A Biological Analysis and Population Assessment of Northern Pike, Inconnu and Lake Whitefish from the Mackenzie River Delta Exploratory Fishery, 1989-1993

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ABSTRACT

Howland, K.L. , M.A. Treble, and R.F. Tallman. 2001. A biological analysis and population assessment of northern pike, inconnu and lake whitefish from the Mackenzie River delta exploratory fishery, 1989-1993. Can. Tech. Rep. Fish. Aquat. Sci. 2330: vii + 73 p.

An exploratory fishery was carried out in the Mackenzie River Delta between 1989 and 1993 to assess the commercial fishery potential in this area. Broad whitefish were the target species of this fishery, however other species such as northern pike, inconnu and lake whitefish were also harvested. In this report, biological data from these three by-catch species were analyzed to assess the impact of the fishery on population abundance and structure.

All three by catch species support subsistence fisheries in the Mackenzie Delta. Inconnu and lake whitefish migrate substantial distances, crossing land claim borders and are likely fished by a variety of user groups. Northern pike, on the other hand tend to be non-migratory with localized populations that are mainly fished by people living in the near vicinity. A concern was that commercial fishing pressure might reduce the numbers of fish available to subsistence users.

Based on trends in size and age frequency, age at maturity, sex ratio, growth rates, and mortality rates, we conclude that inconnu and lake whitefish populations in the Mackenzie Delta have remained healthy and stable at the current harvest levels, however northern pike populations showed a decrease in the proportion of older fish, possibly indicating over-fishing of local stocks. Inconnu and lake whitefish may be able to withstand increased harvest, but to what extent is unknown, given that little reliable information is available on subsistence harvest levels in this region. Increasing harvest levels of pike may be risky and we suggest that a reduction of current commercial harvest quotas be considered.

Key words: Arctic, Mackenzie River, fisheries, catch statistics, northern pike, inconnu, lake whitefish.

RÉSUMÉ

Howland, K.L. , M.A. Treble, and R.F. Tallman. 2001. A biological analysis and population assessment of northern pike, inconnu and lake whitefish from the Mackenzie River delta exploratory fishery, 1989-1993. Can. Tech. Rep. Fish. Aquat. Sci. 2330: vii + 73 p.

Une pêche exploratoire a été entreprise dans le delta du fleuve Mackenzie entre 1989 et 1993 en vue d'évaluer le potentiel d'une pêche commerciale dans cette région. Bien qu'elle ciblait le corégone tschir, du grand brochet, de l'inconnu et du grand corégone ont aussi été capturés accidentellement. L'analyse des données biologiques sur ces trois dernières espèces présentée dans ce rapport vise à évaluer l'impact de la pêche sur l'abondance et la structure des populations.

Les trois espèces capturées accidentellement alimentent des pêches de susbsistance dans le delta du Mackenzie. Comme l'inconnu et le grand corégone franchissent de grandes distances au moment de la migration, traversant les limites de territoires qui font l'objet de revendications territoriales, les mêmes stocks sont probablement pêchés par une gamme de groupes d'utilisateurs. Par contre, le grand brochet n'a pas tendance à migrer; les populations locales sont donc surtout pêchées par les gens qui vivent dans les environs. La pression exercée par la pêche commerciale, qui pourrait donner lieu à une réduction du nombre de poissons disponibles à la pêche de subsistance, préoccupe cependant.

D'après les tendances de la taille et de la fréquence des âges, de l'âge à la maturité, du rapport entre les sexes, des taux de croissance et des taux de mortalité, les auteurs concluent que les populations d'inconnu et de grand corégone du delta du Mackenzie ne sont pas sensiblement

perturbées par la pêche exploratoire. De fait, ces espèces peuvent peut-être alimenter une pêche accrue, mais dans une mesure inconnue étant donné que peu de renseignements fiables sont disponibles sur les niveaux de pêche de subsistance dans cette région. Les populations de grand brochet affichent toutefois une baisse dans la proportion de poissons âgés, ce qui indique peut-être une surpêche des stocks locaux. Comme il pourrait être dangereux d'accroître les niveaux de récolte du grand brochet, les auteurs sont d'avis que les quotas actuels réglementant la pêche commerciale devraient être réduits.

Mots-clés: Arctique, fleuve Mackenzie, pêches, statistiques des captures, *Esox lucius*, *Stenodus leucichthys*, *Coregonus clupeaformis*.

INTRODUCTION

In 1989 the Inuvik Hunters and Trappers Committee (HTC) requested an exploratory fishery license to determine the commercial fishery potential in the middle channel area of the Mackenzie Delta. A license was issued by the Department of Fisheries and Oceans (DFO) and a five year exploratory fishery program was started. The coordination and management of this fishery was later turned over to the Uummarmiut Development Corporation (UDC). The exploratory fishery program, described by Kristofferson and McGowan (1973), was started by DFO in 1973. Fisheries involved in this program normally run for a period of 5 years with an emphasis on the collection of biological data and catch per unit effort data for stock assessment purposes. A conservative, provisional quota is usually set and may vary over the length of the fishery. A review of past attempts at commercial development of fish resources in the Mackenzie Delta is provided in Treble and Tallman (1997).

The main species targeted by commercial fishermen in the Mackenzie Delta exploratory fishery were broad whitefish (*Coregonus nasus*), inconnu (*Stenodus leucichthys*) and northern pike (*Esox lucius*), with broad whitefish being the most abundant. Lake whitefish are also abundant in the delta, but due to high cyst counts of the parasite *Trianophorus crassus* in their flesh, are non-marketable for human consumption. Although non-marketable, large numbers of lake whitefish were still taken by the exploratory fishery as a result of the non-selective gear (commercial 139 mm gill nets) used by fishermen. Efforts were made to utilize some of the by-catch lake as food for dog teams in the area, but due to high numbers of fish there was still wastage (Orman 1992). The DFO Western Arctic Area office, Inuvik, was responsible for collecting biological and CPUE data for all species captured during the Inuvik HTC/UDC exploratory fishery program, 1989 to 1993. This report examines data for northern pike, inconnu and lake whitefish collected during the five year fishery. Data from a sub-sample of the commercial fishermen's catch (exploratory fishery assessment) as well as data from multi-mesh experimental gill nets (population assessment) were analyzed for all three species. An analysis of the broad whitefish data was conducted by Treble and Tallman (1997). Data for other species are unpubished.

STUDY AREA

The Mackenzie River, situated in the western Canadian Arctic has a drainage area of over 1.5 million km^2 with an average total annual discharge of 333 km^3 making it the largest river in Canada (Brunskill 1986). It carries 118 million tons of suspended sediment that is deposited over the Mackenzie delta, an immense network of lakes and channels covering an area of 12,170 km^2 (Fig. 1). Approximately two-thirds of the river's flow is directed through the middle channel of the delta (Brunskill 1986). The ice-free season in the lower Mackenzie River runs from early June to early October (Mackay 1963). Subsistence fishing for species such as northern pike, inconnu, and lake whitefish usually begins in early July and runs until late October at which time most migratory species of fish (with the exception of broad whitefish) have moved upstream and out of the delta.

THE EXPLORATORY FISHERY, 1989-1990

As described by Treble and Tallman (1997), the exploratory fishery generally began in early September of each year and lasted approximately one month, with the start and finish dates varying from year to year. Water and air temperatures begin to decrease at this time of year making it easier to provide fresh high quality fish for market. This time period also coincides with the upstream migration of pre-spawning broad whitefish which are abundant and in peak condition. There is a high abundance of lake whitefish at this time of year as well. Inconnu, however, are less plentiful with the majority of pre-spawners, having already migrated through the delta towards upstream spawning areas. Northern Pike are less migratory and tend to be around throughout the open water period, in contrast to the migratory coregonids (whitefish) which are only seasonally abundant, moving through the Mackenzie delta during specific (usually predictable) time periods.

The fishery was conducted within a 30 km stretch of the middle channel (Figs. 2-6). Fishing was mainly carried out in the vicinity of traditional fish camps along the main channel, but other locations such as the Jackfish Lakes area (Fig. 3), Thrasher Channel (Figs. 5 and 6, Location 6), and the junction of Oniak and East channels (Fig. 6, Location 7) were fished at various times throughout the fishery. Table 1 lists the assigned quotas and actual amounts of northern pike, inconnu and lake whitefish harvested from all locations combined during each year of the fishery.

MATERIALS AND METHODS

Over the five year period of the exploratory fishery, the biological monitoring program was coordinated by three different DFO biologists in different years, resulting in some discontinuity in sampling methods. Below is a summary of the methods used for the different components of the program; the experimental gill netting, the biological monitoring of the exploratory fishery, and the collection of CPUE data from both commercial and experimental gill nets. Full details of the sampling protocols used in 1991 are provided in Orman (1992).

Experimental gill netting program

An experimental gill netting program was started in 1990 to allow for accurate assessment of the fish populations being harvested by the exploratory fishery. The range of mesh sizes offered by experimental gill nets sample a much wider size and age range of fish than commercial gill nets, thereby providing a more accurate representation of a fish population's characteristics.

During the first year of the gill netting program, two sites (Locations 2 and 4; Fig. 2) were chosen to test for spatial differences between the north and south ends of the exploratory fishery area. Fish were collected using 45.7 m (50 yd) multi-mesh experimental nets. Each net consists of five 9.1 m long by 1.83 m deep panels of 38 mm, 64 mm, 89 mm, 114 mm and 139 mm green monofilament mesh connected to form a continuous gang. The experimental nets were set adjacent to harvester's nets at the two above-mentioned locations and positioned at or near the surface in the same manner as commercial nets used by harvesters. Location, duration and catch per mesh size for each species were recorded by field crews each time a net was checked. The following biological data were collected from as many fish as possible: fork length, round weight, dressed weight (for a subset of samples only), sex, maturity and gonad weight. Scales and the right pelvic fin were taken for age determination. Due to sampling time restrictions a portion of the catch could only be sampled for fork length and round weight.

In 1991 only one netting location was used, on the east bank of the middle channel ("experimental site", Fig. 3). In addition to the multi-mesh experimental gill net, a commercial 45.7 m, 139 mm mesh "control" gill net was set at the same location. Experimental and control gill nets were fished at alternating intervals. Also, the experimental gill net was reversed end for end on alternate occasions to vary the location of the small and large mesh panels in relation to the shoreline. The different mesh panels on the experimental net were numbered from 1 to 5, with 1 being the panel closest to shore, and 5 being the panel furthest from shore. The control gill net was divided into 9.1 m panels and numbered to match the experimental net. Catch per panel, as well as per mesh, was recorded for all species caught. The biological sampling was conducted as in 1990 except that the left pectoral fin and otoliths, in addition to the scales, were taken for age determination.

The same experimental site was used in 1992 and 1993, but the recording of catch by panel was discontinued after 1991. Biological data were collected as in 1991 except that the pelvic fin was collected for age determination in 1993.

Biological monitoring of the exploratory fishery

In 1989, broad whitefish and northern pike were sampled during several day visits to fishermen's camps within the delta (Fig. 2). Fork lengths and round or dressed weights were measured, and the dorsal fin was removed for age determination. Information on the sex of individual fish was collected at only two locations.

In 1990 two fishermen (Locations 2 and 4, Fig. 3) agreed to have their catch sampled for biological information. Fork lengths were measured for as many fish as possible. A random sub-sample of the catch was fully processed for fork length, round weight, dressed weight, sex, maturity, gonad weight, and the right pelvic fin and scales were taken for age determination. Species other than broad whitefish, lake whitefish, inconnu and northern pike were only sampled for fork length and round weight.

The sampling protocol used in 1991 was similar to that used in 1990 with the following exceptions: 1) the left pectoral fin was taken for age determination; and 2) gonad weights were only taken for fish collected at the experimental site and a small number that were collected from location 4 (Fig. 4)

In 1992 a third fisherman (Location 6, Fig. 5) agreed to have his catch sampled. The only change in sampling procedures was that gonad weights were once again measured for all fully sampled fish.

In 1993, some sampling was done at the fish plant in addition to the regular sampling at fishermen's camps. Other changes included the measurement of fork length, round weight and removal of an aging structure (pelvic fin) for inconnu from all fishermen's camps and broad whitefish from two additional locations (Fig. 6).

Collection of catch per unit effort data
Field crews based at the north and south fish camps during 1990 (Locations 2 and 4, Fig. 2) and at the Experimental site from 1991 to 1993 recorded net set data and catch by species for experimental and control gill nets. During all years, catch data were recorded by mesh size for experimental nets. During 1991 catch for control and experimental nets was also recorded by panel number. Various environmental variables that could potentially influence CPUE were also recorded by field crews. These included water and air temperature, wind speed, direction and strength, cloud cover, secchi depth, water level fluctuation, wave condition, precipitation and level of debris in the river. The number of variables recorded varied somewhat from year to year. These data were not included in this report and have not yet been published elsewhere.

Catch data was collected from fishermen using log books, designed in 1990. Fishermen were asked to record the time a net was checked, the time they last visited that net, the net's length and the numbers of each species caught. The use of log books was continued through the remaining years of the fishery.

Age determination
Fin Rays (Dorsal, Pelvic, Pectoral)
The first three fin rays were removed from as close to the body as possible using bone cutters. They were then dried, trimmed, cleaned, dipped in epoxy resin and placed on a non-stick surface to dry (Chilton and Beamish 1982). A low speed saw was used to cut three thin cross-sections from the proximal end of the fin rays. The cross-sections were mounted on a glass microscope slide and viewed under a compound microscope using transmitted light. Clear rings or translucent zones surrounding the core of each fin ray are considered annuli and one annuli is believed to correspond to one year of growth.

Otoliths
Otoliths were prepared for reading using a method similar to Barber and McFarlane (1987). Each otolith was scored and broken through the nucleus using a scalpel. One half was then lightly burned in an alcohol flame and mounted (burnt side up) in modeling clay. Cooking oil was applied to the burnt surface prior to reading in order to improve the contrast between growth zones. The otolith was then viewed under a dissecting microscope using reflected light. The dark rings surrounding the central nucleus were counted as annuli.

Although several different people were involved in determining ages of fish taken by the exploratory fishery, all were experienced at aging fish or received assistance from experienced individuals. In the later years of this study discussions were held and comparisons were made between readers in an attempt to determine the aging consistency between years. The results of these comparisons were considered to be positive. There was inconsistency in the choice of aging structures from one year to the next (dorsal fin for 1989, pelvic fin for 1990 and 1993, pectoral fin for 1991 and 1992, and otoliths for a portion of the samples in 1991), however, similar readability between pectoral and pelvic fins has been found with broad whitefish (R. Wastle, Aging Consultant, Winnipeg, personal communication), lake whitefish (K. Mills, DFO, Winnipeg, personal communication) and inconnu (K. Howland, unpublished). Also, comparisons among otolith and pelvic fin ages for broad whitefish (M. Treble, unpublished), and otolith and pectoral fin ages for inconnu (K. Howland, unpublished) yielded no significant differences. The age data collected from dorsal fins (used in 1989), however, was questionable. This fin is not traditionally used to age coregonids or northern pike and was extremely difficult, sometimes impossible, to read (C. Read, DFO, Winnipeg, personal communication). The 1989 data has not been included in this report because of the questionable aging results and extremely low sample sizes for all biological data collected during this year.

Data analyses

The original Lotus data files for each species were verified and their formats standardized prior to the creation of a data base on DFO's Micro Vax computer. This data base was checked for outliers and erroneous data points using plots of fork length against age, round weight against age, and round weight against fork length. Any extreme outliers or data points considered to be in error were removed prior to analyzing the data. All statistical analyses were conducted using PC SAS and were considered significant at $\alpha = 0.05$. Maps and graphs were created using Corel Draw (5.0) and Sigma Plot (4.0).

Catch per unit effort

Daily catch per unit effort was calculated for each net set using the following formula: CPUE = [No. of fish caught x (45.7 m net/net length)] x (24 hours/hours set). A standard net length of 45.7 m (50 yd) was chosen to match the length of experimental and control gill nets. The majority of commercial fishermen used either 50 yd or 100 yd gill nets. In cases where fishermen simply referred to their nets by number, with no corresponding length, a daily CPUE per "net" was calculated using the following formula: CPUE = [no of fish caught x (1 net/ No. nets fished)] x (24 hours/hours set). A mean CPUE for each location and an overall mean CPUE for all locations combined (using data from nets of known length only), was calculated for each year.

Length and Age

Mean length and age were calculated for each sex by year and comparisons were made between sexes using a Student's t-test (Sokal and Rohlf 1981). Between year comparisons of mean length and age for each sex were made using a one-way analysis of variance test (ANOVA) (Sokal and Rohlf 1981). Frequency distributions of length and age were produced by sex and year for each species. Comparisons between years within each sex were made using the Kolmogorov-Smirnov two-sample test for equality of distributions (Sokal and Rohlf 1981).

Maturity and Sex Ratio

Gonad weights were collected to quantify gonad development using the Gonadosomatic Index (GSI). This index was calculated as follows: GSI = [gonad weight (g)*100/round weight (g)]. GSI values were plotted against fork length as well as Julian date for each sex by year. Also, mean GSI was calculated for each sex by year. For each species individual fish were classified as mature or immature/resting based on the distribution of data points in the above-described plots. Although maturities of sampled fish were qualitatively assessed by field technicians during most years of the fishery, inconsistencies in the codes used and the definition of these codes rendered these data questionable. Therefore GSI values were used to calculate percent mature and age at maturity for this report. The ratio of males to females for each species was calculated by year.

Growth

Weight-length relationships were determined using least squares regression analysis on log transformed weight and length data. The regression model was as follows: $\text{Log}_{10}\ W = a(\log_{10} L)+b$, where W = round weight (g), L = fork length (mm), a = slope of the regression line and b = y-axis intercept (Sokal and Rohlf 1981). An analysis of co-variance (ANCOVA) was used to compare length (growth) differences among years for each sex with age as a covariate. The model was as follows: $Y_{ij} = \mu+\alpha_i+\beta_j(X_{ij}-\chi_i)+\varepsilon_{ij}$, where Y_{ij} = j^{th} length in the i^{th} group, μ = grand mean, α_i = fixed effects for group i, $\beta_j(X_{ij}-\chi_i)$ = effect explained by the difference of the variate age (X_{ij}) from the mean of the ith group (χ_i), ε_{ij} = random deviation (Sokal and Rohlf 1981).

Catch at Age

Catch curves (natural log of age class frequency against age) were plotted for each year and a least squares regression was fitted to the descending limb of each curve. This regression included the catches with the greatest abundance plus one year, to the oldest age class. Instantaneous mortality rate (Z), annual survival rate (S) and annual mortality rate (A) were calculated as follows: Z = positive slope of the regression, $S = e^{-z}$, A = 1-S (Ricker 1975).

Some of the above described statistical analyses were initially broken down to comparisons among locations within years. At this level of detail, however, sample sizes were usually too low to conduct the types of tests necessary for a proper fishery analysis. Low sample sizes often result in low statistical power and violations of the assumptions of normality and homogeneity, thus precluding the use of parametric statistical methods.

The above-described analyses were conducted separately for experimental multi-mesh nets (population assessment) and the commercial 139 mm gill nets (including the control gill net used at the experimental site) (exploratory fishery assessment).

RESULTS AND DISCUSSION

Northern pike

Background information

Northern Pike are circumpolar in their distribution, occurring primarily in freshwater areas throughout Canada (Scott and Crossman 1973). They are common throughout the lower Mackenzie River and delta and are generally utilized as dog food by local subsistence fishermen. Pike were fished commercially in the delta for a short period during the 1960's (Barlishen and Webber 1973), but have mainly been used for sport fishing and subsistence purposes.

Pike occurring in northern regions typically mature around ages 5 (males) to 6 (females) and live up to 24-26 years of age (Scott and Crossman 1973). Spawning occurs in the spring following break-up (early June); preferred spawning habitat appears to be heavily vegetated, shallow areas of streams and lakes, of which there is an abundance in the Mackenzie delta. Eggs generally hatch within 12-14 days of being laid (Scott and Crossman 1973). Northern pike are for the most part non-migratory, although they do undergo limited seasonal movements within streams (McCart and Den Beste 1979). Because pike form localized populations that have relatively limited movements, both demographic characteristics and abundance indicators such as CPUE are likely to provide an accurate estimation of any population changes due to fishing pressure within a given area.

Exploratory fishery assessment

Production: The UDC exploratory fishery quotas and production levels for northern pike, inconnu and lake whitefish are provided in Table 1. The northern pike quota was initially set at 6,000 kg, then decreased to 5,000 in 1990, and increased to 10,200 in 1992. Northern pike harvest ranged from 8,757 kg in 1991 down to 0 kg in 1993. Of the total catch (including pike caught in the control net at the experimental site), 28, 163, 242, 298, and 18 northern pike were fully or partially sampled for biological information in 1989, 1990, 1991, 1992, and 1993, respectively.

Catch per unit of effort: The mean CPUE for nets of known length ranged from 0.58 to

4.63 fish/45.7 m net/ 24 hours (Table 2). CPUE remained relatively constant from 1990 to 1992 (3.15 to 4.63 fish/24 h) but dropped off to 0.58 fish/24 h in 1993. It should be noted, however, that the 1993 CPUE value is based on data from the experimental site only, and that this site generally had a lower CPUE (0.15 to 1.57 fish/24 h) than the commercial harvester's nets during all years of the study.

Length and age: To examine the hypothesis that there was no difference among sexes for mean length and age, males and females were compared for each year. In 4 out of 4 years, mean fork length was significantly larger for females, however age was similar for both sexes. Because of the size differences between males and females, both sexes were looked at separately for all further analyses of northern pike.

Summary statistics of mean, mode and range for age and fork length of pike by year are provided in Table 3. These statistics are further broken down by location in Table 4. Fork lengths of female northern pike ranged from 446-1160 mm with the majority falling between 625-1000 mm (Fig. 7). The modal fork length class ranged from 705-755 mm (Table 3). A significant difference in length frequency distributions was found between 1991 and 1992, with the 1992 distribution being skewed towards smaller size classes. An among year difference was also found for mean fork length (p=0.0001), but Scheffe's multiple comparison procedure showed that only 1991 and 1992 were significantly different from each other (mean fork length was lower in 1992). Fork lengths of male northern pike were generally lower than that of the females, ranging from 444-939 mm with the majority between 575-800 mm (Fig. 7). The modal fork length class ranged from 655-745 mm (Table 3). Similar to the females, the length frequency distribution of males was significantly different between 1991 and 1992, with the 1992 distribution containing a higher frequency of smaller fish. The mean fork length of male pike, however, varied little over the course of the fishery.

Female pike ranged from 4-24 years of age with the modal age varying between 11 and 12 years (Fig. 8, Table 3). The age frequency distribution differed significantly among years, with the 1992 distribution containing a higher frequency of young fish than previous years (1990 and 1991). Mean age also different among years (p=0.0001). Based on Scheffe's multiple comparison procedure, pike captured in 1992 were significantly younger than those caught in 1990 and 1991. The ages of male pike were similar to those of the females, ranging from 3-20 years of age with the modal age falling between 11 and 14 years of age (Fig. 8 Table 3). Similar to the females, length frequency distribution of males differed among years; there was a significantly higher frequency of younger fish captured in 1992 as compared to 1991. Mean age also differed between years (p=0.0001); male pike captured by the fishery in 1992 were significantly younger than those captured in 1990 and 1991.

The significant decrease in age as well as size of northern pike 1992 could be due to several things. Different locations were fished in different years so this size/age difference could simply be due to a difference in the catch composition from one year to the next i.e., locations with a high proportion of immature fish and fewer adults, may have been heavily fished in 1992, thus influencing the mean length and age for that particular year. To investigate this question, we looked at the differences between fishing locations from one year to the next. Sites 2 and 4, both main channel locations, were consistently fished from 1990 to 1992. The third fishing location differed from one year to the next; the jackfish lakes area was fished in 1990, the experimental site (located on the main channel) in 1991, and location 6 on Thrasher channel was fished in 1992. The side channel location used in 1992 may have contained more immature fish, thus contributing to the significant results described above. This was the case with broad whitefish, where individuals captured at location 6 were generally smaller and younger than those taken at the main channel fishing locations (Treble and Tallman 1997). A statistical comparison of mean age and length among locations by sex and year, however, does not support this hypothesis. With the exception of 1990, where the age of males at location 2 was significantly older than those from the jackfish lakes area, and 1992 where the fork length of females at location 2 was significantly longer than those at the other locations, fish at all locations within a given year were found to be of similar size and age. However, if we look at the yearly changes in mean age and length of fish captured at locations 2 and 4, which were fished consistently between 1990-1992, we can see that length remained constant, while age decreased slightly from 1990 to 1991. Both age and length decreased more substantially between 1991 and 1992 (Table 4). The decreases at these two locations likely contributed to the significant year effects described above. This drop in size and age could be an indication that larger older individuals are being depleted from these locations. Since pike tend to be less migratory, forming local populations, there is a danger of over-fishing such populations by using the same locations year after year.

Age and length frequency distributions can also provide an indication of how fishing pressure is affecting a stock. Length frequency data are most often used to reconstruct growth patterns of different cohorts (fish hatched during the same year) which can provide an indication of whether growth rates of fish in the stock have changed over time (Hilborne and Walters 1992). The size selective gear and low sample sizes of fish sampled by the exploratory fishery, however, preclude this type of analysis. Examination of age frequency data collected over time can provide an indication of problems with over-harvesting. A steady decline in the number of age groups and of older fish are cause for concern. Also, because they rely on consistently good recruitment, fisheries that take from only a few age classes are generally less stable than those that select from a wide range of age groups in the stock. In the case of the northern pike taken by the exploratory fishery, the wide range of age classes taken during all years is indicative of a healthy, stable population. The shift towards a higher frequency in younger age classes during the last year that age data were examined for pike (1992), however, could be of concern, as it may indicate that older individuals are being removed from the population and more younger individuals are now entering the fishery.

Maturity and sex ratio: Gonadosomatic indices ranged from 0.20-5.08 for female northern pike and from 0.22-3.28 for males (Table 5). Based on the scatter plots of GSI against fork length and Julian day, all males and females were either immature or resting during the fall when the exploratory fishery took place (Figs. 9 and 10). Given that pike are spring spawners it is not surprising to find uniformly low GSI values among all individuals in the population at this time of year. Due to this lack of spawners GSI values could not be used to calculate age at maturity for northern pike, so no such data have been presented for this species.

There were more females than males captured by the fishery during all years, with the ratio of males to females ranging from 1:2.4 to 1:6.1 (Table 6). The high sex ratio may be an indication that females are more vulnerable to the large mesh gill nets used by the fishery, or it could reflect the actual proportion of males and females in the population. If the proportion of females in a fishery is declining, there should be cause for concern since the reproductive potential of the population is dependent on the number of females. In the case of the exploratory fishery, there were no obvious trends in sex ratio over the years and the proportion of females relative to males remained high throughout.

Growth: Tables 7 and 8 contain the parameters for weight-length relationships of male and female northern pike by year. These parameters have been presented for information purposes only and will not be discussed further in this report. Although commonly presented in fishery analyses, weight-length relationships are of little use in evaluating the impacts of a fishery, as there is no accepted response of length-weight relationships to changes in stock size (Hilborne and Walters 1992). The weight - length relationships of fish can vary drastically depending on the season and any observed changes are most likely to represent changes in spawning readiness of individuals.

Length or size at age, however, provides a record of the growth that occurs throughout the year and can only increase with age. It is considered a good indicator of population changes brought about by over-fishing (Healy 1975). When population size is stable, intra-specific competition for resources remains constant and size at age tends to be stable. If the population size is reduced by fishing, more resources become available and the growth rate or size at age will increase gradually. Under extreme fishing pressure there is a drastic increase in size at age followed by a decrease as only one or two age classes come to dominate a fishery. In the case of this fishery, there were no significant changes in size at age from one year to the next (Fig. 11). Based on an ANCOVA the growth rates of both males and females remained stable throughout the years of the exploratory fishery.

Catch at age: Catch curve analysis is based on the idea that there are usually more younger/smaller fish than older/larger fish in commercial catches (Hilborne and Walters 1992). Generally when catch at age is plotted, a pattern very similar to that of the catch curves in Figure 12 (1990-1992) is seen. Two processes are responsible for this sort of pattern: 1) the youngest age classes of fish are less vulnerable to fishing gear, however, as they get older they become more vulnerable until they are "fully recruited" at a given age; 2) catches of older, full recruited fish decline because they are less abundant due to both natural and fishing mortality (Hilborne and Walters 1992). If we assume that catch is proportional to abundance, then the higher the natural and fishing mortality, the steeper the decline in catches of older fish will be. This translates to a steeper regression line for the descending limb of the catch curve. The instantaneous mortality rate (Z) is calculated from this regression which includes only those ages that are fully recruited to the fishery. If age and size at first recruitment remain stable over time, then post-recruitment mortality can give an indication of fishery effects.

