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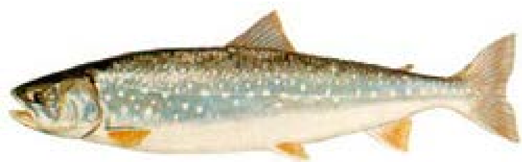
STOCK STATUS AND SUSTAINABLE HARVEST LEVELS FOR ARCTIC CHAR IN IJARUVUNG LAKE, IQALUJJUAQ FIORD AND IRVINE INLET, CUMBERLAND SOUND, NUNAVUT



Arctic Char, Salvelinus alpinus
Illustration by Fisheries and Oceans Canada.

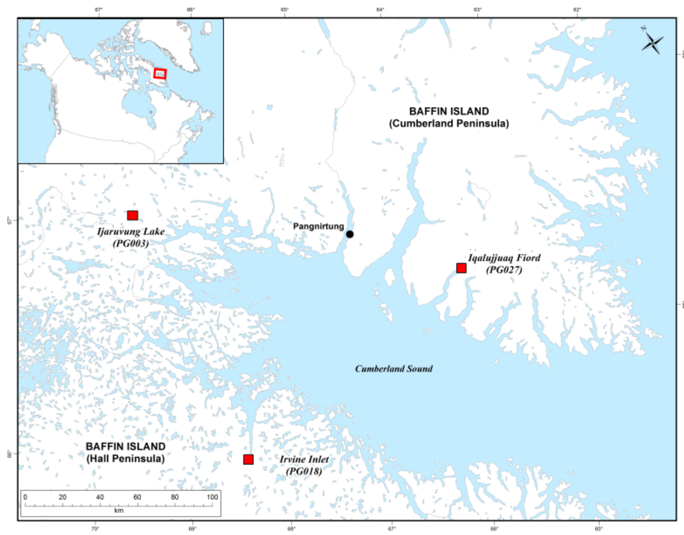


Figure 1. Map of the Cumberland Sound area showing the three Arctic Char commercial fishing areas, Ijaruvung Lake (PG003), Iqalujjuaq Fiord (PG027), and Irvine Inlet (PG018) are shown with stars.

Context:

Arctic Char (Salvelinus alpinus) is the most northerly freshwater fish and has a circumpolar distribution. This species is abundant within the Canadian Arctic and is an important subsistence resource for local Inuit and are important to maintaining traditional lifestyles for local Northern communities. In the Cumberland Sound area, there are numerous waterbodies that are important for the commercial and subsistence harvest of this species. Ijaruvung Lake, Iqalujjuaq Fiord, and Irvine Inlet were declared commercially licensed water bodies in 1984-1985. Fisheries and Oceans Canada (DFO) has been collecting fishery harvest data in the DFO Fisheries Management and Harvest Information System (FMHIS) database since 1984. Test fishery data from these water bodies were collected mostly in the late 1970's and early 1980's. Fishery-dependent (plant sampling) data for these waterbodies were collected in the mid-2000's and in 2012-2013. More recently DFO has collected fishery-independent biological and catch and effort data from 2010-2015 at Iqalujjuaq Fiord and Irvine Inlet, and from 2011-2015 at Ijaruvung Lake. These fisheries were last assessed on a smaller scale back in 1981-1982 (Ijaruvung Lake), and in 1997 (Iqalujjuaq Fiord).The Irvine Inlet Arctic Char stock has never been assessed before. Updated stock assessments with contemporary fishery-independent data, including recently collected catch-effort information, are required to fully understand the impacts of fishing on these waterbodies. DFO Resource Management (RM) has requested that DFO Science provide updates on the stock status, abundance and sustainable harvest levels for each of these commercial waterbodies.

A Regional Science Advisory Process meeting was held in Iqaluit, Nunavut on February 14–15, 2017 to assess the status and sustainable harvest levels for Arctic Char in Ijaruvung Lake, Iqalujjuaq Fiord, and Irvine Inlet. Participants from DFO Science and RM, the Pangnirtung Hunters and Trappers Organization (HTO), territorial governments and boards, the University of Calgary, Memorial University and local fishers attended the meeting. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Ijaruvung Lake (DFO waterbody code PG003), Iqalujjuaq Fiord (PG027), and Irvine Inlet (PG018) were declared commercially licensed water bodies in 1984-1985 for fishing with 140 mm gillnets.
- Fisheries and Oceans Canada (DFO) has been collecting fisheries harvest data since 1985, test fishery data (in late 1970's and early 1980's) and fishery-dependent (plant sampling in mid-2000's and in 2012-2013) data from these water bodies.
- DFO collected fishery-independent biological and catch and effort data from 2010-2014 at Iqalujjuaq Fiord and Irvine Inlet, and from 2011-2015 at Ijaruvung Lake.
- Fork length, age, round weight, and derived indices showed annual variation, but there were no significant trends in the mean values of these metrics.
- Irvine Inlet appears to have substantially lower fishing mortality among the three stocks.
- Three population models, the Baranov catch equation, Catch-Maximum Sustainable Yield (MSY) and Depletion-corrected average catch, were used to estimate population abundance, MSY and evaluate stock status.
- For the Irvine Inlet stock, the Baranov catch equation estimated biomass as 53,304 kg. Keeping an exploitation rate of 5 % gives a harvest level of 2,665 kg per year, which is more than the current mean level of harvest but less than the current quota. The Catch-MSY model provided an MSY limit of 2,733 kg, which is also close to the 5 % level. Fishers have observed no issues or concerns with this stock. Fish tissue is observed to be healthy and fat, indicating to the locals that the population is healthy. Traditional knowledge states that fish need to be taken from the lakes to keep them stable.
- For Ijaruvung Lake, the Baranov catch equation calculated standing stock biomass to be 25,732 kg. Keeping an exploitation rate 5 % gives a harvest level of 1,287 kg per year. The calculated 5 % level is slightly above the current mean level of harvest, while 10 % is higher than the quota limit. The Catch-MSY model calculated standing stock biomass to be 29,916 kg and suggested MSY was 1,683 kg.
- For the Iqalujjuaq Fiord stock, the Baranov catch equation estimated standing stock biomass to be 35,214 kg. Keeping an exploitation rate of 5 % gives a harvest level of 1,761 kg per year, which is above the current quota and mean level of harvest. The Catch-MSY model calculated standing stock biomass to be 40,879 kg and suggested MSY was 2,626 kg, which includes harvest for subsistence purposes. Fishers have traditionally taken a consistent amount from the lake to meet their basic needs.
- In Ijaruvung Lake and Irvine Inlet, estimated MSY was less than the prescribed quotas for these water bodies. MSY for Irvine Inlet was near the present harvest rate, while Ijaruvung Lake MSY was higher than the mean harvest level. For Iqalujjuaq Fiord, estimated MSY was

higher than the allocated quota. However, these MSY calculations included the subsistence harvest, which is high relative to the other two water bodies assessed.

