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# Towards Determining Optimal Harvest Levels for Arctic Char, *Salvelinus alpinus*, in Nunavut: Overview and Proposed Research Plans

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# TOWARDS DETERMINING OPTIMAL HARVEST LEVELS FOR ARCTIC CHAR, *SALVELINUS ALPINUS*, IN NUNAVUT: OVERVIEW AND PROPOSED RESEARCH PLANS

by

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A workshop was held in June 2014 at the Freshwater Institute, Winnipeg, Manitoba to develop a research plan for optimization of Arctic Char, *Salvelinus alpinus*, harvests in the Canadian north generally and for Nunavut specifically. Arctic Char are of great importance in Nunavut and Northwest Territories because they have a high cultural value and provide much needed high-quality protein obtained through the subsistence harvest, and they contribute significantly in some communities to the local economy through the commercial fisheries. It is likely that stocks are not being harvested optimally in some waterbodies i.e. at the optimal (maximum) level that can be sustained over the long term. An overview of four categories of Arctic Char stocks was provided: high priority stocks, commercial stocks with limited data, exploratory fisheries and stocks with no data. Four harvest situations that need management were outlined: key national priority commercial stocks, fisheries that have a commercial quota that do not receive ongoing monitoring, emerging fisheries and subsistence fisheries. The existing models for stock assessment were reviewed, special considerations (e.g. dispersal, fidelity and environmental variation) were outlined and participants were tasked with developing approaches for a research program to estimate Maximum Sustainable Yield (MSY) to achieve biological yield maximization. Research plans with two experimental designs involving development of population process models were proposed with the goal of achieving an active, adaptable management regime that guides actions by fisheries management with biologically based limit reference points within the Department of Fisheries and Oceans (DFO) precautionary approach framework.

# RÉSUMÉ

Tallman, R. F., Hedges, K. J., Martin, Z., Janjua, M. Y., VanGerwen-Toyne, M., Harris, L. N. 2015. Établissement d'un niveau de prises optimal pour l'omble chevalier (*Salvelinus alpinus*) au Nunavut : Aperçu et plan de recherche proposés. Rapp. manuscr. can. sci. halieut. aquat. 3085: vi +85 p.

Un atelier a eu lieu à l'Institut des eaux douces de Winnipeg, au Manitoba, pour que soit conçu un plan de recherche visant à optimiser la pêche de l'omble chevalier (*Salvelinus alpinus*) dans l'ensemble du Nord canadien, et plus précisément au Nunavut. L'omble chevalier est d'une importance capitale au Nunavut et dans les Territoires du Nord-Ouest, puisqu'il a une grande valeur culturelle; de plus, sa pêche de subsistance représente une source essentielle de protéine de bonne qualité et sa pêche commerciale contribue grandement à l'économie locale. Il est probable que la pêche des stocks de certains plans d'eau ne se pratique pas de façon optimale, c.-à-d. au niveau optimal (maximum) qui ne nuise pas à la pêche durable à long terme. Un aperçu des quatre catégories de stocks d'omble chevalier a été fourni : stocks prioritaires, stocks commerciaux pour lesquels on dispose de peu de données, pêches exploratoires et stocks pour lesquels on ne dispose d'aucune donnée. Quatre contextes de pêche qui doivent être gérés ont été énumérés : pêches de stocks commerciaux qui constituent une priorité nationale, pêches commerciales disposant d'un quota qui ne font pas l'objet d'une surveillance continue, pêches émergentes et pêches de subsistance. Les modèles d'évaluation des stocks ont été examinés, les enjeux particuliers (p. ex., dispersion, fidélité, variable environnementale) ont été relevés, et les participants ont reçu la tâche de concevoir des approches en vue d'un programme de recherche permettant d'estimer le rendement maximal soutenu (RMS) pour parvenir à la maximisation du rendement biologique. Des plans de recherche élaborés selon deux concepts expérimentaux comprenant la conception de modèles de processus de population ont été proposés dans l'optique de parvenir à un régime de gestion active et adaptative qui servirait de point de référence limite fondé sur des données biologiques dans le cadre de l'approche de précaution adoptée par Pêches et Océans Canada (MPO).

# 1.0 INTRODUCTION

## 1.1 BACKGROUND MATERIAL

Participants of the workshop included individuals from: DFO Fisheries Management, Iqaluit; DFO Fisheries Management, Winnipeg; DFO Science, Iqaluit; DFO Science, Winnipeg; Government of Nunavut, Rankin Inlet; Michigan State University, East Lansing, USA; University of Alberta, Edmonton; University of Calgary, Calgary; University of Manitoba, Winnipeg (Appendix I). The workshop began with presentations from DFO Science: Ross Tallman, Head of the Arctic Stock Assessment and Integrated Ecosystem Research Section of Arctic Aquatic Research Division, and stock assessment biologists of the Section (Les Harris, Zoya Martin and Melanie VanGerwen-Toyne). The final presentation was by DFO, Fisheries Management (Tyler Jivan and Allison MacPhee) (Appendix II). The presentations were received with interest by the participants and stimulated many questions and much discussion (Appendix III). Presentations appear in Appendix IV.

A summary of the main points from the presentations is as follows:

1) Arctic Char, *Salvelinus alpinus*, in Nunavut likely are not being harvested optimally i.e. at the optimal (maximum) level that can be sustained over the long term;
2) There are many more stocks than can be monitored effectively using a standard practice of monitoring fishery dependent (catch, effort, biological characteristics of the catch) and fishery independent (research survey (netting) index, biological characteristic of the population) metrics;
3) The geographical area of interest is vast, covering the longest coastline in Canada (162,000 km) and encompassing a large physical area (Nunavut: 2,093,190 km² and Northwest Territories: 1,140,835 km² ) over great latitudinal and longitudinal ranges, and therefore environmental conditions;
4) Almost all fisheries are harvested using gillnets – except a few in Cambridge Bay done by weirs;
5) There are four harvest situations that need management:
    a) key national priority commercial fisheries – the sampling goal is to meet a national standard;
    b) fisheries that have a commercial quota that do not receive ongoing monitoring (regional checklist and non-checklist commercial fisheries on Schedule 5 – roughly 170 plus fisheries);
    c) emerging fisheries under exploratory harvest licences (large number in Cumberland Sound and increasing requests elsewhere);
    d) subsistence fisheries – high value culturally and in replacement food value;
6) Demand for fish product in Nunavut and the Northwest Territories is three times the current supply, plus there are boutique markets in Boston and San Francisco;
7) While only a handful of stocks appear to be over-exploited, Arctic Char populations have characteristics (low fecundity, late maturity, concentrated migrations in small systems) that make it vulnerable to over-exploitation;
8) When in doubt, a precautionary harvest rate of 5% (Tallman's Rule) is currently applied to ensure conservation and sustainability.

In terms of stock assessment and information to assess sustainability, Arctic Char stocks fall into four categories:

1) High priority stocks – Stocks in Cambridge Bay and Cumberland Sound – although not fully operational the intent is to develop long time series with fishery dependent (catch per unit effort (CPUE) and biological sampling of catch) and fishery independent (research survey) data and apply analytical models to assessment (see Tallman et al. 2012b for details);
2) Commercial stocks with limited data – usually a catch record and occasional samples;
3) Exploratory fisheries – considered as stage 2 exploratory protocol stocks. Stocks with a set quota for 5 years, catch per unit effort and biological samples taken over 5 year period (see VanGerwen-Toyne and Tallman (2011)) for details of protocol);
4) Stocks with no data – many fisheries are for subsistence only, as well a commercial fisheries proposed for new stocks (not all stocks in Nunavut and Northwest Territories are exploited).

