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Proceedings of the regional peer review on the Estimated abundance and sustainable harvest levels for the Jayko and Halokvik (30 Mile) rivers in the Cambridge Bay commercial fishery, 2010–2015

Meeting dates: January 24–26, 2017
Winnipeg, Manitoba

Chairperson: Kevin Hedges
Editors: Lauren Wiens and Gabrielle Grenier

Freshwater Institute
Fisheries and Oceans Canada
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February 2020

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) regional peer-review meeting was held to assess the stock status of two commercially fished anadromous Arctic Char (*Salvelinus alpinus*) rivers in the Cambridge Bay, NU fishery. The meeting was held at the Freshwater Institute in Winnipeg, MB, on January 24–26, 2017. It was held in response to a request from DFO Fisheries and Aquaculture Management (FAM) for science advice on the current stock status in and sustainability of harvest levels for the Jayko and Halokvik rivers.

The regional science peer-review included participants from DFO Science and FAM, the Ekaluktutiak Hunters and Trappers Organization, Kitikmeot Foods, Nunavut Development Corporation, and the University of Calgary. Commercial fishers also participated in the meeting. Participants reviewed two working papers. The first working paper examined current stock status, which summarized the available biological, harvest, and catch-effort information, including both fishery-independent and fishery-dependent sampling. The second working paper assessed the application of a depletion-based stock reduction analysis and a data-limited model for the assessment of fisheries management and stock status of river-based commercial Arctic Char fisheries.

This proceedings report summarizes the relevant discussions from the peer-review meeting and presents revisions to be made to the associated research documents. The Proceedings, Science Advisory Report, and the supporting Research Documents resulting from this advisory meeting are published on the DFO Canadian Science Advisory Secretariat Website.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) regional peer-review meeting was held on January 24–26, 2017 at the Freshwater Institute in Winnipeg, Manitoba. The purpose of this meeting was to provide advice on the status (stock health) of Arctic Char (*Salvelinus alpinus*) in the Jayko and Halokvik rivers, Cambridge Bay, NU. The goals of the meeting were to provide population abundance estimates and assess the sustainability of harvest levels for these two rivers. This proceedings report summarizes the main points of each presentation along with ensuing discussions.

The Terms of Reference, including objectives for the science review (Appendix 1), were developed in response to a request for advice from DFO Fisheries and Aquaculture Management (FAM), Central and Arctic Region. Participants included DFO (Science, FAM), the Ekaluktutiak Hunters and Trappers Organization (EHTO), Kitikmeot Foods, Nunavut Development Corporation, commercial fishers and the University of Calgary (Appendix 2).

Two working papers and a draft Science Advisory Report (SAR) were prepared and circulated to participants in advance of the meeting and were the basis for the review. Four presentations were given at the meeting, one by FAM and three by DFO Science. Participants were asked questions and discussions occurred throughout the presentations. After each presentation, participants were asked to comment, and further engage in a discussion and question period.

The meeting Chair welcomed the participants and described the role of CSAS in the provision of DFO peer-reviewed science advice. Participants introduced themselves and the Chair acknowledged those that travelled considerable distances to attend the review. Following the introductions the Chair presented and reviewed the meeting agenda (Appendix 3), highlighted the objectives in the Terms of Reference and identified the expected products from the review (Science Advisory Report, Proceedings and two Research Documents). Lauren Wiens and Gabrielle Grenier (DFO, Science) were identified as rapporteurs for the meeting. The Chair emphasized that the DFO Science Advisory process is a technical review that is applied to science data and analyses and that objectivity is maintained to eliminate bias in interpreting results. Guiding principles for the meeting were presented on the basis that all participants had the equal right to speak, advice was reached through consensus and conclusions were based on the scientific evidence presented. The Chair reminded participants of the timelines within which documents were expected. The conclusions and advice resulting from this review will be published as a SAR and used to inform management decisions.

PRESENTATIONS

AN OVERVIEW OF THE MANAGEMENT OF CAMBRIDGE BAY ARCTIC CHAR AND THE NUNAVUT GENERAL MONITORING PLAN

Author and Presenter: Tyler Jivan (DFO, FAM)

Summary

The management of the commercial fisheries in the Cambridge Bay region of Nunavut, is based on a collaborative approach between DFO and the community of Cambridge Bay (i.e., EHTO, Kitikmeot Foods Ltd. and the commercial fishers). The role of DFO FAM (Central and Arctic Region) is to support the management and sustainability of these fisheries and DFO Science and FAM hold annual planning meetings to develop work plans for each fishery with the outcome of identifying the fishery management needs. Cambridge Bay is home to the largest

Arctic Char commercial fishery in Canada and the fishery currently includes the Halokvik, Jayko, Paliryuak and Ekalluk rivers. The fishery is important to DFO and the community; therefore it is imperative that the fishery remains sustainable over the long term. Stock assessment in the area has been sporadic and there is no current estimate of population size of any stock in the Cambridge Bay area. The Sustainable Fisheries Framework (SFF) is the core of management decision making framework aimed at ensuring the sustainability of the population and the economy. There are two main points outlined within the SFF:

1. **Conservation Sustainable Policies** - Use of a fishery decision framework or a precautionary harvest strategy with moderate removal rates (i.e., ability to match the stock status to the harvest rate).
2. **Planning and monitoring tools or an Integrated Fisheries Management Plan (IFMP)** - Long-term objectives of the IFMP in Cambridge Bay is to conserve Arctic Char stocks, through sustainable use and effective fishery management. consistent with conservation principles, while promoting collaboration and participation with resource users, co-management and stakeholders.