- From the biomass calculation using the Baranov catch equation, present quotas were below a 10 % exploitation rate, while recent annual commercial harvests were lower than 5 % of the calculated standing stock biomass.
- Upper and limit reference points (URP, LRP) were calculated using the provisional reference points from the DFO Sustainable Fisheries Framework Precautionary Approach (DFO 2009). The LRP of 0.4 B_{MSY} and the URP of 0.8 B_{MSY} were calculated based on Catch-MSY results.
- These median reference point values for the stocks were in the healthy zone with minimum probability range in the cautious zone.
- Overall, the results of the trends in size and age data, population indices, quantitative models and observations from the local fishers all suggest the Arctic Char stocks in Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet are in the Healthy Zone of the Precautionary Approach framework and the current harvest levels are sustainable.

BACKGROUND

Arctic Char (*Salvelinus alpinus*) are the most northerly freshwater fish and have a circumpolar distribution. This species is abundant within the Canadian Arctic and is an important subsistence resource for local Inuit. Arctic Char fisheries typically harvest anadromous populations as they hold the highest economic value.

In the Cumberland Sound area, there are numerous waterbodies that are important for the commercial and subsistence harvest of this species. Ijaruvung Lake, Iqalujjuaq Fiord, and Irvine Inlet (Figure 1) are three waterbodies that were commercially licensed in 1984-1985. Fisheries and Oceans Canada (DFO) has been collecting fishery harvest data since 1984. Data were compiled from the DFO Fisheries Management and Harvest Information System (FMHIS) database, Pangnirtung Fish Plant harvest data sheets, test fishery data (mostly in late 1970’s and early 1980’s), and fishery-dependent data (plant sampling through the Pangnirtung Fish Plant mid-2000’s and in 2012-2013). More recently DFO collected fishery-independent biological and catch and effort data from 2010-2015 at Iqalujjuaq Fiord and Irvine Inlet, and from 2011-2015 at Ijaruvung Lake using multi-mesh gillnets. These fisheries were last assessed on a smaller scale back in 1982 (Ijaruvung Lake, McGowan 1985) and in 1997 (Iqalujjuaq Fiord, Read 2000). The Irvine Inlet Arctic Char stock has never been assessed. Updated stock assessments with contemporary fishery-independent data, including recently collected biological (age, length, weight) and catch-effort information, are required to fully understand the impacts of fishing on these stocks.

DFO Resource Management (RM) has requested that DFO Science provide an update on the stock status, abundance and sustainable harvest level for each of these three commercial waterbodies.

Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet Fisheries

Ijaruvung Lake, also written as Iyaravung Lake, is located at the head of Clearwater Fiord and is part of the Ranger River System (66°43'N 67°46'W) east of the Ishuituq River system, north of Cumberland Sound (Figure 1). Ijaruvung Lake was included on Schedule V of the Northwest Territories Fishery Regulation with an annual quota of 2,000 kg. It is a winter gillnet commercial fishery with a minimum mesh size restriction of 140 mm (5.5"), but since 1996-1997 it has since developed into a summer fishery. Ijaruvung Lake was first harvested in 1978-1984 as a test or exploratory fishery with a mean catch of 1,308 ± 38 fish per year (Kristofferson and McGowan 1981, McGowan 1985). The quota for Ijaruvung Lake Arctic Char was set around 450 kg in 1978, and since1983-1984, the quota has been fixed at 2,000 kg, but it has been harvested up to quota only for a few years. There is no record or information about this water body being harvested for subsistence purposes.

Iqalujjuaq Fiord (also as Ikalojuak) is located in Cumberland Sound near Miliakdjuin Island at a (65.6674° N, 65.0805° W). It is located about 60 km southeast from the town of Pangnirtung (Figure 1). The Kuugajuaq River drains to the Iqalujjuaq Fiord. A test fishery was conducted in March 1981. The total instantaneous mortality (Z) was estimated to be 0.60 which showed an annual survival rate of 54 % (Kristofferson and McGowan 1981). This indicated that the stock was under moderate exploitation. To avoid heavy exploitation, it was recommended that the quota not exceed 1,600 kg per year. In light of these recommendations, the annual commercial quota was set at 1,400 kg per year. It is a gillnet fishery with a restriction of minimum mesh size of 140 mm. There is no record or information provided about any problem with this fishery. Harvest records are available from 1984-1985. Another test fishery was conducted in 1997 (Read 2000).

Irvine Inlet (McKeand River Area, a.k.a. Aukannilik) is located in Cumberland Sound (65° 30' N, 68° 0' W, Figure 1). It is about 120 km across the sound from the town of Pangnirtung. The McKeand River drains into Irvine Inlet. There is no record of any test or exploratory fishery or prior assessment in this area. Commercial harvest started in 1984-1985 with an annual quota of 4,500 kg. The fishery uses gillnets with a restricted minimum mesh size 140 mm.

ASSESSMENT

Harvest

The total harvest removed from Ijaruvung Lake since 1977-1978 from all sources, excluding subsistence harvest, (i.e., test fishery sampling, fishery-independent sampling, exploratory and commercial harvests) is 39,127 kg round weight. Mean harvest level from 1985-2016 was 1,151 ± 626 kg (Figure 2). According to available information, harvest typically does not exceed quota limits, exceptions are noted in 2006-2007 and 2010-2011. Subsistence harvest is about 100 fish per year (Pangnirtung Hunters and Trappers Organization [HTO], pers. comm.).

For Iqalujjuaq Fiord, commercial fisheries records are available since 1984-1985. For a few years (1986-1988, 1991, and 2001-2003) the commercial fishery was closed by the request of the community. In some years, commercial harvest has exceeded the quota (Figure 3). In two years during the mid-2000's, commercial harvest peaked around 3,000 kg. Mean harvest from 1985-2016 was slightly above the recommended quota at 1,450 ± 640 kg, with a maximum harvest of 3,046 kg in 2004-2005 (Figure 3). Mean commercial catch from 2010-2015 was at the same mean level of 1,450 kg. From 2010-2015, on average, 350 kg per year of Arctic Char was harvested during fishery-independent sampling. Subsistence harvest is about 500 fish per year (Pangnirtung HTO, pers. comm.).

