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ASSESSMENT OF ARCTIC CHAR (*Salvelinus alpinus*) IN THE DARNLEY BAY AREA OF THE NORTHWEST TERRITORIES

*Arctic Char (*Salvelinus alpinus*) by C. Gallagher*

Figure 1. Map of Darnley Bay showing Hornaday and Brock rivers, and harvest monitoring locations.

Context

*Anadromous Arctic Char (*Salvelinus alpinus*) from the Brock River and especially from the Hornaday River is an important subsistence resource for the residents of Paulatuk, NT. Arctic Char from both river systems are co-managed by Fisheries and Oceans Canada (DFO), Fisheries Joint Management Committee, Paulatuk Hunters and Trappers Committee, and Parks Canada via the Paulatuk Char Working Group. The Hornaday Char Monitoring Program collects fisheries information on an annual basis and the data are used to assess trends in the Hornaday River population. A voluntarily established annual harvest limit of 1,700 anadromous Arctic Char that had been in place between 1998 and 2012 and includes both summer (in Darnley Bay) and winter (in the Hornaday River only) fisheries was increased to 1,800 in 2013.*

The Paulatuk Hunters and Trappers Committee requested an increase in the voluntary harvest limit to meet the subsistence needs of the community. Additionally, increased fishing effort has been reported at Lasard Creek where there is uncertainty regarding the stock composition contributing to the harvest at this location and whether this will result in higher catches of char from the Brock and/ or Hornaday systems. As a result, DFO Resource Management has requested Science advice on the current stock status and sustainable harvest level of Arctic Char from the Hornaday River, and information on the contribution of stocks from the Hornaday and Brock rivers to the fishery along the eastern coast of Darnley Bay.

SUMMARY

- Biological and catch indices as well as modelling results indicate that the Hornaday River population is not experiencing overfishing and the current stock status is healthy.
- Data from community harvest surveys (1968-2013) and various sampling programs, most importantly the Hornaday River Char Monitoring Program (established in 1990) were incorporated into population models (depletion-based stock reduction analysis, surplus production and, statistical catch at age models) to estimate maximum sustainable yield (MSY) and population abundance, and evaluate stock status.
- Model estimates of the abundance of Arctic Char from the Hornaday River in 2013 ranged between approximately 17,000 and 33,700 for the fishable component of the population (≥440 mm), and 78,600 for the total population.
- The three models generated relatively similar estimates of MSY with the inverse weighted average among the estimates providing a value (± 1 standard deviation [SD]) of 2,496 (154) fish. Risk to the stock increases as harvest approaches MSY, therefore harvest should be kept below MSY to ensure a sustainable fishery. The voluntary total allowable harvest of 1,800 Arctic Char in 2013 is below MSY and appears to be sustainable.
- Two genetically distinct stocks of Arctic Char, one from the Hornaday River and the other from the Brock River, contribute to the summer coastal fishery in eastern Darnley Bay. Although both stocks are genetically distinct, a high degree of gene flow occurs between them, indicating some interbreeding. The contribution of the Hornaday River stock to the coastal fishery is consistently greater (average among sampling years was >80%) than the Brock River.

INTRODUCTION

Since Paulatuk was settled in the 1940s, anadromous Arctic Char have always provided an important contribution to the subsistence of the community. The majority of the fishing activity occurs along the south and eastern shores of Darnley Bay in summer using gill nets. The harvest is dominated by Arctic Char from the Hornaday River that are caught mainly at the mouth of the river during their upstream migration in August (Figure 1). Arctic Char are also harvested during the winter, typically from mid-October to November, in deep pools in the Hornaday River delta and the upstream area of the river locally known as Coalmine (Figure 1).

The harvest of anadromous Arctic Char by Paulatuk residents has been reported since 1968 (Figure 2). A commercial fishery operated between 1968 and 1986, and was ceased in 1987 due to diminishing catches and reduced size of fish. The decline in the fishery prompted the establishment of the Hornaday River Char Monitoring Program in 1990. The program collects harvest, biological, and catch-per-unit-effort (CPUE, starting in 1997) data annually from the subsistence fishery at the mouth of the Hornaday River during the summer; data are used to examine trends in relative abundance and population demographics. Total annual harvest information, from locations other than the mouth of the Hornaday River during the summer and from the Hornaday River during the winter, is collected by a community-wide survey. The survey, established in its current form in 1997, is conducted multiple times over the course of the year. A voluntary total allowable harvest (TAH) for the Hornaday River char population was set at 1,700 fish by the Paulatuk Char Working Group in 1998, and was increased to 1,800 fish in 2013 due to increased demands by the community. Reported catches between 1998 and 2013 have varied between 479 and 1,949 char (Figure 2). Since 2009, the proportion of Arctic Char reportedly harvested during the summer near the mouth of Lasard Creek (Figure 1) has

increased from <20% (n=<250 fish) to approximately 30-45% (n= 350-690 fish) of the overall harvest of Arctic Char in the Darnley Bay area in most years.