The workshop participants, based on their expertise and the presented material, were tasked to explore approaches to solving these problems, provide some preliminary strategic research designs and propose a research plan whereby the optimal (highest) catch could be estimated that could be sustained over the long term without compromising the productivity or health of a stock.

Participants, in principle, searched for ways to estimate Maximum Sustainable Yield (MSY). By default, the biological objective of fisheries management is to obtain MSY, or in other words, achieve biological yield maximization. The standard indicator of biological yield is the annual weight or number of fish caught.

Within the Department of Fisheries and Oceans (DFO) framework the situation must be taken further to have an active, adaptable management regime that guides actions by fisheries management with biologically based limit reference points that define a precautionary framework (DFO website: http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-back-fiche-eng.htm).

### 1.1.1 The concept of Maximum Sustainable Yield (MSY) and its evolution

An underlying model of the traditional concept of the dynamics of fishery resources is that as fishing effort increases, catch will increase up to a maximum, beyond which even if effort continues to grow, catches (also known as yield) decrease. This leads directly to the concept of maximum sustainable yield (MSY), which has been the “holy grail” of fisheries management (Larkin 1977). The specific shape of the yield curve shown in Figure 1 does not matter. The important principle always holds: zero effort means zero catch; too much effort leads to small or almost zero catch.

Also, in theory there should be a point at which catch reaches a maximum—at least on average— and supposedly once the curve reaches the top, the MSY level has been found. For decades, finding MSY and keeping fisheries at this prescribed level of catch and effort became the sole objective and obsession of fisheries science, as was eloquently put by Larkin (1977).

There are several problems with this concept: the first practical problem being that natural systems have much random variability. In practice, real data will always reflect this variability as "noise." The great danger of focusing stock assessment work solely on finding MSY and its associated optimum effort ($F_{opt}$, defined as the effort level that produces MSY) is that we can seldom be totally sure that we have witnessed the MSY level. Even if managers try to be very careful and cautious by developing a fishery at a very slow pace it never can be guaranteed that the stock will not be overexploited or that opportunities will not be wasted. An excellent example of the difficulties in finding MSY comes from work on Atlantic Yellowfin Tuna, *Thunnus albacares*, published by FAO and cited by Hilborn and Walters (1992). When scientists performed the first assessment of this resource in the mid-1970s, they thought they had already arrived at the MSY level and calculated this at about 50,000 t. However, due to a lack of effective management the fishery continued to grow and a second analysis 10 years later suggested a different MSY level of more than 100,000 t, clearly indicating that the first assessment had led to a "false" MSY. The question remaining was if the second assessment was also an underestimate.

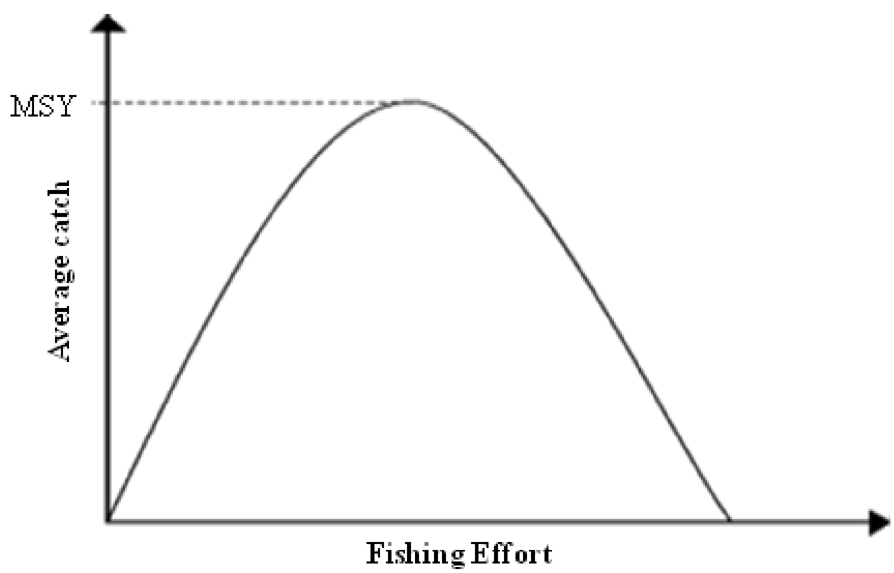


Figure 1. A graphical representation of Maximum Sustainable Yield (MSY).

The real problem in the above example, and in most real fisheries, is that in all cases, and especially in situations with noisy data, we have to go beyond MSY to ensure that we have actually found it. In other words, until yield substantially decreases over a sufficient period of time at increased effort levels we cannot be sure that MSY has been observed. This effectively means that we can never prevent overexploitation, at least not a small amount, in the best case. This is an important principle identified by Hilborn and Walters (1992): "You cannot determine the potential yield from fish stocks without overexploiting them." The challenge is not to overexploit the stock beyond recovery in our effort to find MSY. An additional practical problem is that once fisheries have actually passed the MSY point and gone into the overexploitation phase, more problems arise. In such cases, the fishery has already entered the overcapacity side of the curve. This leads to another sad but important principle stressed by Hilborn and Walters (1992): "The hardest thing to do in fisheries management is to reduce fishing pressure."

In an ideal situation a new fishery should start with all the mechanisms in place to assure: 1) a quick detection of MSY after passing this point (i.e. a good monitoring and data acquisition system should be in place), and 2) there should be mechanisms in place from the onset of exploitation, that will reduce effort effectively without detrimental effects (e.g. high taxes that can be later used to buy back boats or compensate for the lost catches and revenue of each boat). Currently, MSY is a theoretical concept that should hold on average, but it is mostly useful as a general concept that helps us guide our work; it is not the current aim of fisheries assessment. (However, note that currently the European community has decided to use MSY as a target after moving through various types of goals. This is likely because most of their stocks are exploited well to the right side of Figure 1. In present times, the MSY concept is used to derive management targets and limits or biological reference points (BRPs). Biological reference points are levels of total biomass, spawning stock biomass, fishing mortality rate or other measurable characteristics of a fish population and a fishery, which are either the target of management or a limit beyond which the fishery will not be permitted to go. Two common BRPs are the biomass at which the population can produce MSY (BMSY) and the fishing mortality needed to achieve MSY (FMSY). For additional reading about these and related concepts readers should refer to Clark (1991), Jacobsen (1992), Smith et al. (1993), Caddy and Mahon (1995), and Hayes (2000). A further important consideration is that MSY and any reference points based on it assume that the recruitment of the studied population and environmental conditions are constant. However, human-induced (habitat destruction, species depletion) and environmentally driven phenomena (climatic "regime shifts") can all produce changes in MSY. This issue commonly has been either ignored or mishandled in fisheries science.

