and 1985. The number of fish caught, marked and recaptured in each sampling period by size, sex and gear type were determined (Appendix 17). Accessory marks indicated average annual tag loss was 9.5 percent, and handling mortality was estimated at 4.8 percent (Appendix 18). Therefore the number of recaptures each year was increased by 9.5 percent to account for tag loss, and the number marked was reduced by 4.8 percent to account for handling mortality.

Estimates of population size with confidence limits of less than 25 percent ranged from 4386 in Fall 1982 to 7010 in Fall 1985 (Table 3). The most precise estimate (lowest confidence limits) of population size was 7010 mature lake trout (18 trout/hectare) in 1985.

Over half of the mature lake trout population were between 36 and 40 cm in length (Table 4). The most precise estimates of lake trout between 36 and 40 cm ranged from 2627 to 3940. Population estimates with the lowest confidence limits for lake trout between 41 and 45 cm ranged from 488 to 928. Lake trout between 46 and 50 cm made up the smallest portion of the population and the most precise estimates ranged from 106 to 119

Table 3. Fall and spring Petersen estimates (N) for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982-1985.

Year	Method of Recapture	Population Size	Confidence Limits (95%)
Spring 1982	1	6514	3953 - 11660
Fall 1982	1	4386*	3280 - 5965
Fall 1983	1	11855	7374 - 20766
	2	4713	2983 - 8186
Spring 1984	1	7603	4730 - 13319
Fall 1984	1	6457*	4819 - 8762
	2	7491	4546 - 13409
	3	7449	4852 - 11688
Spring 1985	1	7605	5269 - 11581
Fall 1985	1	7010*	5733 - 7746
	4	9829	7547 - 13287

1 fish recaptured the following fall after marking on the spawning shoals
2 fish recaptured the following spring after marking by angling around the shore
3 fish recaptured the following March after marking during the experimental fishery
4 fish recaptured the following winter
* estimates with the smallest confidence limits

Table 4. Fall and spring Petersen estimates (N) partitioned by length classes for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982 - 1985.

Year	Length Interval (cm) 36-40 N	36-40 95% confidence limits	41-45 N	41-45 95% confidence limits	46-50 N	46-50 95% confidence limits
Spring 1982	3915	1714 - 10497	1586	811 - 3532	112	49 - 301
Fall 1982	2627*	1742 - 4106	735*	479 - 1154	-	-
Fall 1983	[1] 7231	3554 - 14405	1556	753 - 3478	-	-
	[2] 1745	941 - 3407	1600	769 - 4305	-	-
Spring 1984	3369	1723 - 7083	1153	598 - 2426	-	-
Fall 1984	[1] 3940*	2942 - 5349	488*	361 - 675	106*	51 - 237
	[2] 5617	2459 - 15062	988	478 - 2207	154	67 - 412
	[3] 3193	1932 - 5699	2879	1120 - 7653	159	62 - 422
Spring 1985	3278	1989 - 5868	1759	908 - 3467	220	96 - 591
Fall 1985	[1] 3627*	2897 - 4353	938*	693 - 1182	119*	58 - 323
	[2] 3378	2404 - 4977	1556	898 - 2905	-	-

[1] recaptured the following fall on the spawning shoals
[2] recaptured the following spring by angling around the lake
[3] recaptured the following winter during the fishery
* Petersen estimates with smallest confidence limits

fish.

Population estimates of lake trout captured in all gear types were compared with estimates from fish caught in gill nets. In most cases estimates determined from fish captured in gill nets were much lower (by 6 to 43 percent) than those determined from fish captured in all gear (Table 5). Ratios of recaptured to marked fish indicated that fish marked and recaptured by angling were less catchable than those in gill nets (Appendix 6).

Petersen estimates were used to determine male lake trout population size (Table 6). Population estimates with the lowest confidence limits were for mature males and ranged from 2564 to 2705. The most precise estimate of males between 36 and 40 cm ranged from 1449 to 1474. The population of male lake trout between 41 and 45 cm ranged from 130 to 432 fish. The male estimate when adjusted to the sex ratio obtained in June 1982 and June 1984 gill netting provided an estimate of the female population (Appendix 19). The female population ranged from 2663 to 2701 lake trout (Table 6). The combined male and female population estimates was estimated at between 5227 and 5406. This low estimate did not include fish which could not be sexed on the spawning shoals.

Petersen estimates were compared to Bailey Triple Catch population estimates. The multiple mark recapture population estimate was lower (by 33 to 54 percent) than the Petersen estimate in all but one case (Table 7).

Table 5. Percent difference in Petersen estimates (N) by length class for lake trout *Salvelinus namaycush* captured in all gear and those captured in gill nets, Squeers Lake, Ontario, 1982 - 1985.

Length	Year	Gear: All Gear N	Gear: Gill net N	Difference (%)
All Sizes	Fall 1982	4386	3605	- 17.8
	Fall 1983	11855	13685	+ 13.4
	Fall 1984	6457	4686	- 27.4
	Fall 1985	7010	4133	- 41.1
	Fall 1982	2627	1948	- 25.9
36-40 cm	Fall 1983	7231	5713	- 21.0
	Fall 1984	3940	3205	- 18.7
	Fall 1985	3627	2078	- 42.7
	Fall 1982	735	739	+ 1.0
	Fall 1983	1556	2028	+ 23.3
41-45 cm	Fall 1984	488	525	+ 7.1
	Fall 1985	938	691	- 26.3
	Fall 1982	-	-	-
	Fall 1983	-	-	-
	Fall 1984	106	97	- 8.5
46-50 cm	Fall 1985	119	112	- 5.9

Table 6. Male and female population estimates (N) for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982 - 1985.

Size Class	Year	Sex Males N	 Females N
All Sizes	Fall 1982	2705	2809
	Fall 1983	4815	5000
	Fall 1984	2564	2663
	Fall 1985	2601	2701
	Fall 1982	1474	1531
36-40 cm	Fall 1983	2707	2811
	Fall 1984	1457	1513
	Fall 1985	1380	1435
	Fall 1982	412	428
	Fall 1983	340	353
41-45 cm	Fall 1984	125	130
	Fall 1985	243	253

Table 7. Percent difference in Petersen estimates (N) and Bailey Triple Catch estimates partitioned by length class for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982-1985.

Length	Year	Population Estimate: Petersen N	Bailey Triple Catch N	Difference (%)
All Sizes	Fall 1983	11855	5959	- 50.0
	Fall 1984	6457	4340	- 33.0
	Fall 1985	7010	4195	- 40.2
	Fall 1983	7231	3847	- 46.8
	Fall 1984	3940	1788	- 54.6
36-40 cm	Fall 1985	3627	1716	- 52.7
	Fall 1983	735	1601	+54.1
	Fall 1984	488	320	- 34.4
	Fall 1985	938	496	- 47.1
41-45 cm	Fall 1983	-		-
	Fall 1984	106	-	-
	Fall 1985	119	184	+35.3

Length Distribution of the Population

Length distribution was best represented by fish captured in June 1982 and 1984 gill netting. Monofilament and multifilament nets composed of a wide range of mesh sizes (1.3 cm to 12.6 cm) were set randomly at all depths throughout the lake. The size of lake trout captured in monofilament and multifilament gill nets increased with increasing mesh size in 1982 and 1984 (Appendix 20). Length distributions were bimodal with a large peak at 25 and 23 cm and a second smaller peak at 39 and 37 cm in 1982 and 1984 respectively (Fig. 7). The size of lake trout captured ranged from 11 cm in both years, to 93 cm in 1982 and 79 cm in 1984. The mean length was 29.8 cm in 1982 and 29.3 cm in 1984. There was no significant difference in mean length between males and females within or between years ($t=1.251$, $t=.6707$ and $t=.5035$, $t=.3567$, $p<.05$).

Aging Comparisons and Verification

Lake trout were assessed significantly older ages when using the otolith method compared to the scale or fin ray method (Table 8; Appendix 21). Differences between otolith, fin ray and scale aged fish occurred after 5 years.

The presence of deformed otoliths reduced the number of lake trout that could be aged. In addition, size at age grossly overlapped in June 1982 and 1984. Subsampling of aging tissues inadequately described the age structure and growth of the population. Therefore in March 1985 otoliths were removed and

Fig. 7. Length distributions of males, females and sexes combined for lake trout (*Salvelinus namaycush*) captured in gill nets in Squeers Lake, Ontario, 1982, 1984.

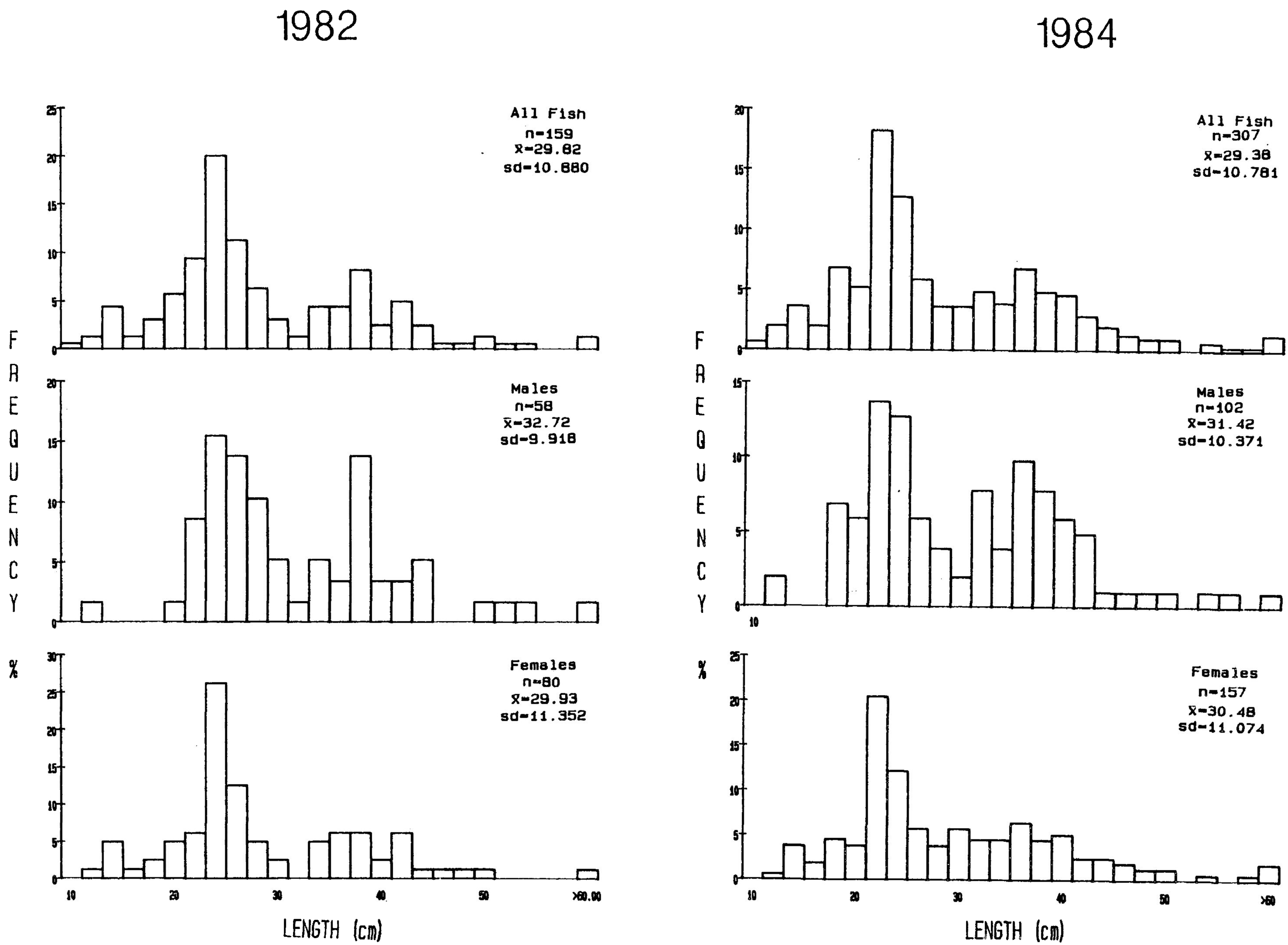

1982
1984
All Fish
n=159
x̄=29.82
sd=10.880
Males
n=58
x̄=32.72
sd=9.918
Females
n=80
x̄=29.93
sd=11.352
All Fish
n=307
x̄=29.38
sd=10.781
Males
n=102
x̄=31.42
sd=10.371
Females
n=157
x̄=30.48
sd=11.074
FREQUENCY %
LENGTH (cm)
10
20
30
40
50
>60.00
>60

Table 8. Comparison of ages derived from scales, fin rays and otoliths for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982.

Aging Tissues	Number of Pairs (number of ties)	Mean Age	Z score[1]
Otoliths Scales	144 (80)	7.76 6.77	6.651[2]
Otoliths Fin rays	57 (10)	8.42 7.54	2.072[2]
Fin rays Scales	63 (26)	7.47 6.18	3.194[2]

[1] Wilcoxin Matched Pairs Signed Ranks Test at p<.05
[2] significant at p<.05

aged from all fish captured. Analysis of winter 1985 aging data indicated that for lake trout less than 40 cm in length, variance in mean length at age could be minimized by aging a minimum of five fish of each sex by 2 cm intervals. All lake trout greater than 40 cm in length were aged to minimize variance.

There was good agreement between otolith ages assessed independently by two technicians. There was no significant differences between readers of the same subsample ($p<.05$; Table 9; Appendix 22).

Age Composition

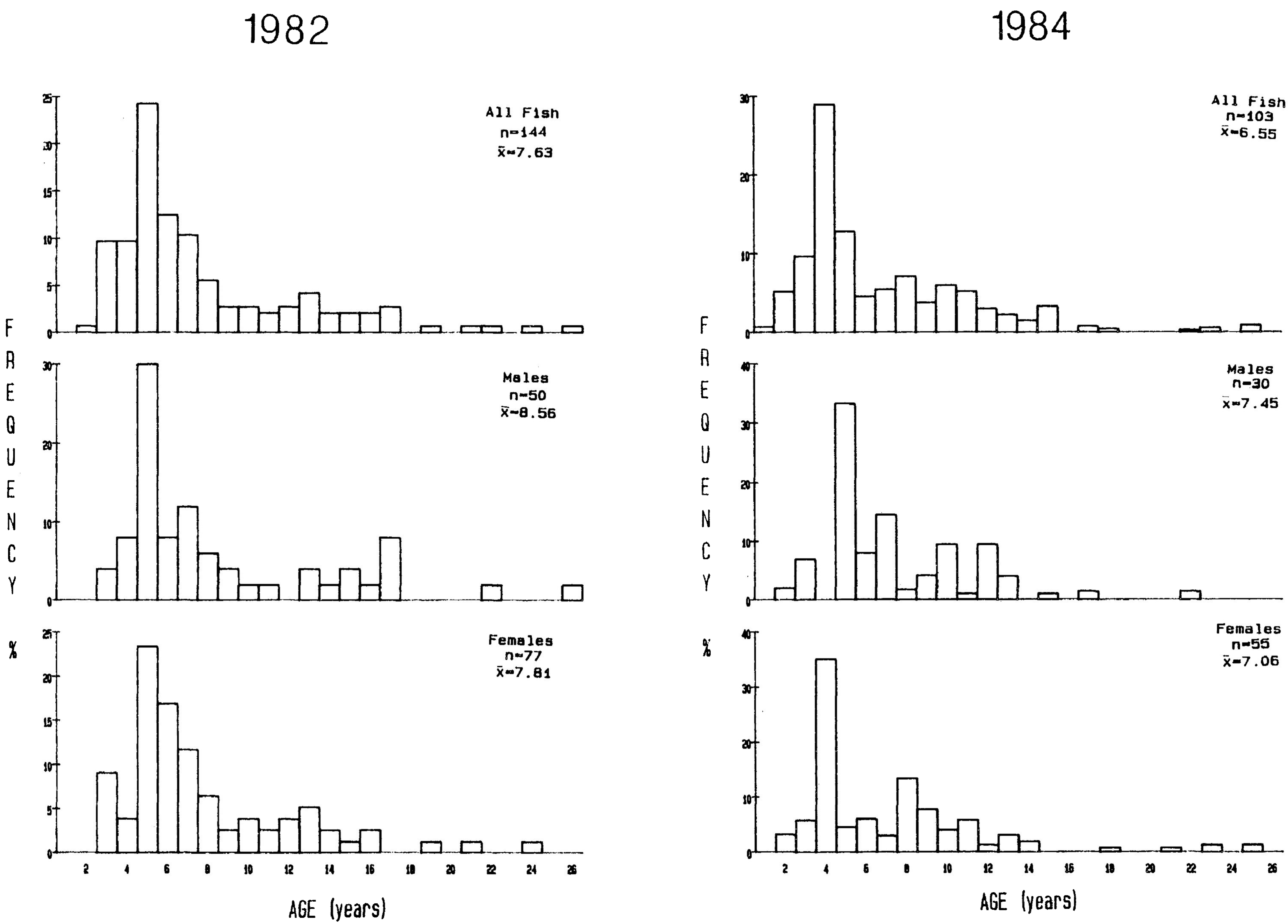
Lake trout captured in June 1982 and 1984 gill netting were used to describe the age structure of the population. Both age distributions were positively skewed peaking at 5 years in 1982 and 4 years in 1984. The peaks are representative of the 1977 and 1980 year classes respectively (Fig. 8). The age of fish captured in June 1982 and 1984 gill netting ranged from 1 year to 26 years. There was no significant difference between the mean age of males (8.78, 7.45) and females (7.51 and 7.06) in 1982 and 1984 ($t=1.495$ and $t=.7455$, $p<.05$). There was no difference in the mean age of females between 1982 and 1984, however males were significantly younger in 1982 ($t=1.825$ and $t=2.474$, $p<.05$ respectively).

Table 9. Comparison of otolith assessed ages between two reader for lake trout *Sallvelinus namaycush* in Squeers Lake, Ontario, 1982.

Comparison Between	Number of Pairs (number of ties)	Mean Age	Z score[1]
A	50	9.72	1.375[2]
B	(20)	9.48	

[1] Wilcoxin Matched Pairs Signed Ranks Test at $p<.05$
[2] significant at $p<.05$

Fig. 8. Age distribution of males, females and sexes combined for lake trout (*Salvelinus namaycush*) captured in gill nets in Squeers Lake, Ontario, 1982, 1984.



1982
1984
All Fish
n=144
x̄=7.63
Males
n=50
x̄=8.56
Females
n=77
x̄=7.81
All Fish
n=103
x̄=6.55
Males
n=30
x̄=7.45
Females
n=55
x̄=7.06
FREQUENCY %
AGE (years)

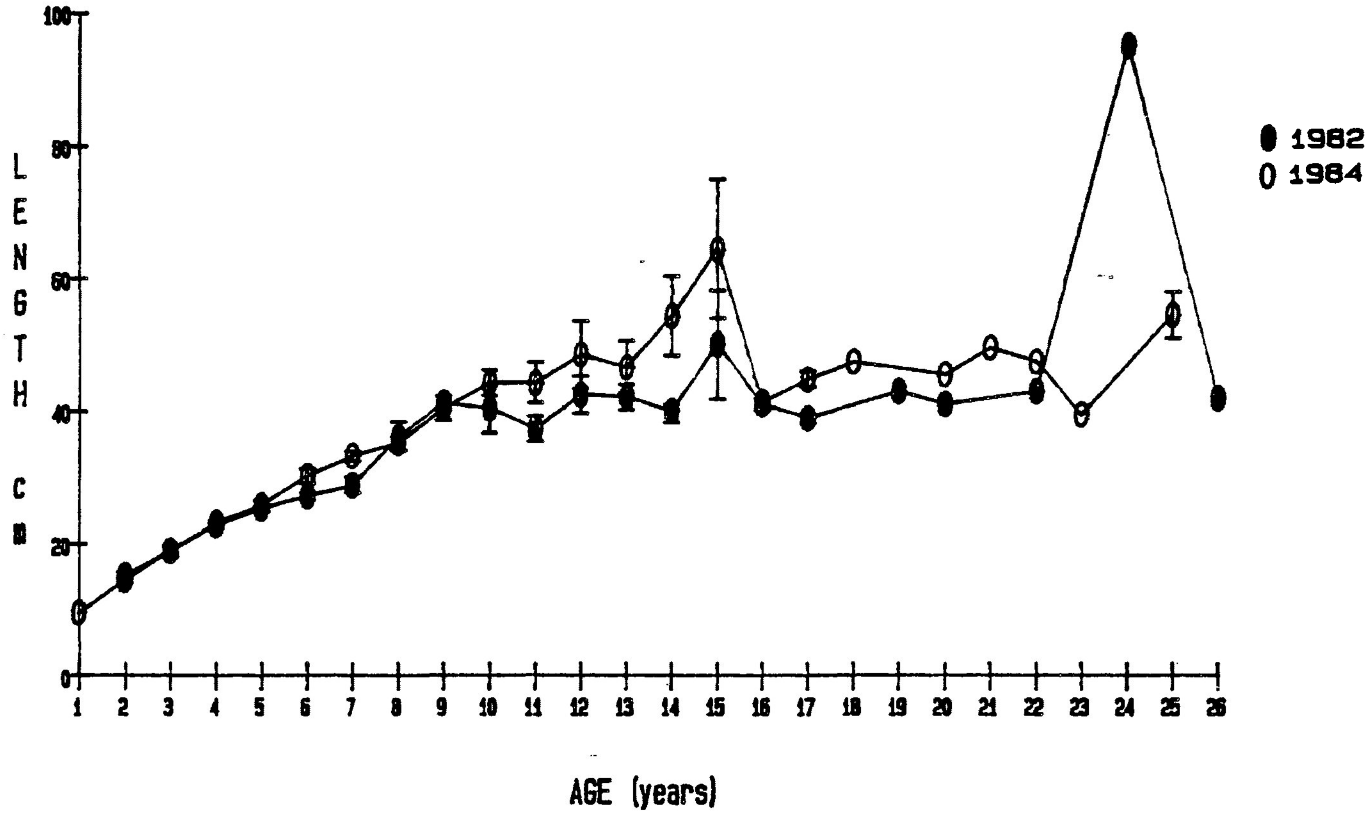
Growth

Comparison of growth rates between males and females (June 1982, 1984 and March 1985,1986) indicated only one difference in mean length at age occurring in 1982 between seven year olds (Appendix 23). Therefore sexes were combined for growth analysis.

Gill netting in June 1982 and 1984 produced the most representative growth pattern because of the wide size range of fish captured. The large variance in length at age, in turn compounded by the small sample size of older fish captured in June 1982 and 1984 gill nets, meant growth of older fish was not adequately described (Appendix 24). The large number of fish aged from March 1985 and 1986 allowed for an accurate assessment of growth of lake trout greater than 7 years.

Lake trout exhibited steady growth of 2 to 3 cm a year for fish between 2 and 7 years of age in 1982, and between 2 and 5 years of age in 1984 (Fig. 9). After the period of uniform growth, size at age increased rapidly. Lake trout increased from a mean of 29 cm in length at age seven, to 36 cm by age eight, and 41 cm by age nine in 1982. Similarly, mean length at age increased from 25 cm at age five, to 30 cm by age six, and to 40 cm by age nine in 1984. The period of rapid growth between 7 and 9 years of age in 1982, and 5 and 9 years in 1984 coincided with a divergence in the growth pattern (Fig. 10). Growth of most lake trout slowed to less than 1 cm a year after age 9 and the maximum size attainable was 50 cm. The pattern of slow growth

Fig. 9. Mean length at age for lake trout (<u>Salvelinus namaycush</u>) captured in gill nets in Squeers Lake, Ontario, 1982, 1984-1986.


100
80
60
40
20
0
L E N G T H
c m
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
AGE (years)
1982
1984

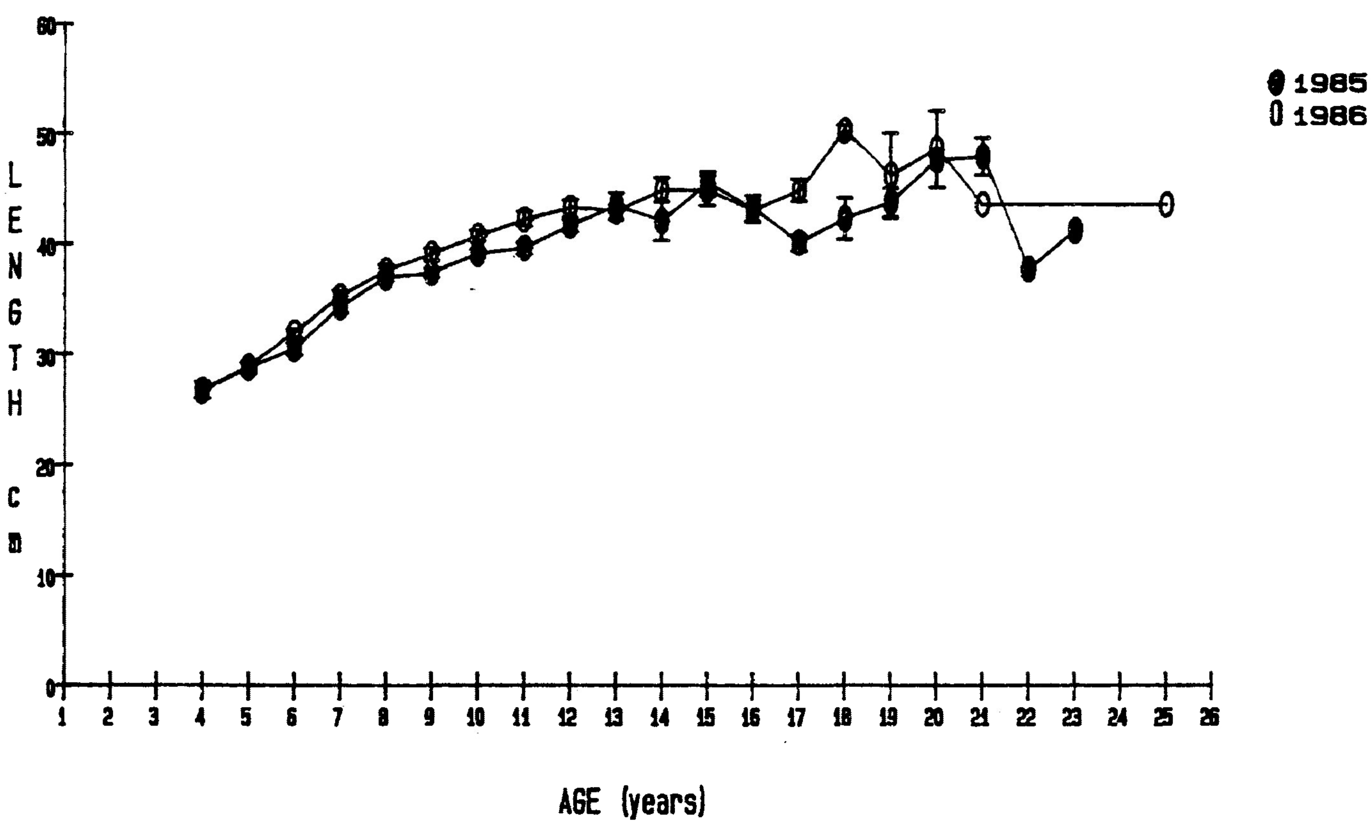
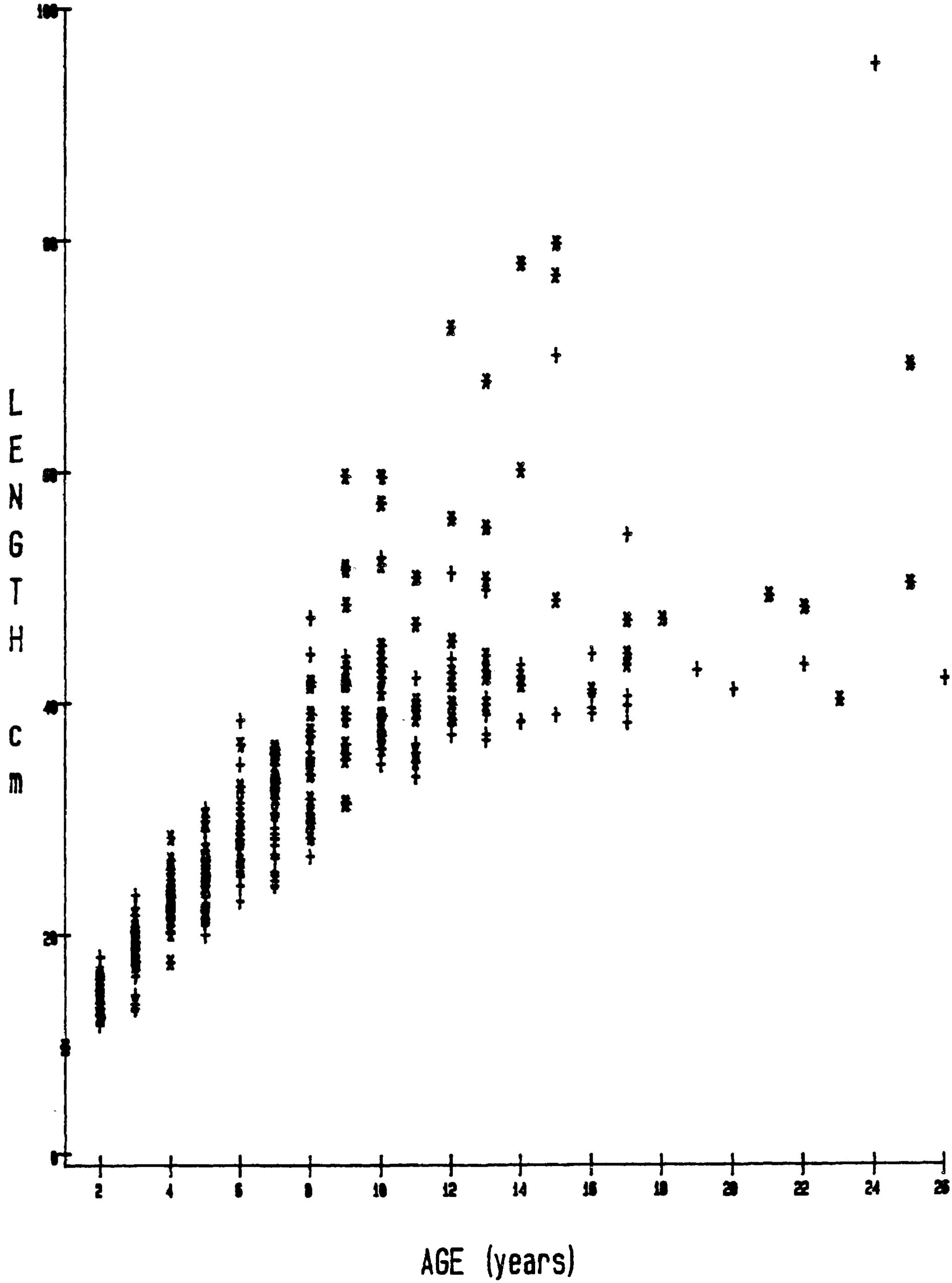

60
50
40
30
20
10
0
L E N G T H
c m
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
AGE (years)
1985
1986

Fig. 10. Length at otolith age for lake trout (*Salvelinus namaycush*) captured in gill nets in Squeers Lake, Ontario. (1982-crosses, 1984-asterix).



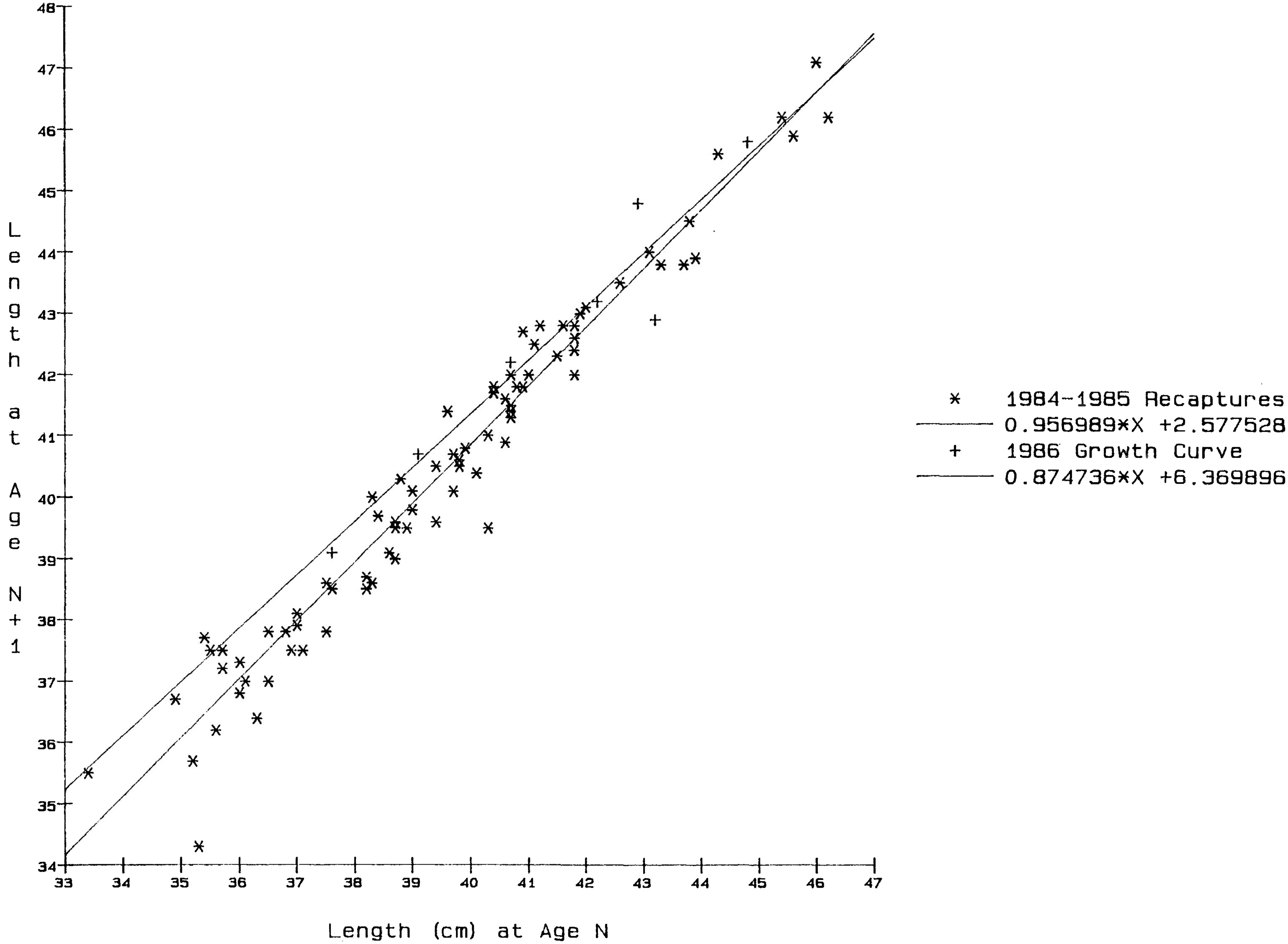
LENGTH cm
AGE (years)

was also well demonstrated by length at age curves derived from angler catches in March 1985 and 1986 (Fig. 9). A small number of lake trout greater than 6 years of age exhibited extremely rapid growth and attained sizes up to 95 cm in length in 1982 and 1984 (Fig. 9).

Growth of lake trout greater than 8 years of age was verified by comparing the slopes of Walford plots using a Students t test (Zar, 1974). Length at age n was plotted against length at age n+1 of lake trout captured in March 1986. This was then compared with the length at recapture against length of tagging of lake trout marked in fall 1984 and recaptured in fall 1985 (Fig. 11). The mean growth from marked and recaptured lake trout was .89 cm between 1984 and 1985 (Table 10). Three of eighty-five fish recaptured in 1985 indicated more than 3.5 cm growth between 1984 and 1985. These fish were eliminated from the analysis because they probably represented the few large fast growing fish in the population. There was no difference between growth described by the length at age curve and growth described by tag recaptures ($t=0.8824$, $p<.05$; Table 10).

Scale, fin ray and otolith age were positively correlated with length (Fig. 12). Regressions of scale, fin ray and otolith age on length were significant ($p<.05$; Fig.12). There was a significant difference between growth assessed by scales, fin rays and otoliths (ANCOV: $F_{1,36}=76$, $p<.05$). Growth determined by length at otolith age was slower than growth assessed by finray and scale age.

Fig. 11. Regression of length at age n on length at age n+1 for lake trout (*Salvelinus namaycush*) captured in March 1986, and regression of length at recapture in fall 1985 on length at marking in fall 1984 in Squeers Lake, Ontario.



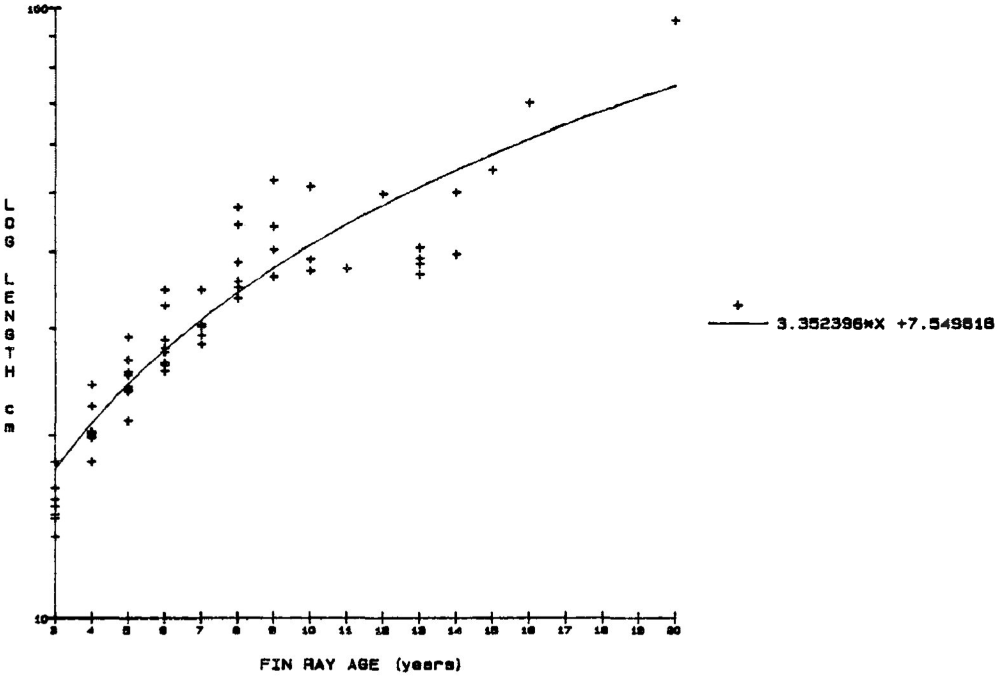
Length at Age N+1
Length (cm) at Age N
1984-1985 Recaptures
0.956989*X +2.577528
1986 Growth Curve
0.874736*X +6.369896
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
33

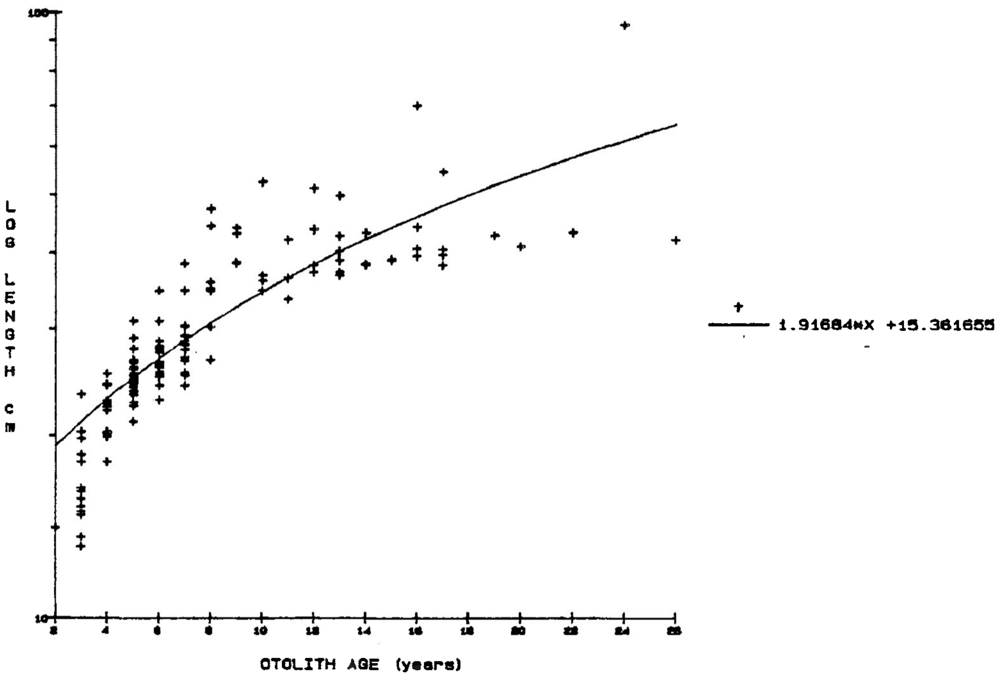
Table 10. Summary of yearly growth based on tag recaptures for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982-1985.