In the case of this fishery, age and size of recruitment remained relatively constant from one year to the next. The age at full recruitment (the modal age plus one year) for northern pike varied between 12 and 13 years (Fig. 12), while mean fork length at full recruitment ranged from 743 to 767 mm. The mortality estimates remained stable across years, fluctuating between 0.27 and 0.33 (Fig. 12), suggesting that the fishery is only taking a small portion of the available stock and that natural mortality factors are dwarfing the effects of the fishery. If the fishery were seriously depleting the available northern pike stocks, one would expect to see an increase in mortality over time, since the probability of dying per individual fish would increase as the fishery harvested a greater and greater proportion of the existing stocks.

Population assessment (experimental gill netting)

Catch per unit effort: A total of 162 (from 46 gill net sets), 44 (27 sets), 11 (19 sets), and 2 (17 sets), northern pike were caught and sampled using the experimental gill nets in 1990, 1991, 1992, and 1993, respectively. Catch per unit effort varied from 8.86 to 0.35 fish per 45.7 m net/24 hours, with a steady decrease from one year to the next (Table 2).

Length and age: Since the exploratory fishery used one mesh size only, it is difficult to draw any conclusions about length frequency changes from the catch data only. The experimental nets were used to provide a less biased estimate of length frequency changes. Unfortunately the sample sizes were too small in most cases resulting in only two years where any comparisons could be made.

Where sufficient data were available for comparison (1990 and 1991), mean fork length of females was significantly larger than males in 2 out of 2 years and mean age was significantly older in 1 out of 2 years. Because of these differences, both sexes were looked at separately for the remaining analyses.

There were no significant differences between years (1990 and 1991) for mean fork length or the length frequency distributions of females and males (Fig.13). Fork lengths of females ranged from 442-

992 mm. The mean and modal lengths varied between 654-658 mm and 535-715 mm, respectively (Table 3). Lengths of males were generally less than females, ranging from 448-877 mm, with the mean and mode falling between 557-598 mm and 505-545 mm, respectively (Table 3). The length ranges sampled by the experimental nets are very similar to those of the commercial nets. The mean and modal lengths of fish captured in experimental nets, however, appears to be much lower, indicating that they are sampling a different (probably more representative) cross section of the population than the commercial nets.

Mean age, and age frequency distributions did not differ significantly among years for females or males (Fig. 14). Female pike ranged in age from 4-15 years, with the exception of one fish of 23 years that was captured in 1991. The mean ages for 1990 and 1991 were 9.7 and 9.9 years, while the modes were 10 and 7 years (Table 3). Male pike ranged from 5-15 years of age, with mean and modal ages of 8.8-8.9 and 5-10 years, respectively (Table 3).

Maturity and sex ratio: The GSI values for male pike ranged from 0.41-2.27 with means of 1.22 and 1.20 in 1990 and 1991, while those of female pike ranged from 0.23-3.95 with a mean of 1.54 in both 1990 and 1991 (Table 5). Based on the scatter plots of GSI, all pike captured in the experimental nets were either immature or resting (Figs. 15 and 16). As explained earlier, we were not able to calculate age at maturity using these GSI values.

As with the commercial nets, the sex ratios of pike captured in the experimental nets were skewed towards more females. The ratio of males to females was 1:1.2 and 1:1.4 in 1990 and 1991, respectively. These ratios, although still skewed towards females, are much lower than those observed for the commercial nets, suggesting that female pike may indeed be more vulnerable to commercial nets than males.

Growth: The parameters for weight-length relationships of male and female pike are presented in Table 9. Length at age growth curves are shown in Fig. 17. Size at age of females differed little between 1990 and 1991. A significant difference ($p = 0.02$) in the size at age of males was seen however (size at age was greater in 1990). Unfortunately, little can be said about these results regarding effects of the fishery on size at age since only two years of data are represented here.

Catch at age: The catch curve parameters for the 1990 experimental netting data were, instantaneous mortality (Z) = 0.39, survival (S) = 0.68, and annual mortality (A) = 0.32. These values are comparable to those observed for the commercial catches. Results for all other years of experimental netting are questionable due to small sample sizes.

Inconnu

Background Information

Inconnu are generally found in large northern rivers, associated lakes, and brackish coastal waters of northwestern North America and northern Eurasia (McPhail and Lindsey 1970). In Canada they are distributed through parts of the Yukon River system, the Mackenzie River to Great Slave Lake, the Slave and Liard Rivers, and north in coastal drainages to the Anderson River (Scott and Crossman 1973). Inconnu may be found in relatively large numbers throughout the lower Mackenzie and it's major tributaries (Peel and Arctic Red Rivers) from Fort Good Hope, north to the Mackenzie Delta and Beaufort Sea Coast. Inconnu are also captured in the upper part of the Mackenzie River between Fort Simpson and Fort Good Hope, but do not appear to be as abundant in this region (Hatfield et al. 1972; Stein et al. 1973). Inconnu are an important species to the domestic fisheries which are located in communities throughout the delta and along the Mackenzie River. Those captured during the summer months are generally dried and smoked for human consumption, while post-spawning inconnu taken in the fall are mainly used as dog food. Commercial fishing of inconnu in the N.W.T. only occurs on Great Slave Lake, where a fishery has been in operation since 1945.

There are at least two life history types of inconnu in the Mackenzie River system. Inconnu in the lower Mackenzie River and its tributaries are anadromous, while those in

Great Slave Lake are freshwater-resident (Howland et al. 2000, 2001). The anadromous form of inconnu is most likely the type that has been harvested by the exploratory fishery. Minimum age at maturity is 6 years for anadromous Mackenzie River inconnu (Stein et al. 1973; Percy 1975), with females generally living longer and reaching maturity at a later age than males (Bond 1982). In the Arctic Red River, male inconnu were found to mature at 7 years of age and reach a maximum age of 24, while females matured at 11 years and reached a maximum age of 34 (K. Howland, unpublished). Inconnu are iteroparous, but there is some question as to spawning frequency after maturity. According to Scott and Crossman (1973), they are suspected to spawn only once every 2, 3, or 4 years. In Alaska, where they have been studied more extensively, mature inconnu leave over wintering sites prior to spring break-up to begin their summer-long migration to spawning grounds in the upper reaches of tributaries (Alt 1977). Mackenzie River inconnu likely follow a similar pattern of movement. This is supported by the fact that most inconnu captured in the estuary or along the coast during the summer months are non-spawners (Bond 1982; Percy 1975). Peak numbers of upstream spawning migrants move through the Arctic Red River area (just upstream of the Mackenzie delta) in early August (Howland et al. 2000). Spawning occurs in late September, just prior to freeze-up, in major tributaries such as the Arctic Red (Howland et al. 2000), and possibly the Peel and mainstem Mackenzie Rivers (Percy 1975; Stein et al. 1973). After spawning, inconnu move downstream to over winter in the Mackenzie Delta and near shore coastal waters (Percy 1975; Jessop and Lilley 1975). Inconnu are thought to hatch in the spring and, like other young-of-the-year coregonids, are thought to be flushed by the spring freshet into the outer delta where they spend the first few years of life (Reist and Bond 1988). Movements of young inconnu in the Mackenzie River system remain poorly understood.

Although anadromous inconnu are migratory, due to timing it is unlikely that the exploratory fishery intercepts spawning individuals. The majority of spawning inconnu have already migrated through the delta at the time when the fishery takes place (late August-early October). Any inconnu that are captured by the fishery are likely to be either immature or resting individuals. Since little is known about movement patterns of juveniles, or the spawning frequency of adults (resting fish), it is difficult to know whether, in this particular case, abundance indicators such as CPUE are being influenced by factors other than actual population size. Both resting and juvenile fish may move from one year to the next, and each year a portion of the resting fish within a given area presumably mature and migrate upstream to spawn. Also, individuals from different spawning stocks may contribute to aggregations of fish within particular areas of the delta. Because of these possible biases, the CPUE data from this study should be interpreted with caution. Demographic characteristics such as age structure, size at age, and mortality are, in this case, likely to provide a more reliable indication of fishery impacts.

Exploratory Fishery Assessment

Production: The inconnu quota was initially set at 6,000 kg, then decreased to 5,000 kg in 1990 and 3,400 kg in 1991. Harvests of inconnu ranged from 474 kg in 1989 up to 9,086 kg in 1992. Of the total catch (including inconnu caught in the control net at the experimental site), 0, 101, 53, 153, and 191 inconnu were fully or partially sampled for biological information in 1989, 1990, 1991, 1992, and 1993, respectively.

Catch per unit of effort: The CPUE for inconnu was generally low, but remained stable throughout the years of the fishery. For nets of known length it ranged from 0.93 to 1.63 fish/45.7 m net/24 hours (Table 10). The overall low CPUE for this species is likely due to the fact that the fishery took place during September. At this time of year spawning inconnu which migrate through the delta have already moved further upstream towards spawning areas and don't usually return from spawning until early to mid-October (Howland et al. 2000). Therefore, only immature or resting individuals that happened to be in the area would have been available to the fishery at this time of year.

Length and age: In comparisons between sexes for mean fork length and age, males and females were only found to differ significantly for length in 1992. Mean age was similar for both sexes in all 4 years examined. Although mean ages and lengths were similar among sexes in this particular case, other studies in the lower Mackenzie have found significant differences among sexes in terms of size, age at maturity and growth of inconnu (de Graaf and Machniak 1977; K. Howland, unpublished). Since there is other evidence for sexual differences in such parameters, we have chosen to look at male and female inconnu separately for the remainder of the analyses presented in this report.

Summary statistics of yearly mean, mode, and range for fork length and age of inconnu are provided in Table 11. These statistics are further broken down by location in Table 12. Fork lengths of female inconnu ranged from 286-983 mm, while mean and modal lengths varied between 650-767 mm and 585-885 mm, respectively (Fig. 18, Table 11). Among year differences were found for both mean fork length and length frequency distributions, however, there were no apparent trends in the data. Scheffe's multiple comparison procedure showed that 1991 was significantly different from all other years (mean length was greater), and that 1992 and 1990 were also different from each other (mean length was significantly higher in 1992). The length frequency distributions in 1991 and 1992 were significantly different from those seen in 1990 and 1993, with the 1990 distribution skewed towards the smaller age classes and the 1993 distribution skewed more towards older age classes. Fork lengths of male inconnu ranged from 432-880 mm with the mean and mode falling between 602-644 mm and 595-670 mm, respectively (Fig. 18, Table 11). There were no significant differences between years for mean fork length or length frequency distributions of males.

The age frequency data for both male and female inconnu, although variable among years, indicates that the commercial gill nets generally selected individuals from a wide range of age classes during all years of the fishery (Fig. 19). Female inconnu ranged from 4-25 years of age, with the mean age varying between 9.5 and 13.6 years (Table 11). The modal age was between 8-10 years, with the exception of 1991 where the age distribution was bimodal and age frequency peaked at both 8 and 18 years (Fig. 19). Significant differences among years were found for both mean age and age frequency, however, no obvious trends were observed. Sheffe's multiple comparison procedure showed that 1991 was significantly different from all other years (mean age was higher), and that 1990 and 1993 were also different from each other (mean age was significantly higher in 1990). The 1993 age frequency distribution was significantly different from 1990 and 1991 (1993 contained a lower frequency of fish in the older age classes). Male inconnu ranged in age from 5-19 years, with mean and modal ages varying between 8-11 years and 7-13 years, respectively (Table 11). Age frequency distributions did not differ significantly among years and mean age was only significantly different between 1990 and 1992 (age was higher in 1990).

The variability in size and age of catch from one year to the next could have been due to the fact that different locations were fished during different years. Location 4, on the main channel, was the only fishing site from which biological data were collected consistently from 1990-1993. Data from the Jackfish Lakes area were collected in 1990, and data from Locations 2 (Main Channel) and 6 (Thrasher Channel) were collected between 1992-1993 (Table 12). The additional data from these side channel or lake sites could have potentially influenced the overall age and length composition during certain years. A statistical comparison of mean age and length among locations by sex and year, however, does not support this. With the exception of 1990, where the female inconnu from the Jackfish Lakes area were significantly older than those from location 4, fish from all locations within a given year were found to be of similar size and age.

Maturity and sex ratio: The GSI values of male inconnu ranged from 0.03-3.33, with yearly means of between 0.08-1.34, while those of female inconnu ranged from 0.03-2.77, with yearly means from 0.27-0.67 (Table 13). Based on the scatter plots of GSI against fork length and Julian day, all inconnu captured during the exploratory fishery were either immature or resting (Figs. 20 and 21). The absence of spawners, as explained above, is probably due to the fact that the majority of spawning inconnu would have already migrated through the delta at the time the exploratory fishery was run each year. Due to the absence of spawners, we were unable to calculate age at maturity from the GSI values for this species.

There were more females than males captured by the fishery in all years. The ratio of male to female inconnu varied from year to year, ranging from 1:1.8 to 1:5.5 (Table 14). The consistently high proportion of females could indicate that they are somehow more vulnerable to commercial gill nets, or it could simply reflect the actual sex ratio of the inconnu populations fished. If the proportion of females were declining from one year to the next, there would be cause for concern. In the case of this fishery, sex ratios, although variable, showed no apparent downward trend in terms of the proportion of females over time.

Growth: The parameters for weight-length relationships of male and female inconnu are shown in Tables 15 and 15. Length at age growth curves are presented in Fig. 22. Size at age of both female and male inconnu did vary considerably among years (female p = 0.0001, male p = 0.0338), however, no trends over time were observed. A multiple comparison procedure using the least squares means indicated that female inconnu collected between 1991-1993 were of a significantly larger size at age than those collected in 1990 (p = 0.0001), however, females captured during 1993 were of a smaller size at age than those taken in 1992 (p = 0.0087). Male inconnu collected during 1992 and 1993 were of a significantly larger size at age than those collected in 1990 (1992 p = 0.0048, 1993 p = 0.0390), but were not found to differ from those collected in 1991.

Catch at age: The age and size of recruitment for inconnu in this fishery remained relatively constant from one year to the next. Age at full recruitment varied between 10 and 11 years (Fig. 23), while the mean fork length at full recruitment ranged from 662 to 682 mm. The mortality estimates varied between 0.25 and 0.35, but showed no obvious trend across years, suggesting that the fishery is only taking a small proportion of the available stock. If the fishery were having a serious impact on inconnu stocks in the area, we would have expected to see an increase in mortality over time.

Lake whitefish

Background Information

The lake whitefish is widely distributed across Canada and may be found in large lakes, rivers, and brackish coastal waters throughout the Northwest Territories (Scott and Crossman 1973). Lake whitefish is the main species targeted by the commercial fishery on great Slave Lake. Although abundant throughout the Mackenzie River system north of Great Slave Lake, infestation by the parasite *T. crassus*, prevents the marketing of these lake whitefish for human consumption. Lake whitefish in the lower Mackenzie River are, however, important in the domestic fisheries where they are taken in substantial numbers to feed dog teams that are still kept by many families in the area.

Similar to inconnu, at least two types of lake whitefish are thought to exist within the Mackenzie River system: a lake-dwelling form and an anadromous form (Reist and Bond 1988). Although both types are thought to be present in the lower Mackenzie, the majority of lake whitefish taken by the fall exploratory fishery are likely of the anadromous type.

In the lower Mackenzie River area, anadromous lake whitefish have been reported to reach sexual maturity between ages 7 and 11 and attain a maximum age of 18-20 (Stein et. al 1973; Percy 1975; de Graaf and Machniak 1977; Bond 1982; Bond and Erickson 1985). Pre-spawning lake whitefish tend to congregate in eddies within the major channels of the Mackenzie delta between August and mid-September and then move upstream just prior to spawning (Stein et al. 1973). Spawning occurs in late September-early October in major tributaries such as the Peel and Arctic Red Rivers, as well as the main stem Mackenzie River (Stein et al. 1973). The post-spawning downstream migration towards over wintering sites in the delta takes place from

October to early November (Stein et al. 1973; Jessop and Lilley 1975). Like other coregonids, lake whitefish eggs hatch in the spring and the young are presumably swept downstream towards the Mackenzie delta (Hatfield et al. 1972). Young lake whitefish appear to rear within back eddies of channels in the delta where they can be found in large numbers during the summer months (Reist and Bond 1988).

The lake whitefish populations taken by the exploratory fishery have migration and life history patterns similar to the broad whitefish. The timing and location of the commercial fishing in combination with such migration patterns makes this an "interception fishery". Treble and Tallman (1997) have outlined some of the reasons why this type of fishery may be difficult manage. In this type of fishery, abundance indicators such as CPUE may be strongly influenced by yearly variations in migration timing and routes, masking real changes in population abundance. This situation may be further complicated by the presence of multiple genetically and /or demographically distinct stocks that may each contribute different numbers of fish to the fishery from one year to the next. Because of these potential biases, the CPUE data presented below should be interpreted with caution. In this particular situation, the demographic characteristics analyzed below (age structure, age at maturity, size at age, mortality) are more likely to provide an accurate indication of population changes due to fishing pressure.

<u>Exploratory Fishery Assessment</u>

<u>Production</u>: Quota and harvest statistics of lake whitefish were only provided by the Department of Fisheries and Oceans in 1989 (1992a). During that year the quota was set at 6,000 kg and the harvest was 6,451 kg (Table 1). Of the total catch (including lake whitefish caught in the control net at the experimental site), 0, 150, 815, 233, and 277 lake whitefish were fully or partially sampled for biological information in 1989, 1990, 1991, 1992, and 1993, respectively.

<u>Catch per unit of effort</u>: The mean CPUE for nets of known length decreased from 18.94 to 3.25 fish/47.7 m net/24 hours between 1990 and 1993 (Table 17). However, these results should be interpreted with caution since CPUE may not be a very reliable measure of relative abundance in this case. The fishery occurred during a time when more than one stock of lake whitefish could have been migrating through the area and fishing was conducted over some what different time periods from one year to the next. This could result in large yearly variations in CPUE for a species such as lake whitefish which is only abundant within a given stretch of the river for a short window of time during migration.

<u>Length and age</u>: Summary statistics of mean, mode and range for age and fork length of lake whitefish by sex and year are given in Table 18. These statistics are further broken down by location in Table 19. Fork lengths of female lake whitefish ranged from 403-543 mm, with the yearly mean and mode varying between 458-471 mm and 435-475 mm, respectively (Table 18). The length frequency distribution of females remained stable over the course of the fishery, but mean fork length varied among years ($p = 0.001$) (Fig. 24). Scheffe's multiple comparison procedure showed that mean fork length was significantly higher in 1992 and 1993 as compared to 1990. Fork lengths of male lake whitefish ranged from 370-569 mm, with the yearly mean and modal lengths varying between 448-468 mm and 445-465 mm, respectively (Table 18). The length frequency distribution of males was significantly different between 1990 and all other years (1990 was skewed towards a higher frequency in larger size classes) (Fig. 24). Mean fork length was also found to be higher in 1990 as compared to other years ($p = 0.0001$).

The age frequency data for male and female lake whitefish, although variable among years, indicates that the exploratory fishery generally selected fish from a wide range of age classes during all years of the fishery (Fig. 25). Female lake whitefish ranged in age from 7-33 years, with the exception of one fish captured in 1991 that was 40 years old (Table 18). The mean and modal ages were between 13-16 years and 11-14 years, respectively. The age frequency distributions and mean ages of females varied among years, but there were no apparent trends with time (Fig. 25). The age frequency distribution in 1991 was significantly different from 1990 and 1992 (the 1991 distribution contained a higher proportion of older fish). Mean age in 1991 was significantly higher than both 1990 and 1992, while mean age in 1993 was higher than in 1990 ($p = 0.0001$). Ages of male lake whitefish ranged from 5-34 years, with the yearly mean and mode varying between 12-15 and 11-15, respectively (Table 18). As with the females, the age frequency distributions and mean ages of males varied among years, but no trends were observed. The age frequency distribution in 1990 was significantly different from 1991 and 1992 (the 1990 distribution contained a higher proportion of younger fish) (Fig. 25). The mean age of males in 1990 was significantly lower than in all other years of the fishery ($p = 0.0001$).

Variation among the fishing locations monitored from one year to the next may account for some of the above described differences in length and age. Biological data were collected from lake whitefish at location 4 (main channel) throughout the fishery. Location 2, also on the main channel, was monitored in 1990 and 1992, the experimental site (main channel) was monitored from 1991-1993, and location 6 (thrasher channel) was monitored in 1992 only. When mean age and length among locations by sex and year were compared, only the following differences were found: during 1991, both males and females from the experimental site were significantly older than those from location 4 (male $p = 0.001$, female $p = 0.01$); in 1992, both males and females from location 9, and males from the experimental site were older than those from location 6 (male $p = 0.0002$, female $p = 0.01$).

Maturity and sex ratio: The GSI values of male lake whitefish ranged from 0.11-3.71, while those of females ranged from 0.08-27.8 (Table 20). Scatter plots of GSI against fork length and Julian day showed that a high proportion of the catch taken by the exploratory fishery were mature spawners (Figs. 26 and 27). The following maturities of male and female lake whitefish were classified based on the distribution of data points in the GSI plots: males, immature/resting GSI ≤ 0.5, mature GSI > 0.5; females, immature/resting GSI ≤ 6.0, mature GSI > 6.0. Percent mature and age at maturity were calculated from the above described GSI values. The mean GSI for mature males varied from 1.11 to 1.69 and for immature males from 0.19 to 0.45. The yearly mean GSI of mature females ranged from 14.1 to 16.7, while immature females varied between 0.84 and 2.29. The youngest age at which mature males and females were observed was six and seven, respectively. Age at maturity for the purpose of this study, however, was considered to be the age group, within a given sex and year, where at least 50% of the fish were mature current year spawners (Morin et. al. 1982). Age at maturity of males increased from six to nine years of age between 1990-1992 and then remained at 9 years of age in 1993 (Fig. 28). Age at maturity for females varied from year to year, ranging between ages seven and nine, but no trends with time were observed (Fig. 29).

The sex ratio of lake whitefish remained stable throughout the years of the fishery. The proportion of females was slightly higher than males, with the female/male ratio ranging from 1.05 to 1.57 (Table 21).

Growth: The parameters for the weight-length relationships of male and female lake whitefish are shown in Tables 22 and 23. Length at age growth curves are presented in Fig. 30. Size at age of both female and male lake whitefish varied among years (female $p = 0.0002$, male $p = 0.0007$), however, no consistent time trends were observed. A multiple comparison using least squares means showed that for both sexes size at age in 1992 and 1993 was significantly greater than in 1990 and 1991, however, each of these years (1990 vs. 1991, and 1992 vs. 1993) did not differ significantly from each other. Although size at age did not increase during every year of the exploratory fishery, the above described differences could be part of a longer term increase in growth rate with time that might only become apparent with continued monitoring of the fishery.

Catch at age: The age and size at full recruitment for lake whitefish in this fishery remained relatively constant from one year to the next. Age at full recruitment was 14 in all years of the fishery, with the exception of 1991 where it was 12 years of age (Fig. 31). The mean fork length at full recruitment ranged from 455 to 469 mm. The mortality estimates varied substantially, ranging from 0.14 to 0.51, but showed no obvious trend across years. If the fishery were having a serious impact on lake whitefish stocks in the area we would expect to see an increase in mortality with time, when in fact, mortality was highest in 1990 and then fluctuated at lower levels between 1991 and 1993.

Population Assessment

Catch per unit effort: A total of 257 (from 46 gill net sets), 77 (27 sets), 48 (19 sets), and 62 (17 sets) lake whitefish were caught and sampled using the experimental gill nets in 1990, 1991, 1992, and 1993, respectively. Catch per unit effort of the experimental nets varied from one year to the next, ranging from 3.16 to 5.45 fish per 45.7 m net/24 hours, with the exception of location 4 in 1990 where CPUE was 10.39 fish per 45.7 m net/24 hours.

Length and age: There were no significant differences among years for mean fork length or the length frequency distributions of females and males (Fig. 32). Fork lengths of females ranged from 284-513 mm. The mean and modal lengths varied from 438-465 mm and 445-465 mm, respectively (Table 18). The lengths of males were similar, ranging from 259-510 mm, with the mean and modal lengths falling between 425-437 mm and 415-445 mm (Table 18). The range of lengths sampled by the experimental nets was wider than the commercial nets, encompassing more of the smaller length classes. Mean and modal lengths were also smaller, indicating that the experimental nets were sampling a different, likely more representative, cross section of the population.

The mean age and age frequency distributions of males and females varied among years, but no trends with time were observed (Fig. 33). Ages of female lake whitefish ranged from 4-26 years, with the mean and mode varying between 11.7-16.1 years and 13-18 years, respectively (Table 18). Based on Scheffe's multiple comparison procedure the mean age of female lake whitefish collected in 1990 was significantly lower than those collected in 1991 or 1993, and mean age of females collected in 1992 was lower than those taken during 1991 ($p = 0.0001$). Similarly, the age frequency distribution of females collected during 1990 differed from that of females collected in 1991 and 1993 (1990 contained a significantly higher frequency of fish in younger age classes). Male lake whitefish ranged in age from 3-20, with mean and modal ages from 12.0-14.1 and 10-16, respectively (Table 18). Mean age and the age frequency distribution of male lake whitefish was only found to differ between 1990 and 1991 (mean age was lower in 1990, $p = 0.0266$; the 1990 age frequency distribution had a higher frequency of fish in younger age classes). The higher proportion of young fish captured during 1990, and the lower mean age of both males and females during this year may, in part, be due to the fact that different fishing locations (2 and 4) were used in this year as compared to the last 3 years of the fishery (1991-1993) when the experimental site was used instead.

Maturity and sex ratio: The GSI values of male lake whitefish captured in the experimental gill nets ranged from 0.09-3.22, with yearly means of 1.2-1.91 (Table 20). The GSI of female lake whitefish ranged from 0.13-25.8; the means varied from 9.93-16.5, with the exception of 1992 when the mean GSI (based on 2 fish) was 0.84 (Table 20). Scatter plots of GSI against fork length and Julian day indicate that a high proportion of the catch taken in experimental nets were mature spawners (Figs. 34 and 35). Age at maturity data from the experimental gill nets was included with the analysis of the commercial net data shown above (Page 14).

The sex ratio of lake whitefish taken by experimental gill nets remained stable throughout the years of the fishery. The proportion of females was slightly higher than males (female/male ratio of 1.04-1.30), with the exception of 1990 where the female/male ratio was 0.78 (Table 21).

Growth: The parameters for the weight-length relationships for male and female inconnu are shown in Tables 24 and 25. Length at age growth curves are presented in Fig. 36. Size at age of female lake whitefish remained stable throughout the fishery. That of the males varied among years ($p = 0.0001$), however, no consistent time trends were observed. A multiple comparison using least squares means showed that size at age of males in 1991 was significantly smaller than in all other years.

Catch at age: The age and size at full recruitment of lake whitefish to the experimental gill nets remained relatively constant from one year to the next. Age at full recruitment was 16 in all years of the fishery, with the exception of 1990 where it was 14 years of age (Fig. 37). The mean fork length at full recruitment ranged from 445 to 459 mm. The mortality estimates varied substantially, ranging from 0.15 to 0.48, but showed no obvious trend across years. Healy (1975) examined natural mortality rates of lake whitefish in 13 unexploited populations in Canada and found the rates to range from 0.19 to 0.74, with an average of 0.49. The mortality rates found in the present study were well within this range, suggesting that fishing mortality is only contributing a minor amount to the total mortality.

SUMMARY AND CONCLUSIONS

We suggest that the fishery may be having some impact on the local northern pike populations within the area. This is based on the fact that both size and age of pike decreased over the years for which biological data were available (1990-1992). Of particular concern is the loss of fish in the older age classes and a shift towards a higher frequency of fish in the younger age classes with time. The loss of the oldest and largest individuals is one of the earliest signs of fishing pressure, particularly when large mesh gill nets are the main fishing gear (Healy 1975). Other changes such as increased size at age (growth rate) and decreased age at maturity may take longer to appear.

Although the age of northern pike shifted with time, other demographic characteristics suggest that populations in the area are still relatively healthy: 1) even though age frequency changed with time (i.e. older age classes were not as well represented in later years) there was still a wide range of ages present during all years of the fishery; 2) a high, relatively stable ratio of females to males was maintained throughout the fishery, indicating high reproductive potential; 3) size at age (growth rate) of northern pike remained stable across years; 4) size and age at recruitment was similar from one year to the next, and total mortality was relatively low (0.27-0.33) and stable, suggesting that the fishery is currently taking a small proportion of the available stock; 5) the high age at recruitment (12-14 years), and contribution of many age classes to recruitment are also characteristic of populations that are not under heavy exploitation.