The IFMP for Cambridge Bay Arctic Char identifies that up-to-date abundance estimates, fishery-dependent catch-per-unit-effort (CPUE) and by-catch discard were lacking. Furthermore the IFMP called for the assessment of current harvest levels and requires sustainable strategies to further promote economic viability while ensuring that stocks are healthy and abundant.

To achieve this, stocks must be conserved through regular, up-to-date stock assessments and monitoring that also enable local participation and promote education and compliance through collaborative efforts. In order to conduct a wholesome stock assessment, the fishery must have five years of data collection and 100 % monitoring, something that most fisheries in the region do not have. To fulfill this gap, local youth were hired in the spring and summer to perform creel surveys, calendars were printed to promote sharing of catch information and the monitoring program is anticipated to transition from science based monitoring to commercial fisher led monitoring. Moving forward, efforts will continue with daily reporting to the fish plant, the collection of CPUE data, multi-year science planning and science advice from the IFMP working group.

Discussion

Upon completion of the presentation there were no questions or comments from participants.

AN OVERVIEW OF ARCTIC CHAR BIOLOGY, MOVEMENTS, STOCKS STRUCTURE AND IMPLICATIONS/COMPLICATIONS FOR MANAGEMENT

Author and Presenter: Les N. Harris

Summary

Arctic Char are the most northerly fish species with a circumpolar distribution. They are the most targeted species in Nunavut and have been fished for subsistence for millennia. In Canada roughly 75,000–95,000 kg of Arctic Char are commercially harvested per year, with 51,000 kg harvested in Cambridge Bay. This is indicative of how large and economically important the fishery in Cambridge Bay is. The current management for Arctic Char in the Cambridge Bay region is carried out on a river-by-river basis. Populations of Arctic Char are believed to be somewhat demographically independent, it is typically believed that fish home to their natal freshwater spawning grounds although some straying is believed to occur and they are known to mix extensively while at sea. Juveniles can spend 3–9 years in the freshwater environment

until smoltification. At this point they begin the migration to sea, returning to freshwater every fall to spawn and/or overwinter. Based on this life history trait, Arctic Char are managed in a river-specific manner.

Within the Cambridge Bay area, the fishery is managed by discrete stock, however, the likelihood of straying (i.e., not returning to the location of birth) has been found to be high, especially among overwintering sites. Overall, there is a limited understanding about the marine migration of Arctic Char in this fishery. In order to address this lack of knowledge, a combination of tagging, telemetry and genetic studies have been implemented to further our understanding.

Some of the methods used to determine migration patterns included Floy tags, acoustic telemetry and genetic/genomic methods (i.e., enzymes. microsatellites and next generation sequencing [NGS]). The results from these studies have shown that dispersal was highest amongst non-spawners (i.e., individuals returning to fresh water only for over-wintering purposes). However, another study suggests otherwise, that there is low fidelity and Arctic Char do not return to their breeding ground for several years (Gilbert et al. 2016). Historical tagging data produced by Dempson and Kristofferson (1987) found that the percentage of recaptures in different rivers from where individuals were tagged was 7–54 %. Recent acoustic telemetry tagging (300 char), found that Arctic Char prefer coastal travel and that there was variation in the rates of straying, which suggests extensive stock mixing.

Lastly, microsatellite DNA (deoxyribonucleic acid) studies were implemented for the Cambridge Bay fishery, which included the five commercial waterbodies (i.e., Lauchlan, Halokvik, Paliryuak, Ekalluk and Jayko rivers), Freshwater Creek and several outgroups. The results from this revealed that there was regional genetic structure but the Cambridge Bay samples showed low differentiation. This supports previous studies suggesting that there are high rates of straying and stock mixing. Further genetic analysis using NGS and the same sampling methods show there is some degree of dispersal/straying among stocks.

In order to further address the new questions revealed from this study and better resolve genetic stock structure in the region, future studies may benefit from sampling spawning fish or trying to capture juveniles in the spawning habitat. This would provide ideal baselines for a more accurate account of stock structure in the current Cambridge Bay fishery.

The presentation highlighted the following points:

1. Discrete stocks are known to mix extensively while at sea.
2. Arctic Char must return to freshwater annually to overwinter regardless of reproductive status, resulting in the potential for two types of dispersal (i.e., breeding and overwintering dispersal).
3. In the Cambridge Bay area, nearly all upstream-migrating individuals are current year no-spawners (CYNS) and have no potential for gene flow in the present year.
4. Therefore, the majority of dispersal events would be overwintering dispersal,
5. Mixing is likely prevalent in some overwintering habitats (e.g., Ferguson Lake).
6. Overall fidelity appears to be quite low for this species in this area.
7. There could be sex-biased dispersal; however this will need to be further investigated.

Discussion

During the presentation a participant inquired about the age of the fish that were being tagged. Fish between the ages of 11 and 26 were tagged. Following the presentation a discussion was generated. A participant suggested that the authors provide more details in the section that describes the genetic methods used to determine genetic stock structure. Some of the methods were described by the presenter to provide clarification. The first method described was the use of microsatellites. Specific primers were used to amplify one gene with several alleles. The author suggested that it was best to look at several genes (~ 20). They then compared the differences in the frequency of alleles within and between populations. The NGS (Double Digest RADseq) method first works by;

1. fragmenting the target genome using both a common and rare digesting restriction enzyme followed by;
2. series of molecular processing steps transform the DNA into a fragment library suitable for sequencing on a NGS platform and then; and,
3. performing either single end or paired end sequencing to generate the appropriate amount of genomic information and markers.