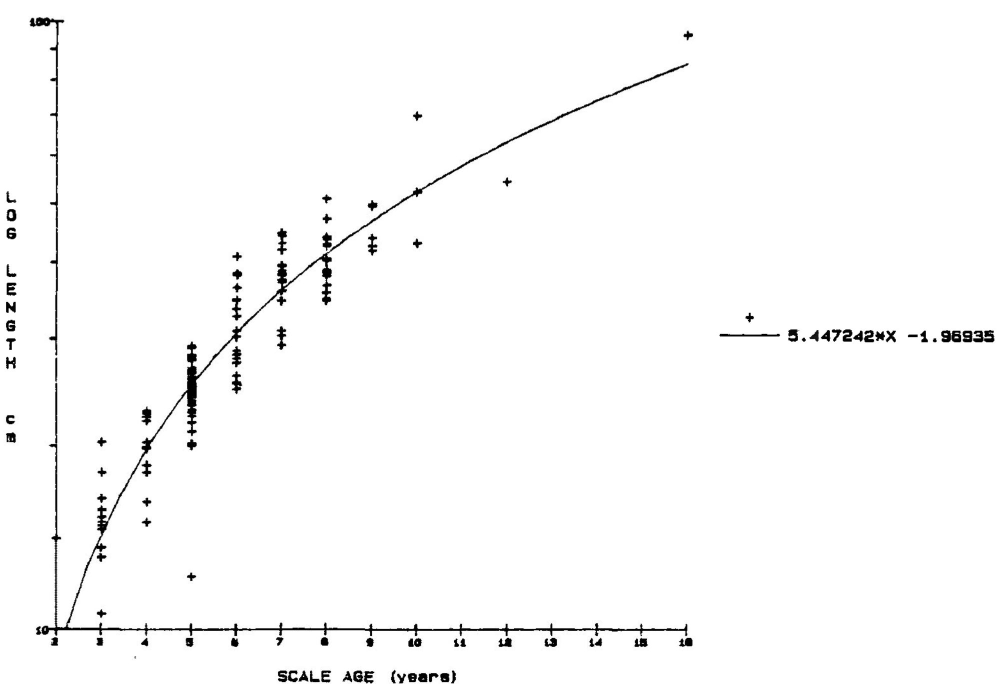
Period of Growth	Time of Marking and Recapture	Sample Size	Mean Length (cm)	Growth (cm)	Standard Error	Growth (cm) per year
1982-1983	1	40	40.5	0.567	0.0821	0.567
1983-1984	1	13	40.4	0.530	0.1700	0.530
1984-1985	1	82	40.5	0.893	0.0566	0.893
	2	20	43.0	1.010	0.1839	1.010
1982-1984	1	31	40.6	1.129	0.1195	0.564
	2	6	41.7	2.700	0.5409	1.350
	1	17	43.0	1.106	0.2132	0.553
1983-1985						
	1	59	41.2	1.949	0.1471	0.650
1982-1985	2	6	44.7	2.983	0.3000	0.994

1 = fish tagged and recaptured in the fall on the spawning shoals by gill nets and angling
2 = fish tagged and recaptured by spring angling

Fig. 12. Fork length regressed on scale, fin ray and otolith ages for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982.


LOG LENGTH cm
3.352396*X +7.549816
FIN RAY AGE (years)


LOG LENGTH cm
1.91684*X +15.361655
OTOLITH AGE (years)


LOG LENGTH cm
5.447242*X -1.96935
SCALE AGE (years)

Survival

Survival was assessed from catch curves derived from June gill netting and March angling, and from fish marked and recaptured on spawning shoals between 1984 and 1985, and 1985 and 1986 (Table 11). Survival of lake trout greater than 5 years of age was 80 percent in June 1982 and 1984. From winter angling in 1985 and 1986, survival of lake trout greater than 8 years of age was 71 percent (Table 11). Similarly, survival rates determined from tag recaptures of fish greater than 36 cm (8 years of age or older) were 70 to 72 percent.

Fecundity

Individual fecundity and population fecundity were assessed from fish captured in fall of 1984 and 1985. Absolute fecundity ranged from 664 eggs for a 36 cm female to 19,671 eggs for a 90.5 cm female (Table 12; Appendix 25). The mean number of eggs per gram of body weight ranged from 1.4 to 1.6 (Table 13). The mean diameter of lake trout eggs was 3.3 mm in June 1984 (Table 14). By spawning time in the fall, eggs ranged from 4.3 to 4.8 mm in diameter.

Absolute fecundity was positively correlated with length, weight and age (Fig 13; Appendix 26). Regressions of absolute fecundity on length and weight were significant in 1984 and 1985 ($p<.05$; Fig. 13). There were no differences between absolute fecundity and length, and absolute fecundity and weight between 1984 and 1985 (ANCOV: $F_{1,69}=1.555$, $F_{1,59}=1.472$, $p<.05$).

Table 11. Comparison of survival estimates derived from catch curves and tag recaptures for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982-1986.

Class	Time Period	Method of Estimation	Survival	Variance
≥ 5 years	1982	Catch Curve [1]	0.7932	0.0015
	1984	Catch Curve [1]	0.8019	0.0002
≥ 8 years	1985	Catch Curve [1]	0.7103	0.0002
	1986	Catch Curve [1]	0.7140	0.0002
≥36 cm	1984-1985	Tag Recapture [2]	0.7292	0.0106
	1984-1985	Tag Recapture [3]	0.6994	0.0182
	1985-1986	Tag Recapture [4]	0.7193	0.0421

[1] Robson and Chapman (1961)
[2] Ricker (1975)
[3] Everhart and Youngs (1981)
[4] Bailey Triple Catch (Ricker 1975)

Table 12. Absolute fecundity differentiated by length class for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1984, 1985.

Length (cm)	1984				1985			
	Sample size	Number of eggs	Range	Standard error	Sample size	Number of eggs	Range	Standard error
30-35	3	773	731-800	17.28	-	-	-	-
36-40	12	992	800-1427	48.61	14	1079	664-1273	44.62
41-45	12	1424	973-2122	98.86	8	1365	1206-1564	88.11
46-50	7	1786	1439-2217	118.94	10	1651	1286-2255	102.65
51-55	3	2306	1959-2693	173.78	2	2430	2343-2518	61.87
56-60	1	3479	-	-	-	-	-	-
61-65	-	-	-	-	-	-	-	-
66-70	1	8366	-	-	-	-	-	-
71-75	1	4419	-	-	-	-	-	-
76-80	2	7547	7191-7902	251.38	-	-	-	-
81-85	-	-	-	-	-	-	-	-
86-90	-	-	-	-	-	-	-	-
91-95	-	-	-	-	1	19671	-	-

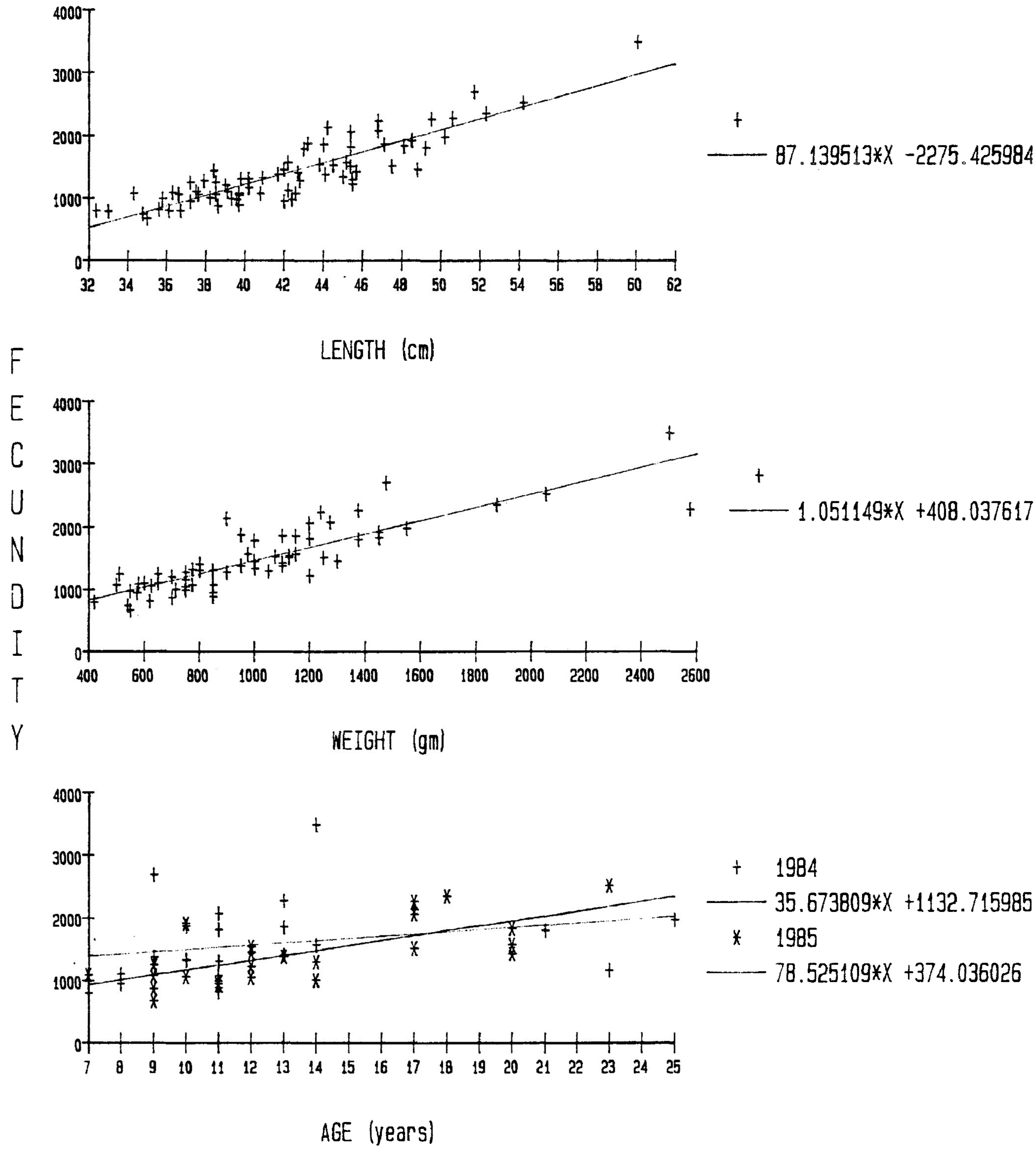
Table 13. Mean number of eggs per gram for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1984, 1985.

Sampling Period	Sample size	Mean number of eggs per gram	Standard error
June 1984	20	1.549	0.0723
August 1984	11	1.413	0.0949
Early September 1985	19	1.395	0.0582
Late September - Early October 1985	16	1.622	0.3488

Table 14. Mean diameter of eggs for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1984, 1985.

Sampling Period	Sample size	Mean diameter (mm)	Standard error
June 1984	16	3.26	0.1093
August 1984	17	4.78	0.0723
Early September 1985	18	4.34	0.0926
Late September - Early October 1985	16	4.58	0.0834

Fig. 13. Regression of absolute fecundity on length, weight, and age for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1984, 1985.



FECUNDITY
LENGTH (cm)
87.139513*X -2275.425984
WEIGHT (gm)
1.051149*X +408.037617
AGE (years)
1984
35.673809*X +1132.715985
1985
78.525109*X +374.036026

Therefore regressions of fecundity on length and weight in 1984 and 1985 were combined. Regressions of absolute fecundity with age were significant in 1985 ($p<.05$, Fig. 13). However, an insignificant correlation of fecundity with age in 1984 did not allow for lumping of 1984 and 1985 fecundity on age data. Logarithmic transformation of all variables did not improve the correlation of fecundity on length, weight or age.

Population fecundity was estimated as 2,996,323 eggs (Table 15). Lake trout between 36 and 40 cm comprised 70 percent of all egg production.

Maturity

Maturity was assessed using lake trout captured in June 1982 and 1984 gill netting (Appendix 27 and 28). Males matured at a smaller size and an earlier age than females in 1982 and 1984 (Table 16). Fifty percent of males were mature by 31.0 cm and 7 years of age, however 50 percent of females were not mature until 36.6 cm and 8.4 years of age. Both males and females reached 100 percent maturity at age 9 in 1982 and age 11 in 1984 (Table 17). Males were 39.5 cm and females were 41.5 cm in length at 100 percent maturity in both 1982 and 1984 (Table 17).

Depth Distribution

Depth distribution of lake trout during early summer was assessed using fish captured in gill nets in June 1982 and 1984.

Table 15. Population fecundity differentiated by length class for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1985.

	Female population size			Population Fecundity	
Length (cm)	N[1]	95% confidence limits	Mean number of eggs	N	95% confidence limits
36-40	2085	1666-2503	992	2068320	1652672-2482976
41-45	539	398-680	1428	769692	568344-971040
46-50	68	33-186	1951	132668	64383-362886
Total				2970680	2285399-3816902

[1] female population size was determined by multiplying the sex ratio (.575) by the fall 1985 population estimate

Table 16. Mean length and age at 50% maturity for males, females and combined sexes determined empirically and by Lysack's method for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982, 1984.

			Age at 50% maturity		Length at 50% maturity	
Year	Sex	Sample size	Lysack	Empirical	Lysack	Empirical
1982	Males	53	-	7-8	32.61	32-34
	Females	76	-	7-8	-	33-34
	All Fish	129	8.2	8	34.36	34
1984	Males	48	7.0	7-8	31.00	31
	Females	101	8.4	8-9	36.70	36
	All Fish	149	7.7	8-9	34.20	34

Table 17. Mean length and age at 100% maturity for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1982, 1984.

	1984			1985		
Sex	Sample size	Age	Length (cm)	Sample size	Age	Length (cm)
Males	53	9	39.5	48	11	39.5
Females	76	9	41.5	101	11	41.5

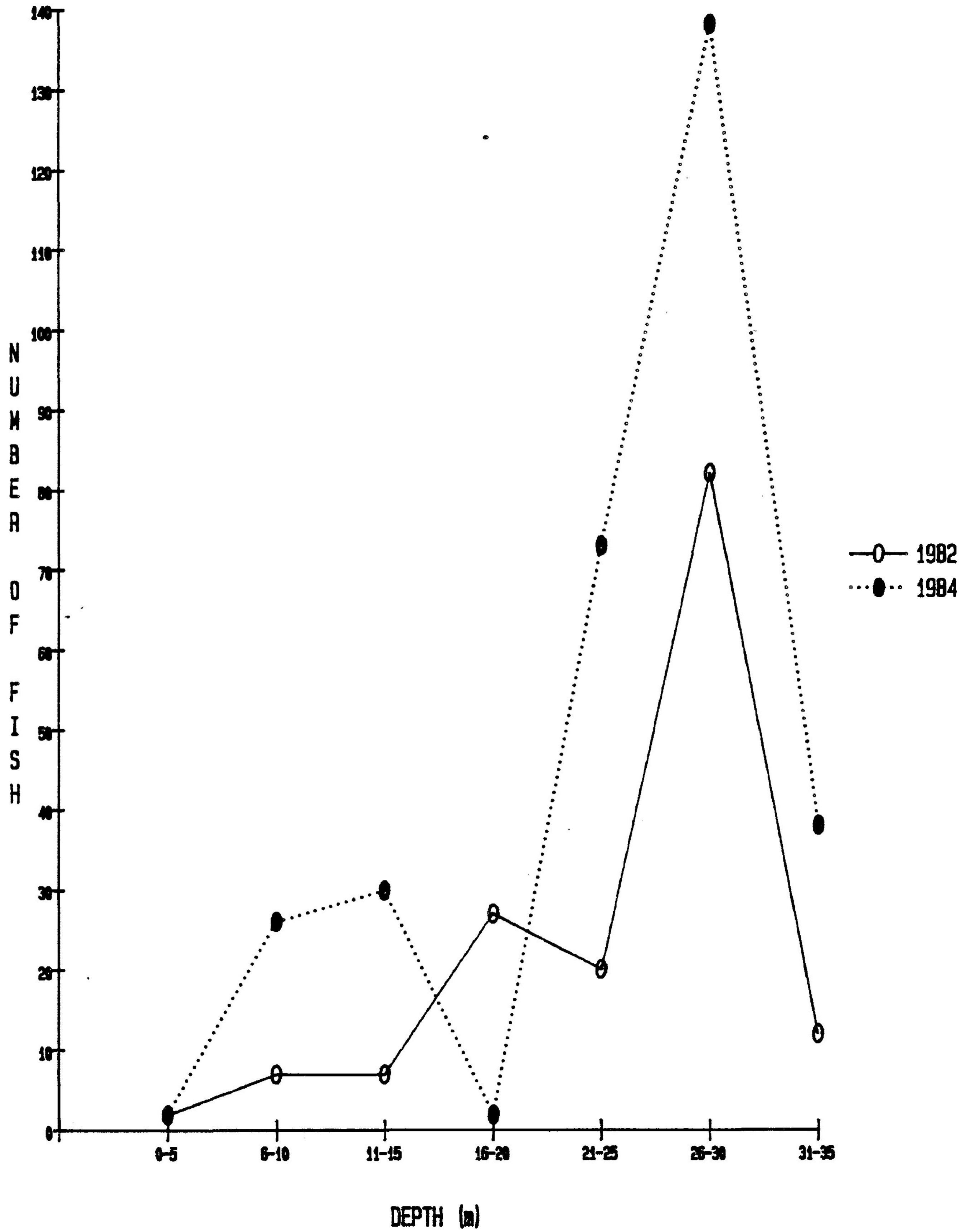
Over half of all lake trout were captured in 26 to 30 m of water (Fig. 14). Catch per unit effort of lake trout mirrored the numbers of fish captured by depth strata (Appendix 29). Smaller lake trout were found in deeper water (Appendix 30). Eighty percent of lake trout captured between 26 and 30 m in depth were less than 28 cm in length. Seventy seven percent of lake trout captured between 1 and 26 m in depth were greater than 28 cm in length.

Seasonal Dietary Changes

Winter

Stomachs collected in March 1985 were analyzed to determine feeding habits of lake trout during the winter. Eleven percent of winter stomachs were empty; a greater proportion than in any other season (except during spawning). The mean number of prey types per stomach was 2.6 (Table 18). Fishes were the major prey item occurring in 55 percent of lake trout stomachs and making up 70 percent of total prey weight (Fig. 15). Lake trout, burbot, ninespine stickleback, redbelly dace and yellow perch were the main fishes consumed (Fig. 15). Crustaceans were also an important food source occurring in 74 percent of all stomachs and contributing 30 percent to total prey weight (Fig. 15). The opossum shrimp, *Mysis relicta* Loven, was the most important crustacean consumed, occurring in 74 percent of winter stomachs. Insects were of minor importance in the diet of lake trout during the winter.

Fig. 14. Depth distribution of lake trout (<u>Salvelinus namaycush</u>) captured in gill nets in June 1982 and 1984 in Squeers Lake, Ontario.

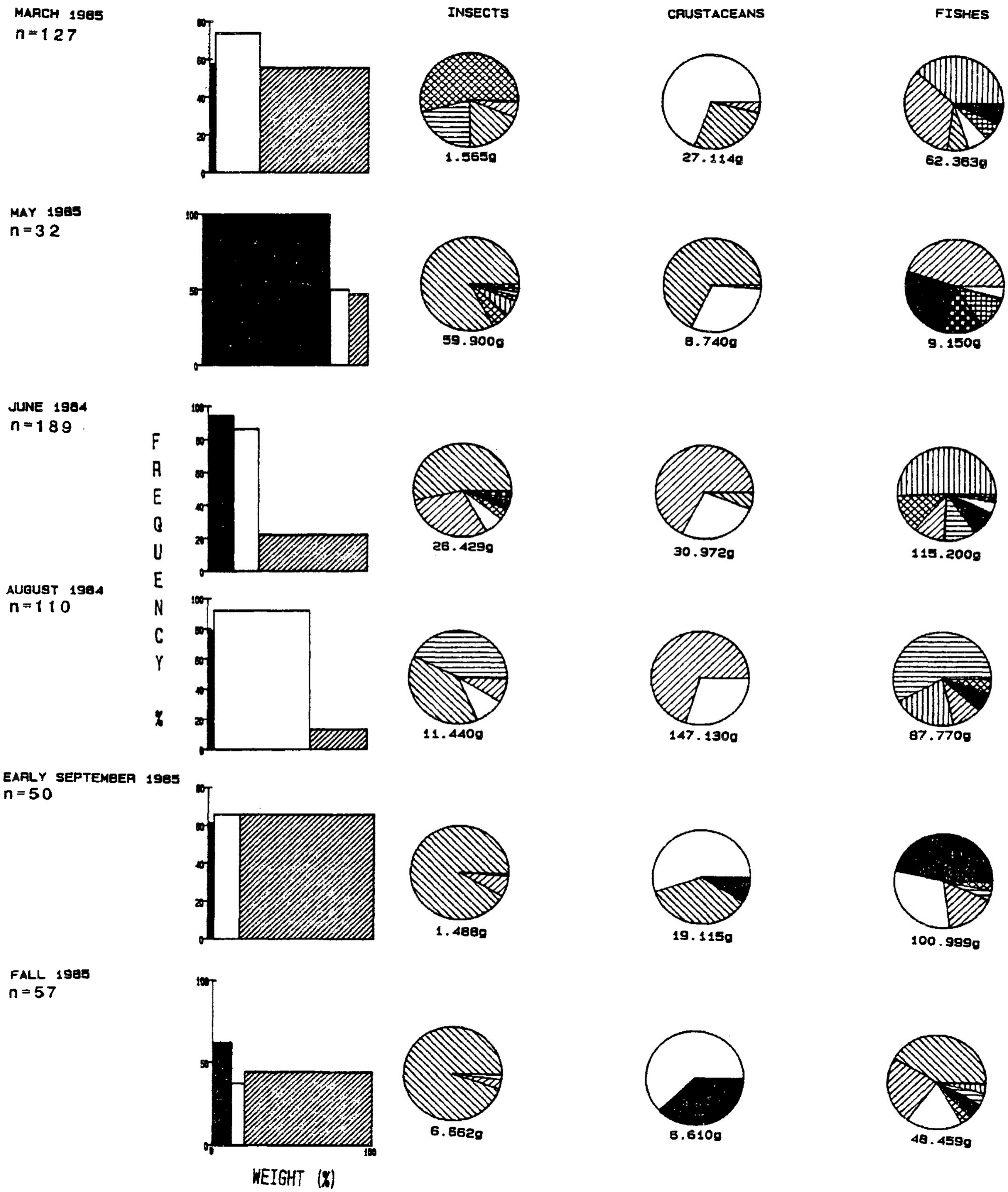


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
NUMBER OF FISH
0-5
6-10
11-15
16-20
21-25
26-30
31-35
DEPTH (m)
1982
1984

Table 18. Mean number of prey items (Order) and percent empty stomachs by season for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1984, 1985.

Season	Mean number of prey items	Percent empty stomachs
Winter		
March 1985	2.6	10.9
Spring		
May 1985	4.6	0.0
Early Summer		
June 1984	3.3	2.1
Late Summer		
August 1984	3.0	5.0
Early September 1985	2.4	12.0
Fall		
Late September - Early October 1985	2.4	29.1

Fig. 15. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (Salvelinus namaycush) in Squeers Lake, Ontario, 1984, 1985.


MARCH 1985
n=127
INSECTS
CRUSTACEANS
FISHES
1.565g
27.114g
62.363g
MAY 1985
n=32
59.900g
8.740g
9.150g
JUNE 1984
n=189
26.429g
30.972g
115.200g
AUGUST 1984
n=110
11.440g
147.130g
87.770g
EARLY SEPTEMBER 1985
n=50
1.488g
19.115g
100.999g
FALL 1985
n=57
6.662g
8.610g
48.459g
FREQUENCY %
WEIGHT (%)

Spring

Stomachs collected in May 1985 were analyzed to determine spring feeding habits of lake trout. All stomachs contained food, averaging 4.6 food organisms per stomach (Table 18).

Insects were of primary importance to the diet of lake trout during the spring, occurring in 100 percent of stomachs examined and contributing 74 percent to total prey weight (Fig. 15). More than 10 orders of insects were consumed, however ephemeropterans, Hexagenia limbata were the primary prey (Fig. 15). Fishes and crustaceans made a small equivalent contribution to spring diet (Fig. 15). Fish species consumed were small and included yellow perch, Iowa darter and ninespine stickleback (Fig. 15). The crayfish, Orconectes virilis Hagen, was the "most important" crustacean preyed upon by weight, however Mysis relicta was more frequently consumed (Fig. 15).

Early Summer

Diet of lake trout during early summer was analyzed using stomachs from fish captured in June 1984 gill netting. Ninety eight percent of stomachs examined contained prey items averaging 3.34 prey types per stomach (Table 18). Although fishes made up 64 percent of total prey weight, they occurred in only 22 percent of lake trout stomachs (Fig. 15). Small fishes were not as important during early summer as they were in spring. Lake trout, sculpins and white suckers were the dominant forage fishes.

Crustaceans and insects were preyed upon by 86 percent and 95 percent of lake trout examined respectively (Fig. 15). Seven orders of insects were consumed but in smaller quantities than in the spring (Fig. 15). Ephemeropterans and dipterans were the most important orders of insects consumed by lake trout in early summer. *Mysis relicta* was the most frequent crustacean preyed upon, however the amphipod, *Pontoporeia hoyi* made up 55.5 percent of total prey weight contributed by crustaceans (Fig. 15).

Late Summer

Diet of lake trout during late summer was examined by analyzing stomachs collected in late August 1984 and early September 1985. Prominent differences in diet between August 1984 and September 1985 were evident, so these two periods are discussed separately.

August 1984

Five percent of stomachs were empty and there were 3.34 prey organisms per stomach (Table 18). Crustaceans were the most important food source in August 1984 (Fig. 15). They occurred in 92 percent of all stomachs examined and contributed nearly 60 percent of prey weight. Amphipods were the most frequently eaten crustacean and contributed the greatest amount to total prey weight (Fig. 15). Fishes occurred in thirteen percent of lake trout stomachs and contributed 37.5 percent to total prey weight. White suckers and lake trout were the most important fishes consumed by lake trout (Fig. 15). Insects occurred in 79 percent of stomachs, but contributed only 2.5 percent to total prey weight.

Early September 1985

Twelve percent of stomachs were empty and the mean number of items was 2.4 per stomach (Table 18). Fishes were the main food source, occurring in 66 percent of all stomachs and making up 83 percent of total prey weight (Fig. 15). The main fish prey were primarily small fishes including yellow perch and ninespine stickleback (Fig. 15). Crustaceans were consumed by 66 percent of fish and contributed only 15 percent to total prey weight. Mysis relicta was the most important crustacean in the diet of lake trout in September 1985 (Fig. 15). Insects were not an important food item for lake trout in September 1985.

Fall

The fall feeding habits were analyzed by examining fish captured on spawning shoals in late September and early October 1985. The highest percentage of empty stomachs (29%) and the lowest mean number of food items per stomachs (2.4) occurred during spawning (Table 18).

Fishes were the most dominant fall prey (Fig. 15). Seventy five percent of lake trout consumed fishes which made up 79 percent of total prey weight in fall 1984. Forty five percent of lake trout consumed fishes which made up 79 percent of total prey weight in fall 1985. Important fish species consumed included ninespine stickleback, burbot, and yellow perch (Fig. 15). Lake trout eggs were eaten by lake trout, but only in small quantities. Few crustaceans and insects were eaten by lake trout during the fall (Fig. 15).

Change in Diet With Length

Less than 20 cm lake trout

Small lake trout (less than 20 cm) were not captured except in June and August 1984. Crustaceans were their primary prey (Fig. 16). *Mysis relicta* was the main crustacean consumed occurring in 89.9 and 96.8 percent of stomachs examined in June and August 1984 respectively. Insects were quite frequently consumed but contributed little to prey weight (Fig. 16). The main insects preyed upon were dipterans in June and ephemeropterans in August. Fishes were rarely consumed by lake trout less than 20 cm (Fig. 16).

20-30 cm lake trout

Lake trout ranging from 20 to 30 cm were captured in all sampling periods except early September 1985. Crustaceans dominated their diet in all seasons, except June 1984 and March 1985 when insects and fishes were most important respectively (Fig. 17). *Mysis relicta* was the most frequently consumed crustacean in June 1984, August 1984 and May 1985, however amphipods predominated by weight in June and August 1984 (Fig.

Fig. 16. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (*Salvelinus namaycush*) less than 20 cm in Squeers Lake, Ontario, 1984, 1985.

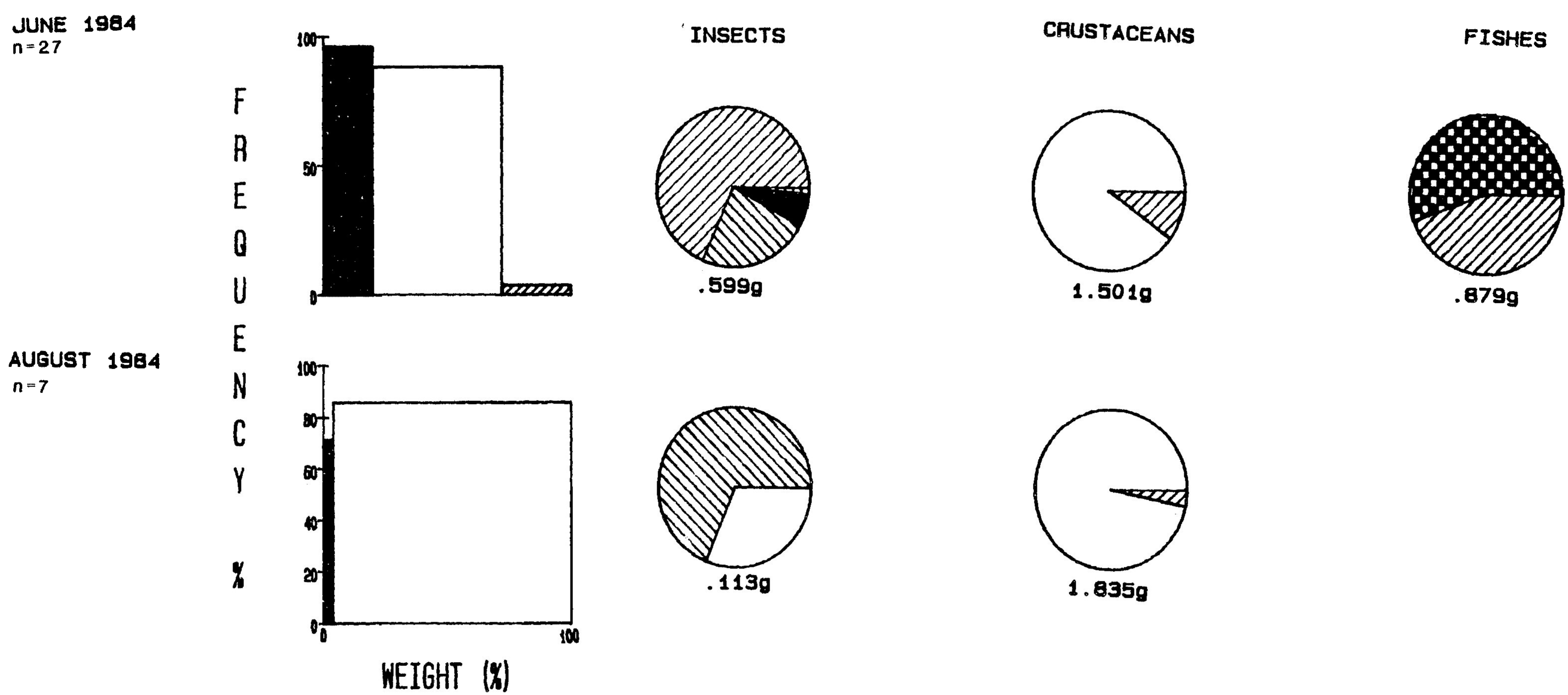
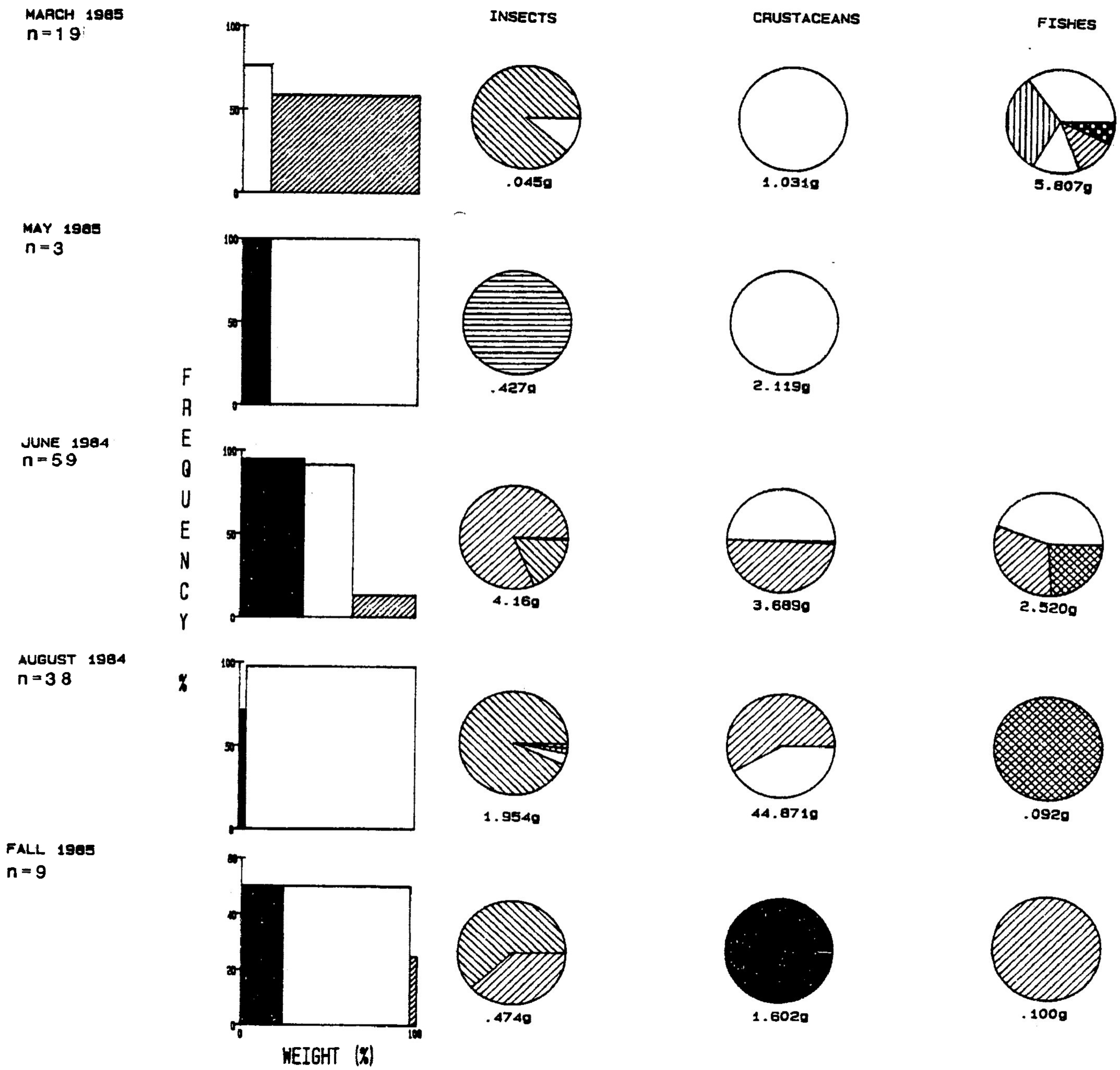

JUNE 1984
n=27
AUGUST 1984
n=7
FREQUENCY %
100
50
0
100
80
60
40
20
0
0
100
WEIGHT (%)
INSECTS
CRUSTACEANS
FISHES
.599g
1.501g
.879g
.113g
1.835g

Fig. 17. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (Salvelinus namaycush) 20-30 cm in Squeers Lake, Ontario 1984, 1985.



MARCH 1985
n=19
INSECTS
CRUSTACEANS
FISHES
.045g
1.031g
5.807g
MAY 1985
n=3
.427g
2.119g
JUNE 1984
n=59
4.16g
3.689g
2.520g
AUGUST 1984
n=38
1.954g
44.871g
.092g
FALL 1985
n=9
.474g
1.602g
.100g
FREQUENCY %
WEIGHT (%)

17). In Fall 1985 cladocerans comprised 98.8 percent of total weight contributed by crustaceans.

Insects were only important in the diet in June 1984 (Fig. 17). At that time insects occurred in 89 percent of all stomachs and made up 40 percent of total prey weight. Dipterans were the most important insects consumed occurring in 81 percent of stomachs. (Fig. 17).

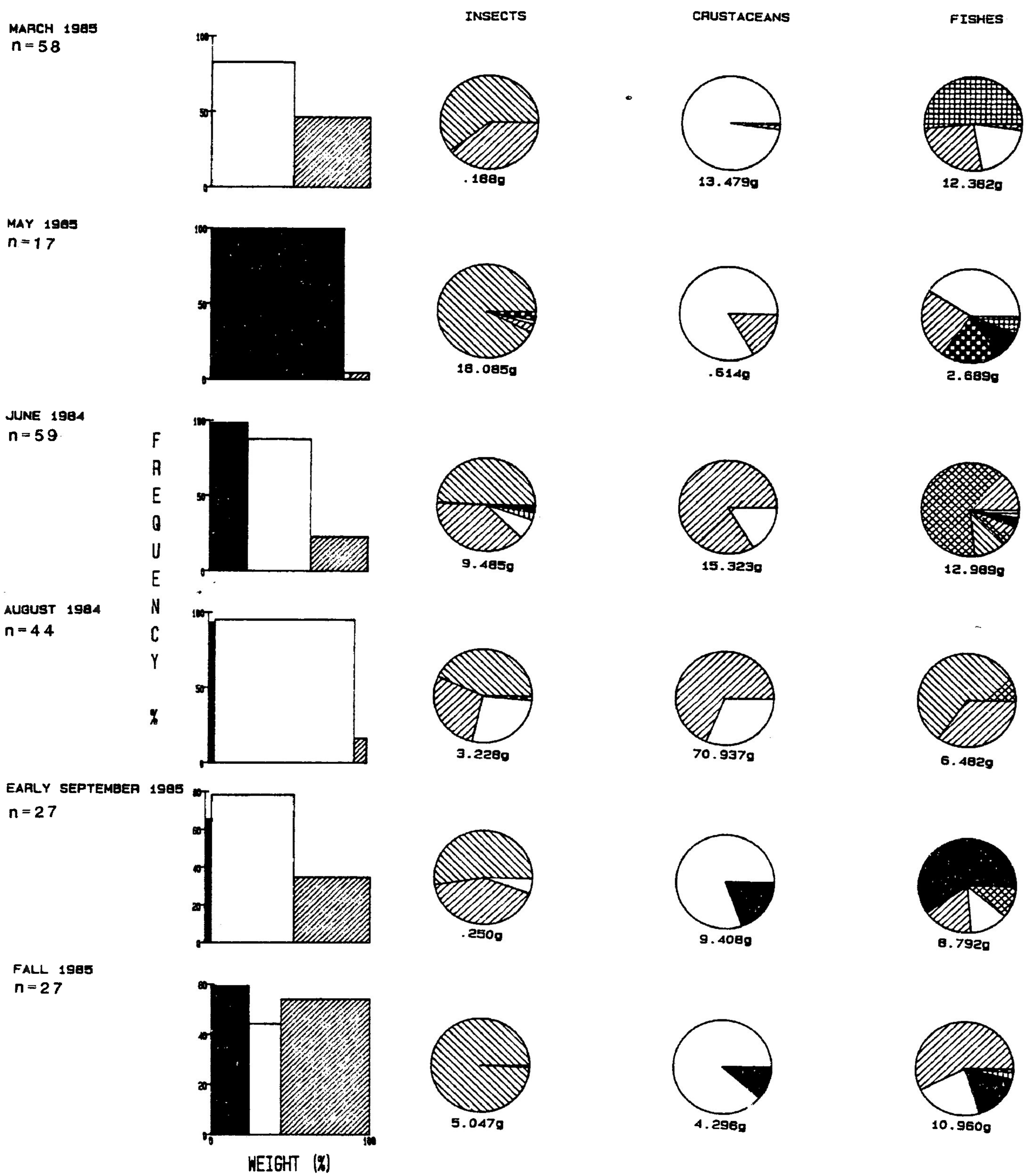
March 1985 was the only month when fishes predominated in the diet (Fig. 17). Fishes occurred in 59 percent of stomachs and made up 84 percent of total weight. Small fishes including unidentified cyprinids, redbelly dace, ninespine stickleback and Iowa darter were most frequently consumed.

30 to 40 cm lake trout

Fishes were more predominant in the diet of 30-40 cm lake trout than in smaller fish. However, crustaceans were the most dominant prey occurring most frequently in June and August 1984, as well as March and early September 1985 (Fig. 18). Mysis relicta was the most frequently consumed crustacean in all seasons. However, in June and August 1984 amphipods contributed most to total prey weight.

Fishes were most important prey items in fall 1985, and were of secondary importance in March 1985 and early September 1985 (Fig. 18). Ninespine stickleback, yellow perch, Iowa darter and lake trout eggs were the main fishes consumed.

Fig. 18. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (*Salvelinus namaycush*) 30-40 cm in Squeers Lake, Ontario, 1984, 1985.



INSECTS
CRUSTACEANS
FISHES
MARCH 1985
n=58
.188g
13.479g
12.362g
MAY 1985
n=17
18.085g
.614g
2.689g
JUNE 1984
n=59
9.485g
15.323g
12.989g
AUGUST 1984
n=44
3.228g
70.937g
6.482g
EARLY SEPTEMBER 1985
n=27
.250g
9.408g
8.792g
FALL 1985
n=27
5.047g
4.296g
10.960g
FREQUENCY %
WEIGHT (%)

Insects were the most important prey item in May 1985 (Fig. 18). All stomachs contained *Hexagenia limbata* which made up 93.2 percent prey weight contributed by insects in May 1985. Ninety eight percent of stomachs contained insects in June 1984, but they contributed only 25 percent to total prey weight (Fig. 18).

40 to 50 cm lake trout

Fishes were the most important food item of 40 to 50 cm lake trout in all seasons except August 1984 and May 1985 (Fig. 19). In addition to smaller forage fishes, larger fishes including lake trout, white sucker and burbot occurred in stomachs.

Crustaceans were of secondary importance except in August 1984 (Fig. 19). Amphipods were the most frequently preyed upon crustacean and contributed the most to prey weight in August 1984. Although *Mysis relicta* was the most frequently occurring crustacean, *Orconectes virilis* contributed the most to prey weight in all other seasons.

Insects were consumed in all seasons but contributed little to total prey weight except in May 1985 (Fig. 19). *Hexagenia limbata* was the most important insect consumed.

