Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/051

PRECAUTIONARY REFERENCE POINTS CONSISTENT WITH THE FISHERY DECISION-MAKING FRAMEWORK FOR ARCTIC CHAR (*Salvelinus alpinus*) IN CAMBRIDGE BAY, NUNAVUT

*Ekalluk River Arctic Char (*Salvelinus alpinus*). Photo by Jean-Sebastien Moore.*

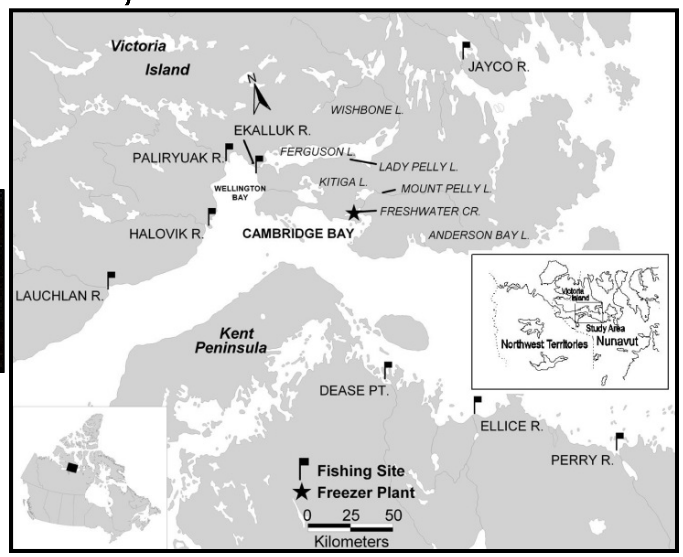

Figure 1. Map of Cambridge Bay showing commercial fishing locations for anadromous Arctic Char.

Context:

Canada, as a signatory to the United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNASF), is committed both domestically and internationally to conserving, managing, and exploiting fish stocks in a sustainable manner. To that end, the Department of Fisheries and Oceans Canada (DFO) adopted a fishery decision-making framework incorporating the precautionary approach (PA) to conserve and manage its fisheries resources. The framework includes the identification of reference points and stock status zones, and the development of harvest decision rules based on a harvest rate strategy. The Cambridge Bay Arctic Char fishery, consisting of fisheries in several commercial waterbodies, was chosen for this pilot project because of the relatively long-term dataset. A regional science advisory process was held in 2010 to update the assessment of the status of geographic stock complexes of Cambridge Bay Arctic Char, at which time it was concluded that using traditional time series analysis of current data could not produce reference points for Cambridge Bay Arctic Char. Therefore, a Bayesian-based model was used to develop reference points for the combined river systems and the results of the analyses were reviewed at this advisory meeting.

This Science Advisory Report is from the January 25-26, 2011 Regional Advisory Process on precautionary reference points for Arctic Char in Cambridge Bay, Nunavut. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

Canada

SUMMARY

- The biomass-based catch-per-unit-effort (CPUE) for Arctic Char in Cambridge Bay waters is standardized by a single-mesh-sized (140 mm) gillnet in August and used as an indicator of changing stock status.
- During 1972-2006, the catch and fishing effort data were intermittently collected, yielding a total of 12 CPUE estimates. Pair-wise correlations between the CPUE and large-scale climate change variables indicated that wintertime Arctic oscillation index (AOI) with a five-year lag was the best explanatory variable. This relationship can better predict CPUE for years missing in the time series.
- Hierarchical Bayesian state-space (HBSS) models were employed to reconstruct historical trends and harvest removal series of population biomass. The model assessment was evaluated by using deviance information criterion (DIC) and multimodel inference (MMI). The best model scenarios were uniform probability distribution function for *K* and *r* (UKR: 7% DIC weight) and lognormal probability distribution function for *K* and *r* along with time-varying catchability (LNKRWQ: 93% DIC weight).
- Essentially, maximum surplus production (MSP) and biomass at MSP (B_{MSP}) were estimated by HBSS model at 93 and 517 t, respectively. The harvest report rate (HRR), which mainly accounted for subsistence uses, was estimated to be 34%, which amounted to 32 t on the basis of MSP.
- With the data currently available it was not possible to estimate the Limit Reference Points for individual stocks (i.e., waterbodies). This does not imply that there should be a change to the current management units or structure of the collection of fishery statistics. However, information should be collected, if possible, that would facilitate definition of individual stock Limit Reference Points.
- For the combined fishery the Limit Reference Point is located at a standing biomass of 207 metric tonnes (t), representing the lowest biomass recorded for the stock (0.0539 t/gillnet). The Upper Stock Point is at a standing biomass of 414 t (0.1078 t/gillnet). The Target Reference Point is located at a stock status of 0.1348 t/gillnet, which is equivalent to a standing biomass of 517 t; the maximum removal rate is 0.1805. These interim reference points should be re-examined and revised as new information is obtained
- The lack of sufficient information regarding mixed-stock CPUE, the stock-recruitment relationship, age structure, discrete stock discrimination, current levels of subsistence harvest, vulnerability of Arctic Char to fishing effort, and localized variations in productivity and environmental factors is responsible for observation uncertainties in the risk assessment. Future research to address these knowledge gaps is required.

