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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 I: Rat River

Synthèse des données biologiques et des renseignements sur la récolte utilisés pour évaluer les populations de la forme nordique du Dolly Varden (*Salvelinus malma malma*) au Canada – Partie I : le Dolly Varden de la rivière Rat

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ABSTRACT

Biological information of anadromous northern form Dolly Varden (*Salvelinus malma malma*) from the Rat River, Northwest Territories, collected primarily between 1989 and 2008 along with harvest statistics are synthesized in order to assess the population and examine for trends over time. Data include length, weight, age, growth, sex, maturity, mortality, and estimated and reported subsistence harvest. Biological data were collected from a harvest monitoring program (1989, 1995-2008) where designated local subsistence harvesters (termed 'monitors') dead-sampled from their own or other harvester's catches during the return migration of Dolly Varden from the Beaufort Sea in August and September. Catch and effort data from harvest monitor's nets, and total harvest numbers from all fishing activity in the monitor's vicinity were also collected. Additionally, biological data were collected from live-sampling of Dolly Varden at the spawning/overwintering area of the Rat River during tagging (1995-2007) and recapturing (2007) of fish for mark-recapture studies to estimate population abundance.

The population size was estimated to have been between 10,140 and 11,190 based on periodic mark-recapture studies between 1989 and 1997, with a notable decrease in abundance observed in 2004 when the estimated size was approximately 2,911 Dolly Varden. By 2007 abundance had increased to between 8,488 and 14,886 fish (based on the results from two recapture methods for the same year). Changes in annual catch-per-unit-effort data from harvest monitor's nets were consistent with increases and declines in population abundance.

Males and females examined from the total sample (all maturity stages) captured in 102 mm mesh gill nets decreased 67 and 53 mm in mean length, respectively, during the decline in population abundance. Dolly Varden rebounded to pre-decline lengths following the subsequent increase in population size. Female current-year spawners captured in 102 mm mesh increased in mean length by 77 mm between 2001 and 2004, while both males and female spawners captured in the seine net on the spawning grounds also increased in mean length. Length frequency distributions demonstrate that the lowest mean and modal sizes were observed in the subsistence harvest when the population abundances was at its lowest in 2004, while length distributions from Dolly Varden sampled at the spawning grounds in that same year were among the highest observed. There is some indication from seining in 2007 that a strong year class, based on the relatively high abundance of juveniles, was the main contributor to increased population size. Age data (only available from the harvest monitoring program) indicate that younger male and female Dolly Varden from all maturity stages were harvested in 102 mm and 114 mm mesh gillnets at Rat River fishing locations following the significant decline in the abundance in 2004. There was no evidence of differences in growth among years based on the analyses of von Bertalanffy curves, however growth information from recaptured tagged fish suggest otherwise. Age-at-first-maturity of Dolly Varden captured in the subsistence fishery between 1989 and 2008 ranged between 3 and 5 years for both males and females. The abundance of spawners, both male and female, in the Rat River has decreased over the years. The data suggest that although the abundance of males relative to females has remained

consistent over the years, males have been spawning less frequently than females, opting to alternate years when spawning occurs. Annual mortality rates of Dolly Varden from the Rat River between 1989 and 2008 averaged 38% and were not significantly correlated with time. The available information suggests resilience in the population, however, the capacity of the population to adapt to additional stresses (e.g., impacts of climate change on habitat conditions) which may threaten the long-term viability of the population is unknown.

RÉSUMÉ

Les données biologiques sur la forme nordique anadrome du Dolly Varden (*Salvelinus malma malma*) recueillies dans la rivière Rat (Territoires du Nord-Ouest), surtout de 1989 à 2008, de même que les statistiques sur la récolte, sont résumées afin d'évaluer la population et d'examiner toute tendance au fil du temps. Les données incluent la longueur, le poids, l'âge, la croissance, le sexe, la maturité, la mortalité ainsi que la récolte de subsistance estimée et rapportée. Les données biologiques ont été recueillies dans le cadre d'un programme de surveillance de la récolte (1989, 1995-2008). Des pêcheurs de subsistance locaux sélectionnés (appelés « contrôleurs ») ont fourni des échantillons de poissons morts à même leurs prises ou celles d'autres pêcheurs durant la migration de retour du Dolly Varden depuis la mer de Beaufort en août et septembre. Des données sur les prises et l'effort de pêche recueillies à partir des filets des contrôleurs de la récolte et des statistiques sur la récolte totale de toutes les activités de pêche dans le secteur de surveillance ont également été amassées. De plus, des données biologiques ont été recueillies à partir d'échantillons vivants du Dolly Varden provenant du lieu de frai ou d'hivernage de la rivière Rat durant les opérations de marquage (1995-2007) et de recapture (2007) de poissons devant servir à estimer l'abondance des populations.

On estime que la population de Dolly Varden compte entre 11 190 et 10 140 sujets, selon des études de marquage et de recapture menées périodiquement entre 1989 et 1997, avec une diminution notable de l'abondance observée en 2004 alors qu'on a estimé la taille de la population à environ 2 911 Dolly Varden. En 2007, l'abondance a augmenté pour se situer entre 8 488 et 14 886 poissons (selon les résultats de deux activités de recapture la même année). Les changements dans les données sur les captures par unité d'effort recueillies à partir des filets des contrôleurs de la récolte étaient conformes aux hausses et aux déclins observés dans l'abondance de la population.

Les mâles et les femelles examinés dans l'échantillon total (pour tous les stades de maturité) capturés à l'aide de filets maillants d'un maillage de 102 mm affichaient une baisse de 67 et 53 mm de leur longueur moyenne, respectivement, durant le déclin observé dans l'abondance de la population. Le Dolly Varden a retrouvé ses longueurs d'avant le déclin à la suite de la hausse subséquente de la taille de la population. Les reproducteurs femelles de l'année capturés dans des filets d'un maillage de 102 mm ont affiché une hausse de leur longueur moyenne de 77 mm entre 2001 et 2004, alors que la longueur moyenne des reproducteurs mâles et femelles capturés à la senne dans les lieux de frai a également augmenté. Les distributions de la fréquence des longueurs montrent que les tailles moyennes et modales les plus faibles ont été observées dans la pêche de subsistance lorsque l'abondance des populations était à son niveau le plus faible en 2004, alors que les longueurs des Dolly Varden échantillonnés dans les lieux de frai la même année étaient parmi les plus élevées observées. Une pêche à la senne menée en 2007 fournit une certaine indication qu'une forte classe d'âge, basée sur l'abondance relativement élevée de juvéniles, a été le principal facteur ayant contribué à la hausse de la taille de la population. Les données sur l'âge (seulement disponibles par le truchement du programme de surveillance de la récolte) indiquent que des mâles et des femelles Dolly Varden plus jeunes, provenant de tous les stades de maturité, ont été récoltés à l'aide de filets maillants d'un maillage de 102 mm et de 114 mm posés dans des lieux de pêche de la rivière Rat après le déclin significatif de l'abondance en 2004. Il n'y a pas de preuves de différences dans la croissance selon les analyses des courbes de Von Bertalanffy, même si des données sur la croissance recueillies sur des poissons marqués recapturés laissent croire le contraire. L'âge de la première maturité des Dolly Varden capturés par la pêche de subsistance entre 1989 et 2008 variait entre 3 et 5 ans pour les mâles comme pour les femelles. L'abondance des reproducteurs, mâles et femelles, dans la rivière Rat a diminué au cours des

années. Les données laissent croire que même si le nombre de mâles par rapport au nombre de femelles est demeuré constant au cours des années, les mâles ont frayé moins fréquemment que les femelles, soit tous les deux ans. Les taux de mortalité annuels du Dolly Varden de la rivière Rat entre 1989 et 2008 se sont élevés en moyenne à 38 p. 100 et n'ont pu être corrélés de manière significative avec le temps. Les données disponibles laissent croire à la résilience de la population, mais la capacité de la population de s'adapter à des stress additionnels (p. ex., effets des changements climatiques sur les conditions d'habitat), qui pourraient menacer la viabilité à long terme de la population, n'est pas connue.

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, maturity, sex ratios and mortality) over time. Anadromous Dolly Varden from the Rat River are addressed in this report.

NORTHERN FORM DOLLY VARDEN

In Canada, northern form Dolly Varden occur west of the Mackenzie River in the Northwest Territories (NT) and Yukon Territory (YT). Northern form Dolly Varden in Canada spawn and overwinter in tributaries of the Mackenzie River Delta and Peel River and in rivers of the Yukon North Slope. These rivers or their tributaries are characterized by localized perennial groundwater springs 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*), Dolly Varden hold cultural and dietary importance for the Inuvialuit and Gwich'in peoples of Canada.

Northern form Dolly Varden in Canada exhibit three life-history types: anadromous, residual 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 residual (or resident) Dolly Varden remain in their natal streams and are known to co-occur with the anadromous life history type during the fall and winter in the spawning/overwintering areas of the Babbage, Big Fish, Firth/Joe Creek and Vittrekwa river systems. Resident fish are smaller 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, 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/residual 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 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).

RAT RIVER DOLLY VARDEN: BACKGROUND INFORMATION

River characteristics

The Rat River flows eastward for approximately 130 km from the Richardson Mountains into the Husky Channel of the Mackenzie Delta (Harwood et al. 2009) (Figure 1). It is located approximately 90 km southwest of Inuvik, NT and drains an area of 1,680 km^2 (Gillman and Sparling 1985). The mouth is situated 35 km northwest of Fort McPherson, NT (DFO 2001). Topography along the river ranges from rugged mountains in upper reaches to rolling foothills in the central portion and low-lying spruce muskeg typical of the Mackenzie Delta at the mouth (Gillman and Sparling 1985). The physical characteristics of the river were described by Gillman and Sparling (1985). In upper mountainous areas, the Rat River consists of clear waters flowing in a narrow (1-4 m) and shallow (0.5-1 m) channel through a wide (0.5-1 km) and steep-sided valley. In the foothills region, the valley widens to 1-2 km and the river varies from a single channel flowing through a steep gorge to many small channels flowing through a wide gravel flood plain. Turbidity increases in this intermediate section due to small inflowing streams. Below the foothills, the river narrows back to a single channel (4-5 m width and 1-4 m deep) that meanders at a slower flow rate into the mouth at Husky channel. This lower portion of the river is characterized by turbid waters and sand-silt and mud bottom substrates. In the upper reaches and foothill regions, bottom substrates mainly consist of gravel and medium size cobbles with a few larger boulders. Tundra vegetation covers most of the river drainage while trees are confined to lower valleys and slopes (DFO 2001). The river is subject to important water level fluctuations, making depth and turbidity highly variable in some sections (Gillman and Sparling 1985).

The Rat River has three main tributaries located in the upper and intermediate portions of the river: Fish Creek, Bear Creek and the Longstick River (Gillman and Sparling 1985). Fish Creek has many deep pools and perennial groundwater springs that maintain a stretch of open water throughout the winter. These pools are locally referred to as the “Fish Hole”. Anadromous Dolly Varden spawn in this area in the late-summer and remain there to over-winter until break-up in late May (Sandstrom et al. 2001). Water temperatures at the spring discharge site are between 4-5^{o}C (Harwood 2001). Fish Hole is the only known spawning and over-wintering area for Dolly Varden in the Rat River drainage (Sandstrom et al. 2009).

At least thirteen other fish species are found in the Rat River on a permanent or seasonal basis (Jessop et al. 1973, DFO 2001). Broad Whitefish (*Coregonus nasus*), Round Whitefish (*Prosopium cylindraceum*), Northern Pike (*Esox lucius*), Burbot (*Lota lota*), Longnose Sucker (*Catostomus catostomus*), Inconnu (*Stenodus leucichthys*) and Arctic Cisco (*Coregonus autumnalis*) are found in the lower reaches of the river during spring, summer and fall (DFO 2001). Arctic Grayling (*Thymallus arcticus*) and Slimy Sculpin (*Cottus cognatus*) are the most common species of fish that co-occur with Dolly Varden at the Rat River spawning and overwintering site (DFO 2001).

The upper reaches of the Rat River including the Fish Hole are within the boundaries of the private lands in the Gwich’in Settlement Area (Gwich’in and INAC 1992). The lower Rat River, Mackenzie channels and coastal waters used by Dolly Varden are within the Inuvialuit Settlement Region (Inuvialuit Final Agreement 1984) (Harwood 2001).

Fisheries

The Rat River is one of two Dolly Varden populations (with the Big Fish River being the other) that have long sustained subsistence fisheries. Resource users are primarily residents of the

nearby communities of Aklavik (to the north) and Fort McPherson (to the south). Rat River Dolly Varden are harvested along the Beaufort Sea coast during the summer and at traditional fishing sites in the lower Rat River and in the Husky and West channels of the Mackenzie Delta upon their return migration from the sea in late-July to mid-September (DFO 2001, Harwood et al. 2009, Sandstrom et al. 2009) (Figure 2). Until the 1950s, Dolly Varden were also harvested directly from overwintering pools at the Fish Hole (Sandstrom et al. 2009). This practice was apparently discontinued in the mid-1980s (DFO 2001).

Subsistence harvests during the upstream run usually take place for three to four weeks each year. Since 1995, Dolly Varden have been caught mainly using 102 mm or 114 mm mesh gillnets that are typically 25 m in length. Smaller mesh (89 mm) gillnets were mainly used prior to 1995 (DFO 2001, Harwood 2001). Dolly Varden from multiple stocks are harvested using gillnets of variable mesh sizes in coastal Beaufort Sea locations during the summer. The exact contributions of Rat River Dolly Varden to these mixed-stock fisheries are not known. Conventional wisdom is held in Aklavik that Dolly Varden captured at Shingle Point come from the Big Fish and Rat Rivers (Stephenson 2003). Tagging studies have shown that approximately fifty percent of the harvests at Shingle Point were from the Big Fish River (Harwood 2001, Stephenson 2003). Based on this, the remaining 50% of the Shingle Point harvest is typically assumed to be Rat River Dolly Varden (DFO 2001, Harwood 2001).

In the late 1970s and early 1980s, declining catch rates prompted concerns by harvesters regarding the status of the Dolly Varden population in the Rat River (Gillman and Sparling 1985, Sparling and Stewart 1986). In 1995, a community-based fishing plan (The Rat River Fishing Plan (Aklavik RRC et al. 2000)) was implemented, with full compliance in 1999 (DFO 2001). The Rat River Fishing Plan recommended harvest levels (voluntary quotas) and defined restrictions with respect to the number, size and depth of nets to be used in the fishery (Harwood 2001, Aklavik RRC et al. 2000). Declining catch-per-unit-effort (CPUE) starting in 2001 (Harwood et al. 2009) and a significant drop in the abundance of the stock in 2004 (Sandstrom et al. 2009) led to a voluntary closure of the Rat River fishery from 2006-2008, although Dolly Varden from the Rat River continued to be harvested in mixed-stock summer fisheries along the Beaufort Sea coast. The fishery in the Mackenzie River Delta and Rat River was reopened in 2009 with a voluntary quota.

Scientific investigations

Studies on Dolly Varden from the Rat River began in the early 1970s as part of the investigation of the fish resources of the Mackenzie Valley (see Jessop et al. 1973 and Stein et al. 1973). In the 1980s, harvesters concerns about the status of the stock prompted the development of population studies aimed at estimating population abundance and determining whether harvest levels were sustainable (see Gillman and Sparling 1985, Sparling and Stewart 1986). Genetic and fish health studies were also conducted during the 1980s (Souter 1986, Reist 1989). A consistent monitoring program for the subsistence fishery was established in 1989 (see Harwood 2001 and Harwood et al. 2009). The status of the population was assessed through mark-recapture and live-sampling at the spawning and overwintering site between 1995 and 2007 (Sandstrom et al. 2009). Table 1 summarizes information on the Rat River Dolly Varden database used in this study.

Life-History

The Rat River population appears to be composed almost exclusively of anadromous, sea-run Dolly Varden. The non-anadromous residual (stream resident) type common in neighbouring stocks is deemed to be virtually absent from the Rat River. There are only three sampling years

when resident Dolly Varden were captured by seine at the Fish Hole: 1989 (n= 4, DFO unpublished), 2004 (n= 1, Sandstrom et al (2009)), and 2008 (n= 1). One resident male was observed in 2004 by Sandstrom et al (2009) at the Fish Hole. There is no known isolated-type Dolly Varden within the Rat River drainage.

POPULATION SIZE AND TRENDS

POPULATION ABUNDANCE

Population abundance is determined by the interrelationship of, among others, recruitment, growth and mortality (natural and fishing). Decreases in abundance are a result of deaths being greater than births. Although the rate of death, from both natural causes and those due to fishing, may remain the same or even decrease, the population may still experience decline if there is poor recruitment to replace those that die. For Dolly Varden from the Rat River, population abundance is periodically determined and is used, in part, to determine how much fishing mortality the population can sustain. It is the only parameter that can be controlled which can have a direct effect on the population. The environmental conditions and biological factors that promote the survival/recruitment of juvenile Dolly Varden are poorly understood and the capacity for enhancement to encourage this is limited.

Estimates of population abundance of anadromous Dolly Varden from the Rat River have been obtained from mark-recapture studies periodically undertaken between 1989 and 2007 (Table 1). In every study year, Dolly Varden ≥300 mm were marked using numbered Floy tags that were inserted between the basal pterygiophores below the posterior half of the dorsal fin. In 1989, fish were captured and marked during the upstream run about 2 km below Destruction City (see Figure 2) using non-selective hoop nets. For the Dolly Varden tagged in 1989, recapture events included same-year subsistence harvests at Destruction City using 89 mm (3.5”) and 114 mm (4.5”) gillnets (Schaefer estimate), and seining and electrofishing at Fish Hole (Petersen estimate). For the 1995-2007 estimates, Dolly Varden were captured and marked at Fish Hole during fall seining surveys and recaptured in the subsistence harvests during the upstream run the following year by harvest monitors (using mainly 102 and 114 mm mesh gillnets) who were employed to collect fisheries information. In 2007, an additional recapture event involved seining at Fish Hole a year after tagging. This allowed for an increased number of recaptures thus providing a more reliable estimate of population size for that year (in 2007 a low number of recaptures were made by the harvest monitors due to the minimal number of samples allocated to the program as a result of the voluntary closure of the fishery between 2006 and 2008).

The Chapman variation of the Petersen (single census) method (Ricker 1975) was used in all years to calculate population abundance. A Shaefer estimate for stratified populations (Schaefer 1951) was also calculated in 1989 but is considered unreliable due to incomplete sampling of the upstream run (DFO unpublished). The Petersen estimate of population size (N) is calculated as:

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1$$

where M= total number of individuals marked, C= total number of individuals in the recapture sample, and R= number of marked individuals in the recapture sample. Uncertainty can be estimated from the variance in N (Var(N)) (normal approximation):

$$Var(N) = \frac{(M+1)^2(C+1)(C-R)}{(R+1)^2(R+2)} - 1$$

and is expressed as 95% confidence intervals (C.I.):

$$C.I. = N \pm (1.96) \times \sqrt{(Var(N))}.$$

Petersen estimates of abundance assume that the ratio of marked to unmarked individuals in the recapture sample is the same as the entire population. The Petersen method implies that the population estimate (N) is normally distributed. Alternatively, uncertainty can be estimated from the probability distribution of recaptures (binomial and Poisson approximations). In this case, 95% confidence limits are determined for the ratio of marked to total recaptures (R/C) (binomial approximation) or for marked recaptures (R) only (Poisson approximation). This can be done using the charts by Clopper and Pearson (1934) and Adams (1951). Confidence limits are then substituted for R in the population size (N) equation to obtain 95% confidence intervals for N (see Ricker 1975). All three methods of measuring uncertainty are presented in this study.

The assumptions of the Petersen mark-recapture method are (Seber 1982):

(1) The population is closed (i.e., no immigration or emigration),
(2) All fish (anadromous Dolly Varden) have an equal chance of being caught in the first sample,
(3) The second (recapture) sample is a random sample,
(4) Marking the fish does not affect their catchability or natural mortality,
(5) Fish do not lose marks between the two sampling periods,
(6) All marks and total number caught are accurately reported in the second sample.

Some of the assumptions of the Petersen method were not fully adhered to with respect to experiments conducted on Dolly Varden from the Rat River. In most instances, violations were adequately controlled for or were not considered serious enough to render the estimates unusable.

Assumption 1: Population is closed (i.e., no immigration or emigration)

Although possible, emigration or immigration of fish to or from other river systems is not considered an issue as genetic and tagging studies have shown that movement between the populations is minimal (Reist 1989, Sandstrom and Harwood 2002). With respect to marking and/or recapturing at the spawning/overwintering area, there are no other documented spawning/ overwintering sites in the Rat River that could be used by Dolly Varden. Hence, it is a relatively safe assumption that all available marks should be present during the recapture event.

Recruitment of smaller fish into the pool of marked fish due to growth between the marking and recapture event would have an adverse effect on the estimate by changing the ratio of marked to unmarked fish. This was corrected for Peterson estimates between 1995 and 2007 by excluding fish in the recapture event that would have been smaller than the size range marked in the tagging event the previous year. To minimize recruitment effects, linear regressions of length at tagging versus length at recapture were used to determine the expected growth of the smallest size tagged fish between the separate periods of mark and recapture (one year) in order to exclude Dolly Varden smaller than the expected size of the smallest tagged fish after one year of growth from the total number of recaptures (Sandstrom et al. 2009). The minimum size at recapture in all years was calculated as follows:

For 1995-2004: Minimum fork length at recapture = 0.7658 (minimum size tagged) + 155

For 2007: Minimum fork length at recapture = 0.7498 (minimum size tagged) + 203

A different intercept in 2007 did not permit combining this sample with the growth relationship from previous years (see Sandstrom et al. 2009). Because not all Dolly Varden captured by the Rat River harvest monitors were measured for fork length, the total number of individuals in the recapture sample (C) that was greater than the predicted minimum size at recapture was determined by examining the proportion of Dolly Varden greater than the minimum size in the sample and applying this proportion to the total number of fish enumerated by the harvest monitors (see Sandstrom et al. 2009).

In 1989, the number of marked Dolly Varden (M) was adjusted for fishing mortality since Dolly Varden were tagged prior to encountering subsistence gill nets. The number of marked Dolly Varden (M) in 2007 was also adjusted for fishing mortality for the calculation of a second abundance estimate for that year based on seine recaptures at Fish Hole in fall 2008.

Assumption 2 and 3: Equal chance of capture and random sample

In most instances, Dolly Varden were captured using one gear type at a specific location and recaptured the same year (1989) or the following year (1995-2007) with a different gear type at a different location. Only one of the two estimates for 2007 was calculated based on capture and recapture events using the same gear type at the same location. Each gear type is likely different with respect to the size of fish that are vulnerable to it. Gear types used to capture fish to insert marks were trapnets (1989) and seine net (1995-2007) while gear used for recapture were an electrofisher (1989), subsistence gill nets (≥89 mm mesh) (all years), and a seine net (1989 and 2007). It is assumed that gear types will sample sizes of Dolly Varden that will overlap considerably, mainly targeting the adult component of the population.

Random assortment of marked and unmarked fish was assumed for estimates generated in 1989 and 1995-2007. In 1989, tags were put on during the upstream migration and recaptured the following month during a period of time after spawning occurred when the vast majority of the population would be situated in a limited geographical area. Recaptures made the following year by gill net or seine ensure the random assortment of marked and unmarked fish.

Recaptures made during the return migration in the fall using gill nets must consider the structuring in size of fish during migration where large current-year spawners will be the first to return while smaller sized smolts will arrive later (Glova and McCart 1974, Griffiths et al. 1975, Macdonell 1987). This problem of non-random structuring of sizes is addressed by having designated harvest monitors set nets during the majority of the migration period (approximately early August to mid-September) in order to more randomly sample the migrating component of the population and intercept tagged fish (Harwood et al 2009). It should be noted that at times it is not possible to set gill nets due to high water conditions or weather, however these occurrences are typically short in duration and would not affect the final ratio of marked and unmarked fish.

Assumption 4: Marking does not affect catchability or natural mortality

Differential mortality of tagged and untagged fish between the marking and recapture period would be problematic, but the presence of a tag is assumed to have a benign effect on the individual (see Mourning et al. 1994). Hence, marked and unmarked fish are lost between the sampling events (e.g., as a consequence of natural mortality) at similar rates, with the ratio of tagged to untagged fish (the measure of interest) remaining unchanged, and thus, not affecting the abundance calculation.

Assumption 5: Fish do not lose marks

The assumption of no tag loss between sampling periods was likely violated for most estimates. The 1995-2007 estimates of abundance were adjusted for tag loss. Incidence of tag loss for Dolly Varden from the Rat River was determined by clipping the adipose fin of all tagged charr during the 2007 seine survey at Fish Hole. The proportion of adipose clipped Dolly Varden found without a tag during the subsequent (fall 2008) survey was equivalent to 8%. This correction was applied to 2007 and previous years (1995-2004) values of M.

Assumption 6: All marks and catch were accurately reported

It is assumed that all marks were reported on discovery in the second sample as there was a monetary incentive to do so. The 2007 estimate was based on recaptures at the Fish Hole in 2008 by scientific investigators who would have recorded every instance of a tagged fish.

The mark-recapture estimate of population abundance (± 95% CI (normal approximation)) for Dolly Varden from the Rat River was 11,190 (8,263-14,118) anadromous fish >300 mm in 1989 (Table 1). The 1995 estimate was slightly lower at 9,035 (6,930-11,140) fish. A decreasing trend in the abundance of Dolly Varden was observed from 1997 (10,410 (6,557-14,263)) to 2001 (7,952 (4,546-11,358)) and 2004 (2,911 (1,932-3,890)). The estimated stock size of approximately 3,000 charr in 2004 was significantly lower than in previous years. A low relative abundance (CPUE) of Dolly Varden was also evident during sampling at the spawning/ overwintering site that year (Sandstrom et al. 2009). In 2007, the population appears to have increased in size based on both the estimate derived from the harvest monitors (14,886 (6,204-23,568)) and seining at the spawning/overwintering area (8,488 (5,097-15,222). The discrepancy in the estimates from both methods in the same year is due to the high amount of uncertainty surrounding the abundance calculated from the harvest monitor's data. This was a result of the limited sampling effort put in place while the stock was in a depleted state. The abundance estimate from the seining is considered more reliable as the confidence intervals are narrower.

RELATIVE ABUNDANCE

Daily catch-per-unit-effort (CPUE) gathered from three to five different fishing sites, during 13 years of monitoring of the subsistence fishery (1996-2008), provided a measure of relative abundance for Dolly Varden from the Rat River (see Harwood et al. 2009). CPUE data from the three most consistent fishing locations are presented: Big Eddy, mouth of the Rat River and Destruction City. Additionally, the data used to calculate CPUE from Destruction City in 2006, 2007 and 2008 were not used due to errors in how the information was collected and are omitted from analyses. To limit potential bias caused by the use of different mesh size gillnets in the fishery, daily CPUE was presented and compared by mesh sizes. CPUE information would be expected to reflect the magnitude of the trends observed in mark-recapture population

estimates. Variations among years in the mean CPUE of Dolly Varden captured at different location were compared using the Kruskall Wallis test. Comparisons were considered significant at $p<0.05$.

The CPUE at Big Eddy varied significantly among sampling years in both the 102 mm (Kruskall Wallis, $H(12)= 176.6$, $p< 0.001$) and 114 mm mesh sizes (Kruskall Wallis, $H(12)= 144.9$, $p< 0.001$). Trends in CPUE demonstrated a similar pattern to population estimates with lower values observed between 2003-2006 (102 mm mesh nets) and 2004-2006 (114 mm mesh nets) at Big Eddy (Figure 3A). Average CPUEs of 8 and 5 Dolly Varden per net per day at this location in 2006 were considerably lower compared to highs of 29-64 fish per net per day in 1996-2001 (102 mm gillnets) and 29-78 fish per net per day in 1997-1999 and 2001 (114 mm gillnets) (Table 2). At the river mouth, average CPUEs for 102 mm gillnets were significantly different among years (Kruskall Wallis, $H(12)= 117.9$, $p< 0.001$) with lower values observed from 2000 to 2007 (11-26 Dolly Varden per net per day) compared to 1997-1999 (66-117 Dolly Varden per net per day) (Figure 3B, Table 2). CPUE in 114 mm mesh varied among years among years at the mouth of the River (Kruskall Wallis, $H(12)= 51.6$, $p< 0.001$) with the lowest value of 4 Dolly Varden per net per day observed in 2004 (Table 2). CPUE at Destruction City varied among years in both the 102 mm mesh (Kruskall Wallis, $H(12)= 355.7$, $p< 0.001$) and 114 mm mesh (Kruskall Wallis, $H(12)= 37.8$, $p< 0.001$). Similarly, CPUE values for Destruction City varied significantly among years in the 102 mm mesh size (Kruskall Wallis, $H(8)= 355.6$, $p< 0.001$) and 114 mm mesh size (Kruskall Wallis, $H(3)= 37.8$, $p< 0.001$), with considerably lower values observed between 2002 and 2004 (102 mm mesh size) and 2005 (114 mm mesh) compared to earlier years (Figure 3C, Table 2).