Lake trout greater than 50 cm

Fishes were the most important prey item in all seasons (Fig. 20). The variety of fish species consumed was reduced while small fishes such as Iowa darter, yellow perch, ninespine stickleback and blacknose shiner occurred only rarely. Large

Fig. 19. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (Salvelinus namaycush) 40-50 cm in Squeers Lake, Ontario, 1984, 1985.

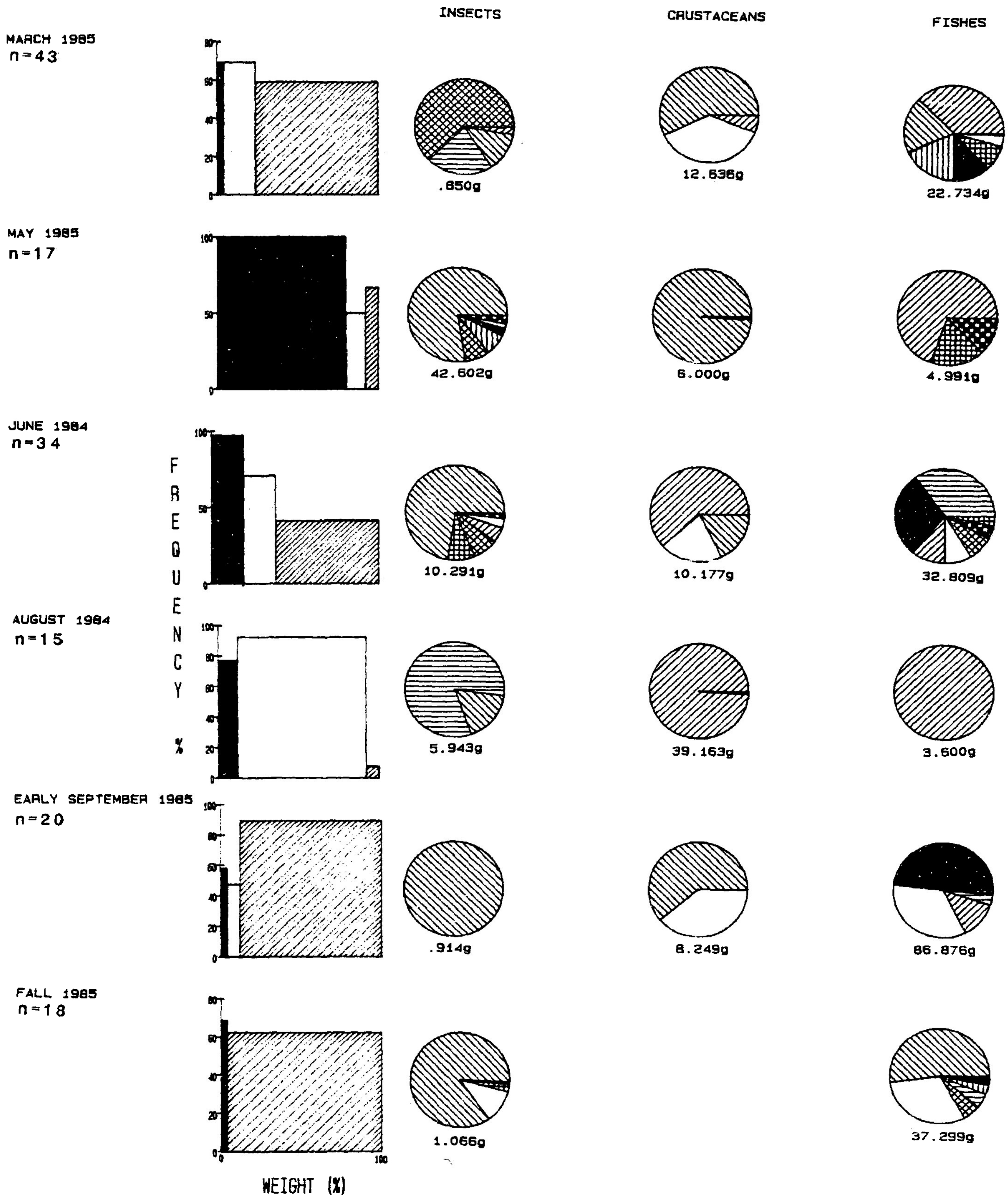
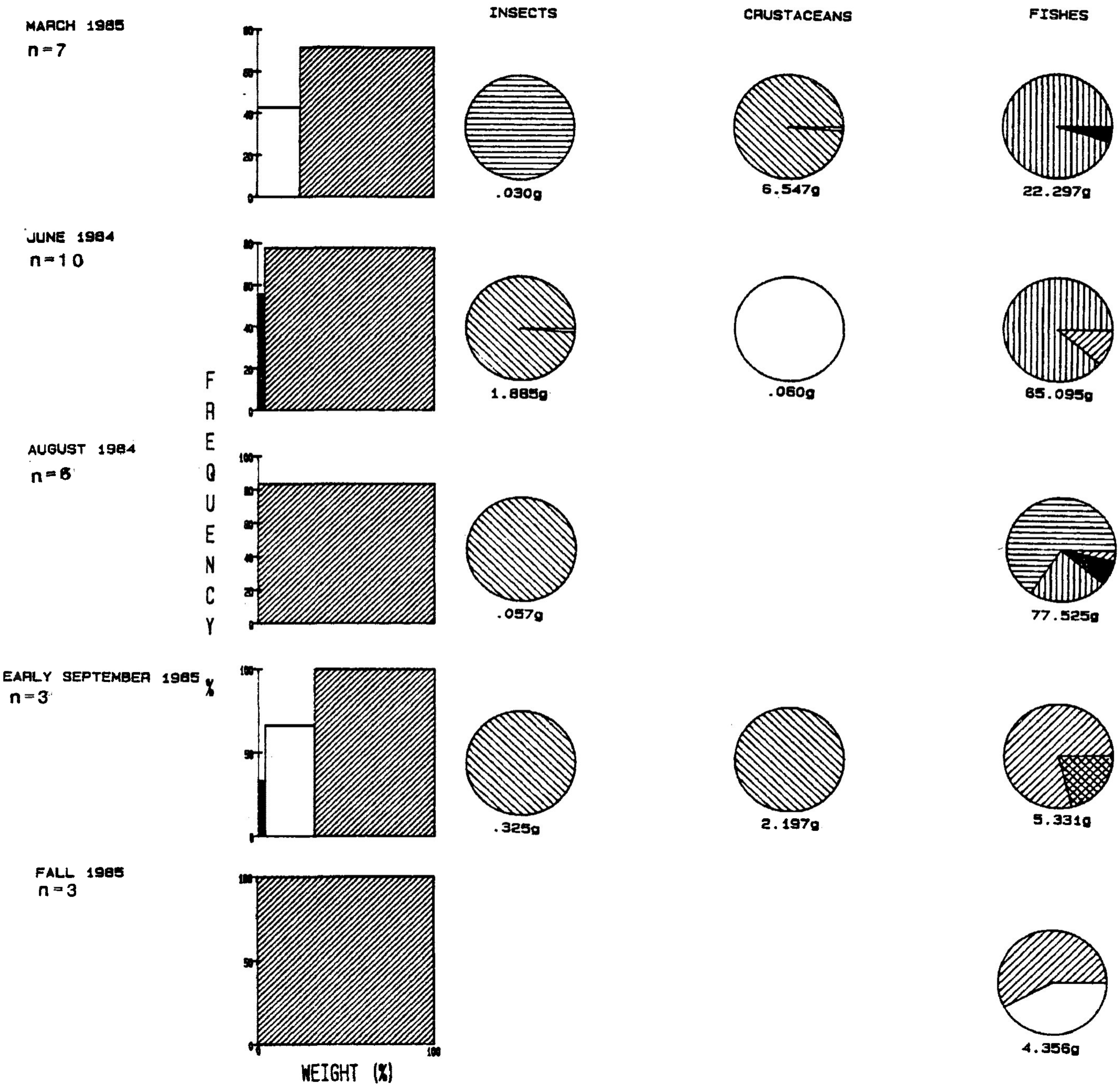

INSECTS
CRUSTACEANS
FISHES
MARCH 1985
n=43
.850g
12.636g
22.734g
MAY 1985
n=17
42.602g
6.000g
4.991g
JUNE 1984
n=34
10.291g
10.177g
32.809g
AUGUST 1984
n=15
5.943g
39.163g
3.600g
EARLY SEPTEMBER 1985
n=20
.914g
8.249g
86.876g
FALL 1985
n=18
1.066g
37.299g
FREQUENCY %
WEIGHT (%)

Fig. 20. Dietary changes with season by frequency of occurrence (%) and weight (%) of prey items consumed by lake trout (Salvelinus namaycush) greater than 50 cm in Squeers Lake, Ontario, 1984, 1985.



INSECTS
CRUSTACEANS
FISHES
MARCH 1985
n=7
.030g
6.547g
22.297g
JUNE 1984
n=10
1.885g
.060g
65.095g
AUGUST 1984
n=6
.057g
77.525g
EARLY SEPTEMBER 1985
n=3
.325g
2.197g
5.331g
FALL 1985
n=3
4.356g
FREQUENCY %
WEIGHT (%)

fishes such as white sucker and lake trout occurred most frequently contributing the most to total prey weight (Fig. 20). Sculpins were also abundant in the diet of large fish.

Crustaceans consumed were mainly crayfish (*Orconectes virilis*) however they contributed little to the diet of lake trout greater than 50 cm (Fig. 20).

Insects were rarely found (Fig. 20). *Hexagenia limbata* being the only insect consumed.

Changes in Diet With Growth Rates

Growth curves derived from June 1984 gill netting indicated that both fast growing and slow growing lake trout occur in the population. Upon comparing the diet of fast growing and slow growing lake trout amphipods were found to be the primary forage of slow growing trout, and contributing 53 percent to total prey weight (Fig. 21). In addition, slow growing fish consume only small fishes, primarily sculpins. Fast growing trout feed on large forage fishes, with lake trout and white sucker contributing 92 percent of the total prey weight (Fig. 21).

Changes in Diet with Depth

Lake trout caught in shallow water (1-10 m) fed mainly on fishes (Fig. 22). A wide range of fishes were eaten including lake trout, yellow perch, ninespine stickleback, Iowa darter, and

Fig. 21. Diet of slow growing and fast growing lake trout (*Salvelinus namaycush*) captured in gill nets in Squeers Lake, Ontario, June 1984.

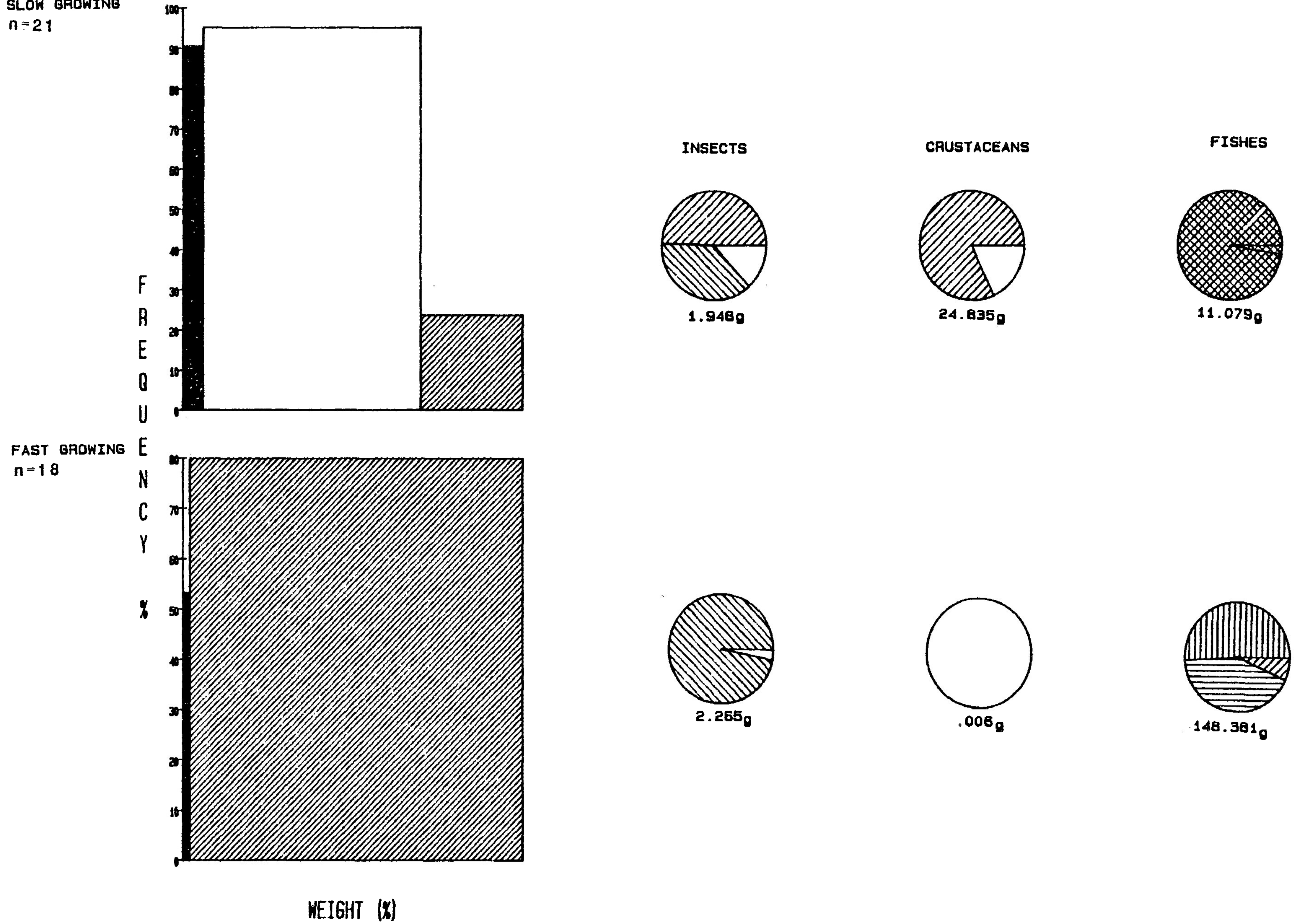
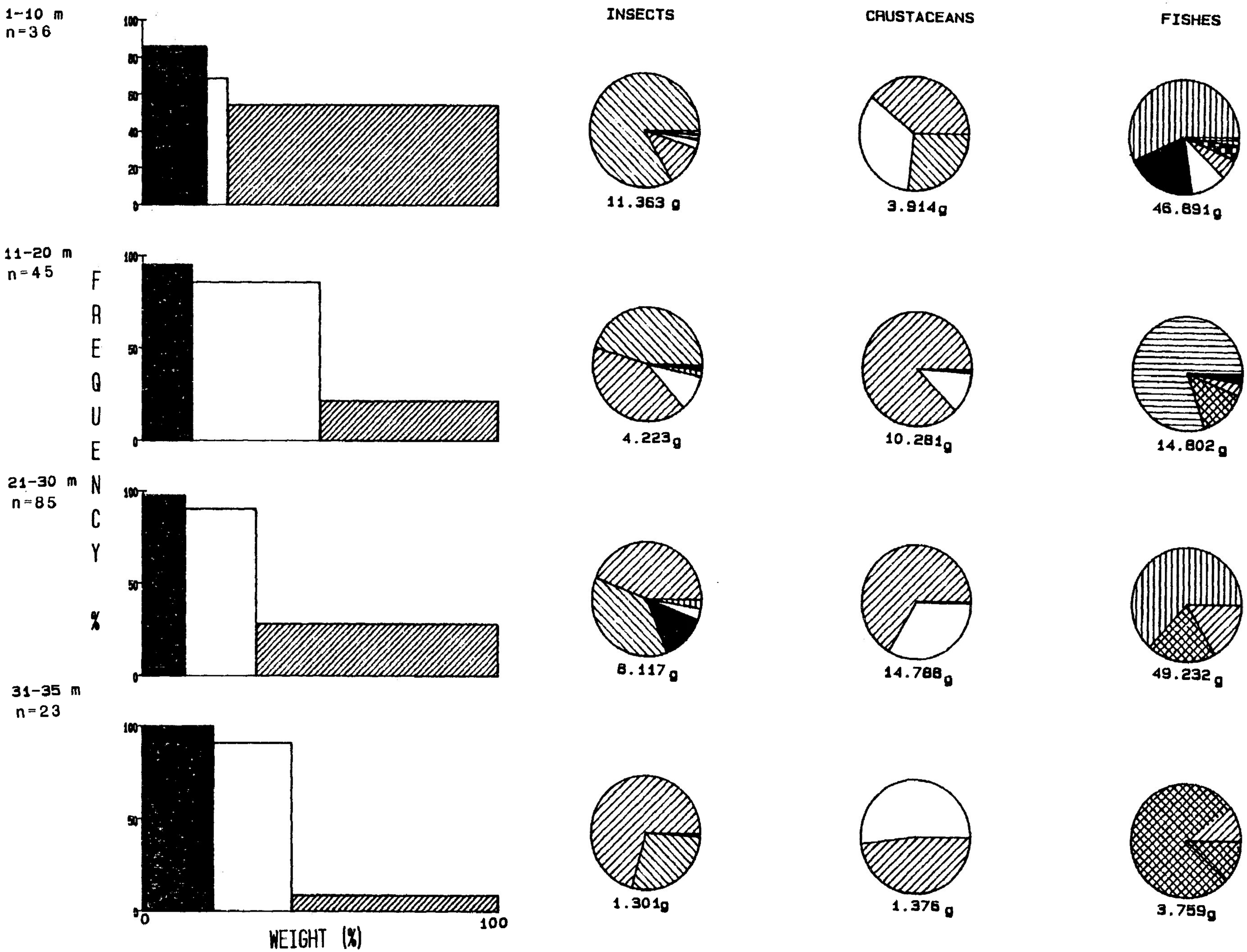

SLOW GROWING
n=21
FAST GROWING
n=18
FREQUENCY %
WEIGHT (%)
INSECTS
CRUSTACEANS
FISHES
1.948g
24.835g
11.079g
2.265g
.006g
148.381g

Fig. 22. Diet of lake trout (*Salvelinus namaycush*) captured at varying depth intervals in Squeers Lake, Ontario, June 1984.


1-10 m
n=36
11-20 m
n=45
21-30 m
n=85
31-35 m
n=23
FREQUENCY %
WEIGHT (%)
0
100
INSECTS
CRUSTACEANS
FISHES
11.363 g
3.914g
46.891g
4.223g
10.281g
14.802g
8.117g
14.788g
49.232g
1.301g
1.376g
3.759g

blacknose shiner. With an increase in depth the variety of fishes available declined substantially. The number of fish species consumed decreasing from five in shallow water (1-10 m) to only one in water deeper than 30 m (Fig. 22). As depth increased sculpins became an increasingly important food item. Although fishes did not frequently occur in lake trout diet at depths below 10 m, when consumed they contributed a substantial amount to prey weight.

Crustaceans were most abundant in the diet of deeper occurring lake trout (Fig. 22). While crustaceans made up only 8 percent of total stomach weight of lake trout captured below 10 m, they comprised 35 percent of total stomach weight of fish at 11-20 m. At depths greater than 2 m crustaceans occurred in at least 85 percent of all stomachs and contributing at least 20 percent to overall prey weight (Fig. 22). Mysis relicta was the most abundant crustacean in the diet at all depths, however amphipods contributed the most to prey weight of lake trout in deep water (>30 m) (Fig. 22). Orconectes virilis frequently occurred in the diet of lake trout captured in 1 to 10 m, but not at all in lake trout at 20 m (Fig. 22).

Insects occurred in greater frequency and variety in stomachs of shallow water trout (< 10 m) (Fig. 22). Six insect orders were eaten by these shallow water trout, while only three orders occurred in trout from 30+ m. Insects occurred in at least 80 percent of shallow water trout (< 10 m) but contributed only slightly to total weight (Fig. 22). Ephemeropterans were the most important for shallow water trout. With increasing depth, dipterans became more frequent in the diet. In deep water (> 30 m) they were the most important insect consumed.

The Winter Fisheries

Catch and Effort

Seventy two percent of anglers selected the first weekend to fish. Of those 48 percent selected the first day to participate in the March 1985 fishery (Table 19). Angler's choice of fishing days was more evenly distributed in March 1986, however 20 percent of anglers still selected the first day to fish (Table 19). Anglers preferred to fish on weekend days, Saturday and Sunday. Fifty-nine percent of anglers selected one of four weekend days while 41 percent selected one of the five weekdays in March 1986.

One hundred and eighty seven anglers fished for 1792 rod hours in 1985 while 517 anglers fished for 5375 rod hours in 1986 (Table 20). Effort was concentrated in the north, northwest and west parts of the lake in both years (Fig. 23). Seventy five percent of anglers thus fished in less than 20 percent of the lake area in 1985 and 1986.

A total of 568 lake trout were caught in March 1985. The majority being harvested in the north and north west region of the lake (Appendix 31). Four hundred lake trout were harvested while 171 were released. The mean number of lake trout caught by each angler was 2.98 and the mean number harvested was 2.09 per angler in March 1985 (Table 20). Anglers were most successful on

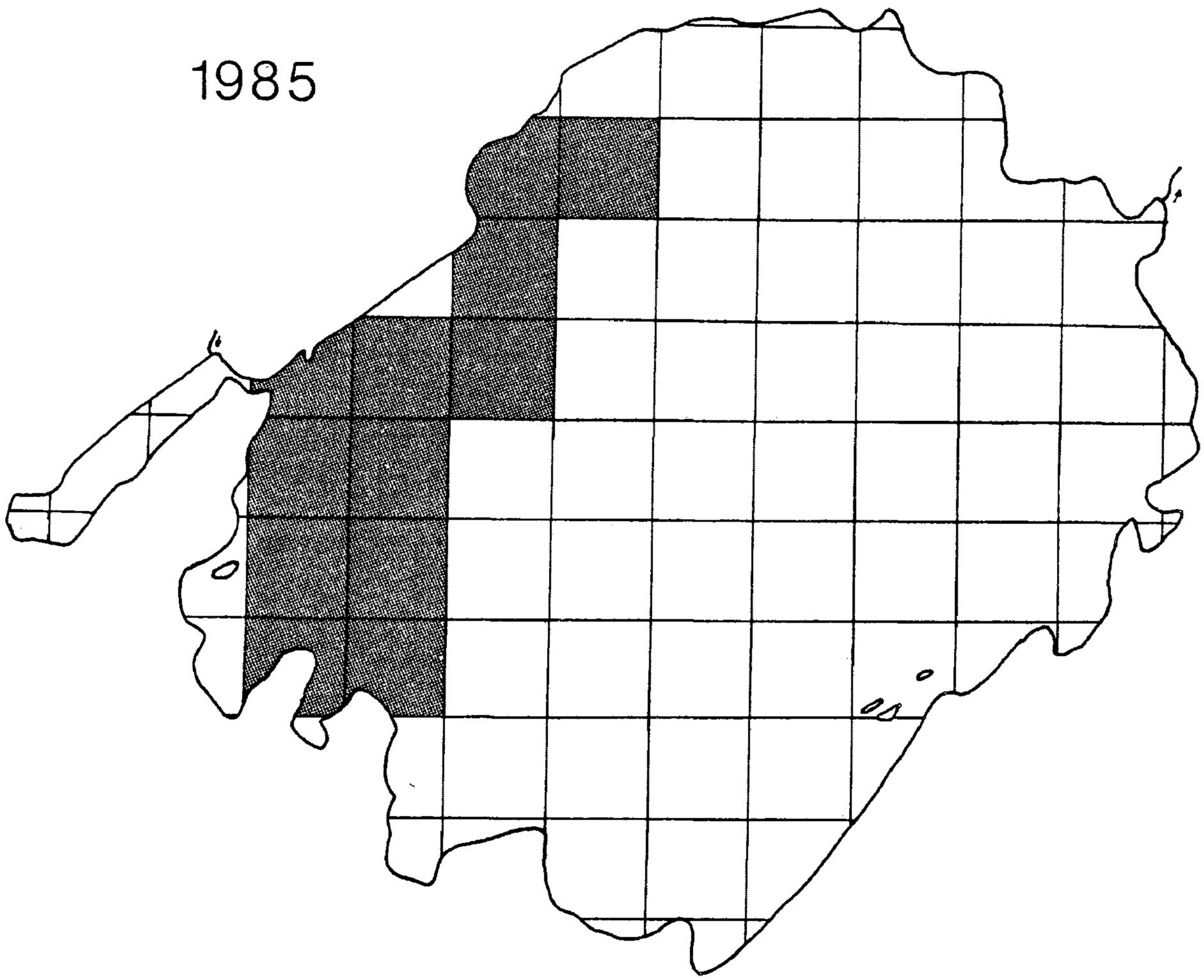
Table 19. Number of applicants by day for the winter fisheries in Squeers Lake Ontario, 1985, 1986.

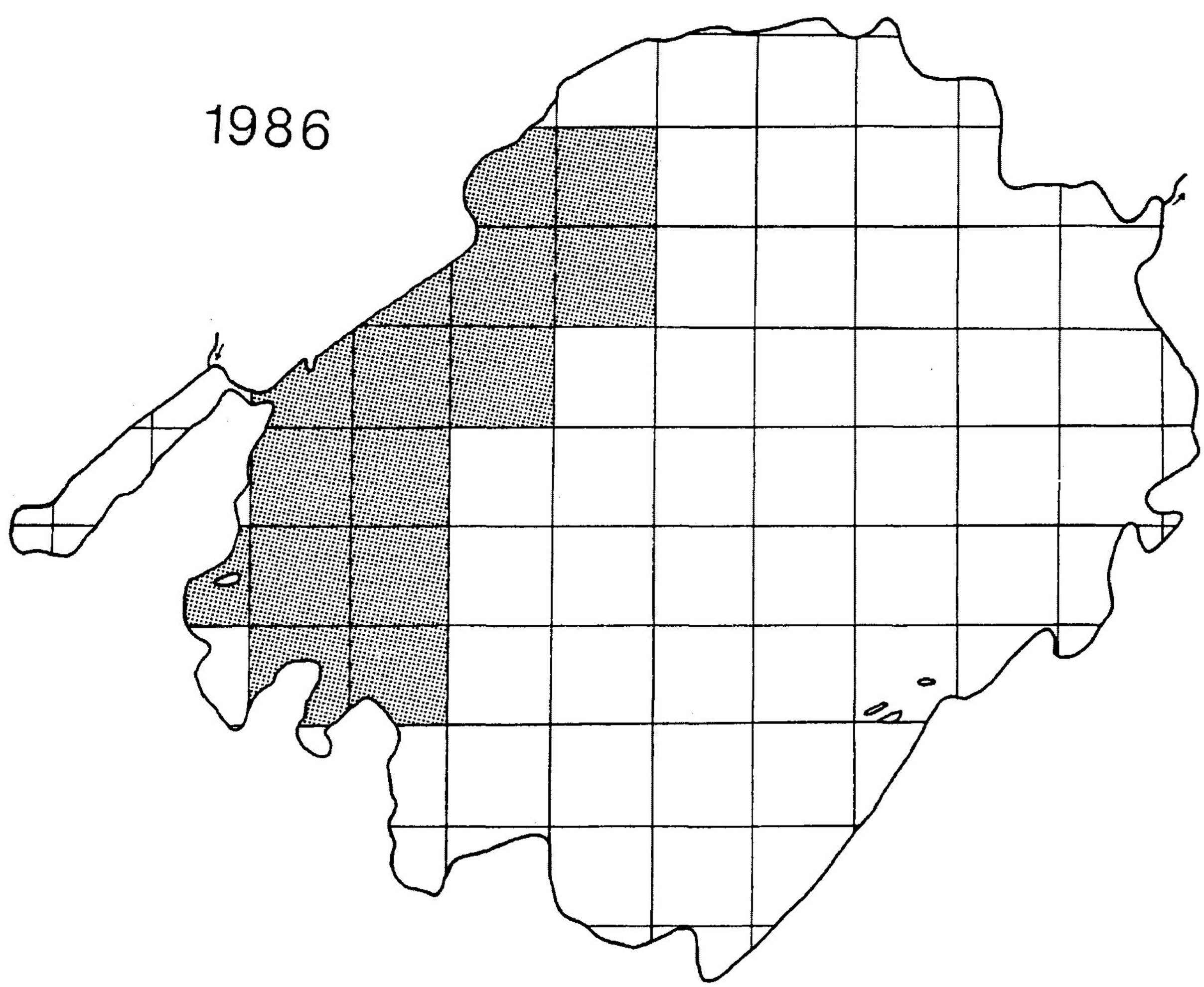
Sampling Date	Number of applications	Number of applicants	Percent of total applicants
1985			
Sat., March 23	198	370	48.2
Sun., March 24	98	179	23.3
Sat., March 30	·78	147	19.2
Sun., March 31	39	71	9.2
Total	413	767	
1986			
Sat., March 15	46	151	20.1
Sun., March 16	38	107	14.2
Mon., March 17	25	70	9.3
Tues., March 18	36	112	14.9
Wed., March 19	18	60	8.0
Thurs., March 20	10	27	3.6
Fri., March 21	12	38	5.0
Sat., March 22	31	103	13.7
Sun., March 23	23	84	11.2
Total	239	752	

Table 20. Effort, catch and catch per unit effort (CPUE) for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1985, 1986.

Sampling period	Number of anglers	Rod hours	Total fish			Number of fish per angler		CPUE	
			Kept	Released	Caught	Kept	Released	Kept	Released
1985									
Sat., Mar 23	27	308	55	30	85	2.0	3.1	0.179	0.276
Sun., Mar 24	31	353	64	15	79	2.1	2.5	0.182	0.224
Sat., Mar 30	65	593	166	96	262	2.5	4.0	0.282	0.442
Sun., Mar 31	64	538	115	30	145	1.8	2.3	0.213	0.269
Total	187	1792	400	171	568	2.1	3.0	0.214	0.303
1986									
Sat., Mar 15	71	810	142	35	177	2.0	2.5	0.172	0.215
Sun., Mar 16	62	627	65	11	76	1.1	1.2	0.103	0.121
Mon., Mar 17	65	668	95	16	111	1.5	1.7	0.133	0.157
Tues., Mar 18	62	485	89	19	108	1.4	1.7	0.181	0.221
Wed., Mar 19	35	295	42	0	42	1.2	1.2	0.142	0.142
Thurs., Mar 20	32	315	51	19	70	1.6	2.2	0.146	0.206
Fri., Mar 21	24	293	45	22	67	1.9	2.8	0.154	0.228
Sat., Mar 22	88	1020	122	62	184	1.4	2.1	0.128	0.199
Sun., Mar 23	78	862	83	21	104	1.1	1.3	0.096	0.120
Total	517	5375	734	205	939	1.4	1.8	0.136	0.175

Fig. 23. Distribution of angling effort by grid during the 1985 and 1986 winter fisheries (shaded areas represent 75 % of angler effort) in Squeers Lake, Ontario.


1985


1986

the west shore, parts of the north and east shore, and by the islands on the south shore (Appendix 32). The CPUE of lake trout caught was .303 per rod hour, and the CPUE of lake trout harvested was .214 per rod hour in March 1985 (Table 20).

Anglers were not as successful in 1986 as they were in 1985. A total of 939 lake trout were caught and of those 734 were harvested while 205 were released (Table 20). The mean number of lake trout caught was 1.80 per angler and the mean number harvested was 1.45 per angler. Anglers were most successful in the same lake areas as those in 1985 (Appendix 32). The west shore, and parts of the south and east shore had the highest success rate. The CPUE of fish caught was .175 per rod hour and the CPUE of fish harvested was .136 per rod hour in March 1986 (Table 20).

CPUE's of lake trout harvested in March 1985 and 1986 were 26 percent and 52 percent lower respectively, than those experienced by anglers on Squeers Lake between 1967 and 1974 (Table 21). Experimental angling in May 1984 and 1985 resulted in CPUE's four to seven times greater than winter CPUE's between 1967 and 1974 (Table 21; Appendix 33).

Characteristics of the Catch

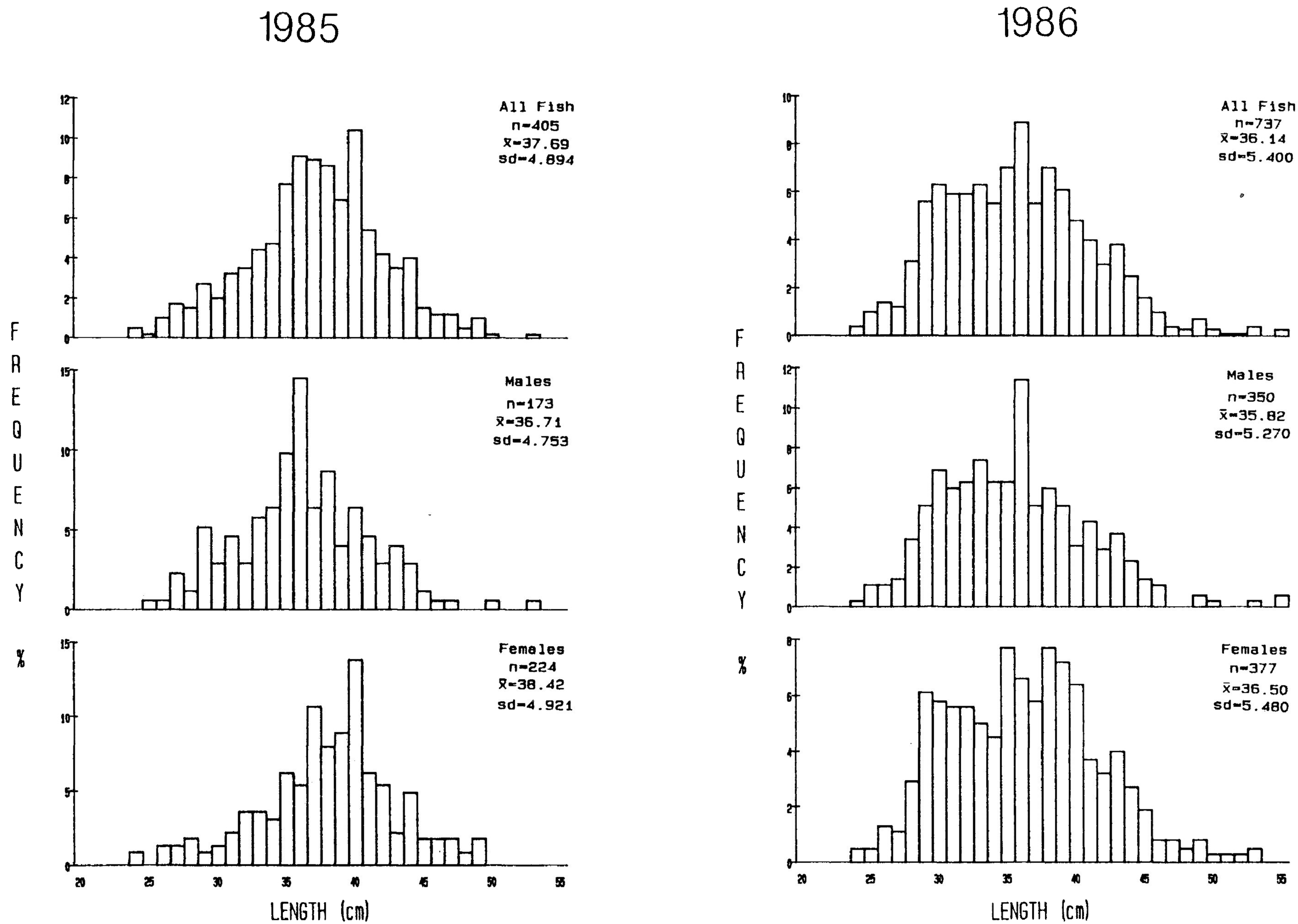
The length distribution of lake trout captured by angling was platykurtic in 1985 and 1986 (Fig. 24). Lake trout ranged from 25 to 54 cm in length with a mean of 37.7 cm in 1985. Females (38.4 cm) were significantly larger than males (36.7 cm)

Table 21. Catch and effort from winter and spring angling for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1967-1986.

Year	Number of anglers interviewed	Effort (rod hours)	Catch	CPUE	Number of fish per angler
Winter					
1967[1]	25	133	31	0.230	1.2
1970[2]	13	91	27	0.300	2.1
1972[2]	49	196	57	0.290	1.2
1973[2]	77	439	103	0.330	2.1
1974[2]	111	581	183	0.290	1.5
1985[3]	187	1792	568[5]	0.317	2.1
			400[6]	0.223	3.0
1986[3]	517	5375	939[5]	0.175	1.8
			734[6]	0.136	1.4
Spring					
1984[4]	-	130	259	1.993	-
1985[4]	-	204	210	1.031	-

[1] anonymous circa
[2] winter check records, Thunder Bay District, Ontario Ministry of Natural Resources (OMNR), 1970, 1972, 1973, 1974.
[3] experimental winter fishery 1985, 1986.
[4] experimental angling carried out by Quetico-Mille Lacs Fisheries Assessment Unit, OMNR, 1984, 1985.
[5] number of fish harvested and released
[6] number of fish harvested

Fig. 24. Length distribution of males and females and sexes combined for lake trout (Salvelinus namaycush) captured by anglers in the 1985 and 1986 winter fisheries in Squeers Lake, Ontario.


1985
1986
All Fish
n=405
x̄=37.69
sd=4.894
Males
n=173
x̄=36.71
sd=4.753
Females
n=224
x̄=38.42
sd=4.921
All Fish
n=737
x̄=36.14
sd=5.400
Males
n=350
x̄=35.82
sd=5.270
Females
n=377
x̄=36.50
sd=5.480
FREQUENCY %
LENGTH (cm)

($t=3.463$, $p<.05$). Lake trout ranged from 24 cm to 63 cm with a mean length of 36.1 cm in 1986. Females (36.5 cm) were again larger than males (35.8 cm) in 1986 ($t=1.751$, $p<.05$). The mean length of males and females was significantly greater in 1985 than 1986 ($t=1.892$ and $t=4.261$, $p<.05$).

Comparisons were made between length distributions of lake trout captured by anglers in March 1985 and 1986 with those from winter angling prior to closure of Squeers Lake, experimental spring angling, June gill netting, and lake trout captured on spawning shoals (Table 22). The mean length of lake trout captured in March 1985 and 1986 was similar to that of lake trout captured in the winter fisheries prior to the lake closing (Table 23). Lake trout captured by anglers in 1985 and 1986 were significantly larger than the mean length of the population ($t=13.775$, $p<.05$). However, those captured in March 1985 and 1986 were significantly smaller than those captured on the spawning shoals or by spring angling ($t=9.550$, $t=5.067$ and $t=10.189$, $p<.05$).

Angling removed 4 to 25 year old fish in 1985 and 1986, with a peak at age 8 years in 1985 and age 6 years in 1986 (Fig. 25). Females were significantly older than males in 1985 and 1986 ($t=4.906$ and $t=4.041$, $p<.05$). Older fish were taken in 1985 (males (8.67) and females (10.23)) compared to 1986 (males (7.58) and females (8.49)) in 1986 ($t=4.30$ and $t=6.19$, $p<.05$).

Table 22. Comparison of winter length distributions with summer, spring and fall length distributions for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1984-1986.

Sampling Period	Sample size	Mean length (cm)	Standard Deviation	Student's t [1]
March 1985	405	37.7	4.893	13.775*
June 1984	309	29.4	10.780	
March 1985	405	37.7	4.893	9.550*
Spring 1985	216	41.5	4.360	
March 1985	405	37.7	4.893	5.067*
Fall 1984	652	39.1	3.721	
March 1986	737	36.1	5.400	10.189*
Fall 1986	1319	38.4	4.311	

[1] students t test at $p< .05$; one tailed
*significant at $p<.05$

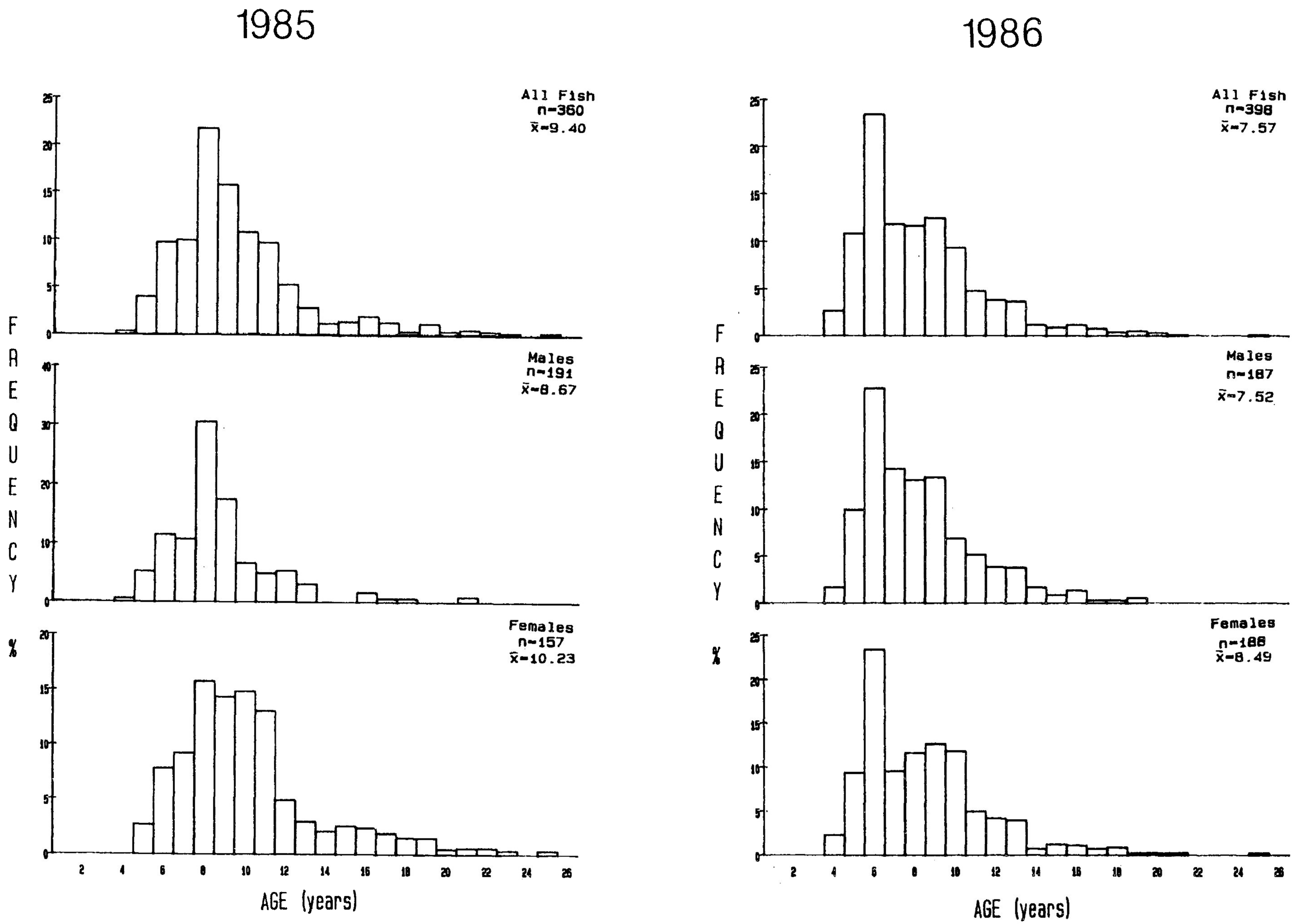
Table 23. Mean length and associated standard error for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1963-1986.