A participant suggested that perhaps the habitat requirements for overwintering and spawning Arctic Char are different and this is what leads to dispersal of char among the different river systems. Discussion was generated over the ability to sample spawning or red char and juveniles. One participant asked whether all spawners had the noticeably red spawning colouration. In other locations there have been mature fish with silver colouration, suggesting that spawners may not always have the characteristic red colouration in all cases. In general, fish close to spawning will display some variation in colour, either red or yellow. Although spawning fish are an important demographic to target for genetics and tagging work, finding juveniles within their natal river system would be ideal, although past attempts to find the spawning grounds and juveniles have proved unsuccessful. Further discussion with the local Hunters and Trappers Organization (HTO) will assist to identify possible locations (e.g., Wishbone Lake, Spawning Lake, Robert’s Bay) to locate juveniles.

To understand the migration patterns of Arctic Char in the Cambridge Bay river systems, one participant suggested examining the microchemistry of otoliths, specifically looking at strontium. Strontium is an element that is incorporated in the ear bones (e.g., otoliths) and can be used to estimate the amount of time a fish was present in freshwater or marine environments. There is currently an ongoing project looking into variation in otolith strontium profiles in the region. This could provide information on the frequency of skipped spawning, which could be indicative of the relative size of the spawning component of the population.

A participant made the comment that due to the migratory nature of char, fish from the Ekalluk River could be caught at sites other than the Ekalluk, such as the Lauchlan River. Further comments were made about the resilience of Arctic Char in this area using an example: In previous years, one of the waterbodies (the Ekalluk River) was consistently fished for the area quota of 45,000 kg over several years (i.e., the full area quota was taken from the one river instead of being harvested across rivers); the river was fished to a point where the stock appeared to be in decline (based on a drastic decrease in mean weight). When this change was noted the fishery was closed and the stock made a full recovery within a few years.

Finally, one participant asked about the timing of the Lauchlan fishery and the presenter noted that the Lauchlan River fishery is executed in the spring.

UPDATED STOCK STATUS OF COMMERCIALLY HARVESTED ARCTIC CHAR (*SALVELINUS ALPINUS*) FROM THE JAYKO AND HALOKVIK RIVER, NU: A SUMMARY OF HARVEST, CATCH-EFFORT AND BIOLOGICAL INFORMATION

Authors: Les N. Harris, Chris Cahill, Xinhua Zhu, Tyler Jivan and Ross Tallman

Presenter: Les N. Harris

Summary

The Cambridge Bay commercial fishery was initiated at Freshwater Creek in 1960. It was moved to the Ekalluk River in 1962 and extended to the Paliryuak (Surrey), Halokvik (30 mile), Lauchlan (Byron Bay), Jayko, Ellice and Perry rivers between 1968 to 1977. Originally, an area quota for all of Wellington Bay was set at 45,400 kg in 1962, however, due to a decline in mean weight in Ekalluk River fish between the years 1963-1969, the fishery was closed. The fishery re-opened in 1973 under river-specific quotas. Currently there are four waterbodies being commercially fished with variable quotas among rivers, Ekalluk River (20,000 kg), Paliryuak River (9,100 kg), Halokvik River (5,000 kg) and Jayko River (17,000 kg). Harvest levels are variable due to a variety of reasons (e.g., economic feasibility, fishing closures, quota modifications, timing of the runs, parasite concerns). The stock assessment for the Cambridge Bay fishery was last conducted in 2013 and included harvest data (1961–2009) and fishery-dependent biological data (1971–2009). This previous assessment concluded that stocks within the fishery were stable and being fished at or below sustainable harvest rates. FAM has recently requested an updated assessment of stock status in the Jayko and Halokvik rivers (Appendix 1).

The Jayko and Halokvik rivers are located 100 and 80 km, respectively from the community of Cambridge Bay and both fisheries have been fished under several different quotas. Both have gone through the transition from a gill net fishery to one that uses a conduit weir. Genetic data confirm a distinct Jayko stock and that the Halokvik stock is considered part of the Wellington Bay complex. The main goal of a stock assessment is to provide advice regarding sustainable harvest levels by assessing trade-offs between maximum harvest and sustainability of the fishery for future generations. To do this, data are collected from a number of sources, including fishery-dependent data (i.e., fish plant sampling) and fishery-independent sampling (i.e., research survey data).

The fishery-dependent sampling program at the Cambridge Bay fish plant has collected data since the early 1970's and is an inexpensive source of data relative to other methods. Fishery-dependent CPUE uses the log book system and has just recently collected five years of data from the commercial fishery. Additional data collection is done through fishery-independent sampling which provides additional information (e.g., sex, maturity, age fecundity).

The Jayko River harvest has varied between years (2010 to 2015) with an average harvest of 13,792 kg; while the harvest in the Halokvik River averaged 3,882 kg between 2010 and 2015. CPUE data suggest that both Halokvik and Jayko are currently stable, except for an anomalous year in 2014 at the Halokvik fishery. Fishery-independent CPUE data suggest that Jayko is highly variable and Halokvik CPUE is steadily increasing.

Additional information collected through the fishery-independent sampling suggested a 1:1 sex ratio, however there were virtually no mature fish caught during the sampling period. A reproductive potential index was calculated using the variables length (L50) and age (A50) when 50% of the individuals in the population are mature. For both systems, there was a decrease in the estimated L50 and A50, which is disconcerting because a closely related species, Lake Trout *Salvelinus namaycush,* demonstrated large declines in these metrics during fisheries collapses in the Laurentian Great Lakes (Walters et al. 1980). However, it was noted during the meeting that this pattern could also be an artifact of inconsistency in maturity stage identification between researchers.

