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Synthesis of biological and harvest information used to assess populations of northern form Dolly Varden (*Salvelinus malma malma*) in Canada. Part III: Comparison among populations

Synthèse des données biologiques et des informations sur la récolte utilisées pour évaluer les populations de la forme nordique du Dolly Varden (*Salvelinus malma malma*) au Canada. Partie III : Comparaison entre les populations

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ABSTRACT

Biological information of anadromous, resident and isolated life history types of northern form Dolly Varden (*Salvelinus malma malma*) collected from the Yukon and Northwest Territories are synthesized, with emphasis placed on populations of anadromous Dolly Varden from the Firth River/Joe Creek, Babbage River and Vittrekwa River. Data collected from all rivers (excluding the Vittrekwa due to low sample size) supporting anadromous populations which included the Big Fish and Rat rivers and the aforementioned systems were compared to elucidate effects of population decline on biological characteristics. Populations known to have experienced declines were compared with others that were believed to have experienced lower harvest rates for time periods when methodologically consistent biological information was available from all river systems (1986-88 and 1993-95). Data includes population sizes, length and age characteristics, growth, and reproduction. The synthesized information suggests some differences in biological characteristics among anadromous populations. Larger size and older ages were attained in the Firth River compared to other systems. Length characteristics between male and female spawners were similar in the Firth River and Joe Creek, however males attained larger sizes than females in the Babbage. There were some differences in age between sexes among years although the data were highly variable. Females and males within each system appeared to mature at similar ages. Females consistently outnumbered males among stocks. Among population comparisons demonstrated that Dolly Varden from the Firth River/Joe Creek and females from the Big Fish River appear to spawn annually upon reaching maturation, which is not the pattern observed in the Babbage and Rat rivers and in males from the Big Fish River. Additional comparisons revealed that declines in abundance appear to change the population demographics such as a decrease in the proportion of large size fish, lower growth rate, and a decrease in the proportion of spawning males. Relatively little information exists on resident and isolated Dolly Varden. These fish are smaller in size, have slower growth and do not attain similar maximal ages compared to anadromous Dolly Varden.

RÉSUMÉ

Les données biologiques sur les types de cycle vital anadrome, résident et isolé des formes nordiques de Dolly Varden (*Salvelinus malma malma*) recueillies au Yukon et dans les Territoires du Nord-Ouest sont résumées, avec l'accent mis sur les populations de Dolly Varden anadrome de la rivière Firth/ruisseau Joe, et des rivières Babbage et Vittrekwa. Les données recueillies dans toutes les rivières (sauf la rivière Vittrekwa en raison de la petite taille de l'échantillon) soutenant les populations anadromes, notamment les rivières Big Fish et Rat et les systèmes d'eau susmentionnés, ont été comparées dans le but de dégager les effets de la diminution de la population sur les caractéristiques biologiques. On a comparé les populations pour lesquelles la diminution est avérée avec d'autres que l'on soupçonne d'un taux de récolte plus bas durant les périodes pour lesquelles des données biologiques prélevées suivant des méthodes uniformes étaient disponibles pour tout le réseau hydrographique (de 1986 à 1988 et de 1993 à 1995). Les données comprennent la taille de la population, les caractéristiques sur la longueur et l'âge, la croissance et la reproduction. La synthèse de l'information suggère certaines différences sur le plan des caractéristiques biologiques parmi les populations anadromes. Les spécimens de la rivière Firth sont plus gros et plus âgés comparativement à ceux prélevés dans les autres rivières. Les caractéristiques sur la longueur entre les géniteurs mâles et les géniteurs femelles étaient les mêmes pour la rivière Firth et le ruisseau Joe; cependant, les mâles étaient plus gros que les femelles dans la rivière Babbage. On a observé certaines différences sur le plan de l'âge entre les sexes au fil des ans, même si les données étaient très variables. Les femelles et les mâles peuplant chaque rivière semblaient atteindre la maturité aux mêmes âges. Les femelles dépassaient constamment les mâles en nombre dans les effectifs. Les comparaisons effectuées entre les populations ont démontré que le Dolly Varden de la rivière Firth/ruisseau Joe et les femelles de la rivière Big Fish semblaient frayer chaque année dès qu'ils ont atteint leur maturité, ce qui ne correspond pas au comportement observé chez les spécimens des rivières Babbage et Rat ni chez les mâles de la rivière Big Fish. Les comparaisons ont également révélé que la diminution de l'abondance semble modifier la démographie de la population, notamment par une diminution de la proportion de gros poissons, par un taux de croissance plus faible et une diminution de la proportion des mâles géniteurs. On dispose de peu d'information sur les espèces de Dolly Varden résidentes et isolées. Ces poissons sont plus petits, croissent plus lentement et n'atteignent pas les mêmes âges maximums comparativement au Dolly Varden anadrome.

INTRODUCTION

The pre-COSEWIC assessment of Northern form Dolly Varden (*Salvelinus malma malma* (Walbaum 1792)) requires the review of all available information in order to (1) synthesize population abundance and harvest data of known Dolly Varden stocks, and (2) assess populations based on analyses of biological parameters (e.g., length, age, length-at-age, age-at-maturity and sex ratio) over time. Biological data from all river systems for the anadromous, resident and isolated life history types were summarized, although emphasis was placed on populations from the Firth River/Joe Creek, Babbage River and Vittrekwa River. A more detailed examination of data from the Big Fish and Rat rivers are presented by Gallagher et al. (2011) and Roux et al. (2012), respectively.

Among population comparisons were made in an attempt to elucidate the effects of harvest on biological characteristics by comparing populations thought to have historically encountered higher harvest levels (Big Fish and Rat rivers) with those thought to have experienced lower levels of harvest (Firth River/Joe Creek and Babbage River). Unfortunately, due to the paucity of available information and inconsistent sampling methods among populations, robust analyses of trends were limited. Comparison of biological characteristics among anadromous populations was only possible for periods when all systems were sampled using consistent methodology in the 1980s and 1990s. The Vittrekwa River was excluded from this comparison because it was not sampled during these periods of time and due to low sample sizes when it was sampled in later times.

NORTHERN FORM DOLLY VARDEN

In Canada, northern form Dolly Varden occurs west of the Mackenzie River in the Northwest Territories and Yukon Territory. Spawning and overwintering occurs in tributaries of the Mackenzie River and Peel River and in rivers of the Yukon North Slope. These rivers or their tributaries are characterized by localized perennial groundwater inflows that maintain year-round stretches of open water used as spawning and over-wintering sites by Dolly Varden. Previously referred to as the Western form of Arctic Char (*Salvelinus alpinus*) (McPhail 1961), Dolly Varden hold cultural and dietary importance for Inuvialuit and Gwich'in peoples of Canada.

Northern form Dolly Varden in Canada exhibit three life history types: anadromous, resident and isolated. Anadromous Dolly Varden are located in the Firth River/Joe Creek, Babbage, Big Fish, Rat and Vittrekwa rivers and also purportedly in the Fish River (Figure 1) and make annual migrations to the Beaufort Sea to feed in the summer, generally after three years of age. Anadromous Dolly Varden have faster growth rates and attain larger sizes compared to the other life history types. Non-anadromous resident (or resident) Dolly Varden remain in their natal streams and co-occur with the anadromous life history type during the fall and winter in the spawning/overwintering areas of the Firth/Joe Creek, Babbage, Big Fish, Rat and Vittrekwa river systems. Resident fish are males that mature at a smaller size and younger age and adopt a "sneaker" reproductive strategy when anadromous Dolly Varden spawn. The isolated life history type is also non-anadromous, consisting of both males and females, and is known to occur in the Babbage, Big Fish, Blackstone and Gayna river systems (Figure 1) (McCart and Bain 1974, Bain 1974, Mochnacz and Reist 2007). This life history type is usually isolated by physical barriers (such as waterfalls), or by distance and intervening unsuitable habitats (Reist and Sawatzky 2010). Isolated Dolly Varden are not sympatric with resident or anadromous Dolly Varden, however possible immigration downstream has not been confirmed (Reist 1989).

Genetically distinct anadromous/resident populations of northern form Dolly Varden have been confirmed in the Firth, Babbage, Big Fish and Rat rivers (Reist 1989). Additionally, there is genetic evidence indicating that Dolly Varden from Joe Creek are distinct from those that spawn

in the Firth River (Reist 1989). Genetic studies published to date have not included fish from the Vittrekwa, Blackstone, Gayna or Fish rivers. Evidence from genetic studies indicates that anadromous and resident Dolly Varden are not genetically different while some isolated populations are different principally as a result of geographical barriers (Reist 1989).

Data sources and analysis

The data examined in this report were obtained from sampling for scientific studies or from sampling of the subsistence harvest between 1986 and 2007. Datasets were obtained from the archives of Fisheries and Oceans Canada, Fisheries Joint Management Committee, and the Gwich'in Renewable Resources Board (Table 1). Some data from the reports of gas exploration studies in the early 1970s are also discussed for historical comparison (e.g., Glova and McCart 1974). Available information on biological parameters was synthesized separately for anadromous, resident and isolated life history types.

Where possible, data were examined separately for males and females among river systems and years. Within sexes, data were examined for both the total sample (non-spawners, maturity not recorded and spawners combined) and for spawners only. There were instances where sex was recorded from a sub-sample only; therefore information was presented for both males and females, and the total combined sample (males, females and individuals for which sex was not recorded). Length and age statistics and frequency distributions were calculated and plotted, respectively. Additionally, length-at-age, minimum age-at-maturity, and sex ratios were examined. Inter-annual differences were examined only if Dolly Varden were collected using consistent capture methods at similar sampling sites (e.g., spawning/overwintering area).

Statistical tests were conducted among all populations (except for the Vittrekwa River due to low sample sizes), mainly to test for differences in length and age. Results were considered significant if a p-value was <0.05. Analytical comparisons among populations were limited by low sample sizes (age and length were only statistically compared where sample size was ≥ 10) and inconsistencies in sampling years and methods. Tests were restricted to analysis of variance or, when parametric assumptions were violated, non-parametric tests such as Mann-Whitney or Kruskall-Wallis (H) tests with post-hoc Mann-Whitney pairwise comparisons adjusted using the Bonferroni correction (at a level of significance of 0.05/number of comparisons). Length-at-age data were visually compared due low sample sizes. Differences in the sex ratios were evaluated by examining the confidence limits for binomial proportions that would indicate whether they differed significantly from 0.5 (i.e., 1:1) (Rohlf and Sokal 1995).

ANADROMOUS LIFE HISTORY TYPE

Available information

Biological data were available for five populations of anadromous northern form Dolly Varden: 1) Firth River and its tributary Joe Creek (which may be a distinct stock), 2) Babbage, 3) Big Fish, 4) Rat, and 5) Vittrekwa rivers (Table 1). Biological data were also available for Dolly Varden captured along the Beaufort Sea coast during the summer. Between 1986 and 1995, biological information was collected from each population at least once, with the exception of the Vittrekwa River. Data from the Vittrekwa River was collected in 1999 (young-of-the-year only; data not presented), 2006 and 2007 (juveniles and adults).

Life history type was identified in 1986 (Firth River and Joe Creek, Babbage and Big Fish rivers), 1988 (Firth, Babbage and Big Fish rivers), 1990-1992 (Babbage River weir), 1995 (Firth River and Joe Creek) and in 2006 and 2007 (Vittrekwa River). There were instances where life history was not identified in a data set and it was unknown if small size fish (<300 mm) were of

the anadromous (small smolt) or resident type. In the Big Fish River, Sandstrom and Harwood (2002) state that anadromous Dolly Varden smolt at approximately 286 mm. Sandstrom et al. (1997) report smolts as small as approximately 200 mm in the Babbage River. Resident Dolly Varden have typically been found to be less than 300 mm in length, however the occasional larger individuals (up to 333 mm), have been captured in the Firth River and Joe Creek systems (see Table 24). For the analyses presented below, we made the assumption that any samples ≥300 mm in length that were not assigned to a life history category were of the anadromous life history type.

Collection methods were highly variable among years in different river systems and in some cases different methods were used within a single year without being distinguished in the dataset (e.g., recorded as angling/seining). Although this data is presented, comparisons of mean length and age, and frequency distributions in certain instances may not be meaningful.

BIOLOGICAL CHARACTERISTICS WITHIN RIVER SYSTEMS

Firth River/Joe Creek

Population size

Glova and McCart (1974) visually estimated the size of the adult anadromous stock in the Firth River (not including Joe Creek) at approximately 32,000 (peak count) on September 21, 1972 based on aerial surveys. Details on the methodology for counting Dolly Varden such as aircraft type, travel speeds, visibility, and species identification were unfortunately not included. It is likely that a large proportion of the peak count was comprised of Arctic grayling (*Thymallus arcticus*) which would result in an overestimate of the abundance of Dolly Varden. This estimate is further confounded by the lack of fish counts from Dolly Varden spawning habitat of the Firth River in Alaska which would conversely result in underestimation of the population size.

Kristofferson et al. (1991) estimated the minimal number of large anadromous Dolly Varden in the Firth River to range between 8,250 and 10,700 based on aerial video surveys conducted in September 1989 using a helicopter in both Alaska and Yukon Territory. Limitations in the methodology were discussed by Kristofferson et al. (1991) which included the decreased visibility in the water due to downwash from rotor blades, decreased accuracy of counts in riffle habitat, and the inability to distinguish between Arctic grayling and Dolly Varden. Due to the seemingly unstandardized approaches in aerial surveys between both studies, it is impossible to confidently evaluate whether the considerable difference in abundance estimates is authentic and suggestive of a decline between 1972 and 1989.

There are no estimates available for the abundance of anadromous Dolly Varden from Joe Creek.

Length

Length data for anadromous Dolly Varden was summarized for males and females from the Firth River (Table 2) and Joe Creek (Table 3). A broad range of sizes between 184 mm and 758 mm characterized Dolly Varden captured by angling (1987), seining (1989) and both methods combined (1995) in the upper reaches of the Firth River (Figure 2).

Statistical comparisons between years and sex could only be made for the Firth River in 1986 and 1995 where consistent methods (seining/angling) were used. No size differences were observed between females (mean= 530 mm) and males (mean= 524 mm) in 1986 (ANOVA, $F= 0.76$, df= 1,51; $p=0.79$) and 1995 (ANOVA, $F= 3.39$, df= 1,146; $p=0.07$) (Figure 2, Table 2).

Mean length was also similar among years in both females (ANOVA, F= 2.19, d.f.=1, 146; p= 0.14) and males (ANOVA, F= 0.21, df= 1,51; p=0.650) (Figure 2, Table 2). Likewise, the mean length of males and females was similar for collections made using various other sampling methods: angling in 1987 (ANOVA, F= 1.7, d.f.= 1, 112, p= 0.19), electrofishing in 1988 (Mann-Whitney, U= 76.0, p= 0.40), and seining in 1989 (ANOVA, F= 0.43, d.f.= 1, 19, p= 0.52) (Figure 2, Table 2).

In Joe Creek, size differences between males and females were not observed in 1986 (Mann Whitney U= 248.5, p= 0.512) or in 1995 (Mann Whitney U= 2080.5, p= 0.144) (Figure 3, Table 3). The 1986 sample collected by seining/angling was predominantly comprised of Dolly Varden >460 mm in length (size range= 271-662 mm) (Figure 3). In contrast, Dolly Varden caught by electrofishing in 1995 were <460 mm and demonstrated a bi-modal length frequency distribution (size range= 247-596 mm) (Figure 3). Unfortunately, evaluating differences between years is confounded by inconsistent use of gear type.

Based on the information from 1986 where similar gear types were used to collect samples, larger-sized Dolly Varden were detected in the Firth River compared to Joe Creek (Mann Whitley, U= 964.0, p= 0.008). Although speculative, this may be related to differences in life histories as there appears to be genetic differences between river systems.

Age

Means ages of males and females captured by seining/angling in the Firth River in 1986 were 9.0 and 9.4, respectively, however sample size for males was to low to allow for statistical comparison between sexes (Table 2). Based on the sample collected in 1995, males (mean= 8.3 years) captured by seining/angling were slightly, albeit significantly, older than females (mean= 8.1 years) (Mann Whitney, U= 1280.0, p= 0.03). Among year differences could not be compared for males due to low sample size, however females collected in 1986 (mean= 9.1 years) were found to be older than those collected in 1995 sample (mean= 8.1 years) (Mann Whitney, U= 835.5, p= 0.003). Age frequency distributions illustrate the higher proportion of females ≤8 years of age in 1995 compared to 1986 (Figure 4). Age data from the remaining years (available only for 1988, electrofishing) indicated no differences between sexes (Mann-Whitney, U= 53.5, p= 0.24). It appears that electrofishing alone did not capture as many Dolly Varden younger than 9 years of age compared to seining/angling (Figure 4). It is unknown whether the observed bimodal distribution in 1995 is an artifact of the combined sampling methods, however the pattern is not observed in 1986 data.

Although no differences were observed between sexes in the sample collected in 1986 by seining/angling from Joe Creek (Mann-Whitney, U= 81.0, p=0.25), males (mean= 5.3 years) collected from Joe Creek in 1995 by electrofishing were significantly younger than females (mean= 6.1 years) (Mann-Whitney, U= 1456.0, p=0.011). Age frequency distributions from both years were similar although there was a higher proportion of males ≤5 years of age in the 1995 electrofishing samples as compared to the 1986 seining/angling sample (Figure 5).

Length-at-age

Evaluating biologically meaningful differences in length-at-age between sexes in the Firth River/Joe Creek was difficult due to low sample size, particularly for males. Length-at-age data of males and females was pooled and qualitatively examined using seining/angling data collected in 1986 and 1995. The sample size of ages from 1988 was too low to examine length-at-age. Although very similar, it appears that Dolly Varden from the Firth River in 1995 had a slightly larger length-at-age suggesting a higher rate of growth compared to 1986 (Figure 6).

Growth of Dolly Varden from Joe Creek did not appear to differ markedly between 1986 and 1995 (Figure 7).

Age-at-maturity

Although the sample size for males among age classes was low, the available information suggests minimum age-at-maturity for Dolly Varden from the Firth River between 1986 and 1995 was six years for males and four years for females (Table 4). Minimum age-a-maturity for males and females was 6 and 4 years, respectively (Table 4). Data from Glova and McCart (1974) indicate that the minimum age-at-maturity of Dolly Varden from the Firth River was approximately four years for both sexes. It should be noted that interpretation is limited by the lack of samples <8 years of age in 1986 and <6 years in 1995. It is possible that maturity for males in 1986 and 1995 may have been attained at a younger age.

Minimum age-at-maturity of Dolly Varden from Joe Creek was approximately five years for males in 1986 and 1995, and six and five years for females in 1986 and 1995, respectively (Table 4) .

Sex ratio

The ratio of male to female Dolly Varden collected from the Firth River indicated a low proportion of males in 1986 (0.29) and 1995 (0.39), and a slightly higher proportion of males relative to females in 1987 (1.26) (Table 2). No significant differences were detected in 1988 and 1989, likely due to low sample sizes. A similar pattern was observed among spawners. Glova and McCart (1974) reported that among anadromous Dolly Varden from the Firth River drainage, females accounted for 65.5% of samples collected. They postulated that more females adopted an anadromous life history since males had the option to become freshwater resident and adopt a “sneaker” reproductive strategy. Generally, twice as many females than males were sampled from Joe Creek in 1986 and 1995 (Table 3).

Spawners

Data on the reproductive status of Dolly Varden from the Firth River were only recorded in 1986, 1988 and 1995. Spawners from the Firth River were generally >400 mm in length (Figure 8) and ≥6 years of age (Table 2; Figure 9). As noted earlier, statistical comparisons between years and sex could only be made for the Firth River in 1986 and 1995 where consistent methods (seining/angling) were used. In 1995, the only year for which statistical comparisons between sexes could be made (due to low sample size), the lengths of male and female spawners were similar (ANOVA, $F= 3.706$, d.f.= 1, 99, $p= 0.06$) although males (10.0 years) were significantly older than females (9.1 years) (ANOVA, $F= 4.22$, d.f.= 1, 84, $p= 0.04$). Comparisons between years could only be made for females (again due to low sample); no differences were observed in the length (ANOVA, $F= 4.22$, d.f.= 1, 84, $p= 0.04$) or age (Mann-Whitney, $U= 689.0$, $p= 0.30$) of females between 1986 and 1995.

Although the majority of spawners from Joe Creek were >400 mm, there were higher proportions of Dolly Varden in spawning condition among smaller size classes (300-309 mm) compared to the Firth River (Figure 10; Table 3). No differences in size were observed between males and females in in 1995 (Mann-Whitney, $U= 1002.5$, $p= 0.61$). Likewise, ages were similar between sexes in 1995 (Mann-Whitney, $U= 678.5$, $p= 0.16$) (Figure 11), the only year where sufficient sample sizes were available for comparison. Evaluation between years should be treated cautiously as different gear types were used to collect samples (seining/angling in 1986 versus electrofishing in 1995). Electrofishing would likely be less size selective and have a higher likelihood of capturing smaller sized fish. Between year differences in males were not

observed for length (Mann-Whitney, U=710.5, p= 0.1). Even though the range of ages are similar, on average, older males were observed in 1986 (mean= 8 years) as compared to 1995 (mean= 6.6 years), however this difference should be interpreted carefully because the 1986 sample size was small, thus precluding statistical analysis. The sample of female spawners collected in 1986 were significantly larger in size (Mann-Whitney, U= 471.5, p= 0.001) and older in age (Mann-Whitney, U= 202.5, p= 0.001) as compared to those collected in 1995 (Figure 10; Table 3).

Babbage River

Evaluating for trends in the biological characteristics of Dolly Varden from the Babbage River among sampling years requires examining data where methodology and timing of fish capture were consistent. Deviation introduces biases related to gear selectivity and possibly the segment of the population that is available for sampling. For example, weirs captured Dolly Varden during a period of migration when the timing of upstream movements by spawners and adult non-spawners (resting), and larger and smaller sized fish is likely stratified (Glova and McCart 1974), while electrofishing was used to sample at the spawning/overwintering area during a period where most of the population was likely concentrated in a small geographic area.

Capture methods and sampling sites that were consistently used on the Babbage River over multiple years include the weir (1990-1992), which was deployed mid-river (N 68° 50’ 22”, W 138° 40’ 05”) in proximity to the confluence of Caribou Creek, and electrofishing (1988, 1990-1992) at the spawning/overwintering area. Data collected using both methods at the two separate locations were used to examine for differences in length and other biological variables between males and females (whenever possible) within and among sampling years.

Population size

One estimate of abundance was generated for the Babbage River in 1991 using Bailey’s triple mark recapture method adjusted for tag loss (Sandstrom et al. 1997). Capture and recapture of Dolly Varden were made using a weir that was operated during the upstream migration between 1990 and 1992. The approximate size, with 95% confidence intervals, of the Babbage River stock was 13,639 (10,615-16,663) fish.

Length

A stratified random dead sample of Dolly Varden captured by weir was taken in 1990 and 1991 while dead sampling in 1992 was completely random (Sandstrom et al. 1997). The biological data from the dead-sample taken in 1990 and 1991 are summarized in Table 5 but were not used for analyses as it is not a representative sample of the population. In 1992, although size ranges were similar, males were larger than females (Mann-Whitney, U= 193619.5, p< 0.001). The length frequency distributions (total live and dead sample) among years were different with 1990 and 1992 demonstrating evident bi-modal distributions between juveniles and adults suggesting variable recruitment among years (Figure 12).

Evaluating differences between males and females captured by electrofishing at the spawning/overwintering area was only possible for 1988 (life history type was described in database) and 1991 (life history was not described but all samples were >300 mm). The remaining years consisted mostly of Dolly Varden <300 mm (life history not described), and when these samples were removed from analyses, the 1990 sample was too small to analyze (n= 4) while only females remained for 1992 and 1993. No differences in mean length were observed between sexes in 1988 (ANOVA, F= 0.021, d.f.=1, 53, p= 0.89). Additionally, length

frequency distributions between sexes in 1988 were similar (Figure 13). However, similar to results from the weir in 1992, males (mean= 519 mm) captured by electrofishing were larger than females (mean= 460 mm) in 1991, although this difference was not statistically compared due to low sample size . Interestingly, males (mean= 539 mm) were also larger than females (mean= 488 mm) in a sample taken by seining at the overwintering area in the fall of 1987 (ANOVA, $F= 59.6$, d.f.= 1, 292, $p< 0.001$). Significant differences in the mean length of female Dolly Varden captured at the spawning/overwintering area by electrofishing were detected among 1988, 1991, 1992 and 1993 sampling years (ANOVA, $F= 192.8$, d.f.= 3, 139, $p< 0.001$). Specifically, length of females increased among sampling years, ranging between an average of 300 mm and 491 mm, although post-hoc analysis revealed no significant difference between 1991 and 1992, and 1992 and 1993. The length frequency of distribution of females indicates a larger proportion of females ≥510 mm in 1993 compared to earlier years (Figure 13). Among year comparisons for males could not be made due to low sample sizes.

Age

No differences in age were observed between males and females captured by weir in 1992 (Mann-Whitney, $U= 2809.0$, $p= 0.37$) (Table 5, Figure 14).

Comparison of median ages between males and females captured by electrofishing was only possible for samples collected in 1988, which demonstrated no difference between sexes (Mann-Whitney, $U= 233.0$, $p= 0.38$). Age data for males captured by electrofishing between 1990 and 1993 at the spawning/overwintering area were absent. The median ages of females captured by electrofishing between 1988 and 1992-1993 were significantly different (Kruskall-Wallis, $H(3)= 74.4$, $p< 0.001$), with the youngest ages observed in 1988 (mean= 4.1 years) and the oldest in 1993 (mean= 8.6 years) (Figure 15). The range of female ages increased from 3-5 years to 6-13 years between 1988 and 1993. The sample size for female ages in 1991 was too low (n= 11) to confidently analyze.

Length-at-age

Qualitative examination of the length-at-age of Dolly Varden captured by weir between 1990 and 1992 suggest that males have a slightly higher rate of growth compared to females, particularly among age classes ≥5 years (Figure 16). Inter-annual variation in length-at-age for males and females appeared minimal (Figure 17). Length-at-age of males and females captured by electrofishing in 1988 appears similar and inter-annual variation appears low, although it is difficult to compare 1988 to the later 1992-1993 samples because age classes do not overlap (Figure 18).

Age-at-maturity

The minimum age-at-maturity for Dolly Varden from the Babbage River was examined using data from samples collected between 1986 and 1993 at the spawning/ overwintering area by electrofishing and the mid-river area using the weir during the return migration from the Beaufort Sea (Table 6). Emphasis was placed on the results from the data collected by weir (1990-1992) as there were a larger number of both age classes and sample sizes available for analysis. Males appeared to mature between 3 and 4 years of age. Females mature at an age similar to males with results suggesting that maturity is attained at approximately age 4. Bain (1974) reported that anadromous male and female Dolly Varden from the Babbage River in 1972 and 1973 started to mature at age 5.

Sex ratio

The ratios of male to female Dolly Varden captured at the spawning area among sampling years were typically skewed towards females (~0.6 males per female) (Table 5). Data from the weir also demonstrated a paucity of males in 1992 (0.68 males per female) while the ratio among spawners followed the same pattern using the total combined sample. Data presented in Bain (1974) indicates that anadromous males were also less frequent (0.47) than females at the spawning area in the early 1970s.

Spawners

Current-year spawners migrating to the spawning area that were encountered by weir ranged from 329 to 661 mm in length and were generally >6 years of age (Table 5). Although dead sampling was not random, interestingly, male current-year spawners captured by weir were significantly larger in length than females in 1990 (ANOVA, $F= 9.65$, d.f.= 1, 54, $p= 0.003$) and 1991 (Mann-Whitney, $U= 3732.5$, $p< 0.001$). The same result was observed with random sampling in 1992 (Mann-Whitney, $U= 29818.0$, $p< 0.001$). No difference in ages was observed between sexes in 1992 (Mann-Whitney, $U= 922.0$, $p< 0.806$).

Sample size was too low to evaluate differences in length and age between male and female spawners captured by electrofishing at the spawning/overwintering area in 1988. The only sampling years where enough female Dolly Varden in spawning condition were captured were 1992 and 1993. No difference in length (ANOVA, $F= 6.92$, d.f.= 1, 80, $p= 0.10$) was observed for females between 1992 and 1993, however, significantly older fish were captured in 1993 (Mann-Whitney, $U= 175.0$, $p= 0.004$) (Figure 19).

Vittrekwa River

Population size

No estimate of abundance exists for Dolly Varden from the Vittrekwa River.

Length

Adult anadromous Dolly Varden (all spawners) from the Vittrekwa River were sampled in 2006 and 2007 using a variety of methods (Table 7). We were unable to differentiate between collection methods among samples in the database and therefore did not conduct statistical analyses. Qualitatively, it appears that the mean and range of lengths between years was similar with males reaching a higher maximum length than females.

Age

Only one adult anadromous Dolly Varden was aged in 2006. It was a 10 year-old female 633 mm in length. Due to the paucity of age information, length-at-age and age-at-maturity could not be examined.

COMPARISON OF BIOLOGICAL CHARACTERISTICS AMONG RIVER SYSTEMS

Comparison of the available biological data among populations of Dolly Varden can provide a means to evaluate differences among river systems. These differences may reflect the natural variation in life history among populations; alternatively they may reflect responses of a stock to harvesting pressure, or a combination of both (which is likely the case). It is difficult to separate the effects of differences in life history characteristics and effects of harvesting when comparing

among populations due to the lack of baseline information, poor understanding of inter-annual variation within each stock, and the unknown dynamic of the response of abundance to different harvest levels.