Sampling period	Sample size	Mean length (cm)	Standard error
Winter			
1963[1]	30	35.8	1.223
1974[2]	47	30.3	0.605
1978-79[3]	73	38.4	0.829
1982[4]	14	36.6	1.668
1985[5]	405	37.7	0.243
1986[5]	737	36.1	0.199
Spring			
1982 (1)[4]	239	42.3	0.269
(2)[4]	40	37.4	0.699
1984[4]	217	41.8	0.261
1985[4]	216	41.5	0.297
Fall			
1982[6]	249	38.7	0.193
1983[6]	45	39.3	0.445
1984[6]	335	38.2	0.161
1985[6]	413	37.3	0.162
1986[6]	414	37.2	0.159

1 reference for data is unknown
2 Chisolm, pers. comm.
3 Black, pers. comm.
4 Quetico-Mille Lacs fisheries Assessment Unit (QMLFAU), Ontario Minsitry of Natural Resources, experimental angling
5 experimental winter fishery
6 QMLFAU - spawning shoals

(1) inshore angling
(2) angling in 10 m of water

Fig. 25. Age distributions of males, females and sexes combined for lake trout (*Salvelinus namaycush*) captured by anglers in the 1985 and 1986 winter fisheries in Squeers Lake, Ontario.



1985
1986
All Fish
n=360
x̄=9.40
Males
n=191
x̄=8.67
Females
n=157
x̄=10.23
All Fish
n=398
x̄=7.57
Males
n=187
x̄=7.52
Females
n=188
x̄=8.49
FREQUENCY %
AGE (years)

Yield and Production

Ricker's yield model (a yield per recruit model) was used to determine biomass and production of lake trout between March 1985 and 1986, and to provide scenarios of harvest at different levels of fishing effort. Mortality and growth was estimated from March 1985 and 1986 winter fishery data. Biomass of fish greater than 8 years of age was estimated at 2829 kg or 7.36 $kg.ha^{-1}$ (Table 24), while production was 437 kg or 1.14 $kg.ha^{-1}$ (Table 24).

Two hundred and twenty three kg (.5795 $kg.ha^{-1}$) of lake trout were harvested with an exploitation rate of 4.9 percent in 1985 (Table 25 and 26). Eighty five percent (.4865 $kg.ha^{-1}$) of fish harvested were 8 years or older. Three hundred and eighty kg (.9886 $kg.ha^{-1}$) of lake trout were harvested at an exploitation rate of 6.5 percent in 1986 (Tables 25 and 26). Seventy four percent of the harvest (.6712 $kg.ha^{-1}$) was composed of fish greater than 8 years old in 1986.

Actual lake trout harvest in 1986 was compared to predicted yield of lake trout employing Ricker's yield model at the same instantaneous rate of mortality (.0672). The yield predicted by the model fell within 6 kg of the actual harvest in March 1986 (Table 27).

Ricker's model was then used to predict harvest of different age groups at varying fishing intensities (Appendix 34). The model indicated the lake trout population in Squeers lake could easily sustain at least five times the fishing mortality which occurred in 1986. Harvest of lake trout under age 12 years (the majority of the population) peaked at four to eight times the

Table 24. Estimates of annual biomass and production between March 1985 and 1986 using Ricker's method (1975) for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario.

Age group	Z [1]	G [2]	K [3]	Wo [4]	B [5]	P [6]	P/B [7]
8-9	0.2944	0.1620	-0.1324	791	741	120.0	0.162
9-10	0.2697	0.2340	-0.0357	592	582	136.0	0.234
10-11	0.5427	0.1971	-0.3456	463	391	77.0	0.195
11-12	0.6622	0.2140	-0.4482	432	348	74.0	0.209
12-13	0.0830	0.0970	0.0140	270	272	26.0	0.096
13-14	0.5928	0.0090	-0.5853	166	130	1.2	0.010
14-15	0.0120	0.0090	-0.0031	71	71	.6	0.009
15-16	0.0000	0.0090	0.0090	84	84	.8	0.009
16-17	0.6512	0.0090	-0.6422	119	88	.8	0.014
17-18	0.8889	0.0090	-0.8799	76	50	.4	0.008
18-19	0.0000	0.0090	0.0090	17	17	.1	0.004
19-20+	0.5715	0.0090	-0.5625	72	55	.5	0.011
Total					2829 7.36 kg/ha	437.4 1.14 kg/ha	0.156

[1] instantaneous rate of mortality
[2] instantaneous rate of growth
[3] growth coefficient
[4] initial weight (mean weight of 8 year olds in March 1985 * population estimate of 8 year olds from previous fall)
[5] biomass
[6] production
[7] turnover rate

Table 25. Actual yield by age class for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1985, 1986.

Age	1985			1986		
	Number harvested	Mean weight (kg)	Yield (kg)	Number harvested	Mean weight (kg)	Yield (kg)
4	1	0.200	0.20	20	0.199	3.98
5	16	0.251	4.02	79	0.251	19.83
6	39	0.297	11.58	172	0.340	58.48
7	41	0.421	17.26	86	0.457	39.30
8	88	0.528	46.46	85	0.549	46.66
9	64	0.545	34.88	91	0.621	56.51
10	44	0.622	27.37	68	0.688	46.78
11	39	0.646	25.19	35	0.756	26.46
12	21	0.747	15.69	28	0.780	21.84
13	12	0.785	9.42	27	0.824	22.25
>13	37	0.830	30.70	42	0.853	35.83
Total			222.78			377.92
			(0.5795 kg/ha)			(0.9831 kg/ha)

Table 26. Exploitation rate (u) and instantaneous rate of fishing mortality (F) for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1985, 1986.

Year	Length and age class	Exploitation rate (u)		Fishing Mortality (F)
		Rt^1/Mt^2	Ct^3/N^4	
1985	> 8 years (37-50 cm)	0.0465	0.0491	0.0503
1986	>8 years (37-50 cm)	0.0634	0.0650	0.0672

1 number of fish marked in the previous fall and recaptured during the following winter fishery
2 number of fish marked in the previous fall
3 number of fish caught in the winter fishery
4 population size from previous fall

Table 27. Comparison of actual yield with yield derived by Ricker's model (1975) by age class at an instantaneous rate of fishing mortality of 0.067 for lake trout *Salvelinus namaycush* in Squeers Lake, Ontario, 1986.

Age class	Actual yield (kg)	Ricker's yield (kg)
8	46.7	53.0
9	56.5	46.4
10	46.8	44.8
11	26.5	31.8
12	21.8	20.3
13	22.3	20.6
>13	35.8	46.9
Total	256.4 (0.668 kg/ha)	263.8 (.0.6863 kg/ha)

1986 fishing effort (Fig. 26). Disappearance of older age groups (20 years of greater) did not begin until fishing mortality was at least five times the 1986 effort (Fig. 26). At four times the 1986 fishing mortality , yield of 8+ fish was 659 kg (1.71 $kg.ha^{-1}$), and at eight times yield was 913 kg (2.38 $kg.ha^{-1}$) (Table 28; Appendix 35).

Response to the Questionnaire

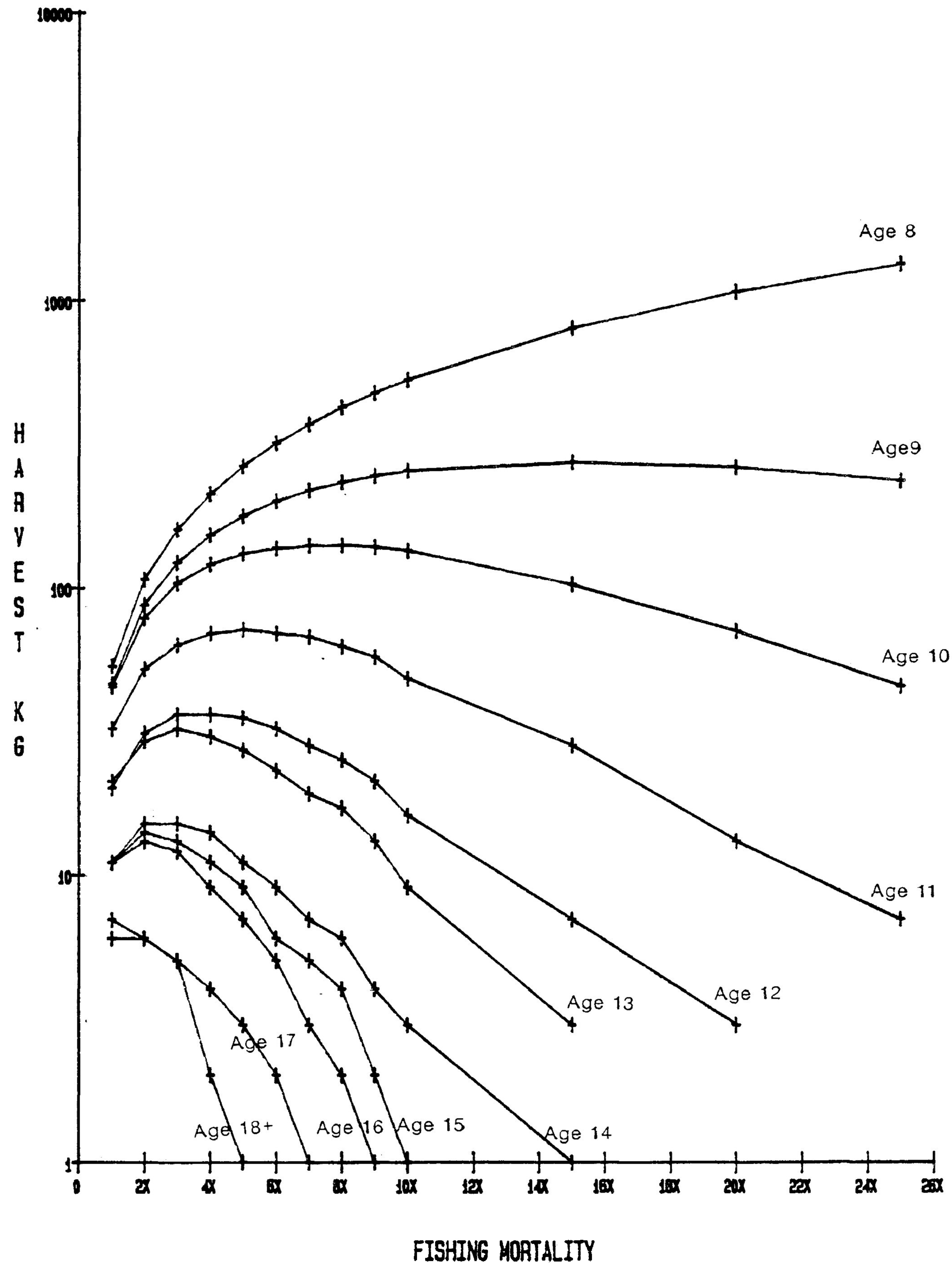
Forty one percent of anglers returned completed questionnaires in 1984 and 1985. A total of 80 questionnaires were received in 1985 and 173 in 1986.

Anglers enjoyed their fishing trips to Squeers Lake in 1985 and 1986. All anglers enjoyed their fishing trip to Squeers Lake in 1985, and 84 percent enjoyed their fishing trip in 1986 (Table 29). Fifteen percent of respondents had a moderately enjoyable day and 1 percent did not enjoy their day in 1986 (Table 29). Ninety five percent of anglers in 1986 said they would apply to participate in the fishery in 1987 (Table 30).

The majority of anglers had not fished Squeers Lake prior to its closure (Table 31). Over 60 percent of anglers had not fished Squeers Lake before the 1985 or 1986 winter fisheries.

Anglers thought they would catch their limit of lake trout during the March 1985 and 1986 fishery. Over 70 percent of respondents expected to catch their limit of fish (Table 32). Fishing success in 1985 was better than in 1986. Seventy two percent of anglers thought fishing was excellent or good in 1985,

Fig. 26. Yield of lake trout (Salvelinus namaycush) by age class with increased fishing effort as predicted by Ricker's yield model between 1985 and 1986 in Squeers Lake, Ontario.



10000
1000
100
10
1
H A R V E S T K G
Age 8
Age9
Age 10
Age 11
Age 12
Age 13
Age 14
Age 15
Age 16
Age 17
Age 18+
0
2X
4X
6X
8X
10X
12X
14X
16X
18X
20X
22X
24X
26X
FISHING MORTALITY

Table 28. Yield and catch per unit effort (CPUE) of lake trout *Salvelinus namaycush* at varying levels of fishing effort employing Ricker's Yield model in Squeers Lake, 1985-1986.

Effort	F[1]	Number of hours per ha	Number of anglers	Yield (kg)	Yield (kg/ha)	CPUE[2]
1X	0.067	13.5	495	264	0.687	0.0509
2X	0.134	27.0	990	438	1.140	0.0422
3X	0.201	40.5	1485	565	1.470	0.0363
4X	0.268	54.0	1980	659	1.714	0.0317
5X	0.335	67.5	2475	738	1.920	0.0284
10X	0.670	135.0	4950	996	2.591	0.0192
15X	1.005	202.5	7425	1208	3.142	0.0155
20X	1.340	270.0	9900	1406	3.658	0.0135
25X	1.675	337.5	12375	1610	4.188	0.0124

1 instantaneous rate of fishing mortality
2 yield per angler per rod hour

Table 29. Number of anglers who enjoyed their fishing trip to Squeers Lake, Ontario, 1985, 1986.

Year	Response			Total
	Yes	Moderately	No	
1985	80(100)	-	0	80
1986	145(84)	26(15)	2(1)	173
Total	225(89)	26(10)	2(1)	253

Table 30. Number of anglers who said they would apply again to participate in the experimental winter fishery in Squeers Lake, Ontario.

Year	Response			Total
	Yes	No	No Response	
1986	160 (92.5)	4 (2.3)	9 (5.2)	173

Table 31. Number of angling trips anglers had made to Squeers Lake, Ontario, prior to closure of the lake in 1979.

Year	Number of trips						
	0	1	2	3	4	5	≥5
1985	53	5	10	0	2	1	9
1986	105	24	9	6	3	7	19
Total	158	29	19	6	5	8	28

Table 32. Number of lake trout *Salvelinus namaycush* anglers expected to catch in Squeers Lake, Ontario, 1985, 1986.

	Expected Number				
Year	0	1	2	3	≥3
1985	5	1	4	58	12
1986	18	6	13	121	15
Total	23	7	17	179	27

Table 33. How anglers rated their fishing success (%) in Squeers Lake, Ontario, 1985, 1986.

	Anglers rating			
Year	Excellent	Good	Fair	Poor
1985	38.8	33.8	18.7	8.7
1986	16.8	27.7	33.5	22.0
Total	23.8	29.6	28.8	17.8

however only 44 percent thought fishing was excellent or good in 1986 (Table 33).

Anglers made more ice fishing trips than open water trips for lake trout (Table 34). Respondents in 1985 had made more fishing trips than those in 1986. Seventy four percent of anglers in 1985 and 56 percent in 1986 had made at least one ice fishing trip that winter. Seventy six percent of anglers in 1985 and 48 percent in 1986 made at least one open water trip for lake trout in the previous year (Table 34).

Lake trout anglers liked to fish in parties of 2,3 or 4 (Table 35). The size of the party was smaller in the summer than the winter. Parties of four people were more common in the winter than in the summer.

Fishing lake trout for fun was most important for 34 percent of anglers (Table 36). Twenty four percent of respondents also liked to fish for lake trout to enjoy the outdoors. Trophy fishing for lake trout and companionship were the least important reasons for fishing lake trout.

Catching several medium size lake trout was most desirable for thirty two percent of anglers (Table 37). Catching at least one lake trout was also desirable. Fishing for trophy lake trout was least important to respondents.

Forty seven percent of anglers believed lake trout populations were declining in northwestern Ontario (Table 38). Fourteen percent of respondents did not think lake trout populations were declining, and the remainder were uncertain or

Table 34. Number of openwater and ice fishing trips anglers made to fish for lake trout *Salvelinus namaycush* in the previous year.

	Number of trips								
Year	0	1	2	3	4	5	6	7-9	≥10
1985									
Openwater	29	7	8	9	6	2	5	4	10
Ice	21	9	9	10	5	3	10	4	9
1986									
Openwater	90	13	20	9	15	4	7	5	10
Ice	76	20	26	15	10	15	4	4	3
Total									
Openwater	119	20	28	18	21	6	12	9	20
Ice	97	29	35	25	15	18	14	8	12

Table 35. Number of companions anglers usually fish with in the summer and winter, 1985, 1986.

	Number of Companions					
Year	0	1	2	3	4	≥5
1985						
Summer	14	3	31	20	9	3
Winter	5	2	27	22	19	5
1986						
Summer	18	12	46	40	43	14
Winter	15	16	46	30	48	18
Total						
Summer	32	15	77	60	52	17
Winter	20	18	73	52	67	23

Table 36. Reasons why anglers like to go lake trout *Salvelinus namaycush* fishing.

Reasons	Rank #1 (3 points)	Rank #2 (2 points)	Rank #3 (1 point)	Importance (total points)
Food	17	15	25	106
Trophy	6	6	5	35
Challenge	12	17	15	85
Relaxation	17	22	22	117
Fun	49	23	20	213
Outdoors	32	32	25	185
Companionship	1	9	8	29
Other	1	0	1	4

Table 37. Angler's preferences in composition of catch for lake trout *Salvelinus namaycuish.*

Preference	Rank #1 (4 points)	Rank #2 (3 points)	Rank #3 (2 points)	Rank #4 (1 point)	Importance (total points)
Trophy Fish	19	34	34	41	287
Limit (3) of Fish	35	35	26	19	316
At Least one Fish	42	21	28	26	313
Several Medium Fish	46	44	29	6	380
Other	3	0	0	0	12

Table 38. Angler's views on whether lake trout *Salvelinus namaycush* populations are declining in northwestern Ontario.

	Response			
Year	Yes	No	Unknown	No opinion
1985	38	11	27	4
1986	78	26	53	16
Total	116	37	80	20

Table 39. Reasons anglers cited for the decline of lake trout *Salvelinus namaycush* populations in northwestern Ontario.

Reasons	1985	1986	Total
Overfishing	22	47	69
Access	17	15	32
Pollution	5	11	16
More people fishing	5	5	10
Lack of enforcement	4	4	8
Not enough stocking	1	4	5
Other [1]	8	8	16

[1] includes habitat destruction, undesirable fish species, non resident anglers, water level fluctuations, commercial fishing, new fishing methods, and low reproductive potential of trout.

had no opinion. Over-fishing was cited most often as the reason for declining lake trout populations (Table 39). Several anglers cited winter fishing as the cause of over-exploitation. Increased accessibility to lake trout lakes due to snowmobiles, all terrain vehicles and the development of logging roads close to lake trout lakes was suggested by many respondents as a major reason for the decline of lake trout populations.

Anglers thought stocking lake trout, making lakes sanctuaries until populations recover and limiting access were the most acceptable management strategies for managing lake trout lakes (Table 40). Other acceptable strategies included restricting land use around lake trout lake and imposing size limits on lake trout harvested. Limiting lake trout anglers to one line, requiring a special license to fish for lake trout, or regulating effort by lottery were not acceptable methods for managing lake trout populations (Table 40).

Table 40. Management options anglers agree with and disagree with for managing lake trout *Salvelinus namaycush* populations.

Management Options	Agree 1985	Agree 1986	Agree Total	Disagree 1985	Disagree 1986	Disagree Total
Limit Access	35	54	89	14	8	22
Sanctuaries	18	74	92	6	1	7
Reduced seasons	9	38	47	22	20	42
Reduced limits	4	10	14	32	25	57
Stocking	34	82	116	7	5	12
Limit one line	3	10	13	51	22	73
Other species	7	22	29	21	0	21
Lake Trout license	4	19	23	46	21	67
Size limits	13	33	46	30	11	41
Other Lakes	9	19	28	4	0	4
Lottery	15	18	33	35	31	66
Land use	22	47	69	3	5	8
Trophy only	5	10	15	29	14	43
Catch and release	5	27	32	31	18	49
Other	0	7	7	1	1	2

DISCUSSION

Spawning

In small lakes, lake trout spawning usually occurs on shoals in less than 6 m of water (Martin and Olver 1980). The shoals are often exposed to prevailing northerly or westerly winds and are frequently close to deep water (Martin and Olver 1980). In Squeers Lake, spawning occurs on shoals 1 to 3 m deep adjacent to a drop off. The two principal spawning shoals are exposed to northwesterly winds as well as southeasterly winds. The largest concentration of spawning fish occurs on the shoal exposed to northwesterly winds.

Lake trout form aggregations adjacent to the spawning areas, several weeks prior to spawning. The exact time and duration of spawning depends on weather conditions (especially wind), light intensity and water temperature (Martin and Olver 1980). In Squeers Lake, the onset of lake trout spawning occurs when water temperature is between 9°C and 12°C, prior to fall turnover (present study). Similarly, Martin (1957) found that thermal stratification was still evident at the onset of lake trout spawning in small Ontario lakes. Martin and Olver (1980) reviewed spawning times of lake trout across their range. Spawning began at 10°C in some lakes, but occurred later in other lakes near the time of fall turnover.

The date of spawning is dependent on latitude. In general, lake trout at high latitudes spawn earlier than those at low latitudes. Lake trout in Algonquin Park, Ontario spawn between late October and early November (Martin 1957). In contrast, lake trout in Arctic waters spawn in late August (Miller and Kennedy 1948; Kennedy 1954). Lake trout in Big Trout Lake, Ontario (53° 45'N, 90°00'W) spawn by mid September (Armstrong 1965). In other small lakes in northwestern Ontario lake trout also spawn during the last week of September and first week of October (Ryan, Quetico-Mille Lacs Fisheries Assessment Unit, OMNR pers. comm. 1987). In Squeers Lake, fish were abundant on the spawning shoals every year from September 25 to October 15. Netting or angling surveys were not conducted prior to or after these dates. Therefore, it appears that lake trout in Squeers Lake begin to aggregate around the shoals by mid September and remain until mid to late October. In addition to latitude, the size of lake may contribute to early spawning. Royce (1936) (1951) in Martin and Olver (1980) suggested lake trout spawn earlier in small lakes. In Squeers Lake, peak spawning occurs at the end of September. However, peak spawning occurs in mid October and is not complete until mid-November in some stocks in Lakes Nipigon and Superior (Ritchie, pers. comm. Lake Nipigon Assessment Unit, OMNR 1987; Goodier 1981).

In Squeers Lake, spawning occurred over a period of at least three weeks in all years except 1983. In 1983, lake trout were difficult to capture on the shoals due to rainy and windy weather (Ryan, pers. comm. 1987). Martin and Olver (1980) suggest heavy onshore winds may reduce the length of the spawning period, while prolonged calm, bright days may extend the prespawning and spawning period.

Martin and Olver (1980) report spawning occurs between dusk and 2300 hours, and it is quite rare to find fish on the shoals during the day. Similarly, lake trout are usually captured on the spawning shoals at night in other lakes in northwestern Ontario (Ryan, pers.comm). In Squeers Lake, there was a preponderance of fish on the shoals during the evening. However, fish were also abundant on the shoals and in areas adjacent to the shoals during the day. The presence of fish on the shoals throughout the day may reflect the high density of lake trout in Squeers Lake.

In the day and early evening, fish were not only susceptible to gill netting but also to angling. Lake trout rarely feed during spawning (Martin and Olver 1980), however in Squeers Lake 70 percent of stomachs examined in fall 1986 contained prey. In Squeers Lake, during late evening and night when spawning activity is greatest angling success declines. Aggressive behaviour by lake trout toward other species of fish on the spawning shoals has not been previously observed (Martin and Olver 1980). However attack on lures by lake trout in Squeers Lake may indicate aggressive behaviour toward other lake trout or fish species around the shoals. Martin and Olver (1980) found an increase in feeding of non-spawning lake trout in the fall. However, they found immature lake trout were rarely found near the spawning shoals. In Squeers Lake, small, unsexed, apparently immature lake trout were captured by angling in areas adjacent to the spawning shoals.

In Squeers Lake, males are more abundant on the shoals than females. Males comprised over 65 percent of lake trout captured on the shoals. Martin and Olver (1980) found a similar ratio of males to females on spawning shoals in Ontario lakes. They suggest males are more active and spend more time around the shoals than females. Capture of lake trout in the fall occurred during the day and early evening prior to dark. Spawning activity occurs at night, and males tend to precede females onto the spawning shoals (Martin and Olver, 1980). This may account for the large ratio of males to females on the spawning shoals.

Evidence of homing behaviour by lake trout has been documented in many lakes (Swanson, 1973; Martin, 1960; Loftus 1958; Eschmeyer 1955). On the two main shoals in Squeers Lake, 95 percent of lake trout recaptured returned to the original site of capture the next year. Martin (1960) found even in a small lake (600 ha) strong homing behaviour existed: 95 of 100 tagged fish returned to the same shoals. A more recent study by MacLean et al (1981) on homing behaviour using numbered and sonic tags on lake trout in Lake Opeongo, suggests lake trout do not home precisely to a single shoal each year. MacLean et al. (1981) found both sexes visit several shoals, although males do not appear to move as far as females. The authors suggest past studies contain biases which underestimate straying. These biases include: a large number of males in the sample, poorly defined distance between distinct home areas, and low recapture rates in succeeding years. In Squeers Lake, the two main spawning shoals are distinct. However, most lake trout examined were males, and there was a low number of recaptures in succeeding years. Some straying occurred, but only to smaller spawning areas around the lake. Hence the evidence suggests male lake trout in Squeers Lake home to the two main shoals.

Population Size

An estimate of population size is fundamental to understanding the dynamics of natural production. It acts as a baseline for determining the relationship between standing crop and yield; for determining the effects of exploitation; and for assessing the consequences of various management strategies (Cooper and Lagler 1956).

Cormack (1969) and Ricker (1975) outline the major assumptions in estimating population size using mark recapture techniques. In Squeers Lake, recruitment effects are probably minimal because growth is slow, and population size is estimated for various length categories. Natural mortality of mature fish is low, and mortality rates did not change between 1982 and 1986. Therefore, mortality probably had little effect on the accuracy of the Petersen estimate. Estimates of handling mortality and tag loss were determined and the number marked and recaptured in the population were adjusted accordingly to minimize biases arising from these factors. The assumption of random mixing between marked and unmarked lake trout probably was not met during the fall sampling. Although tagging data suggests movement occurred between other spawning areas and the main shoals, marking and recapture of fish occurred primarily on two shoals. Differences in the marked to recaptured ratio of lake trout caught by angling, and those caught by gill netting also indicated random mixing did not occur. Gill netting occurred in a small area directly on the spawning shoal, whereas angling occurred in a larger area surrounding the shoal. Therefore, a larger area and greater portion of the population appears to have been sampled by angling.

The ratio of marks to recaptures from angling was low and population estimates could not be determined from fish captured by angling. In comparison, the ratio of recaptures to marked from gill nets was high. Gill nets were set in a small area directly on the shoals, and may have selected for tagged fish. Ricker (1975) found "Petersen tags" made fish more vulnerable to gill nets than untagged fish, because the twine caught under the disk.

Smaller lake trout were captured by angling in areas surrounding the shoals and may result from the size selective regimes of angling. However, the difference in size of lake trout captured by angling and gill netting may also indicate dominance behaviour of larger lake trout over smaller ones during spawning. Gerking (1957) suggests a pecking order in walleye (Stizotedion vitreum), may cause smaller fish to leave preferred areas. Similarly, Reid and Momot (1986) found reduced vulnerability of juvenile walleye to trap net capture on spawning shoals until the dominant adults had been removed. Dominance of smaller lake trout by larger lake trout has also been suggested by several authors (Johnson 1973; Healey 1978; and Martin and Fry 1972).

In Squeers Lake, estimates of population size between fall sampling periods using the Bailey's Triple Catch method are considerably lower than those using the Petersen method. Multiple mark recapture methods may magnify the bias resulting from any of the assumptions of single mark recapture population estimates, resulting in an underestimate of population size (Ricker 1975). Lower estimates may have resulted from "trap-happy" fish which are extremely susceptible to recapture. Ricker (1975) suggests it may be advantageous to kill all recaptures and replace them with fresh fish of the same size given the same mark, as this tends to reduce bias from capture proneness. In Squeers Lake, recaptures were not replaced by other fish, therefore bias from "trap-happy" individuals probably occurred. On the other hand, Petersen estimates do not account for recruitment between marking and recapturing periods, therefore population size using the Petersen method may be inflated. To eliminate the problems of recruitment, Bailey's Triple Catch estimates attempt to determine the exact number of marks in the population prior to recapturing, by using an estimate of survival. However, the accuracy of the survival estimate, and ultimately the Bailey's Triple Catch estimate, depends principally on the magnitude of the three R-items (recaptured fish), especially R23 (Ricker 1975). A good multiple census design should strive to equalize R12, R13 and R23. This is likely if M1 (marked fish) is larger than M2, and C3 (caught fish) is larger than C2 (Ricker, 1975). The present study was not designed for a Bailey's Triple Catch estimate, and recapture values were not equal. Although C3 was larger than C2, M1 was smaller than M2. Therefore, the magnification of problems related to the assumptions of mark-recapture and poor survival estimates in the Bailey Triple Catch estimate, combined with the absence of consideration for recruitment effects in the Petersen estimate, may account for the discrepencies observed between the two estimators of population size.

The larger population estimates derived from winter fishing may be closer to the true population size because of better mixing of marked and unmarked fish, more random distribution of fishing effort and a shorter time period between marking and recapturing. However, differences in vulnerability and catchability of various sizes of trout in the winter fishery increases the confidence limits of the winter estimate.

The density of mature lake trout generally ranges from .22 to 2.8 fish per ha (Healey 1978). Martin and Olver (1980) found the highest density of lake trout (4.1-9.8 fish ha-1) frequently occur in those lakes where the fish mature at a small size, are polyphagous, and where the average length of fish caught is 30-40 cm. Similarly, in Squeers Lake the length of lake trout captured was 30-40 cm, and the density (18 trout ha^{-1}) was highest of any natural lake trout population reported. Recent population estimates for polyphagous trout in Lake Louisa, Algonquin Park indicated a density of 12 mature fish/ha (Monroe and Hicks 1984). Although polyphagous lake trout populations are common (47 % of lake trout lakes in Thunder Bay District) studies on these populations are rare. The high density of lake trout in Squeers Lake may not seem so unusual when more polyphagous populations have been examined.

Length Distribution of the Population

A bimodal length distribution is associated with unexploited populations (Kerr 1979). Johnson (1973) and Healey (1980) found bimodal length distributions of fishes in Arctic lakes. Similarly in Squeers Lake, the length distribution is bimodal with a large juvenile peak followed by a smaller peak of mature adult fish. Lake trout in the first modal group (20-30cm) ranged from 3 to 8 years of age and those in the second modal group (36-40) cm ranged from 7 to 17 years of age. Johnson (1973) suggests a high degree of clustering associated with modal length values is characteristic of a population limited by its resources.

Johnson (1973) and Healey (1980) both suggest the bimodal distribution may result from suppression of a group of smaller younger fish by larger older adults. Johnson (1973) indicates suppression of smaller fish is dependent on an extended period of maturity, long life span and low mortality. Lake trout in Squeers Lake possess these characteristics. The bimodal distribution with a wide range in length at ages within the two modes indicates larger older adults may be suppressing young fish. Martin and Fry (1972), Gerking (1957), and Reid (1985) also have found evidence to support Johnson's (1973) and Healey's (1980) hypotheses.

Johnson (1973) suggests bimodality is enforced when small lake trout are relegated by large lake trout to the periphery of the lake where increased predation occurs. Healey (1980) however suggests suppression of smaller fish may involve inhibition of normal exploratory and foraging activity. Both mechanisms would reduce catchability and result in high juvenile mortality. In Squeers Lake, small lake trout would not survive relegation to the periphery because of lethal temperatures during the summer months. In addition, random index gill netting in Squeers Lake indicated smaller lake trout were found in deep water (Appendix 30). Therefore it appears the hypothesis of limited exploratory and foraging activity as suggested by Healey (1980) is a more viable explanation of the presence of bimodality and suppression of smaller fish in Squeers Lake.

In Arctic populations, juveniles are generally less numerous than adults. In Squeers Lake, the relatively large group of juveniles may reflect natural conditions within the lake (abiotic and biotic), or it may indicate increased recruitment, resulting from the winter sport fishery during the late 1970s. The mean length of lake trout captured on the spawning shoals decreased by 2 cm between 1982 and 1986. However, the shift in mean size on the spawning shoals may have resulted from more intense sampling, thereby increasing the vulnerability of small lake trout. Although the mean length of lake trout did not change significantly between 1982 and 1984 gill netting, each mode in the length distribution decreased by one two cm size interval. The peaks in mean length of juveniles are associated with large year classes (Age 5 and 6 in 1982, and Age 4 in 1984), therefore evidence suggests an increase in recruitment occurred between 1982 and 1984.

AGE ASSESSMENT

Problems with age determination of lake trout were first identified by Webster et al (1959) for fish in Cayuga Lake. Webster et al. (1959) and subsequent authors, Casselman (1983); Dubois and Langueux (1968); Power (1978); and Swainson (1985) indicated assessed otolith age was consistently higher than assessed scale age. They determined assessed ages of lake trout greater than 5 years of age were underestimated using scales. Swainson (1985) found differences between scale and otolith interpretation increased with increasing age. Similarly in Squeers Lake, assessed scale age greater than five years underestimated the true age, and the magnitude of the error appeared to increase with age. Errors in determining ages from scales may result from scale erosion, scale regeneration and from slow growth which results in the scale not growing enough to separate annuli (Carlander 1974). These three processes are accentuated in old, slow growing fish. This may have resulted in difficulties when lake trout from Squeers Lake were aged using scales.

Accurate age determination is required for estimating growth, age at maturity, number of spawning periods per life span, age at harvest, age class composition of catch, abundance of year classes, longevity and mortality rate (Carlander 1974). Underestimating age leads to overestimates of production and subsequent overestimate of annual allowable yield (Swainson 1985). Underestimating age also results in an overestimate of mortality rate, which may falsely indicate overexploitation (Healey 1978; Swainson 1985). Inaccurate assessment of the status of the resource may result in loss of angling opportunities (Swainson 1985). Observation of responses to exploitation such as age at maturity, year class strength, and growth are dependent on accurate ages. Therefore in Squeers Lake and all other lakes, accurate age determination is essential for assessing the status of the population prior to, and following exploitation.

Swainson (1985) recommends using scales to age lake trout less than 20 cm, using any age structure for fish between 20 and 40 cm, and using otoliths for aging fish greater than 40 cm. His study dealt with highly exploited populations in Algonquin Park, southern Ontario. In northern Ontario and Arctic lakes subjected to minimum exploitation, there is a high overlap in mean length at age. In Squeers Lake, lake trout between 25 and 40 cm range from 5 to 23 years of age. A system of aging suggested by Swainson (1985) appears to be inadequate for slow growing populations of northern Ontario and Arctic waters. The choice of aging tissue should depend on age rather than length, and wherever possible ages should be determined from otoliths for consistency and simplicity.

Age Composition

The life span of lake trout increases with latitude (Johnson 1983). Lake trout as old as 62 years were found in Lake Kaminuriak, NWT (Bond, 1975). In southern Ontario, lake trout rarely live longer than 20 years of age (Swainson,1985; Deacon, pers. comm. Acid Precipitation Study, OMNR 1987), however in Big Porcupine Lake, one lake trout was 33 years old (Deacon, OMNR, pers. comm). In northern Ontario, lake trout are often greater than 20 years old, and some fish are greater than 30 years (Table 41). In Agnes lake, northwestern Ontario, one fish was 39 years old (Ryan, OMNR, pers. comm.). In Squeers Lake, lake trout were

· 41. Growth rates determined using length at otolith age for lake trout (Salvelinus namaycush) populations in Canada

AGE GROUP (years)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
ic NWT																															
l Bear n=210											58	56	53	60	62	56	55	62	56	60	61	62	67	60	60	68	67	66	60	60	62
l Slave (1) n=636									42	48	49	51	54	57	59	62	64	66	69	70	72	73	73	75	77	82	86	85	87	88	
(2) n=543						41	45	47	50	52	55	58	59	61	60	63	61	68	63	69	63	58	80	71	60	65	65	59	61		77
murlak n=332						22	28	28	27	32	37	39	43	48	50		54	55	54	56	56	58	62	58	60	63	59	63	62	61	62
John L. n=75		11						34	35	36	38	37	42	41	41	42	49	63			72				73	76		72			
ador																															
kmanuan n=250			18	18	17	27	32	37	41	45	48	52	53	58	59	60	61	63	64	67	67	64	64	63	64	66	70	56	69	60	
hern Quebec																															
assini			21	23	32	36	41	43	48	49	51	54	53	53	54	52	57	58	52	60	59	62	56								
y Mountains, berta																															
emach n=90		12	13	18	20	21	22	23	23	24	24	25	25	27	27		27	29	28	31	28		31					33			
hern Ontario																															
tergood n=245			26	29	31	34	34	35	36	36	37	36	38	35	35	36	41	36			37		34		35						
hell n=75				23		33	37	41	40	45	47	49	58	48	54	55		54		55	58		60	54	57	53		59		60	
le Gull n=51		15	20	24	33	33	36	43	41	50	49	45	37	47	57			52	60	56											
gooning n=52					30				43	42	50	55	57		61	63	61	63	70		69		65				68			54	73
s n=100		19	20	26	29	31	33	36	38	41	43	46	52	34	49	46	47	57	53	51	54	54	52		59			54		88	
nson n=47			23	24	33	40		48	42	47	47	54	49	56		56	55		59	57			57		57	61		56		55	61
it n=43		12	24	30	42	43	47	49	48	52	50	53	53																		
hell n=28						30	29	31	32	38	40	40	45																		
ers n=150		15	19	23	26	30	33	35	40	44	44	48	47	54	64	41	45	47	45	49	47	39	54								
ing Snow n=24					20	23	23	23	25	28																					
mmter	13	21	25	29	32	36	39	43	46	44	50	58	62			51	55	65		69			52	55	71	69					
naga n=39			24		35	35	48	54	56	61	61																				
gon n=93				55	56	60	64	68	71	67			86	93																	
hern Ontario																															
sa n=94			17	20	30	31	32	37	39	40	44	45		45			47														
ngo n=375		13	20	24	29	34	39	44	48	54	60	60	63	66	69	62	65	68	73	66	67										
kani n=46		24	29	32	37	44	45	46																							
Porcupine n=67		25	25	27	33	38	35	37	37	38	39			40	45	40	37	30													
lechere n=107	15	21	27	31	35	39	38	40	41	44	45	43	45	45	43	48	47	46		48	45	43	43		45						
r n=41	18	29	30	33	54	53	55		56	60	61	61	62																		
all n=79					33	35	35	36	35	38	40	42	48	43	43	44	53														
borne n=65			29	28	31	33	37	39	40	43	42	42		48	46	42									42						
ey n=38					28	33	34	34	37	48			44																		
n=19						26	28	29	26	26	43																				
ve Mile n=14					21	25	26	30	31																						

	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	
l Bear n=210	69	65	80		68	66	71	70	61	72	69	70		73	73		94	99		99											100	(Moshenko & Gillman 1978)
l Slave (1) n=636		80	87		93																											(Moshenko & Gillman 1978)
(2) n=543	64		62																													(Moshenko & Gillman 1978)
murlak n=332	63	66	65	62	66	67	67	93	74	77			87			97																(Bond 1975)
John L. n=75	82	83						88			89																					(Craig And Wells 1975)
kmanuan n=250	76		59			63																										(Bruce & Parsons 1979)
assini																																(DuBois And Langueux 196
emach n=90																																(Donald And Alger 1986)
tergood n=245																																(OMNRa, unpub)
hell n=75		61																														(OMNRa, unpub)
le Gull n=51																																(OMNRb, unpub)
gooning n=52																																(OMNRb, unpub)
s n=100																																(OMNRb, unpub)
nson n=47		62	75																													(OMNRb, unpub)
it n=43																																(OMNRb, unpub)
hell n=28																																(OMNRc, unpub)
ers n=150																																(Ball 1988 - present stu
ing Snow n=24																																(OMNRc, unpub)
mmter																																(OMNRb, unpub)
naga n=39																																(OMNRc, unpub)
gon n=93																																(OMNRd, unpub)
sa n=94																																(Swainson, 1985)
ngo n=375																																(Swainson, 1985)
kani n=46		73																														(OMNRe, unpub)
Porcupine n=67																																(OMNRe, unpub)
lechere n=107																																(OMNRe, unpub)
r n=41																																(OMNRe, unpub)
all n=79																																(OMNRe, unpub)
borne n=65																																(OMNRf, unpub)
ey n=38																																(OMNRf, unpub)
n=19																																(OMNRf, unpub)

mple size.
length in cm.

a = Mark Sobchuk, Red Lake District, Ontario Ministry of Natural Resources (OMNR).
b = Phil Ryan, Quetico-Mille Lacs Fisheries Assessment Unit, OMNR.
c = Bob Hamilton, Thunder Bay District, OMNR.
d = Bev Ritchie, Lake Nipigon Assessment Unit, OMNR.
e = Lois Deacon, Acid Precipitation Working Group, OMNR.
f = Chuck Brady, Haliburton Hastings Fisheries Assessment Unit, OMNR.

found to reach a maximum age of 26 years.