Resource conservation and biological and genetic diversity are important biological objectives with increasingly important roles in fisheries management. Explicit directives to avoid putting stocks of target and non-target species at risk of extinction, and to develop plans for their recovery in case they are already endangered, play a key role in fisheries legislation in many parts of the world. This is exemplified in the 1996 Magnuson-Stevens Fishery Conservation and Management Act of the USA. Even more recently, ecosystem-health objectives are beginning to take a very important role in fisheries management (Sainsbury et al. 2000, Stevens et al. 2000). Several fishery management plans already incorporate ecosystem objectives and it is just a matter of time until ecosystem-based objectives replace some of the more traditional biological objectives such as obtaining single-species MSY levels (Tallman et al. 2012a). Regardless, MSY, at least as a conceptual guide, is the desired goal to aim for in advanced fisheries management.

### 1.1.2 The DFO precautionary framework

Canada adopted a harvest strategy compliant with the Precautionary Approach (PA) in 2003 (DFO 2006). The PA recognizes changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to changing environments and human values (FAO 1996). The PA applies prudent foresight and accounts for uncertainties and incomplete knowledge of the fishery and requires increased avoidance where there is risk of serious harm and uncertainty is great. The Canadian framework for applying the PA in harvest strategies states that minimum requirements include: 1) an Upper Stock Reference Point (target reference point), 2) a Limit Reference Point, and 3) a Removal Reference Point (DFO 2006). Definitions of each requirement are provided below. Figure 2 illustrates the removal reference in three Stock Status Zones (Healthy, Cautious and Critical), delineated by the Upper Stock Reference and Limit Reference Points, as both harvest and stock status (e.g. reproductive biomass) increase.

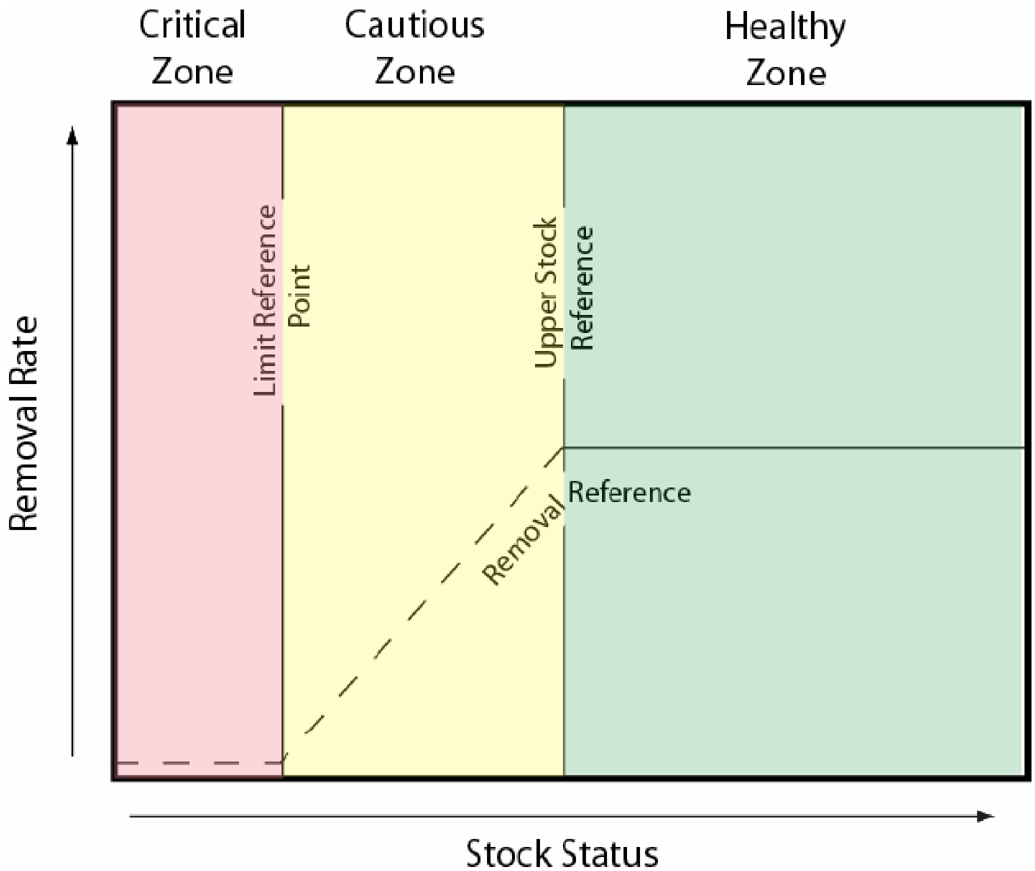


Figure 2. Fisheries management framework consistent with a Precautionary Approach (DFO 2006).

1.1.2.1. <u>Definitions of reference points and zones:</u> The Precautionary Approach framework prescribes three Stock Status Zones bounded by Limit Reference points (DFO 2006):

*Upper Stock Reference Point* - The stock level threshold below which the removal rate is reduced. As such it applies to exploited populations. This reference point is determined by productivity objectives for the fishery. These objectives will vary among species and fisheries and include biological, social and economic factors. The Stock Status Zone above the Upper Stock Reference is called the Healthy Zone.

*Limit Reference Point* - The stock level below which productivity is sufficiently impaired to cause serious harm but above the level where the risk of extinction becomes a concern. In this context, serious harm could be due to over-fishing, other human induced mortality or changes in population dynamics not related to fishing. The Stock Status Zone above the Limit Reference

Point but below the Upper Stock Reference is called the Cautious Zone. The zone below the Limit Reference Point is called the Critical Zone.

*Removal Reference Point*- This is maximum acceptable removal rate. The removal rate is the ratio of all human induced removals to total exploitable stock size. To comply with the United Nations Fish Stocks Agreement (UNFSA), it must be less than or equal to the removal rate associated with maximum sustainable yield. The Removal Reference includes all human-induced mortality.

1.1.2.2 Management actions:

- In the Healthy Zone, the removal rate should not exceed the Removal Reference.
- In the Cautious Zone, fisheries management actions should promote stock rebuilding towards the Healthy Zone. The removal rate should not exceed the Removal Reference.
- In the Critical Zone, fishery management actions must promote stock growth. Removals by all human sources must be kept to the lowest possible level.

## 2.0 ARCTIC CHAR CHALLENGE

Providing advice on appropriate quotas for Arctic Char in Nunavut and Northwest Territories is challenging for a number of reasons. First is the physical scale of the problem relative to the resources at hand. Central and Arctic Region fisheries management is responsible for Arctic Char management in Nunavut and Northwest Territories and the water flowing into the Arctic Ocean from the Yukon Territory. This represents over 3,000,000 km² of land (approximately equivalent to the 7$^{th}$ largest country in the world) and the longest coastline in Canada (162,000 km). Arctic Char and its close relative the Dolly Varden, *Salvelinus malma*, exist throughout the Arctic coastline. Arctic Char have been found as far as in Lake Hazen on Ellesmere Island. There are 195 stocks of Arctic Char listed within fisheries management Schedule 5 (the record of official commercial water bodies for DFO fisheries management) and possibly at least that many again that might be fished in the future. For example, in Cumberland Sound there are three stocks that have commercial licences but estimates from the Pangnirtung Hunters and Trappers Association (HTA) suggest that perhaps 40 to 60 stocks exist in the area (Figure 3). Of these, between 10 and 15 stocks have been under exploratory licence over the last 20 years.