Low numbers of inconnu were taken by the exploratory fishery simply because of timing; the majority of spawning inconnu were at upstream spawning areas at the time of the fishery. Based on the following evidence we suggest that the fishery has had little impact on inconnu population abundance: 1) the CPUE, although generally low, remained stable across years; 2) mean length and length frequency showed some year to year variation for female inconnu, but no trends with time were observed, and male inconnu remained stable across years; 3) mean age and age frequency varied among years for both sexes, but again, no downward trend was seen; 4) a wide range of age classes was represented by the catch throughout 1990-1993; 5) a high, although somewhat variable, ratio of females to males was maintained throughout the fishery, indicating high reproductive potential; 6) size at age varied from year to year, but did not show an increase with time; 7) size and age at recruitment were similar from one year to the next, and total mortality was relatively low (0.25-0.35) and stable, suggesting that the fishery is currently taking a small proportion of the available stock.

Some of the year to year variation in size and age of inconnu may be due to the fact that the fishery was taking mainly immature or resting fish, as the majority of spawning inconnu had already migrated through the delta by September. As previously indicated, little is known about the movements of these life history stages, so much of this variation could simply have been due to movement of individuals into or out of an area. If the immature/resting component of the population tend to be transient, moving from one feeding area to another, there is a high potential for change in the demographic structure of the population within a given area over time. It should also be noted that even though a wide range of ages were represented in the inconnu catch from this fishery, the overall age of these fish was younger than that seen for inconnu sampled during spawning migrations through the lower Mackenzie River area. For example, pre-spawning inconnu captured near the mouth of the Arctic Red River had modal ages of 14 and 19, and age ranges of 3-24 and 4-34, for males and females, respectively (K. Howland, unpublished). In contrast, those captured by the fishery had modal ages of 8-10 and 7-13, and ranges of 5-19 and 4-25, for males and females, respectively. These differences are likely due to the higher proportion of immature individuals taken in the commercial fishery.

The exploratory fishery appears to have had relatively little impact on the population structure and abundance of lake whitefish in the Mackenzie delta. Although the catch per unit of effort did decrease between 1990-1993, as explained earlier, this may not be a reliable indicator of changes in population abundance for lake whitefish in this fishery. The following demographic characteristics, which are more likely to be reliable indicators, suggest that the lake whitefish populations of this fishery have remained healthy and relatively stable: 1) lengths and ages of lake whitefish varied somewhat among years, but no downward trend with time was observed for either parameter; 2) age range of the catch was wide during all years of the fishery, encompassing many ages including a significant portion of older fish; 3) age at maturity of males and females varied among years, but again, no downward trend with time was observed; also, age at maturity was comparable to that reported by other authors for the lower Mackenzie River area; 4) sex ratios remained stable throughout the fishery, with a slightly higher proportion of females; 5) size at age (growth rate) showed some year to year variation, but did not increase over the period of the fishery; 6) age at first recruitment was quite high (12-14 years for commercial nets, 14-16 years for experimental nets) and a wide range of age classes contributed to recruitment indicating very little fishing pressure; 7) mortality was variable (0.14-0.51), but of similar levels to natural mortality observed in unexploited lake whitefish populations (Healy 1975), suggesting that fishing pressure is only a minor contributor to total mortality of these lake whitefish populations.

With the exception of northern pike, the populations of by-catch species (inconnu and lake whitefish) sampled from the Mackenzie Delta exploratory fishery appear healthy and stable at current harvest levels. Nevertheless, caution should be exercised when considering the results of this study. Usable biological data were only collected in 4 out of the 5 years of the exploratory fishery and in some cases in only 2-3 out of the 5 years (northern pike). For both inconnu and lake whitefish, CPUE was not considered a reliable indicator of changes in population abundance; demographic characteristics, although more reliable as indicators, may not show changes during the short time period for which data were collected. For this reason we feel that, if the fishery is maintained, continued monitoring of biological parameters is imperative.

Lake whitefish and inconnu may be able to withstand increased harvests, but to what extent is unknown, given that very little reliable information is available on subsistence harvest levels. In the case of broad whitefish, estimated subsistence and domestic harvests were up to 12 times higher than commercial harvest levels (Treble and Tallman 1997), indicating that commercial fishing may only account for a small fraction of the total fish removed from these populations within a given year. Lake whitefish biology has been studied quite extensively and the responses of this species to exploitation are fairly well understood. On the other hand, the biology of inconnu, particularly within the lower Mackenzie, is poorly understood and the genetic stock structure of both species remains largely unknown for this region.

In the case of this fishery, northern pike may be more vulnerable to over-fishing because of their non-migratory nature. There is a danger of depleting local populations through repeated fishing at the same locations year after year. Although, the populations harvested by the fishery appear to be healthy at the moment there is some evidence of a decrease in numbers of older fish, suggesting that fishing may be having an impact. Given this information it may be risky to further increase harvest levels of pike. In fact a reduction in the current quota might be considered given that during the last two years of the exploratory fishery (1992-1993) pike harvests were no where near the allowable catch (Table 1).

RECOMMENDATIONS

1) If commercial fishing is maintained in the delta, we recommend the continued monitoring and collection of biological data for all species. If possible length, weight and aging structures should be obtained, and sex determined for all fish brought into the fish processing plant to increase sample sizes available for fishery analyses. In addition, trained biologists should sub-sample the catch for information such as gonad weight and maturity. Ideally, sampling of the commercial catch would be accompanied by a small field program involving additional sampling from one or more experimental and "control" gill nets within the commercial fishing area. In the case of the exploratory fishery data and experimental gill netting data provided between 1989-1993, low sample sizes meant that data had to be pooled by locations for each year. If data are to be broken down further, in order to look at differences among fishing locations potentially containing different stocks, larger sample sizes will be required in order to maintain statistical power.

2) Emphasis should be placed on the collection of accurate catch information by fishermen. In many cases a proper measure of CPUE could not be determined due to lack of information regarding net dimensions. This information is quite easy to record and keep track of yet it was missing in many instances. In most cases, fishermen used the same nets throughout the fishing season, so net dimensions and a corresponding net number could be recorded at the beginning of the season. Fishermen would then only need to take note of the net number when recording subsequent catch information. It is important to record not only net length, but also net depth. Net depth was only available from one location during one year (1990) and net length was only provided about 45% of the time. Without this information, catch data cannot be properly standardized for comparisons of population abundance between years.

3) Standardization of maturity indices, and the investigation and development of common maturity codes for species such as broad whitefish, inconnu, northern pike and lake whitefish is important. Common detailed descriptions of these codes and training by experienced persons should be provided to all biologists or technicians involved in sub-sampling the catch for maturity. The collection of accurate maturity data using maturity codes is necessary for the following reasons: 1) although GSI is a useful indicator of spawning state, it cannot be used to distinguish immature and resting fish, thus precluding the estimation of age at maturity in situations where there is a lack of spawners in the population; 2) the use of GSI values may present a bias in age at maturity analyses, since, in the absence of maturity codes, mature resting fish are simply grouped with immature individuals.

4) The subsistence harvest monitoring programs developed by the Inuvialuit, Gwich'in and Sahtu should be continued with an emphasis on the collection of harvest and fishing location information as well as the collection of biological data from all species by sub-sampling fishermen's catches. Such biological data can be used to strengthen data sets that have already been started through the exploratory fishery. The collection of subsistence fishing information will allow for more accurate estimates of total annual harvests in the lower Mackenzie River area.

5) Given that certain species such as pike may be more vulnerable to exploitation, and that other species such as lake whitefish are non-marketable, fishing gear that allows

selection would be more desirable. Gill nets are often lethal or at the very least tend to injure fish upon capture reducing their chances of survival if released. In most cases all fish captured within a net are either kept for market or, if undesirable, are given away as dog food or discarded. The use of fish wheels was suggested in the past (Orman 1992) and seems worthy of consideration. Although, trap nets were tried unsuccessfully during the exploratory fishery (Treble 1997), fish wheels have been used extensively on other large rivers, such as the Yukon, which are similar to the Mackenzie in terms of size and characteristics. Orman (1992) provides details of fish wheel design and operation as well as some of the benefits of using this particular type of fishing gear.

6) All species, with the exception of northern pike, migrate substantial distances, crossing land claim boundaries and are fished at multiple locations throughout the lower Mackenzie. Since any increase in quota will involve a certain degree risk to future production of fish stocks, we recommend that all communities and land claim groups that harvest these species (broad whitefish, inconnu, lake whitefish) be involved in any future decisions regarding commercial fishery quotas.

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Table 1. Uummarmiut Development Corporation Exploratory Fishery harvest data (rd kgs) and quotas, in brackets. Source: Department of Fisheries and Oceans (1992a, 1992b, 1993, 1994, and 1995).

Species	Year				
	1989	**1990**	**1991**	**1992**	**1993**
Northern Pike	1,661 (6,000)	7,184 (5,000)	8,757 (10,200)	2,160 (10,200)	0 (10,200)
Inconnu	474 (6,000)	1,042 (5,000)	2,187 (3,400)	9,086 (3,400)	1,124 (3,400)
Lake Whitefish	6,451 (6,000)				

Table 2. Mean catch per unit of effort (CPUE) by location and net type, for northern pike, 1990 to 1993. An overall mean CPUE has been calculated for the 139 mm mesh gill nets of known length.

Location - Net Type	1990	1991	1992	1993
Loc. 2 - Exp. Net	8.86 ± 13.08			
Loc. 4 - Exp. Net	1.55 ± 1.89			
Exp. Site - Exp. Net		2.92 ± 2.92	0.70 ± 1.48	0.35 ± 0.77
Exp. Site - 139 mm Mesh		1.57 ± 2.70	0.15 ± 0.61	0.58 ± 0.94
Loc. 1 - 139 mm Mesh	3.09 ± 2.15*			
Loc. 2 - 139 mm Mesh	4.27 ± 5.32	10.09 ± 7.91	2.23 ± 2.95*	0.66 ± 1.24*
Loc. 3 - 139 mm Mesh	2.71 ± 2.62	2.22 ± 1.50	7.28 ± 4.23	
Loc. 4 - 139 mm Mesh	2.47 ± 3.98	0.59 ± 1.15*	0.94 ± 1.98*	
Loc. 5 - 139 mm Mesh			0.90 ± 0.77*	0.78 ± 0.73*
Loc. 6 - 139 mm Mesh			6.06 ± 5.58	0.99 ± 0.86*
Loc. 7 - 139 mm Mesh				0.96 ± 0.64*
Mean CPUE =	**3.15**	**4.63**	**4.50**	**0.58**

* This value was not used in calculating the mean because net size was unknown.

Table 3. Summary statistics by sex and year for northern pike from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
		n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	89	790	725	570-1050	38	687	675	448-926	84	13.1	12	8-21	36	12.4	12	4-20
139	1991	201	804	715,755	521-1160	33	723	745	640-850	155	13.3	11	4-24	30	13.2	14	8-18
139	1992	215	756	705,735	446-1120	77	673	655,675	444-939	193	10.9	11	4-21	62	10.4	11	3-18
139	1993	14	807	795	665-1016	4	694	-	565-753	14	10.9	12	7-19	4	11.0	-	9-12
38-139	1990	76	654	535,715	442-992	62	598	505	448-877	76	9.7	10	4-15	60	8.8	10	5-14
38-139	1991	24	658	645,695	485-893	17	557	545	415-690	20	9.9	7	5-23	17	8.9	5,7	5-15

Table 4. Summary statistics by sex, year and location for northern pike from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993. Source Treble *et. al.*, unpubl. data report.

Mesh (mm)	Year	Location No.	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
			n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	2	11	803	-	632-943	7	747	-	614-926	11	14.3	12	12-21	7	15.1	16	10-19
		4	48	793	725,795, 815	570-1050	23	686	695,775	448-846	48	2.8	12,13	8-20	23	12.0	12	4-20
		J. Lakes	30	781	725	580-1000	8	637	675	546-742	25	13.3	14	9-19	6	10.3	-	6-14
139	1991	2	133	807	710	650-1100	20	726	750	640-850	90	13.4	11	4-23	17	13.4	14	9-18
		4	50	803	735,760	521-1160	10	716	725	654-795	48	13.0	11,14	4-24	10	12.8	14	8-17
		Exp. Site	18	786	760,785, 805	619-914	3	721	-	672-751	17	12.3	9,10	7-24	3	15.0	-	13-18
139	1992	2	64	793	735	475-1120	10	712	650	650-843	57	11.5	11	6-21	9	11.1	11,12	8-13
		4	83	748	705	446-1091	37	664	695	444-939	69	10.3	11,12	5-18	27	10.8	10	8-18
		6	60	740	685,785	497-967	28	673	635	464-885	59	11.3	11,12	4-17	24	9.9	9	3-16
139	1993	Exp. Site	14	807	795	665-1016	4	694	-	565-753	14	10.9	12	7-19	4	11.0	12	9-12
38-139	1990	2	58	626	535-545, 565,645	481-908	56	594	505	448-877	58	9.5	8,9	4-15	54	8.7	9	5-14
		4	18	743	595,660, 715	571-992	6	634	-	540-721	18	10.4	10	8-14	6	9.2	10	8-10
38-139	1991	Exp. Site	24	658	645,695	485-893	17	557	540	415-690	20	9.9	7	5-23	17	8.9	5,7	5-15

Table 5. Gonadosomatic index by sex and year for northern pike from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	GSI - Female (mm)				GSI - Male (mm)			
		n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	84	1.69	0.30	0.20-4.46	37	1.26	0.90	0.39-3.08
139	1991	35	1.91	1.30	0.20-5.08	7	1.38	1.30	0.74-1.88
139	1992	132	1.75	1.30	0.18-5.00	43	1.52	1.50	0.22-3.28
139	1993	7	1.61	1.30	0.41-2.72	1	-	-	-
38-139	1990	74	1.54	1.10	0.24-3.67	54	1.22	0.70	0.41-2.27
38-139	1991	24	1.54	1.30	0.23-3.95	15	1.20	0.90	0.54-2.22

Table 6. Sex ratio for female to male northern pike (F/M) from 139 mm mesh and 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	Females	Males	Sex Ratio (F/M)
139	1989	10	3	3.3
139	1990	90	38	2.4
139	1991	202	33	6.1
139	1992	216	78	2.8
139	1993	14	4	3.5
38-139	1990	76	62	1.2
38-139	1991	24	17	1.4

Table 7. Weight-length regression parameters for male northern pike from 139 mm gill nets, 1990 to 1992.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	3.03	-5.20	0.938	37	544.2	0.0001
1991	2.72	-4.28	0.845	32	168.8	0.0001
1992	2.82	-4.59	0.868	69	447.2	0.0001

Table 8. Weight-length regression parameters for female northern pike from 139 mm gill nets, 1989 to 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1989	2.12	-2.56	0.700	9	18.70	0.0025
1990	3.13	-5.49	0.927	88	1106	0.0001
1991	2.97	-5.03	0.901	199	1808	0.0001
1992	2.88	-4.77	0.766	187	608.6	0.0001
1993	3.36	-6.13	0.910	13	123.0	0.0001

Table 9. Weight-length regression parameters for male and female northern pike from 38 mm to 139 mm gill nets, 1990 and 1991.

Year	Sex	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	Male	3.18	-5.61	0.933	55	751.6	0.0001
1991	Male	2.81	-4.55	0.771	14	43.80	0.0001
1990	Female	3.19	-5.67	0.957	74	1621	0.0001
1991	Female	2.57	-3.86	0.684	63	47.50	0.0001

Table 10. Mean catch per unit of effort (CPUE) by location and net type, for inconnu, 1990 to 1993. An overall mean CPUE has been calculated for the 139 mm mesh gill nets of known length.

Location - Net Type	1990	1991	1992	1993
Loc. 2 - Exp. Net	0.30 ± 0.76			
Loc. 4 - Exp. Net	0.05 ± 0.21			
Exp. Site - Exp. Net		0.67 ± 1.59	0.74 ± 1.29	0.05 ± 0.22
Exp. Site - 139 mm Mesh		0.97 ± 1.46	0.33 ± 0.95	0.93 ± 0.26
Loc. 1 - 139 mm Mesh	0.49 ± 0.90*			
Loc. 2 - 139 mm Mesh	2.04 ± 5.48	3.51 ± 4.00	0.53 ± 0.94*	0.18 ± 0.56*
Loc. 3 - 139 mm Mesh	0.32 ± 0.29	0.40 ± 0.47	1.76 ± 1.49	
Loc. 4 - 139 mm Mesh	0.47 ± 1.38	0.17 ± 0.42*	0.22 ± 0.54*	
Loc. 5 - 139 mm Mesh			0.32 ± 0.57*	0.15 ± 0.78*
Loc. 6 - 139 mm Mesh			1.70 ± 2.25	0.58 ± 0.96*
Loc. 7 - 139 mm Mesh				0.28 ± 0.41*
Mean CPUE =	**0.94**	**1.63**	**1.26**	**0.93**

* This value was not used in calculating the mean because net size was unknown.

Table 11. Summary statistics by sex and year for inconnu from 139 mm gill nets, 1990 to 1993.

Mesh (mm)	Year	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
		n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	78	650	585,615	458-856	19	628	665	471-697	78	11.0	10	5-18	19	10.4	9,10,13	6-13
139	1991	50	766	765,865, 875,885	420-983	9	602	670	432-760	40	13.6	8,18	4-25	6	11.0	13	6-15
139	1992	93	693	725	286-925	52	637	635	525-766	93	10.0	9	5-18	52	8.4	9	5-15
139	1993	83	667	655	504-954	36	644	595,625	535-880	81	9.5	9	6-20	34	9.5	7	6-19

Table 12. Summary statistics by sex, year and location for inconnu from 139 mm gill nets, 1990 to 1993. Source Treble *et. al.*, unpubl. data report.

Mesh (mm)	Year	Location No.	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
			n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	4	37	642	585	448-785	10	622	635,665	471-678	37	10.1	10	5-16	10	9.9	10	6-13
		J. Lakes	39	659	605-615, 635,655	525-856	6	624	-	548-680	39	11.8	9	7-18	6	10.5	9,11	9-13
139	1991	2	39	757	875,885	420-955	6	541	-	432-760	30	13.4	8	4-20	3	9.0	-	6-13
139	1992	2	28	676	725	515-925	16	629	560,525 590	554-735	28	9.4	10	5-15	16	8.1	6,9	5-12
		4	11	672	645,755	286-848	5	632	-	563-720	11	10.6	9	6-15	5	7.8	9	6-9
		6	52	703	675,685 725	464-850	30	643	635	525-766	52	10.1	11	5-18	30	8.7	7,10	5-15
139	1993	2	14	665	640,645	504-954	6	686	685	538-880	14	10.6	6,11	6-20	6	10.7	6,14	7-19
		4	4	681	-	606-805	8	636	625	562-700	4	8.3	-	6-11	8	9.8	9	6-14
		6	63	666	655	525-850	20	632	595	535-722	63	9.4	9	6-16	20	9.0	7	6-15

Table 13. Summary statistics for GSI by sex and year for inconnu from 139 mm gill nets, 1990 to 1993.

Mesh (mm)	Year	GSI - Female (mm)				GSI - Male (mm)			
		n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	76	0.27	0.30	0.03-0.97	19	0.08	0.10	0.03-0.22
139	1991	9	0.55	0.30	0.23-1.92	8	1.34	2.10	0.13-3.33
139	1992	38	0.67	0.30	0.16-2.77	8	0.41	0.10	0.05-1.36
139	1993	66	0.31	0.31	0.04-1.26	28	0.33	0.10	0.04-1.62

Table 14. Sex ratio for female to male inconnu (F/M) from 139 mm mesh gill nets, 1990 to 1993.

Mesh (mm)	Year	Females	Males	Sex Ratio (F/M)
139	1990	78	19	4.1
139	1991	50	9	5.5
139	1992	93	52	1.8
139	1993	83	36	2.3

Table 15. Weight-length regression parameters for male inconnu from 139 mm gill nets, 1990 to 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	3.03	-5.11	0.939	18	263.5	0.0001
1991	2.39	-3.29	0.993	8	938.1	0.0001
1992	1.56	-0.98	0.169	43	8.520	0.0056
1993	2.69	-4.13	0.834	35	170.4	0.0001

Table 16. Weight-length regression parameters for female inconnu from 139 mm gill nets, 1990 to 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	3.05	-5.17	0.929	76	976.5	0.0001
1991	2.52	-3.67	0.927	49	609.4	0.0001
1992	2.67	-4.11	0.724	81	209.5	0.0001
1993	2.95	-4.86	0.958	81	1815	0.0001

Table 17. Mean catch per unit of effort (CPUE) by location and net type, for lake whitefish, 1990 to 1993. An overall mean CPUE has been calculated for the 139 mm mesh gill nets of known length.

Location - Net Type	**1990**	**1991**	**1992**	**1993**
Loc. 2 - Exp. Net	4.59 ± 5.31			
Loc. 4 - Exp. Net	10.39 ± 11.03			
Exp. Site - Exp. Net		5.45 ± 7.62	3.16 ± 4.40	4.34 ± 3.01
Exp. Site - 139 mm Mesh		8.79 ± 9.58	6.54 ± 15.44	3.25 ± 3.99
Loc. 1 - 139 mm Mesh	39.14 ± 14.73*			
Loc. 2 - 139 mm Mesh	11.05 ± 13.81	3.65 ± 3.30	1.73 ± 1.80*	2.84 ± 4.33*
Loc. 3 - 139 mm Mesh	27.98 ± 12.61	26.05 ± 5.71	8.87 ± 6.70	
Loc. 4 - 139 mm Mesh	17.78 ± 27.60	5.67 ± 7.67*	7.29 ± 8.81*	
Loc. 5 - 139 mm Mesh			3.83 ± 3.00*	7.65 ± 6.64*
Loc. 6 - 139 mm Mesh			2.20 ± 5.07	0.91 ± 1.47*
Loc. 7 - 139 mm Mesh				1.88 ± 1.10*
Mean CPUE =	**18.94**	**12.83**	**5.87**	**3.25**

* This value was not used in calculating the mean because net size was unknown.

Table 18. Summary statistics by sex and year for lake whitefish from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
		n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	78	458	435	408-525	72	447	455	404-521	78	13.0	12,14	8-20	72	12.3	13	7-19
139	1991	183	465	445,465	403-543	126	463	465	375-528	172	16.1	7-40	11,13	119	15.2	11,14	6-34
139	1992	101	471	475	411-535	97	468	445,465	420-569	97	14.1	14	5-24	95	14.6	15	5-23
139	1993	166	469	465	417-526	106	466	465	370-539	162	14.9	13	9-29	103	14.6	12	8-25
38-139	1990	103	438	445	284-513	81	432	445	259-500	103	11.7	13	4-18	81	12.0	16	3-20
38-139	1991	25	455	465	384-494	32	425	415,435	327-460	24	16.1	15,18	9-26	31	14.1	15	5-19
38-139	1992	24	438	45	338-499	23	437	440	333-487	23	12.8	15	7-17	21	12.8	10,14	5-19
38-139	1993	32	447	455	340-505	30	434	425	282-510	32	14.3	15	5-20	29	12.7	11,13	6-18

Table 19. Summary statistics by sex, year and location for lake whitefish from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993. Source Treble *et. al.*, unpubl. data report.

Mesh (mm)	Year	Location No.	Fork Length - Female (mm)				Fork Length - Male (mm)				Age - Female (years)				Age - Male (years)			
			n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	2	39	464	445	429-525	11	460	455	419-521	39	13.4	12,14	9-20	11	13.0	10,13	10-18
		4	39	451	435	408-493	61	445	455	404-514	39	12.6	10,16	8-19	61	12..2	13	7-19
139	1991	4	105	464	445	403-543	84	462	465	375-528	101	15.2	11	7-33	79	14.1	11,14	6-28
		Exp. Site	78	467	465	415-505	42	454	465,475	422-524	71	17.4	14	10-40	40	17.5	13,15	9-34
139	1992	2	3	478	465	462-505	1	448	-	-	2	16.0	-	15-17	1	13.0	-	-
		4	37	473	475	418-508	43	465	455	427-508	36	13.9	12,13, 15	7-21	42	14.6	15	9-23
		6	11	468	475	438-524	6	472	475	440-492	12	11.6	9,14	5-19	6	9.0	9	5-14
		Exp. Site	50	470	475	411-535	47	470	465	425-569	47	14.9	14	8-24	46	15.4	17	8-21
139	1993	4	123	468	465	417-519	81	464	465	370-539	122	14.7	13,15	9-26	79	14.4	14	8-25
		Exp. Site	43	474	465	429-526	25	471	455,465, 475,485	433-513	40	15.3	13,14	9-29	24	15.0	13	10-24
38-139	1990	2	51	430	455	284-513	37	435	435	279-500	52	11.5	13	4-18	37	12.9	10,14	4-20
		4	52	446	435,445	320-507	44	428	445	259-496	53	11.9	11	4-18	44	11.2	12	3-18
38-139	1991	Exp. Site	25	455	465	384-494	32	425	415,435	327-460	24	16.1	15,18	9-26	31	14.1	15	5-19
	1992	Exp. Site	24	438	455	338-499	23	437	445	333-487	23	12.8	15	7-17	21	12.8	10,14	5-19
	1993	Exp. Site	32	447	455	340-420	30	434	425	282-510	32	14.3	15	5-20	29	12.7	11,13	6-18

Table 20. Summary statistics of GSI by sex and year for lake whitefish from 139 mm and multi-mesh (38 to 139 mm) experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	GSI - Female (mm)				GSI - Male (mm)			
		n	Mean	Mode	Range	n	Mean	Mode	Range
139	1990	78	14.6	14	0.57-25.7	72	1.33	1.20,1.30	0.11-2.56
139	1991	104	15.1	15,16	0.65-25.0	63	1.80	1.40	0.33-3.71
139	1992	47	11.8	12	0.69-21.9	54	1.51	1.50	0.17-3.65
139	1993	104	13.4	15	0.08-27.8	71	1.06	1.10	0.55-1.95
38-139	1990	103	11.7	13	0.13-21.3	79	1.20	1.40	0.09-2.30
38-139	1991	23	16.5	12,13, 16,17	11.5-25.8	26	1.39	0.90,1.00 1.40,1.50	0.70-3.22
38-139	1992	2	0.84	-	0.75-0.92	1	1.91	-	-
38-139	1993	18	9.93	11	0.43-15.8	19	1.25	1.3	0.45-1.98

Table 21. Sex ratio for female to male lake whitefish (F/M) from 139 mm mesh and 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1993.

Mesh (mm)	Year	Females	Males	Sex Ratio (F/M)
139	1990	78	72	1.08
139	1991	183	126	1.45
139	1992	102	97	1.05
139	1993	166	106	1.57
38-139	1990	105	81	1.30
38-139	1991	25	32	0.78
38-139	1992	24	23	1.04
38-139	1993	32	30	1.07

Table 22. Weight-length regression parameters for male lake whitefish from 139 mm gill nets, 1990 to 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	2.47	-3.44	0.670	71	141.9	0.0001
1991	2.56	-3.66	0.666	125	247.5	0.0001
1992	2.35	-3.10	0.604	94	141.9	0.0001
1993	2.28	-2.93	0.681	100	211.3	0.0001

Table 23. Weight-length regression parameters for female lake whitefish from 139 mm gill nets, 1990 to 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	2.49	-3.46	0.666	77	151.7	0.0001
1991	2.33	-3.01	0.679	181	380.2	0.0001
1992	2.29	-2.91	0.509	91	93.24	0.0001
1993	2.05	-2.29	0.605	154	234.7	0.0001

Table 24. Weight-length regression parameters for male lake whitefish from 38 mm to 139 mm gill nets, 1990 and 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	3.14	-5.25	0.932	79	1065	0.0001
1991	3.17	-5.30	0.853	28	156.4	0.0001
1992	3.30	-5.64	0.668	20	38.31	0.0001
1993	3.49	-6.16	0.955	29	592.5	0.0001

Table 25. Weight-length regression parameters for female lake whitefish from 38 mm to 139 mm gill nets, 1990 and 1993.

