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Information to support the Ikaluit Lake (Robert Peel Inlet) Arctic Char (*Salvelinus alpinus*) Assessment

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Canada

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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TABLE OF CONTENTS

ABSTRACT

Within Cumberland Sound there are multiple stocks of Arctic Char (*Salvelinus alpinus*). This evaluation was performed to provide an updated summary of information available to assess the status of the Ikaluit Lake (Robert Peel Inlet) Arctic Char stock and recommend a long-term plan for the fishery. This waterbody was harvested as a test fishery from 1977 until 1982, as an exploratory fishery from 1983 until 1989, and as a commercial fishery (Schedule V) from 1990 until 2000, at which time the Pangnirtung Hunters and Trappers Organization (PHTO) requested that the commercial fishery be closed for a five-year period due to declining catches of larger Arctic Char. The initial quota was set at 1,500 kg for the test fishery and then reduced to 1,400 kg for the commercial licence. The Ikaluit Lake fishery was reopened in 2006 as an exploratory fishery with a reduced quota of 1,000 kg, where it currently remains. In this assessment there are four types of data presented from Ikaluit Lake: test fishery data; fishery-dependent data; fishery-independent data; and plant data. In addition to the licenced harvest, Ikaluit Lake Arctic Char are also harvested for subsistence purposes by both the community of Pangnirtung and the community of Iqaluit, however the rate of subsistence harvesting is not well documented. The results from this assessment suggest that the Ikaluit Lake Arctic Char stock is stable under present harvest levels. Consistency among recent years in Catch-Per-Unit-Effort (CPUE) data, weight-length relationships, length-frequency distributions, age-frequency distributions, mean trend data, length-at-age data, and age-at-maturity data support this conclusion. However, there are some signs that the stock is changing in response to fishing pressure as seen in the catch curves and instantaneous mortality rates over the years. Abundance modelling calculated a potential population size ranging from 4,288 to 9,594 individuals in the Ikaluit Lake stock. After applying a 5% threshold of the modelled abundance for sustainable harvesting (the ‘Tallman Rule’), current harvest rates (not including subsistence fishing) are sustainable for the stock, however when subsistence fishing estimates are factored in, the stock becomes under significant harvest pressure. The recommendations for the long-term plan for Arctic Char in Ikaluit lake are to: more accurately account for subsistence harvesting in future assessments, continue close monitoring of the stock, ensure that future sampling is done in a consistent manner, and to collect and document the available traditional knowledge.

INTRODUCTION

Arctic Char (*Salvelinus alpinus*) are the most northerly freshwater fish and have a circumpolar distribution (Scott and Crossman 1985). This species is abundant within the Canadian Arctic and is an important subsistence resource for local Inuit (Priest and Usher 2004). Within Cumberland Sound there are multiple stocks of Arctic Char; specifically, this report is focused on the stock found in Ikaluit Lake (Robert Peel Inlet; Figures 1 and 2).

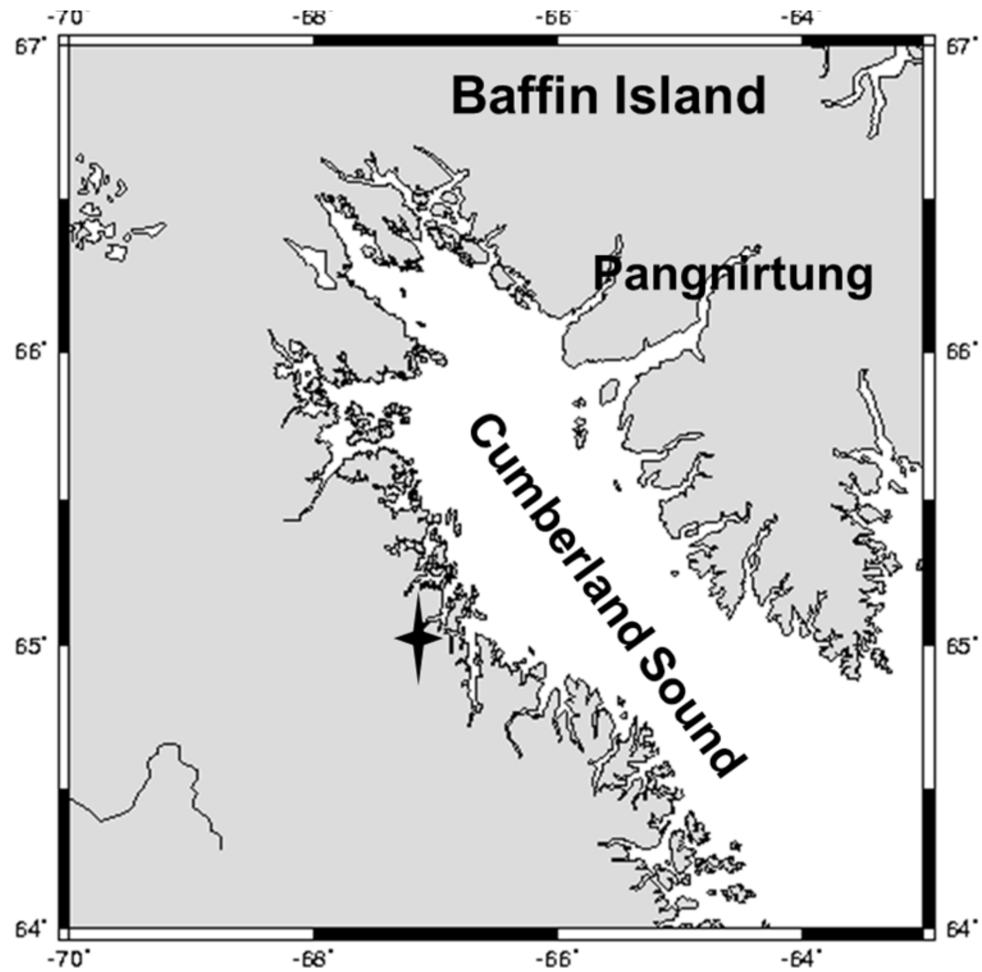

Figure 1. Map of Cumberland Sound with Ikaluit Lake (Robert Peel Inlet) marked with a star.

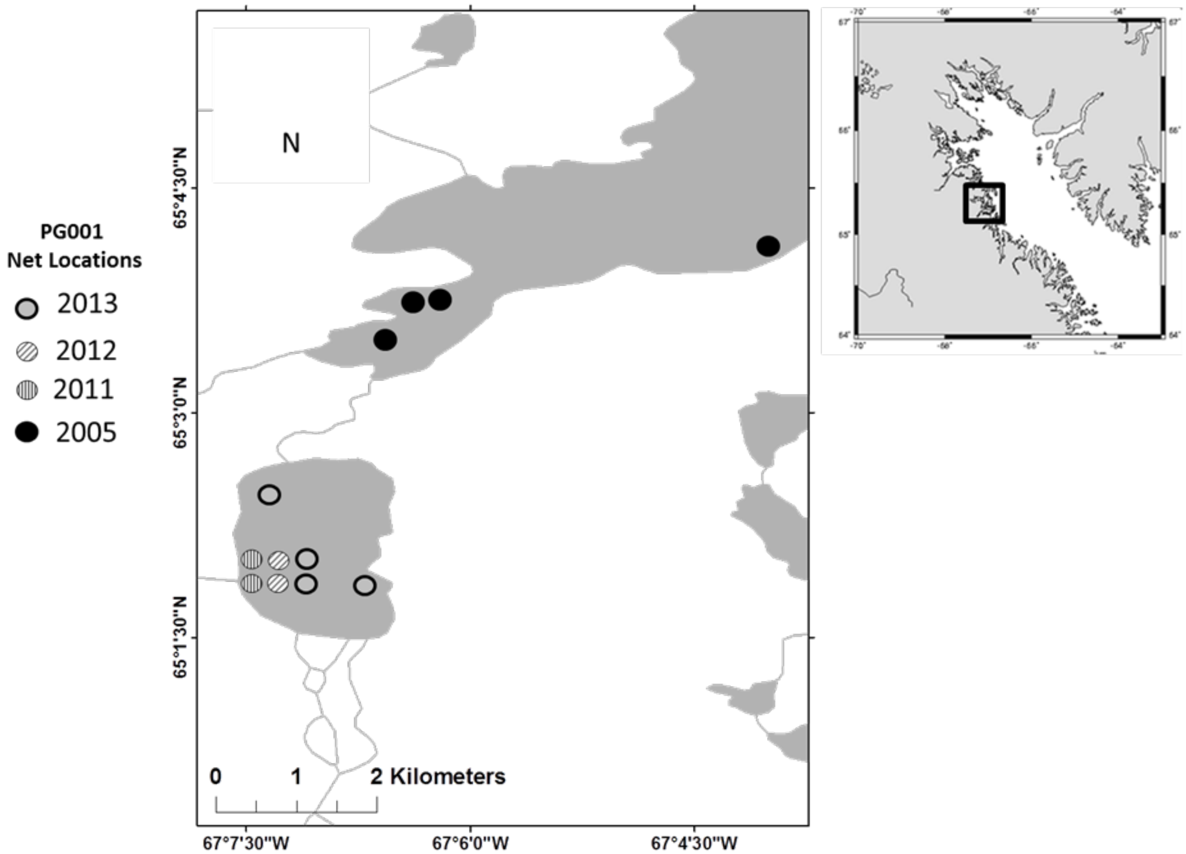

Figure 2. Map of Ikaluit Lake (Robert Peel Inlet) with fishing locations noted. The net set locations for fishery-independent data presented by collection year. Map made by S. Wiley (Fisheries and Oceans, 501 University Crescent, Winnipeg, MB).

Ikaluit in Inuktitut translates to 'many fish', so the direct translation is Many Fish Lake (Robert Peel Inlet). Within Nunavut there are other waterbodies that share the same name 'Ikaluit' or 'Iqaluit' and are licenced for Arctic Char harvest; this assessment is for the Ikaluit Lake located within Robert Peel Inlet and has a DFO waterbody code PG001. This waterbody was harvested as a test fishery from 1977 until 1982, as an exploratory fishery from 1983 until 1989, and as a commercial fishery (Schedule V) from 1990 until 2000 at which time the Pangnirtung Hunters and Trappers Organization (PHTO) requested that the commercial fishery be closed for a five-year period due to declining catches of larger Arctic Char. The request to close the commercial harvest of Ikaluit Lake Arctic Char was presented to the Nunavut Wildlife Management Board (NWMB) in the summer of 2000 and the closure was granted (NWMB Resolution 2000 - 173). In 2002, the PHTO put in a request to reopen the fishery on Ikaluit Lake; which required a review of the Science data by Fisheries and Oceans Canada (DFO). The review concluded that there was moderate risk if the commercial harvest was reopened at the same quota (1,400 kg) and if subsistence fishing remained at historic lows (Appendix A). Following this Science review, the Ikaluit Lake fishery was reopened in 2006 as an exploratory fishery with a reduced quota of 1,000 kg, until present.

In addition to the licenced harvest, Ikaluit Lake Arctic Char are harvested for subsistence purposes by both the community of Pangnirtung and the community of Iqaluit. Currently there is no record of the amount of harvest removed for subsistence purposes from Ikaluit Lake. The community of Iqaluit is believed to harvest more than Pangnirtung due to the community's proximity and access to the lake via snow machine trails. It is unclear if Pangnirtummuit still use Ikaluit Lake for subsistence purposes. During the commercial fishery closure, the NWMB encouraged the communities to minimize subsistence harvest from Ikaluit Lake (NWMB Resolution 2000 – 173).

Ikaluit Lake Arctic Char exhibit anadromous life history traits, no resident life history forms have been found (fisheries independent data and fishery dependent data). Arctic Char fisheries typically harvest anadromous populations as they hold the highest economic value because of their large size and preferred red colour flesh. Additionally, anadromous Arctic Char can be easier to harvest compared to other life history traits as they tend to congregate at specific times of the year in specific places (e.g., times of migration).

*A*nadromous Arctic Char are iteroparious but do not spawn annually (Dutil 1986). In fish species that do not spawn annually the period of time between spawning events is called "resting". This maturity stage can be noted within anadromous Arctic Char and has been considered in this assessment. Biologically it is theorized that the "resting" stage is the time when fish feed and replenish their bodily resources before the next spawning event. Due to the environmental conditions of the Arctic, individual Arctic Char are thought to require two to three years to replenish their body resources between spawning events (Moore et al. 2013). In addition to the lengthened "resting" stage of Arctic Char, it has been reported that in years when fish are not spawning they are more likely to stray to other freshwater lakes for the purpose of overwintering (Gyselman 1994, Moore et al. 2013). In contrast, there is evidence that Arctic Char show a high fidelity to their natal environments in years when they will spawn (Moore et al. 2013).

The purpose of this report is for the Science section of DFO to provide an updated summary of information available from Cumberland Sound Arctic Char Stocks. In this Regional Advisory Process (RAP) DFO Science is assessing the status of the Ikaluit Lake (Robert Peel Inlet) Arctic Char stock and recommending a long-term plan for the fishery.

MATERIALS AND METHODS

STUDY AREA

Ikaluit Lake (Robert Peel Inlet) is located on the south side of Cumberland Sound (65-02 N/67-07 W) (Figures 1 and 2). The lake is in moderately close proximity to the marine environment, with a river length of 1.3 km. Ikaluit Lake is known to be a large (1.57 square km) deep lake with a catchment of 532 square km (Harris et al. 2014)

The tides within Cumberland Sound are among the highest in Nunavut. The tidal change is 11 meters, and low tide often results in limited intertidal habitat and river access for fish. This reduction in fish habitat with tide changes affects the commercial harvest of Arctic Char in the open ice season in all areas of Cumberland Sound, including the Arctic Char from Ikaluit Lake. If fishing near the mouth of a river, fishers' nets will be dry or in very shallow water when the tide is low; in contrast, the nets will be fully submerged and floating in the water column when tides are high. This diel fishing practice results in high catch rate potentials at high tide and no or low catch rates at low tide. Instead of waiting for high-tide fishing, fishers may choose to place their nets in deeper waters to avoid the low catch rate at low tide. It is important to note the affects the tides of Cumberland Sound have on characteristics of harvest in the open ice season.

HARVEST INFORMATION

Ikaluit Lake was originally a winter fishery (licenced harvest), but since licence year 1995/1996 has transitioned into a summer fishery (Table 1). The quota has been reduced over the years.

The initial quota was set at 1,500 kg for the test fishery, reduced to 1,400 kg for the commercial licence, and then was further reduced to 1,000 kg under an exploratory licence when reopened in licence year 2006/2007, where it remains. There is no documentation to show how initial test fishery quotas were established. It is commonly accepted that lake size and traditional knowledge were incorporated into the decision and that the initial quotas were thought to be conservative (R. Tallman, DFO, pers. comm.). As mentioned above, Ikaluit Lake is commonly fished for subsistence purposes by the community of Iqaluit and to a very limited extent by the community of Pangnirtung. It is not known if the rate of subsistence harvest was considered when establishing the initial test fishery quota.

Table 1. Summary of available harvest information from fishery-independent, fishery-dependent, and test fishery data detailing quota, number of fish captured and weight (kg) where available, by year. Data for the exploratory and commercial harvest landings was compiled from Fisheries Management and Harvest Information System (FMHIS). Exploratory and Commercial Harvest Landings reported as dressed/head off (typically open water fishing) were converted to round weight by a factor of 1.15 for licence year 1980 –2006, and a conversion factor of 1.0918 from licence year 2007 to present to account for removed viscera. When 0 appears as the harvest by weight, there was no recorded harvest for that licence year.