Between 2007-2008, average CPUEs returned to higher values similar to those observed prior to 2000 at all locations and for all mesh sizes (excluding Destruction City) (Figure 3, Table 2). A higher Petersen estimate of population abundance was also obtained for 2007 based on the tag returns from seining at Fish Hole in 2008 (8,488 Dolly Varden >300 mm (4,143-12,834)) and the tag returns from the harvest monitoring program in 2008 (14,886 Dolly Varden >300 mm (6,204-23,568)) (Table 1). It should be noted that the 2007 estimate from the harvest monitoring program should be treated cautiously due to the high amount of variation around the estimate (Sandstrom et al. 2009). This increase in population size and CPUEs suggest that management measures (like the closure of the fishery in 2006) had a positive effect on the population. Trends suggest that Dolly Varden from the Rat River did recover from a significant drop in abundance that occurred between 2001 and 2004. The 2007 sample however appeared to be composed mainly by smaller juveniles (DFO unpublished data). This may indicate that the Rat River Dolly Varden population structure was unstable, despite an apparent recovery in the anadromous stock size.

AVAILABLE HARVEST INFORMATION

The harvest of Dolly Varden from the Rat River was estimated in 1972-73, 1975, 1980 and from 1986 to 2008 (Table 3). It should be noted that the harvest data are mainly generated from what has been reported by the harvesters in surveys and in some cases harvesters may have been missed by the survey or have choosen not to participate. The total harvest was estimated by summing 50% of the summer harvest of Dolly Varden at Shingle Point with the estimated numbers of Dolly Varden taken from the Rat River and fishing sites in the Husky and West channels of the Mackenzie Delta.

Total harvest was highest in 1972 at 6,500 fish, however no harvest rates could be calculated for the 1970s due to the lack of a stock size estimate at the time. In 1980 and between 1986 and 1994, the total harvest of Dolly Varden from the Rat River ranged between 376 and 3,125 and averaged 14% of the anadromous stock size. This is above the harvest rate of 11% that

was shown to cause a steady reduction in the size of an Arctic charr population in the central Arctic (Johnson 1980). Higher harvest rates of 32% and 36% were observed between 1996 and 1998, based on 1995 and 1997 estimates of population abundance. A downward trend in harvests after 1998 (Figure 4) is partly related to compliance with the Rat River fishing plan and associated voluntary quotas. However, harvest rates remained high in 2001 (22%), 2004 (27%) and 2005 (23%), because harvest levels did not change enough to compensate for the significant reduction in the size of the stock over this period. Total harvests reported for 2006-2008 do not include potential harvests of Rat River Dolly Varden in coastal Beaufort Sea fisheries because this data was unavailable. Exploitation rates for these years may therefore be slightly higher than the reported 4% (in 2006) and 1% (in 2007-2008).

BIOLOGICAL CHARACTERISTICS

DATA LIMITATIONS

Twenty seven years of data were available for Dolly Varden from the Rat River, ranging from 1971 to 2008 (Table 4). Among studies, sampling was performed for various purposes, at different times of the year and using different collection methods. This needs to be taken into consideration before comparing results over time. In most years, Dolly Varden were collected between the months of August and September during the upstream migration however in 1995, 1998 and 1999, the monitoring of the subsistence harvest started earlier, in late-July (Table 4). Data collections at Fish Hole were done in late September, although in some years this was extended into early October (1995 and 2001). These temporal differences are mainly attributable to inter-annual variability in the timing of the upstream run. Some Dolly Varden were also collected during summer months (from June to September) in 1972. Sampling locations were generally similar among years and included Fish Hole (situated in Fish Creek, the spawning/ overwintering site for Dolly Varden from the Rat River) and traditional fishing locations on the river itself (mouth of the Rat River and Destruction City), in the Husky Channel of the Mackenzie Delta (Big Eddy), in the Peel Channel (in 1972-73 only) and in the West Channel near the hamlet of Aklavik (in 1995-1998) (Figure 2). Gillnets were the predominant method of capture in most years at river locations. Exceptions to this included angling of Dolly Varden in the 1970s, a weir study in 1983 and a hoopnet study in 1989. Seining was the principal method of capture for Dolly Varden at Fish Hole, except for angling in the 1970s and electrofishing for genetic studies in 1986 and 1988.

Different fishing gear types and mesh sizes (for gillnets) can introduce bias in the analysis of trends in biological parameters over time. Unfortunately, little information was available on the mesh sizes of gillnets used in the Rat River fishery prior to 2001. There is no existing mesh size information from the 1970s to 1995. From 1996 to 2000, mesh size information was recorded only for the catch (CPUE) data, not for individual fish. Mesh size information for individual fish samples has only been recorded from 2001 to 2008 inclusively. Based on traditional knowledge, smaller mesh (89 mm) gillnets dominated the fishery until 1994 (Harwood 2001, DFO 2001). In 1995, larger mesh (102 mm) gillnets became the principal fishing gear and have been used together with 114 mm mesh nets (starting in 1996), 127 mm mesh nets (starting in 2002) and 140 mm mesh nets (in 2005) (Harwood 2001, Harwood et al. 2009). The transition from the use of mainly smaller (89 mm) to mainly larger (102 mm) mesh size gillnets was one of the management measures implemented by the Rat River Fishing Plan in 1995. The use of 89 mm mesh gillnets for subsistence harvests was discontinued in 1998 (last documented use was in 1996-97 (Harwood 2001, Harwood et al. 2009)). Similarly, there is no existing mesh size information for gillnets used in coastal Beaufort Sea fisheries. A wide range of mesh sizes (38-114 mm) is reportedly used in the Shingle Point fishery (Stephenson 2003).

Due to inconsistencies in sampling methods and locations, low sample sizes by sex in some years, and the lack of mesh size information prior to 2001, statistical trends in length, age and length-at-age were only analyzed for male and female Dolly Varden caught using 102 mm (4") mesh gillnets (and in some cases 114 mm (4.5") mesh gillnets). Data were pooled from the three harvest monitoring locations (Big Eddy, Destruction City and Rat River mouth) that were consistently sampled between 2001 and 2008. Length data for Dolly Varden caught during seine surveys at Fish Hole, 1995-2008, was also considered.

All Rat River Dolly Varden in the archived data were assumed to be of the anadromous life-history type. This is supported by field observations of the apparent paucity of resident-type Dolly Varden at the Rat River spawning and overwintering site (Sandstrom et al. 2009). Only three resident male Dolly Varden were caught at the Rat River Fish Hole (one in 2004 (FL =235 mm) and 2 in 2008 (FL= 231 mm and 244 mm)). These samples were removed from analyses.

STATISTICAL METHODS

Variations in the mean length and age of Dolly Varden between sexes and among years were compared using t-tests or one-way analysis of variance (ANOVA). In cases where assumption of normality and homogeneity of variance were not met, the following non-parametric tests were used: Mann-Whitney U and Kruskall-Wallis. Pair-wise differences in ANOVAs were evaluated using Bonferonni's test, which adjusts the observed level of significance for the fact that multiple comparisons are made. Statistical tests on length and age data were only conducted if sample sizes were ≥10. Statistical differences in length and age frequency distributions were examined using the Kolmogorov-Smirnov two-sample test (KS). A Bonferonni adjustment was made to the level of statistical significance (αadj=α/n (n being the number of groups compared)) when comparing more than 2 distributions. Changes in growth were evaluated among year by fitting length-at-age data to the von Bertalanffy growth equation using the nonlinear procedure in SYSTAT. Von Bertalanffy growth curves were statistically compared using the analysis of residual sum of squares (ARSS). The frequency of spawners and non-spawners was statistically examined among years using the Pearson Chi-square test. Standardized residuals converted to z-scores ((observed-expected)/(expected)2)) were compared to the critical z-value of $\pm$1.96 (corresponding to an alpha of 0.05) to determine whether expected and observed counts differed among years. 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). 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). All statistical analyses were conducted using SYSTAT software (Wilkinson 2000). All tests were considered significant at $p < 0.05$.

LENGTH

Available length information for male and female Dolly Varden from all maturity stages caught in gillnets at different locations in the Rat River and adjacent channels of the Mackenzie Delta, 1972-2008, is presented in Table 5. The same information for Dolly Varden (sex and maturity stage pooled) caught using various gear types at the Rat River spawning site, 1971-2008, is shown in Table 6. The largest fork length observed for a male Dolly Varden from the Rat River was 724 mm in 2004 (Table 5). The largest fork length observed for a female Dolly Varden from the Rat River was 667 mm in 2001 (Table 5). Larger Dolly Varden of both sexes (mean FL =498 mm for females and ≥506 mm for males) were harvested in the Rat River fishery in 1999-2000 relative to other years (Table 5). This observation however is not independent from changes in the mesh sizes of gillnets used in the fishery over time. The effect of variable mesh size gillnets on the mean length of harvested Dolly Varden is demonstrated for fishery samples from 2001-

2008 in Table 7. Unfortunately, no mesh size information for individual fish samples was available prior to 2001 to quantitatively assess the impact of this change in fishing gear on the biological characteristics of Rat River Dolly Varden during this period. Between 2001 and 2008, the mean fork lengths of harvested Dolly Varden increased with mesh sizes (Table 7). This result suggests that the transition from the use of mainly smaller mesh (89 mm) to larger mesh (≥ 102 mm) gillnets in the Rat River fishery in 1995 likely affected the size composition of the catch. This is illustrated in Figure 5 by the shift in the percentage of Dolly Varden ≤ 400 mm and ≥ 550 mm in the catches before and after 1995.

Length information for male and female Dolly Varden harvested in spawning condition using gillnets at Rat River fishing locations, 1972-2008, is presented by year in Table 8. The same information for male and female spawners caught using different gear types at the Rat River spawning site, 1972-2008, is shown in Table 9. The minimum size for male spawners in the Rat River ranged from 231- 492 mm while the minimum size for female spawners ranged from 282 - 478 mm (Table 8). It should be noted that the lower end of these ranges likely represent fish that were erroneously recorded as preparing to spawn in the current year, given that these length values are extremely small for anadromous spawners and that in all other years (including spanwers captured by seining at the Fish Hole) minimum lengths were considerably larger. Alternatively, the male Dolly Varden may have been a resident life history type preparing to spawn in the current year that was foraging in the lower reaches of the river. Larger spawners of both sexes (mean FL ≥500 mm) were generally caught in or after 1999 in the subsistence fishery (Table 8). However this trend is not independent from changes in fishing gear. Larger male spawners (mean FL ≥529 mm) were also observed in samples from the Rat River spawning site in and after 2001 relative to earlier years, but this trend was not evident in females (Table 9).

Trends in length: all maturity stages

Trends in the mean length of male and female Dolly Varden of all maturity stages combined were examined for samples from the subsistence fishery that were harvested using 102 mm and 114 mm gillnets in 2001-2008 (Table 10). Non-spawning fish at the spawning/overwintering site could not be sexed as they were only live-sampled. There are no external indications of sex at this stage and therefore they were not included in this analysis.

There were no consistent differences between lengths of females and males harvested in the fishery. Females were larger than males in 102 mm mesh gillnets in 2002 (t-test, t=2.607, df=304, p=0.010) and 2003 (t-test, t=2.188, df=236, p=0.030), and in 114 mm mesh gillnets in 2006 (t-test, t=2.905, df=6, p=0.027) (Table 10). Males were larger than females in samples from 102 mm gillnets in 2008 (t-test, t=2.749, df=69, p=0.008) and 114 mm gillnets in 2001 (t-test, t=2.852, df=184, p=0.005) and 2004 (t-test, t=2.265, df=47, p=0.028) (Table 10).

Females: subsistence harvests (2001-2008)

The mean length of females caught in subsistence harvests using 102 mm gillnets differed among years (ANOVA $F_{(7,803)}$=15.63, p<0.0001). Bonferroni post-hoc tests among 2002, 2003 and 2004 were significantly different suggesting a decreasing trend from 2002 to 2004 (Figure 6A). Significantly smaller females were harvested in 2004 (mean FL=420 mm) relative to 2001-2003 and 2005 (mean FL ≥458 mm). Likewise, females harvested in 2006 and 2007 (mean FL= 437 mm and 435 mm) were significantly smaller than females caught in 2001-2002 and 2005 (Figure 6A, Table 10A). Females in 2008 did not show any significant differences from earlier years except when compared to 2002. A similar pattern was observed for females harvested using 114 mm gillnets (ANOVA $F_{(6,348)}$=10.39, p<0.0001) (Figure 6B). Post-hoc tests showed

that smaller females were caught in 2005 (mean FL= 468 mm) relative to 2001-2003 (mean FL ≥501 mm), and in 2004 (mean FL=472 mm) and 2008 (mean FL=465 mm) compared to 2002 and 2003 (Figure 6B, Table 10B).

Males: subsistence harvests (2001-2008)

Similar to females, the mean length of male Dolly Varden harvested using 102 mm mesh gillnets differed among years (ANOVA $F_{(7,423)}$=6.21, p<0.0001) and showed a decreasing trend from 2001 to 2004 (Figure 6C, Table 10A). Post-hoc tests showed that males harvested in 2004 (mean FL=418 mm) were smaller than males harvested in 2001, 2002 and 2008 (mean FL ≥461mm). Sizes increased subsequently however there were no significant differences in pair-wise comparisons from 2005 to 2008. The mean length of males harvested using 114 mm mesh gillnets also differed among years (ANOVA $F_{(6,231)}$=5.23, p<0.0001), however significant pairwise differences were only found when 2005 (mean FL=474 mm) was compared to 2001 (mean FL= 530 mm) and 2002 (mean FL= 541 mm) (Figure 10D, Table 10B).

Trends in length: spawners

Trends in the mean length of female Dolly Varden that were going to spawn in the current year were examined in samples from the subsistence fishery that were harvested using 102 mm and 114 mm gillnets from 2001-2008 (pooled data from the Mouth of Rat River, Destruction City and Big Eddy locations) and from females in spawning condition that were collected by seine at the Rat River spawning/overwintering site between 1995 and 2008 (Table 9, Table 11). Samples of males from the subsistence fishery between 2001 and 2008 were too low to analyze statistically (Table 11). Males captured by seining at the Fish Hole were only statistically compared among the 1995, 1997 and 2001 sampling years for which sufficient sample sizes were available.

The only years where it was possible to compare mean length between male and female spawners captured in subsistence gillnets (102 and 114 mm mesh size) was 2001. No significant differences were observed in the 102 mm (ANOVA, F= 1.2, d.f.= 1, 208, p= 0.27) and 114 mm (ANOVA, F= 0.63, d.f.= 1, 284, p= 0.43) mesh sizes in 2001 (Table 11). Other years were not analysed due to low sample size. For Dolly Varden captured by seining at the Fish Hole, male spawners were larger than female spawners in 1995 (t-test, t=2.363, df=292, p=0.019) and 2001 (t-test, t=3.002, df=158, p=0.003) but no differences were observed in 1997 (t-test, t= 0.004, df= 238, p= 0.95)(Table 9).

Female spawners: subsistence harvests (2001-2008)

The mean fork length of female spawners harvested using 102 mm mesh gillnets differed among years (ANOVA $F_{(6,191)}$=5.05, p<0.0001) and increased from 483 mm in 2001 to 560 mm in 2004 followed by a decrease to 490 mm in 2007 (Figure 7A). Post-hoc tests showed female spawners harvested in 2001 were significantly smaller compared to 2002 and 2004 (Figure 7A, Table 11A). In contrast, the mean length of female spawners harvested using 114 mm gillnets showed a decreasing trend from 2002 (552 mm) to 2005 (507 mm) (Figure 7B). While this corresponded to a significant difference in mean fork length among years (ANOVA, $F_{(4,133)}$=2.56, p=0.042), pair-wise comparisons yielded no significant differences. No female spawners were caught in 102 mm mesh gillnets in 2008 and sample sizes for female spawners caught in 114 mm gillnets in 2006-2008 were too small for statistical comparisons.

Female spawners: spawning/overwintering area (1995-2008)

The mean length of female spawners harvested using a seine at the Rat River spawning site differed among years (ANOVA $F_{(5,899)}$=11.87, p<0.0001) (Figure 8A, Table 9). Larger female spawners (mean FL ≥486 mm) were caught in 2001, 2004 and 2007 relative to 1995 (mean FL=466 mm) and 1997 (mean FL=467 mm) (Table 9). The average length of female spawners caught in 2008 (471 mm) was similar to that observed in 1995-1997.

Male spawners: spawning/overwintering area (1995-2008)

Similar to female spawners, the mean length of male spawners captured using a seine net at Fish Hole differed among years (ANOVA $F_{(3,90)}$=7.412, p<0.0001). Post-hoc tests revealed that mean length was higher in 2001 (529 mm) relative to 1995 (486 mm) and 1997 (467 mm) (Figure 8B, Table 9). Sample sizes for 2004, 2007 and 2008 were too small for statistical comparisons (Table 9).

Length frequency distributions

Length frequency distributions (10 mm fork length intervals) are presented and compared for female and male Dolly Varden from all maturity stages harvested using 102 mm gillnets in the Rat River fishery in 2001-2008 (pooled data for the mouth of the Rat River, Destruction City and Big Eddy) (Figures 9 and 10), and for all Dolly Varden (sex and maturity stage pooled) collected during seine surveys at Fish Hole between 1995 and 2008 (Figure 11). Annual sample sizes were too small in samples collected in the subsistence fishery to allow for comparisons of length frequency by maturity stage. Likewise, annual sample sizes for male and female Dolly Varden caught using 114 mm and other mesh size gillnets in the subsistence fishery (2001-2008) were generally too small to allow useful comparisons of length distributions.

Subsistence harvests (2001-2008)

The length frequency distributions of Dolly Varden harvested using 102 mm mesh gillnets differed between sexes in 2002 (KS (α=0.05), D=0.223, p=0.003) and 2003 (KS (α=0.05), D=0.206, p=0.026). In both years, females exhibited a higher frequency of larger length classes and a weak representation of <350 mm fish relative to males (Figure 9 and 10). The length distributions of male and female Dolly Varden were variable among years. Similar distributions for female samples from 2001 and 2002 statistically differed from all other years with larger modes (460 mm and 470 mm respectively) and a broad range of length classes (280-580 mm in 2001 and 280-640 mm in 2002) (Figure 9) (KS (α=0.002) all pair-wise comparisons p<0.0001). Similarly for males, the 2001 distribution differed from those of 2002-2004 and 2006-2007 with a higher frequency of males in the 440-470 mm size range (Figure 10) (KS (α=0.002) all pair-wise comparisons p<0.01). There was a gradual increase in the frequency of smaller size fish in the catch from 2001 (≤400 mm fish =7% in females and 3% in males) to 2004 (≤400 mm fish =49% in females and 43% in males). Lowest mean and modal sizes characterized the 2004 length distributions in both sexes. In male Dolly Varden, the 2004 distribution was bimodal and characterized by a smaller mode at 340 mm and a larger mode at 440 mm which could suggest variable year class strengths (Figure 10). A similar pattern was observed for females in 2003, with a smaller mode at 400 mm and a larger mode at 520 mm (Figure 9). The 2004 length distributions statistically differed from those of 2001-2002, 2005 and 2008 in males (KS (α=0.002), all pair-wise comparisons p<0.01), and from 2001-2003, 2005 and 2008 distributions in females (KS (α=0.002), all pair-wise comparisons p<0.0001). A lower range of length classes was generally observed in and after 2005 in both sexes, but this pattern was not independent from a reduction in sample sizes. In both males and females, the 2008 length distribution was

dominated by a strong 450 mm length class, with steep left and right tails indicating few fish <400 mm and >550 mm in the sample. No females >540 mm and few females <350 mm were harvested in 2007 and 2008 (Figure 9).

Spawning/overwintering area (1995-2008)

The length frequency distributions of Dolly Varden (sex and maturity stage pooled) caught using a seine at Fish Hole were statistically similar between 2001 and 2004 and between 2007 and 2008, but differed in all other years (KS (α=0.003) all pair-wise comparisons $p \leq 0.001$). A broader range of sizes (190-680 mm) was observed in the 2001 distribution. Steep left tails characterized the 1995 and 1997 distributions, indicating few Dolly Varden <350 mm in those years compared to 2001-2008. This may be related to a change in sampling gear (i.e., modifications to seine design in 2001 (Sandstrom et al. 2009) and/or in the spatial extent of sampling (more spatially extensive surveys were conducted in 2001-2008 than in 1995-1997 (S. Sandstrom pers. com.)). The 2007 and 2008 length distributions were clearly bi-modal, peaking at 360 mm and 430 mm (in 2007) and at 340 mm and 460 mm in 2008. A higher frequency of smaller length classes was particularly marked in 2007, with the first peak (360 mm) being the modal length class for the entire distribution. In years with bimodal length frequencies, the modal peak among juvenile size classes (~ <400 mm) suggest pulses of recruitment into the population.

Trends in length: summary

Differences in the spatial extent of sampling and the fishing gear used for catching Dolly Varden at the Rat River spawning site, and the lack of mesh size information for gillnets used to harvest Dolly Varden in the subsistence fishery prior to 2001, limit the analyses of trends in length of Dolly Varden from the Rat River over time. Nonetheless, available length information makes it possible to evaluate changes in the length of Dolly Varden during a period of significant decline in stock abundance (2001-2004) and apparent recovery (2005-2008).

During the period of significant decline in the abundance of the Rat River Dolly Varden stock (2001-2004), there was a statistically significant reduction in the mean length of males and females (all maturity stages) that were harvested in the Rat River fishery. Male and female Dolly Varden harvested in 102 mm gillnets were on average 67 mm and 53 mm smaller, respectively, in 2004 compared to 2001. A similar pattern of decline in mean length was observed in the 114 mm mesh size up to 2005. Male and female Dolly Varden caught in 114 mm mesh nets were 67 mm and 65 mm, respectively, smaller in 2005 compared to 2002. In both sexes, there was a gradual increase in the proportion of smaller size ($\leq$ 400 mm) Dolly Varden in the catch from the 102 mm mesh size between 2001 ($\leq$ 7%) to 2004 (between 43% and 49%). The 2004 length distributions generally differed from other years with lower mean and modal length class values. In males, it was characterized by two distinct modes, a smaller (340 mm) and a larger length class (440 mm). This pattern was observed in females a year earlier (2003), with modal length classes of 400 mm and 520 mm. A reduction in the range of sizes of female Dolly Varden spawners was also observed in the 2001-2004 period for samples collected in the fishery and for male and female spawners caught using a seine at the Rat River spawning/overwintering site. This reduced range of sizes may explain the apparent increase in the mean length of spawners during those years.

During the period of increase in abundance of the population size of Dolly Varden from the Rat River (2005-2008), a higher frequency of smaller length classes of Dolly Varden was observed at Fish Hole, suggesting a pulse of juvenile recruitment (i.e., in 2007-2008 relative to earlier years). Average fork lengths of female Dolly Varden from all maturity stages caught in the

subsistence fishery remained smaller in 2006-2008 compared to 2001-2002 (102 mm gillnets) and 2001-2003 (114 mm gillnets). In contrast, the mean fork length of harvested male Dolly Varden increased back to pre-stock decline values in 2008 in 102 mm mesh gillnets. In 2008, the length frequency distributions of male and female Dolly Varden caught at Rat River fishing locations were dominated by a strong length class (450 mm) and a narrow range of sizes (few fish <400 mm and >550 mm). A weak occurrence of larger length classes was particularly evident in females in both 2007 and 2008. These latter observations may indicate that the length structure of Dolly Varden from the Rat River was partially eroded. Thus the population may have been unstable, despite an apparent recovery in the estimated stock size.

AGE

Dolly Varden from the Rat River were aged using whole otolith techniques by G. Carder at the Freshwater Institute (Department of Fisheries and Oceans) in Winnipeg. From the 1970s to 1990 inclusively, Dolly Varden were aged according to Grainger (1953), which counted the nucleus of the otolith as age 1. Starting in 1991, Dolly Varden were aged according to Nordeng (1961), which involved counting the first annuli as age 1. In order to standardize these data, a year was subtracted from all Dolly Varden aged according to Grainger until 1990.

Available age information for male and female Dolly Varden harvested in 102 mm and 114 mm gillnets at different locations in the Rat River and adjacent channels of the Mackenzie Delta, 1972-2008, is presented in Table 5 (maturity stages pooled) and Table 8 (spawners only). Age data for Dolly Varden collected at the Rat River spawning site was only available in 1981-82, 1986 and 1988, and is shown in Table 6 (sex and maturity stage pooled) and Table 9 (male and female spawners). Age information from Dolly Varden captured using gillnets with 127 mm mesh were not statistically analyzed due to small sample sizes.

The maximum age observed for a male Dolly Varden from the Rat River was 11 years for males (in 1989 and 2005) and 12 years for females (in 1994) (Table 5). The minimum age recorded for a Dolly Varden spawner from the Rat River was 3 years in both sexes. A male current-year spawner 3 years of age was caught in the subsistence fishery at Husky Channel in 2001 (Table 8). A female current-year spawner 3 years of age was harvested in 1990 (at Destruction City), in 1996 (at Husky Channel) and in 2005 (at Big Eddy).

Similar to fork length, changes in the mean and modal ages of Dolly Varden from the Rat River over time are likely biased by variable sampling gear and locations. For years when mesh size information was available for individual fish (2001-2008), the median age of Dolly Varden increased significantly with the mesh sizes of gillnets in 2002, 2003, and 2007 (Table 7B). Trends in age are thus examined separately by mesh size for male and female Dolly Varden harvested using gillnets in the Rat River fishery (at the river mouth, Destruction City and Big Eddy), between 2001 and 2008.

Trends in age: all maturity stages

Older female than male Dolly Varden from all maturity stage were harvested in 102 mm gillnets in the Rat River fishery in 2002 (Mann-Whitney, U= 6945.5, p= 0.027) and 2003 (Mann-Whitney, U= 20207, p= 0.002) and in 114 mm mesh gillnets in 2008 (Mann-Whitney, U= 61, p= 0.004). All other comparisons between males and females among years and for both the 102 and 114 mm mesh were not statistically significant.

Females

The mean age of female Dolly Varden harvested in 102 mm (Kruskall-Wallis, H(7)= 64.9, p< 0.001) and 114 mm (Kruskall-Wallis, H(7)= 26.2, p< 0.001) mesh gillnets differed significantly among years and was generally lower in or after 2006 relative to 2001-2005 (Figure 12). Post-hoc tests (Bonferroni correction of α= 0.006) for the 102 mm mesh size revealed that ages were significantly younger in 2003 (mean age= 5.5) compared to 2002 (mean age= 5.9), and that 2006, 2007 and 2008 (range of mean age= 5-5.2 years) had significantly younger ages compared to all years ≤2004 (except 2008 compared to 2003, which were not different from one another). All other pair-wise comparisons were insignificant (Figure 12A, Table 10A). The modal age of females harvested in 102 mm mesh gillnets decreased from 6 years in 2001, 2002 and 2004, to 5 years in 2005-2008 (Table 10A). The mean age of female Dolly Varden harvested in larger (114 mm) mesh gillnets was significantly lower in 2005 (mean age= 5.5) relative to 2003 (mean age= 6.5), 2002 (mean age= 6) and 2001 (mean age= 5.9) (Figure 12B). All other pair-wise comparison among years were not significantly different.

Males

The mean age of male Dolly Varden from all maturity stages caught in 102 mm gillnets differed among years (Kruskall-Wallis, H(7)= 55.9, p< 0.001). Post-hoc tests (Bonferroni correction of α= 0.006) demonstrate no significant differences among pair-wise comparisons from 2001 to 2005, apart from significantly younger ages in 2003 (mean age= 5.3) when compared to 2001 (mean age= 5.7). Ages in 2006 (mean age= 4.5) were significantly younger compared to all years ≤2004 (range of mean age= 5.2-5.7), were no different from 2005 (mean age= 5.3) and 2007 (mean age= 4.7), and significantly younger than 2008 (mean age= 5.3). Similarly, 2007 had many instances of younger ages when compared to years ≤2004, apart from 2003 (mean age= 5.2) where no differences were detected. No differences were observed between 2007 and both 2005 and 2006, while older ages were observed in 2008 compared to 2007. No significant differences were observed when 2008 was compared to 2001-2005 (Figure 12C, Table 10A).