Actual differences in age structure between populations may be masked by varying levels of exploitation. Longevity of fish may be reduced through exploitation (Colby 1984). The most heavily exploited lake trout populations which exist in southern Ontario, exhibit a younger age structure (Table 41). However, prior to exploitation it is unlikely trout in southern Ontario populations ever reached 50-60 years of age, as observed in Arctic populations.

Martin (1966) proposed that slow growing, polyphagous lake trout have shorter life spans than piscivorous fish. This apparent difference noted by Martin (1966) was probably due to problems with age determination. Annuli on scales of fast growing fish being more distinct than those on scales from slow growing fish (Carlander 1974), making it is more difficult to age polyphagous lake trout. However, Swainson (1985) using otoliths showed piscivorous fish in Lake Opeongo, Algonquin Park, were slightly older than polyphagous fish in Lake Louisa, Algonquin Park. These differences may have resulted from varying levels of exploitation on the two lakes. Ryder and Johnson (1972) suggest the impact of exploitation is greater in small lakes, since fish are easier to locate. Therefore, exploitation may have greatly impacted the age structure of lake trout in Lake Louisa when lake size is considered. Age structure of polyphagous and piscivorous populations (except Fallingsnow Lake, Thunder Bay District) were quite similar (Table 41). Lake trout populations from Sassenach

Lake and Squeers Lake are polyphagous, and maintain an old age structure. Fallingsnow Lake has a polyphagous population with a young age composition, however it is one of the most heavily exploited lakes in the Thunder Bay District (Payne and Roche, 1984). The ensuing age structure probably reflects the high level of exploitation. Differences in age structure between polyphagous and piscivorous populations noted in the literature, may thus be caused by difficulties in age assessment as well as differing levels of exploitation, rather than reflecting any inherent biological characteristics of the different populations.

Female lake trout generally live to a slightly older age than males (Martin and Olver 1980). In Squeers Lake, no significant differences existed in the age compositions of males and females, however a larger number of females lived to an older age. The mean age of males was higher than females in both years and may result from problems with identification of immature fish. In female lake trout, development of eggs makes sex determination of immature fish easier than in males. A good portion of fish whose sex could not be identified were probably males. Therefore, the mean age of males is probably lower than indicated, and similar to the mean age of females.

In Squeers Lake, the age distribution is skewed to the left with a long slowly descending right hand limb. The distribution indicates low and stable recruitment. The absence of certain older age groups may result from heavy exploitation in the late 1970s. However, missing year classes in older age groups can be observed in relatively unexploited populations (Table 41), and may result from variable natural mortality between year classes.

In Squeers Lake, peaks in the age distribution in 1982 and 1984 represent the 1977 and 1980 year classes respectively. Dominance of the 1980 year class may result from heavy exploitation during the late 1970s. The abundance of 4 year olds captured in June 1984, represent survival of progeny from the 1980 year class. The spawning population in 1980 was the first year class to be protected by closure of the lake. Subsequent year classes of juvenile lake trout observed in Squeers Lake were not as prominent. Although there was a relatively large number of 5 year olds in 1982 gill netting, 7 year olds were not abundant in 1984 gill netting. Similarly, the two strong year classes from gill net catches in 1982 and 1984 (5 and 4 year olds respectively) did not appear in large numbers in the winter fisheries of 1985 and 1986.

The apparent poor recruitment of strong juvenile year classes may be due to different selective regimes of the gear employed. Selectivity may depend on the length composition and the biological state (maturity, fat content, state of nutrition) of the population (Nikolski 1969). Johnson (1976) speculates low food availability makes fish more vulnerable to angling; and as a result fast growing fish are most likely to be exploited. Strong year classes may not be the fastest growing cohort, angling therefore may select for an entirely different age group of fish. Angling selectivity is primarily dependent on the type and size of bait presented (Nikolski 1969). In Squeers Lake, there is a gross overlap in length at age and since angling selects for fast growing fish (regardless of age), angler caught fish may not represent actual year class abundance. Alternatively, recruitment may have been prevented by suppressed growth or high mortality in young age groups. These observations support Johnson's (1973) hypothesis that if opportunities are not available for juveniles to move into the adult population, there is a dampening effect on juvenile recruitment. The bimodal length distribution further supports this hypothesis.

GROWTH

Growth is influenced by various factors, including the amount and size of food available; the number of fish using the same food resource; temperature and oxygen; and the size, age and sexual maturity of the fish (Everhart and Youngs 1975). Growth varies with size and age, and between stocks because of the wide geographic distribution and diversity of habits and habitats of lake trout (Martin and Olver 1980).

The effects of temperature on lake trout growth have been examined by several authors. Martin (1952), Rawson(1961) and Van Whye and Peck (1968) found lake trout grow more slowly in northern lakes than in southern ones. However, Healey (1978) compared growth rates of various northern populations and did not find any evidence to support this hypothesis. The results from his study may have been confounded, because comparisons were made from growth rates assessed from scales and otoliths. However, in the present study, comparisons of growth rates (using otolith aged fish only) indicates there is no consistent decline in growth rates with latitude (Table 40).

Overlap in length at age increases with latitude and suggests other factors are important in determining growth rates. When stunted polyphagous lake trout were transferred to a lake containing large forage fishes (cisco), growth equalled that of the resident lake trout population (Martin 1970). Martin (1970) concluded there was no major genetic fixation of growth rates. Similarly, MacLean et al. (1981) found growth of planted and wild native fish in Lake Opeongo was similar, and differences in growth rate between native and hatchery fish were not obvious.

Martin and Olver (1980) suggest the major factor regulating growth of lake trout is the availability, quantity and quality of the food supply. Kerr (1979) found diet was an important determinant of the observed growth pattern of lake trout, resulting in a bimodal size structure. Lake trout make a transition in diet from plankton or crustacea, to large readily available forage fishes. They need access to some large food items if they are to achieve large body size (Kerr 1971). The metabolic costs of acquiring larger prey items are lower, resulting in higher levels of growth efficiency which can be sustained to a relatively large body size (Kerr 1979). In Squeers Lake, a small number of lake trout attain a large size.

Divergence in growth may be caused by varying growth rates between sexes. However it is uncommon in lake trout populations (Martin and Olver 1980), and does not appear to account for different growth rates in Squeers Lake. In Squeers Lake, feeding studies indicate divergence in growth occur from changes in diet. Fast growing lake trout switch from primarily feeding on mysids and amphipods to an almost completely piscivorous diet in the summer. Large size was achieved either by cannibalizing, or by foraging on large fish species such as white sucker and burbot.

Where pelagic forage fishes are not available, lake trout are unable to make the transition and are trapped on a steeply declining planktivore K-line (Kerr 1979). Stunting occurs because of high metabolic demands required to forage for small and dispersed organisms (Kerr and Martin 1970). Similarly, Konkle and Sprules (1986) suggest low abundance of large prey and gastric inefficiency may all contribute to stunting. If pelagic forage fishes are not available, lake trout must continue eating plankton or invertebrates during the summer. When the water cools down they consume inshore forage fishes, however low environmental temperatures slow metabolic processes and preclude significant amounts of growth. In Squeers Lake, pelagic forage fishes are not available and fish primarily feed on mysids and amphipods in the summer. Therefore, growth is slow compared to piscivorous populations. Similarly Martin (1966) and Donald and Alger (1986) found the lack of pelagic forage fishes contributed to stunting in Algonquin Park and Rocky Mountain lakes respectively.

Mysis relicta is an important food item in the first years of a lake trout's existence. Griest (1976) found with establishment of *Mysis relicta* in Twin Lakes Colorado, lake trout grew faster. The absence of mysids in Lake Opeongo (Dadswell 1974) may result in the slow growth of juvenile trout (Table 40). In Squeers Lake, the majority of lake trout feed on mysids and amphipods throughout their life (Black 1982; present study). Donald and Alger (1986) attributed extremely slow growth in Sassenach Lake, Rocky Mountains, primarily to the lack of trout foods such as mysids and amphipods. The presence of mysids and amphipods in Squeers Lake appears to allow lake trout to grow relatively fast, and to attain a larger body size than other polyphagous populations. Kerr (1971) found the prime determinant of fish growth is the size composition of the prey resource. Therefore, differences in growth rates between strictly plankton feeding populations, and those feeding on mysids and amphipods in the summer may be attributed to different prey size. Mysids and amphipods are larger food items than zooplankton, and tend to clump in a contagious pattern (Gregg 1976). Therefore, the metabolic energy required for foraging is less, and the relatively larger size of prey allows the predator to obtain greater body size.

Slow growth may also result from crowding which limits the available food supply. From catch per unit effort (CPUE) data based on gill netting, Donald and Alger (1986) did not find unusually high densities in Sassenach Lake, Rocky Mountains. However, pelagic forage fishes are absent and densities of lake trout are high in Lake Louisa, Fallingsnow Lake and Squeers Lake. With increasing density of trout, the energy required to search for food increases and subsequently the amount of food consumed per individual will be less, and growth will be slowed.

Growth is often considered a progression over time, however Johnson (1976) believes growth is size dependent and opportunistic. He suggests there are forces acting on an individual to achieve and retain a certain size, which are much greater than the tendency for fish to increase regularly with time. Young fish recruited to the established population grow rapidly toward asymptotic size. Dubois and Langueux (1968) and Swainson (1985) found reduced growth was associated with attainment of sexual maturity. In Squeers Lake, trout approach asymptotic size by the age of maturity. Lake trout grow rapidly before maturity to attain a maximum length of 36-40 cm. Once this size is reached very little growth occurs, and there is a large overlap in size at age. The reduced growth following maturity was substantiated by tag recaptures on the spawning shoals.

Healey (1977) found that growth curves of lake whitefish were distinctly asymptotic, while those for lake trout were not. He suggests the lack of a clear asymptote may be due to problems with age assessment. Scales assess age accurately up to 5-6 years of age (prior to when most populations attain asymptotic size), therefore the asymptote may not be observed if the population is aged using scales. Asymptotic size was attained in all lake trout populations examined in this study (except Lake Nipigon). Therefore, lack of an obvious asymptote in previous studies may have been caused by problems in age assessment.

Maximum length varies between polyphagous and piscivorous populations (Table 41). Martin (1966) showed that upper asymptotic size attained was related to food supply. He found polyphagous fish grow more slowly and do not reach as great an ultimate size as fish in piscivorous populations. The difference between polyphagous and piscivorous lake trout can be explained in the same context as Healey's (1977) comparison of lake trout and lake whitefish. He observed lake whitefish fed on small benthic animals and may reach a size at which feeding efficiency is too low to permit further growth, whereas lake trout can switch to larger more available prey items. There are no pelagic forage fishes in Squeers Lake, therefore the asymptotic size of lake trout is small and the reduction in growth is more pronounced than in piscivorous populations.

Survival

Mortality is usually divided into death caused by fishing and by natural elements. Natural mortality is determined by factors such as old age, abiotic conditions, predators and parasites, disease and food supply (Nikolski 1969). Lack of food and predation are often the direct causes of mortality in the early life history stages. In later stages food becomes an indirect factor by reducing growth; fishing, predation and old age (where predators are minimal) are important in later stages of life (Nikolski 1969).

Assessment of mortality from catch curves assumes aging is accurate, and the age classes used in the estimate are equally vulnerable to the gear (Healey 1977). Fast growth and incorrect aging may cause bias in mortality estimates from catch curves. In addition, changing mortality with age and variable year class strength may affect estimates. In Squeers Lake, age was determined by otoliths, growth was slow and recruitment to the mature population was constant. Therefore, most of the problems associated with determining mortality rates from catch curves were minimized.

Generally, most estimates of natural mortality for lake trout have been determined from catch curves derived from scale ages, and from exploited populations. Separation of natural and fishing mortality in exploited populations is difficult. Mortality rates assessed from scale ages often overestimate mortality (Healey 1978; Swainson 1985). Therefore, any comparisons of survival rates between populations in this study were made with lake trout aged from otoliths.

Each species has an inherent mortality rate. A species with a short life cycle adapts to a more labile death rate than one with a long cycle with late maturity (Nikolski 1969). Lake trout are adapted to climatic conditions in northern boreal lakes. They have a long life span and a low rate of natural mortality which act as an adaptive response to variable year class production (Johnson 1976). In unexploited, long-lived Arctic populations, annual natural mortality rates ranged from 0.19-0.31 (Healey 1978). Yaremchuk (1986) indicated natural mortality rates were as low as 0.08. In southern Ontario populations, mortality has not been assessed from otoliths. However, lake trout in lower latitudes have a shorter life span and should incur higher mortality than populations at higher latitudes. In Squeers Lake, mortality was spread over many age classes, and 28 percent of lake trout greater than 8 years of age died from natural causes. The low rate of mortality spread over many age classes implies density dependent factors are regulating natural mortality.

Predation is often a major cause of mortality at all life stages (Nikolsky 1969). In Squeers Lake, there are no major predators of lake trout. Cannibalism does occur, however not frequently enough to have any major impact. The northern pike population in the lake is quite small and the presence of lake trout in the diet of pike is minimal (Laine, pers. comm.). Laine (pers. comm) found predation by northern pike on lake trout occurred primarily during the spring and fall when the distribution of the two species habitats overlapped. Separation of lake trout and northern pike during the summer months by thermal barriers limits predation. Therefore, it appears predation represents only a small contribution to natural mortality.

In Squeers Lake with absence of predation and exploitation, the main factor contributing to natural mortality must be limited food resources during early life stages. Disease, old age and to a lesser extent limited food supply contribute to natural mortality in older fish.

Sex Ratios and Maturity

Martin and Olver (1980) found no differential natural mortality of the sexes and concluded lake trout should exhibit balanced sex ratios. Most lake trout populations they examined exhibited a 50:50 sex ratio (within 5 percent). Similarly, lake trout in Squeers Lake exhibit a balanced sex ratio (Appendix 19).

Maturation is influenced by environmental factors such as temperature and biological factors such as available forage, and exploitation (Nikolski 1969). Onset of maturity is often related to attainment of a given size and age. Largest members of an age group generally mature first, and males usually mature at an earlier age and smaller size than females (Martin and Olver 1980). Age at first maturity (based on otoliths) for lake trout populations range from 4 to 19 years (Table 42). In Squeers Lake, lake trout mature within the range of other populations, and all fish mature by 11 years. Martin and Olver (1980) found

Table 42. Age at maturity for lake trout *Salvelinus namaycush* populations in Canada.

Lake	Age at First Maturity			Age at 100% Maturity		
	Males	Females	Both	Males	Females	Both
Southern Ontario						
Big Porcupine[1]	5	5	-	8	8	-
Nanikani[1]	5	4	-	7	7	-
Sherborne[1]	6	5	-	8	9	-
Kimball[1]	-	-	-	7	7	-
Clear[1]	4	5	-	5	5	-
Bonnechere[1]	4	5	-	7	7	-
Northern Ontario						
Robinson[2]	9	8	-	12	12	-
Pettit[2]	5	6	-	7	9	-
Agnes[2]	7	6	-	12	12	-
Pekagoning[2]	11	12	-	12	13	-
Little Gull[3]	-	-	-	10	10	-
SQUEERS LAKE[4]	5	7	-	11	11	-
Scattergood[5]	4	5	-	9	9	-
Big Shell[5]	-	8	-	10	10	-
Northern Quebec						
Mistassini[6]	7	9	-	-	-	-
Northern Quebec[7]	8	8	-	-	-	13
Ossokmanuan[8]	-	-	9	-	-	-
Arctic						
Old John[9]	-	-	10	-	-	15
Kaminuriak[10]	13	19	-	-	-	-
Great Bear[11]	14	12	-	-	-	-
Great Slave[11]	10	9	-	-	-	-

1 Ms. Lois Deacon, Acid Precipitation Working Group, OMNR.
2 Mr. Phil Ryan, Quetico-Mille Lacs Fisheries Assessment Unit, OMNR.
3 Laine (1987)
4 present study
5 Mr. Mark Sobchuk, Red Lake District, OMNR.
6 Dubois et al. (1968)
7 Magnin et al. (1978)
8 Bruce and Parsons (1979)
9 Craig and Wells (1975)
10 Bond (1975)
11 Moshenko et al. (1978)

the size of lake trout at first maturity ranged from 28 to 65 cm. However, Donald and Alger (1986) found lake trout in a mountain lake first matured at 18 cm. In Squeers Lake, lake trout first mature at a small size of 28 cm and all are mature by 41.5 cm.

Rate of growth regulates maturity, and since energy availability influences growth rates and longevity, northern stocks generally mature later and at a larger size than southern stocks (Healey 1978). Populations in northern Ontario tend to mature at an older age than those in southern Ontario and at an earlier age than those in Arctic waters (Table 42). Exploitation rates may increase growth and condition, in turn reducing mean age at maturity (Nikolski 1969). Therefore, the differences in age at maturity between unexploited northern and exploited southern populations may be exaggerated.

In Squeers Lake, food supply is apparently a greater determinant of growth rate than latitude, and therefore will have a greater influence on the size at which lake trout reach maturity. Donald and Alger (1986) found lake trout mature at a very small size in a mountain lake which contained no "trout food". Martin (1966) found slow growing polyphagous lake trout in Lake Louisa, southern Ontario matured at a smaller size than fast growing piscivorous lake trout in Lake Opeongo, southern Ontario. In Squeers lake, no forage fish are available, and lake trout mature at one of the smallest sizes recorded (28 cm).

Food supply may also be a factor in determining age at maturity. Bagenal (1973) found better fed rainbow trout grew faster and hence matured faster. However, Martin (1966) found slow growing "short lived" polyphagous lake trout matured at a younger age, and when transferred to an environment with large forage fish they matured at an older age. Martin's (1966) findings contrast the belief that age at maturity is inversely related to growth rate. In addition, in Squeers Lake the comparatively old age at maturity for lake trout does not support Martin's findings. It appears Martin's (1966) differing conclusions may result from differences in aging lake trout from scales and otoliths. Slow growth makes age assessment from scales difficult. Fast growth in piscivorous populations means age assessment of older fish using scales is easier.

Fecundity

Fecundity is species specific and is directly related to environmental conditions and food supply (Bagenal 1973). Nikolski (1969) suggests high latitude forms of lake trout are less fecund than low latitude forms. Martin and Olver (1980) found there was no decrease in number of eggs or number of eggs per kg of fish with increasing latitude. Similarly in Squeers Lake, lake trout have a similar number of eggs per kg as fish in Arctic and southern Ontario waters.

Fecundity is directly related to mortality due to predators and other causes not associated with aging (Nikolski 1969). A change in fecundity is often observed as an adaptation to parasites, predators and food supply. Differences between populations of a given species reflect changes in food supply and exposure to predators.

In Squeers Lake, mortality from predation appears low, therefore food supply probably regulates fecundity. Population fecundity and density in salmonids appear to be inversely related (Bagenal, 1973; Jensen, 1971). When fish are crowded, food supply is poor but when density is low more food is available. Vladykov (1956), and Scott (1962) found higher fecundity in salmonids with improved diet. When polyphagous lake trout were transferred into a lake with forage fish, fecundity increased (Martin 1966).

In Squeers Lake, the absolute number of eggs per female is lower than that recorded from other populations. Egg counts are similar to those of lake trout from Lake Louisa. The low egg counts result from the small size of lake trout in both lakes, primarily as a result of poor diet. Most mature fish in Squeers Lake are 36 to 50 cm in length and their absolute fecundity ranges between 793 and 2255 eggs.

Although individual egg counts are quite variable, there is an irregular trend toward increased fecundity with size and age (Martin and Olver 1980). Hanson and Wickwire (1967) and Martin (1970) found there is a stronger correlation between weight and fecundity than between size or age and fecundity. In Squeers Lake, a strong correlation exists with fecundity and size and weight, however the relationship with age is weak. Fecundity increases with length and there is a high overlap of length at age, therefore a weak relationship between age and fecundity is not unexpected.

Nikolski (1969) suggests size of egg may compensate for low fecundity, since larger eggs may have increased survival. Bagenal (1973) found lake trout has the lowest variation in egg size of all freshwater fish studied. Egg size varies seasonally but maximum egg size diameter in ripe fish may vary from 3.7 mm to 6.8 mm (Martin and Olver 1980). In Squeers Lake, eggs from females ranged from 3.57 to 5.42 mm in diameter. Bagenal (1973) found increased competition and less food may lead to decreased fecundity and less uniformity in egg size. In Squeers Lake, the wide range in fecundity and egg size may thus reflect the level of competition resulting from the high density of trout.

Nikolski (1969) found eggs produced by more rapidly growing fish are larger, hence larger lake trout tend to have larger eggs than small trout. These results suggest survival and hence recruitment will be greatest from larger, older, and more fecund females. Older and larger fish in a population tend to be removed first in a fishery, therefore the impact from exploitation may be quite rapid and intense. Martin and Olver (1980) found larger lake trout tend to have larger eggs, however other authors (Eschmeyer 1955; Martin 1970) could not find any consistency in the relationship. There is no significant relationship between egg size and size of lake trout in Squeers Lake. Larger lake trout did have more eggs, however the number of eggs per kg of body weight (relative fecundity) was generally less compared to smaller fish. In Squeers Lake, most spawners are between 35 and 40 cm and their relative fecundity is higher than larger fish in the population. This group of fish (35-40 cm) is most important in reproduction as they contribute over 70 percent of all egg production.

Food Habits

Lake trout being omnivorous consume plant material, annelids, crustaceans, insects, arachnids, molluscs, fishes and mammals (Martin and Olver 1980). The kind and quantity of food varies by fish population, season and size of lake trout.

Seasonal changes in lake trout diet may occur because certain prey items are present only at specific times of the year, and/or are only available at certain times of the year due to thermal and chemical (O^2) barriers. In cold temperate lakes different prey items attain seasonal peaks in numbers at different times. Therefore a generalist feeding strategy is advantageous in a northern climate (Keast 1978 in Ritchie 1984). In Squeers Lake, lake trout are opportunistic and their diet reflects annual and seasonal changes in prey abundance and availability. This strategy is probably a result of intraspecific competition, rather than a reflection of adaptation to climate. By consuming a variety of organisms fish can avoid competition.

The highest number of empty stomachs and the lowest mean number of prey items per stomach (with the exception of the spawning season) occurred in the winter. Martin (1954) found a similar trend in small Ontario lakes. In the winter, diet was less varied, with plankton and bottom fauna being reduced, and shallow water fishes more common than in the summer. Similarly in Squeers Lake, shallow water fishes were more important prey items in winter than in summer. During the summer months the thermal barrier restricts trout foraging on inshore fishes.

The variety of insects fed upon by Squeers Lake fish was low in winter compared to spring and summer months. The most active feeding period of lake trout occurs in the spring after ice break (Martin and Olver 1980). Similarly, in Squeers Lake, all lake trout feed heavily in the spring on the largest variety of food items. In Lake Opeongo, Algonquin Park, fish and insects were equally important in the diet of lake trout during the spring. During the spring in Squeers Lake, fishes were only of secondary importance in the diet of lake trout. *Hexagenia limbata* occurred in all stomachs and contributed the most weight to lake trout diet in the spring. Similarly, in Lake Opeongo Martin (1970) found insects, particularly mayflies were at peak abundance in lake trout stomachs during the spring. In northern Ontario, Riklik and Momot (1982) found peak emergence of *Hexagenia limbata* occurred in June or early July. Therefore, lake trout in Squeers Lake cannot take full advantage of peak mayfly availability (at time of emergence) because of summer thermal barriers restricting foraging activity.

In summer, the number of empty stomachs increased and the number of food items per stomach decreased. Once spawning began, nearly 30 percent of all stomachs were empty. Similarly, Martin and Olver (1980) found an increase in the number of empty stomachs over summer and by fall, over half of lake trout stomachs were empty. During summer, many shallow water invertebrate species disappear from the diet and insects are not available to lake trout. Hatches are over and increasing water temperatures create thermal barriers (Martin and Olver 1980). If pelagic forage fishes are not available, lake trout must consume plankton, deepwater invertebrates and benthic fishes. In Squeers Lake, between spring and summer there was a decline in the number and variety of insects consumed, and a sharp increase in the number of crustaceans consumed. In the summer, ninespine sticklebacks and sculpins are available to lake trout, but are not extensively preyed upon.

In Squeers Lake, there were also changes in the types of crustaceans consumed between spring and summer. In May, Mysis relicta occurred most frequently in the diet, however crayfish contributed the most to total prey weight. By June, Mysis relicta were again most frequent in the diet, however amphipods contributed the most to prey weight. By August, amphipods occurred most frequently and contributed the greatest to prey weight. The reduction of crayfish in the summer diet again reflects the influence of the thermal barrier in restricting trout from foraging in shallow water where crayfish are more abundant.

Diet may also be related to cycles of abundance of amphipods and mysids. In Twin Lake, Colorado, Gregg (1976) found Mysis peaked in August and September, when they were also most abundant in lake trout stomachs. In Squeers Lake, the great difference in diet between late August 1984 (amphipods dominate) and early September 1985 (fishes dominate) appears to relate to change in seasonal temperature regime between these months. In early September 1985, water temperatures were lower and allowed lake trout to move onshore and consume small fish species (Appendix 3). During spawning, if trout were feeding they consumed mostly inshore fishes such as yellow perch and ninespine stickleback.

Not only do feeding habits of lake trout change with size, but diet at given sizes displays seasonal changes. In Squeers Lake, lake trout between 20 and 50 cm feed on an increasing variety and quantity of organisms. Lake trout greater than 50 cm fed on fewer select food items, but overall weight of the food items was greater.

Small lake trout tend to feed on benthos or plankton (Martin and Olver 1980). Martin (1970) found small lake trout in Lake Opeongo feed more on crustacea than on insects. Although dipterans are the most important insect consumed by small lake trout in Squeers Lake, crustaceans were more important in the diet in all months except for June 1984. Several authors have found small lake trout (less than 2000 g) consume substantial quantities of freshwater amphipods Pontoporeia and mysids M.

relicta (Cuerrier 1954; Dryer et al 1965; Miller and Kennedy 1948; Paterson 1968; and Rawson 1961; in Donald and Alger (1986); and Eschmeyer 1955). In Squeers Lake, lake trout less than 20 cm feed primarily on mysids *M. relicta* while amphipods are not important. However, as size increases, amphipods become the most important crustacean consumed, but the relative contribution of crustaceans is reduced. Similarly, Martin and Olver (1980) found fewer crustaceans consumed with increasing lake trout size. In Squeers Lake, crayfish was the only crustacean consumed in any quantity by large trout.

The most important insect in the diet of lake trout greater than 30 cm were ephemeropterans in Lake Opeongo, Ontario. Martin (1970) found empheropterans to be the most frequently consumed insects of lake trout 38-63 cm in length. In Squeers Lake, *Hexagenia limbata* was the most important prey item for lake trout between 30 and 50 cm in May 1985.

The variety of insects consumed increases with increasing size of lake trout. Larger lake trout may have better foraging ability because they are more mobile and do not generally live in as deep water as do younger fish (Martin and Olver 1980). In Squeers Lake, smaller lake trout are also found in deeper water (Appendix 30).

Forage fishes become increasingly important in the diet as size of lake trout increases (Martin and Olver 1980). The variety of fish species consumed by trout in Squeers Lake increases with increasing size of lake trout between 20 and 50 cm. Fish are rare in the diet of lake trout less than 20 cm. Only during March were fish important in the diet of 20-30 cm lake trout, which primarily fed on ninespine sticklebacks and sculpins. Similarly, Eschmeyer (1956) found these fish species are predominant in the diet of small lake trout in Lake Superior. Between 30 and 50 cm the variety and number of fish in the diet increases with increasing size. Martin and Olver (1980) suggest as lake trout become larger they tend to eat larger members of a forage species, rather than more smaller individuals. Fish are most important in the diet of lake trout greater than 50 cm during all seasons, however the variety and number of fish consumed is reduced. Large lake trout feed on large fish species such as white suckers, lake trout, and burbot.

In Squeers Lake, cannibalism was quite common in larger fish examined. Martin and Olver (1980) pointed out cannibalism is most common in Arctic lakes where density of forage species is low, and lake trout may be one of the few species present. Similarly, Skreslev (1973) found cannibalism occurs in Arctic charr stocks, particularly if food is limited. Johnson (1983) found the largest trout in Gavia Lake, NWT were cannibalistic.

Changes in Diet with Depth

Analysis of the forage of lake trout at varying depths helps describe the vertical and horizontal migrations of the predator (Hickey Jr. 1975). In addition it portrays the distribution and availability of various food types at various depths. Eck and Wells (1983) found seasonal changes in the bathymetric distribution of lake trout with respect to those of forage fish of a suitable size for prey. They found thermal barriers determined the size and species compositions of fish in the seasonal diet of lake trout.

In Squeers Lake, the variety of insects, crustaceans and fish, and the quantity of food per lake trout was greatest in those fish inhabiting 1-10 m of water. Larger forage also appeared more available in water less than 20 m deep. Small insects such as dipterans were more abundant in fish from deep water (>26 m), but larger insects (ephemeropterans) were found in fish from shallower water (<10 m). Large crustaceans such as decapods were consumed primarily by fish in less than 10 m, whereas amphipods (Pontoporeia affinis) and mysids were consumed primarily by lake trout found in depths greater than 20 m of water. A wide variety and size of fish species are more available in shallow water, whereas only deepwater sculpins are available in very deep water. Growth of lake trout depends on obtaining larger food items (Kerr 1971). These differences in availability and size of food with depth may explain why larger lake trout are generally found in shallower water than are smaller lake trout (Appendix 31). For lake trout to obtain larger and more variety of food organisms they must venture into shallow water. Other authors have found lake trout make periodic foraging excursions into the warm summer epilimnion (Martin and

Olver 1980; Konkle and Sprules 1986). Healey (1978) suggests that foraging activity of small lake trout may be suppressed by larger trout. Small food items are found in deepwater, therefore if fish are restricted physiologically and can not move into shallower water (to avoid competition or cannibalism by larger lake trout) they will not grow fast enough to join the mature population. In Squeers Lake, older, larger fish may limit the exploratory and foraging activity of small lake trout. This suppresses the growth of smaller fish and may be the mechanism preventing them from moving into the mature population.

Biomass and Production

Biomass and production in part measure a population's response to its environment (Carlander 1974). Biomass is a measure of standing crop and represents the total weight of a fish population present in a given lake at a given time (Everhart and Youngs 1975). Production is the increase in biomass over a given time from growth of new tissue or by the production of new offspring (Pitcher and Hart 1982). Growth rate influences total biomass and production but does not influence the distribution of biomass and production by age group (Healey 1977). Mortality rate however, strongly influences the distribution of both production and biomass (Healey 1977).

In Squeers Lake, growth and mortality of lake trout are low, and therefore production is low. Production estimates for lake trout in Squeers Lake are however much higher than indicated because estimates included only those fish greater than 8 years of age. Production is usually greatest in the young age groups.

In Arctic lakes, though production is low, it is sufficient to maintain simple food webs leading to high standing crops (Johnson 1976). The majority of the energy in a system goes to maintaining a large number of adults rather than toward production of pre-recruits (Johnson 1976). In Squeers Lake, there is an accumulation of biomass in the mature population resulting from low mortality rates. Lake trout lakes with high standing crops tend to harbour small polyphagous populations (Martin and Olver 1980). Estimates of standing crop range from 1.12 kg/ha in Indian Lake, Quebec (Kennedy 1941) to 4.76 kg/ha in Butler lake, Ontario (Fry 1939). The standing crop of lake trout in Squeers Lake (7.36 kg/ha of mature fish only) is larger than that of any lake previously reported.

The ratio of production to mean biomass (P/B) represents the turnover time of the population. Turnover time is equivalent to the reciprocal of the mean life span (Leigh 1965 in Johnson 1976). The long life span of lake trout means a low rate of turn over. Johnson (1976) believes a dominant species tends toward a state in which its P:B ratio assumes a minimum value. Stock homeostasis and biomass accumulation were fundamental characteristics of Arctic fish stocks examined by Johnson (1976). Accumulated biomass of lake trout in Squeers Lake is extremely high and production is low, indicating a stable homeostatic stock. The P/B ratio of lake trout in Squeers Lake, however would be much higher if fish less than 8 years of age were considered. Low P/B ratios in Squeers Lake may be exaggerated by the inefficient use of energy in the system. Lake trout are spatially prevented (due to thermal barriers) from utilizing the food web in an efficient manner.

<u>The Winter Fishery</u>

Development of logging roads in northern Ontario has increased accessibility to lake trout lakes. When unexploited lakes become accessible, large numbers of anglers venture to the lake. Increased access combined with winter fishing has been cited as one of the major causes of over-exploitation of lake trout (Ryder and Johnson 1972). Ryder and Johnson (1972) described how anglers removed 2-4 times the annual harvest (as determined by the MEI) from a small lake in northern Ontario in a single afternoon in March. In 1978, development of the Burchell Lake logging road enabled large numbers of anglers to access Squeers Lake. Estimation of effort and yield in 1978 and 1979 is difficult. A Conservation Officer's records indicated on one weekend, effort tripled and all anglers caught their limit of fish (Ryan and Ball 1985). In the 1960s and early 1970s, catch and effort data from winter angling checks indicated anglers prior to development of the logging road did not catch their limits (Ryan and Ball 1985), therefore it is unlikely all anglers caught their limits in 1978 and 1979. Regardless of this discrepancy, harvest was substantial in 1978 and 1979. On February 29, 1979, Squeers Lake was closed and declared a provincial fish sanctuary.

In winter of 1985, Squeers Lake was temporarily reopened for experimental exploitation and a winter fishery was chosen primarily for logistical reasons. There is no direct access by road to Squeers Lake (a steep, rugged 350 m portage), therefore summer access with a boat is difficult. For the purpose of an experimental management project on Squeers Lake a winter fishery required less capital expenditure than a summer fishery, and allowed everyone to participate. In addition, the fishery was held after the winter lake trout season on other lakes had closed. These factors increased the chance of recruiting a large number of anglers to participate over a short period of time, helped minimize costs of harvesting, and ensured accurate monitoring of catch and effort. The fishery was held in March to avoid extreme temperature and ice conditions. In addition, demand for ice fishing is greatest in March. Payne and Roche (1984) found that within Thunder Bay District, the greatest proportion of fishing pressure occurs in March. In both years, anglers overwhelmingly chose the first day to fish indicating perhaps, an angler's desire to be first to a lake before it is fished out.

Fishing on weekends was preferred over weekdays. This is typical of most fisheries, since leisure hours are usually available on weekend days. In Thunder Bay, Payne and Roche (1984) found weekends were fished slightly more than weekdays (56.5 and 43.5 percent respectively). Fishing is probably distributed over weekdays and weekends more evenly in Thunder Bay than other areas of the province, because employment in northern Ontario is often seasonal.

The number of fish harvested and released in 1986 was less than in 1985. However, population estimates did not indicate a decrease in abundance of lake trout. In many fisheries, catch and effort from angling does not necessarily reflect abundance (Roff 1983, Richards and Schnute 1985). In Squeers Lake, effort was concentrated in a small area in 1985 and 1986. There were nearly four times as many anglers fishing in 1986, however distribution of effort was similar in both years. In 1986, ice conditions were poor (.5-1 m of slush) and temperatures were extreme, restricting movement of anglers. A large number of anglers in a small area, means areas may be "fished out" or fish may develop hook avoidance as observed for northern pike by Beukema (1970). In Squeers Lake, the highest catch per unit effort (CPUE) occurred in areas with the fewest number of anglers. Regier and Loftus (1972) found as each new site was exploited in a commercial fishery, it contributed to an initial burst of high catch. Catches then declined partly due to reduced biomass.

Hudgins and Davies (1984) suggest environmental variation affected catchability among fishing trips within a year, and therefore introduced subjectivity into evaluation of fishing success. Hughson (1966) observed angling pressure and catch of lake trout were related to snow conditions and accessibility to fishing areas. He found with poor snow conditions effort and catch decreased. When weather conditions are poor, anglers are not able to tend their lines as well, resulting in reduced fishing success. The poor ice and weather conditions on Squeers Lake undoubtedly contributed to the relatively poor catch in 1986. In 1986, anglers appeared to be less experienced than anglers in 1985. Questionnaires indicated that 1985 anglers made more ice fishing and openwater trips during the previous year, than the 1986 anglers. Ball (1984) found experienced anglers had better fishing success than inexperienced ones. In 1986, anglers were allowed to apply in larger parties up to four people, however in 1985 the size of party was restricted to two. Therefore, there were more families and larger party groups in 1986 than in 1985. The larger fishing parties had lower CPUE's which may have contributed to the reduced fishing success in 1986. In Squeers Lake, a party of two harvested 0.2905 lake trout per man hour, and a party of three or four harvested 0.2470 fish per man hour.

The CPUE was low in the 1985 and 1986 experimental winter fisheries, compared to those in the 1960s and 1970s. Decreased abundance of lake trout from exploitation in the late 1970s may have caused the lower harvest in the 1985 and 1986 fisheries. Prior to 1978, the logging road was not developed and access to the lake was much more difficult. (Ryan and Ball 1985). Anglers in the 1970s were probably more experienced than the majority of anglers participating in the 1985 and 1986 winter fisheries, and therefore more successful. In addition, in 1967 and 1974 creel census was haphazard and may not accurately represent catch and effort.

In Squeers Lake, the winter CPUE (0.40 and 0.25 per man hour in 1985 and 1986 respectively) was high compared to other lake trout lakes across the province (Payne and Roche 1984). Martin and Olver (1980) found CPUE highest in lakes containing polyphagous trout (0.31-0.45 fish per man hr). The high CPUE of polyphagous populations probably reflects the high density of fish. In addition, Martin (1954) suggests polyphagous lake trout are more susceptible to fishing in the winter, because small inshore minnows (ie. similar to bait used by anglers) are the main forage. Purych (1975) and Bernier (1977) found that during the first few weeks of a winter lake trout fishery, the CPUE is highest. In Squeers Lake, fishing was temporary and occurred over a short period of time, therefore CPUE's should be higher than in lakes that are open all winter.

Lake trout are highly vulnerable to angling in the spring because their movement is not affected by thermal barriers. Therefore, they are feeding heavily on inshore fishes and emerging insects. Similarly, Martin (1970) found lake trout were highly vulnerable to angling in spring months. In May 1984 and 1985, experimental angling resulted in CPUE's four to seven times greater than winter CPUE's between 1967 and 1974.

In March 1985 and 1986, harvested lake trout ranged from 25-55 cm in length. In both years, lake trout captured by winter angling were smaller, and younger with a higher percentage of immature fish compared to those captured on spawning shoals and during experimental spring angling. Schumacher (1960) found winter angling removes smaller trout and nearly 2/3 of the fish caught were immature. In Algonquin Park lakes, Martin (1954) found winter catches were comprised of smaller trout, and had a larger proportion of immature fish than in the summer fisheries. In 1986, the increase of small lake trout in the catch may reflect increased numbers of small fish being recruited into the catchable population. Alternatively the poor fishing success in 1986 may have encouraged anglers to keep smaller fish rather than releasing them. In addition, with fishing effort being restricted to a small area, large dominant fish are removed quickly and small subdominant fish become susceptible to harvest. In 1985 and 1986, the mean length of fish captured was similar to 1967 and 1974 values. Hudgins and Davies (1984) found catch was affected by temporal fluctuation (hour, day, week, month or season) in catchability of fish. Therefore, the variation in size between 1985 and 1986 may be a result of natural year to year variation.

ANGLER ATTITUDES

The overall quality of a fishing trip depends on satisfactions such as relaxation, having fun, enjoying the outdoors and catching a few fish, without being hindered by dissatisfying experiences such as restrictive regulations, user conflicts, and poor catch (Dawson 1980). An angler's interest is not solely in the fish he catches but fishing itself. Dawson (1980) found the most direct products of recreational fisheries management are not only fish (or at least a reasonable probability of catching one or more fish) but also the fishing experiences which produce human satisfactions and benefits. Of 4000 Ohio fishermen more than half obtained as much enjoyment from a fishing trip if they caught no fish, as they did if they caught fish (Addis and Erickson 1968). Weithmann and Katti (1979) also found anglers rated their fishing quality to be good, although fishing was poor. Similarly in Squeers Lake, the majority of anglers had an enjoyable day regardless of the number of fish they caught.

Hudgins and Davies (1984) suggest anglers differentiate between fishing success and trip quality. In many instances factors other than fishing success significantly influence fishing enjoyment. Anglers have indicated factors such as site facilities, privacy, natural beauty and water quality are more important to their enjoyment of an angling trip than is catch (Moeller and Engelken 1972). Other authors found relaxing, having fun and enjoying the outdoors were very important elements in a fishing experience (Hicks et al. 1983; Duttweiler 1976). Similarly, respondents from Squeers Lake indicated having fun and enjoying the outdoors were the most important factors determining trip quality.

Moeller and Engelken (1972) suggest that in the long run, the size and number of fish caught are very important to fishing enjoyment. Dawson (1980) indicates anglers need at least a good probability of catching at least one fish before they frequent a lake. Hicks et al. (1983) found most anglers who did not enjoy their trip blamed poor fishing. In Squeers Lake (1986), a few anglers (1 %) did not enjoy their fishing day. They had poor fishing success, and commented on the poor ice conditions. Therefore, poor fishing success combined with poor weather resulted in an overall unfavorable fishing experience.