The Brock River is also utilized by anadromous Arctic Char, however it was not known whether these were a separate stock from those of the Hornaday River and how much either stock contributed to the coastal fisheries at Lasard Creek and mouth of Hornaday River. Given this uncertainty, data from the Lasard Creek fishery were collected between 2011 and 2013, and a genetic mixed-stock fishery analysis was conducted using tissue samples collected between 2010 and 2013 in order to determine the relative contributions of char from the Hornaday River to the coastal fisheries at Lasard Creek and mouth of Hornaday River.

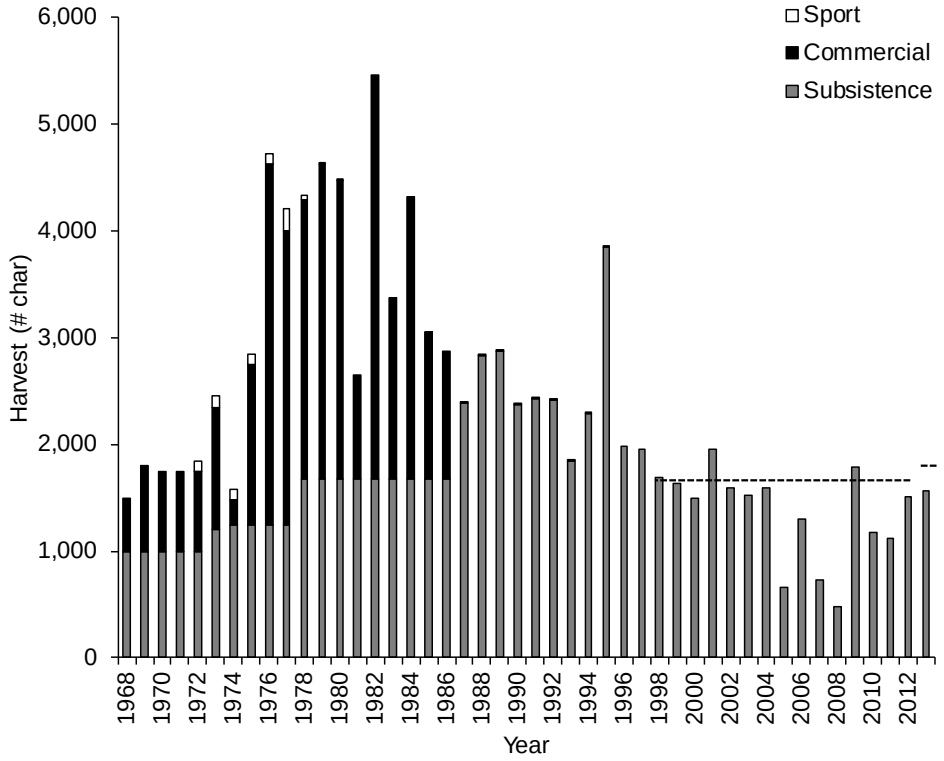

Figure 2. Estimated and reported harvest of anadromous Arctic Char from 1968 to 2013 in the Darnley Bay area (all seasons and locations). Dashed line is the voluntary total allowable harvest: 1,700 annually fish between 1998 and 2012, and 1,800 fish in 2013.

Although fewer char are harvested on the west side of Darnley Bay, a monitoring program at Tippitiuyak (Tippi) (Figure 1) was established in 2012 to collect biological data from char harvested at this location, with the intention of sampling char locally known as ‘blue char’ that are reported to be morphologically different from other Arctic Char. Information from the various programs was synthesized in order to characterize Arctic Char relative abundance, demographics and stock structure in Darnley Bay, and the time-series data from the Hornaday River were modelled to assess stock status.

ASSESSMENT

Biological data used in the assessment were length, weight, sex, maturity and age, which were then used to estimate growth, condition factor, mortality and survival. Fishery data (e.g., harvest and CPUE) were also available. Data sources were:

1) the commercial fishery (1968-1986) which was periodically sampled beginning in 1973;

2) the subsistence fishery (1968-2013) with sampling in 1988 and 1989 (although sex, maturity and age were not always collected);
3) a small test fishery (1981);
4) a conduit weir study (1987); and
5) the Hornaday River Char Monitoring Program (1990-2013) with CPUE data collected only since 1997. Samples were randomly selected throughout the duration of the fishery (maturity data were only available starting in 1996, no age were data available in 2011).