Mean age also differed among years for males harvested in 114 mm mesh gillnets (Kruskall-Wallis, H(5)= 38.5, p< 0.001) (excluding 2006 and 2007 due to low sample sizes). Post-hoc tests only demonstrated significant younger ages in 2003 (mean age= 6) when compared to 2002 (mean age= 6.4), and when 2005 (mean age= 5.4) is compared to both 2001 (mean age= 5.9) and 2002. Unlike the 102 mm mesh, ages in 2008 (mean age= 4.8) were significantly younger than all prior years. The modal age of male Dolly Varden from all maturity stage reached a low value of 4 years in 2006 (in 114 mm mesh gillnets) and 2007 (in 102 mm mesh gillnets) (Table 10A and 10B).

Trends in age: spawners

Small sample sizes by year and gear type limited the analyses of trends in age of male spawners caught in the Rat River fishery between 2001 and 2008. The only year with a large enough sample size to compare between males and females was 2007 and there were no significant differences in median age (Mann-Whitney, U= 3563, p= 0.44). There were also no significant differences in the median age of male and female spawners caught at the spawning/ overwintering site using a seine in 1981-1982 (pooled data) (Mann-Whitney, U= 71, p= 0.12), however females were significantly older than males captured through electrofishing in 1986 and 1988 (pooled data) (Mann-Whitney, U= 147.5, p= 0.008).

Female spawners

The mean age of female spawners caught in 102 mm mesh gillnets did not differ among years (Kruskall-Wallis, H(4)= 4.6, p= 0.33) (excluding 2004 and 2006 due to low sample size, and 2008 because no spawners were captured and sampled) (Figure 13A). The mean age of female spawners harvested in 114 mm mesh gillnets was statistically similar between 2001 and 2005, while small sample sizes in 2006 and 2008 precluded statistical comparisons (Figure 13B). The mean ages of female spawners ranged from 5.7 years (in 2001) to 6.8 years (in 2004) for females caught in 102 mm gillnets, and from 5.9 years (in 2004) to 7 years (in 2008) for female spawners harvested in 114 mm mesh gillnets (Table 11A and 11B). In both gear types, a broader range of ages of female spawners (3-11 years in 102 mm mesh nets and 4-10 years in 114 mm mesh nets) characterized the 2005 samples relative to other years. Modal ages of female spawners varied between 5 and 7 years, but showed no particular trend with time (Table 11A and 11B).

Male spawners

Sample sizes of male spawners were too small to allow for statistical comparisons among years. The mean age of male spawners caught in 102 mm gillnets ranged from 4.8 years (in 2007) to 7 years (in 2006), and from 5 years (in 2002 and 2005-2006) to 8 years (in 2004) for male spawners harvested in 114 mm mesh gillnets (Table 11A and 11B).

Age frequency distributions

Age frequency distributions are shown for male and female Dolly Varden from all maturity stages harvested in 102 mm mesh gillnets in 2001-2008 at three fishing locations (Rat River mouth, Destruction City and Big Eddy) in Figures 14 and 15. Annual sample sizes for male and female caught in larger (114 mm) mesh gillnets were generally small (i.e., $\leq$ 25) (especially in males) and thus were not analysed as frequency distributions.

In both sexes, a lower frequency of older age classes ($\geq$ 6 years) generally characterized the 2003 and 2006-2008 age distributions. This explained significant differences in the age distributions of male Dolly Varden between 2001, 2002 and/or 2004 relative to 2003 and/or 2006-2007 (KS (α=0.002) 2001-2003 D=0.346, p=0.002; 2001-2006 D=0.513 p<0.0001; 2001-2007 D=0.411 p<0.0001; 2002-2006 D=0.386, p=0.001; 2004-2006 D=0.399, p=0.001; 2004-2007 D=0.384 p=0.001) (Figure 14). Similarly for females, significant differences in age distributions from 2001-2002 and 2004 relative to 2006, and in 2003 and 2007-2008 relative to 2002, were related to a weak occurrence of older age classes of females in the catch from 2003 and 2006-2008 (KS (α=0.002) 2001-2006 D=0.345 p=0.001; 2002-2006 D=0.431 p<0.0001; 2004-2006 D=0.362 p=0.001; 2003-2002 D=0.223 p=0.001; 2007-2002 D=0.378 p<0.0001; 2008-2002 D=0.394 p<0.0001) (Figure 15). The age distributions of male and female Dolly Varden in 2008 were dominated by a strong cohort of 5 year-old fish, which represented close to 70% and 50% of male and female Dolly Varden in the 2008 samples, respectively (Figures 14 and 15). The same cohort also dominated the 2007 age distribution for males (Figure 14). These fish would have been born in 2003, when stock size was declining. A smaller range of age classes also characterized the 2008 age distributions in males (4-7 years) and females (4-8 years). In females, similarly narrow ranges of age classes were observed in 2003 (4-8 years) and 2007 (3-7 years) (Figure 15). In males, an even smaller range of age classes was observed in 2005 (4-6 years), but may be related to a smaller sample size that year (Figure 14).

Age-specific and cohort abundance

Age specific abundance was compiled as sample sizes and percentage of total catch for ages 3 to 8 Dolly Varden (sex and maturity stage pooled) harvested using 102 mm and 114 mm mesh gillnets at three fishing locations (Rat River mouth, Destruction City and Big Eddy) in 2001-2008 (Table 12). The proportions of 3 and 4 year-old Dolly Varden in the catch peaked in 2006-2007 in 102 mm mesh nets (Figure 16) and in 2005 and 2006 in 114 mm mesh gillnets (Figure 17). The percentage of five year-old Dolly Varden in the harvest was variable among years but highest (56%) in 2008 in both gear types (Table 12). No five year-old Dolly Varden (2001 cohort) were caught in 114 mm gillnets in 2006 (Figure 17). The percentage of 6 year-old Dolly Varden in the catch from 102 mm mesh gillnets generally decreased from a high of 41% in 2001 to a low of 9% in 2006 and remained at lower values (±16%) in 2007 and 2008 (Table 12A). Similarly, the percentage of 7 year-old Dolly Varden decreased from 20% in 2002 to 5% in 2005-2006 and remained low (between 6% and 9%) in 2007 and 2008 (Table 12A, Figure 16). Changes in the proportions of 6 and 7 year-old Dolly Varden in the catch from 114 mm mesh gillnets were more variable over time and likely biased by small sample sizes in 2006-2008 (Table 12B, Figure 17). The percentage of 6-year old Dolly Varden in 114 mm gillnets was lowest in 2005 (25%) but increased again in 2007 (53%), while abundance remained low (≤ 6 specimens). The percentage of age-7 Dolly Varden in 114 mm mesh gillnets peaked in 2002-2003 (33-34%) and 2006 (33%) before dropping to 7% in 2007 and zero in 2008. There was a steady decrease in the percentage of 8 year-old Dolly Varden caught in 114 mm mesh nets from 2003 (12%) to 2005 (3%), and these fish were completely absent from the catch in 2006-2008 (Table 12B, Figure 17). Likewise, the proportion of age-8 Dolly Varden caught in 102 mm mesh gillnets was lower in 2006 and 2008 (±1%) and nil in 2007, compared to a high of 10% in 2005.

Three different cohorts (1998, 1999 and 2000) could be traced from the ages of 3 to 8 (or 9) in fishery samples from 102 mm mesh gillnets in 2001-2008 (Table 13). Peak cohort abundance expressed as a percentage of total catch decreased from 1998 to 2000 (Figure 18). Dolly Varden born in 1998 entered the fishery in 2001 at the age of 3 and their relative abundance peaked in 2003 as 5 year-old fish representing 46% of the total harvest that year. The 1998 cohort remained in the catch for six years, until 2006. Dolly Varden born in 1999 and 2000 entered the fishery at 3 years of age in 2002 and 2003, respectively, and their abundance peaked at 5 year-old in 2004 and 2005, respectively. Five year-old Dolly Varden from the 1999 and 2000 cohorts represented 38% and 34% of the total catch from 2004 and 2005. The 1999 cohort was absent from 2007 fishery samples as 8 year-old fish, but was sampled as 9 year-old Dolly Varden in 2008 (Table 13, Figure 18). The 2000 cohort remained in the fishery for six years, from 2003 to 2008, when sampling ended.

Trends in age: summary

Similar to fork length, available age data for Dolly Varden from the Rat River made it possible to evaluate trends in age during a period of significant decline in stock abundance (2001-2004) and apparent recovery (2005-2008).

Over the entire time series, the maximum age observed for male (12 years) and female (13 years) Dolly Varden from the Rat River was slightly lower than the maximum age observed for male (13 years) and female (13-14 years) Dolly Varden from the Babbage and Firth River populations, which are typically assumed to undergo little or no exploitation. Available cohort abundance information demonstrated that Rat River Dolly Varden tend to enter the fishery at age 3, and are fully recruited into the fishery by age 6 or 7. Peak cohort abundance typically

occurred at age 5 and its contribution to total harvests was not constant from year to year (i.e., was higher for the 1998 compared to 1999 and 2000 cohorts).

Younger male and female Dolly Varden from all maturity stages were harvested in 102 mm and 114 mm mesh gillnets at Rat River fishing locations following a significant decline in the abundance of the Rat River stock in 2004. Females were significantly younger in or after 2006 compared to those harvested in 2001-2004, and their modal age appeared to have stabilized at a lower value (5 years) in 2005-2008. Younger males were harvested in 2005-2008 relative to 2001-2004 depending on gear type, and a lower modal age class (4 years) was observed for males caught in 2006 (in 114 mm mesh gillnets) and 2007 (in 102 mm mesh gillnets). Few significant changes in the mean age of male and female Dolly Varden were observed between 2001 and 2004, when population abundance was in decline. The lower mean ages observed in or after 2005 were likely related to an increase in the proportion of younger (ages 3 and 4) Dolly Varden in the catch from all gear types in 2005 or 2006-2007, and to a parallel reduction in the proportion of older (≥ 6 years) Dolly Varden (sexes combined). The percentage of ages 6 and 7 Dolly Varden harvested in 102 mm mesh gillnets decreased from 2004 to 2006 and remained low until 2008. The percentage of 8 year-old Dolly Varden harvested in 114 mm mesh gillnets began to decrease in 2003 and has not since recovered. A lower frequency of older (≥ 6 years) age classes of both males and females characterized the age distributions from 2003 (a year prior to the estimated drop in stock size in 2004) and in 2006-2008, when stock size appeared to be recovering. These observations suggest that the observed decline in the abundance of the Rat River stock may have been linked to the natural loss or selective removal of older individuals from the population. Dolly Varden born in 2003 dominated the age distributions from 2007-2008 (in males) and 2008 only (in females). The weak representation of younger and older age classes in the 2008 sample (i.e., Dolly Varden born in 2002 and 2004-2006) again suggest that the population structure of Dolly Varden from the Rat River remains eroded and probably unstable, despite an apparent recovery in the estimated stock size in 2007-2008.
No directional trends in the mean age of male and female spawners could be identified in our sample. Only a broader range of ages of female spawners (including a 3 year-old female spawner) was observed in 2005, a year after the significant reduction in stock size in 2004.

Analyses of trends in age for Dolly Varden from the Rat River demonstrate that changes in mean and modal ages, age frequency distributions and age-specific abundance were mainly detected subsequent to a significant drop in population abundance, not before.

LENGTH-AT-AGE

Available length-at-age data is synthesized for male and female Dolly Varden from all maturity stages collected using variable gear types at different locations in the Rat River and adjacent channels of the Mackenzie River Delta, 1981-2008. Larger mean fork lengths-at-age were generally observed in or after 1999-2000 in both sexes (Tables 14 and 15). Male Dolly Varden had larger mean fork lengths at ages 4, 5 and 6 in 2007-2008 (Table 14). Females had larger mean fork lengths at age 4 and 5 in 2002 and 2001, and larger mean fork lengths at age 6 and 7 in 2006 (Table 15). These observations corroborate the findings from Harwood et al. (2009) and Sandstrom et al. (2009) of a recent increase in the growth of Dolly Varden from the Rat River.

Trends in growth

Due to uncertainties in sampling gear and locations and generally small sample sizes by sex for Dolly Varden caught in larger (≥114 mm) mesh gillnets, trends in length-at-age were only

examined for male and female from all maturity stage harvested in 102 mm gillnets at three fishing locations (Destruction City, mouth of the Rat River, and Big Eddy), in 2001-2008.

Changes in growth were evaluated by fitting length-at-age data to the non-linear von Bertalanffy growth equation:

$$L_t = L_\infty * (1 - e^{-K*(t-t0)})$$

Where L_t is the length at age t, L_∞ is the asymptotic maximum length (or theoretical length that would be reached if fish were to grow indefinitely), K is the slope or growth coefficient expressing the rate at which the asymptotic maximum length is approached, and t_o is the hypothetical age at zero length (Ricker 1975). Von Bertalanffy growth curves were compared among year pairs (i.e., 2001-2002, 2003-2004, etc.) in order to increase sample sizes and obtain a more representative range of available ages. The available/comparable age range in all pairs of years was 3 to 7 years for males and 3 to 9 years for females (Table 16).

The estimated parameters of the von Bertalanffy growth curves were highly variable among pairs of years in both sexes (Table 17). Growth coefficient K varied from 0.283 (in 2001-02) to 0.036 (in 2003-04) in males, and from 1.07 (in 2001-02) to 0.12 (in 2003-04 and 2005-06) in females. Females had a larger asymptotic length in 2005-06 (701 mm), while males had larger than normal asymptotic lengths in both 2003-04 (1484 mm) and 2007-08 (1059 mm). It should be noted that these larger than normal asymptotic lengths generated by the model are not realistic and are likely a result of insufficient data for older and younger age classes (see further explanation in summary section below). No significant differences in the growth curves of male and female Dolly Varden were observed among year pairs (ARSS for males: $F_{(3,,8)}$=3.22, p=0.08; ARSS for females $F_{(3,16)}$=2.51, p=0.096) or between sexes within each year pair (ARSS 2001-02: $F_{(3,6)}$=1.29, p=0.36; 2003-04: $F_{(3,6)}$=0.92, p=0.48; 2005-06: $F_{(3,6)}$=1.11, p=0.41; 2007-08: $F_{(3,6)}$=2.90, p=0.12).

Age 3 and 4 males had larger mean lengths in 2005-06 and 2007-08 relative to earlier years (Table 16A, Figure 17). Older (age 6 and 7) males reached larger sizes in 2001-02 and 2007-08 (Figure 17). The average length of males ≥ 4 years-old was generally lower in 2003-04, and in 2005-06 for males age 6 and 7 years. The growth rate of male Dolly Varden within the age range considered appeared to be highest in 2001-02 (K=0.283, L_∞=596 mm), with a more important increase in length (+175 mm from age 3 to 7) compared to other year groups (Table 16A, Figure 17). Likewise, female Dolly Varden exhibited a distinctive growth pattern in 2001-02 (K=1.067, L_∞=511 mm), with an important increase in length from age 3 to 6 (+189 mm) followed by little or no growth from age 6 to 9 (Table 16B, Figure 17). The mean length of females at age 3 was highest in 2007-08 (FL(pred)= 396 mm). Older females (age 8 and 9) were largest in 2005-06 and smallest in 2007-08 (Table 16B, Figure 17). The average length of ≥ 4 year-old females was generally lower in 2003-04 and 2007-08.

Trends in growth: summary

There were no significant differences in the von Bertalanffy growth curves of male and female Dolly Varden from the Rat River during a period of decline (2001-2004) and recovery (2005-2008) in population abundance. Although not directly comparable because males and females were examined separately, the results appear to contradict the observation by Sandstrom et al. (2009) who found that growth in 2007 was higher compared to earlier years. The data used by Sandstrom et al. (2009) are from direct measurements of recaptured fish while the results from the von Bertalanffy model may have been affected by overparameterization (Sainsbury 1980), partly due to low sample sizes among older age classes; low sample sizes could have resulted

in a large amount of variation and failure to reject the null hypothesis of no changes among years.

Changes in length-at-age over time can occur as a result of changing environmental conditions and food resources availability, and/or density-dependent effects linked to changes in population abundance. Unfortunately, the lack of environmental information from the Rat River precludes distinguishing between these alternative factors. Possible changes in growth linked to the observed change in the abundance of the Rat River stock from 2001 to 2008 may include: (1) lower growth rates (as K) in 2003-04 and a reduction in the mean length-at-age of ≥ 4 year-old Dolly Varden of both sexes in or after 2003-04; and (2) an increase in the mean length-at-age of younger (age 3 and/or 4) Dolly Varden starting in 2005-06. Lower K values (in 2003-04 for males and in 2003-04 and 2005-06 for females) and lower mean lengths-at-age in ≥ 4 year-old fish in 2004 could reflect greater energy allocation towards reproduction (at the expense of somatic growth) in individual fish, as a means to increase recruitment. Enhanced growth of younger (age 3 and/or 4) Dolly Varden subsequent to the reduction in stock size in 2004 may reflect greater resource availability for younger fish, however it is unlikely that this is directly linked to a reduction in the abundance of larger and older individuals, since juveniles and adults do not compete for food during the summer feeding period.

MATURITY, PROPORTION OF SPAWNERS AND SEX RATIO

Maturity and sex information for Dolly Varden from the Rat River were available from the 1970s up to 2008. Maturity data from the 1970s was not considered reliable due to uncertainty in collectors, collection methods, and maturity coding, and is therefore not presented in this document. Maturity data collected during the 1989-1994 period of monitoring of the Rat River fishery is presented but should be interpreted with caution due to uncertainty in the amount of training of the fishery monitors (Harwood 2001). Maturity and sex information gathered from the monitoring of the subsistence fishery between 1995 and 2008, and from seine surveys conducted at Fish Hole in 1995, 1997, 2001, 2004, and 2007-2008, were considered reliable and were used to examine trends in maturity parameters and sex ratios.

Dolly Varden collected in the subsistence fishery were dead-sampled with sex recorded as ‘male’ or ‘female’ and maturity assigned as ‘mature’ or ‘immature’. A fish was considered ‘mature’ if it was going to spawn in the current year and ‘immature’ if it was a resting adult who likely spawned in previous years or a juvenile that had yet to spawn. Dolly Varden captured by seine net at the Fish Hole were live-sampled with sex identified only if the fish was in spawning condition, while all others were categorized as ‘silvers’ (a term used by harvesters referring to Dolly Varden that will not spawn [i.e., resting adults or sexually immature juveniles] and will retain their silver colouration during the spawning period). In order to standardize maturity to compare data between the subsistence fishery and seining, maturity was classified as either current-year spawner or silver, with no distinction between immature versus resting silvers. Consequently, it was impossible to assess the contribution of male or female adult resting Dolly Varden to the pool of mature individuals in the population, particularly among samples ≤450 mm.

Fecundity

There is limited fecundity information available for Dolly Varden from the Rat River. Fecundity was examined in 1983 (as number of eggs/female) and reported by Gillman and Sparling (1985). Mean total egg count was 4,221 eggs/female (range of 1,787-8,395), for a sample of 21 females. This is nearly double that observed for Dolly Varden from the Big Fish River which had an average of 2,329 eggs per female in 1997 (MacDonell 1987) and 2,276 eggs/female in 1991

and 1993 (Sandstrom 1995), and slightly higher than the 3,468 eggs per female reported for Dolly Varden from Babbage River (Clarke et al. 1989). Mean egg size for Dolly Varden from the Rat River was 3.68 mm (range of 2.85-4.26 mm). This is smaller than the egg diameter reported for females (≥400 mm FL) from the Big Fish River (Sandstrom and Harwood 2002).

Age-at-first-maturity

Although sample sizes were relatively low for males, the age-at-first-maturity of Dolly Varden of both sexes captured at the spawning/overwintering area between 1981 and 1988 ranged between 5 and 7 years of age (Table 18). Age-at-first-maturity of Dolly Varden captured in the subsistence fishery between 1989 and 2008 ranged between 3 and 5 years for both males and females (Table 18). The highest age-at-first-maturity (7 years) was observed only in the 1986 sample for both sexes at the Fish Hole. Males and females appear to mature at a similar age, generally within one year of each other, apart from three years where both matured at the same age (1992, 1995 and 2000) (Figure 20). From samples collected at the three monitoring locations between 1995 and 2008, males appeared to attain maturity one year earlier than females between 1997 and 1999, while the opposite was observed between 2001 and 2005. Between 2006 and 2007, once again males consistently attained maturity one year earlier than females.

The age-at-first-maturity of females captured in the fishery between 1989 and 1999 varied between 3 and 6 years, with a mean of 4.5 years. However, during the period of decline between 2000 and 2004, female age-at-first-maturity declined and consistently remained at 4 years, and decreased yet again to 3 years in 2005 (Table 18, Figure 20). Subsequently, female age-at-first maturity increased to 5 and 6 years. Males did not vary as much as females in their age-at-fist-maturity in earlier sampling years ranging from 4 to 6 years (mean of 4.8 years) between 1989 and 1995. Maturity remained constant at 4 years of age between 1996 and 2000, decreasing to 3 in 2001. In the following years during the decline in population abundance, age-at-first-maturity increased to 5 years of age for three consecutive years, and decreased again to 4 years between 2005 and 2007 before increasing to 5 in 2008 (Table 18, Figure 20). The 1995-2008 data suggest that during the decline in population abundance, female age-at-first-maturity decreased compared to earlier years and remained constant at 4 year of age while males increased their age-at-first-maturity compared to earlier years to age 5.

Upon reaching maturation the number of times a Dolly Varden from the Rat River will spawn over the remainder of their life appears to vary between and within the sexes. Using fish recapture information, Sandstrom et al. (2009) demonstrate that 56% and 17% of female and male, respectively, Dolly Varden spawn sequentially over the course of one year. The results suggest that males may not spawn as frequently compared to females.

Proportion of spawners

Trends in the proportion of spawners at the spawning/overwintering area (1995-2008)

The majority of Dolly Varden collected from the Rat River Fish Hole in 1981-82 (90-100%) and 1988 (74%) were current-year spawners (Table 19). From 1995 to 2008, the proportion of spawners collected during seine surveys at Fish Hole varied among sampling years (χ^2= 250.7, df=13, p<0.0001) and decreased significantly from 66% in 1995 to a low of 6% in 2008 (Table 19, Figure 21) (Pearson correlation, r= -0.78, p= 0.03). Female spawners among the 1981-1997 sampling years generally accounted for a high proportion of the total Dolly Varden seined at the Fish Hole, however considerable decreases were observed in 2007 (22.5%) and 2008 (5.6%) (Table 19). The proportion of male spawners was always lower than females among years.

Although the proportion of male spawners was highest in 1981 and 1982, it should be noted that sample sizes were low in these years. Between 1995 and 2008, the proportion of male spawners in the sample decreased from 6.5% to 0.4%. Although the proportion of spawners has decreased in recent sampling years, it should be noted that this may in part be due to the increased abundance of non-spawners mainly in juvenile size classes (Table 19),

Trends in the proportion of spawners in subsistence catches (1995-2008)

The frequency of male and female Dolly Varden harvested in spawning condition in the Rat River fishery, 1995-2008, varied among sampling years (for males: χ^2=107.2, df=13, p<0.0001; for females: χ^2=204.0, df=13, p<0.0001) (Table 20). Changes in the percentage of male and female spawners among years generally mirrored each other, although the percentage of spawning females in the catch exceeded that of spawning males in all years except in 1998 and 2008 (Figure 21). In both sexes, the proportion of spawners was highest in 1999 (42% for males and 60% for females) and 2001 (27% for males and 54% for females). Following 1999, the frequency of spawners decreased significantly over time for both males (Pearson correlation, r= -0.86, p<0.0001) and females (Pearson correlation, r= -0.72, p< 0.0001). Considerably fewer male spawners (≤7%) were observed in 1995, 1997 and 2004 (Table 20, Figure 21), while relatively fewer female spawners (≤13%) were observed in the catch in 1995, 1997-1998, 2004 and 2008 (Table 20, Figure 21).

Trends in the proportion of spawning male and female by age class (1995-2008)

Changes in the proportions of males and females harvested in spawning condition at ages 4 to 8 years were examined for Dolly Varden caught in gillnets at three fishing locations (Rat River Mouth, Destruction City and Big Eddy) in the Rat River fishery, 1995-2008. Samples were pooled into three year groups (1995-1999, 2000-2004 and 2005-2008) in order to increase sample sizes by age class. Percentages of male and female spawners by age class and year group are shown in Table 21A and 21B, respectively. Fewer male Dolly Varden were harvested in spawning condition at ages 5 and 6 in 2005-2008 compared to earlier years (Figure 22). There was a significant relationship between the proportion of male spawners at age 5 and the different time periods (χ^2=7.461, df=2, p=0.024). This was explained by the lower proportion of male spawners at age 5 in 2005-2008 (5% (2-10%)) relative to 1995-99 (15% (11-19%) and 2000-04 (16% (12-21%)). The proportion of female spawners in the catch varied significantly among time periods at age 4 (χ^2=8.99, df=2, p=0.011), age 5 (χ^2=24.18, df=2, p<0.0001), and age 6 (χ^2=7.83, df=2, p=0.020), with a significantly higher proportions of age 4 (17% (10-27%) and age 5 (27% (23-32%)) females harvested in spawning condition in 2000-2004 relative to earlier (1995-1999) and later (2005-2008) time periods (Table 21B). The proportion of female spawners at age 6 was lower in 1995-1999 (20% (17-23%)) relative to 2000-04 (28% (24-33%)) and 2005-2008 (27% (18-38%)), but this difference was not statistically significant.

Sex ratio

The sex ratio (male:female) of Dolly Varden was calculated using both the total sample (all maturity stages) and spawners only from the harvest monitoring studies between 1989 and 2008; spawners only were examined for the spawning/overwintering site between 1981 and 2008 (Table 22). In all years from the total sample, female Dolly Varden outnumbered males, a pattern observed in other anadromous northern-form Dolly Varden populations in Canada (Gallagher et al. 2012).

Trends in sex ratios (all maturity stages) in subsistence catches (1986-2008)

The ratio of male to female Dolly Varden from all maturity stages (total sample) in the Rat River fishery were calculated using data collected from Destruction City (lower Rat River) between 1986 and 1994, and from all three harvest monitoring locations (Destruction City, mouth of the Rat River and Big Eddy) from 1995 to 2008 (Table 22, Figure 23). In the total sample between 1986 and 2008, the sex ratio averaged 0.60 and ranged between 0.27 and 0.86 males for every female. Similar values were observed when the samples from the three monitoring locations between 1995 and 2008 were examined (mean= 0.63). The ratio of males to females was different from 1:1 in all years with the exceptions of 1986, 2004, and 2006-2008. There was no relationship between year (1986-2008) and sex ratio (Pearson correlation, r= 0.35, p= 0.12) suggesting that the sex ratio in the population had not changed significantly over time and was not affected during the period of population decline and subsequent increase. Interestingly, between 2000 and 2003, the sex ratio did temporarily decrease from 0.68 to 0.44 males for every female.

Trends in sex ratios of spawners in subsistence catches (1986-2008)

The ratios of male to female current year spawners captured in subsistence gill nets were calculated from the same data sources as 'all maturity stages' (see above). Females generally outnumbered males, however the opposite was sometimes observed when the total spawner sample size was low (<10) (Table 22, Figure 23). In years when the number of spawners was >10, the average sex ratio was 0.29, ranging between 0.07 and 0.97 males for every female. Similar values were observed when the samples from the three monitoring locations between 1995 and 2008 were examined (mean= 0.32). Where sample sizes were >10, the ratio of males to females was different from 1:1 in all years with the exceptions of 1998 and 2006. There was no correlation between year (1986-2008) and sex ratio (Pearson correlation, r= 0.17, p= 0.52) suggesting that the sex ratio of spawners in the population did not change significantly over time and was not affected during the period of population decline and subsequent increase. Interestingly, the male:female ratio was nearly 1:1 in 1998 and decreased considerably thereafter to 0.11 in 2005, which encompasses the period of population decline. It appears that the sex ratio among years for current-year spawners is more cyclical compared to the total sample, where a decline over several years (1988-1990, 1995-1997, 1999-2005) is followed by a subsequent increase (Figure 23).

Trends in sex ratios of spawners at the spawning/overwintering area (1981-2008)

Dolly Varden captured by seining at the Fish Hole were live-sampled (with the exception of 1982 and 1986) and sex could only be identified if a fish was in spawning condition. Similar to what is observed from samples captured in gill nets, females outnumbered males. In years when the total sample size was >10, the average male:female ratio was 0.18, ranging between 0.07 to 0.53 (Table 22). Between 1995 and 2008, years coinciding with the harvest monitoring program at Destruction City, mouth of the Rat River and Big Eddy, and when sample sizes were relatively large, sex ratios averaged 0.10. The sex ratio was lowest in 2004 during a period of population decline and appeared to remain low thereafter.

Trends in maturity and sex ratios: summary

The interrelationships among frequency of spawning, fecundity, age-at-first-maturity, abundance of spawners, and sex ratio all have a bearing on the productivity of Dolly Varden from the Rat River. However, whether Dolly Varden reproduction is successful is likely influenced more by habitat conditions for egg incubation and rearing of fry and juveniles (see Paul et al. 2000).