Hudgins and Davies (1984) found anglers adjust their fishing success expectations to fish population densities. Squeers Lake had been closed for 5 years prior to the experimental winter fishery, and anglers were informed of the high lake trout density. Therefore, the majority of anglers who fished expected to catch their limit of fish (3 fish). Catching their limit, however was not an important requirement for enjoying their fishing trip. Many anglers who did not catch their limit, had an enjoyable day. Anglers thought catching at least one or several medium sized trout was more important than catching their limit. Similarly, Hicks et al. (1983) found catching at least one trout was most important, and catching a limit was only somewhat important. Nesler (1986) suggested the main attraction of fishing for lake trout is their trophy quality. Nesler (1986) found the attractiveness of a lake trout fishery lies as much in the tangible value attached to it by anglers for its trophy fish potential as in the actual magnitude of harvest or angler success rate. At Twin Lake, Colorado interviews with lake trout anglers indicated 38 cm was regarded as minimal acceptable length, and that lake trout became more desirable as they approached 50 cm in length (Nesler 1986). Trophy fishing for lake trout was least important to respondents from Squeers Lake. Trophy anglers may not be attracted to Squeers Lake. There are many other lakes in Thunder Bay District which support trophy fisheries. Lake Superior has some large trophy fish and is accessible all year round. However, many of the lake trout captured from Lake Superior have large fat deposits and are not very palatable (Goodier 1981). Therefore, it appears anglers may fish small inland lake trout lakes to catch a few medium size fish to eat.

Historically, regulation has favored free accessibility of the resource to all fishermen, with the catch being controlled by progressively reducing the numbers of fish that each may retain, and by gear restrictions and closures. In Ontario, present angling regulations have not prevented the decline of lake trout populations, and regulations are becoming increasingly complex. Similarly, in British Columbia's salmon fishery, increasing numbers of potential fishermen and less available catch meant managers needed to increase regulations to preserve the fishery. They realized by further decreasing bag limits and increasing gear restrictions, regulations may jeapodize the value of sport fishing opportunity. Therefore, they took an alternative approach; by regulating access and reducing the expansion in numbers of fishermen, total pressure on the stocks was controlled and the opportunity to remove a satisfying catch was preserved (Pearse 1982). In Ontario, the sensitivity of lake trout to exploitation, and increasing pressure on lake trout stocks means present regulations are inadequate and alternatives are needed. New alternatives for management must out of necessity prevent the decline of lake trout populations, yet still maintain fishing opportunities and trip quality.

The majority of anglers who participated in the Squeers Lake fishery thought lake trout populations were declining, and cited overfishing as the reason for the decline. Therefore, anglers realize exploitation has caused the decline of lake trout populations, and therefore should accept regulations to prevent further decline. Information about anglers' views and expectations is the key element in developing management strategies likely to receive public support (Hicks et al. 1983). Renyard and Hilborn (1986) suggest user preference surveys clarify the position of all anglers regarding the acceptability of alternative policies, and may become a major tool in fisheries management.

Respondents from Squeers Lake were not in favour of limiting anglers to one line, requiring a special license to fish for lake trout, or regulating effort by lottery to manage lake trout populations. Anglers enjoyed partaking in the experimental lottery, however they did not view it as a fair or acceptable management strategy. Renyard and Hilborn (1986) found anglers prefer regulations that least affect their fishing behaviour. Similarly, anglers from Squeers Lake thought increased stocking, making lakes sanctuaries until populations recovered and limiting access were the most acceptable management strategies. Stocking of lake trout in inland lakes is expensive, the gene pool of native fish is often lost and stocked fish rarely spawn. Therefore, stocking is not a viable alternative. Limiting access prevents fishing on certain lake trout lakes. It does not control the amount of effort, but redistributes it to fewer lakes. If an angler wants to fish for lake trout and his favorite lake is closed, he will fish in an alternate lake. With snowmobiles, all terrain vehicles and increased development of logging roads nearly all lakes are accessible. Therefore, controlling access to the resource, by regulating effort on each lake may be an alternative form of lake trout management.

Opening lake trout lakes to anglers for a year or two (or some predetermined time period with closure during spawning Sept 15-Sept 30), then closing them for 5 to 6 years may be a viable alternative (rotational pulse fishing). A similar idea was suggested by Adams and Olver (1977) for management of commercial percid fisheries. Rotational pulse fishing would allow anglers to fish in the summer and winter, and further restrictions on bag limits, seasons and gear would not be necessary. Anglers would be able to have a satisfying experience and good fishing without overly restrictive regulations. Martin and Baldwin (1953) and Martin (1966) experimented with alternate year closures on lake trout lakes in Algonquin Park. However they could not detect any positive effects from the closure. However this study was inadequate because with a long lived species such as lake trout, the lake would need to be left to fallow for at least 5 to 6 years (ie. the time it takes a fish to reach spawning age). Slow growth and reproduction rates necessitate the passage of several years to restore populations to former levels of abundance, even with relatively short-lived salmonids (Ryder and Johnson 1972). However, a long fallow period would allow biologists to assess the status of the fishery prior to and following exploitation. Questionnaires indicate the approach is understandable and acceptable to anglers. Closure of a lake until the population recovers, or a modification of this management technique should be researched and assessed further.

GENERAL DISCUSSION - EXPLOITATION

In Squeers Lake, two experimental designs for the fishery were considered. One approach to determine effects of exploitation on population structure was to set exploitation at a very high rate (20 percent additional mortality). Healey (1978) suggests lake trout can withstand 50 percent total mortality. At a high level of exploitation complicated fishing up processes can be bypassed (Healey 1977). Changes which occur during the fishing up period of a moderately exploited fishery are generally difficult to interpret because of overlapping generations (Ricker 1958). In Squeers Lake, natural mortality of lake trout greater than 8 years was 28 percent, therefore to observe the effects of exploitation, at least 20 percent or 1400 kg (1.82 kg/ha) of mature fish would have to be removed. The mandate for the present study was to mimic a natural fishery as closely as possible. Ricker's (1975) yield model indicated 2000 anglers would be required to remove 1.82 kg/ha. Logistically, recruitment and accommodation of a large number of anglers required to harvest 1.82 kg ha^{-1} over a short time period was not feasible. Long term commitment to assessment of the lake trout stock in Squeers Lake by Quetico-Milles Lacs Fisheries Assessment Unit of the Ontario Ministry of Natural Resources allowed the experiment to take an alternative approach. The alternative approach was to increase effort arithmetically over a number of years to establish a relationship between fishing effort and the instantaneous rate of fishing mortality. Three possible relationships between fishing effort and fishing mortality may be derived from this study: every additional unit of fishing effort may become greater than, proportional to or less than any fishing mortality change. The form of the relationship between fishing effort and fishing mortality is extremely important to formulating management decisions. If a relationship can be established, prediction of fishing mortality on a given lake resulting from a given level of effort may be estimated. This would provide managers with a tool for managing many small lake trout lakes.

By slowly increasing fishing effort and thus mortality over a long period of time, it will also be possible to monitor the effects of exploitation, and determine the ultimate capacity of lake trout populations to respond when subjected to slowly increasing levels of exploitation. Healey (1978) suggests in lake trout populations having an old age structure and numerous prereproductive year classes a significant lag in development of compensating mechanisms may occur. He suggests the best exploitation strategy should let a trout fishery build up slowly to allow compensatory mechanisms time to develop.

Ricker's model was used to predict harvest of different age groups at varying fishing intensities. The model assumes fishing effort is proportional to fishing mortality. In Squeers Lake, yield of lake trout determined by the MEI is 0.5 kg per ha. Martin and Fry (1972) also concluded lake trout can withstand a harvest level of 0.5 kg/ha. Similarly, Healey (1978) using maximum yields attained from exploited lake trout populations, population density, productivity, and permissible total mortality concluded sustainable yields are unlikely to exceed .5 kg/ha 1. To maximize yield without affecting population structure, Ricker's yield model indicates effort should be increased 4 to 8 times the 1986 level and over four times that recommended by the MEI. This translates to an annual yield of 1.71 to 2.38 kg/ha-1 of fish greater than 8 years of age.

In Squeers Lake, 981 kg of mature lake trout die from natural causes annually. According to Healey (1978), an additional 22 percent or 784 kg (2.0 kg/ha) of mature fish could be harvested. This value derived empirically from population estimates and mean weight, results in a harvest level very similar to that suggested by Ricker's Yield model. If any natural mortality is translated to fishing mortality, harvest may be increased still further. In 1985 and 1986 fisheries, 18 and 26 percent of fish harvested were less than 36 cm. Therefore, yield of lake trout (without severely effecting population structure) will reach levels substantially higher than those estimated by Ricker's Yield model.

At the initial outset of a fishery, yield is high because accumulated stock is cropped off. The high CPUE and yield during the Squeers Lake winter fisheries may indicate a cropping off effect of the most vulnerable fish. Schumacher (1960) in Trout Lake, Minnesota and Fry (1939) in Merchants Lake, Algonquin Park found lake trout yields increased rapidly and then within several years harvest fell further from the original yield, even when effort was increased. In Squeers Lake, present catch levels will probably not be maintained. With cropping off of the accumulated biomass production should increase, however yield will depend on how much fishing mortality substitutes natural mortality, and how much growth and recruitment change.

Fishing yield estimates are not sensitive to abiotic and biotic changes in the environment which may affect biomass, therefore other alternatives must be considered. A functional relationship between fish production and such parameters as competition, food supply and habitat has not been established. Therefore, using parameters of the fish population as an index of productivity is probably the least risky approach to management. Currently the simplest approach appears to be the examination of a few basic indicators such as mortality rates, length and age compositions, growth rates, age and length at maturity and fecundity.

Fish in unexploited populations usually have a high survival rate and a relatively long life span. The natural mortality rate of unexploited lake trout populations ranges from 20-30 percent (Martin and Olver 1980). In Squeers Lake, natural mortality rates of lake trout are similar to those of an unexploited population, with fish living up to 26 years of age. Since fishing competes with natural mortality for the fish available, the number of deaths from natural mortality is reduced, but the rate of natural mortality at a given age is not affected or even lowered (Ricker 1958). In the usable stock as a whole the rate of natural mortality may decrease because a fishery often reduces the number of older age groups, and these tend to have a higher mortality than do middle or younger age groups (Ricker 1958). In another context, with decreased abundance of fish there may be less mortality from parasites and disease. Therefore with increased food availability and decreased mortality from natural causes, survival rate may increase. Under exploitation, some lake trout populations can withstand an additional 30-40 percent mortality, up to a total mortality rate of about 50 percent (Healey 1978). All lake trout populations with mortality rates greater than 50 percent appeared to be endangered and rapidly declining (Healey 1978). Therefore, lake trout in Squeers Lake should be able to maintain at the very least, an additional 20 percent mortality, and if natural mortality decreases fishing mortality may be further increased.

Exploitation can significantly alter the characteristics of a population. Length distribution of exploited populations differs markedly from that of unexploited ones. In unexploited populations there tends to be a high variance of length within a given age class, and the size distribution tends to be bimodal (Kerr 1979). In Squeers Lake, the length distribution is bimodal and there is a high overlap in length at age. The first larger peak consists of smaller younger fish and may be the result of the 1978-1979 fishery. It appears, however that the large year classes making up the first peak are subsequently suppressed by the mature population. With increased exploitation recruitment may not be regulated by mature fish. Therefore, the length distribution should then shift to a unimodal one, and the variance in length at age should be reduced. Martin (1966) found a unimodal size distribution strongly associated with age in exploited lake trout stocks. Exploitation often reduces the mean size and age of the population. In Squeers Lake, the mean age of the population is high and there is a long descending right hand limb on the catch curve, indicating a large number of pre-reproductive year classes. Therefore, if exploitation occurs there may be a significant lag in compensatory processes.

Since exploitation reduces the number of age classes in the population, the mode of the population shifts to a younger age group. In the early stages of a fishery the decrease in abundance from an initial high level reduces the intraspecific competition and increases the likelihood of younger fish surviving and recruiting into the fishery. Martin and Fry (1972) found 30-70 percent more immature lake trout were harvested from Lake Opeongo, Algonquin Park compared to 50 years ago. Schumacher (1960) and Keleher (1972) found the mean age of lake trout decreased with increasing exploitation in Minnesota Lakes, and Great Slave Lake, NWT respectively. In Squeers Lake, the growth of small lake trout may be regulated by the adult population (via limiting forage activity). Exploitation may reduce intraspecific competition, resulting in increased survival and recruitment of juveniles into the fishery.

A population with a young age structure will have violent oscillations in yield since occasional spawning failure, or above average juvenile survival may not stabilize, but be directly reflected in yields (Momot, unpub). Usually the efficiency of reproduction increases as the number of spawners is reduced. The population tends to stabilize at a level of reproduction corresponding to the amount of fishing effort. The removal of an excess number of older fish lowers the reproductive resilience of the population (Momot, unpub). Reduction in fish longevity eventually decreases the probability for successful spawning and self replacement of year classes. Two thirds of the fish in Trout Lake, Minnesota were taken by anglers before reaching spawning size (Schumacher 1960). If the mean age of the population is reduced below the mean age at maturity overexploitation has occurred. Adjusting harvest rates so that nearly all fish spawn once, many spawn twice, and some three to four times would prevent wild oscillations (Healey 1977). In Squeers lake, 50 percent of fish are mature between 7 and 8 years and all are mature by 11 years, therefore maintaining an average life span of 11 to 12 years should maintain stability and yield.

Growth rate of a population may be affected by the level of exploitation. Latitude, type of food available, and the density of stock are the most important factors determining growth rates (Ricker 1958; MNR 1983). Under natural conditions abundant populations grow more slowly than sparse ones. In Squeers Lake, density of lake trout is very high, and growth is slow. Therefore, a population undergoing exploitation will show an increase in total mortality (unless fishing mortality substitutes total mortality) and should respond with an increase in growth. Rapid growth is most often associated with heavily exploited, piscivorous populations from lower latitudes. When the populations of lake trout in Lakes Michigan, Huron and Superior were declining rapidly due to exploitation and sea lamprey attacks several decades ago, growth attained a maximum rate (Healey 1978). The fastest growing lake trout population examined by the author was a heavily exploited Lake Nipigon stock (Table 41). Healey (1978) found exploited lake trout populations in the Arctic increased their growth rate in response to exploitation, however not to the extent of exploited southern populations. Growth rates of juveniles increased, however growth rates of adults did not change. This may have occurred because competition for food and limited foraging activity usually enforced by the older mature fish in the population was reduced. Therefore juveniles grew rapidly to recruit into the mature population. The lack of increased growth in mature fish may have resulted from additional energy being directed into increased egg production. Healey (1978) found increased fecundity in exploited populations.

If the rate of growth responds to a change in stock density the response should be immediate, as occurred in Great Slave Lake (Healey 1978). Some studies have shown a large increase in growth occurs soon after a fishery starts, or after it becomes intensive. Others have shown that little or no change in growth occurs (Schumacher 1960). Ricker (1958) suggests a response of increased growth may not occur if the species only utilizes a small fraction of an abundant resource, or where it is only a minor component of its habitat. In Squeers Lake, lake trout are the most important component of the environment, and it appears growth is limited by food supply. Therefore, with increasing exploitation a growth response should be evident, however it probably will not be very large since growth appears to be limited more by the size and availability of prey rather than the quantity.

Age at maturity in unexploited populations usually occurs at an old age. In Squeers Lake, although some fish are mature by 5 years, all lake trout are not mature until age 11. Age at maturity, like growth, responds to changes with density. With increased exploitation abundance of available food often leads to increased growth and increased condition in fish which are essential in reducing the mean age at maturity (Nikolski 1969). In exploited populations it appears lake trout cannot lower their age at first maturity (Healey 1978). The effectiveness of compensation by increasing growth rate is offset by an apparent minimum age to maturity of 5 to 6 years (Healey 1978). Healey (1978) found the range of ages which maturation takes place in lake trout is the same in exploited and unexploited populations, however a higher percentage of intermediate aged trout are mature in exploited populations. This study, however indicates lake trout can lower their age at maturity, since heavily exploited populations appear to have a lower age at maturity. Lake trout in heavily exploited lakes such as Nipigon, Bonnechere, Clear and Scattergood are mature by 4 years (Table 41). It also appears the age where all fish are mature can be reduced. Healey's

(1978) conclusions may result from difficulties with aging fish using scales as discussed earlier. With exploitation, a greater percentage of fish in Squeers Lake should mature at an earlier age, and the age at which all fish are mature should also be reduced.

Increase in fecundity compensates for mortality due to fishing. In unexploited lake trout populations there are great variations in fecundity, and it does not appear to be lower among northern populations (Healey 1978). Lake trout respond to exploitation by an increase in individual fecundity, in connection with either increased growth or response to reduced population density. Fecundity of trout in all exploited lake trout populations studied by Healey (1978) increased but it did not vary in an adjacent unexploited lake. He found fecundity of trout was not directly related to the intensity or pattern of exploitation but it did significantly increase in all of the exploited populations. Although fecundity has shown response to exploitation there is no clear relation between egg production and surviving progeny. Bagenal (1973) suggests the lack of evidence to support higher recruitment with higher population fecundity indicates fecundity provides a compensatory process. He suggests fecundity variations form a density dependent population regulating mechanism and will tend to reduce wide fluctuations in recruitment but will not be the cause of increased recruitment resulting from exploitation. Therefore, provided density dependence operates at the egg to juvenile stage, increased exploitation in Squeers Lake may result in increased fecundity but may not be reflected by an increase in recruitment.

Lake trout from winter harvest do not necessarily reflect actual population characteristics. Harvest from angling fisheries may not reflect the actual length, age and maturity structure of the population. Angling fisheries often remove the fastest growing fish (Johnson 1976). In Squeers Lake, fish captured in the winter were larger at a given age than those captured by gill nets in 1982 and 1984. Although faster growing fish are removed, winter angling tends to take smaller, younger immature fish. In Squeers Lake, harvested lake trout were smaller compared to the mature spawning population. During March, gonads are poorly developed. Therefore, accurate assessment of maturity and fecundity is difficult.

In Squeers Lake, present population characteristics essentially reflect those of unexploited populations. Therefore, effects of experimental winter exploitation on Squeers Lake should be representative of the effects of exploitation on other unexploited lake trout stocks. Effects of winter fishing will be determined by observing the relationship between fishing effort and mortality, monitoring changes in actual abundance and production in relation to yield, and examining basic indicators such as mortality rates, age and length at maturity, growth rates and fecundity. The study should be able to provide managers with an indication of the amount of effort and harvest a polyphagous lake trout population in a small lake can withstand.

Healey (1978) found the response of lake trout to exploitation was both slow and of low magnitude. The small size and slow growth of non-piscivorous fish primarily limited by food supply, may further reduce the magnitude of any response. Index gill netting and population estimates, in conjunction with monitoring catch and effort during winter fisheries are essential to properly monitor and assess the effects of future winter exploitation on the lake trout population.

Present regulations do not prevent overfishing in small lake trout lakes, thus experimental projects are required to determine inexpensive management alternatives to preserve lake trout populations and maintain fishing quality. If low cost indices to measure empirical estimates of sustainable effort can be determined, managers will have an empirical basis for closing lakes. A rotational system could be established where lakes are open for several years (the exact time period depending on effort levels) then closed for 5-6 years to recover. According to size and accessibility of a lake, and the characteristics of a given population, some lakes could be open all year (except during spawning), and others only for winter or summer fishing. Lakes not accessible in the summer could be opened on a rotational basis for winter fishing. For example, in Thunder Bay, seven lakes including Squeers Lake are virtually inacessible in the summer. They would be an ideal set of lakes to determine the feasibility and acceptability of rotational winter fishing on small lake trout lakes. A system of lake closure appears to be acceptable, and would maintain fishing quality, preserve opportunities for summer and winter fishermen (without excessive and unacceptable regulations), as well as maintain the lake trout resource.

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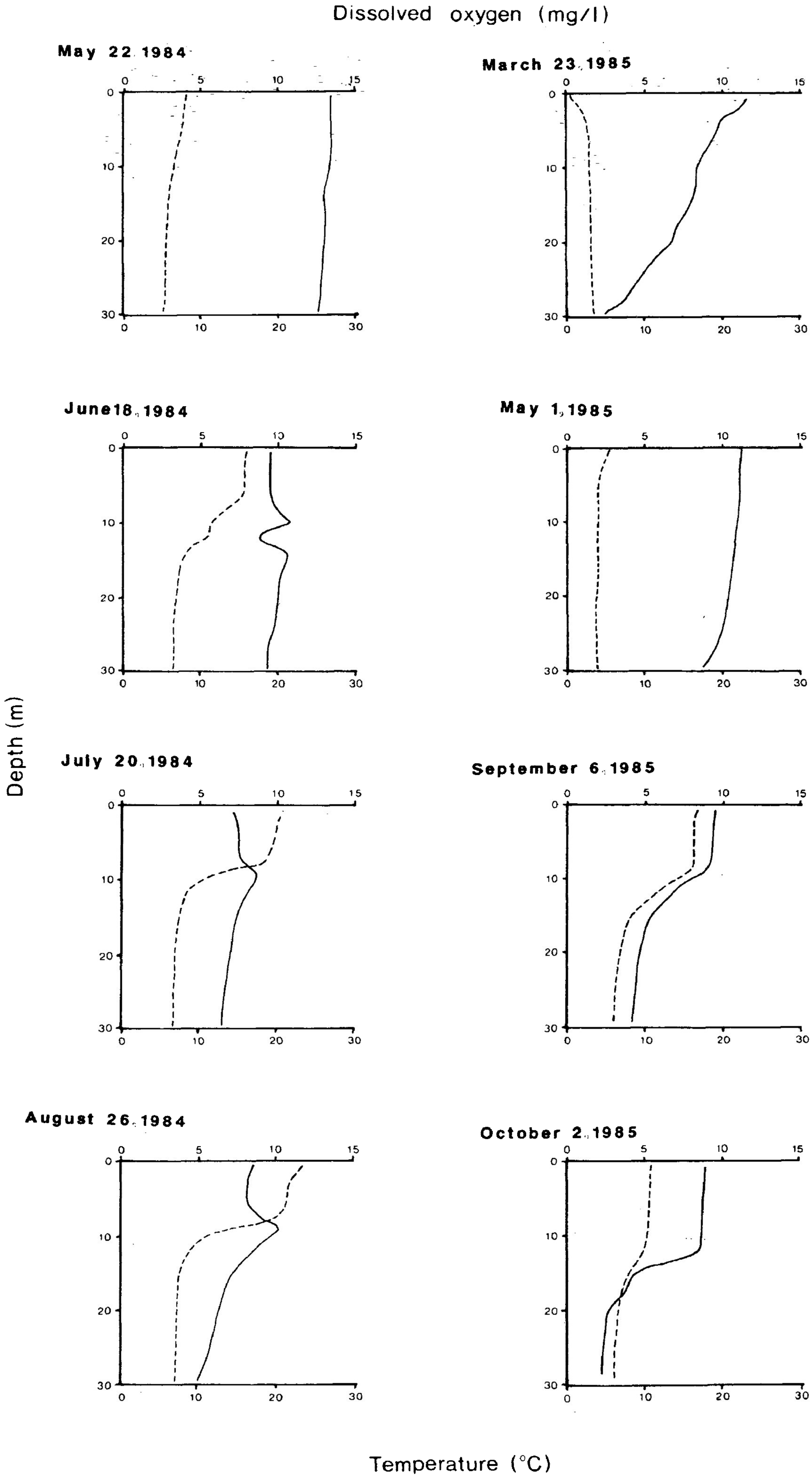
Appendix 1. Oxygen temperature profiles taken during 1984 and 1985 sampling periods on Squeers Lake, Ontario.

--- Temperature

___ Oxygen



Dissolved oxygen (mg/l)
May 22 1984
March 23, 1985
June18, 1984
May 1, 1985
July 20, 1984
September 6, 1985
August 26, 1984
October 2, 1985
Depth (m)
Temperature (°C)

Appendix 2. Period of marking, serial number of tags, and accessory marks applied to lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982-1986.

Time of marking	Tagging series	Accessory clip
Spring 1982	24000-24149[1]	Adipose Clip
April 7	B125763-B125987	
May 13-18		
Fall 1982	B145400-B145987	Dorsal Spine Punch
Sept 29-Oct 5		
Oct 12-14		
Fall 1983	B142700-B142999	-
Sept 29-Oct 4	B143001-B143013	-
Spring 1984	24154-24158[1]	Upper or Lower Caudal Punch
May 16-22	B143493-B143499	
May 31-Jun 5	B143596-B143699	
	B143800-B143978	
	B144052-B144193	
Fall 1984	23800-23999	Rear Dorsal Clip
Sept 26-Oct 3	24000-24367	
Oct 13		
Spring 1985	21900-21956	Upper or Lower Caudal Clip
May 2-9	22011-22099	
May 13-21	B136901-B136996	
	B143200-B143245	
Fall 1985	22176-22799	Anal Clip
Sept 26-Oct 10	23700-23799	
	24384-24399	
	24700-24999	
	285900-285999	
	286400-286499	
	B143255-B143299	
	B143500-B143595	
	B143700-B143791	
	B144610-B144628	
Fall 1986	288000-288999	
Sept 27-Oct 6	289000-289039	

[1] yellow tags applied

Appendix 3. Body regions used to record location of wounds and scars, and frequency of scars and wounds occurring on lake trout (*Salvelinus namaycush*) Squeers Lake, Ontario, 1982-1986.

Sampling Period	Sample Size	Scars	Wounds
Fall 1982	614	42(6.8)	23(3.8)
Fall 1983	373	44(11.8)	9(2.4)
Spring 1984	260	57(21.9)	9(3.5)
June 1984	309	5(1.6)	5(1.6)
August 1984	114	4(3.5)	2(1.8)
Fall 1984	654	91(13.9)	17(2.6)
Winter 1985	405	61(15.1)	10(2.5)
Spring 1985	217	11(5.1)	4(1.8)
Sept 1985	57	1(1.7)	0(0)
Fall 1985	1344	150(11.2)	22(1.6)
Winter 1986	735	91(12.4)	7(1.0)

number within parentheses is % occurrence

Appendix 4. Description of sex and sexual maturity assigned to lake trout (<u>Salvelinus namaycush</u>) in Squeers Lake, Ontario.

Sex 0-male
1-female

Development

0 immature. Gonad very small and thread like; gametes not discernable by eye.

1 dormant. Gonads are flaccid and contain small gametes; gonadal epithelium is enlarged in relation to the volume occupied by the gametes.

2 developing. Gonads have not reached their maximum size; eggs are clearly discernable by eye, and are larger than recruitment stock eggs, but may vary in size.

3 fully developed. Gonads are maximum size and fill the body cavity; testes are white; gametes are mature (eggs are typically round, transparent and uniform in size). Fish probably ready to spawn at time of capture.

4 spawning condition. Sexual products flow freely from gonads.

5 spent. Gonads are emptied of most mature gametes; some sexual products may remain in gonads; gonads are red with prominent vessels.

6 unknown. The stage of maturity cannot be determined.

Appendix 5. Length weight regressions by season and sex of lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982-1986.

Date	Sex	Regression equation	r[1]
Spring 1982	All	Log Wt[2] = 2.9552 * Log Fl[3] + -4.7841	.9666
June 1982	All	Log Wt = 2.8275 * Log Fl + -4.5403	.9197
	Males	Log Wt = 2.8810 * Log Fl + -4.6716	.9417
	Females	Log Wt = 3.1591 * Log Fl + -5.3722	.9543
Fall 1982	All	Log Wt = 3.0024 * Log Fl + -4.9654	.9378
Fall 1983	All	Log Wt = 2.8569 * Log Fl + -4.5951	.9563
Spring 1984	All	Log Wt = 3.0391 * Log Fl + -5.0529	.9300
June 1984	All	Log Wt = 2.8397 * Log Fl + -4.5357	.9580
	Males	Log Wt = 3.1035 * Log Fl + -5.2201	.9970
	Females	Log Wt = 3.0705 * Log Fl + -5.1237	.9960
August 1984	All	Log Wt = 3.2047 * Log Fl + -5.4548	.9937
	Males	Log Wt = 3.1950 * Log Fl + -5.4161	.9970
	Females	Log Wt = 3.1857 * Log Fl + -5.4138	.9937
Fall 1984	All	Log Wt = 3.0948 * Log Fl + -5.19633	.9705
Winter 1985	All	Log Wt = 2.9689 * Log Fl + -4.9024	.9711
	Males	Log Wt = 3.0098 * Log Fl + -5.0107	.9743
	Females	Log Wt = 2.9235 * Log Fl + -4.7825	.9675
Spring 1985	All	Log Wt = 3.1169 * Log Fl + -5.2709	.9602
Sept 1985	All	Log Wt = 2.9189 * Log Fl + -4.7092	.9731
	Males	Log Wt = 2.8631 * Log Fl + -4.5610	.9454
	Females	Log Wt = 2.9460 * Log Fl + -4.7825	.9831
Fall 1985	All	Log Wt = 3.1862 * Log Fl + -5.4348	.8985
Winter 1986	All	Log Wt = 3.0070 * Log Fl + -5.0000	.9783
	Males	Log Wt = 2.9972 * Log Fl + -4.9729	.9852
	Females	Log Wt = 3.0248 * Log Fl + -5.0478	.9953

[1] correlation coefficient
[2] Log Weight
[3] Log Fork Length

Appendix 6. The ratio of recaptured to marked lake trout (*Salvelinus namaycush*) differentiated by size, sex and gear type for lake trout in Squeers Lake, Ontario, 1982-1986.

Period of Sampling[1]	Sex[2]	All	Length group (cm) 36-40	41-45	46-50
RF82/MS82					
All Gear	C	.075	.062	.083	.253
Angling	C	.006	.019	-	-
RF83/MF82					
All Gear	C	.075	.070	.134	-
	M	.060	.060	.110	-
	F	.038	.016	.055	.055
Gill net	C	.082	.076	.099	-
	M	.030	.023	.071	-
	F	-	-	-	-
Angling	C	.009	-	.052	-
	M	-	-	-	-
	F	.030	-	.090	-
RS84/MF83					
All Gear	C	.045	.046	.047	-
Angling	C	.009	-	.052	-
RF84/MF83					
All Gear	C	.047	.039	.064	-
	M	.060	.034	.106	-
	F	-	-	-	-
Gill net	C	.016	.016	.027	-
	M	.026	.021	.062	-
Angling	C	-	-	-	-
RF84/MS84					
All Gear	C	.073	.084	.090	-
Angling	C	.028	-	-	-
RW85/MF84					
All Gear	C	.034	.040	.024	.091
	M	.039	.056	.038	-
	F	.364	.231	.250	-
Angling	C	.034	.037	.125	-
	M	.071	.095	.125	-
	F	-	-	-	-
RS85/MF84					
All Gear	C	.023	.010	.060	.150
Angling	C	.024	.011	.115	.286

Appendix 6 (continued)

RF85/MS85					
All Gear	C	.148	.173	.128	.150
Angling	C	.005	.013	-	-
RF85/MF84					
All Gear	C	.179	.151	.507	.343
	M	.252	.251	.846	-
	F	.727	.545	.889	-
Angling	C	.008	.011	-	-
	M	.007	.012	-	-
Gill net	C	.163	.123	.365	.329
	M	.271	.202	.966	-
	F	.222	.333	-	-
RW86/MF85					
All Gear	C	.044	.047	.053	.227
	M	.053	.051	.115	.428
	F	.074	.096	.083	.333
Angling	C	.030	.043	.041	-
	M	.046	.061	.091	-
	F	-	-	-	-
RF86/MF85					
All Gear	C	.170	.174	.300	.258
	M	.268	.273	.585	-
	F	.030	.042	-	-
Angling	C	.006	.006	.022	-
Gill net	C	.209	.202	.331	.048
	M	.270	.260	.548	-
	F	.050	.050	.048	-

[1]RtF82, RtF83, RtF84, RtF85, RtF86, RtS84, RtS85, RtW85, RtW86 - recaptures in the fall's of 1982, 1983, 1984, 1985 and 1986, spring's of 1984, 1985 and winter's of 1985, 1986 respectively. MtF82, MtF83, MtF84, MtF85, MtS82, MtS84, MtS84 - marks in the fall's of 1982, 1983, 1984, 1985, spring's of 1982, 1984, 1985 respectively.

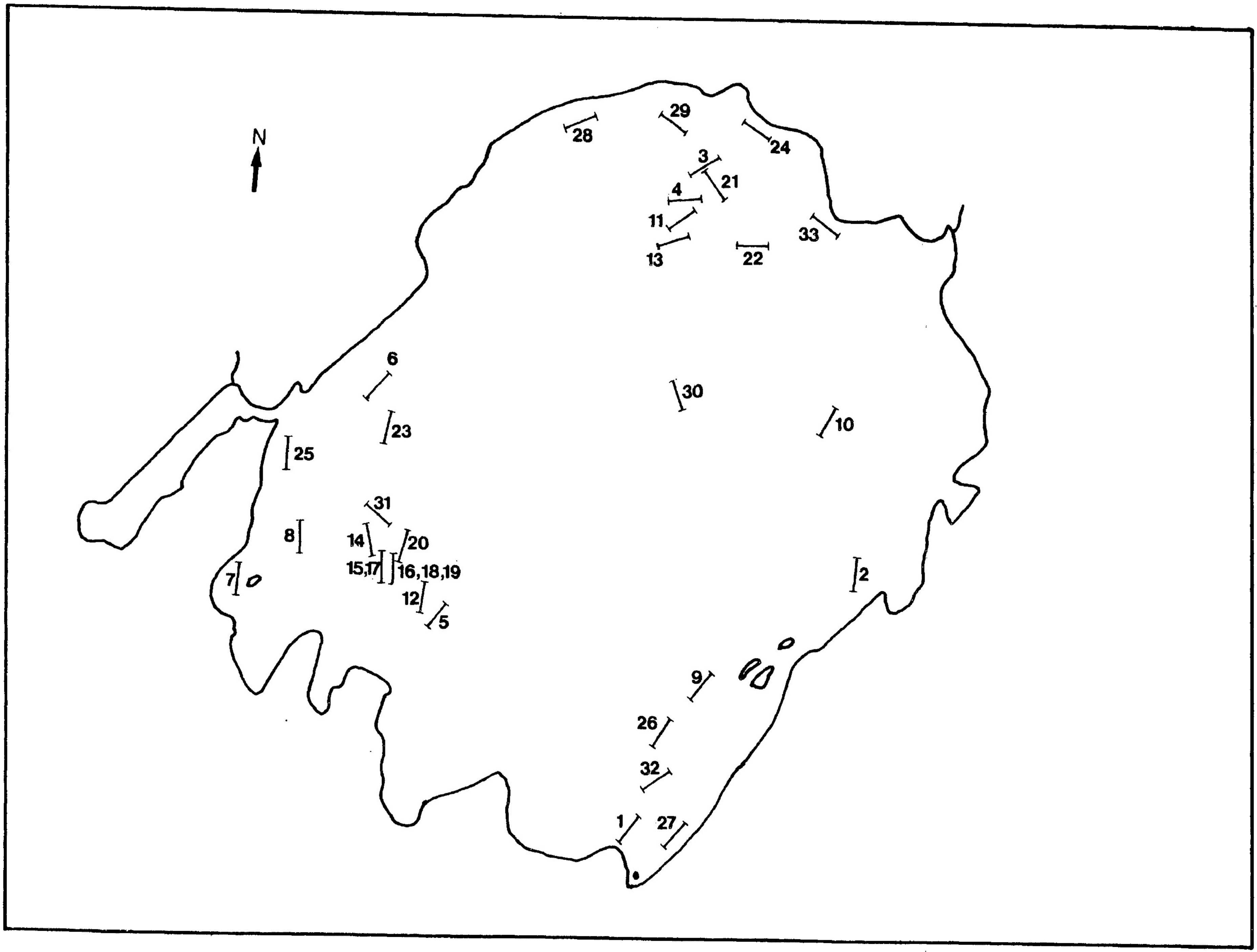
[2] C is sexes combined, M is males, F is females

Appendix 7. Changes in number of marked fish using Ketchen's method to adjust for size vulnerability for lake trout (Salvelinus namaycush) in Squeers Lake, Ontario, 1985,1986.

Length (cm)	% Mt[1] Fall 84	% Ct[2] March 85	% Mt-Ct	% Mt Fall 85	% Ct March 86	% Mt-Ct
23	-	-	-	.095	-	.095
24	-	-	-	-	.48	-
25	-	.493	-	.190	.95	-
26	-	.247	-	.095	1.361	-
27	-	.988	-	.381	1.224	-
28	-	1.728	-	.667	3.129	-
29	-	1.481	-	.286	5.578	-
30	.187	2.716	-	1.143	6.259	-
31	.374	1.975	-	1.619	5.850	-
32	1.121	3.210	-	2.476	5.850	-
33	2.430	3.457	-	3.238	6.259	-
34	7.850	4.444	3.406	6.476	5.442	1.034
35	10.841	4.691	6.150	9.714	7.074	2.640
36	12.897	7.654	5.243	11.048	8.844	2.204
37	12.523	9.136	3.387	13.524	5.442	8.082
38	12.336	8.889	3.447	14.000	6.939	7.061
39	8.411	8.642	-	8.667	6.122	2.545
40	10.280	6.914	3.366	5.619	4.762	.857
41	6.729	10.370	-	7.143	3.946	3.197
42	3.364	5.432	-	6.000	2.993	3.007
43	2.430	4.198	-	2.095	3.810	-
44	1.682	3.457	-	1.810	2.450	-
45	1.682	3.951	-	.952	1.633	-
46	1.869	1.481	.381	1.048	.952	.096
47	1.121	1.234	-	.857	.408	.449
48	.561	1.234	-	.095	.272	-
49	.187	.494	-	-	.680	-
50	.374	.988	-	.095	.272	-
51	-	.247	-	.286	.136	-
52	.187	-	.187	.190	.136	-
53	-	-	-	-	.408	-
54	.187	.247	-	-	-	-
55	-	-	-	.095	.272	-
56	.187	-	.187	-	-	-
57	.187	-	.187	-	-	-
58	-	-	-	-	-	-
59	-	-	-	-	-	-
60	-	-	-	.095	-	.095
61	-	-	-	-	-	-
62	-	-	-	-	.136	-
Total			25.941			31.566

[1]number of fish marked.
[2]number of fish caught.

Appendix 8. Map of Squeers Lake, Ontario showing gill net locations in June 1982 and 1984 (locations 1 to 12 were set in 1982 and locations 1 to 33 were set in 1984).


N
28
29
24
3
21
4
11
33
13
22
6
30
10
23
25
31
8
14
20
15,17
16,18,19
7
12
5
2
9
26
32
1
27

Appendix 9. Frequency of stomachs analyzed differentiated by length class and season for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1984-1985.

Length (cm)	Jun 84	Aug 84	Mar 85	May 85	Sept 85	Sept-Oct 85
<20	27	7	0	0	0	0
21-30	59	38	19	3	0	9
31-40	59	44	58	17	27	27
41-50	34	15	43	12	20	18
>50	10	6	7	0	3	3
Total	189	110	127	32	50	57

Appendix 10. Frequency of stomachs analyzed differentiated by length class and depth for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, June 1984.

Length	Depth (m)			
	1-10	11-20	21-30	≥ 30
<20	4	0	20	3
20-29	9	9	26	15
30-39	8	22	25	4
40-49	12	12	9	1
>50	3	2	5	0
Total	36	45	85	23

Appendix 11. Number of applicants and participants in the winter fisheries at Squeers Lake, Ontario, 1985 and 1986.

Year	applications	applicants	anglers chosen	anglers participating
1985				
Mar 23	198	370	35	27
Mar 24	98	179	36	31
Mar 30	78	147	36(49)[1]	65
Mar 31	39	71	35(48)[1]	64
Total	413	767	239	187
1986				
Mar 15	46	151	90	71
Mar 16	38	107	90	62
Mar 17	25	70	74	65
Mar 18	36	112	85	62
Mar 19	18	60	70	35
Mar 20	10	27	50	32
Mar 21	12	38	38	24
Mar 22	31	103	103(7)	66
Mar 23	23	84	86(7)	78
Total	239	752	700	495

[1] (n) = additional anglers chosen at a later date.

Appendix 12. Scientific collectors permit issued to anglers to fish in Squeers Lake, Ontario.

Appendix 13. Diaries given to anglers to monitor fishing effort, harvest and location of fishing in Squeers Lake, Ontario.

COMMENTS:

FISHING DIARY

Squeers Lake Experimental Fishery

1986

Can you please record information for us as you fish? Thank you.

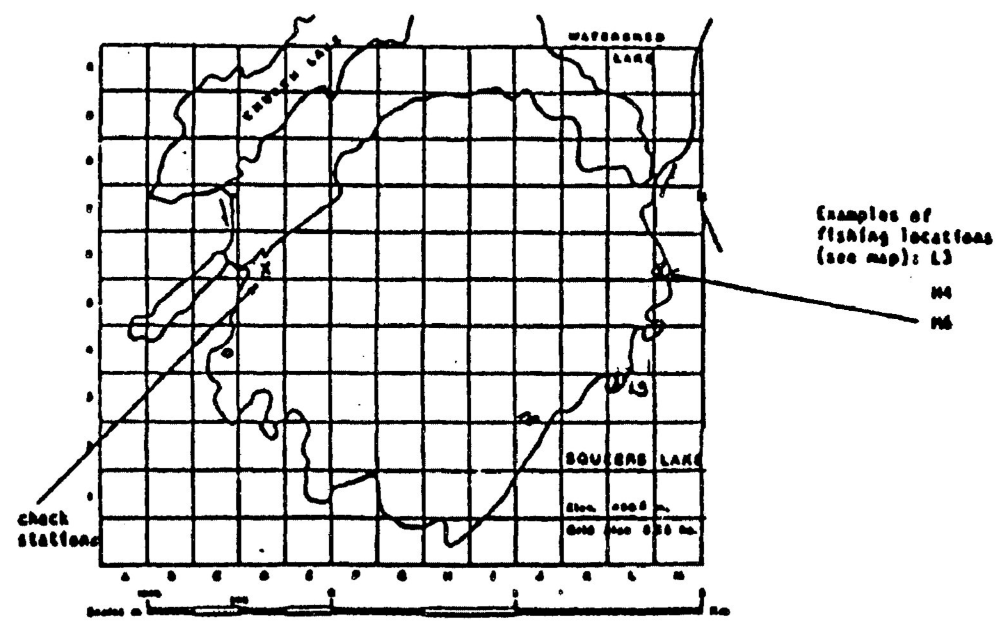
Angler Name: ______________________

Angler No.: ______________________

NOTE: PLEASE DO NOT REMOVE TAGS FROM FISH.