Emphasis will be placed on comparing populations that appear to have been harvested at a higher level (Big Fish River and Rat River) relative to others that are thought to have had lower harvest pressure (Firth River, Joe Creek and Babbage River) in an attempt to elucidate the effects of population decline on biological parameters. Proper evaluation ideally requires comparable data among systems, consistent methods and timing of sampling events with an adequate sample size, reliable time series abundance estimates, and detailed stock-specific harvest information. Although a complete suite of data are not available for Dolly Varden from all river systems, it was possible to combine data for some sampling years in the 1980s and 1990s where Dolly Varden were collected from spawning/overwintering areas in all systems. Although collection methods were not always standardized among systems and time periods, we pooled and compared data from methods that were most likely to be selective for similar size ranges of fish. Data were grouped into two time periods for comparison among river systems:

1986-1988
Firth River: seining/angling (1986) and electrofishing (1988),
Joe Creek: seining/angling (1986),
Babbage River: seining/angling (1986) and electrofishing (1988),
Big Fish River: seining/angling (1986) and seining/electrofishing (1988),
Rat River: electrofishing (1986 and 1988),

1993-1995
Firth River: seining/angling (1995),
Joe Creek: electrofishing (1995),
Babbage River: electrofishing (1993), (only female spawners were collected)
Big Fish River: seining and electrofishing (1993), and seining (1994),
Rat River: seining (1995) (age and sex/maturity were not recorded).

Additionally, it was possible to examine length information of Dolly Varden from the Babbage and Big Fish rivers that were captured by weirs placed in the mid-river area in 1991.

During these periods of time, sampling was mainly done for the purposes of collecting tissue for genetic studies. There were likely some biases in the selection of sample sizes for males and females (e.g., all 1986-88 data and Babbage River in 1993), however it is thought that the selection of individual fish of a particular sex was random. Therefore, interpretation of sex ratio data should be treated cautiously.

The emphasis can be placed on elucidating differences that are a result of reduced abundance as we have incorporated data from the Big Fish River during a period when it is thought that the population status was declining (late 1980s). It has never been well established whether the decline was a result of harvest levels, habitat change that may have affected carrying capacity, or a combination of both (Sandstrom and Harwood 2002).

The lack of age and sex information for the Rat River in 1995 precludes any comparison of age and sex related metrics among systems during this period of time. Age data from 1993-95 from all systems were presented but not analyzed among males due to low sample sizes.

Population size

There are no abundance estimates available for all stocks in the 1986-88 and 1993-95 time period. Some estimates were generated during or near these periods of time (Table 8). Although variation is high, some overlap in abundance estimates was observed among populations; however, the Big Fish River was considerably lower compared to the Rat and Babbage rivers in the early 1990s.

Length

Length information of Dolly Varden was statistically compared among systems for males and females, and using the total combined sample for the periods of 1986-88 and 1993-95. Comparisons between both time periods using the combined sample were also made.

For the total sample (both sexes combined), significant differences in length were detected among river systems using pooled data from Dolly Varden collected at the spawning/overwintering area between 1986 and 1988 (ANOVA, $F = 48.1$, d.f.= 4, 425, $p < 0.001$) (Figure 20). Pair-wise post-hoc testing revealed no differences in length between the Babbage and Big Fish rivers, and the Rat River and Joe Creek and significant differences among all other pair-wise combinations. The largest Dolly Varden were from the Firth River (mean= 542 mm), followed by the Rat River (mean = 458 mm) and Joe Creek (mean = 394 mm), while the lowest average sizes were observed in the Babbage (mean = 313 mm) and Big Fish (mean = 406 mm) rivers. Interestingly, during this period, local harvesters were reporting a decline in the abundance of Dolly Varden from the Big Fish River.

Similar patterns were observed when males and females were examined separately. Significant differences were observed in males (ANOVA, $F = 8.4$, d.f.= 4, 120, $p < 0.001$) and females (ANOVA, $F = 40.8$, d.f.= 4, 289, $p < 0.001$) among systems using data collected between 1986 and 1988 (Figure 20, Table 9). Post-hoc tests revealed the mean length of male Dolly Varden from the Babbage and Big Fish rivers, and the Firth River and Joe Creek did not differ significantly. Similarly, Dolly Varden from the Rat River were not significantly different from the Babbage and Big Fish rivers, and Joe Creek. All other pair-wise comparisons were significant. The order among systems of largest to smallest males was Firth River, Joe Creek, Rat River, Babbage River and Big Fish River. For females, the only non significant post-hoc comparison among systems was between the Rat River and Joe Creek. The order among systems of largest to smallest for females was Firth River, Rat River/Joe Creek, Babbage and Big Fish. Although there is some variation in ordering, the Firth River consistently had the largest fish, while the Big Fish River had the smallest fish for males, females and the total combined sample.

Greater proportions of smaller size classes (<350 mm) were observed in both the Babbage and Big Fish rivers (Figure 20). Although the reasons for this are uncertain, it is possible that a larger number of juveniles could have been encountered in these systems if a greater range of spawning/overwintering habitat was sampled. Glova and McCart (1974) describe how Dolly Varden are geographically structured with their size/maturity during spawning with spawners occupying habitat upstream of the aufeis area while smolts and resting fish are predominantly found closer to or in the aufeis area. It is possible that sampling in the Babbage and Big Fish rivers occurred over a wide enough area to sample a variety of habitat and collect a wide range of sizes. This may also explain why Dolly Varden from the Firth River appears to have large average lengths. Due to the very large size of the spawning/overwintering area in the Firth, it is possible that only upstream locations were sampled which tend to be dominated by large spawning individuals.

Interestingly, proportions of larger size classes (e.g., >500 mm) were lowest in the Big Fish River. The prevalence of large size Dolly Varden would be less influenced by sampling effort provided that areas upstream of the aufeis field were sampled in each system; this is likely to be the case given that most of the sampling targeted areas with fish in spawning condition. Thus, the lower proportion of large sized Dolly Varden in the Big Fish River may represent a response to the decline in population size. The harvest rates estimated for the Rat River between 1986 and 1988 ranged from 10 and 15% with no indication of population decline based on scientific information (Roux et al. 2012). The length frequency information suggests that the presence of Dolly Varden >500 mm in the Rat River, which accounted for approximately one third of the sample, was not adversely affected at these harvest rates (Figure 20)

Significant differences in length were also detected among river systems using pooled data from the total sample of Dolly Varden collected from the spawning/overwintering area between 1993 and 1995 (ANOVA, $F= 91.1$, d.f.= 4, 1661, $p< 0.001$) (Figure 21). The only non-significant post-hoc comparisons among systems were between the Big Fish River and Joe Creek, and between Firth and Babbage rivers. The largest sized Dolly Varden were from the Firth River (mean= 518 mm), followed by the Babbage River (496 mm), Rat River (mean= 463 mm),Joe Creek (mean= 434 mm), and Big Fish River (mean= 423 mm).

Similar patterns were observed when males and females were examined separately. Differences in mean length among systems were observed in males (Firth River, Joe Creek and Big Fish only) (ANOVA, $F= 19.3$, d.f.= 2, 149, $p< 0.001$), with post-hoc tests demonstrating significant differences between Firth and Big Fish rivers, and Firth River and Joe Creek, and no significant differences between Big Fish River and Joe Creek; the longest Dolly Varden were found in the Firth River and the shortest in Joe Creek/Big Fish River (Figure 21, Table 10). Females among river systems (Firth River, Joe Creek, Babbage River and Big Fish River) also differed in length (ANOVA, $F= 35.2$, 3, 754, $p< 0.001$) with the only non-significant post-hoc comparison being between the Firth and Babbage rivers. The largest females were in the Firth/Babbage rivers, followed by Big Fish River and Joe Creek (Table 10).

Statistically significant differences in length (sexes combined) between 1986-1988 and 1993-1995 were observed in all river systems with the exception of the Rat (ANOVA, $F= 0.017$, d.f.= 1, 549, $p= 0.90$) and Big Fish (ANOVA, $F= 3.9$, d.f.= 1, 955, $p= 0.213$) rivers. Mean length increased in the Babbage River (ANOVA, $F= 41.7$, d.f.= 1, 183, $p< 0.001$), and decreased in the Firth River (ANOVA, $F= 4.6$, d.f.= 1, 216, $p= 0.03$) and Joe Creek (ANOVA, $F= 44.3$, d.f.= 1, 202, $p< 0.001$) (Table 11).

Similar to 1986-88, a relatively large proportion of smaller size classes (<350 mm) was observed in the Big Fish River compared to other sites in 1993-95. Interestingly, a considerably larger proportion of Dolly Varden >500 mm were observed in the Big Fish River in 1993-95 (19.5%) compared to 1986-88 (3.8%), suggesting more fish were able to attain larger sizes and reproduce. Not as many juveniles were sampled in the Babbage River in 1993-95 compared to 1986-88 although this is likely due to limited sampling effort in 1993-95 which consequently increased the average length observed in the sample. Conversely, a higher proportion of juvenile Dolly Varden were collected in the Firth River and Joe Creek in 1993-95 compared to 1986-88. Similar to 1986-88, the proportion of large size Dolly Varden in the Rat River in 1993-95 accounted for approximately one third of the sample when harvest rates were between 13 and 17% (Roux et al. 2012).

It appears that in the late 1980s and early to mid-1990s, Dolly Varden from the Firth River were consistently the largest in size while those from the Big Fish River remained among the smallest.

The length frequency distributions of Dolly Varden captured by weir in the Babbage (mean= 466 mm) and Big Fish (mean= 450 mm) rivers in 1991 were compared by Sandstrom and Harwood (2002) who noted that a lower frequency of fish >500 mm were observed in the Big Fish River compared to the Babbage River (Figure 22). The lower proportion of larger-sized Dolly Varden in the Big Fish relative to the Babbage may suggest a response in the size demographics of the Big Fish River population due to harvest or spawning/overwintering habitat loss. It should be noted that attempts to use a weir on the Big Fish River to enumerate the population were unsuccessful due to wash-out nor did it operate during similar periods (i.e., from July to September compared to August and September at the Babbage River). Although male Dolly Varden from the Big Fish River encountered by the weir appear to have a narrower range of sizes and lower mean and modal ages than the Babbage, comparisons should be treated cautiously.

Age

Age information of Dolly Varden was statistically compared among systems for males and females, and using the total combined sample for the periods of 1986-88 and 1993-95. Age data in 1993-95 was only available from the Firth River, Joe Creek, Big Fish River and Babbage River (females). Comparisons between both time periods using the combined sample were also made.

For the total sample (both sexes combined), significant differences in age were detected among river systems using pooled data from Dolly Varden collected from the spawning/overwintering area between 1986 and 1988 (Kruskall-Wallis, $H(4)= 95.0$, $p< 0.001$) (Figure 23). Results of non-parametric post-hoc tests between systems using a corrected □ of 0.005 indicate no significant differences between the Firth River (mean= 9.7 years) and Joe Creek (mean= 8.6 years), the Big Fish River (mean= 7.4 years) and Joe Creek, and the Big Fish River and the Rat River (mean= 6.8 years), and significant differences among all other pair-wise combinations. The oldest average age of Dolly Varden were found in the Firth River while the youngest were in the Babbage (mean= 5.9 years)

Differences among systems were also detected when males (Kruskal-Wallis, $H(4)= 20.1$, $p< 0.001$) and females (Kruskal-Wallis, $H(4)= 80.0$, $p< 0.001$) were examined separately. In males, significantly older Dolly Varden were found in the Firth River (9.5 years) as compared to the Babbage (5.9 years), Big Fish (6.6 years) and Rat (6.5 years) rivers, while no post-hoc differences were observed between all other pair-wise comparisons (Table 9; Figure 23). Similar to males, significantly older female Dolly Varden were found in the Firth River (9.8 years) as compared to the Babbage (6.0 years), Big Fish (7.8 years) and Rat (6.9 years) rivers, while no differences were observed between Joe Creek and the Big Fish River, and between Babbage River and Rat River (Table 9; Figure 23). All remaining pair-wise comparisons were significantly different.

Age frequency distributions using data collected from spawning/overwintering areas between 1986 and 1988 demonstrate higher proportions of age classes ≥10 in samples collected from the Firth River (56.9%) and Joe Creek (34.4%) compared to other systems (Babbage= 11.1%, Big Fish= 9.1% and Rat= 2.4%) while a proportionately higher number of younger ages (≤5) were observed in the Babbage River (54.4%) compared to other systems (Firth= 17.9%, Joe= 6.3%, Big Fish= 16.4% and Rat= 11.0%) (Figure 23). Modal values between males and females were similar in the Firth (10 and 9 years, respectively), Babbage (4, 4-5 years, respectively), and Rat (7 years) rivers. Noticeable differences were observed in Joe Creek where multiple modes were observed among males (6, 7 and 11 years) while the female mode was 9 years. Compared to females, a greater abundance of young males was observed in the Big Fish River, with modal values for males and females equal to 6 and 9 years, respectively. The poor

representation of older age classes in the Big Fish and Rat rivers that are thought to have experienced higher rates of fishing compared to other populations suggest the presence of older age classes in a population may provide a more sensitive indication of population status for Dolly Varden compared to length information.

Significant differences in age were detected among river systems (excluding the Rat River) using data from female Dolly Varden (males not included due to low sample sizes) collected from the spawning/overwintering area between 1993 and 1995 (Kruskall-Wallis, $H(3)= 45.6$, $p< 0.001$). Results of non-parametric post-hoc tests (corrected α of 0.005) between systems indicated no differences between Firth and Babbage Rivers, which had the highest average ages, and no differences between Joe Creek and Big Fish River, which had the lowest average ages. All other pair-wise tests were statistically significant.

Age frequencies of females in 1993-1995 show a higher proportion of fish ≥10 years of age in the Firth River (30.2%) compared to other systems (Joe Creek= 9.6%, Babbage River= 24.4% and Big Fish River= 21.5%) (Figure 24). No Dolly Varden ≤5 years of age were observed in the Babbage while these age classes accounted for nearly a quarter of the samples in Firth River (23.3%) and Joe Creek (24.1%), and almost half (47%) in the Big Fish River. With the exception of the Babbage River, Dolly Varden samples collected between 1993-95 had a higher proportion of younger age classes compared to those collected in 1986-88.

Statistically significant differences in age (sexes combined) between 1986-1988 and 1993-1995 among the river systems were observed. A significant decrease in median age was observed in the Firth River (Mann Whitney, $U= 821.5$, $p< 0.001$), Joe Creek (Mann Whitney, $U= 713$, $p< 0.001$), and Big Fish River (Mann Whitney, $U= 2329$, $p= 0.001$). From 1986-88 to 1993-95, the mean age decreased more substantially in the Big Fish River (2.7 years) compared to the Firth River (1.5 years) (Table 11). The only statistically significant increase in age from 1986 to 1993-95 was observed in the Babbage River, which demonstrated a change of 2.7 years (Table 11).

Based on the 1986-88 and 1993-95 data, it appears that the decline in population observed in the Big Fish River was accompanied by a decline in the proportion of older age classes while the range of ages did not change. A lower proportion of fish ≥10 years of age were also observed in the other harvested system, the Rat River.

Length-at-age

Growth information of Dolly Varden among systems were visually assessed for males and females, and using the total combined sample for the periods of 1986-88 and 1993-95. Age data in 1993-95 was only available from the Firth River, Joe Creek and Babbage River (females). Comparisons between both time periods using the combined sample were also made. The growth rates were not statistically examined due to low samples sizes among males and relatively low sample sizes among older age classes of females.

The growth of males among river systems collected at the spawning areas between 1986-88 did not demonstrate noticeable differences at younger ages (Figure 25). However, Firth River samples appeared to reach greater size at age among older (≥9 years) age classes. Females showed clearer patterns of differences in growth among populations due to decreased variation as a result of higher sample sizes (Figure 25). Females from the Rat and Firth River had similar mean length-at-age values which were higher than the other systems, particularly the Big Fish River which had the lowest length-at age. No apparent differences were evident between males and females from the Firth River/Joe Creek, Babbage River and Rat River. Conversely, it appears that males from the Big Fish River had higher rates of growth than females. The

combined data indicate a similar pattern to what was observed in females (Figure 25), which is not surprising as sample sizes were higher among females than males.

Although the data collected between 1993-95 is limited in terms of among-system comparisons it is still useful for several systems. Males in the Firth River and Joe Creek were not noticeably different with respect to mean length-at-age. In contrast, females from the Firth were higher than Joe Creek and Babbage River. The combined data indicate a similar pattern to what was observed in females (Figure 26).

Comparisons between the 1986-88 and 1993-95 time periods among Firth River, Joe Creek and Babbage River reveal no noticeable differences except for the Big Fish River (Figure 27). The Firth River, Joe Creek and Babbage Rive are thought to have been harvested at a much lower level compared to the Big Fish and Rat rivers. These data suggest that there has not been any factor, environmental or anthropogenic, that has influenced the growth pattern of Dolly Varden from the Firth River, Joe Creek and Babbage River between 1986-88 and 1993-95. During the decline in population abundance of Big Fish River during the late 1980s, growth rate was lowest relative to other populations, suggesting a response to the reduction in numbers or possibly to changes in the environment. Additionally, length-at-age for Dolly Varden in the Big Fish River appeared lower in 1986-88 compared to 1993-95 (Figure 27). It should be noted that in the early 1990s, Sandstrom (1995) found no differences in female growth between the Babbage and Big Fish rivers (samples collected between 1991 and 1993).

Recent data is only available from the Rat River and although samples were collected from the harvest monitoring program using gill nets set in the Husky channel of the Mackenzie River, mouth of the Rat River and the Rat River proper. Increased growth rates of Rat River Dolly Varden have been recently observed (Sandstrom et al. 2009). Comparing length-at-age data collected in 2007 to other systems (1986-88 sampling years) it appears that Dolly Varden from the Rat River now have a similar rate of growth to the Firth River in the 1980s (Figure 25). Sandstrom et al. (2009) state that the increased growth is due to earlier ice free periods in the Beaufort Sea resulting in better foraging opportunities for Dolly Varden. It is currently unknown if Dolly Varden from the Firth River have also experienced an increase in growth rate.

Age-at-maturity

The age-at-first-maturity of female Dolly Varden among river systems in both 1986-88 and 1993-95 were relatively similar, typically ranging between 4 and 6 years of age (Table 12). In females, differences were observed among populations between the 1986-88 and 1993-95 sampling period with a decline in age-at-first-maturity ranging between three to one years in the Firth River, Joe Creek and Big Fish River, and an increase by two years in the Babbage River. The age-at-first-maturity of male Dolly Varden among river systems in both 1986-88 and 1993-95 were relatively similar among most populations, typically ranging between 5 and 8 years of age, with the exception of the Babbage which had some males mature at age 3 (1986-88 only) (Table 12). With the exception of Joe Creek, differences were observed in males among populations between the 1986-88 and 1993-95 sampling period, however the extent was not as great as in the females. Age-at-first-maturity declined by two years in the Firth River and one year in the Big Fish River.

Sex ratios

There was a consistent paucity of males compared to females among all the river systems examined based on the data from the combined total sample of males and females captured from the spawning/overwintering areas between 1986 and 1988 (Table 9) and 1993 and 1995 (Table 10). Although the Big Fish River population was experiencing a decline in the 1986-88

time period, the ratio of male:female (0.40) was not lower or higher than other stocks that were thought to have a stable population such as the Firth River (0.27) and Babbage River (0.68). Interestingly, the Big Fish River had a particularly low proportion of males (0.12) in the 1993-95 sample during a period when the population size remained small.

Spawners

The length of spawners among river systems captured at the spawning/overwinterng sites between 1986 and 1988 differed for both males (ANOVA, F= 4.6., d.f.= 4, 78; p= 0.002) and females (ANOVA, F= 4.6., d.f.= 4, 213, p< 0.001) (Table 9). Post-hoc tests revealed that the only significant differences in males were when the Big Fish (mean= 430 mm) and Rat (mean= 444 mm) rivers, both among the smallest in mean length, were compared to the Firth River (mean= 541 mm), which had the largest mean length. Female spawners were significantly the longest in the Firth River (mean= 547 mm) and the shortest in the Big Fish River (mean= 426 mm), while no differences were observed among Joe Creek (mean= 500 mm), Babbage River (mean= 468 mm) and the Rat River (mean= 469 mm). Length frequency distributions illustrate the larger sizes (>500 mm) that characterize spawners at the Firth River (81.2%) and Joe Creek (63.5%) while the lowest proportion of large size spawners were observed in the Big Fish River (5.5%) (Figure 28). The proportions of large size spawners were intermediate for, and similar, between the Babbage (28.5%) and Rat (33.7%) rivers in 1986-88. Populations other than the Firth River had a range of smaller sizes that overlapped considerably with modal values ranging between 400 and 500 mm.

The length of spawners among river systems captured at the spawning/overwinterng sites between 1993 and 1995 differed for both males (ANOVA, F= 26.4, d.f.= 2, 113, p< 0.001) and females (ANOVA, F= 58.9, d.f.= 3, 645, p< 0.001) (Table 10). Post-hoc pair-wise tests of females captured at the spawning/overwintering areas between 1993 and 1995 (excluding the Rat River) were all significant except for the Big Fish River and Joe Creek (Figure 29). Of the three sites available for males (Firth River, Joe Creek and Big Fish River), the only non-significant post-hoc tests were between Joe Creek (mean= 455 mm) and Big Fish River (mean= 504 mm), while the largest male spawners were in the Firth River (mean= 572 mm) (Figure 29).

Significant differences in the age of spawning males captured among sites between 1986 and 1988 were detected (Kruskall-Wallis, H(4)= 16.6, p= 0.002) with significant pairwise differences observed between the Firth (mean= 9.9 years) and Big Fish (mean= 6.9 years) rivers, and the Firth and Rat rivers (mean= 6.2 years) (Figure 30). All other pair-wise tests between systems for male spawners were not significant. Significant differences in the age of spawning females among sites were also observed (Kruskall-Wallis, H(4)= 56.1, p< 0.001). Females from the Firth River (mean= 9.8 years) were significantly older than all other sites except for Joe Creek (mean= 9.2 years), while females from the Rat River (mean= 7.1 years) were younger compared to Joe Creek and Big Fish (mean= 8.4 years) rivers. Females from Joe Creek were significantly older than Babbage River (mean= 8.5 years). All other pair-wise comparisons were not significantly different.

Too few data were available for among-system comparisons of age for males captured between 1993-95. Significant differences were observed among sites for females (Kruskall-Wallis, H(3)= 45.6, p= 0.001), with only the pair-wise comparison between the Firth (mean= 9.1 years) and Babbage (mean= 8.5 years) rivers, and Joe Creek (mean= 6.9 years) and Big Fish River (mean= 7.1 years) being non-significant (Figure 31). Among female spawners between 1993-95, the lowest ages were observed in the Big Fish River (mean= 7.1 years) and Joe Creek (mean = 6.1).

There were many similarities among sites for males and females, although a greater number of significant pair-wise differences were observed in females. Consistent differences between the length and age for largest/oldest and smallest/youngest averages were observed, although females from the Big Fish were the smallest while those from the Rat River were the youngest. The length and age of male and female spawners from the Big Fish River between 1986 and 1988 were either the lowest or among the lowest compared to other sites, which may reflect the declining status of the stock during this period.

The ratio of male to female spawners among river systems demonstrated a pattern similar to that observed in the total sample (all maturities combined). Generally, there were more females spawners than male spawners in 1986-88 and 1993-95 with the Big Fish River demonstrating a particularly low occurrence of male spawners (0.09) in 1993-95 following the decline in population abundance. It should be noted that in 1986-88, the male:female sex ratio of spawners was similar between the Firth (0.24) and Big Fish rivers (0.25).

Among-system comparison synopsis

It is difficult to draw a definitive conclusion in the response of Dolly Varden populations to declines in population size, particularly due to harvest, using the available data. When biological characteristics of a system experiencing a decline were compared to other systems that were considered stable, some differences were observed which may be attributed to the decline. Some indication was observed from the Big Fish River that declines over a short period of time resulted in a decrease in the proportion of large sized (e.g., >500 mm) and older fish (>10 years), a decrease in average size and a decreased growth rate. There was some indication of a decrease in the proportion of spawning males which was also observed in the Rat River in the decline observed in 2004 (Roux et al. 2012). It was difficult to evaluate the response of Dolly Varden from the Rat River to the harvest levels in the late 1980s and early 1990s. Mean length of males and females, and the proportion of large size fish the Rat, appear to be intermediate between systems with high and low harvest rates. However, the mean length of male spawners was low and similar to the Big Fish River. There appears to have been no change in length characteristics in the Rat between 1986-88 and 1993-95. In contrast, age characteristics from the Rat River suggested not as many older fish were present which was similar to the pattern observed in the Big Fish River. Evaluating these changes in population demographics while comparing with other populations should be treated cautiously as baseline information among all the populations is lacking that could indicate pre-existing differences due to variation in life history.

HARVEST INFORMATION

Anadromous Dolly Varden have been harvested from spawning/overwintering areas and along the Beaufort Sea coast for subsistence, commercial and recreational purposes, and for scientific sampling. Currently no or occasional harvesting occurs at some spawning/overwintering areas (K. Bill pers. comm.) and there is no commercial fishing. Commercial fishing occurred on a relatively small scale for a short duration in the mid-1960s (see Baker 1987 and Papik et al. 2003 for details). Recreational fishing is currently popular on the Firth River and is regulated by Parks Canada. The recreational catch and possession limit in the park is both 3, while outside of the park along the North Slope it is 5 and 10, respectively. Currently, the majority of harvesting occurs for subsistence by Inuvialuit and Gwich'in along the Beaufort Sea coast during the summer, in a mixed stock fishery, or in the channels of the Mackenzie River or Rat River during the return migration of Dolly Varden. Some Canadian Dolly Varden are also harvested in subsistence coastal fisheries in Alaska (Krueger et al. 1999). Papik et al. (2003) provides a synopsis on fishing activities and its importance to the Inuvialuit gathered from

discussion with knowledgeable fishers and elders while Haszard and Shaw (2000) report how Dolly Varden are an important resource for the Gwich'in.

Big Fish and Rat rivers

Stocks of Dolly Varden from the Big Fish and Rat rivers have sustained subsistence fishing activities for over a period >40 years, although the population decline in the 1980s resulted in a closure of the Big Fish River between 1987 and 1991 (DFO 2003). Recently, a decline in the Rat River population prompted a voluntary cessation of harvesting, with the exception of samples collected for monitoring purposes between 2006 and 2008. Harvest information for Dolly Varden from the Big Fish and Rat rivers are summarized in Gallagher et al 2011 and Roux et al 2012, respectively. There has been relatively little harvest of Dolly Varden from the Babbage River and Firth River/Joe Creek populations (DFO 2003).

Firth River/Joe Creek

Papik et al. (2003) reported that one person recalled that the Firth River was fished by Alaskans during the winter in the 1930s in times of hardship. In addition to harvest for subsistence, the small commercial fishery that operated along the Beaufort Sea coast during the mid-1960s may have also harvested Dolly Varden originating from the Firth River and Joe Creek (DFO 2003). Sampling for scientific studies began in the early 1970s (Glova and McCart 1974) and have occurred intermittently up to 1995. Average annual recreational harvests by sport fishers in the Firth River was equal to 91 Dolly Varden between 1988 and 2001 (range= 38-126) (J.B. Eddy unpubl. data). Currently, Parks Canada voluntarily keeps track and reports the annual harvest of anglers to Fisheries and Oceans Canada.

Babbage River

In the past, Dolly Varden from the Babbage River were fished by residents of Phillips Bay (Niaqulik Point) (Papik et al 2003) while the stock was also fished by travelers from/to Alaska and Beaufort Sea camps or en route to Aklavik (DFO 2003). Subsistence harvests from the river were reported in 1994 (n= 101 Dolly Varden) and 1999 (n= 350 Dolly Varden). The Department of Fisheries and Oceans Canada has no available harvest data for Dolly Varden from the Babbage River since 1999. A small commercial fishery that operated along the Beaufort Sea coast in the mid-1960s likely harvested Dolly Varden from the Babbage River population (DFO 2003). This commercial fishery removed approximately 7,300 kg of Dolly Varden in 1965 and 363kg in 1966 (Baker 1987, DFO 2003). Currently, the Babbage River stock is believed to be lightly exploited by sport fishers visiting Ivvavik National Park or Parks Canada staff (DFO 2003), but no numbers are available. It is also likely that some Dolly Varden at the overwintering area are harvested although harvest numbers have not been reported to Fisheries and Oceans Canada (K. Bill pers. comm.). Sampling for scientific research began in 1972 (Bain 1974) and has occurred intermittently until 1993, although live sampling of Dolly Varden occurred in brackish water (Phillips Bay) near the mouth of the Babbage River in 2007 and 2008 during the summer (J. Johnson, pers. comm.).

Beaufort Sea coast

The fishery along the Beaufort Sea coast is a mixed stock fishery consisting of Dolly Varden from the multiple river systems (Krueger et al. 1999, DFO 2003). Available harvest information for Dolly Varden in the Beaufort Sea is presented in Table 13 along with more recent (2006-2008) data. Some of the traditional coastal fishing sites along the Yukon North Slope are shown in Figure 32, while Papik et al. (2003) provides additional detailed descriptions of traditional fishing sites along the North Slope. Numbers of Dolly Varden harvested along the coast vary

among years and are incomplete, since not all harvests were reported annually (DFO 2003, K. Bill pers. comm.).

There are no numbers for Canadian Dolly Varden harvested in Alaskan waters. Krueger et al. (1999) demonstrated that Dolly Varden from the Firth and Babbage rivers contributed up to 25% of Dolly Varden catches in some coastal Alaskan locations. Their study also showed that a large percentage (65%) of Dolly Varden from United States Arctic Refuge populations was found in samples taken at Phillips Bay.

Little is known on the contributions of different Dolly Varden populations to the mixed stock coastal fisheries. The relative contributions of Big Fish and Rat river stocks to the Shingle Point harvest were estimated to be 50% each (Harwood 2001, Sandstrom and Harwood 2002). Catches at Phillips Bay and Herschel Island were typically assumed to consist of Babbage River and Firth River/Joe Creek Dolly Varden, respectively. Tagging data however has shown that Babbage River Dolly Varden are also found in the catch at Shingle Point during summer (DFO 2003b).

Length and age data for Dolly Varden collected from the Beaufort Sea are summarized by year and location in Table 14 and further compiled by sex in Table 15. Size frequency distributions of Dolly Varden caught in Phillips Bay in 1986 and 2007 differ among summer months (Figure 33). In both years, greater proportions of smaller sized Dolly Varden were caught in July (or in both June and July) relative to August, when comparatively larger mean and modal lengths are observed. Among sites along the Beafort Sea Coast some differences in length characteristics are observed (Figure 34). No Dolly Varden larger than 360mm were caught in gillnets at Herschel island in 1988, while larger sized individuals were predominant in 1989 (Figure 34). At Shingle Point, length distributions of Dolly Varden caught in subsistence fisheries in 1993 and 1994 were significantly different (Kolmogorov-Smirnov test $D= 0.387$, $p< 0.0001$) suggesting either that there are annual differences in the size structure of Dolly Varden feeding along the coast in August or it could reflect the use of different sized gillnet mesh between years. The majority (>50%) of Dolly Varden collected in subsistence harvests at King Point in 1994 were ≥600mm in length (Figure 34).