Currently, there is a broad distribution of sizes present in the fishery with a trend over time of increasingly high proportions (>30%) of char >600 mm in length. Median length (Figure 3), weight, and condition factor appear to be stable. Harvested Arctic Char are mainly between 6 and 8 years of age (Figure 4), with modal values increasing over the past five years.

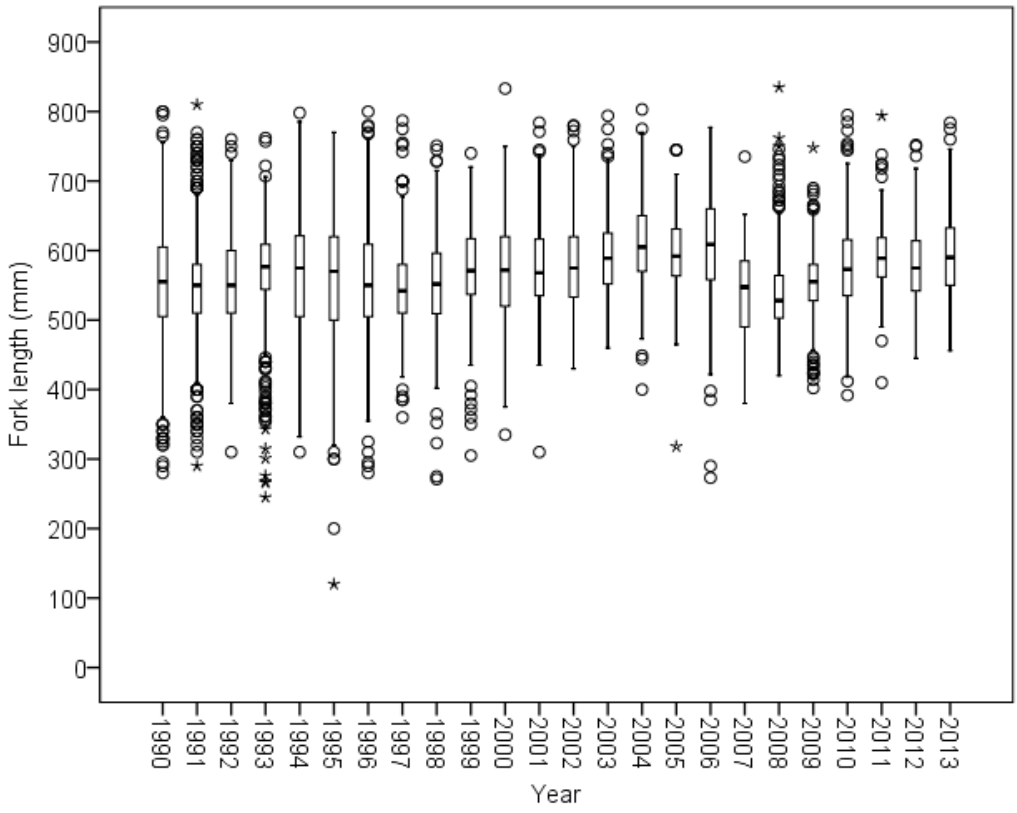

Figure 3. Box plot of fork length (median, quartiles and outliers (○, ✶)) of Arctic Char harvested at the mouth of the Hornaday River between 1990 and 2013.