Year	Harvest Month	Quota		Harvest by Weight		Source	Fishery-Independent Data	
		kg	lb	kg	lb		Number	Weight (kg)
1977/1978*	8	1,500	3,300	286	629	Kristofferson and McGowan 1981 andFMHIS	-	-
1978/1979	-	No known harvest, unsure if licenced this year				-	-	-
1979/1980*	-	1,500	3,300	797	1,753	Excel spreadsheet	-	-
1980/1981*	3	908	1,997.6	797	1,753	McGowan 1985	-	-
1981/1982*	-	1,500	3,300	1,500	3,300	Excel Spreadsheet	-	-
1982/1983*	-	1,500	3,300	1,500	3,300	McGowan 1985	-	-
1983/1984*	-	1,500	3,300	1,334	2,935	Excel Spreadsheet	-	-
1984/1985	-	-	-	0	0	-	-	-
1985/1986*		1,500	3,300	2,552	5,614	Excel Spreadsheet	-	-

Year	Harvest Month	Quota		Harvest by Weight		Source	Fishery-Independent Data	
		kg	lb	kg	lb		Number	Weight (kg)
1986/1987	-	-	-	0	0	-	-	-
1987/1988	-	-	-	0	0	-	-	-
1988/1989	3	?	?	227	499	FMHIS	-	-
1989/1990	-	-	-	0	0	-	-	-
1990/1991	3	1,400	3,080	1,182	2,600	McGowan et al. 1993 FMHIS	-	-
1991/1992	3	1,400	3,080	1,400	3,080	FMHIS	-	-
1992/1993	3	1,400	3,080	1,816'	3,995	FMHIS	-	-
1993/1994	3	1,400	3,080	998	2,196	FMHIS	-	-
1994/1995	3	1,400	3,080	1,356	2,983	FMHIS	-	-
1995/1996	8	1,400	3,080	1,680'	3,696	FMHIS	-	-
1996/1997	5,7,8,3	1,400	3,080	4,747'	10,443	FMHIS	-	-
1997/1998	7	1,400	3,080	1,001	2,203	FMHIS	-	-
1998/1999	7,3	1,400	3,080	1,410	3,103	FMHIS	-	-
1999/2000	5,8	1,400	3,080	2,289'	5,036	FMHIS	-	-
2000/2001	-	CLOSED				FMHIS/ DFO survey	172	405
2001/2002	-	CLOSED				FMHIS/ DFO survey	134	330
2002/2003	-	CLOSED				FMHIS	-	-
2003/2004	-	CLOSED				FMHIS	-	-
2004/2005	-	CLOSED				FMHIS	-	-

Year	Harvest Month	Quota		Harvest by Weight		Source	Fishery-Independent Data	
		kg	lb	kg	lb		Number	Weight (kg)
2005/2006	-	CLOSED				FMHIS/ DFO survey	138	444
2006/2007	7	1,000	2,200	956	2,103	FMHIS	-	-
2007/2008	7,8	1,000	2,200	2,034’	4,475	FMHIS	-	-
2008/2009	8	1,000	2,200	719	1,582	FMHIS	-	-
2009/2010	7	1,000	2,200	1,422’	3,128	FMHIS	-	-
2010/2011	7,8	1,000	2,200	1,058	2,328	FMHIS/ DFO survey	191	300
2011/2012	-	1,000	2,200	995	2,194	FMHIS/ DFO survey	190	232
2012/2013	-	1,000	2,200	292	644	FMHIS/ DFO survey	197	281
2013/2014	-	1,000	2,200	984	2,170	FMHIS	-	-
Total	-	-	-	35,332	77,742	-	1,022	1,992

* Harvest information found in other sources and files than FMHIS. Excel spreadsheet can be found only in resource management files, but not yet entered formally anywhere.
‘ years when harvest exceeded the quota.

DATA SOURCES

In this assessment there are four types of data presented from Ikaluit Lake: test fishery data; fishery-dependent data; fishery-independent data; and plant data. The test fishery data, fishery-independent data, and plant data are reported on the calendar year. The fishery-dependent data is reported by licence year; which runs from April 1 of the first year to March 31 the following year. For all datasets, fish caught in summer months (July and August) were caught in the marine environment when fish were migrating back to Ikaluit Lake, and fish caught in winter months were caught directly in Ikaluit Lake. When location of fishing was unknown, but date of fishing was known, the previous statement was assumed to be correct. Note, for summer collections, it is difficult to perfectly time sampling with fish migration as migrations are greatly dependent on environmental cues, resulting in uncontrolled variance among year-to-year samples (Wootton 1999); whereas, in the winter (under the ice) it is assumed that all fish are in the lake and a better representative sample of the stock can be taken.

FISH COLLECTION AND BIOLOGICAL SAMPLING

Test Fishery

The test fishery data were collected in 1977, 1980, and 1990 in both summer and winter (Table 1 and Table 2). The nets used were 139.7 mm or 114.0 mm gill nets and targeted the portion of the population that was vulnerable to a commercial fishery (Kristofferson and McGowan 1981). The data collected from individual fish included: fork length (cm), round weight (g), sex, and sagittal otoliths for fish age determination (McGowan 1985). The objective of the test fishery was to gather baseline biological information for comparison with future studies to assess population structure responses to harvest over time (Kristofferson and McGowan 1981). Catch-Per-Unit-Effort (CPUE) data was collected in March and April in 1980 and 1990, respectively, but this data are not considered comparable to the more recent CPUE data collected in August/September, due to seasonal differences. Additionally, CPUE could not be calculated for every year of the test fishery, due to incomplete records in some years. Thus, the CPUE data from the test fisheries are used with caution in this assessment and only as historical reference points.

Table 2. Summary of historical test fishery data (from Kristofferson and McGowan 1981, McGowan 1985) and DFO survey data (from McGowan et al. 1993) including sample dates, location fished, number of fish captured in 139.7 mm nets, and total number of fish captured per year.

Sampling Year	Start Date	End Date	Number of fish captured	Total soak time (hours)	Location fished
1977	August 25	August 25	51	Insufficient Data	River/Ocean?
1980	March 14	March 14	100	54.4	Lake
1990*	April 23	April 24	158	53	Lake

* DFO survey completed similar to a test fishery but with smaller mesh net (114.0 mm).

Fishery-Independent Sampling

Fishery-independent data from scientific sampling undertaken by DFO were collected between July and August in 2000, 2001, 2005; and February and March in 2011, 2012 and 2013 (Table 3). Summer sampling locations were in the saltwater environment (inter-tidal zone, estuary and fiord), while the winter sampling locations were in the freshwater environment (lake) (see Table 3 and Figure 2 for details).

Table 3. Summary of fishery-independent data including samples dates, gear type used, number of net sets, total soak time, number of fish captured for each net type, and total number of fish captured (categorized by year). Total soak time was calculated by adding all the hours that each net type was left to soak for each set.

Sampling Year	Start Date	End Date	Number of fish captured		Multi-mesh net mesh size (mm)	Number of nets set		Total soak time (hours)	Total number of fish captured	Location fished
			139.7 mm mesh net	Multi-mesh net		139.7 mm mesh net	Multi-mesh net			
2000	August 13	August 17	172	-	-	27	-	75.64	172	Mouth of the river
2001	July 31	August 1	134	-	-	unknown	-	48.00*	134	Mouth of the river
2005	August 16	August 18	133	5	38.1–101.6	17	2	115.76	138	Tidal Area
2011	February 22	February 26	-	191	38.1–139.7	-	32	281.47	191	Lake
2012	March 21	March 24	-	190	38.1–139.7	-	23	135.12	190	Lake
2013	February 27	March 4	-	197	38.1–139.7	-	29	228.67	197	Lake

* Total soak time (hours) are estimated because no net set data was recorded, only dates on the individual sampled fish (July 31 and August 1).

Sampling methods in 2000 and 2001 were limited to stretched single mesh gill nets (139.7 mm) being used and fishing taking place in the same locations as the fishery. Samples taken in 2005 were collected using single mesh nets similar to 2000 and 2001 with the addition of a multi-mesh net; however, few fish were captured in the multi-mesh net (n = 5), majority of the fish sampled in 2005 were caught in the single mesh nets (n = 133). In contrast, samples taken in 2011, 2012, and 2013 were collected using multi-mesh nets to gather a representative sample of the stock and fishing locations randomly. The nets were set in a variety of locations and at depths ranging from 5 m to 32 m. Multi-mesh nets ranged in mesh size from stretched 38.1 mm (1.5 inch) to stretched 139.7 mm (5.5 inch). The 139.7 mm mesh was included to provide samples for direct comparison to the fishery. The combination of nets used varied from year to year; see Table 3 for details. Multi-mesh nets catch a larger size range of fish compared to the single mesh size nets (38.1 mm nets and 139.7 mm) and provide a better size and age representation of the entire stock.

For each net set catch and effort data were recorded and the fish were sampled for fork length (± 1 mm), round weight (± 1 g), sex, maturity stage, gonad weight (± 1g) and sagittal otoliths. The following maturity stages were used: immature, mature, resting, spent, and unknown. It should be noted that this was a highly subjective classification assigned by the sampler at the time the fish was sampled.

The age of individual fish were either determined or verified by the same age reader for all years. Arctic Char were aged at the Freshwater Institute in Winnipeg, MB. The protocol is to age fish age 10 or under by whole otoliths; and to age fish older than 10 years with an epoxy and cross section method (Babaluk et al. 2007). There has not been any work to validate the age reading with tagging data, so there is a possibility that fish may be over- or under-aged. It can be assumed that if there is over- or under-aging happening that this error is consistent within the data as the same age reader aged or verified all samples.

Fishery-Dependent Sampling

Fishery-dependent data were compiled from the FMHIS database which provides trade record information (round weight in kg) on the fish that were caught under a fishing licence during the licence year (i.e., April 1 the first year to March 31 the following year). The weights of fish harvested in the winter are reported as round weight; whereas, weights of fish harvested in the summer months are reported as dressed weight. Until 2007, a conversion factor of 1.15 was used to convert dressed weight to round weight, but after 2007 the conversion factor was updated to 1.10 (T. Loewen, DFO, pers. comm.).

Plant Sampling

Plant sampling data for Ikaluit Lake Arctic Char was available for 2006 and 2008. Plant sampling of harvested fish sold to Pangnirtung Fishery Ltd. is contracted annually through DFO Science. The contracts stated that up to 200 fish from the Ikaluit Lake harvest should be sampled for: fork length and two otoliths, and that the selection of individual fish should be done randomly while the fish are being processed. Ideally all summer harvest fish are sampled without freezing, but this is not always the case and in situations where the fish have been frozen prior to sampling, a conversion factor must be applied to any measurements taken. It is assumed that the 2006 and 2008 samples were not frozen prior to processing or if they were, that all applicable conversion factors have been applied.

Subsistence Fishery Data

In addition to the empirical data listed above, information on subsistence fishing was also used in this assessment. Subsistence fishing is commonly practiced by many families in both Pangnirtung and Iqaluit at various waterbodies in both Cumberland Sound and Frobisher Bay, respectively. The level of subsistence harvest on the Ikaluit Lake Arctic Char stock is however not documented. It is understood that residents of Iqaluit harvest from Ikaluit Lake more than Pangnirtung harvesters; but when harvest takes place, how many people harvest and how many fish are removed is not recorded. A subsistence harvest study undertaken in Nunavut (Priest and Usher 2004) reports that 181 harvesters from Iqaluit annually harvest 6,264 Arctic Char; while 208 harvesters from Pangnirtung annually harvest 35,065 Arctic Char. It is likely that the annual subsistence harvest of Arctic Char by the community of Pangnirtung was below the reported value as it is believed that some commercial harvest was mistakenly reported as subsistence. The harvest study is over 10 years old and does not provide any details regarding the locations of subsistence harvesting, therefore there is a need to validate these figures.

Pangnirtung fishers and representatives of the PHTO were present at the meeting and able to provide information regarding the level of subsistence harvest of Ikaluit Lake Arctic Char by their community. In the past, people from Pangnirtung did more subsistence harvesting of Arctic Char from Ikaluit Lake, while they were in the area to hunt caribou. Presently, with reduced numbers of caribou in the area, people from Pangnirtung no longer travel to Ikaluit Lake to subsistence fish; especially not in the winter as sea ice and snow conditions make travel to that location difficult. In general, the community of Pangnirtung prefers to harvest Arctic Char for subsistence at locations that are closer to their community and from locations where fish have a preferred taste (e.g., Kingnait). There is one family that has an outpost camp at the mouth of Ikaluit Lake River who may harvest Arctic Char for subsistence, but the extent and frequency are unknown. For the purpose of this assessment, we assume that the subsistence harvest level on the Ikaluit Lake Arctic Char stock by the community of Pangnirtung is minimal.

Information on the subsistence harvest of Arctic Char from Ikaluit Lake by fishers from the community of Iqaluit was provided after the meeting by the Amaruq Hunters and Trappers Organization (AHTO). Over the years, the number of families who harvest Arctic Char for subsistence from Ikaluit Lake has not changed very much. The best time to travel to Ikaluit Lake for fishing is April which is also a good time to hunt while in the area. On average annually each family will take approximately 300–500 fish for subsistence. The AHTO estimates that 3,000 lbs of Arctic Char are harvested from Ikaluit Lake annually for subsistence by Iqaluimmuit. The AHTO noted that neither they nor the fishers have noticed any change in the condition or number of fish in Ikaluit Lake.

DATA ANALYSES

Some populations of Arctic Char show no difference in the basic biological parameters (e.g., length, weight) between sexes (Dempson and Green 1985). This is the case for the Ikaluit Lake Arctic Char. When length and weight are log transformed there is no significant difference between the sexes ($p = 0.6$) (statistical analysis completed by Samantha Fulton, DFO Winnipeg, MB). Sexes were either combined or kept separate where appropriate. Additionally, gear type used greatly affects the size of the fish caught (e.g., small mesh sizes catch a higher proportion of small sized fish). When the gear type used was known to influence results it was kept separate, otherwise where applicable, gear type was standardized and/or combined.

Catch-Per-Unit-Effort (CPUE)

Where possible from the fishery-independent data, catch and effort data were recorded for every net set and included: date net set, time net set, date net lifted, time net lifted, number of fish captured from each mesh size, and total number of fish in the net. These data were then used to calculate the CPUE which may be used as an index of abundance in the absence of other independent sources of abundance (Hubert 1996). CPUE data were presented as number of fish caught per hour per 100 m long, 1.83 m high net. When multi-mesh nests were used for fishery-independent data collection CPUE was standardized to 139.7 mm (5.5 inch) mesh (Table 4). Mesh standardization was calculated in the following manner: the catch rate (standardized CPUE) for each mesh size was divided by the catch rate for 139.7 mm mesh nets (Howland 1997).

Table 4. Standardization ratio applied to Catch-Per-Unit-Effort (CPUE) by mesh size for each year a multi-mesh net was used in the fishery-independent datasets. Mesh size was standardized to 139.7 mm (5.5 inch) mesh.