RESIDENT LIFE HISTORY TYPE

Data available for the resident life history type of Dolly Varden is very limited and cannot be used for assessment purposes. The information presented is intended to provide a basic description of biological characteristics. Data collections for resident Dolly Varden among river systems are summarized in Table 16. In each river, resident males were found co-occurring with the anadromous life history type.

Population size

No population size estimates have been calculated for any of the populations except for the Firth. Glova and McCart (1974) estimated that there may be over 860,000 stream-resident Dolly Varden, including young-of-the-year, in the upper Firth River area. This number was calculated based on density estimates from mark-recapture studies.

Length, age, growth and maturity characteristics

Summary statistics of length and age for each population were tabulated by year with maturity information in Table 17.

The maximum fork length recorded for a resident male Dolly Varden was 333 mm (4 years-old), while the oldest sample was 11 years-old, both from Joe Creek. The length and age frequency distribution of resident and anadromous male spawners are presented in Figures 35 and 36. The length frequency distributions by populations clearly demonstrate the smaller size and distinct size range (130-300 mm) of resident male spawners relative to the anadromous fish. The length distribution of resident spawners from Joe Creek overlapped slightly with anadromous spawners from the same system while the smaller range of lengths (130-220mm) of resident spawners observed in the 1988 Babbage River sample could be a result of small sample size. Age frequency distributions overlapped between resident and anadromous male spawners (Figure 36). Mean and modal ages of resident male spawners varied between 3 and 4 years among populations. Resident male spawners older than 6 years of age were only observed in the Big Fish and Vittrekwa rivers.

Mean length-at-age of resident male Dolly Varden is compiled by river in Table 18. Despite low sample numbers, these data demonstrate the slower growth of resident males compared to anadromous male Dolly Varden.

Nearly all resident males were current-year spawners, except for a few juveniles and resting adults collected in the Firth River and Joe Creek in 1986 and 1995.

Ratio of resident to anadromous male spawners

Resident male Dolly Varden are known to spawn with anadromous Dolly Varden. Ratios of resident to anadromous male spawners were compiled for each population for years when both life-history types were collected (Table 19). The results indicate that the ratio of resident to anadromous male spawners can be highly variable over time in different stocks. Resident spawners outnumbered anadromous spawners in 1988 in the Babbage and Firth rivers, in 1986 in Joe Creek, and in 2006 and 2007 in the Vittrekwa River. Lower ratios of resident spawners were observed in the Big Fish River (1988), and Firth River/Joe Creek (1995). The abundance of resident male Dolly Varden in the Vittrekwa River sample suggests that this life-history type is an important contributor to the spawning component of this population. Conversely, few resident Dolly Varden were sampled at the Rat River in 1989 suggesting they may not be as important a contributor to the spawning component of the population. These results however should be interpreted cautiously due to low sample sizes and the use of different sampling gear in certain years which likely effect vulnerability.

Harvest information

No harvest information for resident Dolly Varden is available from any of the river systems. Due to the relatively small size of these Dolly Varden, they are likely not targeted by harvesters.

ISOLATED LIFE HISTORY TYPE

Biological information was available for four populations of isolated northern form Dolly Varden (Table 20). Isolated Dolly Varden from the Babbage and Big Fish rivers have been shown to be both genetically and meristically distinct from downstream (below-falls) anadromous and resident Dolly Varden (Reist 1989). A population inhabits the Blackstone River in the Peel basin and is likely isolated by distance (Reist and Sawatzky 2010). The fourth population is found in the Gayna River (lower Mackenzie basin) and is also isolated by waterfalls (N. Mochnacz pers. comm.).

Population size

No population size estimates have been calculated from any of the populations.

Length, age and growth characteristics

Summary statistics of length and age for each isolated Dolly Varden population are presented by year in Table 22, and by sex in Table 23. Average lengths-at-age of both sexes are presented in Table 24 and demonstrate that the growth of isolated Dolly Varden is slower than the anadromous life history type yet similar to residents. Data collected in the Blackstone and Gayna rivers indicated that isolated males may be growing faster than isolated females after reaching 5 or 6 years of age. Length and age characteristics of current-year spawners among populations are summarized in Table 25.

The maximum length recorded for an isolated male Dolly Varden was 440 mm (4 years-old) in the Blackstone River while the maximum length recorded for an isolated female Dolly Varden was 288 mm (7 years-old) in the Gayna River (Table 25). These results could suggest that isolated male Dolly Varden may reach larger sizes than females. The maximum age recorded in both males and females was 10 years, and was observed in the Blackstone River (male) and in the Gayna River (female) (Table 25). Female spawners were comparatively smaller and younger in the Babbage River, while the average length and age of male spawners were lowest in the Big Fish River.

Length and age frequency distributions (sexes pooled) are shown by year for each population in Figures 37 and 38, respectively. A greater range of sizes were caught in gillnets in the Blackstone River in 1992, with a modal length of 170 mm and a modal age of 4 years. No Dolly Varden >260 mm were caught by seining or electrofishing in the Babbage and Big Fish rivers in 1986 and 1988. The ages ranged between 1 and 7-8 years in these populations while only adult Dolly Varden (≥4 years) were collected from the Gayna River. Samples from the Gayna River had modal length ranging from 220 mm to 260 mm between 2006 and 2007 while modal age varied from 8 to 4 years.

Maturity and sex ratios

Only limited maturity data were available for isolated Dolly Varden. Proportions of sexually mature individuals by age class are shown in Table 26, however these results should be interpreted cautiously due to low sample sizes. Age at maturity appears to be lowest in the Babbage River for females, and in the Big Fish River for males. Dolly Varden from the Blackstone River appear to be maturating at a slightly older age (4 years for both male and female) relative to Babbage and Big Fish rivers. Dolly Varden from the Gayna River cannot be compared to other populations because only fish ≥4 years of age were collected from the system.

Variable male to female sex ratios characterize isolated Dolly Varden populations, although differences were not statistically significant (Table 27). Samples size were too low to test for differences in proportion between males and females in the Gayna River.

Harvest information

No harvest information for isolated Dolly Varden is available from any of the river systems. Due to the relatively small size and degree geographic seclusion of these Dolly Varden, they are likely not targeted by harvesters.

CONCLUSIONS

Biological data has been sporadically collected from known populations of northern form Dolly Varden in Canada. Most of the information collected has been on the anadromous life history type which is important for the diet of Inuvialuit and Gwich'in peoples. Data has been collected intermittently among most river systems although rivers that have or continue to sustain important subsistence fisheries have a longer history of study such as the Rat and Big Fish rivers. Populations have generally been studied since the 1970s while most available archived data sets generally span between 1986 and 1995 and are currently outdated, with the exception of the Rat River, Vittrekwa River (1999, 2006-2007) and along the coast near the Babbage River (2007 and 2008). The paucity of information collected over time from the Firth River/Joe Creek, Babbage and Vittrekwa rivers does not permit analyses of trends in biological parameters over time that would allow for an assessment. Conclusions should be treated cautiously due to low sample sizes and inconsistent sampling methods. The most comparable period of time when samples were collected from most river systems was between 1986-1988 and 1993-1995.

Evaluating trends over time within a river system using biological characteristics such as length, age, sex and maturity are limited due to differences in the capture methods and timing of sample collections. The synthesized information suggests some differences in length, age, growth and reproductive characteristics among anadromous populations. Larger size and older ages are attained in the Firth River compared to Joe Creek and other populations. No differences in mean length were detected between males and females from the Firth River and Joe Creek. A similar pattern was observed in the Babbage River in 1988 (electrofishing), while males were larger than females in 1992 (weir and electrofishing). Growth was similar between the sexes in the Firth River and Joe Creek, while males from the Babbage appear to grow faster than females. Compared to other systems, males also demonstrated a higher rate of growth than females in the Big Fish River, while similar length-at-age values between sexes were observed for Dolly Varden in the Rat River. Among populations, anadromous adults of both sexes had higher mean length-at-age in the Babbage and Firth rivers, while younger (age 3) Dolly Varden currently appear to be growing faster in the Rat River compared to other systems in the 1980s. Age structure was similar between males and females in the Firth River, Joe Creek and Babbage River, with the exception of younger males observed in Joe Creek in 1995. The proportion of females is typically twice that of males among populations.

There were differences in the mean length and age of anadromous spawners among populations. The mean length of spawners was highest in the Firth and Vittrekwa (although sample size was low) rivers, and lowest in the Big Fish River. Spawners of both sexes were on average older in the Firth River compared to other stocks. The mean age of female spawners was lowest in the Rat River and Joe Creek compared to all other populations. The minimum age-at-maturity of Dolly Varden in 1986-88 ranged between 3-6 years of age for males and 4-6 years for females. The sex ratios of spawners were variable but appeared to favor females.

Evaluating the response of biological characteristics of Dolly Varden to population declines is difficult mainly due to lack of comprehensive time-series information on assessment and harvest. Changes observed in the Big Fish River a few years after it experienced a sustained decline included a decrease in the proportion of large size Dolly Varden (≥500 mm), decreased size-at-age (growth rate), and a decrease in the proportion of spawning males. Although the Rat River likely also experienced relatively high harvest rates compared to other populations, the population abundance between the late 1980s and early 1990s did not appear to change nor were there any indications in the length information that suggested excessive harvesting.

Alternatively, age data indicated that the population did not have as many older age classes which may have been a result of harvesting pressure.

The harvest of Dolly Varden mostly occurs for subsistence purposes along the Beaufort Sea coast in the Inuvialuit Settlement Region in a mixed stock fishery, although the contribution of each stock to the fishery is unknown. However, it has been estimated that, for example, the composition of fish harvest at Shingle Point is from the Big Fish (50%) and Rat (50%) rivers, although other stocks have been shown to contribute to the harvest. Harvesting at Herschel Island is thought to remove Dolly Varden from the Firth and Babbage river stocks. Additional subsistence harvesting occurs in the Mackenzie Delta, Rat River and lower reaches of the Peel River. Harvest in the Firth and Babbage rivers is considered to be low. The current harvest (what is being reported) appears lower compared to 40 years ago.

Relatively little information exists on resident and isolated Dolly Varden. These fish are smaller in size, have slower growth and do not attain similar maximal ages compared to anadromous Dolly Varden. Inconsistent relative abundance of male resident Dolly Varden among locations with anadromous life history types may suggest variability in their importance towards reproductive success of the stock. Isolated Dolly Varden attain similar sizes and length-at-age compared to resident fish. Similar to anadromous Dolly Varden, isolated samples demonstrate variable sex ratios among populations.

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Figure 1. Rivers inhabited or likely inhabited (Fish River) by northern form Dolly Varden in Canada.

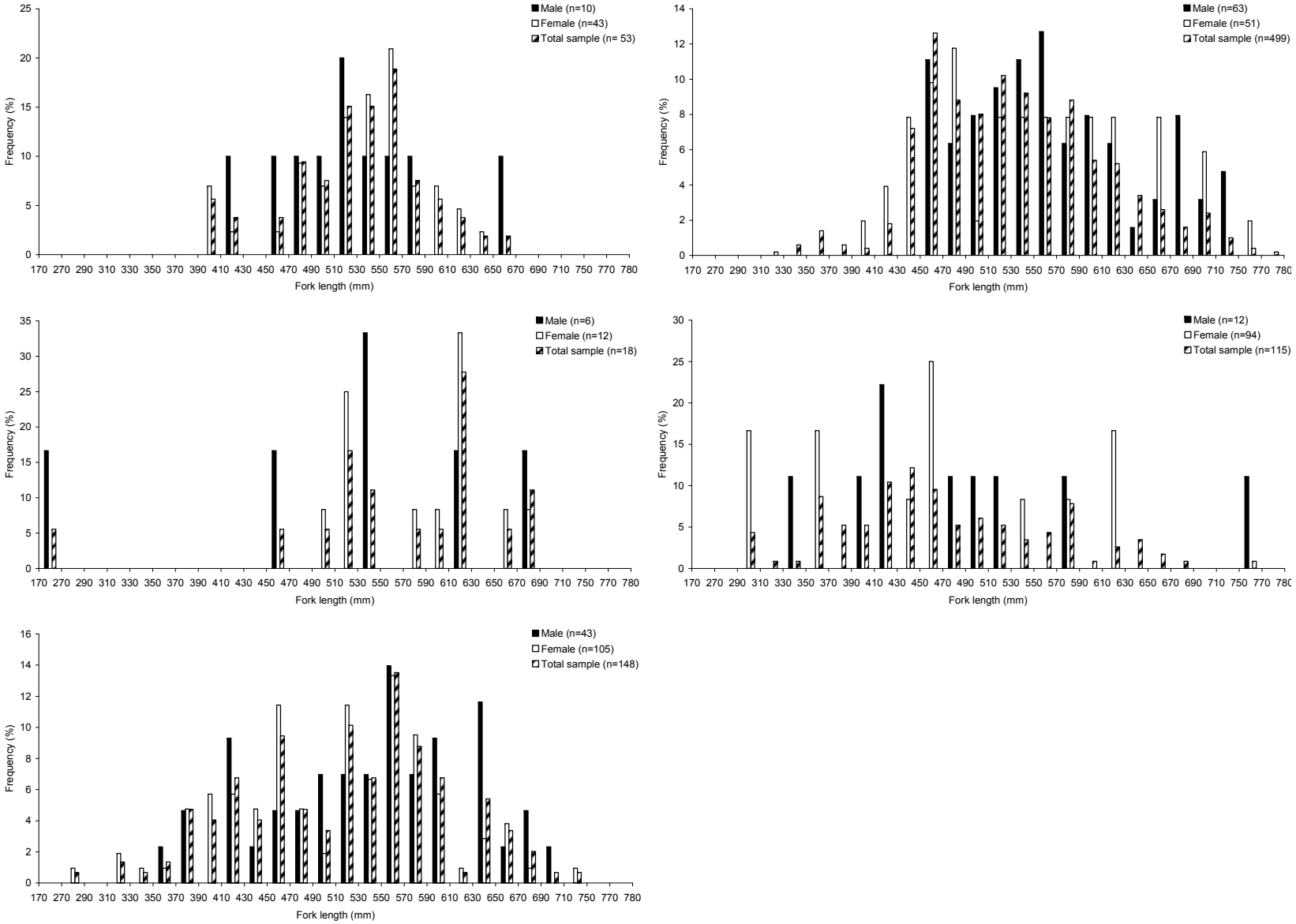


Figure 2. Fork length frequency distributions of Dolly Varden captured from the Firth River in A) 1986 (seining/angling), B) 1987 (angling), C) 1988 (electrofishing), D) 1989 (seining) and E) 1995 (seining/angling).

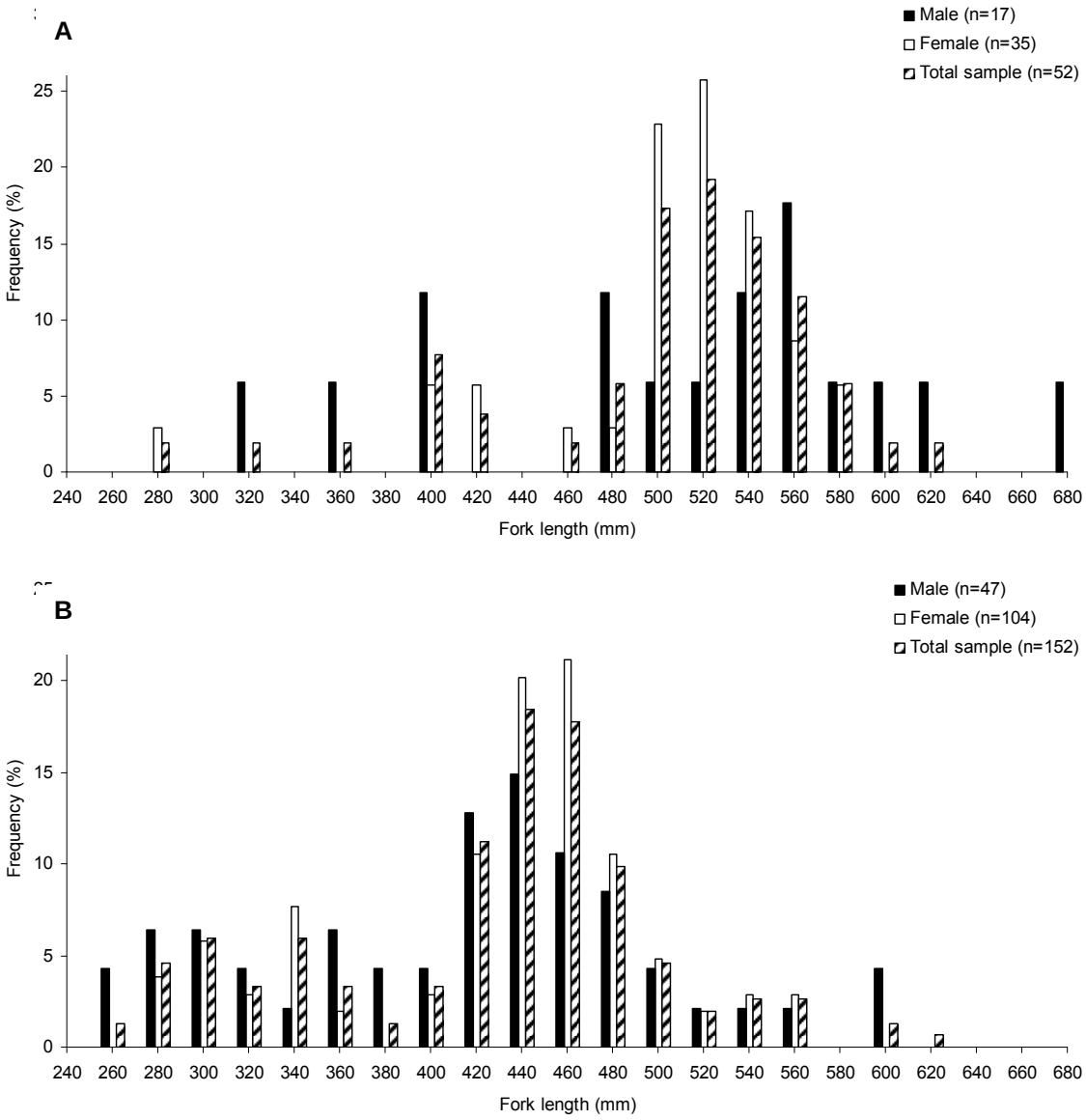


Figure 3. Fork length frequency distributions of Dolly Varden captured in Joe Creek in A) 1986 (seining/angling) and B) 1995 (electrofishing).

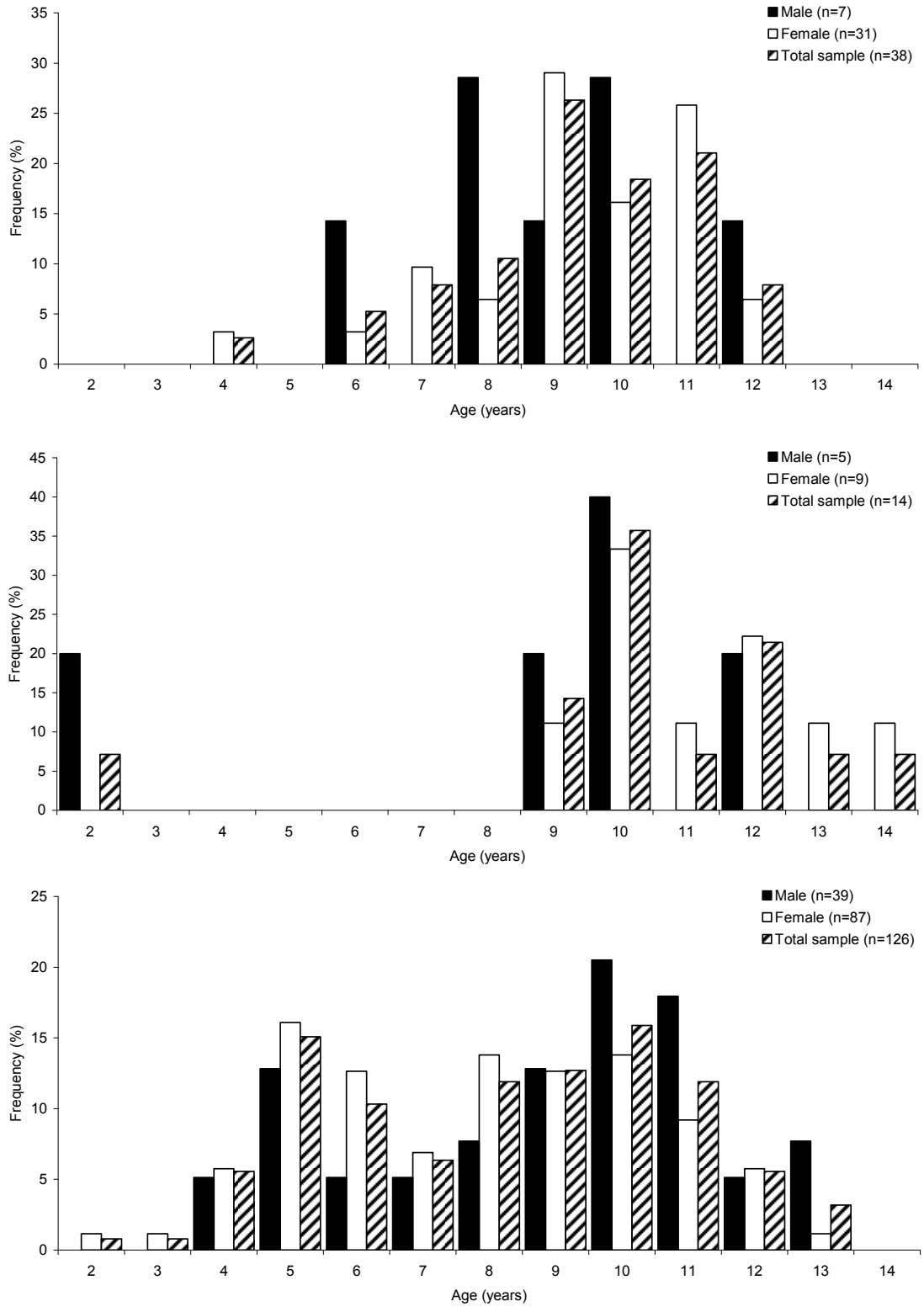


Figure 4. Age frequency distributions of Dolly Varden captured from the Firth River in A) 1986 (seining/angling), B) 1988 (electrofishing), and C) 1995 (seining/angling).

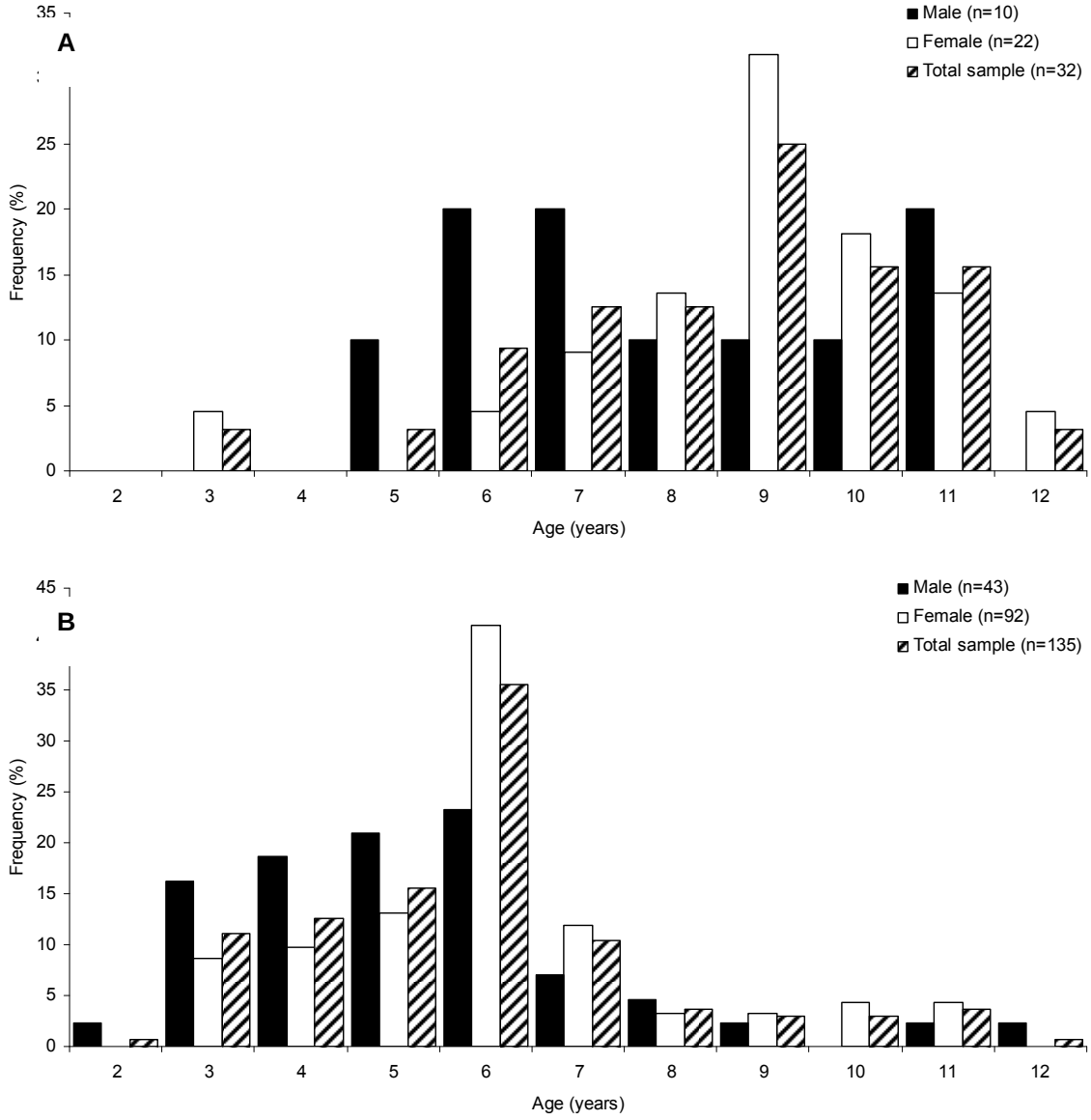


Figure 5. Age frequency distributions of Dolly Varden captured in Joe Creek in A) 1986 (seining/angling) and B) 1995 (electrofishing).

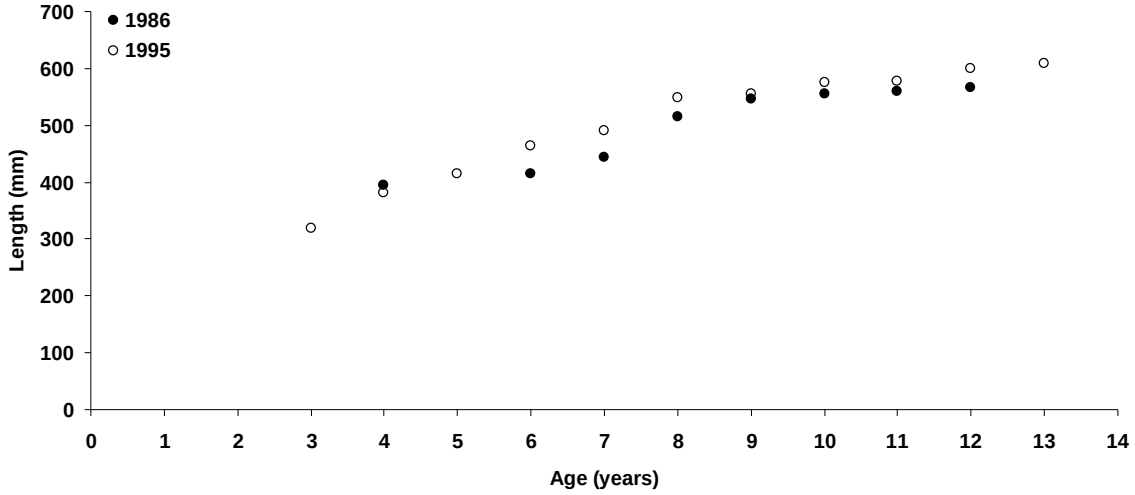


Figure 6. Length-at-age of Dolly Varden from the Firth River captured in 1986 and 1995 (seining/angling for both years).

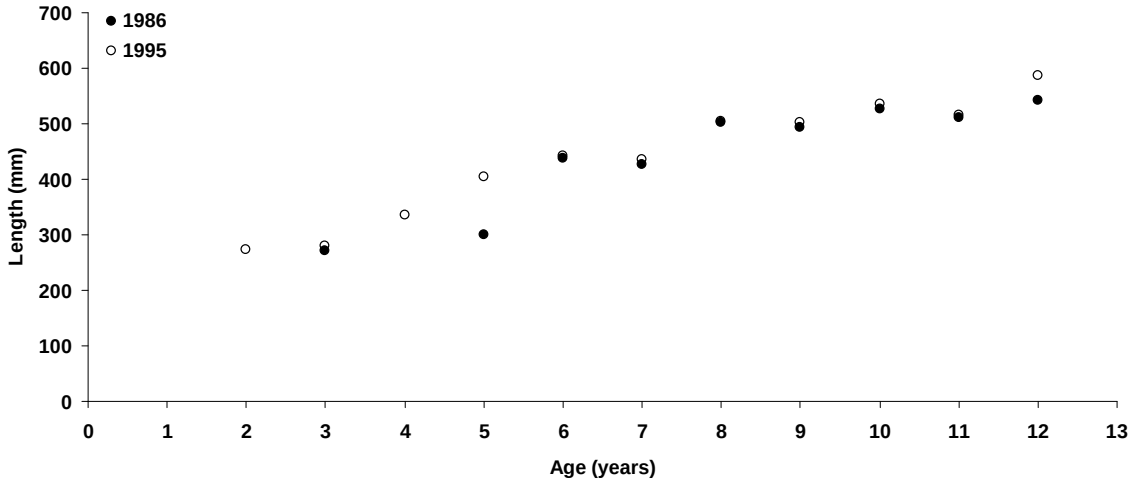


Figure 7. Length-at-age of Dolly Varden from Joe Creek captured in 1986 (seining/angling) and 1995 (electrofishing).