Trends in the weights of fish caught during fishery-dependent studies show a sinusoidal pattern. Fish weight for the Jayko River followed a normal distribution and the mode has remained

consistent. In Halokvik, fish weight followed a normal distribution with a consistent mode from the years 1970 to present. Trends in length followed a sinusoidal pattern in both the Jayko and Halokvik rivers and both also followed a normal distribution with consistent modal values for length and age. Body condition followed a sinusoidal trend (1970's to present) with decreasing trends in Jayko since 1999 and Halokvik since 2005. Within both river systems, body condition was considered fair-to-good based on Fulton's condition factor (K), $K = \sim 1.25$) (Barnham and Baxter 1998). (Mortality estimates indicate that in the Jayko River mortality has been stable based on fishery-dependent data, however fishery-independent mortality estimates were much lower. The Halokvik fishery-dependent sampling suggested that mortality has been decreasing throughout the decades (1970's to present) with the fishery-independent estimates being much lower. Moving forward, there is concern with respect to the accuracy of past aging methods, the lack of information regarding the amount of subsistence harvest in both rivers (i.e., low sample numbers), that there are no funds for fishery-dependent CPUE data collection, inconsistency among maturity classification among those sampled and a lack of fecundity information.

Discussion

The presentation addressed the methods used for data collection, the analyses and the outputs of the analyses. The trends in age, length, weight, body condition, maturity (L50 and A50), and mortality within the Jayko and Halokvik rivers were presented with the main conclusions being:

- weight, body condition and length follow a sinusoidal pattern but have been increasing over time;
- mortality has been decreasing over time (but only assessed per decade); and,
- Arctic Char from these rivers may be reaching maturity at younger and smaller sizes.

During the presentation a participant inquired about the effects that changing ice condition would have on the spawning ground of char and how this may impact future stocks. The response to this question was that ice could impact the spawning success of char, lowering recruitment into the fishery. Following this response discussion continued on the impacts of climate change. One participant pointed out that there has been greater variation in the weather in the area, extreme highs and lows. Fluctuating climate could have an impact on the stocks. The effects that climate change could have on recruitment could be assessed by closely monitoring CPUE. There was a suggestion that water levels and the amount of snow could affect runs, therefore acquiring weather data to correlate with catch data could provide some explanation of changes in runs.

A participant inquired about new methods of fishing, such as trawlers or long-lines, and asked about a possible quota change. The response to the inquiry was that quotas are river specific and based upon the type of gear that is used. In order for the fishing gear to change, impacts on the ecosystem would need to be considered. Currently weirs are being used in the fishery and there were some questions over the use of weirs since they cannot be used in deep water and can easily collapse. Additional comments were made on the timing of the char runs. It has been observed that fish have been moving up the river later as the thaw has been earlier in the west than in the east. However, there is uncertainty as to whether this is due to temperature variation. A comment was made that there are warmer temperatures in the west and temperatures get cooler moving east; the fish in the more western areas will run first.

When the presenter was discussing the CPUE in Jayko and Halokvik it was pointed out by a participant that the year 2014 was an outlier and the confidence intervals are tight. It was suggested that some of the run could have been missed which would provide an explanation for the confidence intervals. In 2014, the weir caught the full quota in two days. One participant provided some anecdotal information, stating that in recent years the run in the Jayko River has been later, previously loads have gone out at the end of August and now loads have gone out in the beginning of September. A participant asked for the definition of “load”. A load was described as 13 tubs of Arctic Char, the number of tubs that fit in the float plane used for fish transport. Discussion about the use of the weir continued. The weir uses poles to separate and contain larger fish while allowing the smaller fish to get through. Almost everything in the weir is then processed.

One participant provided an observation that provided evidence of behavioural differences in Arctic Char due to different environmental factors. During years with lots of snow coverage there were more fish seen in the rivers and creeks. The opposite occurs in years when there is low water. Based on these observations, the participant suggested that low CPUE could be just as important as high CPUE when considering environmental impacts on stock productivity. Discussion continued on how this may be achieved using a weir, in which the low and high points are taken into account. According to accounts in the field there are no days in which zero fish are observed in the weir. It was suggested that to quantify the strength of the run the weir should be checked more consistently without removing fish and count data recorded.

It was suggested by a participant that one could record the total number of days that the weir is fished, and the total number of char caught within those days, as a proxy for CPUE. Continued discussion occurred around the collection of biological data during the study. Historically, there has been a reliance on logbooks from fishermen; however the environmental and climate conditions remain unknown. A future project could provide a descriptive report on the conditions of each year in which a time series provides information for factors that may have been affecting the fish. A way in which this can be implemented is through modification of the logbooks to be able to record data on environmental conditions. It was suggested by a participant that further information can be gathered at the end of the fishing season. There are pre- and post-fishing meetings and it might be possible to glean some of that data form the fishers then.

Multiple participants commented on the output of the CPUE data and how it was represented. There was some concern regarding the calculation of the CPUE, and the variability in the catches. In some years the full load could be caught in two days, while in other years it could take six days. It was stated that CPUE was calculated by standardizing all data based upon the first scoop from the weir. There were questions on the variability of the timing of the first scoop, and if the run was compressed there may be higher catches during the first scoop. To improve this method it was suggested that a consistent way to count would be to wait 24 hours after the first scoop, or to treat the run as a time series and use the top three days in the calculation.

Explanation on how a weir is operated in terms of gear saturation was asked by one participant. When the weir is fished, a gate is opened and all fish are pushed into the “sock”.

A participant inquired about the use of new equipment for enumerating fish using sensors. A suggestion was the use of Didson sonar technology to detect individuals. This method has been used in the Sylvia Grinnell river system.