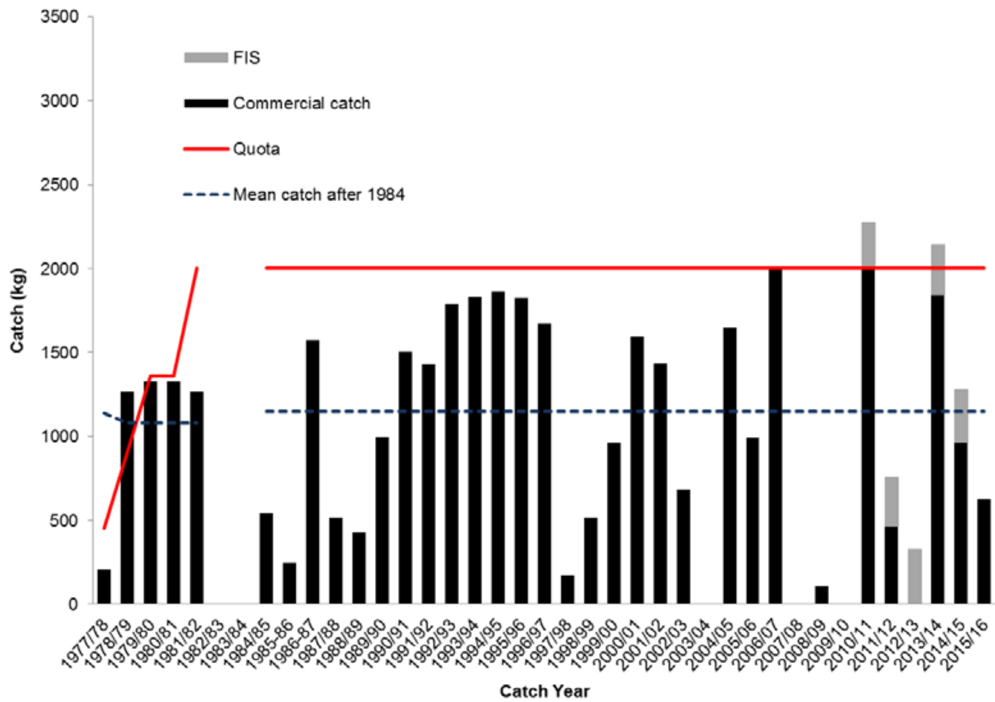


*Figure 2. Commercial harvest of Arctic Char (*Salvelinus alpinus*) for Ijaruvung Lake, Cumberland Sound, since the inception of the test fishery in 1978. Annual commercial harvest (black bars), quota level (solid red line), and mean commercial harvest (dashed line) are provided. Fishery-independent survey (FIS) catch data is shown by the grey portion of bars.*

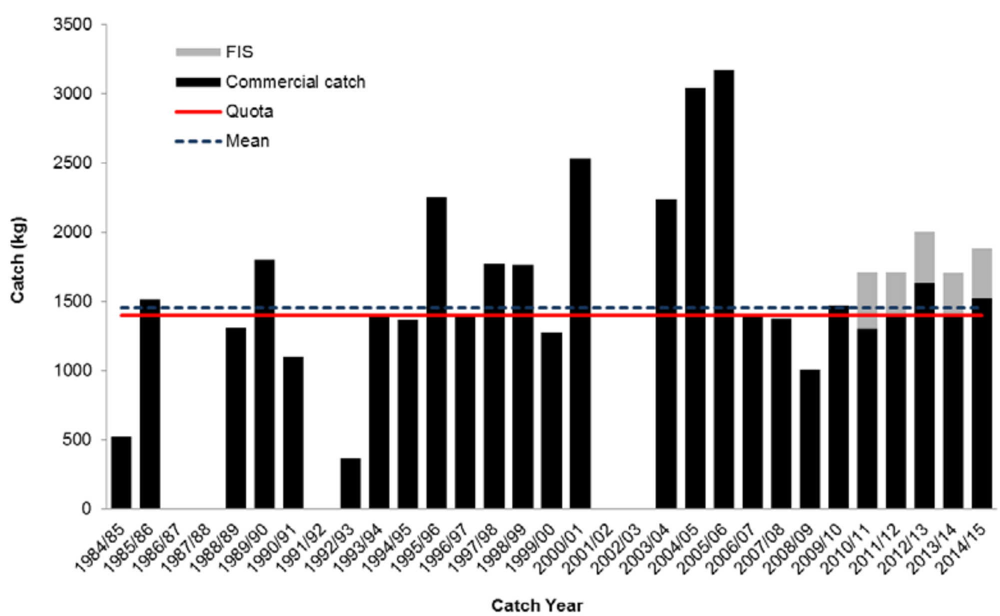


*Figure 3. Commercial harvest of Arctic Char (*Salvelinus alpinus*) for Iqalujjuaq Fiord, Cumberland Sound, since the inception of the test fishery in 1984-85. Annual commercial harvest (black bars), quota level (solid red line), and mean commercial harvest (dashed line) are provided. Fishery-independent survey (FIS) catch data is shown by the grey portions of bars.*

For Irvine Inlet, harvest records are available since 1985-1986. Mean annual harvest was 2,392 kg (Figure 4). In only one year (2001-2002) harvest was above the quota, and in only a few years harvest was near the quota level. The mean harvest since 1984 (2,392 kg) was below the quota limit. From 2010-2015, mean commercial harvest was around 2,000 kg. This decrease in harvest appears to be related to economic factors (Pangnirtung HTO, pers. comm.). This area is further away from the community of Pangnirtung than the other fisheries, which means it is more costly to travel there to catch the quota. On average, 280 kg/year was caught from 2010-2014 for the fishery independent sampling. This stock also supports a subsistence harvest of around 100 fish per year (Pangnirtung HTO, pers. comm.).