INTRODUCTION

Arctic Char, *Salvelinus alpinus* (L), is a circumpolar salmonid that disperses into coastal estuaries and inland freshwater watersheds connected to marine channels around the northern hemisphere (Johnson 1984, Kristofferson and Berkes 2005). Because of its seasonal migrations between marine and freshwater habitats, Arctic Char has become a cornerstone species, affecting the structure and function of Arctic ecosystems. In addition to its extraordinary importance to Arctic ecosystems, Arctic Char is highly sought by Inuit for commercial, recreational and subsistence uses. Since 1960, fishing for Arctic Char has usually occurred in mid-July, when sea-run migrants were found at the mouths of the Lauchlan, Halovik, and Paliryuak rivers, north of Wellington Bay (Figure 1), and in the mid-August and early September, when sea-return migrants were found in several river mouths around Cambridge Bay. As fishing activities expanded, fishers switched from primarily using gillnets to using both gillnets and weirs. During 1960-2010, the total commercial harvest ranged from 5.77 t in 1962 to 67.94 t in 1978, with an overall annual average of 41.17 ± 2.20 t (Figure 2). Variation in the harvest among locations primarily resulted from successively harvesting from the same stock or sub-stocks. There are no reported data for the amount of subsistence fisheries allocated for human and other consumption (e.g., sled dogs). Based on the Nunavut wildlife harvest study, the subsistence catch is approximately 50% of the commercial catch. The fisheries are managed based on quotas and fishing license controls. There is no fishable size limit but the minimum mesh size of the gears used has been set at 140 mm. To prevent a single char stock from over-exploitation, a watershed-based quota system was initially established in 1962 and river-specific quotas followed thereafter.

