Results of a Nine Year Study (1972-80) of the Sport Fishing Exploitation of Lake Trout (*Salvelinus namaycush*) on Great Slave and Great Bear Lakes, NWT: the Nature of the Resource and Management Options

G.C.B. Yaremchuk

Western Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

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by

G. C. B. Yaremchuk

Western Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

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ABSTRACT

Yaremchuk, G.C.B. 1986. Results of a nine year study (1972-80) of the sport fishing exploitation of lake trout (Salvelinus namaycush) on Great Slave and Great Bear lakes, NWT: the nature of the resource and management options. Can. Tech. Rep. Fish. Aquat. Sci .1436: vi + 80 p.

Data from creel census, tagging, and experimental gillnetting at sport fishing lodges on Great Slave and Great Bear lakes are examined in order to ascertain the status of lake trout (Salvelinus namaycush) stocks in the lakes and develop a rationale for their management. Tag returns suggest that a small percentage of trout move long distances but the average movement is so small that the fish in different areas of the lake, exploited by different lodges, should be managed as separate stocks.

At most lodges age and length distributions of fish sampled from the catch shifted from large, old fish to smaller, younger fish during the early seventies, but are now stabilizing.

Total instantaneous mortality rate, determined by analysis of catch curves derived from otolith growth zone data, varies widely between lodges and years. Recent estimates vary between 0.17 and 0.33. Instantaneous natural mortality rate is estimated at 0.09.

Density of fish older than 20 yr is estimated at 0.49 fish/ha for shallow inshore waters.

The lake trout in Great Slave Lake grow more quickly than those in Great Bear Lake, particularly at larger sizes. Lake trout in Great Slave Lake mature at ages 7-14 while those in Great Bear Lake mature at ages 10-16. Historical yields, particularly of extremely large fish from Great Bear Lake, exceed equilibrium yield predictions generated by a Ricker yield per recruit model. However, yields have decreased to approximately 0.4 kg/utilized ha on Great Slave Lake and approximately 0.3 kg/ha on Great Bear Lake, lower than the estimated maximum sustainable yields for inshore areas of 0.60 kg/ha for Great Slave lake and 0.36 kg/ha for Great Bear Lake.

Effects of exploitation level on angling quality and possible alternate uses of the resource are discussed. A socio-economic study of the values of the resource to various uses and limitation of aggregate yields to prevent management of the resource for short-term objectives are recommended.

Key words: mortality rate; growth rate; yield per recruit; maximum sustainable yield; modelling; economics; tagging; population density.

RÉSUMÉ

Yaremchuk, G.C.B., 1986. Results of a nine year study (1972-80) of the sport fishing exploitation of lake trout Salvelinus namaycush) on Great Slave and Great Bear Lakes, NWT: the nature of the resource and management options. Can. Tech. Rep. Fish. Aquat. Sci. 1436: vi + 80 p.

Les données obtenues par le dénombrement des prises, des travaux d'étiquetage et la pêche expérimentale au filet maillant dans les stations de pêche sportive situées sur le Grand lac des Esclaves et le Grand lac de l'Ours sont examinées afin d'établir l'état des stocks de touladi (Salvelinus namaycush) dans ces lacs et d'élaborer principes pour leur gestion. Les données obtenues grâce aux étiquettes retournées semblent indiquer qu'un faible pourcentage de touladis se déplacent sur de longues distances, et que le déplacement moyen est si minime qu'il faudrait gérer comme des stocks distincts les populations des divers secteurs de ces lacs, exploitées à l'heure actuelle par des stations différentes.

Dans la plupart des stations, la distribution selon l'âge et la longueur des sujets échantillonnés dans les prises avait permis de constater la diminution progressive, au cours des années 1970, de la taille et de l'âge des sujets, mais la situation est maintenant en voie de stabilisation.

Le taux de mortalité totale instantanée, établi par l'analyse des prises tirées de données sur les cercles de croissance otolithiques, varie énormément d'une station à l 'autre et d'année en année. Les récentes estimations le situent entre 0,17 et 0,33. Le taux de mortalité naturelle instantanée est évalué à 0,09.

La densité des poissons de plus de 20 ans est évaluée à 0,49 par ha, pour ce qui est des eaux peu profondes près du littoral.

Le touladi du Grand lac des Esclaves croît plus rapidement que celui du Grand lac de l'Ours, et cela est particulièrement vrai des plus gros sujets. Le touladi du Grand lac des Esclaves atteint sa maturité entre 7 et 14 ans, tandis que celui du Grand lac de l 'Ours l'atteint entre 10 et 16 ans.

Les taux de rendement antérieurs, en particulier pour ce qui est des très gros poissons du Grand lac de l'Ours, dépassent les prévisions de rendement équilibré produites à l'aide d'un modèle de rendement par recrue de Ricker. Les rendements ont toutefois décru jusqu'à environ 0,4 kg par ha exploitée dans le Grand lac des Esclaves et à environ 0,3 kg par ha dans le Grand lac de l'Ours, ce qui est inférieur aux taux estimatifs de rendement maximum soutenu pour les secteurs du littoral, de l'ordre de 0,60 kg par ha et de 0,36 kg par ha, pour le Grand lac des Esclaves et le Grand lac de l'Ours, respectivement.

Les incidences du niveau d'exploitation sur la qualité de pêche et d'autre possibilités d'utilisation de cette ressource sont abordées dans le rapport. On recommande la réalisation d'une étude socio-économique des valeurs de cette ressource selon le genre d'utilisation ainsi que la limitation de l'exploitation globale afin de prévenir la gestion de cette ressource en fonction d'objectifs â court terme.

Mots-clés: taux de mortalité; taux de croissance; rendement par recrue; rendement maximum soutenu; modélisation; facteurs économiques; étiquetage; densité de la population.

INTRODUCTION

BACKGROUND

Prior to 1960 Great Bear Lake and the east arm of Great Slave Lake contained large stocks of unusually large lake trout (Salvelinus namaycush). During the nineteen sixties a number of sport fishing lodges were built on the lakes. These lodges have become an important part of the local economy. Because commercial net fishing was uneconomic, the resource was largely reserved for the use of this sport lodge industry. Exploitation continued through the sixties. Neither harvest levels nor the effects of exploitation on the resource were monitored during this period. In the early seventies concerns were expressed that exploitation might be reducing lake trout stocks. Conflicts between net fishing and the sport lodge industry were also growing. Data were not available on the abundance of lake trout in the lakes, stock/ recruitment relationships for lake trout, or the relation between density and lake trout growth rates.

In 1972 the Department of Fisheries and Oceans (DFO), which has responsibility for the management of fisheries in the Northwest Territories, commenced an investigation of the status of the lake trout sport fishing industry on Great Bear Lake and the east arm of Great Slave Lake. The objectives of the study were:

1) to determine the level of exploitation of lake trout stocks by the sport lodge industry;
2) to determine the effects of this exploitation on the stocks;
3) to produce preliminary predictions on the responses of the stocks to different levels of exploitation.

Summaries of the data from these investigations have been published in a series of reports (Falk et al. 1973, 1974a, 1974b, 1975, 1981, 1982; Gillman and Roberge 1982; Moshenko and Gillman 1978a, 1978b, 1983).

This report integrates the data obtained during the course of these studies to arrive at conclusions on the status of the lake trout stock in the vicinity of each of the lodges.

The data is also analyzed for information on the relations between exploitation level and lake trout growth rates and maturation. Estimates of natural mortality and population density are produced. Simple mathematical modeling is used to produce estimates of sustainable yield, standing stock, and size composition of the catch under different exploitation strategies.

The results of these analyses and information on the responses of other lake trout stocks to exploitation are applied in evaluation of future options for use of the resource.

DESCRIPTION OF THE LAKES

Great Bear Lake is an extremely oligotrophic lake located in the Northwest Territories of Canada between 65° and 67° north latitude and 118° and 125° west longitude. The lake has a water surface area of 30 397 km^2 with a mean depth of 71.7 m. Water clarity is high with maximum Secchi transparencies of 30 m. Dissolved solids are low (78.4 to 81.0 ppm) and pH ranges between 7.8 and 7.9 (Johnson 1975a). Lake trout are widely distributed in the lake, reaching greatest densities in depths less than 24 m. Lake whitefish (Coregonus clupeaformis) have a limited distribution within the lake, occurring along the edges of the large bays (Johnson 1975b). Ciscos (Coregonus sp.) occur throughout the lake.

Great Slave Lake is located approximately 300 km to the southeast of Great Bear Lake between 61° and 63° north latitude and 109° and 117° west longitude. The lake has two distinct regions: a western basin of 14 400 km^2 (water area) lying within a region of Paleozoic sedimentary rock, the Mackenzie lowlands, and an eastern arm of 5 980 km^2 (water area) lying within the Precambrian Shield. Mean depth in the western basin is 41 m and 45% of the basin is less than 25 m deep. The east arm is much deeper, with an irregular bottom, maximum depth of 625 m, and mean depths for the various sections and arms varying between 76 m and 249 m. Turbidity is higher in the western basin with maximum Secchi disc readings of less than 5 m, compared to a maximum of 17 m in the east arm. The western basin has a pH of 7.7-8.3. The east arm has a pH of 6.6-6.9 (Rawson 1950). Dissolved solids are lower in the east arm. Warming starts approximately a month later in the east arm resulting in lower mean surface temperatures than found in the west. Lake trout, lake whitefish, and ciscos, among other species, occur throughout the lake (Rawson 1947). Densities of lake whitefish are higher in the generally more productive western basin while lake trout are more common in the more oligotrophic east arm (Keleher 1972).

HISTORY OF FISHERIES AND REGULATORY MEASURES

Miller (1947) reported limited use of the fish of Great Bear Lake by domestic fisheries based at Fort Franklin (estimated annual yield 186 600 kg all species) and by two domestic whitefish fisheries at the Johnny Hoe and Whitefish rivers. The Fort Franklin fishery still exists and takes an undetermined quantity of lake trout and whitefish from Keith Arm and the two rivers.

There has never been a commercial net fishery on Great Bear Lake. Sport fishing lodge development began in the 1960's with the establishment of four lodges in McTavish Arm (Falk et al. 1973). In the late 60's two of these lodges relocated to other parts of the lake and a new lodge was established on Smith Arm. A sixth lodge, Sah-Tew, operates intermittently in the Fort Franklin area. Histories and guest capacities of the lodges are listed in Table 1. Prior to 1974 daily catch and possession limits for lake trout were 5 and 10 respectively. In 1974 these limits were reduced to 3 and 5. In 1979 they were further reduced to 2 and 3 with the additional limitation to possession of one lake trout in excess of 70 cm fork length

(Gillman and Roberge 1982). There has been little recent lodge expansion but there has been a trend towards shorter durations of stay, possibly resulting in larger seasonal numbers of anglers and increased harvests. Fishing appears to be constantly expanding into new areas of the lake in pursuit of large fish.

The fish of Great Slave Lake are currently being exploited by domestic, commercial, and sport fisheries. Rawson (1947) estimated an annual domestic harvest of all species of approximately 375 000 kg, taken in the immediate vicinities of nine communities. There has been a continuing domestic harvest in all areas of the lake, of unknown quantity, including a harvest taken with nets in the vicinity of Snowdrift in the east arm.

Commercial fishing commenced on Great Slave Lake in 1945. Lake whitefish were predominant in the western basin fishery and lake trout predominated in the east arm fishery (Keleher 1972). During the first 20 yr of the fishery trout harvests in the east arm averaged approximately 0.84 kg/ha. Catch of lake trout in the western basin fishery sharply declined after 1956. Bond and Turnbull (1973) detected signs of a similar decline in the east arm and in 1974, the east arm was closed to commercial fishing. Commercial fishing continues in the western basin with lake trout contributing approximately 7-8% of the catch.

Sport fishing lodge operations are largely limited to the east arm. The first lodge on Great Slave Lake was established in 1938 at Taltheilei Narrows (Keleher and Meeker 1962). A lodge was established in the Snowdrift area in the early 1960's. During the 60's three additional lodges were established, resulting in the current total of five. (Table 1, Falk et al. (1973). Fishing is primarily for lake trout. Catch and possession limits have been the same as for Great Bear Lake.

Although no expansion of the sport lodge industry has been allowed in recent years, increasing numbers of anglers who do not stay at lodges (itinerants) are fishing in Great Slave Lake. There is also a trend towards shorter durations of stay at lodges, resulting in higher numbers of guests in a season. There is continued pressure to allow expanded commercial fishing in the east arm.

MATERIALS AND METHODS

Field programs completed during the 1972-80 study are listed, by lodge, in Table 2.

Additional information on fishing effort was obtained from records of licence sales at the lodges and from DFO Field Services personnel.

CREEL CENSUS

Falk et al. (1974, 1975) and Moshenko and Gillman (1978a) described methods used in conducting the creel censuses. A complete creel census included collection of data by DFO personnel on effort, catch per unit effort (CPUE), areas fished, and quantity of harvest over most of the fishing season. A partial census included a subset of this data, often collected by lodge personnel (voluntary). Each day the number of people fishing was recorded and a sample of the anglers was questioned as to location and duration of fishing. The numbers of fish caught, brought back to the lodge (retained), and used as shore lunch were also recorded. Biological data was taken from a sample of the retained catch which usually did not include fish destined for taxidermy, a factor which introduces some bias into the data.

CPUE was calculated from the number of fish caught and time spent fishing. The average number of lake trout killed per angler, including fish used for trophies, fillets, and shore lunch, was multiplied by an estimate of the number of anglers using the lodge during the year to arrive at a yearly harvest. Release mortality of 7% of released fish was included in the total yield figures (Falk et al. 1974c). This estimate was multiplied by the mean weight of sampled fish to arrive at an annual yield in weight. Various estimates of the yearly total of anglers were used depending on data availability. In some cases the average number of anglers fishing each day during the census period was multiplied by the number of days the lodge was open. In other cases the seasonal number of anglers was estimated from licence sales or by multiplying an occupancy rate by the number of guest beds and the length of the season in weeks. In 1972 total yields were calculated for some lodges by applying average yields per angler from surveyed lodges to estimates of the seasonal total of anglers for lodges not surveyed.

Annual yields were divided by the number of hectares of trout habitat utilized by each lodge to arrive at yields per utilized hectare. Utilized hectares were defined as being the area of water within 1.61 km of a shore along which fishing was taking place. This definition is based on distribution of fishing effort and also reflects the bathymetry of the lakes and the preference of trout for depths of less than 40 m (Johnson 1975b).

EXPERIMENTAL NETTING

The experimental gillnetting program utilized 38 mm stretched measure gillnets to minimize netting mortality. Nets were set in areas utilized by the lodges.

TAGGING

Fish for tagging were caught by experimental gillnetting and, at Plummer's Great Slave Lake Lodge in 1973-74, by angling. Lake trout in good condition were tagged with numbered Floy tags using a Dennison tagging gun (Model DFM68). Tags were inserted on the left side of the fish near the base of the dorsal fin and anchored through the posterior pterigiophores. The fork length (±1 mm) of tagged trout was recorded. Trout were released immediately after tag3 ging. The tagging program was advertised and a reward was offered for tag returns.

BIOLOGICAL SAMPLING

Fork length (± 1 mm) and round weight (± 50 g) were recorded for samples of fish obtained by creel census and experimental gillnetting. Sex and maturity were determined by examination of the gonads. Prior to 1979 fish were assigned one of five maturity codes (Falk et al. 1973). This scale was modified in 1979 (Falk et al. 1981). All codes were converted to the equivalent 1979 code prior to analysis (Appendix 4).

Age was determined in all years except 1972 by counting annuli in the saggital otolith. The convex surface of the otolith was ground on a fine carborundum stone. The otolith was then emersed in a 3:1 solution of benzyl-benzoate and methyl salicylate and annuli were counted under a dissecting microscope.

DATA ANALYSIS

Histograms of percent frequency by age and fork length class were prepared for creel census and gillnet samples for each year for each lodge. Mean ages and lengths were calculated. Pairwise comparisons were made using Student's t-test.

Growth curves were fitted by eye for each lake. The effects of location within lakes (lodges) and year on length and weight at age were investigated using the Statistical Analysis System General Linear Models procedure (SAS 1979). The mean lengths attained at ages 7 and 17 were also compared among locations and year.

Mortality rates were calculated for each lodge and year using catch curve analysis. Catch curves were smoothed by a running average of three. Data were not pooled among year due to apparent changes in the age of full recruitment. The slopes of least squares regressions fitted to linear sections of the right hand limb of the curve were interpreted to represent mortality rates, following Ricker (1975). The first age class to the right of the dome of the curve was used as the age of full recruitment.

Due to the recent changes in the fishery, the slope of the first linear segment after the age of full recruitment was considered to represent the current mortality rate. Slopes of some linear segments further to the right were interpreted as to represent natural mortality before the fishery.

The Ricker yield per recruit model (Ricker 1975) was used to produce estimates of equilibrium yield under a range of ages of recruitment and fishing mortalities. The computer program described by Paulik and Baliff (1967) was used. Equilibrium yields of 'large' (longer than 700 mm) and 'trophy' (longer than 900 mm) lake trout were also calculated.

The model used an estimate of recruitment derived from data on apparent equilibrium catch and mortality rates at a lodge on Great Bear Lake and an estimate of natural mortality rate before the fishery derived by catch curve analysis.

Yield in weight was calculated using growth scale divisions of one year. Weight at age input was read from growth curves. The arithmetic mean of biomass over each year was used. Total yield in length was also calculated using growth curve lengths at age as input. This was divided by estimated yield in numbers, calculated by setting all weights at age in the Ricker model equal to one, to arrive at a mean length in the catch.

Standing stock of fish age 15 and older was calculated for each exploitation strategy by taking the integral from 15 to the age of recruitment of the exponential decay function

$$R_{T_1} \quad R_{T_0} e^{-M(T_1-T_0)}$$

(where R_{T1} is the number of fish alive at time T_1 (age of recruitment), R_{T0} is the number of fish alive at time T_0 (age 15), and M is the natural mortality rate) and adding the integral from the age of full recruitment to infinity of the similar equation describing decrease after recruitment (M is replaced with F+M where F = instantaneous fishing mortality).

Equilibrium catches of fish longer than 700 and 900 mm were estimated by computing the numerical yield of fish of each age class (the difference between estimates of number alive at successive ages as derived from the exponential decay function, multiplied by the fishing mortality divided by total mortality), multiplying this figure by an estimate of the fraction of fish within each age class over the target length, and summing over age classes. The fractions of fish longer than the two lengths in each age class were calculated by assuming a normal distribution of lengths at each age. The values of 700 and 900 mm were standardized by subtraction of the mean length at each age and division by the square root of the estimate of variance in length at age pooled for all ages. Variance in length at age displayed no trend over age. Probabilities of fish exceeding these values were then read from a table of the standard normal distribution.

RESULTS

AREAS UTILIZED BY LODGES

The areas of the lakes exploited by each lodge appear on Fig. 1 and Fig. 2. Detailed maps of areas utilized by the lodges are contained in Appendix 2. Estimates of the numbers of hectares utilized by each lodge appear in Table 3. No estimate is available for Arctic Circle Lodge.

RELEASE RATES

The release rate for trout caught at the lodges has generally increased (Table 4).

Changes in retention policy may be detected by examining catch curves for evidence of changes in the age of full recruitment. There is a trend towards a higher release rate for small fish. Age of full recruitment advanced at three lodges (Branson's Cameron Bay - 4 yr, Frontier - 6 yr, Arctic Star - 4 yr) during the period of the study, and now stands at over 19 yr for all lodges.

POPULATION AND HARVEST STATISTICS

Great Bear Lake

Yields and CPUE are presented by lodge and year in Table 5 together with sample sizes, mean lengths and ages, and catch curve instantaneous total mortality rates (Z) for all creel census and research gillnet samples. Length and age distributions for all samples are contained in Appendix 1.

Great Bear Trophy Lodge

Mean length in creel census samples ranged from 598 to 651 mm with grand mean of 610 mm (Table 5). The decrease in mean length between 1976 and 1980 was highly significant (P=0.006). Year to year variation was caused by the appearance and disappearance of a secondary mode of extremely small fish, rather than to a change in the primary mode or the disappearance of large fish.

Mean age in creel census samples ranged from 18.3 to 20.1 yr and generally followed mean length (Table 5). There were notably fewer fish older than 27 yr in samples taken after 1973.

The mean length of a sample collected with gillnets in 1980 was 623 mm while the modal length was 600-625 mm (Fig. 3).

The average estimate of total instantaneous mortality rate was 0.24. Right hand limbs of the catch curves were reasonably regular and linear (Fig. 4).

CPUE nearly doubled between 1976 and 1980. Total yield and yield per utilized hectare averaged 9 800 kg and 0.32 kg/ha respectively.

Plummer's Great Bear Lake Lodge: The mean length in creel census samples from this lodge did not change significantly between 1973 and 1977, averaging 664 mm over the two samples. The modal length class was constant at 625-650 mm.

In contrast mean age decreased significantly (P<0.001) from 27.6 to 25.3 yr. There was a decrease in the number of fish older than 30 yr. Age of full recruitment was stable at approximately 29 yr.

Total instantaneous mortality increased from 0.08 in 1973 to 0.27 in 1977 (Fig. 5). The 1973 catch curve probably does not represent mortality caused by the fishery. It corresponds roughly to the segment of the 1977 catch curve between ages 34 and 43 for which a mortality rate of 0.09 was calculated. The 1973 catch curve was highly irregular.

Yields decreased over the 1972-77 period (Table 5).

Great Bear Lodge: Mean length in creel census samples declined from 733 mm in 1972 to 619 mm in 1979. The modal length remained constant at 600-625 mm. Secondary modes are present in the 1973 data at 450-475 mm and in the 1979 data at 200-250 mm. There was a decline in the catch of fish longer than 712 mm.

Mean age increased but the 1979 mean is based on a small subsample. Heavy harvests of fish younger than 10 yr were taken in all years with secondary modes appearing in the age distributions at 6-9 yr. Age frequency distributions were highly irregular. Disregarding the mode of extremely young fish, full recruitment occurred at age 27-28.

Total mortality was estimated at 0.50 in 1973 (Fig. 6).

There was no trend in CPUE, which averaged 0.72 fish per angler hour.

Yield decreased from 11 050 kg (0.94 kg/ utilized ha) in 1974 to 4 976 kg (0.49 kg/ utilizes ha) in 1979.

Branson's Cameron Bay Lodge: Mean length in creel census samples increase from 632 mm in 1974 to 689 mm in 1978. Mean age advanced 4 yr during this period. These changes are probably at least partially due to an increase in the age of full recruitment from approximately 24 to 29 yr (Fig. 7).

The 1978 catch curve has a reasonably linear right arm (Fig. 7). A mortality rate of 0.17 was calculated for the 1978 data.

There was little change in CPUE, which averaged 0.84 fish per angler hour. Total yield decreased between 1974 and 1978 (Table 5).

Arctic Circle Lodge: Data are available from only one year.

Age of full recruitment was approximately 19 yr. The catch curve drawn from the data is highly irregular (Fig. 8). Mortality rate is estimated at 0.20.

Great Slave Lake

Yields and CPUE are presented by lodge and year in Table 6, as are sample sizes, mean lengths and ages, and mortality estimates. Length and age distributions for all samples are contained in Appendix 1.

Frontier Fishing Lodge: Mean length and age in creel census samples increased during the 1970's (Table 6). The increases between 1975 and 1980 are significant (P<0.001). Modal size and age classes also advanced from 550-575 mm to 650-675 mm and from 10 to 15 yr respectively. Age of recruitment advanced from 13 yr in 1973 to approximately 19 yr in 1980 (Fig. 10). At least some of the increases in mean lengths and age in the catch may be attributed to this.

Mean and modal lengths in a 38 mm gillnet sample were 252 mm and 500-525 mm, the lowest

observed in a gillnet sample from Great Slave Lake (Fig. 9).

The 1973-75 catch curves had reasonably linear descending arms (Fig. 10). The 1980 catch curve was irregular and no estimate of mortality rate could be obtained.

CPUE increased from 0.74 in 1974 to 1.22 in 1975. There was no trend in yield through 1975. The average was 9833 kg (0.23 kg/utilized ha).

Plummer's Great Slave Lodge: Mean length in the catch decreased sharply between 1972 and 1973 from 699 mm to 612 mm. Mean age was stable at 16-17 yr. Age of full recruitment was stable at approximately 15 years (Fig. 11).

Length distributions in a 38 mm gillnet sample were similar to those obtained at other lodges (Fig. 9). The mean length in the gillnet sample (572 mm) was between those obtained for Arctic Star Lodge and Trophy Lodge.

Catch curve mortalities were fairly consistent between years, averaging 0.18. Age of full recruitment remained stable at approximately 15 yr (Fig. 11).

Catch per angler hour varied little, averaging 0.45 fish. Yield fluctuated but showed no trend, averaging 12 450 kg or 1.48 kg/utilized hectare. This was the highest yield observed.

Indian Mountain Lodge: Data are available from Indian Mountain Lodge for only one year. Age of full recruitment was approximately 17 yr.

The descending limb of the catch curve (Fig. 12) changed slope at age 22, but is otherwise quite regular and linear.

Arctic Star Lodge: Mean length in the catch fluctuated widely during the study period. A significant ($P < 0.03$) drop from 667 to 576 mm occurred between 1974 and 1978.

Mean age rose from 15.2 to 21.4 yr between 1974. However, only 11 fish were aged in 1974 .

Little change was apparent in the length and age distributions. There was a slight increase in modal length and age with time. This reflects an increase in age of full recruitment from approximately 18 yr in 1973 to 21 yr in 1978 (Fig. 13).

Mean length in a gillnet sample taken in 1978 was between means for similar samples at Trophy and Great Slave lodges (Table 6). Mean age was the highest observed in a Great Slave lake gillnet sample.

The 1973 and 1978 catch curves (Fig. 13) were irregular giving an average mortality rate estimate of 0.16.

Yield statistics were very incomplete. The 1978 yield of 6 420 kg or 0.38 kg/utilized ha is probably more typical of the fishery than the 1978 yield of 2 960 kg.

Trophy Lodge: Mean length in the 1974 creel census sample was 517 mm, lowest of all lodges surveyed. Mean age in the 1979 catch was high (19.3), significantly higher than that in the 1974 sample (14.5, $p<0.01$). Modal length was low at 525-550 mm, however, age of full recruitment was relatively high at 20 yr (Fig. 14).

Mean length in the 1979 gillnet sample was the highest observed in any Great Slave Lake gillnet sample.

The catch curve for the 1979 creel census data was concave upwards towards its right hand tail. Mortality rates estimated from the 1979 creel census and gillnet samples averaged 0.14.

Yield was low, averaging 719 kg (0.16 kg/ utilized ha).

GROWTH AND MATURITY

Growth curves for lake trout in the two lakes are parallel for most of their lengths (Fig. 15). Great Slave lake trout are longer and heavier at most ages. The rate of increase in length decreases with increasing age. The weight curve indicates an increasing growth rate to about age 20. There appears to be more difference in growth rates between lodges on Great Slave than Great Bear Lake (Fig. 16).

A three way analysis of variance was performed for each lake using the SAS general linear model procedure. Lodge and year of sample had significant ($P<0.001$) effects on mean length and weight after blocking on age. A significant ($P<0.001$) interaction between lodge and year of sample was detected for Great Slave Lake. Interaction could not be tested for Great Bear Lake.

Ages of first and 100% maturity were generally lower for Great Slave Lake (Table 7), averaging 15 and 26 yr respectively for samples from Great Bear Lake and 11 and 17 yr respectively for samples from Great Slave Lake.

TAG RETURNS

The number of tag returns obtained from Great Bear lake was insufficient for analysis. The returns from Great Slave Lake indicated that most fish moved very little between tagging and recapture, with 65% of the trout at liberty up to nine months moving less than 5 km. Mean distances moved were quite high and had large standard deviations, indicating that most fish were sedentary with some moving long distances. Mean distance moved was not obviously related to location of tagging, size of fish or time at liberty (Tables 8 and 9).

EQUILIBRIUM YIELDS

Estimates of standing stock, total numerical yield, yield in weight, numerical yield of fish longer than 700 and 900 mm, and mean length in the catch, at equilibrium, are presented in Appendix 3. Estimates were calculated for ages of recruitment (A) from 15 to 28 yr and fishing mortalities (F) from 0.05 to 0.60.

Numerical yield is directly proportional to fishing mortality and inversely proportional to age of recruitment. Predicted yield ranges from 0.016 fish/utilized ha (A=28, F=0.05) to 0.16 fish/utilized ha (A=15, F=0.6, Fig. 17). Yield in weight follows a similar pattern, ranging from 0.066 and 0.097 (A=28, F=0.05) to 0.366 and 0.545 (A=15, F=0.60) kg/utilized ha on Great Bear and Great Slave lakes respectively. The biomass curve does not peak within the age range used. Mean length in the catch is directly proportional to age of recruitment and inversely proportional to fishing mortality, ranging from 582 mm and 623 mm to 699 mm and 782 mm on Great Bear and Great Slave lakes respectively.

The largest yield from Great Bear Lake of fish longer than 700 mm is negatively associated with age of recruitment and positively associated with fishing mortality (Fig. 18) and does not reach a maximum within the parameter range used. The largest predicted yield of fish longer than 700 mm was 0.5 kg/utilized ha (0.045 fish/utilized ha or 7.3 fish/km of shoreline).

On Great Slave Lake the highest predicted yield of fish longer than 700 mm, 0.068 fish/ utilize ha (11.0 fish/km of shoreline), is associated with ages of recruitment of 23 or 24 yr and high fishing mortalities (Fig. 18). Total sustainable yields for these strategies are predicted to exceed 0.078 fish or 0.40 kg per utilized ha, approximating current levels.

Maximum yield of fish longer than 900 mm would occur at ages of recruitment greater than 27 yr on both lakes. Exploitation strategies using recruitment ages higher than 28 yr were not considered due to the low numerical yields they would generate. Largest yield of fish longer than 900 mm is therefore predicted for ages of recruitment of over 27 yr on Great Slave and 28 yr on Great Bear (Fig. 19). Instantaneous fishing mortalities of between 0.1 and 0.3 are predicted to maximize yield of fish longer than 900 mm on Great Slave. Fishing mortalities in excess of 0.3 are predicted to produce the largest yields of large fish on Great Bear Lake. Largest predicted yields of fish longer than 900 mm are approximately 0.006 fish/utilized ha (0.96 fish/km of shoreline) on Great Slave Lake and 0.0006 fish/utilized ha (0.09 fish/km of shoreline) on Great Bear Lake (Appendix 3). These yields are associated with total yields of 0.18 kg (0.044 fish)/utilized ha on Great Bear and approximately 0.26 kg (0.047 fish)/utilized ha on Great Slave.

DISCUSSION

EFFECTS OF EXPLOITATION

Comparison of distributions of, and mean values for, lengths and ages of fish in samples collected in the same way in different years can provide an indication of changes occurring in the stock as a result of exploitation. Negative trends in any of these statistics indicate that the population has not attained a stable structure after an increase in exploitation rate and may indicate stock depletion. Low values indicate the possibility of a high exploitation rate and depleted stock. Mean age is the most direct indication of exploitation rate. Changes in length and weight can be mitigated by the increase in growth rate which usually accompanies exploitation. The interpretation of trends in sample means for size and weight must include consideration of the underlying distributions and the possibility of changes in sampling bias between sampling periods. Non-normality of the underlying distribution, such as skewdness or bimodality, to some extent invalidates statistical comparison of mean values, although the student's t-test is fairly robust against deviations from normality. Secondary modes of smaller, younger fish occurred at Great Bear Trophy and Great Bear lodges. Skewdness and biomodality may result from fluctuations in year class strength, sampling bias such as angler selectivity may introduce into a creel census sample, or some underlying population mechanism such as postulated by Johnson (1976).

A more important function of detailed analysis of distributions, particularly for a short time series of data, is the detection of groups of strong year classes which can cause the means for size and age to advance as the age classes age, even though the long term trend is downward. Groups of strong year classes will appear as secondary modes or skewdness in size or age distributions which move to the right with time.

Changes in the sampling method between sampling periods also hinder interpretation of size or age monitoring data. Positive trends in mean length and age may be due to changes in sampling bias towards larger, older fish. The data on release rates and advances in the age of full recruitment at three lodges (Branson's Cameron Bay - 4 yr, Frontier - 6 yr, Arctic Star - 4 yr) suggest that this occurred with the creel census data. An unknown proportion of the observed advances in mean length and age therefore may be due to the release of a greater proportion of smaller, younger fish rather than to increases in the population means.

The effects of depletion of exploited stocks on sample size and age distributions also may be masked in creel census data by the presence of fish from new areas into which the fishery has expanded. This process is known as 'fishing up'. While the lodges probably did not greatly expand their fishing areas during the seventies, there can be little doubt that peripheral expansion in search of very large fish has contributed to the continued representation of very large, old fish in the creel census samples.

Changes in creel census sampling bias and fishing up may be detected through comparison of samples collected by creel census and experimental gillnetting.

Total mortality among fully recruited age classes may be used as an indicator of exploitation rate and as a basis of comparison of stocks with equal reproductive potentials. The age classes exploited also must be considered when making comparisons. Mortality rates derived from catch curves are a poor method for monitoring population trends since the curves respond slowly to changes in exploitation rate.

CPUE is a measure of stock size or abundance. A decrease in CPUE indicates depletion of the stock.

Harvest statistics indicate trends in effort and, when used in conjunction with mortality rates, give an indication of stock size. Harvest statistics must be related to a stock or area of utilization in order to have meaning.

Some conclusions may still be drawn on the status of the trout stocks in the lakes. At most lodges the catch of fish longer than 1000 mm and older than 30 yr declined during the early seventies. This was probably the last phase of a decline dating from the opening of the lodges. The yields which caused this decline are unfortunately unrecorded. Although the short monitoring period and the possibility of changes in sampling bias in the creel census data prevent firm conclusions, the stocks at most lodges appear to have stabilized during the seventies. A synopsis of the conditions at each lodge is given in Table 10.