Year	Mesh	Standardization Ratio
2011	1.5	0.54
2011	2.5	0.54
2011	3.5	0.90
2011	4.5	1.12
2011	5.5	1.00

Year	Mesh	Standardization Ratio
2012	1.5	0.48
2012	2.5	0.45
2012	3.5	0.87
2012	4.5	0.76
2012	5.5	1.00
2013	1.5	0.65
2013	2.5	0.49
2013	3.5	0.78
2013	4.5	0.96
2013	5.5	1.00

Weight-Length Relationship

The weight-length analysis shows the relationship between fish fork length and weight and can be used as a measure of condition (Anderson and Neumann 1996). The weight-length relationship was log transformed and then graphed as a scatter plot by year and fit with a power-tend line. The equation used was:

$$LogNatural(y) = a * LogNatural(x)^b$$

where, y = round weight (g), x = fork length (mm) and a and b are parameters. This linear equation provides information on the weight-length relationship as the fish grows. The parameter b changes in relation to the robustness of the fish as length increases. If $b > 3.0$ then fish are more robust as length increases, if $b < 3.0$ the fish are less robust as length increases, and if $b = 3.0$ the shape of the fish does not change with increasing length (Anderson and Neumann 1996).

Length-Frequency Distribution

The annual length-frequency distributions derived from fishery-independent and plant sampling data are presented as histograms by gear type (multi-mesh nets, 139.7 mm nets), sexes combined.

Age-Frequency Distribution

Annual age-frequency of fishery-independent and plant sampling data are presented as distribution histograms in two ways:

1. Gear type and sexes pooled (there was no significant difference between mean age of females and males, $p = 0.2$), allowing for comparison of the annual age-curves.
2. Where multi-mesh nets were used, histograms are presented by gear type, with sexes pooled. This allows for detailed comparison of age-class vulnerability to different mesh sizes.

Trend Analysis

Using fishery-independent and plant sampling data, comparisons of trends were graphed (trend analysis), where mean fork length (mm), mean otolith age (year), mean round weight (g) and mean condition factor (K) were used to assess the response of the Ikaluit Lake Arctic Char to harvest pressure. For these analyses sexes and gear type were pooled. Mean fork length, mean age, mean round weight, and mean condition factor for each year of the fishery-independent data were summarized and compared to the historical fishery data.

Condition factor (K) is an index of the condition (well-being) of a fish which standardizes weight-length interactions (Anderson and Neumann 1996). The formula used for condition factor (K) was:

$$K = \frac{W \times 10^5}{L^3}$$

where, W = round weight (g), L = fish fork length (mm) (Kirstofferson and McGowan 1985, Anderson and Neumann 1996).

Length-at-Age

Mean fork length at age from fishery-independent data is presented as a line graph, where years and sexes were kept separate but gear types (multi-mesh nets, 139.7 mm nets) were combined (it is not necessary to account for gear selectivity in this analysis). Plotting the growth of the sexes separately highlights any differences in length-at-age between the sexes.

Additionally, statistical averages of fish length-at-age and an ANOVA were used to test for the difference between years in fish length-at-age. Sexes and gear type were pooled.

Sex and Maturity

Arctic Char sex ratios (defined as the proportional representation of males to females in the catch) were calculated for each year of the fishery-independent data and compared to the 1977, 1980, and 1990 test fishery data. Sex ratios were calculated for all gear types combined.

The percentage of different maturity stages (immature, mature, resting, unknown), mean age of mature fish, and age at first maturity for the fishery-independent data were determined. There was no maturity stage information provided from the historical fishery data for Ikaluit Lake but comparisons to other populations of Arctic Char in Cumberland Sound can be made.

Catch-Curve

Annual catch curves were constructed using the fishery-independent data and plant data from 2008. Plant data from 2006 could not be used as no ages were available. Gear type and sexes were pooled. The natural log of the age class frequency was plotted against age for each year and linear regression was then applied to fit the descending limb of the catch curve (from modal year class plus one year to the oldest year class where n > 1). Instantaneous mortality (Z), annual survival (S), and annual mortality (A) were determined from the catch curves as follows:

$$Z = positive\ slope\ of\ regression,$$

$S = e^{-Z}$, $A = 1 - S$ (Ricker 1975)

where, A refers to the annual average mortality over the period of time fish were recruited to the fishery.

Additionally, data from years that were close together were pooled (2000 and 2001; 2005 and 2008; 2011, 2012 and 2013) and catch curves were graphed.

Abundance Modelling

In the absence of information from fish counting facilities, mark-recapture, or other methods such as acoustic techniques, it is difficult to provide advice on the current abundance of the Ikaluit Lake Arctic Char population. However, using information that is available from various sampling programs, it is possible to provide a plausible range of what the population size could be in recent years. Fishery-independent and fishery-dependent data were used in the abundance model, and estimates of subsistence harvest were provided by the Pangnirtung and Amaruq Hunters and Trappers Organization for Pangnirtung and Iqaluit, respectively.

An estimate of the commercial harvest at Ikaluit Lake is available as the fishery is under quota control. In addition, estimates of total instantaneous mortality (Z), derived from catch-curves (Ricker 1975), can be obtained from the fishery-independent data collected in recent years. Given an assumed range of natural mortality (M), estimates of fishing mortality (F) can then be determined. Local knowledge indicates that the subsistence harvest at Ikaluit Lake could be equal to, or up to four times greater than the commercial catch. Accordingly, these data are used to infer a potential range of population size. However, given the limitations with the data, caution is advised so as not to interpret results as a definitive estimate of the current abundance.

The abundance model used is commonly called the Baranov catch equation (Ricker 1975, Liu and Heino 2014):

$$Catch = \frac{FAN}{Z}$$

where A = $(1 - e^{-Z})$, the annual mortality rate. Rearranging the equation allows solving for N, the size of the population. In the current situation catch has two components, commercial (C) and subsistence (S), thus total catch (TC) = C + S. Therefore,

$$N = \frac{(TC * Z)}{(F * A)}$$

Liu and Heino (2014) report that the Baranov catch equation can still provide a good approximation even in situations where the assumption of constant fishing mortality is violated.

RESULTS

HARVEST INFORMATION

The test fishery data were collected in 1977, 1980, and 1990 (Table 2). Sampling was completed in the summer in 1977 and it is assumed that the sampling location was in the fiord/river (saltwater environment) (Kristofferson and McGowan 1981). Sampling in 1980 (McGowan 1985) and 1990 (McGowan et al. 1993) were completed in the winter and were limited to the lake (freshwater environment).

Fishery-independent data were collected in the summer of 2000, 2001, and 2005 and in the winter of 2011, 2012, and 2013 (Table 3). Summer sampling was limited to the saltwater environment, while winter sampling was limited to the freshwater environment (Table 3, Figure 2). The number of fish captured ranged from n = 134 in 2001 to n = 197 in 2013. The type of gear used changed over the years, see Table 1 for details.

Historically this waterbody was mostly a winter fishery, but since 1996/1997 licence year it has developed into a summer fishery (Table 1). There have been 7 years where harvest was reported to be in excess of the quota, see Table 1 for details. The total harvest removed from Ikaluit Lake since 1977 from all sources (test fishery sampling, fishery-independent sampling, exploratory and commercial harvests) was 37,324 kg (82,113 lbs) round weight. Since 2006/2007 licence year the average annual harvest from the exploratory fishery was 1,058 kg (2,327 lbs) round weight (calculated from Table 1).

DATA ANALYSIS

Catch-Per-Unit-Effort (CPUE)

For CPUE only the test fishery data and fishery-independent data were used as no CPUE could be determined for fishery-dependent data or plant sampling data. It can be stated that the average CPUE has decreased over time, but with variability (Figure 3). There is a large amount of variability in the CPUE from the fishery-independent data that was collected in the summer in the saltwater environment (2000, 2001, and 2005). In contrast, there is very little variability in the CPUE for fishery-independent data collected in the winter (2011, 2012, and 2013). The highest CPUE was recorded in 2001, while the lowest CPUE was recorded in 2011 (Figure 3). When comparing the three most recent years (all winter samples), it appears that CPUE is stable at a lower level.

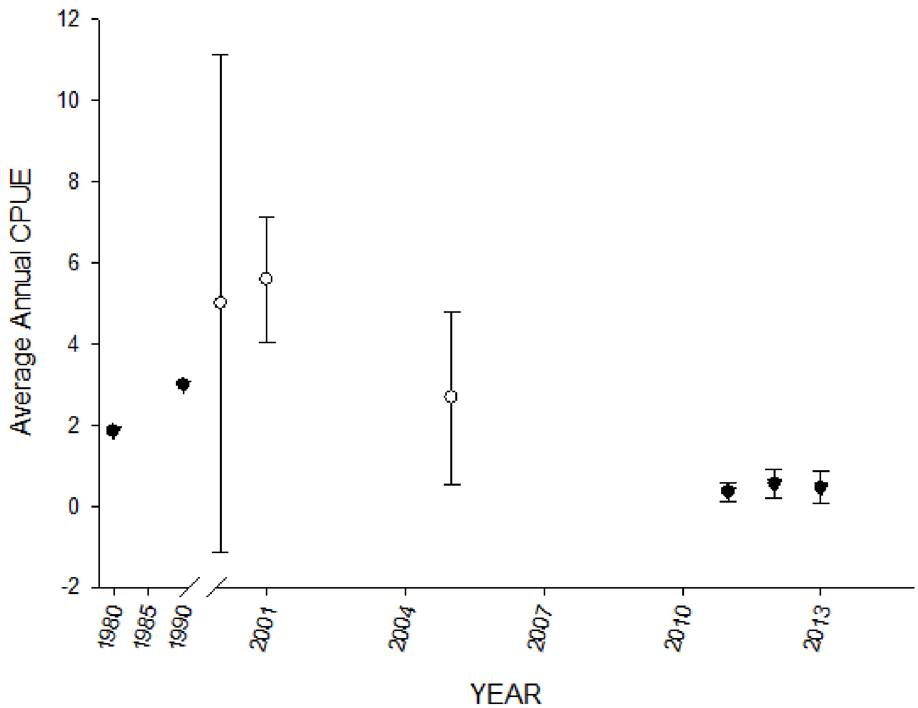

Figure 3. Catch Per Unit Effort (CPUE) for Ikaluit Lake, average annual CPUE with standard deviation error bars. 1980, 1990, 2011, 2012 and 2013 were all winter sampling in the freshwater lake environment (closed circles symbol); 2000, 2001, 2005 were all summer sampling done in the estuary environment (open circle symbol). The 1980 data came from McGowan 1985; the 1990 data came from McGowan et. al. 1993; all other data was from fishery-independent surveys conducted by DFO.

Weight-Length Relationships

For the weight-length relationships fishery-independent data and plant sampling data from 2008 were used. Over all the years, there appears to be no trend in the weight-length relationship, indicating that the size of the fish is consistent. For years (2000, 2001, 2005, and 2008) when only single mesh 139.7mm (5.5 inch) nets were used, fork length increased faster than round weight, meaning fish robustness decreased with fork length ($b < 3.0$) (Figure 4). In contrast, in years when multi-mesh nets were used (2011, 2012, and 2013, gear types pooled) round weight increased faster than fork length, meaning fish robustness increased with fork length ($b > 3.0$).

This observation is supported by the b parameter in the power trend-line of the graphs (top right-hand corner on each graph). The R^2 values (top right-hand corner of each graph) indicate that the power trend line is a good or reasonable fit to all the data; but, the power-trend line fits the pooled multi-mesh data better than the single mesh data.

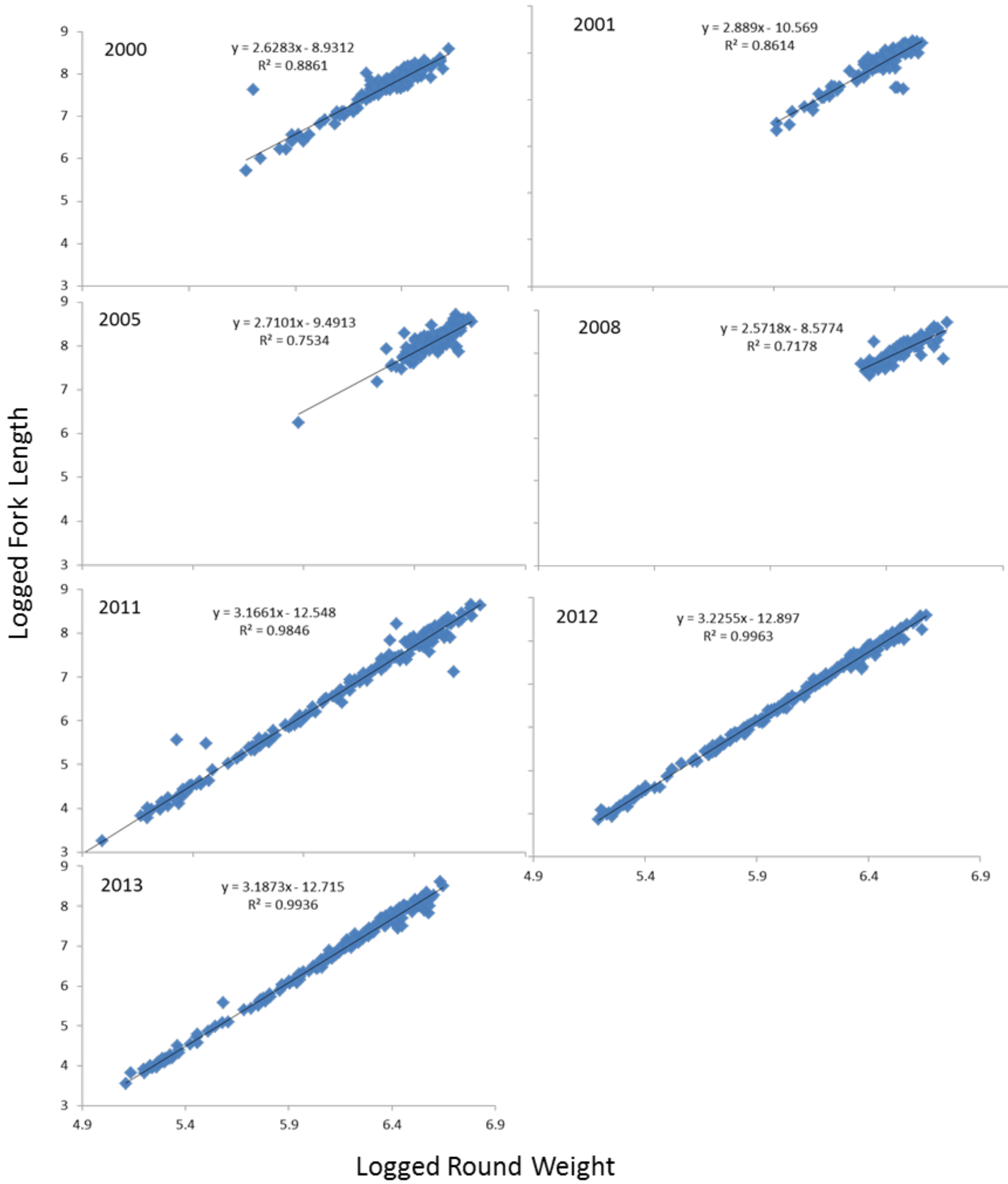

Figure 4. The Log Natural Length-Weight relationship of Ikaluit Lake (Robert Peel Inlet) Arctic Char from plant sampling data (2008) and fishery–independent data (2000, 2001, 2005, 2011, 2012, 2013). Sexes and gear type have been pooled. Power trend-lines have been applied to each graph, the equation of the power line and the associated R^2 value are presented on each graph.

