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Information to support the assessment of Arctic Char (*Salvelinus alpinus*) in the Sylvia Grinnell River, Nunavut, 2009–2011

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

From 2009 through 2011, a research program was undertaken on Arctic Char (*Salvelinus alpinus*) in the Sylvia Grinnell River, Frobisher Bay, Nunavut. The primary objectives were to estimate abundance of the Sylvia Grinnell stock and recommend a sustainable harvest level, but additional information was collected to evaluate stock status (biological characteristics and catch-per-unit effort (CPUE), and proportion the relative removal of Arctic Char caught in the Sylvia Grinnell among various fishing methods (i.e., snagging, angling, gillnets). To better understand the stock structure of Arctic Char in Frobisher Bay, fish movement and genetic stock discrimination analyses were performed on Arctic Char from Sylvia Grinnell River and the nearby Bay of Two Rivers.

A mark-recapture experiment was conducted to determine stock abundance but a reliable estimate could not be calculated due to insufficient data and violation of the Jolly-Seber mark-recapture model assumptions. As such, sustainable harvest was not calculated. However, age frequency data show good recruitment of juveniles, suggesting the stock has the potential to sustain itself under current harvest levels

Biological and CPUE data were collected from Arctic Char caught in small-mesh gillnets. Fork length of individual fish ranged from 159 mm to 621 mm, with a mean of 350 mm. Age of fish ranged from five to 26 years, with a mean of eight years. The ratio of females to males was 1.37 (58% females) and total instantaneous mortality was 0.44. Daily CPUE varied greatly and was not significantly different annually, but was significantly higher in August compared to July. Comparisons to historic biological and CPUE values for Arctic Char in Sylvia Grinnell were avoided due to differences in gear type used.

Information on the proportion of Arctic Char caught with differing gear types was gathered through voluntary interviews with local fishers and information collected from tag-return forms (completed when a marked fish was recaptured by a local fisher). Reported results suggest that gillnetting was the main method of fish capture and incidents of snagging had declined relative to historic levels. However, the data were limited and contradictory evidence was noted.

Analyses of movement of Arctic Char marked in Sylvia Grinnell River and the Bay of Two Rivers showed limited mixing of stocks in Frobisher Bay, and genetic analyses showed that the two stocks are discreet.

Information à l'appui de l'évaluation de l'omble chevalier (*Salvelinus alpinus*) dans la rivière Sylvia Grinnell, au Nunavut, de 2009 à 2011

RÉSUMÉ

De 2009 à 2011, un programme de recherche a été mené sur l'omble chevalier (*Salvelinus alpinus*) dans la rivière Sylvia Grinnell, dans la baie Frobisher, au Nunavut. Les principaux objectifs étaient d'estimer l'abondance du stock de la rivière Sylvia Grinnell et de recommander un niveau de prises durable, mais d'autres renseignements ont été recueillis pour évaluer l'état du stock (caractéristiques biologiques et capture par unité d'effort [CPUE]) et déterminer la proportion des prélèvements relatifs d'ombles chevaliers pêchés dans la rivière Sylvia Grinnell selon diverses méthodes de pêche (c.-à-d. accrochage, pêche à la ligne, filets maillants). Afin de mieux comprendre la structure du stock d'ombles chevaliers dans la baie Frobisher, on a réalisé des analyses discriminantes du stock génétique et du déplacement de l'omble chevalier de la rivière Sylvia Grinnell et de la Bay of Two Rivers.

Une expérience de marquage-recapture a été réalisée pour déterminer l'abondance du stock, mais il a été impossible d'obtenir une estimation fiable en raison du manque de données et de la violation des hypothèses du modèle de marquage-recapture de Jolly-Seber. En conséquence, on n'a pas pu calculer de niveau de prélèvement durable. Cependant, les données sur la fréquence selon l'âge indiquent un bon recrutement des juvéniles, ce qui donne à penser que le stock est susceptible de se maintenir selon les niveaux de prises actuels.

Des données biologiques et sur la CPUE ont été collectées sur les ombles chevaliers pris dans des filets maillants à maillage serré. La longueur à la fourche des individus variait de 159 à 621 mm, avec une moyenne de 350 mm. L'âge des poissons allait de 5 à 26 ans, avec une moyenne de 8 ans. La proportion de femelles par rapport aux mâles était de 1,37 (58 % de femelles), et la mortalité instantanée totale s'élevait à 0,44. La CPUE variait grandement chaque jour, mais pas vraiment d'une année à l'autre; toutefois, elle était beaucoup plus élevée en août qu'en juillet. On a évité de faire des comparaisons entre les valeurs biologiques antérieures et les valeurs de la CPUE quant à l'omble chevalier de la rivière Sylvia Grinnell en raison des différents types d'engins utilisés.

Des renseignements sur la proportion d'ombles chevaliers pêchés au moyen de différents types d'engins ont été recueillis par le biais d'entrevues volontaires avec des pêcheurs locaux ainsi que par l'analyse des formulaires renvoyés sur les poissons marqués (lorsqu'un pêcheur local pêche un poisson marqué, il doit remplir un tel formulaire). Les résultats rapportés laissent entendre que la pêche au filet maillant constitue la principale méthode de capture des poissons, et que les incidents liés à l'accrochage ont décliné par rapport aux niveaux historiques. Cependant, les données étaient limitées, et on a observé des éléments probants contradictoires.

Les analyses du déplacement des ombles chevaliers marqués dans la rivière Sylvia Grinnell et la Bay of Two Rivers révèlent un mélange limité des stocks dans la baie Frobisher, et les analyses génétiques montrent que les deux stocks demeurent distincts.

INTRODUCTION

The Sylvia Grinnell River is located in Frobisher Bay, Nunavut, Canada, near the city of Iqaluit (Figure 1). The anadromous Arctic Char, *Salvelinus alpinus*, (hereafter referred to as char) in the Sylvia Grinnell River is an important species for the people of Iqaluit. Historically, two attempts have been made to develop a commercial fishery for char in the Sylvia Grinnell River; from 1947 to 1951, and again from 1959 to 1966 (Hunter 1976). In both cases, the commercial fisheries reportedly ceased due to decreasing catch-per-unit-effort (CPUE) and reduction in fish size (Hunter 1976). No further attempts have been made to develop a commercial fishery. The subsistence fishery and a small recreational fishery have persisted.

Several studies have evaluated the status of the Sylvia Grinnell char stock and have concluded that the stock has not recovered to its pre-commercial state (Kristofferson and Sopuck 1983; Bodaly et al. 1992; Cosens et al. 1993). Gallagher and Dick (2010) studied the stock in 2002 and 2004 and concluded that while the stock remained relatively depleted, it showed signs of the early stages of recovery; that is, increased length at age, increased mean weight, older and longer fish and an overall decrease in total mortality rate, as compared to 1977.

Since 2006, concern has been expressed about the fishing method ‘snagging’ and whether it has impacted the sustainability of the current harvest. Snagging uses a rod and reel or a hand-held line with a large, weighted, treble hook or fishing lure attached. The hook is cast into the water and, while quickly being retrieved, impales char pulling them to shore. If the char is landed successfully, it is either retained by the fisher, discarded along the shoreline, or released back into the water. Survival is unknown for char that are released or snagged but not landed.