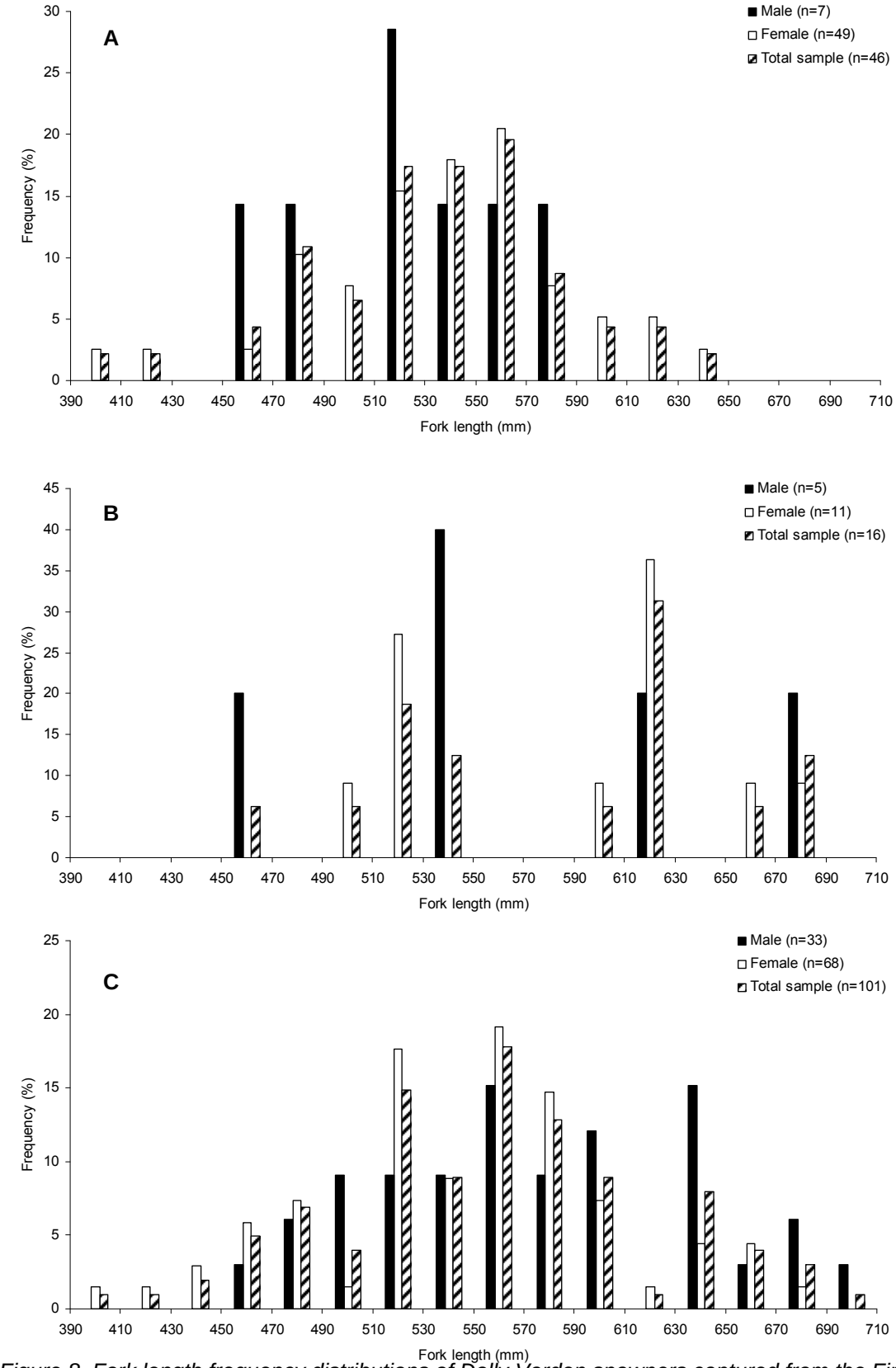


Figure 8. Fork length frequency distributions of Dolly Varden spawners captured from the Firth River in A) 1986 (seining/angling), B) 1988 (electrofishing), and C) 1995 (seining/angling).

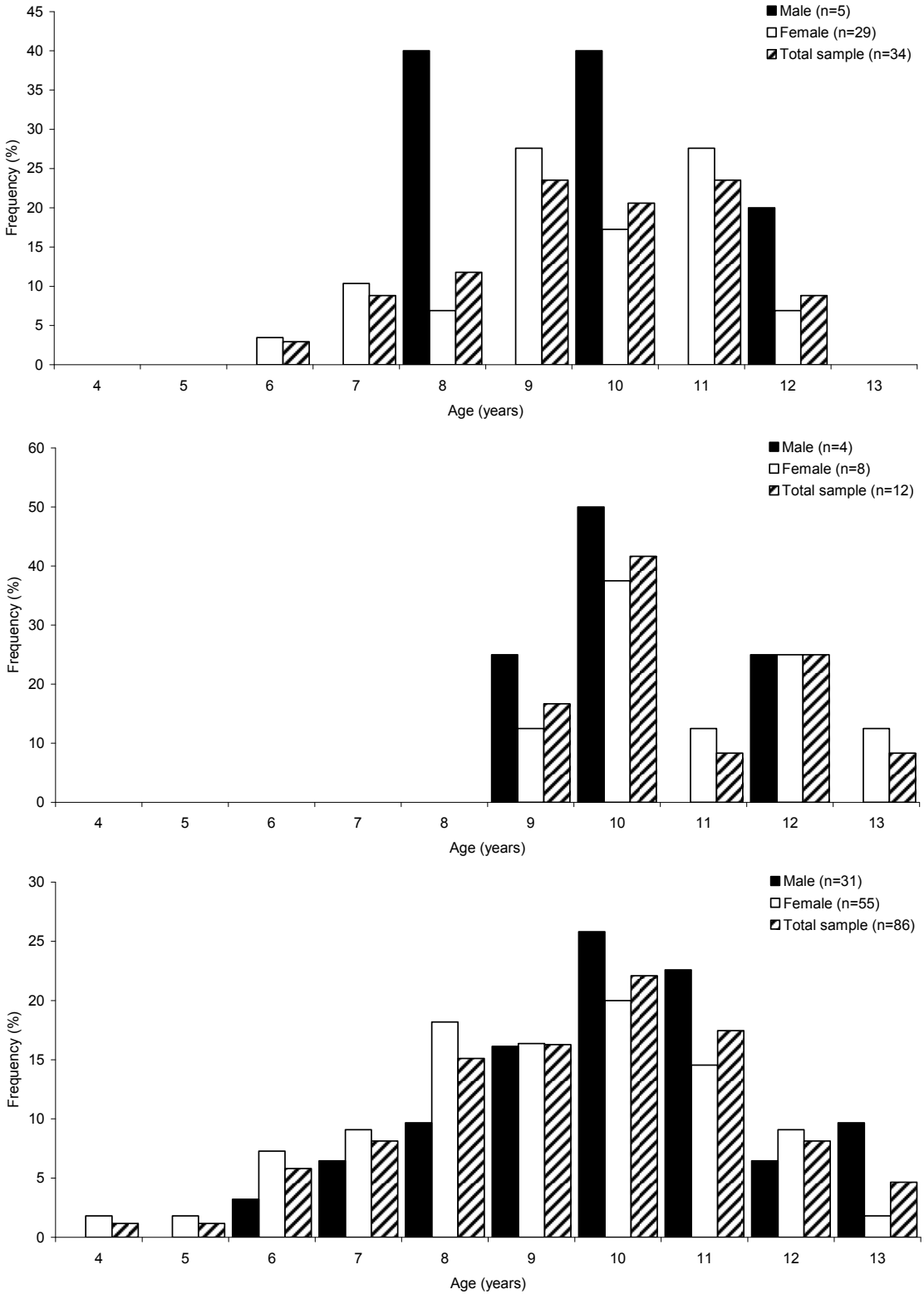


Figure 9. Age frequency distributions of Dolly Varden spawners captured from the Firth River in A) 1986 (seining/angling), B) 1988 (electrofishing), and C) 1995 (seining/angling).

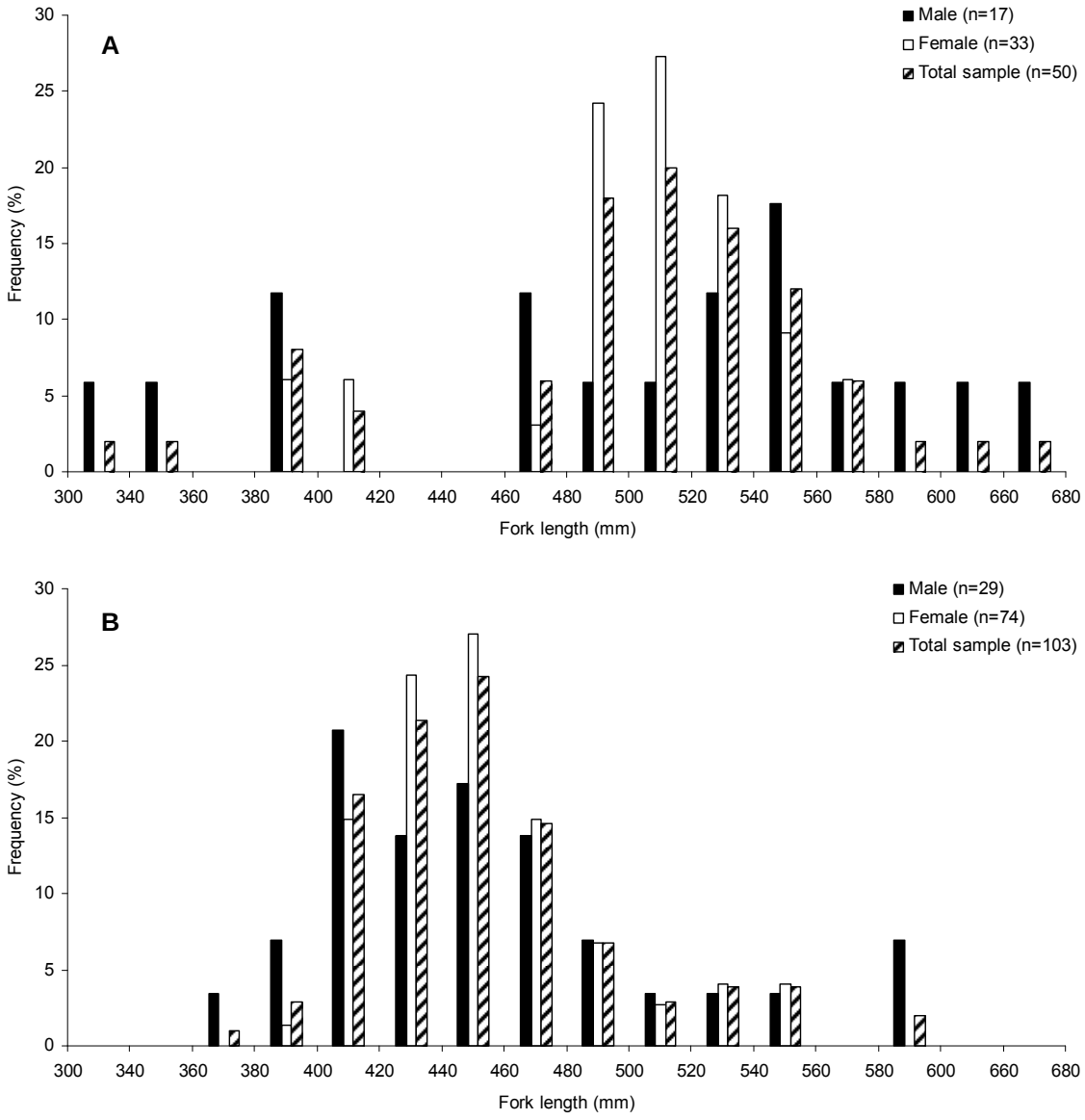


Figure 10. Fork length frequency distributions of Dolly Varden spawners captured in Joe Creek in A) 1986 (seining/angling) and B) 1995 (electrofishing).

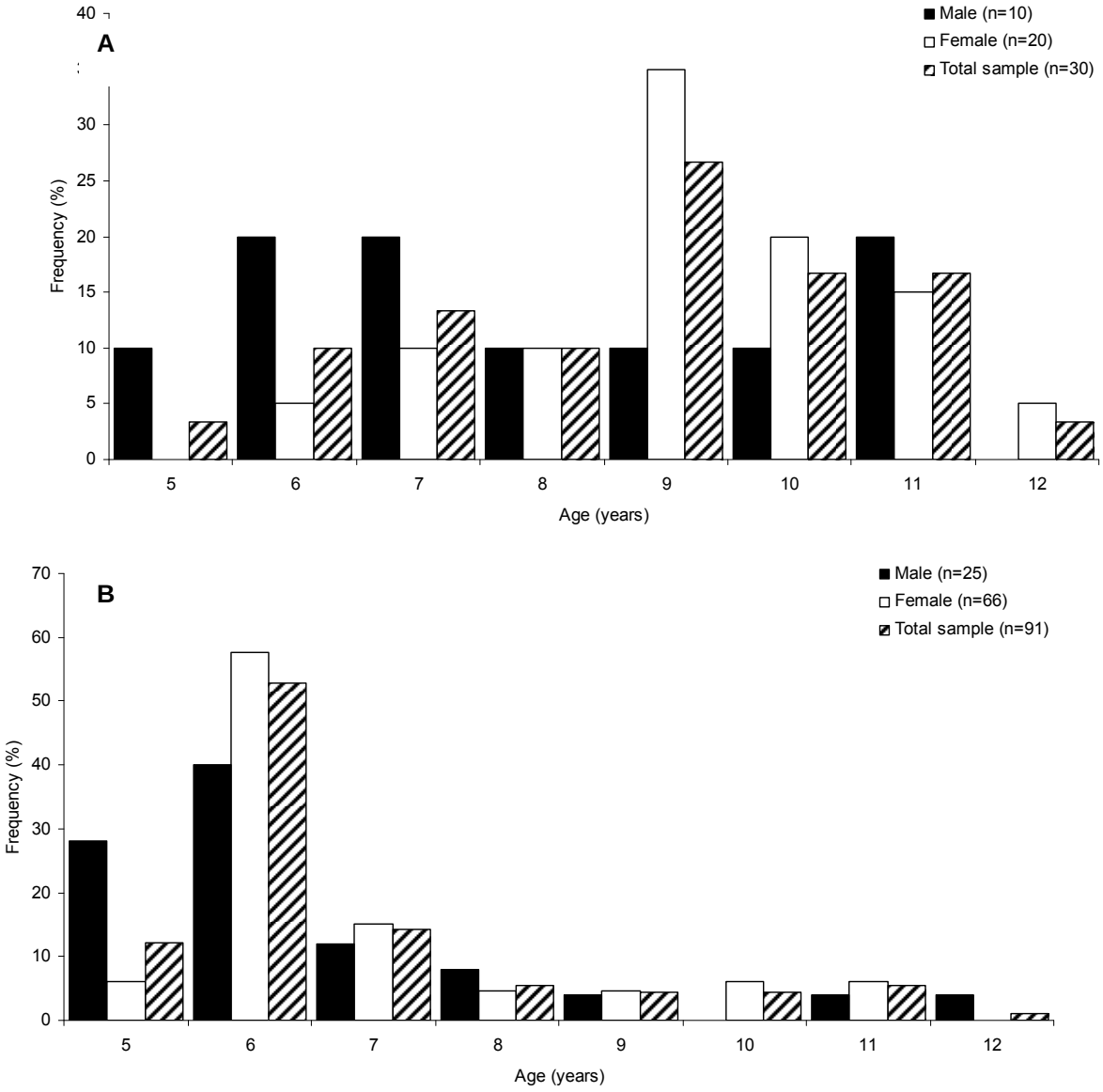


Figure 11. Age frequency distributions of Dolly Varden spawners captured in Joe Creek in A) 1986 (seining/angling) and B) 1995 (electrofishing).

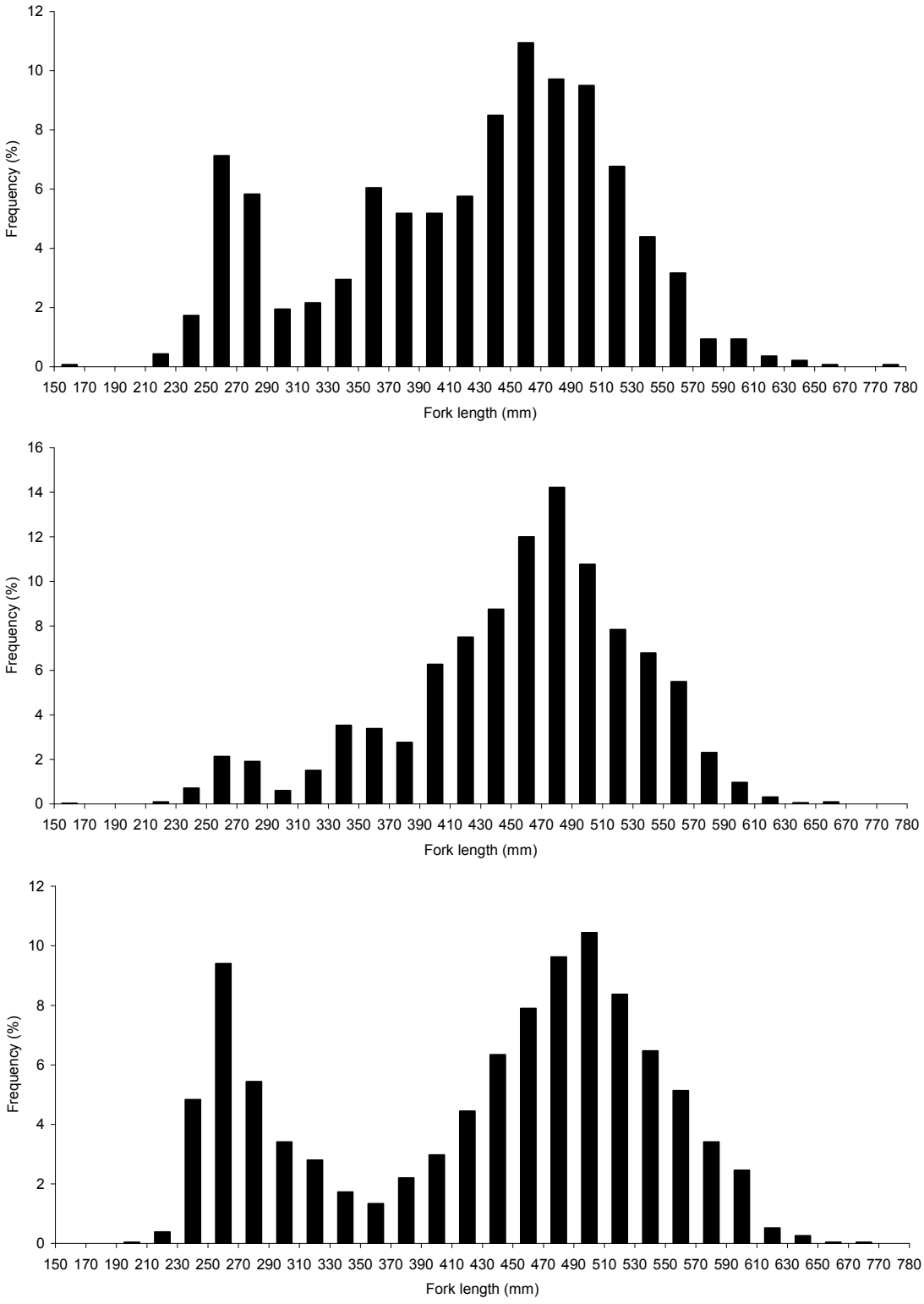


Figure 12. Fork length frequency distributions of Dolly Varden from the Babbage River captured by weir in A) 1990, B) 1991 and C) 1992.

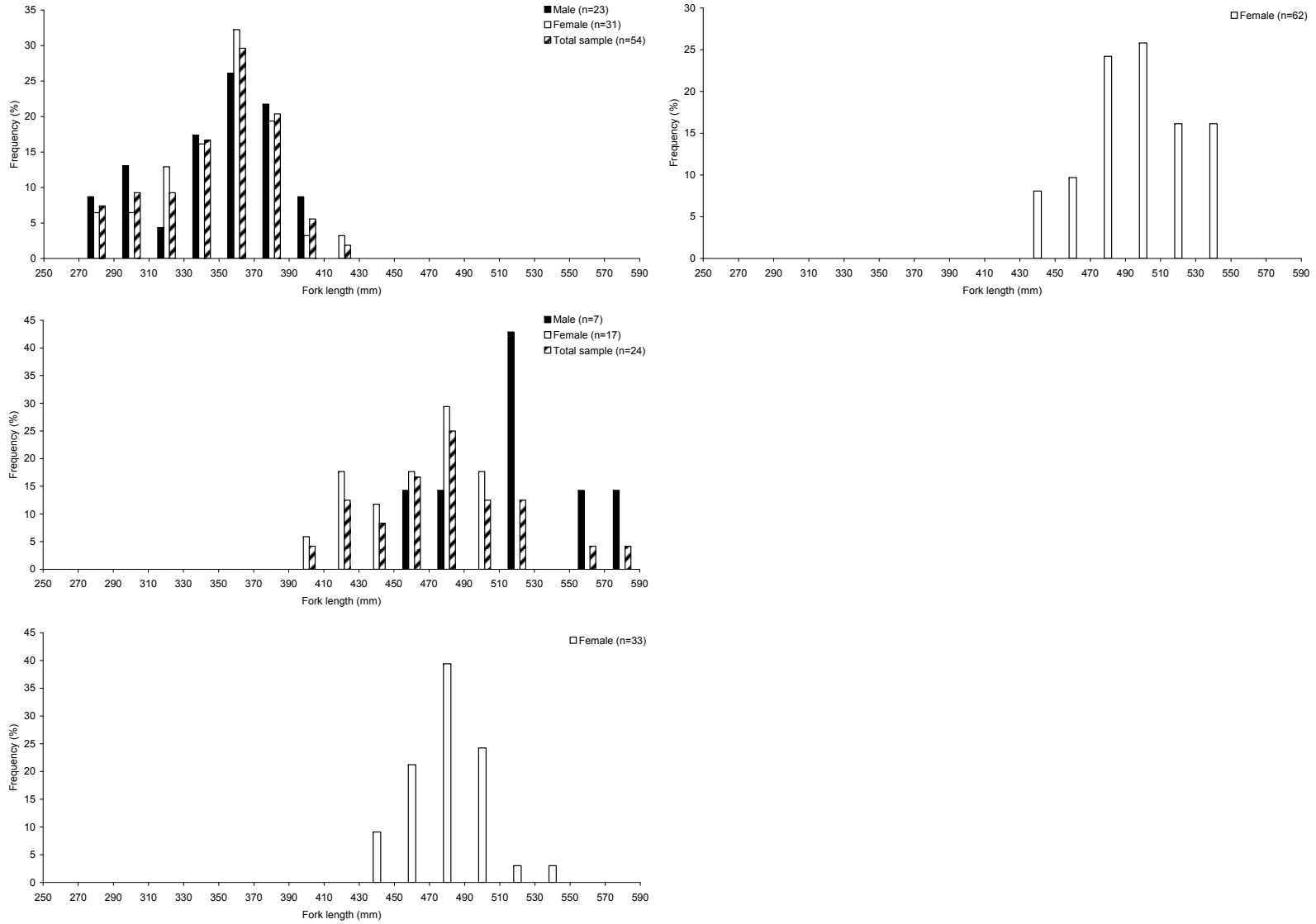


Figure 13. Fork length frequency distributions of Dolly Varden from the Babbage River captured by electrofishing at the spawning/overwintering area in A) 1988, B) 1991, C) 1992 and D) 1993.

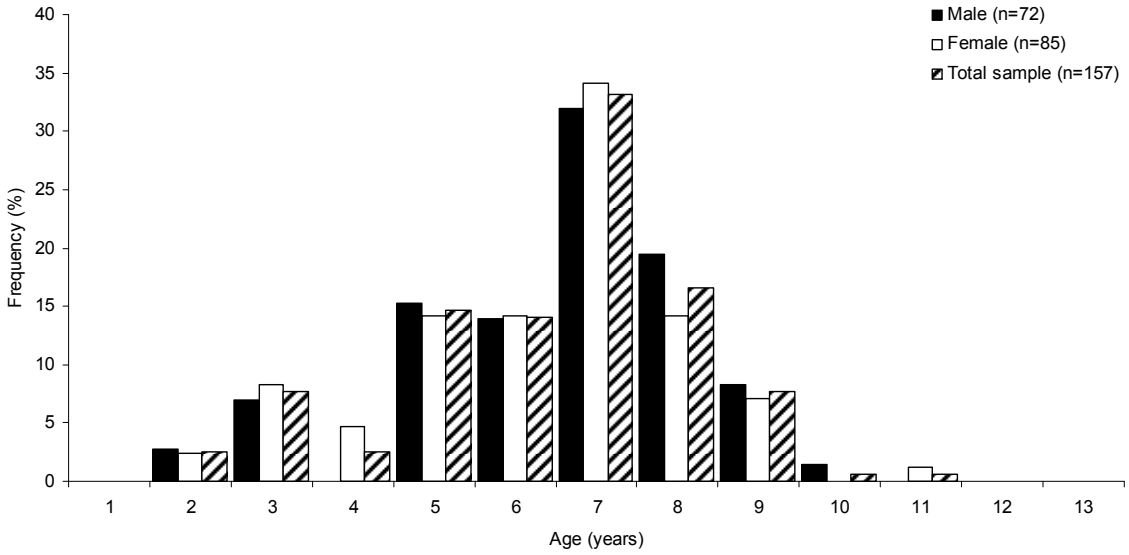


Figure 14. Age frequency distribution of Dolly Varden from the Babbage River captured by weir in 1992.

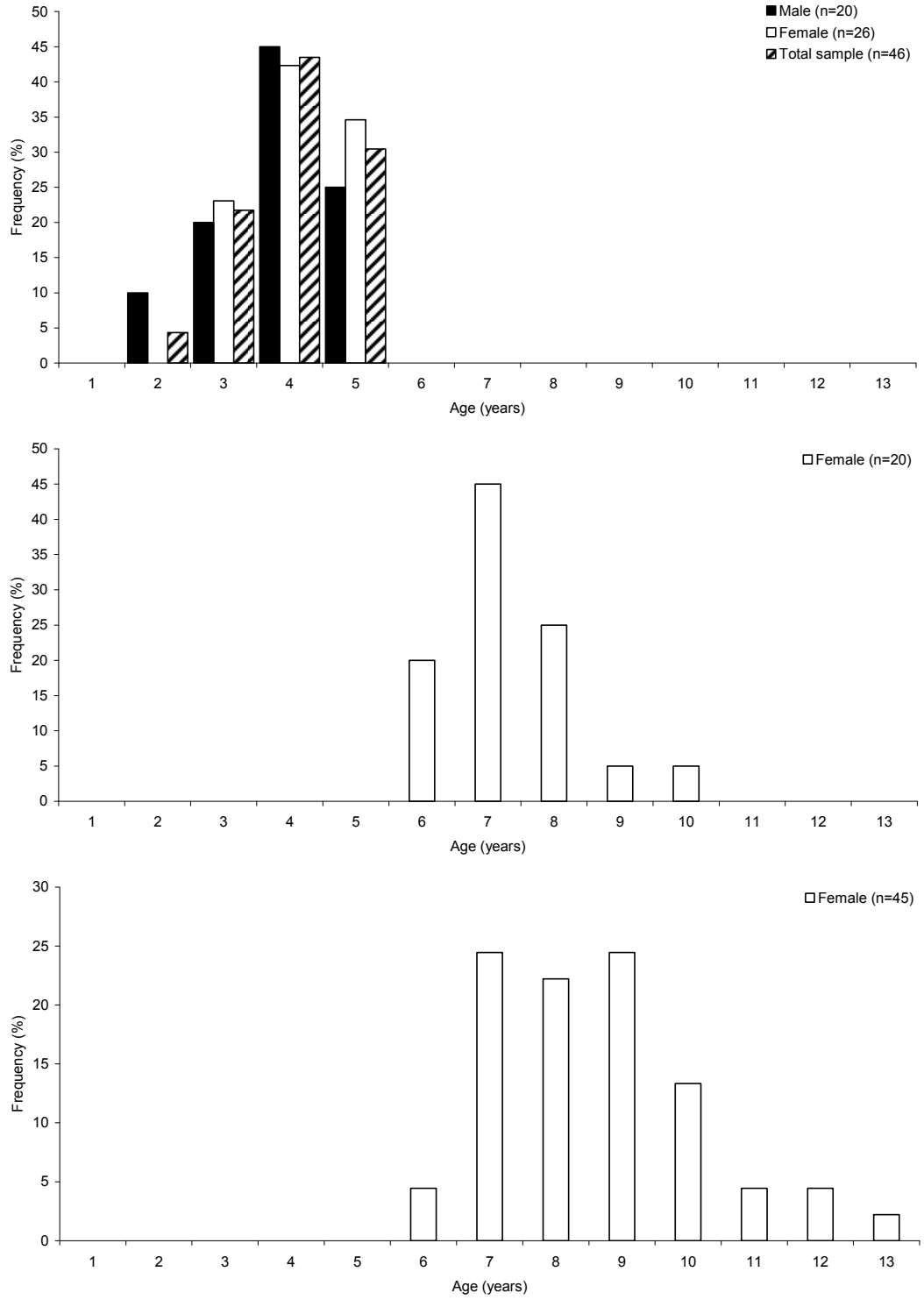


Figure 15. Age frequency distributions of Dolly Varden from the Babbage River captured by electrofishing at the spawning/overwintering area in A) 1988, B) 1992, C) 1993.