The stock utilized by Great Bear Trophy Lodge appears stable. Variations in mean age and length, including the decrease in both between 1975 and 1980, appear to result from the presence or absence of secondary modes consisting of much younger, smaller fish. Similar bimodal distributions were observed in gillnet collections from Great Slave Lake, suggesting that the distributions may reflect year class variation. However, secondary modes were not observed in gillnet collections from Great Bear Lake, the modes therefore also may be due to changes in angler selectivity. Excluding the secondary modes the length frequency distributions for the three years are remarkably similar, especially to the right of the common mode at 637.5 mm. The age frequency histograms are also similar, although less regular, indicating that the population has been stabilizing since at least 1976 at a total instantaneous mortality rate of approximately 0.24 for fish older than 20 yr and annual yields of approximately 0.38 kg/utilized ha. The high mean lengths in the 1980 gillnet sample and the creel census samples indicate that little fishing down of the original population has occurred and that the availability of large fish is still high.

The decrease in average age, disappearance of fish older than 30 yr, and increase in total mortality rate, at Great Bear Lake Lodge (established in 1968) during the mid-seventies illustrates the fishing down of standing stock during the early years of a fishery. Mean length in the catch was probably maintained only by a change in lodge policy on the retention of small fish. The harvest taken by the lodge decreased from 0.49 kg/utilized ha in 1972 to 0.23 kg/ utilized ha in 1977. If maintained, this lower yield should soon be reflected in a lowering of the catch curve mortality rate (estimated at 0.27 in 1977) and stabilization of the population. The stock exploited by Great Bear Lodge declined rapidly during the seventies. The stock appeared to contain a large number of big fish in the early seventies. The lodge took, at least until 1974, a yield of over 0.9 kg/ utilized ha. This caused a rapid decline in the average length in the catch. Age data for the fish from the lodge are very sketchy but a mortality rate of 0.50, calculated from 1973 data, is probably reasonably accurate. The yield was reduced by one half in 1979. This may lead to stabilization of the stock but this has not yet been reflected in the population statistics.

The stock of "trophy" size fish in the vicinity of Branson's Cameron Bay Lodge was exhausted by 1972 (Falk et al. 1973). This conclusion is supported by the comparatively low mean length and age in the 1978 gillnet sample. The comparatively high CPUE may indicate a shift to larger numbers of smaller fish in response to exploitation. Both the mean length and age in the angled catch increased dramatically during the seventies. This is probably attributable to an increased release of smaller fish. The decrease in yield from 0.21 kg/utilized ha between 1972 and 1974 to 0.14 kg/utilized ha in 1978 may aid stock recovery. The estimate of total mortality (0.17) is low compared to the yield. This may be another indication that population density and biomass have increased in response to exploitation with larger numbers of small fish replacing the naturally dominant large, old fish.

The lake trout stock in the vicinity of Frontier Fishing Lodge on Great Slave Lake may have stabilized or undergone a modest recovery during the seventies. The area's long history of exploitation is reflected in the extremely low mean length and age in the sample taken by gillnet in 1980 and possibly in a high CPUE, which again may indicate a shift to larger numbers of smaller fish. Mean length and age in the angled catch increased throughout the seventies and are now relatively high. This, together with the fairly low yield taken by the lodge and extremely high release rate (Table 4) indicates a concerted attempt on the part of the lodge to improve the stock by releasing fish. Unfortunately this policy also makes determination of population trends through creel census impossible. The relatively high mortality rate calculated for the creel census data (0.32-0.33 Table 6) may be partially due to domestic fishing in the area.

Plummer's Great Slave Lodge has offered high quality angling since its establishment at Taltheilei Narrows in the early 1950's, despite apparent high rates of harvest. Falk et al. (1973) speculated that this might be due to high growth rates of trout in this area or movement of fish into the area due to the lodge's location on a major strait.

Although yields averaged approximately 1.5 kg/utilized ha, the stock appears to be stable, with no changes in length or age distributions, and good availability of large fish as indicated by the length and age means in the 1977 gillnet sample. The mortality rate calculated from the creel census sample was low, averaging 0.20, indicating a sustainable level of yield and that the lodge is drawing upon an unusually large population for the size of the area exploited,

either because of high population density or an unusual amount of movement of fish into the area.

The wide fluctuations in mean length and age in creel census samples at Arctic Star Lodge, probably due to small sample size in 1973 and 1974, make determination of trends impossible. The population is probably stable, although a trend towards the release of more small fish may be masking a slow decline in mean size in the population. The 1978 mortality rate of 0.18 and moderate yield of 0.38 kg/utilized ha indicate a sustainable yield. The high length and age means in the 1978 sample taken by gillnet indicate that the stock has not been seriously fished down.

The low yield and mortality rate calculated for Trophy Lodge, together with the high mean age in the angled catch and mean length in the gillnet sample taken from the vicinity of this lodge suggest that there has been little exploitation of the local stock and that the stock is stable. Mean length and age in creel census samples increased during the seventies, with a larger representation of very large, old fish in 1979 than in 1974. This probably indicates expansion of fishing into new areas but may be a recovery from commercial net fishing prior to 1974.

FISH MOVEMENTS

It appears from the tag returns, and from the work of Johnson (1975b) on Great Bear Lake that the lake trout of these lakes occasionally move large distances but that the degree of interchange between lodge fishing areas is probably small enough to require management of trout in different areas of the lake as self contained stocks.

No greater movement of fish in the Taltheilei Narrows area is apparent. Possibly fish move into the area but do not move through it. Such movement would not be detected by tagging in the area.

GROWTH AND MATURITY

Growth rate and age of maturity are important factors in determining the yield which can be generated by a fish stock. Generally, sustainable yield increases with increased growth rate and decreased age of maturity. Increased exploitation causes an increase in growth rate and decrease in age of maturity in many species. These responses are an important management consideration.

The lake trout of Great Slave Lake are from at least age 5, longer and heavier than Great Bear lake trout of similar age. Growth in length is similar until age 25, when the rate for Great Bear lake trout decreases (Fig. 15).

The significant difference in length and weight at age between lodges and years and significant effect of location on the effect of year of sample is not surprising, given the large sample sizes available. If trout are largely sedentary, differences in local conditions would be expected to produce differences in growth rates. Healey (1978a) has found indications of increased growth rates in exploited lake trout populations.

The lower age of maturity of lake trout from Great Slave Lake as compared with those from Great Bear Lake suggests that these lake trout could be exploited at a younger age, generating a larger sustained yield.

NATURAL MORTALITY RATES

Catch curves from Plummer's Great Bear Lake Lodge in 1973 and 1977 have linear segments with slopes of 0.08 and 0.09 respectively (Fig. 5). The ages of the trout within these segments suggest that these slopes are estimates of the instantaneous mortality rate in the population before the advent of the fishery. Total instantaneous mortality in the vicinity of Branson's Cameron Bay, Arctic Circle and Trophy lodges is estimated at 0.11 to 0.25. Natural mortality must be a fraction of this rate. Instantaneous natural mortality is therefore probably between 0.08 and 0.12.

This estimate is well below those cited by Healey (1978b), however, most of these are derived from scale age data. Dubois and Lagueux (1968) presented evidence that counting otolith rings produced significantly higher estimates of age than scales from the same fish, for fish older than six year. Bond (1975) estimated annual mortality to be 41% (Z=0.53) for unexploited lake trout in Kaminuriak Lake, Northwest Territories. (The figures cited by Healey (1978b) do not appear in Bond's report and presumably arise from later analysis by Healey). Power (1978) supports the position that scale techniques underestimate age. This would lead to overestimation of mortality rates. Bond used otoliths but did not consider the estimate to be reliable, since it was drawn from a highly irregular catch curve. Falk et al. (1982), using otoliths, calculated an instantaneous mortality rate for lake trout in Kasba Lake, Northwest Territories, of 0.16. The lake was commercially fished intermittently during the nineteen sixties and has been lightly fished by patrons of a sport fishing lodge since 1971. Harvest by this lodge was estimated at 0.03 kg/ha of lake. Speller et al. (1979), also using otoliths, estimated instantaneous mortality rate of lake trout in two small, probably very lightly fished lakes in the Northwest Territories, to be 0.13. McLeod et al. (1976) estimated the trout instantaneous mortality rate in Baker Lake, Northwest Territories, to be 0.24. Baker Lake has a history of intermittent commercial and domestic exploitation.

It is not possible to verify the estimate of natural mortality rate. It is consistent with observations made by previous authors on the longevity of northern lake trout (Powers 1978) and with recent estimates of northern lake trout mortality obtained from otolith data which indicate that natural mortality for a wide range of northern trout populations is between 0.1 and 0.15.

POPULATION DENSITIES AND ANNUAL RECRUITMENT

The lake trout stock at Great Bear Trophy Lodge seems to have approached a steady state during the seventies. The descending arms of the 1976 and 1980 catch curves are nearly linear and length and age distributions seem stable. The conditions of this steady state were: a yield of 0.32 kg (0.097 fish)/utilized ha/yr (1972, 73, 78 average), a total instantaneous mortality rate of 0.24, and an age of full recruitment of approximately 20 yr.

Because 0.496 of the fish in the 1976 and 1980 creel censuses were age 20 or over we arrive at an estimated catch of fully recruited age groups of 0.048 fish/utilized ha.

At equilibrium $C = FR/F+M$

where C = catch
F = instantaneous fishing mortality
M = instantaneous natural mortality
R = annual recruitment

We have estimates of Z and M and therefore F, and can estimate annual recruitment at age 20, R_{20} = 0.083 fish/ha. This estimate is for a population undergoing fishing mortality among partially recruited age groups totalling 0.49 fish/ha. Apportioning this total among partially recruited age groups according to frequencies observed in the catch and applying the estimated natural mortality rate we arrive at an estimated 0.035 additional fish/ha which would have reached age 20 in the absence of fishing mortality. This estimate assumes density independent natural mortality. The total estimate of R_{20} in the absence of fishing mortality is therefore 0.118 fish/ha.

This estimate gives a population estimate for fish age 20 and older, in the exploited population (N_{20}) of 0.49 fish/ha (Z=0.24, N=R/Z, Ricker 1975) or 1.18 fish/ha in the unexploited population (Z=M=0.1). This assumes constant recruitment. These estimates are higher than estimates derived from the literature by Healey (1978b) (Table 11). The Great Bear Lake population estimates have been adjusted for comparison. The estimate of recruitment was first adjusted to the appropriate age using

$$R_{T2} : R_{20}\, e^{-Z(T2\ -20)}$$

where R_{T2} is the estimate of recruitment at age T_2 and Z = M = 0.1.
Average population in the unexploited population was then calculated using

$$N_{T2} = R_{T2}/0.1.$$

The other estimates presented were derived from mark-recapture experiments (Fry 1949, Paterson 1968, Deroche and Bond 1955), virtual population estimates (Fry 1952, Martin and Fry 1973), and decline in catch with fishing (Healey 1978b).

The higher Great Bear Lake estimates may result from the definition of a utilized hectare, which is confined to shallow inshore water. Trout are more abundant in shallow water in Great Bear Lake (Johnson 1975). The discrepancy also may be due to the use of scale aging to generate most of the data cited by Healey. This would probably result in lower estimates of fish age and therefore population size.

STOCK RECRUITMENT RELATIONSHIP AND MAXIMUM SUSTAINABLE YIELD

Evidence is accumulating that lake trout have a more elastic stock recruitment relationship than has been previously assumed. The trout stock of Lac La Ronge has provided a sustained yield of 0.23 kg/ha. Recruitment appears to have increased, even though mean length in the catch has been reduced to 574 mm (Chen 1977). Martin and Fry (1972) reported that recruitment of Opeongo lake trout was dependent on spawning escapement when total mortality was estimated at 50% (Z=0.69). Seventy-five percent of the catch was made up of trout of age 6 to 9 yr. The age of first maturity was 6 yr. These estimates are partially based on scale ages, however the technique should be reasonably accurate with young fish.

Healey (1978b) estimated that lake trout populations are liable to be over-exploited when yield exceeds 0.5 kg/ha and that sustainable yields may be lower in the north, based on the failure of the lake trout fishery in the western basin of Great Slave Lake at yields of 0.37 to 0.67 kg/ha (Bond and Turnbull 1973; Keleher 1972). However, probably only a fraction of the shallow, sedimentary western basin is good trout habitat. Low sustainable yield per ha would result from division of the observed yield by the total area of the western basin. Initial high yields per hectare appear to have been generated by sequential fishing down of pre-exploitation standing stocks as the fishery expanded into new areas (Scott 1956). This would explain the predominance of old fish in the historical catch (Rawson 1951). The east arm produced yields of 0.5 kg/ha (Keheler 1972). Bond and Turnbull (1973) fail to provide evidence of imminent collapse of the stocks in the east arm at this level of exploitation. There is therefore little evidence that the trout stocks in the east arm of Great Slave Lake or Great Bear Lake are any less dense or more subject to recruitment failure than those in other lakes, such as Superior or Lac La Ronge, Saskatchewan.

Individual lake trout in Great Bear and Great Slave lakes do not spawn every year (Falk et al. 1973). This may be common in lake trout populations (Rawson 1961; Martin 1966). Fecundities for lake trout from Great Slave Lake are higher than those for trout from other lakes (Healey 1978b). Age of first maturity is probably about 15 yr on Great Bear Lake and 10 yr in Great Slave.

Allowing for possible reduction in reproductive potential due to non-consecutive year

spawning, maximum sustainable yield probably would be achieved by fishing strategies involving ages of full recruitment of 16-17 on Great Bear Lake and 10-11 on Great Slave, combined with total instantaneous mortalities of 0.4 0.6 (33-45% annual mortality). For Great Bear Lake, this is somewhat to the left of the 0.13 fish/utilized ha isopleth (Fig. 17). Maximum sustainable yields on Great Slave Lake would be in excess of 0.15 fish/utilized ha. This corresponds to maximum sustainable weight yields of approximately 0.36 kg/utilized ha for Great Bear Lake and in excess of 0.55 kg/utilized ha for Great Slave Lake.

ACCURACY OF EQUILIBRIUM YIELD PREDICTIONS

The yield per recruit models used contain assumptions that natural mortality, growth rate and recruitment are constant over the range of fishing mortalities used. The assumptions are certainly violated to a degree. Chen (1977) presents data that suggests that recruitment in lake trout is directly proportional to exploitation rate over a range of fishing mortalities. However, because the parameter estimates used here are drawn from a population undergoing approximately the exploitation rate of most interest, error from violation of these assumptions should be small.

A more serious restriction on the reliability of the predictions is the dependance of the estimate of recruitment upon the yield at Great Bear Trophy Lodge being an equilibrium yield. The short period of monitoring makes this a dangerous assumption. Application of this recruitment estimate to Great Slave Lake is largely an arbitrary decision.

The estimates of equilibrium yield derived from the model should therefore be viewed as first approximations. Particularly with regards to the quantum of the yield, which is very dependent upon recruitment. Assumptions and parameters should be tested by continued monitoring.

EQUILIBRIUM YIELDS AND MANAGEMENT OPTIONS

It appears that large historical yields, particularly of extremely large fish on Great Bear Lake, resulted from the fishing down of standing stocks. These stocks accumulated due to an extremely low natural mortality rate among Great Bear and Great Slave lake trout. During the early years of the sport lodge fisheries on the lakes large fish were removed at a greater rate than they were replaced by growth. This has resulted in a decrease in fishing quality due to a decrease in the standing stocks of large fish. There is no evidence that removal of these large fish affected recruitment rates. During the seventies the population size and age structures appear to have stabilized as the lodges restricted themselves to removing large fish at approximately the same rate they were produced (equilibrium yield).

Changing the exploitation strategy by increasing age of recruitment and lowering yields will increase standing stocks and yield of large fish. Management strategy must be based on estimates of equilibrium yield. The modeling exercise provides estimates of equilibrium yield, yield of large (longer than 700 mm) and 'trophy' (longer than 900 mm) fish and standing stock for a range of fishing mortalities and ages of recruitment. These predictions can be used in choosing management objectives, such as managing for more or bigger fish, and in selecting a management strategy to attain these objectives.

Production of fish longer than 900 mm in Great Bear Lake is predicted to be very small. Maximum sustained yield is predicted for high ages of recruitment (greater than 28 yr) and high fishing mortalities. The maximum estimated within the range of values used in the model is 6×10^{-4} fish/utilized ha (0.096 fish/km of shoreline). This yield can only be obtained by reducing total numerical yield to 0.04 fish/ utilized ha.

In contrast, strategies predicted to produce maximum yield of fish longer than 700 mm are also predicted to produce the highest numeric yields. The limiting factor for yields under these conditions would be reduction of standing stock, which reduces CPUE. Recruitment ages of 15 to 16, combined with fishing mortalities of 0.1 to 0.15 are predicted to reduce standing stock of fish age 15 and older to one-half of that predicted for the unexploited population. Predicted yields for these strategies are 0.026-0.042 fish longer than 100 mm, 1.6×10^{-4} fish longer than 900 mm, and total yield of 0.095 fish (0.255 kg)/utilized ha.

The decision on exploitation strategy for sport lodge exploitation of Great Bear Lake depends upon the economics of the industry. Management to maximize the stock and yield trophy fish (longer than 900 mm) would require a very small total yield, which might be attained through low retention limits. Management to maximize yield of fish longer than 700 mm would provide a much greater total yield.

Since the lake trout of Great Slave Lake mature at an earlier age, a greater yield could be taken by using a lower age of recruitment than on Great Bear Lake. Growth rates are also higher, particularly for fish longer than 700 mm. Maximum yield of fish longer than 900 mm is predicted for ages of recruitment above 26 yr combined with fishing mortalities of 0.05 to 0.33 It is estimated to be approximately 6×10^{-3} fish/utilized ha (0.96 fish/km of shoreline), ten times the maximum yield on Great Bear Lake.

A maximum yield of 0.068 fish/utilized ha for fish longer than 700 is predicted for Great Slave Lake. This yield is associated with ages of recruitment of 23-24 yr and fishing mortalities of 0.4 or greater. These strategies are predicted to produce total catches of approximately 0.07 fish per/utilized ha and standing stocks of approximately three quarters that predicted for the unexploited population.

If implementation of a strategy approximating any of the studied strategies were desired, yield could be restricted to the predicted yield and a minimum size limit equal to the mean size of fish at the age of recruitment could be imposed.

IMPLICATIONS FOR MANAGEMENT OF THE RESOURCE

There has been recurring interest in expanding the sport lodge industry on the lakes and in establishing commercial net fisheries in the sport lodge fishing areas. Except for the Keith Arm of Great Bear Lake it appears that the current lodges are utilizing all of the trout stocks. There is therefore no opportunity to expand the sport lodge industry by exploiting previously unexploited stocks. There also does not appear to be any opportunity for expanding the sport lodge industry by increasing exploitation rates for currently exploited stocks. While the current yield is well below maximum sustainable yield it is probably at or above the yield which provides the combination of fishing quality and exploitation rate which provides the greatest profit from the use of the resource by the lodge industry. Any increase in exploitation would result in a decreased availability of large fish, which appears to be unacceptable to the lodge industry. It is therefore recommended that no expansion of the lodge industry on the lakes which would result in increased yields be allowed, except on the Keith Arm of Great Bear Lake.

Commercial net fisheries in the sport lodge fishing areas would also increase the exploitation rates for trout and decrease the availability of large fish, resulting in a decreased economic yield from the sport lodge industry. It is therefore recommended that no commercial net fishing be allowed in the sport lodge fishing areas unless it can be illustrated that the economic gain from such a use of the resource would exceed the economic loss resulting from damage to the sport lodge industry.

Some native domestic net fishing is done within the sport lodge areas. While native domestic fishermen have the highest allocational priority for the resource, their needs can be most efficiently filled by confining their fishing to special areas which can be managed for maximum sustainable yield. It is therefore recommended that DFO continue to seek the cooperation of native domestic fishermen in restricting domestic net fishing to areas not utilized by the lodges.

Identifying the combination of fishing quality, yield per angler, and number of anglers which would provide the highest profit from the use of the resource by the lodge industry is a difficult biological and economic problem. The economic aspects of the problem might be solved by a formal study or by allowing the lodges to manage the resource in response to market forces.

Lodge owners cannot be expected to manage the resource for maximum societal gain unless they have an exclusive right to use a portion of it. When a resource is common property, everyone having a right to use it, users compete to obtain as much of the resource as possible rather than managing the resource for maximum long term economic gain.

Current policy is to control access to the lodge fishery by a licensing system. The area fished by a lodge is controlled by controlling lodge location. This is equivalent to awarding rights to the use of the resource. Since the lodge owners are to an extent de facto owners of the resource in their area they can be expected to be profit maximizing and therefore might be allowed to be self-regulating.

An improvement to the system would be marketing of the right to fish an area. The sedentary nature of the trout lends itself to this type of management. A rights market, once established, could also be used to make allocational decisions between competing uses.

The current levels of exploitation have evolved through consultation with the industry and through industry self-regulation. It appears that, left to itself, the sport lodge industry will choose levels of exploitation that produce less than the maximum sustainable yield. Perhaps lodge owners should be allowed to choose the economically optimal exploitation strategy (age of recruitment, fishing mortality), guided by the yield predictions and restricted by limits on exploitation level.

Government, as the long term rights owner, should protect the resource from management for short term goals. Regulation of exploitation levels to prevent depletion of the standing stocks to levels obviously inconsistent with maintenance of a sport lodge industry is probably necessary.

A reasonable lower limit for standing stock on Great Bear Lake is one-half the estimated virgin standing stock of fish over 15 yr of age. Standing stock is estimated at 1.9 fish/utilized ha. With a natural mortality rate of 0.1, standing stock is reduced by ten fish for every annual removal. This produces an upper limit for annual yield of 0.095 fish/ utilized ha (0.25 kg/utilized ha). Because the lake trout of Great Slave Lake mature at a younger age and grow more quickly a different criterion might be used. However, because the trout of Great Slave Lake have greater potential for management for production of very large fish, and the lodges are trending towards managing for such fish the same limit should be imposed on Great Slave Lake, where it is predicted to provide a weight yield of approximately 0.40 kg/utilized ha. This means that the greater potential of the Great Slave Lake resource would be utilized to produce larger rather than more fish.

One method of applying these limits would be to limit aggregate yield per utilized ha. This would be very difficult to enforce. Control of exploitation levels is currently maintained by limits on lodge guest bed capacity and catch and possession limits. A yield of 0.095 fish/utilized ha translates to 15.3 fish per km of shoreline. If we assume retention of five fish by each angler, a weekly rotation of anglers, and a season of 10 weeks, each guest bed would require 3.25 km of shoreline.

Control by limiting guest bed capacity relies on assumptions about yield per angler and rotation. Direct limits on yield per angler and number of anglers per season would be preferable. While this would limit the freedom of the lodges to optimize their profits, it is the only real alternative to regulating aggregate yield. While the actual limits could be developed in consultation with the industry, a retention limit (total number of fish killed during stay) for sport lodge areas of five lake trout per angler and a seasonal limit of three anglers per km of shoreline are useful first approximations.

It must be emphasized that the conclusions reached on the responses of the lake trout populations to exploitation are preliminary. Continued monitoring of yields, distribution of fishing effort within the lakes, and the responses of the populations to exploitation is critical for the testing and refinement of these conclusions.

PROGRAM EVALUATION AND RECOMMENDATIONS

In the absence of better information on stock-recruitment relationships, densities and density dependence of growth and mortality rates management must continue to proceed by trial and error. Monitoring of the quantity of harvest and of the lake trout stocks, possibly through monitoring mean length, are basic to the management effort. We can then start to build a body of knowledge on sustainable harvests and associated population conditions. Estimates of mortality rates generated from catch curves allow the use of simple models such as those used in this report to extrapolate observations to other fishing conditions. The parameters of such models can be refined as predictions are tested by monitoring.

Creel census has proven to be a poor method for monitoring the populations due to the sampling bias introduced by the high and varying release rate.

Three alternative methods for future monitoring are:

1) sampling with gillnets.
2) sampling with gillnets supported by creel census.
3) collection of data by guides on all fish caught (not just retained fish) by a sample of anglers.

Collection of data by guides would provide a reproducible, high quality sample of the exploited population at low cost. Data must be collected on every fish hooked during the angling sessions sampled, but need not be collected from all angling sessions. Length data would be sufficient. A simple method by which guides could record the length of all fish boated during a sampling period, and whether the fish was retained or released should be developed. Age and weight data could be collected by less frequent concentrated sampling of the retained catch or a gillnet sample.

Harvest estimates are necessary for the prediction of population responses and the regulation of the fishery. Harvest estimates could be calculated from data on average kill per angler which could be collected by guides, creel census, or an angler diary program and the number of anglers using a lodge. Lodge managements should provide yearly summaries of guest numbers and maps of areas utilized.

CPUE data is probably too variable to be useful. Sex ratio and age of maturity is likely to change slowly if at all. Data on these parameters could be collected at infrequent intervals, but should be collected by trained personnel.

It seems that little useful information can be obtained by further tagging studies.

Periodic sampling of the angled catch to obtain length, weight and age data for the determination of relations between these parameters should be done by trained personnel, possibly with a frequency of 3 to 5 yr.

Catch curve analysis is the only feasible method for estimating mortality rates, although high year class variability and changing exploitation rates lower the accuracy of estimates obtained by this method.

Samples of 150-250 fish appear to give catch curves adequate for determination of mortality rates. Samples of from 200-300 fish produced 95% confidence intervals for mean fork length in the vicinity of ±12 mm. This was reduced to ±10 mm for sample sizes of 300-400 and ± 8.5 mm for sample sizes of 400-600 fish. A length sample of 300-400 fish therefore probably is sufficient for monitoring.

When the monthly means for fork length were compared by analysis of variance and Duncan's multiple range test (SAS 1979) it was found that the means differed significantly at four of five lodges. Mean length was higher in the first month of the season and in one case decreased significantly throughout the season, possibly due to in-migration of large fish during the winter or to seasonal changes in catch-ability of large fish. It would therefore be important that any census of less than season length be performed at the same time as previous censuses at the same lodge. Ideally, data should be collected throughout the season, again indicating the advantage of having guides collect data.

There is a need for research on lake trout population densities and stock-recruitment relationships. The most promising direction is an intensive experimental fishing program, using mark-recapture techniques in a small closed system such as was utilized by Healey (1978a).

To date fisheries management in the territories has been primarily concerned with defining the populations of unexploited lakes. It is now time to produce conclusions about unexploited populations from this data and redirect effort into population research and monitoring of developing and developed fisheries to ascertain the yields which can be expected from northern systems.

SUMMARY

BIOLOGICAL

1) The lake trout populations of Great Bear and Great Slave lakes appear to be stabilizing after a period during which standing stock was reduced as the populations adapted to higher mortality rates imposed by the advent of the fisheries.

2) Lake trout in Great Bear Lake grow very slowly once an age of 27 and length of approximately 650 mm is reached. Great Slave lake trout grow more quickly, particularly at larger sizes.

3) Most lake trout in Great Bear mature at ages 10-16 as compared to ages 7-14 for lake trout in Great Slave .

4) Natural mortality among trout in the lakes appears to be very low and is estimated at approximately 9% per year.

5) Estimates of population densities in inshore waters are higher than estimates published by the other authors for lake wide average densities. Density of fish older than twenty years is estimated at 0.49 fish/ utilized ha.

6) Most lake trout in the lakes appear to be sedentary, however, a small percentage of trout do move large distances. Distance moved is not obviously correlated with time at liberty or the size of the fish.

MANAGEMENT

1) Equilibrium yields (annual production), particularly of extremely large fish on Great Bear Lake, are much lower than historical yields. Historical yields resulted from the fishing down of a large standing stock which accumulated due to an unusually low natural mortality rate. There is little or no potential for increasing the harvest taken by the sport lodge industry without decreasing fishing quality and probably the economic performance of the industry.

2) There is no reason to believe that current levels of exploitation are causing reduced spawning success.

3) Annual production of fish longer than 900 mm on Great Bear lake is extremely low, due to low growth rates of fish longer than 650 mm. Maximizing the yield of fish longer than 900 mm would require adoption of strategies which would reduce total weight yields to less than one half of currently observed levels. Adopting a strategy which maximizes yield of fish longer than 700 mm would produce numerical and weight yields close to those currently observed.

4) The lake trout of Great Slave Lake represent a greater resource than do those of Great Bear Lake, due to their lower age of maturity and greater growth rate. Due to the higher growth rate among large trout management of Great Slave Lake for extremely large fish is more feasible than is similar management on Great Bear Lake.

5) lodge owners are largely de facto rights holders over the resource and could therefore be expected to harvest the resource in an optimum manner, given biological and economic advice. Overall exploitation should be regulated to ensure management for long term optimization. The limitation of annual yield on both lakes to 15.4 fish/km of shoreline is recommended. The limit could be enforced through regulation of total catch per angler and imposition of a limit on the yearly number of anglers.

6) Maximum sustainable yield is estimated at 0.36 kg/utilized ha (inshore) for Great Bear Lake and approximately 0.6 kg/utilized ha for Great Slave Lake. The yield taken from the lakes could therefore almost certainly be increased beyond that observed in the mid-seventies. Any increase would be accompanied by a decline in angling quality. Increased harvests, such as would be caused by increased net fishing, should only be allowed when the economic benefits from the new harvest outweigh the economic losses to the lodge industry from any decline in fishing quality.

7) A socio-economic study of the values of the resource to alternative users should be undertaken.

8) The lakes may be zoned for management purposes. Such zoning is the most efficient way to accommodate alternative uses of the resource.

9) The characters of the fisheries and exploitation rates changed dramatically during the nineteen seventies and may have continued to change since the latest data was collected. Current data is necessary for economic planning and refinement and testing of predictions on the responses of the lake trout populations to exploitation. Data should therefore be collected on harvest rates by monitoring the numbers of anglers using the lodges and yields taken by each angler.

10) A simple method by which guides could record the length of all fish boated and whether the fish was retained or released should be developed.

11) Summaries of the seasonal number of guests and areas utilized should be obtained from lodge management.

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Table 1. Guest capacities and histories of sport fishing lodges on Great Bear and Great Slave lakes.

Lodge	Guest Capacity (current)[1]	Establishment Date[2]
Great Bear Lake		
Great Bear Trophy Lodge	40	1967
Plummer's Great Bear Lake Lodge	54	1968 (present location)
Great Bear Lodge	54	1965
Branson's Cameron Bay Lodge	40	early 60's
Arctic Circle Lodge	34	1965
Great Slave Lake		
Frontier Fishing Lodge	24	1962
Plummer's Great Slave Lake Lodge	44	1965
Indian Mountain Lodge	10	1971
Arctic Star Lodge	32	1967
Trophy Lodge	16	1966

[1]source GNWT Dep. of Tourism
[2]personal communication B. Wong, DFO, Yellowknife, NWT

Table 2. Summary of studies carried out on the lake trout of Great Bear and Great Slave lakes, by year, 1972-80.

Lodge	Creel Census		Biological Sampling (angler catch)	Experimental Gillnetting	Tagging
	Partial	Complete			
Great Bear Lake					
Arctic Circle Lodge	-	75	75	-	-
Branson's Cameron Bay Lodge	73	72,74,78	72,73,74,78	78	78
Plummer's Great Bear Lake Lodge	-	72,73,77	72,73,77	-	-
Great Bear Lodge	-	72,73,79	72,73,79	79	79
Great Bear Trophy Lodge	-	73,76,80	73,76,80	80	80
Great Slave Lake					
Arctic Star Lodge	72,73,74	78	73,74,78	78	78
Frontier Fishing Lodge	-	72,73,74,75,80	72,73,74,75,80	80	80
Plummer's Great Slave Lake Lodge	-	72,73,74,77	72,73,74,77	77	73,74,77
Indian Mountain Lodge	-	76	76	-	-
Trophy Lodge	74	79	79	79	79

Table 3. Areas utilized by sport fishing lodges on Great Bear and Great Slave lakes.

Lodge	Area Utilized (ha)
Great Bear Lake	
Great Bear Trophy	30780
Plummer's Great Bear Lake	49210
Great Bear	11740
Branson's Cameron Bay	50820
Great Slave Lake	
Frontier Fishing Lodge	43190
Plummer's Great Slave Lodge	8410
Indian Mountain Lodge	8580
Arctic Star Lodge	16760
Trophy Lodge	4380

Table 4. Release rates for trout caught at lodges on Great Bear and Great Slave lakes.

Lodge	Release rate by year								
	72	73	74	75	76	77	78	79	80
Great Bear Lake									
Arctic Circle				0.81					
Branson's Cameron Bay	0.48	0.47					0.88		
Plummer's Great Bear Lake	0.35	0.42	0.76		0.76				
Great Bear	0.84	0.77						0.94	
Great Bear Trophy		0.53			0.58				0.93
Great Slave Lake									
Arctic Star	0.47	0.37	0.66				0.56		
Frontier Fishing	0.60	0.54	0.48	0.61					0.90
Plummer's Great Slave	0.24	0.63	0.52			0.68			
Indian Mountain	0.69				0.44				
Trophy			0.80				0.76		

Table 5. Statistics from creel census and experimental gillnetting of lake trout, Great Bear Lake, 1972-80.

Lodge	Year	Gear	Length n	Length Mean	Age n	Age Mean	Yield (kg) Total	Yield (kg) /Utilized Hectare	Z	Age Range for Z (years)	CPUE
Great Bear Trophy	72	angling	-	-	-	-	7210	0.23	-	-	-
	73	angling	732	598	674	20.0	13070	0.42	-	-	0.83
	76	angling	401	651	397	20.1	9130	0.30	0.25	21-33	0.65
	80	angling	149	561	146	18.3	-	-	0.22	22-36	1.23
		gillnet	405	623	-	-	-	-	-	-	-
Plummer's Great Bear Lake	72	angling	-	-	-	-	27410	0.49	-	-	-
	73	angling	513	659	463	27.6	18780	0.34	0.08	29-48	0.74
	77	angling	326	671	311	25.3	13070	0.23	0.27	29-32	0.56
Great Bear	72	angling	253	733	-	-	6520	0.56	-	-	-
	73	angling	502	678	110	13.4	11210	0.95	0.50	27-30	0.66
	74	angling	-	-	-	-	4976	0.49	-	-	-
	79	angling	319	619	59	17.8	10890	0.93	-	-	0.78
Branson's Cameron Bay	72	angling	220	620	-	-	10490	0.21	-	-	-
	73	angling	-	-	-	-	8760	0.17	-	-	0.75
	74	angling	210	632	181	23.0	12890	0.25	-	-	0.93
	78	angling	347	689	281	26.9	7210	0.14	0.17	30-41	0.83
	78	gillnet	263	541	57	18.4	-	-	-	-	-
Arctic Circle	75	angling	538	656	515	19.6	6520	-	0.20	18-36	1.75

Table 6. Statistics from creel census and experimental gillnetting of lake trout, Great Slave Lake, 1972-80.