In total, there are 13 commercial stocks in Nunavut that DFO considers high priority: eight (8) are national priority stocks from the Cambridge Bay and Cumberland Sound areas and five (5) are regional priority stocks (Kivalliq Area and Sylvia Grinnell near Iqaluit - Figures 4, 5 and 6). In addition, DFO has developed an emerging fisheries program for new Arctic Char and marine fisheries, which is mainly focused on the harbour development in Pangnirtung on Cumberland Sound. Assessments of exploratory fisheries in the area are proceeding with the development of 5 year time series. DFO also has priority fisheries for Arctic Char and Dolly Varden in the Northwest Territories near the communities of Holman, Paulatuk and Sachs Harbour as well as in several rivers on the west side of the Mackenzie and Yukon North Slope (Dolly Varden). Monitoring to develop fishery dependent and fishery independent indexes is proceeding according to the plan in Tallman et al. (2012b). For the remaining stocks (approximately 170) listed under Schedule 5, and new exploratory fisheries, there is little active monitoring and only occasional sampling for fisheries data. The question of what to do with these and newly-harvested stocks is central to this workshop.

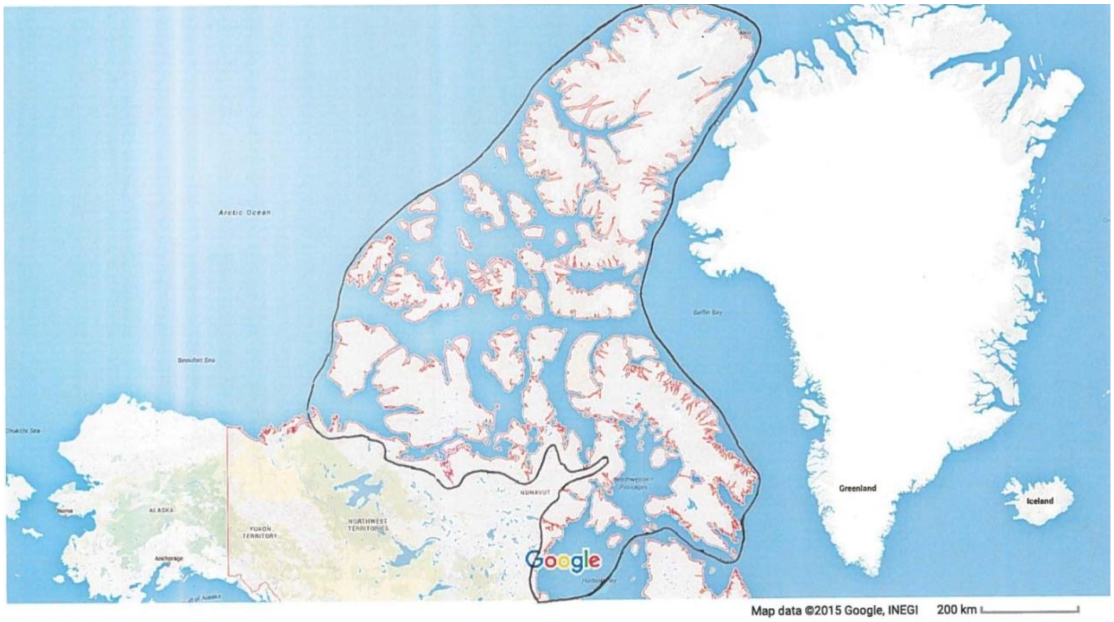


Figure 3. The area (inside black line) of Arctic Char distribution managed by the Central and Arctic Region of DFO.

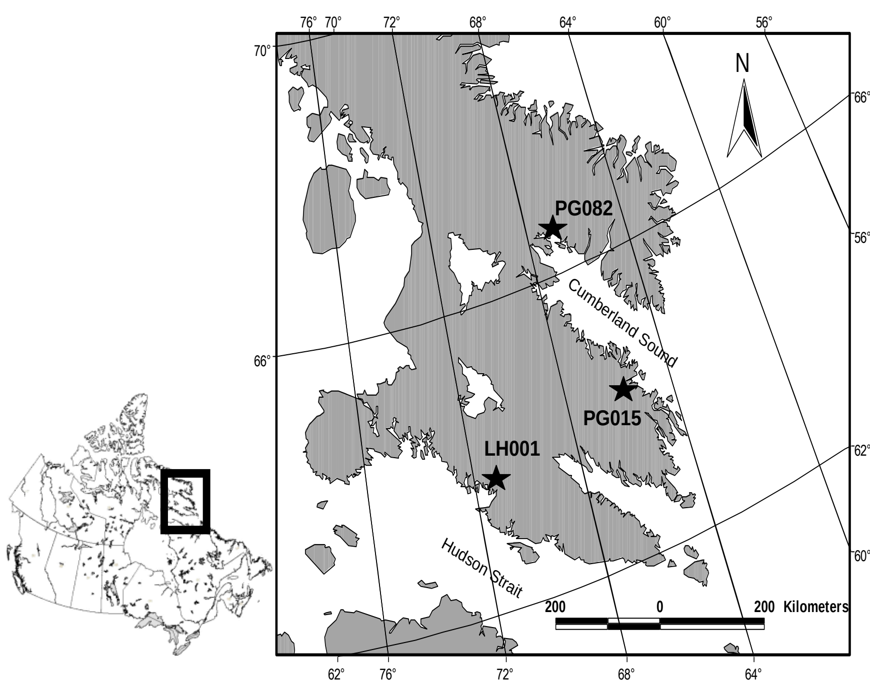


Figure 4. Map of Cumberland Sound and Frobisher Bay, Baffin Island. The stars indicate active commercial fisheries: Iqalugaarjuit Lake (PG080), Qasigiyat (PG015), and Qinngu (LH001).

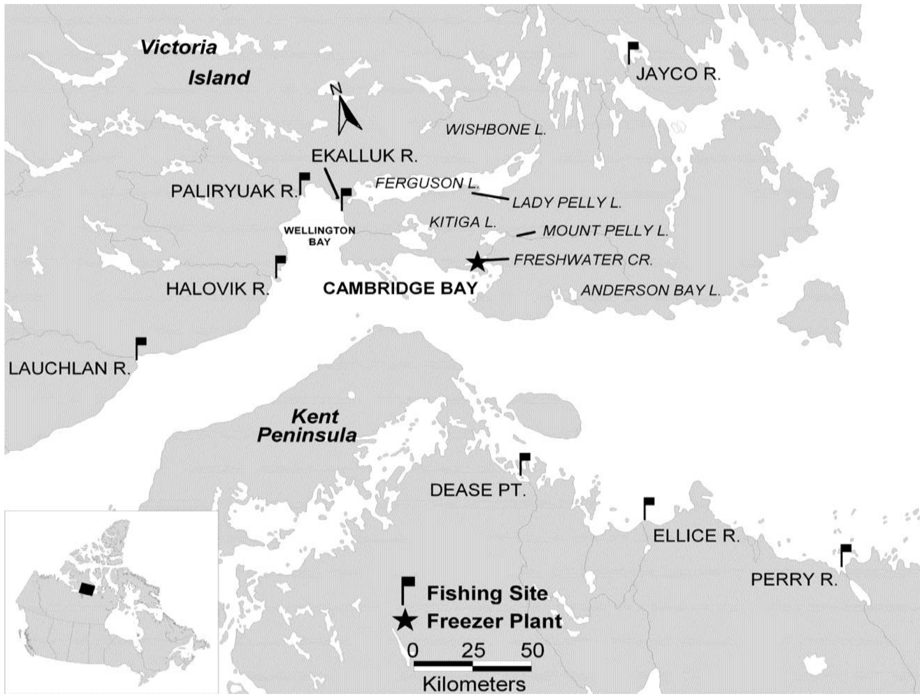


Figure 5. Cambridge Bay showing commercially harvested stock locations: Lauchlan, Halovik, Paliryuak, Ekalluk and Jayco rivers. Flags represent present and past fishing sites. The star marks the location of a fish processing plant.