In reference to the CPUE data presented, a participant asked whether the timing of the sampling was during the tail end of the run or during the peak of the run. The sampling was performed during the peak of the runs, between August 21–28. A participant asked whether the fishery-independent sampling and the fishery-dependent study coincided. There has been some overlap in the sampling at both fisheries although not on an annual basis.

In regards to the L50 data presented, a participant asked whether this was a random decrease or if there was an outlier in 2015. In the Jayko and Halokvik rivers there was a substantial drop in L50 in both rivers.

For future research, suggestions were made to gather eggs at natal sites using scuba gear, and to place transmitters in female oviducts which would be expelled with eggs thus allowing for spawning sites to be precisely located.

Participants were interested in the mark-recapture methods used. The method in the first year was to catch fish in the weir during the stock enumeration. It is important to note that some fish in the run were missed due to the spacing of the conduit pipes of the weir. The fish in the weir were counted and tagged followed by release upstream. In 2013 and 2014, 948 and 1548 Arctic char were tagged and subsequent recapture data were used to generate population estimates for this system. The mark-recapture population estimates (using a modification of the Peterson method) derived for this fishery were 34,951 and 56,067 for 2014 and 2015 respectively. There is currently no tagging study being done. Acoustic tagging studies are currently being implemented and it was noted that the recapture of fish and return of tags is important to determine exploitation rates.

Concerns were raised over the high instantaneous total mortality rates (i.e., Z) estimated, particularly when compared to the best available instantaneous natural mortality rates for anadromous Arctic Char. A standard fisheries modeling assumption is that the instantaneous fishing mortality (i.e., F) and instantaneous natural mortality (i.e., M) sum to Z (Ricker 1975). Moreover, a common fisheries assessment metric or guideline is that F should be $\leq$ M. The best available natural mortality estimates for anadromous Arctic Char are from the Murchinson River, which suggests M ~ 0.1. If a value of approximately 0.1 is assumed for the Cambridge Bay fisheries assessed in this report series, catch-curve data indicate that F is potentially much higher than M for some years in these Cambridge Bay fisheries. While there are concerns regarding the catch-curve data used to generate Z values, the authors felt it was precautionary to note that at present there appeared to be high instantaneous fishing mortality values. It was suggested that the high Z values may be caused by the pooling of samples and looking at the samples by years and not decades may provide more accurate Z values. Another participant suggested this could be a signal of high harvest. A participant suggested looking at the effects of the environment through the correlation between growth and Z. A plot of harvest over changes in condition and length could be informative, but was not completed. Plotting growth over mortality could be challenging as higher mortality creates faster growth in subsequent years. It was suggested that an analysis such as a cohort style analysis with age classes recruited into the fishery be used instead. This can be adjusted according to the equivalent CPUE, looking at the mortality for the current year and the next year. One could then follow the cohort through time and perform a mortality analysis.

A participant asked if the terms S, A and Z, in the model could be defined. The term S is the annual finite survival rate, the term A is the annual finite mortality rate and Z is the instantaneous total mortality rate (Ricker 1975). Total instantaneous mortality Z is an estimate of the rate at which a fish will die at any point in time, whereas A can be interpreted as the fraction of fish that die due to natural death and fishing within a given period (Ricker 1975).

APPLICATION OF A HARVEST-BASED MODEL TO ASSESS POPULATION DYNAMICS OF ARCTIC CHAR IN JAYCO AND HALOVIK RIVERS OF CAMBRIDGE BAY, NUNAVUT, CANADA

Authors: Xinhua Zhu, Les N. Harris, Chris Cahill, Ross F. Tallman and Theresa J. Carmichael

Presenters: Ross Tallman and Chris Cahill

Summary

Two catch-based models that have been used to understand and assess population dynamics of Arctic Char are Depletion Corrected Average Catch (DCAC) and Depletion-Based Stochastic Stock Reduction Analysis (DB-SRA). DCAC calculates the average catch after a windfall catch to estimate sustainable yield. The assumption is that the harvest of the stock reaches equilibrium after the initial windfall. The model incorporates uncertainty of the model parameters such as M (mortality), ratios of BMSY (Biomass at Maximum Sustainable Yield (MSY)) to B0 (current biomass), FMSY (fishing mortality at MSY) to M and the relative changes in biomass using Monte Carlo simulations. DB-SRA is an extension of DCAC and is a stock reduction analysis that includes more detailed stock assessment methods through the use of historical catch data and estimates of stock reduction due to fishing. These analyses are used to reconstruct the possible trajectories of recruitment rates, stock size, and stock declines. These models link production and biomass, and consider alternative hypotheses in regards to changes in biomass during the historical catch period. The model equations for growth are based upon the von Bertalanffy growth model. Additional equations calculate the natural mortality (M), however to obtain an accurate value an unfished stock is required, an example being the Murchinson River. When otolith age was graphed with M, there was a convergence in natural mortality which may change with age in the Halokvik and Jayko rivers. Further, results on the trajectory of biomass show that there was a steady drop in biomass over several decades. There is high variance around the best estimates; however, this is a standard occurrence in assessment models that strive to embrace, rather than ignore, uncertainty (Walters and Martell 2004).

These modeling results have broad implications in the management of stocks. Current assessment practices are based upon the precautionary approach, which considers stock status and the removal rate to establish upper and lower limit reference points. When a stock is below the lower limit reference point it suggests that recruitment overfishing is occurring, and the stock is in the/a critical zone. Stocks between the upper and lower limits suggest that growth overfishing is occurring and the stock is in the cautious zone. Stocks above the upper limit reference are in the healthy zone. Based on biomass estimates, the Jayko and Halokvik river stocks fall within the cautious zone of the precautionary approach framework, however there is a lot of variance around both points. For both fisheries, every upper 95% CI falls above the USR, however, it should be noted that a few of the lower 95% CI’s do fall below the LLRP. A point of reference for the fishing mortality would be the Murchinson River which has remained unfished, where M = 0.1. For future catch-based models, information such as fishing effort could be used in surplus production models, and age and size structure can be used in age structured models such as VPA (virtual population analysis) or stock synthesis.