Length-Frequency Distribution

For the length-frequency distributions, fishery-independent data and plant sampling data were used. Due to variation in sampling (summer vs winter, different mesh sizes used) it is difficult to determine if there is any trend, although what can be stated is that the modal size from 2000 to 2008 seems to be consistent. The modal peak in fork length of the single mesh nets is consistently around 600 mm, while the multi-mesh nets show no consistent modal peak. The length-frequency distributions show annual variation within and among gear types (single mesh nets, multi-mesh nets) (Figure 5). The range in fork length from single mesh nets (2000, 2001, 2005, 2006, and 2008) appears to be limited to larger fish. No fish under the fork length of 250 mm was captured in the single mesh nets. Whereas, the multi-mesh nets (2011, 2012 and 2013) show a wider range in the fork length distribution, from 125 mm to 800 mm. Further, single mesh nets have more bell-shaped distributions, while the multi-mesh nets do not have a bell-shaped curve.

Age-Frequency Distribution

For the age-frequency distributions fishery-independent data and plant sampling data from 2008 were used. No significant difference between mean age of females and males was found (ANCOVA $p = 0.2$); therefore, all sexes were pooled for this analysis. Between sampling years there is some variability in the age-frequency distributions (Figure 6). The age range from the single mesh nets (2000, 2001, 2005, and 2008) is skewed to larger fish; no fish younger than age 6 was captured in these nets. The age ranges from the multi-mesh nets extend from age four to 19 years and are slightly skewed to the left. Over all the years the range in ages remains consistent from year-to-year indicating that there is no change in the age structure of the Ikaluit Lake stock. In most years fish ranged from age 4–23.

From these graphs age classes can be followed throughout the years. Specifically, 1990 may have been a strong year class, appearing in 2000 as age class 10 and in 2001 as age class 11. Additionally, the presence of young fish (< age 6) indicates successful recruitment occurred.

To remove age selected bias of the different mesh sizes, the modal age from fish captured in mesh size 139.7 mm (5.5 inch) over all years was compared: 2000 modal age = 10; 2001 modal age = 11; 2005 modal age = 13; 2008 modal age = 11; 2011 modal age = 11; 2012 modal age = 9; and 2013 modal age = 13. There is no trend in the modal age of fish captured in 139.7mm mesh nets since 2000.

The age distribution of fish captured in the different mesh sizes of the multi-mesh nets is illustrated in Figure 7. Mesh size 63.5 mm captured the most fish (n = 57 in 2011, n = 64 in 2012 and n = 63 in 2013); whereas, mesh size 139.7 mm captured the fewest fish (n = 20 in 2011, n = 14 in 2012 and n = 16 in 2013). In addition to capturing the most fish, mesh size 63.5 mm also captured the largest range of fish, age four to 19 years. Sample year 2011 shows that, younger fish are captured in the smaller mesh sizes, and the older fish in the larger mesh sizes. This trend was not noticed in sample years 2012 and 2013.

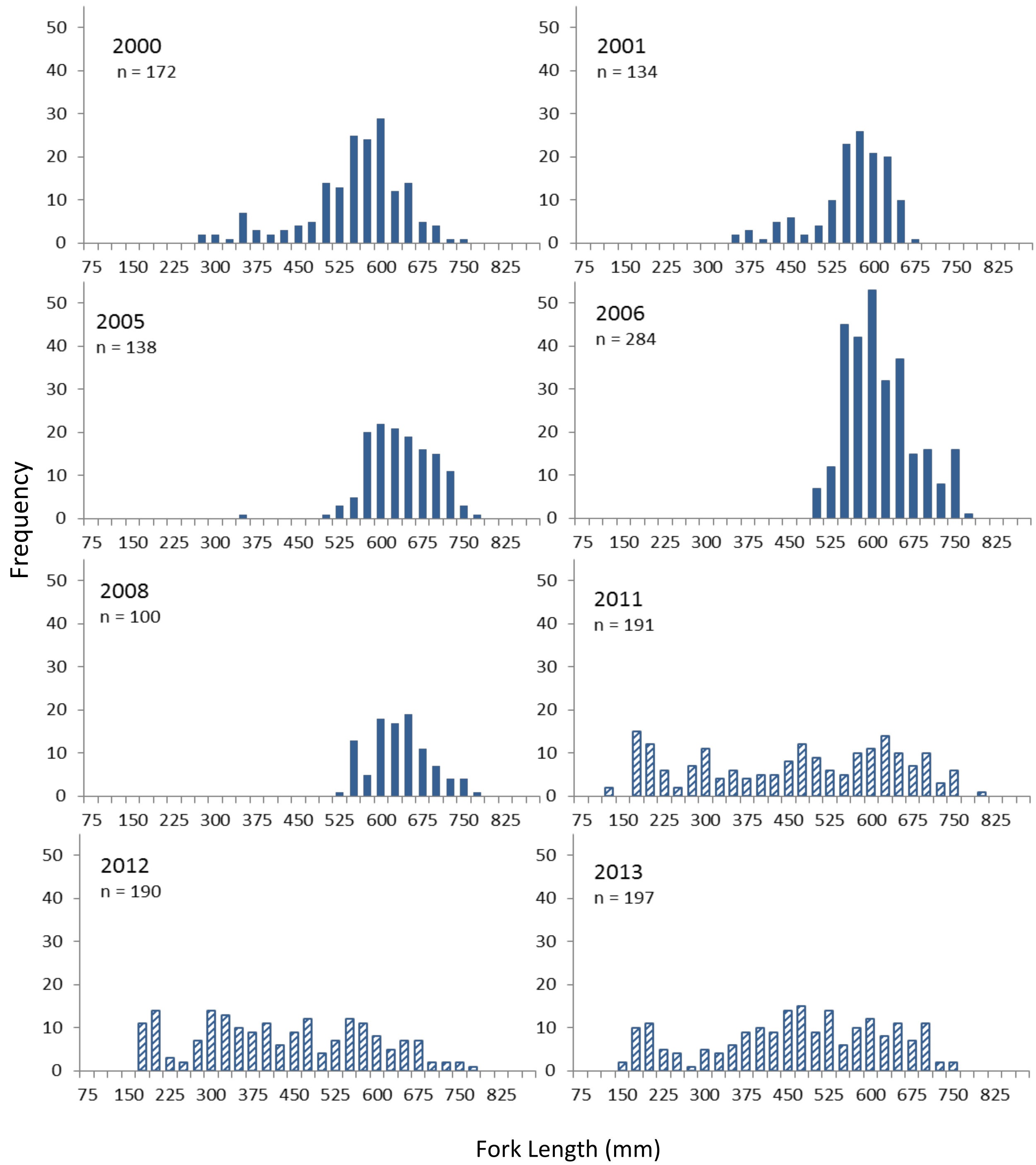

Figure 5. Length-frequency distributions of Arctic Char from Ikaluit Lake (Robert Peel Inlet) fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013) sexes pooled and plant sampling data (2006, 2008) sexes combined. Solid lined data represents 139.7 mm mesh nets, hash lined data represents multi-mesh nets (38.1–139.7 mm), n = sample size.

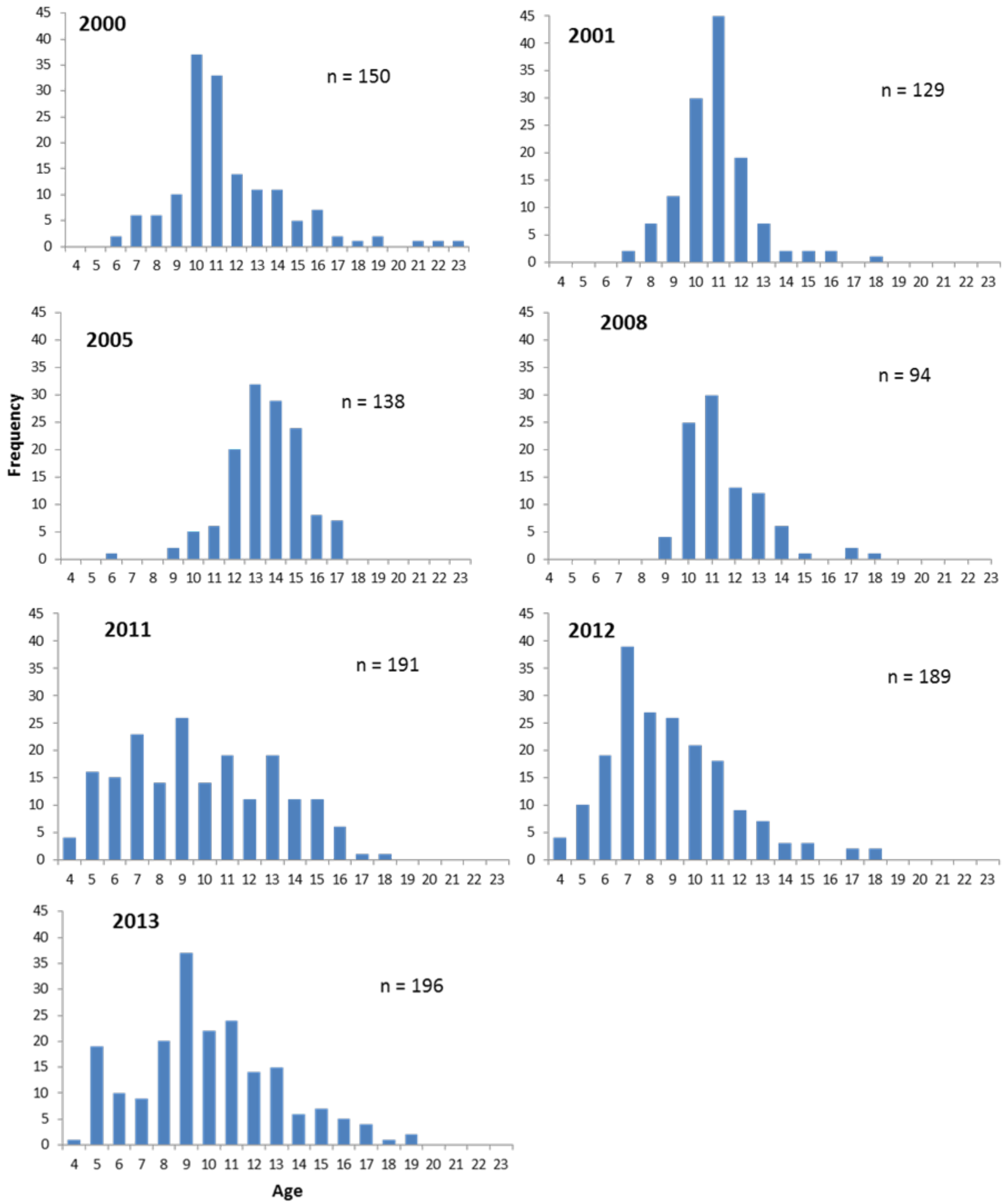

Figure 6. Age-frequency distributions of Arctic Char from Ikaluit Lake (Robert Peel Inlet) fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013) and plant data (2008), gear type and fish sex pooled, n = sample size. Graph made by E. Sudlovenick (Fisheries and Oceans, 630 Mivvik, Iqaluit, NU).

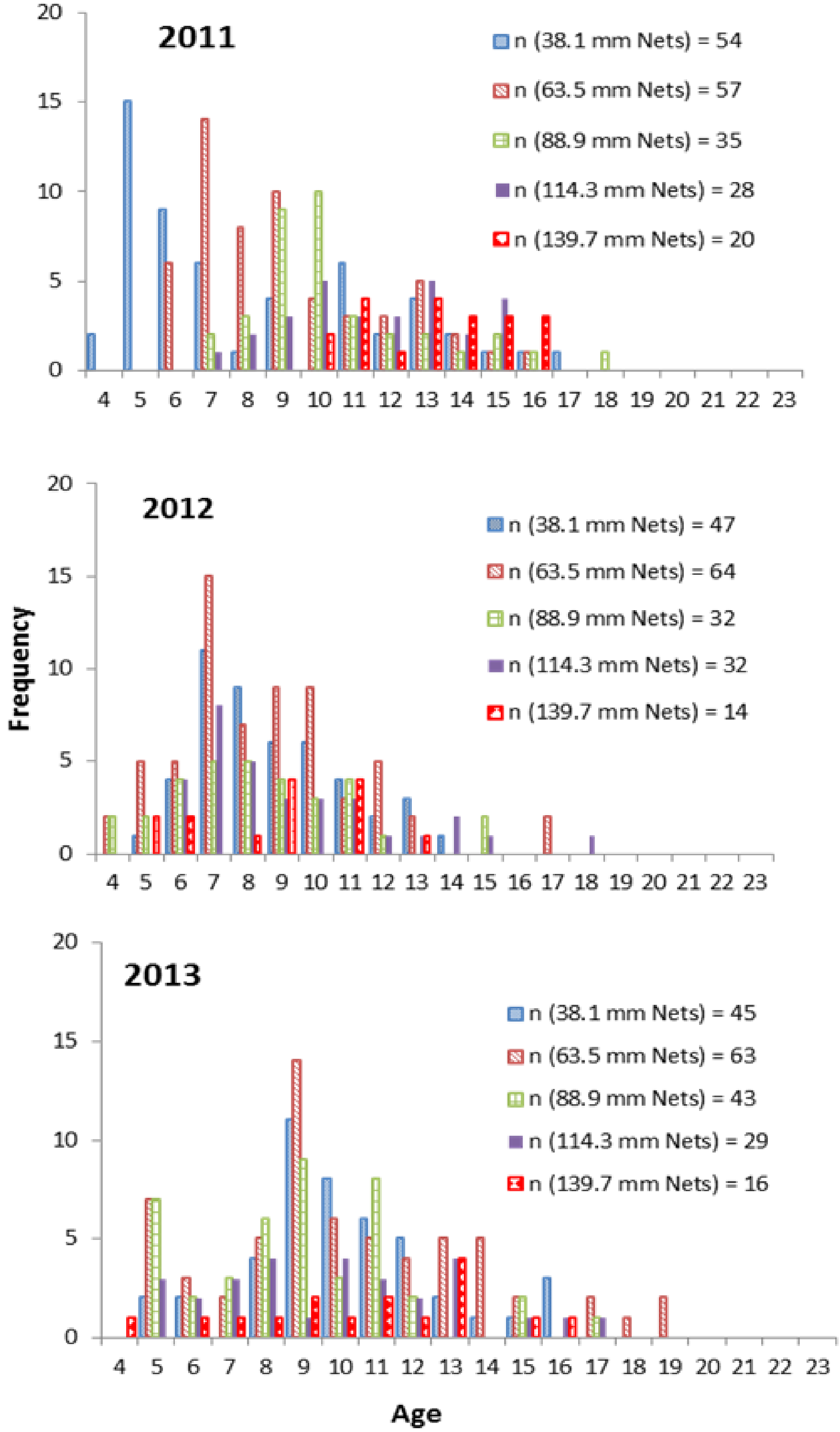

Figure 7. Age-frequency distributions by mesh size of Arctic Char from Ikaluit Lake (Robert Peel Inlet) fishery-independent data, n = sample size. Graph made by E. Sudlovenick (Fisheries and Oceans, 630 Mivvik, Iqaluit, NU).

Trend Analysis

Fishery-independent data, test fishery data and plant data were used where applicable for the trend analysis.

Mean fork length (mm) (Figure 8) for fish captured in single mesh nets (1977, 1980, 1990, 2000, 2001, 2005, 2006 and 2008) were consistent over time, ranging from 562 mm in 2000 to 674 mm in 1977. In contrast, the mean fork length of fish captured in the multi-mesh nets (2011, 2012 and 2013) ranged from 445 mm in 2012 to 478 mm in 2013. Despite the difference in mean fork length the standard error bars from all years overlap, indicating that there is neither a trend nor a change in the mean fork length over time and suggests that the length of fish has remained relatively stable over time.