Year	Slope	Intercept	R-square	Total DF	F-value	p-value
1990	3.53	-6.25	0.893	101	842.0	0.0001
1991	3.84	-7.05	0.800	22	83.96	0.0001
1992	2.56	-3.65	0.573	10	22.79	0.0002
1993	3.40	-5.91	0.848	30	162.0	0.0001

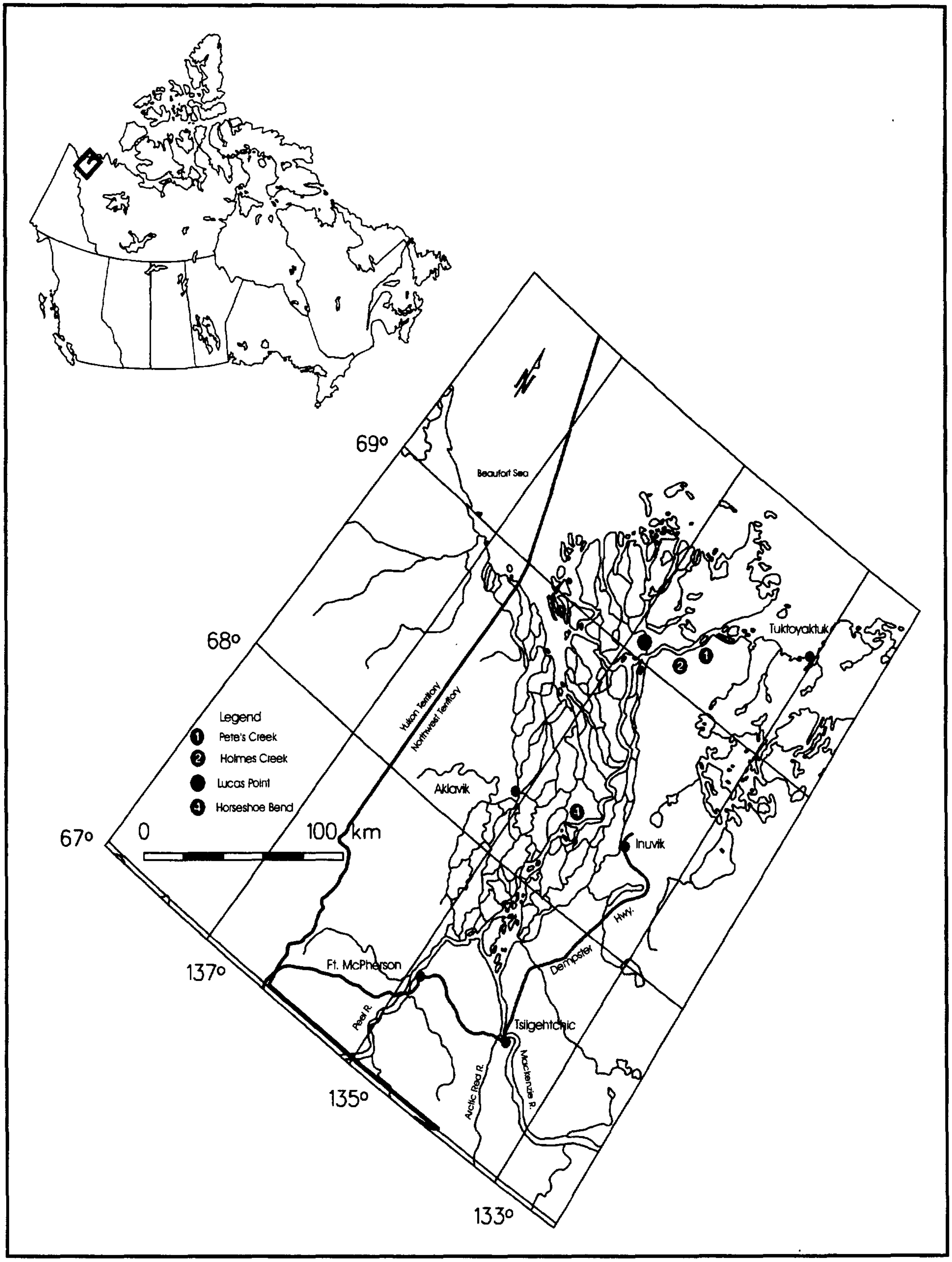

Figure 1. The Mackenzie River delta showing communities and sample collection sites for the Uummarmiut Development Corporation Exploratory Fishery, 1989-1993.

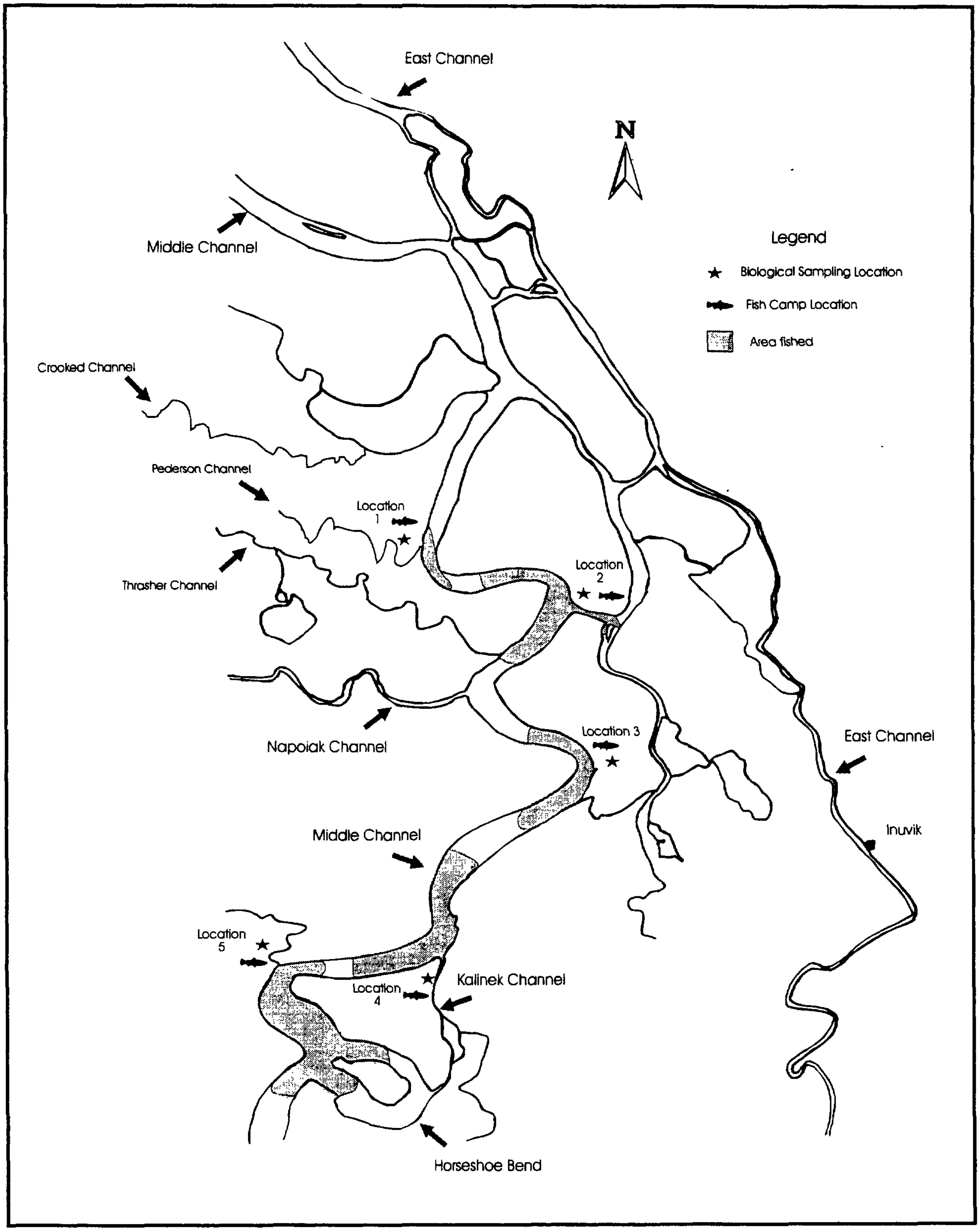

Figure 2. Biological sampling and fish camp locations in the Horseshoe Bend area, 1989.

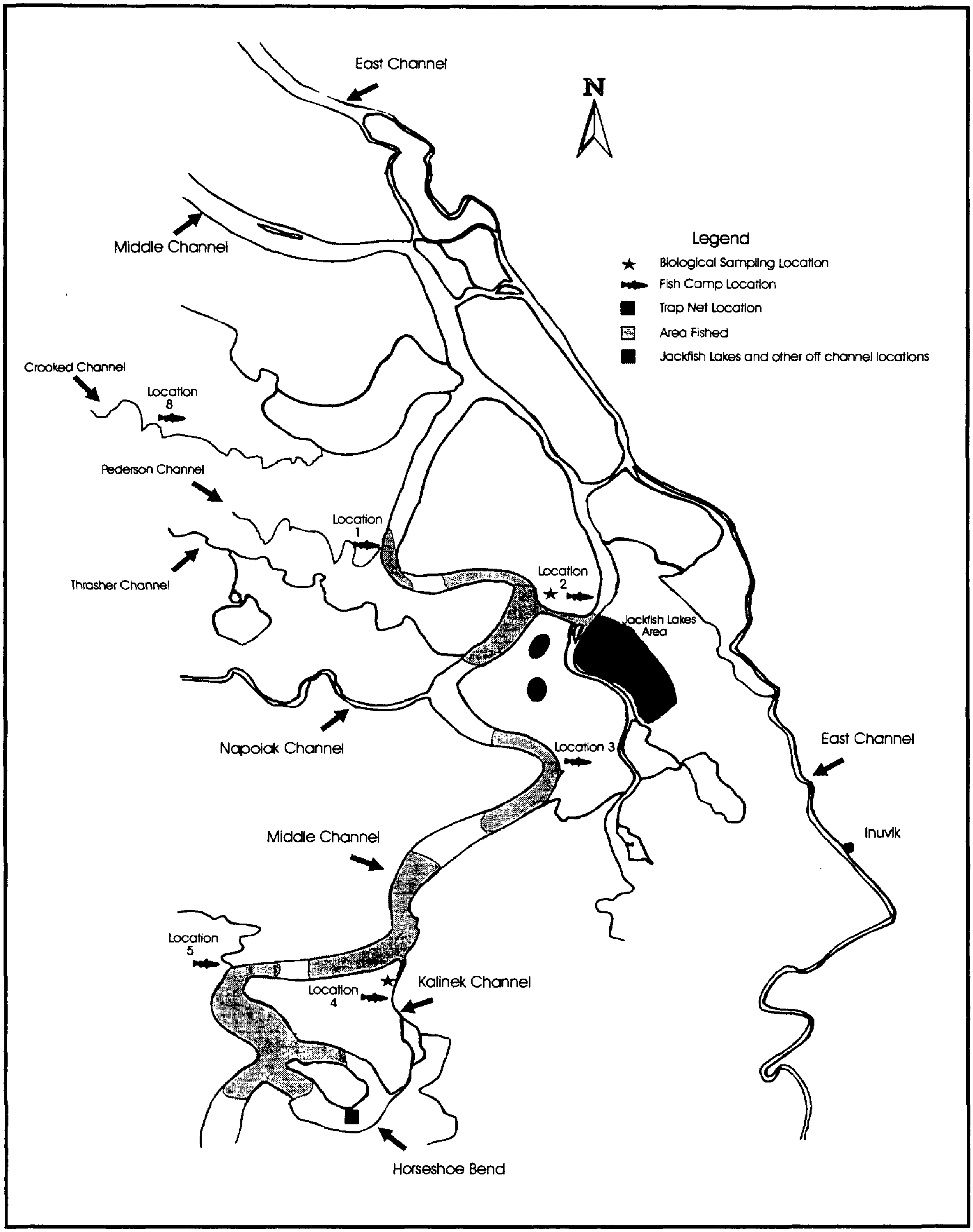

Figure 3. Biological sampling and fish camp locations in the Horseshoe Bend area, 1990.

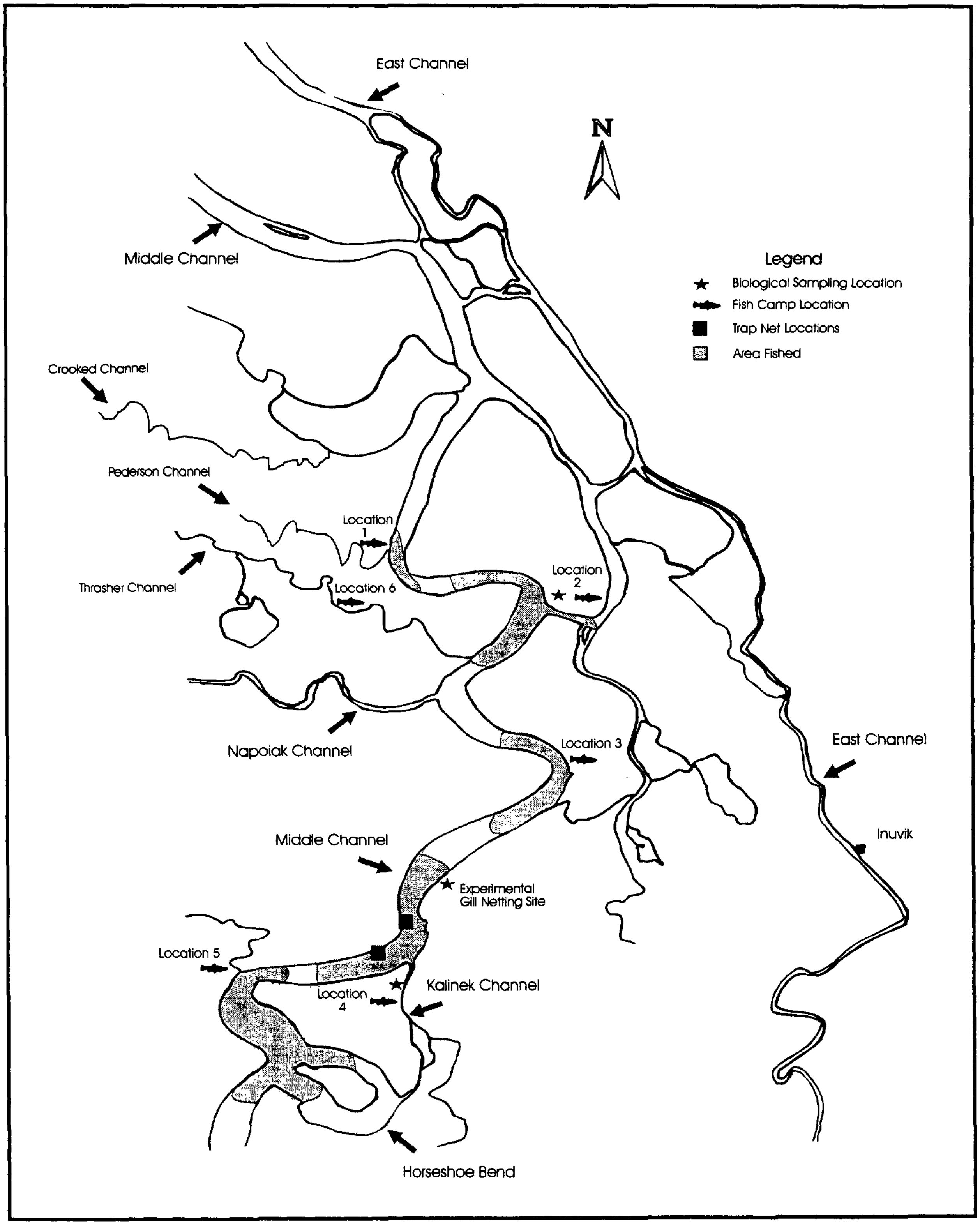

Figure 4. Biological sampling and fish camp locations in the Horseshoe Bend area, 1991.

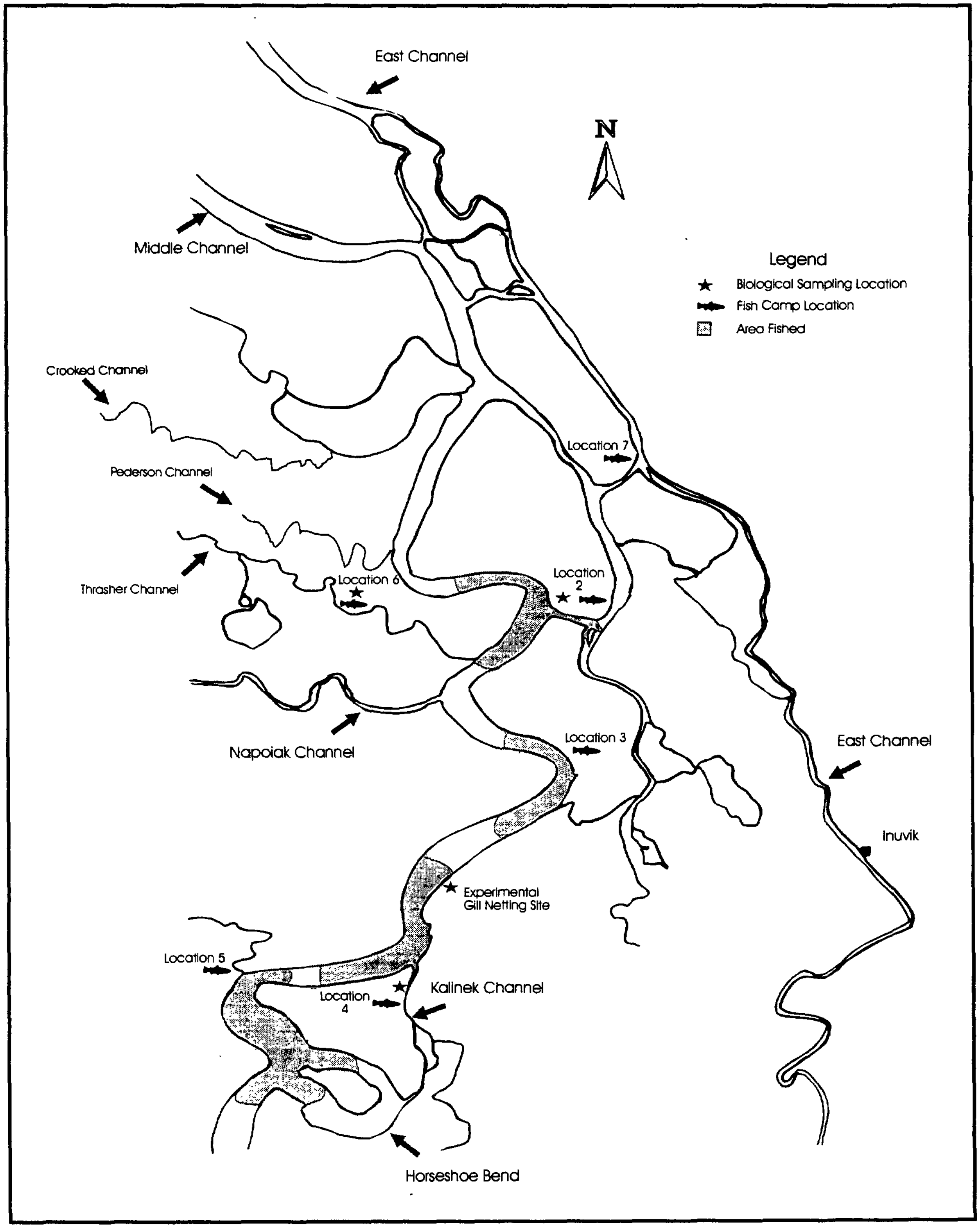

Figure 5. Biological sampling and fish camp locations in the Horseshoe Bend area, 1992.

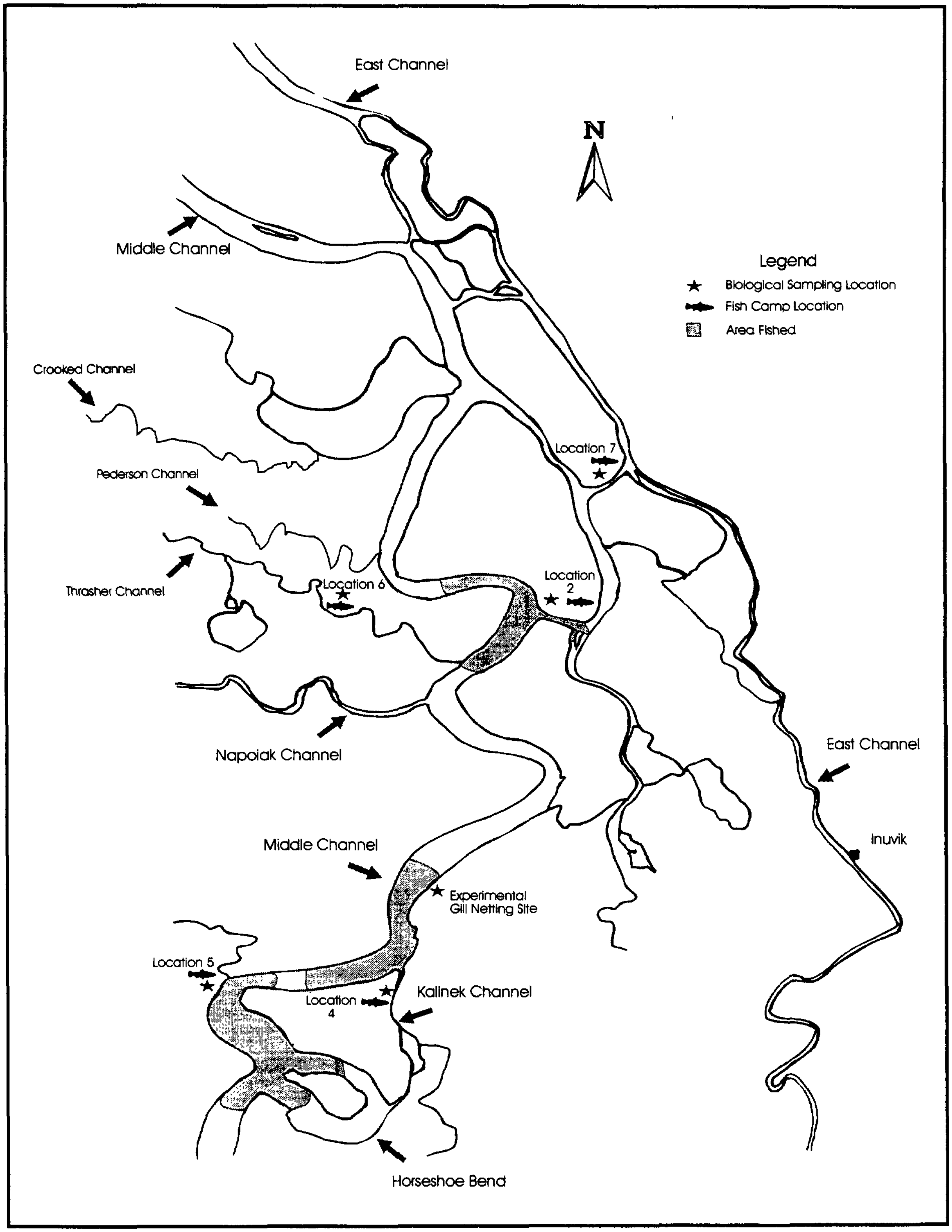

Figure 6. Biological sampling and fish camp locations in the Horseshoe Bend area, 1993.

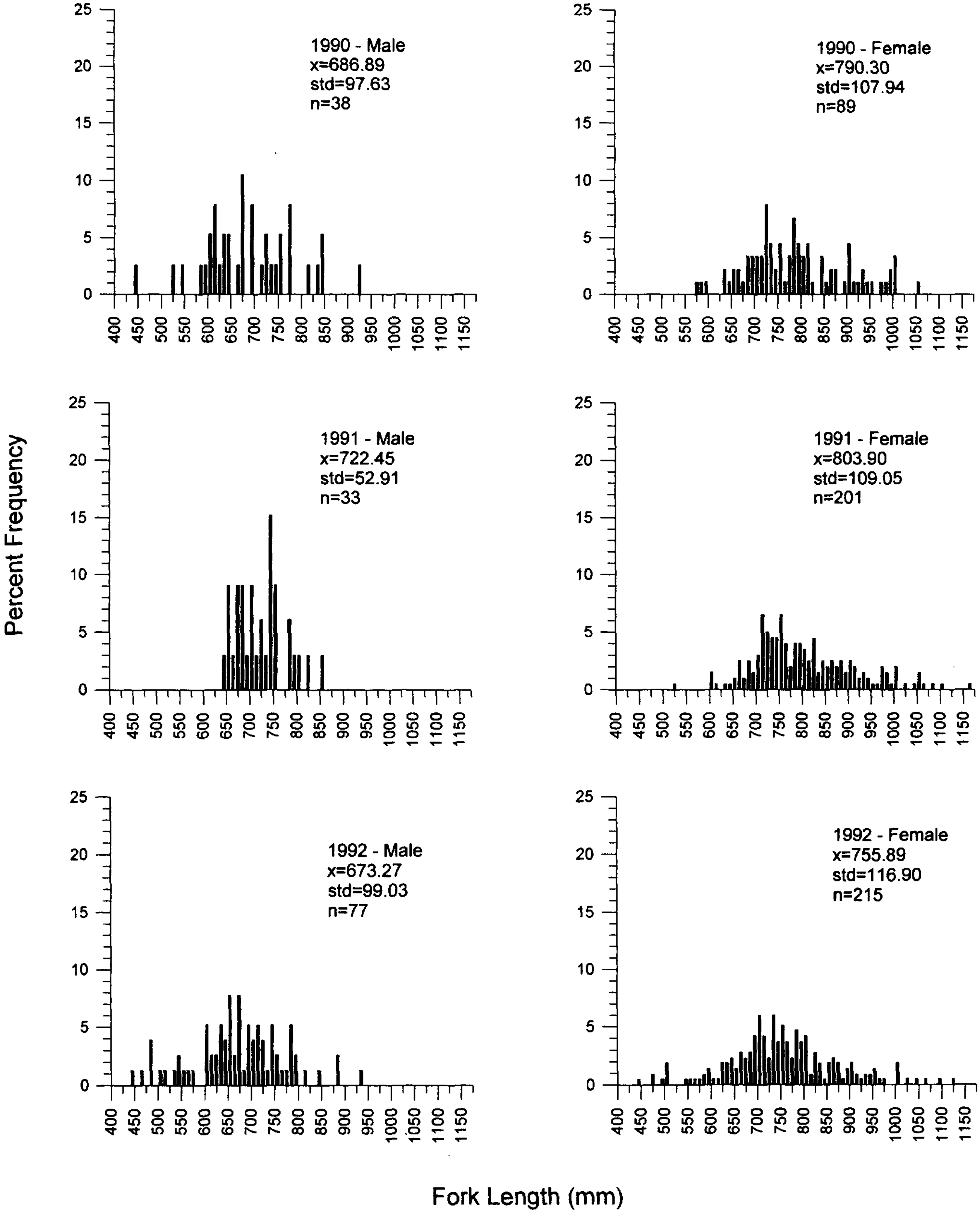

Fig. 7. Length frequency data for northern pike from 139 mm gill nets, 1990 to 1992.

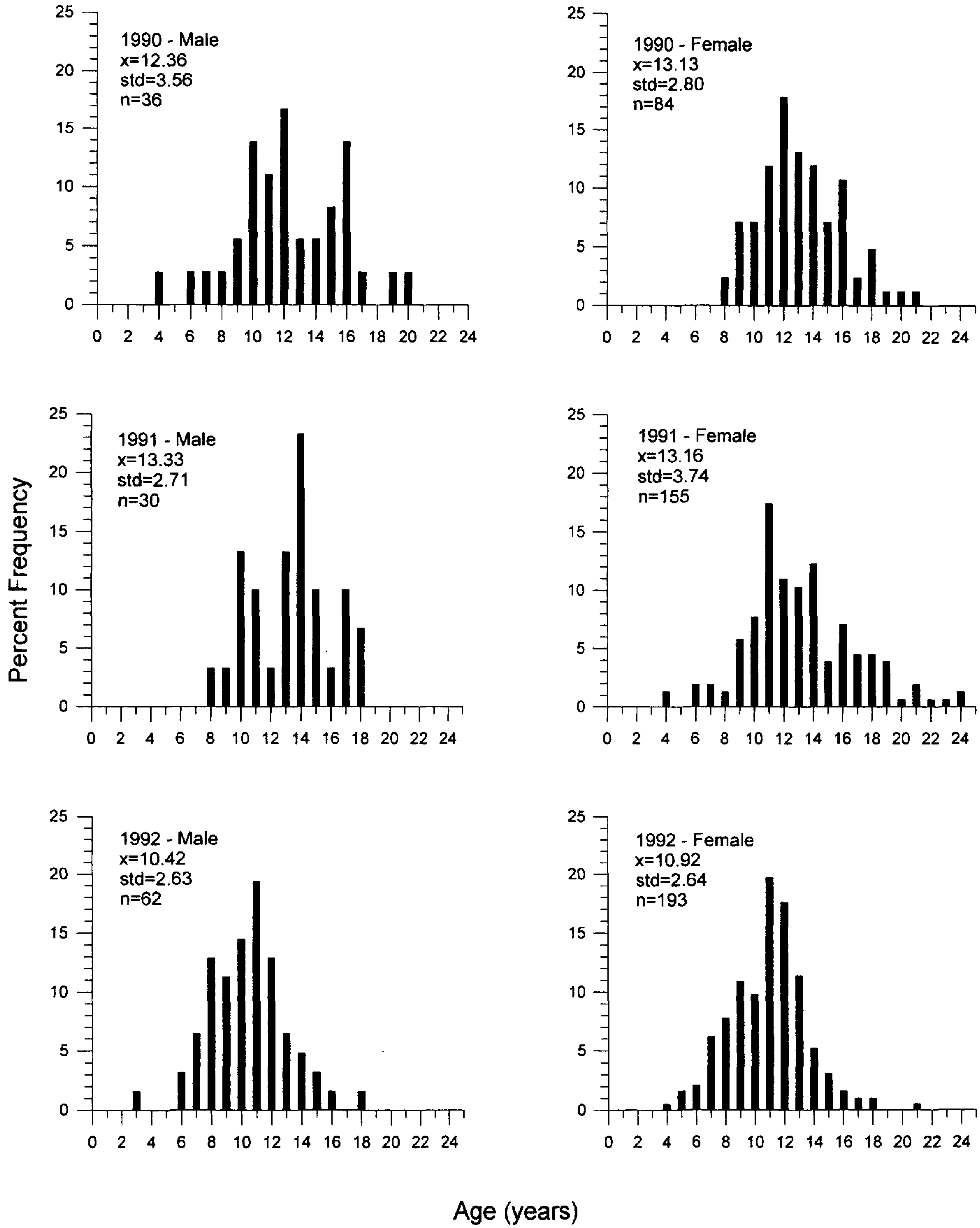

Fig. 8. Age frequency data for northern pike from 139 mm gill nets, 1990 to 1992.