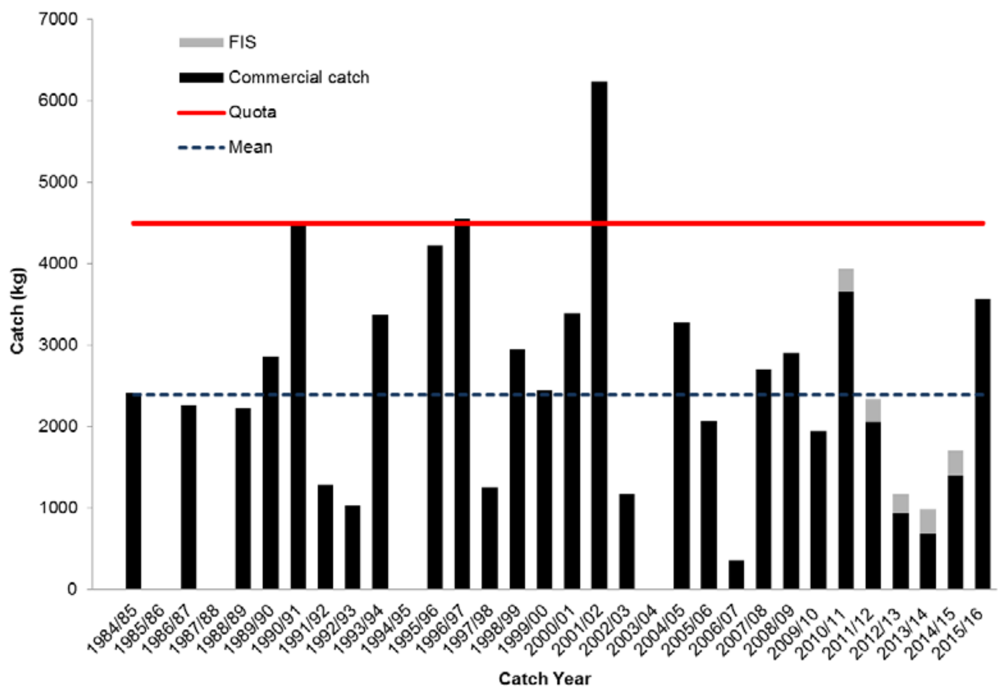


Figure 4. Commercial harvest of Arctic Char (Salvelinus alpinus) for Irvine Inlet, Cumberland Sound, since the inception of the test fishery in 1985-86. Annual commercial harvest (black bars), quota level (solid red line), and mean commercial harvest (dashed line) are provided. Fishery-independent survey (FIS) catch data is shown by the grey portion of bars.

Data collection

In this assessment, four types of data are utilized. For Ijaruvung Lake, non-DFO random sampling or test fishery data (May 1978, February 1980 and 1981), fish plant sampling (2006, 2013), fishery-independent data (March 2011-2015) and commercial harvest data (1984-2016) was utilized. For Iqalujjuaq Fiord, test fishing data were collected in March 1983 and August 1997, fish plant sampling in August 1997, 2006 and 2012, fishery-independent sampling from 2011-2015 (February and March) and commercial harvest data were collected from 1984-2016. For Irvine Inlet, fish plant sampling (2005, 2006, 2013), fishery-independent sampling from 2010-2014 (August, September) and commercial harvest data from 1984-2016 were used. Fish plant sampling was limited to fork length or fork length and mean weight only. Fishery harvest data were compiled from the DFO FMHIS database and Pangnirtung Fish Plant harvest data sheets.

Catch-per-unit-effort (CPUE)

For Ijaruvung Lake, effort data from the test fishery (1978-1981) and fishery-independent survey (2010-2015) were used. For Iqalujjuaq Fiord and Irvine Inlet, effort data from fishery-independent surveys were available. CPUE could not be determined for fishery-dependent data or plant sampling data. In Ijaruvung Lake, a test fishery was conducted using 100 m long, 140 mm mesh net. In 1978 catch rates were abnormally high and in 1980 they were exceptionally low. Using fishery-independent survey data from all three water bodies, CPUE was calculated using 50 m long and 1.8 m deep experimental multi-mesh nets with a panel mesh-size sequence of: 38 mm, 64 mm, 89 mm, 114 mm and 140 mm. CPUE was calculated as the number of fish landed in 24 hours. Variability in CPUE was observed among years (Figure 5) however, there were no consistent trends in the data. It is difficult to draw any biological inferences from the CPUE data.

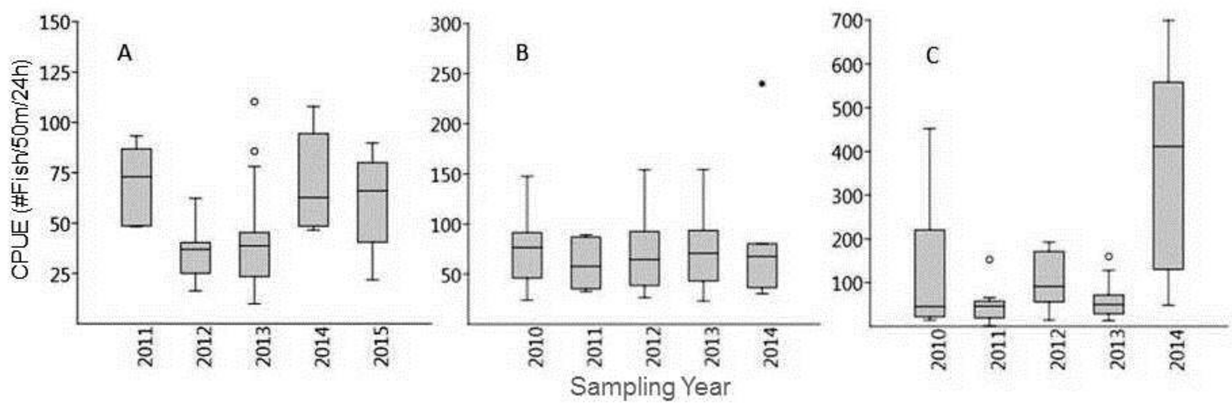


*Figure 5. Box plots of catch-per-unit-effort (CPUE) for Arctic Char sampled using 50 m multi-mesh gillnets during multi-mesh fishery-independent surveys in (A) Ijaruvung Lake, (B) Iqalujjuaq Fiord, and (C) Irvine Inlet in Cumberland Sound, Nunavut. Median, quartiles and outliers (○ values ≥1.5 x and * values ≥ 3 x interquartile ranges, respectively) are also shown. Note: y-axis ranges differ among panels corresponding to the range of variation in CPUE within each waterbody.*

Stock Trends in Biological Characteristics

The status of the Ijaruvung Lake, Iqalujjuaq Fiord, and Irvine Inlet stocks were inferred from trends in biological characteristics that were collected as part of the test fishery, fishery-dependent (fish plant sampling) and fishery-independent programs. Analyses of fork length (mm), age, round weight (g), and condition (k) were used to assess the responses of these stocks to fishing.