Snagging takes place at the bottom of the water falls at the mouth of the Sylvia Grinnell River (Figure 1). Char congregate there in August waiting for high tides to help them ascend the river to spawning and overwintering areas. While snagging is not a new harvest method, its impact on the stock was questioned. Concern for the char stock led the Amaruq Hunters and Trappers Association (AHTA) to implement a voluntary ban on snagging and gillnetting in the river (including the falls area), and gillnetting in Sylvia Grinnell Lake from 2002–2006. However, Gallagher and Dick (2010) reported numerous char harvested in 2002 and 2004 in the river. In 2007 and 2008, Fisheries and Oceans Canada (DFO) Fisheries Management staff estimated approximately 2,993 fish each year were discarded along the shoreline near the falls (DFO 2008). In 2008, DFO evaluated these data and concluded there was insufficient information to determine if snagging posed a conservation concern for the stock (DFO 2008). In 2009, DFO Fisheries Management in Iqaluit initiated a public awareness campaign to try and reduce the incidence of snagging and discarding of char, which included the increased presence of Fisheries Officers at the falls area during peak fishing periods.

Further complicating the management of char in the Sylvia Grinnell River is a limited understanding of the stock structure of char in Frobisher Bay. Management of char is based on discreet stocks and while there is some information that suggests this to be true for the Sylvia Grinnell char (Hunter 1976, local knowledge), additional work on fish movements and genetic stock discrimination was required.

The objectives of the research discussed here were to: 1) estimate abundance of char in the Sylvia Grinnell River, 2) evaluate stock status by examining biological characteristics and CPUE, 3) recommend a sustainable harvest level, and 4) proportion the relative removal of char into various fishing methods (i.e. snagging, angling, gillnets). However, to better understand the stock structure, additional work was undertaken on char movements and genetic stock discrimination (J.S. Moore, unpubl. data) for fish caught in the Sylvia Grinnell and nearby Bay of Two Rivers.

METHODS

ESTIMATE OF STOCK ABUNDANCE

Model Selection and Assumptions

The Jolly-Seber model was selected to estimate stock abundance because it was developed for open populations in which there is possible death, recruitment, immigration and permanent emigration (Seber 1982). This model fits with the circumstances of an anadromous stock that seasonally enters the sea for a period each year. This model also incorporates the use of multiple mark and recapture periods. The assumptions for this model include the following (Seber 1982):

a) Every animal in the population, whether marked or unmarked, has the same probability of being caught in the i^{th} sample, given that it is alive and in the population when the sample is taken.

b) Every marked animal has the same probability of surviving from the i^{th} to the $(i+1)^{th}$ sample and of being in the population at the time of the i + 1 sample, given that it is alive and in the population immediately after the i^{th} release.

c) Every animal caught in the i^{th} sample has the same probability of being returned to the population: in many experiments this probability can be regarded as the probability of accidental death through handling, etc.

d) Marked animals do not lose their marks and all marks are reported on recovery.

e) All samples are instantaneous, i.e., sampling time is negligible, and each release is made immediately after the sample.

Fish Capture, Marking and Recapture

Anadromous char were captured in the summers of 2009, 2010, and 2011 in three areas of the Sylvia Grinnell River system (Table 1, Figure 2). Fish were caught predominantly with individual small-mesh gillnets (51 mm to 64 mm stretched mesh) to minimize stress and injury so char could be marked and released in optimal condition. Single 13 mm and 102 mm mesh gillnets were used on one occasion each in the Sylvia Grinnell, but resulted in only one fish marked from each net. All gillnets were 50 m long, 2 m deep, and monitored continuously. Gillnets were set at optimal fishing times during the day, as determined by the tide schedule; that is, char were most actively moving during high tides so gillnets were set as the tide was coming in and removed as the tide was receding. In 2009, a small amount of angling was used to supplement gillnet catches during slow catch periods (Table 1).

In 2009 and 2010, char caught were held in plastic tubs and assessed for suitability for marking. Fork length (± 1 mm) and round weight (± 10 g) were recorded for most char. All healthy char approximately 300 mm or longer were marked with blue or white, uniquely numbered, external T-bar tags (Hallprint, Australia). Tags were inserted using a Dennison tagging gun just below the dorsal fin on the left side and anchored in the basal pterygiophores. After being marked, fish were released into a second tub and monitored until strong enough to be released into the river (generally less than 10 minutes).

In 2010 and 2011, any previously marked fish caught were noted and released. Char captured in 2011 were not marked because this was the recapture-only phase of the experiment.

To collect recaptures from the subsistence and recreational fisheries, a reward ($10) was offered to anyone who caught and returned a marked char from 2009 through 2012. Fishers were asked to complete a tag-return form (Appendix 1) which included questions on date and

location of char capture, fishing method used, and the number of other (un-marked) char they caught during the same fishing event.

Statistical Analyses

Data used in the initial abundance estimate was restricted to char caught, marked, and recaptured in the Sylvia Grinnell River system using only the small-mesh DFO gillnets. An additional abundance estimate was also investigated using char marked in the Sylvia Grinnell River system, but recapture data pooled from DFO nets and tag-return forms.

STOCK STATUS

Biological Characteristics

Char Caught in DFO Nets

Fork length (mm) was recorded for fish over approximately 300 mm caught in DFO nets in the Sylvia Grinnell River system; smaller fish were not suitable for mark-and-release so were released without recording length or weight. Char caught in Sylvia Grinnell were also weighed (round weight, g) and a subsample of fish were lethally processed for additional biological characteristics such as otoliths (to determine age of fish), gender, and fin tissue (for genetic analyses). All char that were subsampled were cleaned and donated to the AHTA for distribution to local elders. Age determination of fish was performed by DFO's Arctic Aquatic Research Division Fish Ageing Lab, following procedures described by Chilton and Beamish (1982). Specifically, a whole otolith method was used for fish aged less than 10 years and a section method was used for fish older than 10 years. Fish gender was determined by visual inspection of the gonads. Age data from 2009 to 2011 were pooled and total instantaneous mortality was calculated (Ricker 1975).

Discarded Char

Char discarded on the shoreline of Sylvia Grinnell River below the falls were sampled on September 2, 2010, August 23, 2011, and September 1, 2011. Fish were measured (fork length, mm) and sampled for ageing structures (otoliths). Data from both years were pooled for analyses.

Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) was calculated for DFO gillnets set in the Sylvia Grinnell River as the number of char caught divided by the number of hours fished for each gillnet set (char/h/net).

SUSTAINABLE HARVEST LEVEL

An exploitation rate of 5% for char stocks is considered sustainable and likely a low-risk exploitation rate (DFO 2005, 2009). Therefore, sustainable harvest level could be calculated as 5% of the stock abundance estimate.

RELATIVE HARVEST BY FISHING METHOD

Fisher Interviews

Information on recreational and subsistence fishing methods (gillnetting, angling, and snagging) were collected through voluntary interviews with fishers on seven occasions from July through August, 2011. Interviews were timed to occur generally when and where fishers were congregated (i.e., near or below the falls, or around low tides when char are more concentrated). One interview was conducted on a weekend when the number of fishers is

generally higher (weather dependent). Fishers were asked a range of questions about their fishing activity that day, as well as over the summer. Questions included: purpose of fishing (recreational vs. subsistence), method of fishing, number of char caught, and time spent fishing (Appendix 2).

Tag-Return Forms

Information on fishing method (gillnetting, angling, snagging, and jigging (ice-fishing with a rod and reel) was acquired from recreational and subsistence fishers in completed tag-return forms (Appendix 1). The form included a range of questions including the method of fishing and their total harvest at the time the marked fish was caught.