Lodge	Year	Gear	Length n	Length Mean	Age n	Age Mean	Yield (kg) Total	Yield (kg) /Utilized Hectare	Z	Age Range for Z (years)	CPUE
Frontier Fishing	72	angling	847	564	-	-	7900	0.18	-	-	-
	73	angling	765	549	689	12.5	9890	0.23	0.33	12-25	-
	74	angling	543	563	516	12.5	10510	0.24	0.32	12-24	0.74
	75	angling	926	609	774	14.7	11040	0.26	0.33	18-28	1.22
	80	angling	222	649	222	18.9	9374	0.28	-	-	-
	80	gillnet	252	478	72	7.9	-	-	0.20	-	-
Plummer's Great Slave	72	angling	974	699	-	-	11910	1.42	-	-	-
	73	angling	572	612	514	15.9	17210	2.05	0.26	19-29	0.44
	74	angling	636	641	514	17.3	8120	0.97	0.16	16-33	0.36
	77	angling	454	627	428	17.0	12570	1.49	0.19	17-32	0.53
	77	gillnet	679	572	171	11.1	-	-	0.33	-	-
Indian Mountain	73	angling	-	-	-	-	1320	0.15	-	-	-
	76	angling	342	607	329	15.6	1810	0.21	0.29	17-27	-
Arctic Star	72	angling	40	669	-	-	2960	0.18	-	-	-
	73	angling	46	568	43	16.8	-	-	0.14	16-27	-
	74	angling	34	667	11	15.2	-	-	-	-	-
	78	angling	384	576	357	21.4	6420	0.38	0.18	21-37	-
	78	gillnet	682	553	172	13.6	663	-	-	-	-
Trophy (Reliance)	74	angling	28	517	28	14.5	775	0.15	-	-	0.76
	79	angling	114	559	106	19.3	-	0.18	0.11	19-30	0.85
	79	gillnet	513	586	-	-	-	-	0.17	-	-

Table 7. Ages of first and complete maturity for lake trout from creel census.

Lodge	Year	Age of Maturity 1st	Age of Maturity 100%
Great Bear Lake			
Great Bear Trophy	73	-	-
	76	12	27
	80	16	21
Plummer's Great Bear Lake	73	-	-
	77	13	19
Great Bear	73	-	-
	79	23	23
Branson's Cameron Bay	74	-	-
	78	18	36
Arctic Circle	75	10	31
Great Slave Lake			
Frontier Fishing Lodge	73	7	17
	74	7	16
	75	8	20
	80	9	9
Plummer's Great Slave Lodge	73	9	12
	74	12	29
	77	12	21
Indian Mountain Lodge	76	11	19
Arctic Star Lodge	73	12	14
	74	14	16
	78	13	21
Trophy Lodge	74	12	12
	79	13	20

Table 8. Mean distances travelled by lake trout tagged on Great Slave Lake grouped by time at liberty and location of tagging.

Years at Liberty	n	Distance Moved by Water (km) Mean	Std. Dev.
Great Slave Lodge (Taltheilie Narrows)			
0-0.5	15	30.8	69.8
0.6-1.0	16	24.1	41.9
1.1-2.0	17	14.1	25.3
2.1-3.0	14	18.1	31.7
≥3.1	20	24.8	44.1
Total	82	22.4	
Other Lodges			
0-0.5	4	29.0	33.5
0.6-1.0	4	30.8	40.4
1.1-2.0	6	52.8	72.4
2.1-3.0	4	2.0	3.4
≥3.1	2	0.5	0.7
Total	20	28.2	
Grand Total	102	23.5	

Table 9. Mean distance travelled by lake trout tagged on Great Slave Lake grouped by fork length at tagging.

Length at Tagging	n	Distance Moved by Water (Km) Mean	Std. Dev.
350-599	31	21.3	33.3
600-699	29	38.8	62.8
700-799	21	31.2	44.7
800-899	16	11.9	39.5
900-999	5	1.4	2.2

Table 10. Status of the fisheries and lake trout stocks at sport fishing lodges on Great Bear and Great Slave lakes. Numbers in parenthesis indicate sample year. Multiple years indicate average values.

Lodge	Mean Length (mm)		Harvest (kg/utilized ha)	Stock Status
	Angled Catch	38 mm Gillnet		
Great Bear Lake				
Great Bear Trophy	610 (73, 76, 80)	623 (80)	0.32 (72, 73, 76)	Stable or slowly declining.
Plummer's Great Bear	664 (73, 77)	-	0.23 (77)	Probably stabilizing after decline in early 70's.
Great Bear	620 (76)	-	0.49 (79)	Mean size and age declining.
Branson's Cameron Bay	689 (78)	541 (78)	0.14 (78)	Stable or recovering.
Great Slave Lake				
Frontier Fishing	649 (80)	478 (80)	0.23 (72, 73, 74, 75, 80)	Probably stable.
Plummer's Great Slave	627 (77)	572 (77)	1.48 (72, 73, 74, 77)	Probably stable.
Arctic Star	576 (78)	-	0.38 (78)	Mean length possibly declining slightly.
Trophy (Reliance)	551 (79)	586 (79)	0.16 (74, 79)	Stable or recovering.

Table 11. Estimates of lake trout population densities as cited by Healey (1978) and estimates for the same age groups, Great Bear Lake.

Lake	Reference	Area (ha)	Ages	Estimated Fish/ha	Great Bear Lake Estimated Fish/ha
Cold Stream Pond	Deroche and Bond, 1955	1468	4+	.87 1.38	5.83
Swan	Paterson, 1968	200	6+	.88 1.13	4.79
Opeongo	Martin and Fry, 1973	5860	8+	0.12	3.89
Lake Huron	Fry, 1972	7770	4+	1.78 2.23	5.83
Alexie	Healey, 1978	420	7+	2.14 2.86	4.30
Drygeese	Healey, 1978	547	4+	2.65 3.20	5.83

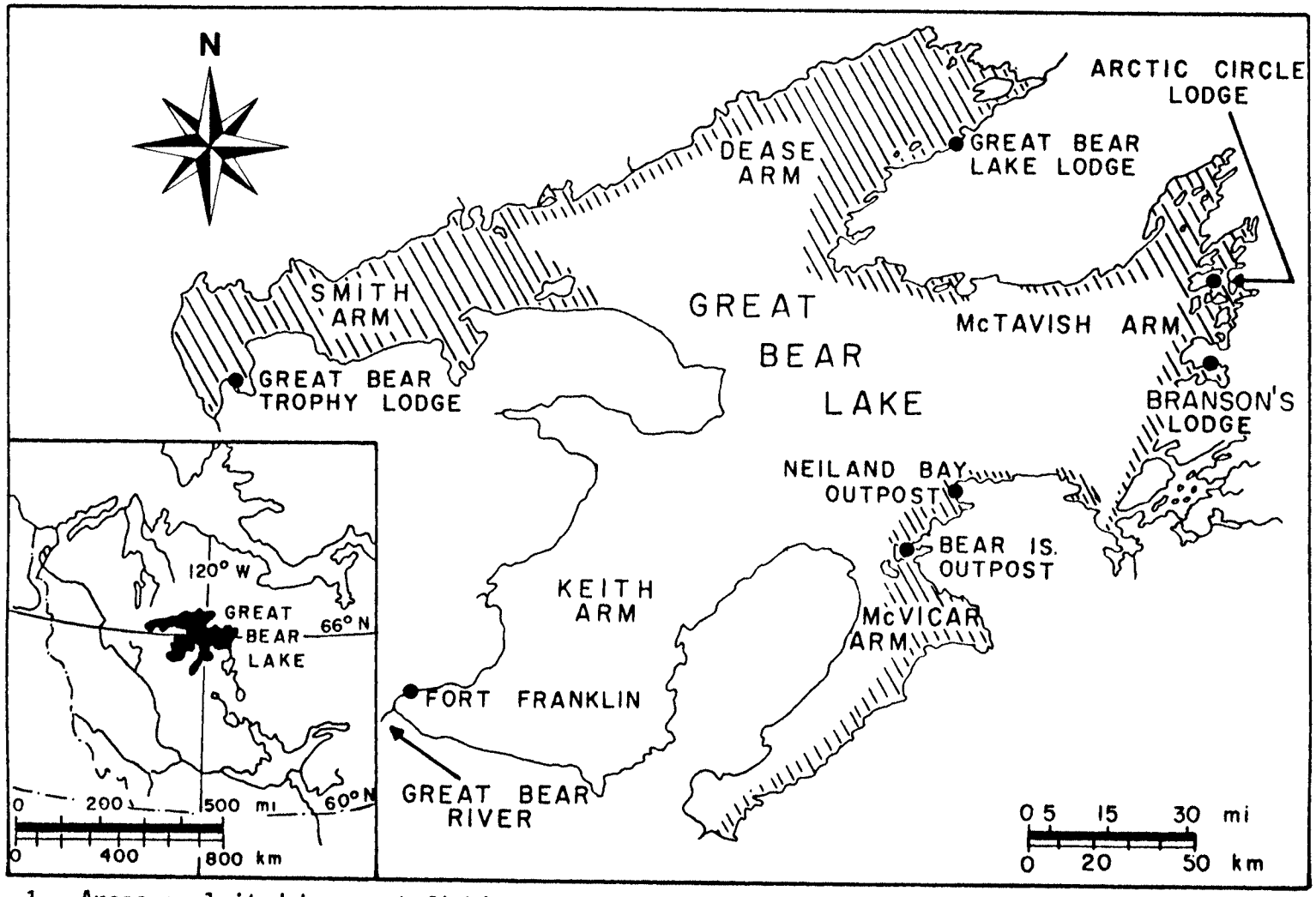

Fig. 1. Areas exploited by sport fishing lodges on Great Bear Lake. Neiland Bay and Bear Island are outposts of Great Bear Lodge.

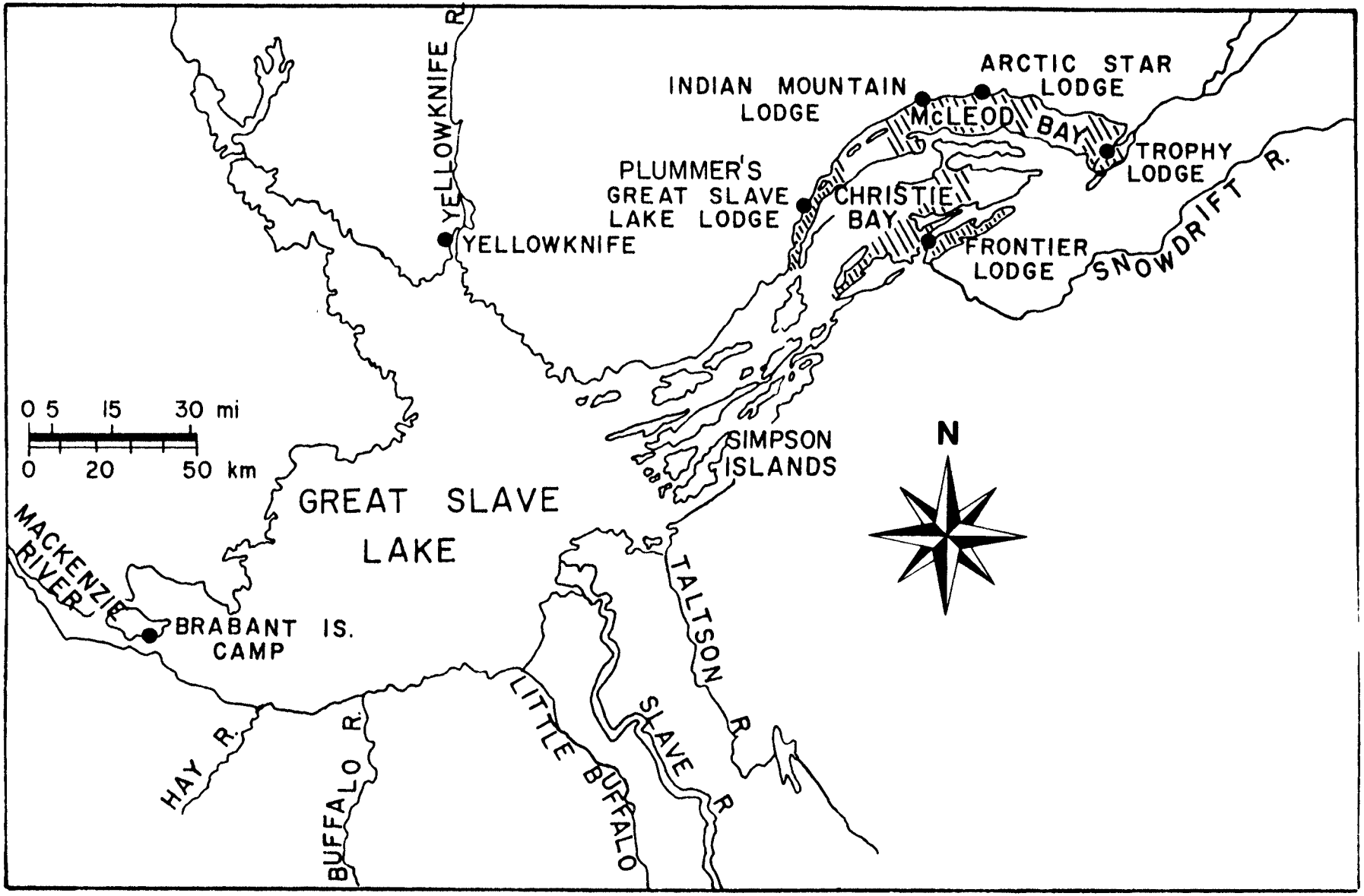

Fig. 2. Areas exploited by sport fishing lodges on Great Slave Lake.

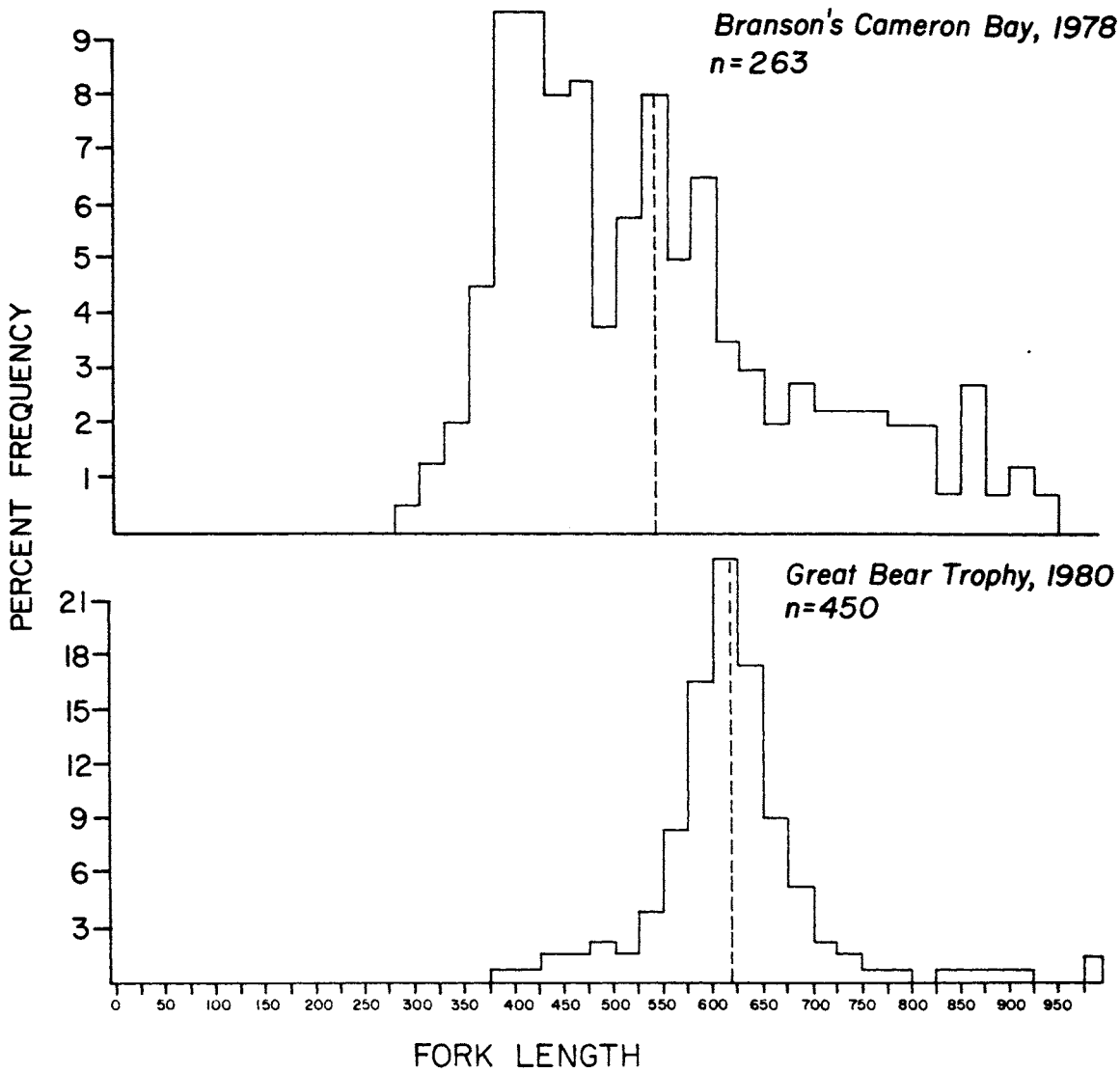

Fig. 3 . Length class percent frequencies in 38 mm gillnet samples, Great Bear Lake. Broken line indicates mean.

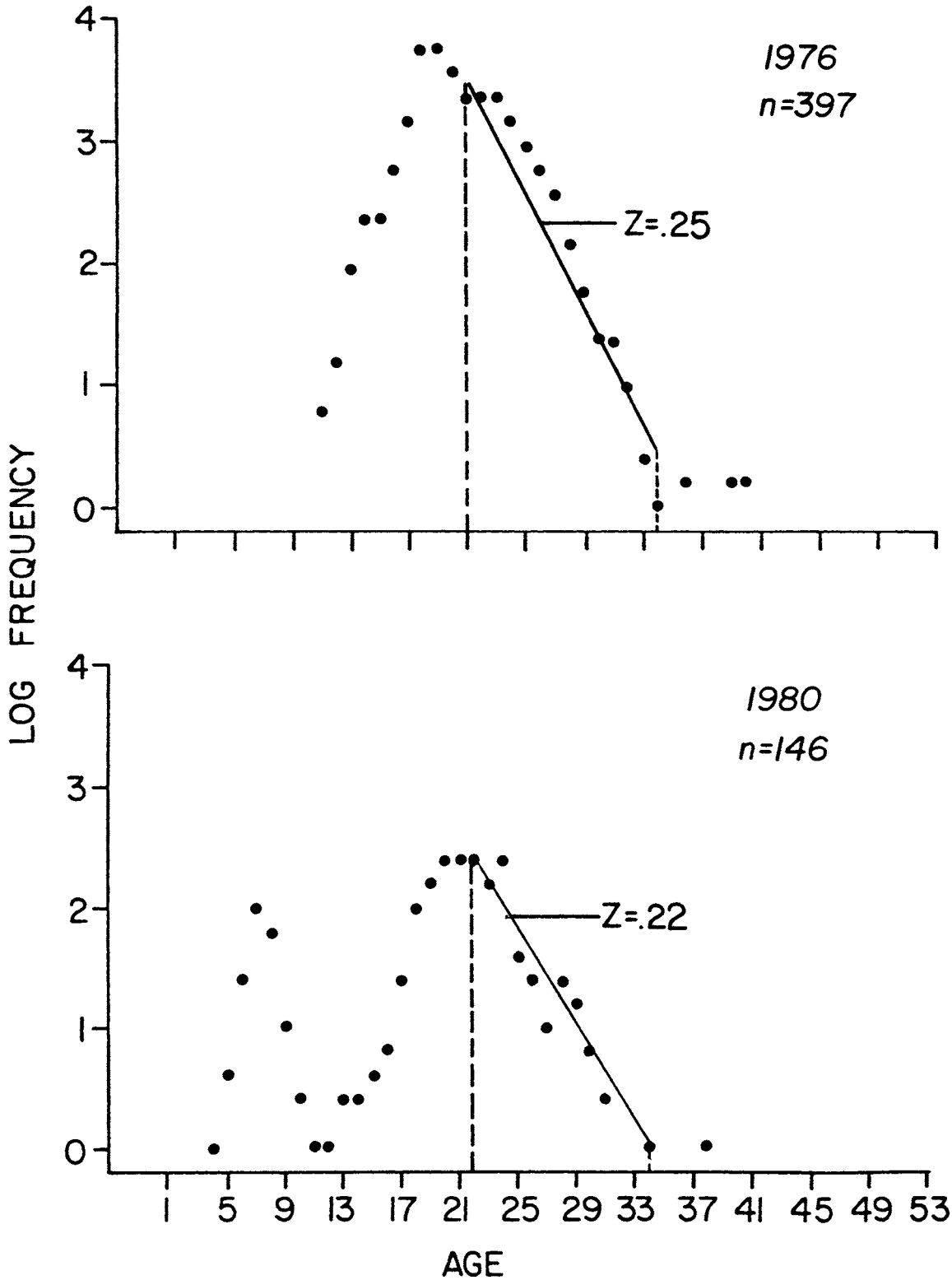

Fig. 4. Catch curves, smoothed by a running average of three, for the angled catch, Great Bear Trophy Lodge.

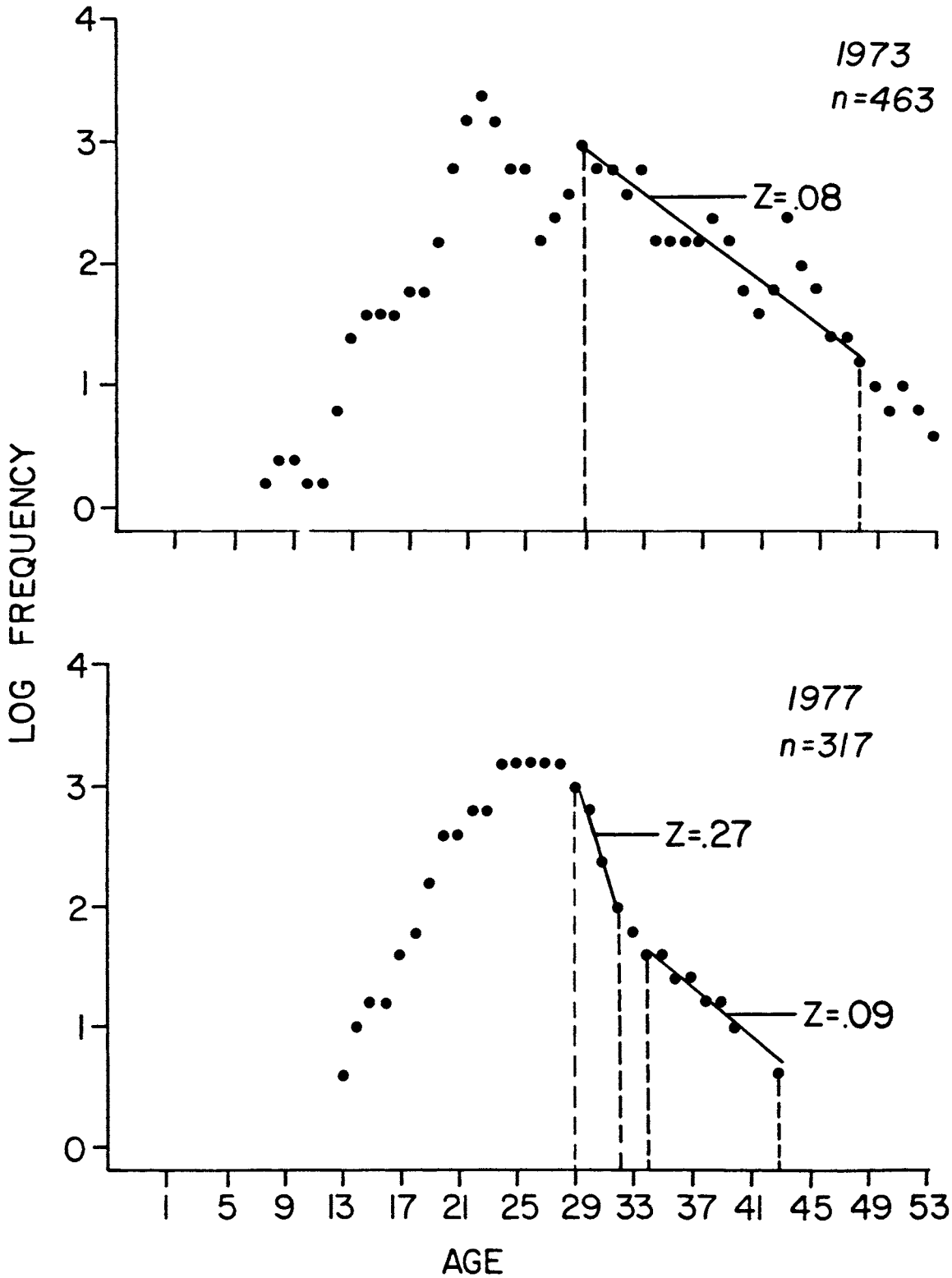

Fig. 5. Catch curves, smoothed by a running average of three, for the angled catch, Plummer's Great Bear Lake Lodge.

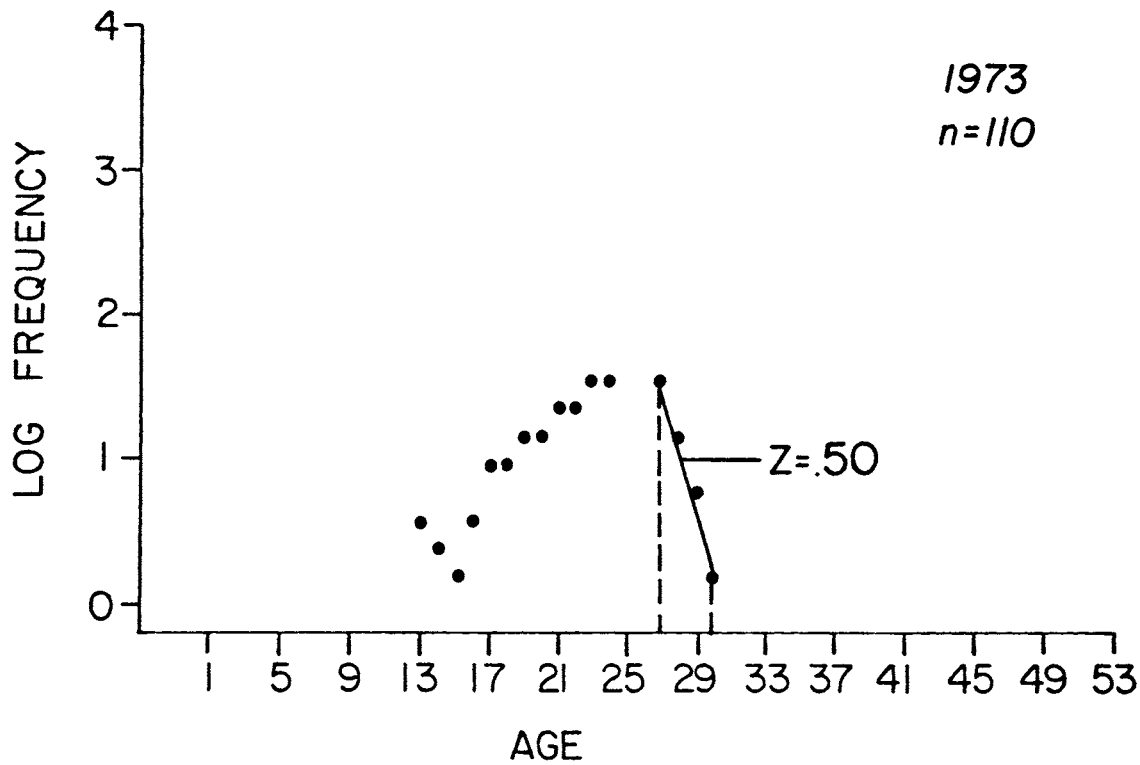

Fig. 6. Catch curve, smoothed by a running average of three, for the angled catch, Great Bear Lodge.

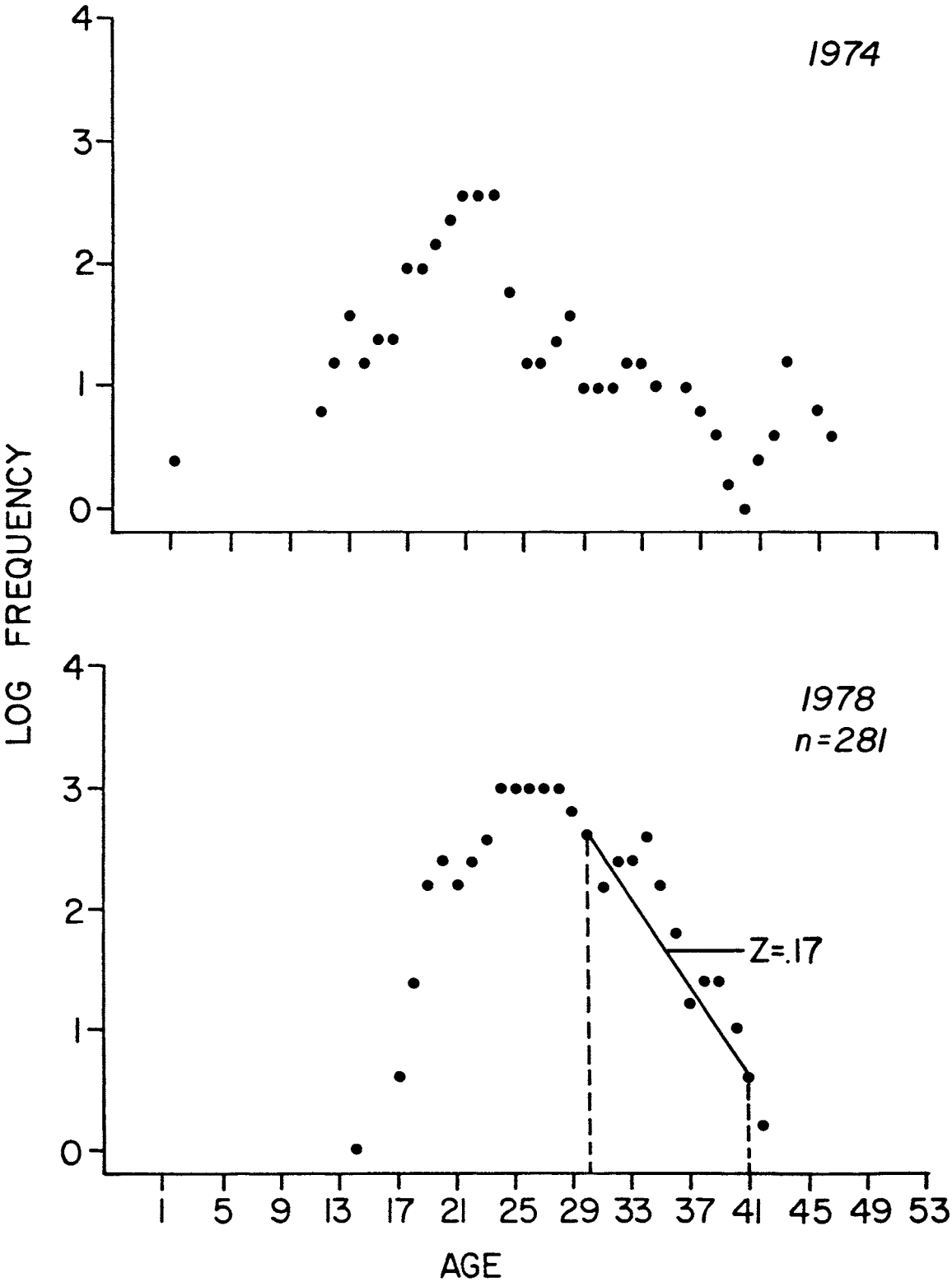

Fig. 7. Catch curves, smoothed by a running average of three, for the angled catch, Branson's Cameron Bay Lodge, 1978.

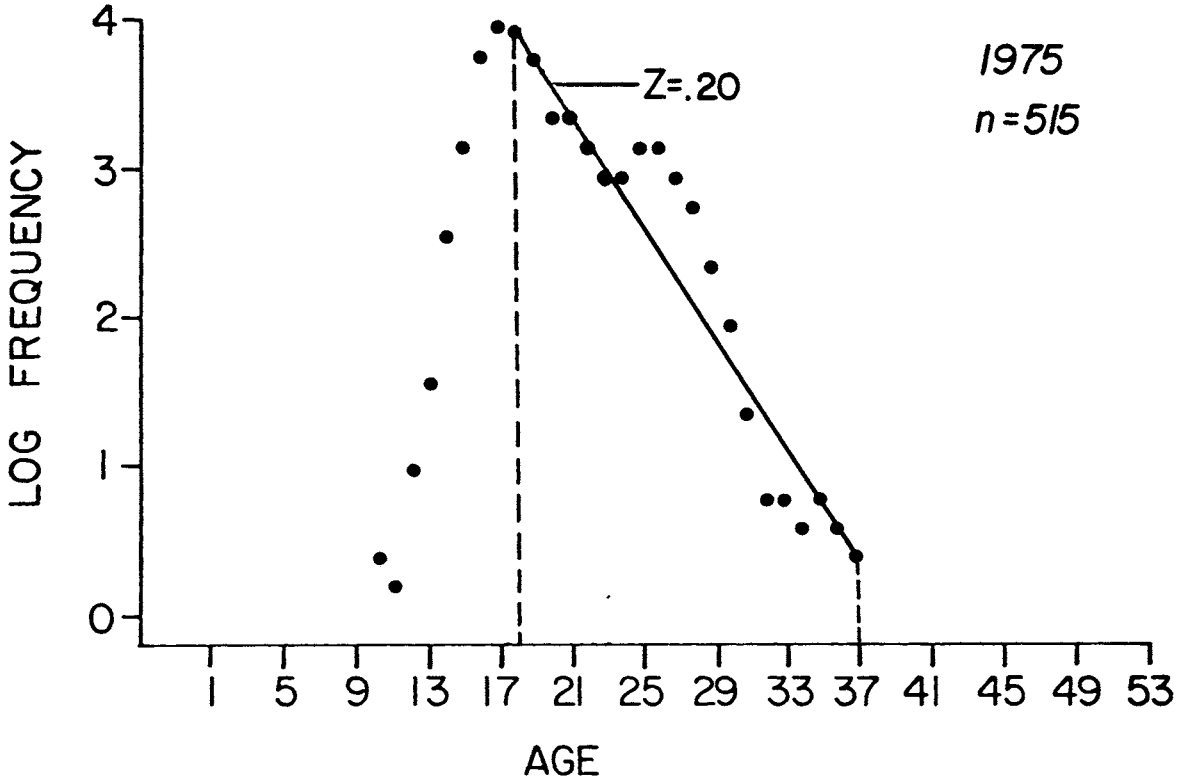

Fig. 8. Catch curve, smoothed by a running average of three, for the angled catch, Arctic Circle Lodge, 1975.