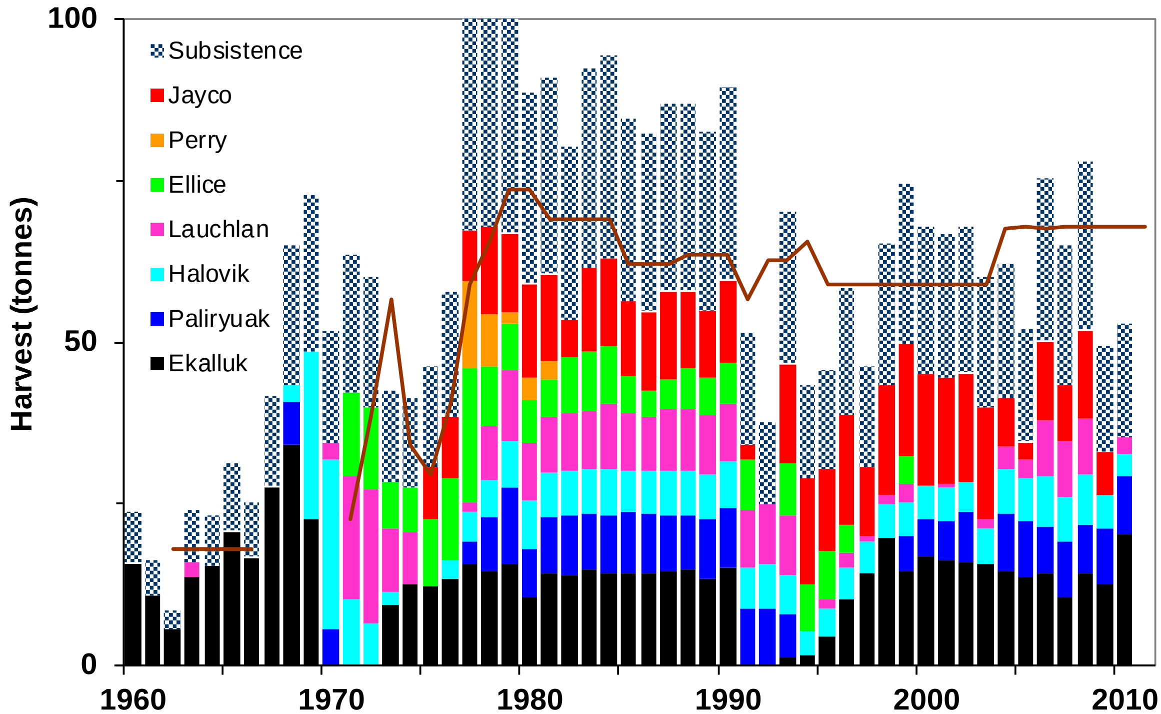

Figure 2. Changes in Arctic Char fisheries in Cambridge Bay, Nunavut, Canada, during 1960-2010. Colored bars indicate commercial fisheries from individual rivers and hatched bars show estimated amounts of subsistence fisheries. The brown line is the commercial fisheries quota.

ASSESSMENT

Standardization of fisheries-dependent CPUE

Catch per unit effort (CPUE) data were collected by a number of DFO-designed experimental gillnet and weir projects since 1972. Paralleling gillnet use in commercial and subsistence operations, weirs were alternatively employed for CPUE sampling. Overall, 12 years of CPUE data are available up to 2006. Analysis of Variance showed that there is neither significant effect of the month of sampling (August and September) nor the gear used (gillnet and weir) on CPUE (Zhu et al. 2014a). Because of consistent data collection protocols, the CPUE series was standardized using August gillnet data. To predict CPUE for years missing in the time series, pairwise correlation between CPUE and large-scale climate change indices were evaluated. Among these abiotic indices, the north Atlantic oscillation (NAO), the Arctic oscillation index (AOI) and the northern hemisphere sea surface temperature index (NHSST) were chosen as corresponding covariates commensurate with climate trends and synchrony in changes in fish populations (Zhu et al. 2014a). A robust normal regression model was employed, resulting in a significant positive correlation (r=0.7858, p=0.0041) between wintertime (March) AOI anomalies with a five-year lag and log-transformed CPUE (Zhu et al. 2014a). There was no significant correlation between the NHSST or NAO and CPUE.

Constructing working models

Within a hierarchical Bayesian framework a generalized surplus production model (also called a Pella-Tomlinson model; Hilborn and Walters 1992, Quinn and Deriso 1999) was constructed for Cambridge Bay Arctic Char, which incorporated a number of kernel population dynamics parameters, including virgin stock (i.e., an unfished stock) biomass (carrying capacity; K), the intrinsic population growth rate (r), the catchability coefficient (q), a shape parameter (z) between relative biomass and production, fishing effort (f), and the harvest report rate (HRR). An informative prior for HRR was set to a normal probability distribution function (pdf) with a mean of 0.5. A random walk log-scaled catchability coefficient (q) was used to compare the biomass estimate with the common option of a constant (See Zhu et al. 2014b for more details).

Three categories of input data were required to run the hierarchical Bayesian state-space model: observed information of harvest and weight-based CPUE on an annual basis; specification of non-informative or informative prior[1] pdfs; and initial values for model parameters. Four model scenarios were manipulated for structuring model parameter priors: uniform, lognormal, half-Cauchy lognormal and lognormal pdfs with random walk. Two Gibbs chains were run for 3,250,000 iterations each and sampled in a thin of 325 iterations, following a 650,000-iteration burn-in period. This yielded a chain length of 8,000 samples for posterior inference. Model convergence was diagnosed using the R-based CODA package and the deviance information criterion (DIC) was used for model selection. To calculate DIC weight, multimodel inference (MMI) was used to select single or multiple sets of models for model averaging.

Kernel parameters for each model scenario are shown in Table 1. Associated with DIC and MMI, uniform for K and r (UKR) and lognormal for K and r with random walk for q (LNKRWQ) were considered as better working models. These models tracked temporal trends in the 'observed' CPUE series quite well (Figure 3a). The model outputs showed lower biomass early in the time series and higher values after the mid-1970s compared to constant q models (Figure 3b). Throughout the period from 1960 to 2008, Cambridge Bay Arctic Char underwent a fully-exploited period from the mid-1970s through to 1990, based on changes in relative biomass and fishing mortality (Figure 3c). Also, there were evident differences in catchability which might have caused over-estimates of biomass (Figure 3d).

[1] A prior is the probability distribution that expresses uncertainty about a parameter or variable. An informative prior expresses specific, definite information while an uninformative prior expresses vague or general information.

Table 1. Kernel model parameters from the hierarchical Bayesian statistics. Quantities of maximum sustainable production (MSP) for commercial use are represented by values in parenthesis.