Susceptibility of Char to Different Gear Types

On August 19, 2011 char were caught by fishers using both angling and snagging methods, allowing for a comparison of CPUE (char/h) between these two gear types.

STOCK STRUCTURE

Fish Movement

In addition to char marked in the Sylvia Grinnell River, anadromous char were also marked in the Bay of Two Rivers (Figure 2) from July 13 to July 15, 2010. These char were caught with individual 51 mm and 102 mm mesh gillnets and angling was again used in slow catch periods. Char larger than 300 mm were marked with external T-bar tags in the same manner as that described for fish in the Sylvia Grinnell River. Char movement was then investigated by comparing the locations where individual char were marked and later recaptured.

Genetic Stock Discrimination

Pectoral fin tissue samples were collected from char in the Sylvia Grinnell River and the Bay of Two Rivers. Total DNA was isolated from the samples and 11 microsatellite loci were combined in three different PCR multiplexes. Multiple complimentary analyses (GENETIX, FSTAT, ARLEQUIN (Excoffier et al. 2005), and STRUCTURE (Pritchard et al. 2000)) were used to test for the presence of stock structure at two hierarchical levels: (1) among sampling sites within the Sylvia Grinnell River system, and (2) between the Bay of Two Rivers and the Sylvia Grinnell River. The program GENECLASS2 (Piry et al. 2004) was used to conduct genetic assignment tests and identify putative dispersers in the dataset (J.S. Moore, unpubl. data).

RESULTS

ESTIMATE OF STOCK ABUNDANCE

Fish Capture, Marking and Recapture

A total of 895 char were marked in the Sylvia Grinnell River system in 2009 (n=400) and 2010 (n=495). One marked char was recaptured in the DFO small-mesh gillnets in each of 2010 and 2011 at site # 1 (metal dump). An additional 81 marked char were caught from 2009 through 2012 by local fishers.

Statistical Analyses

With only one marked fish recaptured each year in the DFO nets, there was insufficient data to reliably estimate stock abundance.

An estimate of stock abundance incorporating information collected from fisher tag-return forms was investigated, but was determined to be inappropriate because certain model assumptions could not be met.

STOCK STATUS

Biological Characteristics

Char Caught in DFO Nets

Fork length (mm) was recorded for 1,416 char caught in the Sylvia Grinnell River (2009–2011). Mean fork length was found to be significantly different between years (ANOVA, df=2, α=0.05, p<0.00). Char collected in 2011 were significantly smaller (Tukey HSD, α=0.166, p<0.00) than those collected in 2009 and 2010, which were not significantly different from one another (Tukey HSD, α=0.166, p=0.725, Table 2). However, the length frequency distributions appear similar in that the most abundant length class was the 300 to 350 mm range with few fish 450 mm or longer (Figure 3). The total length distribution ranged from 159 mm to 621 mm.

The age of char caught in the Sylvia Grinnell River ranged from five to 26 years, with a modal age of eight to nine years (Figure 4). No significant difference in mean age (eight years) was found between years (n=282, ANOVA, df=2, α=0.05, p=0.522).

Gender was determined for 245 char and the ratio of females to males was 1.37 (58% females).

Total instantaneous mortality was 0.44 (n=282).

Discarded Char

A total of 115 discarded char were collected from the shore of Sylvia Grinnell River near the falls. The fork length of discarded char ranged from 145 mm to 590 mm (Figure 5), with a mean ± 1 standard deviation fork length of 366 mm ± 77 mm (n=114). The age of discarded char ranged from four to 16 years (Figure 6), with a mean ± 1 standard deviation age of 8.5 ± 2 years (n=99).

Catch-Per-Unit-Effort

CPUE (char/h/net) was calculated for 33 net-sets (Table 3). Mean CPUE was lowest in 2011, but the difference was not statistically significant (ANOVA, df=2, α=0.05, p=0.136). When all data were pooled by month, mean CPUE for July was significantly lower than that for August (mean=8.64 and 15.05 char/h/net, respectively, T-test, df=31, α=0.05, p=0.03).

SUSTAINABLE HARVEST LEVEL

Sustainable harvest level could not be calculated as intended without a stock abundance estimate.

RELATIVE HARVEST BY FISHING METHOD

Fisher Interviews

A total of 46 fishers were interviewed and an additional 41 fishers who were asked chose not to participate (Table 4). Of the participating fishers, 26 (57%) were fishing for recreation while 20 (43%) were fishing for subsistence (Table 4). All recreational fishers attempted to catch char via angling, while subsistence fishers used both angling and snagging methods. Of the 12 fish caught on the days of the interviews, a single char was caught by a recreational fisher and the rest caught by subsistence fishers; five by angling and six by snagging (Table 4). When

subsistence and recreational harvests were combined, an equal number of char were harvested by angling and snagging in 2011.

Fishers were also asked about their general fishing activity for that summer, prior to the day of the interview. However, details of fishing method and purpose were not documented, so here we assumed that they were the same as that reported for their fishing activities on the day of the interview. The fishers interviewed reported a total of 222 fish caught in the summer of 2011. Subsistence fishers dominated the catch (68%, Table 5) even though there were fewer of them (Table 4). A total of 23% of fish were reported to having been caught throughout the summer by snagging (Table 5).

Tag-Return Forms

A total of 940 char were reported in tag-return forms; 81 were marked individuals and an additional 859 un-marked char were caught at the same time as a marked char (Table 6). The majority of char were caught by gillnetting, followed by angling. In 2012, almost all reported fish were caught by gillnetting (n=263, 90%), with few from angling or jigging, and none reported from snagging (Table 6).

Susceptibility of Char to Different Gear Types

On August 19, 2011 nine fishers chose to participate in the survey, eight were angling and one was snagging. Two of the nine fishers were fishing for subsistence purposes and only these two fishers caught char (four by angling, six by snagging). A total of 19.5 hours was spent angling by all fishers combined, while the one fisher who reported snagging did so for 1.75 hours. Mean CPUE for char caught by angling and snagging were 0.20 (char/h) and 3.43 (char/h), respectively.

STOCK STRUCTURE

Fish Movement

The majority of char marked in the Sylvia Grinnell were recaptured within the Sylvia Grinnell system or east towards the Iqaluit area within Frobisher Bay (Figure 2). However, five char were recaptured in Frobisher Bay west of the Sylvia Grinnell system, but not within the Bay of Two Rivers system. A total of 72 char were marked at the Bay of Two Rivers. Five of these were recaptured during the study; three within or near the Bay of Two Rivers, and two between Sylvia Grinnell and Iqaluit (Figure 2).

Genetic Stock Discrimination

Genetic analyses found no significant difference in char caught within the Sylvia Grinnell system, but the char caught in the Bay of Two Rivers were genetically distinct from Sylvia Grinnell char. Further, the genetic assignment procedure suggested the presence of a few dispersers between the two stocks (details will be published in a separate manuscript by J.S. Moore).