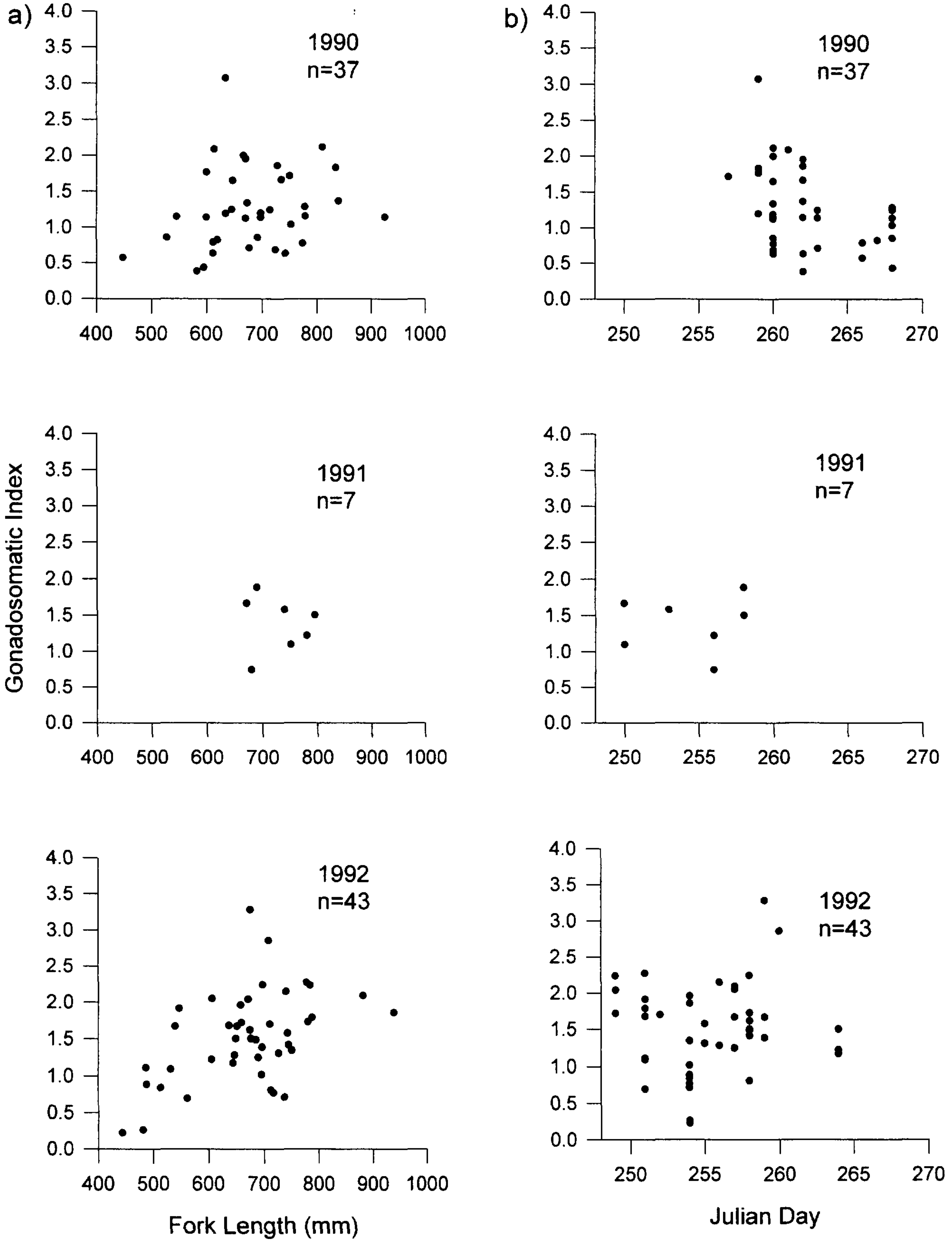

Fig. 9. Gonadosomatic index plotted against a) fork length, and b) julian day for male northern pike from 139 mm gill nets, 1990 to 1992.

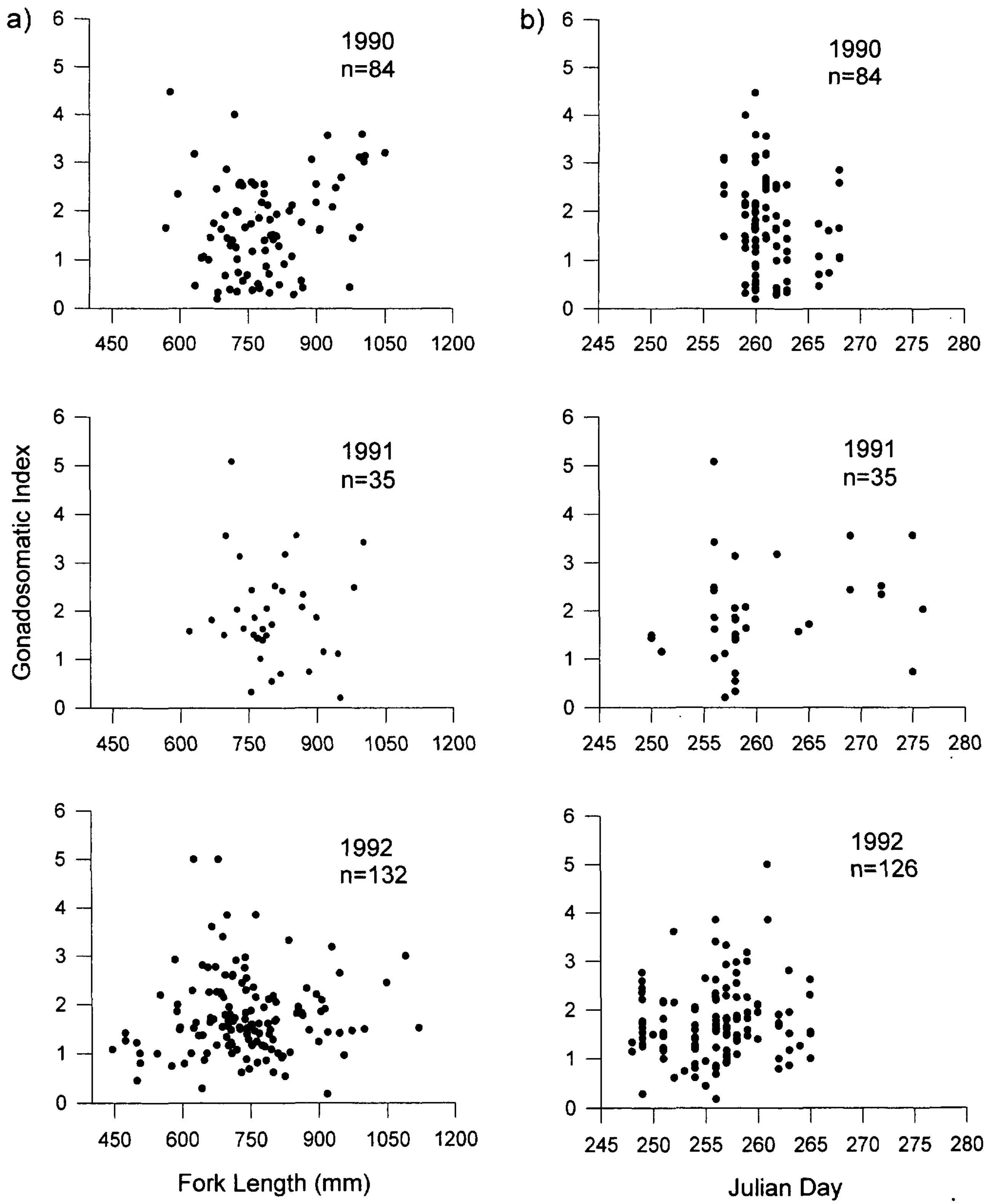

Fig. 10. Gonadosomatic index plotted against a) forklength, and b) julian day for female northern pike from 139 mm gill nets, 1990 to 1992.

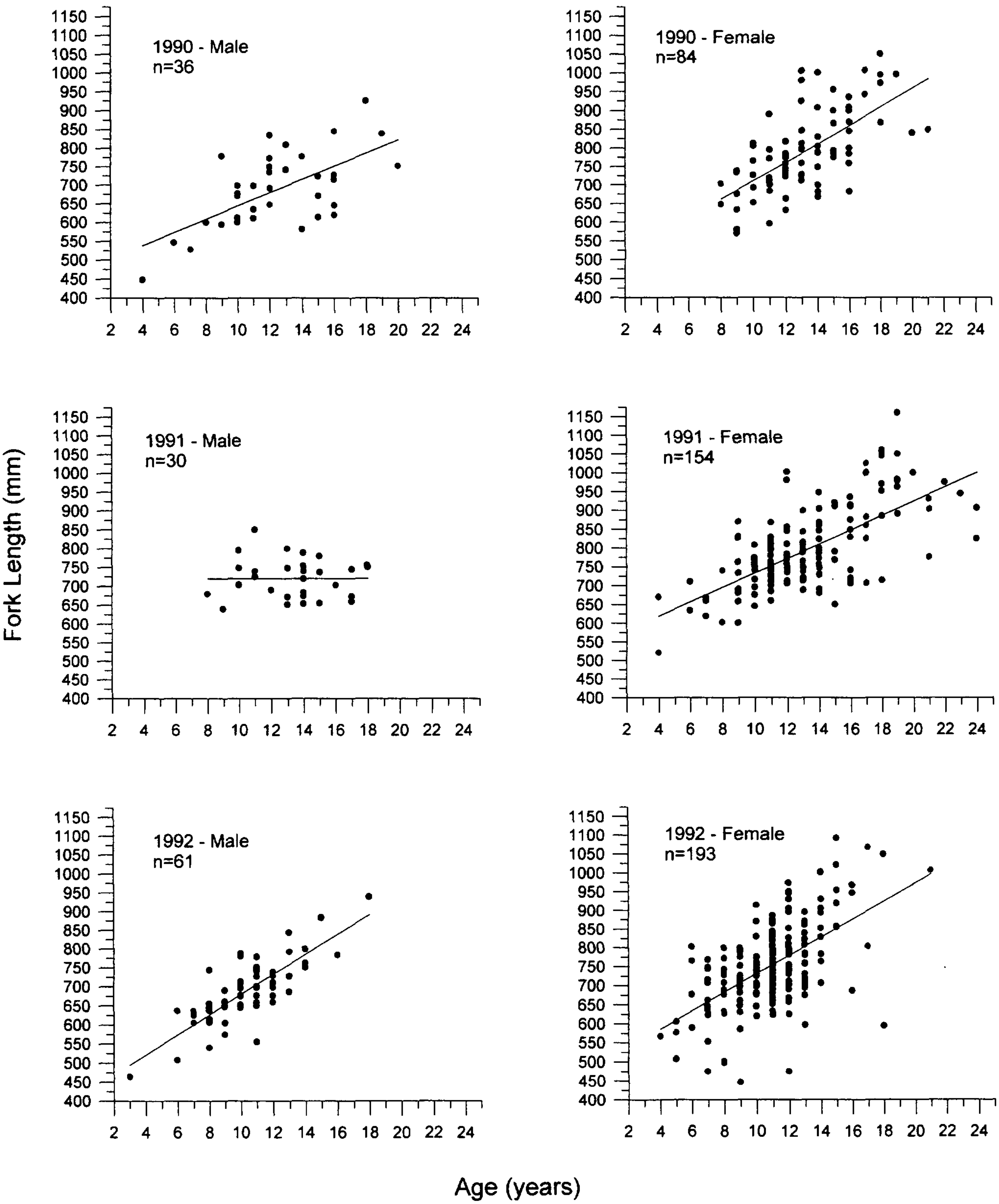

Fig. 11. Growth curves (length at age) for male and female northern pike from 139 mm gill nets, 1990 to 1992.

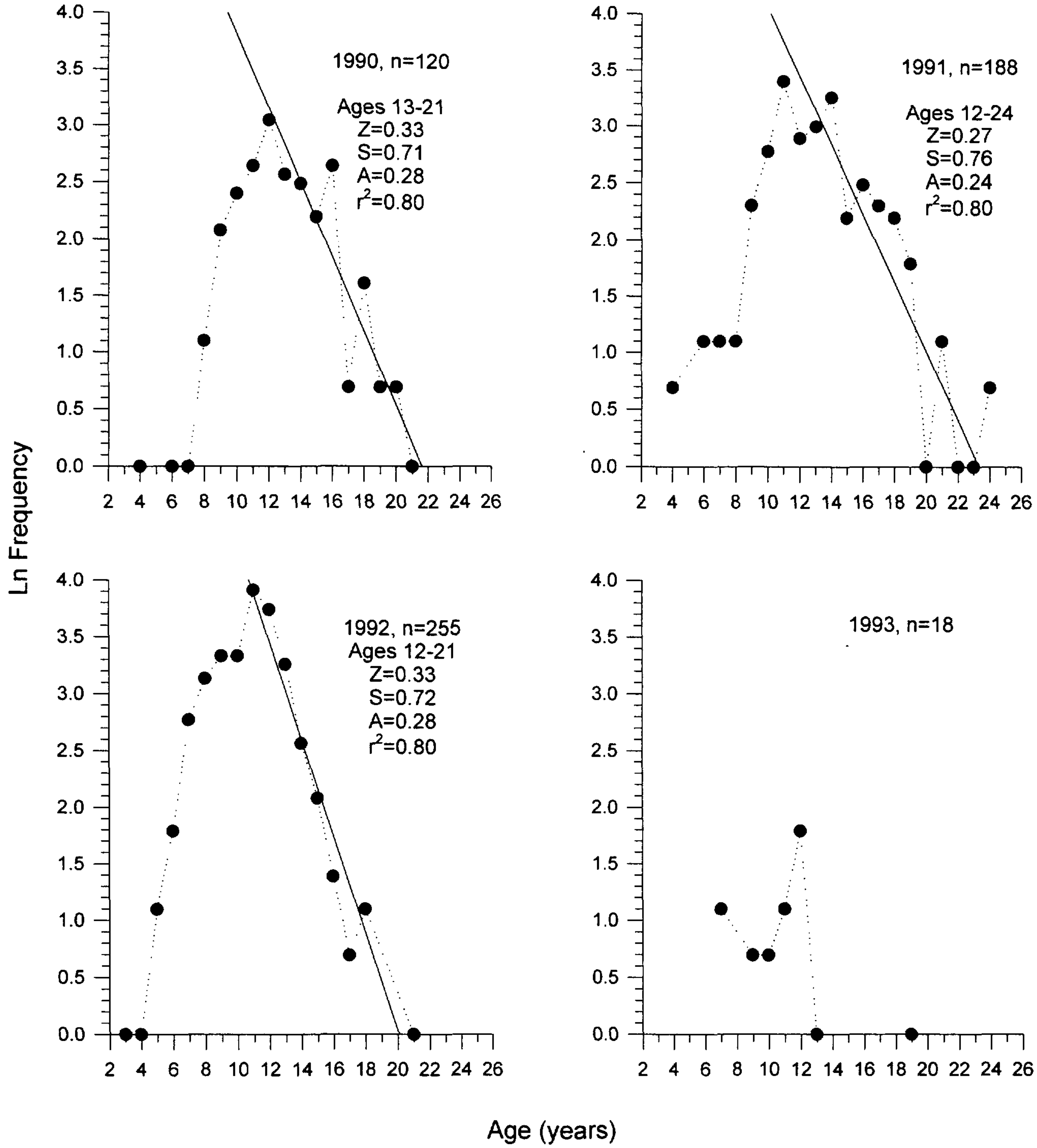

Fig. 12. Age frequency catch curves for northern pike from 139 mm gill nets, 1990 to 1993. Instantaneous mortality (Z), survival (S), and annual mortality (A) rates have been calculated where appropriate.

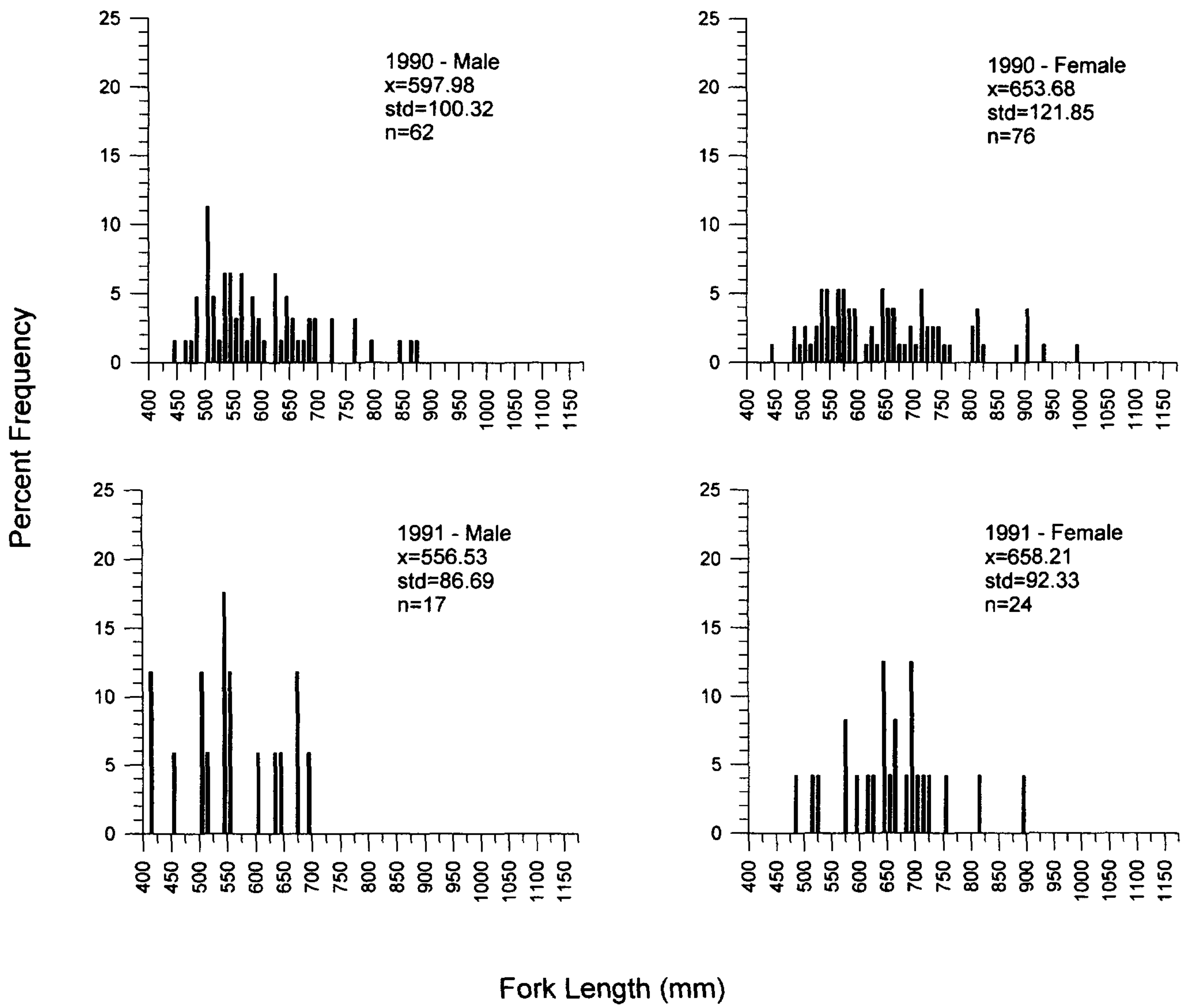

Fig. 13. Length frequency data for northern pike from 38 to 139 mm multi-mesh experimental gill nets, 1990 to 1992.

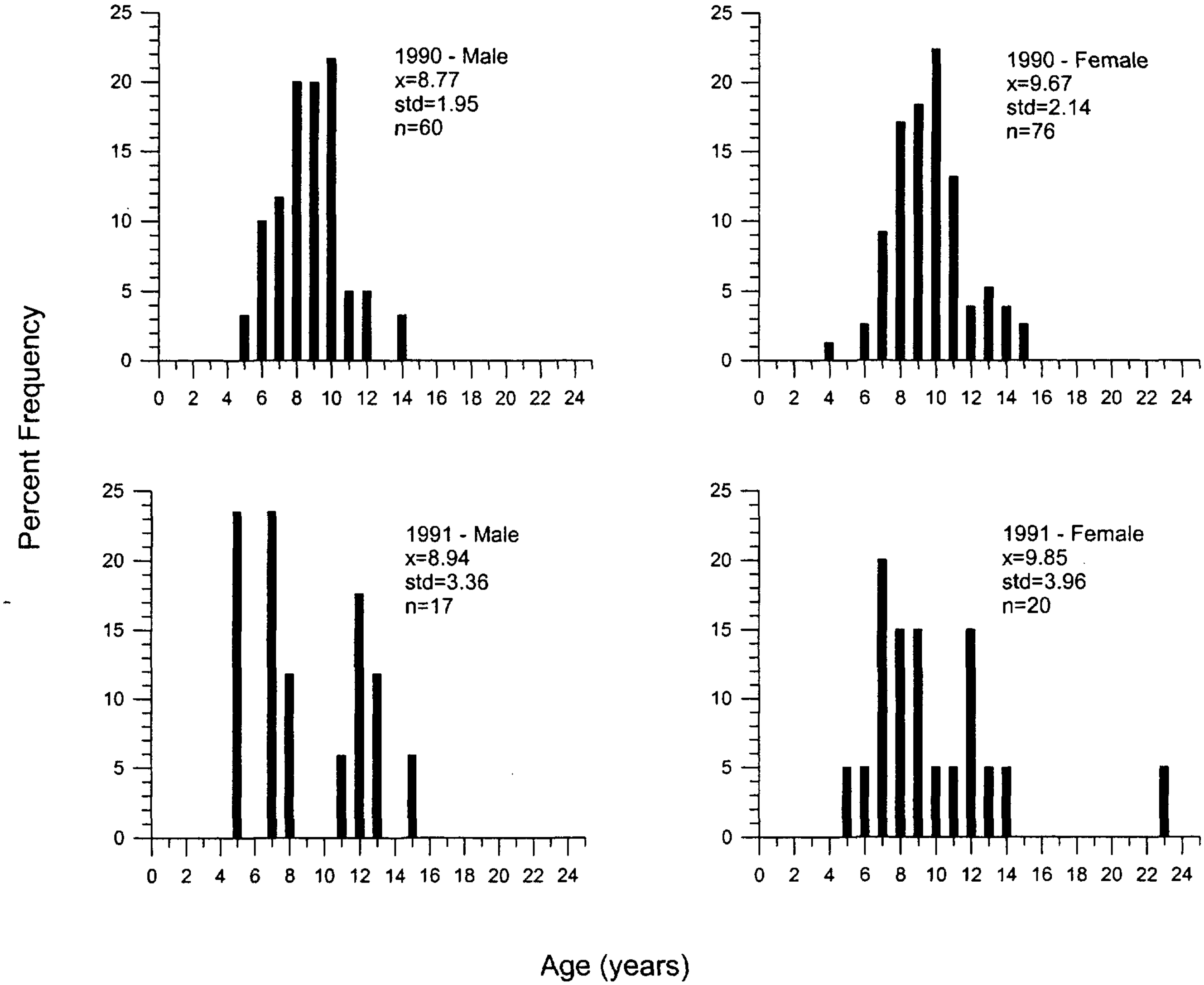

Fig. 14. Age frequency data for northern pike from 38 to 139 mm multi-mesh experimental gill nets,1990 to 1991.

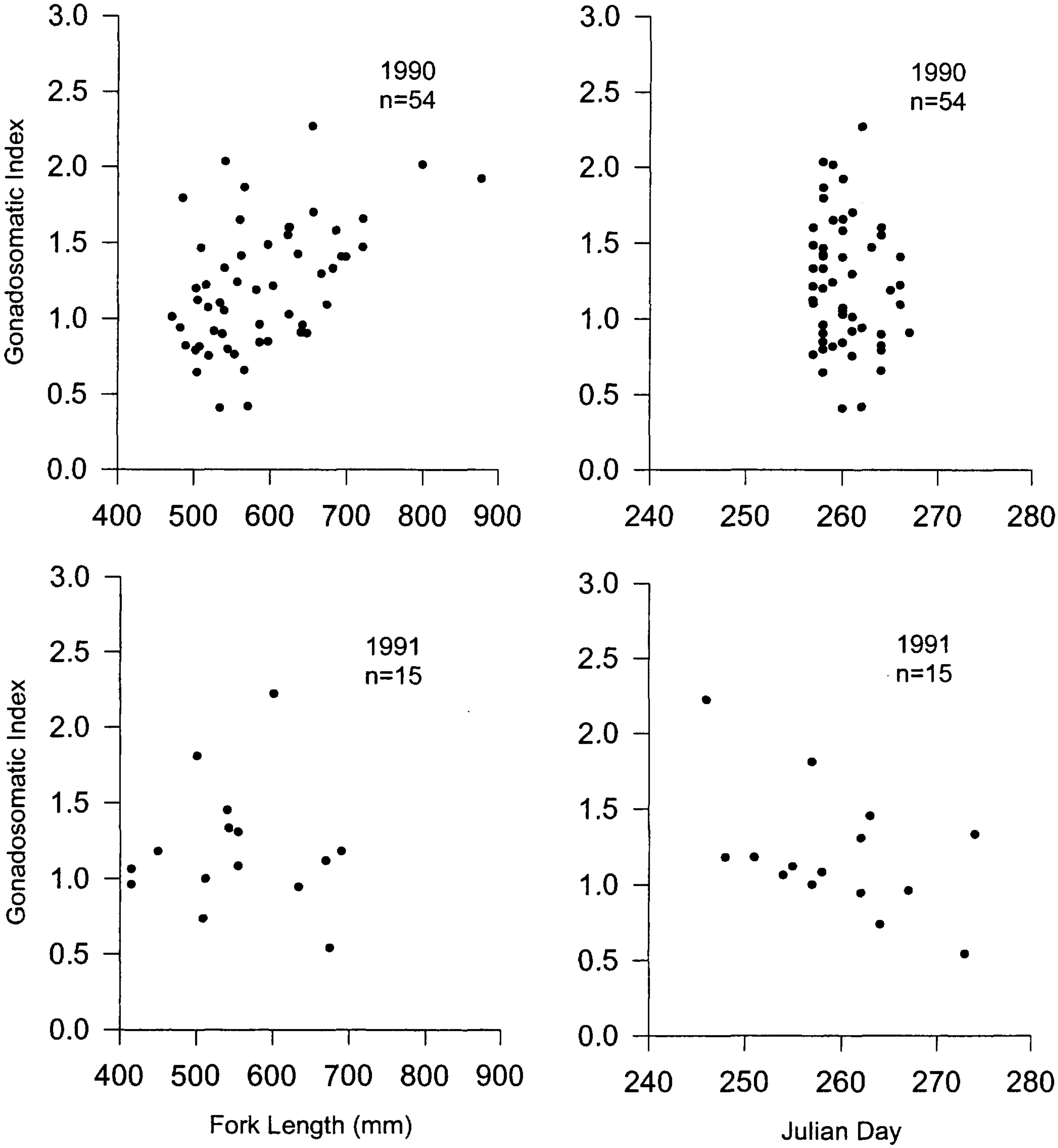

Fig. 15. Gonadosomatic index plotted against a) fork length, and b) julian day for male northern pike from 38 to139 mm multi-mesh experimental gill nets, 1990 to 1991.