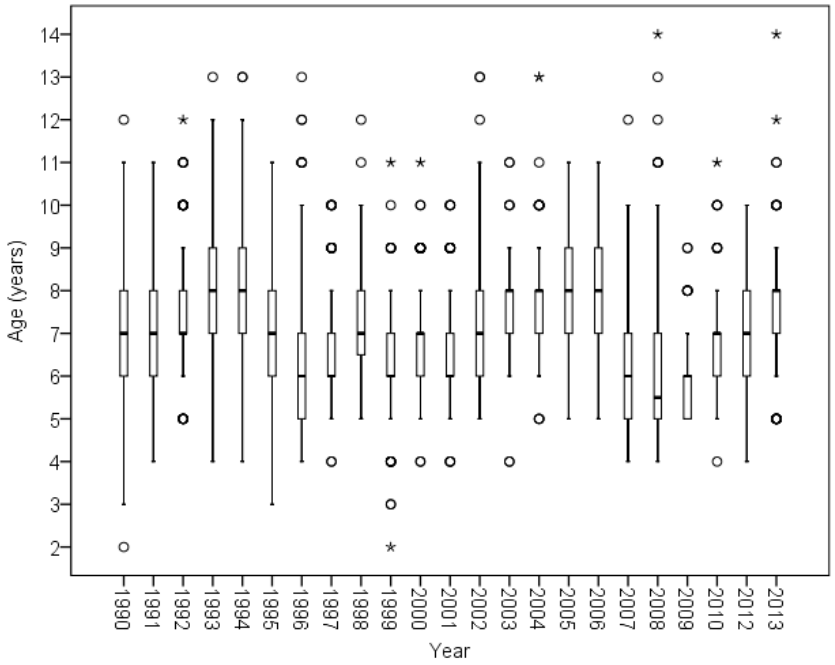

Figure 4. Box plot of age (median, quartiles and outliers (○, ✶)) of Arctic Char harvested at the mouth of the Hornaday River between 1990 and 2013. No data available for 2011.

Since 2007, with the exception of 2010, a greater proportion of males (~60%) have consistently been harvested. The growth (length-at-age) of Arctic Char has not changed considerably over the past ten years. CPUE records were mainly from 114 mm and 140 mm mesh, and indicate that relative abundances in recent years are at the upper end of the range of values observed since 1997 (Figure 5).

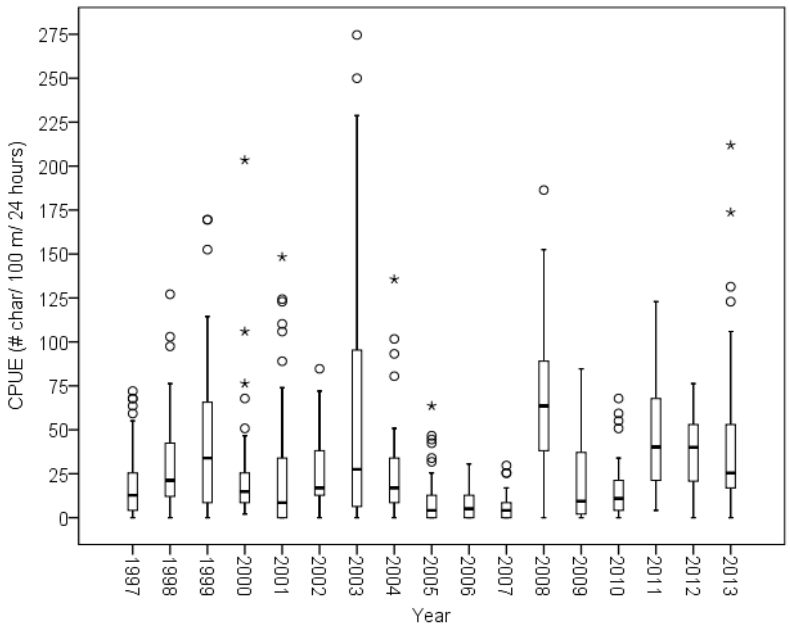

Figure 5. Box plot of catch-per-unit-effort (median, quartiles and outliers (○, ✶))of Arctic Char captured in 114 mm mesh gill nets by harvesters monitored at the mouth of the Hornaday River from 1997 to 2013. Note: one outlier in 2013 had a CPUE equal to 432 (not shown).

Three models were used to estimate total abundance and biomass, and maximum sustainable yield (MSY), abundance (N_{MSY}), biomass (B_{MSY}), fishing mortality (F_{MSY}), and exploitation rate (U_{MSY}) at MSY:

1) Depletion-based stochastic stock reduction analysis (DB-SRA);
2) Surplus production model (SPM); and
3) Statistical-catch-at-age model (SCA).

MSY (± 1 SD) in terms of number of fish and exploitation rate (± 1 SD) at MSY, respectively, was estimated as: 2,189 (434) and 17.5% (4.2%), using DB-SRA; 2,797 (347) and 11.8% (2%), using SPM; and 2,372 (769) and 17.3% (3.1%) using SCAA.

The inverse-variance weighted average of each parameter estimated by the three models was calculated in order to generate a single estimate (Table 1). The modelling results indicated that the current voluntary harvest limit is below MSY. The models generated different estimates of either the fishable (component of the population vulnerable to fishing gear; ≥440 mm) or total abundance (includes all ages of fish) for 2013, with the DB-SRA (fishable), SPM (fishable) and SCA (total) predicting approximately 17,000, 33,700, and 78,600 Arctic Char, respectively (Figure 6). The DB-SRA model indicated population abundance has been relatively stable since the 1980s with an increasing trend starting in 2007, while SPM indicated abundance had increased steadily since the mid-1990s and has remained stable since 2009. The SCA model demonstrated a period of high variation in abundance between 1995 and 2008 followed by a period of stability up to 2013. The models all identified periods of overfishing ($F/F_{MSY} > 1$ and $N/N_{MSY} < 1$) between approximately 1977 and 1989, and in the mid-1990s, although DB-SRA estimated fewer years with overfishing (Figure 7). All three models suggest that the population is currently not experiencing overfishing and the stock status is healthy.