The age-at-first-maturity of female Dolly Varden was lowest, at 3-4 years, between 2000-2005 when stock size had declined, and increased to 5 - 6 years thereafter. Age-at-first-maturity of males between 1997 and 1999 was 4 years, which was lower than females, but then increased to age 5 between 2002 and 2004, which was also higher than females by 1 year, during the period of population decline only to decrease back to 4 years of age during the recovery phase.

The abundance of spawners, both male and female, in the Rat River has generally decreased over time. The decrease began during the decline in population abundance and continued even while the population abundance subsequently increased. The percentage of male and female Dolly Varden harvested in spawning condition in the Rat River fishery was significantly lower in 2004 when stock size was significantly reduced compared to earlier years and 2008. In contrast, the percentage of spawners from both sexes seined at the Rat River spawning site was higher in 2004 than in pre-decline (1997, 2001) and recovery (2007-2008) years. This could indicate that spawning Dolly Varden either did not migrate to sea and/or were less vulnerable to the fishery in 2004.

Interesting patterns in the frequency of spawning can be elucidated by simultaneously examining the total sample and spawner sex ratio data collected from the subsistence fishery/ harvest monitoring program. Between 1986 and 2008, the male:female sex ratio from the total sample has remained considerably higher (average= 0.60) compared to the spawners (average= 0.29) suggesting that although the abundance of males relative to females was consistent over the years, males spawned less frequently than females. A similar observation was made by Sandstrom et al. (2009) based on tag recapture information from males and females at the spawning/ overwintering area. Sandstrom et al. (2009) suggested higher reproductive costs for males compared to females or the need for greater reproductive fitness in males may be a reason for this strategy which requires more energy accumulation at sea during the summer.

A peculiar pattern in the sex ratio of current year spawners was observed when data from the subsistence fishery was compared to the seining data from the spawning/ overwintering area collected in the same year. With the exception of 1997, there consistently was a greater paucity of male spawners relative to female spawners at the spawning/ overwintering area compared to the subsistence fishery (see Figure 23).

Another inconsistency between the data collected from the subsistence fishery and seining at the spawning/overwintering area was in regards to the proportion of male and female spawners in the total sample. It would be logical to assume that the proportion of spawners would be similar when comparing both sampling programs when they occurred in the same year. The proportion of female spawners was considerably lower in the fishery relative to the seining at the spawning/overwintering area in all years except in 2001, 2007 and 2008 (see Figure 21). In contrast, the proportion of male spawners was higher in the fishery relative to the seining at the spawning/overwintering area in all years except 1997, 1995 and 2004 (Figure 21).

The reason for the discrepancy in the expected pattern in the sex ratio and proportion of spawners from both sampling programs is unclear. Both programs sample Dolly Varden in a random manner and of similar sizes. One reason may have to do with how maturity is assigned by the harvest monitors based on gross observation of the gonads. Another may be a result of current-year spawners that do not migrate to sea (e.g., see De Cicco 1989) and are therefore not vulnerable to the fishery, yet are captured as spawners by seining in the fall. Another reason is that male and female spawners may have differential susceptible or timing of migration in relation to the fishery.

The decrease in the proportion of spawners which appeared to occur concurrently with a decrease in population abundance suggests either more Dolly Varden were opting to refrain from spawning in consecutive years in order to invest in growth or that current-year spawners were experiencing higher rates of mortality either from natural and/or anthropogenic sources. Given the limited lifespan of Dolly Varden from the Rat River, a reduction in the number of spawners in a given year may have a profound effect on recruitment. This is particularly true for males, given that they do not spawn as often as females and had an age-at-first maturity that in recent years was greater than females.

While this may increase the vulnerability of the population, the limited fecundity data indicates that the Rat River has a higher fecundity compared to Dolly Varden from the Big Fish and Babbage rivers. The increased fecundity may help offset the potential decrease in productivity resulting from a paucity of reproducing fish.

These results indicate that lower ratios of male to female spawners, the retention of a lower age-at-first-maturity in female Dolly Varden, an increase in the relative abundance of female spawners from younger age classes, and decreasing proportions of spawning Dolly Varden (particularly males) in fishery samples, were concurrent with a downward trend in the population abundance of Dolly Varden from the Rat River. The shift to a lower age-at-first-maturity for females during the population decline was likely a compensatory response of the population to increase the amount of reproduction.

It is difficult to infer the present status of the Rat River Dolly Varden stock based on the quality of available maturity and sex ratio information. The weak occurrence of spawners and very low ratios of male to female spawners at the Rat River spawning/overwintering site in recent years however, may be viewed as a source of concern for the stock. One explanation for the weak occurrence of spawners (mostly males) may be that longer food acquisition periods at sea and potentially enhanced food resources available in coastal environments in recent years (as suggested by Harwood et al. 2009 and Sandstrom et al. 2009), currently favour growth over a reproduction strategy, with larger fish potentially having greater reproductive fitness in the long term. Alternatively, the weak occurrence of male and female spawners may be related to changing habitat, like transient loss of spawning and overwintering habitat due to low water levels, as observed in recent years in the Rat River system (S. Sandstrom, pers. com.).

MORTALITY

An earlier estimate of mortality for Dolly Varden from the Rat River was calculated for Dolly Varden (n=115) caught in gillnets at Destruction City in 1989 using a linearized catch curve (natural log of age frequency against age) (DFO unpublished). Instantaneous mortality (Z) was equivalent to 0.78 and annual mortality was 53% (for age classes 7-12).

Mortality was calculated for all Dolly Varden and separately for male and female collected in gillnets during all years of monitoring of the subsistence fishery (1989-2008). Annual mortality was estimated using the Chapman and Robson's method (Miranda and Bettoli 2007):

$$\text{Annual Mortality} = 1 - (T / N + T - 1)$$

where N is the total number of fish fully recruited to the gear (modal age + 1 year), and T is derived from the coded distribution of vulnerable ages in the sample (Miranda and Bettoli 2007). This method appears to have greater accuracy and lower bias compared to regression estimators (Dunn et al. 2002).

The age at full recruitment of Dolly Varden from the Rat River (sexes combined) ranged between 6 and 7 years (Table 23). Female Dolly Varden were generally fully recruited to the fishery at the age of 6 or 7, typically one year earlier than males. Female and male mortality were similar among years. The annual mortality of the total sample of Dolly Varden from the Rat River between 1989 and 2008 averaged 38%, ranging between 28% and 46% (Table 23). No significant relationship was detected between year and mortality (Pearson Correlation, r= 0.14, p= 0.95) suggesting mortality has not changed over time. Interestingly, mortality was not considerably different in years of high (e.g., 1998) or low (e.g., 2006-2008) harvest rates (see Table 4). Although uncertain, these results suggest that either harvest levels did not impact overall mortality of the population or they did not alter the relative distribution of proportions of the older age classes in the population (which were used to calculate mortality).

CONCLUSION

Based on the results of mark-recapture studies, anadromous (≥ 300 mm) Dolly Varden from the Rat River underwent a significant decline in population abundance from approximately 10,400 fish in 1997 and 8,000 fish in 2001, to 3,000 fish in 2004. This decline was also evident in CPUE data from the Rat River fishery, which dropped from 29-78 Dolly Varden per net per day at Big Eddy (Husky Channel) between 1997 and 2001, to some 5-8 Dolly Varden per net per day in 2006 (in 102 mm and 114 mm mesh gillnets, respectively). Reported harvests of Dolly Varden from the Rat River were highest in 1972 (6,500 fish) and in 1996-1998 (≥ 2,900 fish annually). Exploitation rates peaked at an average of 34% of the anadromous stock size in 1996-1998. These results suggest that high (≥ 30%) exploitation rates in 1996-1998 could have been linked to the significant decline in the anadromous stock size that occurred 6 years (1 generation) later, in 2004.

Changes in the biological parameters of Dolly Varden were observed during the period of significant decline (2001-2004) and recovery (2005-2008) in the abundance of the Rat River stock:

- Changes in length were observed while stock size was declining, and included an increase in the proportion of smaller size (≤ 400mm) Dolly Varden in the catch and a reduction in the mean length of 67 and 53 mm for males and females, respectively, harvested from the fishery (102 mm mesh gill nets) from 2001 to 2004. Female and male Dolly Varden remained smaller during the initial recovery phase but approached sizes that were similar to pre-decline values by 2008. Although the maximum length of female spawners captured at the spawning/overwintering area remained consistent throughout time, there was a decreased range of sizes during the decline between 2001 and 2004, which may explain the apparent increase in the mean length of female spawners during those years. The increase in population abundance in 2007 was accompanied by a high relative abundance of juveniles based on the length frequency results from seining at the spawning/overwintering area.

- Changes in age were only observed subsequent to the significant decline in the abundance of the stock observed in 2004. Younger male and female Dolly Varden were harvested in the Rat River fishery in or after 2005-2006. Lower modal ages also characterized females harvested during the period of recovery in stock abundance (2005-2008) and males harvested in 2006-2007. Downward changes in mean and modal age were linked to increasing proportions of younger (age 3 and 4) Dolly Varden in the catch during the recovery phase in 2005-2007, and to a corresponding decrease in the occurrence of older (≥ 6 years) Dolly Varden in the catch in or after 2006.

- There were no statistically significant changes in the von Bertalanffy growth curves of Dolly Varden between 2001-2008, although lower growth rates (as K values) were observed in both sexes in 2003-04 relative to other year pairs, and there was a visible increase in the mean length-at-age of younger (age 3 and 4) Dolly Varden (mainly males) during the period of recovery in the abundance of the stock (2005-2008). A different analysis looking at growth based on tag return information showed a significant increase in growth in 2007 compared to earlier years and is likely a more reliable method than the use of Von Bertalanffy models.

- Changes in maturity parameters linked to changes in population abundance were most pronounced in females, and included the retention of a younger age-at-maturity, along with an increase in the proportion of younger (age 4 and 5) female spawners in fishery samples, while stock size was declining (2000-2005). A broader range of ages of female spawners likewise characterized the 2005 fishery samples, a year after the significant decline in stock size occurred. The significant drop in population abundance of 2004 was also accompanied by a lower percentage of Dolly Varden harvested in spawning condition in the Rat River fishery (in 2004) and by lower ratios of male to female spawners at the spawning/overwintering site (in 2004) and in fishery samples (in 2005).

Together, these results indicate that changes in length, age-at-first-maturity, proportion of spawners and spawner sex ratio, accompanied a change in population abundance of northern-form Dolly Varden from the Rat River during a period of population decline, while changes in age were only noticeable after the decline had occurred.

Based on the available data and information, it is difficult to assess the present status of the Rat River Dolly Varden stock. The population appears to be resilient and to have quickly, positively responded to reductions in harvests since 2004. However, the eroded size and age structure observed in the 2008 sample may indicate instability and a currently limited capacity to handle additional stress caused by environmental factors like habitat loss or degradation. There is concern for the reproductive potential of the stock, which appears to be reduced based on the observation of a very low ratio of male to female spawners and a reduced number of spawning Dolly Varden of both sexes at the spawning site in recent years. Further investigations are required to identify how environmental/habitat conditions affect the population dynamics.

The capacity of the population to adapt to additional stresses which may threaten the long-term viability of the population is unknown. Therefore, we recommend the continued monitoring of Dolly Varden harvests and the collection of biological information (including fecundity data) on Dolly Varden from the Rat River in order to better assess the population and predict how it will respond to changes in fishing pressure. Further studies should also focus on characterizing the available and sensitive habitats in the Rat River system and investigating the potential impacts of climate change on these habitats and the population.

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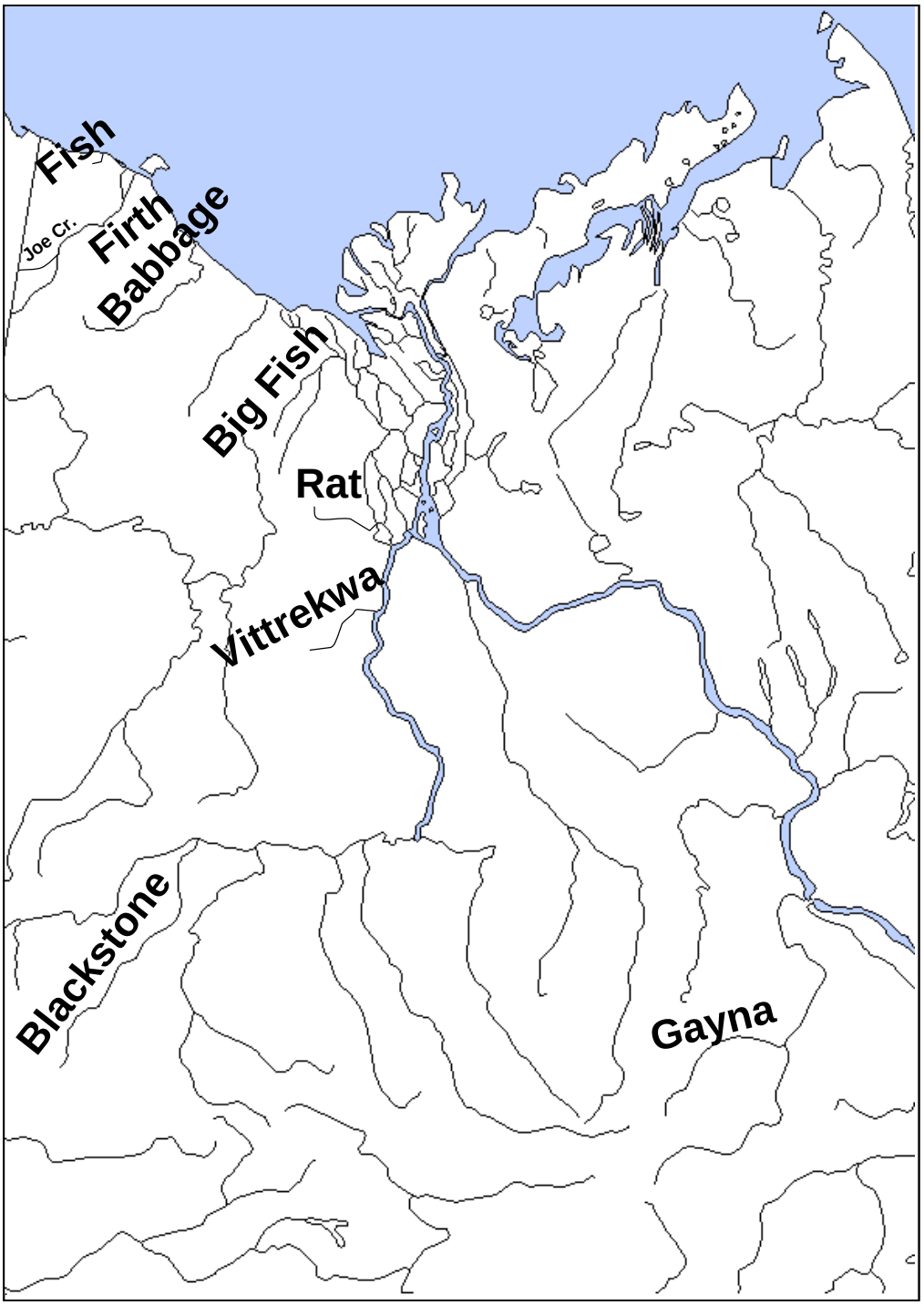


Figure 1. Rivers inhabited or likely inhabited by northern form Dolly Varden in Canada.

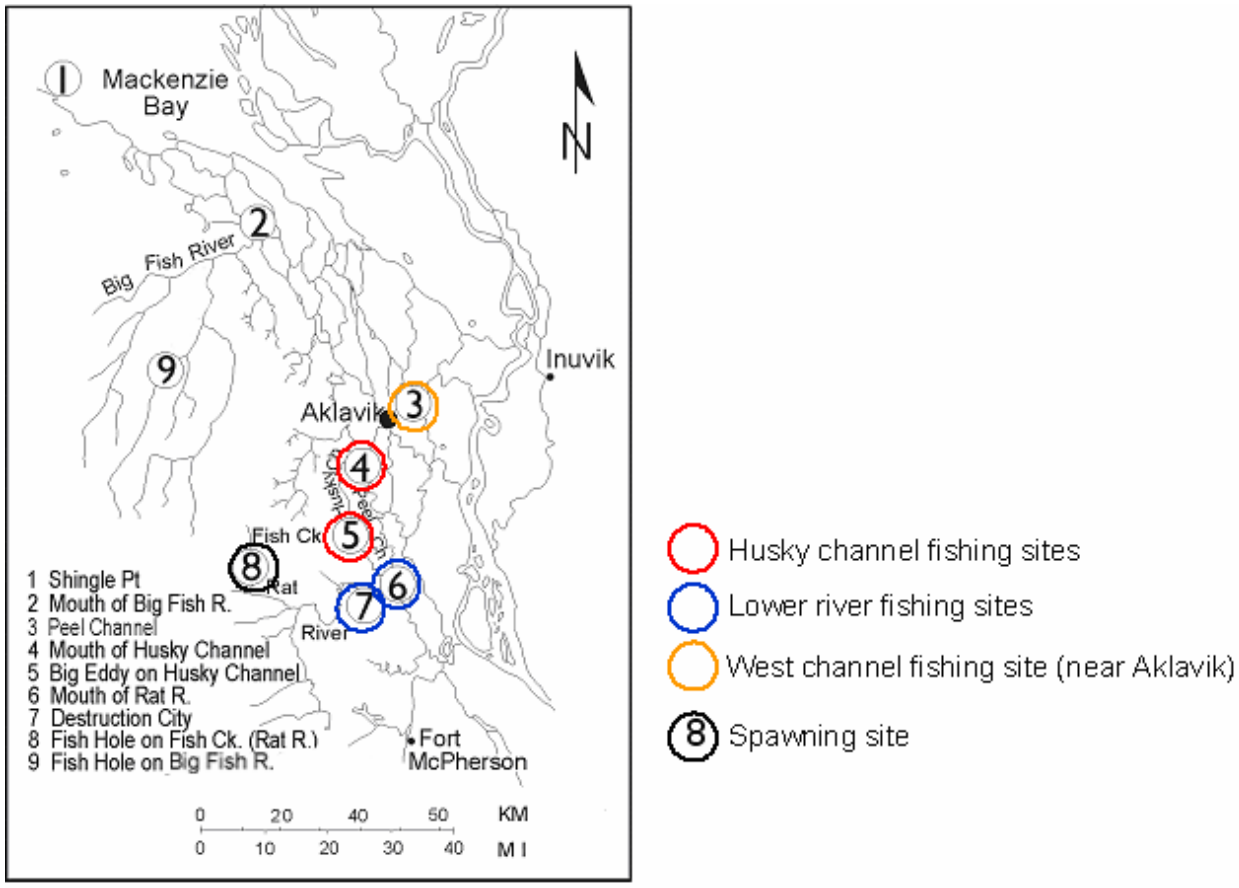


Figure 2. Traditional fishing sites and sampling locations for Dolly Varden in the Rat River. Different colors indicate different waterbodies distinguished for the purpose of this study.

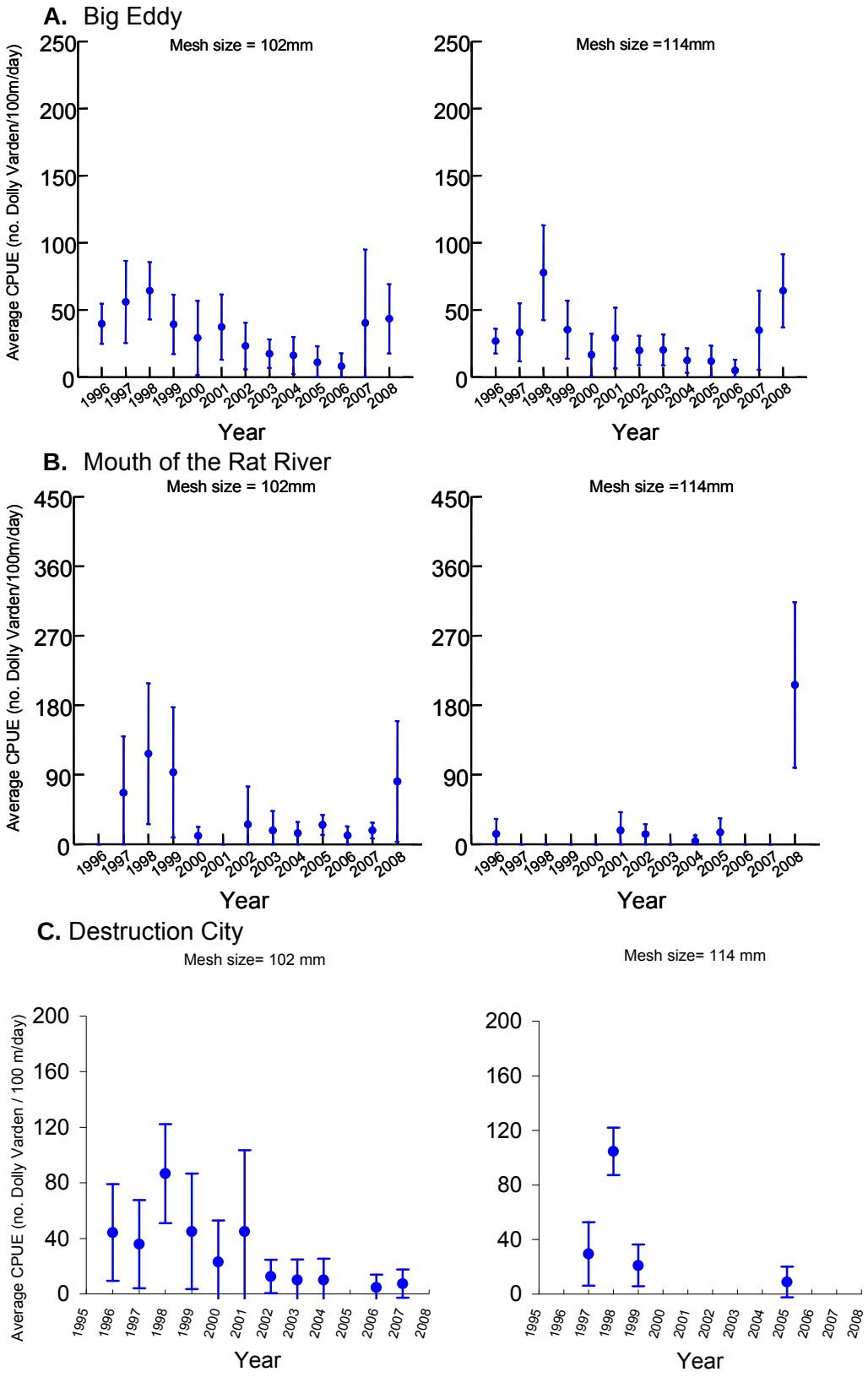


Figure 3. Mean CPUE (Catch per Unit Effort) (±1 std dev) by year and mesh size for subsistence harvests of Rat River Dolly Varden (1996-2008) at (A) Big Eddy (Husky Channel), (B) mouth of the Rat River Mouth and (C) Destruction City.

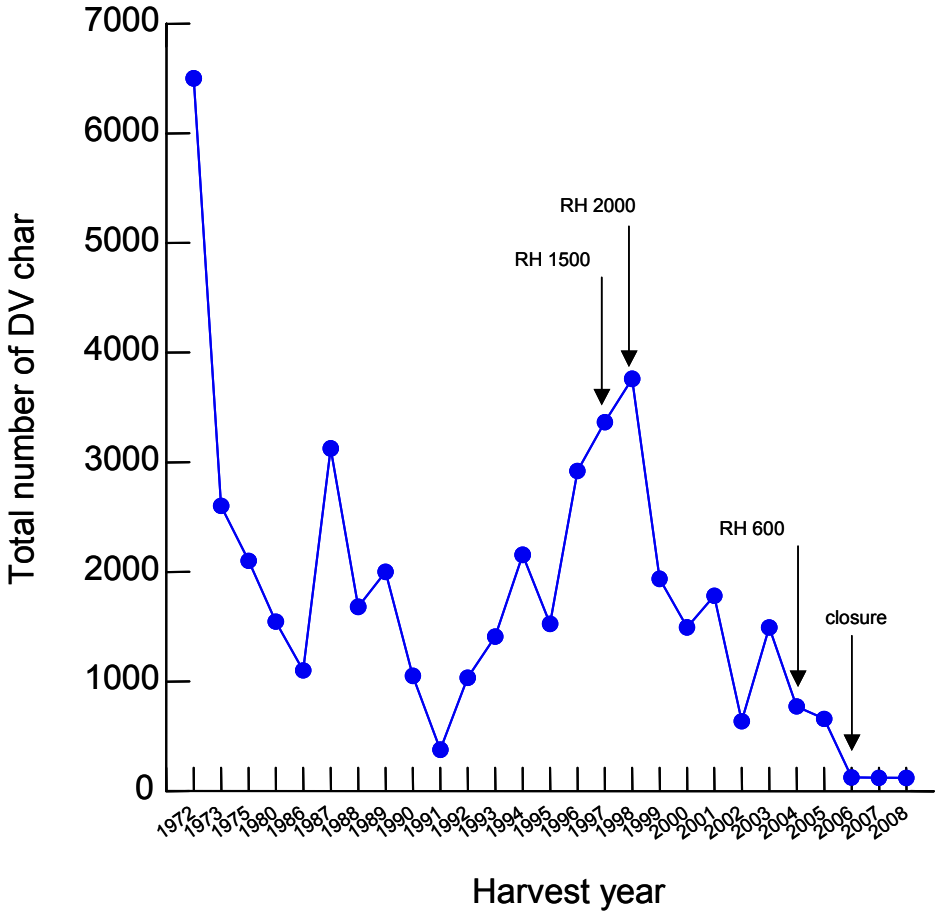


Figure 4. Total estimated annual harvests of Rat river Dolly Varden from 1972 to 2008. RH= Recommended Harvest (as outlined in the Rat River Fishing Plan).

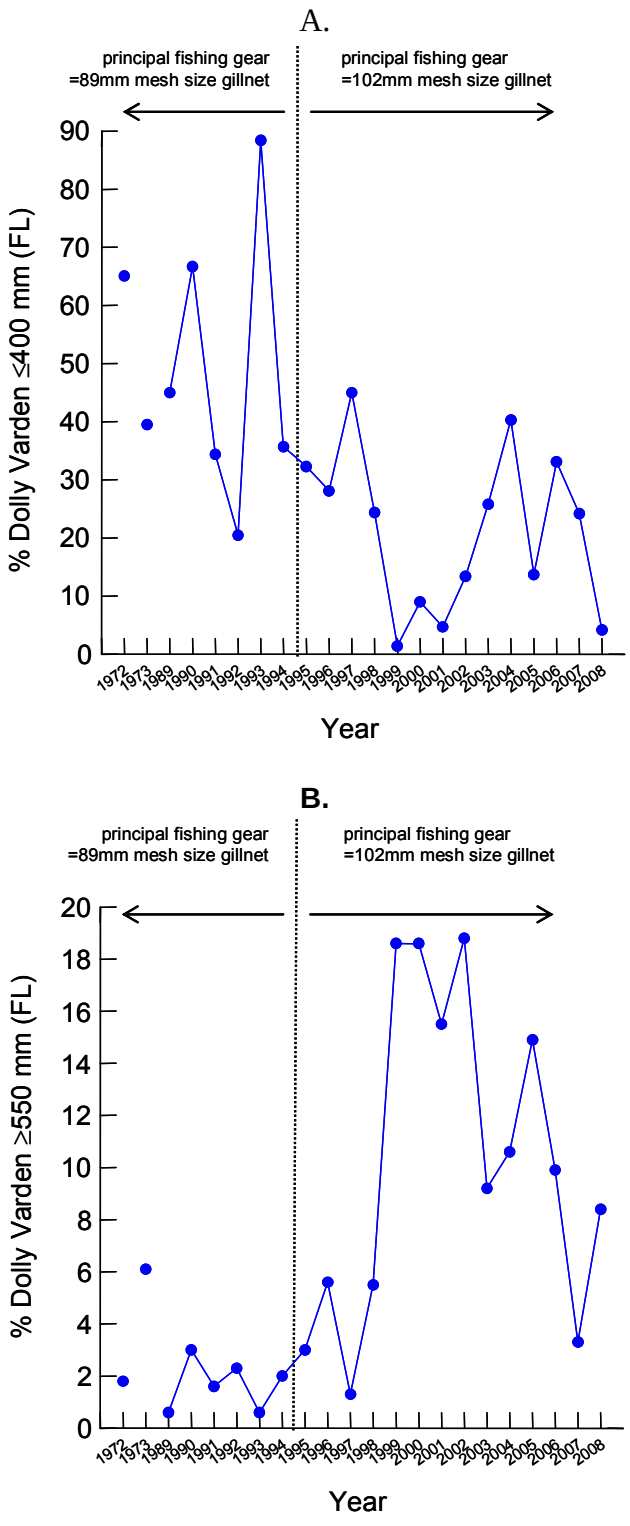
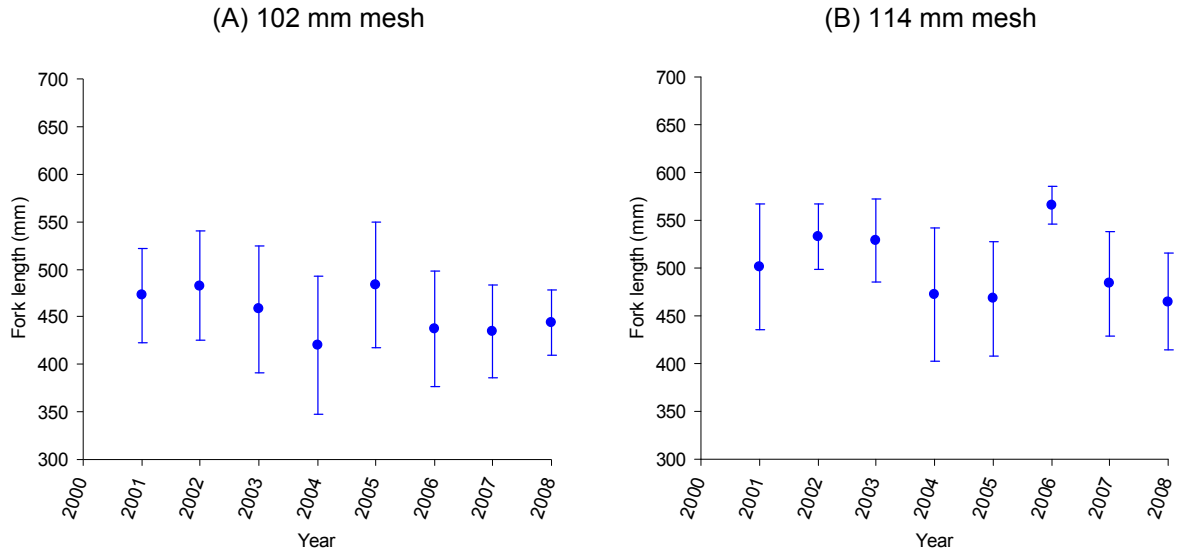


Figure 5. Percentage of Dolly Varden (A) ≤400mm and (B) ≥550 mm (FL) in annual catches at traditional fishing sites during the monitoring period of the Rat River fishery (1989-2008) and in 1972-73. Dotted lines mark the transition from the use of 89 mm mesh gillnets to the use of mainly 102 mm mesh gillnets as principal fishing gear in 1995.