Length

Mean fork length varied among years and between sexes and gillnet types (Figure 6). Mean fork length from commercial mesh sampling was higher than from multi-mesh net sampling. This is expected and is a product of the mesh sizes. Despite some annual variation in fork length the error bars from all years overlap, indicating that there were no trend or change in the mean fork length over time. There were some annual differences in length frequency distributions, but no trend or change with time.

Age

In all three water bodies, mean age varied among sampling years and between sexes and gillnet type used. There was variation in age structure among years (Figure 6). In Ijaruvung Lake, at the start of fishery, there was a slight negative trend in mean age, but there was no significant trend in mean age data during recent years (2011-2015). In Iqalujjuaq Fiord, from the test fishery data, mean age declined during the initial years (1983-1997). However, these data must be interpreted with caution because of uncertainty associated with fish aging at that time and the fact that different age readers were used. There was no trend in the age data in recent years (2010-2014), however the time period may be too short to detect any noticeable changes. In Irvine Inlet, mean age differed significantly among years, but there was no trend in the age data that would have been indicative of over-exploitation, however the time period may be too short to pick up any detect any noticeable changes. Truncations in age distributions in commercial fisheries could be a sign of over-exploitation. However, no age truncation was observed and fishery-independent data included both young and older age classes.

Weight and condition

Round weight varied among years and between sexes and net types (Figure 7). Long-term declines in mean weight can be indicative of heavy exploitation. Long-term declines were not found during this assessment. There was no trend in mean round weight in fishery-independent data. Condition factor is used as an index of fish health and wellbeing. The condition factor of fish can be affected by several factors, such as stress, sex, season, availability of food and water quality parameters. There was variability among years and between net and sampling seasons for all locations. Condition factor was higher for fish sampled in summer because they were well fed, having spent the summer feeding at sea, compared to fish sampled during late winter. However there was no overall trend in condition factor for all locations among years. The weight-length relationship has been widely used in fish biology with several purposes, e.g. inter-specific and intra-population comparisons and to assess the index of the well-being of the fish populations. Over recent years (2010-2015), fish showed positive allometric growth, meaning they grew longer and fatter at the same time, in all three water bodies. However, in the early years of sampling (test sampling) at Ijaruvung Lake and Iqalujjuaq Fiord, fish showed strong negative allometric growth, with fish growing longer without growing much fatter at the same time. The most recent and comprehensive analysis based on a wider weight and length range showed that the Arctic Char stocks weight increased slightly with fork length.

Mortality

Instantaneous mortality rates (Z) calculated following the Chapman and Robson method using test fishery data (140 mm mesh) and fishery-independent data (multi-mesh). Instantaneous mortality rates ranged from Z=0.29 (2011, 2013, 2014) to Z=0.53 (1980) at Ijaruvung Lake, from Z=0.63 (1983) to Z=0.27 (2010) in Iqalujjuaq Fiord, and from Z=0.19 (2012) to Z=0.24 (2010) in Irvine Inlet (Table 1). Instantaneous mortality rates calculated using fishery-independent data were lower than those calculated using fishery-dependent data or test fishery data. No trends in mortality or survival could be determined from these data. Overall, annual survival was higher (~80 %) in Irvine Inlet compared to the other two water bodies (~72 %).