Mean age (years) (Figure 8) of fish captured in Ikaluit Lake shows a decreasing trend. The single mesh nets show older fish being caught in 1977 (mean age 17) and younger fish being caught in 2001 (mean age 11). It should be noted that the methods and age readers were not consistent from the 1977 to 2001. This inconsistency is not believed to account for the 6 year age difference, therefore there is perhaps a true trend of decreasing overall mean age in the Ikaluit Lake Arctic Char stock. The multi-mesh nets have a lower mean age (age 9–10) with less annual variability compared to the single mesh nets. Despite the overall decrease in mean age, the standard error bars overlap, leading to the conclusion that overall age distribution of the stock has remained relatively stable.

Mean round weight (g) (Figure 8) shows an overall decreasing trend from year to year, with standard error bars that overlap. Gear type, sampling location, and timing of sampling changed over the years (Table 1, Table 2). Comparing within gear types alone there is no trend in mean round weight. The lack of trend in the mean round weight when comparing within gear types also suggests that the size of Arctic Char has remained stable over time.

Mean condition factor (K) (Figure 8) for the Ikaluit Lake Arctic Char stock also appears to be stable over time. Although there is annual variability, overall there is no trend. The lowest mean condition factor values with the least amount of annual variability were measured in recent years (2011–2013). Sampling in these years took place in the lake environment in the winter. In contrast, 2001 measured the highest mean condition factor with the greatest amount of variability; where samples were taken in the summer in the saltwater environment.

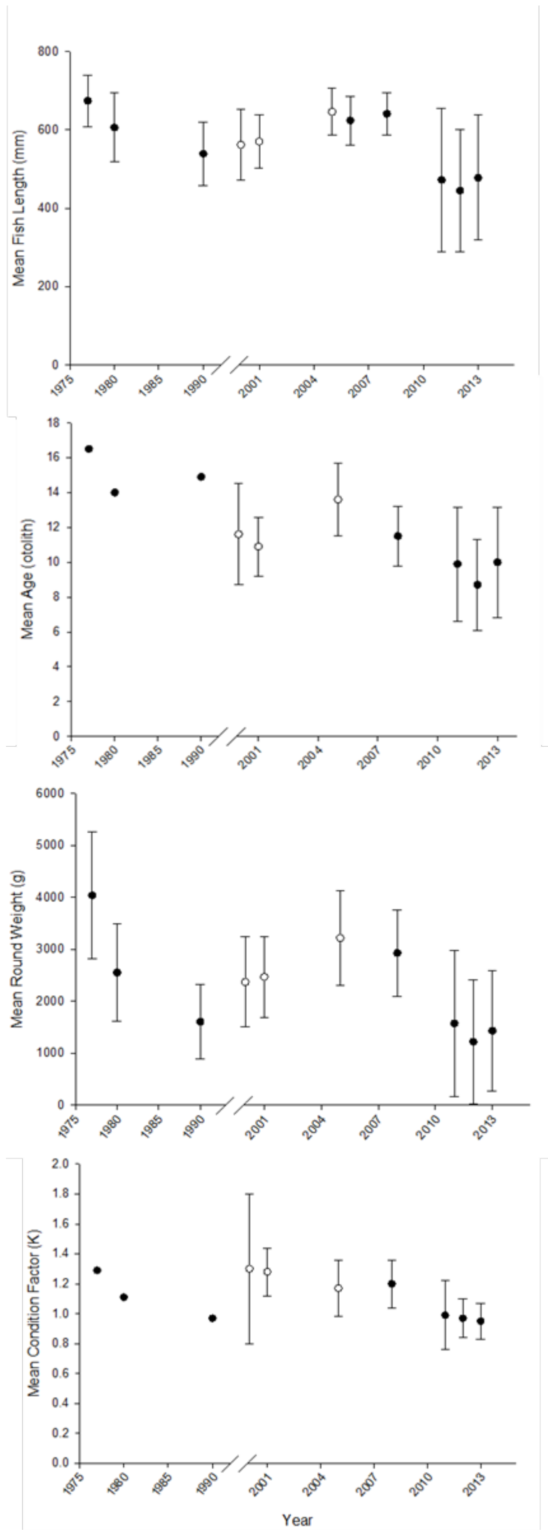

Figure 8. Trend analysis – plot of means (fork length mm, age year, round weight g, condition factor K) from test fishery (1977- Kristofferson and McGowan 1981; 1980 – McGowan 1985; 1990 – McGowan et. al. 1993) fishery-independent (2000, 2001, 2005, 2011, 2012, 2013) and plant data (2006, 2008). Standard error bars of the mean included. Closed circles represent winter fishing, open circles represent summer fishing. Single mesh nets were used in every year except 2011, 2012 and 2013 when multi-mesh nets were used.

Empirical Growth Model: Length-at-age

Fishery-independent data was used for this analysis, all other data were insufficient.

The mean length-at-age (Figure 9) appears to be increasing from year-to-year. The statistical average of length-at-age shows that in 2000, fish aged 15 have a mean fork length of 619 mm (n = 5); whereas, in 2012 fish aged 15 have a mean fork length of 712 mm (n = 3). To test this further an ANOVA comparing age 11 fish caught in 139.7 mm (5.5 inch) mesh nets over the years were compared. Overall the fork length of age 11 fish was significantly different ($p = 2.2e^{-16}$), but interestingly the pairwise comparison indicates that it was the 2008 plant data that differed from the two years of the fisheries-independent data (2000 and 2005). All other years were found to be not significantly different (Table 5).

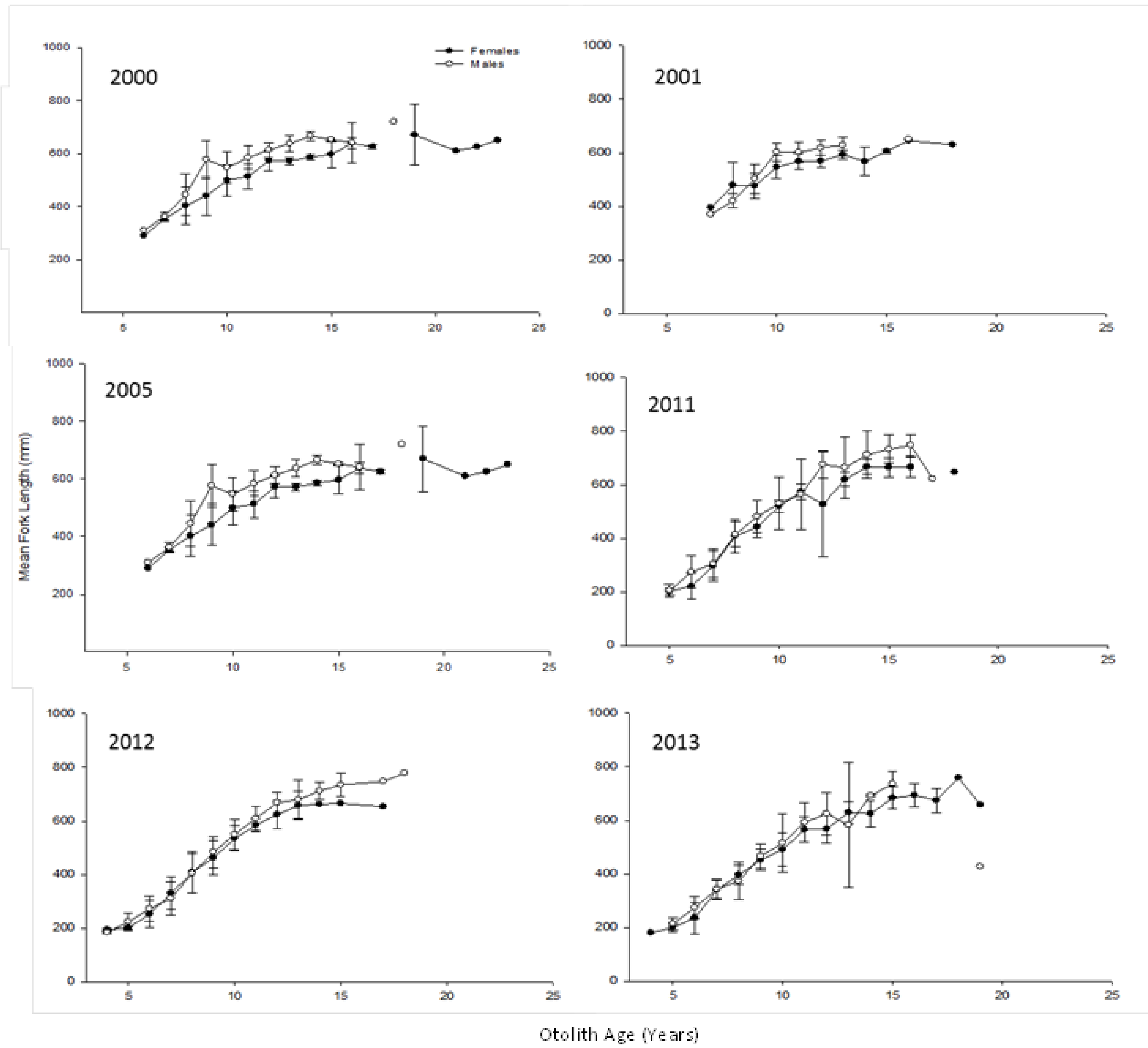

Figure 9. Mean fork length at age from fishery-independent data by year and sex. Standard deviation bars included.

Table 5. Tukey's Pairwise comparison of the means – fork length of age 11 fish caught in 139.7 mm mesh nets, from fishery-independent and plant sampling datasets.

	2000	2001	2005	2008	2011	2012	2013
2000	-	NS	NS	NS	NS	NS	NS
2001	NS	-	NS	$1.0e^{-06}$	NS	NS	NS
2005	NS	NS	-	0.05	NS	NS	NS
2008	NS	$1.0e^{-06}$	0.05	-	NS	NS	NS
2011	NS	NS	NS	NS	-	NS	NS
2012	NS	NS	NS	NS	NS	-	NS
2013	NS	NS	NS	NS	NS	NS	-

Females have a shorter mean fork length compared to males (females: 502.4 mm; males: 536.6 mm), but as previously indicated the fork length between males and females is not significantly different ($p = 0.6$). For both sexes, fish fork length asymptotes at approximately age 14 and fish length of 619 mm and 695 mm for females and males, respectively.

Sex and Maturity

Fishery-independent data and test fishery data are presented here; no other data included sex and maturity information.

Sex ratio data for Ikaluit Lake Arctic Char presented in Table 6 have gear type pooled. The mean sex ratio for all years was 1.6, meaning that overall there were more males than females caught, with the exception of 1990 and 2013 (Table 6). There was some variability over the years. The lowest sex ratio 0.75 was calculated in 1990, the highest sex ratio 3.6 was calculated in 1977. If grouped by timing of sampling, the lowest sex ratios were calculated from winter samples (1980, 1990, 2011, 2012 and 2013); the highest sex ratios were calculated from summer samples (1977, 2000, 2001, and 2005). However, overall the sex ratio appears to be declining, indicating that the stock sex ratio may be changing. From the data available it is unclear if the decreasing sex ratio is a product of sampling or a true representation of a shift in the Ikaluit Lake Arctic Char stock.

Table 6. Summary of the sex and maturity of Arctic Char captured in Ikaluit Lake (Robert Peel Inlet) from test fishery data (1977, 1980, 1990 - Kristofferson and McGowan 1981; McGowan 1985; McGowan et al. 1993) and fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013). Data from all nets have been pooled.

Year	Sex			Ratio M:F	Maturity Percentage					Mean Age of Maturity		Age at First Maturity	
	Male	Female	Unknown		Immature	Mature	Resting	Spent	Unknown	M	F	M	F
1977	40	11	-	3.6	-	-	-	-	-	-	-	-	-
1980	64	36	-	1.8	-	-	-	-	-	-	-	-	-
1990	36	48	-	0.75	-	-	-	-	-	-	-	-	-
2000	110	61	-	1.8	71	29	-	-	-	12.4	13.8	9	8
2001	81	53	-	1.5	39	44	15	-	2	11.3	11.0	8	7
2005	83	54	-	1.5	1	3	96	-	-	13.7	13.8	9	9
2011	98	82	11	1.2	38	29	22	6	5	11.9	12.1	7	8
2012	102	88	-	1.2	58	22	20	-	-	11.0	11.1	8	8
2013	97	100	-	0.97	48	1	51	-	-	11.3	12.9	7	8
Average	79.0	59.2	11	1.6	42.5	21.3	33.8	6	3.5	11.9	12.5	8	8

Maturity stage data were only available from the fishery-independent data. The majority of fish captured in all years were recorded as immature, mature, resting or spent (Table 6). On average, immature fish made up 42.5% of the catch, ranging from 1% in 2005 to 71% in 2000. The 2000 maturity stage data should be used with caution, it is believed that larger fish (>500 mm) who were classified as immature should have been classified as resting. Mature fish (current year spawners) on average made up 21.3% of the catch, ranging from 1% in 2013 to 44% in 2001. Resting fish on average made up 33.8% of the catch, ranging from 15% in 2001 to 96% in 2005. The variation in the range of maturity levels annually is most likely a by-product of sampling difference (season, location) and sampler's ability to determine maturity stage accurately. It is best to use the average of the maturity ratios and to use them with caution.

For the mean age of maturity, only fishery-independent data were used (Table 6). The mean age of mature females ranged from 11.0 (2001) to 13.8 (2005); while the mean age of mature males ranged from 11.0 (2012) to 13.7 (2005). Females on average had a slightly higher age-at-maturity (12.5) compared to males (11.9). The age-at-first maturity for females and males ranged from 7–9, with the average age-at-first maturity being 8.

Catch Curve

Fishery-independent data and plant data from 2008 were used for the catch curves and mortality estimates.

The catch curves of the Ikaluit Lake Arctic Char stock appear to be stable (Figure 10).

Instantaneous mortality (Z) shows little variability among years and ranges from 0.1075 in 2011 to 0.2217 in 2001 (Table 7). It should be noted that the 2000 fishery-independent data were taken at the same time as the commercial harvest and 2001 had the highest instantaneous mortality.

Data from the pooled catch curves (Figure 11) show instantaneous mortality rates that are higher than any single year. The pooled data from 2000 and 2001 has the highest instantaneous mortality rate (Z = 0.3688) while the pooled data from 2005 and 2008 have a lower instantaneous mortality rate (Z = 0.2008).

No trends in mortality (annual or instantaneous) or survival could be resolved from these data but overall, it appears that survival is high and mortality is moderately low.