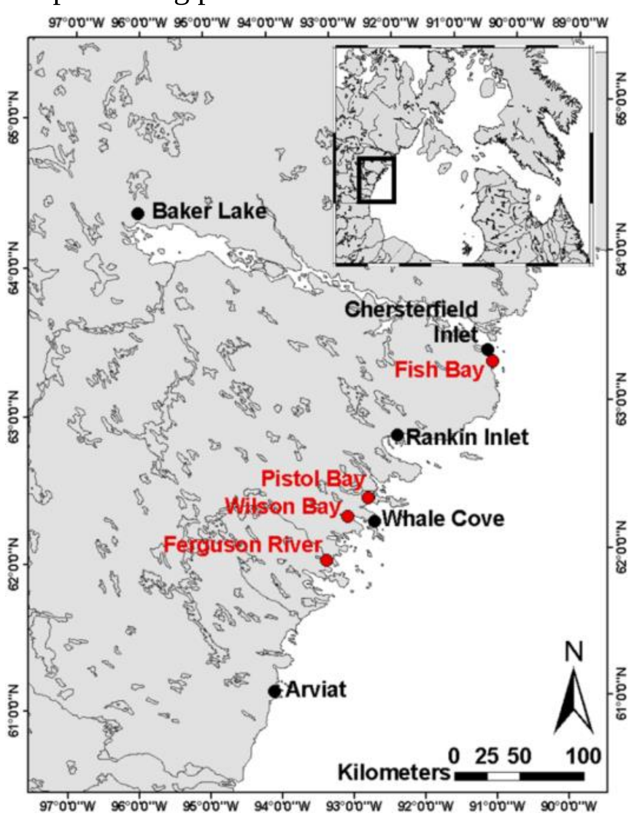


Figure 6. Kivalliq Area – commercially harvested fishing sites are shown in red.

One question to ask is "Why bother with management?" Each of the fished stocks is relatively small compared to DFO's other fishery responsibilities. One argument is that the communities have harvested some stocks for long periods of time and probably will be able to conserve them. However, the record since the 1970s show numerous cases where stocks have shown declines (C. Cahill, University of Calgary, pers. comm.) For example, Read (2004) noted that in the Coppermine River upward of 500 nets were set on the run into the river in the 1990s. Subsequently, the stock did not support a fishery for some time. Overall, Arctic Char contribute significantly to the Nunavut economy (see Figure 12 in BDSI 2004) and are projected to do so into the indefinite future if they are well managed. Every community in Nunavut utilizes Arctic Char and the subsistence harvest provides much needed high-quality protein. Arctic Char is a traditional country food that can be acquired with limited technological investment. The commercial harvest is accessible to individual beneficiaries and a large part of the revenue stays in the communities. Arctic Char is also iconic as a symbol of the North. Evidence of how iconic it is may be found in the fish restaurants of Yellowknife where the first item on the menu is Arctic Char, even though there is not a stock within 1000 km. Tourists expect to eat Arctic Char as a northern experience. Further, there is strong anecdotal evidence of declines in the Sylvia Grinnell fishery (Gallagher and Dick 2010) and in the Ekalluk River near Cambridge Bay. Community evidence suggests fish in these systems declined in size and quality shortly after fishing began, suggesting overfishing Arctic Char stocks is possible (Kristofferson and McGowan 1981).

Demographics and new economic opportunities will likely increase the pressure to develop more Arctic Char stocks and increase the harvest levels on existing ones. Arctic Char has traditionally been marketed as a boutique item to southern interests, such as the Boston Fish Market. It commands the highest price of any salmonid sold. In recent years it has been estimated that the domestic demand in Nunavut alone is 3 fold the current supply. Moreover, the human population of Nunavut is booming. Many people are turning away from traditional means of living, but all beneficiaries have a right to the resource, and so just by virtue of human numbers, mortality of Arctic Char may increase due to various fishing activities. DFO will be expected to provide scientific advice and work with Nunavut communities and agencies to achieve sound fisheries management.

Populations in the genus *Salvelinus* (to which Arctic Char belongs), have seen some of the most serious collapses of resources under fisheries management. For example, in the Laurentian Great Lakes and in Great Slave Lake, lake trout, *Salvelinus namaycush*, stocks have collapsed and in most cases have not recovered to their previous abundance (Muir et al. 2012). In Alberta, 60% of the stocks of bull trout, *S. confluentis,* have been extirpated (Post and Johnston 2002, COSEWIC 2012). *Salvelinus* are highly prized by fishers, and specific life history traits such as relatively low fecundity, slow growth, late age at sexual maturation, and frequent occupancy of top predator status appear to make them particularly susceptible to overexploitation.

In general, Arctic Char stocks appear to have been well conserved. Arctic Char management by DFO in Nunavut appears to be largely successful, where only one stock apparently has fallen into a state of serious harm, and a handful have been exploited to the point where changes in quota were deemed necessary (e.g. Tugaat River). However, communities have often voiced concerns regarding the impacts of fishing on Arctic Char stocks throughout the Central and Arctic Region (Bond 1972, Kristofferson et al. 1982, Kristofferson 2002, Kristofferson and Berkes 2005, Gillman and Kristofferson 1984, McGowan 1987, McGowan and Low 1992, Carder 1995, DFO 2004, Read 2004). Because there have been few cases where stocks have been exploited to their maximum and beyond, it is mostly unknown if the current quotas are near or well below MSY. The monitoring process can only determine if the current harvest is safe and sustainable, but not whether a harvestable surplus remains in the water.

## 2.1 OTHER CONSIDERATIONS (DISPERSAL, FIDELITY AND ENVIRONMENTAL VARIATION)

There are several other aspects to the problem to keep in mind. Arctic Char return to their natal system to spawn, but may not do so to over-winter. Arctic Char may not spawn every year and in some cases spawn only once every several years. In the intervening years they may or may not return to their natal systems. As well, genetic analyses indicate natal site fidelity may be somewhat lower than Pacific salmon. Regardless, sampling of Arctic Char stocks may be confounded by adjacent populations.

The territories of Canada are so vast that climate and other environmental differences are markedly different among locations. Presumably, the ecology of Arctic Char also varies with these environmental clines, through few studies have explicitly explored this.