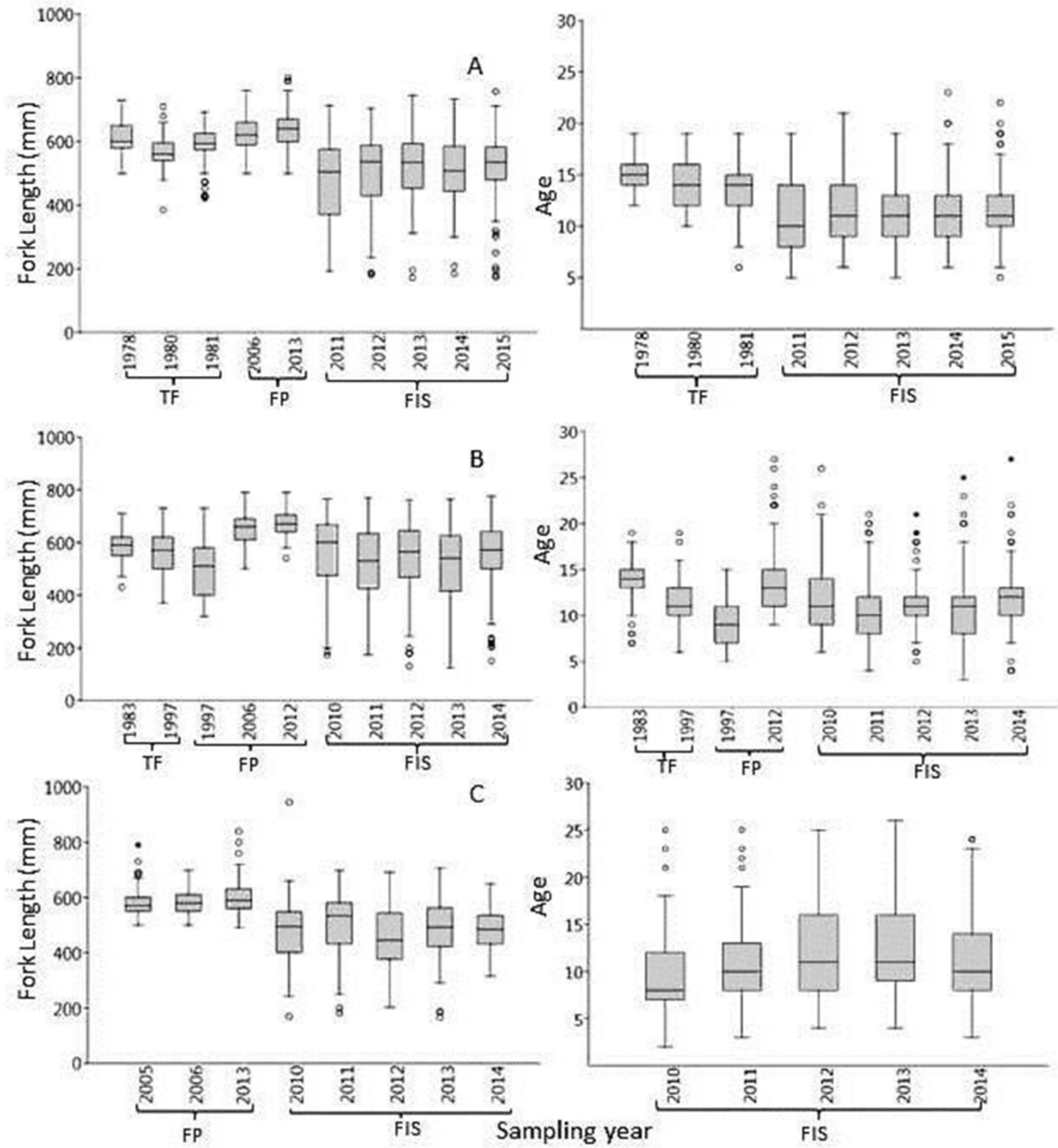


*Figure 6. Box plots of fork length (mm) (left panel) and age (right panel) for Arctic Char sampled from test fishery (TF) using commercial gillnets, fish plant (FP) using commercial gillnet and from the fishery-independent survey (FIS) using 50 m multi-mesh gill nets in (A) Ijaruvung Lake, (B) Iqalujjuaq Fiord and (C) Irvine Inlet in Cumberland Sound, Nunavut. Median, quartiles and outliers (○ values ≥1.5 x and * values ≥ 3 x interquartile ranges, respectively) are also shown.*

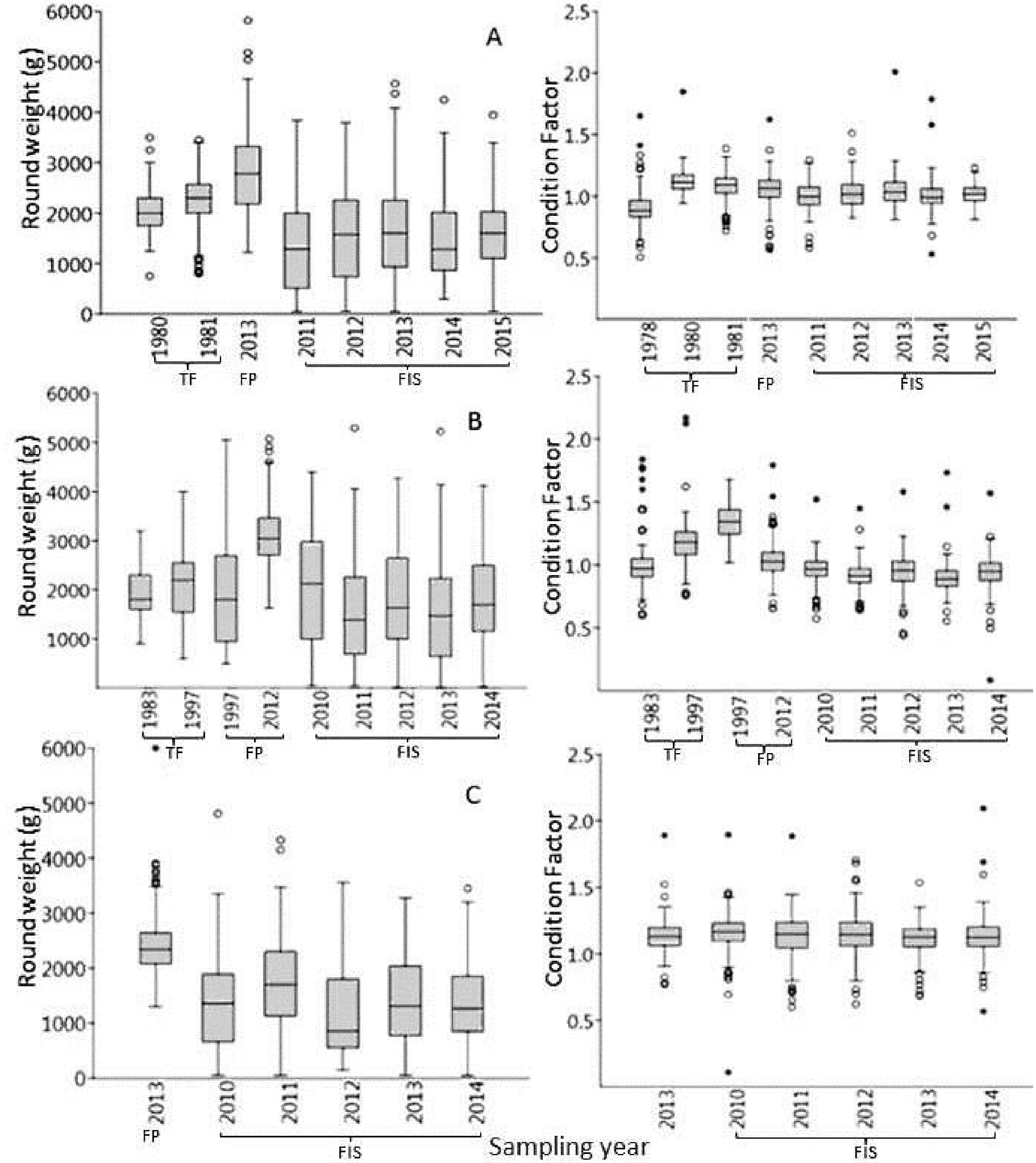


*Figure 7. Box plots of round weight (g)(left panels) and condition factor (right panels) for Arctic Char sampled from test fisheries (TF) using commercial gillnets, fish plant (FP) using commercial gillnet and from the fishery-independent survey (FIS) using 50 m multi-mesh gill nets in (A) Ijaruvung Lake, (B) Iqalujjuaq Fiord and (C) Irvine Inlet in Cumberland Sound, Nunavut. Median, quartiles and outliers (○ values ≥1.5 x and * values ≥ 3 x interquartile ranges, respectively) are also shown.*

Table 1. Robson-Chapman instantaneous mortality (z) and the rate of survival (S) for Arctic Char from Ijaruvung Lake, Iqualujjuaq Fiord and Irvine Inlet, using data from test fisheries, fishery-dependent sampling (1978-1997), and fishery-independent sampling (2010-2015).