Discussion

A participant asked whether the numbers in this presentation were based on the values that were presented earlier in the meeting. The data collected from the fishery-independent and dependent sampling were used to create the equation models along with the number of fish recruited into the population.

When discussing natural mortality a participant made the point that ice and water levels can affect the mortality of fish at the spawning grounds. Traditional knowledge suggests that if water levels are high, there is an increase in bugs, which increases the food supply for the fry. The amount of light that reaches the eggs also has an effect on the hatch time which suggests that the ice thickness could have an effect. If there is an early melt and thin ice the eggs will hatch earlier.

Jayko experienced a large parasite load in the 2010's, and the community closed the fishery. In 2010 and 2011 when the Jayko River was not fished, there was a slight increase in the body condition, length and weight. Historically, the community also made the decision to close the fisheries at Ekalluk River and Freshwater Creek. There was a suggestion for future research to determine the cause of declines in the char stocks, including the traditional knowledge that noted changes in the fish. A participant noted that if fish are larger, then the quota will be reached faster. An example of fishery collapse in the Laurentian Great Lakes was given, where there was consistent harvest before a collapse. Before the collapse there was a decrease in age at maturity and high mortality, which is concerning. The Arctic Char in Jayko and Halokvik rivers have variable rates of mortality, based upon this information a participant asked what a high mortality rate for char was. The mortality rate relates to the natural mortality (M) and values of M depend on the fish species. For Arctic Char, if the fishing mortality (F) is above M this would be cause for concern.

A participant mentioned that a traditional knowledge project is currently occurring in Cambridge Bay to look at the importance of Arctic Char migration and char as a food source.

A participant inquired about what data were input into the models. In the depletion-based model, life history information was used. In the DB-SRA model, M or mortality were based on life history. Weight, length at age and von Bertalanffy were used when calculating M.

A participant made the comment that there is biological information lacking for the models, in which case assumptions are made. A number of methods were suggested for providing added information on age, spawning biomass and migration patterns (e.g., otoliths, continued tagging studies, hydroacoustics, survey transects across the lakes).

REVIEW OF THE SCIENCE ADVISORY REPORT

Participants reviewed the draft Science Advisory Report (SAR). The author noted changes directly in the document based on the discussions generated at the meeting. Summary bullets were drafted and reviewed. A list of sources of uncertainty was drafted for the SAR and reiterated below:

Consistent criteria for ageing. Arctic Char throughout the history of the fishery-dependent plant sampling program have been aged by different readers. Initially otoliths were aged whole and then by sectioning for older individuals. There is a possibility that Arctic Char may have been under-aged in earlier years of sampling as has been noticed in other Arctic Char stocks in the region. If this is the case, the proportion of older age classes in the population would have been underestimated resulting in mortality estimates that would be over-estimated. An age-comparison study is underway to address this concern. Having better age data will ensure more reliable estimates of mortality and will permit the use of different and improvement stock assessment models.

Unknown subsistence harvest. The total harvest of Jayko and Halokvik river Arctic Char is unknown due to the uncertainty of subsistence harvest at these locations. Zhu et al. (2014b) suggested that the subsistence harvest of Arctic Char in Cambridge Bay is upwards of 50% of the annual commercial harvest. This is likely a gross over-estimate of the true subsistence harvest at these locations given the distances from the community. However, it is imperative to understand the total removals, including subsistence harvest, for the models used in this assessment. Work aimed at collecting information on subsistence and recreational harvest of Arctic Char should be initiated. Furthermore, there is a large subsistence harvest of Arctic Char at the area locally known as Gravel Pit and it is unknown what proportion of Jayko and Halokvik

Arctic Char, if any, are harvested at this location. Funding opportunities should be explored as a means to resolve subsistence harvest at these locations.

The harvest of mixed stocks. It is likely that the Halokvik River stock is also harvested in subsistence and commercial mixed-stock fisheries (e.g., in Ferguson Lake during over-wintering and the area locally known as Gravel Pit described above) and this may be especially true in years when Arctic Char are not spawning. This also leads to situations where total harvest of this stock is not known. Collecting genetic baseline samples from juvenile Char or spawning individuals would be required to perform mixed-stock fisheries analyses to address this unknown. Samples from all known contributing stocks would be required for accurate mixed-stock fishery analysis.

Demographic independence and genetic discreteness of stocks. The management of anadromous Char from the Halokvik system is based on the notion that Char in this system represents a discrete stock. This assumption, however, has not been tested directly because samples from spawning individuals have not yet been available. Although recent genetic work (Harris et al. 2016) and ongoing next-generation sequencing initiatives (Moore et al. 2017) have shed some light on genetic stock structure among Arctic Char in the region, samples used in these studies came directly from the commercial harvest or from sampling designs intended to mirror the commercial harvest. Although several important management implications were gleaned from this work, assessing genetic stock structure among samples collected at coastal fishing locations does not truly represent stock structure in the region. Thus, it is recommended that spawning individuals or juveniles that have not left their natal system be sampled and assessed. This would undoubtedly be beneficial for resolving genetic stock structure, furthering our understanding of the demographic independence of commercially exploited stocks and the degree of mixed-stock harvest in the region.