Table 1. Median (standard deviation in brackets) of inverse weighted average of the maximum sustainable yield (MSY), abundance (N_{MSY}), biomass (B_{MSY}), fishing mortality (F_{MSY}) and exploitation rate (U_{MSY}) at MSY.

	Abundance	Biomass (kg)
MSY	2,496 (154)	5,724 (187)
N_{MSY}	14,635 (1021)	-
B_{MSY}	-	29,826 (1851)
F_{MSY}	0.184 (0.0133)	0.195 (0.0133)
U_{MSY}	0.147 (0.009)	0.155 (0.009)

The genetic mixed-stock fishery analysis indicated that from 2010 to 2012, the contribution of Hornaday River char to the coastal fishery ranged between 80.9% and 92.7% at the mouth of the Hornaday River, and 64.3% to 89.9% at the mouth of Lasard Creek. Among these years, the contribution of Brock River char ranged between 5.4% and 18.9% to the fishery at the mouth of the Hornaday River, and 9.0% and 32.4% at the mouth of Lasard Creek. Concurrent monitoring at Lasard Creek and Hornaday River indicated that catch-rates were similar between sites although maximum CPUE was higher at Lasard Creek. The length and age structure (median and frequency distribution) were comparable, which is expected given the results of the mixed-stock fishery.

Although samples sizes were low (n= 58), the preliminary results from the monitoring of Arctic Char harvested in the western area of Darnley Bay at Tippi indicated that those identified as ‘blue char’ (n= 47) had similar size (range 430-730 mm) and age (range 4 to 11 years) structure compared to char captured at the Hornaday River.