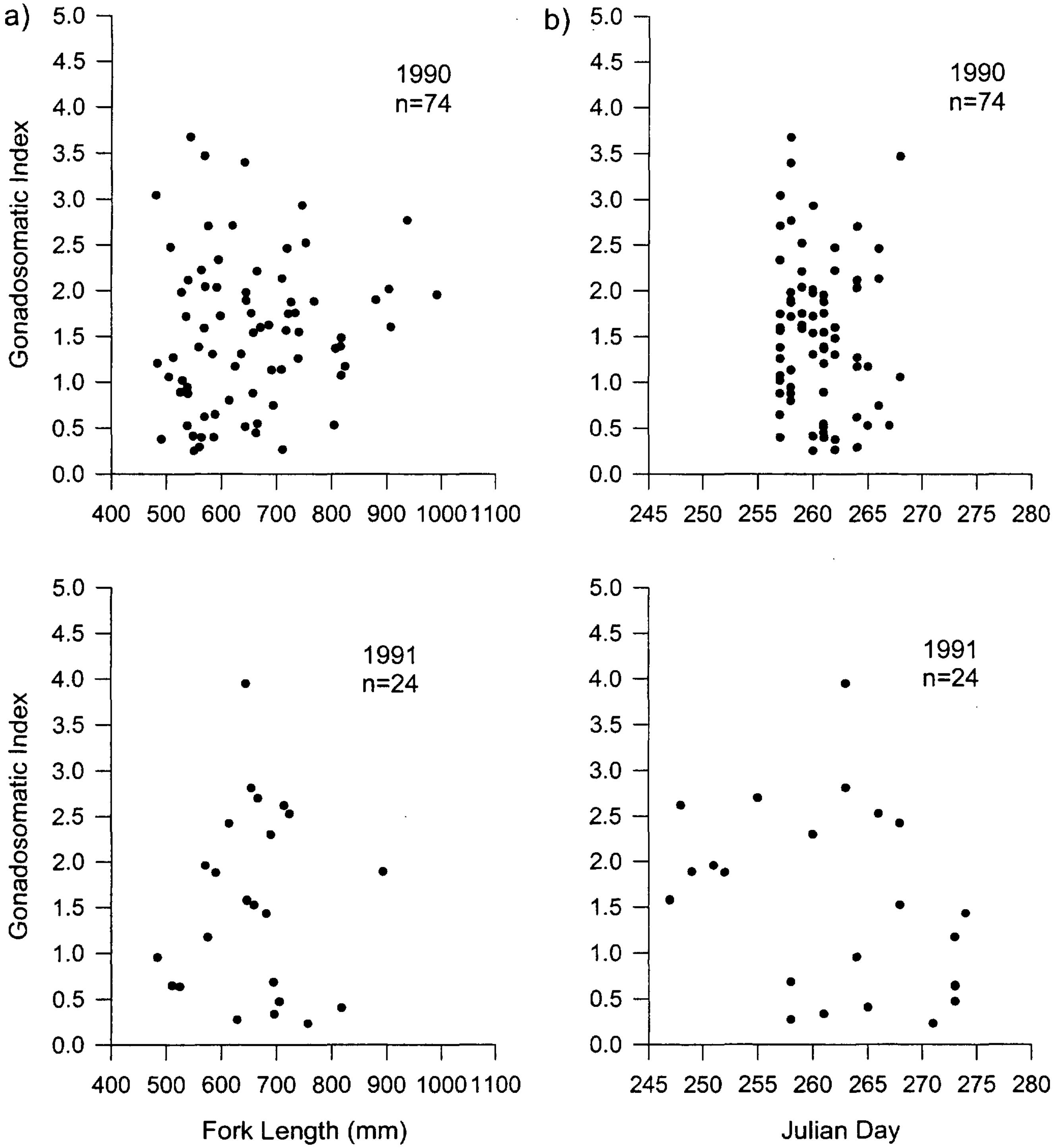

Fig. 16. Gonadosomatic index plotted against a) fork length, and b) julian day for female northern pike from 38 to 139 mm multi-mesh experimental gill nets, 1990 to 1991.

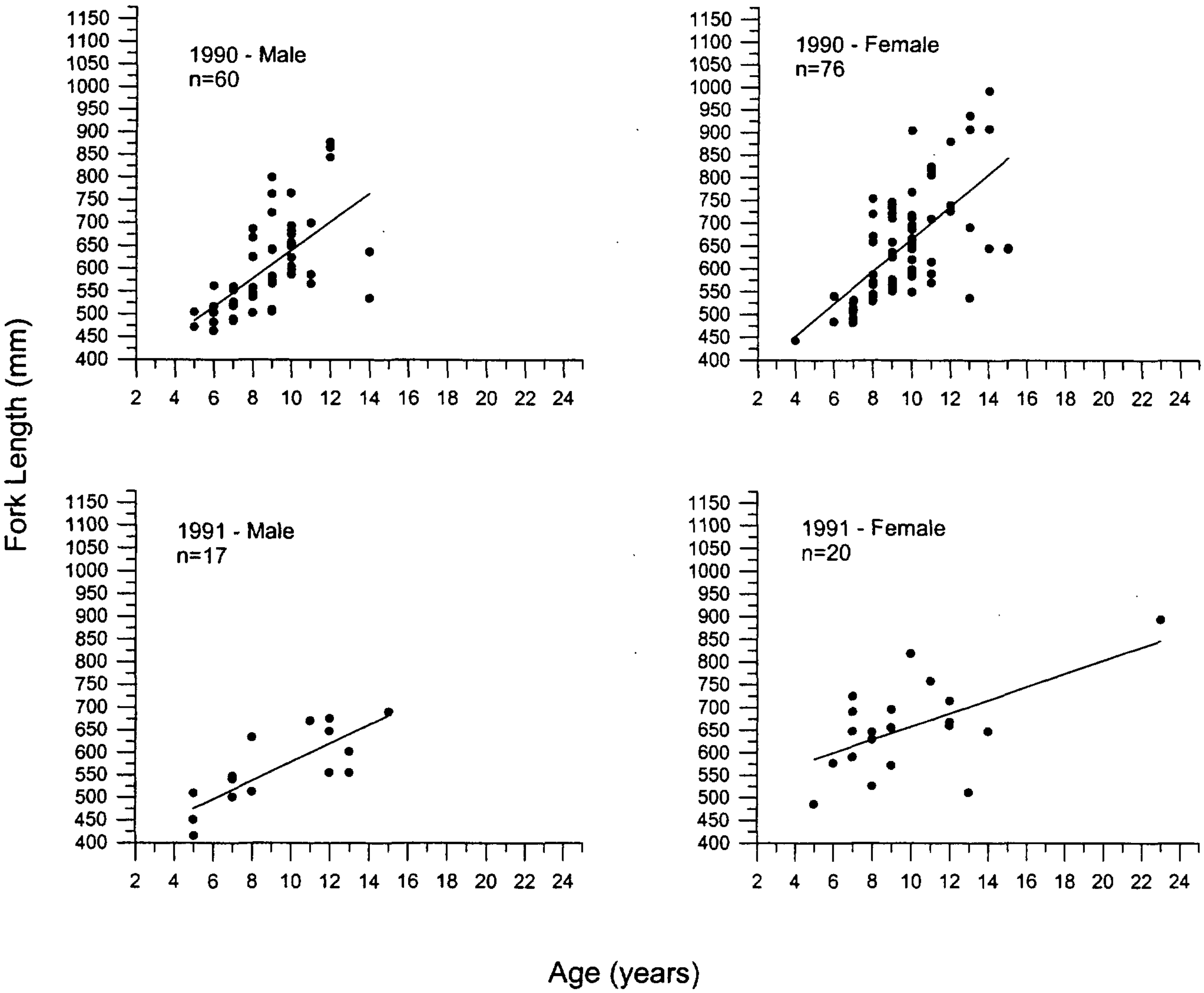

Fig. 17. Growth curves (length at age) for male and female northern pike from 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1991.

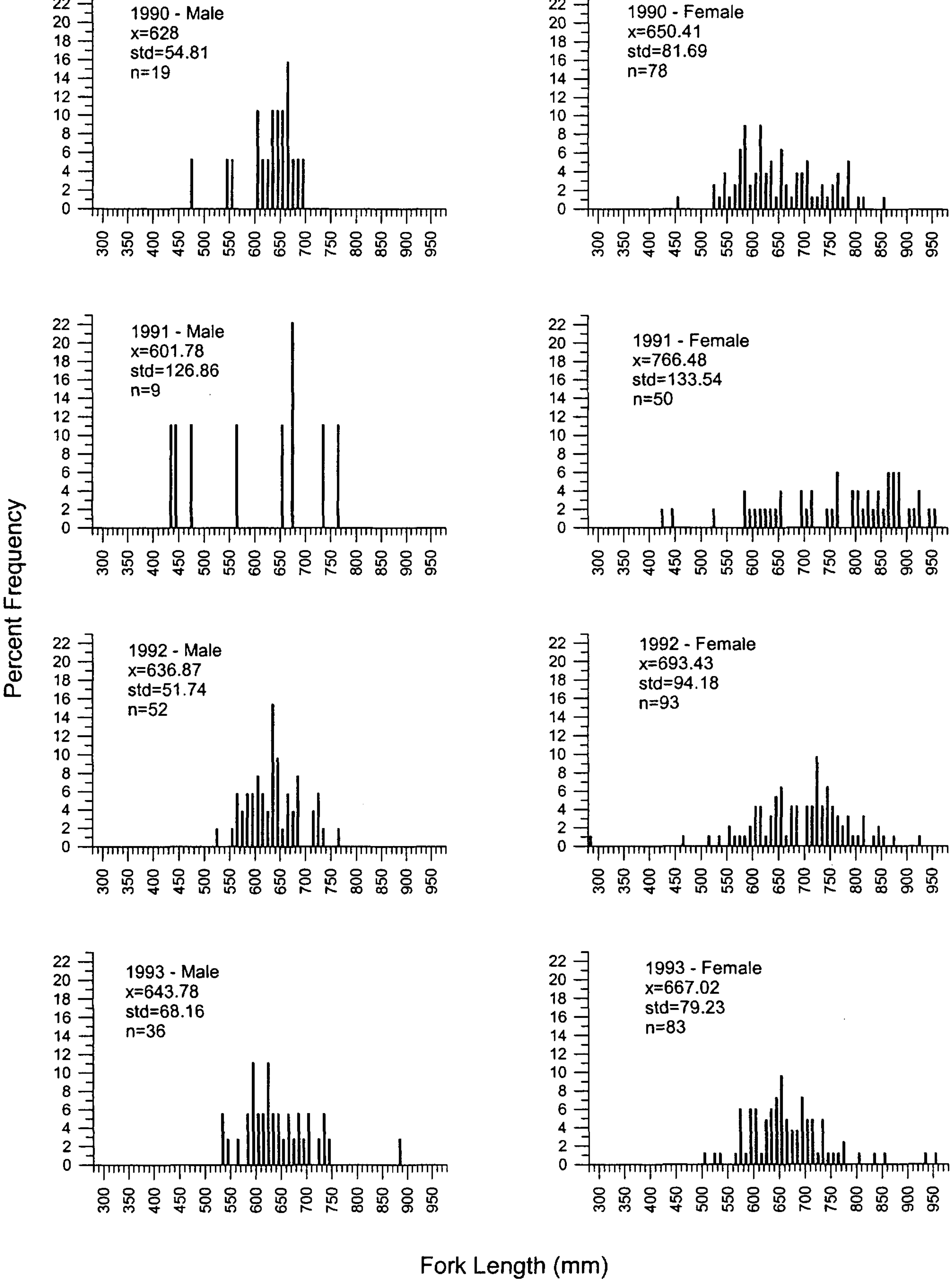

Fig.18. Length frequency data for male and female inconnu from 139 mm gill nets, 1990 to 1993.

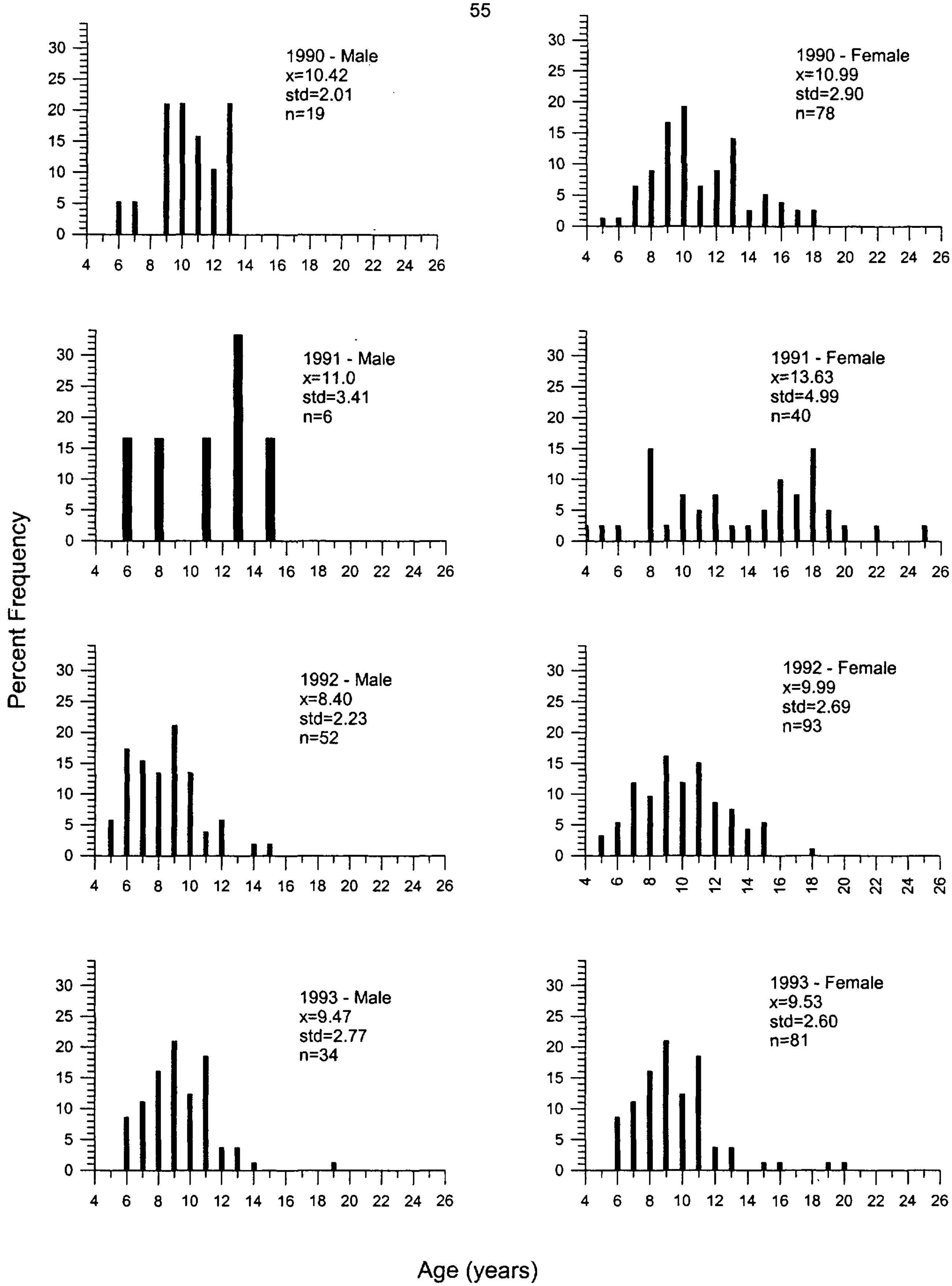

Fig. 19. Age frequency data for male and female inconnu from 139 mm gill nets, 1990 to 1993.

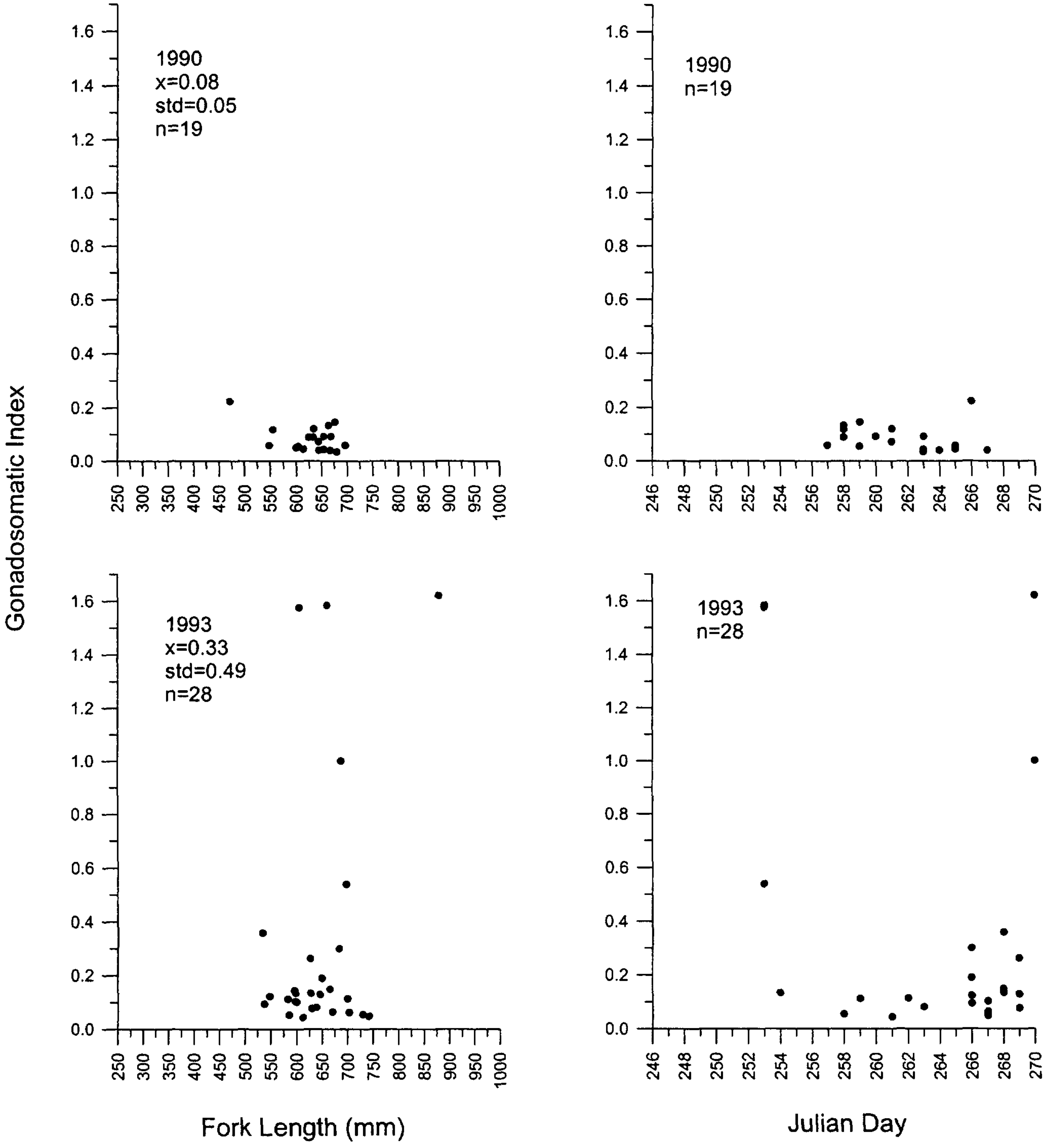

Fig. 20. Gonadosomatic index plotted against a) forklength and, b) julian day for male inconnu from 139 mm gill nets, 1990 and 1993.

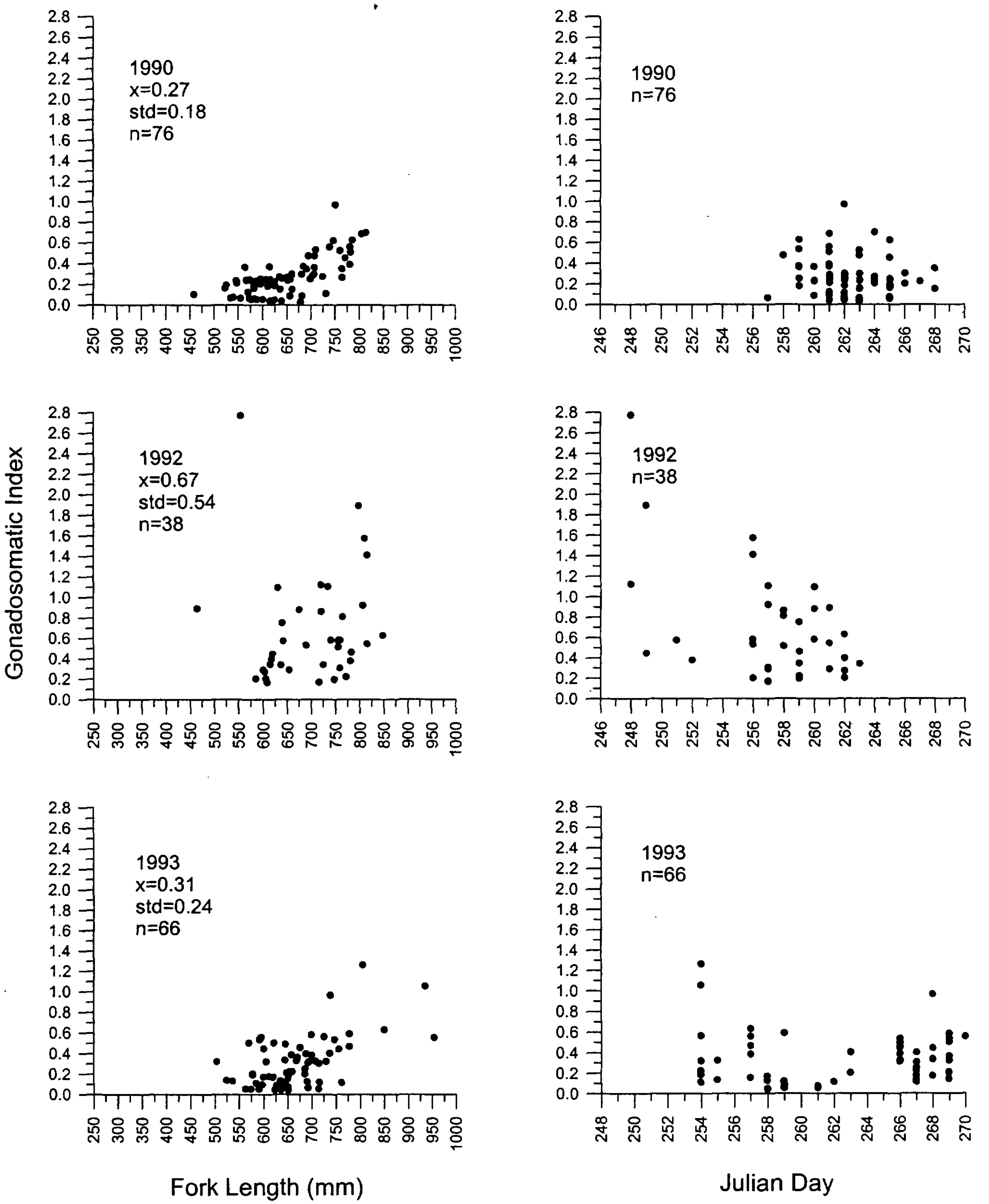

Fig. 21. Gonadosomatic index plotted against a) forklength and, b) julian day for female inconnu from 139 mm gill nets, 1990, 1992 and 1993.

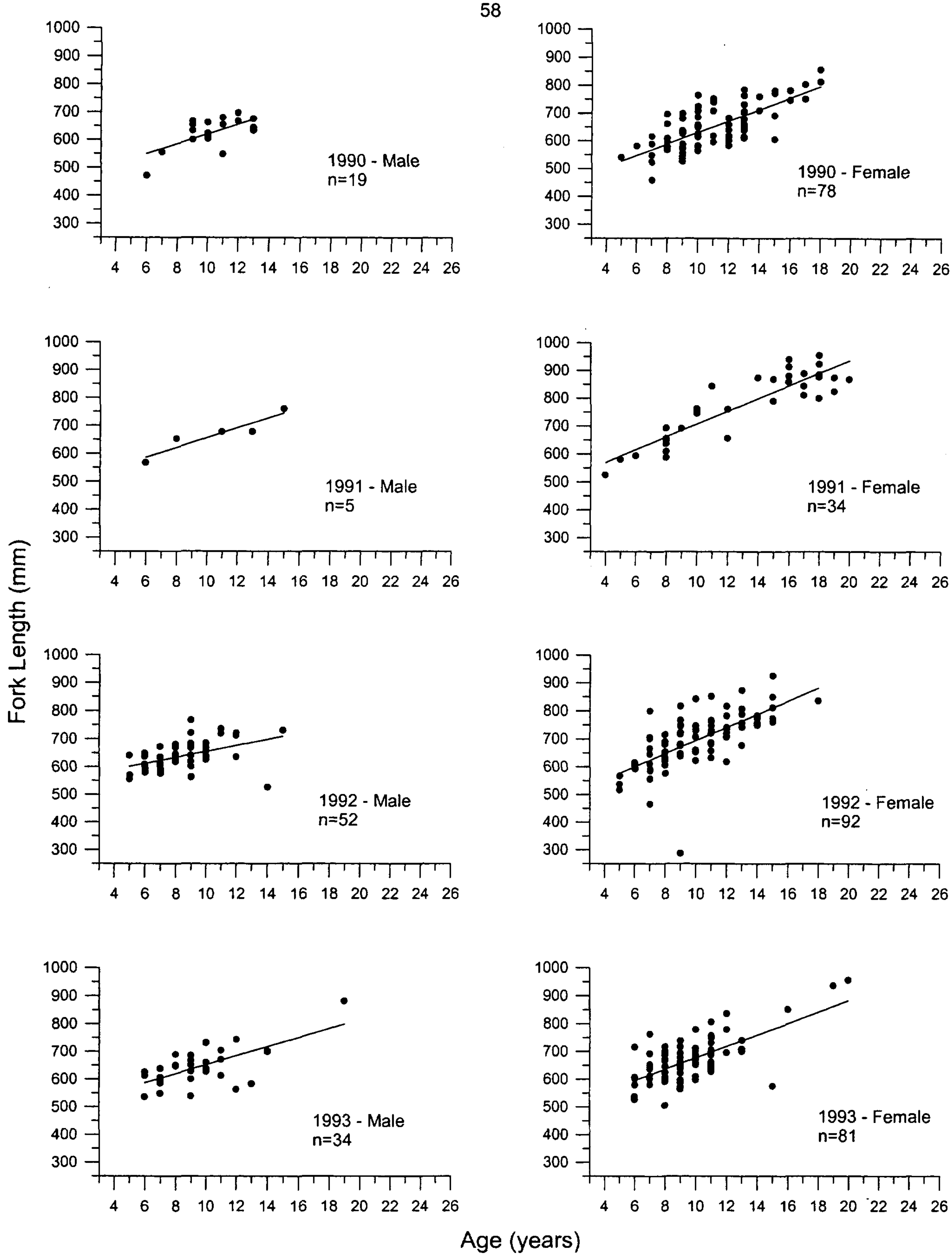

Fig. 22. Growth curves (length at age) for male and female inconnu from 139 mm gillnets, 1990 to 1993.