Female (all maturity stage)



Male (all maturity stage)

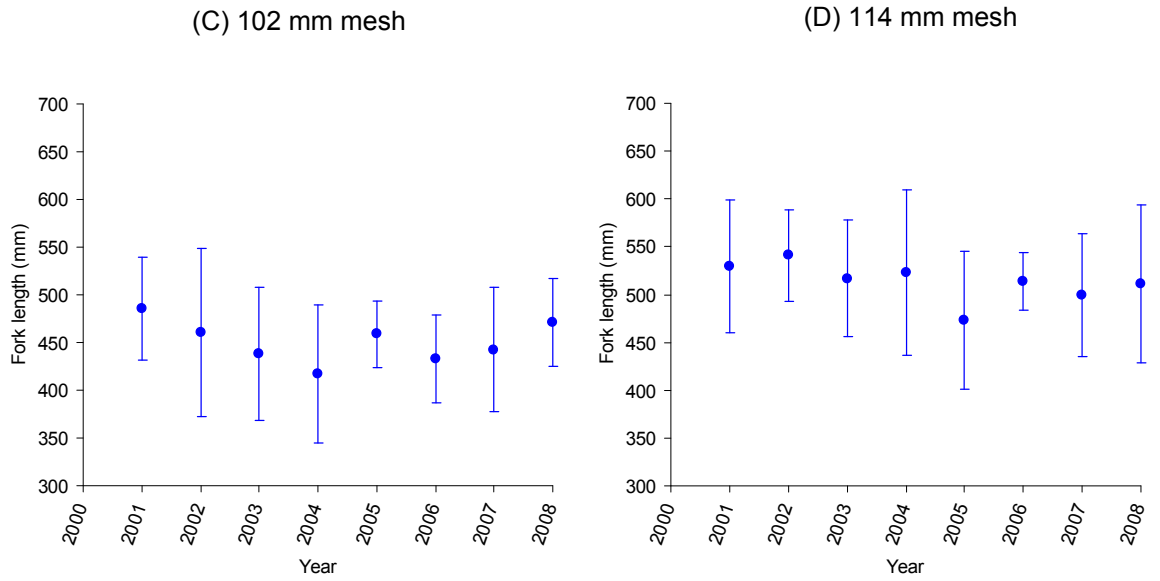
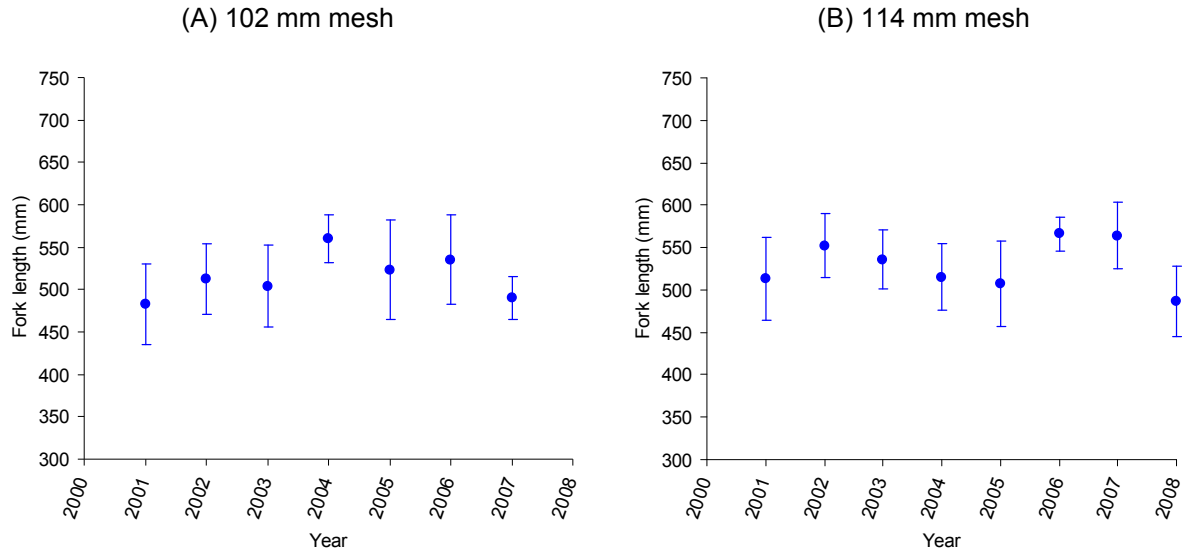


Figure 6. Average fork length of female Dolly Varden harvested using (A) 102 mm and (B) 114 mm mesh gillnets, and of male Dolly Varden harvested using (C) 102 mm and (D) 114 mm mesh gillnets in the Rat River fishery, 2001-2008 (all maturity stage, fishing locations = mouth of the Rat River, Destruction City and Big Eddy (Husky Channel)). Error bars= 1 standard deviation.

Female (current-year spawner)



Male (current-year spawner)

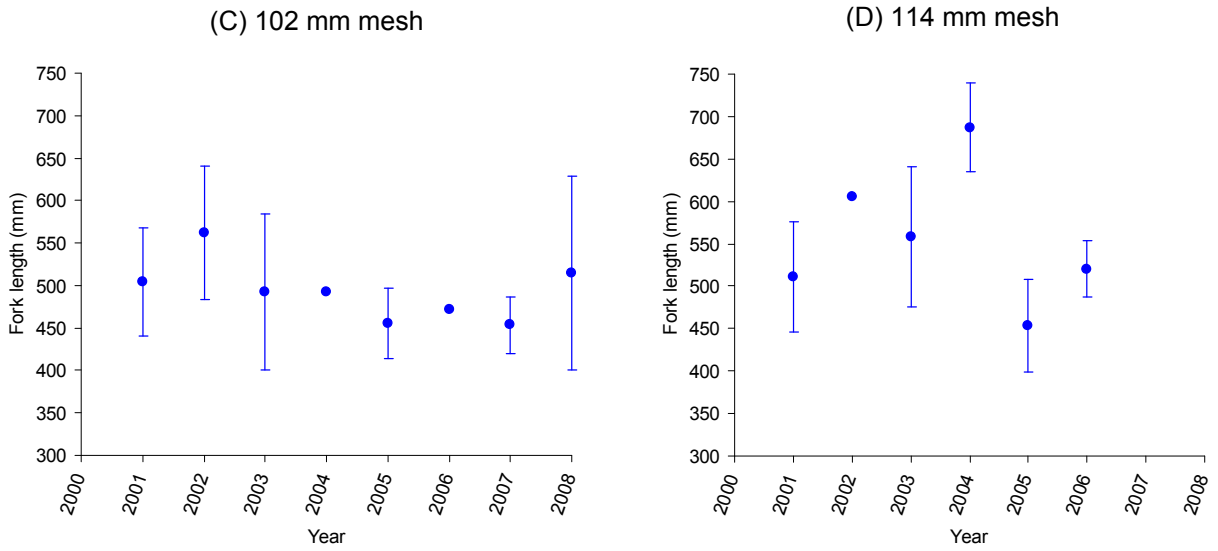
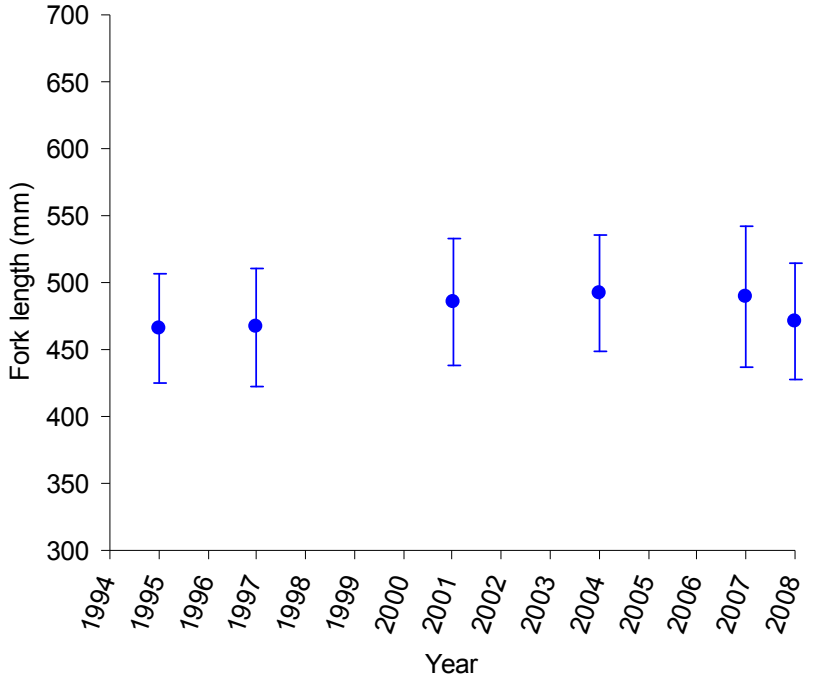


Figure 7. Average fork length of female Dolly Varden that were current-year spawners harvested using (A) 102 mm and (B) 114 mm mesh gillnets, and of male Dolly Varden that were current-year spawners harvested using (C) 102 mm and (D) 114 mm mesh gillnets in the Rat River fishery (3 fishing locations pooled: mouth of the Rat River, Destruction City and Big Eddy (Husky channel)). Error bars= 1 standard deviation.

(A) Female spawners



(B) Male spawners

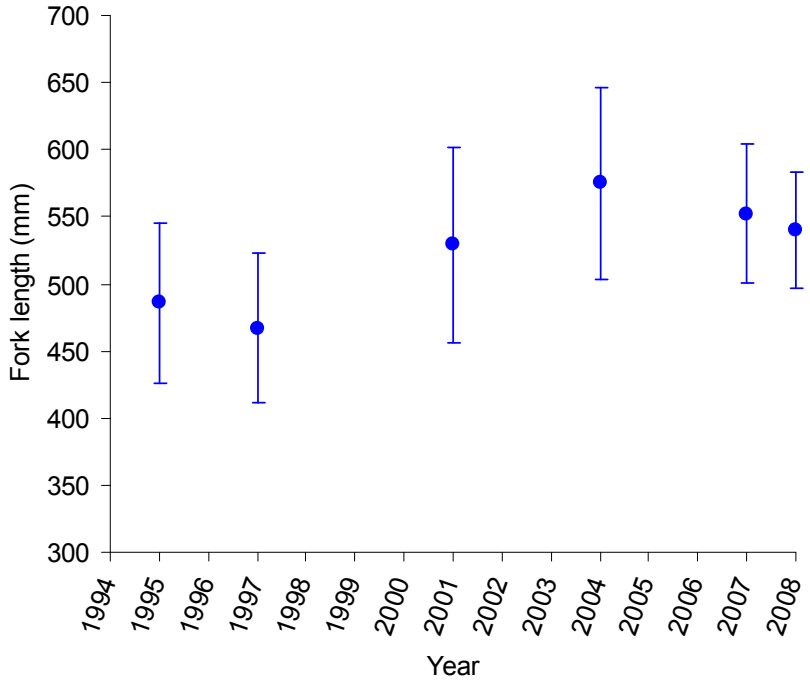


Figure 8. Mean fork length among study years for (A) female and (B) male Dolly Varden caught in spawning condition using a seine at the Rat River spawning/overwintering site, 1995-2008. Error bars= 1 standard deviation.

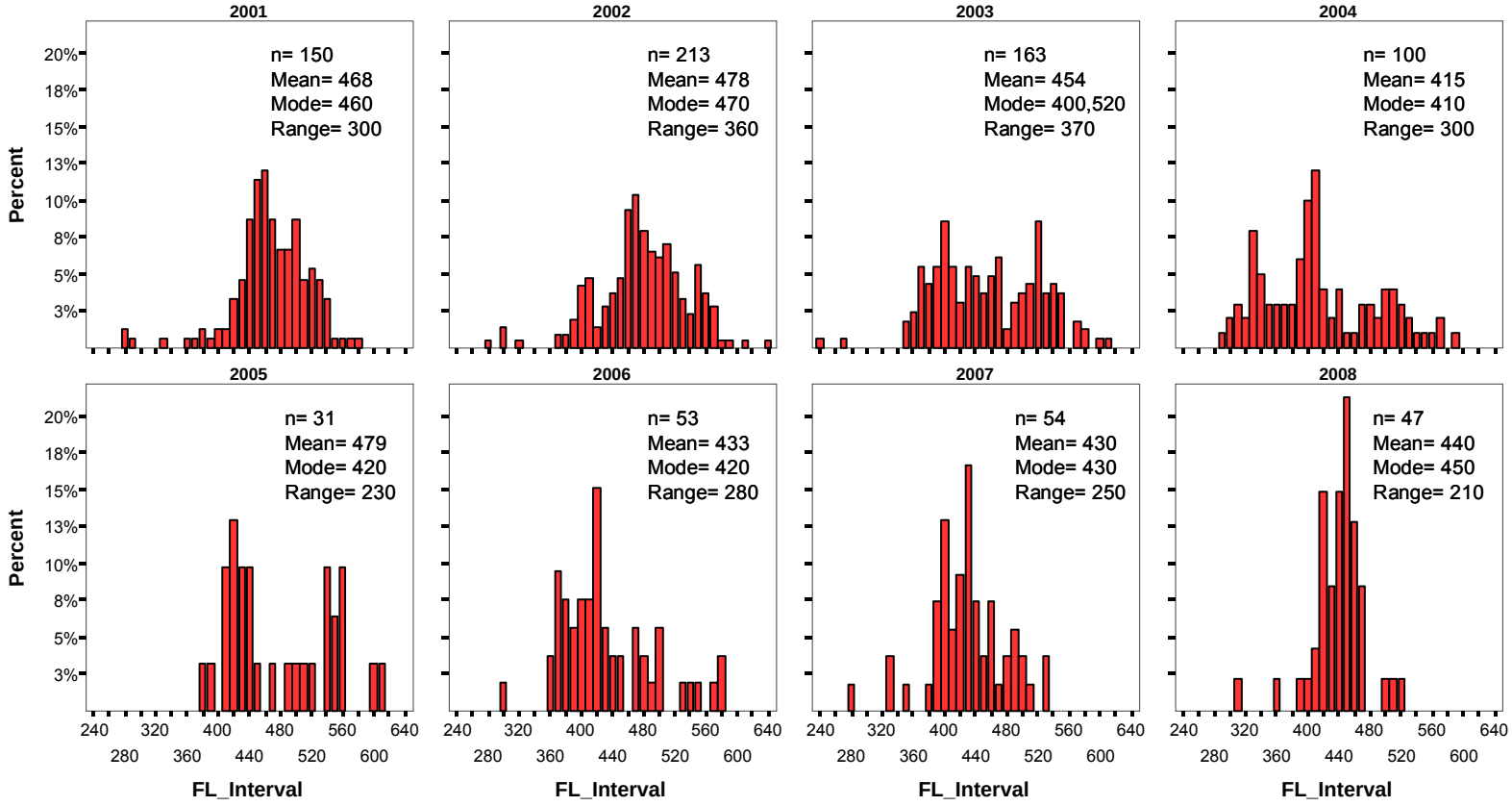


Figure 9. Length frequency distributions (10 mm fork length (FL) intervals) for female Dolly Varden (all maturity stage) harvested using 102 mm gillnets at three locations (Desctruction City, mouth the of Rat River and Big Eddy) in the Rat River fishery, 2001-2008.

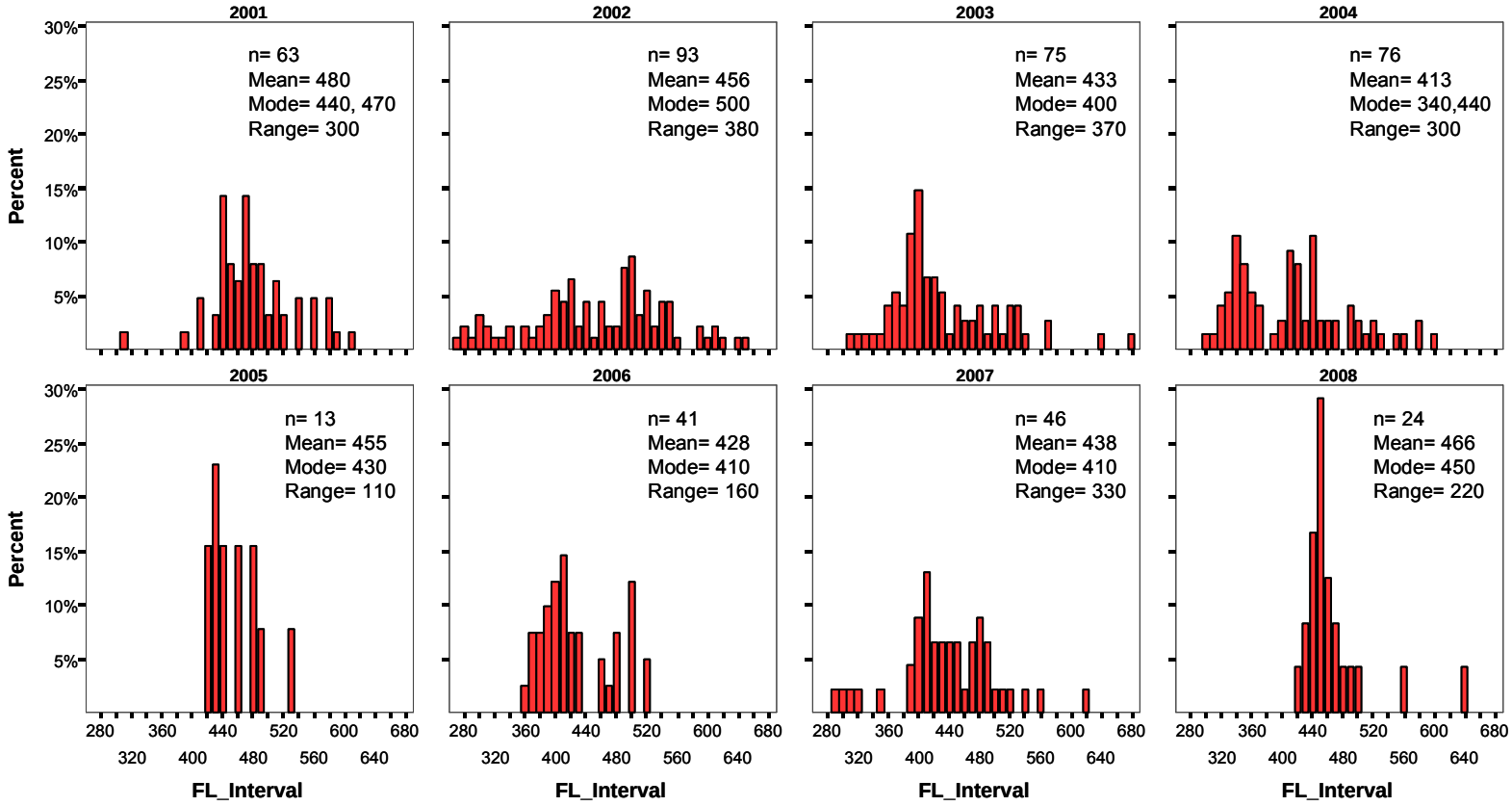


Figure 10. Length frequency distributions (10 mm fork length (FL) intervals) for male Dolly Varden (all maturity stage) harvested using 102 mm gillnets at three locations (Desctruction City, mouth of the Rat River, and Big Eddy) in the Rat River fishery, 2001-2008.

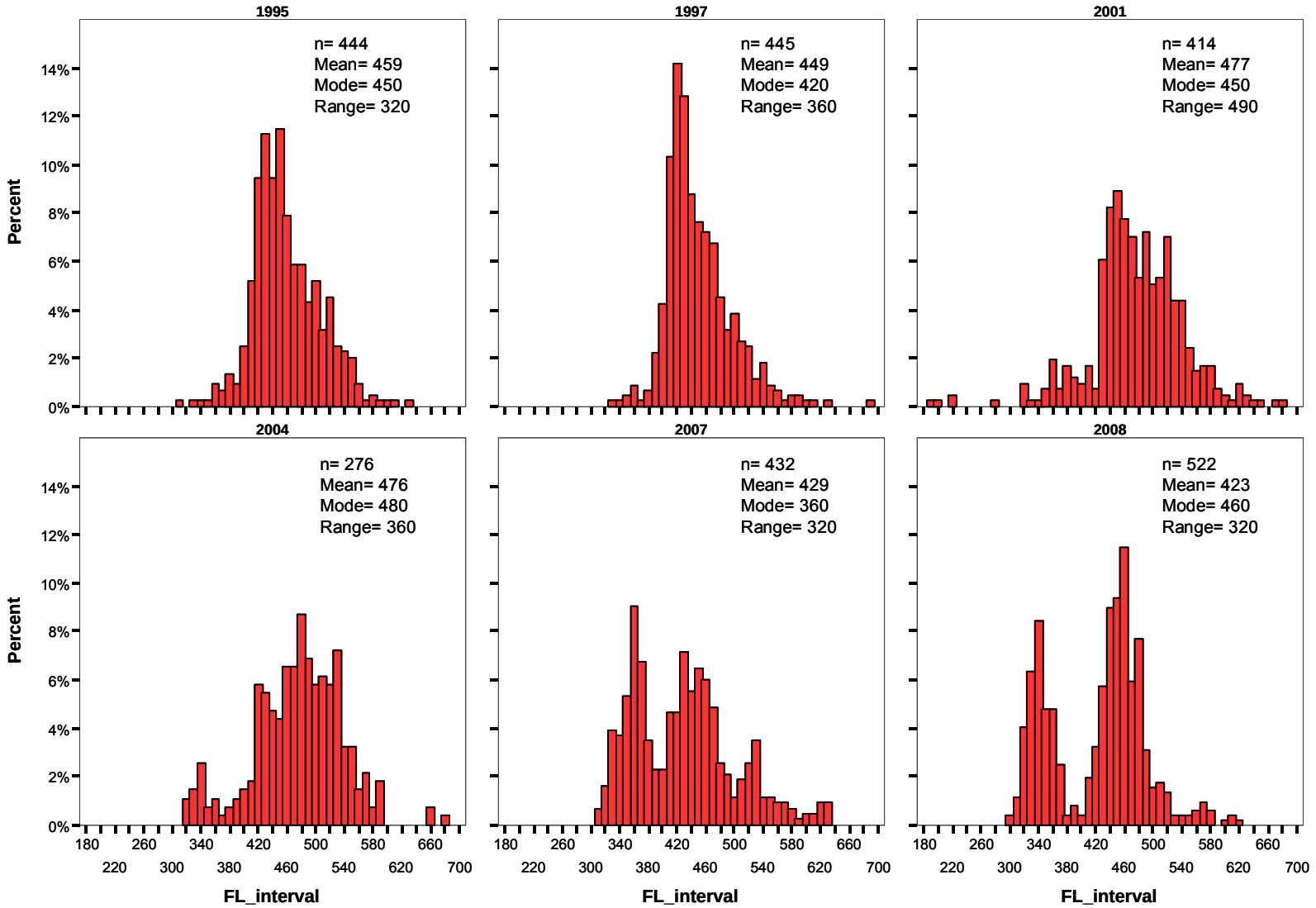
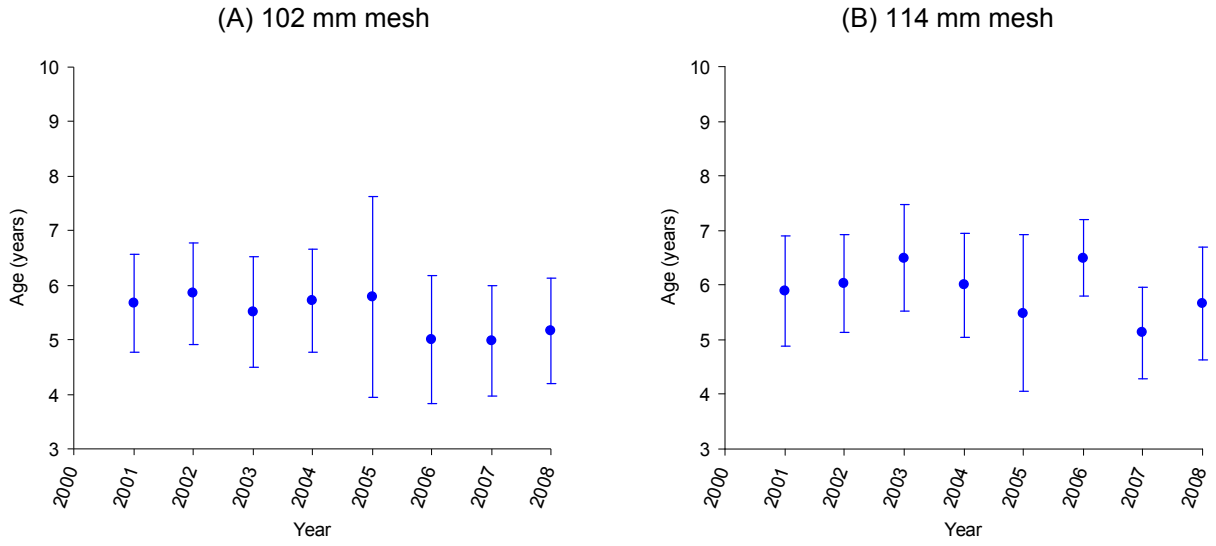


Figure 11. Length frequency distributions of Dolly Varden from the Rat River (sex and maturity stage pooled) caught using a seine at the Rat River spawning/overwintering site, 1995-2008.