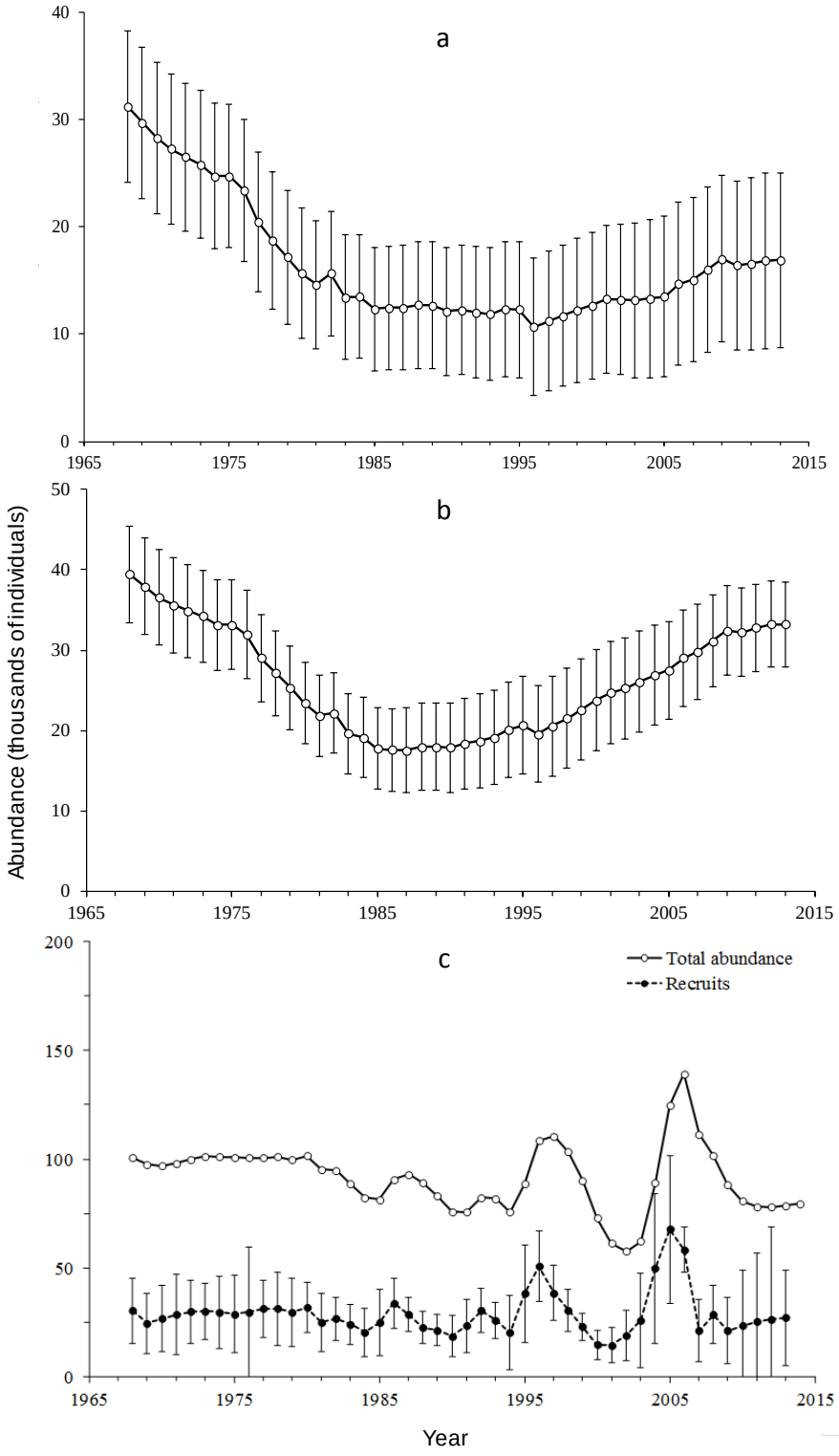

Figure 6. Estimates (mean ± SD) of abundance of harvestable-size (≥440 mm) from a DB-SRA (top panel a) and Surplus Production (middle panel b) model, and total abundance from a Statistical Catch-at-Age (lower panel c) model for Arctic Char from the Hornaday River from 1968 to 2013. For lower panel c, abundance of both total population and age-1 recruits were estimated.