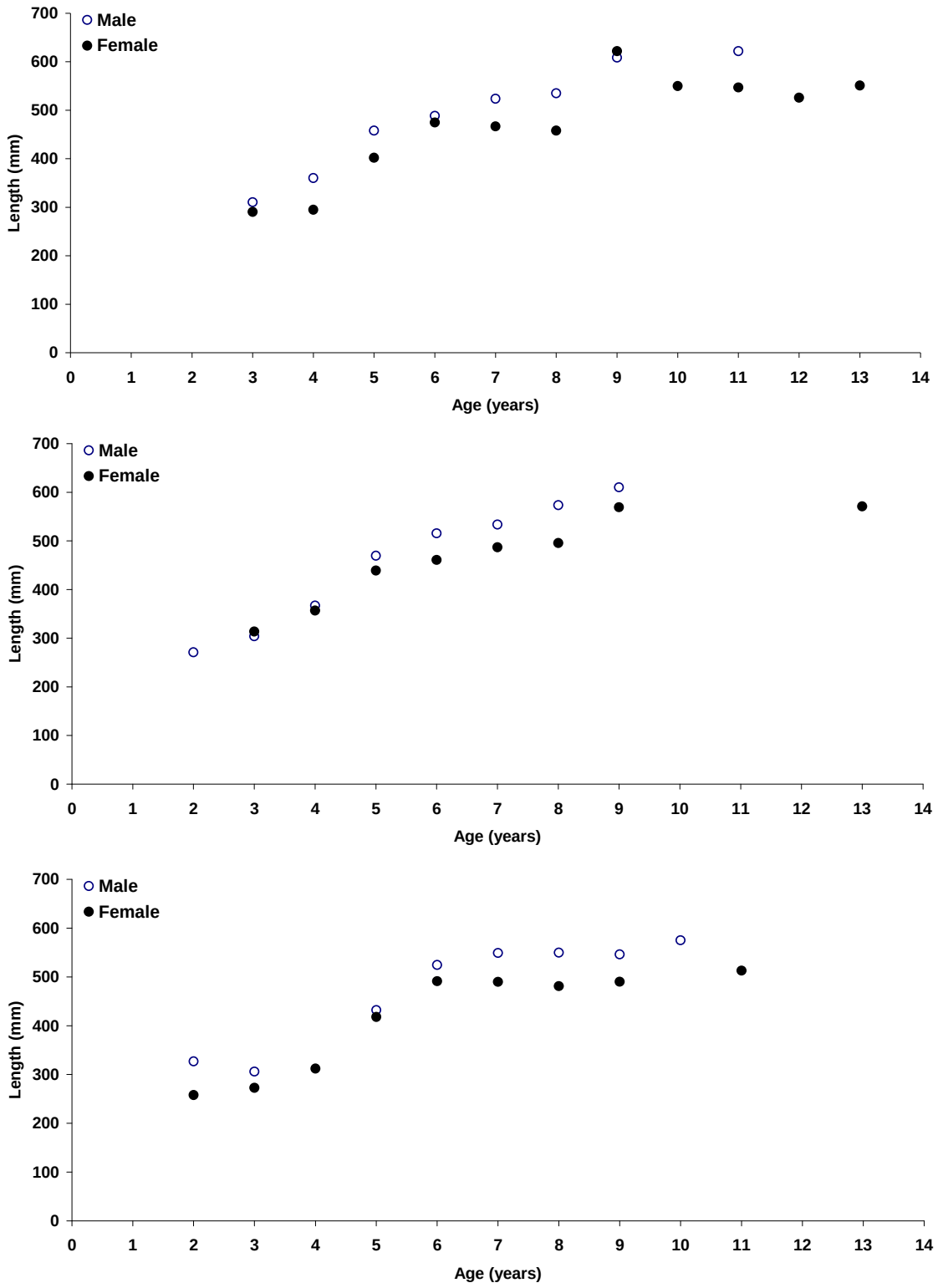


Figure 16 . Length-at-age of male and female Dolly Varden from the Babbage River captured by weir in A) 1990, B) 1991 and C) 1992.

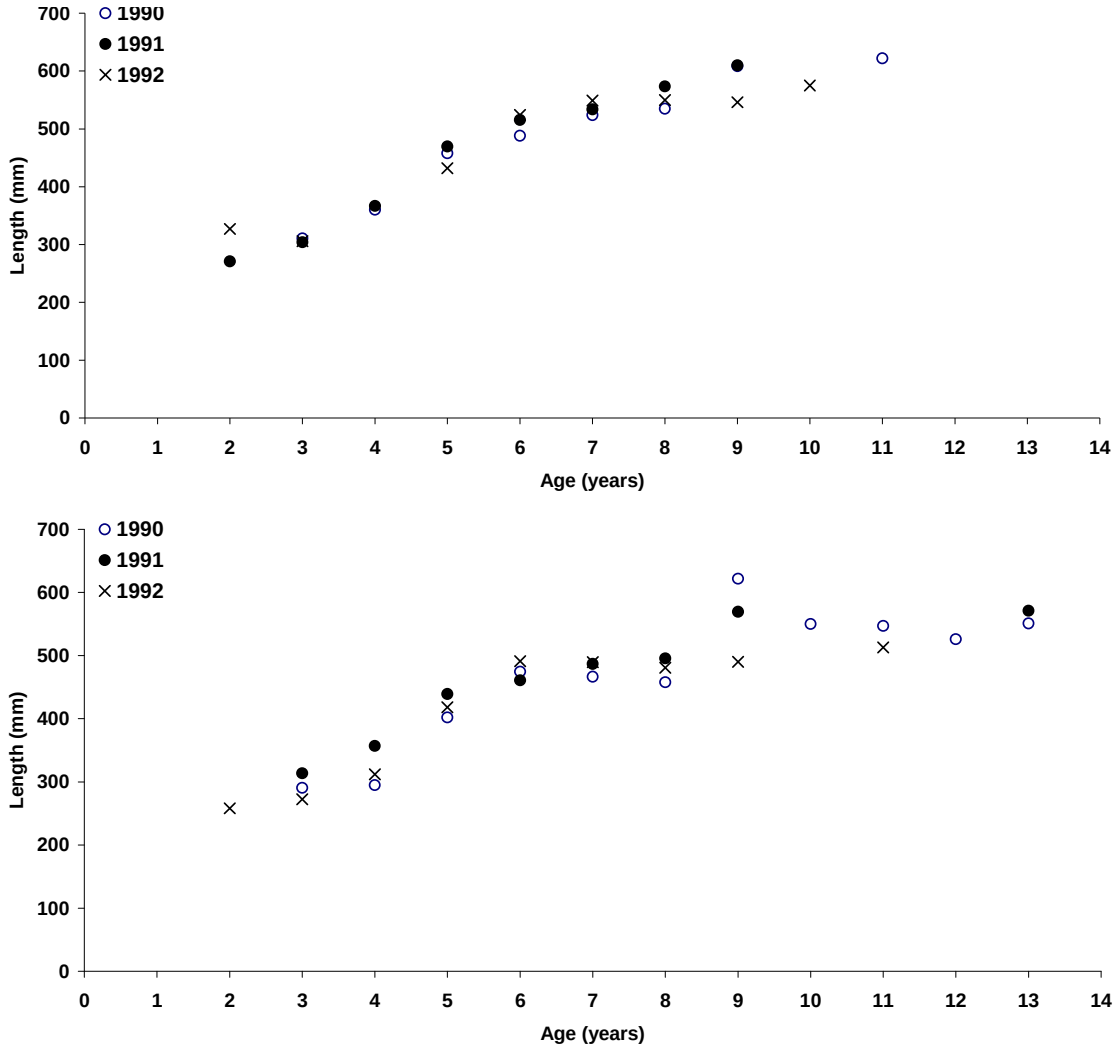


Figure 17. Length-at-age of A) male and B) female Dolly Varden from the Babbage River captured by weir in 1990, 1991 and 1992.

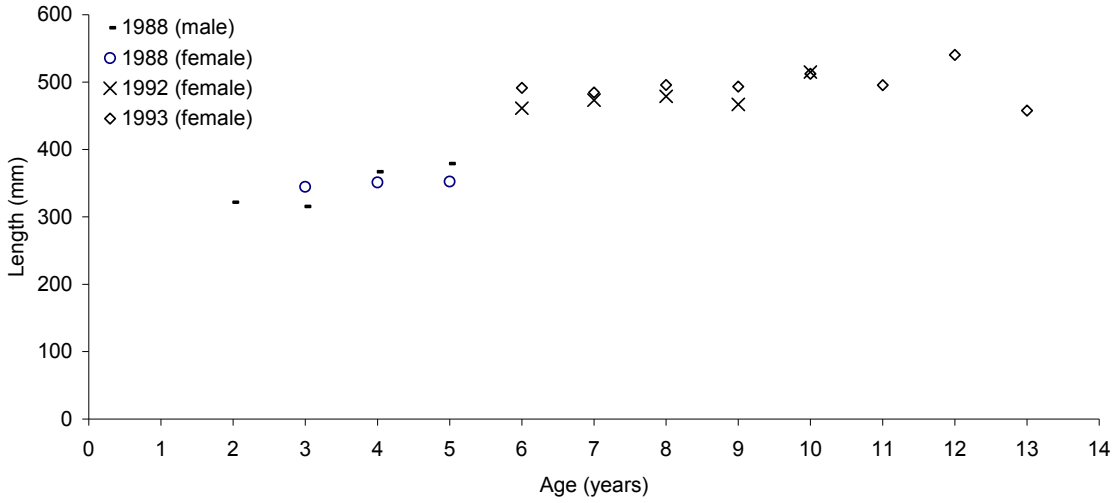


Figure 18. Length-at-age of male and female Dolly Varden from the Babbage River captured by electrofishing at the spawning/overwintering area between 1988 and 1993.

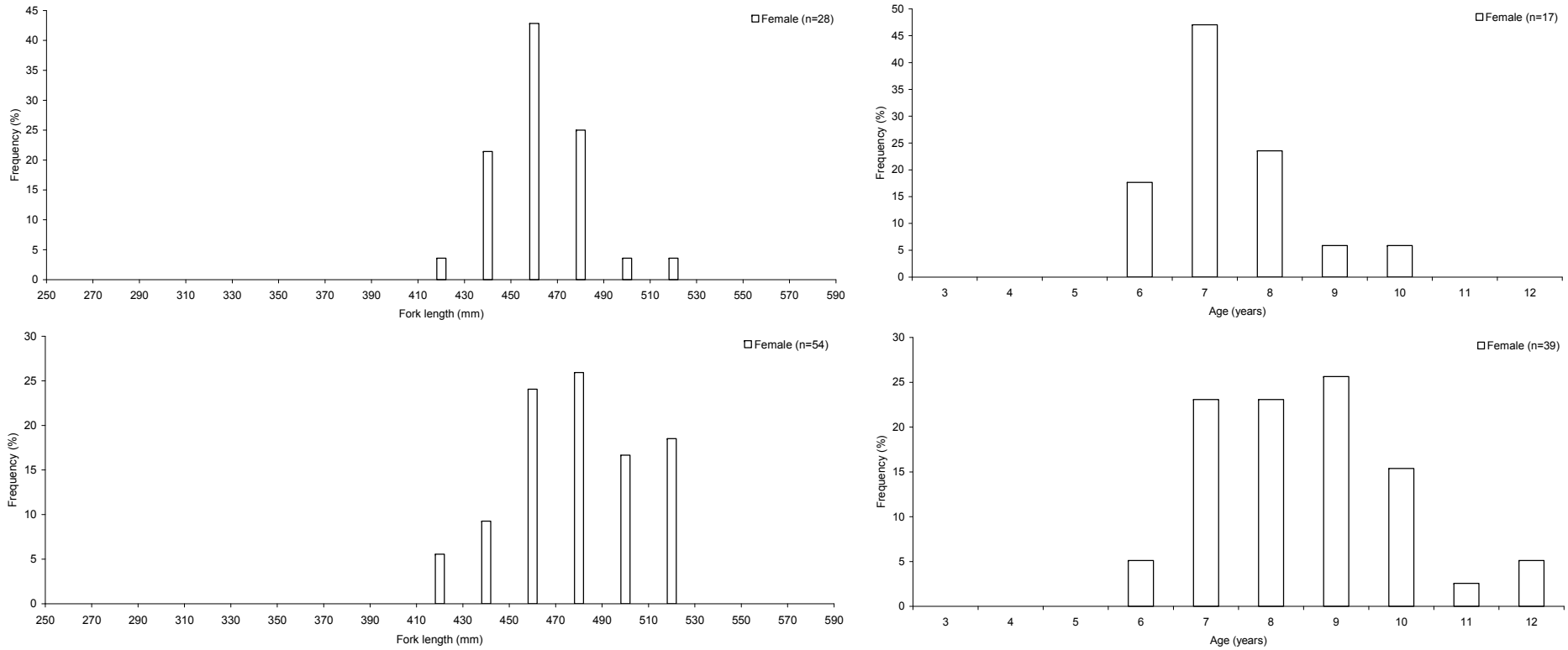


Figure 19. Length (A and B) and age (C and D) frequency distributions of Dolly Varden spawners captured by electrofishing in the Babbage River in 1992 (A and C) and 1993 (B and D).

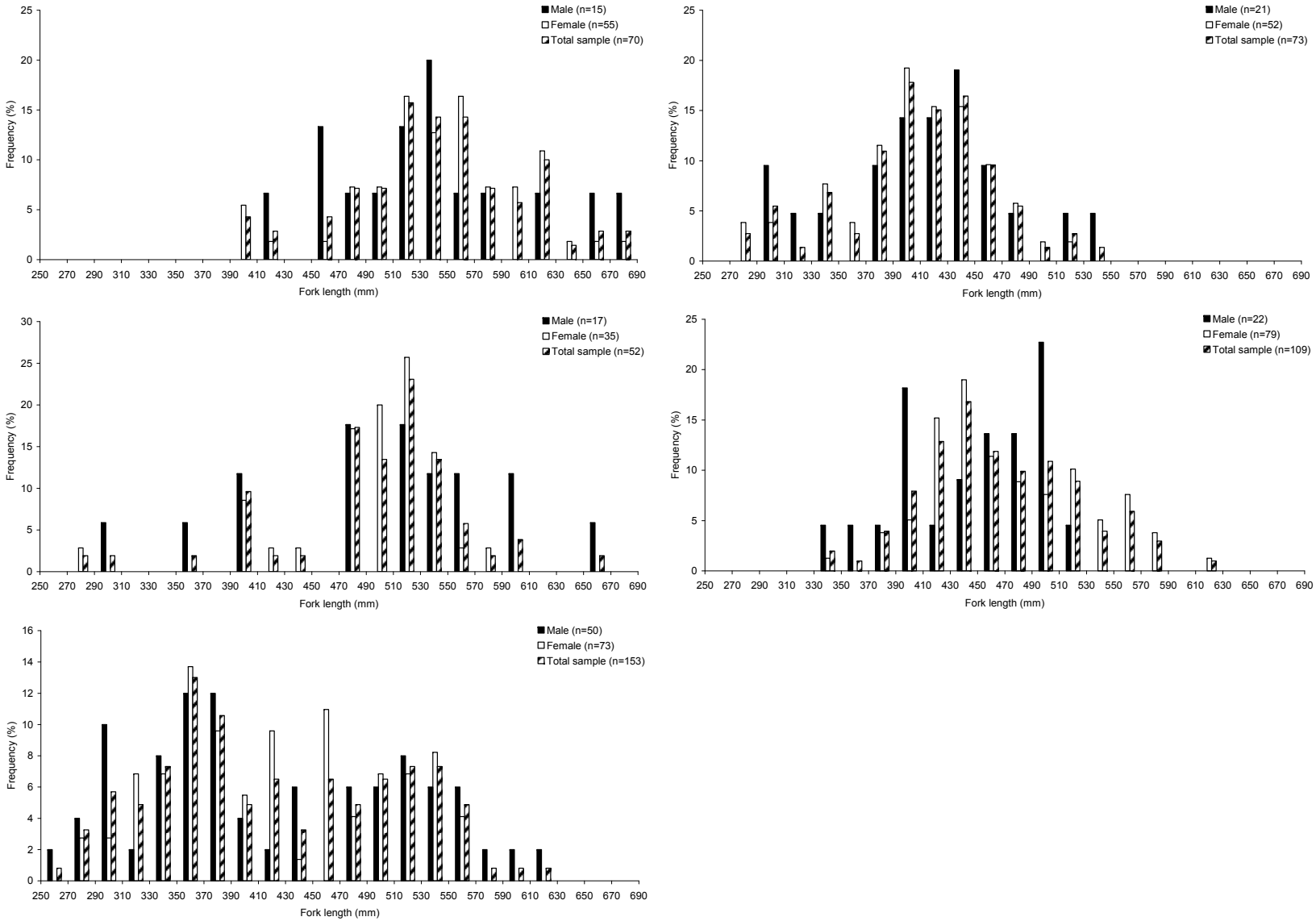


Figure 20. Length frequency distributions of anadromous Dolly Varden captured between 1986 and 1988 from the spawning/overwintering area of the A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River and E) Rat River.

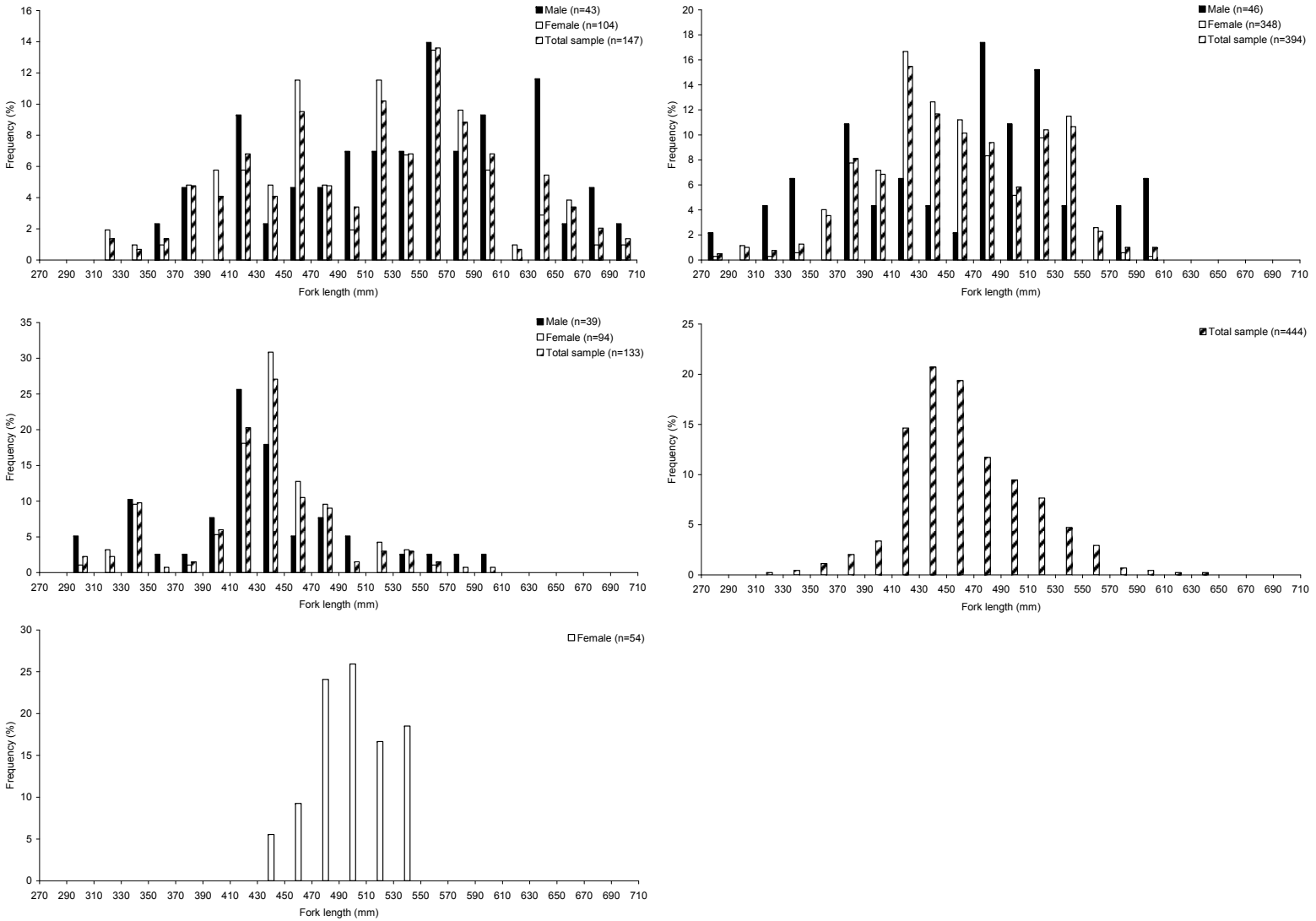


Figure 21. Length frequency distributions of anadromous Dolly Varden captured between 1993 and 1995 from the spawning/overwintering area of the A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River and E) Rat River.

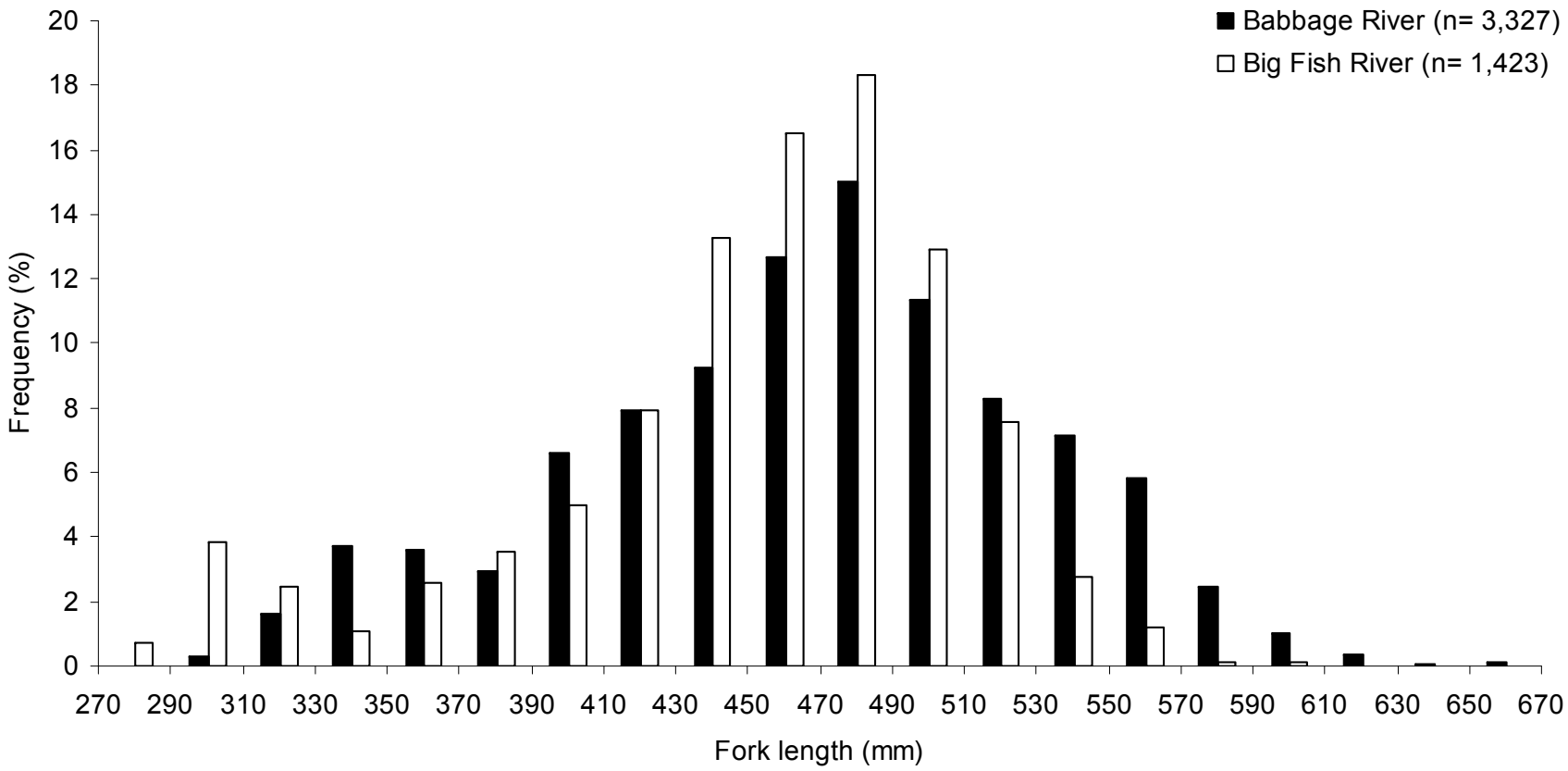


Figure 22. Length frequency distribution of anadromous Dolly Varden from the Babbage River and Big Fish River captured by weir in 1991.

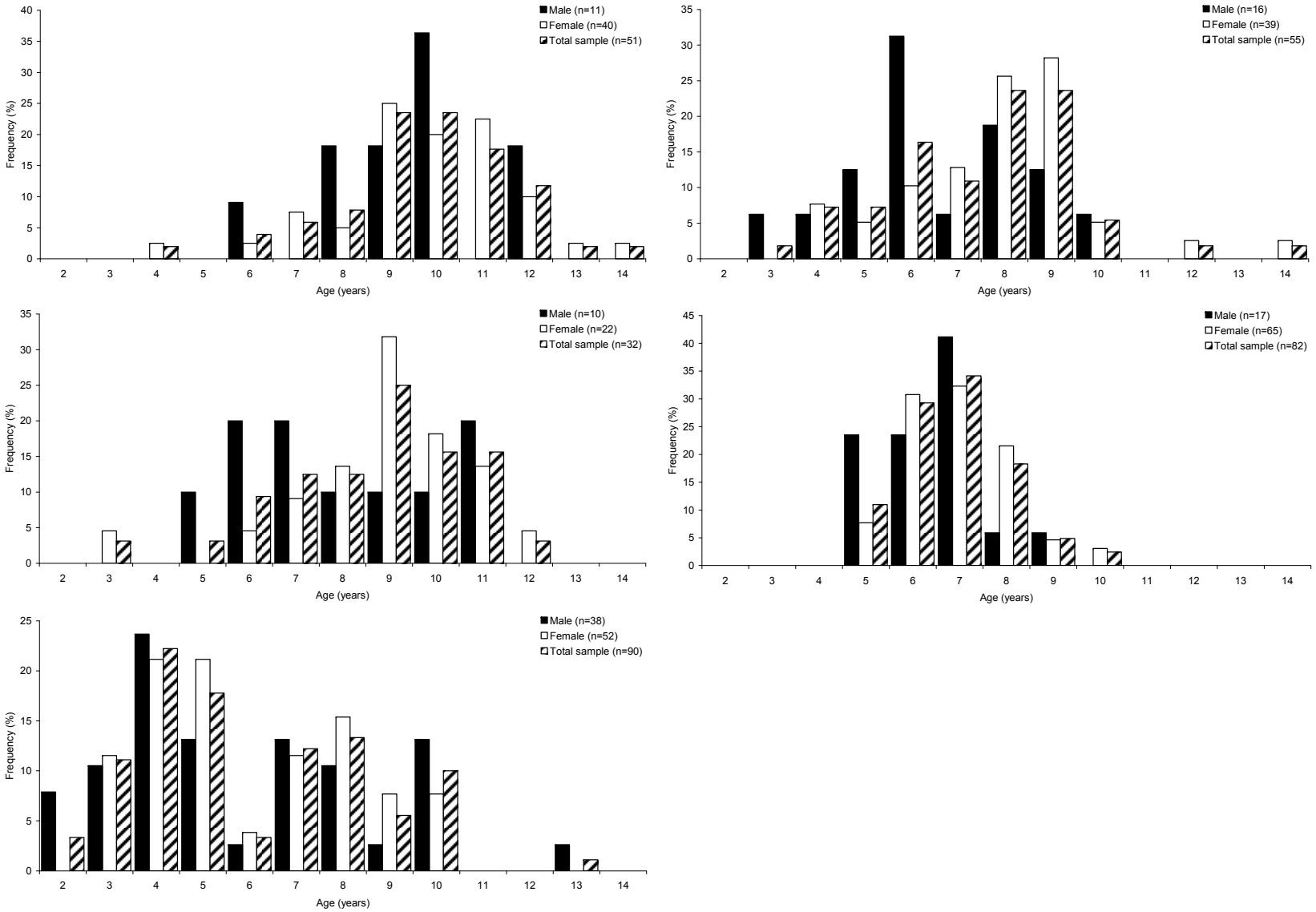


Figure 23. Age frequency distributions of Dolly Varden captured between 1986 and 1988 at the spawning/overwintering area from A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River, and E) Rat River.