Unknown census population sizes. Little is still known regarding the population sizes of stocks harvested in Cambridge Bay Arctic Char fisheries. Such information is vital for establishing and refining quotas and for understanding Arctic Char responses to exploitation. Unfortunately enumerating upstream runs of Arctic Char is incredibly expensive and only provides single-year point estimates (snap shots) of abundance. Furthermore, although mark-recapture techniques have recently been employed, many underlying assumptions (e.g., closed systems, incomplete mixing of tagged and untagged fish, etc.) could be violated in the models we fit. Thus the results generated form these methods should be interpreted with caution. Continuing to collect fishery-dependent and fishery-independent data including effort data for both types, will prove valuable for exploring quantitative models that will allow for the estimation of abundance or biomass. If funding becomes available, however, it may be prudent to update point estimates of abundance at Arctic Char commercial fisheries in the Cambridge Bay region. Such estimates, however, show variability from year to year for a variety of reasons (dispersal, recruitment successes or failures, etc.).

Lack of fishery-dependent CPUE. Fishery-dependent CPUE data are virtually absent from all commercial Arctic Char stocks in Nunavut with the exception of those harvested in the Cambridge Bay region. For these latter stocks, it is only recently that CPUE data have become available as a result of funding for a monitoring program provided by the Nunavut General Monitoring Plan. Despite obvious problems with fishery-dependent CPUE, it still remains an important tool for parameterizing quantitative models. Given that the funding for this program ends in 2018 and given the importance of CPUE data for stock assessments and monitoring potential changes in stock size over time, it is recommended that the monitoring of commercial CPUE continue and funding opportunities be explored to do so.

Spawning areas unknown. Very little information is available on spawning and juvenile rearing locations in either system. Identifying and/or improving knowledge of these critically important habitats is of paramount importance in regions such as Cambridge Bay, where mineral exploration and development can be anticipated. Furthermore, identifying these areas would allow for the collection of true "baseline" genetic samples (described above) that would allow for better resolution of genetic population structure among Arctic Char in the region and would permit the application of mixed-stock fishery analyses for resolving contributions to mixed-stock harvest.

Subjective maturity classification. Classifying maturity status is somewhat subjective, especially when distinguishing between 'immature' and 'resting' fish. Research should be undertaken to resolve this concern given the importance of understanding potential changes in age and length at maturity as it pertains to commercial exploitation of these stocks. Other methods/ways to identify maturity status (e.g., histological methods) should also be explored to remedy this concern.

Frequency of spawning and stock recruitment. Arctic Char at northern latitudes are presumed not to spawn yearly, yet the frequency of spawning and number of life time spawning events remain unknown. Furthermore there is virtually no information/data on fecundity for Cambridge Bay Arctic Char. Both these unknowns hinder our understanding of Arctic Char recruitment which has implications for stock assessment modelling. Potential identification of chemical markers through otolith micro-chemical analyses may be promising for furthering our understanding of spawning events and lifetime reproductive output. Furthermore, the collection of ripe ovaries should also be undertaken to further our understanding of fecundity and the reproductive biology of Arctic Char in the region.

Ecosystem-based fisheries management. Research focusing on better understanding of the ecosystem in general and trophic relationships is needed. This is especially true given recent pushes for adaptive ecosystem-based management approaches to the conservation of fisheries resources. Such information will be valuable for understanding the environmental, biological and ecological drivers of Char productivity and for resolving spatial variation in resource availability.

Life-cycle unknowns. Freshwater resident individuals (i.e., those that do not migrate to marine waters for feeding after smolting) have been identified in other areas of the Canadian Arctic but have yet to be confirmed in the Cambridge Bay region. Residents typically spawn with their anadromous counterparts and therefore impact recruitment where they exist. Work should be undertaken to confirm if resident Arctic Char exist in the Cambridge Bay region and to expand our knowledge on Arctic Char life history in general.

Parasites. Previously, there were concerns regarding heavy parasitism in Jayko River arctic Char, such that commercial fishing ceased at this location for several years. Samples for parasitological analyses should be analyzed to confirm if Jayko River Arctic Char are more heavily parasitized in comparison to other commercially fished waterbodies.

Quantitative fisheries stock assessment. The Cambridge Bay Arctic Char fishery has been identified as a typical data-poor or data-limited example because of;

1. unclear resolutions of meta-population dynamics or mixed stock discrimination;
2. incomplete fisheries harvest statistics (DFO manages commercial fisheries but does not have a clear understanding of subsistence and recreational uses);
3. lack of long term fishery-dependent or independent abundance indices; and,
4. missing data regarding growth, mortality, fecundity, recruitment, reproduction and fishing effort (Day and Harris 2013; Tallman et al. 2014; Zhu et al. 2014a,b).

Several assessment methodologies have been proposed, provided that some informative data exist. DB-SRA is one model option that uses fishery harvest, if the data are accurate without errors. In addition, a set of biological parameters that might be used as auxiliary measurements of fish stock status are under investigation.

The DB-SRA model requires less data than other models but is extremely sensitive to catch, thus a complete understanding of overall Arctic Char removals, including commercial, subsistence and recreational harvests, is needed. As mentioned above, existing monitoring programs primarily aimed at collecting commercial harvest and catch-effort information should continue. Future actions are purposed to reconcile proportions and possible temporal changes in subsistence and recreational harvests due to changes in local populations. Through the continuation of fishery-dependent and –independent surveys, other sets of quantitative fisheries assessment models can be applied to inter-calibrate outputs and confounding uncertainties from respective models. Furthermore, a multi-model comparison may be feasible when sufficient time series of CPUE, age composition matrix, and overall harvest are available.