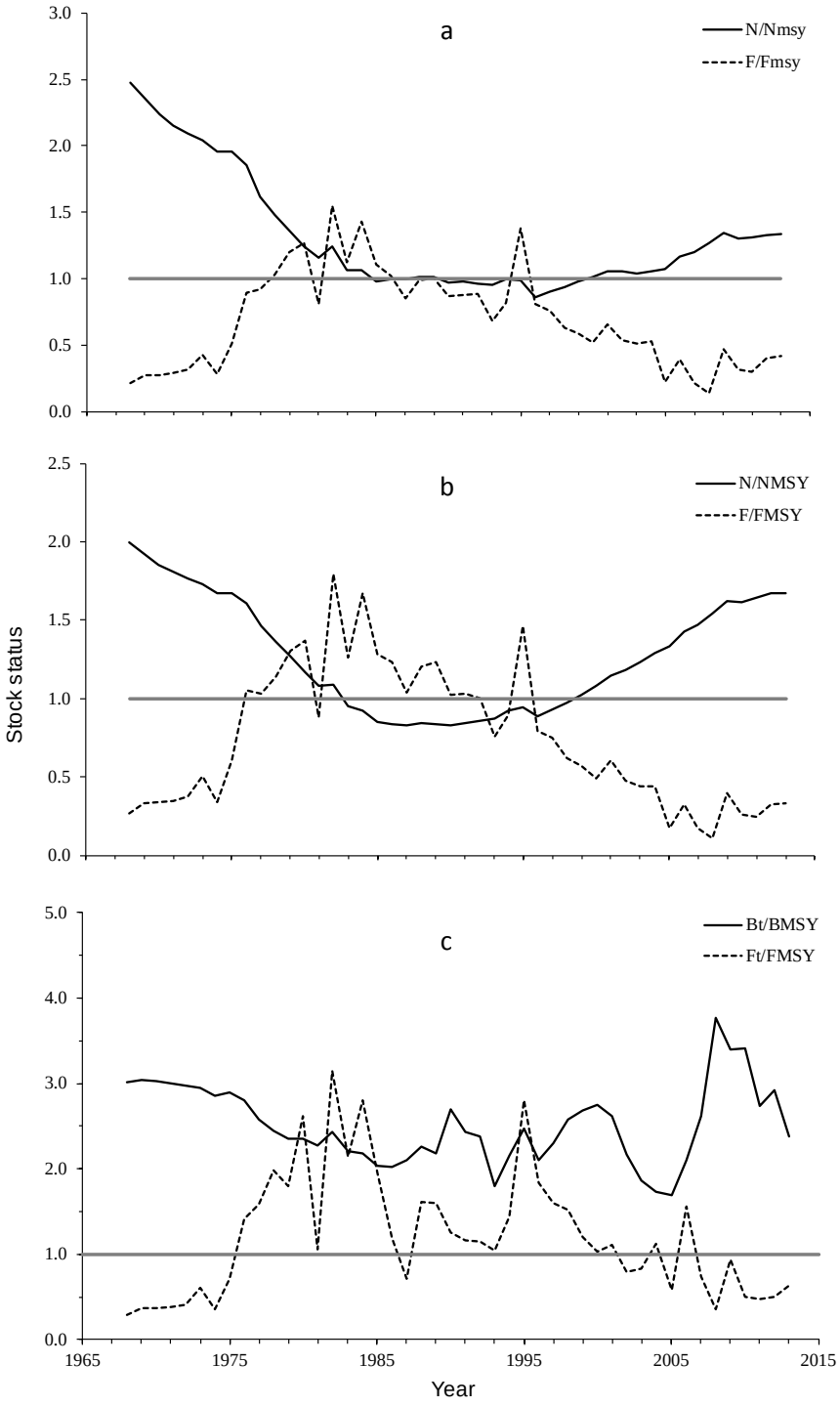

Figure 7. Arctic Char stock exploitation history during 1968-2013, shown by posterior median trends in stock status (N/N_{MSY} or B/B_{MSY}) and fishing status (F/F_{MSY}) from a DB-SRA (upper panel a), Surplus Production (middle panel b), and Statistical Catch-at-Age (lower panel c) model. The critical reference to the stock status is delineated by the grey line.

Sources of Uncertainty

Decreases in the flow of water in the east channel of the Hornaday River delta has been observed, starting in the mid-1990s and were especially evident by 2005. The Hornaday River Char Monitoring Program is conducted in this channel and it is possible that the catch-effort data may have been impacted if char have shifted to using other channels during migration, possibly limiting its direct comparability among years.

The CPUE data from the fishery may not be an accurate index of abundance for the Hornaday River char stock, particularly in years with high variance due to low sample sizes. Multiple factors can affect CPUE data at the mouth of the Hornaday River among years and include the timing of the fishery relative to that of the upstream migration, weather conditions (e.g., wind), wave action, gear type, and soak time of the net. These will have important effects on the outputs of population models that use CPUE (SPM and SCA) that are used to assess the population and generate estimates of sustainable harvest levels.

Hornaday River monitoring occurred at the same location every year and used consistent sampling methods. However, the lack of fishery-independent data decreases the accuracy of metrics such as mean length, weight, age, and mortality because samples from the fishery are likely not representative of the entire population given that larger-sized char would be more susceptible to the subsistence gill nets (mainly 114 and 127 mm mesh). Additionally, fishing locations and timing were not random but were rather timed to coincide with the upstream migration of char in August in most years.

The models used in the assessment assumed that the Arctic Char spawned in consecutive-years after reaching sexual maturity. Although fecundity and spawning frequency in char from the Hornaday stock is poorly known, it is assumed that most adults will not reproduce in the year following spawning in order to invest energy in growth rather than reproduction and will presumably spawn the year after. Additionally, it is assumed that most current-year spawners remain in the Hornaday River all summer long and are not vulnerable to the summer fishery. The effect of the assumption of consecutive-year spawning on the models would be to overestimate the spawning stock biomass/ reproductive potential for the population.

In the SCA model, it was assumed that growth and natural mortality were constant, gear selectivity followed a constant logistic function, stock recruitment was best described using the Beverton-Holt model, and that harvest was reported without error. These assumptions are either unrealistic or not directly known and provide uncertainty to the results from the modelling.

The genetic baseline collected from the Hornaday River was intended to be juvenile char that had yet to undertake seaward migrations, however, only adult non-spawners sampled during the winter at Coalmine were available. It was assumed that these char had all originated from the Hornaday River, which may be incorrect given the ability of adults of this species to stray to non-natal systems in the years when they are not spawning. Additionally, genetic data from both river systems are restricted to only one year of sampling, therefore inferences pertaining to the temporal stability of population structure and contributions to mixed-stock fisheries in the region cannot be drawn.

Although unlikely, there is a possibility that populations in addition to the Hornaday and Brock rivers may make a small contribution to the fishery in eastern Darnley Bay.

During the commercial fishery, the subsistence harvest was not systematically reported and estimated values from personal communication were used in the models.