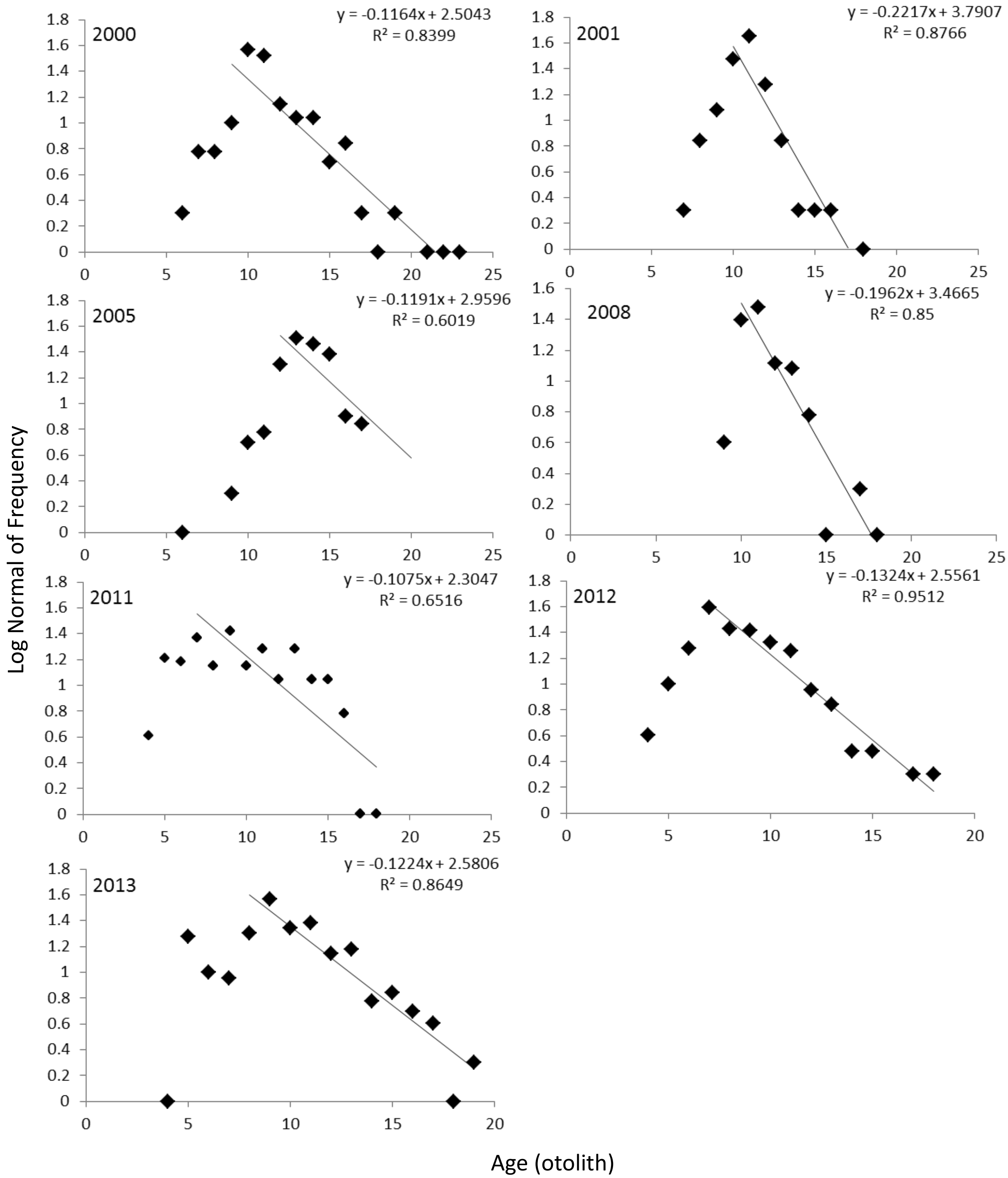

Figure 10. Annual age frequency catch curves for Arctic Char from Ikaluit Lake (Robert Peel Inlet), fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013) and plant data (2008). Linear regression is applied to the descending part of the curve, line equation and fit of the trend line are present on the graph.

Table 7. Calculations of the instantaneous mortality (Z), rate of survival (S) and annual total mortality (A) for Arctic Char from Ikaluit Lake (Robert Peel Inlet), both fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013) and plant data (2008) are presented annually. Sex and gear type are pooled.

Year	Instantaneous Mortality Z	Rate of Survival S	Annual Total Mortality A
2000	0.1164	0.8901	0.1099
2001	0.2217	0.8012	0.1988
2005	0.1191	0.8877	0.1123
2008	0.1962	0.8218	0.1782
2011	0.1075	0.8981	0.1019
2012	0.1324	0.8760	0.1240
2013	0.1224	0.8848	0.1152

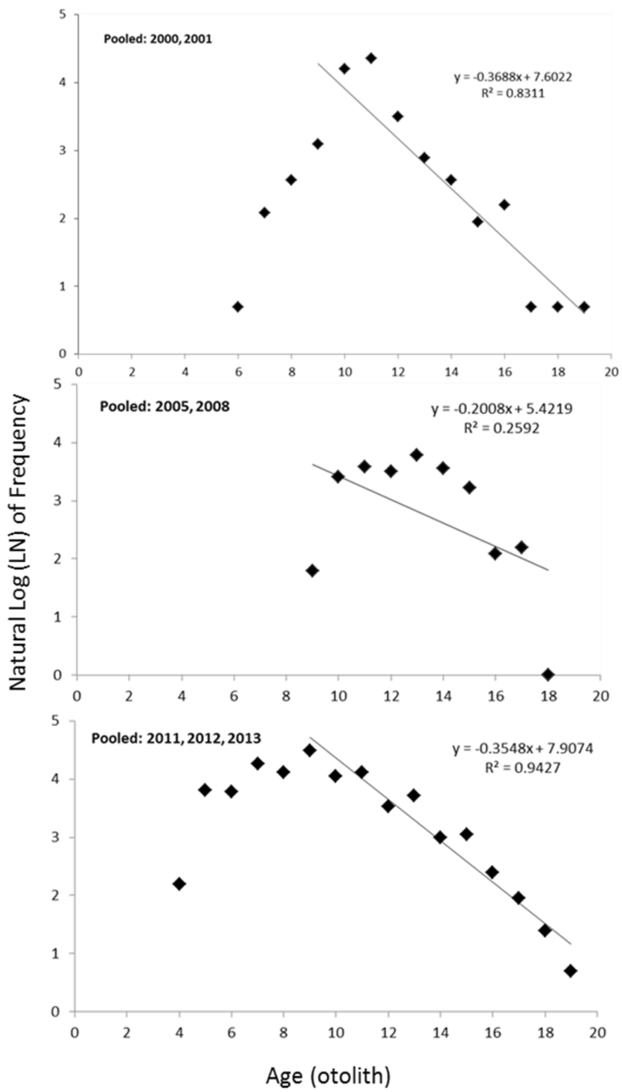

Figure 11. Pooled annual age frequency catch curves for Arctic Char from Ikaluit Lake (Robert Peel Inlet), fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013) and plant data (2008). Linear regression is applied to the descending part of the curve, line equation and fit of the trend line are present on the graph.

Abundance Modelling

Fishery-independent data, fishery-dependent data and estimates of subsistence harvest were used in the abundance model.

To estimate population size (N), we allowed the rate of natural mortality (M) to vary uniformly between 0.12 and 0.18. The total catch (TC) was equal to the average commercial harvest over the past five years (950 kg, or approximately 328 fish by number), plus the subsistence harvest that was also allowed to vary uniformly from one (equal to) to four times the commercial harvest. Total mortality (Z) was estimated from a catch curve pooled over the 2011 to 2013 years for fish ages nine to 19 years. Pooling was done to compensate for variations in recruitment or low sample size (Miranda and Bettoli 2007). For the modelling process, Z was randomly drawn from a normal distribution based on the estimated value of Z from the slope of the catch curve and its standard error ($Z = 0.355 \pm 0.29$). Two-thousand realizations were run to provide a distribution of possible population sizes.

The following summarizes the median (50th percentile) along with the 10th and 90th percentiles of the estimated population size in numbers of fish (Table 8). With this approach the median abundance is 6,588 Arctic Char and would pertain to the overall range of fish sizes taken in both subsistence and commercial fisheries gear. It has been found that harvest levels of 10% or higher are excessive for anadromous Arctic Char populations (Johnson 1980). In response, a harvest level of 5% has been proposed to be sustainable for anadromous Arctic Char populations but this remains to be tested (DFO 2009, Tallman et al. 2015). Applying a harvest level of 5% (the 'Tallman rule') would suggest a commercial catch of 329 fish is sustainable. This is similar to the current commercial quota of 1,000 kg, or approximately 345 individual Arctic Char based on a mean weight of 2.9 kg.

Table 8. Abundance modelling summary of the percentiles of estimated population size (number of fish) from a combination of fishery-independent data (2000, 2001, 2005, 2011, 2012, 2013), fishery-dependent data (compiled from the DFO Fisheries Management and Harvest Information System ((FMHIS)) database from 1988–2014), and estimates of subsistence harvest (provided by the Pangnirtung and Amaruq Hunters and Trappers Organization for Pangnirtung and Iqaluit, respectively).

Percentile	N	Tallman rule (5%)
10th	4,288	214.4
50th	6,588	329.4
90th	9,594	479.7

The addition of a subsistence harvest four times that of the commercial catch would also mean that overall harvest rates on the Ikaluit Lake population could be 20% based on the median values. It is expected that the mean size of Arctic Char caught in the subsistence fishery would likely be smaller than those captured using 139.7 mm mesh commercial gill nets.

DISCUSSION

The results from this assessment suggest that the Ikaluit Lake Arctic Char stock is stable under present harvest levels. Consistency among recent years in CPUE data, weight-length relationships, length-frequency distributions, age-frequency distributions, mean trend data, length-at-age data, and age-at-maturity data support this conclusion. However, there are some signs that the stock is changing in response to fishing pressure as seen in the catch curves and the instantaneous mortality rates over the years. If applying the ‘Tallman Rule’ to the abundance model, current harvest rates (not including subsistence fishing) are sustainable for the stock. When subsistence fishing estimates are factored into the model it is clear that the stock is under significant harvest pressure.

Annual CPUE is highly variable with a large amount of uncertainty due to seasonal, sampling, and equipment inconsistencies. It appears that overall, there is a declining trend in the CPUE until 2011, at which point CPUE stabilizes at a lower level. This declining trend is most likely a product of inconsistencies in data collection. Looking at only the last three years of data collection (the fishery-independent study design where gear type and study season were consistent), CPUE was stable. The conclusion that there has been no change in the catch rates over the last three sampling years thus no perceived change in the abundance, means the Ikaluit Lake stock is able to support present harvest levels (Hubert 1996). Higher catch rates with more variability were recorded in summer sampling years compared to winter sampling years. This seasonal difference in catch rates is most likely a product of the time and location of sampling. Often with summer sampling, nets were only wet during high tide (12 hours out of a 24-hour period); whereas, the winter sampling nets would be wet for the entire duration of the set. This difference in soak time between seasons cannot be corrected for within the given data, but it is acknowledged that soak time differed between seasons and this difference most likely affects CPUE rates. Sampling in the summer was conducted in the saltwater environment (mouth of river, fiord) and the Arctic Char were captured on their return migration. If the neap tide was sampled this may greatly overestimate the CPUE, but if the neap tide was not sampled this may greatly underestimate the CPUE. In contrast, sampling in the freshwater environment (lake) in the winter is thought to provide more reliable CPUE estimates as all individuals are assumed to be in the lake and therefore, a representative sample of the whole population can be collected, as opposed to sampling in a short period of time during a fish migration and potentially catching a sub-sample of the whole population.

The weight-length relationships show no trend, from which it can be concluded that the Ikaluit Lake stock is stable. There is a difference in fish robustness between sampling years that is most likely a by-product of the gear type used. In 2000, 2001 and 2005 only large mesh nets were used (single mesh 139.7 mm) which catch larger and older fish who may no longer be at their optimal growth, thus showing a decrease in robustness with increased fork length. In contrast, in 2011, 2012, and 2013, multi-mesh nets (38.1 mm–139.7 mm mesh nets) were used which sample a wider length range of the stock. The data from these years show that fish robustness increases with fork length. Looking at the most recent and comprehensive data (widest fork length range) it appears that the Ikaluit Lake Arctic Char stock is healthy, this is concluded from the fact that fish robustness increases with fork length.

Length-frequency distributions reflect interactions between rates of reproduction, recruitment, growth, and mortality of age groups (Anderson and Neumann 1996). Monitoring the change in length-frequency over time can help in understanding the dynamics of a fish population and can help in identifying problems such as year class failure, slow growth, or excessive annual mortality (Anderson and Neumann 1996). The length-frequency distributions of Ikaluit Lake Arctic Char show high variability which is most likely the result of gear type size selectivity and timing of sampling. Gill nets are designed to be size selective, meaning larger mesh nets should primarily capture larger fish, while smaller mesh nets should capture smaller fish. The fact that different nets with different mesh sizes were used in different years makes it difficult to compare annual length-frequency distributions. From the single mesh net catches, it can be determined that fish become vulnerable to the fishery when they reach an approximate fork length of 400 mm. In addition to gear type differences, there were differences in the timing and location of sampling, which can affect the size of fish captured. As mentioned above, in summer sampling years Arctic Char were captured in the saltwater environment during their migration to fresh water. There is natural annual variability in the timing of Arctic Char migration back to fresh water (Moore 1975a) which is attributed to the variability of the environmental cues that signal fish to return. Depending on environmental signaling and the timing of the fishery-independent data collection, different portions of the stock may have been sampled in different years as Arctic Char in Cumberland Sound are believed to have stratified migrations. Stratified migrations occur when a species migrates in groups such as, small fish first, big fish last or males first, females last. The behavior of stratified migration is noted in many Arctic migrating fish species (Moore 1975b, VanGerwen-Toyne et al. 2008, Martin 2010). In contrast to the summer sampling, in the winter sampling it is assumed that Arctic Char are randomly and evenly distributed throughout a lake, but this may not be the case for Arctic Char. New emerging research is showing that Arctic Char may size segregate within a lake environment (A. Young, University of Manitoba, pers. comm.). All this information together, makes it difficult to compare year by year length-frequency distributions. Despite these data limitations, the range of fish fork length can be compared year-to-year. It appears that when factoring for the gear type used there is consistency in the range of fish length, which indicates that there is stability in the Ikaluit Lake Arctic Char stock.

Age-frequency distributions allow for the comparison of relative abundance of age-groups (year classes) within the catch. Consecutive years of age data allow the abundance of year-class to be tracked through time. Tracking year classes through time and comparing them to other year classes of the same stock provides general information on year-class strength, year-class abundance, and year-class mortality over time (Smith 1994). The overall range in age distributions between gear types and the shape of the distributions within gear types appears to be consistent, providing evidence that the Ikaluit Lake Arctic Char stock is stable. The overall age range has remained between four to 23 years, despite variation in sampling. In 2012, there was a higher proportion of younger fish captured compared to early years (2001). This may be a by-product of the gear type used, timing of sampling (summer vs winter) and/or the location of sampling (lake vs. mouth of the river) or it may be a stock response to fishing pressure. When harvest begins on a stock, the older fish are removed and the relative proportion of younger fish increases either due to higher recruitment rates or because fish are maturing at an earlier age; this is known as the ‘fishing up’ effect (Smith 1994). The effect of ‘fishing up’ is not fully realized in a stock until as many years of harvest pass as there are ages classes in the stock. After the ‘fishing up’ period has passed, the harvested portion of the stock will be younger and smaller than the initial catches (Smith 1994). Due to the difference in sampling between years it cannot be concluded that the increased presence of younger fish in recent years is a true trend of the stock structure change or a by-product of inconsistent sampling methods. However, it can be concluded that the consistent age range and the presence of young fish supports the statement that the Ikaluit Lake Arctic Char stock is stable and shows signs of recruitment.