DISCUSSION

ESTIMATE OF STOCK ABUNDANCE

Stock abundance was to be determined using a Jolly-Seber mark-recapture model with data from char caught in small-mesh DFO gillnets. However, with only one char re-captured in each year of the study the data were insufficient to reliably estimate abundance. Data collected from

subsistence and recreational fishers on tag-return forms was considered for use in the Jolly-Seber model but were found to be inappropriate due to the following:

1) Incomplete reporting of harvest (marked and unmarked fish) - Some fishers caught marked char but did not return the tags to DFO, and numerous fishers caught unmarked char but this information was not recorded.
2) Mixing of char from adjacent river systems - There are at least two rivers in Frobisher Bay that support char, the Sylvia Grinnell and Bay of Two Rivers (there may also be other smaller systems within the Frobisher Bay watershed that produce char). Genetic analysis (J.S. Moore, unpubl. data) indicate the char from these two systems are distinct stocks and this finding is supported by observations of fish movement data from this study. The fisher recapture locations were primarily in the Iqaluit area of Frobisher Bay, outside of the Sylvia Grinnell River study area, where the tag-return data suggest there is some mixing of the two stocks therefore, it is possible the abundance estimate produced by the fisher data would not be representative of the Sylvia Grinnell population.
3) Violation of the Jolly-Seber model assumption "Every animal in the population, whether marked or unmarked, has the same probability of being caught in the i*th* sample, given that it is alive and in the population when the sample is taken." - Discrepancies between DFO and fisher gear and harvest locations violated this assumption. For example, DFO gillnets were predominantly 51 mm to 64 mm while local fishers generally use gillnets with mesh size 102 mm or larger. Therefore, some fish marked in the small-mesh DFO nets may not have been susceptible to the larger mesh nets used by the local fishers (see DFO 2013 for more details).

STOCK STATUS

The information on biological characteristics and CPUE of char caught in the DFO nets suggest the status of the Sylvia Grinnell char stock has been stable in recent years. However, it must be recognised that the small-mesh gillnet was selected to minimize stress of fish so they could be marked and released and were not the same as the multi-mesh gillnets used historically to assess stock status. Therefore, while information on biological characteristics and CPUE have been reported historically (Grainger 1953; Hunter 1976; Kristofferson and Sopuck 1983; Bodaly et al. 1992; Cosens et al. 1993; Gallagher and Dick 2010), we do not make any comparisons here. Also, in this study fish smaller than 300 mm were sometimes released without being measured (because they were not suitable for marking) and it is possible that the largest fish were less susceptible to capture in the small-mesh gear. Both of these factors could result in a condensed age and length frequency distribution, and potentially alter the interpretation of results. For example, the total instantaneous mortality found in this study is relatively high for char (which could result in slow recovery of the stock), but this interpretation would not be accurate if there was truncation of older fish in the age frequency distribution (the mortality estimate would be artificially inflated). However, even with these limitations some valuable observations were made. The age frequency distribution showed a reasonable number of young (presumably immature) fish, suggesting successful recruitment. Further, females were more abundant than males, suggesting potential for continued recruitment in the future.

The length and age frequency distributions for char found discarded along the shoreline of the Sylvia Grinnell also contained a wide range of fish, larger than those found in 1976 and 1977 (Kristofferson and Sopuck 1983), but smaller compared to 2002 and 2004 (Gallagher and Dick 2010). Theoretically, smaller/younger char would be more likely to be discarded because of limited use for consumption (not enough flesh to make desirable fillets), yet larger carcasses were still found; the reason for discarding these relatively large fish is unknown.

CPUE of char caught in the Sylvia Grinnell system was not significantly influenced by year of capture, but it was significantly higher in August compared to July. Higher catches in August are likely due to the study nets being set solely in the upper estuary or river. In July, char are more likely to be feeding in the outer estuary or in Frobisher Bay, while in August fish are migrating upstream to overwintering sites (Hunter 1976; Gallagher and Dick 2010; DFO 2013).

SUSTAINABLE HARVEST LEVEL

Sustainable harvest could not be calculated as planned, but the presence of young char in the age frequency distribution suggests that recruitment is occurring and the stock is likely sustainable at the current rate of fishing.

RELATIVE HARVEST BY FISHING METHOD

Information reported in fisher interviews and in tag-return forms suggest that gillnetting is the dominant gear used to catch char in or near the Sylvia Grinnell River in summer, and that the amount of fish caught by snagging has decreased compared to historic levels. Kristofferson and Sopuck (1983) estimated the number of char caught by snagging to be 1,920 in 1976 and 4,923 in 1977 (65% of total subsistence harvest). Gallagher and Dick (2010) estimated it to be 4,914 in 2002 and 5,535 in 2004 (52% and 62% respectively, of total subsistence fishing). DFO (2008) estimated a minimum of 2,993 char were discarded (most likely after being snagged) over a three week period in August in each of 2007 and 2008. In 2009, the DFO public awareness campaign to reduce char snagging and discarding was initiated, and from 2009 through 2011, DFO staff in Iqaluit observed less than 200 char discarded annually on the shore/rocks at the falls area. While results reported in fisher interviews and tag-return forms and observations by DFO staff present are encouraging, they may not accurately reflect a reduction in snagging and discarding due to: reports of people collecting discarded fish to use for dog food (an activity not reported previously), large numbers of fish observed on the river bottom, observations of fish that were caught containing scars that were likely caused by snagging, potential misreporting of the harvest method used due to the negative stigma associated with snagging, and fishers not returning marked char to DFO because the reward offered ($10) was too low (DFO 2013).

Data reported in fisher interviews on August 19, 2011 suggest that char are more susceptible to being caught via snagging as compared to angling. While this seems logical given the technique of the methods, data from one day of fishing is not sufficient to draw a conclusion.

STOCK STRUCTURE

The results of this research provide new information about the population structure of char in the Sylvia Grinnell River system and the general Frobisher Bay area. Char marked in the Bay of Two Rivers were caught near the Sylvia Grinnell system, but not vice-versa. Similar results were found by Spares et al. (2012) who acoustically tagged char in the Sylvia Grinnell River and the Bay of Two Rivers and tracked fish movement within each estuary and in Frobisher Bay. They detected char in the freshwater and estuaries of both rivers and in Frobisher Bay between the two, but did not differentiate the movement of individual fishes. However, unpublished data from the study reveal that seven fish marked at Bay of Two Rivers were detected in the Sylvia Grinnell River estuary and one fish marked at Sylvia Grinnell River was detected at the Bay of Two Rivers estuary (A. Spares pers. comm.). Local fishers also differentiate char from the Sylvia Grinnell River and Bay of Two Rivers, reporting that Bay of Two Rivers char are larger and travel to the Sylvia Grinnell River but char from Sylvia Grinnell River do not go to the Bay of Two Rivers (DFO 2013). Hunter (1976) found that char from the Sylvia Grinnell River, which have migrated to the sea for summer feeding, remained close to the river mouth and that returning tagged fish indicated a high degree of homing to their natal river. Further, J.S. Moore

(unpubl. data from this study) found the Sylvia Grinnell River and Bay of Two Rivers stocks to be genetically distinct, but with some mixing.

RECOMMENDATIONS FOR FUTURE WORK

1) A minimum five-year experimental gillnet survey to collect information on biological and CPUE data would be beneficial to more accurately compare current stock status to historic levels. This dataset may also be useful in estimating stock abundance using age-based population models such as Virtual Population Analysis.
2) A harvest survey performed consistently from July through September would be useful to update estimates of recreational and subsistence harvests by gear type.
3) If undertaken, future determination of stock abundance should consider other approaches to mark-recapture experiments (e.g., single event recapture – mark then recaptured later in the same year, weir counts) or an alternative approach such as DIDSON Sonar estimates. In either case the approaches should be complemented with biological sampling.
4) The public awareness campaign initiated by DFO Fisheries Management in Iqaluit, and increased presence by DFO Fishery Officers in the falls area of Sylvia Grinnell River during the summer months should be encouraged and undertaken as a joint effort with the community and co-management partners (DFO 2013).