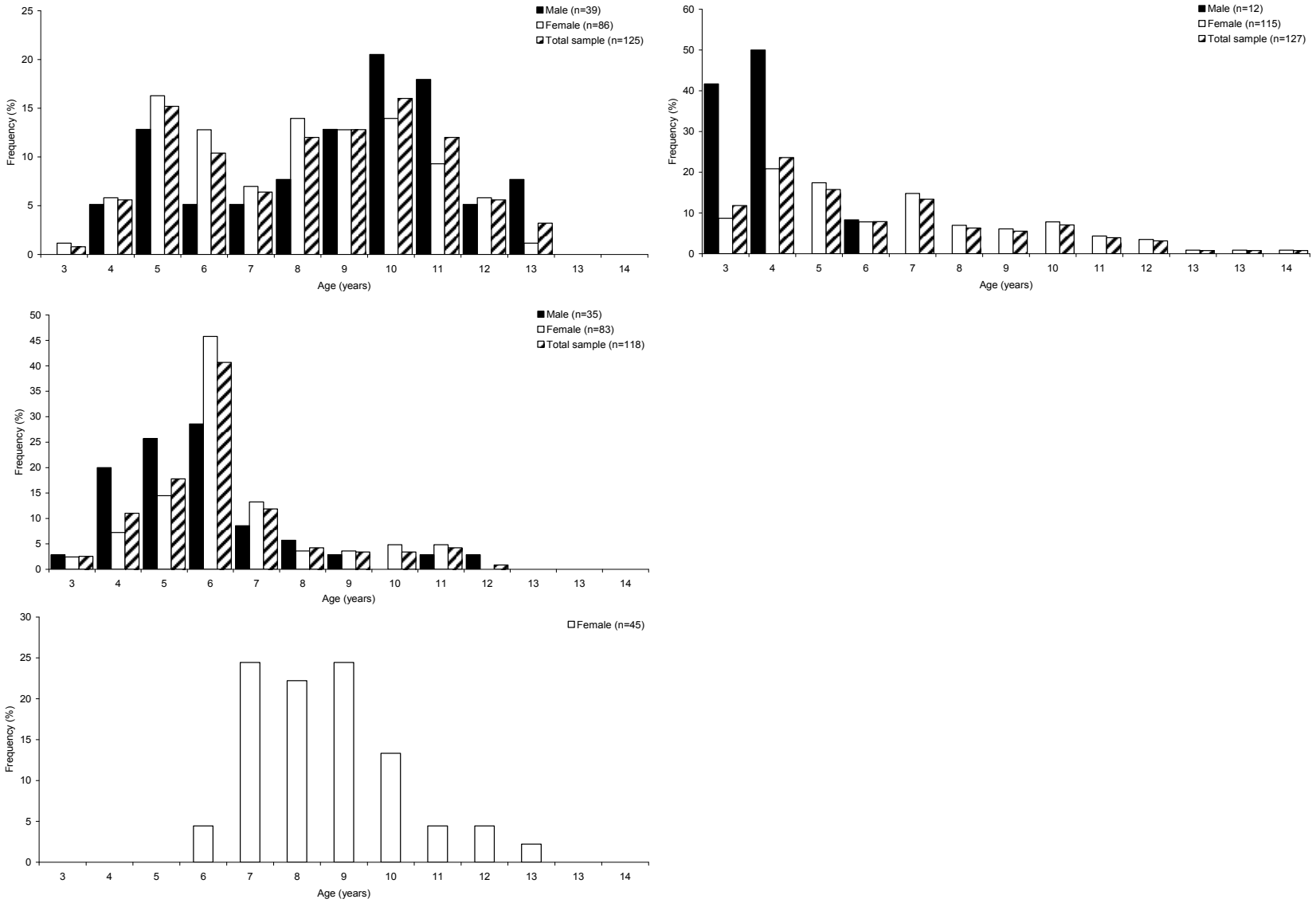


Figure 24. Age frequency distributions of Dolly Varden captured between 1993 and 1995 at the spawning/overwintering area from A) Firth River, B) Joe Creek, C) Babbage River, and D) Big Fish River.

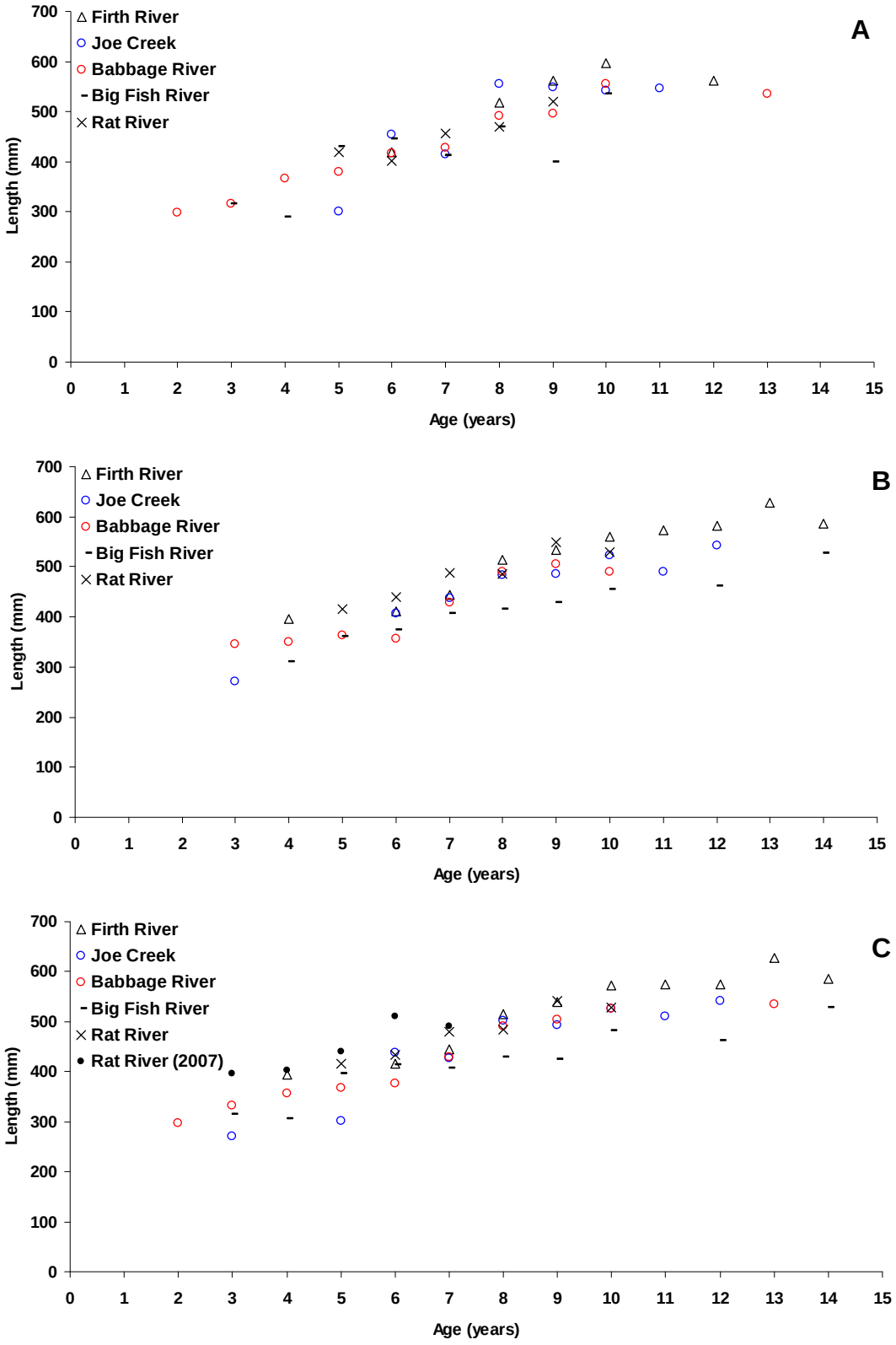


Figure 25. Length-at-age of A) male, B) female and C) total sample Dolly Varden among populations sampled at the spawning/overwintering areas between 1986 and 1988.

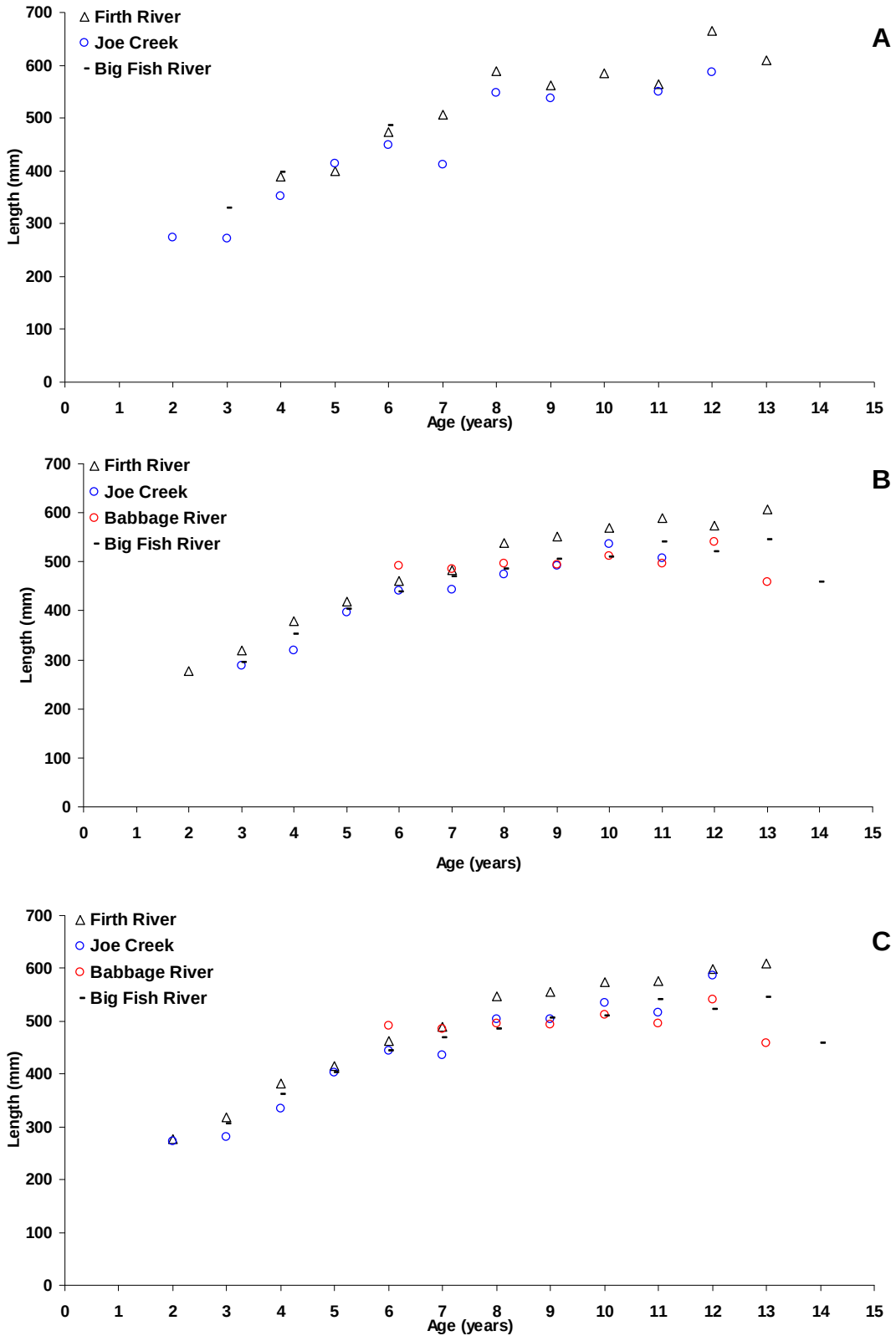
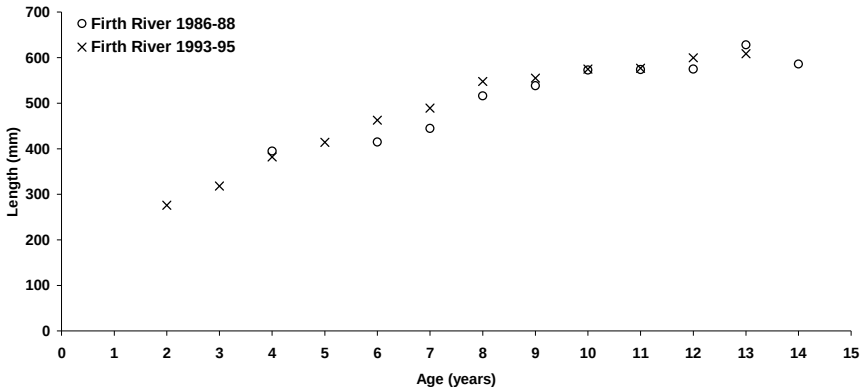
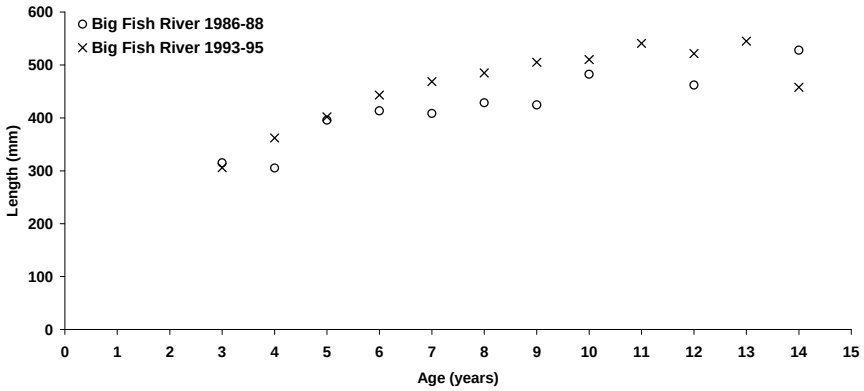
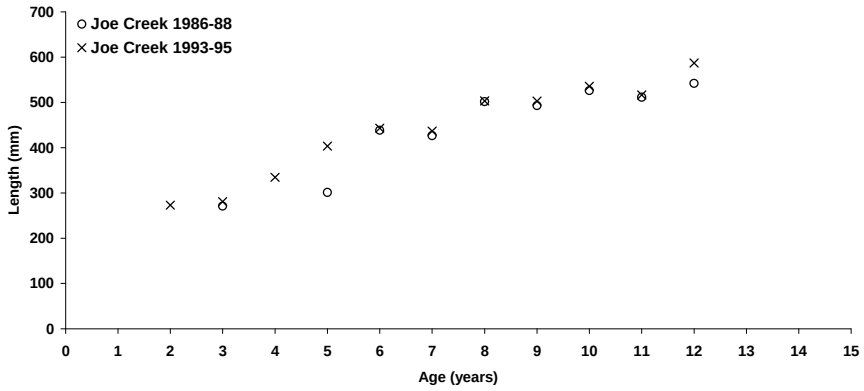


Figure 26. Length-at-age of A) male, B) female and C) total sample Dolly Varden among populations sampled at the spawning/overwintering areas between 1993 and 1995.







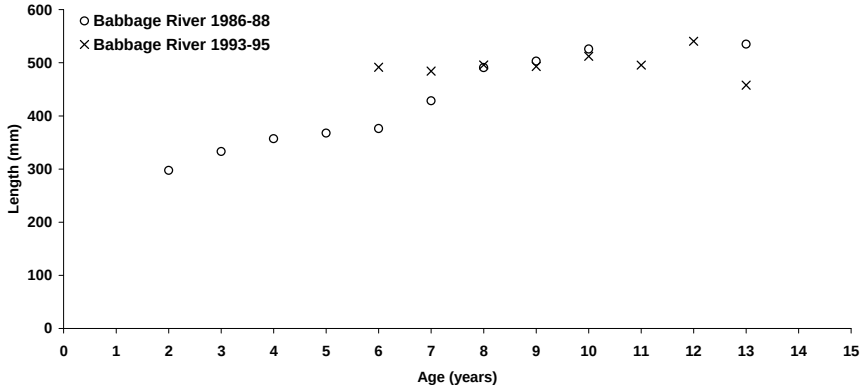


Figure 27. Length-at-age of Dolly Varden (total sample) sampled at the spawning/overwintering areas from Firth River, Joe Creek and Babbage River between 1986-88 and 1993-95.

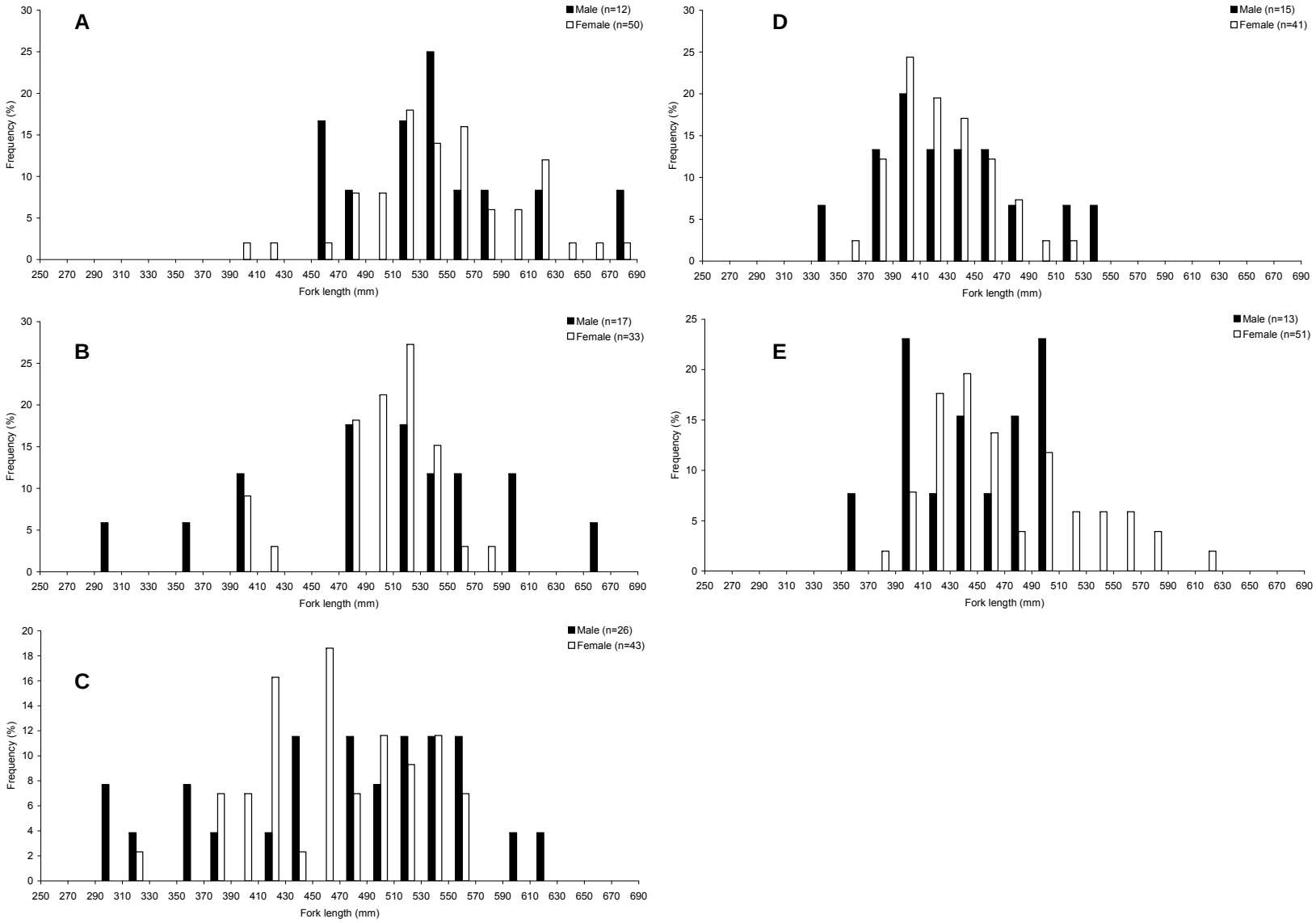


Figure 28. Fork length frequency distributions of Dolly Varden in spawning condition captured from the A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River, and E) Rat River between 1986 and 1988.

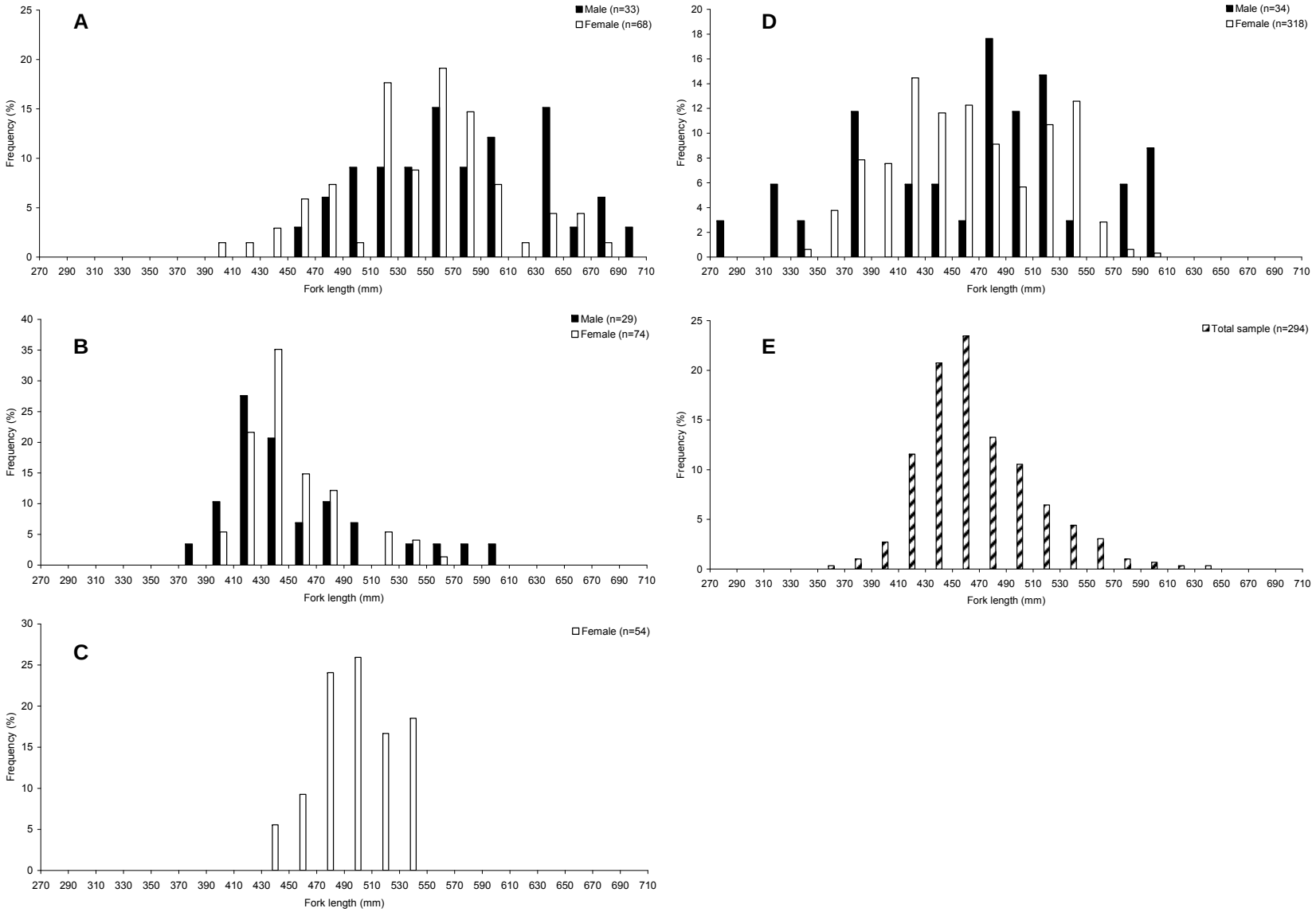


Figure 29. Fork length frequency distributions of Dolly Varden in spawning condition captured from the A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River, and E) Rat River between 1993 and 1995.

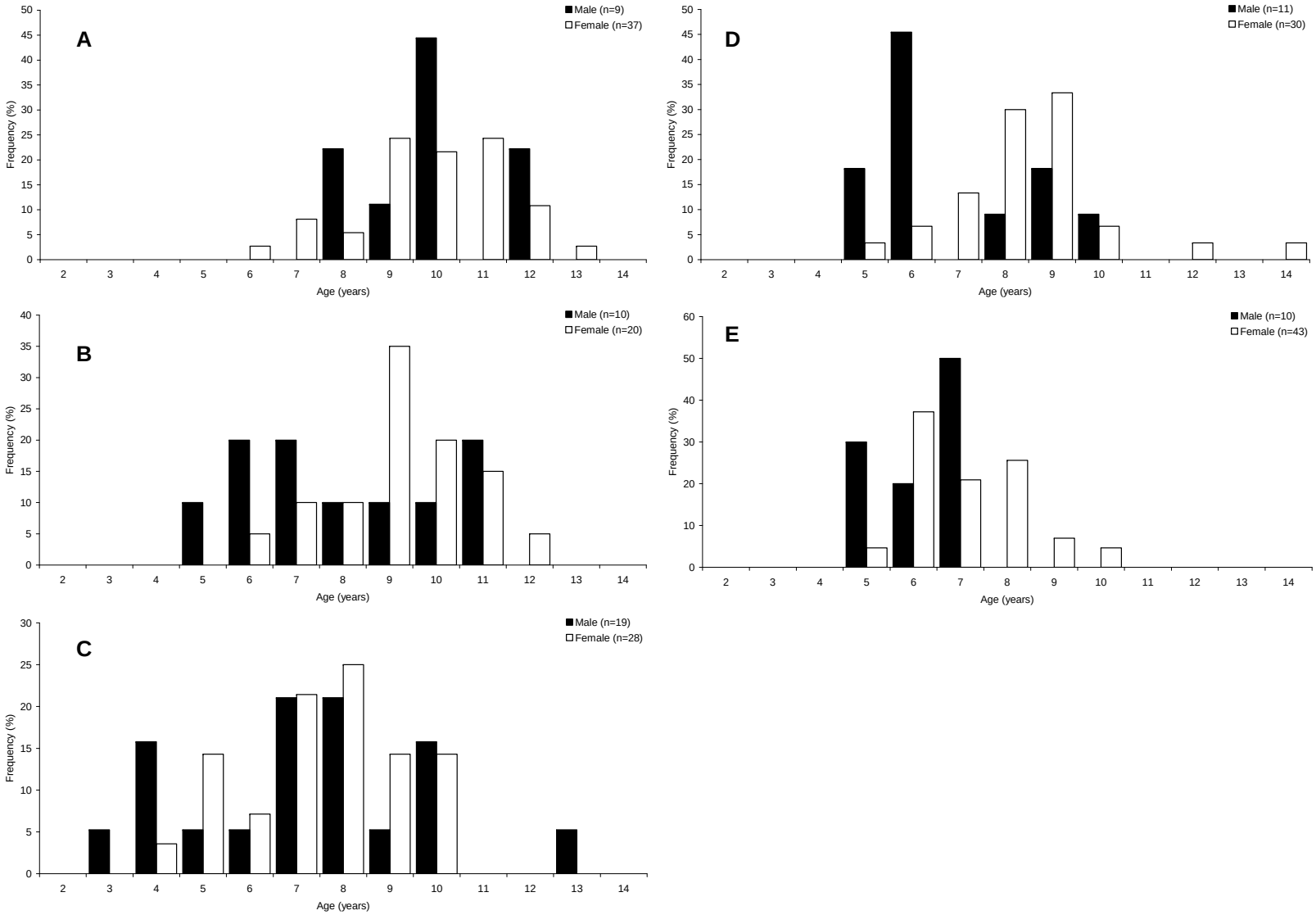


Figure 30. Age frequency distributions of Dolly Varden in spawning condition captured from the A) Firth River, B) Joe Creek, C) Babbage River, D) Big Fish River, and E) Rat River between 1986 and 1988.

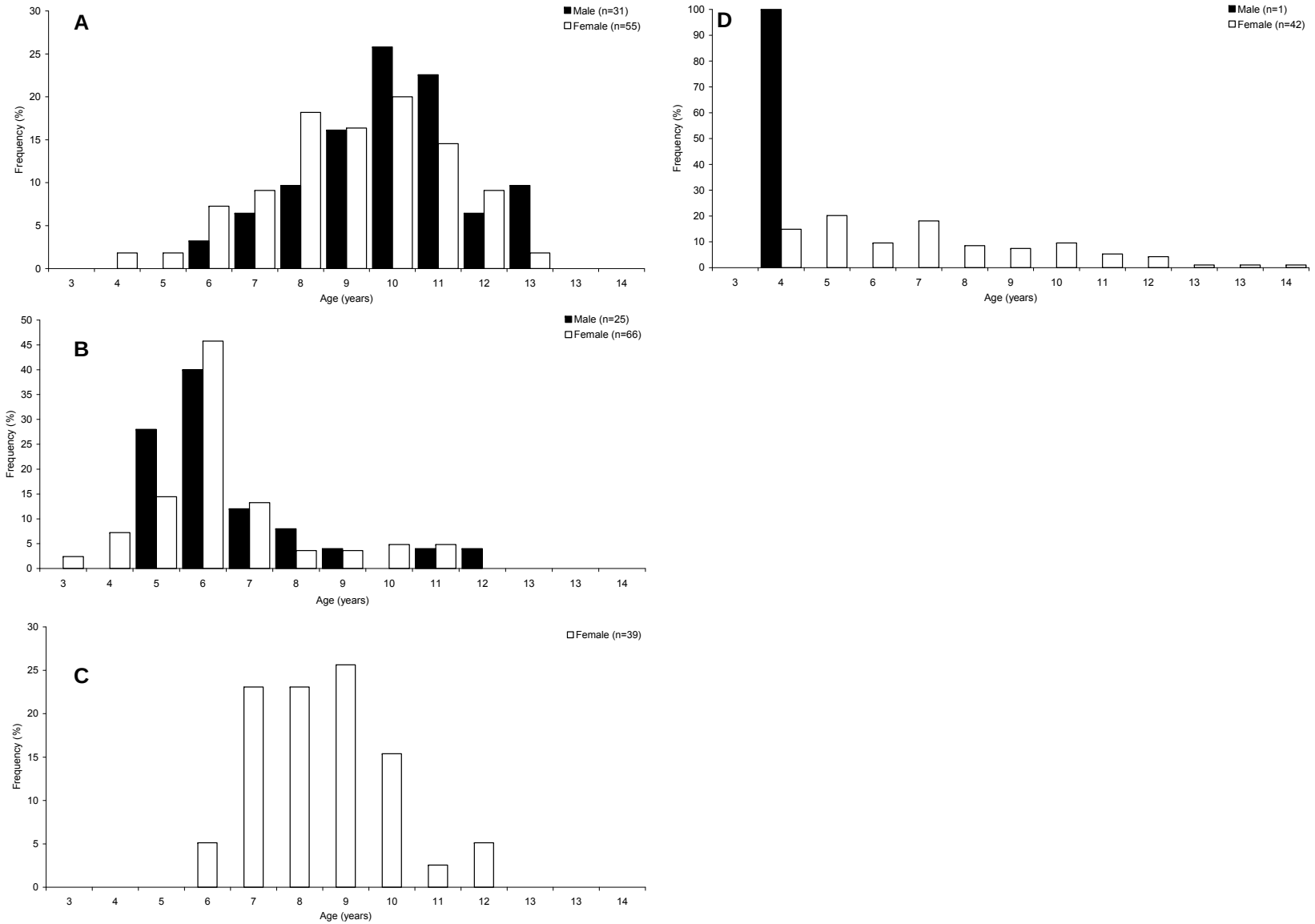


Figure 31. Age frequency distributions of Dolly Varden in spawning condition captured from the A) Firth River, B) Joe Creek, C) Babbage River, and D) Big Fish River between 1993 and 1995.