The mean trend data (fork length, age, round weight and condition factor) is highly variable but shows no overall trend. The variance in mean fork length and mean round weight is greatly biased by the use of different gear types and sampling at different times and locations in the environment. The variance in mean age may be a by-product of the different gear type used; smaller mesh nets used in recent years captured smaller and younger fish. Or it may be a response to fishing pressure; older fish may have been removed from the population at the start of the fishery and the present stock has a higher proportion of younger fish compared to the historical stock, which is a common response of harvested stocks. The overall distribution of ages has not changed, just the proportion of individuals in each age group (younger, older). There is a higher number of young fish and fewer old fish in recent years (2011–2013) compared to historical records from the Test Fishery (1977–1982). The variance in mean condition factor is most likely a by-product of the timing of sampling. The mean condition factor showed annual variability, but no overall trends. It is theorized that anadromous Arctic Char only feed in the salt water and do not feed in fresh water which would result in natural seasonal variation in body condition (well-being); where an individual would have a lower condition factor in late winter (pre-feeding) compared to late summer (post-feeding). Additionally, it is expected that variability in condition factor among post-feeders would be much higher than among pre-feeders. This variability is a by-product of the relationship between when the fish was captured and the last time it fed; where condition would be higher for individuals who just consumed prey compared to an individual who has not eaten in hours or longer. A stable mean condition factor indicates that fish can feed well in their environment, potentially resulting in better overall reproductive health. Condition factor is an important variable in determining reproductive potential (Marteinsdottir and Begg 2002).

The length-at-age data shows that males tend to be slightly larger than females (but not significantly different) and that overall the stock is showing an increasing trend in length-at-age, indicating stock stability and potentially improving health. Since length-at-age is not influenced by gear type, timing of sampling, or location of sampling, this trend is a good health indicator for a stock. Larger length-at-age in more recent years (mean fork length at age 15: 2000 = 619 mm, 2001 = 600 mm, 2005 = 664 mm, 2011 = 690 mm, 2012 = 712 mm and 2013 = 698 mm) indicates ample resources for the Ikaluit Lake Arctic Char to exploit. Within the last decade, a diet shift has been documented among some stocks of Arctic Char in Cumberland Sound with the emerging presence of Capelin (*Mallotus villosus*) (Ulrich 2013), which may possibly be one of the reasons for the increased length-at-age for Ikaluit Arctic Char, although this cannot be concluded. In addition to the potential new prey source, over the past decade the ice free season in the Arctic has been lengthening (Maslanik et al. 1996). Food sources are scarcer in the Arctic compared to temperate regions (Gross et al. 1988) and anadromous Arctic Char are assumed to only feed during the ice free season in the saltwater environment (Moore and Moore 1974). The more time Arctic Char spend in salt water equals more time for them to feed and should result in increased growth within the stock. The Ikaluit Lake Arctic Char stock plateaus in growth around age 14. This may represent a shift in energy allocation. It is not uncommon for organisms to divert energy from growth to reproduction at older ages and larger sizes, resulting in slower or no growth. Ikaluit Lake Arctic Char appear to reach an asymptotic length of approximately 650 mm around age 14. This is similar for stocks in close proximity to Ikaluit Lake (e.g., Qasigiyat) (Martin and Tallman 2013), but differs from stocks that are in other areas of Cumberland Sound who show no growth plateau (e.g., Isuituq) (Harris and Tallman, 2010).

The Ikaluit Lake stock has a sex ratio of more males to females which is consistent with other stocks in the Cumberland Sound area (Moore 1975b, Martin and Tallman 2013). However, the sex ratio is decreasing, and this may represent either a true shift in the Ikaluit Lake Arctic Char stock structure, or it may be a by-product of sampling. As previously mentioned, it is common for populations of Arctic fish who migrate to do so in a segregated fashion (e.g., males first, females second) (VanGerwen-Toyne et al. 2008, Martin 2010). If Arctic Char in Ikaluit Lake are migrating in a segregated fashion it is expected that this will affect the sex ratio calculations of summer sampling if only part of the migration is sampled. There has been no research on the migration strategy of Arctic Char in the Cumberland Sound area, so it cannot be concluded if the difference in the sex ratio between years is a product of timing and location of sampling or a true representation of a shift in the stock.

The overall maturity stage data indicates that the Ikaluit Lake Arctic Char stock has good recruitment with the presence of 36.25% immature individuals (average of 2005, 2011, 2012, and 2013 calculated from Table 6). As expected with the life history of Arctic Char, the Ikaluit

Lake stock has a large proportion of individuals that are classified as resting (33.8%) and a portion of individuals classified as mature (21.3%). The proportions of mature individuals are similar to some locations (Harris and Tallman 2010) and different from others (Martin and Tallman 2013). The proportion of immature fish appears to be overrepresented in the Ikaluit Lake stock, and the proportion of resting individuals appears to be underrepresented when compared to other stocks (Harris and Tallman 2010, Martin and Tallman 2013). As previously mentioned, classifying maturity stage is a highly subjective task and is prone to human error. It is suspected that the 2000 and potentially the 2001 maturity classifications of immature fish are overestimated and that individuals who were resting were incorrectly classified as immature. The maturity stages of the Ikaluit Lake Arctic Char stock should be used with caution.

The abundance model calculates a potential population size ranging from 4,288 to 9,594 individuals in the Ikaluit Lake stock. It should be noted that the information applied to the model was limited and a more specific (smaller range) population estimate would require more data – specifically catch and effort information from fishery-dependent data, longer data sets (more years) and harvest numbers from the subsistence fishery. Despite the limitations of the model it does indicate that the Ikaluit Lake Arctic Char stock is heavily harvested when all sources of harvest are accounted for (fishery-independent, fishery-dependent and subsistence). If the "Tallman Rule" is applied to the estimate at the 50^{th} percentile, 329.4 individuals would be the recommended harvest rate from all sources of harvest; which falls in line with the current exploratory quota of 1,000 kg. When the exploratory harvest levels are added to the estimated subsistence harvest levels, the harvest rate on the Ikaluit Lake stock increases up to 20%. More research is required to understand harvest impacts on Arctic Char populations and to determine stock responses to harvest. Without this information it is not possible to state what harvest rate would be appropriate for Arctic Char stocks and thus, if the "Tallman Rule" is an appropriate harvest level.

The annual catch curves from the Ikaluit Lake Arctic Char stock appear to be relatively stable. This is supported by the calculated high survival rate and low mortality rate when compared to other Arctic Char stocks in the Canadian Arctic. The Isuituq Arctic Char stock has mortality rates that range from Z = 0.27 to Z = 0.68 (Harris and Tallman 2010); while the Hornaday River Arctic Char stock has historical mortality rates of Z = 0.61 to Z = 0.98 and Arctic Char stocks around Pond Inlet have mortality rates up to Z = 0.63 for Arctic Char aged 14 years or greater (Cosens et al. 1998). The catch curves show a fishery response in 2001. In license year 1999/2000 there was an overharvest of 1.6 times the quota and the fishery-independent data was collected at the same time (200 individual fish). We see the instantaneous mortality rate increase substantially from Z = 0.1164 in 2000 to Z = 0.2217 in 2001. The fishery was closed in 2000 at the request of the Pangnirtung Hunters and Trappers Organization and the instantaneous mortality rate decreased to Z = 0.1191 in 2005 and Z = 0.1075 in 2011.This is further supported by the pooled catch curves from 2005 and 2008; which were the years around the fishery closure with a low instantaneous mortality rate (Figure 11). This information supports the conclusion that the Ikaluit Lake stock appears stable at present harvest levels. When a fishery is harvested beyond the level of sustainability the mortality rate increases (Ricker 1975); this does not appear to be the case with the Ikaluit Lake stock from the information available.

RECOMMENDATIONS

The recommendations for the long-term plan for Arctic Char in Ikaluit Lake are:

1. The Ikaluit Lake stock is heavily harvested for subsistence purposes. This harvest needs to be accurately accounted for in any future assessments to ensure longevity of the subsistence harvest. It is recommended that a management partner work with DFO Science

and Stakeholders to collect information and estimates of the annual subsistence harvest of Ikaluit Lake Arctic Char.

2. Continued and close monitoring of the Ikaluit Lake Arctic Char stock is recommended as it is a heavily harvested population and an important subsistence fishery for the community of Iqaluit.
3. It is recommended that any future sampling of this population be conducted as consistently as possible: same methods, same sampling equipment, same location and same time of year.
4. Traditional knowledge from experienced fishers and elders in the community is available but needs to be documented. Local fishermen have a wealth of information, and we recommend that this information be collected, documented and incorporated into all fishery plans, including science sampling plans.

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APPENDIX A. DECEMBER 2002 MEMORANDUM TO DFO FISHERIES MANAGEMENT ON THE DFO SCIENCE ADVISORY MEETING ON REOPENING COMMERCIAL FISHERIES AT KINGNAID FIORD AND IQALUIT LAKE

Fisheries and Oceans | Pêches et Océans | MEMORANDUM | NOTE DE SERVICE

To / A: Karen Ditz, Fisheries Management, Fisheries and Oceans Canada, Iqaluit, NU

From / De: Kathleen Martin, Arctic Stock Assessment and Conservation Research, Arctic Research, DFO, Winnipeg, MB

Security Classification - Classification de sécurité: Unclassified/Non Classifié

Our File - Notre référence:

Your File - Votre référence:

Date: 11 December 2002

Subject / Objet: Advisory meeting on reopening commercial Fisheries at Kingnait Fiord and Iqaluit Lake

The following are the results of the 11 December, 2002 meeting held in Winnipeg which was attended by Kathleen Martin, Susan Cosens, Tracy Loewen, Kim Howland, Margaret Friesen, Ross Tallman and Al Kristofferson. Leesee Papatsie and Martine Giangioppi attended via telephone.

The DFO Eastern Area Office received a request from the Pangnirtung HTA to reopen the commercial fisheries at Kingnait Fiord and Iqaluit Lake. They have asked Science Stock Assessment for advice in this matter and specifically whether the reopening of these water bodies would constitute a risk to the fish stocks and therefore the sustainability of the fisheries. The HTA has sited three reasons to reopen the fisheries:

Members want the sites to be reopened,

New information from indicated that small fish not just large fish spawn,

Research indicates that fish in Kingnait Fiord are getting older.

BACKGROUND INFORMATION

A commercial fishery has operated at Kingnait Fiord (off Cumberland Sound east of Pangnirtung) and at Iqaluit Lake (Ikaluit Lake, Robert Peel Inlet) for a number of years. Experimental/Commercial harvest data is available from 1982 to 1999 for Kingnait Fiord and from 1977 to 1999 for Iqaluit Lake (Table A1). There is also a domestic/subsistence and sport fishery in both locations. Fishers from Pangnirtung fish at Kingnait Fiord and Iqaluit Lake while fishers from Iqaluit also fish at Iqaluit Lake.

In 1995, DFO and the HTA expressed concern for the level of harvest of the Kingnait Fiord Arctic char stocks. There had been a number of years (1986, 1988, 1989, 1993, 1995) when the commercial harvest was higher than the allotted quota.

In 2000, the HTC requested that the NWMB close Kingnait Fiord and Iqaluit Lake to commercial fishing. The board decided to close the waters to commercial fishing for at least five years. The subsistence fishery continued although the NWMB suggested that the two communities be encouraged to minimize subsistence fishing in these waters over this period in order to facilitate recovery of the stocks.

In 2002, the HTA requested that Kingnait Fiord and Iqaluit Lake be reopened to commercial fishing for the reasons listed above.

CLARIFICATION - "SMALL SPAWNERS"

Although, Dr. Tallman was pleased that the community found his presentation interesting, his intention was to provide general information on char biology and to identify areas where knowledge gaps exist. In some lakes, along with sea-run or anadromous char, there is another form of Arctic char present, the smaller resident char. We do not yet understand the relationship between the sea run char and these residents. Research on the biology of these two forms is needed. There may be some aspects of the biology that will be important for assessments in the future but information that Dr. Tallman presented was not a justification for a change in fisheries management policy. For Iqaluit Lake and Kingnait Fiord there is no information yet available as to whether there are resident char. Small fish in these lakes may be juvenile anadromous char.

CLARIFICATION - "KINGNAIT FISH ARE GETTING OLDER"

Leesee Papatsie suggested that the statement regarding the older fish from Kingnait Fiord might have come from Traditional Knowledge information. Some fishers had said that there are still big fish in Kingnait Fiord. Large fish may have been equated with older fish. Fisheries Management data indicated that there were more larger and older fish in 1997 than in 1991 (Figure A1). Unfortunately this data is now out of date and may not reflect the current status of the population. In 1998 commercial harvest removed 3,186 kg of char from the population along with an additional 5,170 char removed by the domestic fishery. This equates to over 13,000 kg of fish harvested (assuming 2 kg per fish). It is unknown whether this level of domestic harvest was unusual. There is no recent data available to assess the status of this stock.

SCIENCE ADVICE

Kingnait Fiord

There is little information available on the Kingnait Fiord stock. The data from 1991 and 1997 would have been insufficient to result in the original closure. The harvest levels for the domestic fishery are largely unknown except for 1997,1998, and 1999 when they were reported to be 20, 885, and 5,170 fish respectively. The fiord and the river system at the head have been identified as important locations for domestic fisheries in part due to the proximity to the community. The total harvest of a stock from all sources is very important in determining the population characteristics and the sustainable harvest levels. Without recent data we are unable to assess the risk of reopening the fishery. In order to assess the risk a current sample taken at the same location with the same mesh size as the previous samples would be required to compare the length and age structure of the population.

One option to minimize the risk to the population would be to retain the closure until samples are collected and analyzed to determine the current status of the stock.

A second option might be to open the stock to a limited experimental fishery where the fishers are required to provide samples from which the data would be collected and analyzed to assess the stock.

In both cases it is very important to know the total amount of harvest from all sources in order to assess the effects on the population. Knowledge of the subsistence harvest is needed.

The final option is to reopen the fishery at the original levels, which would have the highest level of risk of the three options.

Iqaluit Lake

More data is available for the Iqaluit Lake stock. The commercial harvest levels have only been markedly higher than the quota for two years and otherwise have been fairly constant. There are only data for 1996 (583) and 1998 (22) subsistence fisheries although the lake is reported to be used for this purpose by both Pangnirtung and Iqaluit residents. Length frequency (Figure A2) and age frequency (Figure A3) data is available for 1977, 1980, 1990 and 2000. Samples from 2001 have been measured but not aged. The 2000 and 2001 samples were collected for Dr. Tallman's on-going research program in the area. There may be a reduction in fish length over time although the size ranges are roughly comparable. The age distributions do indicate a reduction in the age of the fish. The modal age of 10 in 2000 as compared to 14–18 for the other years sampled does indicate a change in the population resulting from the harvest. The level of harvest in 1999 was quite high and may have influenced the level of change observed in the 2000 sample. A catch curve for the 2000 data (Figure A4) estimates the instantaneous mortality rate (Z) to be 0.36 which although quite high, is not excessive and may also have been influenced by the previous years level of harvest. The original commercial quota of 1400 kg seems to have been adhered to fairly well. The total harvest including both the commercial and the unknown subsistence harvest (over 20 years) has resulted in changes in the population. A large number of age and sizes classes of fish remain in the population at this level of harvest and the population may now be stationary. Monitoring the population to compare with previous data is important to determine if the age structure continues to change further which would be cause for alarm. Catch curves could be constructed for comparison purposes. It is essential to know the total harvest in order to assess the status of the stock. Changes in the subsistence harvest could have important consequences to the fish stock.

Based on the available data the risk would be moderate if the commercial fishery was reopened at the previous quota level (also assuming that the subsistence fishery remains at the historic levels).

If the age structure of the population is changing the risk to the population, however, would be high.