Female (all maturity stage)



Male (all maturity stage)

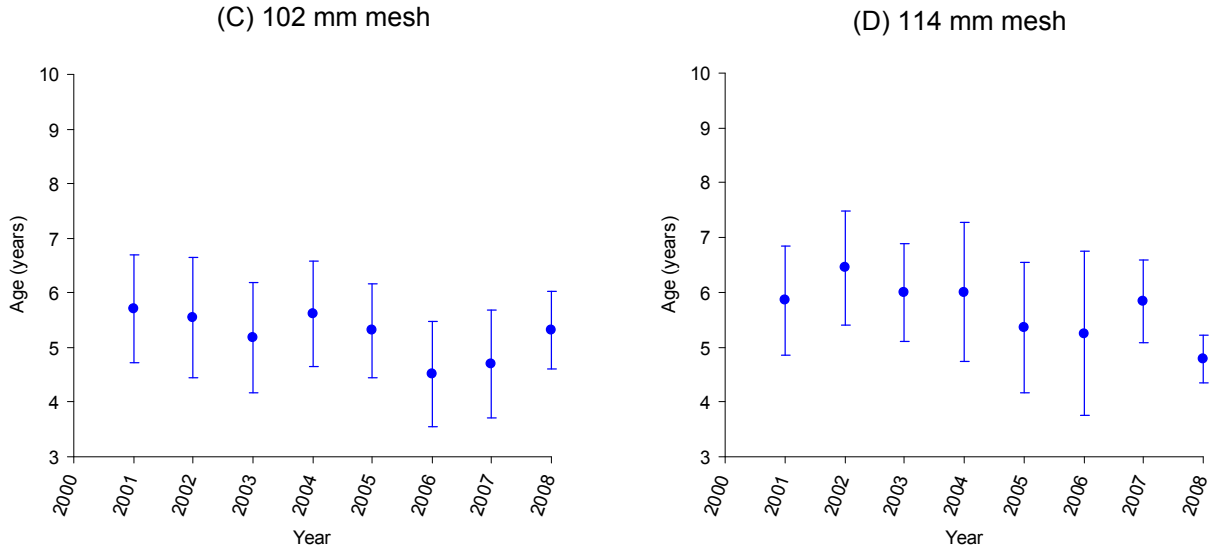
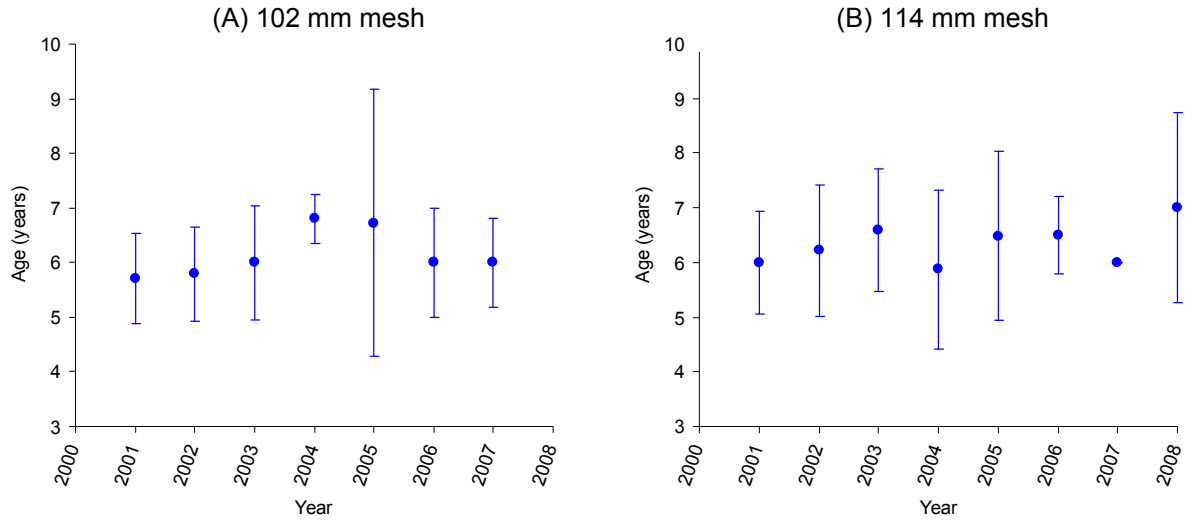


Figure 12. Mean age of female Dolly Varden from all maturity stage harvested using (A) 102 mm mesh gillnets and (B) 114 mm mesh gillnets, and of male Dolly Varden from all maturity stage harvested using (C) 102 mm mesh gillnets and (D) 114 mm mesh gillnets at three locations (mouth of the Rat River, Destruction City and Big Eddy) in the Rat River fishery, 2001-2008. Error bars= 1 standard deviation.

Female (current-year spawner)



Male (current-year spawner)

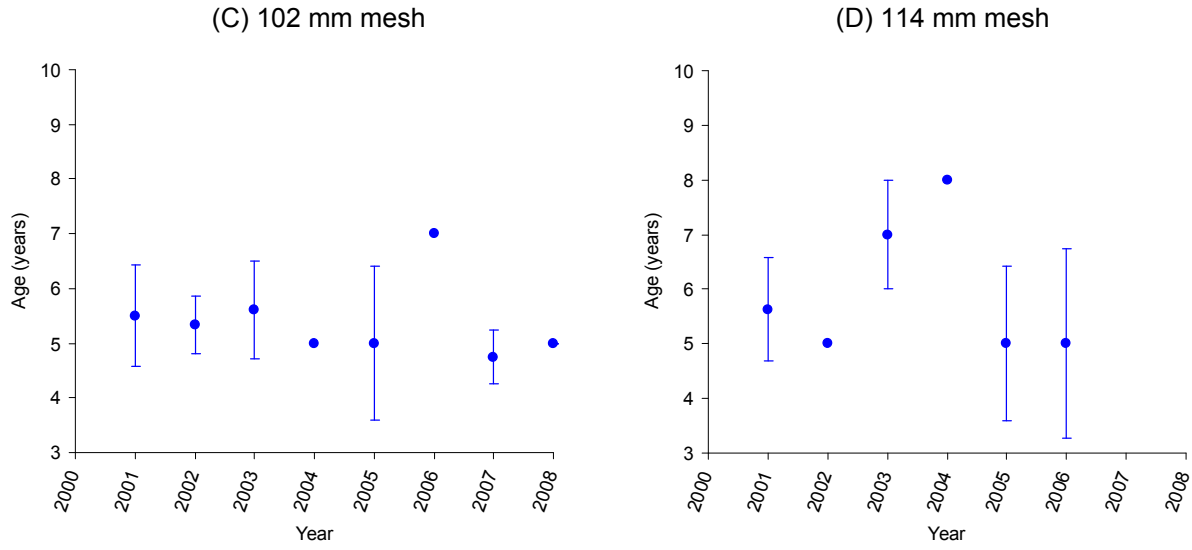


Figure 13. Average age of female Dolly Varden current-year spawners harvested using (A) 102 mm mesh gillnets and (B) 114 mm mesh gillnets, and of male Dolly Varden that were current-year spawners harvested using (C) 102 mm and (D) 114 mm mesh gillnets in the Rat River fishery (3 fishing locations pooled (mouth of the Rat River, Destruction City and Big Eddy (Husky Channel)). Error bars = one standard deviation.

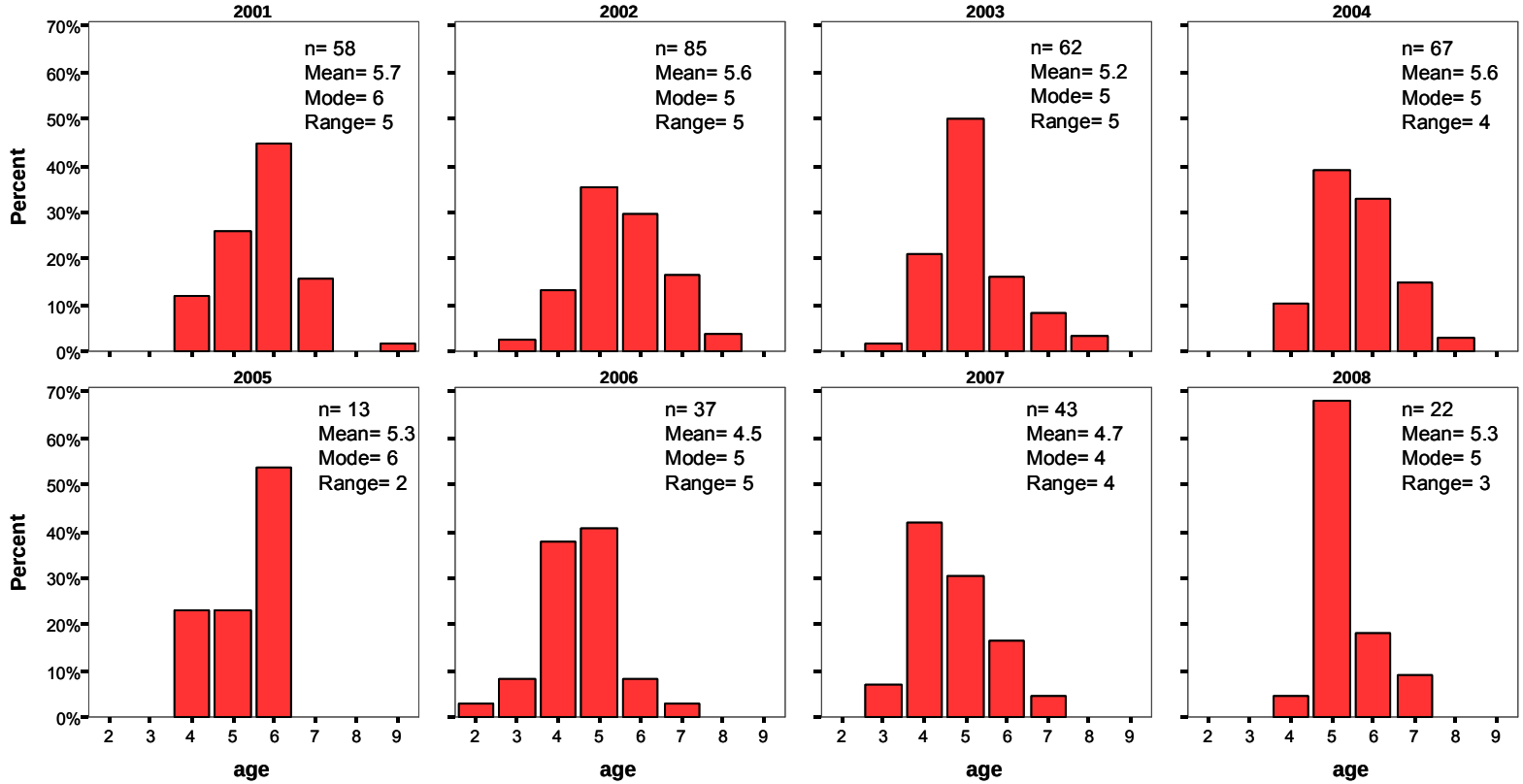


Figure 14. Age frequency distributions of male Dolly Varden from all maturity stage caught in 102 mm mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy) in the Rat River fishery, 2001-2008.

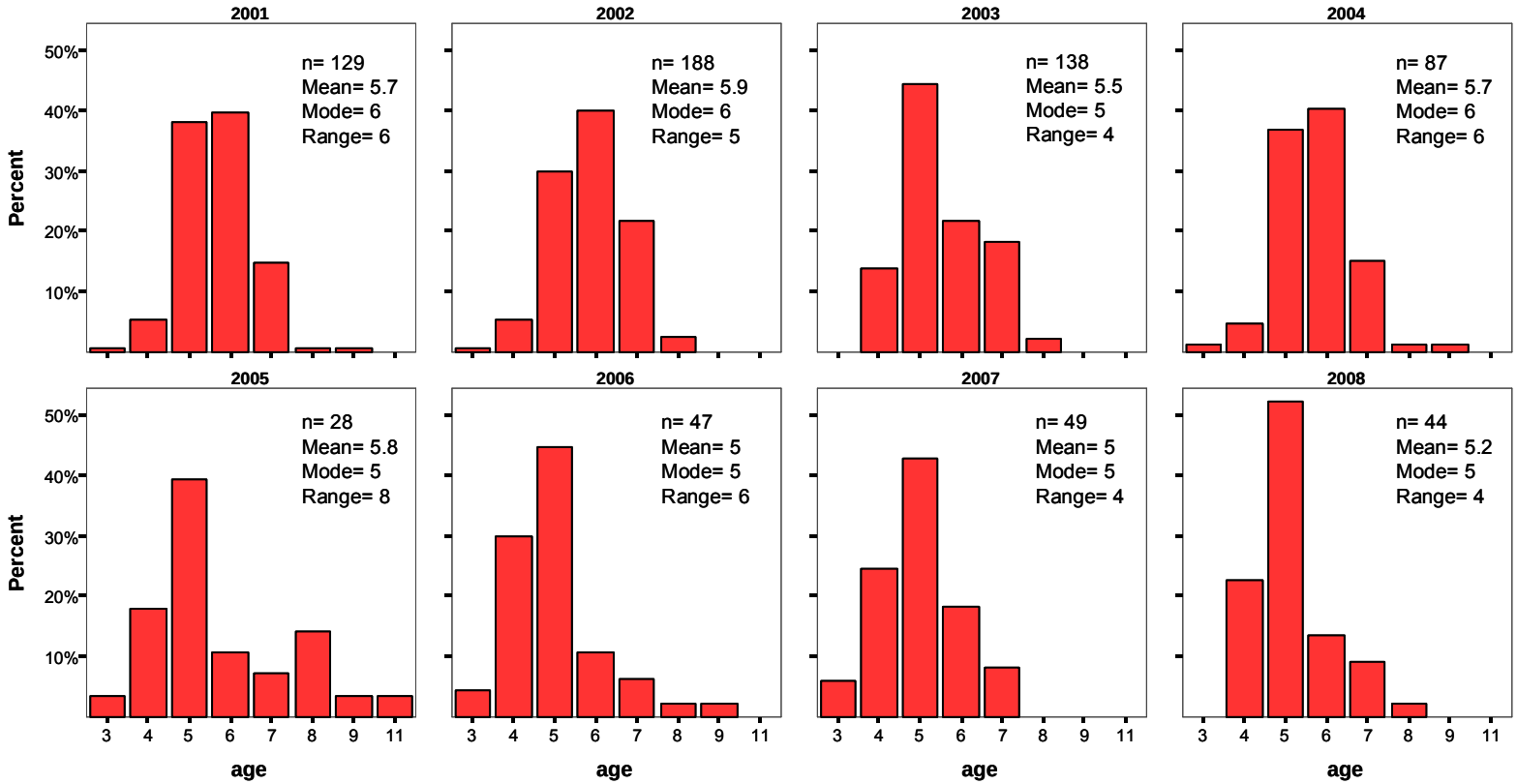


Figure 15. Age frequency distributions of female Dolly Varden from all maturity stage caught in 102 mm mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy) in the Rat River fishery, 2001-2008.

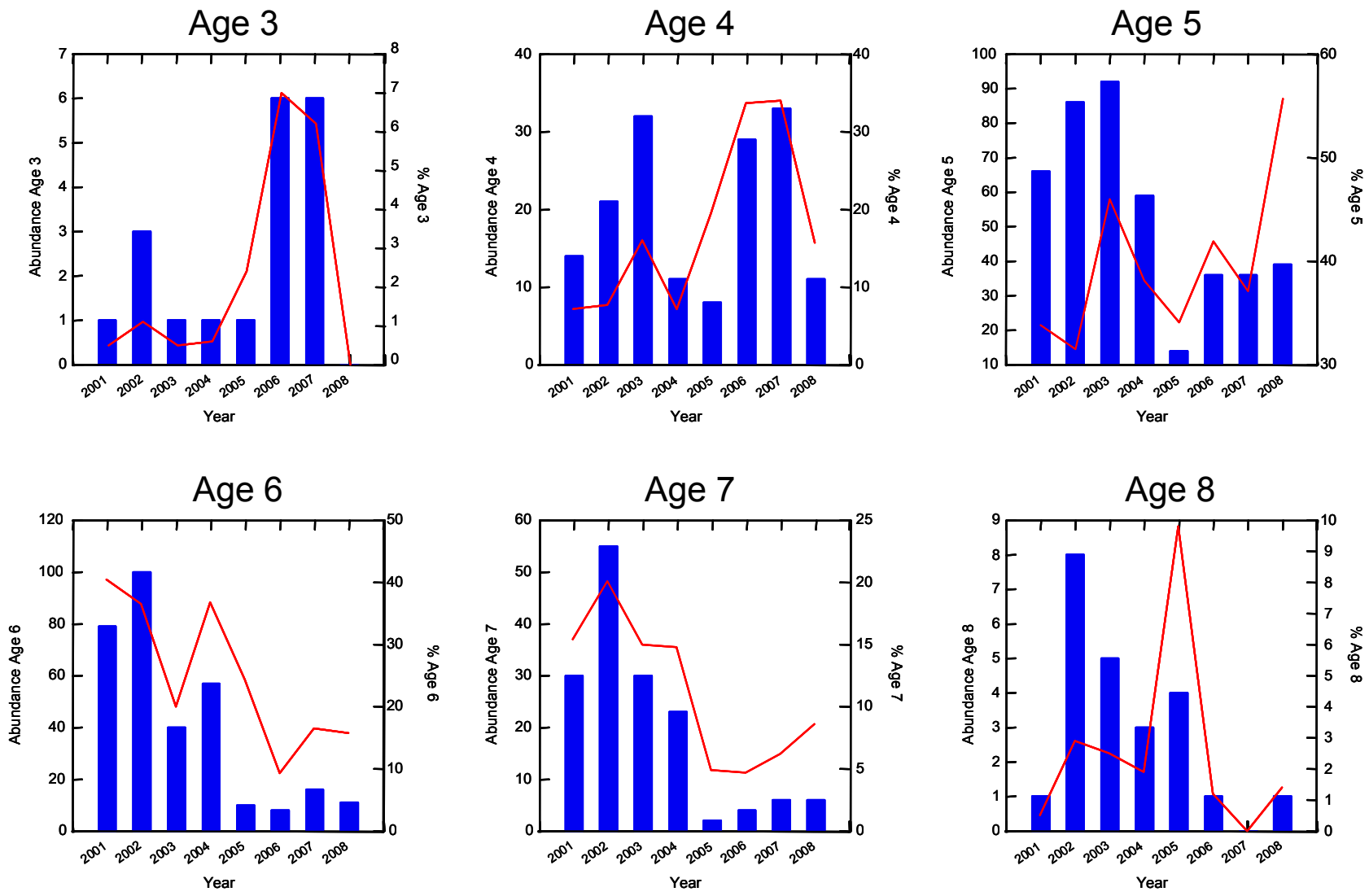


Figure 16. Abundance as sample sizes (bars) and percentage (trend line) of ages 3 to 8 Dolly Varden (all sex and maturity stage) in the catch from three fishing locations on the Rat River (mouth of the Rat River, Destruction City and Big Eddy), 2001-2008, using 102 mm mesh gillnets.

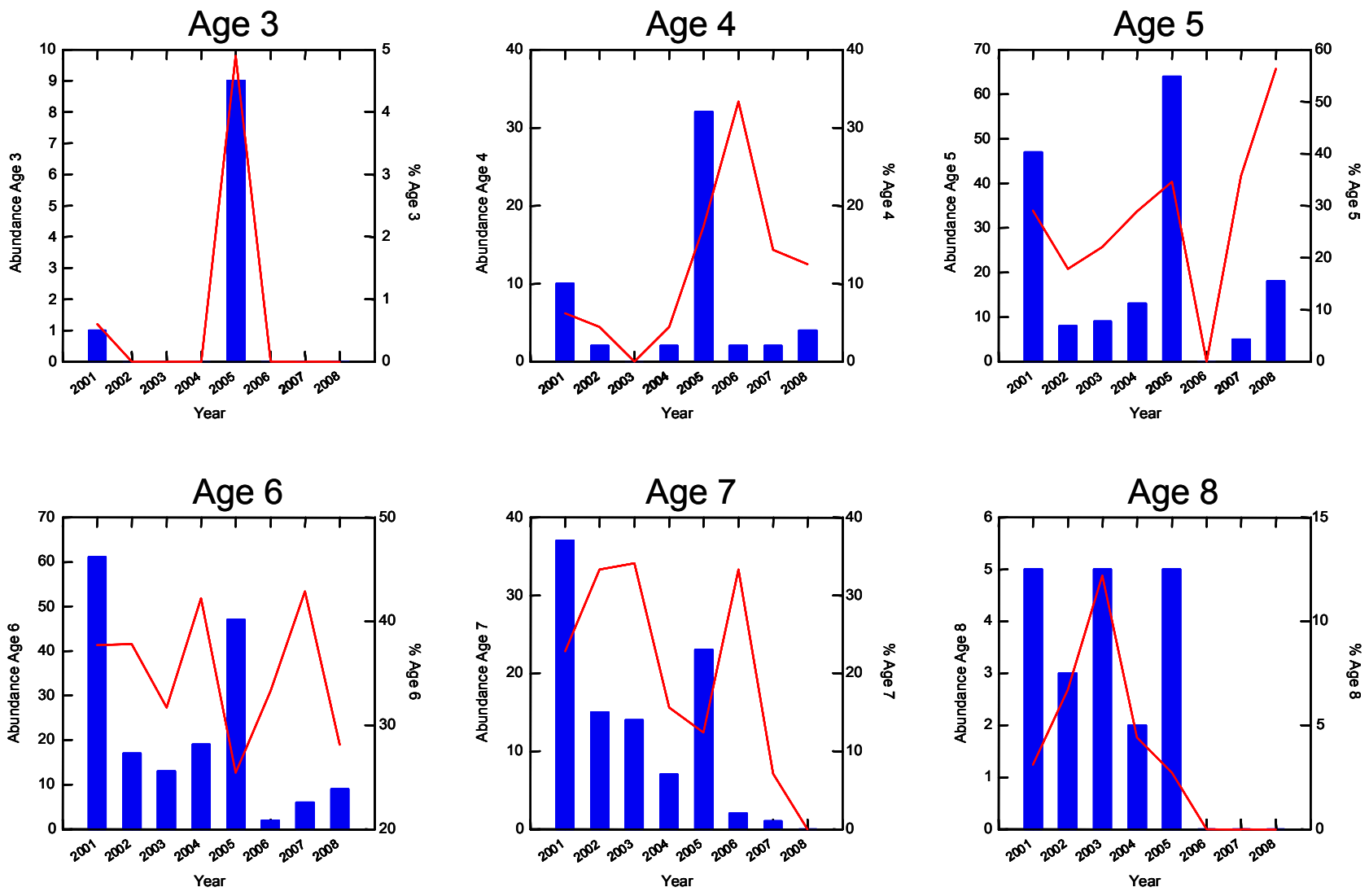


Figure 17. Abundance as sample sizes (bars) and percentage (trend line) of ages 3 to 8 Dolly Varden (all sex and maturity stage) in the catch from three fishing locations on the Rat River (mouth of the Rat River, Destruction City and Big Eddy), 2001-2008, using 114 mm mesh gillnets.

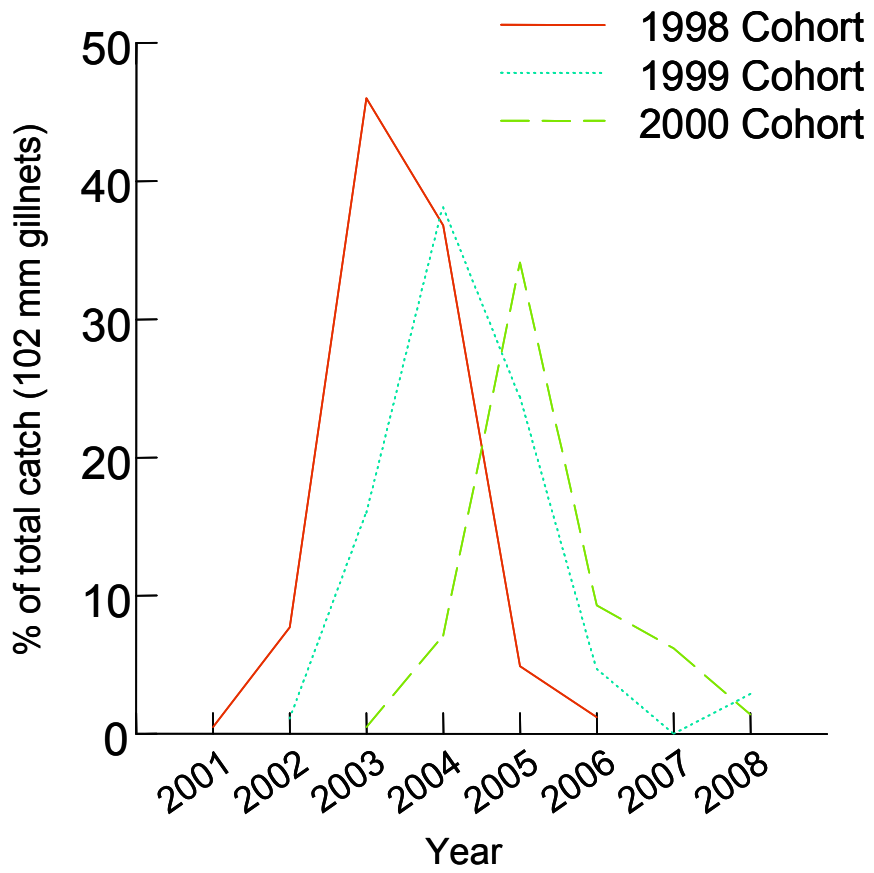


Figure 18. Cohort abundance as percent of total catch for Dolly Varden born in 1998, 1999 and 2000 and harvested in 102 mm mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy), 2001-2008.

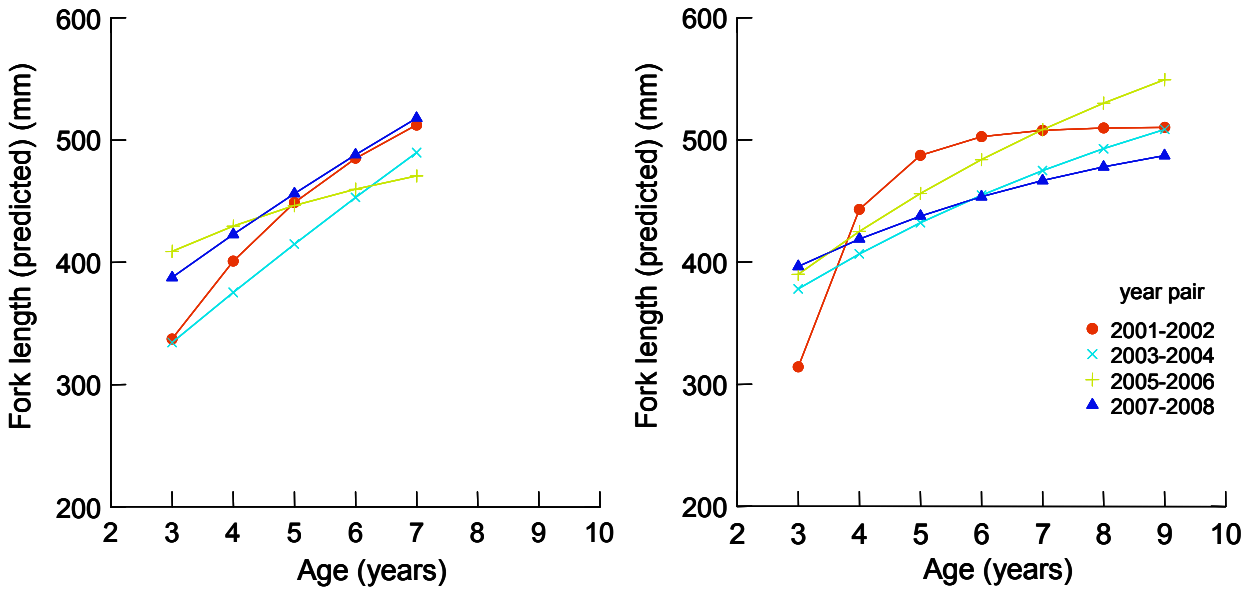


Figure 19. Von Bertalanffy growth curves fitted to length-at-age data for male (left) and female (right) Dolly Varden from the Rat River, 2001-2008. (All maturity stage pooled; samples caught in 102 mm gillnets at three fishing locations: mouth of the Rat River, Destruction City and Big Eddy).