Catch Year	Ijaruvung Lake		Iqualujjuaq Fiord		Irvine Inlet	
	Instantaneous Mortality (Z)	Rate of Survival (S)	Instantaneous Mortality (Z)	Rate of Survival (S)	Instantaneous Mortality (Z)	Rate of Survival (S)
1978	0.46	62.99 %	-	-	-	-
1980	0.53	58.41 %	-	-	-	-
1981	0.34	69.79 %	-	-	-	-
1983	-	-	0.63	53.25 %	-	-
1997	-	-	0.55	57.69 %	-	-
2010	-	-	0.27	76.66 %	0.24	78.32 %
2011	0.29	74.50 %	0.34	71.17 %	0.22	80.03 %
2012	0.35	70.83 %	0.38	67.83 %	0.19	82.78 %
2013	0.29	74.56 %	0.32	72.61 %	0.21	81.01 %
2014	0.29	74.63 %	0.33	71.60 %	0.22	80.24 %
2015	0.43	64.34 %	-	-	0.22	80.62 %
5 Years Pooled	0.32	72.93 %	0.33	72.92 %	0.24	78.32 %

Quantitative Modelling

Without a longer time series of data, it is difficult to run standard abundance models (e.g., catch at age models, surplus production models). We therefore, used the Baranov catch equation (Ricker 1975; Liu and Heino 2014) and Catch-MSY models (Martel and Froese 2013) to estimate abundance (Tables 2 & 3). Harvest information from commercial fisheries, fishery-independent data and approximate information on the subsistence harvest were used for quantitative modeling.

For Ijaruvung Lake, the Baranov catch equation estimated the median standing stock biomass around 25,732 kg. A target exploitation rate of 5 % would result in a harvest level of 1,287 kg per year. The Catch-MSY model estimated the median standing stock biomass was around 29,916 kg and MSY was estimated to be 1,651 kg.

For Iqalujjuaq Fiord, the Baranov catch equation estimated the median standing stock biomass was about 35,214 kg. A target exploitation rate of 5 % would correspond to a harvest level of 1,761 kg per. The Catch-MSY model estimated the median standing stock biomass around 40,879 kg and MSY was around 2,626 kg.

For Irvine Inlet, the Baranov catch equation estimated the median standing stock biomass as 53,304 kg. A target exploitation rate of 5 % would result in a harvest level of 2,665 kg per year. The Catch-MSY model estimated the median stock biomass around 53,361 kg and MSY was 2,703 kg.

Kristofferson et al. (1991) suggested that harvest rates of 5-10% are sustainable in Arctic char fisheries. Johnson (1980) found that an exploitation rate of 11 % could be excessive and would likely lead to population decline in a high Arctic population. It should be noted that there is no estimate of harvest level resilience in Arctic Char stocks on Baffin Island; this is an area where research is warranted.

Table 2. Simulations results for Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet Arctic Char populations. Abundance and biomass (kg) were calculated using a model based on the Baranov catch equation.

	Ijaruvung Lake			Iqalujjuaq Fiord			Irvine Inlet		
	Median	5 %	95 %	Median	5 %	95 %	Median	5 %	95 %
Abundance	10,931	8,028	17,110	15,211	10,439	28,511	21,972	13,764	48,487
Biomass (kg)	25,732	18,898	40,277	35,214	24,166	66,002	53,304	33,391	117,629
5 %	1,287	945	2,014	1,761	1,208	3,300	2,665	1,670	5,881
10 %	2,573	1,890	4,028	3,521	2,417	6,600	5,330	3,339	11,763

Table 3. Catch-MSY Model parameters and results.

	Ijaruvung Lake				Iqalujjuaq Fiord				Irvine Inlet			
	Mean	SD	Median	G. Mean	Mean	SD	Median	G. Mean	Mean	SD	Median	G. Mean
k	61,059	32,557	58,845	51,117	86,233	45,556	78,495	74,313	116,583	71,701	100,331	98,306
r	0.158	0.109	0.113	0.130	0.167	0.112	0.126	0.137	0.128	0.085	0.1	0.108
m	0.15	0.02	0.15	0.15	0.15	0.02	0.15	0.15	0.171	0.028	0.172	0.169
MSY	1,683	307	1,651	1,656	2,592	514	2,626	2,538	2,733	688	2,703	2,653
B-MSY	30,530	16,278	29,422	25,559	43,116	22,777	39,248	37,156	58,291	35,850	50,165	49,153
F-MSY	0.08	0.05	0.06	0.06	0.08	0.06	0.06	0.07	0.064	0.043	0.05	0.054
U-MSY	0.07	0.05	0.05	0.06	0.07	0.05	0.06	0.06	0.056	0.036	0.045	0.048
B_{2016}	33,552	19,525	29,916	27,632	49,280	30,319	40,879	40,613	67,339	50,617	53,361	52,692
B_{2016}/B_{MSY}	1.11	0.22	1.15	1.08	1.12	0.22	1.17	1.09	1.099	0.225	1.157	1.072

Reference Point

The Fisheries and Oceans Canada Fishery Decision-making Framework incorporating the Precautionary Approach (DFO 2009), requires stock status to be characterized using the best available reference points. The preferred approach is always to have reference points and harvest rules based on the best available information. However, in cases when there is insufficient information available to calculate a stock-specific precautionary reference point and harvest rules a provisional limit reference point (LRP) of 0.4 B_{MSY} and an upper stock reference point (USR) of 0.8 B_{MSY} may be used. These default reference points were developed from reviews of a wide variety of fish stocks and are in line with international practices and standards. B_{MSY} is the estimated long-term equilibrium biomass when the stock is fished at the exploitation rate that results in maximum sustainable yield (MSY). Stocks are considered to be in the “critical” zone when B_t < LRP, in the “cautious” zone when LRP < B_t < USR and in the “healthy” zone when B_t > USR. The reference points adopted for this assessment are: LRP = 0.4 B_{MSY} and USR = 0.8 B_{MSY}. Figure 8 shows the current status of each stock relative to the provisional limit and upper stock reference points (DFO 2009). These stocks at the beginning of 2016 are estimated to be above the upper stock reference points in the healthy zone. The assessment concluded the Ijaruvung Lake Arctic Char stock is currently in the healthy zone with a 12 % probability of being in the Cautious zone. Iqalujjuaq stock is also in the healthy zone with a 11 % probability of being in the Cautious zone. Similarly, the Irvine Inlet stock is also in the healthy zone with a 14 % probability of being in the Cautious zone.