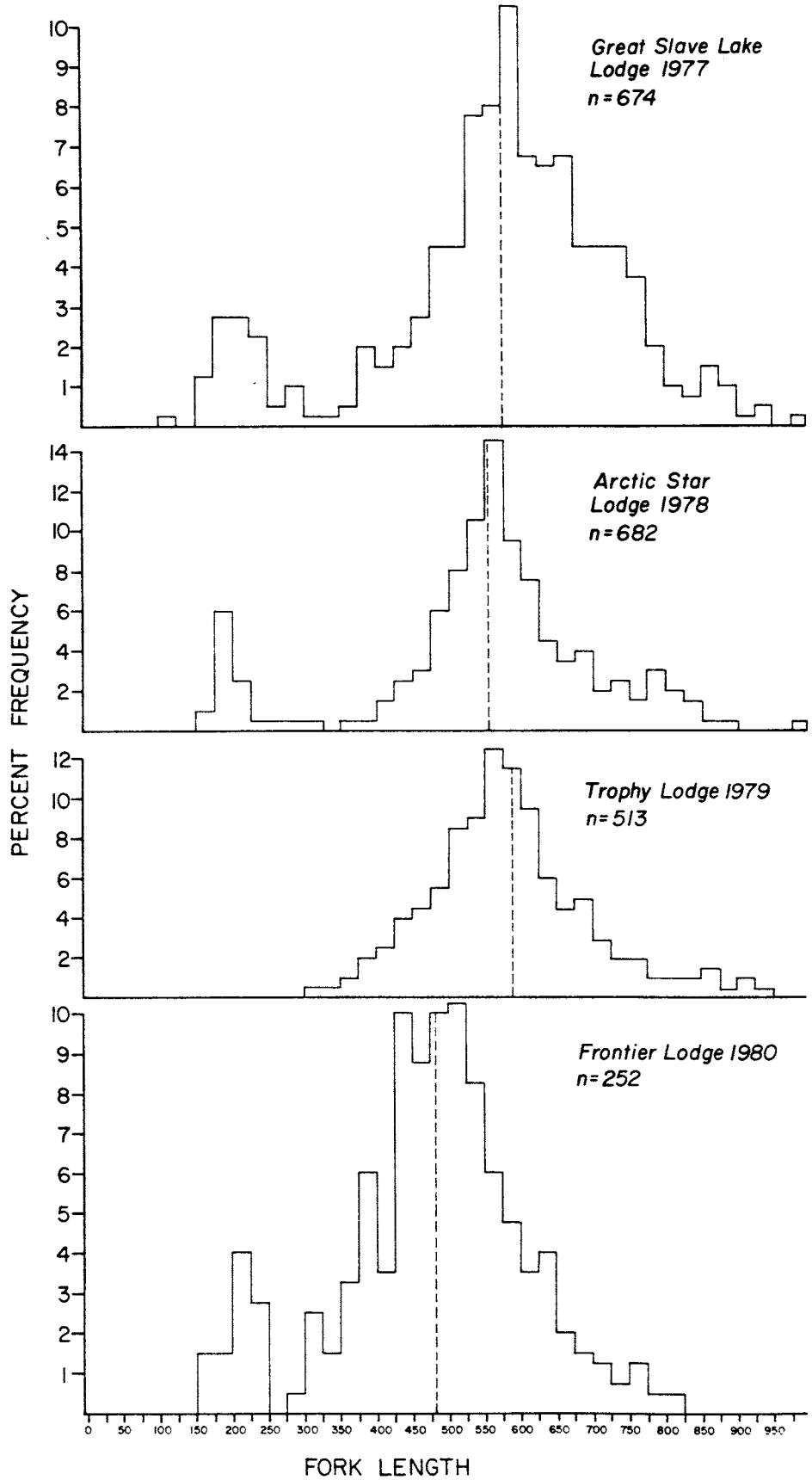

Fig. 9. Length class percent frequencies in 38 mm gillnet samples from Great Slave Lake. Broken line indicates mean.

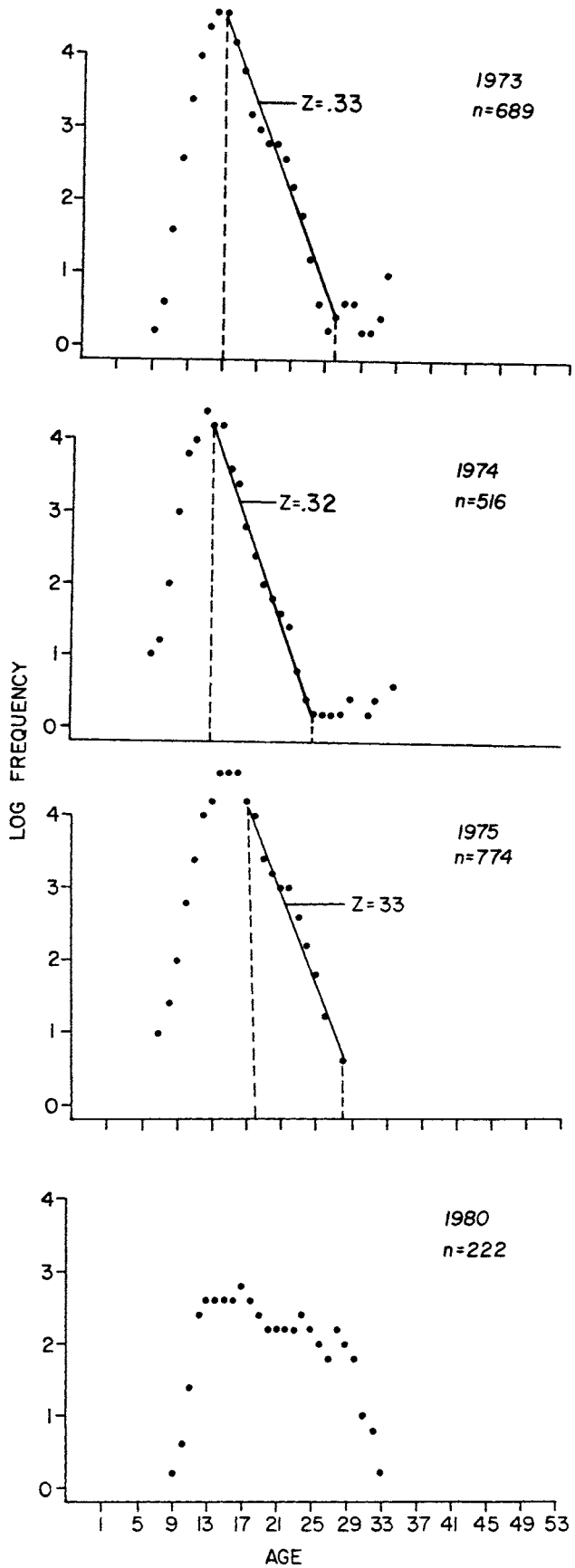

Fig. 10. Catch curves, smoothed by a running average of three, for the angled catch, Frontier Fishing Lodge.

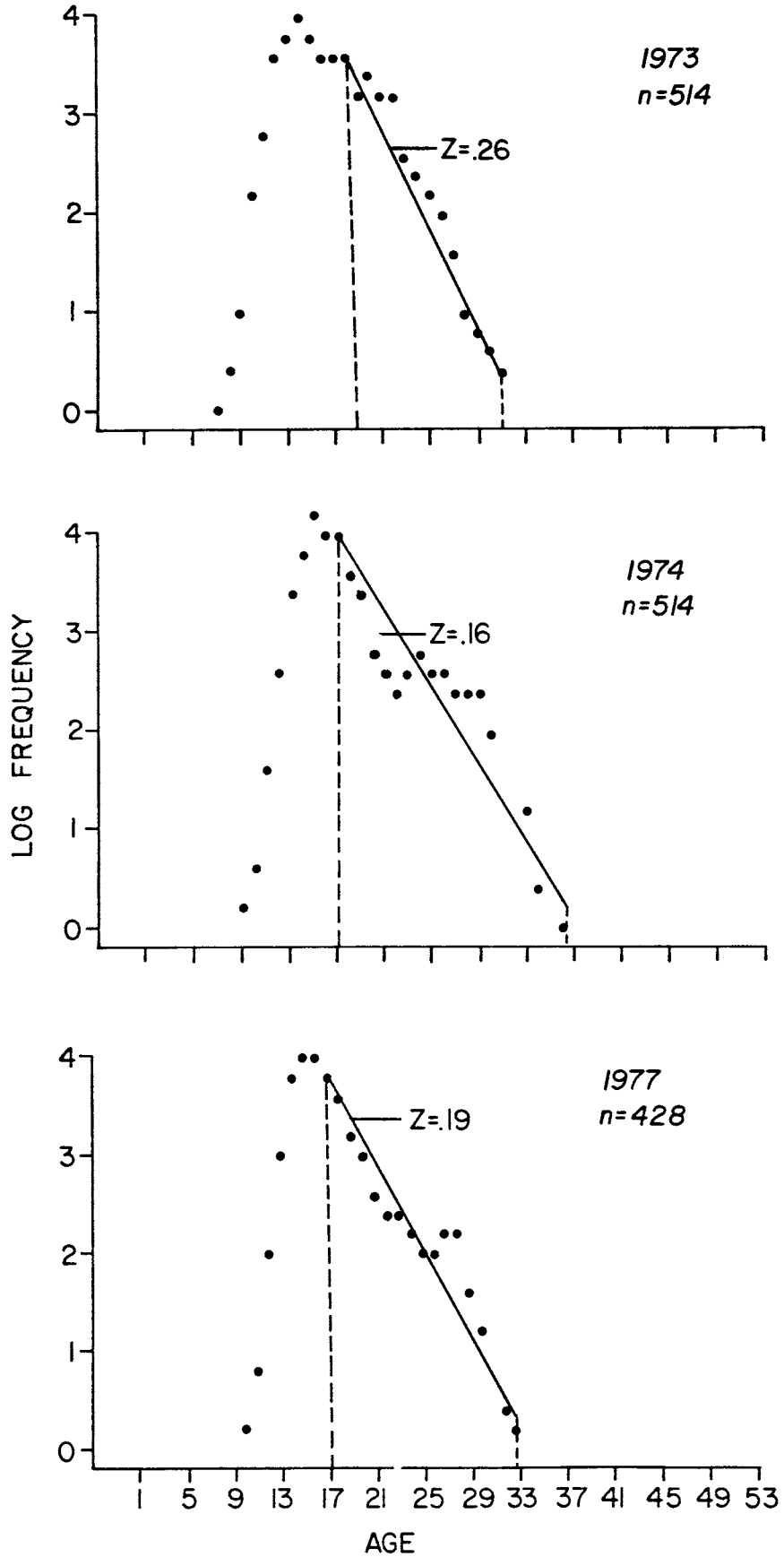

Fig. 11. Catch curves, smoothed by a running average of three, Plummer's Great Slave Lodge.

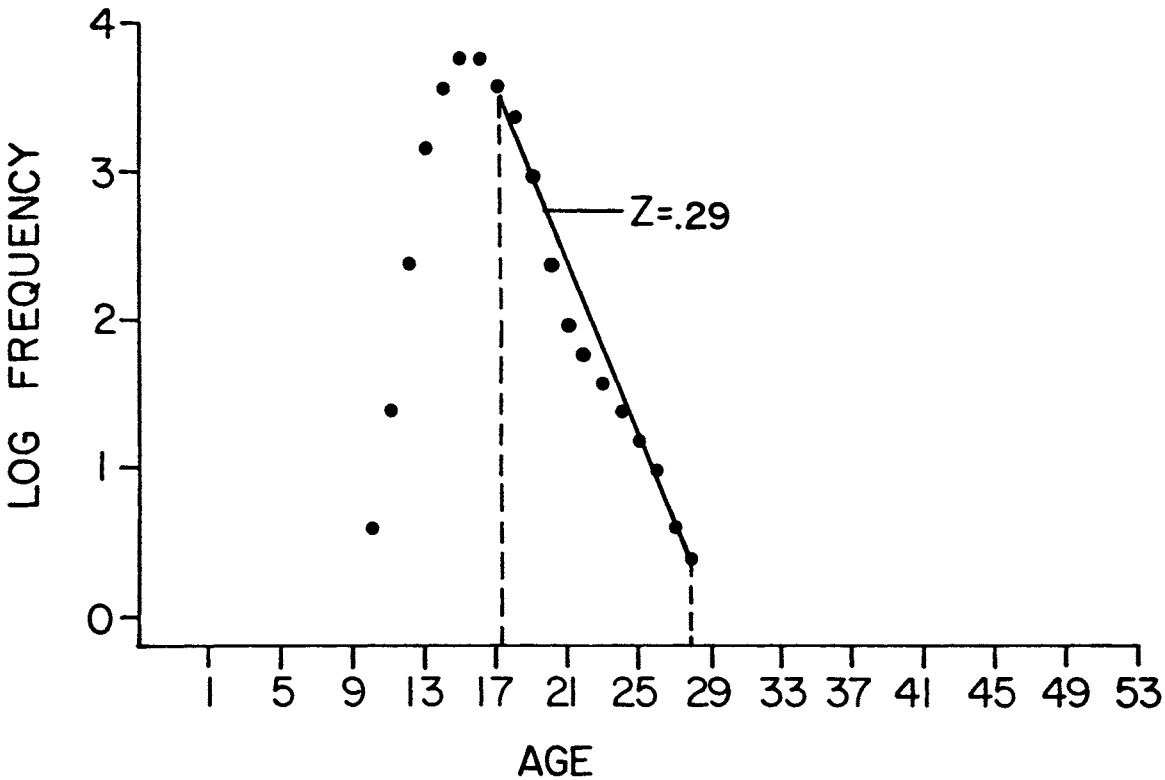

Fig. 12. Catch curve, smoothed by a running average of three, Indian Mountain Lodge.

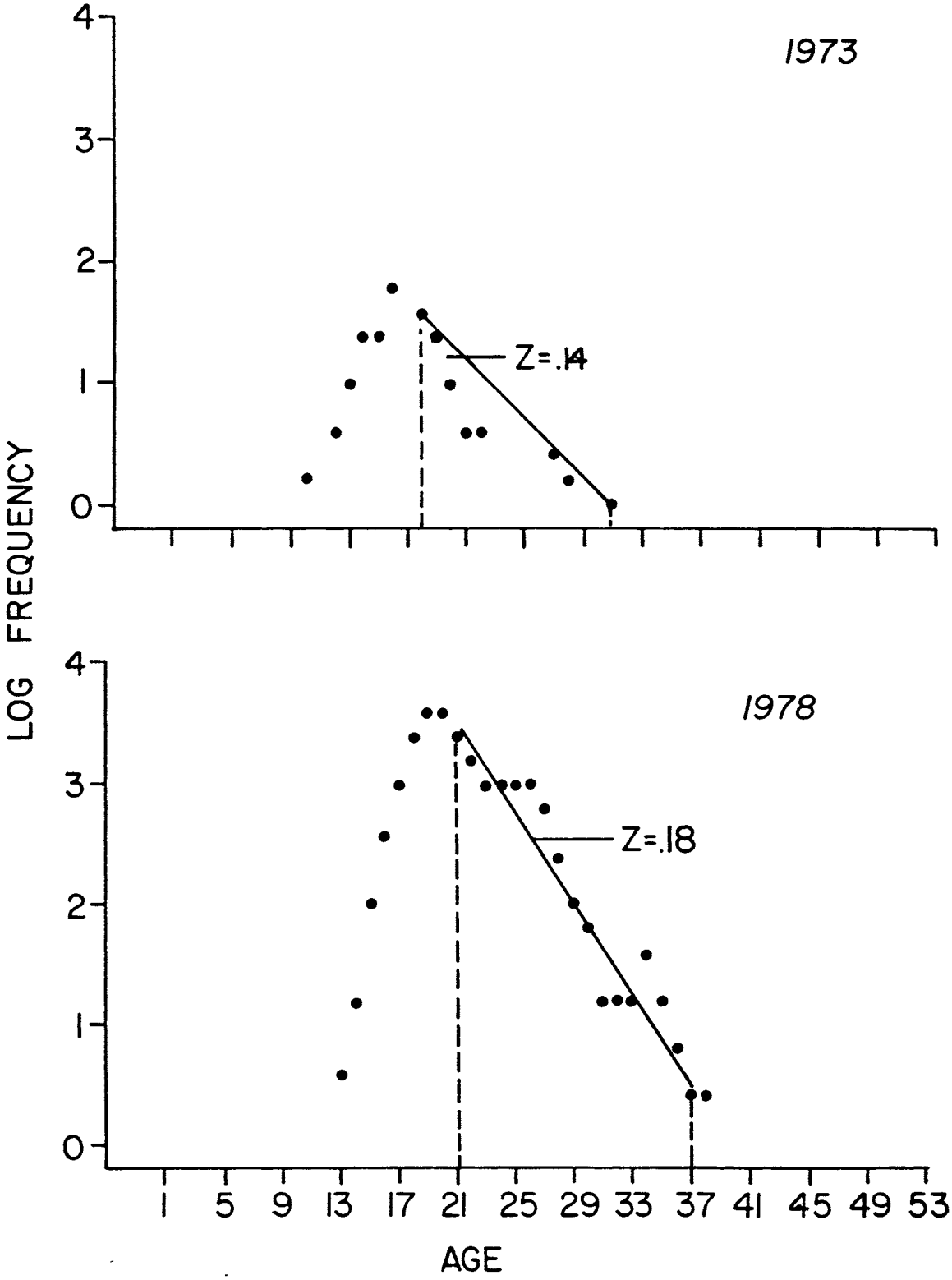

Fig. 13. Catch curves, smoothed by a running average of three, Arctic Star Lodge.

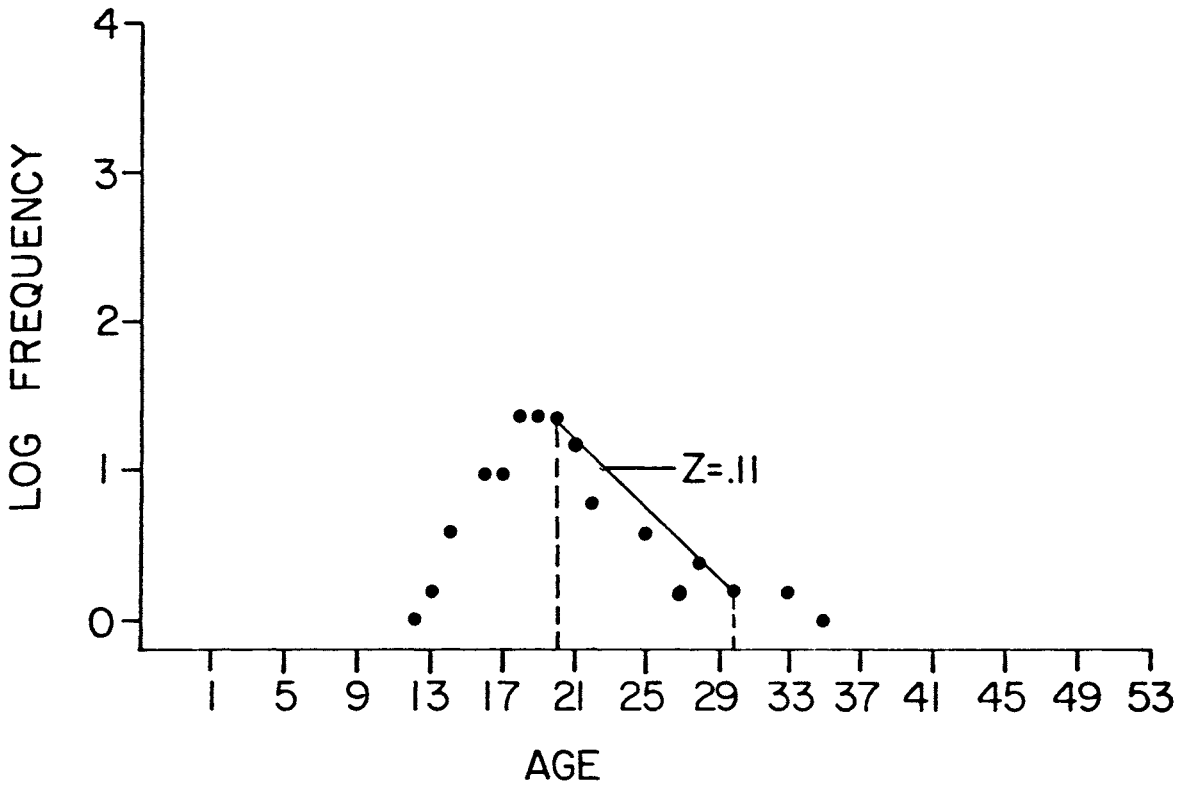

Fig. 14. Catch curve, smoothed by a running average of three, Trophy Lodge, 1979.

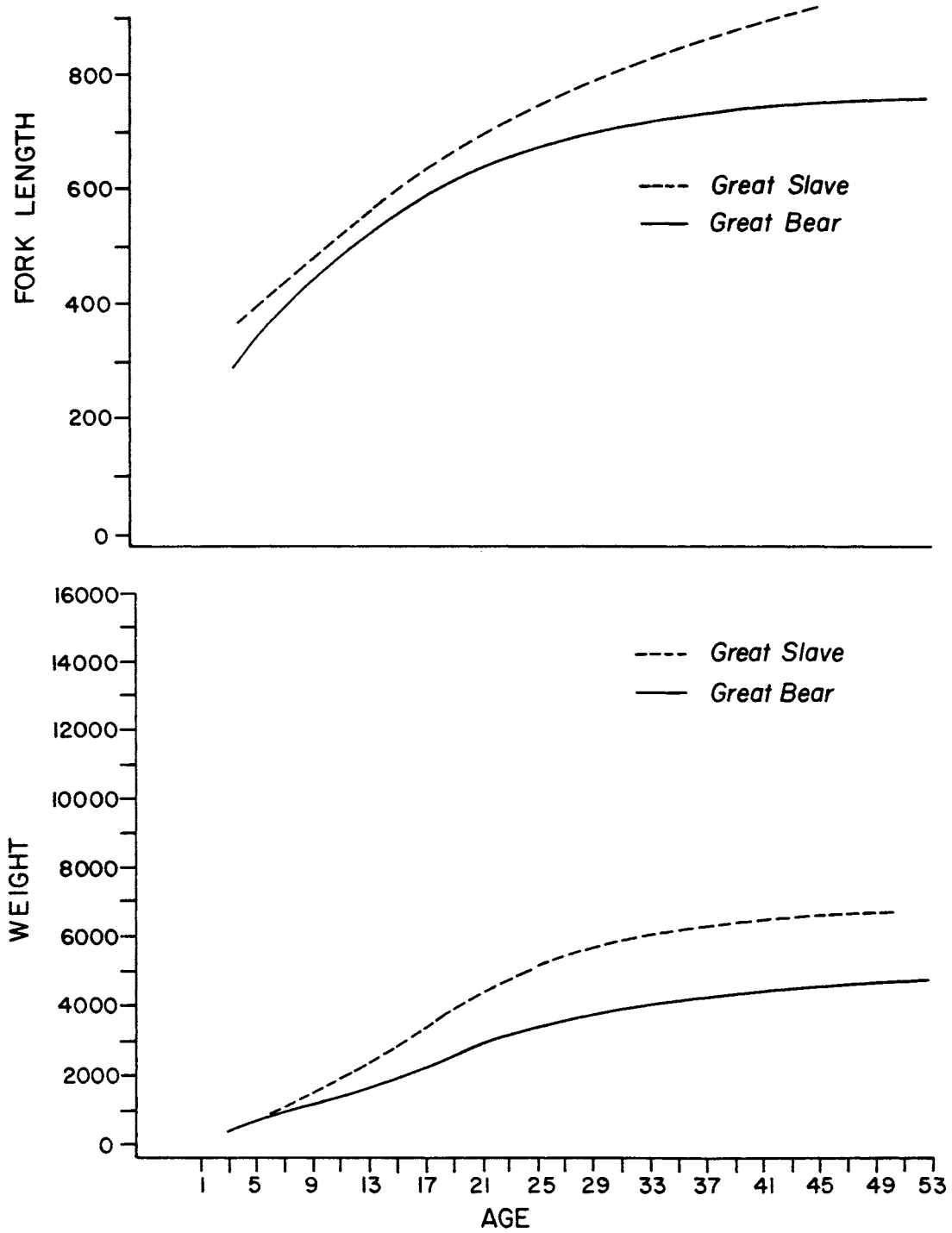

Fig. 15. Mean length and weight at age plotted against age for Great Bear and Great Slave lakes, all creel census samples combined.

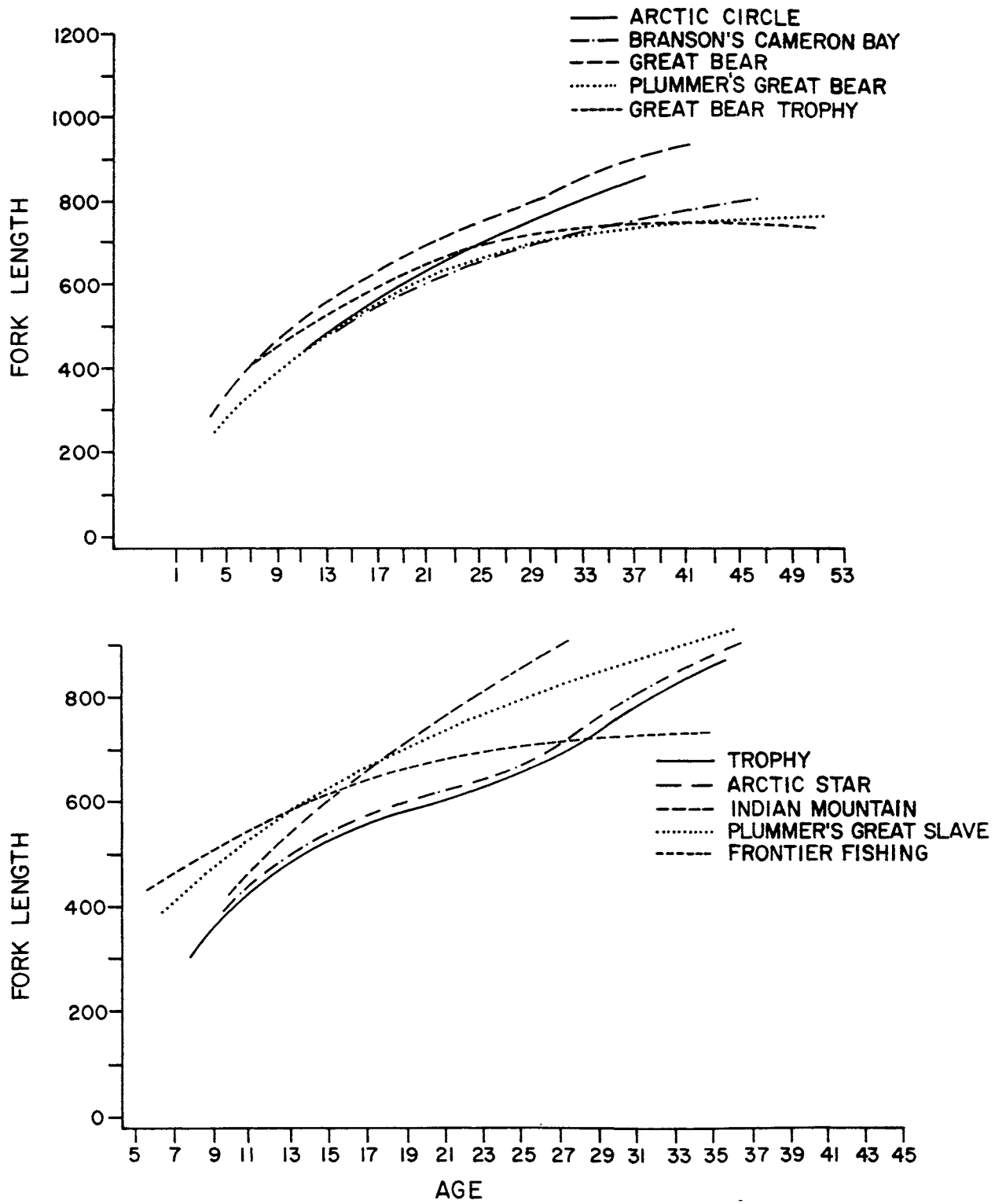

Fig. 16. Mean length and weight at age plotted against age for individual lodges in Great Bear and Great Slave lakes, all creel census data combined.

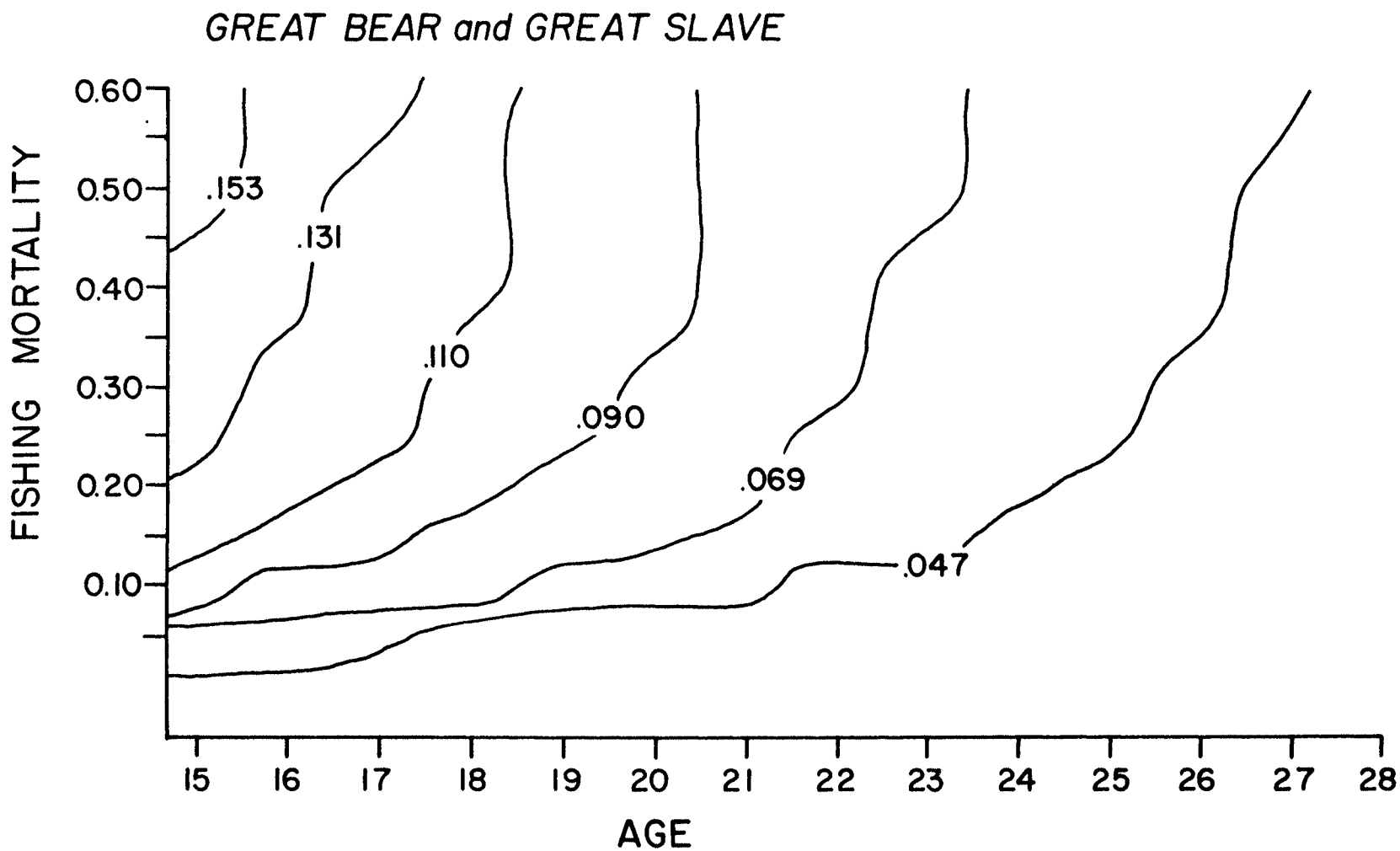

Fig. 17. Yield isopleths for total numerical equilibrium catch per utilized ha for different fishing mortalities and ages of recruitment, Great Bear and Great Slave lakes.