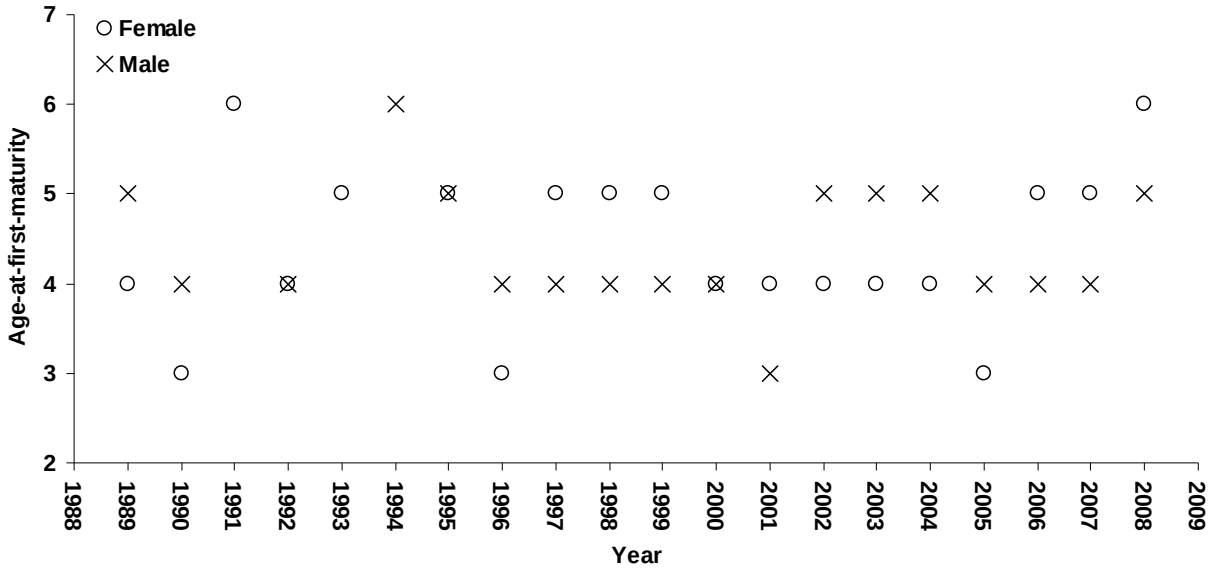


Figure 20. Age-at-first-maturity of female and male Dolly Varden from the Rat River captured in the subsistence fishery.

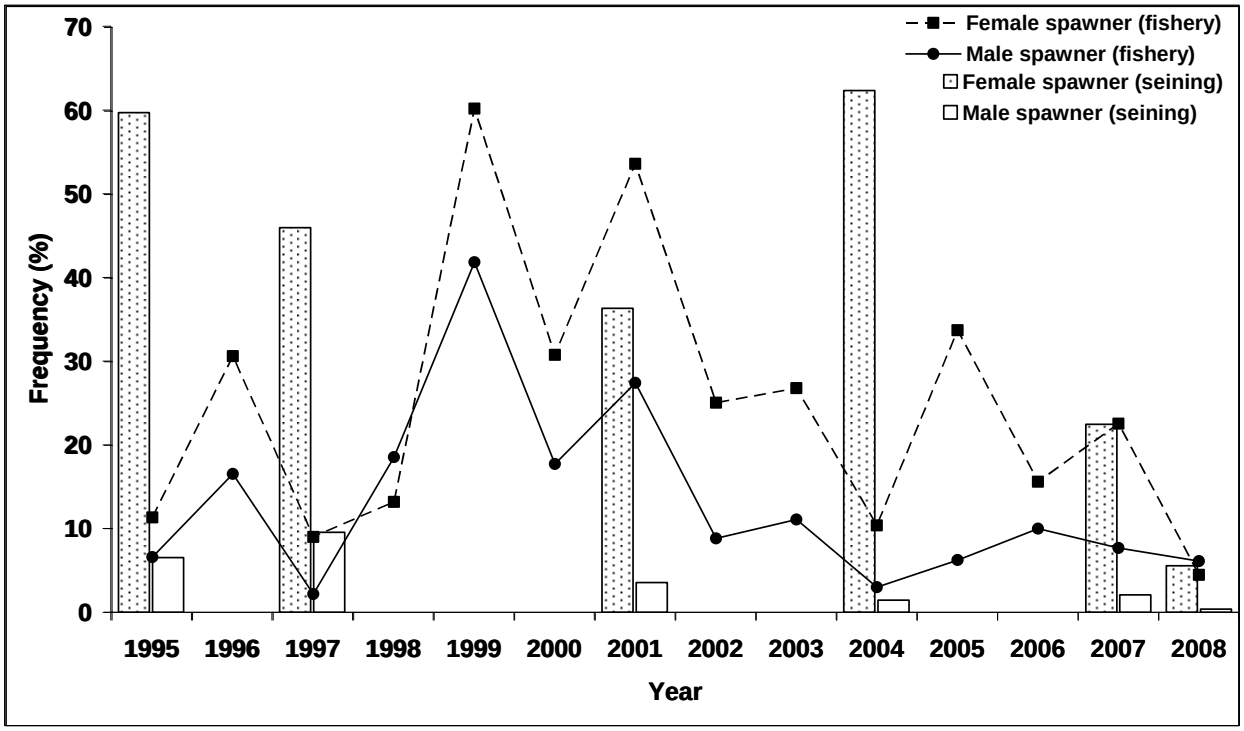


Figure 21. Percentage of male and female Dolly Varden harvested in spawning condition in the Rat River fishery, 1995-2008 (three monitoring stations pooled: mouth of the Rat River, Destruction City and Big Eddy), and live-sampled (seining) in spawning condition at the spawning/overwintering area.

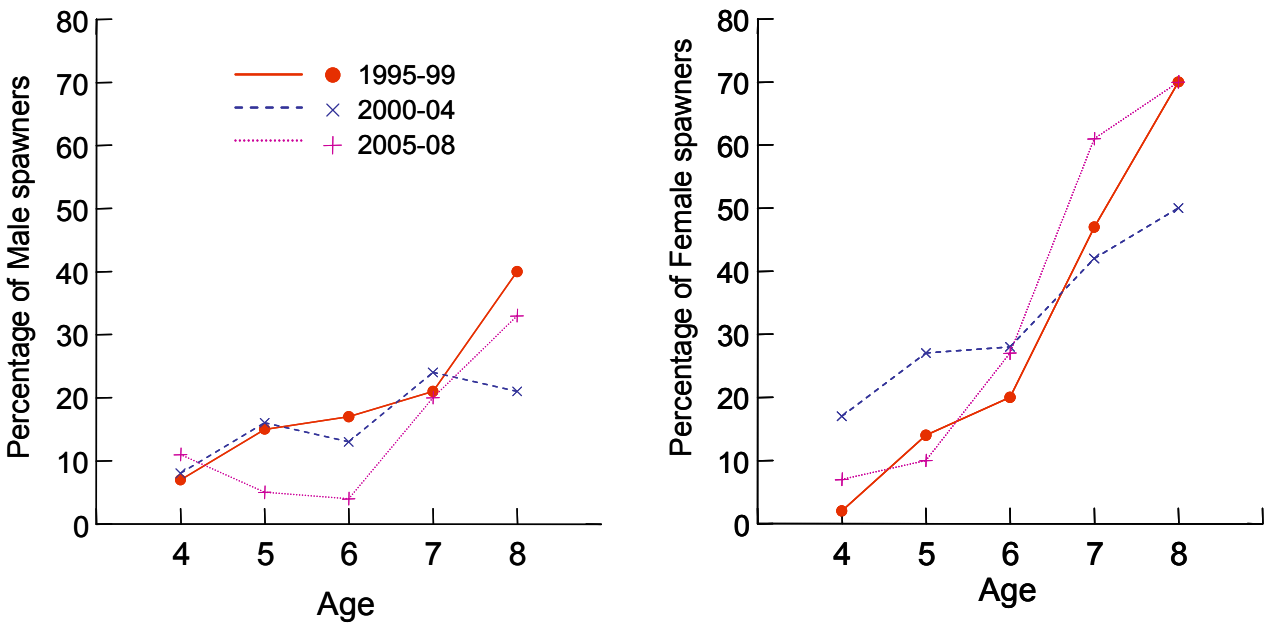


Figure 22. Percentage of male (left) and female (right) Dolly Varden harvested in spawning condition by age class (ages 4 to 8 years) in the Rat River Fishery, between 1995-1999, 2001-2004 and 2005-2008. (data from three harvest monitoring locations pooled: Big Eddy, Destruction City and mouth of the Rat River).

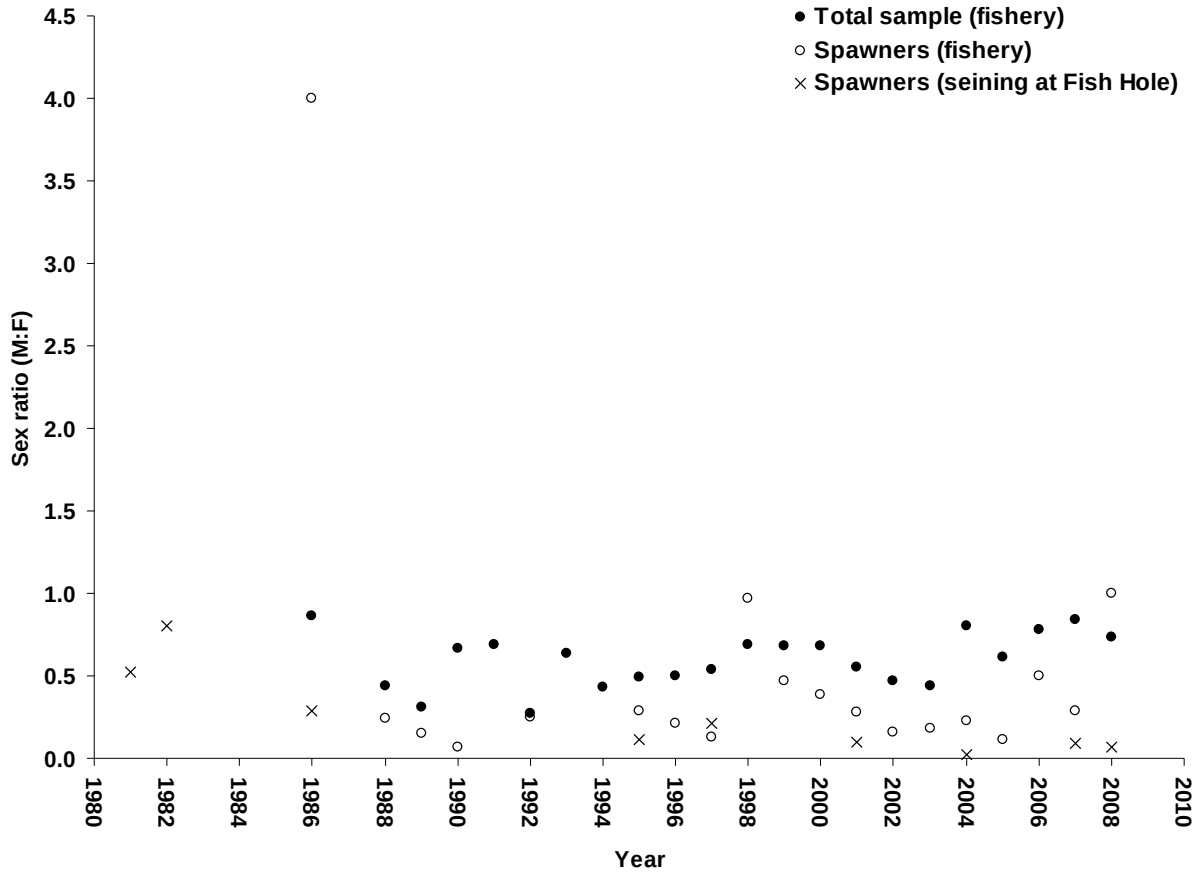


Figure 23. Sex ratio (male:female) of Dolly Varden captured in the fishery, 1995-2008 (data pooled from three monitoring locations: mouth of the Rat River, Destruction City and Big Eddy), and by seining at the Rat River spawning/overwintering site, 1995-2008.

Table 1. Summary of available population estimates for Dolly Varden from the Rat River.

Year	**Population estimate**	95% CI (normal approx)	95% CI (binomial approx)	95% CI (Poisson approx)	sample size (marked)	sample size (recaptures)	sample size (marked recaptures)	Method	Reference
1989*	**11,190**	8,263-14,118	8,629-14,837	8,528-14,976	825	690	50	Petersen	Stephenson & Lemieux 1990
1989	**8,928**				972	987	133	Schaefer	Stephenson & Lemieux 1990
1990									
1991									
1992									
1993									
1994									
1995**	**9,035**	6,930-11,140	7,164-11,593	7,124-11,632	357	1690	66	Petersen	Sandstrom et al. 2009
1996									
1997**	**10,410**	6,557-14,263	7,202-15,663	7,141-15,755	389	693	25	Petersen	Sandstrom et al. 2009
1998									
1999									
2000									
2001**	**7,952**	4,546-11,358	5,191-12,856	5,130-12,947	358	420	18	Petersen	Sandstrom et al. 2009
2002									
2003									
2004**	**2,911**	1,932-3,890	2,085-4,224	2,047-4,277	256	339	29	Petersen	Sandstrom et al. 2009
2005									
2006									
[a]2007**	**14,886**	6,204-23,568	8,317-28,916	8,233-29,076	389	381	9	Petersen	Sandstrom et al. 2009
[b]2007***	**8,488**	4,143-12,834	5,097-15,222	5,025-15,327	380	303	12	Petersen	Sandstrom et al. 2009

Note: tagged fish were ≥300 mm in all years.

*M adjusted adjusted for fishing mortality.

**M adjusted for tag loss, C adjusted for recruitment.

***M adjusted for tag loss and fishing mortality, C adjusted for recruitment.

[a] based on recaptures in the gillnet fishery

[b] based on seined recaptures at Fish Hole

Table 2. Average daily CPUE (no. of Dolly Varden per 100m net per day) by year and mesh size for subsistence harvests of Rat River Dolly Varden at Big Eddy (Husky Channel) and at the mouth of the Rat River (1996-2008).

	Big Eddy mesh size=102mm			Big Eddy mesh size=114mm			Big Eddy mesh size=140mm		
Year	**n**	**mean CPUE**	**range**	**n**	**mean CPUE**	**range**	**n**	**mean CPUE**	**range**
1996	32	39.750	12-64	26	26.769	12-44			
1997	31	55.968	15-120	30	33.333	4-72			
1998	28	64.278	32-134	29	77.726	24-151			
1999	28	39.255	0-90	33	35.314	8-88			
2000	29	29.138	0-85	31	16.484	0-48			
2001	72	37.330	8-104	70	29.078	0-96			
2002	38	23.201	0-72	25	19.829	0-40			
2003	31	17.411	0-48	28	20.267	0-48			
2004	45	16.122	0-56	22	12.364	0-32			
2005	32	11.016	0-45	26	11.827	0-38	2	7.5	0-15
2006	29	8.103	0-30	12	5.000	0-24			
2007	23	40.335	0-200	12	34.867	0-86			
2008	4	43.400	0-90	17	64.277	32-120			

	Rat River Mouth mesh size=102mm			Rat River Mouth mesh size=114mm			Rat River Mouth mesh size=127mm		
Year	**n**	**mean CPUE**	**range**	**n**	**mean CPUE**	**range**	**n**	**mean CPUE**	**range**
1996				95	13.204	0-88			
1997	55	66.473	0-328						
1998	26	117.231	0-288						
1999	18	93.111	0-264						
2000	97	10.845	0-48						
2001				192	17.847	0-107			
2002	60	25.694	0-360	17	12.941	0-40	9	1.389	0-13
2003	82	17.884	0-115						
2004	33	14.303	0-48	54	3.759	0-40			
2005	2	25	20-30	47	15.355	0-70	13	3.077	0-13
2006	13	11.282	0-43				32	3.167	0-21
2007	24	17.706	4-40						
2008	8	81.25	30-230	9	257.407	83-667	14	123.81	0-333

	Destruction City mesh size= 102 mm			Destruction City mesh size= 114 mm		
Year	**n**	**Mean CPUE**	**range**	**n**	**Mean CPUE**	**range**
1996	96	44.252	0-180			
1997	135	35.899	0-190	23	29.399	0- 84
1998	64	86.657	27-196	3	104.571	86-120
1999	91	45.04	0-180	15	20.971	0- 60
2000	110	23.069	0-144			
2001	154	45.016	0-274			
2002	88	12.525	0-60			
2003	56	10.102	0-77			
2004	90	10.07	0-60			
2005				118	8.923	0- 40
2006	92	4.609	0-48			
2007	61	7.419	0-43			
2008						

Table 3. Summary of available harvest information for Dolly Varden from the Rat River (1972-2008).

Year	Total Harvest[a,b,c]	Exploitation rate[d]	Management measure
1972	6500		
1973	2600		
1975	2100		
1980	1545	0.14	
1986	1100	0.10	
1987	3125	0.28	
1988	1681	0.15	
1989	1999	0.18	
1990	1051	0.09	
1991	376	0.03	
1992	1034	0.09	
1993	1409	0.13	
1994	2155	0.19	
1995	1524	0.17	
1996	2920	0.32	
1997	3393	0.33	1500 quota
1998	3760	0.36	2000 quota
1999	1911	0.18	2000 quota
2000	1493	0.14	2000 quota
2001	1781	0.22	2000 quota
2002	635	0.08	2000 quota
2003	1492	0.19	2000 quota
2004	772	0.27	600 quota
2005	658	0.23	600 quota
2006	124	0.04	closure
2007	120	0.01	closure
2008	119	0.01	closure

[a]Total harvest =50% of Dolly Varden caught at Shingle Point + 100% of Dolly Varden caught in the Rat River fishery.

[b]See Harwood (2001) for more detailed harvest information for 1972-2000.

[c]2006-2008 harvest corresponds to samples collected for monitoring purposes only.

[d]Exploitation rate=total harvest divided by current (or previous) year population estimate (see Table 2).

1980-1994: exploitation rate based on 1989 estimate of abundance; 1995-1996: exploitation rate based on 1995 estimate of abundance;

1997-2000: exploitation rate based on 1997 estimate of abundance; 2001-2003: exploitation rate based on 2001 estimate of abundance;

2004-2006:exploitation rate based on 2004 estimate of abundance; 2007-2008:exploitation rate based on 2007 (seined recapt) estimate of abundance

Table 4. Summary of information on available data sets for Dolly Varden from the Rat River.

year	month(s)	locations	Type of collection	method	N (total)	Publication or report	authors
1971	08-09	SS	Biological (population) analysis	angling	15	Fish resources of the Mackenzie River Valley Interim Report II	Stein et al. 1973
1972	06-09	HC, RR, PC	Biological (population) analysis	gillnet	868	Fish resources of the Mackenzie River Valley Special Report	Jessop et al. 1973
1972	09	SS	Biological (population) analysis	angling, seine	56	Fish resources of the Mackenzie river valley interim rep. II	Stein et al. 1973
1973	08-09	HC, RR, PC	Biological (population) analysis	gillnet	147	Fish resources of the Mackenzie river valley: Special Rep.	Jessop et al. 1973
1973	08	SS	Biological (population) analysis	angling	29	Fish resources of the Mackenzie River Valley Interim Report II	Stein et al. 1973
1981	09	SS	Fish health study	seine	29	Can. Tech. Rep. Fish. Aquat. Sci. 1441	Souter 1986
1982	09	SS	Fish health study	seine	10	Can. Tech. Rep. Fish. Aquat. Sci. 1441	Souter 1986
1983	08	RR	Biological (population) analysis	Weir	1008	Can. Data Rep. Fish. Aquat. Sci. 535	Gillman and Sparling 1985
1986	09	RR	Biological (population) analysis	gillnet	110	Fisheries Joint Management Committee Report #86-002	Sparling and Stewart
1986	09	SS	Biological (genetic) analysis	Electrofishing	58	Physiol. Ecol. Japan, Spec. Vol 1: 405-420	Reist 1989
1988	09	SS	Biological (genetic) analysis	Electrofishing	119	Unpublished data	J. Reist
1989	08-09	RR	Biological (population) analysis	Hoopnet	1084	Fisheries Joint Management Committee Report #89-008	Stephenson and Lemieux 19
1989	08-09	RR	Subsistence harvest monitoring	gillnet	508	Research Document 2001/090	Harwood 2001
1990	08-09	RR	Subsistence harvest monitoring	gillnet	165	Research Document 2001/090	Harwood 2001
1991	09	RR	Subsistence harvest monitoring	gillnet	61	Research Document 2001/090	Harwood 2001
1992	08-09	RR	Subsistence harvest monitoring	gillnet	220	Research Document 2001/090	Harwood 2001
1993	08-09	RR	Subsistence harvest monitoring	gillnet	329	Research Document 2001/090	Harwood 2001
1994	08-09	RR	Subsistence harvest monitoring	gillnet	196	Research Document 2001/090	Harwood 2001
1995	07-09	HC, WC, RR	Subsistence harvest monitoring	gillnet	857	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
1995	09-10	SS	Biological (population) analysis	seine	444	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Sandstrom et al 2009
1996	08-09	HC, WC, RR	Subsistence harvest monitoring	gillnet	732	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
1997	08-09	HC, WC, RR	Subsistence harvest monitoring	gillnet	682	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
1997	09	SS	Biological (population) analysis	seine	445	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Sandstrom et al 2009
1998	07-09	HC, WC, RR	Subsistence harvest monitoring	gillnet	667	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
1999	07-09	HC, RR	Subsistence harvest monitoring	gillnet	436	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2000	08-09	HC, RR	Subsistence harvest monitoring	gillnet	501	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2001	08-09	HC, RR	Subsistence harvest monitoring	gillnet	516	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2001	09-10	SS	Biological (population) analysis	seine	414	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Sandstrom et al 2009
2002	08-09	HC, RR	Subsistence harvest monitoring	gillnet	367	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2003	08-09	HC, RR	Subsistence harvest monitoring	gillnet	391	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2004	08-09	HC, RR	Subsistence harvest monitoring	gillnet	226	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2004	09	SS	Biological (population) analysis	seine	280	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Sandstrom et al 2009
2005	08-09	HC, RR	Subsistence harvest monitoring	gillnet	255	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2006	08-09	HC, RR	Subsistence harvest monitoring	gillnet	121	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2007	08-09	HC, RR	Subsistence harvest monitoring	gillnet	120	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Harwood et al 2009
2007	09	SS	Biological (population) analysis	seine	432	Can. Tech. Rep. Fish. Aquat. Sc. (in prep)	Sandstrom et al 2009
2008	08-09	HC, RR	Subsistence harvest monitoring	gillnet	119	Unpublished data	K. Howland

Legend: SS=Spawning/overwintering site, RR=lower Rat River (includes mouth of the Rat River and Destruction City), WC= West Channel of Mackenzie Delta (near Aklavik), HC=Husky Channel of Mackenzie Delta (includes channel mouth and Big Eddy), PC= Peel Channel of Mackenzie Delta.

Table 5. Summary statistics of length and age for male and female Dolly Varden (all maturity stage) caught in gillnets at traditional fishing locations in the lower Rat River and adjacent channels of the Mackenzie Delta.

		Male							Female						
Year	locations	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
1972	BE, LR, PC	138	409	307-604	0				152	392	228-590	0			
1973	BE, LR, PC	42	434	293-660	0				51	419	290-598	0			
1986	LR	51	371	286-533	39	4.4	5	3-7	59	369	256-572	46	4.9	5	3-8
1989	DC	120	385	231-601	87	5.6	5	2-11	386	424	265-540	283	6.4	6	3-11
1990	DC	64	386	317-651	55	4.8	5	2-7	95	392	304-568	89	4.9	4	3-8
1991	DC	22	398	285-563	18	4.5	5	3-7	32	430	365-513	24	5	4,5,6	3-7
1992	DC	46	441	353-539	38	5.7	5	4-7	173	452	341-571	140	6.3	6	4-11
1993	DC	74	358	312-498	57	5.2	5	4-7	115	365	294-516	101	5.4	5	4-8
1994	DC	51	440	379-568	44	5.8	6	4-7	118	426	343-551	101	5.9	6	4-12
1995	BE,DC, HC, RM, WC	267	430	290-624	187	6	6	4-9	566	437	294-626	343	6.2	6	4-10
1996	BE,DC, HC, RM, WC	244	425	276-619	206	5.1	5	3-8	488	452	285-652	417	5.8	5	3-11
1997	BE,DC, HC, RM, WC	249	417	298-607	201	5.7	5	3-8	433	412	295-581	356	5.8	6	3-11
1998	BE,DC, HC, RM, WC	266	449	318-605	226	5.8	5	4-9	393	438	260-661	331	5.8	6	3-8
1999	BE, DC, HC, RM	174	510	404-658	149	6.1	6	4-9	260	498	387-661	228	6.3	6	3-9
2000	BE, DC, HC, RM	193	506	312-694	152	5.9	5	3-10	304	498	260-667	250	6.1	6	4-10
2001	BE, DC, HC, RM	185	502	271-669	164	5.8	6	3-9	319	486	266-613	277	5.8	6	3-9
2002	BE, DC, HC, RM	116	475	277-651	106	5.8	5	3-8	250	489	282-640	221	5.9	6	3-8
2003	BE, DC, HC, RM	123	450	270-686	102	5.3	5	3-8	267	474	248-627	224	5.7	5	4-8
2004	BE, DC, RM	100	443	307-724	89	5.7	5	4-9	125	431	299-598	110	5.8	6	3-9
2005	BE, DC, RM	95	474	293-651	88	5.4	5	3-11	158	472	322-611	141	5.8	5	3-11
2006	BE, DC, RM	50	447	369-588	46	4.7	4,5	2-8	63	450	303-615	54	5	5	3-9
2007	BE, DC, RM	52	449	292-627	49	4.8	4	3-7	62	441	282-592	57	5	5	3-7
2008	BE, DC, RM	49	496	418-698	46	5	5	4-7	66	450	310-561	63	5.3	5	4-9

locations: BE=Big Eddy, HC=Husky Channel (mouth), DC=Destruction City, LR=Lower River, PC=Peel Channel, RM=mouth of Rat River, WC=West Channel near Aklavik

Table 6. Summary statistics of length and age for Dolly Varden (sex and maturity stage pooled) caught using different gear types at the Rat River spawning/overwintering site, 1971-2008.

Year	method	Fork length (mm)			Age (years)			
		n	mean	range	n	mean	mode	range
1971	angling	15	463	335-570	0			
1972	angling	36	525	442-660	0			
1972	seine	20	69	43-110	0			
1973	angling	29	456	356-554	0			
1981	seine	29	454	243-589	22	6.3	6	5-10
1982	seine	10	476	402-590	8	6.5	6	6-8
1986	electrofishing	58	465	0-619	38	7	7	4-10
1988	electrofishing	119	236	57-558	115	2.7	0	0-10
1995	seine	444	463	315-633	0			
1997	seine	445	454	331-690	0			
2001	seine	415	477	190-680	0			
2004	seine	281	480	320-680	0			
2007	seine	432	429	310-630				
2008	seine	522	426	300-620	0			

Table 7. Differences in (A) mean fork length (FL) and (B) mean age of Rat River Dolly Varden among the different mesh size gillnets used in the subsistence fishery, 2001-2008.

(A)

	Mesh size = 102 mm			Mesh size = 114 mm			Mesh size = 127 mm			difference in means	
Year	n	FL (mm)	% of catch	n	FL (mm)	% of catch	n	FL (mm)	% of catch	statistic	p-value
2001	224	480	43.5	291	503	56.5	0			t=4.468 df=513	<0.0001
2002	314	475	85.6	52	539	14.2	1	570	0.3	$F_{2,364}$=21.60	<0.0001
2003	239	452	61.1	152	490	38.9	0			t=5.608, df=389	<0.0001
2004	177	419	78.3	49	497	21.7	0			t=6.539, df=224	<0.0001
2005	44	476	17.3	206	471	80.8	5	577	2	$F_{2,252}$=6.85	0.001
2006	98	434	81.7	8	540	6.7	14	513	11.7	$F_{2,117}$=22.60	<0.0001
2007	106	439	88.3	14	490	11.7	0			t=3.236, df=118	0.002
2008	75	453	63	33	486	27.7	11	526	9.2	$F_{2,116}$=12.49	<0.0001

(B)

	Mesh size= 102 mm		Mesh size= 114 mm		Mesh size= 127 mm		difference in medians*	
Year	n	Age (years)	n	Age (years)	n	Age (years)	statistic	p-value
2001	195	5.7	254	5.9			U= 21980	0.31
2002	278	5.8	48	6.3	1	7	U= 4866.5	0.002
2003	200	5.4	126	5.9			U= 9497	<0.001
2004	155	5.7	45	6			U= 2941.5	0.09
2005	41	5.6	185	5.4	4	7.3	U= 3671	0.74
2006	86	4.8	6	5.7	10	5.2	-	-
2007	97	4.8	14	5.4			U= 436	0.02
2008	70	5.3	32	5.3	11	4.8	U= 1100.5	0.88

* difference between 102 and 114 mm only due to low sample sizes in 127 mm
2006 was not analyzed due to low sample size

Table 8. Summary statistics of length and age for male and female Dolly Varden caught in spawning conditions using gillnets at traditional fishing locations in the lower Rat River and adjacent channels of the Mackenzie Delta, 1972-2008.