Further, the environment and harvesters are dynamically changing entities. Hence, sampling and assessment must deal with:

1) A high degree of uncertainty - uncertainty in catch information, biological statistics and so on;
2) Random variability – system changes that are not directly applicable to processes being measured in the assessment – e.g. inter-annual variations in climate;
3) Variation in fisher behaviour;
4) Situations with an abundance of data (e.g. Cambridge Bay), while other fisheries are data-poor (e.g. Cumberland Sound and Western Hudson Bay); and
5) Model choice (some models are better suited to capturing the underlying dynamics of a given resource than others, but it is often impossible to determine which model is more correct for a particular stock).

# 3.0 PROPOSED APPROACHES FOR ESTIMATION OF MSY

One advantage of the Arctic Char situation is that there are a large number of stocks. In addition, while it is a source of problems in one respect, the wide variability in vital rates, such as age at maturity, growth and fecundity may prove advantageous for using certain data-poor assessment methods. These modelling approaches may provide the results that are needed to estimate yields more precisely.

As well, given the large number of stocks it may be possible to use experimental harvesting to develop data with sufficient contrast to determine MSY. The specific focus of this workshop is to consider experimental designs that could yield suitable data.

As a starting point, we will consider four scenarios whereby variation in harvest rate could be accomplished:

1) Communities and harvesters will be used to increase harvest (via gillnet) on selected stocks and collect biological and catch per unit effort (CPUE) information for 5 years, and will pass these data to DFO for analyses. Separate programs would be run for the Cambridge Bay, Cumberland Sound and Kivalliq areas with *status quo*, moderate increase in harvest and high increase in harvest treatments.

2) DFO would set weirs to enumerate stocks and collect biological data. The community (and/ or DFO) would apply low, moderate and high levels of harvest to stocks for 5 years in each of the Cambridge Bay, Cumberland Sound and the Kivalliq areas and collect biological data and CPUE from the harvest.

3) DFO would conduct mark-recapture experiments to estimate stock numbers. The community (and/ or DFO) would apply low, moderate and high levels of harvest to stocks in each of the Cambridge Bay, Cumberland Sound and Kivalliq areas and collect biological data and CPUE from the harvest.

4) DFO would conduct a study using weirs to assess rivers for 5 years without fishing, 5 years of low, moderate and high harvests, and 5 years of recovery. This also would be done in each of the three major regions mentioned above.

## 3.1 RESEARCH PROGRAM

### 3.1.1. Problem definition

Additional discussion was held to narrow the problem. Two high priority gaps were identified to exist for Arctic Char. First, most harvests are considered sustainable because, with the exception of the Sylvia Grinnell, stock assessments based on current information have shown the fisheries to be in the Healthy Zone. However, it is unknown whether the current quotas are providing the maximum economic benefit while maintaining the stock in this zone. Research to establish an optimum harvest rate for commercial stocks is desirable, particularly for priority stocks. Second, while the method for assessing exploratory Arctic Char fisheries is well established (VanGerwen-Toyne and Tallman 2011) the method to set the initial harvest is not well defined. This second problem can contribute to the first since if fisheries go through the exploratory phase and then move to commercial status, the existing quota is likely to be below the maximum sustainable harvest.

### 3.1.2 Development of population process models

Discussion led to a conclusion that before one developed a field research program to address either question, process models need to be developed and accepted to make explicit the nature of the stock population dynamics and to guide the collection of field data. However, the first step toward the development of a set of population models is to develop a database of all available Arctic Char data, and to perform meta-analyses of these data. A thorough synthesis of

Arctic Char life history traits (weight-length, growth, and age-at-maturation) is currently lacking, and represents a fundamental step toward assessing the stocks. This step is perhaps particularly important for Arctic Char because the *Salvelinus* genus is a remarkably diverse vertebrate group (Muir et al. 2015), and because basic life history traits ultimately structure the level of harvest that a given population can sustain. Arctic Char life history traits likely vary substantially across the landscape (e.g. Kristofferson and Sopuck 1983, Woods 2011), and thus another important need is to better understand whether traits vary predictably according to landscape level descriptors (i.e. covariates or biological hypotheses). Also, an inventory of the reports for each stock should be compiled. Comparisons between life history analyses and inventory reports may provide important information on historical and/or current fishery status. Further, it may be possible to use pre-existing age-structure data coupled with information from old reports to determine the degree to which certain fish stocks have responded to harvest. Studies that examine the role the environment plays in structuring life history characteristics will help determine an appropriate number of experimental harvests, and will provide some information on biologically ideal locations in which to undertake experimental activities.

In addition to basic life history traits, information on natural mortality rate and recruitment likely form the next step in terms of their utility for determining sustainable harvest levels for northern Char stocks. Both are key population dynamic parameters that drive estimates of harvestable surplus in population models. Exploration of the data compiled above for situations where fish populations are unexploited or lightly exploited may be a useful approach for determining natural mortality (Kenchington 2015). In unexploited or lightly exploited situations, it may be possible to ground-truth other natural mortality proxies commonly used in fisheries assessments (e.g. natural mortality estimators such as Pauly's, Hoenig's, etc. (Pauly 1980, Hoenig 1983)). Similar to above, an attempt should be made to link estimates of natural mortality to landscape level predictors, as this may greatly improve stock assessments (Tallman 2011). Recruitment is another driving parameter in any fish population model, yet no estimated stock-recruit relationships exist for Arctic Char. Thus, any contributions that improve understanding of stock and recruitment relationships in northern *Salvelinus* stocks would greatly enhance efforts to conserve Arctic Char stocks. Hierarchical modelling approaches should be considered for both mortality and recruitment, as this approach can be used to steal information from data-rich stocks, and improve parameter estimation in data-poor stocks (Punt and Hilborn 1997). Further, this modelling approach may allow biologists to borrow information from closely related, data-rich species (e.g. Lake Char from the Laurentian Great Lakes, Dolly Varden from the Yukon) to improve parameter estimation in Arctic Char assessments.

A comprehensive analysis of life history invariants should be explored as invariants have a strong scientific basis, and because they have been used in stock assessments worldwide (Charnov 1993, Mangel 1996). Life history invariants are ratios of life history parameters that have the same units, and the resulting ratios are dimensionless allowing for among-population or among-species comparisons; life history invariants represent an elegant approach for estimating difficult to measure quantities in data-poor fish stocks (Beverton 1992). For example, life history invariants can be used to approximate difficult to measure quantities, such as natural mortality rate, using easier to measure quantities, such as growth rate (Mangel 1996). However, the use of such invariant quantities first requires the life history meta-analyses be completed (see above). Further, as with natural mortality and recruitment, it likely will be necessary to look across the *Salvelinus* genus to improve estimation of these invariant life-history distributions e.g. using hierarchical models.