CONCLUSIONS

A reliable estimate of stock abundance could not be produced for Sylvia Grinnell char due to insufficient data and violation of mark-recapture model assumptions. Without this information, an estimate of sustainable harvest level could not be made. However, age-frequency data show good recruitment of juveniles and presence of mature fish in the sample (ages eight to 26 years), suggesting the stock has the potential to sustain itself under current harvest levels.

We also achieved an increased understanding of char movements that suggests there is limited mixing in Frobisher Bay of char from Sylvia Grinnell River and Bay of Two Rivers. This is supported by genetic analyses, which also determined that the two stocks are discreet with limited mixing in Frobisher Bay (J.S. Moore, unpubl. data).

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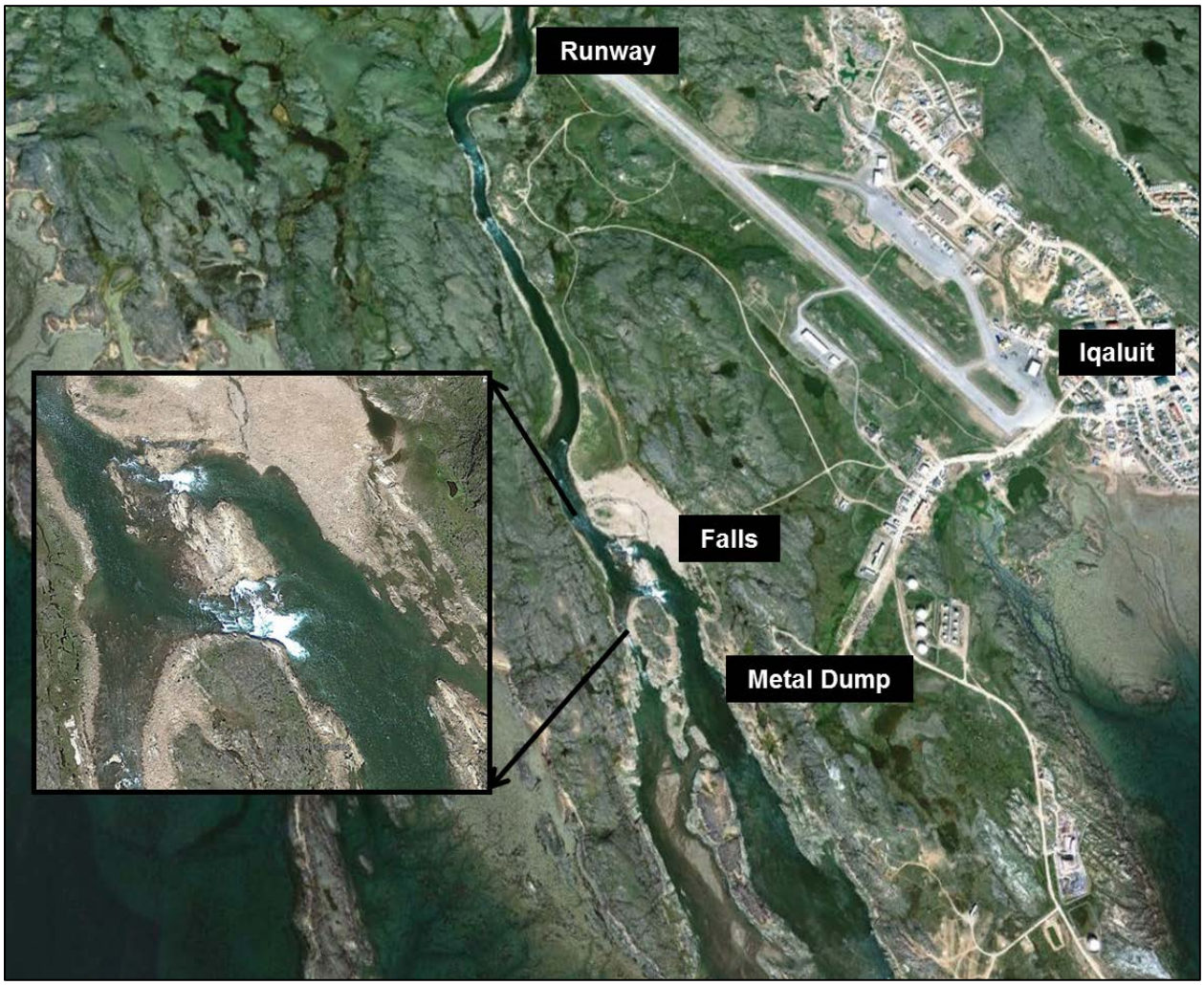


Figure 1. Map of Sylvia Grinnell River showing sites sampled for Arctic Char from 2009 to 2011. Insert map shows a magnified view of the 'falls' area. (map from Google Earth)