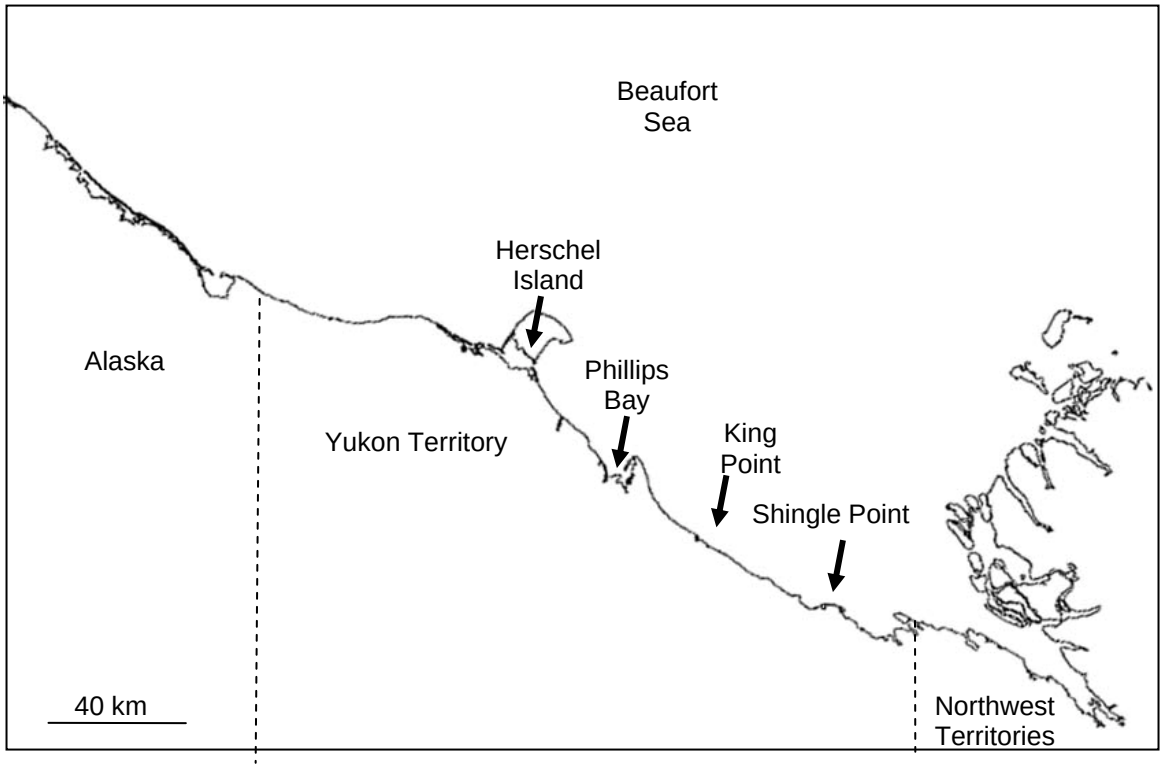


Figure. 32. Locations of selected traditional fishing sites for Dolly Varden along the Beaufort Sea coast.

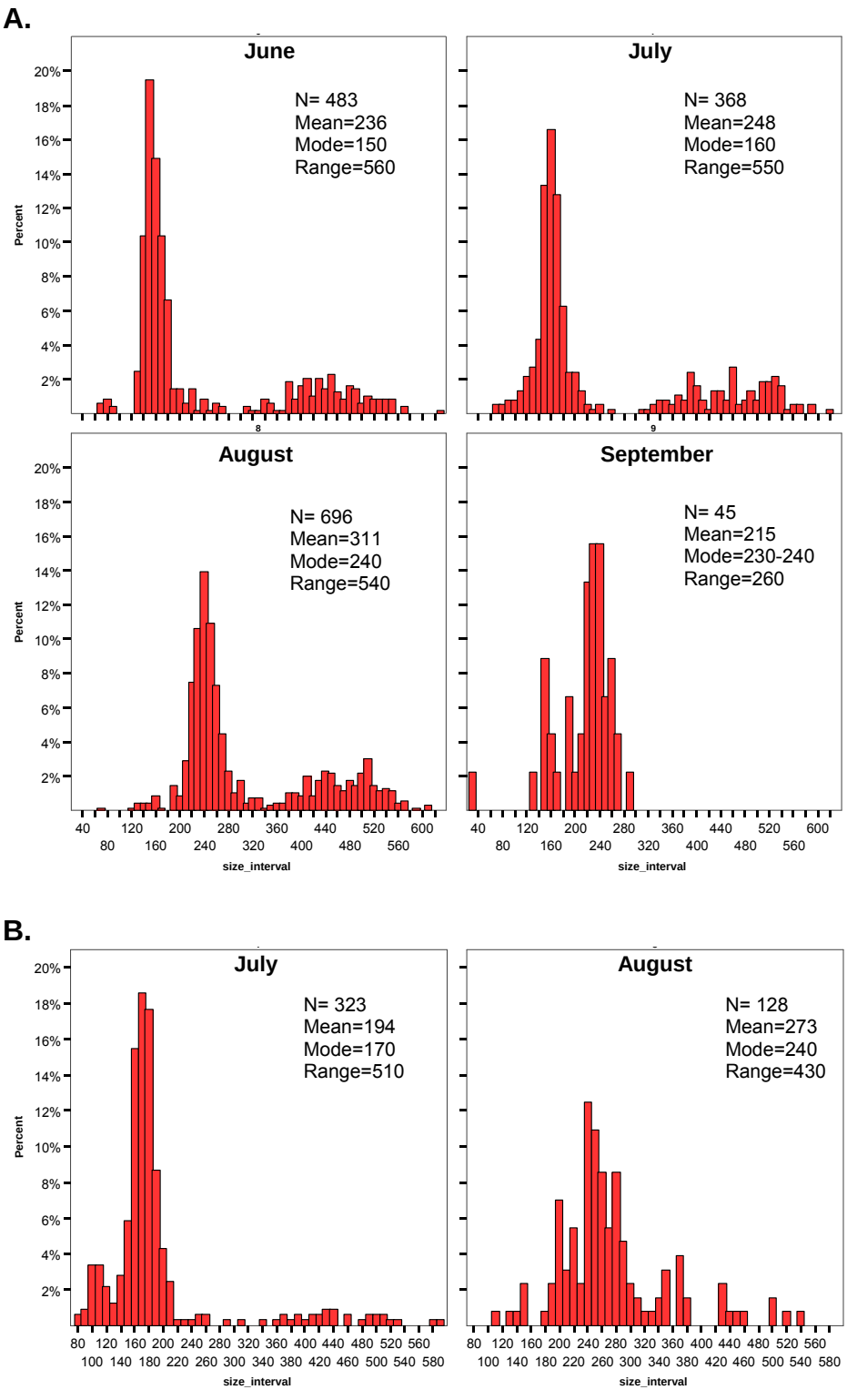


Figure 33. Length frequency distributions among summer months of Dolly Varden captured at Phillips Bay (Beaufort Sea coast) using trapnets in (A) 1986 and gillnets in (B) 2007.

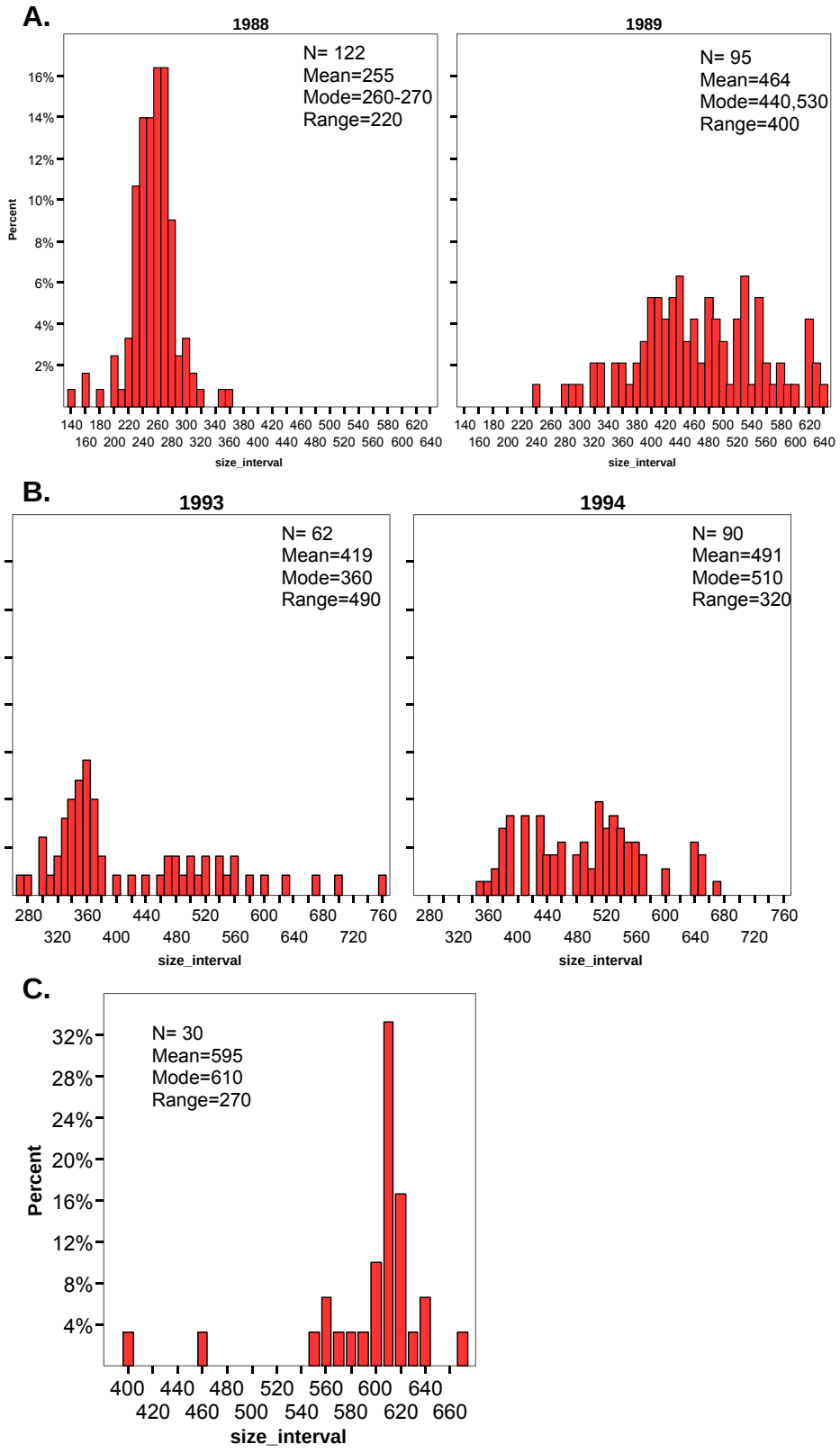


Figure 34. Length frequency distributions of Dolly Varden captured using subsistence gill nets along the Beaufort Sea coast in August at A) Herschel Island (1988 and 1989), B) Shingle Point (1993 and 1994) and C) King Point (1994).

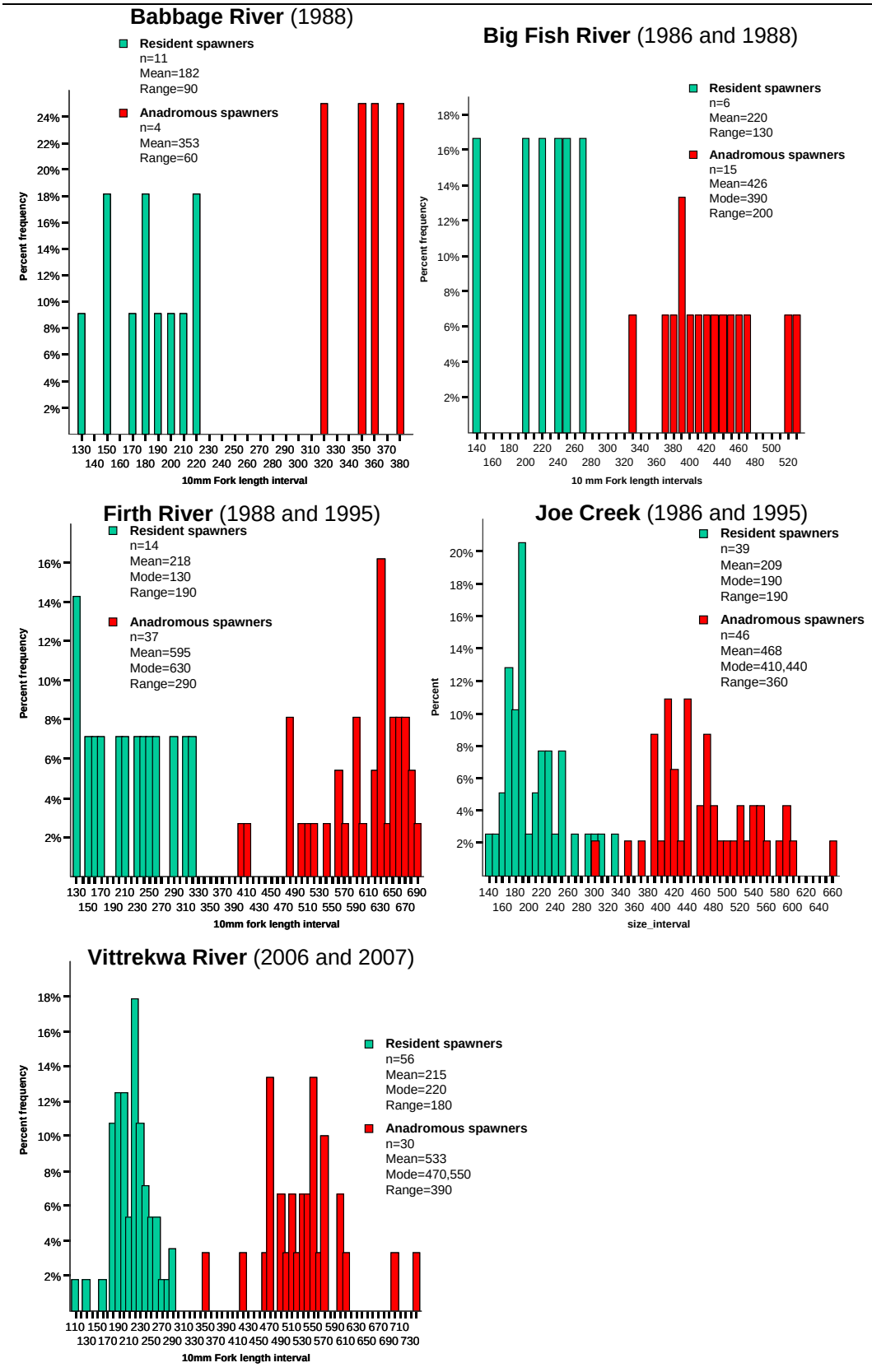


Figure 35. Length frequency distributions of co-occurring resident and anadromous male Dolly Varden spawners among different populations (sampling years were pooled to increase sample size where possible).

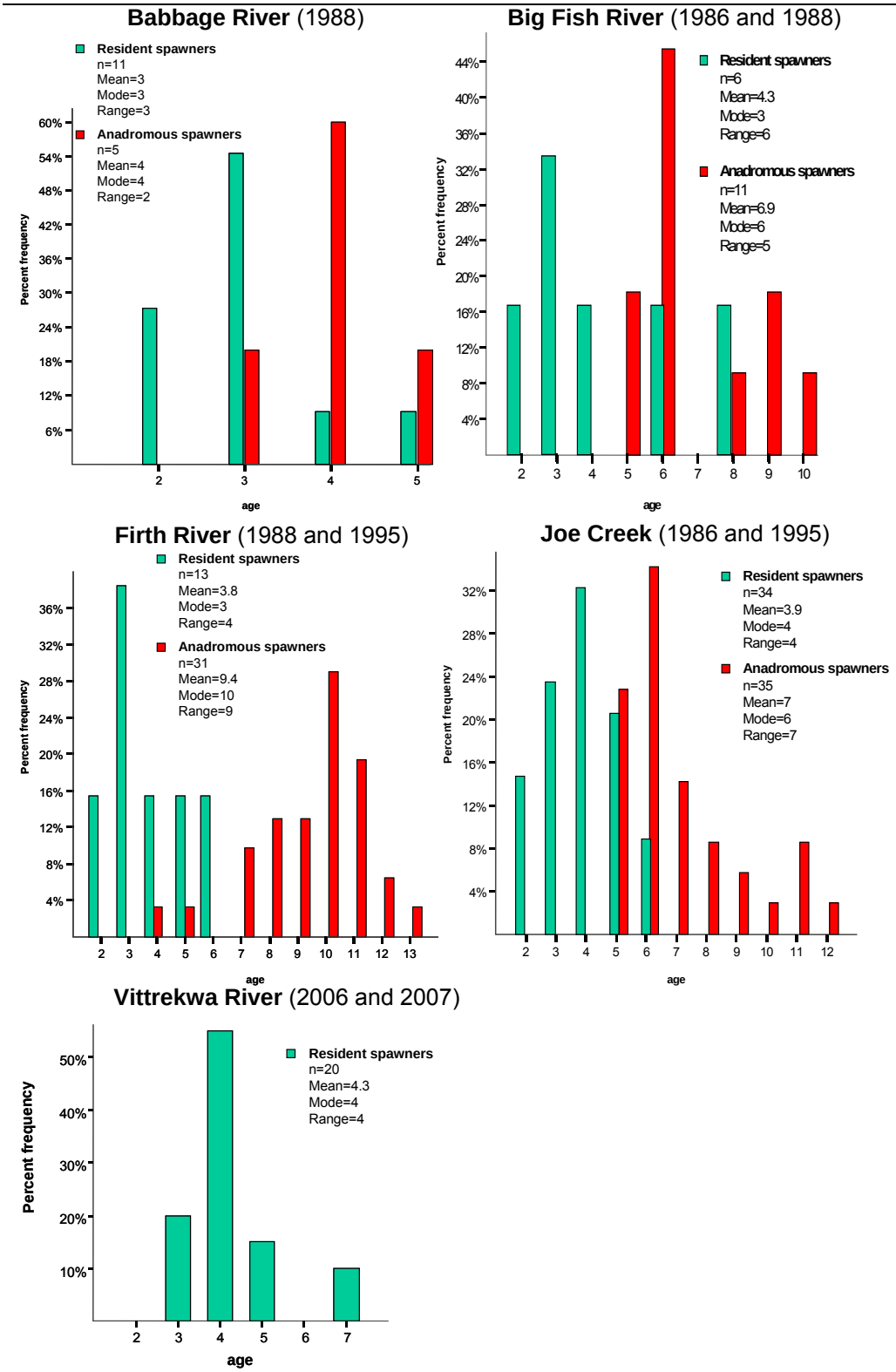


Figure 36. Age frequency distributions of co-occurring resident and anadromous male Dolly Varden spawners among different populations (sampling years were pooled to increase sample size where possible).

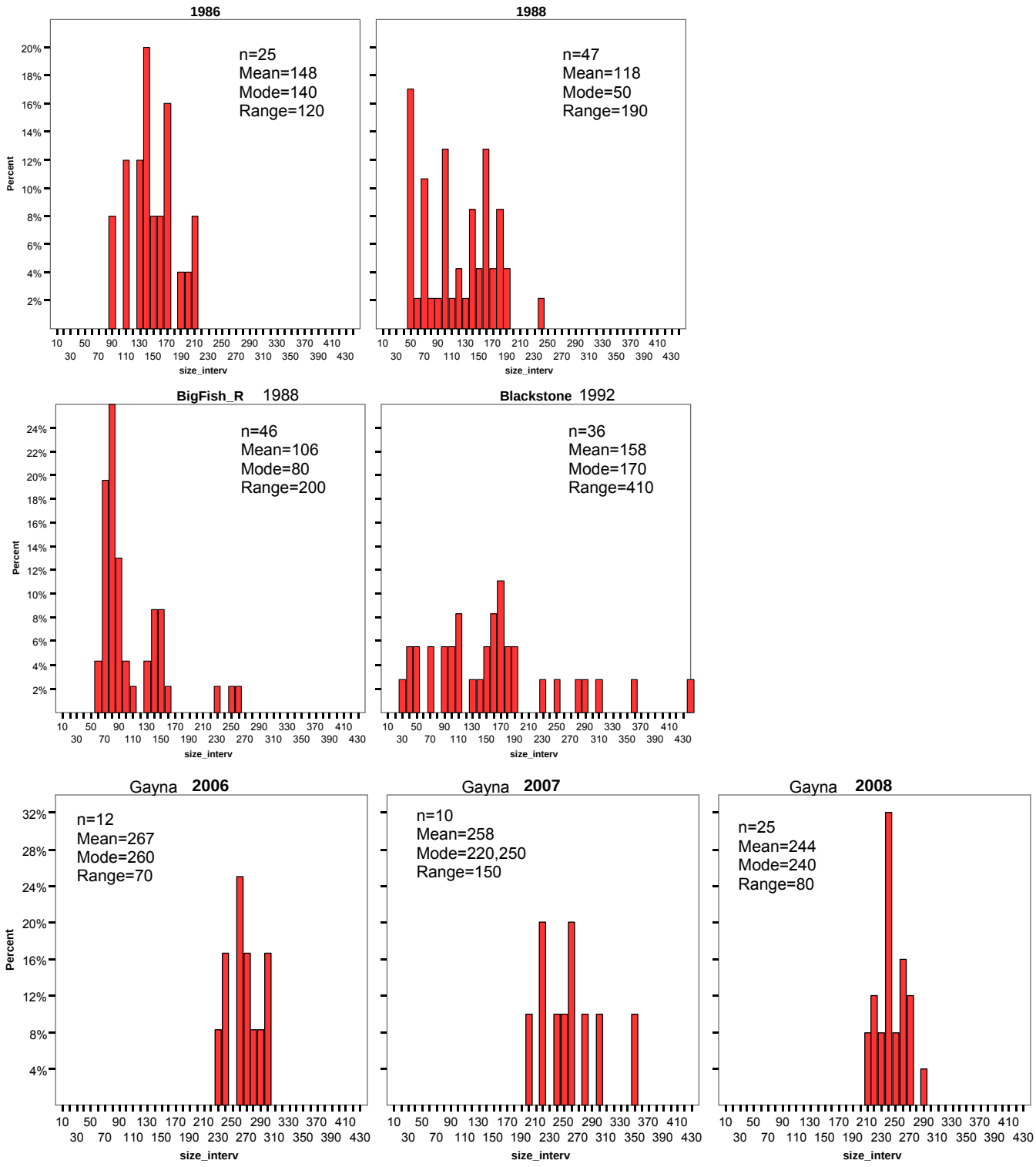


Figure 37. Length frequency distributions by year among isolated Dolly Varden populations.

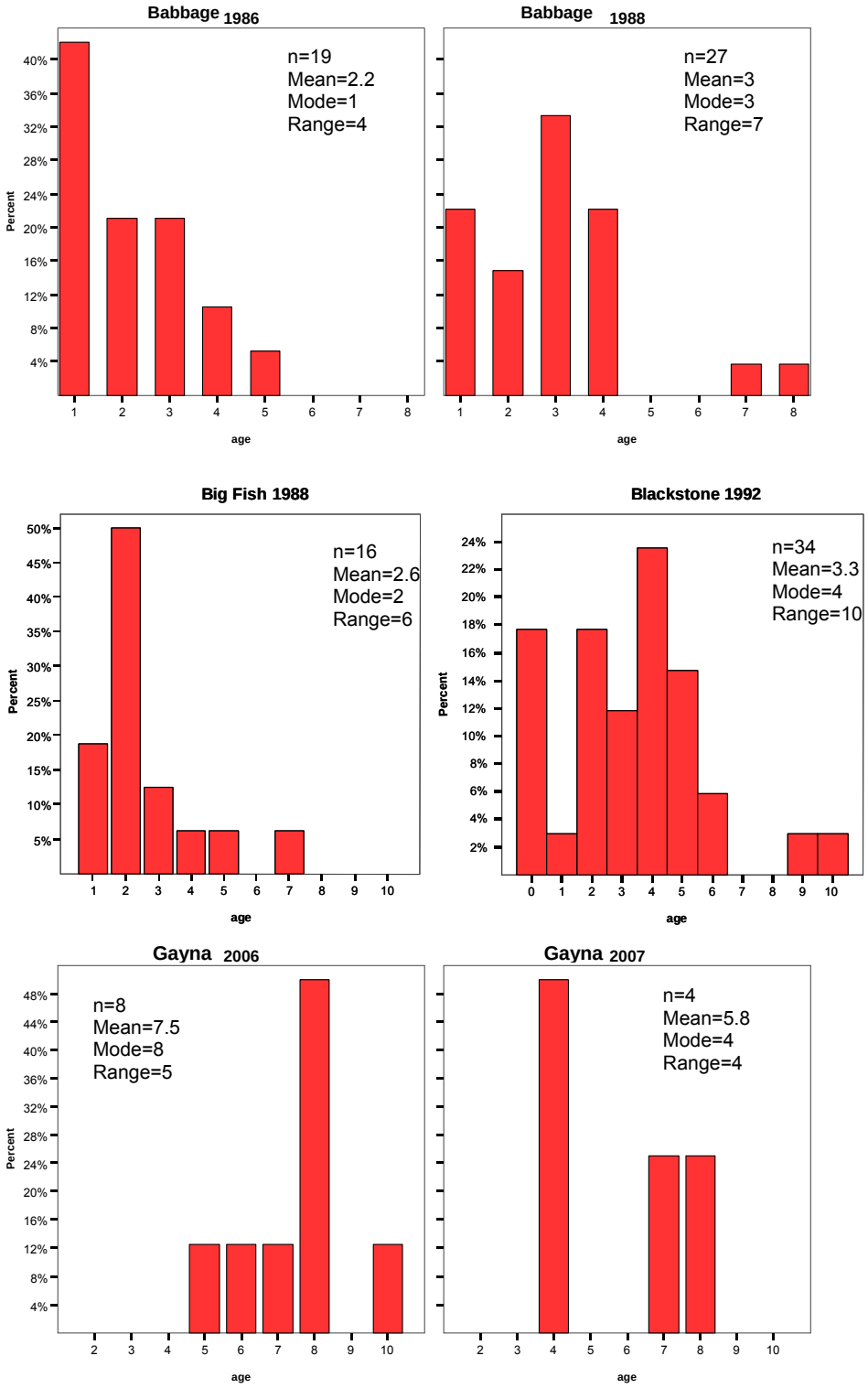


Figure 38. Age frequency distributions by year among isolated Dolly Varden populations.

Table 1. Summary information on available datasets of Dolly Varden collected from the Babbage, Firth, Joe Creek and Vittrekwa rivers, and the Beaufort Sea coast.

population	year	months	locations	Collector (s)	Type of Collection		method	Publication/Report
Babbage River								
	1986	9	SS	Reist	Biological (genetic) Analysis		seine/angling	Physiol. Ecol. Japan, Spec. Vol. 1: 405-420 & Amer. Fish. Soc. Symp. 19:250-261
	1987	9	SS	Baker	Biological (population) Analysis		seine	Unpublished Data
	1988	8	MR	Stephenson	Biological (population) Analysis		hoopnet	Unpublished Data
	1988	9	SS, BF	Reist	Biological (genetic) Analysis		electroshock	Amer. Fish. Soc. Symp. 19:250-261
	1990	8, 9	MR	Sandstrom, Lemieux and Reist	Biological (population) Analysis		weir	Can. Data Rep. Fish. Aquat. Sci. 1018: iv + 132p.
	1990	6, 7, 8	SS, MR, BF, CC	Reist	Biological (population) Analysis		electroshock, hoopnet, gillnet, angling	Unpublished Data
	1991	7, 8, 9	MR	Sandstrom, Lemieux and Reist	Biological (population) Analysis		weir, angling	Can. Data Rep. Fish. Aquat. Sci. 1018: iv + 132p.
	1991	7, 9, 10	SS, MR	Reist	Biological (population) Analysis		electroshock, seine	Unpublished Data
	1992	7, 8, 9	MR	Sandstrom, Lemieux and Reist	Biological (population) Analysis		weir, angling	Can. Data Rep. Fish. Aquat. Sci. 1018: iv + 132p.
	1992	5, 10	SS	Reist	Biological (population) Analysis		electroshock, angling	Unpublished Data
	1993	8, 9	SS	Reist	Biological (population) Analysis		electroshock	Unpublished Data
	1993	?	SS	Sandstrom	Biological (population) Analysis		electroshock	Unpublished Data
Firth River								
	1986	9	MR	Reist	Biological (genetic) Analysis	September	seine/angling	Physiol. Ecol. Japan, Spec. Vol. 1: 405-420 & Amer. Fish. Soc. Symp. 19:250-261
	1987	8	ML	Baker	Biological (population) Analysis	August	angling	Unpublished Data
	1988	9	MR	Reist	Biological (genetic) Analysis	September	electroshock, seine	Amer. Fish. Soc. Symp. 19:250-261
	1989	9	ML	Kristofferson et al.	Biological (population) Analysis	September	seine	Can. Data Rep. Fish. Aquat. Sci. 861: iv + 21 p.
	1995	9	MR	DFO/Parks, J. Johnson	Biological (population) Analysis	September	seine/angling	Unpublished Data
Joe Creek								
	1986	9	?	Reist	Biological (genetic) Analysis	September	seine/angling	Physiol. Ecol. Japan, Spec. Vol. 1: 405-420 & Amer. Fish. Soc. Symp. 19:250-261
	1995	9	?	DFO/Parks, J. Johnson	Biological (population) Analysis	September	electroshock, seine	Unpublished Data
Vittrekwa River								
	1999	?	NC	S. Stephenson	Biological (population) Analysis		seine	Unpublished Data
	2006	8, 10	MR, NC	Nathan Miller (GRRB)	Biological (population) Analysis		angling, dip net, trap net, seine	Unpublished Data
	2007	8	MR, NC	Nathan Miller (GRRB)	Biological (population) Analysis		angling, dip net, trap net	Unpublished Data
Coastal Areas								
(Beaufort Sea)	1985	6, 7, 8	Babbage R. mouth	Bond and Erickson	Biological (population) Analysis		gillnet	Can. Data Rep. Fish. Aquat. Sci. 635: v + 39 p.
	1986	6, 7, 8, 9	Babbage R. mouth	Bond and Erickson	Biological (population) Analysis		trapnet	Can. Tech. Rep. Fish. Aquat. Sci. 1676: vi +102 p.
	1988	8	Herschel I.	Reist	Biological (genetic) Analysis		gillnet	Amer. Fish. Soc. Symp. 19:250-261
	1989	8	Herschel I.	Reist	Biological (genetic) Analysis		gillnet	Amer. Fish. Soc. Symp. 19:250-261
	1989	8	Shingle point	Reist	Biological (genetic) Analysis		gillnet	Amer. Fish. Soc. Symp. 19:250-261
	1993	7, 8	Shingle point	Harwood	Subsistence Harvest Monitoring		gillnet	Unpublished Data
	1994	8	Shingle point, King p	Harwood	Subsistence Harvest Monitoring		gillnet	Unpublished Data
	2007	7, 8	Phillips bay	J. Johnson	Biological (population) Analysis		trapnet	Unpublished Data

locations: BF=below falls, CC=Caribou Creek, ML=multiple locations, MR= main river, NC= Ne'edilee Creek, SS= Spawning site.
Gear separated by a slash indicate that gear cannot be separated in the database, while a comma indicates that it is possible to separate gear type

Table 2. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden from the Firth River using data from all maturity stages combined and spawners only (in brackets).