		Male spawners							Female spawners						
Year	location(s)	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
1972	BE, LR, PC	21	424	310-558	0				23	418	305-590	0			
1986	LR	4	440	386-472	3	5.3	5	5-6	1	433		0			
1989	DC	33	434	231-601	23	6.7	7	5-11	213	460	349-540	160	7	7	4-11
1990	DC	3	411	375-438	3	5	4,5,6	4-6	41	439	333-568	38	5.6	5	3-8
1991	DC	0							5	453	413-498	4	6.5	6,7	6-7
1992	DC	38	442	353-514	32	5.8	6	4-7	155	457	341-571	129	6.4	6	4-11
1993	DC	0			0				3	359	331-412	3	6	5,6,7	5-7
1994	DC	1	478		1	6			0			0			
1995	BE,DC, HC, RM, WC	38	488	401-624	31	6.6	6	5-9	100	488	379-626	72	6.7	6	5-10
1996	BE,DC, HC, RM, WC	50	441	276-610	41	5.3	5	4-8	179	484	357-652	159	6.5	7	3-10
1997	BE,DC, HC, RM, WC	23	444	350-576	19	5.8	6	4-7	39	472	393-581	37	6.2	6	5-11
1998	BE,DC, HC, RM, WC	53	474	328-600	46	6	5	4-8	52	488	410-580	42	6.5	7	5-8
1999	BE, DC, HC, RM	84	519	412-658	70	6.1	6	4-9	170	511	403-661	152	6.5	6	5-9
2000	BE, DC, HC, RM	44	536	398-694	40	6.4	7	4-10	111	522	372-640	88	6.6	7	4-10
2001	BE, DC, HC, RM	54	504	415-650	51	5.8	6	3-7	177	498	282-613	150	5.9	6	4-8
2002	BE, DC, HC, RM	11	569	408-651	8	5.5	5	5-7	61	518	444-640	52	5.9	6	4-8
2003	BE, DC, HC, RM	10	518	357-648	8	6.1	5	5-8	64	512	425-627	49	6.2	7	4-8
2004	BE, DC, RM	3	622	492-724	2	6.5	5,8	5-8	13	533	460-598	13	6.2	6	4-9
2005	BE, DC, RM	6	504	415-604	6	5.8	4,6	4-8	53	513	388-611	46	6.6	7	3-11
2006	BE, DC, RM	5	502	471-541	5	5.2	4	4-7	10	547	478-589	7	6.1	7	5-7
2007	BE, DC, RM	4	454	419-490	4	4.8	5	4-5	14	501	446-592	12	6	6	5-7
2008	BE, DC, RM	3	515	435-645	2	5	5		3	487	442-523	3	7	6	6-9

locations: BE=Big Eddy, HC=Husky Channel (mouth), DC=Destruction City, LR=Lower River, PC=Peel Channel, RM=mouth of Rat River, WC=West Channel near Aklavik

Table 9. Summary statistics of length and age for male and female Dolly Varden caught in spawning condition using variable gear types at the Rat River spawning/overwintering site, 1972-2008.

		Male spawners							Female spawners						
Year	method	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
		n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
1972	angling	0			0				9	506	445-587	0			
1973	angling	6	454	375-534	0				22	454	356-554	0			
1981	seine	10	434	243-554	8	5.9	6	5-7	19	464	390-589	14	6.6	7	5-10
1982	seine	4	501	458-590	3	6.3	6	6-7	5	452	402-501	5	6.6	6	6-8
1986	electrofishing	4	437	402-496	3	7	7	7	14	530	394-619	10	8	7	7-10
1988	electrofishing	9	448	366-507	7	5.9	5	5-7	37	446	389-558	33	6.8	6	5-10
1995	seine	29	486	365-612	0				265	466	372-633	0			
1997	seine	43	467	375-636	0				195	467	355-612	0			
2001	seine	13	529	440-670	0				147	486	390-650	0			
2004	seine	4	575	525-680	0				172	492	405-590	0			
2007	seine	9	552	480-630	0				97	490	400-630	0			
2008	seine	2	540	509-570	0				29	471	390-570	0			

Table 10. Summary statistics of length and age for male and female Dolly Varden (all maturity stage) harvested using (A) 102 mm (4") and (B) 114 mm (4.5") mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy (Husky Channel), 2001-2008.

(A) 102 mm mesh gillnets

	Male (4")							Female (4")						
Year	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
	n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
2001	63	485	312-617	58	5.7	6	4-9	150	473	282-582	129	5.7	6	3-9
2002	93	461	277-651	85	5.6	5	3-8	213	483	282-640	188	5.9	6	3-8
2003	75	438	310-686	62	5.2	5	3-8	163	458	248-615	138	5.5	5	4-8
2004	76	418	307-609	67	5.6	5	4-8	100	420	299-598	87	5.7	6	3-9
2005	13	459	421-539	13	5.3	6	4-6	31	483	388-611	28	5.8	5	3-11
2006	41	433	369-521	37	4.5	5	2-7	53	437	303-589	47	5	5	3-9
2007	46	442	292-627	43	4.7	4	3-7	54	435	282-538	49	5	5	3-7
2008	24	471	427-645	22	5.3	5	4-7	47	444	310-520	44	5.2	5	4-8

(B) 114 mm mesh gillnets

	Male (4.5")							Female (4.5")						
Year	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
	n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
2001	79	530	271-669	67	5.9	6	4-8	107	501	266-613	95	5.9	6	3-9
2002	19	541	446-623	18	6.4	7	4-8	30	533	453-576	27	6	6	4-8
2003	15	517	406-648	11	6	6	5-8	42	529	403-627	30	6.5	7	5-8
2004	24	523	336-724	22	6	5	4-9	25	472	355-575	23	6	6	4-9
2005	80	474	293-651	73	5.4	5	3-11	125	468	322-600	111	5.5	5	3-10
2006	4	514	482-541	4	5.3	4	4-7	4	566	545-589	2	6.5		6,7
2007	6	500	435-604	6	5.8	6	5-7	8	484	432-592	8	5.1	5,6	4-6
2008	15	511	418-698	14	4.8	5	4-5	18	465	335-561	18	5.7	6	4-9

Table 11. Summary statistics of length and age for male and female Dolly Varden harvested in spawning condition using (A) 102 mm (4") and (B) 114 mm (4.5") mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy (Husky Channel)), 2001-2008.

(A) 102 mm mesh gillnets

	Male spawners (4")							Female spawners (4")						
Year	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
	n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
2001	19	504	415-617	18	5.5	6	4-7	73	483	282-582	60	5.7	5	4-7
2002	9	562	408-651	6	5.3	5	5-6	52	512	444-640	43	5.8	6	4-7
2003	6	492	357-641	5	5.6	5	5-7	36	504	432-615	27	6	7	4-8
2004	1	492		1	5			5	560	524-598	5	6.8	7	6-7
2005	2	456	426-485	2	5		4,6	14	523	388-611	11	6.7	8	3-11
2006	1	471		1	7			6	535	478-589	5	6	5,7	5-7
2007	4	454	419-490	4	4.8	5	4-5	12	490	446-538	10	6	6	5-7
2008	3	515	435-645	2	5		5	0			0			

(B) 114 mm mesh gillnets

	Male spawners (4.5")							Female spawners (4.5")						
Year	Fork length (mm)			Age (years)				Fork length (mm)			Age (years)			
	n	mean	range	n	mean	mode	range	n	mean	range	n	mean	mode	range
2001	20	511	434-650	19	5.6	5	4-7	65	513	337-613	56	6	6	4-8
2002	1	605		1	5			9	552	453-574	9	6.2	6,7	4-8
2003	4	558	482-648	3	7	6,7,8	6-8	19	536	494-627	15	6.6	7	5-8
2004	2	687	650-724	1	8			8	515	460-565	8	5.9	6	4-9
2005	2	454	415-492	2	5		4,6	37	507	405-600	33	6.5	7	4-10
2006	3	520	482-541	3	5	4	4-7	4	566	545-589	2	6.5		6,7
2007	0			0				2	564	536-592	2	6	6	6
2008	0			0				3	536	494-627	3	7	6	6-9

Table 12. Age-specific abundance and percentage of total catch for Dolly Varden (sex and maturity stage pooled) harvested in (A) 102 mm mesh gillnets and (B) 114 mm mesh gillnets at three fishing locations on the Rat River (mouth of the Rat River, Destruction City and Big Eddy), 2001-2008.

(A)

	Age-3		Age-4		Age-5		Age-6		Age-7		Age-8	
year	abundance	percent	abundance	percent	abundance	percent	abundance	percent	abundance	percent	abundance	percent
2001	1	0.5	14	7.2	66	33.8	79	40.5	30	15.4	1	0.5
2002	3	1.1	21	7.7	86	31.5	100	36.6	55	20.1	8	2.9
2003	1	0.5	32	16	92	46	40	20	30	15	5	2.5
2004	1	0.6	11	7.1	59	38.1	57	36.8	23	14.8	3	1.9
2005	1	2.4	8	19.5	14	34.1	10	24.4	2	4.9	4	9.8
2006	6	7	29	33.7	36	41.9	8	9.3	4	4.7	1	1.2
2007	6	6.2	33	34	36	37.1	16	16.5	6	6.2	0	0
2008	0	0	11	15.7	39	55.7	11	15.7	6	8.6	1	1.4

(B)

	Age-3		Age-4		Age-5		Age-6		Age-7		Age-8	
year	abundance	percent	abundance	percent	abundance	percent	abundance	percent	abundance	percent	abundance	percent
2001	1	0.6	10	6.2	47	29	61	37.7	37	22.8	5	3.1
2002	0	0	2	4.4	8	17.8	17	37.8	15	33.3	3	6.7
2003	0	0	0	0	9	22	13	31.7	14	34.1	5	12.2
2004	0	0	2	4.4	13	28.9	19	42.2	7	15.6	2	4.4
2005	9	4.9	32	17.3	64	34.6	47	25.4	23	12.4	5	2.7
2006	0	0	2	33.3	0	0	2	33.3	2	33.3	0	0
2007	0	0	2	14.3	5	35.7	6	42.9	1	7.1	0	0
2008	0	0	4	12.5	18	56.3	9	28.1	0	0	0	0

Table 13. Cohort abundance for Dolly Varden from the Rat River born in 1998, 1999 and 2000 in fishery samples from 102 mm gillnets, 2001-2008 (3 fishing locations combined: mouth of the Rat River, Destruction City and Big Eddy).

	1998 cohort			1999 cohort			2000 cohort		
year	abundance	age	% total catch	abundance	age	% total catch	abundance	age	% total catch
2001	1	3	0.5						
2002	21	4	7.7	3	3	1.1			
2003	92	5	46	32	4	16	1	3	0.5
2004	57	6	36.8	59	5	38.1	11	4	7.1
2005	2	7	4.9	10	6	24.4	14	5	34.1
2006	1	8	1.2	4	7	4.7	8	6	9.3
2007	0		0	0	8	0	6	7	6.2
2008	0		0	2	9	2.9	1	8	1.4

Table 14. Synthesis of available length-at-age information for male Dolly Varden from the Rat River, 1981-2008. Mean fork length-at-age is presented by year for males (all maturity stage) collected using variable gear types at various locations in the Rat River and adjacent channels of the Mackenzie River Delta. Larger mean fork lengths by age groups over the time series are indicated in bold.

Year	AGE=3		AGE=4		AGE=5		AGE=6		AGE=7		AGE=8		AGE=9		AGE=10		AGE=11	
	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean
1981					2	340	5	480	1	427								
1982							2	478	1	**590**								
1983			2	404	4	407	2	379	1	480			1	555	1	582		
1986	8	304	13	333	16	397	4	440	5	451	1	470						
1988					3	408	3	410	3	479			1	519				
1989	6	338	11	351	27	362	23	397	12	464	4	445	1	498	1	572	1	601
1990	2	343	18	349	24	386	7	445	3	504								
1991	5	332	3	360	7	429	2	439	1	563								
1992			3	379	14	423	13	449	8	476								
1993			4	337	40	351	11	376	2	388								
1994			2	456	11	419	24	439	7	488								
1995			9	318	52	388	69	440	47	467	8	519	2	468				
1996	1	285	52	390	93	413	45	447	12	514	3	596						
1997	1	320	11	363	68	391	96	431	23	496	2	576						
1998			5	420	91	407	78	453	44	513	7	546	1	605				
1999			5	470	37	484	63	507	31	547	9	551	3	506				
2000	1	**457**	8	440	60	467	42	518	28	542	10	576	2	**616**	1	**622**		
2001	1	437	15	444	46	486	68	504	30	538	3	566	1	477				
2002	2	339	12	383	32	456	30	475	25	522	5	524						
2003	1	324	17	397	51	424	21	487	8	520	4	598						
2004			8	422	35	413	27	423	14	507	4	611	1	543				
2005	2	361	14	441	34	448	26	505	8	547	2	**628**					1	**636**
2006	3	412	17	438	17	446	5	479	2	506	1	573						
2007	3	401	18	400	15	447	10	**525**	3	523								
2008			6	**497**	34	**496**	4	479	2	481								

Table 15. Synthesis of available length-at-age information for female Dolly Varden from the Rat River, 1981-2008. Mean fork length-at-age is presented by year for females (all maturity stage) collected using variable gear types at various locations in the Rat River and adjacent channels of the Mackenzie River Delta. Larger mean fork lengths by age groups over the time series are indicated in bold.

YEAR	AGE=3		AGE=4		AGE=5		AGE=6		AGE=7		AGE=8		AGE=9		AGE=10		AGE=11	
	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean
1981					2	449	5	446	6	479					1	532		
1982							3	431	1	465	1	501						
1983	2	295	7	318	11	408	23	457	8	499	7	497	3	533	1	**619**		
1986	7	305	10	332	14	373	16	418	17	505	7	523	2	**578**	1	500		
1988						416	16	428	6	447	8	463	1	489	1	558		
1989	2	339	19	361	48	375	99	419	62	456	33	482	16	493	3	521	1	505
1990	5	341	33	350	31	407	11	429	6	454	3	511						
1991	3	407	6	403	6	435	6	421	3	489								
1992			3	407	33	421	58	452	28	467	9	509	7	500			2	534
1993			1	294	65	352	30	385	4	392	1	487						
1994			4	408	19	403	63	427	13	451	1	543						
1995			6	402	58	389	169	434	87	467	20	502	2	526	1	500		
1996	9	374	43	402	136	416	103	463	95	490	20	517	8	548	2	592	1	564
1997	4	394	14	332	97	388	200	419	35	447	4	489	1	528			1	542
1998	2	381	14	400	102	414	148	441	58	482	7	497						
1999	2	**420**	6	429	38	474	92	491	66	516	23	**556**	1	545				
2000			19	449	65	474	75	494	66	521	17	524	4	507	4	541		
2001	2	305	17	456	82	**481**	111	476	57	519	6	508	2	532				
2002	1	282	11	**475**	62	475	90	491	51	510	6	506						
2003			4	401	87	442	56	488	52	525	7	529						
2004	1	388	5	427	36	388	49	437	16	519	1	477	2	532				
2005	8	400	25	430	44	452	31	481	19	525	8	543	3	551	2	554	1	**611**
2006	2	382	16	401	21	432	8	**521**	4	**539**	1	508	1	557				
2007	3	393	14	406	24	434	12	498	4	469								
2008			11	459	30	452	15	448	4	409	1	477	1	496				

Table 16. Mean fork length (FL) at age observed (Obs) and predicted (Pred)(from von Bertalanffy growth curves) for (A) male and (B) female Dolly Varden from all maturity stage among year pairs, 2001-2008 (samples caught in 102 mm mesh gillnets at three fishing locations: mouth of the Rat River, Destruction City and Big Eddy).

(A)

Age	2001-2002			2003-2004			2005-2006			2007-2008		
	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)
3	2	339	337	1	324	334	3	412	409	3	401	387
4	18	395	401	20	403	375	17	429	430	19	403	423
5	45	460	449	57	404	415	18	442	446	28	453	456
6	51	477	485	32	433	453	10	464	460	11	501	488
7	23	515	512	15	503	490	1	471	471	4	516	518

(B)

Age	2001-2002			2003-2004			2005-2006			2007-2008		
	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)	n	FL (Obs)	FL (Pred)
3	2	310	314	1	388	378	3	403	390	3	393	396
4	17	465	443	23	398	407	18	412	425	22	421	419
5	105	469	487	93	413	432	32	440	456	22	438	438
6	126	480	503	65	454	455	8	472	484	15	474	453
7	60	500	508	38	515	475	5	543	508	8	439	467
8	6	514	510	4	476	493	5	545	530	1	477	478
9	1	539	510	1	504	509	2	527	549	1	496	487

Table 17. Estimated parameters of the von Bertalanffy growth equation fitted to length-at-age data of male and female Dolly Varden (all maturity stage) among year pairs, 2001-2008. (Samples caught in 102 mm mesh gillnets at three fishing locations (mouth of the Rat River, Destruction City and Big Eddy)).

year pair	sex	**Linf**	**K**	**t_0**	**age range**
2001-2002	male	596	0.283	0.048	3-7
	female	511	1.067	2.105	3-9
2003-2004	male	1484	0.036	-4.031	3-7
	female	635	0.118	-4.645	3-9
2005-2006	male	516	0.215	-4.327	3-7
	female	701	0.120	-3.782	3-9
2007-2008	male	1059	0.054	-5.440	3-7
	female	536	0.175	-4.675	3-9

(Linf= asymptotic maximum length, K= growth coefficient, t_0=theoretical length at age zero)

Table 18. Age-at-maturity information for male and female Dolly Varden from the Rat River collected using variable gear types at Fish Hole in 1981-82, 1986 and 1988, and using variable mesh size gillnets at different locations (DC= Destruction City, MR= mouth of the Rat River, and BE= Big Eddy) in the Rat River fishery, 1989-2008. Age at first maturity is the first age group with mature, current-year spawners.

		Male			Female		
Location	**Year**	**n=**	**range of sample**	**age-at-first-maturity**	**n=**	**range of sample**	**age-at-first-maturity**
Fish Hole	1981	10	5-7	5	19	5-10	5
Fish Hole	1982	4	6-7	6	6	6-8	6
Fish Hole	1986	11	4-8	7	41	5-10	7
Fish Hole	1988	19	0-9	5	43	0-10	5
DC	1989	87	2-11	5	283	3-11	4
DC	1990	55	2-7	4	89	3-8	3
DC	1991	18	3-7		24	3-7	6
DC	1992	38	4-7	4	140	4-11	4
DC	1993	57	4-7		101	4-8	5
DC	1994	44	4-7	6	101	4-12	
DC, MR, BE	1995	187	4-9	5	343	4-10	5
DC, MR, BE	1996	206	3-8	4	417	3-11	3
DC, MR, BE	1997	201	3-8	4	356	3-11	5
DC, MR, BE	1998	225	4-9	4	330	3-8	5
DC, MR, BE	1999	149	4-9	4	228	3-9	5
DC, MR, BE	2000	152	3-10	4	250	4-10	4
DC, MR, BE	2001	164	3-9	3	277	3-9	4
DC, MR, BE	2002	106	3-8	5	221	3-8	4
DC, MR, BE	2003	102	3-8	5	224	4-8	4
DC, MR, BE	2004	89	4-9	5	110	3-9	4
DC, MR, BE	2005	88	3-11	4	140	3-11	3
DC, MR, BE	2006	46	2-8	4	54	3-9	5
DC, MR, BE	2007	49	3-7	4	57	3-7	5
DC, MR, BE	2008	46	4-7	5	63	4-9	6

n= total sample size (number of Dolly Varden with both age and maturity data).
Blank values indicate that none of the sampled Dolly Varden were preparing to spawn in the current year.

Table 19. Percentage of Dolly Varden identified as non-spawners, female spawners and male spawners in samples from Fish Hole, 1981-2008.

Year	n	% Non-spawners	% Female spawners	% Male spawners	% total spawners
1981	29	0.0	65.5	34.5	100.0
1982	10	10.0	50.0	40.0	90.0
1995*	444	33.8	59.7	6.5	66.2
1997*	481	44.5	45.9	9.6	55.5
2001	414	61.4	35.5	3.1	38.6
2004*	276	36.2	62.3	1.4	63.8
2007*	432	75.5	22.5	2.1	24.5
2008*	522	94.1	5.6	0.4	5.9

n=total sample size
% total spawners= %female + %male spawners
*indicates a significant contribution to explain a significant difference in the proportion of spawners (males and females combined) among years (assessed for the 1995-2008 seine surveys only).

Table 20. Percentage of female and male Dolly Varden non-spawners and current-year spawners harvested from three combined monitoring locations (mouth of the Rat River, Destruction City and Big Eddy) in the Rat River fishery, 1995-2008.

Year	n	%Female non-spawners	% Female spawners	% Male non-spawners	% Male spawners	% total non-spawners	% total spawners
1995*	552	59.4	7.6	30.8	2.2	90.2	9.8
1996	524	46.2	20.4	27.9	5.5	74.0	26.0
1997*	393	59.0	5.9	34.4	0.8	93.4	6.6
1998[a]	448	51.3	7.8	33.3	7.6	84.6	15.4
1999*	335	23.6	35.8	23.6	17.0	47.2	52.8
2000	376	41.2	18.4	33.2	7.2	74.5	25.5
2001*	399	29.8	34.6	25.8	9.8	55.6	44.4
2002	356	51.1	17.1	28.9	2.8	80.1	19.9
2003	295	50.8	18.6	27.1	3.4	78.0	22.0
2004*	225	49.8	5.8	43.1	1.3	92.9	7.1
2005	253	41.1	20.9	35.6	2.4	76.7	23.3
2006	114	47.4	8.8	39.5	4.4	86.8	13.2
2007	114	42.1	12.3	42.1	3.5	84.2	15.8
2008[b]	116	55.2	2.6	39.7	2.6	94.8	5.2

n=total sample size
% total spawners= %female + %male spawners
% total non-spawners= %female + %male non-spawners
* indicates a significant contribution to explain a statistically significant difference in % spawners among years for both males and females.
a, b: indicates a significant contribution to explain a statistically significant difference in % spawners for both females (a) and males (b) among years.

Table 21. Percentage of (A) male and (B) female Dolly Varden from different age classes harvested in spawning condition at three monitoring locations (Big Eddy, Destruction City and mouth of the Rat River) in the Rat River fishery, 1995-2008. Results are presented and were statistically compared among year groups (1995-98, 2000-04 and 2005-08) in order to increase sample sizes. 95% CI= 95% confidence intervals.

A.

	1995-99			2000-04			2005-08		
Age	n	n sp	% sp	n	n sp	% sp	n	n sp	% sp
4	60	4	7	51	4	8	56	6	11
5*	237	35	15	183	29	16	100	5	5
6	239	40	17	155	20	13	45	2	4
7	103	22	21	89	21	24	15	3	20
8	20	8	40	19	4	21	3	1	33

B.

	1995-99			2000-04			2005-08		
Age	n	n sp	% sp	n	n sp	% sp	n	n sp	% sp
4*	55	1	2	63	11	17	67	5	7
5*	294	40	14	297	80	27	119	12	10
6*	452	90	20	310	88	28	66	18	27
7	247	115	47	189	80	42	31	19	61
8	50	35	70	28	14	50	10	7	70
9	8	1	13	6	2	33	5	3	60

n=total sample size
n sp= number of spawners in the sample
* indicates a significant contribution to explain a statistically significant difference in % sp among years.

Table 22. Sex ratio (male:female) of Dolly Varden captured by seine at the Fish Hole and by gill net at various locations during the harvest monitoring program. Ratios are calculated using both the total sample and spawners only.

Location	Year	Total sample of males	Total sample of females	Total number of male spawners	Total number of female spawners	M:F ratio (total sample)	M:F sex (spawners only)
Fish Hole	1981			10	19		0.53
Fish Hole	1982	4	6	4	5	0.67	0.80
Fish Hole	1986	11	41	4	14	0.27*	0.29*
Fish Hole	1995			29	265		0.11*
Fish Hole	1997			46	221		0.21*
Fish Hole	2001			15	154		0.10*
Fish Hole	2004			4	172		0.02*
Fish Hole	2007			9	97		0.09*
Fish Hole	2008			2	29		0.07*
DC	1986	51	59	4	1	0.86	4.00
DC	1988	19	43	9	37	0.44*	0.24*
DC	1989	120	386	33	213	0.31*	0.15*
DC	1990	64	95	3	41	0.67*	0.07*
DC	1991	22	32	0	5	0.69	0
DC	1992	46	173	38	155	0.27*	0.25*
DC	1993	74	115	0	3	0.64*	0
DC	1994	51	118	1	0	0.43*	-
DC, MR, BE	1995	182	370	12	42	0.49*	0.29*
DC, MR, BE	1996	175	349	29	136	0.50*	0.21*
DC, MR, BE	1997	138	255	3	23	0.54*	0.13*
DC, MR, BE	1998	183	265	34	35	0.69*	0.97
DC, MR, BE	1999	136	199	57	120	0.68*	0.47*
DC, MR, BE	2000	152	224	27	69	0.68*	0.39*
DC, MR, BE	2001	142	257	39	138	0.55*	0.28*
DC, MR, BE	2002	113	243	10	61	0.47*	0.16*
DC, MR, BE	2003	90	205	10	55	0.44*	0.18*
DC, MR, BE	2004	100	125	3	13	0.80	0.23*
DC, MR, BE	2005	96	157	6	53	0.61*	0.11*
DC, MR, BE	2006	50	64	5	10	0.78	0.50
DC, MR, BE	2007	52	62	4	14	0.84	0.29*
DC, MR, BE	2008	49	67	3	3	0.73	1.00

total sample= 'silvers' and spawners combined

DC= Dectruction City, MR= mouth of Rat River and BE= Big Eddy

Blank entries in the total sample columns for Fish Hole indicates these values are the same as 'spawners'

* denotes significantly different from a 1:1 ratio

Table 23. Chapman and Robson estimates of survival (S) (± 95% CI) and annual mortality (A) for females, males and the total sample of Dolly Varden harvested using gillnets of variable mesh sizes during all years of monitoring of the subsistence fishery (1989-2008).

Year	Female				Male				Total sample			
	Age range	Age of full recruitment	S	A	Age range	Age of full recruitment	S	A	Age range	Age of full recruitment	S	A
1989	3-11	7	0.63 (0.054)	0.37	3-12	7	0.64 (0.088)	0.36	2-11	7	0.63 (0.05)	0.37
1990	3-8	5	0.62 (0.083)	0.38	3-8	7	0.59 (0.21)	0.41	2-8	6	0.69 (0.142)	0.31
1991					4-8	7	0.67 (0.413)	0.33	3-7	6	0.68 (0.215)	0.32
1992	4-11	7	0.63 (0.087)	0.38	5-8	7	0.59 (0.139)	0.41	4-11	7	0.60 (0.091)	0.4
1993	4-8	6	0.67 (0.207)	0.33					4-8	6	0.54 (0.094)	0.46
1994	4-12	7	0.56 (0.175)	0.44					4-12	6	0.68 (0.103)	0.32
1995	4-10	7	0.53 (0.071)	0.47	5-10	8	0.55 (0.088)	0.45	4-10	7	0.55 (0.051)	0.45
1996	3-11	6	0.68 (0.047)	0.32	4-10	7	0.57 (0.083)	0.43	3-11	7	0.67 (0.076)	0.33
1997	3-11	6	0.69 (0.078)	0.31	4-9	8	0.53 (0.138)	0.47	3-11	7	0.54 (0.082)	0.46
1998	3-8	7	0.53 (0.084)	0.47	4-9	6	0.60 (0.054)	0.4	3-9	7	0.62 (0.114)	0.38
1999	3-9	7	0.56 (0.068)	0.44	5-10	8	0.58 (0.096)	0.42	3-9	7	0.57 (0.056)	0.43
2000	4-10	7	0.59 (0.066)	0.41	4-11	8	0.56 (0.116)	0.44	3-10	7	0.59 (0.054)	0.41
2001	3-9	7	0.54 (0.083)	0.46	4-10	8	0.67 (0.224)	0.33	3-9	7	0.54 (0.065)	0.46
2002	3-8	6	0.66 (0.067)	0.34	4-9	7	0.68 (0.092)	0.32	3-8	6	0.67 (0.054)	0.33
2003	4-8	6	0.61 (0.056)	0.39	4-9	7	0.60 (0.107)	0.4	3-8	6	0.57 (0.066)	0.43
2004	3-9	7	0.57 (0.151)	0.43	5-10	7	0.61 (0.089)	0.39	3-9	7	0.69 (0.163)	0.31
2005	3-11	6	0.66 (0.069)	0.34	4-12	7	0.59 (0.103)	0.41	3-11	7	0.62 (0.1)	0.38
2006	3-9	6	0.64 (0.159)	0.36	3-9	7	0.63 (0.223)	0.37	2-9	6	0.63 (0.128)	0.38
2007	3-7	6	0.57 (0.166)	0.43	4-8	6	0.59 (0.147)	0.41	3-7	6	0.56 (0.123)	0.44
2008	4-9	6	0.60 (0.137)	0.4	5-8	7	0.62 (0.275)	0.38	4-9	6	0.73 (0.14)	0.28