BRING FISH UNCLEANED AND WHOLE TO THE CHECK STATION.

Time	Fishing?	Location	Lake Trout KEPT	Lake Trout REL	Pike KEPT	Pike REL	# Lines	Fishing Methods
8:30-8:45								
8:45-								
9:00-								
9:15-								
9:30-								
9:45-								
10:00-								
10:15-								
10:30-								
10:45-								
11:00-								
11:15-								
11:30-								
11:45-								
12:00-12:15								
	Record as: X=active fishing 0=not fishing	Record # from map (eg., A6)	Record fish as caught		Record fish as caught			



	Fishing?	Location	Lake Trout KEPT	Lake Trout REL	Pike KEPT	Pike REL	# Lines	Fishing Methods
30								
0								
	Record X or 0	Record # from map	Record fish as caught		Record fish as caught			Still: 10 minnow, 20 smelt, 30 worms, 61 other; Jigging: 11 minnow, 21 smelt, 31 worms, 41 spoon, 51 jig

Appendix 14. Questionnaire given to anglers in 1985 to investigate angler attitudes, opinions and ideas about lake trout management.

1985 Squeers Lake Check Station Questionnaire

Angler #: ____________________ Date: ____________________

This questionnaire has been developed by Miss Helen Ball, a graduate student at Lakehead University, who is undertaking a study of lake trout in Squeers Lake. She wants to learn about the goals, interests, opinions and ideas of lake trout fishermen.

INSTRUCTIONS: Please answer the questionnaire while waiting for your catch to be checked. Our check station staff will review it with you during the interview. Thank you for your cooperation.

QUESTIONS

1. Did you have an enjoyable day? Yes ☐ No ☐

2. How many lake trout fishing trips have you made in the past year?

   1984 open water season: ________ winter 1985: ________

3. Please list the lakes that you fished and the number of trips to each on the chart below.

1984 open water season — Lake	# Trips	winter 1985 — Lake	# Trips

4. How many people do you usually fish with?

   in summer? ________ in winter? ________

5. How many times have you fished in Squeers Lake before today? ______ trips

6. How would you rate the fishing today? (Mark 'X' in box)

   Excellent ☐ Good ☐ Fair ☐ Poor ☐

7. How many fish did you expect to catch today? ____________________

8. In this question we would like to find out what you feel are the important components on a lake trout fishing trip. We think that there are four categories of important components but suspect that you may have other goals when fishing. Can you rank the importance of these components and add any other components or goals that you have which are not listed?

(a) Category: Fishing Success

Component	Very Desirable	Desirable	Not Important	Undesirable	Very Undesirable	No Opinion
catch large fish						
catch a limit of fish						
catch at least 1 fish						
solving the puzzle of how to catch fish in a given situation						
________ (other)						
________ (other)						

Category: Social/Personal

Component	Very Desirable	Desirable	Not Important	Undesirable	Very Undesirable	No Opinion
have a good time with friends						
have a good time with family						
mental relaxation						
meet other fishermen						
enjoy solitude						
________ (other)						
________ (other)						

Category: Aesthetic

Component	Very Desirable	Desirable	Not Important	Undesirable	Very Undesirable	No Opinion
enjoy scenery						
see wildlife						
being outdoors						
________ (other)						
________ (other)						

(d) Category: General

Component	Very Desirable	Desirable	Not Important	Undesirable	Very Undesirable	No Opinion
driving skidoos, boats, ATV's						
camping out						
________ (other)						
________ (other)						

9. Can you rank the major categories in question 8 as far as their importance to you? (1 = most important, 4 = least important)

Fishing Success ☐ Social/Personal ☐ Aesthetic ☐ General ☐

10. Do you think that lake trout populations are declining in northwestern Ontario?

Yes ☐ No ☐ Uncertain ☐ No Opinion ☐

11. If you answered 'YES' to question number 9, what do you feel are the reasons for the decline?

____

____

____

____

12. How long have you lived in the Thunder Bay area? ____________ years

or those lakes that you have fished regularly, can you tell us if there as been any change in fishing quality?

ake	Years Fished	Type of Change/No Change

We are interested in finding out whether you know about some of the strategies or techniques available for lake trout management and whether you think that they are useful methods.

	Useful	Not Useful	No Opinion	Not Aware of Strategy
(a) limiting access to lakes by location of roads				
(b) making sanctuaries of lakes until populations recover				
(c) shorter fishing seasons				
(d) reduced catch limits				
(e) stocking				
(f) limit to 1 line/angler for ice fishing				
(g) encourage angling for other species				
(h) require lake trout license				
(i) impose size limits				
(j) encourage angling in other lakes				

14.

	Useful	Not Useful	No Opinion	Not Aware of Strategy
(k) limit the number of anglers/year by a lottery system				
(l) restrict development (land use) around lake trout lakes				
(m) designate some lakes as trophy angling only				
(n) designate some lakes as catch and release fisheries				

15. Do you have any other ideas for management other than those listed above?

(use reverse side if necessary)

16. Of all of the above, what do you think are the three most important strategies?

(1) __________

(2) __________

(3) __________

17. Please comment on the experimental fishery on Squeers Lake if you haven't already on the back of your diary.

Appendix 15. Revised 1985 questionnaire given to anglers in 1986 to investigate anglers attitudes, opinions and ideas about lake trout management.

1986 SQUEERS LAKE QUESTIONNAIRE

This questionnaire has been developed by Miss Helen Ball, a graduate student at Lakehead University who is undertaking a study of the lake trout in Squeers Lake. She wants to learn about the interests, opinions, and ideas of lake trout fishermen. Thank you very much for your cooperation.

QUESTIONS

1. Did you have an enjoyable day? Yes ☐ Moderately ☐ No ☐

2. How many lake trout fishing trips have you made this past year?

   1985 open water season: ________ winter 1986: ________

3. Please list the lakes where you have fished for lake trout and the number of trips you have made to each this year, on the chart below. In addition, please comment on whether you have found any changes in quality of fishing in these lakes over the past year.

   1985 Open Water Season / Winter 1986

Lake	#trips	Changes in Quality	Lake	#trips	Changes in Quality

4. How many people do you usually fish with? summer ______ winter ______

5. How many times have you fished at Squeers Lake before today? ________

6. How would you rate the fishing today?

   Excellent ☐ Good ☐ Fair ☐ Poor ☐

7a. How many fish did you catch today? ________

b. How many fish did you expect to catch today? ________

8. Do you think that lake trout populations are declining in northwestern Ontario?

   Yes ☐ No ☐ Uncertain ☐ No Opinion ☐

   If you answered "YES" to the above question, what do you feel are the reasons for the decline?

   ____

   ____

   ____

   ____

9. Why do you go fishing for lake trout? Rank in order of importance (1 to 3), the THREE main reasons. Use number 1 for the most important.

____ for food ____ for fun

____ for trophy fish ____ to get outdoors

____ for the challenge ____ for companionship

____ for relaxation ____ other (please specify and rank)

10. What do you prefer to catch? Rank in order of importance (1 to 4). Use 1 for the most important.

____ trophy fish ____ several medium size fish

____ lots of fish (your limit) ____ other (please specify and rank)

____ at least one fish

11. The following are some of the strategies available to manage lake trout.

a) limit access to lakes by location of roads
b) make sanctuaries of lakes until populations recover
c) shorter fishing seasons
d) reduced catch limits
e) stocking
f) limit to 1 line/angler for ice fishing
g) encourage angling for other species
h) require lake trout license
i) impose size limits
j) encourage angling in other lakes
k) limit the # of anglers/year by lottery
l) restrict land use development around lake trout lakes
m) designate some lakes as trophy angling only
n) designate some lakes as catch and release fisheries
o) other, please specify

Of all the above, which do you think are the three most important strategies?

1. ______________________________

2. ______________________________

3. ______________________________

Are there any strategies which you do not agree with? Please list below.

____

____

12. If we run the experimental fishery next year will you apply again?

Yes ☐ No ☐

13. Please comment on the experimental fishery held at Squeers Lake.

____

____

____

Appendix 16. Number and percentage (in parentheses) of lake trout (<u>Salvelinus</u> <u>namaycush</u>) captured on the spawning shoals differentiated by sex and gear type in Squeers Lake, Ontario, 1982-1986.

Year	Gear	Males	Females	Unknowns	Total
1982	Gill net	225	62	48	335(54.5)
	Angling	149	80	20	249(40.5)
	Trap net	19	12	0	31(5.0)
	Total	393 (63.9)	154 (25.0)	68 (11.1)	615
1983	Gill net	193	82	53	328(87.9)
	Angling	11	20	14	45(12.1)
	Total	204 (54.7)	102 (27.3)	67 (18.0)	373
1984	Gill net	174	22	117	313(48.2)
	Angling	164	9	162	335(51.5)
	Trap net	0	1	1	2(.3)
	Total	338 (52.0)	32 (4.9)	280 (43.1)	650
1985	Gill net	569	181	141	891(67.6)
	Angling	161	108	144	413(31.3)
	Trap net	2	2	11	15(1.1)
	Total	732 (55.5)	291 (22.1)	296 (22.4)	1319
1986	Gill net	597	40	347	984(69.9)
	Angling	166	18	239	423(30.1)
	Total	763 (54.2)	58 (4.1)	586 (41.7)	1407

Appendix 17. Numbers of lake trout (*Salvelinus namaycush*) caught, marked and recaptured used to calculate population estimates in Squeers Lake, Ontario, 1982-1985.

Sampling Period[1]	Combined Sexes Length Classes(cm)					Males Length Classes(cm)				
	All	31-35	36-40	41-45	46-50	All	31-35	36-40	41-45	46-50
S82										
MtS82	159	-	53	79	13	-	-	-	-	
AdjMtS82	151	-	51	75	12	-	-	-	-	-
CtF82	605	-	322	157	36	-	-	-	-	-
RtF82	12	-	3	6	3	-	-	-	-	-
AdjRtF82	13.1	-	3.3	6.6	3.3	-	-	-	-	-
F82										
MtF82	560	-	299	147	-	377	-	220	85	-
AdjMtF82	533	-	285	140	-	359	-	209	81	-
CtF83	367	-	200	107	-	203	-	129	37	-
RtF83	40	-	19	18	-	24	-	16	6	-
AdjRtF83	43.8	-	20.8	19.7	-	26.3	-	17.5	6.6	-
F83										
MtF83	310	-	174	85	-	-	-	-	-	-
AdjMtF83	295	-	166	81	-	-	-	-	-	-
CtS84	259	-	101	104	-	-	-	-	-	-
RtS84	14	-	8	4	-	-	-	-	-	-
AdjRtS84	15.3	-	8.8	4.4	-	-	-	-	-	-
F84										
MtF83	303	-	168	73	-	165	-	102	31	-
AdjMtF83	289	-	160	70	-	157	-	97	30	-
CtF84	622	-	339	122	-	330	-	178	46	-
RtF84	13	-	6	6	-	9	-	5	3	-
AdjRtF84	142	-	6.6	6.6	-	9.9	-	5.5	3.3	-
S84										
MtS84	194	-	78	73	-	-	-	-	-	-
Adj S84	185	-	74	70	-	-	-	-	-	-
CtF84	622	-	339	122	-	-	-	-	-	-
RtF84	13	-	6	6	-	-	-	-	-	-
AdjRtF84	14.2	-	6.6	6.6	-	-	-	-	-	-
F84										
MtF84	398	-	255	85	22	-	-	-	-	-
AdjMtF84	379	-	267	81	21	-	-	-	-	-
CtW85	405	-	167	111	22	-	-	-	-	-
RtW85	18	-	12	2	2	-	-	-	-	-
AdjRtW85	19.7	-	13.1	2.2	2.2	-	-	-	-	-

Appendix 17 (continued)

<u>F84</u>										
MtF84	519	-	290	83	20	-	-	-	-	-
AdjMtF84	494	-	276	79	19	-	-	-	-	-
CtS85	213	-	86	79	32	-	-	-	-	-
RtS85	12	-	3	5	3	-	-	-	-	-
AdjRtS85	13.1	-	3.3	5.5	3.3	-	-	-	-	-
<u>F84</u>										
MtF84	509	-	291	80	16	255	-	142	26	-
AdjMtF84	485	-	277	76	15	243	-	135	25	-
CtF85	1220	-	634	262	42	654	-	378	120	-
RtF85	83	-	40	37	5	56	-	31	22	-
AdjRtF85	90.9	-	43.8	40.5	5.5	61.3	-	34	24.1	-
<u>S85</u>										
MtS85	170	-	76	60	22	-	-	-	-	-
AdjMtS85	162	-	72	57	21	-	-	-	-	-
CtF86	1221	-	634	262	42	-	-	-	-	-
RtF86	23	-	12	7	3	-	-	-	-	-
AdjRtF86	25.2	-	13.1	7.7	3.3	-	-	-	-	-
<u>F85</u>										
MtF85	719	-	440	177	-	-	-	-	-	-
AdjMtF85	685	-	419	168	-	-	-	-	-	-
CtW86	735	-	236	109	-	-	-	-	-	-
RtW86	46	-	26	10	-	-	-	-	-	-
AdjRtW86	504	-	28.5	110	-	-	-	-	-	-
<u>F86</u>										
MtF85	1004	245	529	179	17	494	131	291	61	7
AdjMtF85	964	233	504	170	16	474	125	277	58	7
CtF86	1274	302	667	299	37	700	165	379	143	10
RtF86	156	16	84	49	4	116	13	69	31	2
AdjRtF86	170.8	17.5	92	53.7	4.4	127	14.2	75.6	34	2.2

[1] S82, S84 = Springs 1982, 1984
F82, F83, F84, F85, F86 = Falls 1982-1986
Mt = number of fish marked
Adj Mt = number of marked fish adjusted for handling mortality
Ct = number of fish caught
Rt = number of fish recaptured
AdjRt = number of fish recaptured adjusted for tag loss

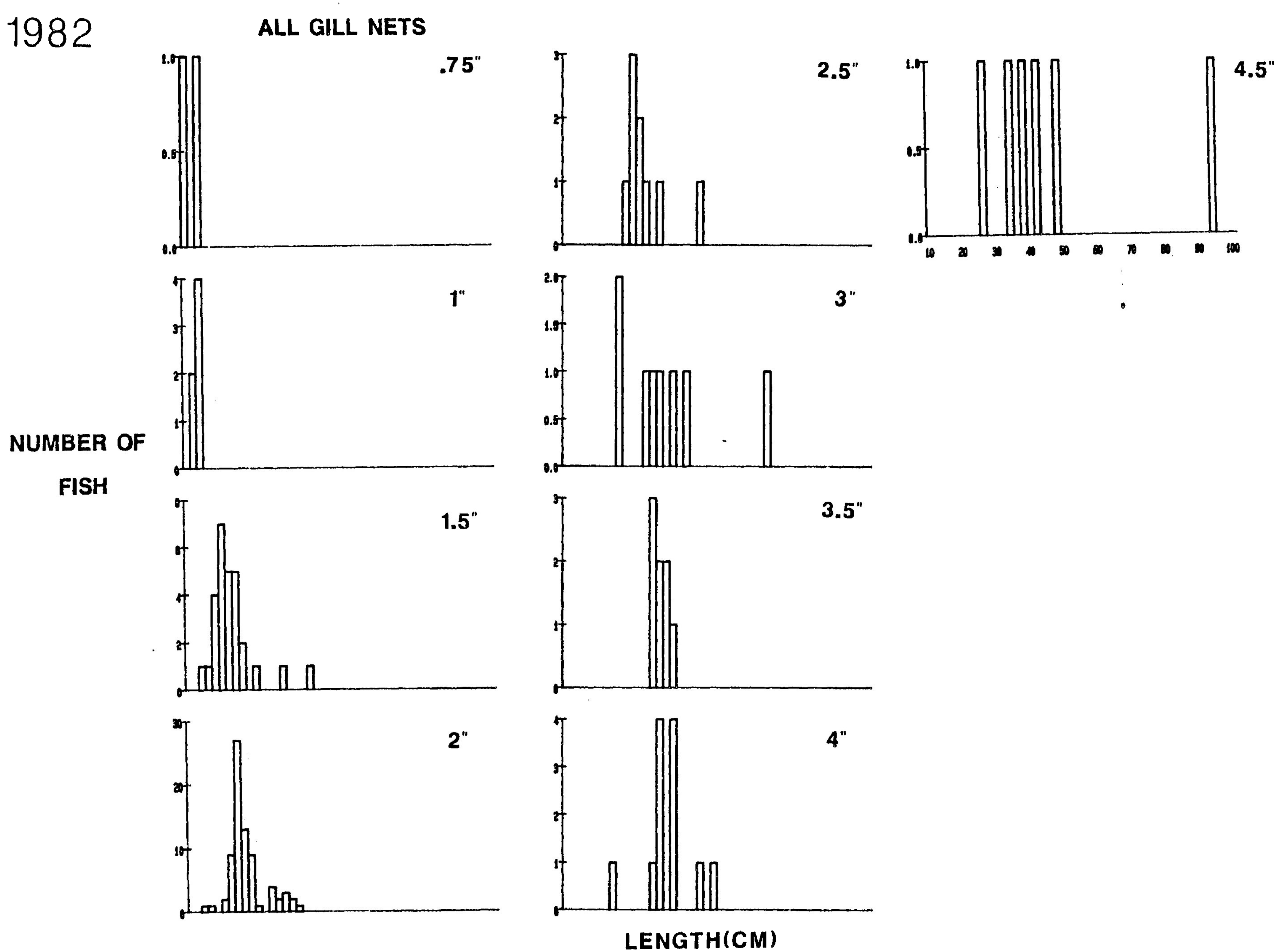
Appendix 18. Assessed mortality from handling and tag for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982,1983.

Date	Duration of holding(hrs)	Method of capture	Number held	Number died	Percent mortality
May 82	24	Angling	26	1	3.8
Fall 82	24	Trap net	15	0	
	48	Gill net	24	1	
	96	Gill net	2	1	
	48	Angling	1	0	
	72	Angling	16	1	
			58	3	5.2
Fall 83	16	Gill net	22	1	
	16	Gill net	12	0	
	16	Gill net	76	6	
	16	Gill net	36	0	
			146	7	4.8
Total			230	11	4.8

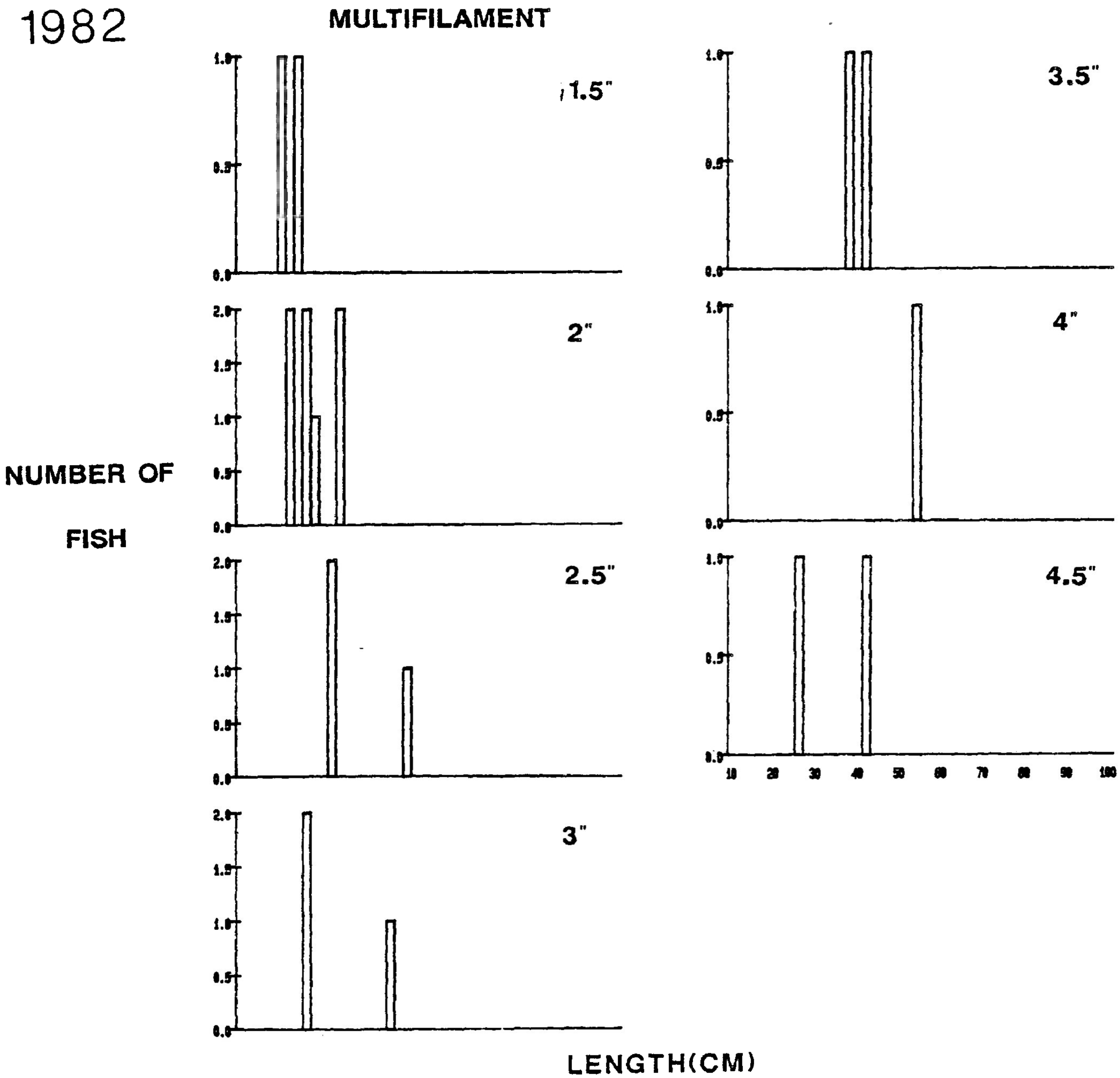
Appendix 19. Number and percent of lake trout (*Salvelinus namaycush*) differentiated by sex captured in gill nets in Squeers Lake, Ontario, 1982 and 1984.

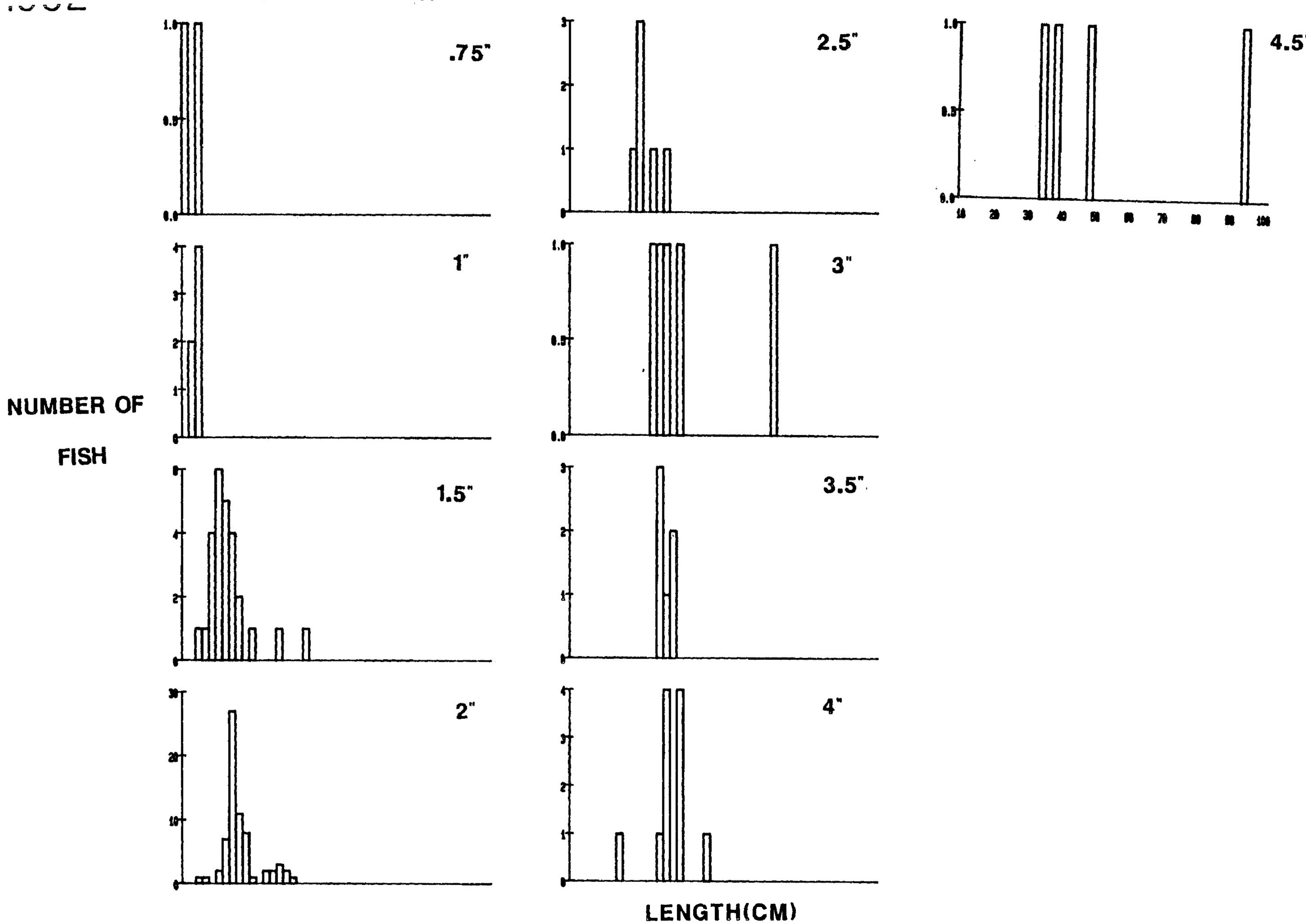
Length Group	June 1982		June 1984	
	Males	Females	Males	Females
≥ 25 cm	48 (44.4)	60 (55.5)	100 (40.3)	148 (59.7)
≥ 36 cm	25 (51.0)	24 (49.0)	62 (42.5)	84 (57.5)
Mature Fish	22 (47.8)	24 (52.2)	69 (49.6)	70 (50.4)

Appendix 20. Size of lake trout captured by mesh size for monofilament, multifilament and all gill nets in 1982 and 1984.


1982
ALL GILL NETS
NUMBER OF FISH
.75"
1"
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
LENGTH(CM)

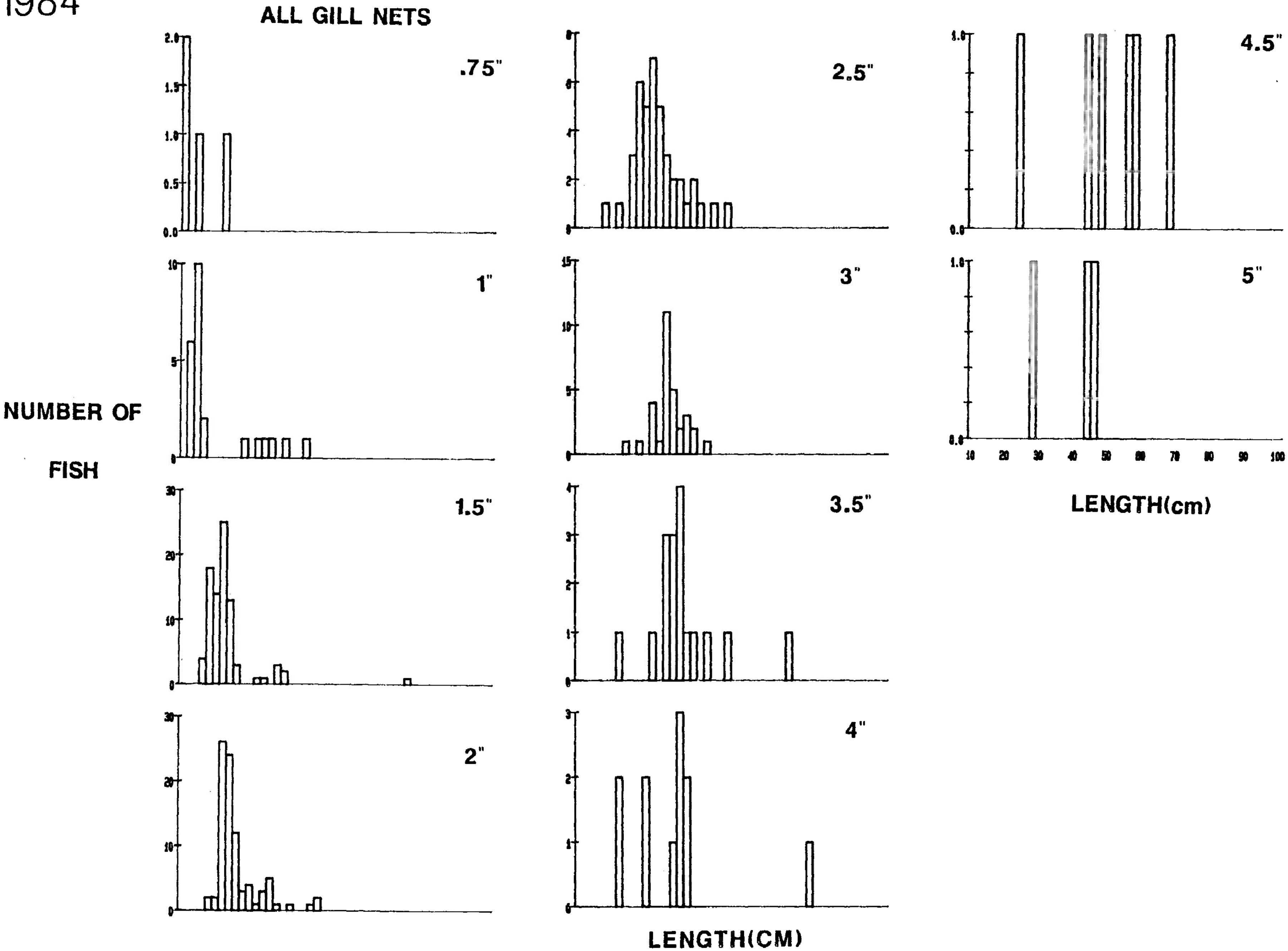
1982


MULTIFILAMENT
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
NUMBER OF FISH
LENGTH(CM)
10
20
30
40
50
60
70
80
90
100

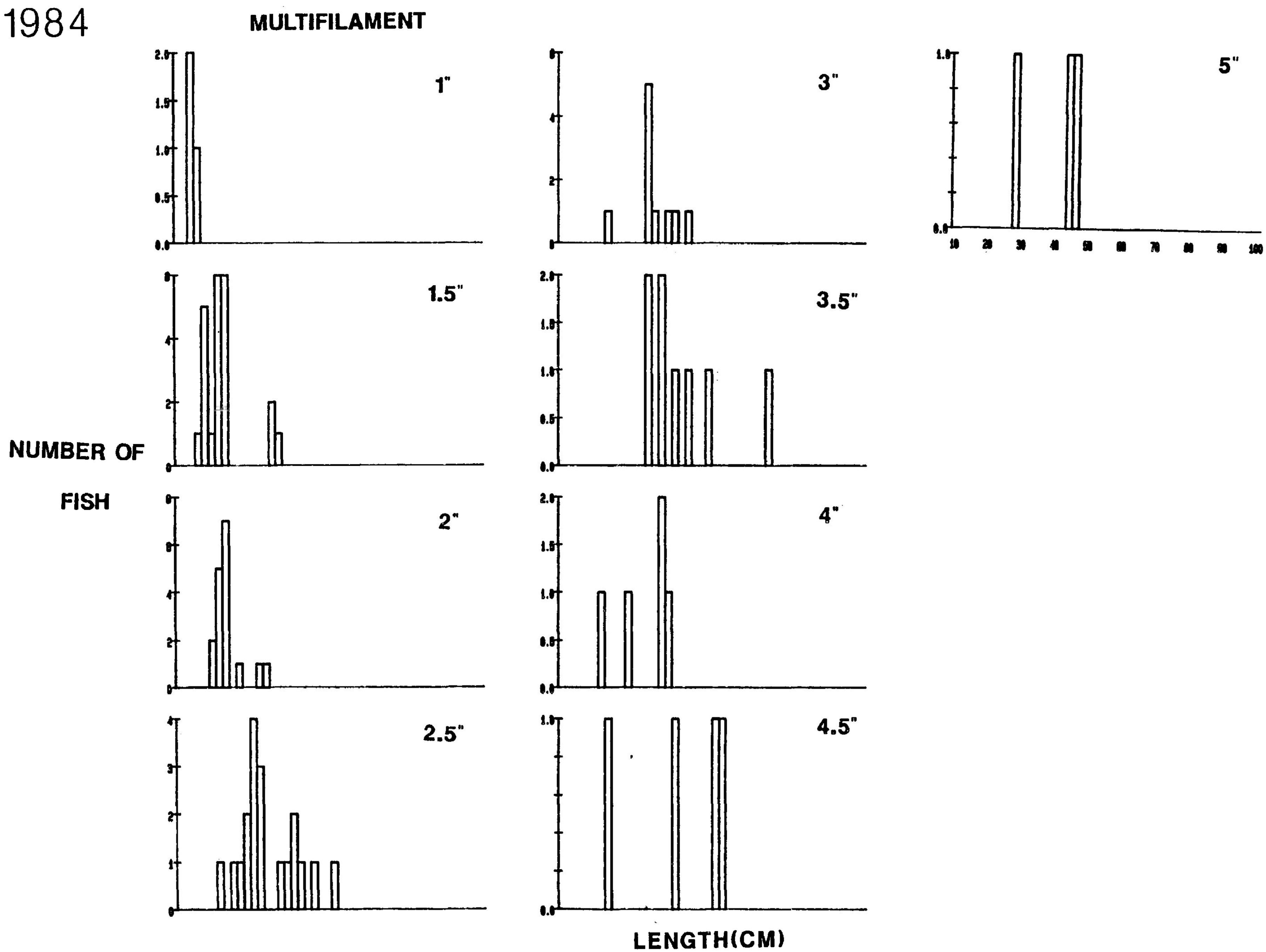


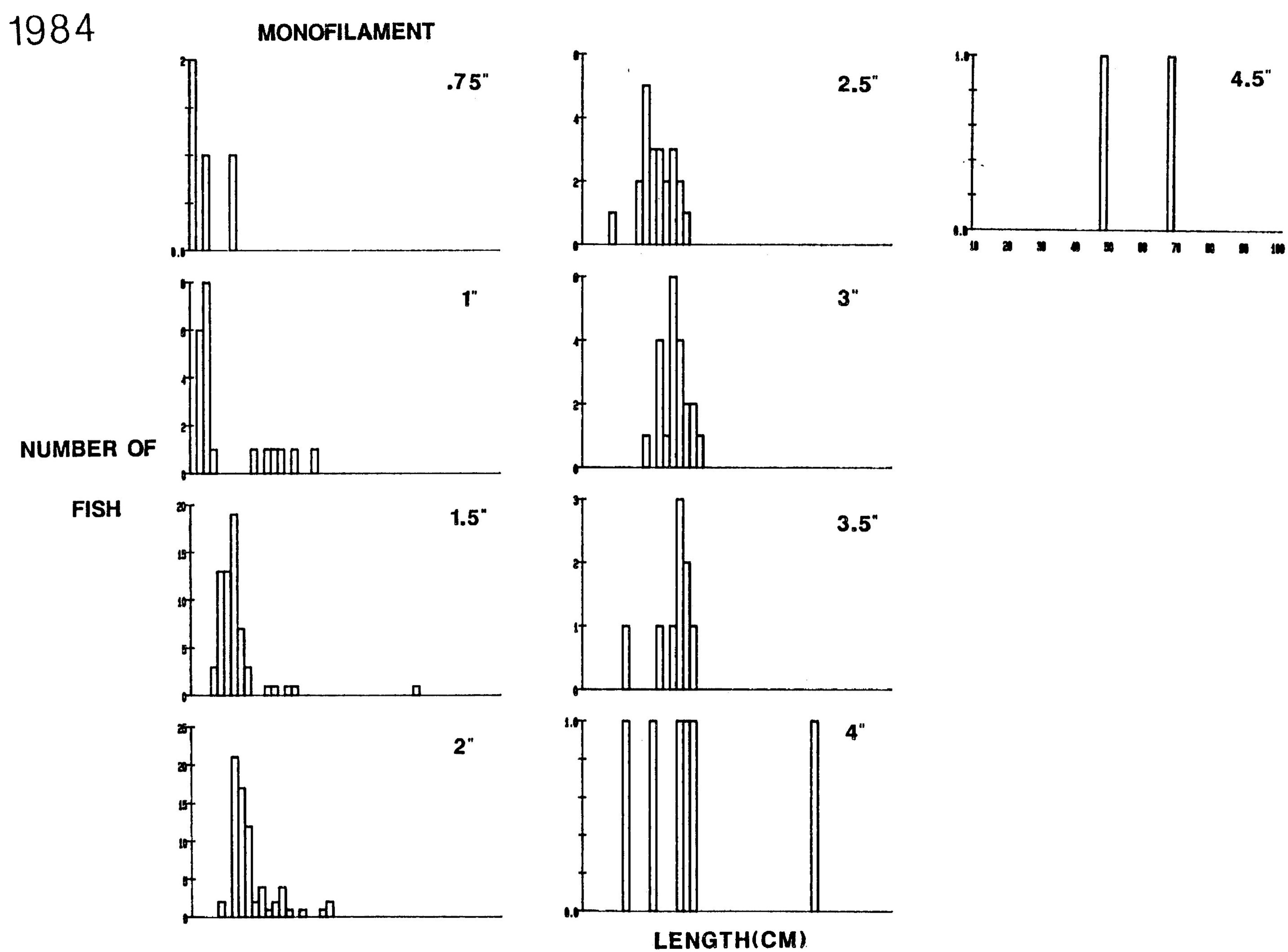
NUMBER OF
FISH
.75"
1"
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
LENGTH(CM)

1984



ALL GILL NETS
.75"
1"
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
5"
NUMBER OF FISH
LENGTH(CM)
LENGTH(cm)


1984
MULTIFILAMENT
1"
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
5"
NUMBER OF FISH
LENGTH(CM)


1984
MONOFILAMENT
NUMBER OF
FISH
.75"
1"
1.5"
2"
2.5"
3"
3.5"
4"
4.5"
LENGTH(CM)

Appendix 21. Scale(Sc), fin ray (Fr) and otolith (Ot) ages for lake trout (*Salvelinus namaycush*) captured in Squeers Lake Ontario, 1982.

No.	Age Sc	Age Fr	Age Ot	No.	Age Sc	Age Fr	Age Ot	No.	Age Sc	Age Fr	Age Ot	No.	Age Sc	Age Fr	Age Ot
1	3	-	3	46	5	-	6	91	-	-	-	136	4	4	4
2	7	-	14	47	7	-	11	92	3	3	-	137	5	6	6
3	5	-	4	48	7	-	14	93	5	5	5	138	6	6	6
4	6	-	8	49	8	-	13	94	4	4	4	139	6	7	10
5	5	-	7	50	7	-	14	95	5	4	4	140	10	9	10
6	8	-	16	51	8	-	15	96	5	4	-	141	8	8	8
7	5	-	6	52	7	-	8	97	5	5	5	142	7	8	8
8	6	-	6	53	6	-	9	98	5	7	7	143	9	9	9
9	-	-	-	54	2	-	2	99	5	5	5	144	3	3	3
10	7	-	7	55	3	-	-	100	5	4	4	145	3	3	3
11	6	-	8	56	5	-	5	101	6	8	11	146	3	3	3
12	6	-	5	57	4	-	4	102	10	16	16	147	7	13	17
13	8	-	10	58	4	-	4	103	3	-	-	148	6	7	7
14	5	-	5	59	4	-	3	104	3	3	3	149	5	4	4
15	5	-	5	60	5	-	5	105	8	9	13	150	3	3	3
16	8	-	9	61	3	-	4	106	8	8	8	151	5	5	5
17	7	-	12	62	5	-	5	107	8	6	6	152	8	13	16
18	7	-	16	63	2	-	2	108	8	-	12	153	7	10	13
19	5	-	5	64	4	-	3	109	8	7	7	154	5	5	5
20	4	-	3	65	4	-	4	110	7	7	7	155	8	8	8
21	5	-	5	66	5	-	5	111	9	14	-	156	7	11	-
22	5	-	6	67	4	-	4	112	6	6	-	157	8	10	12
23	5	-	5	68	4	-	3	113	9	-	19	158	9	12	13
24	5	-	5	69	6	-	7	114	6	-	20	159	16	20	24
25	6	-	6	70	5	-	7	115	8	13	13				
26	5	-	6	71	5	-	7	116	7	10	13				
27	5	-	6	72	5	-	5	117	7	14	17				
28	5	-	4	73	5	-	5	118	8	-	9				
29	5	-	7	74	5	-	-	119	9	-	26				
30	5	-	7	75	5	-	6	120	8	13	15				
31	6	-	5	76	5	-	7	121	12	14	17				
32	6	-	7	77	5	-	-	122	3	3	3				
33	5	-	5	78	5	-	5	123	4	4	4				
34	6	-	6	79	5	-	6	124	4	4	3				
35	5	-	5	80	5	-	5	125	5	5	5				
36	7	-	7	81	5	-	6	126	6	7	7				
37	5	-	6	82	5	-	5	127	4	4	4				
38	5	-	7	83	5	-	8	128	5	6	6				
39	5	-	5	84	5	-	5	129	6	6	6				
40	5	-	3	85	6	-	6	130	6	5	5				
41	7	-	5	86	5	-	6	131	4	4	4				
42	6	-	12	87	5	-	5	132	6	6	6				
43	8	-	17	88	5	-	6	133	5	6	6				
44	7	-	10	89	10	-	22	134	5	5	5				
45	8	-	-	90	5	-	5	135	6	9	11				

Appendix 22. Assessed otolith ages of two independent aging technicians for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1985.