Once information on among-population variation in life history traits, mortality, recruitment, and life-history invariants is available, it will be possible to build a suite of population models aimed at guiding an adaptive experimental harvest program. There are two basic families of models: surplus production or logistic-style models, and age-structured models. While several variants exist for either style, surplus production models are typically simpler models that use a composite measure of biomass as the primary variable of interest. Age-structured models attempt to incorporate more biological realism through the inclusion of a variety of life-history and ecological dynamics, and are best exemplified by the yield-per-recruit, virtual population analysis, and statistical catch at age models or integrated models (Hilborn and Walters 1992). While counterintuitive, more complex models are not necessarily better for ensuring the sustainable management of a natural resource (Walters and Martell 2002). As a result, many assessment agencies use ensembles of models to bracket uncertainty and to design strategies that are robust to a wide range of potential futures using Management Strategy Evaluations (MSE) ( Butterworth and Punt 1999). Once a candidate set of models is created, it will be possible to make recommendations on sustainable harvest levels and management strategies for stocks with and without data. Further, performing sensitivity or perturbation analyses will allow biologists to highlight the critical uncertainties in the Arctic Char data; this information should then be used to design adaptive experiments that seek to explicitly reduce such uncertainties and set realistic quotas.

For the key commercial stocks where there is a need to estimate harvest rate to achieve some form of MSY (priority gap 1 identified above), the process models likely would be along the lines of a surplus production approach (non-age structured) or an age structured model e.g. cohort analysis or statistical catch at age. However, dynamic pool models may also provide an important tool for assessing Char stocks; these models are an intermediary between the simpler surplus production models and more complex age-structured assessments.

To establish initial precautionary quotas for exploratory fishery requests (priority gap 2 identified above), a different type of analysis is likely required since there will not be data for the stock until the fishery commences. At best one might expect that a test fishery could be done, but in most cases there will be little information available. In this case, alternative methods, possibly using landscape features coupled with a productivity-susceptibility analysis (where some preliminary samples are possible), might yield an acceptable approach. In the event that an exploratory fishery occurs in a location where data from historical sampling exists, it will be possible to provide advice using results from the meta-analyses, mortality, recruitment, and life-history invariant studies recommended above.

An intermediate but very common situation is where there is a commercial stock that has a simple time series of catch and little other data. Investigation and adoption of data-poor methods such as various catch based analyses could be used. Additionally, it will be possible to employ Bayesian methods coupled with the meta-analyses, mortality, recruitment, and life-history invariant studies recommended above.

## 3.2 EXPERIMENTAL APPROACHES

Two experimental designs, both needing the creation of process models to test expectations before field work is begun, were proposed:

### 3.2.1 Experimental Design 1

The sampling program would use weirs to sample the entire population returning from sea each year. The design requires sampling over a 15 year period of three similar sized rivers within a region, such as the south Baffin Region. Three stocks in each of the three areas (e.g.south Baffin, Kitikmeot and Kivalliq) would be tracked to account for broad scale environmental variation. Sampling should consist of standard biological data that are currently gathered at other Char fisheries (length, age, sex, maturity, fecundity, weight). Three time period phases of sampling would be undertaken: 1) 5 years pre-manipulation; 2) 5 years of experimental fishing under varying exploitation rates (5%, 15%, 25% exploitation rates); 3) 5 years post-fishing (all stocks fished at 5%).

### 3.2.2 Experimental Design 2

This study would have two phases. The first to get immediate information on existing commercial fisheries responses to changes in harvest rate. The second phase would be focused on understanding environmental contrasts. Similar biological data would be collected as in the first study.

*Phase 1*

Existing commercial fisheries with long time series could be used from 2 or 3 areas. The study would occur over a 3 year period. In some fisheries one would halve the harvest rate and in others one would double the harvest rate. The responses in the most abundant ages in the catch would be recorded to see if there were sharp changes in stock growth (through recruitment or growth processes) and mortality rate.

*Phase 2*

Twenty-five stocks would be studied with 5 years of data each to provide environmental contrast. There would be 5 groups of 5 stocks spread over a large area with exploitation ranging from nil to high. The expected response would be an increase in weight among the more abundant ages. Using this information one would fit the process models.

## 3.3 MODEL DEVELOPMENT

Various models were discussed as needing development for this research. Foremost was the use of an age structured model, but models to determine vital rates from meta-analysis, stage structured models and models that incorporate life history and fishery characteristics were also suggested. The models would be aimed at predicting how Arctic Char populations respond to exploitation rates and how this varies across regions, and would be used to define hypotheses and guide sampling to fill data gaps.

### 3.3.1 Existing modelling

3.3.1.1 Bull trout model: Post et al. (2003) developed a model for bull trout that allowed the examination of the tradeoffs among catch rate, harvest rate, and fish size across a range of minimum size limits for harvest, and to contrast the effects of static and dynamic responses in angler effort to changes in fishing quality. This model allowed delimited combinations of regulations and effort that lead to sustainability or collapse of fisheries, and the qualitative patterns could be applied across other fisheries.

3.3.1.2 Productivity – susceptibility analysis: An alternate framework for assessment using life-history information as it determines stock productivity and resilience to harvesting. is presented in Roux et al. (2011). This framework combines: 1) a risk assessment tool (productivity–susceptibility analysis - PSA) to evaluate the relative vulnerability of Arctic Char stocks to harvest and 2) a conceptual model for quantitative assessment to determine sustainable harvest levels. Using this as a basis, Von-Bertalanffy $L\infty$ and K were calculated and then used to estimate natural and fishing mortality to derive biomass and maximum sustainable production (MSP). PSA vulnerability and MSP were combined to determine whether the stock was in the Critical, Cautious or Healthy Zone of DFO's Precautionary Approach framework. Diversity in Arctic Char life history and contrast in vulnerability scores derived from PSA assessment are demonstrated for a sample of 76 anadromous stocks from throughout Nunavut. These data provide evidence to support an alternate strategy for assessment by integrating the diversity in Arctic Char life history for improved generalization and representativeness. Arctic Char fisheries in Arctic regions exemplify the need for stock assessment and management alternatives to ensure fish conservation in remote, sensitive ecosystems and in data-poor circumstances.

3.3.1.3 Stage-based matrix model**:** This model uses data from commercial fishery sampling including: age (from otoliths), weight, length and sometimes sex. An age and stage structured model will be developed. Population dynamics is represented by four types of parameters: survival rates, fecundity (f), rate of transition from the immature to mature stage ($\alpha c$), and rate of transition from mature to reproducing individual ($\beta c$) (Figure 7). Climate can influence the value of the last two parameters (Day and de March 2004). These parameters are applied to six stages: juvenile, immature, mature, reproducing, post-reproduction (rest year following reproduction) and senescent (no longer reproducing). The time spent in a stage is different for each individual and will depend on several parameters including climate. Thus, two individuals of the same age can be found in different stages e.g. one is still immature while the other is reproducing. Therefore, a model could not be developed based only on the age of the individuals. Rather a discrete time model will be used because data are annual. The age of an individual usually reaches 20 years and can exceptionally reach 30 years. A last important characteristic about Arctic Char biology is that an individual can spawn more than once during its lifetime but spawning three or more times is a rare event (Day and de March 2004, Dutil 1986).

A mathematical analysis based on graph theory and the Perron-Frobenius theorem (Caswell 2001) will be performed to deduce some characteristics of the model: the asymptotic rate of growth ($\lambda 1$), the reproductive number (R0), the contribution to reproduction ($v1$), the stable population distribution ($\omega 1$) and the sensitivity of the model to parameters. Parameters of the model will be estimated by fitting the stable population distribution, ($\omega 1$) of the model population to observed individuals for each age obtained from the commercial fisheries data. As before, it is not possible to know the number of times an individual goes through the reproducing stage. To account for this, a Markov chain will be employed (Seneta 2006). This Markov chain can demonstrate that an individual cannot reproduce more than two times in its lifetime given the observed estimated parameters. Finally, population dynamics will be simulated with this model under two different climate scenarios: 1) a succession of favourable years, and 2) a succession of unfavourable years for the population.