Parameter	UKR[1]	LNKR[2]	HCLNKR[3]	LNKRWQ[4]	MMI
K	898	870	863	897	897
B_{MSP}	460	493	490	522	518
MSP (Commercial)	110 (63)	80 (53)	80 (51)	92 (61)	93 (61)
r	0.4659	0.2748	0.2735	0.2880	0.3005
F_{MSP}	0.2390	0.1624	0.1619	0.1761	0.1805
HRR	43.04	34.31	35.14	33.76	34.41
q	2.60E-04	2.8E-04	2.8E-04	2.9E-04	2.88E-04
z	1.13	2.12	2.16	2.53	2.43

[1] Uniform priors for K and r
[2] Lognormal priors for K and r
[3] Half-Cauchy priors for lognormal K and r
[4] Lognormal priors for K and r with random walk

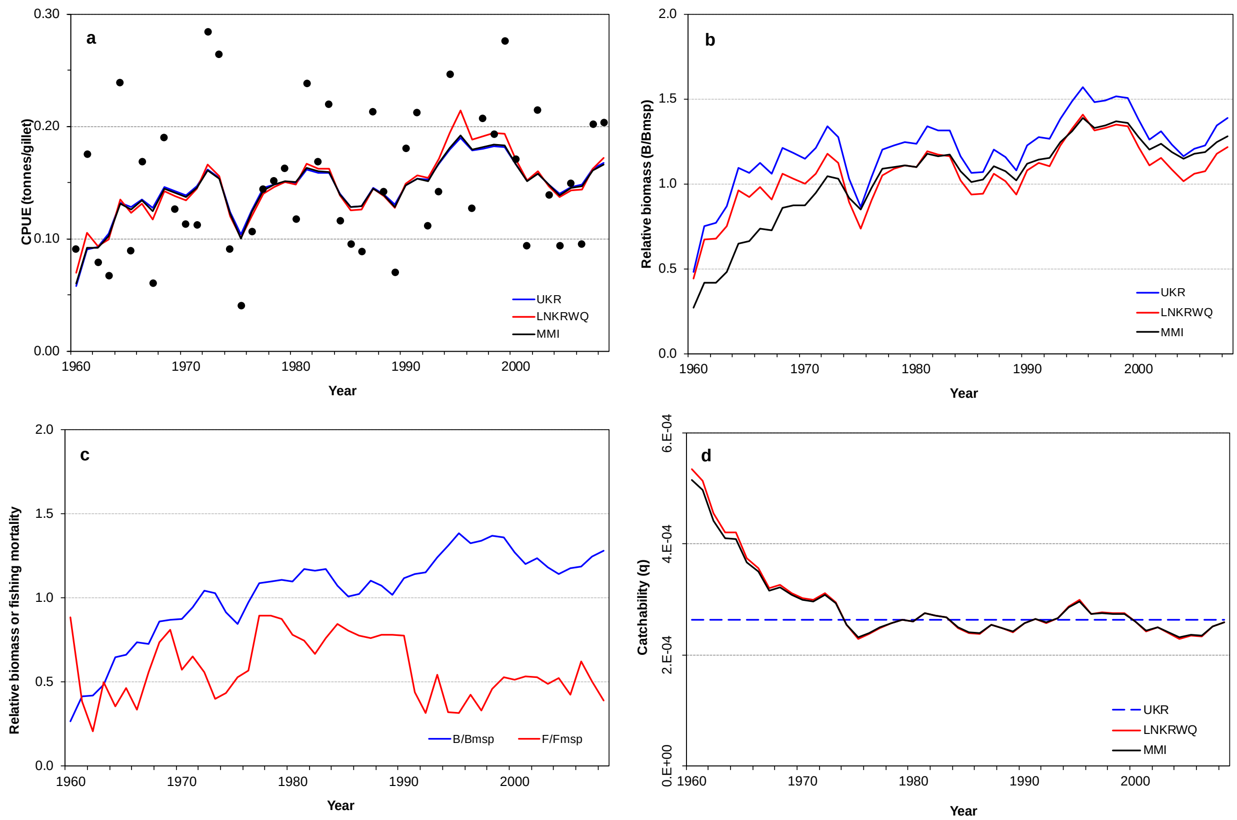

Figure 3. Model outputs by setting pdfs of uniform (UKR), lognormal priors of K and r combined with a random walk prior for catchability (q; LNKRWQ), and multimodel inference (MMI) to assess Arctic Char population dynamics in Cambridge Bay. (a) weight-based CPUE fit by lines and 'observed' values as black dots, (b) biomass, (c) relative biomass (B/Bmsp) and fishing mortality (F/Fmsp), and (d) the catchability coefficient (q)

Defining reference points

Arctic Char is slow-growing and has low fecundity and infrequent spawning so reducing the risk of population collapse is one of the priorities for managing this species (Kristofferson and

Berkes 2005). Fish stock assessment and management normally consist of two objective-oriented stages: risk assessment and risk management (Francis and Shotton 1997). Biological reference points (BRPs) are critical components of risk assessments aimed at maintaining or rebuilding exploited or threatened stocks and they aid fisheries managers in their efforts to maintain a precautionary approach. Currently, there are no identified reference points for Arctic Char stocks in the Canadian Arctic. The reference points were established in this study to provide a quantitative assessment of the performance of the stocks rather than to set targets or limits to trigger specific management actions.