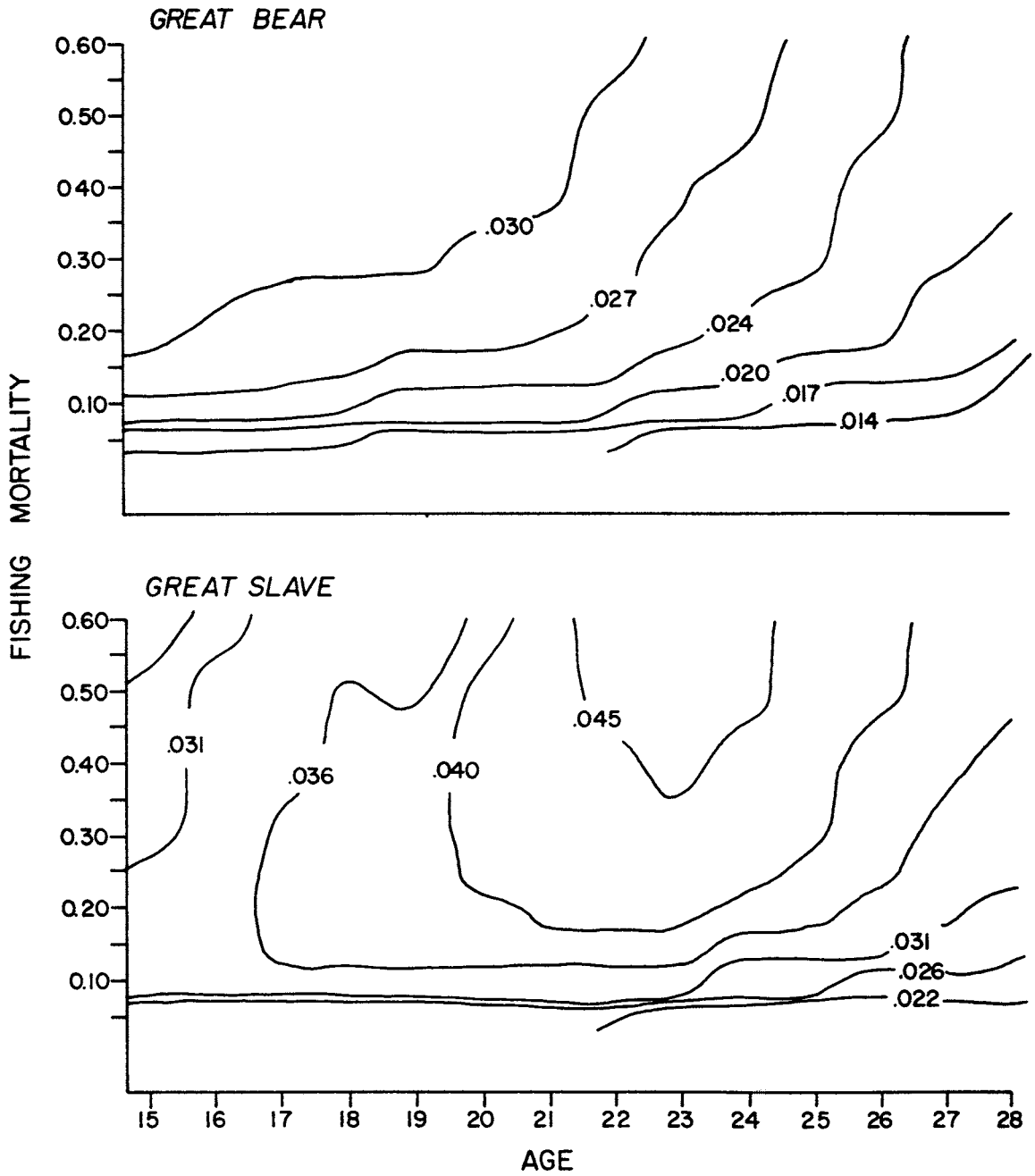

Fig. 18. Yield isopleths for equilibrium catch of fish over 700 mm in length, per utilized ha, for different fishing mortalities and ages of recruitment, Great Bear and Great Slave lakes.

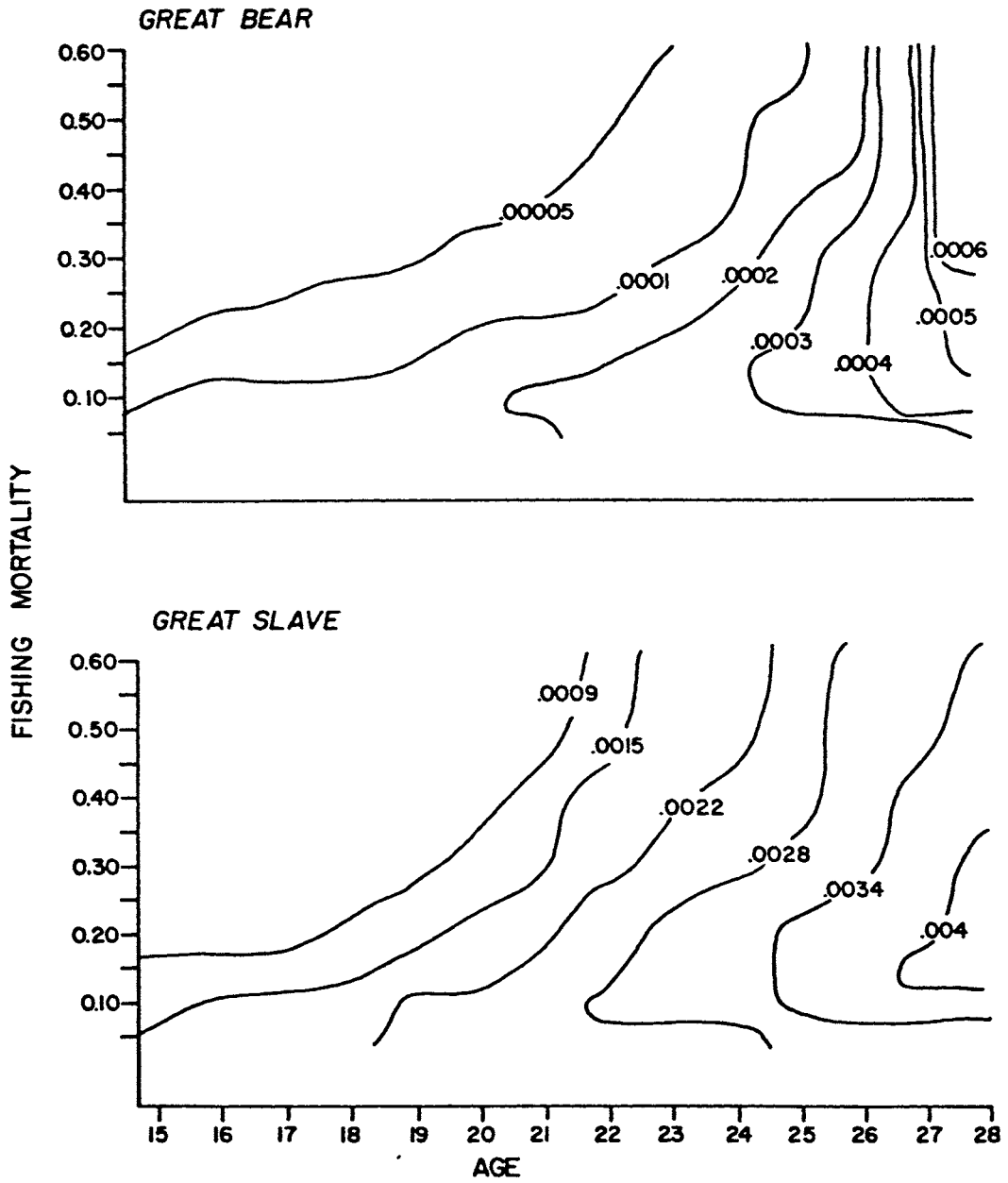

Fig. 19. Yield isopleths for equilibrium catch of fish over 900 mm in length, per utilized ha, for different fishing mortalities and ages of recruitment, Great Bear and Great Slave lakes.

APPENDIX 1

Age class and length class histograms

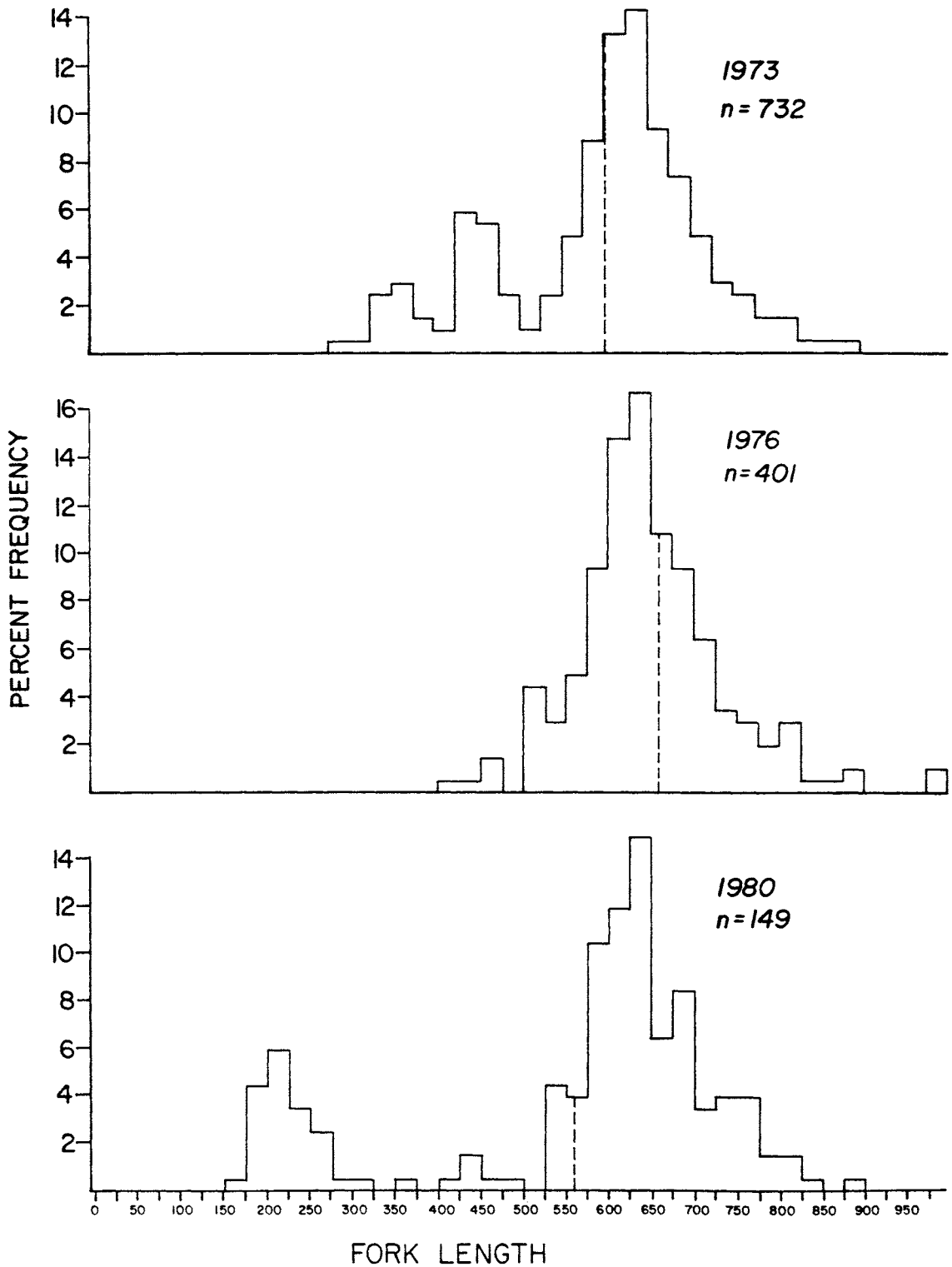

Fig. A1.1. Length class percent frequencies in the angled catch, Great Bear Trophy Lodge. Broken line indicates mean.

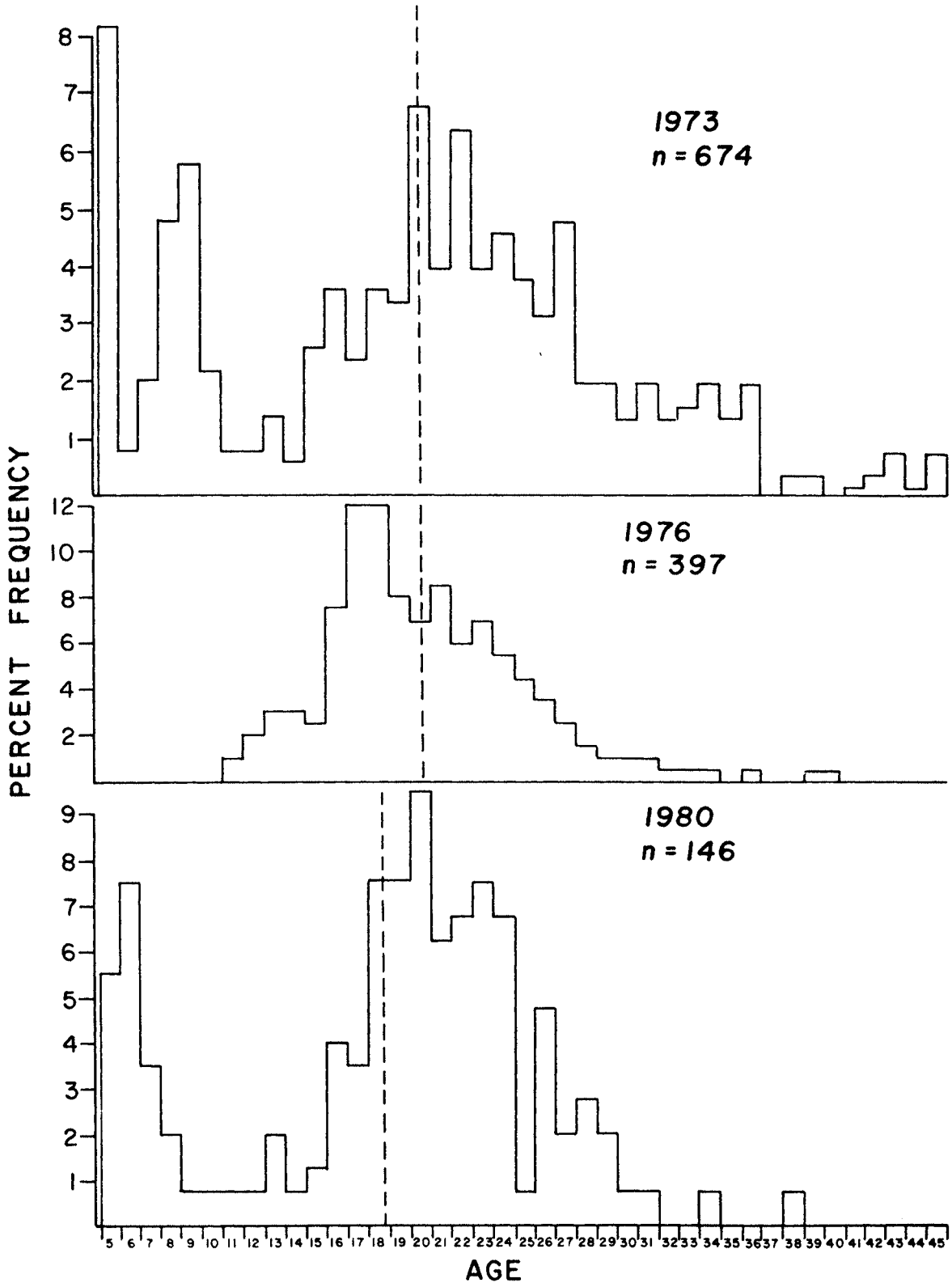

Fig. A1.2. Age group percent frequencies in the angled catch, Great Bear Trophy Lodge. Broken line indicates mean.

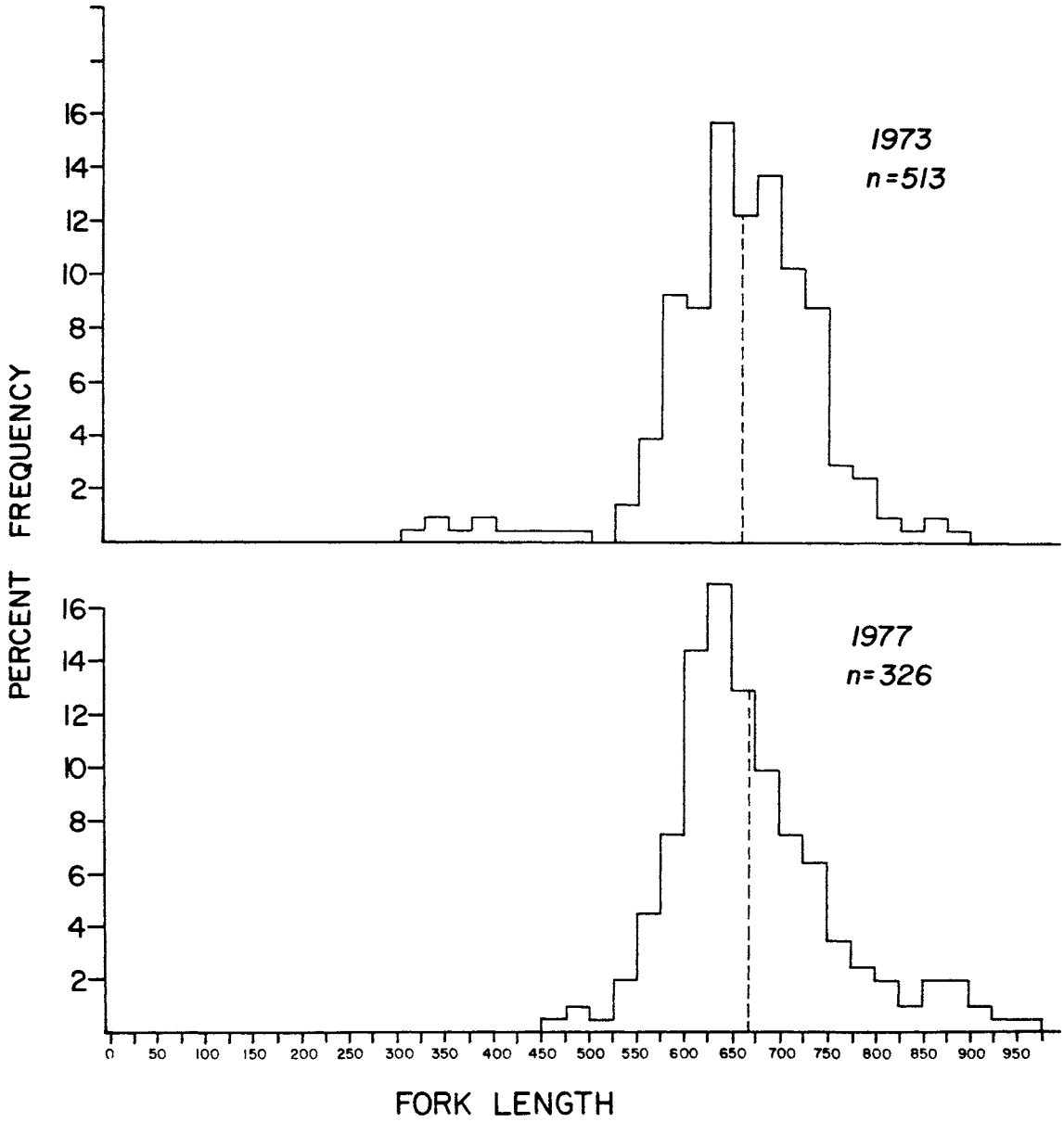

Fig. A1.3. Length class percent frequences in the angled catch, Plummer's Great Bear Lake Lodge. Broken line indicates mean.

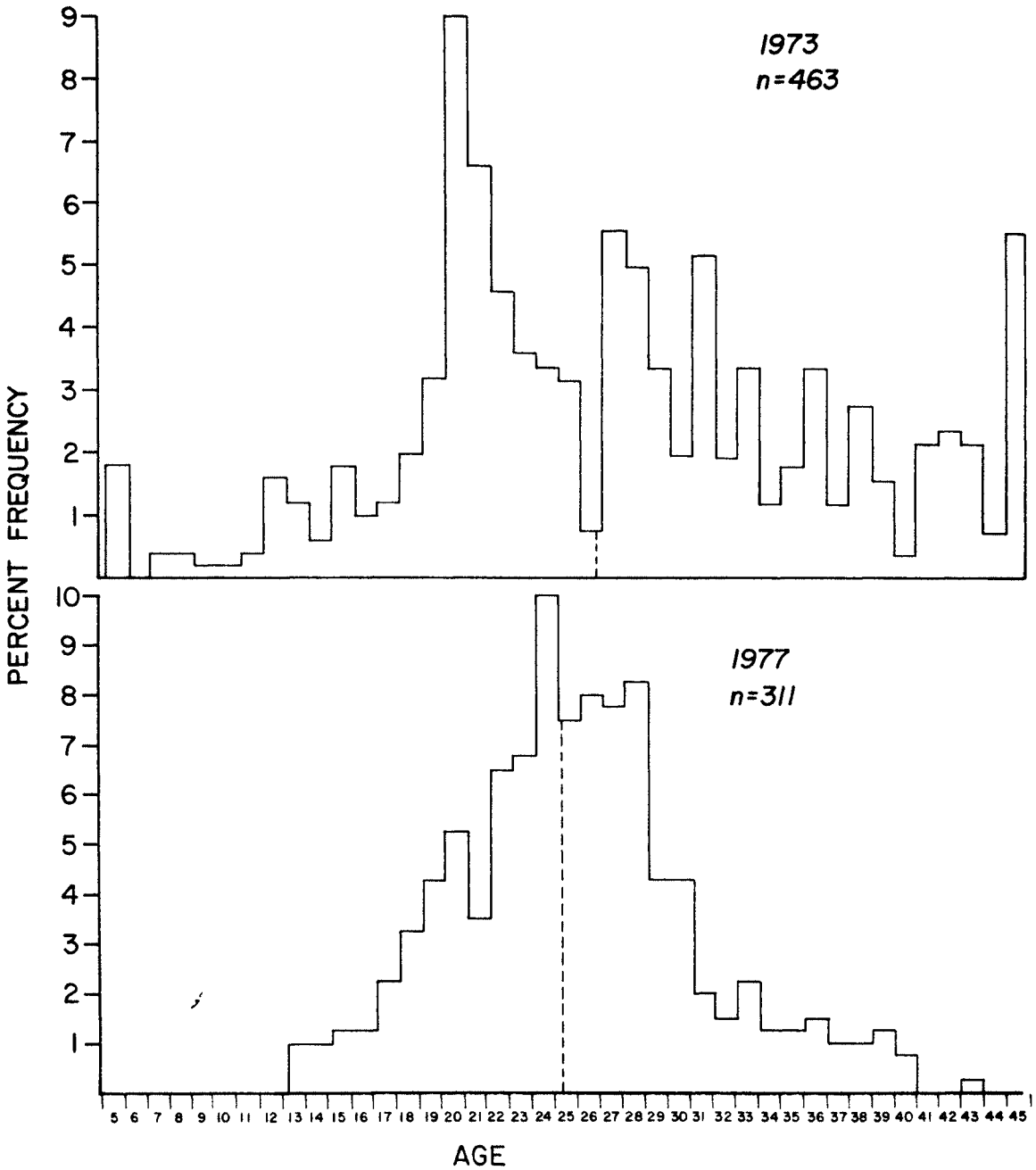

Fig. A1.4. Age group percent frequencies in the angled catch, Plummer's Great Bear Lake Lodge. Broken line indicates mean.

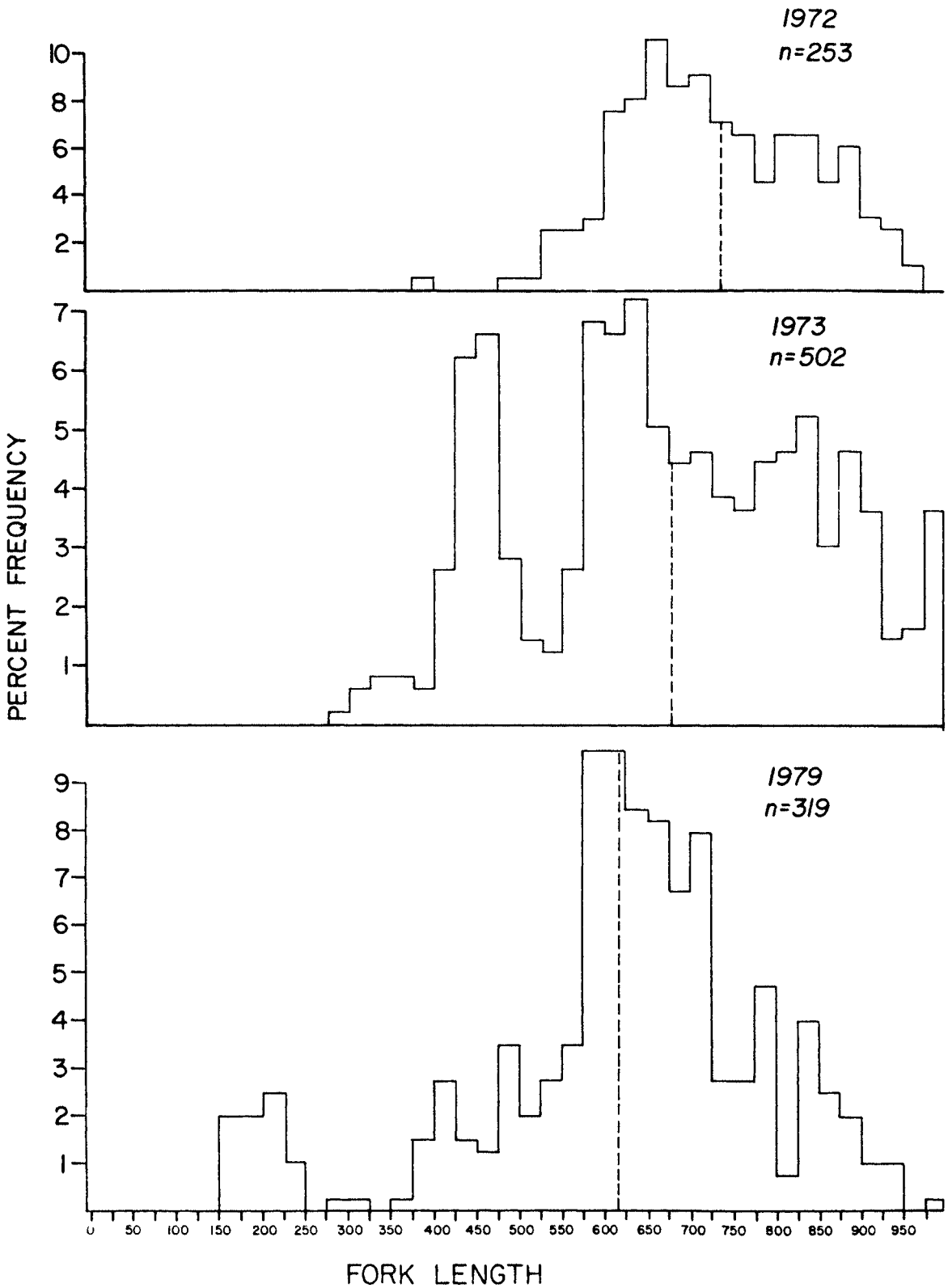

Fig. A1.5. Length class percent frequencies in the angled catch, Great Bear Lodge. Broken line indicates mean.

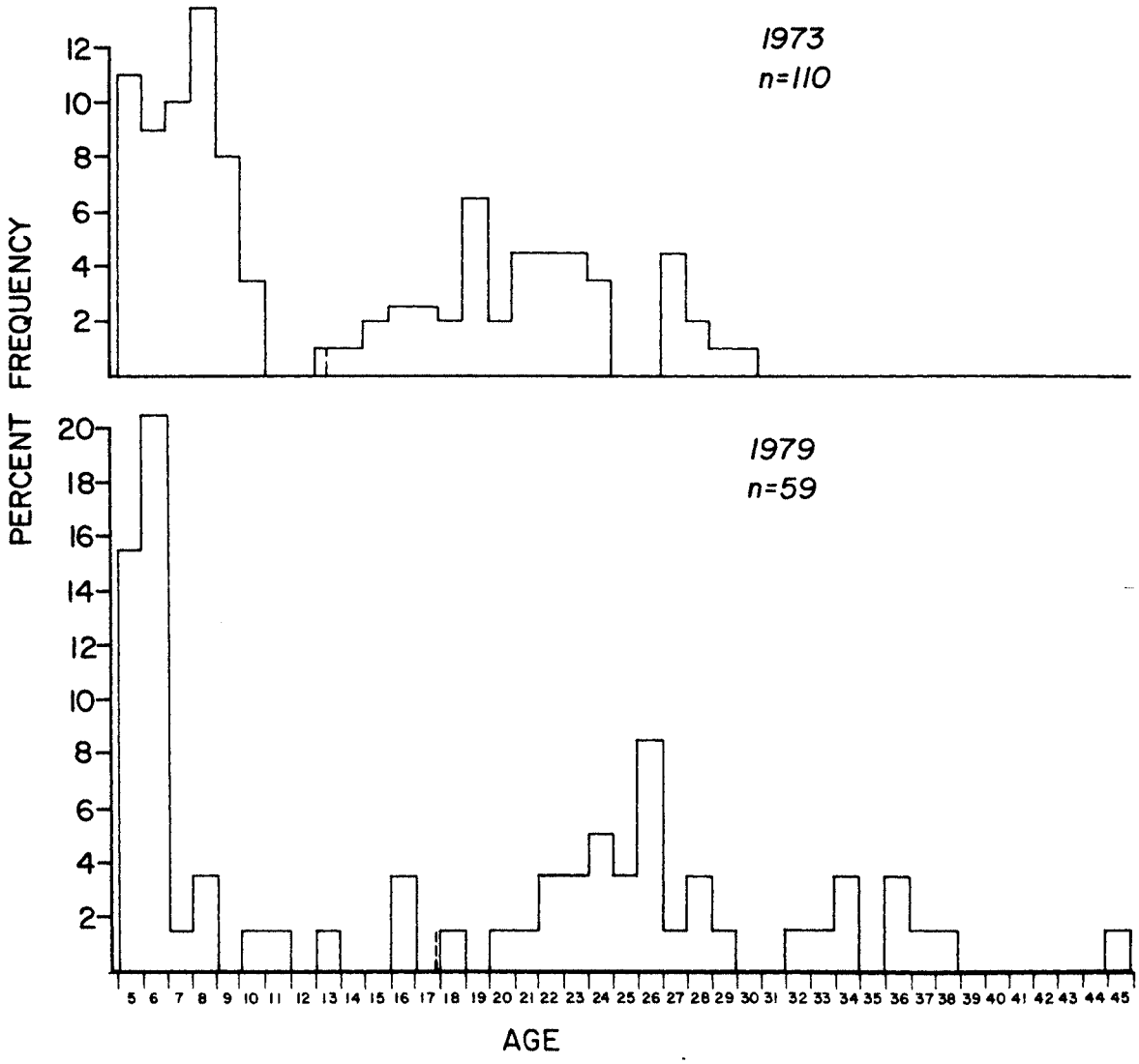

Fig. A1.6. Age group percent frequencies in the angled catch, Great Bear Lodge. Broken line indicates mean.

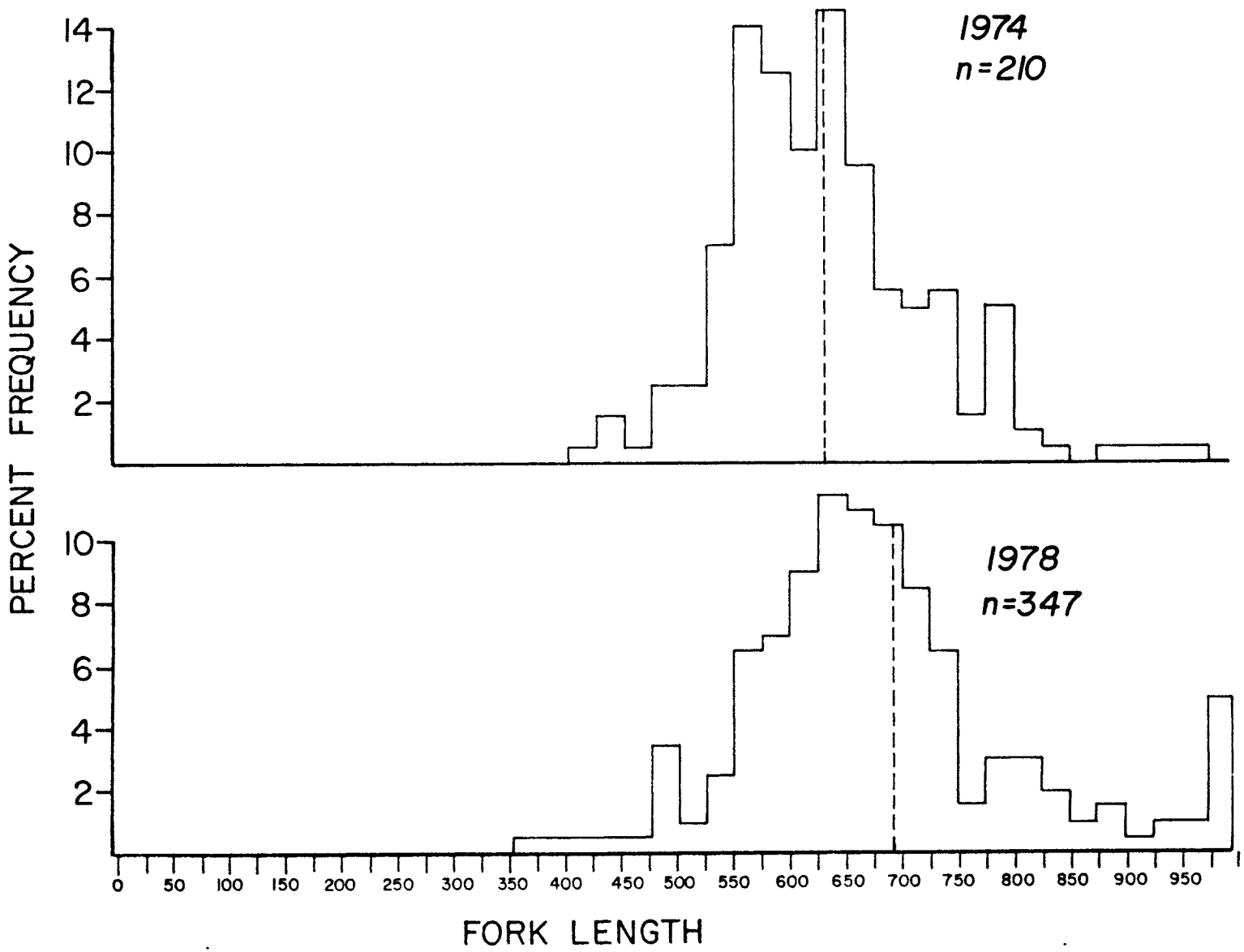

Fig. A1.7. Length class percent frequencies in the angled catch, Branson's Cameron Bay Lodge. Broken line indicates mean.