CONCLUDING REMARKS

The third day of the meeting consisted of revising the summary points in the Science Advisory Report, during which points were revised or added for clarification based upon the discussions above.

The Chair thanked participants for attending and indicated documents would be sent to all participants for their final review in the near future.

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APPENDIX 1. TERMS OF REFERENCE

Estimated abundance and sustainable harvest levels for the Jayko and Halokvik (30 Mile) rivers in the Cambridge Bay commercial fishery, 2010–2015

Regional Peer Review – Central and Arctic Region

January 24–26, 2017
Winnipeg, MB

Chairperson: Kevin Hedges

Context

Arctic Char, *Salvelinus alpinus*, in the Cambridge Bay region of Nunavut is a valuable resource, historically used for subsistence purposes, which has also been harvested commercially since 1960. The Cambridge Bay commercial fishery was last assessed in 2010 (DFO 2013) when the harvest levels were considered to be sustainable. In 2011, preliminary precautionary reference points were developed based on available data for the Cambridge Bay fishery as a whole (DFO 2014). As the fishery is currently managed by waterbody, the ultimate goal under the Sustainable Fisheries Framework is to establish limit reference points for each waterbody in the fishery.

In 2014, DFO published the Integrated Fisheries Management Plan (IFMP) for the Cambridge Bay Arctic Char Commercial Fishery, Nunavut Settlement Area. The IFMP identifies an ongoing need to update population abundance estimates and establish sustainable harvest level recommendations for commercial waterbodies. The goal is to ensure that the fishery will continue to be sustainable over the long term. As a result, DFO Resource Management has requested Science advice on the current status and sustainable harvest levels for the Jayko and Halokvik waterbodies, two of the four main waterbodies associated with this commercial fishery.

Objectives

The objectives of this meeting are to undertake a science-based peer review of all available information relevant to providing advice on the status for Arctic Char stocks from the Jayko and Halokvik rivers. Specifically, the meeting will address the following objectives:

1. Assess trends in harvest, catch-effort and biological fishery-dependent data through the Cambridge Bay plant sampling program and the Nunavut General Monitoring Plan;
2. Assess trends in fishery-independent catch-effort and biological data collected (2010–2015) as part of the fishery-independent sampling program;
3. Incorporate these data into population models to estimate the population abundance/biomass, sustainable harvest levels, and identify associated uncertainties;
4. Develop reference points for each river under a precautionary approach framework; and
5. Discuss research needs and current monitoring for Arctic Char in these river systems.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document(s)

Participation

- Fisheries and Oceans Canada (DFO) (e.g., Science and Resource Management)
- Kitikmeot Foods Ltd. (Nunavut Development Corporation)
- Ekaluktutiak Hunters and Trappers Organization
- Province of British Columbia, Ministry of Environment
- Academics
- Other invited experts

References

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APPENDIX 2. LIST OF PARTICIPANTS

Name	Organization/Affiliation
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Ross Tallman	Fisheries and Oceans Canada - Science
Kevin Hedges (Chair)	Fisheries and Oceans Canada - Science
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Lauren Wiens (Rapporteur)	Fisheries and Oceans Canada and University of Manitoba Graduate Student
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Stephane Lacasse	Manager - Kitikmeot Foods
Kyle Tattuinee	Nunavut Development Corporation
Chris Cahill	University of Calgary

APPENDIX 3. AGENDA

Estimated abundance and sustainable harvest levels for the Jayko and Halokvik (30 Mile) rivers in the Cambridge Bay commercial fishery, 2010–2015

January 24–26, 2017
Central and Arctic Advisory Meeting
Large Seminar Room, Fisheries and Oceans Freshwater Institute, Winnipeg, MB
Chair: Kevin Hedges

Day 1 – Tuesday, January 24, 2017

1:00 p.m.	Welcome and Introductions (Chair) • Participant Introductions • Overview of CSAS peer review process • Terms of Reference and Meeting Objectives • Review Agenda
1:30 p.m.	Presentation by Tyler Jivan: An overview of the management of Cambridge Bay Arctic Char and the Nunavut General Monitoring Plan
2:00 p.m.	Discussion
2:30 p.m.	BREAK
2:45 p.m.	Presentation by Les Harris: Overview of Cambridge Bay Arctic Char: background of exploitation, biology and genetic stock structure
3:00 p.m.	Discussion
3:30 p.m.	Presentation by Les Harris: Summary of harvest, catch-effort and biological information for fishery-dependent and fishery-independent sampling programs
4:00 p.m.	Discussion
5:00 p.m.	Adjournment

Day 2 – Wednesday, January 25, 2017

9:00 a.m.	Review Day 1, Agenda for Day 2 (Chair)
9:30 a.m.	Presentation by Ross Tallman/Xinhua Zhu: Depletion-based stock reduction analysis modelling and reference points
10:00 a.m.	Discussion
10:30 a.m.	BREAK
10:45 a.m.	Discussion continued
12:00 a.m.	LUNCH
1:15 p.m.	Discuss sources of uncertainty (Chair)
2:00 p.m.	Discuss future research needs (Chair)
2:30 p.m.	BREAK
2:45 p.m.	Develop Summary Bullets for Science Advisory Report (Chair)
4:30 p.m.	Day 2 Wrap-up

Day 3 – Thursday, January 26, 2017

9:00 a.m. Review Day 2 (Chair)

9:30 a.m. Review Draft Science Advisory Report (Chair)

10:30 a.m. BREAK

10:45 a.m. Review Draft Science Advisory Report

11:45 a.m. Concluding remarks (Chair)

12:00 p.m. Meeting Complete – THANK YOU / KOANA!