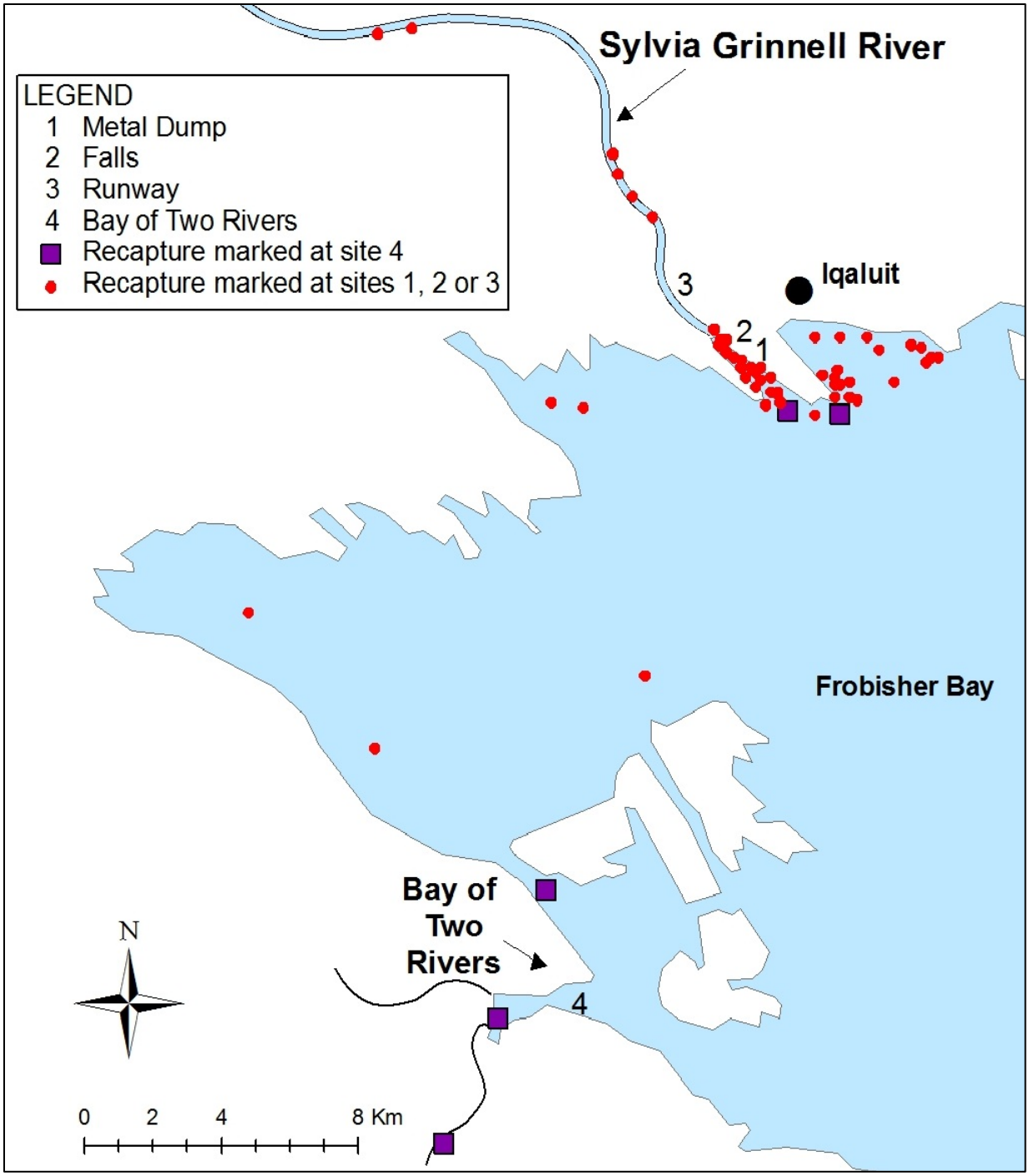


Figure 2. Map of Frobisher Bay, Nunavut, showing the locations where Arctic Char were marked with T-bar tags (1, 2, 3, 4), and location of subsequent recaptures (circles and squares).

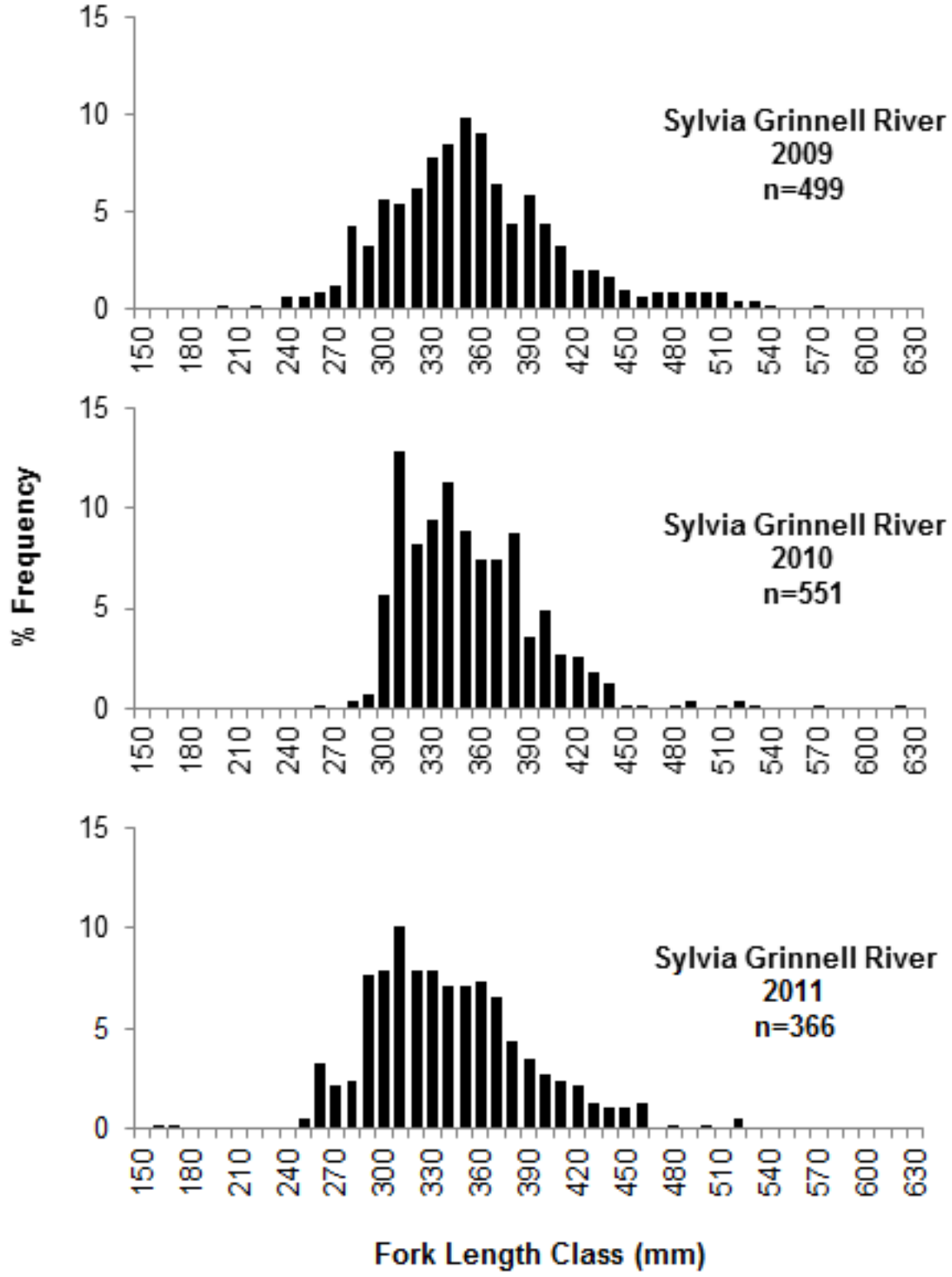


Figure 3. Fork length frequency distribution for Arctic Char caught in DFO gillnets in the Sylvia Grinnell River from 2009 to 2011.