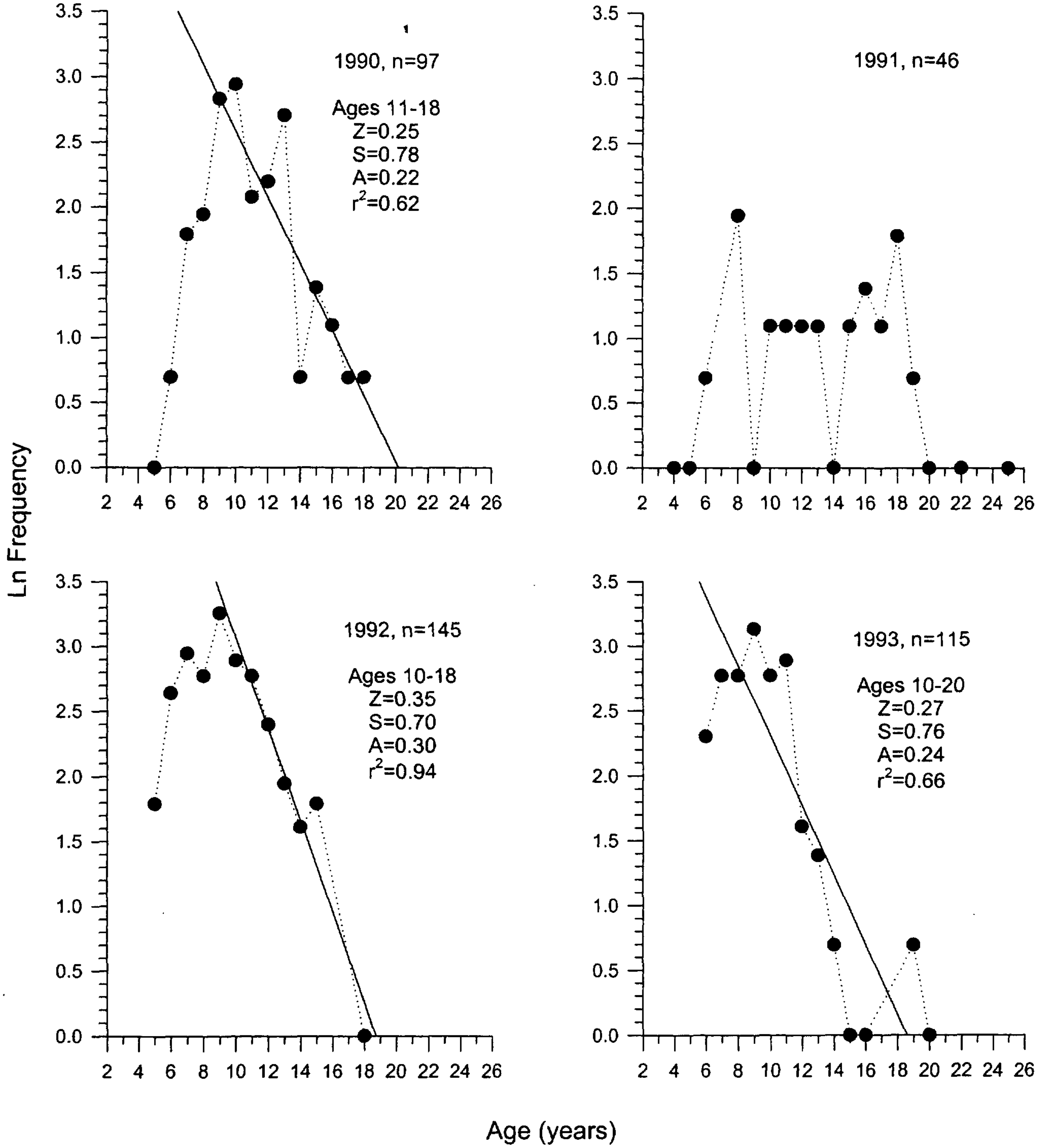

Fig. 23. Age frequency catch curves for inconnu from 139 mm gill nets, 1990 to 1993. Instantaneous mortality (Z), survival (S), and annual mortality (A) rates have been calculated where appropriate.

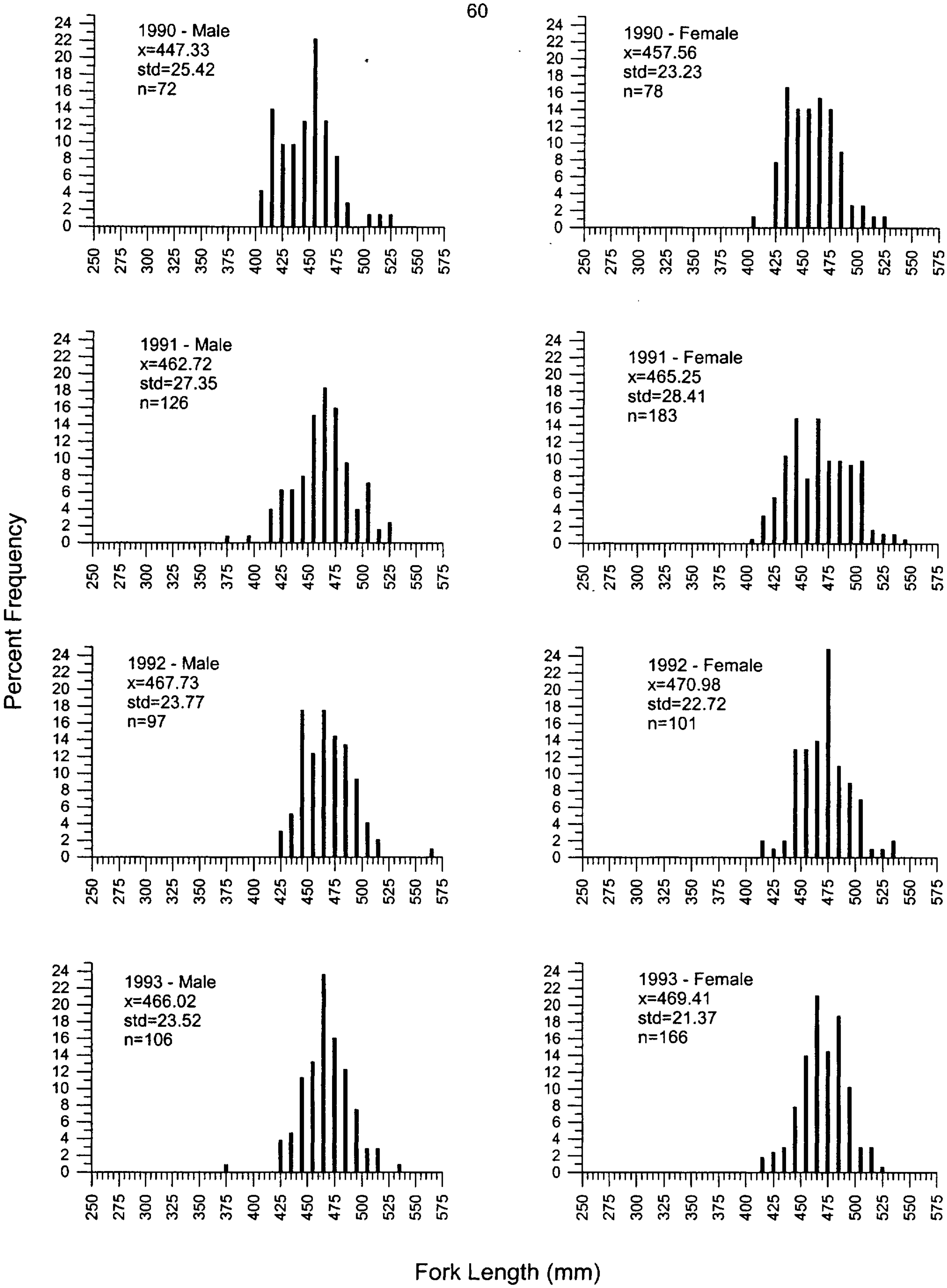

Fig. 24. Length frequency data for male and female lake whitefish from 139 mm gill nets, 1990 to 1993.

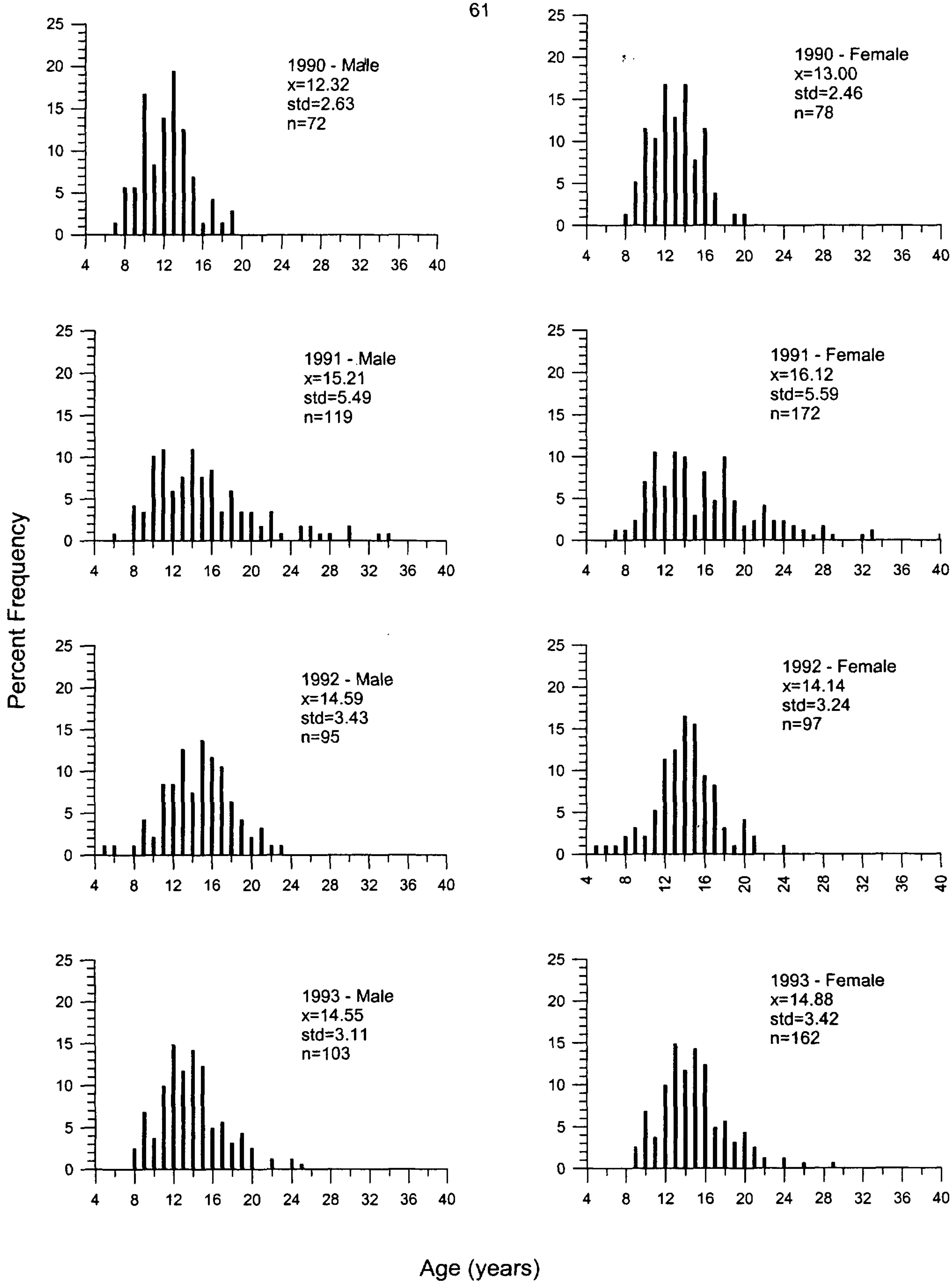

Fig. 25. Age frequency data for male and female lake whitefish from 139 mm gill nets, 1990 to 1993.

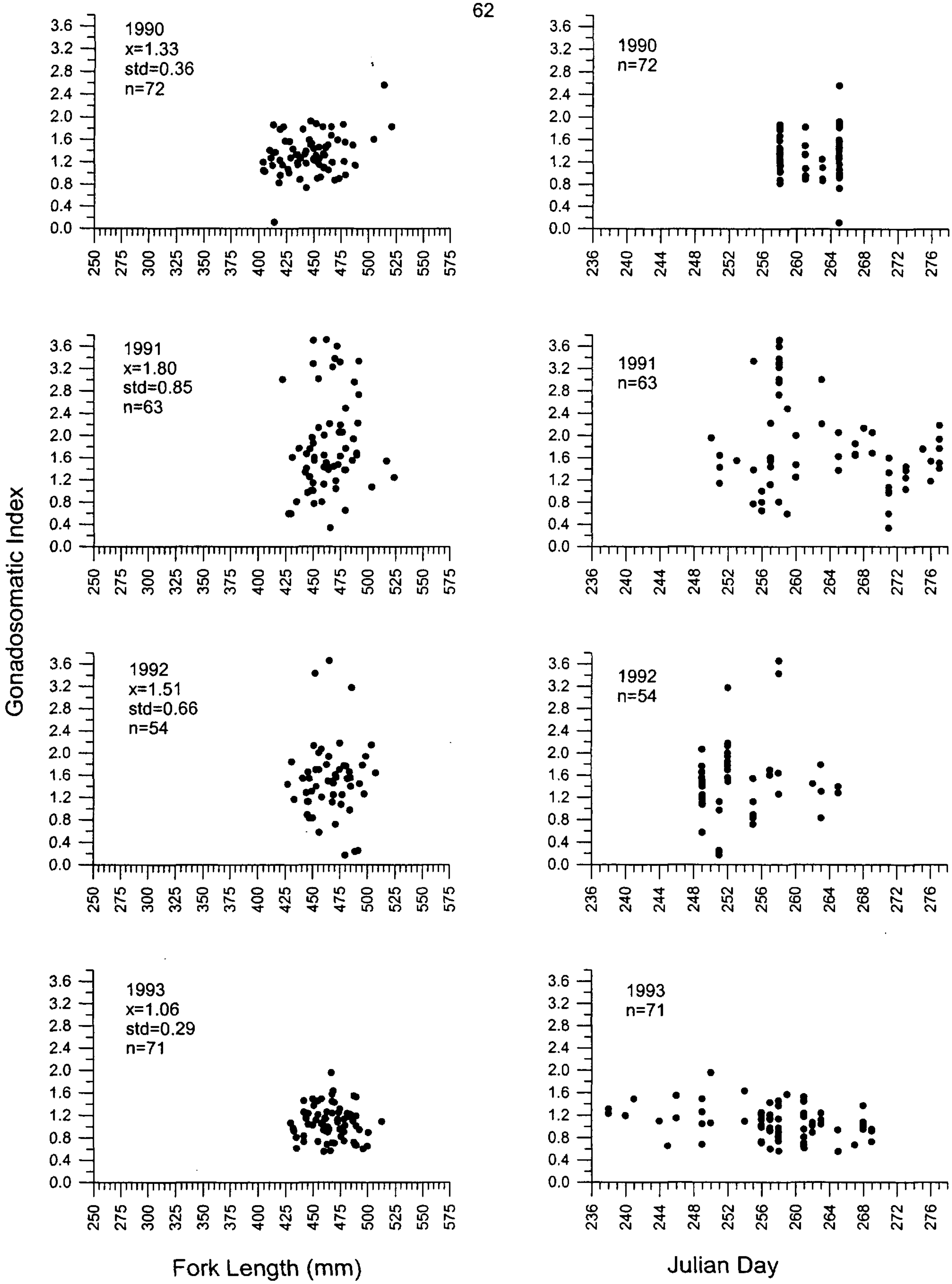

Fig. 26. Gonadosomatic index plotted against a) fork length, and b) julian day for male lake whitefish from 139 mm gill nets, 1990 to 1993.

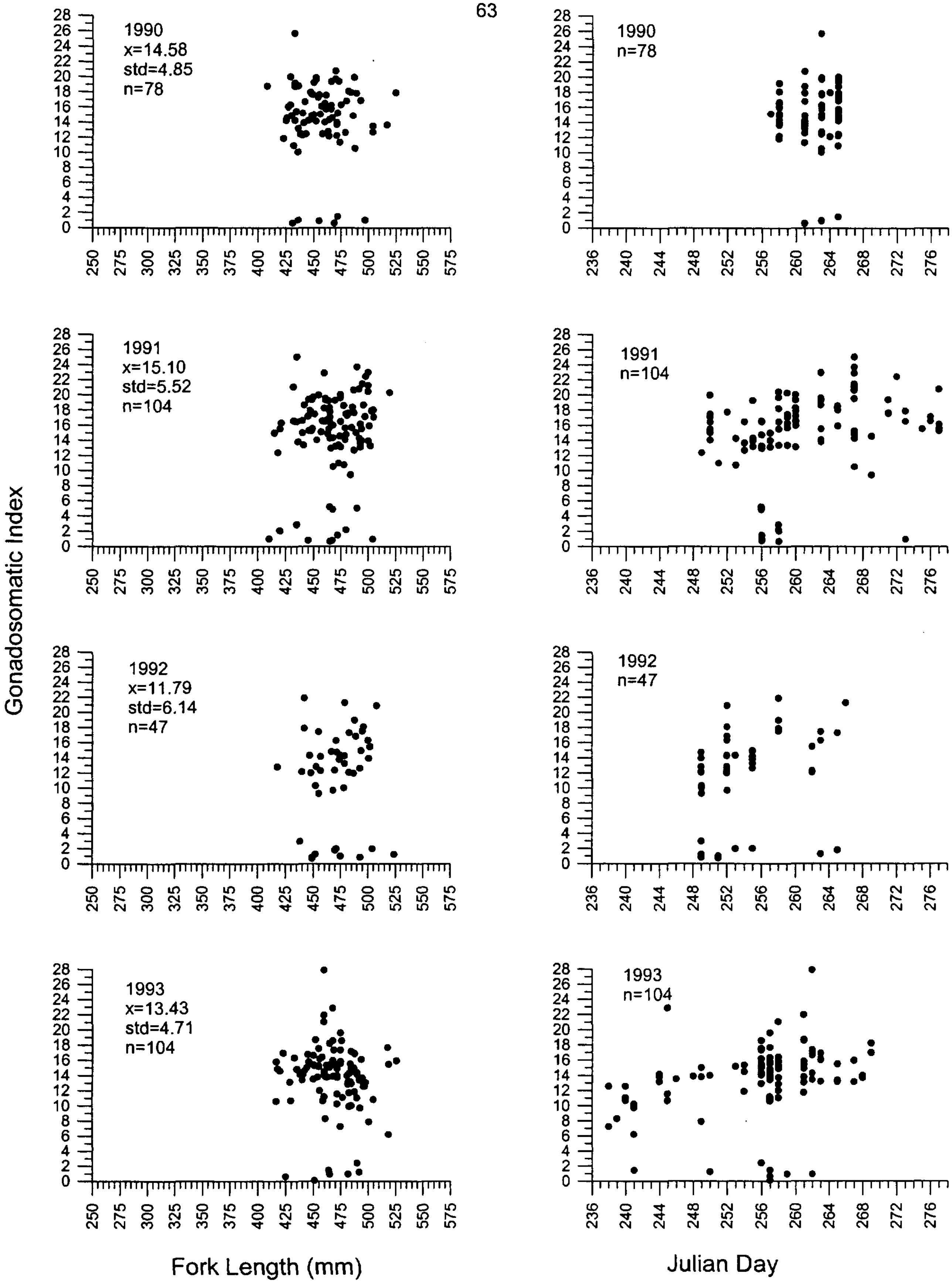

Fig. 27. Gonadosomatic index plotted against a) fork length, and b) julian day for female lake whitefish from 139 mm gill nets, 1990 to 1993.

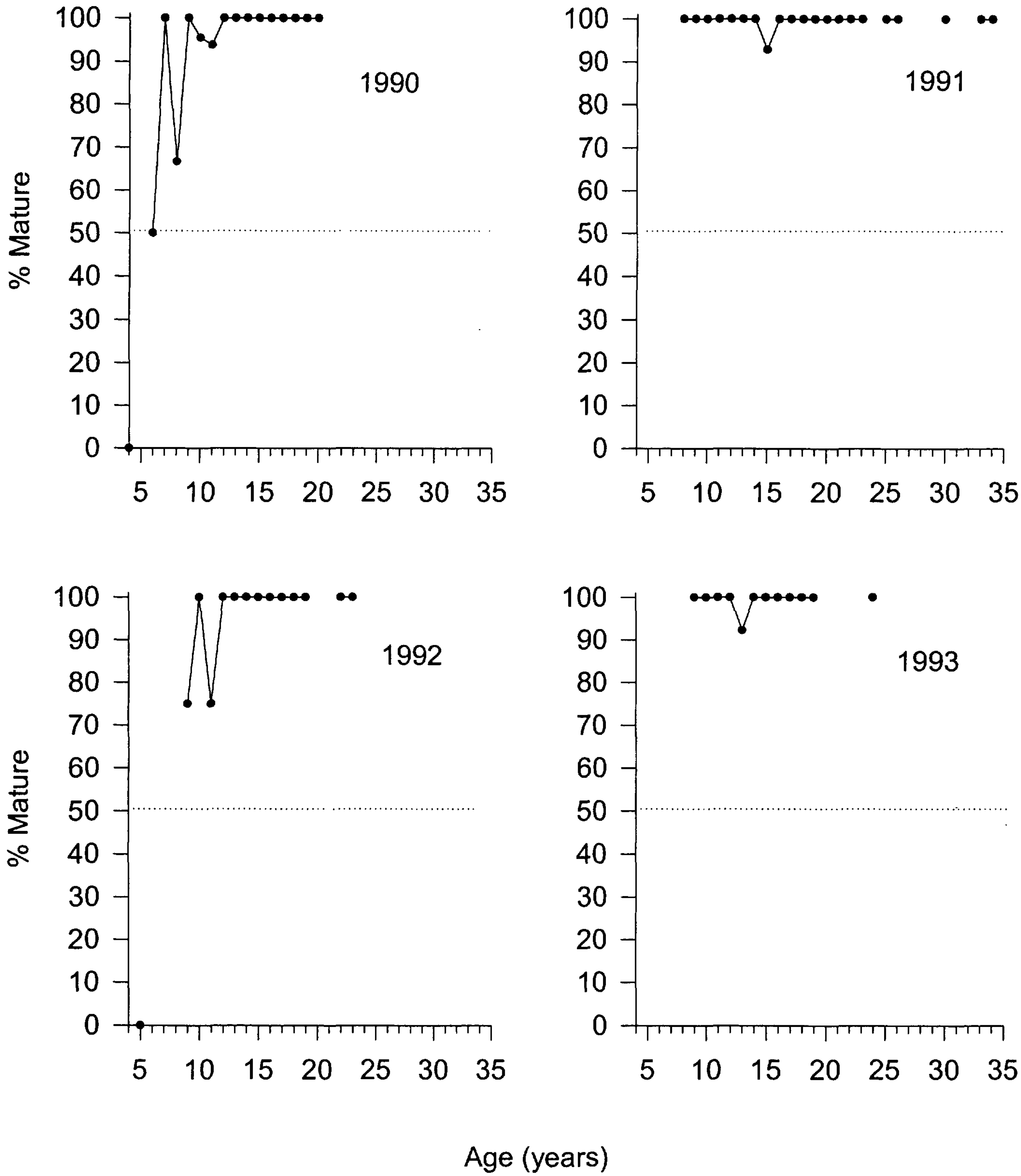

Fig. 28. Percent mature males in each age class for lake whitefish from 139 mm gill nets and 38 to 139 mm multi-mesh experimental gill nets, 1990 to 1993. Broken lines indicate the 50% mature level.

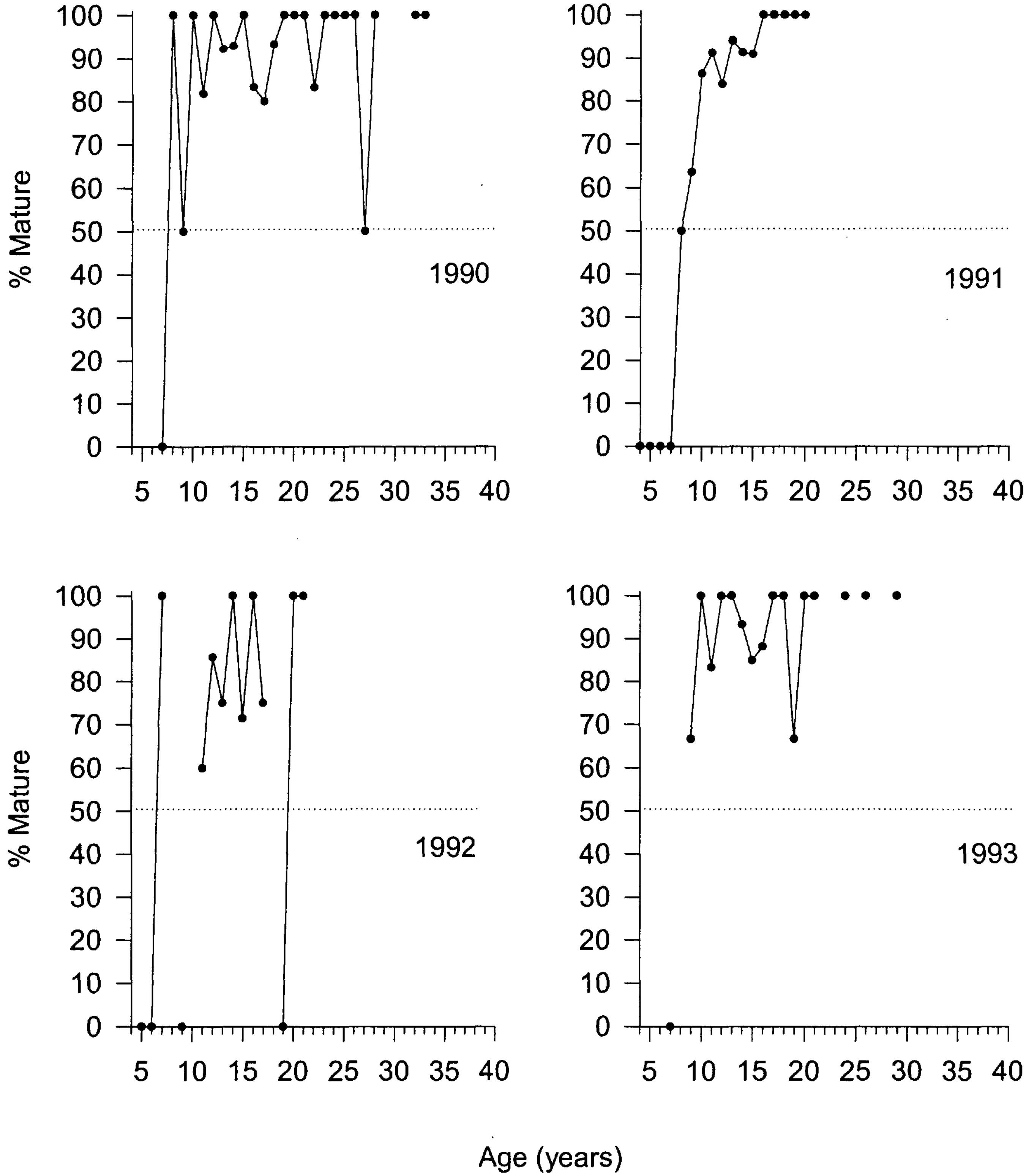

Fig. 29. Percent mature females in each age class for lake whitefish from 139 mm gill nets and 38 to 139 mm multi-mesh experimental gill nets, 1990 to 1993. Broken lines indicate the 50% mature level.

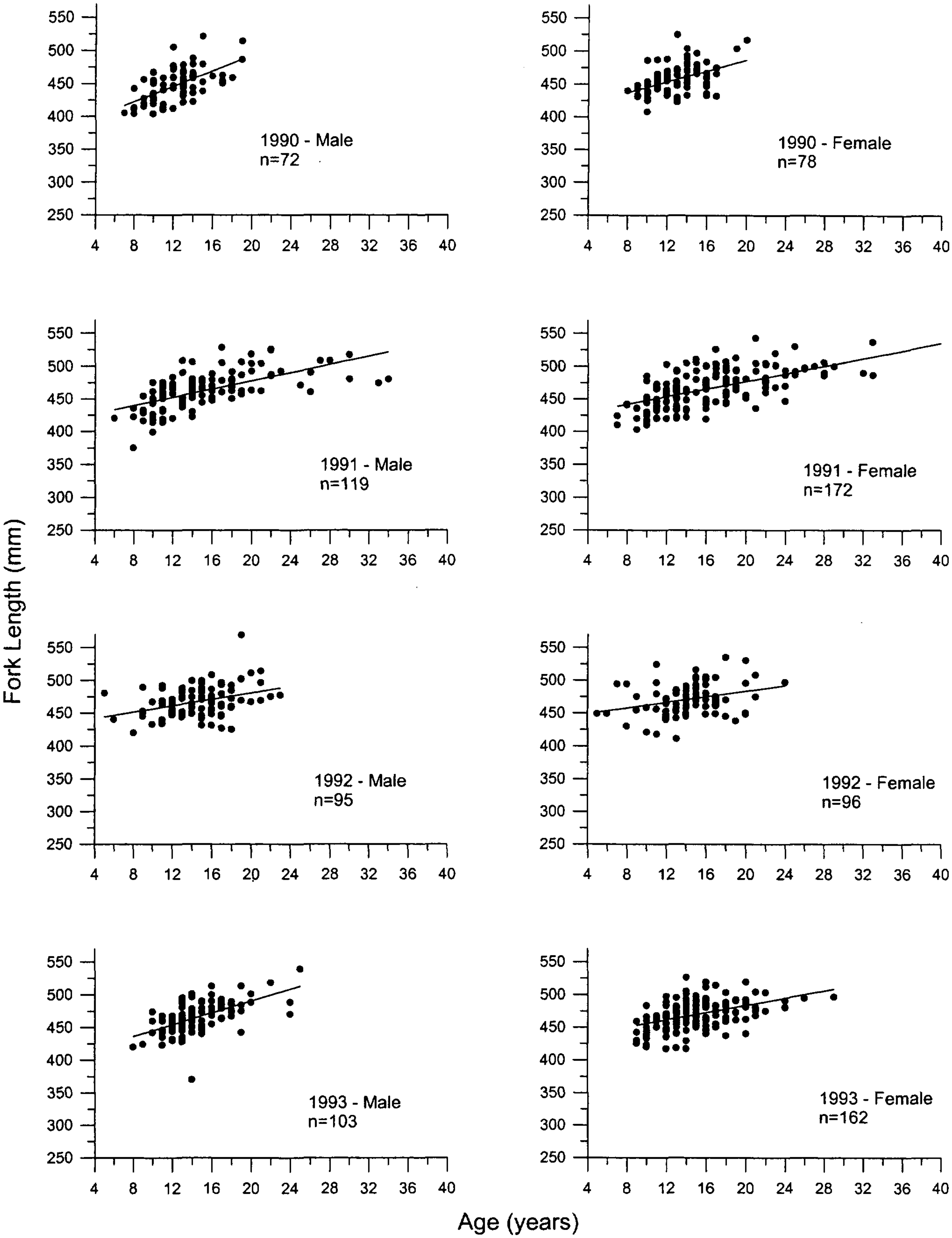

Fig. 30. Growth curves (length at age) for male and female lake whitefish from 139 mm gillnets, 1990 to 1993.