Following the DFO (2009) decision-making framework, several precautionary reference points were delineated across the stock status zones. The critical and cautious zones were defined by the threshold values of 40% and 80% of biomass at MSP level (B_{MSP}; DFO 2009), which accounted for the Limit Reference Point (LRP) and the Upper Stock Reference (USR), respectively. The Target Reference Point (TRP) consisted of target indicators of stock status MSP and fishing mortality rate F to ensure the stock is at the level of MSP. Using MMI, the corresponding biomass values for LRP, USR and TRP were 207, 414, and 517 t (Figure 4), respectively.

Consistent with the United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNASF), F_{MSP} (fishing mortality at maximum surplus production) is the minimum standard for the removal reference in the application of PA to fisheries. In the context of the Canadian fishery PA framework, exploitation rates in the healthy zone should not exceed F_{MSP} (DFO 2009). The multiple sets of model outputs indicated that the values of the removal rate were 0.1619~0.2390 per year, resulting in 0.1805 per year by MMI (Table 1). Therefore, harvest rate strategies for Arctic Char in Cambridge Bay should not exceed the rate defined by this PA framework. With a minimum biomass of 414 t, the exploited population (or stock) is in the healthy zone. The biomass ranges between 207-414 t in the cautious zone, and the harvest rate should be scaled linearly, down to biomass levels through this range. When the biomass is less than 207 t the stock is in the critical zone. The exploitation rate should be reduced to a minimal level as a result of directed fishing, and other removals should be reduced to a level consistent with the growth criteria identified to allow the stock to grow out of the critical zone within a reasonable time frame.

Sources of Uncertainty

Tagging experiments conducted on Arctic Char in the Cambridge Bay fishery showed that fish undergoing spawning migrations appear to be separated by individual natal spawning sites with a high degree of fidelity, resulting in the establishment of discrete local populations or stock units, both between and within river systems (Kristofferson et al. 1984, Kristofferson and Berkes 2005). However, non-spawning schools are mixed without any distinct separation by habitat origins. At present, data are insufficient to explicitly define the stock unit, including stock size, migration routine, the spawning-recruitment relationship, and vulnerability to exploitation (Day and March 2004). Anadromous Arctic Char around Cambridge Bay may belong to a "metapopulation"; in that the overall fishery stock consists of a number of discrete local populations or stocks which interact to an unknown degree. Therefore, it is possible that one independent stock can disperse and be fished in several rivers during the non-spawning season, and in one fishing location, the target population may consist of several discrete stocks.

There are also a number of other uncertainties about Arctic Char in the Cambridge Bay fishery. The time series of CPUE data is quite short and no side-by-side comparison has been made to deal with catchability difference between gillnets and weirs. No recent/quantitative information has been collected on the subsistence harvest or annual bycatch. Fecundity data are also lacking and the data currently available for size- and age-at-maturity were collected in an uncertain way, making it less than ideal for addressing current management questions about the relationship between recruitment and spawners. The accuracy of ageing methods for Arctic Char needs refinement. Localized variations in productivity and environmental factors are responsible for observation uncertainties in the risk assessment.