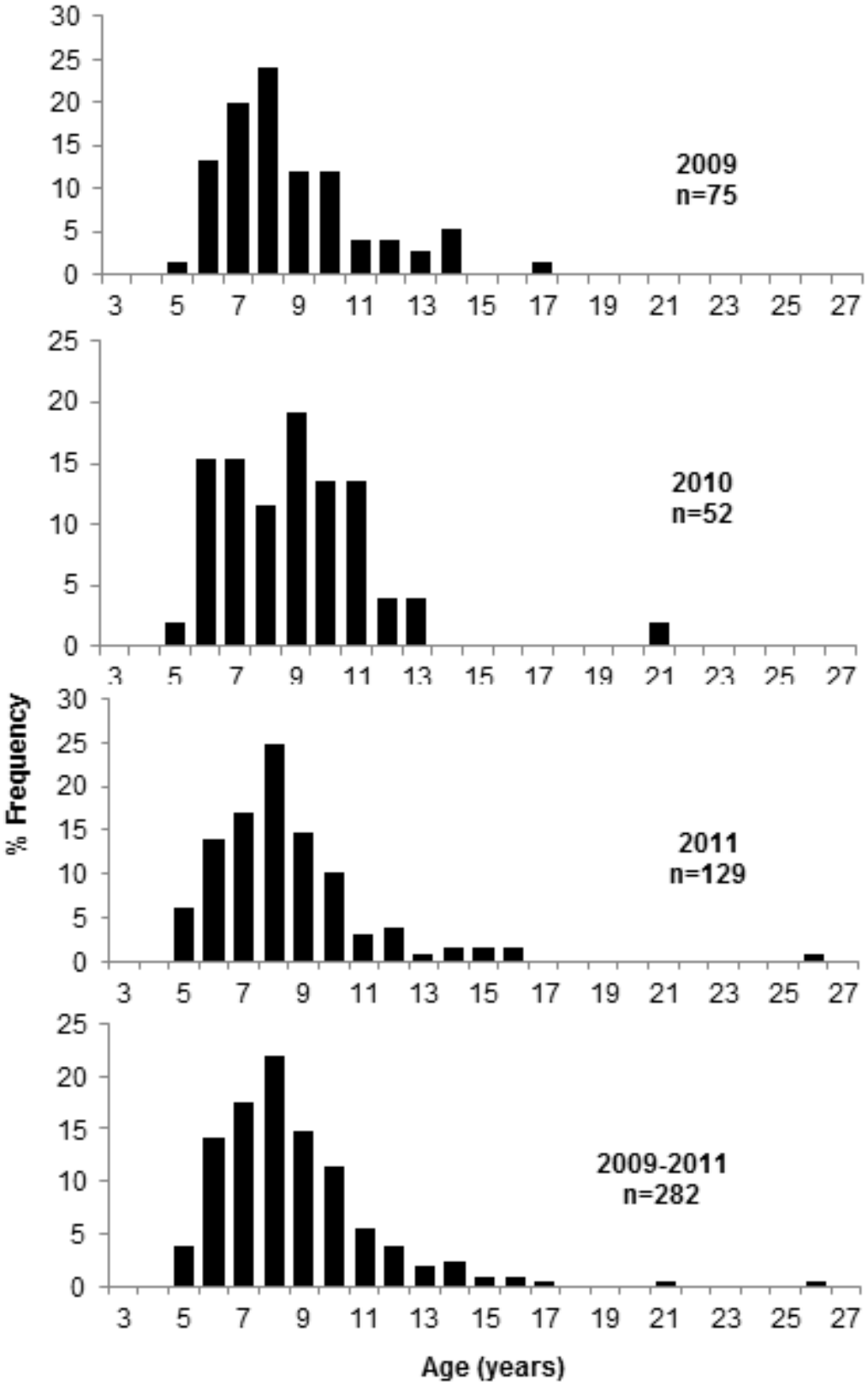


Figure 4. Age frequency distribution for Arctic Char caught in DFO gillnets in the Sylvia Grinnell River from 2009 to 2011.

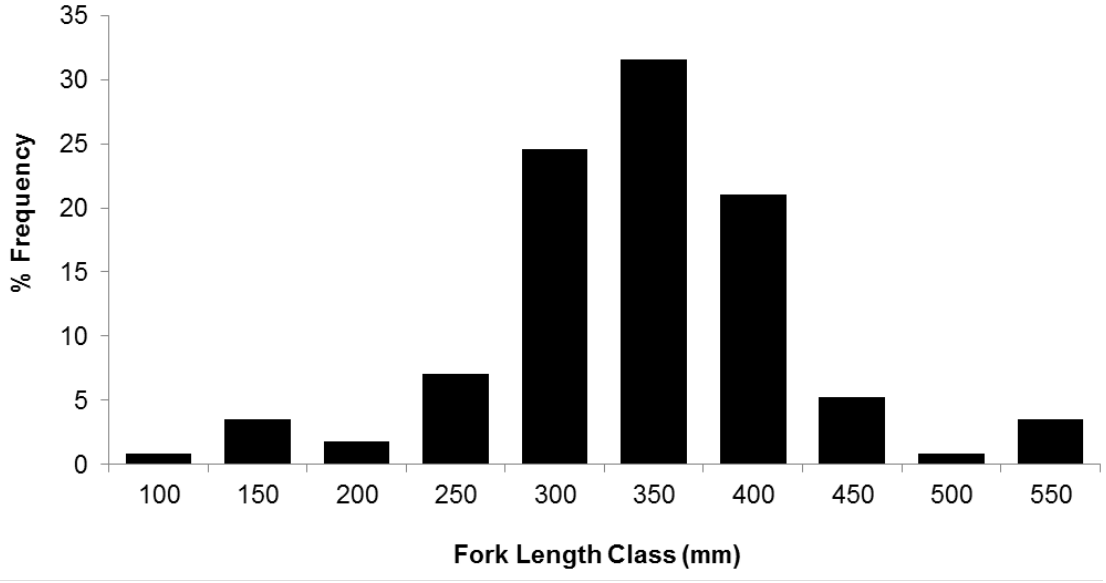


Figure 5. Fork length frequency distribution (50 mm length classes) for Arctic Char found discarded along the shoreline of Sylvia Grinnell River below the falls area in 2011 (n=114).

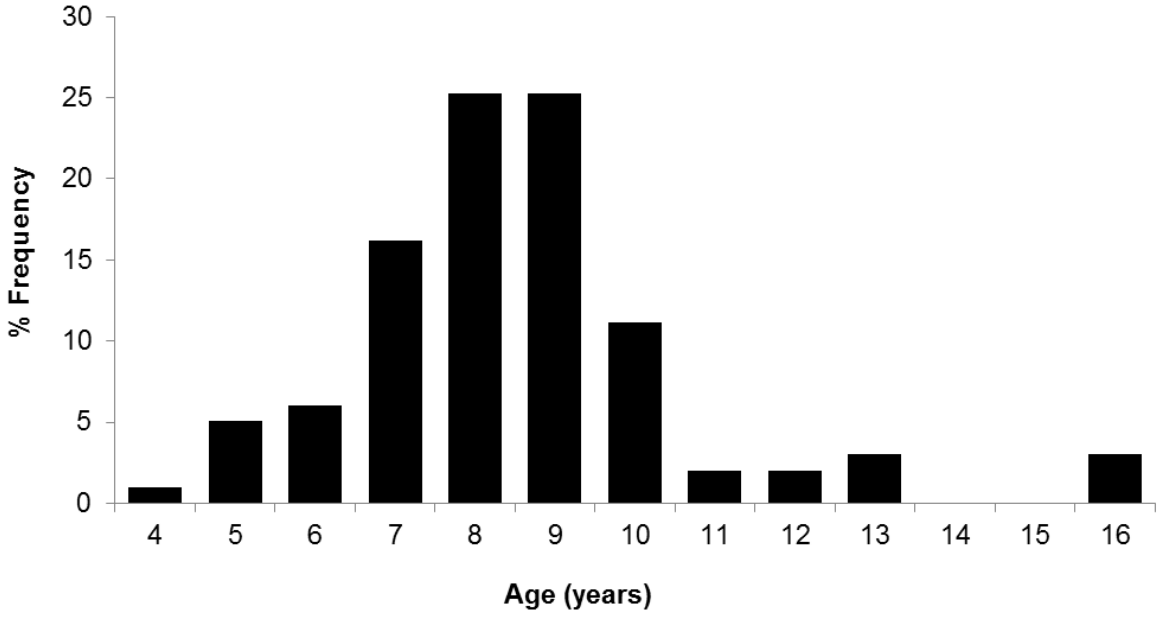


Figure 6. Age frequency distribution for Arctic Char found discarded along the shoreline of Sylvia Grinnell River below the falls area in 2011 (n=99).

Table 1. Location, gear type, and days fished for Arctic Char in the Sylvia Grinnell River from 2009 to 2011. "A" is angling and "G" is gillnet.