The same age reader and ageing method (whole) has been used to age otoliths of char since the monitoring program began. However, new methods (e.g., thin sectioning) that have been

employed in recent years may provide more accurate ages. An age comparison study was carried out between the current age reader and a second age reader familiar with both types of methods. The objective was to determine if differences existed between readers and/ or methods and to evaluate the impact that any differences may have on age-related metrics such as growth and mortality. Results indicated that for Arctic Char ≥7 years of age the current age reader tended to produce older ages, therefore, the proportion of older age classes in the population may have been underestimated and the growth and mortality of the population overestimated. This could affect population dynamic modelling (SCA), however, consistency in ageing is more important to model outputs and in this case a single age reader provided the age readings used in this assessment.

CONCLUSIONS AND ADVICE

Trends in the biological and catch-effort data time-series give no indication that Arctic Char from the Hornaday River is currently overharvested. All the models indicated the Hornaday River population is not currently experiencing overfishing and that stock status is healthy.

The three models used in the assessment provided relatively similar estimates of MSY (the maximum number of char that could be currently sustainably harvested) with a relatively low level of variation, thus providing confidence in the predictions. The inverse weighted average among the three estimates of MSY provided a value (± 1 SD) of 2,496 (154) char.

Increases in harvest should not surpass MSY. Risk to the stock increases as harvest approaches MSY and given the amount of uncertainty in the models combined with the objective to work within a Precautionary Approach framework, harvest should be kept well below MSY in order to ensure a sustainable subsistence fishery and conservation of the stock. The voluntary TAH of 1,800 Arctic Char established in 2013 appears to be sustainable.

The DB-SRA and SPM models generated different estimates of abundance, 17,000 and 33,700, respectively, for the fishable component of the Hornaday River population (≥440 mm) in 2013. The total abundance of the population estimated by the SCA model was 78,600 individuals. All three models demonstrated that abundance has been stable since 2008.

Two populations of Arctic Char, one from the Hornaday River and the other from the Brock River, contribute to the summer coastal fishery in eastern Darnley Bay. Although both are genetically distinct, a high degree of gene flow occurs between populations.

The proportion of the contribution of either stock to both fishing locations remained relatively consistent among years. The smaller contribution of the Brock River stock to the coastal fishery (average was approximately 10% among sampling years) indicates this population is likely less abundant than the Hornaday River population, which is consistent with observations by harvesters from the community of Paulatuk.

Data indicate that most char captured at Lasard Creek are from the Hornaday River, therefore, comprehensive biological and catch-effort monitoring at Lasard Creek becomes less of a priority if monitoring is already occurring at the Hornaday River.

Data were insufficient to characterize the genetic characteristics of Arctic Char identified as ‘blue char’ from the Tippitiuyak area of Darnley Bay, although samples of ‘blue char’ taken in 2012 and 2013 appeared to have similar length, weight, and age characteristics to Arctic Char sampled at the mouth of the Hornaday River. Further scientific analyses and a comprehensive traditional knowledge study on ‘blue char’ would be beneficial.

To help ensure a sustainable subsistence fishery in the Hornaday River it is important to continue with the annual Hornaday River Char Monitoring Program. Collecting genetic samples

from Hornaday River and Lasard Creek char for use in a mixed-stock fishery analysis could possibly provide an indicator of relative abundance. The survey of community harvest also needs to be maintained in order to collect information for stock assessment purposes and to evaluate compliance with management objectives.

OTHER CONSIDERATIONS

Additional research or data collection that would be beneficial for future assessment of Arctic Char from the Hornaday River include:

1) Determining whether char have changed their use of the east and west channels in the delta when moving upstream into the Hornaday River. This could be achieved by conducting experimental test fisheries concurrent with the Hornaday River Monitoring Program to evaluate catches and characteristics of char from both channels.
2) Collecting catch-effort and biological data during the winter fishery in the delta and Coalmine area could provide information useful for assessment and monitoring. Evaluating the feasibility of using methods other than modelling to estimate population size such as mark-recapture, weir, or DIDSON (dual-frequency identification sonar).
3) Monitoring changes in groundwater flows and water levels over time in sensitive spawning and overwintering areas. Proper documentation of spawning areas and the amount of overwintering habitat available in the Coalmine area as well as migration and overwintering habitat in the delta are necessary to ensure these critical habitats are protected.
4) Identifying and/ or improving knowledge of critical summer feeding habitat (e.g., Pearce Point and other coastal locations) and characterization of the trophic ecology of char by examining diet content and stable isotopes.
5) Improving interpretation of maturity status by measuring gonad weight.
6) Improving the community harvest survey by asking additional questions about perceived stock status and factors, such as environmental conditions (e.g., ice cover), that may influence harvest.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 6-7, 2014 Assessment of Arctic Char in the Darnley Bay area of the Northwest Territories. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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