Number	A[1]	B[2]	Sample #	A	B
1	8	8	26	4/5	6
2	6	6	27	12	12
3	10	9	28	8	7
4	8	8	29	8	8
5	6	7	30	9	10
6	8/9	8	31	9	11
7	13	10-12	32	10	11
8	8	8	33	17	14-16
9	8	8	34	6	6
10	8	7	35	8	10
11	5/7	5	36	6/7	7
12	7	9	37	7/8	7
13	10	10	38	8	9
14	17	15-18	39	8	8
15	12	13	40	7	8
16	9	9	41	10	11
17	11/12	13	42	12	12
18	9/10	9	43	7	8
19	8	10	44	10	10
20	10	9	45	12	12
21	13	15	46	8	10
22	13	16	47	8	9
23	28-29	24-27	48	10	9
24	8	8	49	5	6
25	13	11	50	5	5

[1] Shayne MacClellan, Dept. of Fisheries and Oceans, Nanaimo, British Colombia.

[2] Jon Tost, Quetico-Mille Lacs Fisheries Assessment Unit, Ontario Ministry of Natural Resources, Thunder Bay, Ontario.

Appendix 23. Comparison of fork length (cm) at age between males (M) and females (F) using a Mann-U-Whitney Test for lake trout (Salvelinus namaycush) in Squeers Lake, Ontario, 1982-1986.

Age	June 1982 F.L. M	June 1982 F.L. F	June 1982 U	June 1984 F.L. M	June 1984 F.L. F	June 1984 U	March 1985 F.L. M	March 1985 F.L. F	March 1985 U	March 1986 F.L. M	March 1986 F.L. F	March 1986 U
3	-	-	-	20.2 (3)[2]	18.4 (7)	6	-	-	-	-	-	-
4	23.9 (5)	20.8 (3)	2	23.1 (5)	23.7 (17)	35	-	-	-	25.0 (3)	27.9 (5)	5
5	26.3 (12)	25.0 (7)	72	26.8 (3)	26.5 (6)	8	29.1 (8)	28.4 (5)	18	28.3 (19)	28.8 (17)	156
6	27.7 (9)	27.3 (13)	54	30.5 (2)	31.1 (5)	5	31.2 (16)	29.9 (15)	90	31.5 (30)	32.0 (37)	496
7	30.5 (4)	28.0 (9)	4[1]	33.2 (8)	33.2 (7)	24	33.1 (16)	35.3 (17)	80	35.3 (17)	34.2 (15)	108
8	38.2 (3)	35.1 (5)	5	38.5 (2)	34.4 (11)	6	37.1 (49)	36.8 (28)	681	37.0 (21)	37.7 (19)	191
9	41.5 (2)	41.5 (2)	2	40.1 (7)	40.7 (10)	31	37.3 (27)	38.1 (28)	322	38.6 (24)	39.0 (20)	239
10	≥43.4 (16)	43.4	123	41.5 (8)	46.7 (8)	17	38.5 (11)	39.5 (30)	138	41.2 (18)	40.3 (24)	176
11				45.5 (2)	44.0 (8)	6	39.2 (8)	39.6 (26)	91	41.6 (13)	42.5 (12)	75
12				≥48.9 (13)	52.0 (17)	88	40.9 (9)	41.5 (10)	43	42.1 (13)	45.5 (9)	36
13							45.4 (5)	42.0 (6)	8	42.0 (11)	43.9 (10)	37
14							≥42.7 (8)	43.2 (29)	115	45.2 (6)	44.2 (3)	9
15										46.8 (3)	42.2 (3)	1
16										42.5 (4)	42.3 (5)	10
17										≥45.0 (8)	43.5 (9)	54

[1] significant at $p<.05$

2 (n) is sample

Appendix 24. Mean and standard deviation (SD) of fork length (FL) at age for lake trout (<u>Salvelinus namaycush</u>) captured in Squeers Lake, Ontario, 1982-1986.

	1982		1984		1985		1986	
Age	FL	SD	FL	SD	FL	SD	FL	SD
1	-	-	9.5	-	-	-	-	-
2	14.1	1.48	14.6	1.31	-	-	-	-
3	17.2	2.81	19.0	1.86	-	-	-	-
4	21.9	1.70	23.2	2.20	26.7	-	26.8	2.60
5	25.4	1.94	25.8	2.46	28.8	1.99	28.9	2.24
6	27.4	2.55	30.3	2.99	30.5	3.02	32.0	3.13
7	28.2	3.97	33.2	2.72	34.3	2.87	35.3	2.94
8	36.1	6.17	35.2	4.21	37.0	2.60	37.6	3.58
9	41.1	2.28	40.4	8.06	37.4	3.32	39.1	4.11
10	40.0	7.39	44.3	7.83	39.1	2.55	40.7	3.24
11	37.4	3.40	44.3	9.72	39.6	3.27	42.2	3.44
12	42.6	5.59	48.5	12.76	41.6	2.48	43.2	3.90
13	40.8	5.40	46.6	9.69	43.4	4.13	42.9	3.23
14	39.9	2.36	54.3	13.42	42.1	3.70	44.8	3.40
15	49.3	14.16	64.5	15.00	45.4	2.46	44.8	3.40
16	41.0	1.87	41.5	-	43.2	3.42	43.0	2.78
17	43.2	3.41	44.8	1.89	40.1	1.61	44.8	2.49
18	-	-	47.5	-	42.3	2.69	50.2	.94
19	42.8	-	-	-	43.7	2.73	46.2	6.80
20	41.0	-	45.5	-	47.6	-	48.5	5.00
21	43.2	-	49.5	-	47.9	2.40	43.5	-
22	95.0	-	47.5	-	37.7	-	-	-
23	42.0	-	39.5	-	41.2	-	-	-
24	-	-	54.5	5.00	-	-	-	-
25	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	43.5	-

Appendix 25. Fecundity, eggs/gm of female, and mean diameter (diam) of eggs for lake trout (Savlvelinus namaycush) in Squeers Lake, Ontario, 1984, 1985.

Year	FL (cm)	Wt (gm)	Age	Ovary Weight (gm)	Number of eggs	Eggs/gm	Diam (mm)
June 1984							
1	34.8	540	-	13.343	731	1.350	3.16
2	44.2	900	17	29.438	2122	2.358	2.77
3	72.4	4800	12	86.760	4419	.921	3.06
4	40.2	750	23	28.050	1157	1.543	3.46
5	43.2	950	10	23.130	1865	1.963	2.95
6	37.2	575	8	17.925	944	1.642	3.17
7	39.3	750	11	17.312	989	1.319	-
8	51.7	1475	9	25.640	2693	1.826	-
9	45.0	1000	10	33.607	1335	1.335	-
10	33.0	-	-	11.318	787	-	3.02
11	40.8	-	-	31.653	1065	-	3.61
12	39.1	650	8	16.032	1097	1.688	3.06
13	36.7	-	-	12.900	793	-	3.11
14	36.6	-	-	26.780	1050	-	-
15	50.2	1550	25+	65.469	1959	1.264	3.69
16	42.4	-	-	37.049	973	-	4.39
17	35.6	620	11	12.237	808	1.303	-
18	40.2	800	11	19.900	1294	1.617	2.93
19	45.4	1200	11	27.673	1808	1.507	2.60
20	46.8	1240	-	22.444	2217	1.788	-
21	42.7	800	13	22.753	1397	1.746	-
22	49.2	1375	21	46.659	1791	1.302	3.47
23	69.2	4900	25+	246.611	8366	1.707	3.64
24	47.1	1100	-	33.843	1845	1.677	-
25	77.9	7000	14	200.328	7902	1.129	-
August 1984							
26	39.7	850	11	64.192	1071	1.260	5.05
27	42.2	975	14	69.644	1555	1.595	4.64
28	50.6	2575	13	157.596	2266	.880	5.42
29	42.2	-	-	49.805	1113	-	4.48
30	36.1	-	-	43.947	800	-	5.01
31	32.4	420	7	34.129	800	1.905	4.69
32	38.5	-	-	72.133	1061	-	4.80
33	35.8	-	-	40.339	989	-	4.64
34	41.7	950	9	59.391	1378	1.450	4.76
35	39.7	850	11	20.050	878	1.030	4.30
36	44.0	1150	13	79.688	1846	1.605	4.52
37	60.1	2500	14	162.887	3479	1.392	4.97
38	48.8	1300	-	98.787	1439	1.107	4.85
39	40.9	775	10	65.185	1321	1.704	4.63
40	46.8	1275	11	114.722	2070	1.623	5.05
41	38.4	-	-	62.400	1427	-	4.34
42	76.9	-	15	539.420	7191	-	5.13

Appendix 25 (continued)

Date	FL (cm)	Wt (gm)	Age	Ovary Wt (gm)	Number of Eggs	Eggs/gm	Diam (mm)
Sept 1985							
43	44.5	1075	>10	107.219	1519	1.413	5.14
44	45.5	1050	14	94.200	1286	1.225	4.54
45	36.3	580	7	59.800	1080	1.862	4.12
46	43.0	1000	-	108.800	1771	1.771	4.30
47	42.0	1000	12	104.000	1437	1.437	4.38
48	45.2	1150	20	83.000	1564	1.360	4.02
49	42.0	850	11	54.400	943	1.109	4.45
50	38.2	715	14	65.700	994	1.390	4.68
51	37.6	625	10	73.300	1057	1.691	4.63
52	45.4	1200	17	113.200	2052	1.710	4.07
53	35.0	550	9	46.700	664	1.207	4.43
54	45.5	1200	12	83.500	1206	1.005	4.91
55	45.4	1125	-	91.700	1506	1.339	-
56	43.8	1125	12	86.000	1535	1.364	4.11
57	45.7	1100	20	60.600	1416	1.287	3.71
58	49.5	1375	17	107.200	2255	1.640	3.67
59	52.3	1875	18	194.500	2343	1.250	4.62
60	54.2	2050	23	166.100	2518	1.228	3.90
61	38.6	700	9	57.200	871	1.224	4.38
Fall 1985							
62	37.9	750	-	103.000	1273	1.697	4.55
63	39.6	550	-	70.400	966	1.756	4.41
64	44.1	1100	13	124.000	1373	1.248	4.59
65	39.7	750	12	80.200	1046	1.395	4.56
66	48.1	1450	20	165.100	1820	1.255	4.88
67	48.5	1450	10	154.700	1900	1.310	4.81
68	90.5	11400	36	1936.200	19671	1.725	4.92
69	34.3	500	9+	56.400	1074	2.148	4.39
70	37.5	600	-	78.500	1097	1.828	4.67
71	42.6	775	-	62.100	1069	1.379	3.57
72	47.5	1250	17	121.900	1501	1.201	4.79
73	37.2	510	9+	71.600	1244	2.439	4.25
74	38.5	650	9	99.900	1240	1.908	4.70
75	39.0	700	-	77.500	1250	1.721	4.48
76	42.8	900	-	106.100	1273	1.414	4.89
77	39.8	850	-	113.900	1294	1.522	4.79

Appendix 26. Regression equations of absolute fecundity on fork length (FL), weight (Wt) and age for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1984, 1985.

Absolute Fecundity with Length			
1984	n=42	Absolute Fecundity = -2566 + 94.86 (FL)	r[1]=.9073
1985	n=30	Absolute Fecundity = -1841 + 75.63 (FL)	r=.8571
84 & 85	n=72	Absolute Fecundity = -2776 + 87.15 (FL)	r=.8827
Absolute Fecundity with Weight			
1984	n=28	Absolute Fecundity = 460 + 1.047 (Wt)	r=.8341
1985	n=34	Absolute Fecundity = 392 + 1.023 (Wt)	r=.8890
84 & 85	n=62	Absolute Fecundity = 408 + 1.051 (Wt)	r=.8554
Absolute Fecundity with Age			
1984	n=24	Absolute Fecundity = 1133 + 35.67 (Age)	r=.2553
1985	n=24	Absolute Fecundity = 100 + 91.93 (Age)	r=.6908

[1] regression coefficient

Appendix 27. Maturity schedule of length at maturity for male (M) and female (F) lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982, 1984.

		1982			1984		
Length (cm)	Sex	n	# mature	% mature	n	# mature	% mature
13-14	M	1	0	0	2	0	0
	F	1	0	0	6	0	0
15-16	M	-	-	-	-	-	-
	F	5	0	0	3	0	0
17-18	M	-	-	-	-	-	-
	F	1	0	0	3	0	0
19-20	M	-	-	-	9	0	0
	F	3	0	0	11	0	0
21-22	M	-	-	-	10	0	0
	F	4	0	0	18	0	0
23-24	M	8	0	0	22	0	0
	F	5	0	0	36	0	0
25-26	M	9	0	0	10	0	0
	F	21	0	0	19	0	0
27-28	M	7	1	14.3	10	2	20.0
	F	11	0	0	13	1	7.8
29-30	M	5	2	40.0	3	1	33.3
	F	3	0	0	11	0	0
31-32	M	2	0	0	8	5	62.5
	F	-	-	-	9	1	11.1
33-34	M	1	1	100.0	7	6	85.7
	F	-	-	-	12	2	16.7
35-36	M	3	2	66.6	14	11	78.6
	F	7	6	85.7	15	7	46.7
37-38	M	5	4	80.0	9	6	66.7
	F	4	4	100.0	13	8	61.5
39-40	M	5	5	100.0	15	15	100.0
	F	4	2	50.0	15	11	73.3
41-42	M	3	2	66.6	8	8	100.0
	F	2	2	100.0	12	12	100.0

Appendix 27 (continued)

43-44	M	4	3	75.0	5	5	100.0
	F	4	4	100.0	6	5	83.3
45-46	M	-	-	-	2	2	100.0
	F	1	1	100.0	3	3	100.0
47-48	M	-	-	-	2	2	100.0
	F	1	1	100.0	4	4	100.0
49-50	M	1	1	100.0	1	1	100.0
	F	1	1	100.0	4	4	100.0
51-52	M	-	-	-	-	-	-
	F	1	1	100.0	4	2[1]	100.0
53-54	M	1	1	100.0	-	-	-
	F	-	-	-	-	-	-
55-56	M	1	1	100.0	1	1	100.0
	F	-	-	-	1	1	100.0
57-58	M	-	-	-	1	1	100.0
	F	-	-	-	-	-	-
59-60	M	-	-	-	1	1	100.0
	F	-	-	-	2	2	100.0
67-68	M	-	-	-	1	1	100.0
	F	-	-	-	-	-	-
69-70	M	1	1	100.0	-	-	-
	F	-	-	-	1	1	100.0
71-72	M	-	-	-	-	-	-
	F	-	-	-	1	1	100.0
77-78	M	-	-	-	-	-	-
	F	-	-	-	1	1	100.0
79-80	M	-	-	-	1	1	100.0
	F	-	-	-	-	-	-

[1] large lake trout with very little gonadal development may be alternate year spawners.

Appendix 28. Maturity schedule of age at maturity for male (M) and female (F) lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982, 1984.

Age	Sex	1982 n	1982 # mature	1982 % mature	1984 n	1984 # mature	1984 % mature
2	M	1	0	0	1	0	0
	F	4	0	0	5	0	0
3	M	1	0	0	3	0	0
	F	4	0	0	7	0	0
4	M	5	0	0	4	0	0
	F	3	0	0	17	0	0
5	M	12	0	0	3	1	33.3
	F	18	0	0	6	0	0
6	M	8	2	25.0	2	0	0
	F	14	0	0	5	0	0
7	M	5	2	40.0	8	6	75.0
	F	8	0	0	7	1	14.3
8	M	3	1	33.3	2	1	50.0
	F	5	3	60.0	11	5	45.4
9	M	2	2	100.0	7	6	85.7
	F	2	2	100.0	10	6	60.0
10	M	1	1	100.0	8	7	87.5
	F	3	3	100.0	8	7	87.5
11	M	1	1	100.0	2	2	100.0
	F	2	2	100.0	6	6	100.0
12	M	-	-	-	-	-	-
	F	3	3	100.0	1	1	100.0
13	M	2	2	100.0	3	3	100.0
	F	4	3	75.0	5	5	100.0
14	M	1	1	100.0	-	-	-
	F	2	2	100.0	4	4	100.0
15	M	2	2	100.0	2	2	100.0
	F	-	-	-	1	1	100.0
16	M	3	3	100.0	1	1	100.0
	F	1	1	100.0	2	2	100.0

Appendix 28 (continued)

17	M	4	4	100.0	1	1	100.0
	F	-	-	-	1	1	100.0
18	M	-	-	-	-	-	-
	F	-	-	-	-	-	-
19	M	-	-	-	-	-	-
	F	1	1	100.0	-	-	-
20	M	-	-	-	-	-	-
	F	1	1	100.0	-	-	-
21	M	-	-	-	-	-	-
	F	-	-	-	1	1	100.0
22	M	1	1	100.0	1	1	100.0
	F	-	-	-	-	-	-
23	M	-	-	-	-	-	-
	F	-	-	-	1	1	100.0
24	M	-	-	-	-	-	-
	F	1	1	100.0	-	-	-
25	M	-	-	-	-	-	-
	F	-	-	-	2	2	100.0
26	M	1	1	100.0	-	-	-
	F	-	-	-	-	-	-

Appendix 29. Catch and effort of multifilament, monofilament and combined gill nets differentiated by depth for lake trout (*Salvelinus namaycush*) in Squeers Lake, Ontario, 1982(1), 1984(2).

Depth (m)		Multifilament			Monofilament			Combined Gear		
		Effort[1]	Catch[2]	CPUE[3]	Effort	Catch	CPUE	Effort	Catch	CPUE
0-5	(1)	135	2	.0148	90	0	0	225	2	.0089
	(2)	540	1	.0018	210	1	.0048	750	2	.0027
6-10	(1)	-	-	-	90	7	.0778	90	7	.0778
	(2)	810	18	.0222	120	8	.0667	930	26	.0279
11-15	(1)	135	7	.0518	-	-	-	135	7	.0518
	(2)	540	24	.0444	135	6	.0444	675	30	.0444
16-20	(1)	-	-	-	90	27	.3000	90	27	.3000
	(2)	135	2	.0148	-	-	-	135	2	.0148
21-25	(1)	-	-	-	135	20	.1481	135	20	.1481
	(2)	270	10	.0370	225	63	.2800	495	73	.1475
26-30	(1)	-	-	-	225	82	.3644	225	82	.3644
	(2)	270	17	.0630	270	121	.4481	540	138	.2555
31-35	(1)	135	12	.0888	-	-	-	135	12	.0888
	(2)	135	20	.1481	45	18	.4000	180	38	.2111
Total	(1)	405	21	.0518	630	136	.2158	1035	157	.1517
	(2)	2700	92	.0341	1005	217	.2159	3705	309	.0834

[1] metres of net
[2] numbers of fish
[3] numbers of fish/metre of net

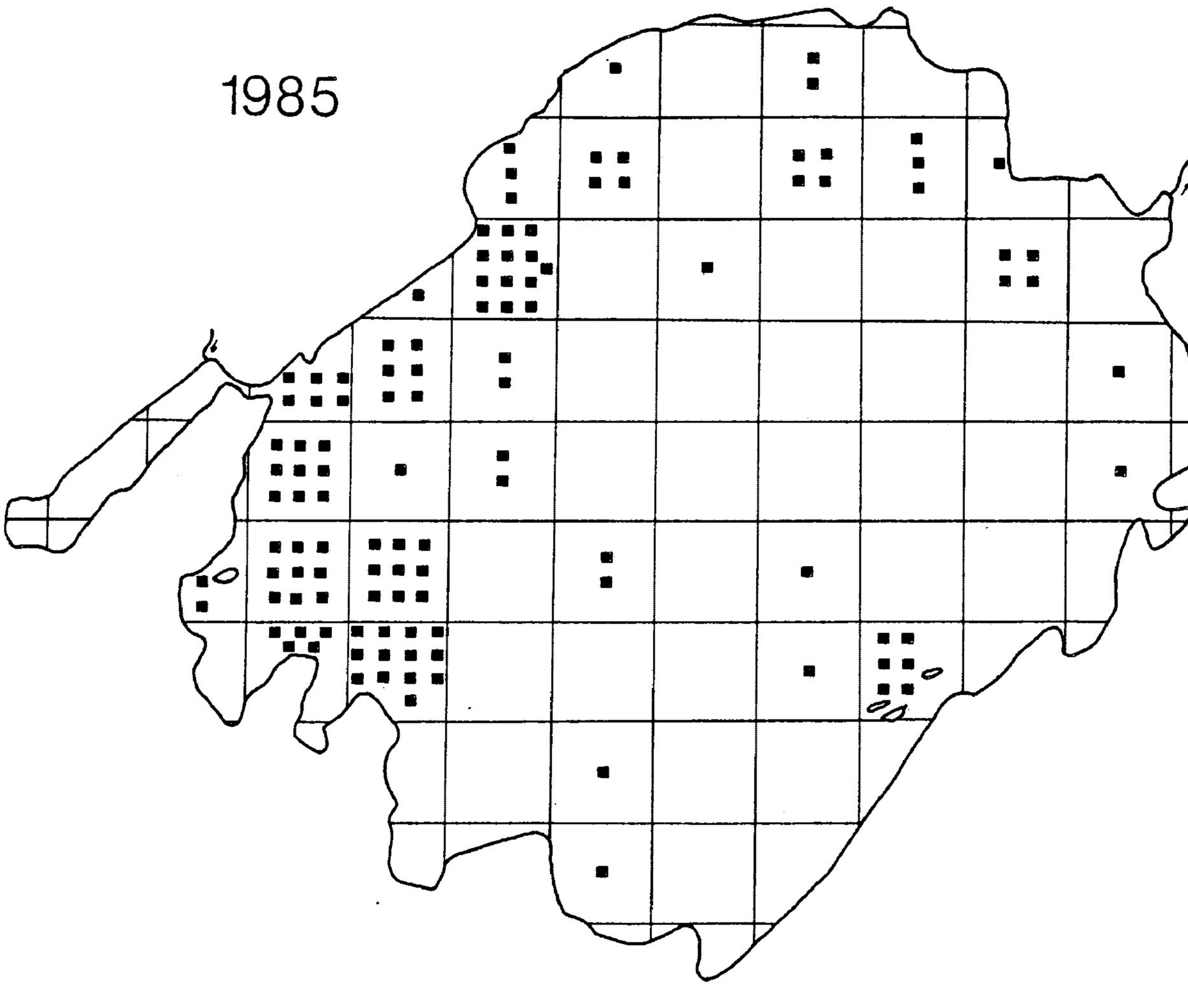
Appendix 30. Size of lake trout (Salvelinus namaycush) captured at varying depths in Squeers Lake, Ontario, 1982, 1984.

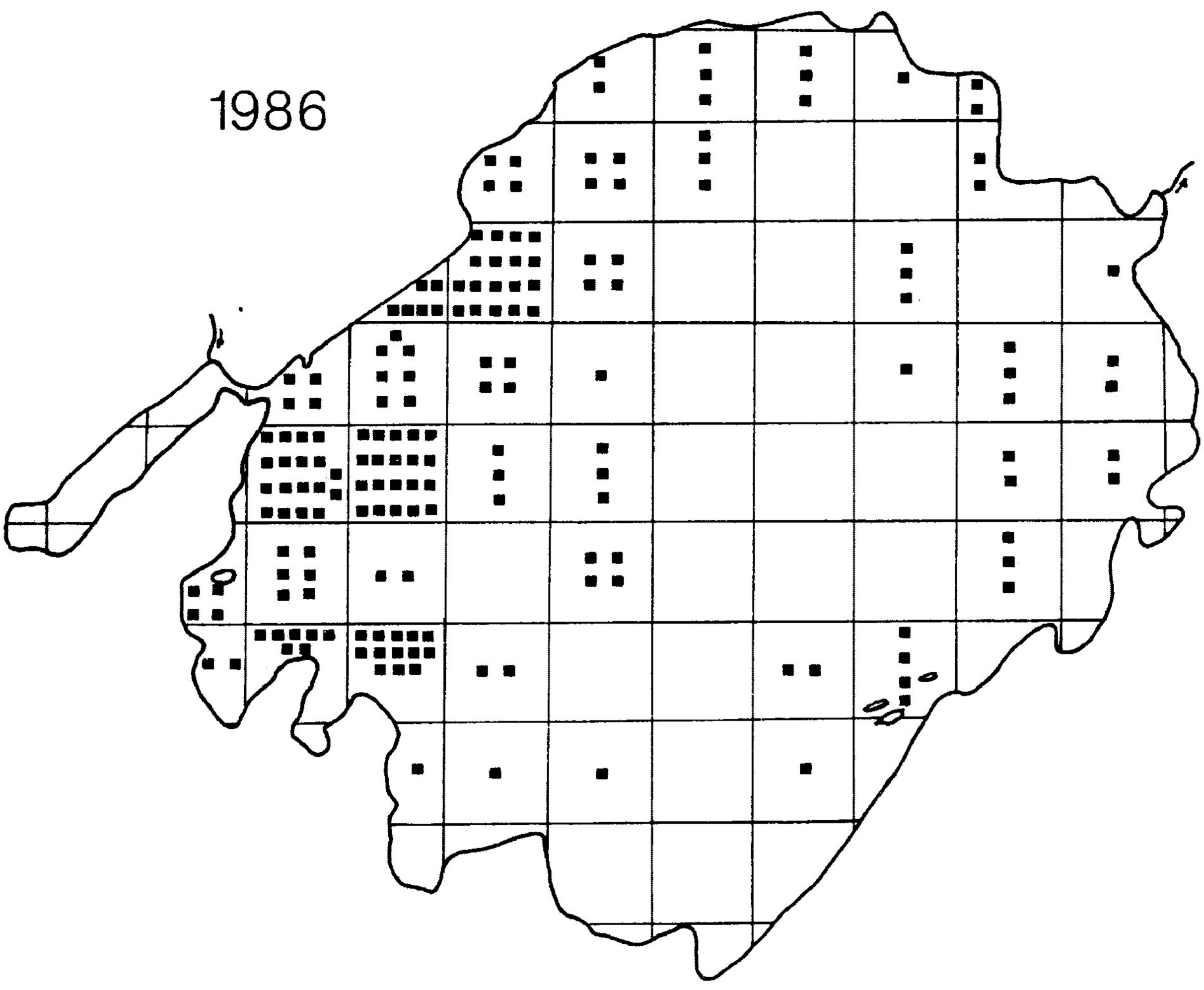
Length (cm)	Year	Depth (m) 0-5	6-10	11-15	16-20	21-25	26-30	31-35	Total
10-11	1982	0	1	0	0	0	0	0	1
	1984	0	1	0	0	0	1	0	1
12-13	1982	0	0	0	2	0	0	0	2
	1984	0	0	0	0	2	4	0	6
14-15	1982	0	1	0	1	0	5	0	7
	1984	0	2	0	0	1	8	0	11
16-17	1982	0	0	0	1	0	1	0	2
	1984	0	0	0	0	0	6	0	6
18-19	1982	0	0	0	0	0	5	0	5
	1984	0	1	0	0	0	17	3	20
20-21	1982	0	0	0	0	0	8	1	9
	1984	0	0	0	0	0	13	3	3
22-23	1982	0	0	0	1	0	12	2	15
	1984	0	1	0	3	1	46	5	56
24-25	1982	0	0	0	6	1	24	1	32
	1984	0	3	1	6	1	22	6	39
26-27	1982	0	0	2	0	11	5	5	23
	1984	0	2	0	2	0	13	1	18
28-29	1982	0	0	0	2	0	6	1	9
	1984	1	1	1	0	3	5	1	12
30-31	1982	0	1	0	1	1	3	0	6
	1984	0	1	1	2	1	5	1	11
32-33	1982	0	0	0	0	0	1	1	2
	1984	0	3	4	2	4	1	1	15
34-35	1982	0	1	1	2	1	2	0	7
	1984	0	1	2	2	2	5	0	14
36-37	1982	0	0	0	3	3	1	0	7
	1984	0	5	3	2	8	3	1	22
38-39	1982	0	1	1	4	6	1	0	13
	1984	0	1	0	6	6	1	1	15
40-41	1982	0	1	0	1	2	0	0	4
	1984	0	4	2	2	4	1	1	14
42-43	1982	0	1	1	0	5	0	1	8
	1984	0	2	3	1	2	1	0	9
44-45	1982	0	0	0	0	0	1	0	1
	1984	0	3	2	0	1	0	0	6
46-47	1982	0	1	0	0	0	0	0	0
	1984	0	2	2	0	0	0	0	4
48-49	1982	0	0	0	0	0	1	0	1
	1984	0	2	2	0	0	0	0	0
50-51	1982	0	0	0	0	0	2	0	2
	1984	0	0	0	2	0	1	0	3
52-53	1982	0	1	0	0	1	0	0	2
54-55	1982	0	1	0	0	0	0	0	1
	1984	0	2	0	0	0	0	0	2

Appendix 30 (continued)

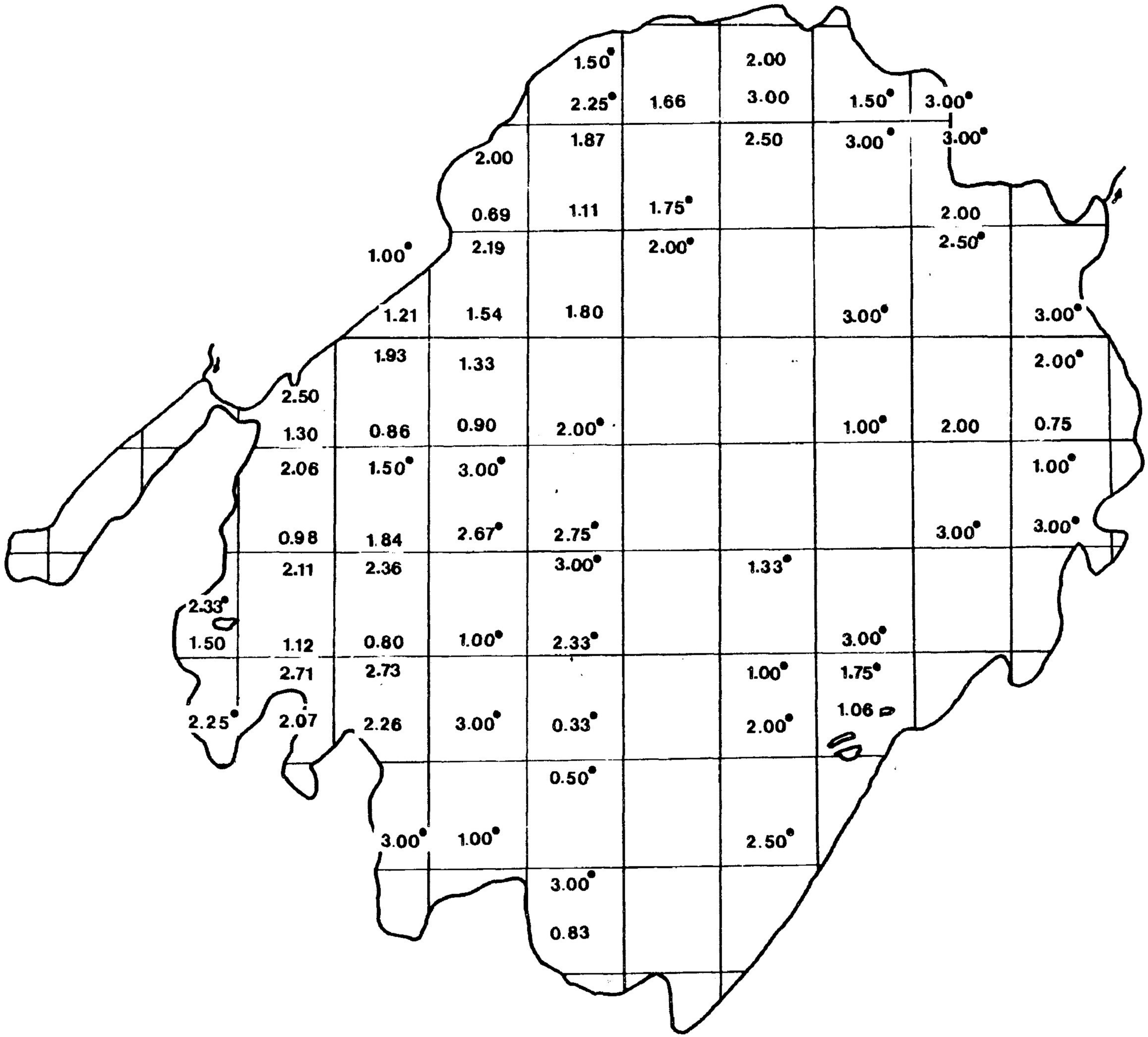
56-57	1984	0	2	0	0	0	0	0	2
58-59	1984	0	1	0	0	0	0	0	1
68-69	1984	0	0	0	0	1	0	0	1
72-73	1984	0	0	0	0	0	1	0	1
76-77	1984	0	0	0	0	0	1	0	1
78-79	1984	0	0	0	0	0	1	0	1
Total	1982	0	9	4	26	20	84	12	155
	1984	1	36	22	30	39	157	24	309

Appendix 31. Catch by grid for 1985 and 1986 winter fisheries in Squeers Lake, Ontario (1 square equals 5 fish)


1985


1986

Appendix 32. Harvest of lake trout per angler in the 1985 and 1986 winter fisheries in Squeers Lake, Ontario (number on top of grid is 1985 harvest and number on bottom is 1986 harvest.


1.50•
2.00
2.25•
1.66
3.00
1.50•
3.00•
1.87
2.50
3.00•
3.00•
2.00
0.69
1.11
1.75•
2.00
1.00•
2.19
2.00•
2.50•
1.21
1.54
1.80
3.00•
3.00•
1.93
1.33
2.00•
2.50
1.30
0.86
0.90
2.00•
1.00•
2.00
0.75
2.06
1.50•
3.00•
1.00•
0.98
1.84
2.67•
2.75•
3.00•
3.00•
2.11
2.36
3.00•
1.33•
2.33•
1.50
1.12
0.80
1.00•
2.33•
3.00•
2.71
2.73
1.00•
1.75•
1.06
2.25•
2.07
2.26
3.00•
0.33•
2.00•
0.50•
3.00•
1.00•
2.50•
3.00•
0.83

Appendix 33. Daily catch, effort and catch per unit effort (CPUE) data for lake trout (*Salvelinus namaycush*) captured by angling in Squeers Lake, Ontario, 1984, 1985.

Date	Effort (angler hrs)	Catch	CPUE
1984			
May 16	8.33	38	4.56
17	15.50	42	2.71
18	14.83	43	2.90
19	10.50	17	1.62
20	9.67	29	3.00
21	7.50	23	3.10
22	13.50	27	2.00
31	9.33	8	.86
June 1	12.33	7	.57
2	9.27	2	.22
3	4.33	1	.23
4	9.00	17	1.89
5	5.83	5	.86
Total	129.90	259	1.99
1985			
May 2	8.98	9	1.00
3	12.84	23	1.79
4	7.75	5	.65
5	14.82	23	1.55
6	10.67	10	.94
7	13.51	8	.59
8	11.98	7	.58
9	19.98	12	.60
13	6.50	10	1.54
14	10.40	16	1.54
15	9.88	19	1.92
16	6.82	4	.59
17	10.61	15	1.41
18	27.63	28	1.01
19	12.66	6	.47
20	6.89	4	.58
21	11.82	11	.93
Total	203.74	210	1.03

Appendix 34. Yield of lake trout (*Salvelinus namaycush*) at varying fishing intensities by age class employing Ricker's Yield model (1975) in Squeers Lake, Ontario, 1986.

1X Fishing Intensity .067

Age Group	G[1]-M[2]-F[3]	e^{G-M-F}	Wt[4]	Wt X F
			791	53
8-9	- .1324	.8760	693	46
9-10	- .0357	.9649	669	45
10-11	- .3456	.7078	474	32
11-12	- .4482	.6388	303	20
12-13	.0140	1.0140	307	21
13-14	- .5838	.5578	171	11
14-15	- .0030	.9970	170	11
15-16	.0090	1.0090	172	11
16-17	- .6422	.5261	90	6
17-18	- .8799	.4148	37	2
18-19	.0090	1.0090	38	3
19-20+	- .5625	.5698	2	2
				263

2X Fishing Intensity .134

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	106
8-9	- .1994	.8192	648	87
9-10	- .1027	.9024	585	78
10-11	- .4126	.6619	387	52
11-12	- .5152	.5974	231	31
12-13	- .0530	.9484	219	29
13-14	- .6508	.5216	114	15
14-15	- .0700	.9324	106	14
15-16	- .0580	.9436	100	13
16-17	- .7092	.4920	49	7
17-18	- .9469	.3879	19	3
18-19	- .0580	.9436	18	2
19-20+	- .6295	.5328	10	1
				438

Appendix 34 (continued)

3X Fishing Intensity .201

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	159
8-9	- .2664	.7661	606	122
9-10	- .1697	.8439	511	103
10-11	- .4796	.6190	316	63
11-12	- .5822	.5587	177	36
12-13	- .1200	.8869	157	32
13-14	- .7178	.4878	76	15
14-15	- .1370	.8720	67	13
15-16	- .1250	.8825	59	12
16-17	- .7762	.4601	27	5
17-18	-1.0140	.3628	10	2
18-19	- .1250	.8825	9	2
19-20+	- .6970	.4983	4	1
				565

4X Fishing Intensity .268

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	212
8-9	- .3334	.7165	567	152
9-10	- .2367	.7892	447	120
10-11	- .5466	.5789	259	69
11-12	- .6492	.5225	135	36
12-13	- .1870	.8294	112	30
13-14	- .7848	.4562	51	14
14-15	- .2040	.8155	42	11
15-16	- .1920	.8253	34	9
16-17	- .8432	.4303	15	4
17-18	-1.0810	.3393	5	1
18-19	- .1920	.8253	4	1
19-20+	- .7635	.4660	2	0
				659

5X Fishing Intensity .335

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	265
8-9	- .4004	.6700	530	177
9-10	- .3037	.7381	391	131
10-11	- .6136	.5414	212	71
11-12	- .7162	.4886	103	35
12-13	- .2540	.7757	80	27
13-14	- .8518	.4266	34	11
14-15	- .2710	.7626	26	9
15-16	- .2590	.7718	20	7
16-17	- .9102	.4024	8	3
17-18	-1.1480	.3173	3	1
18-19	- .2590	.7718	2	1
19-20+	- .8305	.4358	1	0
				738

Appendix 34 (continued)

6X Fishing Intensity .402

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	318
8-9	- .4674	.6266	496	199
9-10	- .3707	.6902	342	137
10-11	- .6806	.5063	173	69
11-12	- .7832	.4569	79	32
12-13	- .3210	.7254	57	23
13-14	- .9188	.3990	23	9
14-15	- .3380	.7132	16	6
15-16	- .3260	.7218	12	5
16-17	- .9772	.3764	4	2
17-18	-1.2150	.2967	1	0
18-19	- .3260	.7218	1	0
19-20+	- .8975	.4076	0	0
				800

7X Fishing Intensity .469

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	371
8-9	- .5344	.5860	463	217
9-10	- .4377	.6455	299	140
10-11	- .7476	.4735	142	67
11-12	- .8502	.4273	60	28
12-13	- .3880	.6784	41	19
13-14	- .9858	.3731	15	7
14-15	- .4050	.6670	10	5
15-16	- .3930	.6750	7	3
16-17	- 1.044	.3520	2	1
17-18	- 1.282	.2775	1	0
18-19	- .3930	.6750	0	0
19-20+	- .9645	.3812	0	0
				858

8X Fishing Intensity .536

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	424
8-9	- .6014	.5480	433	232
9-10	- .5047	.6037	261	140
10-11	- .8146	.4428	116	62
11-12	- .9172	.3996	46	25
12-13	- .4550	.6344	31	17
13-14	-1.0530	.3489	11	6
14-15	- .4720	.6237	7	4
15-16	- .4910	.6120	4	2
16-17	-1.1110	.3292	1	1
17-18	-1.3490	.2595	0	0
				913

Appendix 34 (continued)

9X Fishing Intensity .603

Age Group	G-M-F	e^{G-F-M}	Wt	Wt X F
			791	477
8-9	- .6684	.5125	405	244
9-10	- .5717	.5646	229	138
10-11	- .8816	.4141	95	57
11-12	- .9842	.3737	35	21
12-13	- .5220	.5933	21	13
13-14	-1.1200	.3263	7	4
14-15	- .5390	.5833	4	2
15-16	- .5580	.5723	2	1
16-17	-1.1780	.3079	1	1
17-18	-1.4160	.2427	0	0
				958

10X Fishing Intensity .670

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	530
8-9	- .7354	.4793	379	254
9-10	- .6387	.5280	200	134
10-11	1.0160	.3620	72	48
11-12	-1.1180	.3269	24	16
12-13	- .5890	.5549	13	9
13-14	-1.2540	.2854	4	3
14-15	- .6060	.5455	2	1
15-16	- .5940	.5521	1	1
16-17	-1.2450	.2879	0	0
				996

15X Fishing Intensity 1.005

Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	795
8-9	-1.0700	.3430	271	272
9-10	- .9737	.3777	102	102
10-11	-1.2840	.2770	28	28
11-12	-1.3860	.2501	7	7
12-13	- .9240	.3969	3	3
13-14	-1.5220	.2183	1	1
14-15	- .9410	.3902	0	0
				1208

Appendix 34 (continued)

20X Fishing Intensity		1.340		
Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	1060
8-9	-1.4050	.2454	194	260
9-10	-1.3090	.2701	52	70
10-11	-1.6190	.1981	10	13
11-12	-1.7120	.1789	2	3
12-13	-1.2590	.2839	0	0
				1406

25X Fishing Intensity		1.675		
Age Group	G-M-F	e^{G-M-F}	Wt	Wt X F
			791	1325
8-9	-1.740	.1755	139	233
9-10	-1.644	.1932	27	45
10-11	-1.954	.1417	4	7
11-12	-1.594	.2031	0	0
				1610

[1] instantaneous rate of growth
[2] instantaneous rate of mortality
[3] instantaneous rate of fishing mortality
[4] weight in grams