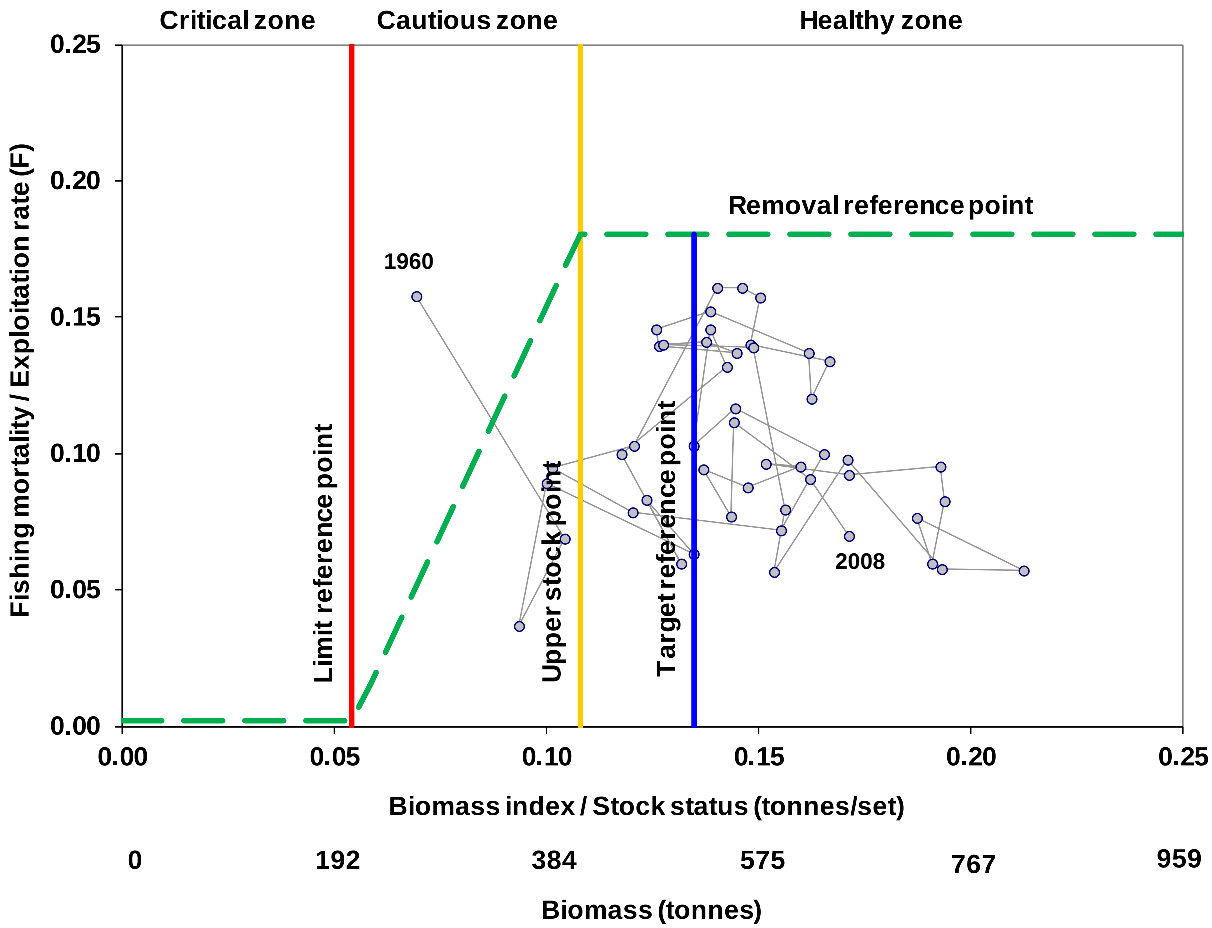

Figure 4. Precautionary approach model for managing Cambridge Bay Arctic Char fisheries based on the outcomes of multimodel inference (MMI). Reference zones are shown in green, indicating different harvest strategies depending on actual status of the stock.

CONCLUSIONS AND ADVICE

Precautionary reference points for Arctic Char in Cambridge Bay were calculated on the basis of weight-based commercial-sized adults fished at the minimum 140-mm-mesh-size gear limit. Only 12 years of effort data were available for 1972-2006 so missing values were estimated using the relationship between winter (March) AOI anomalies and the limited years of observed CPUE. Hierarchical Bayesian state-space surplus production models were employed to reconstruct historical trends and harvest removal series of population biomass. Quantities of interest to fisheries management were taken into account, including virgin biomass or carrying capacity and the intrinsic population growth rate. Maximum surplus production (MSP) and biomass at MSP (B_{MSP}) were estimated by hierarchical Bayesian state-space model at 93 and 517 t annually, respectively. Assuming a constant harvest report rate for subsistence use over years, HRR was estimated as 34%, or 32 t of fish.

The derived assessment results demonstrated that the current status of Cambridge Bay Arctic Char is in the healthy zone and the exploitation rate is below the target removal reference. The current quota system is only applied to the commercial fisheries. Assessments should incorporate subsistence fisheries in the future. Current lack of information for subsistence fisheries was identified as a source of uncertainty in the estimation of a removal reference. Our working model by MMI has taken this component into account when specifying a LRP of 207 t. This refers to the lowest biomass status (0.0539 t/gillnet). The USP is estimated at 414 t (0.1078 t/gillnet), where the removal reference approaches the target fishing mortality (F=0.1805). The TRP is estimated at a biomass index of 0.1348 t/gillnet, which is equivalent to a standing biomass of 517 t. Relative biomass has been within the healthy zone since the mid-1970s, but fishing mortality was near, or occasionally above the removal reference.