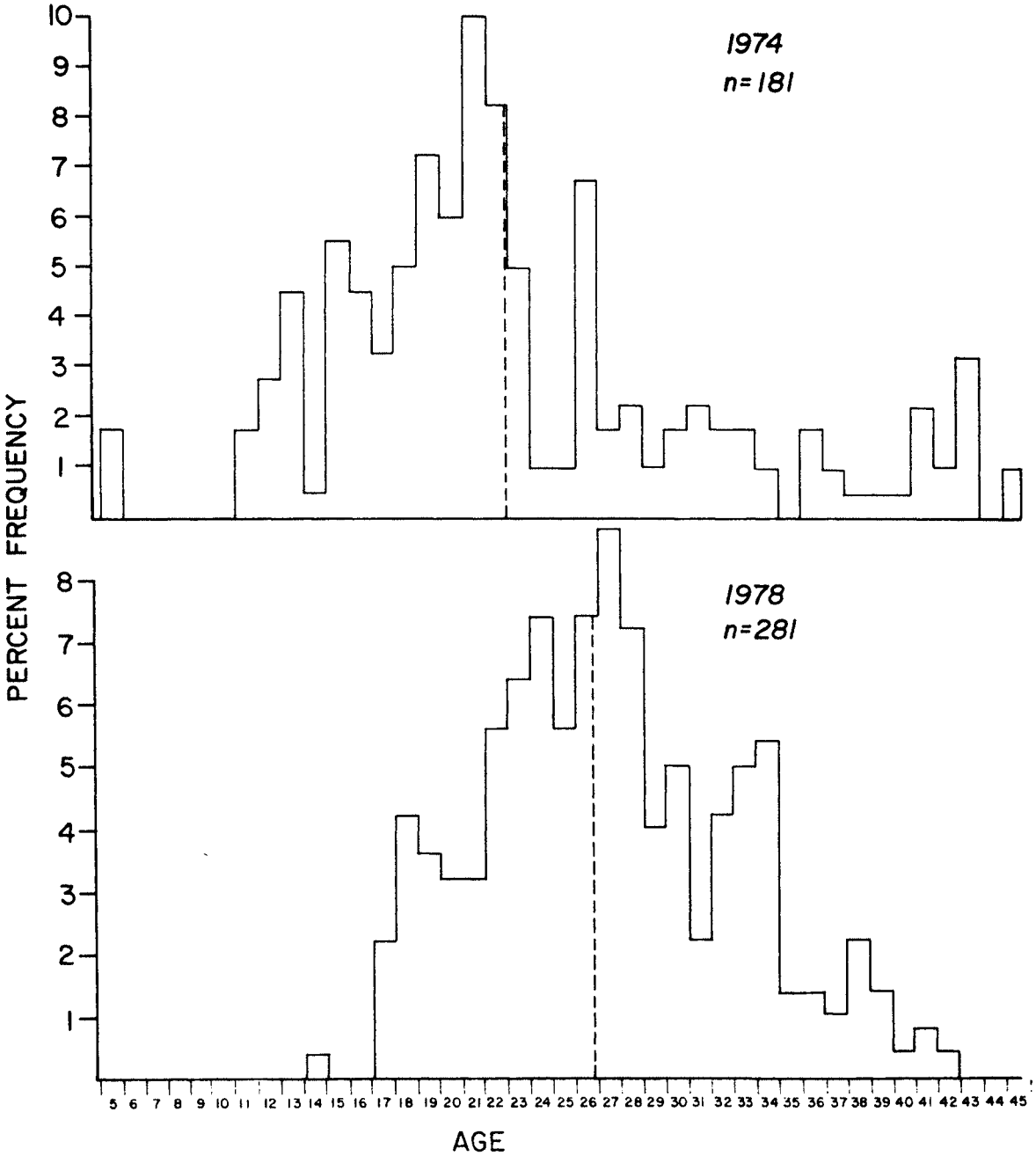

Fig. A1.8. Age group percent frequencies in the angled catch, Branson's Cameron Bay Lodge. Broken line indicates mean.

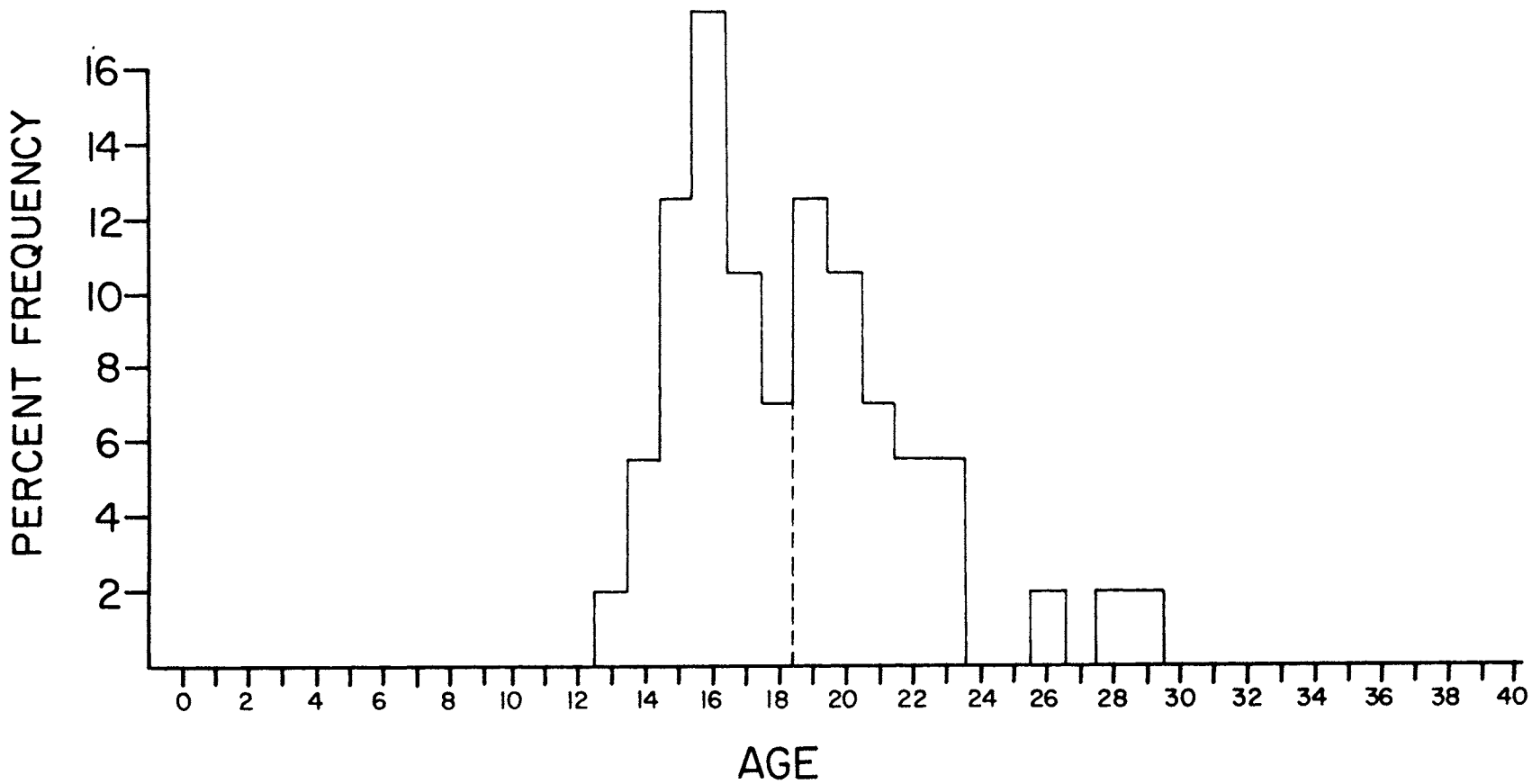

Fig. A1.9. Age group percent frequences in 38 mm gillnet sample. Branson's Cameron Bay Lodge. Broken line indicates mean.

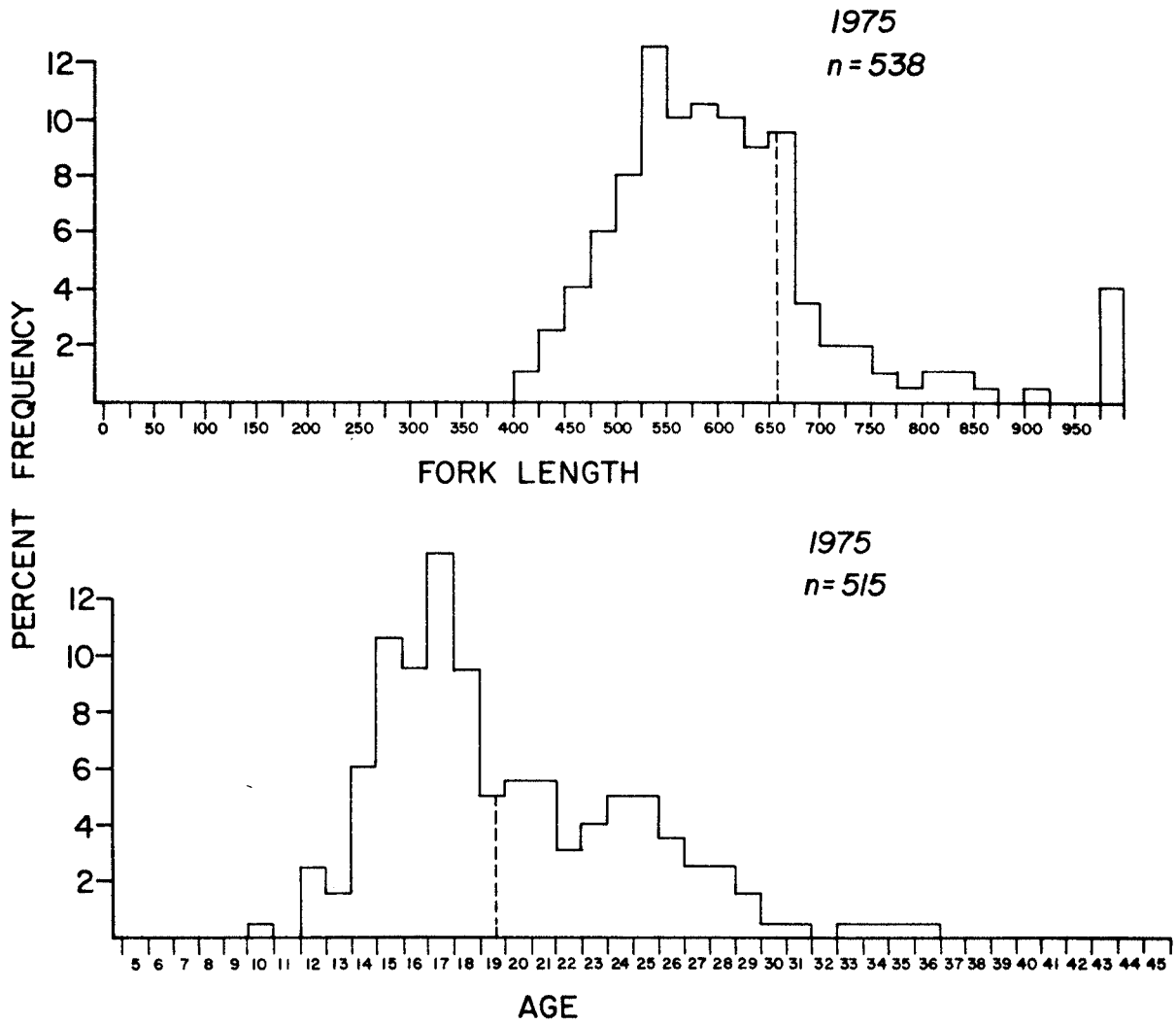

Fig. A1.10. Length class and age group percent frequencies in the angled catch, Arctic Circle Lodge, 1975. Broken line indicates mean.

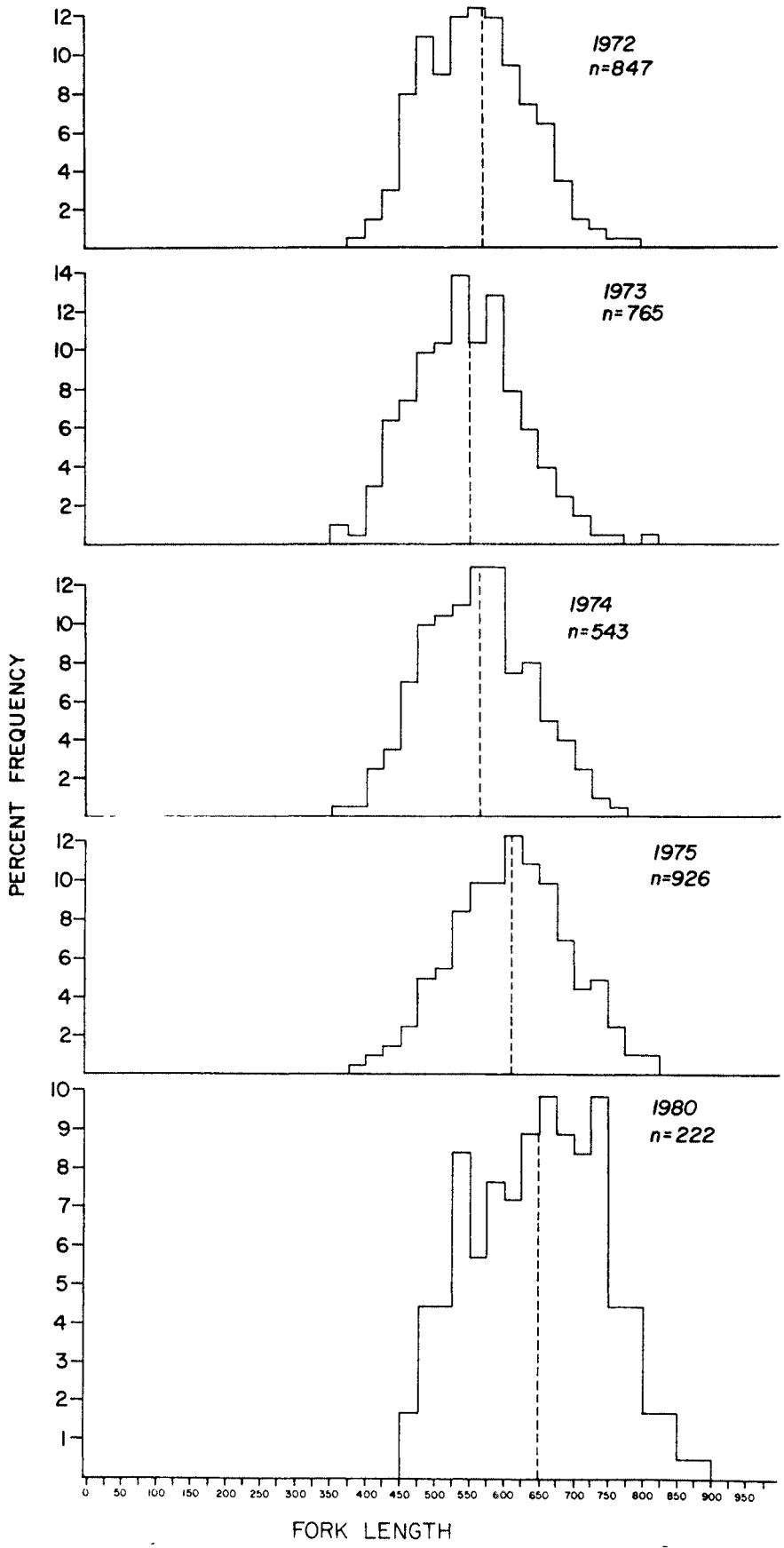

Fig. A1.11. Length class percent frequencies in the angled catch, Frontier Fishing Lodge. Broken line indicates mean.

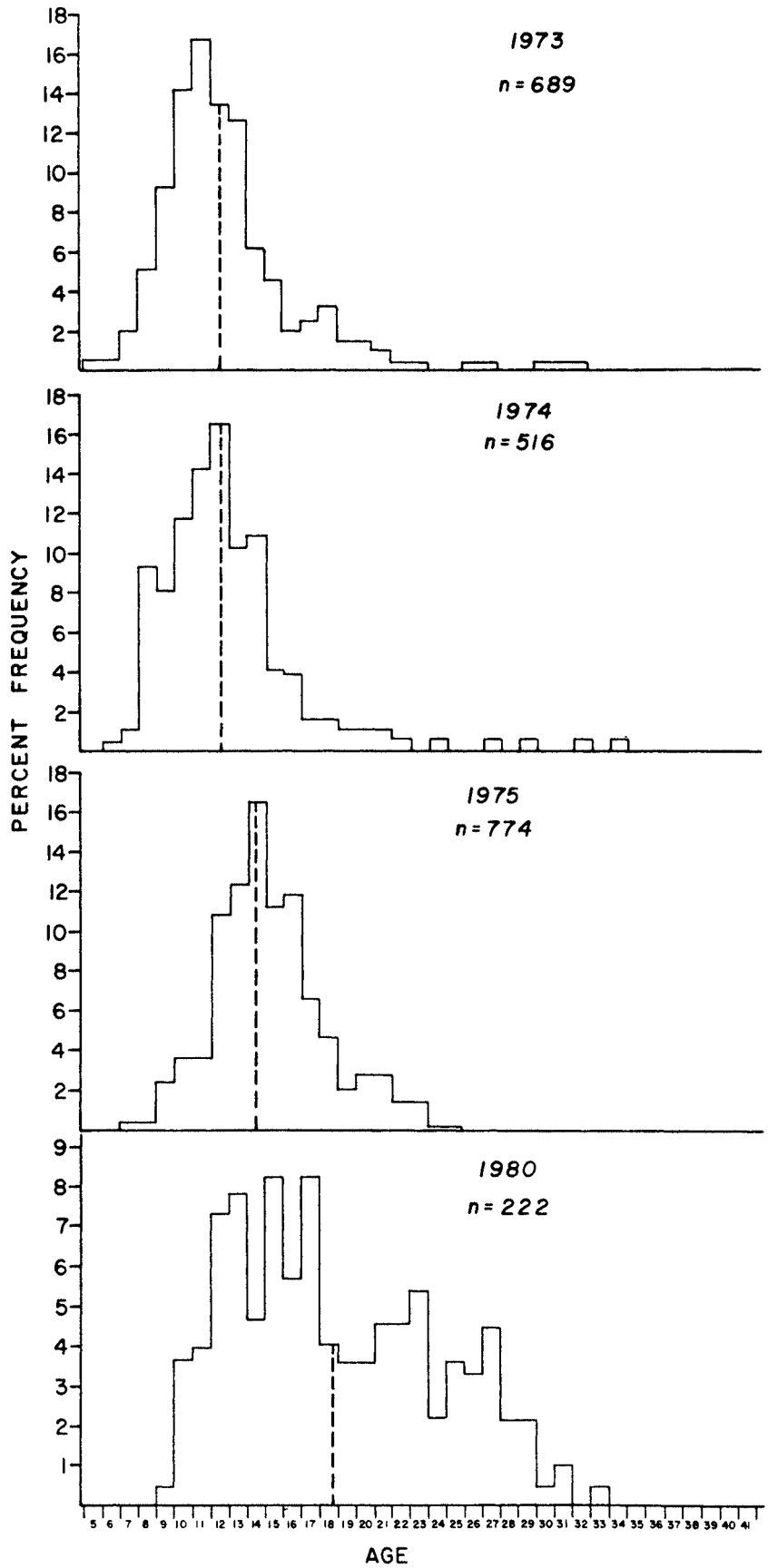

Fig. A1.12. Age group percent frequencies in the angled catch, Frontier Fishing Lodge. Broken line indicates mean.

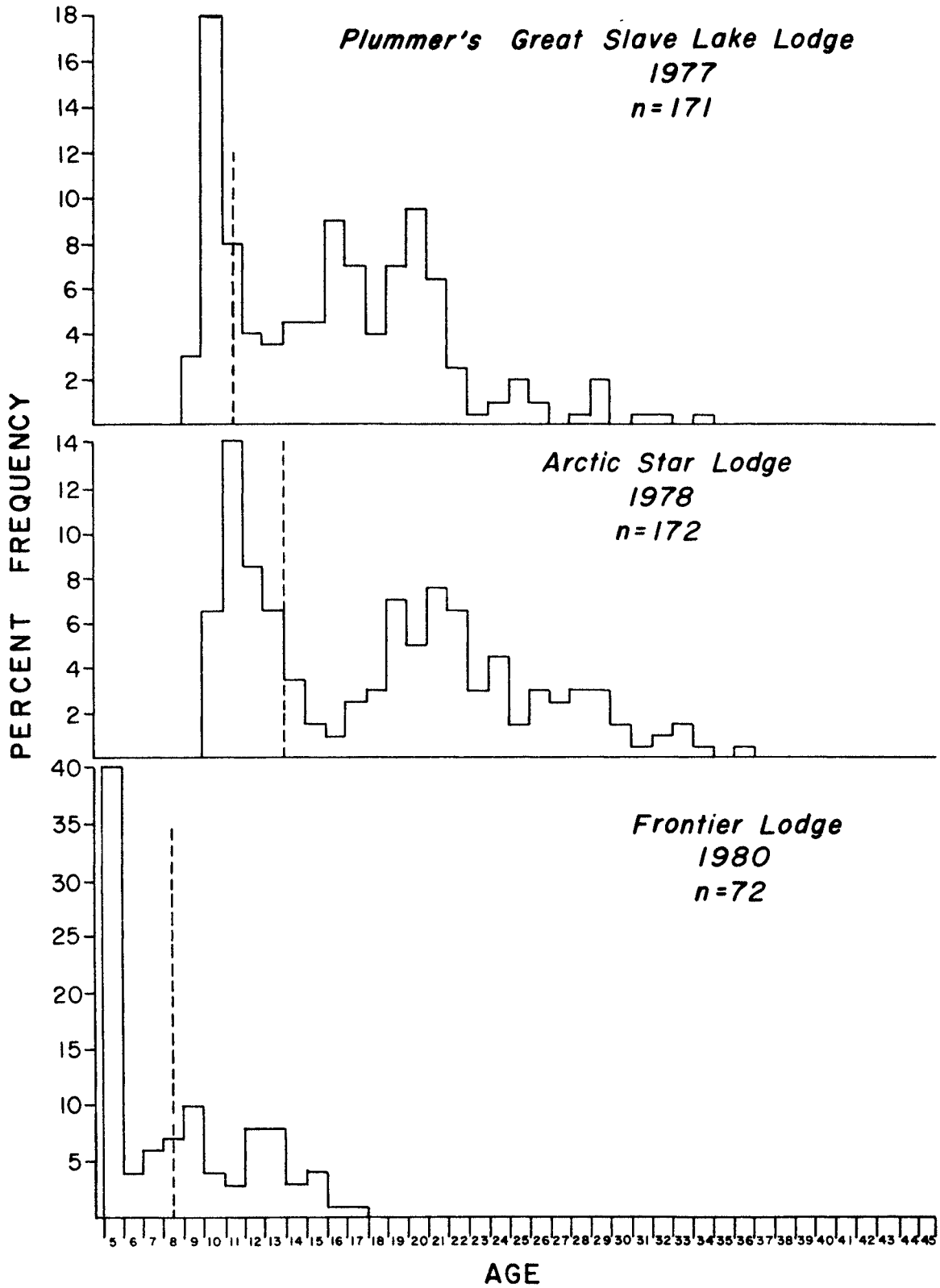

Fig. A1.13. Age group percent frequencies in 38 mm gillnet samples from Great Slave Lake. Broken line indicates mean.

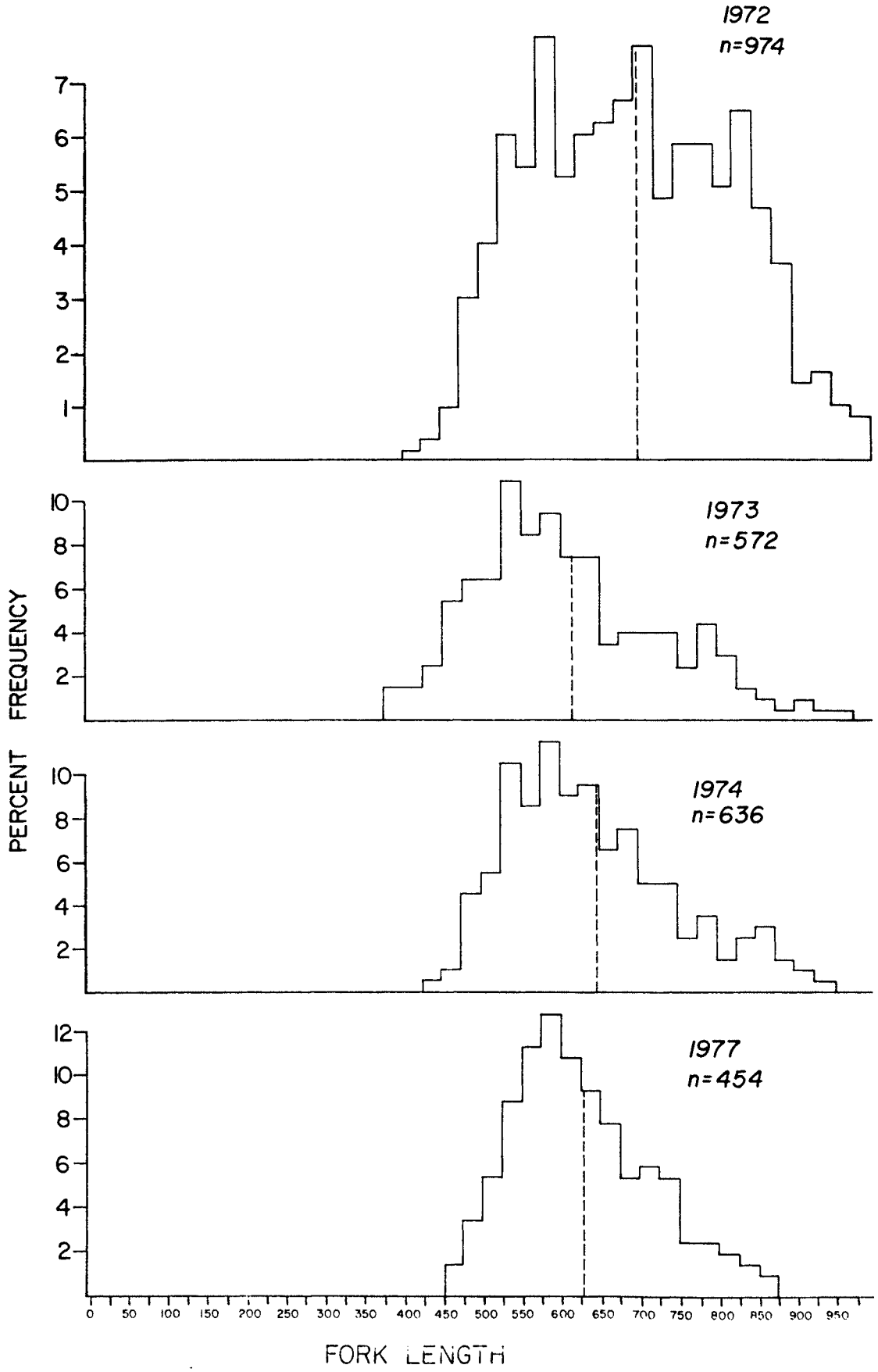

Fig. A1.14. Length class percent frequencies in the angled catch, Plummer's Great Slave Lodge. Broken line indicates mean.

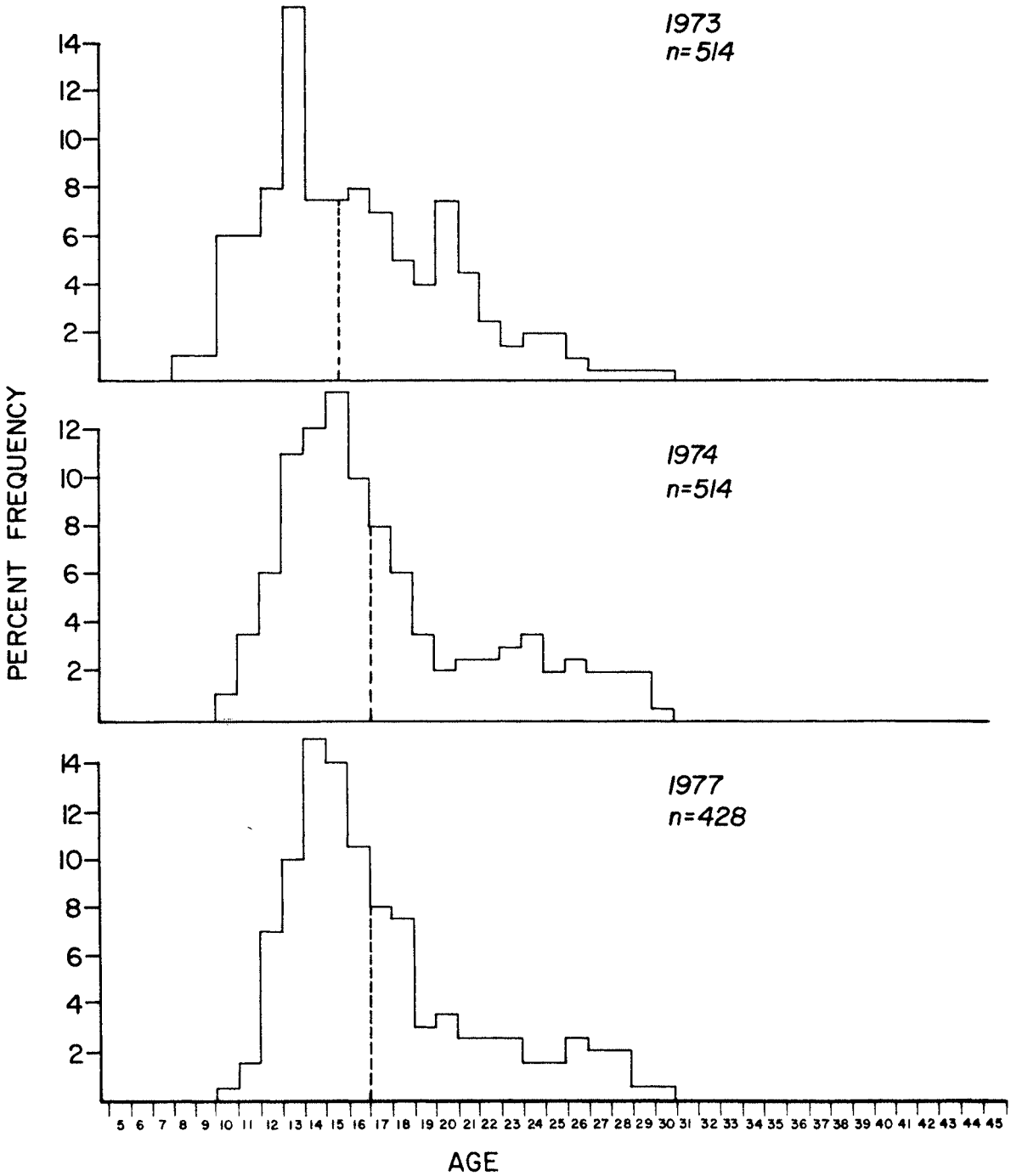

Fig. A1.15. Age group percent frequencies in the angled catch, Plummer's Great Slave Lodge. Broken line indicates mean.

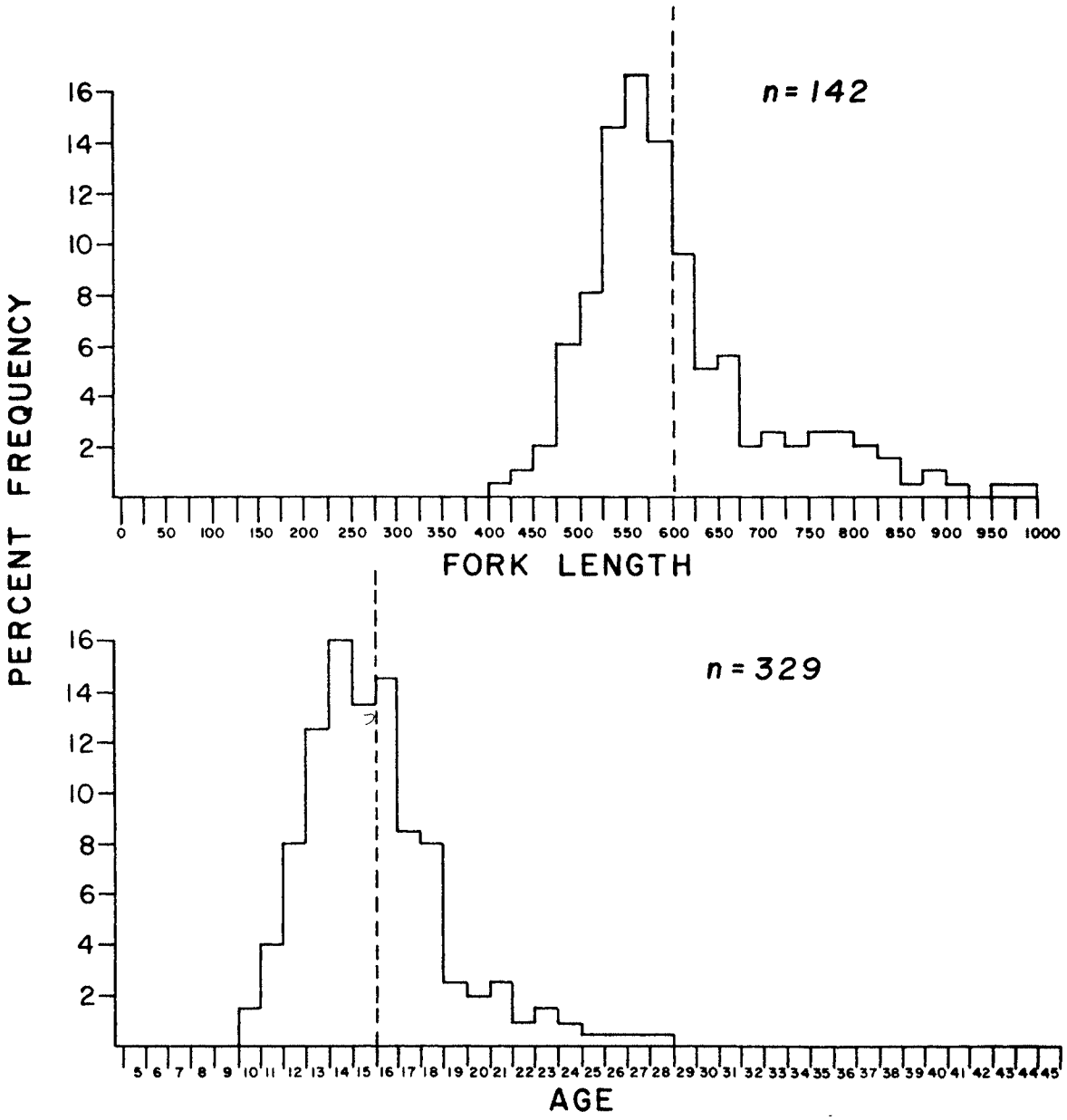

Fig. A1.16. Length class and age percent frequencies in the angled catch, Indian Mountain Lodge, 1976. Broken line indicates mean.