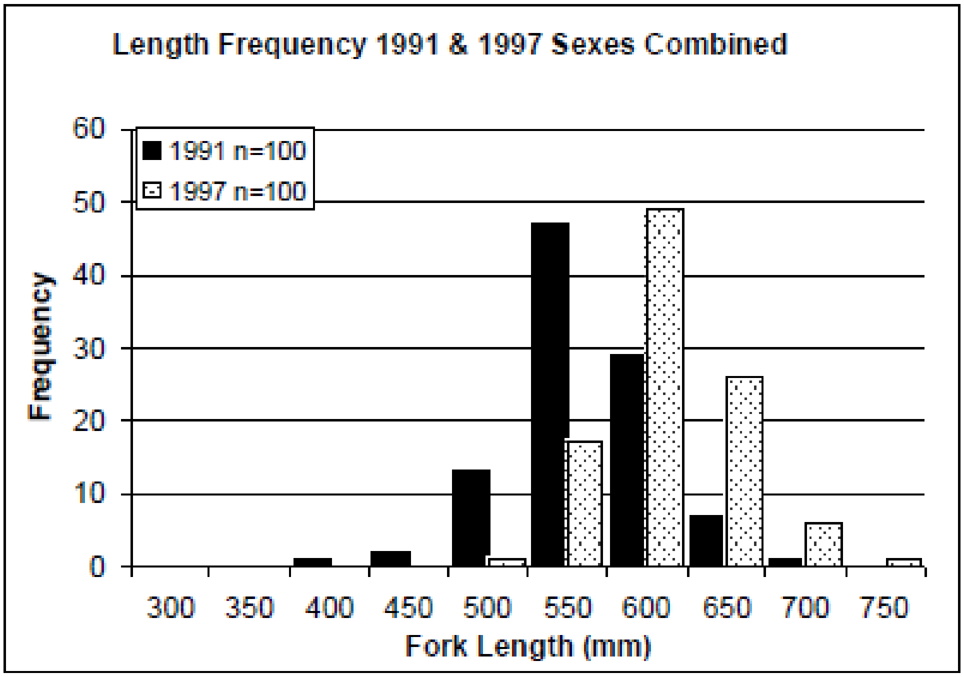
If the additional information is required please do not hesitate to contact me.

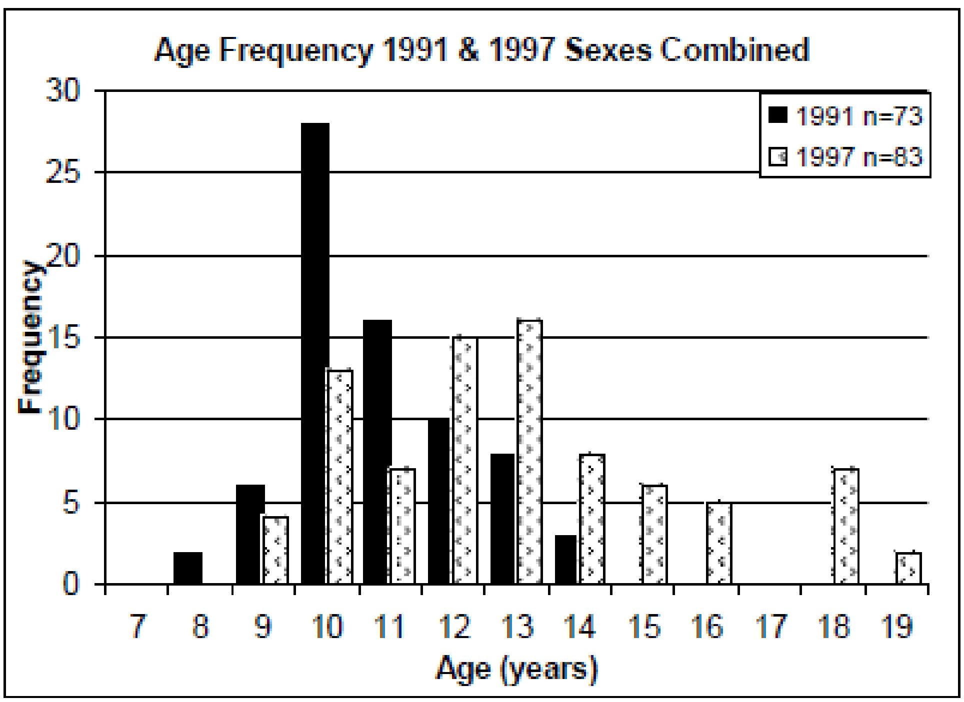
Kathleen Martin

APPENDIX B. TABLES AND FIGURES

Table A1. Summary of Harvest Data for Ikaluit Lake and Kingnait Fiord. Note: "E" indicates experimental licence (otherwise commercial licences)

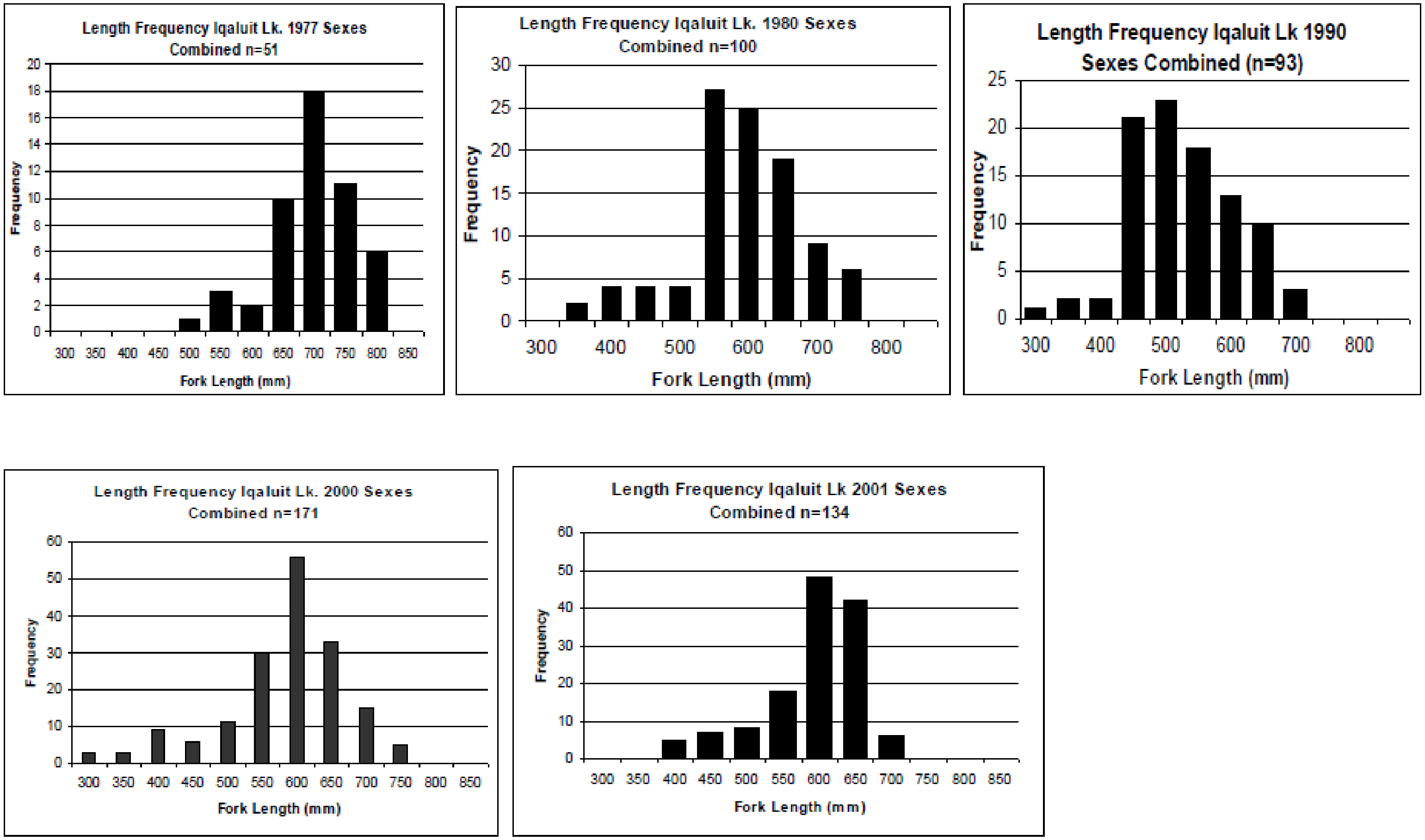
Location	Year	Quota (kg)	Harvest (kg round)	Subsistence (no.)
Ikaluit Lake (Robert Peel Inlet) (PG001)	1977	1,500E	286	-
	1979	1,500E	797	-
	1980	900E	797	-
	1981	1,500E	1,500	-
	1983	1,500E	1,334	-
	1985	1,500E	2,552	-
	1990	1,400	1,182	-
	1991	1,400	1,400	-
	1992	1,400	1,816	-
	1993	1,400	998	-
	1994	1,400	1,356	-
	1995	1,400	1,680	-
	1996	1,400	1,797	583
	1997	1,400	1,152	-
	1998	1,400	1,030	22
	1999	1,400	3,073	-
Kingnait Fiord (PG014)	1982	4,500	4,500	-
	1983	4,500	4,545	-
	1984	4,500	1,346	-
	1985	4,500	4,871	-
	1986	4,500	5,600	-
	1988	4,500	6,018	-
	1989	4,500	7,603	-
	1990	4,500	1,000	-
	1991	4,500	4,545	-
	1992	4,500	4,955	-
	1993	4,500	6,247	-
	1994	4,500	5,598	-
	1995	4,500	7,184	-
	1996	1,000E	334	20
	1997	4,500	3,200	885
	1998	4,500	3,186	5,170
	1999	4,500	4,127	-





Mesh Size (1991&1997): 127 mm (5")

Figure A1. Kingnait Fiord 1991 and 1997 Length and Age Frequency.



Mesh Sizes:
1977: 140mm (5.5") 1980: 140 mm (5.5") 1990: 114 mm (4.5") (Data Report) 2000: 140 mm (5.5") 2001: 140 mm (5.5")

Figure A2. Iqaluit Lake Length Frequency 1977, 1980, 1990, 2000, 2001.

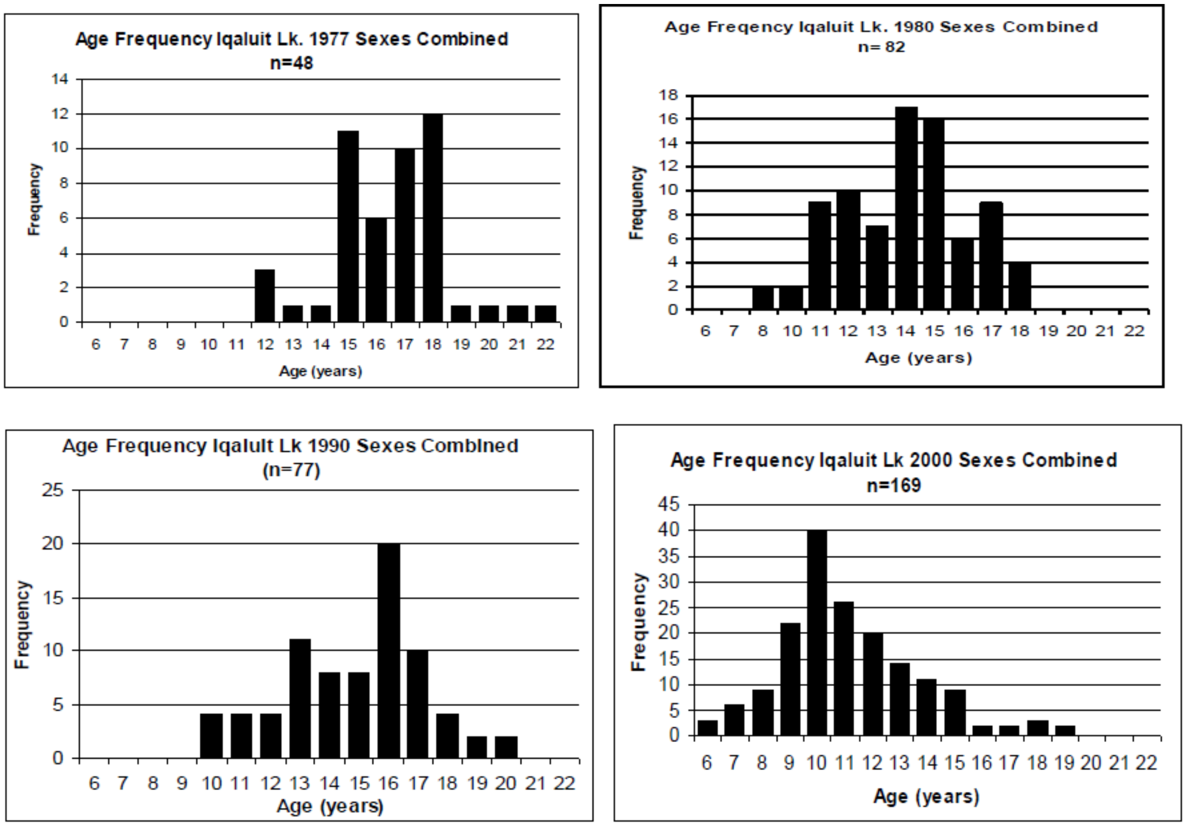


Figure A3. Iqaluit Lake Age Frequency: 1977, 1980, 1990, 2000.

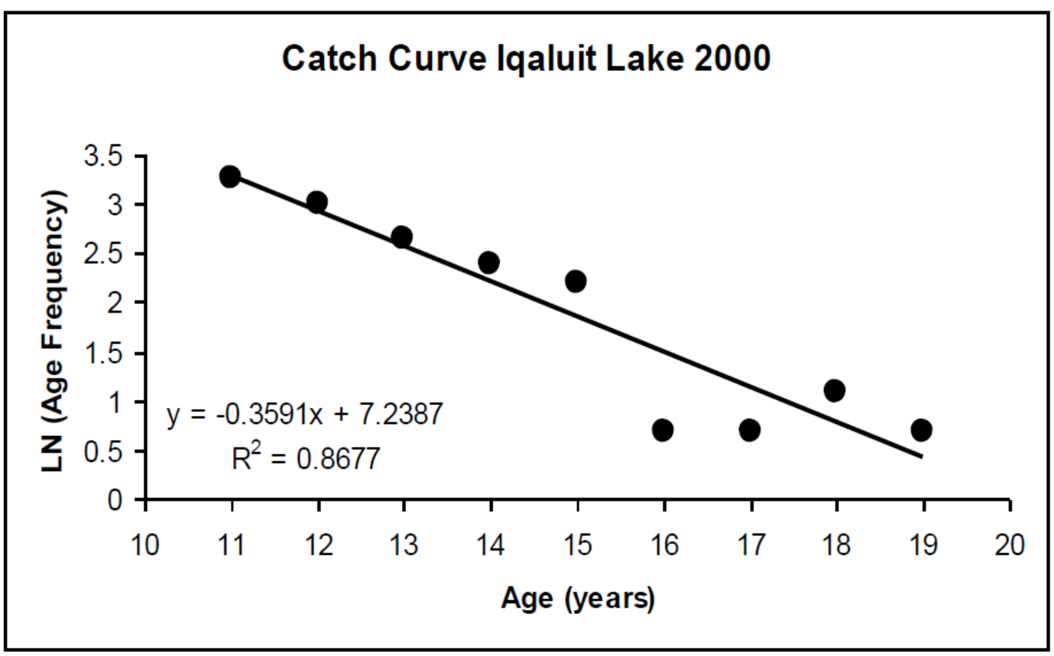


Figure A4. Catch Curve for Iqaluit Lake 2000. Instantaneous Mortality Rate (Z) = 0.3591, Annual Survival Rate ($S = e^{-z}$) = 0.6983, Annual Mortality Rate (1-S) = 0.3017.