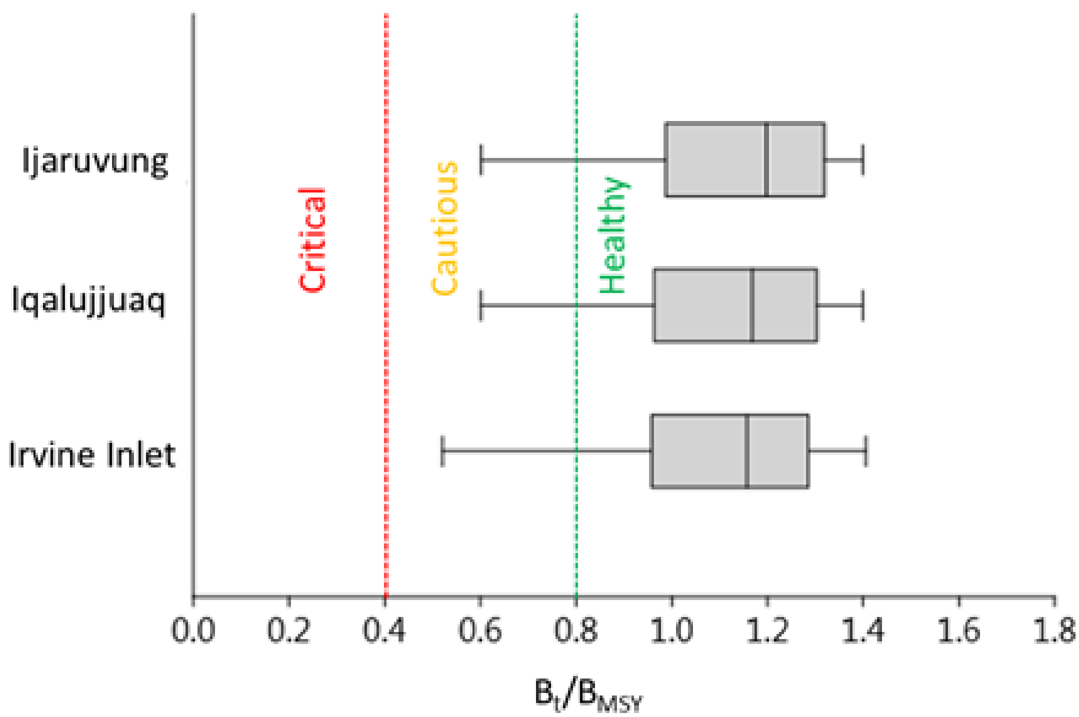


Figure 8. Current status of three Cumberland Sound commercial Arctic Char stocks relative to the provisional DFO Precautionary Approach reference points of 0.4B_{MSY} and 0.8B_{MSY}. The value of B_t/B_{MSY} is based on 2016 data. Boxplots show the 25, 50, 75 percentiles, minimal and maximal values from Monte Carlo simulations results.

Sources of Uncertainty

- In the absence of subsistence fishery data, harvest data are not complete. We have an indication of subsistence harvest in these water bodies; these estimates were included in the total harvest from each stock.
- No direct estimates of abundance are available. Only five years of CPUE data are available as an indirect estimate of abundance. The CPUE data were not used in the current modeling exercise.
- Our estimates of natural mortality have a high degree of uncertainty; we do not know the mortality of young ages.
- It is assumed that all three of these stocks operate as individual populations. However, there may be some degree of straying.
- It is difficult to estimate growth parameters due to the small number of older age classes in the samples. Ages younger than year 4 are also missing.
- Classification of maturity stages in fish is highly subjective; human error is quite possible. Assessing maturity status of fish sampled in the winter is difficult. These factors would affect estimates of age at maturity, the proportion of mature individuals and spawning stock biomass.
- All of the input parameters used in these models, natural mortality, carrying capacity K, intrinsic rate of increase r, and depletion level, have associated uncertainties. Some of these inputs (e.g. total mortality) and catch data are from directly measured values. The intrinsic rate of increase was estimated using reasonable biological assumptions for Arctic Char. Carrying capacity and depletion level are based on the minimum and maximum catches.
- Models can have inherent biases because of their underlying assumptions. These effects could influence the output and need to be explored in the context of Arctic Char.

Future Research

- Quantify egg production per female and lifetime fecundity in each waterbody/stock.
- Quantify natural mortality rates on young ages of Arctic Char.
- Assess timing, age, and frequency of Arctic Char migration.
- Implement a program to report catch and effort data from commercial fisheries.
- Future fishery-independent monitoring should have a larger number of sets per year over a longer period to increase sample size.
- Comprehensive environmental data should be collected during fish sampling.
- Conduct a tagging study to estimate population size and harvest rate through mark-recapture methods.
- Try a different growth model other than the Von Bertalanffy to fit growth.
- Conduct a harvest pressure study to review harvest rate potentials (i.e.,. resilience to harvest pressure) for Baffin Island Arctic Char.
- Further studies on uncertainty, sensitivity, and biases associated with quantitative models used for stock assessment.

CONCLUSIONS AND ADVICE

- There are no clear trends in the biological and catch-effort data to indicate that the Arctic Char stocks in these three water bodies are currently overharvested.
- Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet Arctic char stocks appear to be sustainable and in the Healthy Zone, with less than 15 % probabilities of being in the Cautious Zone of the Precautionary Approach framework.
- For Ijaruvung Lake and Iqalujjuaq Fiord, the current commercial harvests and quotas are appropriate to achieve the target exploitation rate for each stock. For Irvine Inlet, the current annual quota of 4500 kg exceeds the target exploitation rate. Reducing the Irvine Inlet quota from 4500 kg to 3000 kg would achieve the 5 % target exploitation rate and be in line with the current mean harvest level (2000 kg).
- Local survey and traditional knowledge should be used to determine the proper level of subsistence harvest for each waterbody.
- A program to report catch and effort data from commercial fisheries should be implemented.
- Monitoring of this fishery should continue as part of a fish plant sampling program with local assistance.

SOURCES OF INFORMATION

This Science Advisory Report is from February 14–15, 2017 Stock status and sustainable harvest levels for Arctic Char in Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet, Cumberland Sound, Nunavut. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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