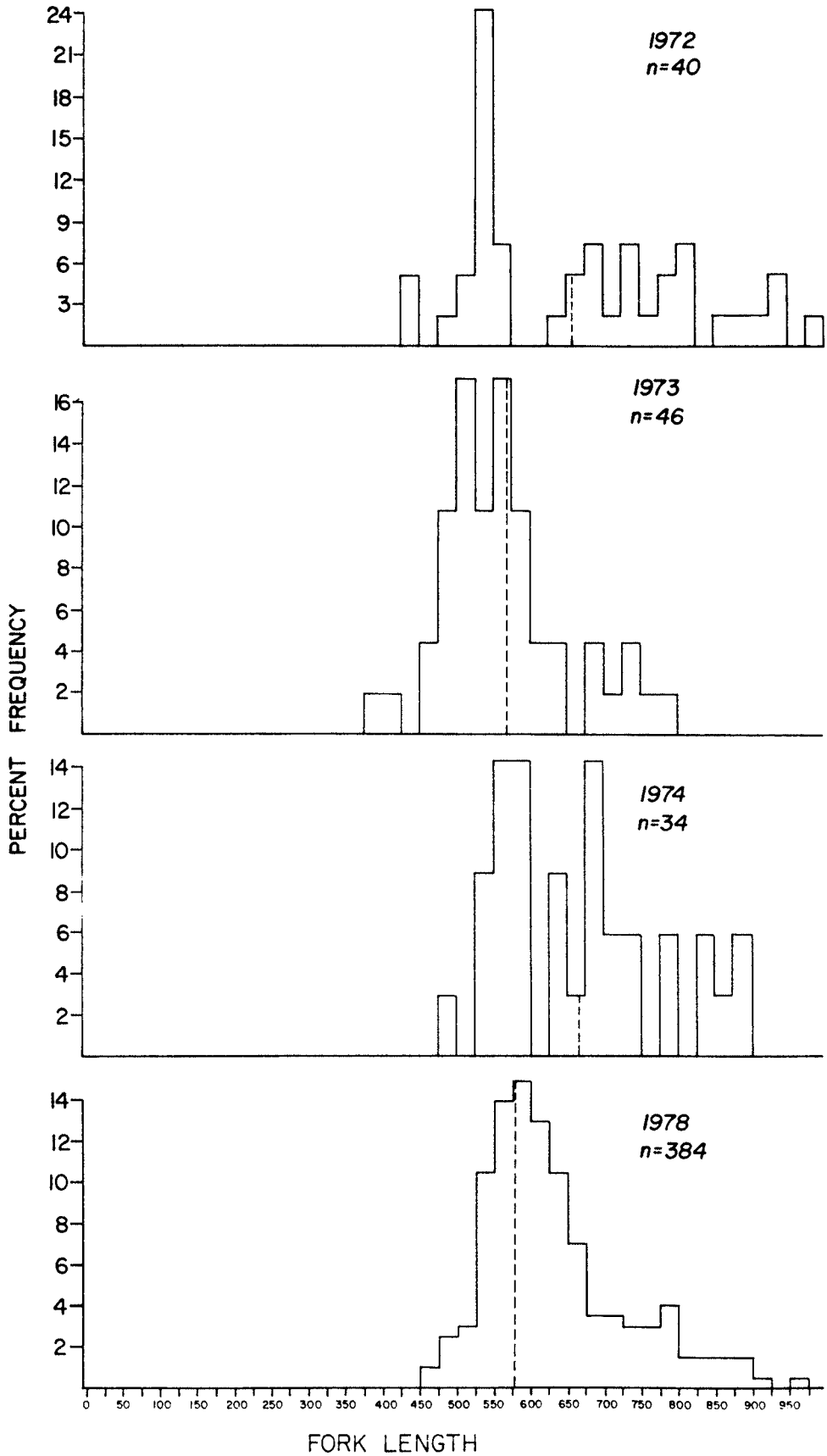

Fig. A1.17. Length class percent frequencies in the angled catch, Arctic Star Lodge. Broken line indicates mean.

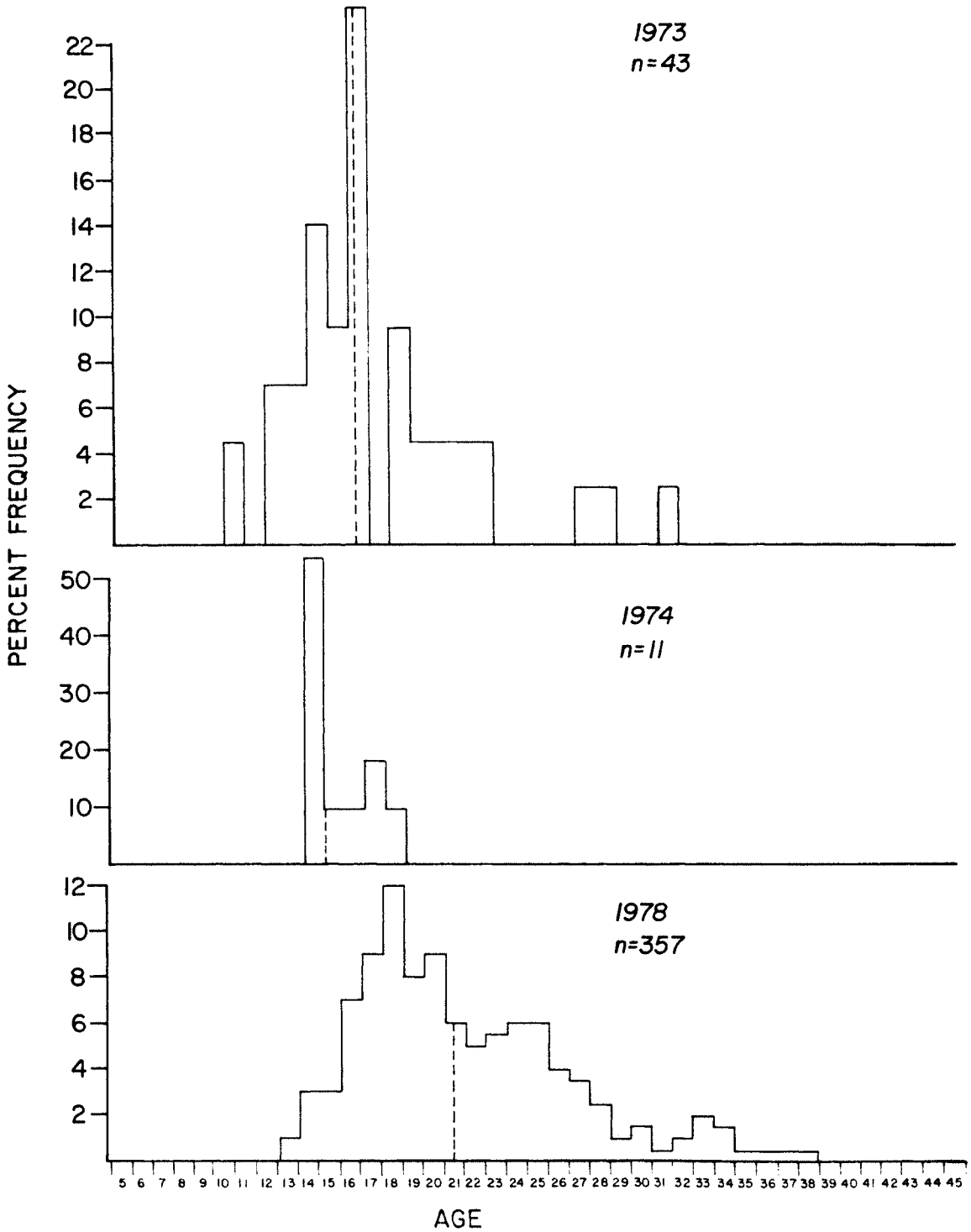

Fig. A1.18. Age group percent frequencies in the angled catch, Arctic Star Lodge. Broken line indicates mean.

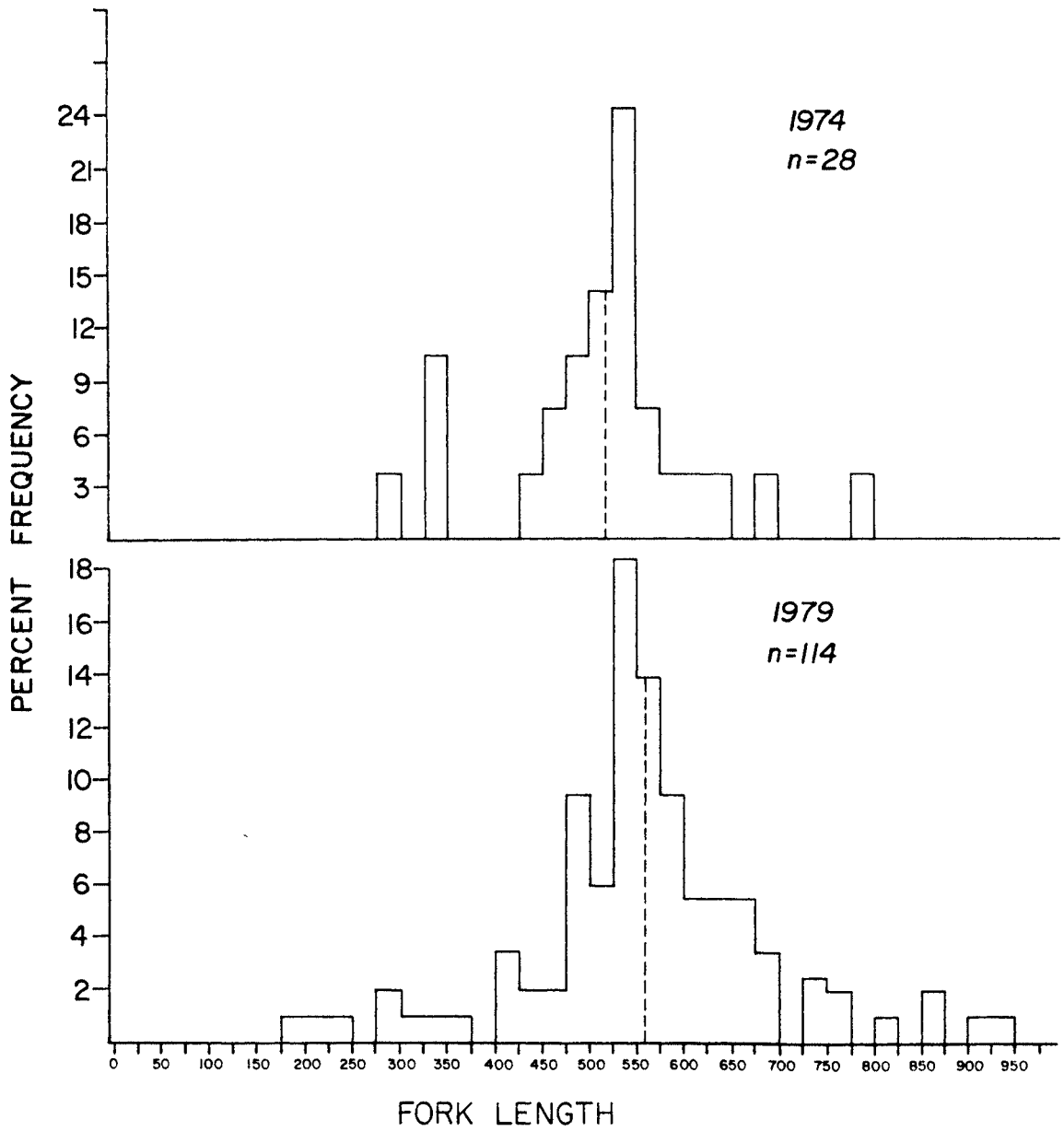

Fig. A1.19. Length class percent frequencies in the angled catch, Trophy Lodge. Broken line indicates mean.

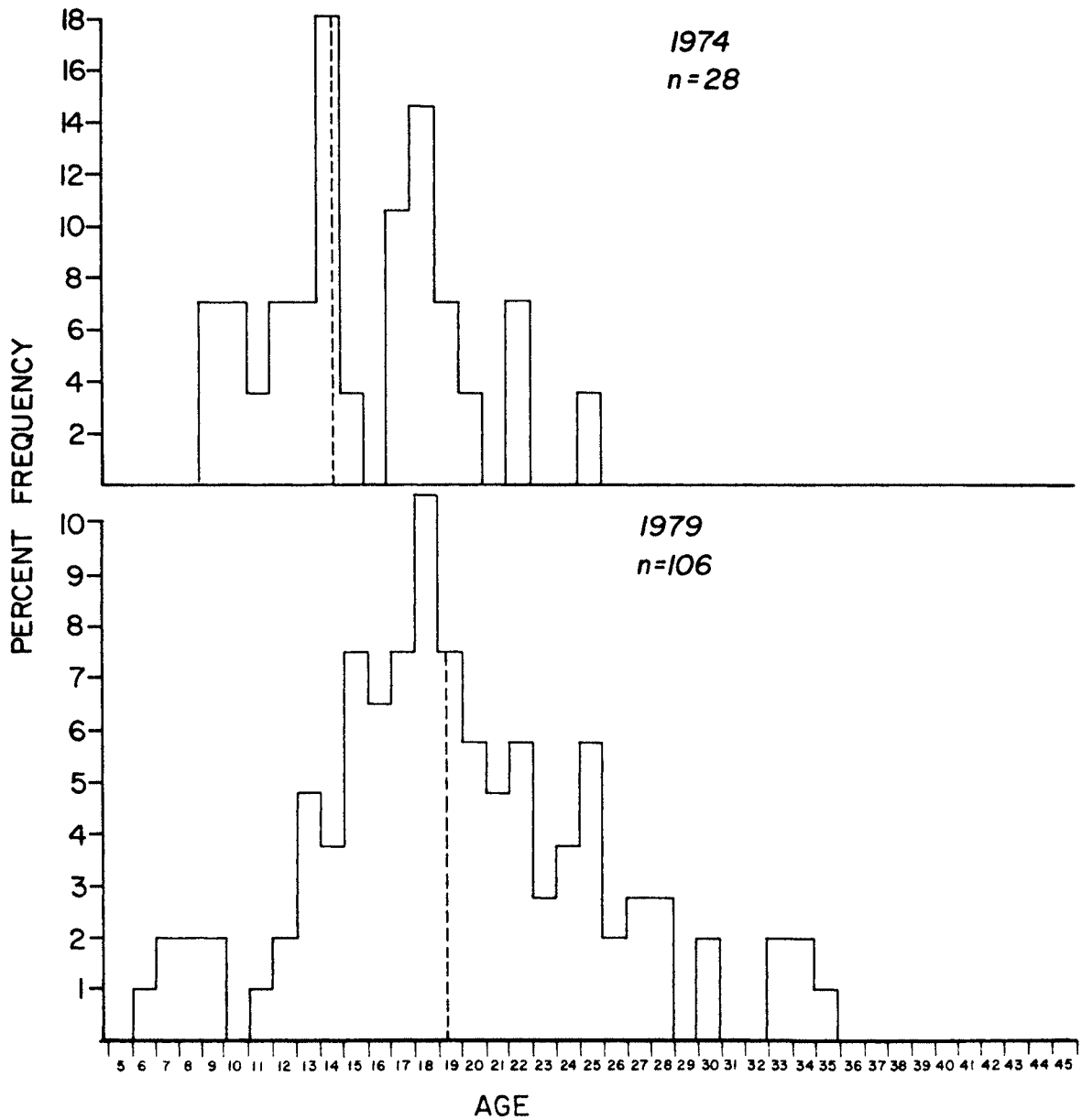

Fig. A1.20. Age group percent frequencies in the angled catch, Trophy Lodge. Broken line indicates mean.

APPENDIX 2

Areas utilized by sport fishing lodges on Great Bear and Great Slave lakes

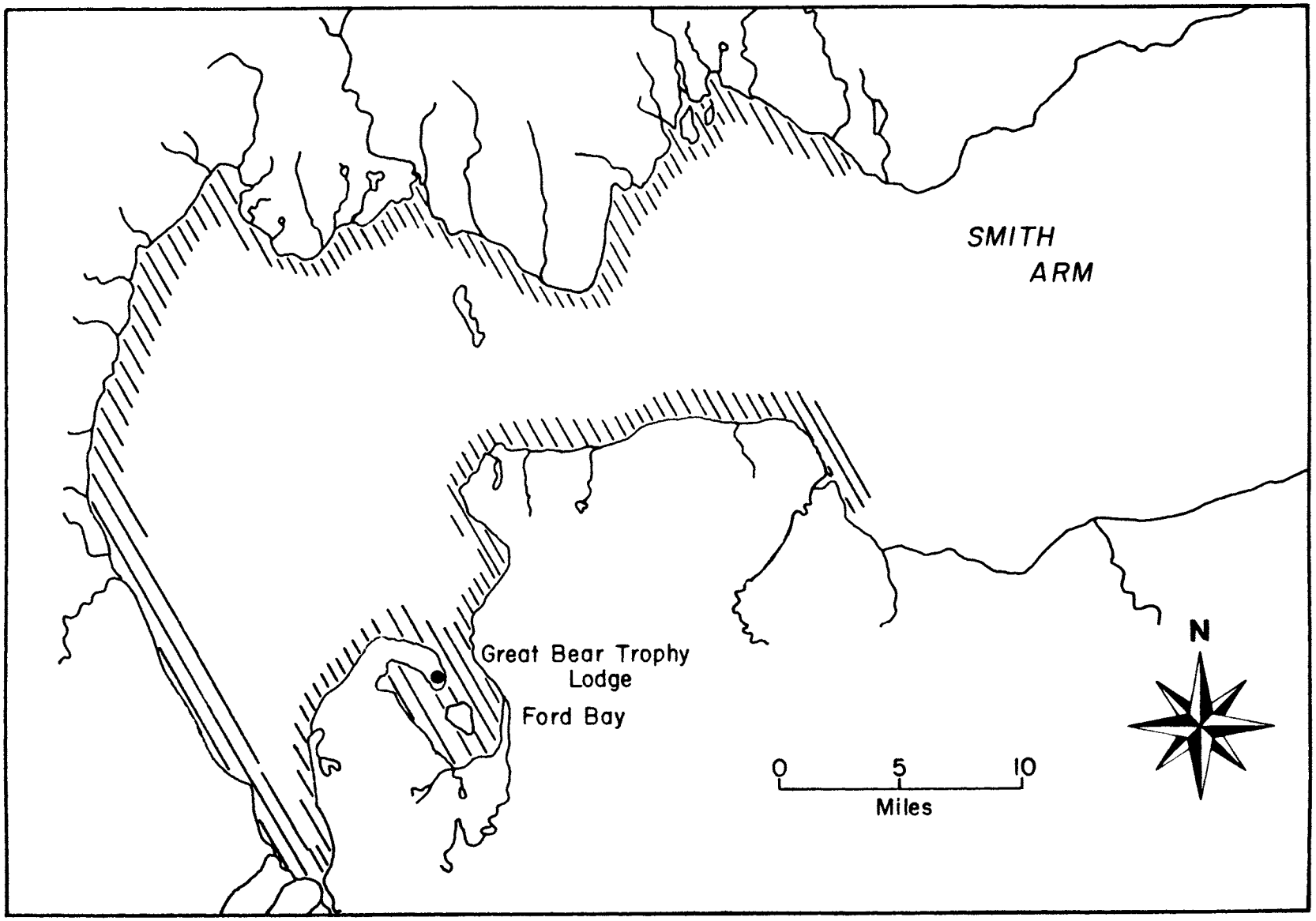

Fig. A2.1. Area utilized by Great Bear Trophy Lodge, Great Bear Lake.

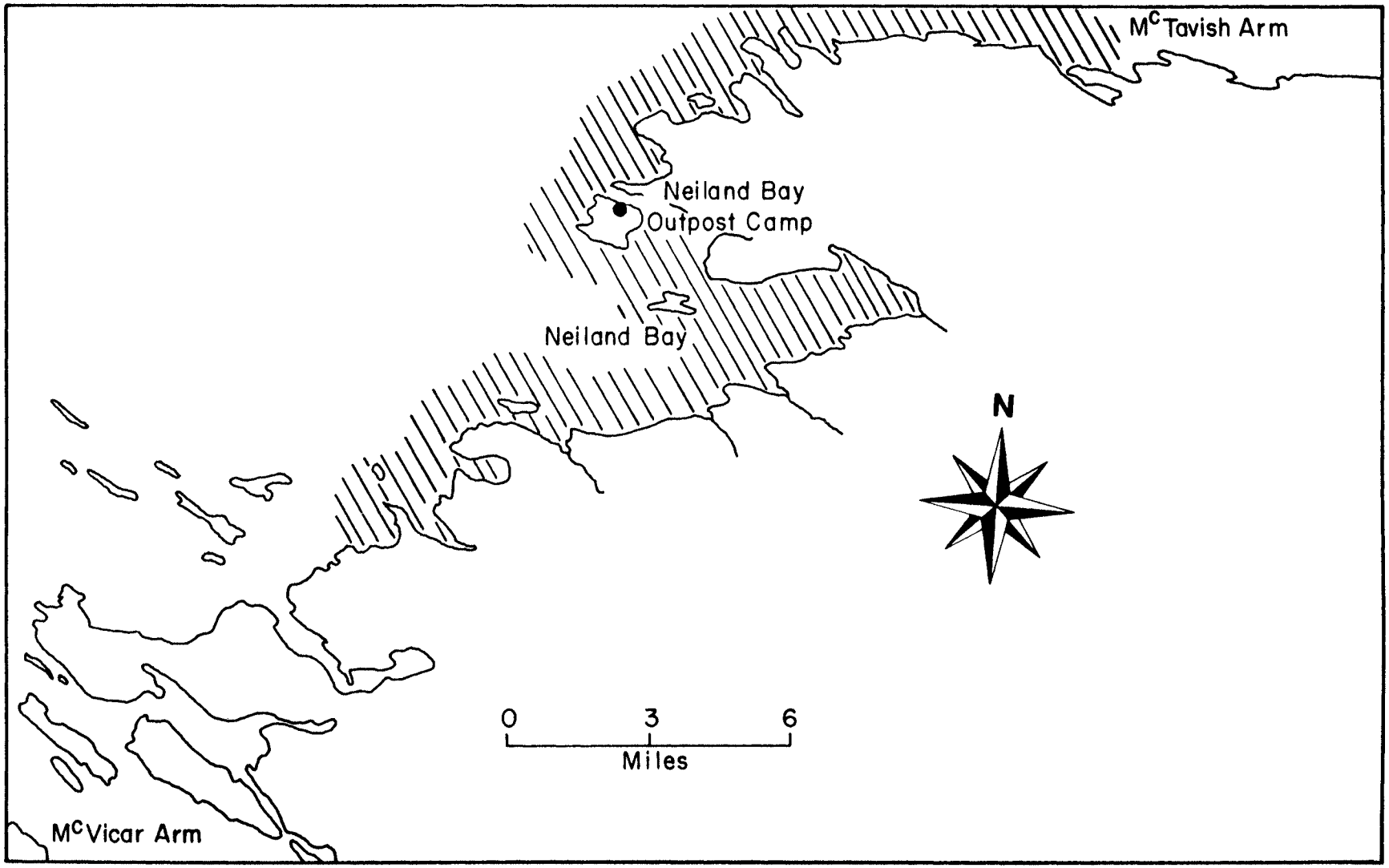

Fig. A2.2. Area utilized by Neiland Bay Outpost Camp of Great Bear Lodge, Great Bear Lake.

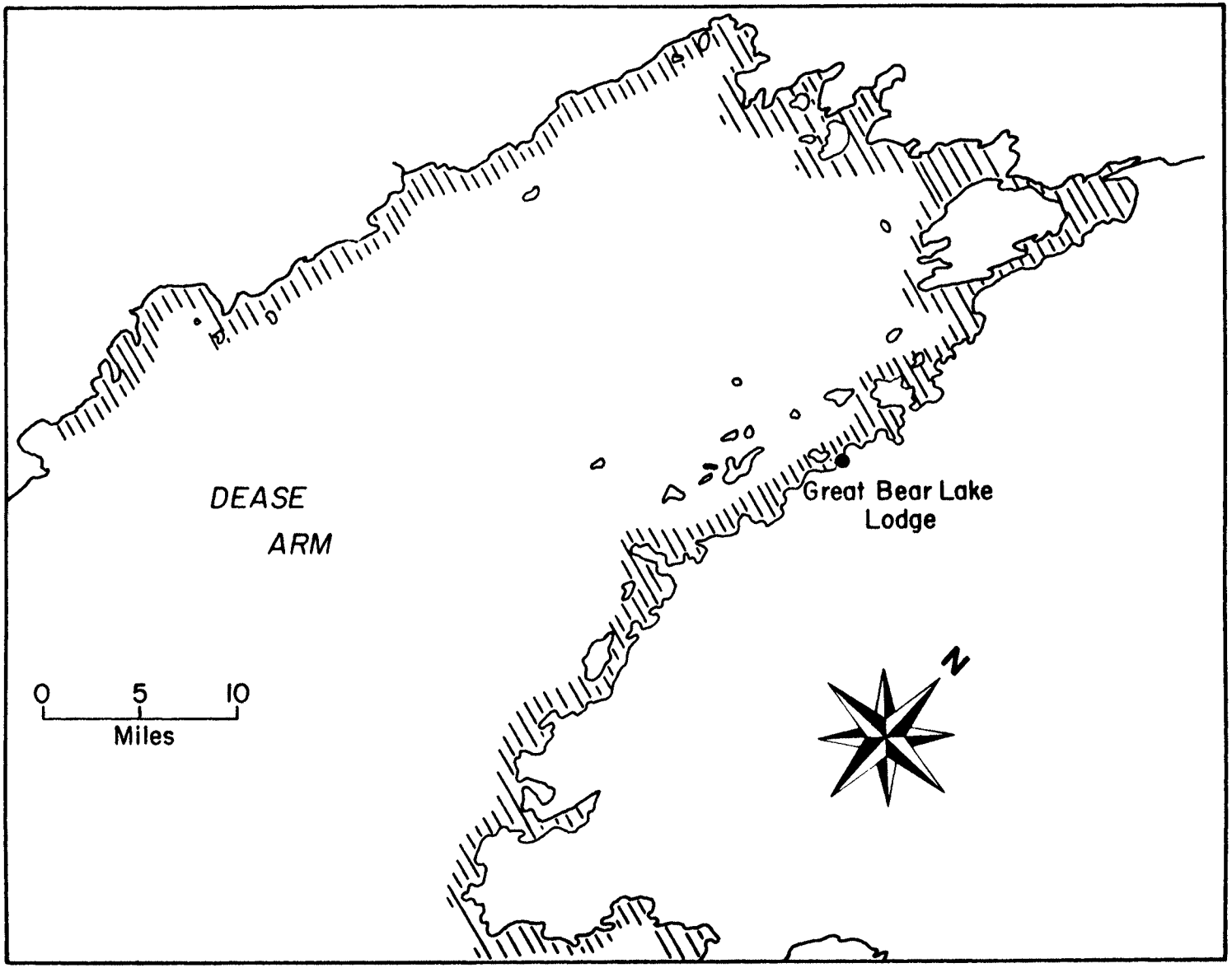

Fig. A2.3. Area utilized by Plummer's Great Bear Lake Lodge, Great Bear Lake.

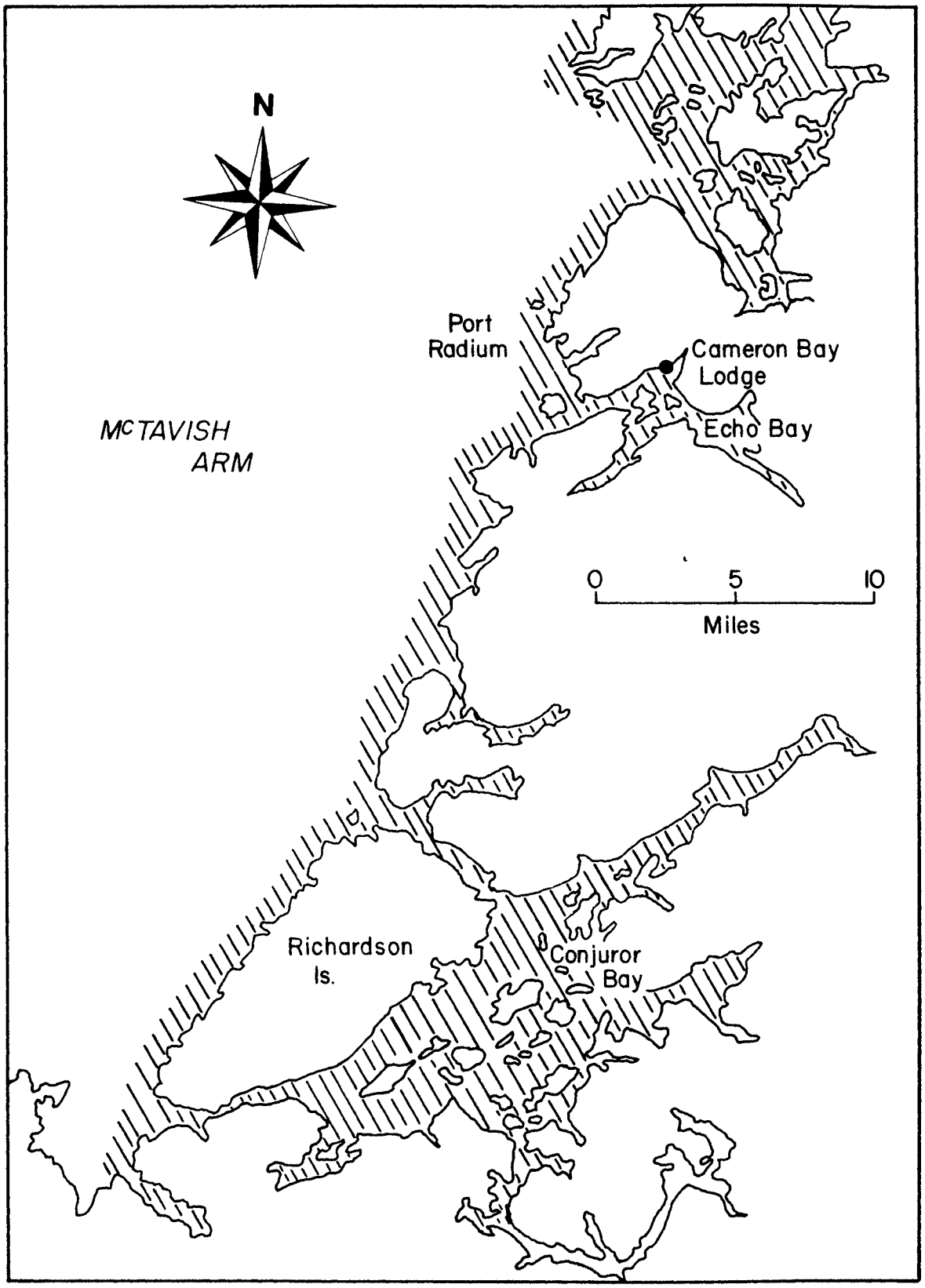

Fig. A2.4. Area utilized by Branson's Cameron Bay Lodge, Great Bear Lake.