It should be noted that these interim reference points are specific to the combined population of adult Arctic Char in Cambridge Bay and its adjacent waters, and should be subject to timely re-examinations and revisions as further information, especially regarding the spawner-recruitment relationship, is obtained. Arctic Char requires careful management because of its vulnerability to heavy exploitation, relatively slow growth rate, low fecundity, and infrequent spawning (Johnson 1984). Given the uncertainties in stock discrimination within the Cambridge Bay fishery it would be prudent to calculate Limit Reference Points for each river system. However, under the current data-poor conditions without a river-specific time series of fishing effort, Limit Reference Points can only be calculated for the Cambridge Bay fishery as a whole as limit reference points for individual stocks (i.e., waterbodies) are not available. This does not imply that there should be a change to the current management units or structure of the collection of fishery statistics. However, information should be collected, if possible, that would facilitate definition of individual stock Limit Reference Points.

OTHER CONSIDERATIONS

We were confronted with a number of scientific issues when formulating precautionary reference points: mobile fishing locations, CPUE standardization, accounting for fishing effort, stock identification, general fish biology, and logistics. In terms of available harvest statistics, traditional Cambridge Bay char fisheries largely occurred in locations close to Wellington Bay (the Ekalluk, Paliryuak, and Halovik rivers) and Coronation Gulf (the Lauchlan River) as well as north of Cambridge Bay (the Jayco River); however, no samples have been taken from the Ellice and Perry rivers, close to Queen Maud Gulf, since 2000. Commercial fishing locations varied between years (i.e., commercial fisheries occurred in different rivers every year) which increased the uncertainty in tracking river-specific general patterns, like the time series of CPUE and catch-at-age for the anadromous populations. Because different rivers are fished frequently, it is difficult to collect information on harvest and fishing effort especially for recreational fisheries. Collection of gear-specific CPUE is an issue for monitoring the spatiotemporal patterns of the exploited fish populations. Most historical CPUE series in this study were sampled in one location (except two locations were sampled in 1975, 1980 and 1981), generally the Ekalluk and Jayco rivers. An effective CPUE time series should be accumulated for all six locations in a single year. From a quantitative fisheries stock assessment perspective, a well-designed sampling protocol should be developed and implemented, detailing CPUE data and biological measurements as a standard for a long-term char monitoring program. Because of multiple gears (gillnet and weir), gear-specific capture efficiency should be experimentally compared to validate the results from statistical analyses, like ANOVA and hierarchical state-space model estimation. Simultaneous CPUE comparisons may be initially made for gillnets and weirs in at least two if not all of the five above locations in August. This sampling program should also include the collection of, fishery-independent biological data, such as age-growth, recruitment and maturation, feeding habits, and density-dependent or density-independent fishing mortality every year. Environmental indicators should be included in long-term monitoring programs for Arctic Char. Although a CPUE series can be estimated by a predictive function linked to a large-scale climate covariant, wintertime AOI, future observations are necessary for model validation and timely adjustments. Fishing effort data are scarce (or non-existent), especially for Arctic Char subsistence fisheries in the Canadian north. But it is a very important measure which can be used to assess fish stock dynamics and implement harvest controls within the IFMP framework. Despite the fact that the minimum mesh size for gear used is fixed, it is still impossible to estimate fishing mortality without fishing effort information, such as the number of nets used, setting frequency, soak time, and gear configuration. Also, no information is available for sport fisheries, therefore we assume these fisheries are minimal or absent in the study area. To effectively manage Arctic Char fisheries, a number of options can be used to improve the current data collection of fishing effort, such as a pilot survey, a creel survey, interviews, and logbooks. Although these surveys do not need to be conducted every year, it is valuable to collect and track changes in fishing behaviors within a defined time period.

The Cambridge Bay Arctic Char fishery is data-poor, although monitoring has occurred for more than thirty years and it has been managed for more than 50 years. Based on a twelve-year dataset and a derived model, a weight-based CPUE series was constructed to account for temporal variation in population production. Caution must be taken when determining biological reference points and harvest control decisions, from these data. To improve the efficacy of the candidate working model, we hope to have well-defined sampling protocols and consistent monitoring plans in the future.