Year	Site #	Gear Used	Gillnet Mesh Size (mm)	# Days Fished	Start	End
2009	1,2,3	A, G	13, 51, 64	15	Aug 08	Aug 25
2010	1	G	51, 64, 102	17	Jul 12	Sep 02
2011	1	G	51, 64	21	Jul 01	Sep 01

Table 2. Fork length (mm) of Arctic Char (Char) caught in the Sylvia Grinnell River from 2009 to 2011.

Year	# of Char	Min	Max	Mean	St. Dev.
2009	499	200	574	355	55
2010	551	260	621	353	43
2011	366	159	523	339	50

Table 3. CPUE (char/h/net) for Arctic Char caught in DFO gillnets set in the Sylvia Grinnell River from 2009 to 2011.

2009		2010		2011	
Date	CPUE	Date	CPUE	Date	CPUE
Aug 15	18.8	Jul 12	3.2	Jul 08	15.7
Aug 16	32.3	Jul 21	4.4	Jul 12	6.3
Aug 20	28.5	Jul 22	15.3	Jul 18	2.3
Aug 21	5.8	Aug 06	7.6	Jul 20	7.2
Aug 22	19.4	Aug 09	9.5	Jul 26	14.7
Aug 23	10.7	Aug 10	13.0	Aug 03	16.6
Aug 25	1.0	Aug 11	6.1	Aug 05	2.5
		Aug 12	21.0	Aug 15	9.3
		Aug 13	29.2	Aug 16	7.0
		Aug 14	23.8	Aug 26	13.5
		Aug 16	28.8	Aug 30	4.2
		Aug 18	9.1		
		Aug 20	32.8		
		Aug 23	14.7		
		Aug 27	10.8		
# Nets	7		15		11
Mean CPUE	16.7		15.3		9.0

Table 4. Summary of fishing activity for each day on which fisher interviews were conducted in 2011 near the falls area of Sylvia Grinnell River. Char refers to Arctic Char.

Interview Date	**Jul 19**	**Jul 21**	**Jul 22**	**Jul 28**	**Aug 02**	**Aug 14**	**Aug 19**	**Total**
Weekday	Tue	Thur	Fri	Thur	Tue	Sun	Fri	-
Time on Site	9:30am-1:00pm	2:00pm -4:00pm	1:00pm-1:30pm	2:00pm-4:30pm	2:45pm-3:00pm*	1:00pm-4:30pm	1:00pm-2:30pm	-
# Interviews conducted	14	13	3	4	0	4	8	46
# recreational fishers	10	5	2	2	0	1	6	26
# subsistence fishers	4	8	1	2	0	3	2	20
# char caught by angling	1	1	0	0	0	0	4	6
# char caught by snagging	not used	not used	not used	not used	not used	not used	6	6
# Interviews declined	2	2	8	0	4	25	0	41

*area closed due to polar bear

Table 5. Number of Arctic Char reported in fisher interviews in 2011 that were caught in the summer of 2011 (not just on the day of the interview).

Fishery	**Angling**	**Snagging**	***Total***
Recreational	71		*71 (47%)*
Subsistence	99	52	*151 (68%)*
Total	*170 (77%)*	*52 (23%)*	*222*

Table 6. Number of Arctic Char (marked and un-marked) caught by fishing method, as reported on the tag-return forms for 2009 to 2012.

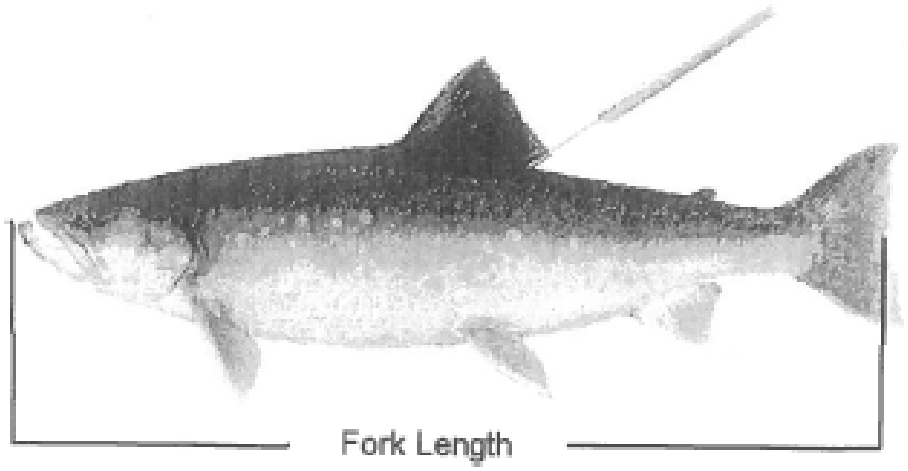
Year	**Angling**	**Gillnet**	**Jigging**	**Snagging**	**Total**
2009	0	16	0	0	16
2010	68	156	0	42	266
2011	136	212	0	18	366
2012	13	263	16	0	292
Total	217	647	16	60	940

APPENDIX 1.

Tag-return form used to document information about harvest of recaptured Arctic Char marked with T-bar tags in the Sylvia Grinnell River and Bay of Two Rivers.

SYLVIA GRINNELL RIVER TAG RETURNS

Tag Color	☐ blue ☐ white
Tag #	
Date Caught	
Location Caught (GPS coordinates if possible)	
Gear Type	☐ angling ☐ gillnet Other _____
# of Other Fish Caught	
Name of Fish Harvester	
Contact Information (email, phone)	
Fork Length (mm)	
Weight (grams)	
Sex	☐ male ☐ female
Paid ($10)	☐ YES ☐ NO
Paid By	
Paid From (personal $, petty cash etc.)	
Comments	



APPENDIX 2.

Questionnaire used for interviews of Arctic Char fishers in 2011.

<table>
<tr><td rowspan="2">Monitor:_____
Date:_____
Time:_____
Fishers' name:_____
_____
Fishing location:_____
_____
Residence: Iqaluit ☐
Other:_____</td><td>Purpose</td><td>Method</td><td>Net</td><td>Tackle (angling)</td></tr>
<tr><td>Subsistence ☐

Sport ☐</td><td>Net ☐
Angling ☐
Snagging ☐</td><td>Net no. _____ Mesh size:_____
Length of net:_____
Depth of mesh:_____
Net location (lat/long):
_____</td><td>Jig ☐
Spoon ☐
Fly ☐
Live bait ☐
Other:_____</td></tr>
<tr><td></td><td colspan="2">Harvest duration (hours)</td><td>Harvest number</td><td colspan="2">Number of Fish Released</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Notes:</td><td colspan="4">APPEARANCE (Areas of external deformities or presence of parasites):
_____
_____</td></tr>
<tr><td colspan="6">FISHING TRENDS: Years spent fishing:_____ Abundance: increased☐, decreased☐, same☐ Length: increased☐, decreased☐, same☐

Days Spent Fishing this summer: _____ Fish Caught this summer: _____ Fish Harvested this summer: _____ Any Tagged fish? _____</td></tr>
<tr><td colspan="6">WEATHER: Wind direction:_____ (none☐, light☐, moderate☐, strong☐), Sunny☐, Cloudy (overcast☐, partially☐), Rain (drizzle☐, heavy☐)</td></tr>
<tr><td colspan="6">SAMPLED CATCH (Fish I.D.): _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____</td></tr>
<tr><td colspan="6">COMMENTS:</td></tr>
</table>