Year	Method	Male							Female							Sex Ratio
		Fork length			Age				Fork length			Age				
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
1986	seining/angling	10	524	419-656	7	9.0	7	6-12	43	530	391-647	31	9.4	9	4-12	0.23[a]
		(7)	(523)	(454-583)	(6)	(8.3)		(6-12)	(39)	(534)	(391-647)	(27)	(9.3)		(4-12)	(0.18)[a]
1987*	angling	63	565	450-718	0				51	545	408-758	0				1.24[a]
1988	electrofishing	6	504	184-670	5	8.6	2	2-12	12	591	505-681	9	11.2	2	9-14	0.50[b]
		(5)	(568)	(469-670)	(5)	(10.3)		(9-12)	(10)	(592)	(505-681)	(7)	(11.4)		(9-14)	(0.50)[b]
1989*	seining	9	487	341-750	0				12	453	302-615	0				0.75[b]
1995	seining/angling	43	538	360-695	39	8.9	10	4-13	105	508	276-710	87	7.8	5	2-13	0.41[a]
		(33)	(572)	(460-695)	(33)	(10.0)		(6-13)	(68)	(547)	(405-678)	(68)	(9.1)		(4-13)	(0.49)[a]

[a] statistically significant, [b] not statistically significant

*Maturity not recorded

Table 3. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden from Joe Creek using data from all maturity stages combined and spawners only (in brackets).

Year	Method	Male							Female							Sex ratio
		Fork length			Age				Fork length			Age				
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
1986	seining/angling	17	501	301-662	10	8	6,7,11	5-11	35	492	271-577	22	8.9	9	3-12	0.49 [a]
		(18)	(501)	(301-662)	(8)	(8)		(5-11)	(33)	(500)	(391-577)	(20)	(9.2)		(6-12)	(0.9) [a]
1995	electrofishing	47	403	247-596	43	5.3	6	2-12	104	418	265-550	92	6.1	6	3-11	0.45 [a]
		(29)	(455)	(374-596)	(25)	(6.6)		(5-12)	(74)	(452)	(398-550)	(66)	(6.9)		(5-11)	(0.39) [a]

[a] statistically significant

Table 4. Number and percent (based on the sum of spawner and non-spawner sample) sexually mature spawners by age class of anadromous male and female Dolly Varden from the Firth River and Joe Creek.

Sex	Age	Firth River						Joe Creek			
		1986		1988		1995		1986		1995	
		n	%	n	%	n	%	n	%	n	%
Male	5							1	100	7	77.7
	6					2	100	2	100	10	100
	7					2	100	2	100	3	100
	8	2	100			2	66.6	1	100	2	100
	9	1	100			4	80	1	100	1	100
	10	1	100	1	100	4	50	1	100		
	11					5	71	2	100	1	100
	12	1	100	1	100	2	100			1	100
	13					2	66.6				
Female	4	1	100								
	5					5	35.7			4	33.3
	6	1	100			9	81.8	1	100	38	100
	7	3	100			5	83.3	2	100	10	90.9
	8	2	100			7	58.3	2	66.6	3	100
	9	7	77.7	1	100	7	63.6	7	100	3	100
	10	5	100	2	66.6	9	75	4	100	4	100
	11	6	75			3	37.5	3	100	4	100
	12	2	100	2	100			1	100		
	13			1	100						
	14			1	100						

Table 5. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden collected at the spawning site and other locations on the Babbage River using data from all maturity stages combined and spawners only (in brackets).

Location	Year	Method	Male							Female							Sex ratio
			Fork length			Age				Fork length			Age				
			n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
Spawning site	1986	seining/angling	27	484	250-611	18	8.2	7,10	2-13	42	476	324-565	26	7.9	8	5-10	0.64 [b]
			(22)	(492)	(300-611)	(14)	(8.4)		(6-13)	(40)	(473)	(324-565)	(25)	(7.8)		(5-10)	(0.55) [a]
	1987	seining	115	539	372-671	0				179	488	337-623	0				0.64 [a]
			(95)	(538)	(389-671)					(154)	(488)	(360-602)					(0.61) [a]
	1988	electrofishing	23	348	270-401	20	3.9	4	2-5	31	343	278-427	26	4.1	4	3-5	0.74 [b]
			(4)	(356)	(320-384)	(5)	4.0		(3-5)	(3)	(399)	(384-427)	(3)	(4.7)		(4-5)	(1.3) [b]
	1990	electrofishing	1*	300	-	0				1*	495	-	0				1.0 [c]
		angling	(0)							(2)	(469)	(402-535)					-
	1991	electrofishing	7	519	454-582	0				15	465	398-506	10*	5.2	5	3-7	0.47 [b]
			(5)	(539)	(515-582)	(0)				(14)	(463)	(398-506)					(0.36) [b]
	1992	electrofishing	(0)			0				28*	483	449-548	17	7.4	7	6-10	-
		angling	(2)	(303)	(301-305)	(0)				(0)							-
	1993	electrofishing	0	-	-	0				54*	498	443-549	39	8.5	7,9	6-12	-
River																	
below falls	1988	electrofishing/ seining	2	242	332-353	2	4	1,4	4-4	2	339	326-352	0	-	2,3	-	1.0
			(0)			(0)				(0)			(0)				
mid river	1990	weir	52	502	331-660	43	6.3	7	3-11	50	470	325-622	43	6.5	6	3-13	1.04 [b]
			(27)	(530)	(432-641)	(20)	(7.3)		(6-11)	(29)	(492)	(425-622)	(25)	(7.3)		(5-13)	(0.93)
below falls	1990	angling	2*	397	315-479	0*				3	422	343-480	0				-
										(2)	(462)	(444-480)	(0)				(1.0) [c]
mid river	1991	weir	301	509	303-660	56	5.8	6	3-9	91	452	318-626	65	5.8	6	3-13	3.3 [a]
			(256)	(514)	(329-660)	(17)	(6.0)		(3-9)	(46)	(480)	(357-626)	(32)	(6.3)		(4-13)	(5.6) [a]
mid river	1991	angling	13	521	447-586	12	6.5		5-9	18	486	415-555	14	5.9		5-9	0.72 [b]
			(4)	(506)	(472-523)	(4)	(6.0)		(6-6)	(10)	(491)	(432-555)	(7)	(6.3)		(5-9)	(0.4) [b]
mid river	1992	weir	400	521	300-661	68	6.8	7	2-10	584	475	315-649	75	6.3	7	3-11	0.68 [a]
			(310)	(535)	(362-661)	(37)	(7.2)		(5-9)	(464)	(483)	(318-594)	(50)	(7.1)		(4-11)	(0.67) [a]
mid river	1992	angling	(3)	(533)	(477-576)	(3)	(6.5)		(6-7)	(0)							-

* denotes that all of these samples were also spawners.
[a] statistically significant, [b] not statistically significant, [c] sample size is too low to evaluate statistically

Table 6. Number and percent (based on the sum of spawner and non-spawner sample) sexually mature by age class of anadromous male and female Dolly Varden from the Babbage River captured by electrofishing and weir.

Sex	Age	Electrofishing										Weir					
		1986		1988		1991		1992		1993		1990		1991		1992	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Male	2			1	25												
	3			3	33.9									1	33.3		
	4			1	20									3	37.5		
	5													1	14.3	4	36.4
	6	1	100									3	33.3	10	34.5	5	45.5
	7	4	80									12	70.6	3	18.8	16	66.7
	8	4	100									3	75	2	66.7	10	71.4
	9	1	100									1	50	1	50	4	66.7
	10	3	60														
	11											1	100				
	12																
	13	1	100														
Female	3					1	100										
	4			1	9.1	1	100							4	28.6	1	50
	5	2	100	2	22.2	4	100					3	33.3	9	50	2	15.4
	6	2	100			3	100	3	100	2	100	9	56.3	12	46.2	11	91.7
	7	6	100			1	100	8	100	9	100	5	71.4	8	66.7	20	69
	8	8	87.5					4	100	9	100	3	100	3	100	10	83.3
	9	4	100					1	100	10	100	1	100	2	50	5	83.3
	10	4	100					1	100	6	100	1	100				
	11									1	100	1	100			1	100
	12									2	100	1	100				
	13											1	100	1	100		

Table 7. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden from the Vittrekwa River.*

Year	Method	Male							Female							Sex ratio
		Fork length			Age				Fork length			Age				
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
2006	angling, dip net, trap net, seining	9	540	470-700	0				6	523	445-602	0				1.5 [b]
2007	angling, dip net, trap net	21	536	355-746	0				12	539	401-663	1	10			1.8 [b]

* A sample of young-of-the-year was taken by seining in 1999 (n= 38 males, n= 30 females).
[b] not statistically significant

Table 8. Confidence intervals (95%) of published population estimate of Dolly Varden among river systems within or near the period of 1986-88 and 1993-95. Year of estimate is provided in brackets.

Population	1986-88	1993-95
Firth River*	8,250-10,700 (1989)	-
Joe Creek	-	-
Babbage River	-	10,615-16,663 (1991)
Big Fish River	6,300-14,300 (1984)	3,397-5,563 (1993)
Rat River	8,263-14,118 (1989)	6,930-11,140 (1995)
Vittrekwa River	n.a.	n.a.

*range based on visual observation rather than from a capture-recapture study.

Table 9. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden from multiple population using data from all maturity stages combined and spawners only (in brackets) collected from the spawning/overwintering areas between 1986 and 1988.

Location	Method	Male							Female							Sex ratio
		Fork length			Age				Fork length		Age					
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
Firth River	Seining, angling, Electrofishing	15 (12)	539 (541)	419-670 (454-670)	11 (9)	9.5 (9.9)	10 (10)	6-12 (8-12)	55 (50)	543 (547)	391-681 (391-681)	40 (37)	9.8 (9.8)	9 (9,11)	4-14 (6-13)	0.27[a] (0.24)[a]
Joe Creek	Seining/angling	17*	501	301-662	10*	8.0	6, 7, 11	5-11	35 (33)	492 (500)	271-577 (391-577)	22 (20)	8.9 (9.2)	9 (9)	3-12 (6-12)	0.48[a] (0.51)[a]
Babbage River	Seining/angling, Electrofishing	50 (26)	421 (471)	250-611 (300-611)	38 (19)	6.0 (7.4)	4 (7,8)	2-13 (3-13)	73 (43)	422 (468)	278-565 324-565	52 (28)	5.9 (7.5)	4,5 (8)	3-10 (4-10)	0.68[b] (0.60)[b]
Big Fish River	Seining/angling, seining/electrofishing	21 (15)	412 (430)	290-536 (332-536)	16 (11)	6.6 (6.9)	6 (6)	3-10 (5-10)	52 (41)	408 (426)	278-565 (324-565)	39 (30)	7.8 (8.4)	9 (9)	4-14 (5-14)	0.40[a] (0.37)[a]
Rat River	Electrofishing	22 (13)	445 (444)	331-519 (366-507)	17 (10)	6.5 (6.2)	7 (7)	5-9 (5-7)	79 (51)	471 (469)	342-619 (389-619)	65 (43)	6.9 (7.1)	7 (6)	5-10 (5-10)	0.28[a] (0.25)[a]

* denotes that all of these samples were also spawners.
[a] statistically significant, [b] not statistically significant

Table 10. Summary statistics of available length (mm) and age (years) data by sex, sampling year and collection method of anadromous Dolly Varden from multiple population using data from all maturity stages combined and spawners only (in brackets) collected from the spawning/overwintering areas between 1993 and 1995.

Location	**Method**	**Male**							**Female**							**Sex ratio**
		Fork length			Age				Fork length			Age				
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	M:F
Firth River	Seining/angling	43	538	360-695	39	8.9	10	4-13	104	510	318-710	86	7.8	5	2-13	0.41[a]
		(33)	(572)	(460-695)	(31)	(10.0)	(10)	(6-13)	(68)	(547)	(405-678)	(55)	(9.1)	(10)	(4-13)	(0.49)[a]
Joe Creek	Electrofishing	39	431	300-596	43	5.3	6	2-12	94	433	308-550	92	6.1	6	3-11	0.41[a]
		(29)	(455)	(374-596)	(25)	(6.6)	(6)	(5-12)	(74)	(452)	(398-550)	(66)	(6.9)	(6)	5-11	(0.39)[a]
Babbage River	Electrofishing	0							54*	498	443-594	39*	8.5	9	6-12	-
Big Fish River	Seining, Electrofishing	59	457	282-606	12	3.8	4	3-6	498	455	280-595	115	6.5	4	3-14	0.12[a]
		(43)	(504)	(408-606)	(1)	(4.0)	(4)		(453)	(463)	(337-595)	(94)	(7.1)	(5)	(4-14)	(0.09)[a]
Total sample																
Rat River	Seining	444	463	315-633	0											

[a] statistically significant, [b] not statistically significant

Table 11. Mean fork length (mm) and age (years) of anadromous Dolly Varden (total data combined) collected from the spawning/overwintering areas in 1986-88 1993 and 1993-95.

	1986-88		1993-95	
	Length	Age	Length	Age
Firth River	542	9.7	518	8.2
Joe Creek	495	8.6	434	6.2
Babbage River	422	5.9	496	8.6
Big Fish River	406	7.4	423	4.7
Rat River	462	6.8	463	n.a.

Table 12. Minimum age-at-maturity among populations of anadromous Dolly Varden captured at spawning/ overwintering areas in 1986-88 and 1993-95.

	1986-88		1993-95	
	Male	Female	Male	Female
Firth River	8	6	6	4
Joe Creek	5	6	5	3
Babbage River	3	4	n.a.	6
Big Fish River	5	5	4	4
Rat River	5	5	n.a.	n.a.

Table 13. Summary of available harvest information over time for Dolly Varden harvested along the Beaufort sea coast.

Year	Location	Subsistence	Sport	Notes	Reference
1965-66	Herschel Is			Small commercial fishery harvested approx. 7,700 kg of Dolly Varden in 1965-66	Baker (1987)
1971	Herschel Is	200	100 (200 kg)	Approx. Sport Fishery by DEW line personnel along the coast.	Baker (1987); Karasiuk et al. (1992)
1972	Herschel Is	1000	100 (200 kg)	Approx. Sport Fishery by DEW line personnel along the coast.	Baker (1987); Karasiuk et al. (1992)
1973	Herschel Is	200	100 (200 kg)	Approx. Sport Fishery by DEW line personnel along the coast.	Baker (1987); Karasiuk et al. (1992)
1987	Herschel Is	73			Inuvialuit Harvest Study
1987	Shingle Pt	259			Inuvialuit Harvest Study
1988	Herschel Is	55		July (5), August (50)	Inuvialuit Harvest Study
1988	King Pt	50		August	Inuvialuit Harvest Study
1988	Shingle Pt	147		July (36), August (111)	Inuvialuit Harvest Study
1989	Heschel Is	25		August	Inuvialuit Harvest Study
1989	Shingle Pt	30		July	Inuvialuit Harvest Study
1989	King Pt, Shingle Pt	75		July	Inuvialuit Harvest Study
1990	Shingle Pt.	214		June (25), July (127), August (62)	Inuvialuit Harvest Study
1990	Phillips Bay	5		-	Inuvialuit Harvest Study
1991	Herschel Is	30		July	Inuvialuit Harvest Study
1991	Shingle Pt.	7		August	Inuvialuit Harvest Study
1992	King Pt	24		July (21), September (3)	Inuvialuit Harvest Study
1992	Shingle Pt	17		July (15), August (2)	Inuvialuit Harvest Study
1992	Herschel Is	20		-	Inuvialuit Harvest Study
1993	Shingle Pt	119		July (96), August (23)	Inuvialuit Harvest Study
1993	Herschel Is	19		July	Inuvialuit Harvest Study
1994	Schingle Pt	33		July (22), August (11)	Inuvialuit Harvest Study
1994	King Pt	36		August	Inuvialuit Harvest Study
1994	Phillips Bay	16		August	Inuvialuit Harvest Study
1994	Herschel Is	130		August	Inuvialuit Harvest Study
1995	Herschel Is	38		June (6), July (25), August (7)	Inuvialuit Harvest Study
1995	Herschel Is	10		August	Inuvialuit Harvest Study
1995	Schingle Pt	63		July (1), August (62)	Inuvialuit Harvest Study
1996	Herschel Is	560		August (560)	Inuvialuit Harvest Study
1996	Schingle Pt	805		July (330), August (475)	Inuvialuit Harvest Study
1997	Herschel Is	100		August	Inuvialuit Harvest Study
1997	Herschel Is	30		July	Inuvialuit Harvest Study
1997	Schingle Pt	123		July (73), August (50)	Inuvialuit Harvest Study
1998	Herschel Is	200			Inuvialuit Harvest Study
1998	Herschel Is	33			Inuvialuit Harvest Study
1998	King Pt, Shingle Pt	35			Inuvialuit Harvest Study
1998	Schingle Pt	541			Inuvialuit Harvest Study
1999	Schingle Pt	250		Estimated, Harvest from July 9 to August 21	DFO
2000	King Pt	15		as per data available November 24	Inuvialuit Harvest Study
2006	Shingle Pt	127			K. Bill (DFO Inuvik)
2007	Shingle Pt	106			K. Bill (DFO Inuvik)
2008	Shingle Pt	29			K. Bill (DFO Inuvik)
2007	Herschel Is	113			K. Bill (DFO Inuvik), Herschel Is (Yukon) Terr. Park
2008	Herschel Is	41			K. Bill (DFO Inuvik), Herschel Is (Yukon) Terr. Park

Table 14. Summary statistics of available length (mm) and age (years) data by year, location and capture method for Dolly Varden collected in the Beaufort Sea.

Year	Month	Location	Sub locations	Method	Fork length			Age			
					n	mean	range	n	mean	mode	range
1985	06-08	Phillips Bay	BM	gillnet	104	428	187-635				
1986	06-09	Phillips Bay	BM	trapnet	159 2	275	33-634				
1988	08	Herschel Island	PB	gillnet	122	259	148-363				
1989	08	Herschel Island	TB, PC, PB	gillnet	95	469	242-644	75	7.6	6	2-14
1989	08	Shingle Point		gillnet	16	439	354-623	12	5.6	4	3-9
1993	07-08	Shingle Point		gillnet	86	436	270-760				
1994	08	Shingle Point		gillnet	90	494	350-670				
1994	08	King Point		gillnet	30	598	408-670				
2007	07-08	Phillips Bay		gillnet	451	221	80-594				

sub-locations: BM=Babbage river mouth, PB= Ptarmigan Bay, PC=Pauline Cove, TB=Thetis Bay

Table 15. Summary statistics of available length and age data by sex of Dolly Varden collected among locations along the Beaufort Sea coast.

Year	Location	Male							Female							Sex ratio (M:F)
		Fork length			Age				Fork length			Age				
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range	
1985	Phillip's Bay	26	453	352-635					65	436	187-576					0.40
1988	Herschel Is	62	264	148-363					55	255	165-352					1.18*
1989	Herschel Is	34	490	287-644	27	7.5	6	2-12	61	457	242-627	48	7.7	6	3-14	0.56
1989	Shingle Pt	9	426	369-497	7	5.0	4	3-9	7	455	354-623	5	6.4	6	4-9	1.29*
1993	Shingle Pt	37	476	305-760					49	406	270-585					0.76*
1994	Shingle Pt	29	500	360-670					38	477	350-640					0.76*
1994	King Pt	22	605	460-670					8	578	408-619					2.75

*not statistically different from a 1:1 ratio, all other values are significantly different.

Table 16. Summary information of data collections of resident-type Dolly Varden among different river systems.

year	month	locations	Collector (s)	Type of Collection	method	n
Babbage River						
1988	9	SS	Reist	Biological (genetic) analysis	electroshock	11
Big Fish river						
1986	9	SS	Reist	Biological (genetic) analysis	seine/angling	4
1988	9	SS	Reist	Biological (genetic) analysis	seine/electroshock	3
Firth River						
1988	9	MR	Reist	Biological (genetic) analysis	electroshock	9
1995	9	MR	DFO/Parks, J. Johnson	Biological (population) analysis	seine/angling	9
Joe Creek						
1986	9	?	Reist	Biological (genetic) analysis	seine/angling	26
1995	9	?	DFO/Parks, J. Johnson	Biological (population) analysis	electroshock	21
Rat river						
2004	9	SS	S. Sandstrom	Biological (population) analysis	seine	1
Vittrekwa River						
2006	8	SS, NC, MR	Nathan Miller (GRRB)	Biological (population) Analysis	angling, trap net	14
2007	8	SS, NC	Nathan Miller (GRRB)	Biological (population) Analysis	angling, dip net, trap net	42

n = total number of Dolly Varden examined

locations: MR= main river, NC= Ne'edilee Creek, SS= Spawning site.

Table 17. Summary statistics of size and age and maturity information by year for resident male Dolly Varden collected in different river systems.

year	Fork length			Age				Maturity
	n	mean	range	n	mean	mode	range	
Babbage river								
1988	11	186	136-229	11	3	3	2-5	all spawners
Big Fish river								
1986	3	248	228-271	4	4.8	2-8	2-8	all spawners
1988	3	202	149-256	2	3.5	3.4	2-4	all spawners
Firth river								
1988	7	176	133-256	6	2.8	3	2-4	all spawners
1995	9	254	185-322	7	4.6	3,5-6	3-6	7 spawners, 2 resting adults
Joe Creek								
1986	25	194	159-259	22	3.2	3	2-5	22 spawners, 3 resting adults
1995	19	238	149-333	17	5.3	4	3-11	17 spawners, 1 resting adult
Rat river								
2004	1	235		0				not determined
Vittrekwa river								
2006	14	238	180-294	0				all spawners
2007	42	213	116-292	20	4.3	4	3-7	all spawners

Table 18. Mean fork length at age for resident Dolly Varden among river systems.

Age	Babbage		Big Fish		Firth		Joe Creek		Vittrekwa	
	n	mean FL	n	mean FL	n	mean FL	n	mean FL	n	mean FL
1	0		0		0		1	132	0	
2	3	165	1	na	1	135	5	176	0	
3	6	185	2	214	4	185	12	183	4	198
4	1	210	1	256	2	269	12	213	11	206
5	1	229	0		2	285	7	262	3	218
6			1	271	2	268	3	222	0	
7			0		0		0		2	232
8			1	244	0		0		0	
9					0		1	289	0	
10					0		0		0	
11					0		1	245	0	

Table 19. Ratios of resident to anadromous male spawners for years when both life-history types were collected among populations.

Location	n	Ratio (resident:anadromous)	Year	Sub-location
Firth	14	9/4 (2.3)*	1988	UMR
	40	7/33 (0.21)	1995	UMR
Joe Creek	40	22/18 (1.22)	1986	
	46	17/29 (0.59)*	1995	
Babbage	16	11/5 (2.2)*	1988	SS
Big Fish	8	4/4 (1.0)*	1986	SS
	14	3/11 (0.27)*	1988	SS
Rat	694	4/690 (0.006)	1989	SS
Vittrekwa	24	14/10 (1.4)*	2006	SS, NC, MR
	63	42/21 (2)*	2007	SS, NC

n = number of male spawners identified for life-history types.
Locations: SS=spawning site, MR=Main River, UMR=Upper Main River, NC=Ne'edilee Creek
*not statistically different from a 1:1 ratio, all other values are significantly different

Table 20. Summary information of available datasets of isolated Dolly Varden populations.

year	month	location (s)	Collector (s)	Type of Collection	method	n	Publication/Report
Babbage River							
1986	9	AF	Reist	Biological (genetic) analysis	seine	33	Amer. Fish. Soc. Symp. 19:250-26
1988	9	AF	Reist	Biological (genetic) analysis	electroshock	53	Amer. Fish. Soc. Symp. 19:250-26
Big Fish river							
1988	9	AF	Reist	Biological (genetic) analysis	seine/electroshock	59	Amer. Fish. Soc. Symp. 19:250-26
Blackstone river							
1992	?	main river?	?	Biological study	electroshock	36	unpublished data
Gayna river							
2006	9	MR (reach 1)	N. Mochnacz	Biological study	angling	12	unpublished data
2007	9	MR (reach 1 & 2)	N. Mochnacz	Biological study	electroshock	10	unpublished data
2008	8	MR (reach 1 & 2)	N. Mochnacz	Biological study	angling	29	unpublished data

n = total number of Dolly Varden examined
location: AF=Above falls, MR= main river

Table 22. Summary statistics of available size and age data by year for isolated Dolly Varden populations.

Year	Location	Method	Fork length (mm)			Age (years)			
			n	mean	range	n	mean	mode	range
1986	Babbage	seining	25	154	95-210	19	2.2	1	1-5
1988	Babbage	electrosfishing	47	123	50-249	27	3	3	1-8
1988	Big Fish	seining/electrofishing	46	111	61-265	16	2.6	2	1-7
1992	Blackstone	gillnet	36	162	33-440	34	3.3	4	0-10
2006	Gayna	angling	12	272	236-305	8	7.5	8	5-10
2007	Gayna	electrofishing	10	262	208-352	4	5.8	4	4-8
2008	Gayna	angling	25	249	215-290	0			

Table 23. Summary statistics of size and age by sex and year for isolated Dolly Varden populations.

Year	Population	Male							Female						
		Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
		n	Mean	Range	n	Mean	Mode	Range	n	Mean	Range	n	Mean	Mode	Range
1986	Babbage	14	156	111-210	10	1.7	1	1-3	9	162	113-210	8	2.9	2	1-5
1988	Babbage	13	151	100-249	11	3.2	3	1-8	18	154	103-199	14	3.1	4	1-4
1988	Big Fish	11	133	84-239	7	2.1	2	1-4	15	135	76-265	7	3.1	2	1-7
1992	Blackstone	16	210	102-440	15	4.5	4	2-10	13	162	90-257	13	3.5	4	1-6
2006	Gayna	3	281	245-305	3	7	8	5-8	5	265	236-281	5	7.8	8	6-10
2007	Gayna	3	261	208-352	3	5.3	4	4-8	1	288		1	7		

Table 24. Average length-at-age for isolated male and female Dolly Varden among populations.

Male

Age	Babbage		Big Fish		Blackstone		Gayna	
	n	mean FL	n	mean FL	n	mean FL	n	mean FL
1	8	134	1	159	0		0	
2	2	144	3	145	3	108	0	
3	8	165	1	148	2	161	0	
4	0		1	239	4	246	2	216
5	0		0		3	217	1	245
6	0		0		1	362	0	
7	1	249	0		0		0	
8	1	185	0		0		3	317
9	0		0		1	315	0	
10	0		0		1	291	0	

Female

Age	Babbage		Big Fish		Blackstone		Gayna	
	n	mean FL	n	mean FL	n	mean FL	n	mean FL
1	2	108	1	109	1	90	0	
2	5	132	3	131	3	121	0	
3	4	163	1	144	2	138		
4	8	173	0		4	189		
5	1	210	1	251	2	213		
6	0		0		1	195	1	267
7	0		1	265	0		2	262
8	0		0		0		2	271
9	0		0		0		0	
10	0		0		0		1	281

Table 25. Summary statistics of size and age for male and female spawners among isolated Dolly Varden populations.

	Male spawners							Female spawners						
	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
population	n	Mean	Range	n	Mean	Mode	Range	n	Mean	Range	n	Mean	Mode	Range
Babbage river	20	166	111-249	14	3.1	3	1-8	18	169	137-210	16	3.4	4	2-5
Big Fish river	7	156	115-239	7	2.1	2	1-4	3	219	140-265	2	6	5.7	5-7
Blackstone River	9	270	172-440	9	5.8	4.5	4-10	4	214	168-257	4	5.0	5	4-6
Gayna River	3	317	293-352	3	8	8	8	5	267	236-288	5	7.2	7.8	6-8

Table 26. Percent male and female spawners by age class among isolated Dolly Varden populations.

Age	Babbage				Big Fish				Blackstone				Gayna			
	Male		Female		Male		Female		Male		Female		Male		Female	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1	9	33	2	0	2	100	1	0	0		1	0	0		0	
2	2	50	6	50	3	100	3	0	3	0	3	0	0		0	
3	8	100	5	80	1	100	1	0	2	0	2	0	0		0	
4	0		8	100	1	100	0		4	75	4	25	2	0	0	
5	0		1	100	0		1	100	3	100	2	100	1	0	0	
6	0		0		0		0		1	100	1	100	0		1	100
7	1	100	0		0		1	100	0		0		0		2	100
8	1	100	0		0		0		0		0		3	100	2	100
9	0		0		0		0		1	100	0		0		0	
10	0		0		0		0		1	100	0		0		1	0

n= total number of male Dolly Varden identified for maturity.

Table 27. Sex ratios (male to female) among isolated Dolly Varden populations.

Year	Location	n	Ratio
1986	Babbage	27	1.45*
1988	Babbage	32	0.68*
1988	Big Fish	31	0.72*
1992	Blackstone	29	1.23*

*not statistically different from a 1:1 ratio, all other values are significantly different. Ratios were calculated for sample sizes ≥10.