Due to a lack of information on Arctic Char population ecology, we are still unable to understand the role of environmental variability in regulating the localized distribution, migration, growth, and survival of fish within their complicated life cycle. This may limit our understanding how Arctic environmental variability impacts the Arctic Char population production and about how Arctic Char will adapt to increasing anthropogenic activities in the Arctic. Using fish biomass dynamics models, sets of Threshold or LPR values that appear to be conservative under the prevailing environmental conditions may generate considerable controversy. For example, with respect to setting reference points, it is also critical to understand whether population increases are due to density-independent factors affecting survival and growth or density-dependent factors related to overall carrying capacity and habitat expansion. Further examination of the interaction between natural variation in population production and human dimensions is of critical importance and timely updates need to be made when new observations of CPUE and climate data are available. Moreover, a mechanistic study is essential to improve our understanding of the direct impacts of climate change on time-varying life history traits, recruitment, reproductive behaviors, food-web configuration, and the vulnerability of population productivity under regime shifts.

Overall, the risk assessment of harvest strategies relative to the PA has been developed for the combined Cambridge Bay Arctic Char fishery. For fisheries that specifically target adults in particular rivers, special attention needs to be paid to the minimum fishable size (size-at-maturity), sex ratio, and the proportion of spawning adults because of the lower fecundity and growth potential of this species. Special attention is also needed to address the possible consequence of changes in fish production dynamics under varying environments (local versus regional climate change) and anthropogenic activities, such as exploration for gas, oil, and mineral resources. This being the case, future development of decision controls should consider the realization of a substantial balance between resource availability and renewability. Socio-economic factors, such as the number of fishing licenses, the spatial distribution of allocations among rivers, and local economic development, also need to be included in PA decisions. Furthermore, ecosystem-based fisheries management integrated with population dynamics, food webs, exploitation, and socio–economic factors is promising, and may advance the data-rich transition required to provide timely updates of precautionary reference points and adaptive management practices in the Canadian North.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 25-26, 2011, regional advisory meeting on Reference Points Consistent with Fishery Decision-Making Framework for Arctic Char in Cambridge Bay, Nunavut. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

Day, A. C. and de March, B. 2004. Status of Cambridge Bay anadromous Arctic Char Stocks. Can. Sci. Advis. Sec. Res. Doc. 2004/052. ii + 78 p.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

Francis, R.I.C.C., and Shotton, R. 1997. "Risk" in fisheries management: a review. Can. J. Fish. Aquat. Sci. 54: 1699-1715.

Hilborn, R., and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Kluwer Academic Publishers, Boston, MA. 570 p.

Johnson, L. 1984. Charr and man: the philosophy of limited interaction. *In* Biology of the Arctic Char. Edited by L. Johnson, and B.L. Burns. Proceedings of the International Symposium on Arctic Char, Winnipeg, Manitoba, May 1981. University of Manitoba Press, Winnipeg, MB. p. 523-532.

Kristofferson, A.H., McGowan, D.K., and Carder, G.W. 1984. Management of the commercial fishery for anadromous Arctic Char in the Cambridge Bay area, Northwest Territories, Canada. *In* Biology of the Arctic Char. Edited by L. Johnson and B.L. Burns. Proceedings of the International Symposium on Arctic Char, Winnipeg, Manitoba, May 1981. University of Manitoba Press, Winnipeg, MB. p. 447-461.

Kristofferson, A.H., and Berkes, F. 2005. Adaptive co-management of Arctic Char in Nunavut territory. *In* Breaking ice: renewable resource and ocean management in the Canadian North. Edited by F. Berkes, R. Huebert, H. Fast, M. Manseau and A. Diduck. University of Calgary Press, Calgary, AB. p. 249-268.

Quinn II, T.J., and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York. 560 p.

Zhu, X., Day, A.C., Carmichael, T.J., and Tallman, R.F. 2014a. Temporal variation in a population biomass index for Cambridge Bay Arctic Char, *Salvelinus alpinus* (L.), in relation to large-scale climate changes. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/095. v + 28 p.

Zhu, X., Day, C.A., Carmichael, T.J., Tallman, R.F. 2014b. Hierarchical Bayesian modeling for Cambridge Bay Arctic Char, *Salvelinus alpinus* (L.), incorporated with precautionary reference points. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/096. v + 35 p.

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB
R3T 2N6

Telephone: 204 983-5131
E-Mail: xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2014. Precautionary reference points consistent with the fishery decision-making framework for Arctic Char (*Salvelinus alpinus*) in Cambridge Bay, Nunavut. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/051.

Aussi disponible en français :

*MPO. 2014. Points de référence de précaution pour l'omble chevalier de la baie Cambridge (*Salvelinus alpinus*), au Nunavut, conformément au cadre décisionnel pour les pêches. Secr. can. de consult. sci. du MPO, Avis sci. 2014/051.*