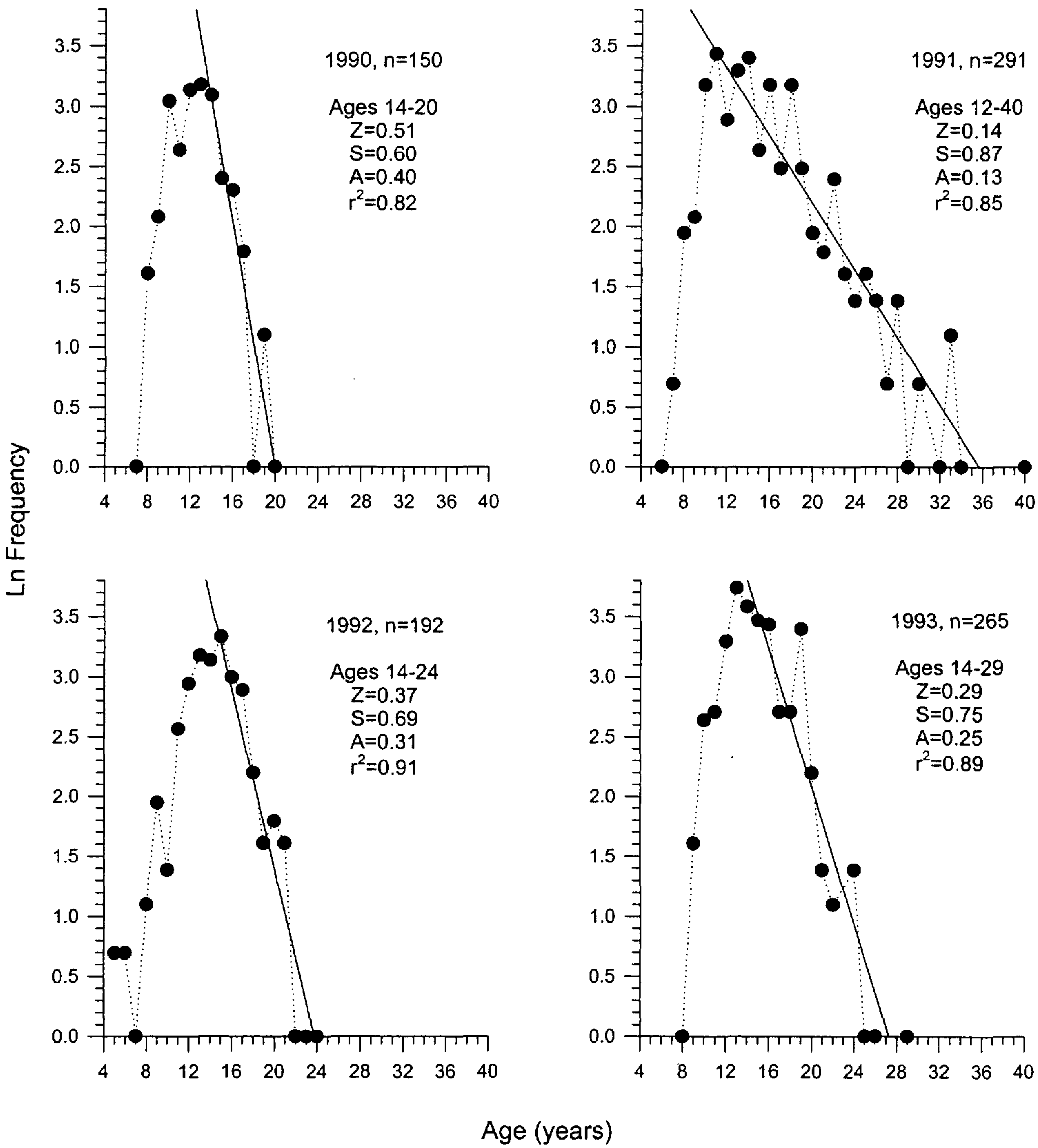

Fig. 31. Age frequency catch curves for lake whitefish from 139 mm gill nets, 1990 to 1993. Instantaneous mortality (Z), survival (S), and annual mortality (A) rates have been calculated where appropriate.

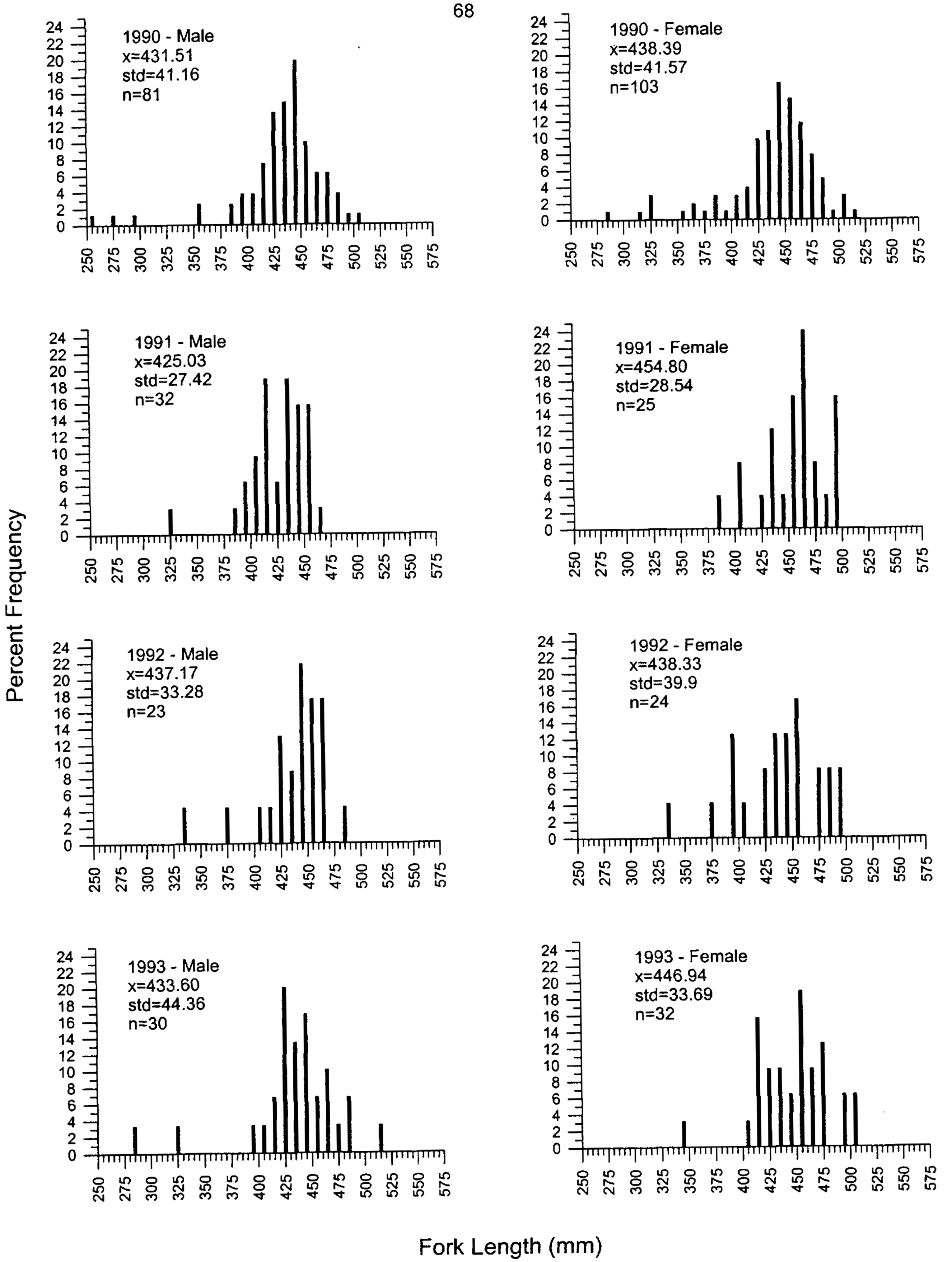

Fig. 32. Length frequency data for male and female lake whitefish from 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1993.

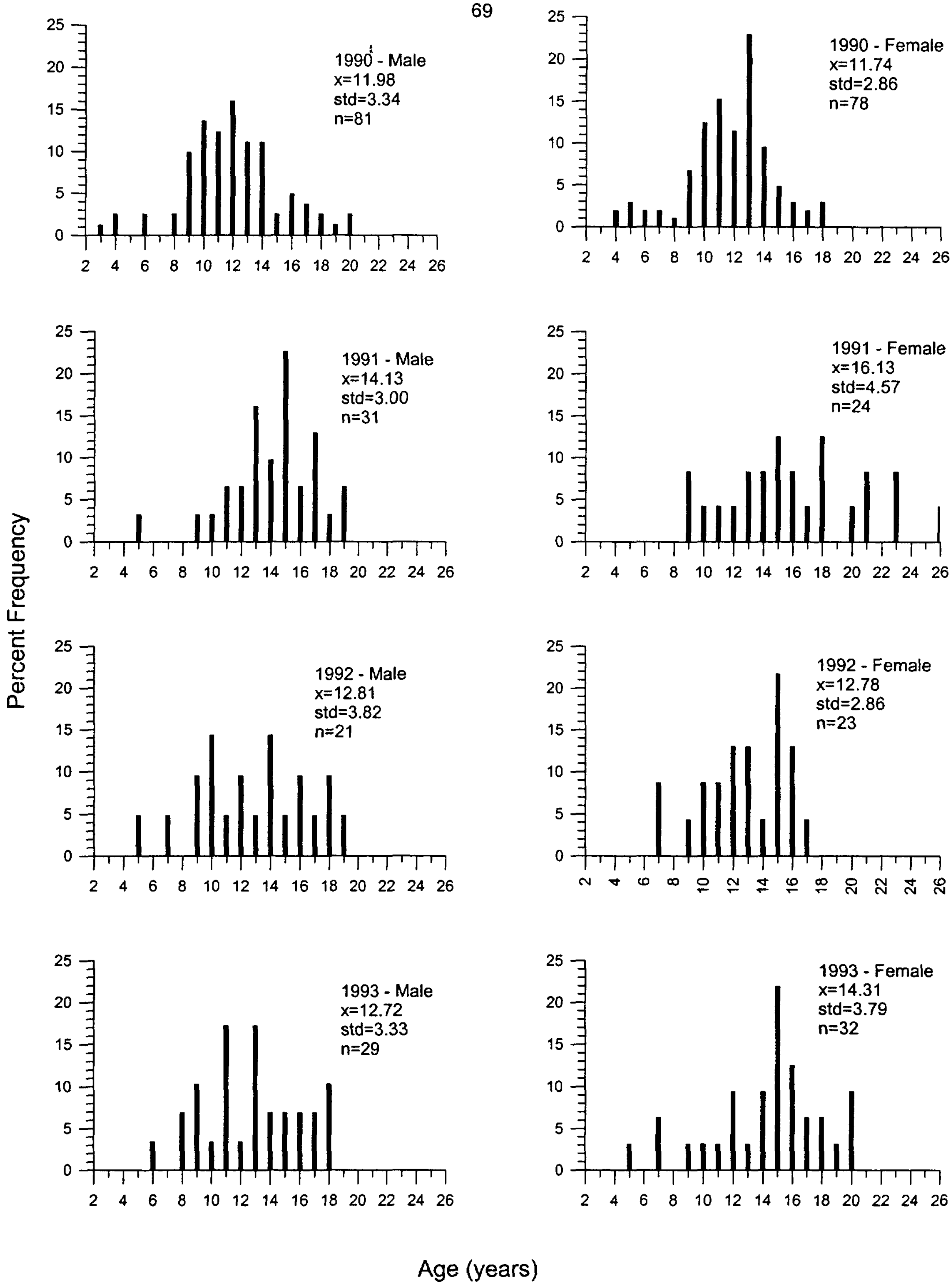

Fig. 33. Age frequency data for male and female lake whitefish from 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1993.

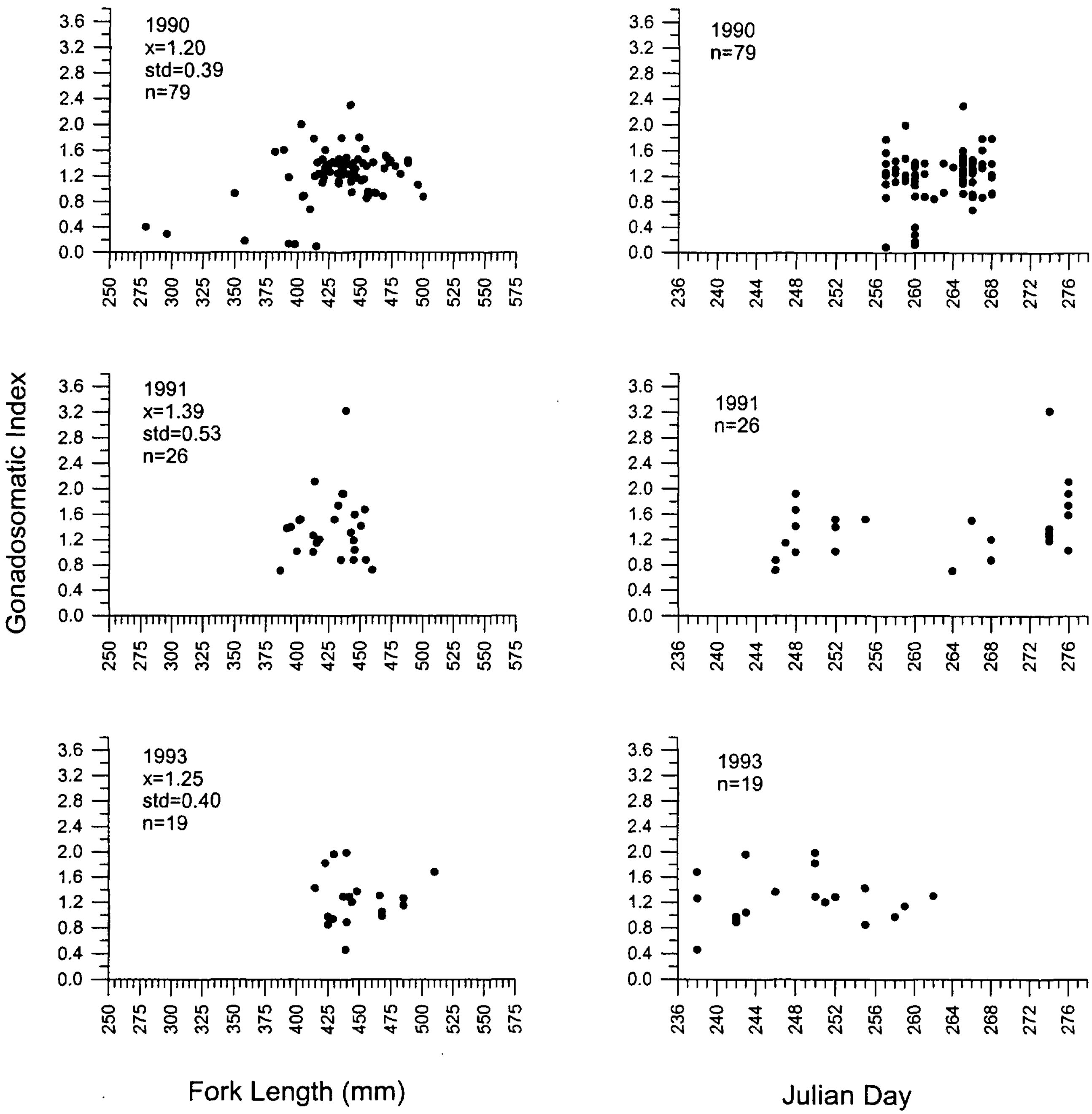

Fig. 34. Gonadosomatic index plotted against a) fork length, and b) julian day for male lake whitefish from 38 mm to 139 mm multi-mesh experimental gill nets, 1990, 1991 and 1993.

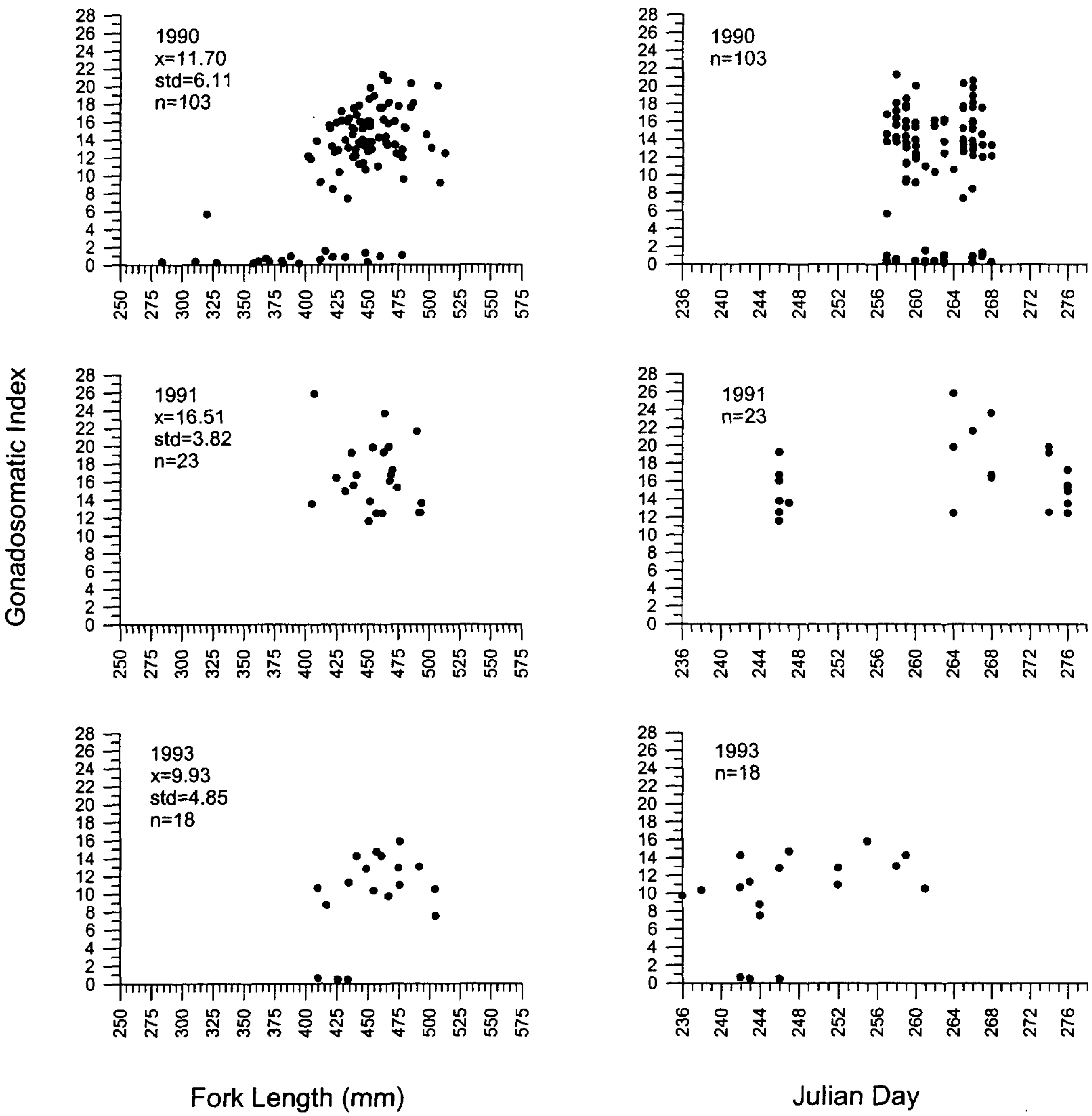

Fig. 35. Gonadosomatic index plotted against a) fork length, and b) julian day for female lake whitefish from 38 mm to 139 mm multi-mesh experimental gill nets, 1990, 1991 and 1993.

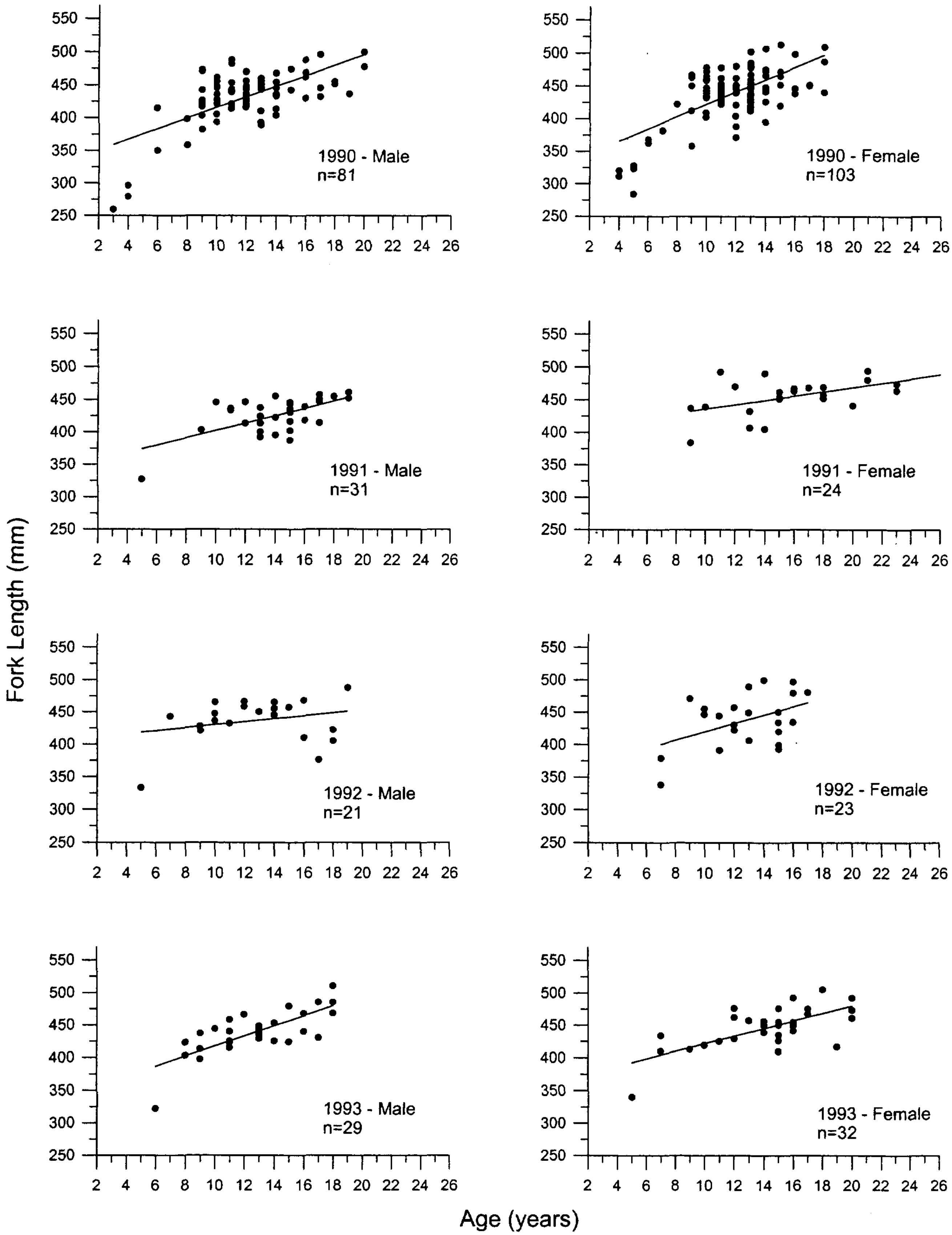

Fig. 36. Growth curves (length at age) for male and female lake whitefish from 38 mm to 139 mm multi-mesh experimental gillnets, 1990 to 1993.

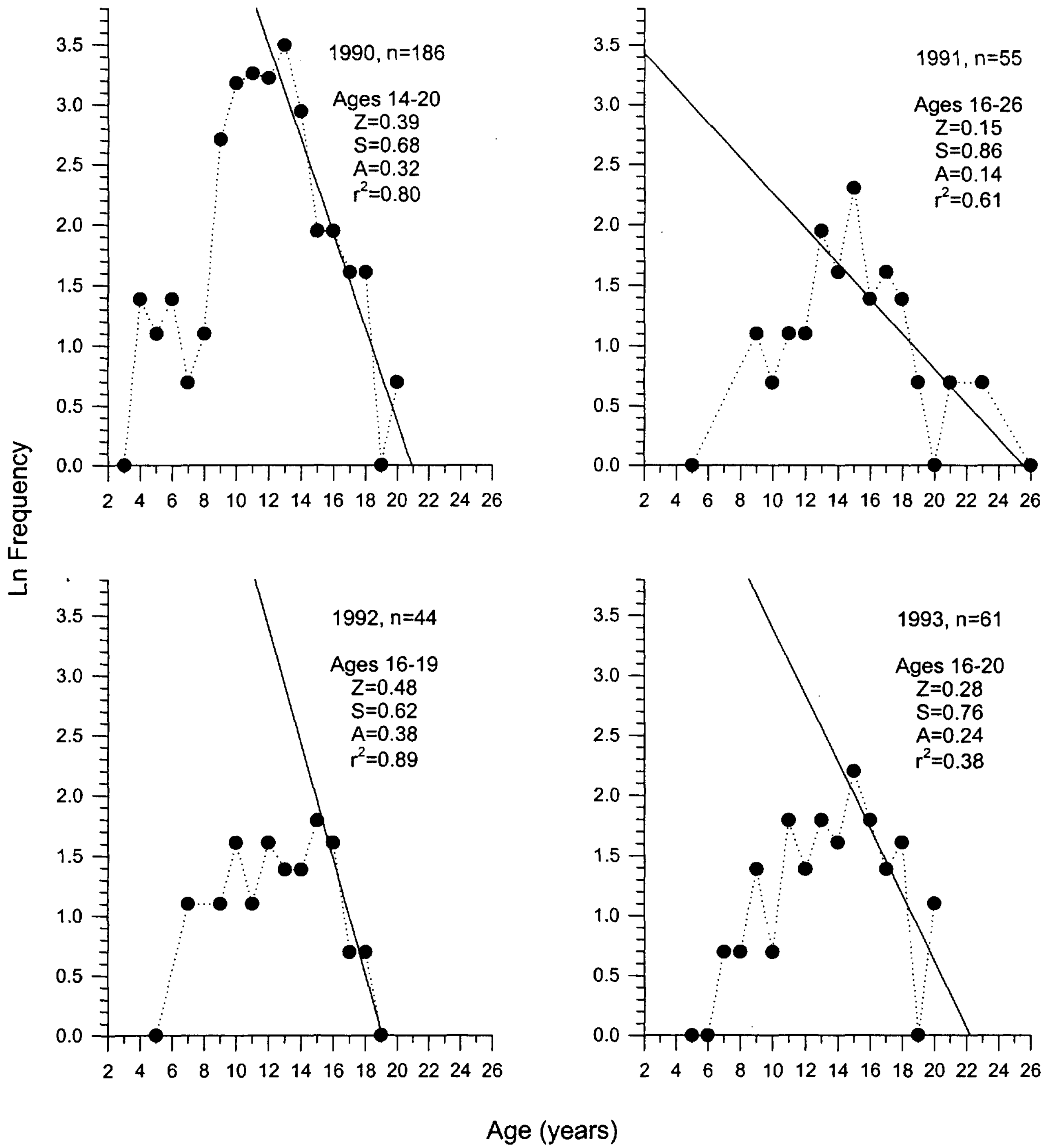

Fig. 37. Age frequency catch curves for lake whitefish from 38 mm to 139 mm multi-mesh experimental gill nets, 1990 to 1993. Instantaneous mortality (Z), survival (S), and annual mortality (A) rates have been calculated where appropriate.