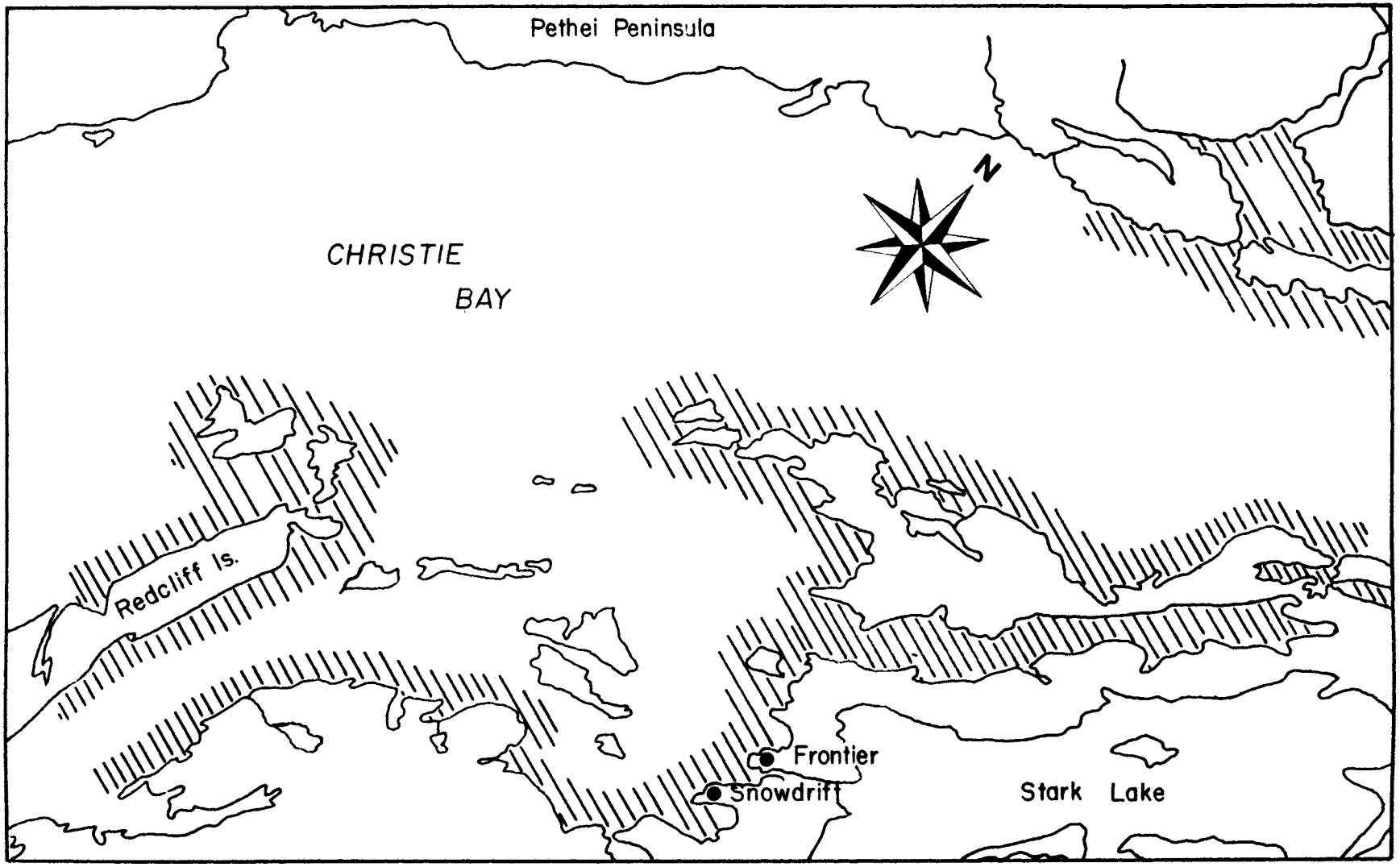

Fig. A2.5. Area utilized by Frontier Fishing Lodge, Great Slave Lake.

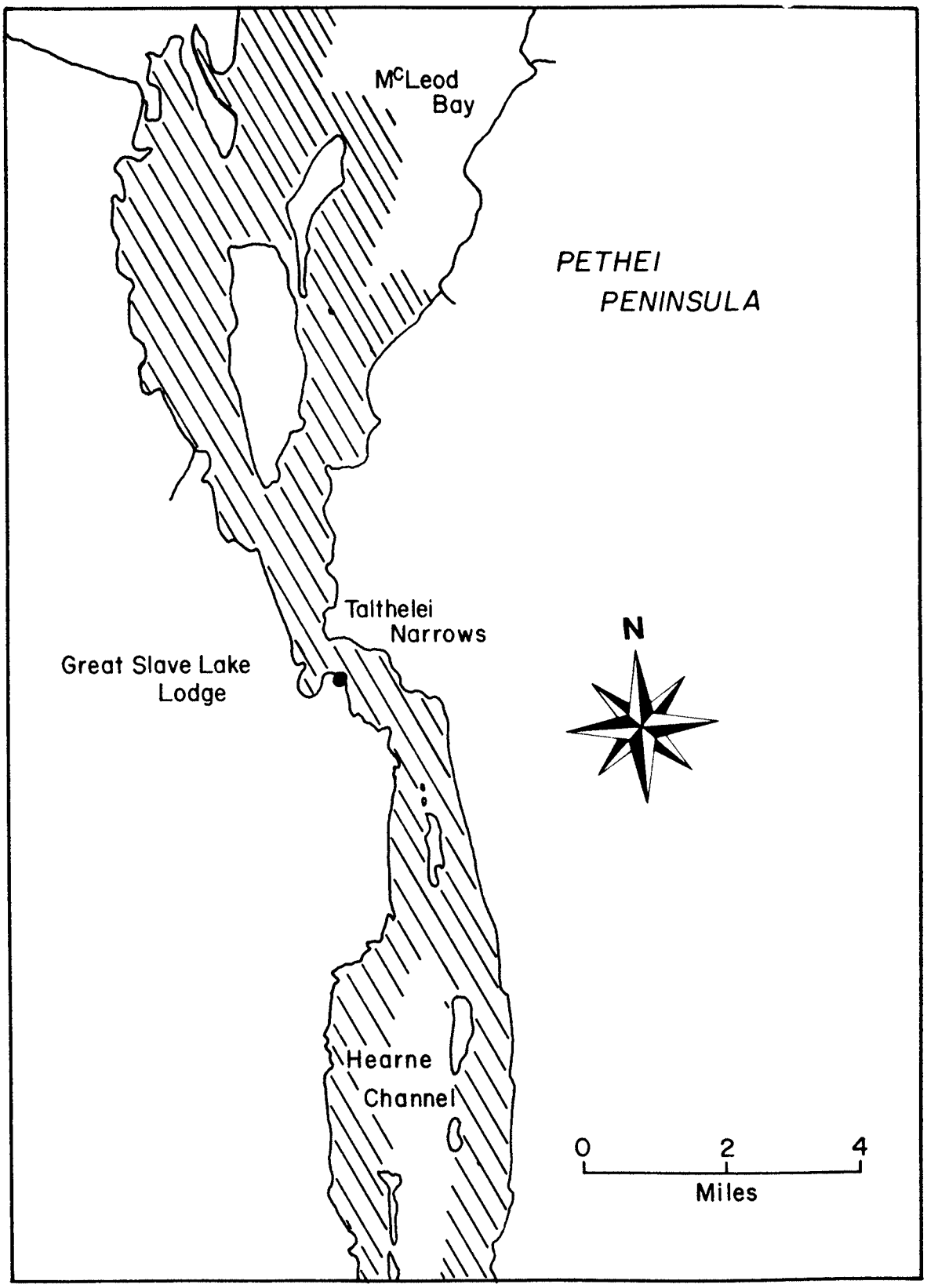

Fig. A2.6. Area utilized by Plummer's Great Slave Lake Lodge, Great Slave Lake.

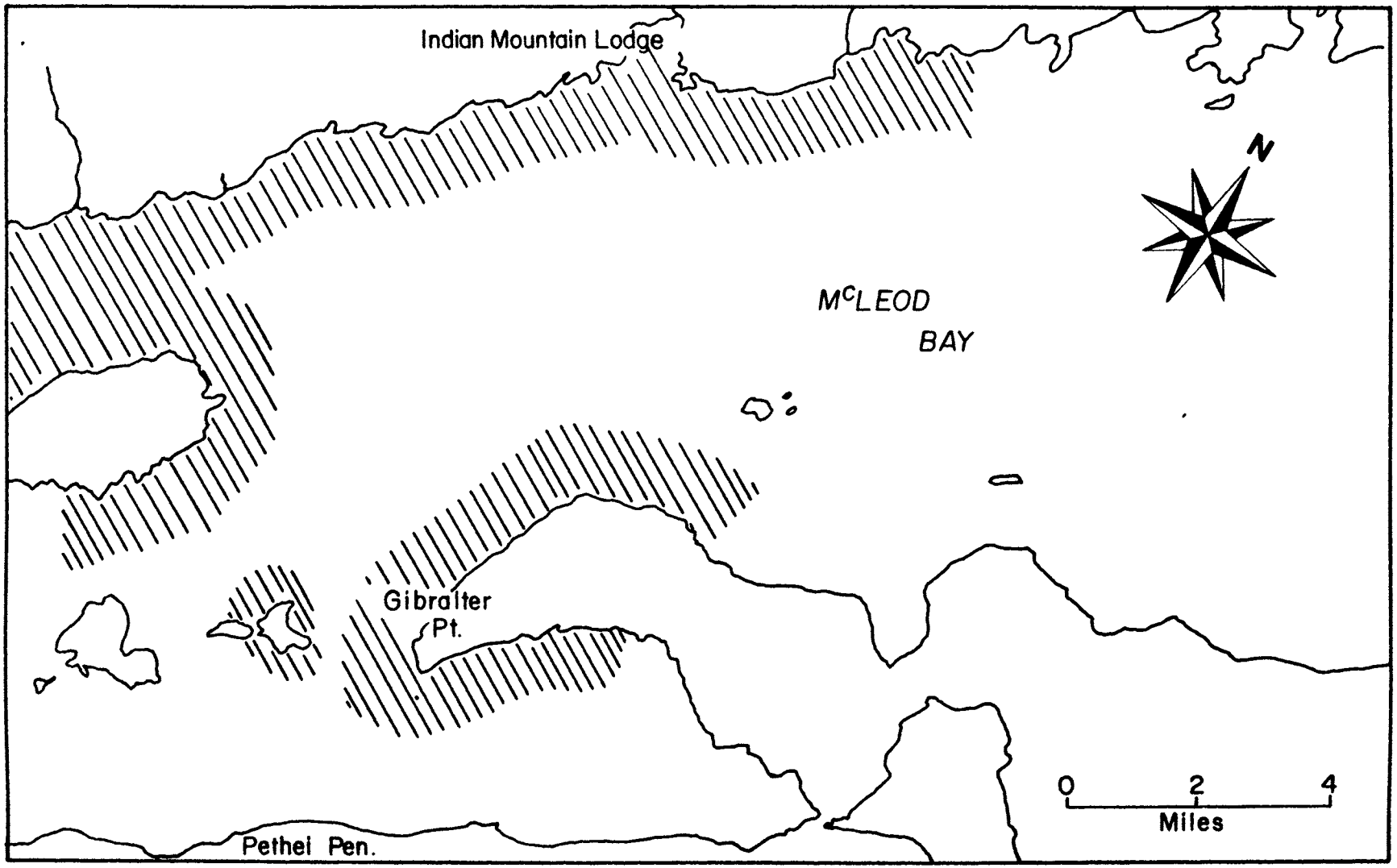

Fig. A2.7. Area utilized by Indian Mountain Lodge, Great Slave Lake.

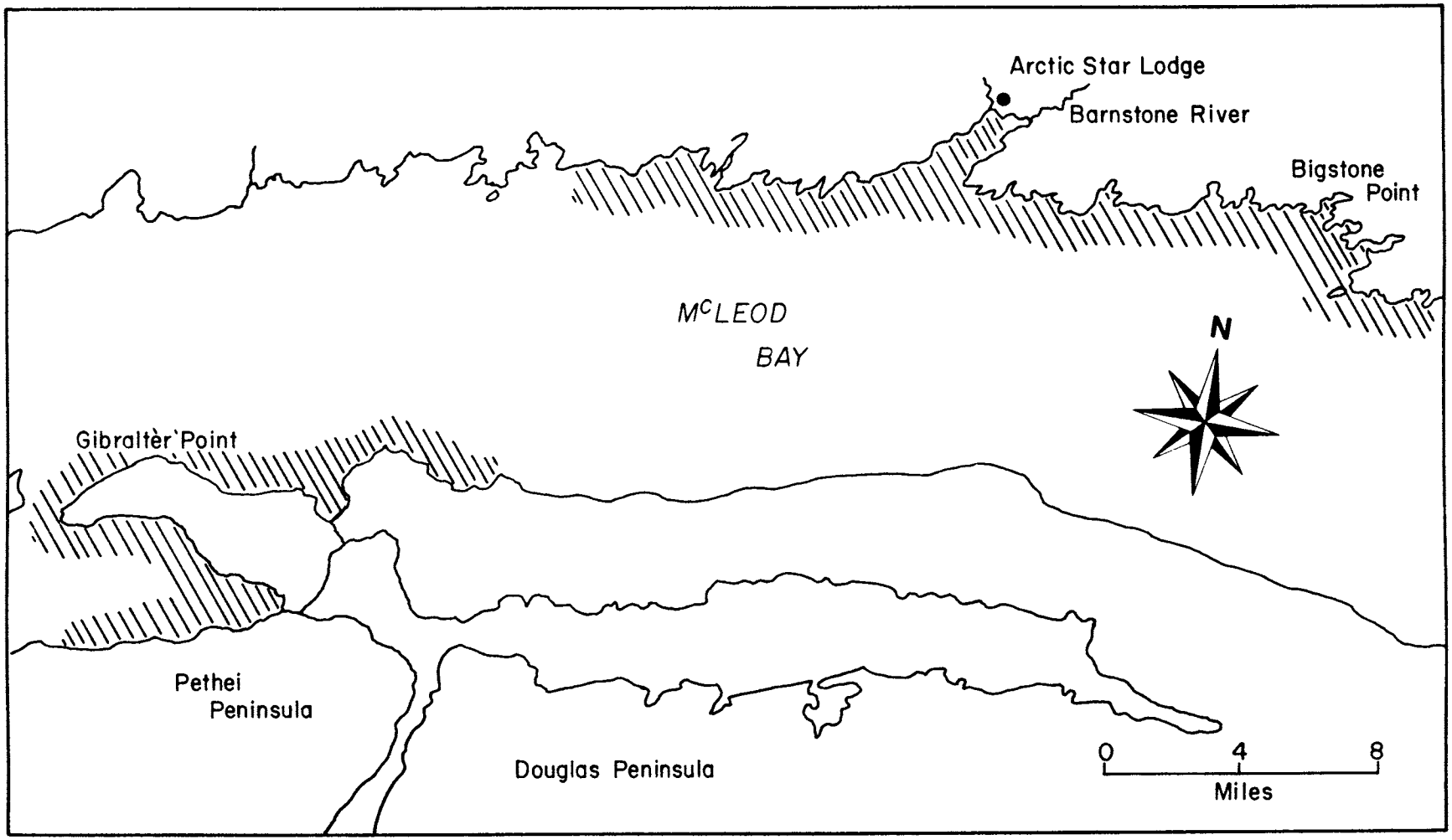

Fig. A2.8. Area utilized by Arctic Star Lodge, Great Slave Lake.

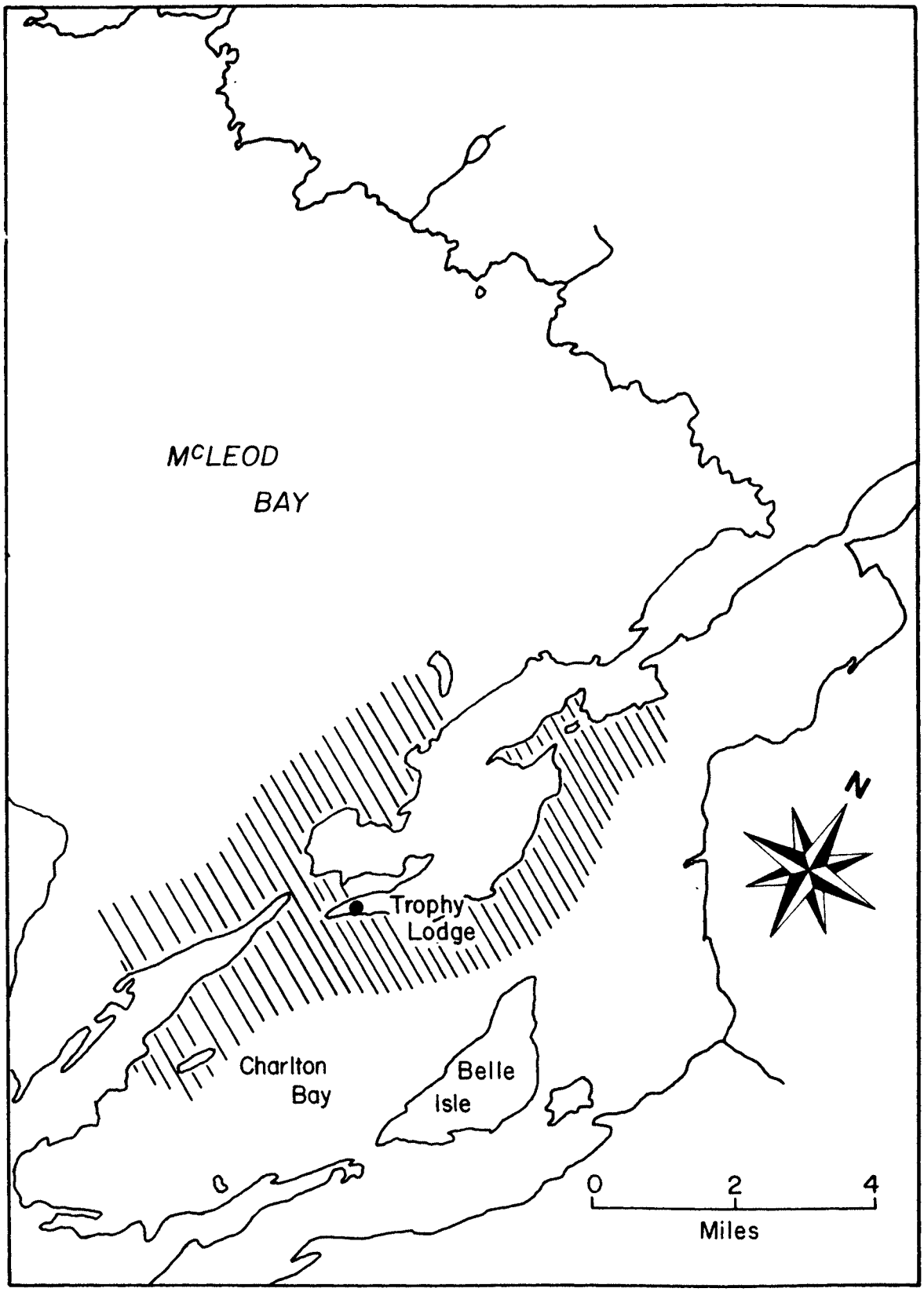

Fig. A2.9. Area utilized by Trophy (Reliance) Lodge, Great Slave Lake.

Appendix 3. Predicted equilibrium yields and stock sizes. All figures for a utilized hectare. Standing stock is number of fish aged 15 and over

Age of Recruitment	Fishing Mortality	Standing Stock	Numerical Yield	Great Bear				Great Slave			
				Weight of Catch (kg)	Mean Length in Catch (mm)	Numerical Yield, fish longer than		Weight of catch (kg)	Mean Length in Catch (mm)	Numerical Yield, fish longer than	
						700 mm	900 mm (x100)			700 mm	900 mm (x100)
15	0.050	1.268	0.063	0.179	630	0.027	0.016	0.269	692	0.036	0.265
"	0.100	0.951	0.095	0.255	615	0.037	0.012	0.382	672	0.045	0.212
"	0.150	0.761	0.114	0.293	606	0.041	0.007	0.440	661	0.047	0.138
"	0.200	0.634	0.127	0.315	598	0.043	0.004	0.472	652	0.046	0.086
"	0.250	0.543	0.136	0.328	596	0.044	0.002	0.492	641	0.044	0.054
"	0.300	0.475	0.143	0.338	591	0.044	0.001	0.506	639	0.043	0.034
"	0.400	0.380	0.152	0.350	585	0.045	0.000	0.524	629	0.040	0.014
"	0.500	0.317	0.158	0.359	583	0.045	0.000	0.536	636	0.038	0.006
"	0.600	0.272	0.163	0.366	582	0.045	0.000	0.545	623	0.037	0.003
16	0.050	1.328	0.057	0.169	634	0.026	0.017	0.254	699	0.036	0.279
"	0.100	1.041	0.086	0.244	624	0.036	0.014	0.366	688	0.047	0.234
"	0.150	0.869	0.103	0.281	617	0.040	0.008	0.423	679	0.050	0.160
"	0.200	0.754	0.115	0.303	608	0.042	0.005	0.457	664	0.050	0.106
"	0.250	0.672	0.123	0.317	603	0.043	0.002	0.478	659	0.049	0.070
"	0.300	0.611	0.129	0.327	601	0.044	0.001	0.493	654	0.048	0.047
"	0.400	0.525	0.138	0.340	594	0.044	0.000	0.513	649	0.046	0.022
"	0.500	0.467	0.143	0.348	592	0.044	0.000	0.526	643	0.045	0.011
"	0.600	0.426	0.148	0.349	588	0.044	0.000	0.537	638	0.044	0.005
17	0.050	1.383	0.051	0.160	645	0.025	0.018	0.240	711	0.036	0.293
"	0.100	1.124	0.077	0.232	636	0.035	0.015	0.348	698	0.048	0.258
"	0.150	0.969	0.093	0.269	627	0.039	0.010	0.405	687	0.052	0.186
"	0.200	0.865	0.104	0.291	619	0.041	0.006	0.438	675	0.052	0.129
"	0.250	0.791	0.111	0.305	615	0.043	0.003	0.460	673	0.052	0.090
"	0.300	0.736	0.117	0.316	612	0.043	0.002	0.476	671	0.052	0.063
"	0.400	0.658	0.124	0.329	607	0.044	0.000	0.497	656	0.050	0.033
"	0.500	0.606	0.130	0.339	601	0.044	0.000	0.372	653	0.049	0.018
"	0.600	0.569	0.133	0.346	600	0.044	0.000	0.523	653	0.049	0.010
18	0.050	1.432	0.046	0.151	652	0.024	0.019	0.226	721	0.035	0.308
"	0.100	1.197	0.070	0.219	648	0.034	0.017	0.330	712	0.048	0.286
"	0.150	1.056	0.084	0.256	639	0.039	0.011	0.385	700	0.052	0.217
"	0.200	0.962	0.094	0.278	634	0.041	0.007	0.418	692	0.054	0.158
"	0.250	0.895	0.101	0.294	630	0.043	0.004	0.441	685	0.054	0.115
"	0.300	0.845	0.106	0.304	625	0.044	0.002	0.457	682	0.053	0.086
"	0.400	0.775	0.113	0.319	620	0.044	0.001	0.480	675	0.052	0.049
"	0.500	0.728	0.117	0.328	615	0.045	0.000	0.495	667	0.051	0.029
"	0.600	0.694	0.121	0.336	613	0.045	0.000	0.507	663	0.051	0.018

Appendix 3. Cont'd.

Age of Recruitment	Fishing Mortality	Standing Stock	Numerical Yield	Great Bear: Weight of Catch (kg)	Great Bear: Mean Length in Catch (mm)	Great Bear: Numerical Yield, Fish Longer Than 700 mm (x100)	Great Bear: Numerical Yield, Fish Longer Than 900 mm (x100)	Great Slave: Weight of Catch (kg)	Great Slave: Mean Length in Catch (mm)	Great Slave: Numerical Yield, fish longer than 700 mm (x100)	Great Slave: Numerical Yield, fish longer than 900 mm (x100)
19	0.050	1.478	0.041	0.140	665	0.023	0.020	0.210	737	0.034	0.323
"	0.100	1.267	0.063	0.207	652	0.033	0.019	0.310	718	0.047	0.315
"	0.150	1.140	0.076	0.243	646	0.038	0.013	0.364	708	0.052	0.251
"	0.200	1.055	0.085	0.264	645	0.041	0.009	0.397	705	0.054	0.192
"	0.250	0.994	0.091	0.280	637	0.042	0.006	0.420	694	0.054	0.148
"	0.300	0.949	0.095	0.291	634	0.043	0.004	0.436	690	0.053	0.115
"	0.400	0.886	0.102	0.280	631	0.044	0.001	0.459	687	0.051	0.073
"	0.500	0.843	0.106	0.316	626	0.045	0.000	0.475	677	0.050	0.049
"	0.600	0.813	0.109	0.325	622	0.045	0.000	0.487	677	0.048	0.033
20	0.050	1.518	0.037	0.131	678	0.022	0.021	0.196	750	0.034	0.340
"	0.100	1.326	0.057	0.194	663	0.032	0.021	0.290	733	0.049	0.349
"	0.150	1.210	0.069	0.228	659	0.037	0.016	0.341	725	0.055	0.292
"	0.200	1.134	0.077	0.249	651	0.040	0.011	0.374	714	0.058	0.236
"	0.250	1.079	0.082	0.264	650	0.042	0.007	0.396	711	0.059	0.190
"	0.300	1.038	0.086	0.275	648	0.043	0.005	0.412	708	0.059	0.156
"	0.400	0.980	0.092	0.289	641	0.044	0.002	0.434	698	0.059	0.110
"	0.500	0.942	0.096	0.301	638	0.045	0.001	0.450	693	0.059	0.081
"	0.600	0.914	0.099	0.309	638	0.045	0.000	0.462	689	0.058	0.061
21	0.050	1.555	0.034	0.121	678	0.021	0.022	0.181	757	0.033	0.357
"	0.100	1.381	0.052	0.180	672	0.031	0.023	0.271	745	0.048	0.385
"	0.150	1.277	0.062	0.213	671	0.036	0.018	0.320	742	0.055	0.339
"	0.200	1.208	0.069	0.234	662	0.039	0.013	0.350	731	0.059	0.287
"	0.250	1.158	0.074	0.248	661	0.040	0.010	0.372	730	0.060	0.244
"	0.300	1.121	0.078	0.258	659	0.042	0.007	0.387	724	0.061	0.210
"	0.400	1.069	0.083	0.272	652	0.043	0.003	0.409	715	0.062	0.164
"	0.500	1.034	0.087	0.283	651	0.044	0.001	0.425	712	0.062	0.133
"	0.600	1.009	0.089	0.291	649	0.045	0.000	0.437	709	0.061	0.111
22	0.050	1.587	0.030	0.112	686	0.019	0.024	0.167	770	0.032	0.376
"	0.100	1.430	0.047	0.167	676	0.029	0.025	0.251	754	0.047	0.427
"	0.150	1.335	0.056	0.198	673	0.034	0.021	0.298	749	0.055	0.395
"	0.200	1.272	0.063	0.218	671	0.037	0.017	0.328	746	0.059	0.352
"	0.250	1.227	0.067	0.232	668	0.039	0.013	0.348	741	0.062	0.314
"	0.300	1.194	0.071	0.242	666	0.040	0.009	0.364	738	0.063	0.285
"	0.400	1.146	0.076	0.255	662	0.042	0.005	0.385	731	0.065	0.245
"	0.500	1.115	0.079	0.265	662	0.043	0.003	0.400	731	0.065	0.220
"	0.600	1.093	0.081	0.273	659	0.043	0.001	0.412	725	0.065	0.204
23	0.050	1.617	0.027	0.103	685	0.018	0.025	0.154	773	0.031	0.389
"	0.100	1.475	0.042	0.155	685	0.027	0.028	0.232	770	0.046	0.458
"	0.150	1.389	0.051	0.185	681	0.032	0.025	0.236	761	0.054	0.438
"	0.200	1.332	0.057	0.203	675	0.035	0.020	0.305	752	0.058	0.401
"	0.250	1.292	0.061	0.216	674	0.037	0.016	0.325	752	0.061	0.367
"	0.300	1.261	0.064	0.225	670	0.038	0.013	0.339	744	0.063	0.339
"	0.400	1.219	0.068	0.238	669	0.039	0.008	0.359	739	0.066	0.302
"	0.500	1.190	0.071	0.248	666	0.040	0.005	0.374	737	0.067	0.279
"	0.600	1.170	0.073	0.255	664	0.041	0.003	0.386	735	0.068	0.265
24	0.050	1.645	0.025	0.095	692	0.017	0.026	0.142	781	0.028	0.396
"	0.100	1.516	0.038	0.144	693	0.025	0.031	0.215	780	0.043	0.480
"	0.150	1.439	0.046	0.171	687	0.030	0.029	0.257	770	0.051	0.470

Appendix 3. Cont'd.

Age of Recruitment	Fishing Mortality	Standing Stock	Numerical Yield	Great Bear: Weight of Catch (kg)	Great Bear: Mean Length in Catch (mm)	Great Bear: Numerical Yield, Fish Longer Than 700 mm	Great Bear: Numerical Yield, Fish Longer Than 900 mm (x100)	Great Slave: Weight of Catch (kg)	Great Slave: Mean Length in Catch (mm)	Great Slave: Numerical Yield, fish longer than 700 mm	Great Slave: Numerical Yield, fish longer than 900 mm (x100)
24	0.200	1.388	0.051	0.189	683	0.033	0.025	0.284	763	0.056	0.437
"	0.250	1.351	0.055	0.201	683	0.035	0.021	0.303	763	0.059	0.403
"	0.300	1.324	0.058	0.210	678	0.036	0.017	0.316	754	0.061	0.375
"	0.400	1.285	0.062	0.222	677	0.038	0.012	0.336	753	0.064	0.334
"	0.500	1.260	0.064	0.231	672	0.039	0.008	0.350	747	0.065	0.307
"	0.600	1.241	0.066	0.238	668	0.039	0.005	0.361	742	0.067	0.289
25	0.050	1.668	0.022	0.087	703	0.016	0.028	0.129	797	0.026	0.407
"	0.100	1.551	0.034	0.133	694	0.024	0.034	0.198	786	0.040	0.511
"	0.150	1.481	0.042	0.159	693	0.028	0.034	0.237	785	0.048	0.514
"	0.200	1.434	0.047	0.176	688	0.031	0.031	0.263	771	0.053	0.489
"	0.250	1.401	0.050	0.187	686	0.033	0.027	0.280	767	0.056	0.460
"	0.300	1.376	0.053	0.196	684	0.034	0.024	0.294	764	0.058	0.435
"	0.400	1.341	0.056	0.208	684	0.036	0.018	0.312	764	0.061	0.396
"	0.500	1.317	0.058	0.217	678	0.037	0.014	0.325	754	0.062	0.371
"	0.600	1.301	0.060	0.224	678	0.038	0.010	0.337	754	0.064	0.354
26	0.050	1.693	0.020	0.079	703	0.014	0.029	0.118	797	0.024	0.407
"	0.100	1.589	0.031	0.122	702	0.022	0.037	0.182	793	0.037	0.526
"	0.150	1.527	0.037	0.147	696	0.026	0.039	0.219	784	0.044	0.543
"	0.200	1.485	0.042	0.163	696	0.029	0.037	0.243	784	0.049	0.526
"	0.250	1.455	0.045	0.173	694	0.030	0.035	0.260	778	0.052	0.502
"	0.300	1.433	0.047	0.182	694	0.032	0.032	0.271	778	0.054	0.478
"	0.400	1.402	0.050	0.194	692	0.033	0.027	0.289	777	0.057	0.442
"	0.500	1.381	0.052	0.202	692	0.034	0.022	0.301	772	0.059	0.418
"	0.600	1.366	0.054	0.208	691	0.035	0.019	0.312	770	0.060	0.402
27	0.050	1.712	0.018	0.072	718	0.013	0.030	0.108	806	0.022	0.413
"	0.100	1.617	0.028	0.112	715	0.020	0.042	0.167	806	0.034	0.550
"	0.150	1.560	0.034	0.135	710	0.024	0.045	0.201	804	0.041	0.579
"	0.200	1.522	0.038	0.150	707	0.027	0.046	0.224	798	0.046	0.570
"	0.250	1.495	0.041	0.160	706	0.029	0.045	0.239	797	0.049	0.550
"	0.300	1.475	0.043	0.168	698	0.030	0.044	0.251	784	0.051	0.529
"	0.400	1.446	0.046	0.179	697	0.031	0.041	0.268	784	0.054	0.494
"	0.500	1.427	0.047	0.187	696	0.032	0.038	0.279	777	0.055	0.470
"	0.600	1.414	0.049	0.193	692	0.033	0.035	0.289	773	0.057	0.453
28	0.050	1.728	0.016	0.066	718	0.012	0.032	0.097	822	0.020	0.419
"	0.100	1.641	0.025	0.102	718	0.019	0.047	0.152	819	0.032	0.573
"	0.150	1.589	0.031	0.124	718	0.023	0.053	0.185	816	0.039	0.616
"	0.200	1.555	0.034	0.139	708	0.025	0.057	0.206	802	0.043	0.617
"	0.250	1.530	0.037	0.149	706	0.027	0.058	0.221	796	0.046	0.602
"	0.300	1.511	0.039	0.155	704	0.028	0.060	0.232	793	0.048	0.584
"	0.400	1.485	0.042	0.166	704	0.030	0.062	0.248	792	0.051	0.551
"	0.500	1.468	0.043	0.173	704	0.031	0.063	0.259	791	0.053	0.526
	0.600	1.455	0.045	0.179	699	0.031	0.064	0.267	782	0.054	0.508

Appendix 4. Description of stages of maturity used in 1972-78 and 1979-82 and conversions.

1972-78[a]				1979[a]							
				Female				Male			
Maturity Stage	Code by Sex F	Code by Sex M	Description	Maturity Stage	1979 Code	1972-78 Code	Description	1979 Code	1972-78 Code	Description
Immature	1	6	virgin fish, gonad thin and threadlike, often incomplete.	Immature	1	1	ovaries granular in texture, up to full length in body cavity, hard and triangular in shape, firm membrane; eggs distinguishable.	6	6	testes puttylike firmness, tubular and scalloped in shape, long and thin, and may be full length in body cavity.
Maturing	2	7	virgin or non-virgin fish not spawning in current year, gonad full length, gonads partially filling body cavity.	Mature	2	3	current year's spawner; ovaries fill body cavity; eggs nearing full size but not loose.	7	8	current year's spawner; testes large and lobate; white-purplish in colour; milt not expelled by pressure.
Mature	3	8	fish spawning in current year, gonad full size filling body cavity, eggs prominent, full size.	Ripe	3	4	ovaries greatly extended, fill body cavity; eggs full size; eggs expelled by slight pressure.	8	9	testes full size; white and lobate; milt expelled by slight pressure.
Ripe	4	9	mature fish in spawning condition, eggs translucent, milt or eggs expelled under slight pressure.	Spent	4	5	spawning complete; ovaries flaccid; seed eggs apparent; presence or residual mature eggs.	9	10	testes flaccid with some milt, blood vessels obvious with pink-violet coloration.
Spent	5	10	mature fish completed spawning, gonads collapsed with ruptured blood vessels prominent.	Resting	5	2	non-virgin; not spawning in current year.	10	7	non-virgin; not spawning in current year.

[a]Fish of unknown sex were coded as 0.

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