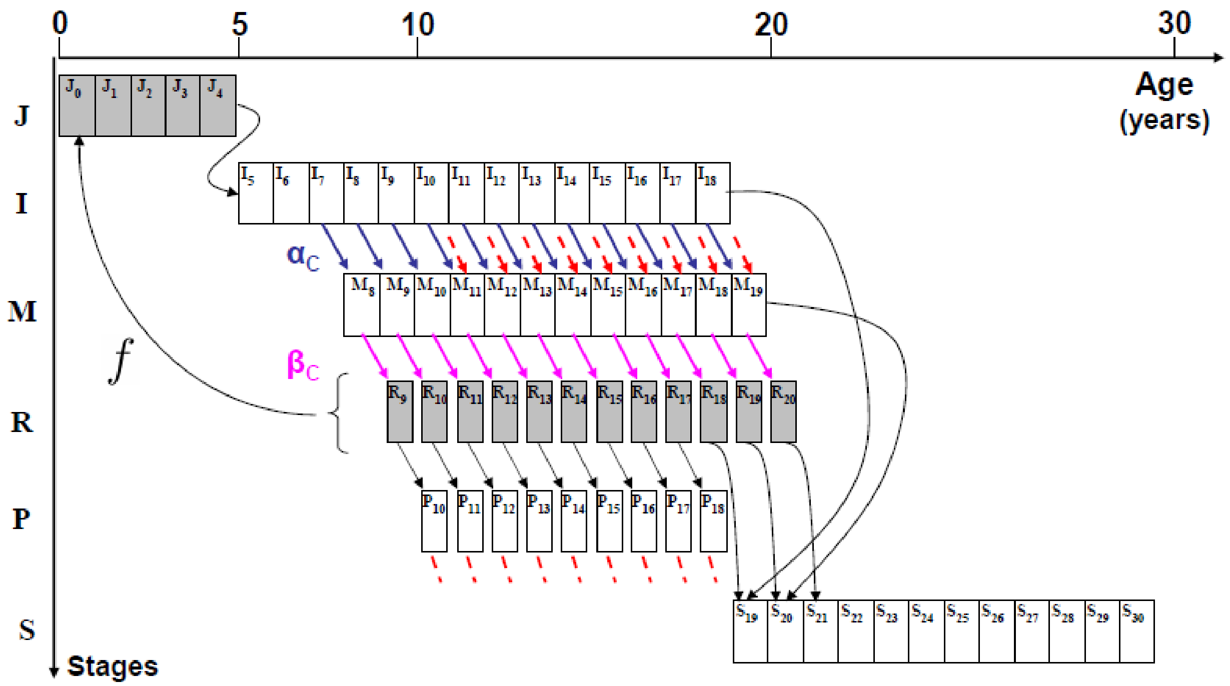


Figure 7. Age and stage structure of Arctic Char life cycle model. Red dotted arrows show transition from post-reproducing to mature stages/ages; for example, from P10 to P11. The arrow linking reproducers to juveniles of ages 0 (J0) represent fecundity (f). Greyed compartments are those in which individuals are in a non-migrating stage. Neighbouring compartments separated by a dotted line and with an arrow indicate compartments between which left-to-right transitions are possible e.g. I11 to I12, while those separated with a continuous line and showing no arrow do not allow transitions e.g.transition from P18 to P19 is not possible. Three types of parameters are explicitly represented here: fecundity (f), rate of transition from the immature to mature stage (αc), and rate of transition from mature to reproducing individual (βc)

3.3.1.4. <u>Landscape-based population estimation:</u> The principle for this method is to develop a relationship between the limiting freshwater habitat and population abundance. Freshwater habitat is critical to the spawning, early rearing, and over-wintering phases of the life cycle. The research on this topic is not complete. Many quotas were initially assigned in the 1980s using a rough rule-of-thumb approach based on available freshwater habitat.

3.3.1.5. <u>Data- poor methods:</u> MacCall (2009) developed the depletion-corrected average catch (DCAC) method. The formula is an extension of the potential-yield formula, and it provides useful estimates of sustainable yield for data-poor fisheries on long-lived species. Over an extended period (e.g. a decade or more), the catch is divided into a sustainable yield component and an unsustainable "windfall" component associated with a one-time reduction in stock biomass. The size of the windfall is expressed as being equivalent to a number of years of sustainable production, in the form of a "windfall ratio". The DCAC is calculated as the sum of catches divided by the sum of the number of years in the catch series and this windfall ratio. Input information includes the sum of catches and associated number of years, the relative reduction in biomass during that period, the natural mortality rate (M), and the assumed ratio of FMSY to M. These input values are expected to be approximate, and based on the estimates of their imprecision, the uncertainty can be integrated using Monte Carlo exploration of DCAC values. Details of the calculations for DCAC are in MacCall (2009). For Arctic Char we used an FMSY ratio of 0.5 and used the M estimated using the FAO method for each stock. Alternative methods, such as a "Status Quo TAC" method based on the Baranov catch equation have been proposed by Tallman and Sinclair (1988). Tallman et al. (2011) has reviewed data poor methods for use in Arctic Char fisheries.

3.3.1.6 Life history invariant: Trade-offs between key life-history traits, such as growth rate and natural mortality rate, are known as life history invariants because they are relatively constant across taxa (Charnov 1993, Tallman et al. 1996). In situations where no real catch and effort time series exist, estimation of potential sustainable yield is usually based on rough estimates of standing stocks and the general knowledge of some biological characteristics of the species. If fishing mortality at maximum sustainable production (FMSP) is assumed to be a specific function of natural mortality, it is possible to describe the surplus function by estimating maximum sustainable production (MSP) when the data are limited to estimates for catch and mean biomass. Two equations have been proposed in the past to estimate the potential yield, and the simplicity and ease of their use contribute to their extensive use in data limited situations. Gulland (1971) proposed the following equation to estimate the MSP of a virgin stock when estimates of the natural mortality rate (M) and the biomass (B) of the virgin stock are available.

$$MSP = 0.5\ M*B$$

This equation has been used extensively. It is based on the observation that, in the Schaefer (1954) production model, the Biomass at MSP (BMSP) is equal to half the biomass in the virgin state and on the basis of the assumption made by Alverson and Pereyra (1969) that the FMSP is roughly equal to M. However, Gulland's equation is not applicable when significant fisheries exploitation has already occurred. A generalized version of Gulland's equation was proposed by Cadima (in Troadec, 1977) for exploited fish stocks using the instantaneous total mortality coefficient (Z).

$$MSP = 0.5*Z*B$$

Until 1990, these equations were more frequently used for fisheries where real catch and effort time series were not available. However, Gulland's equation has been criticized by many researchers because FMSP is often lower than M. Beddington and Cook (1983) concluded that Gulland's equation can overestimate MSP by a factor of 2 to 3. Patterson (1992) reported that fishing mortality rates above 0.67*M are often associated with stock declines. Walters and Martell (2002) found that FMSP was substantially lower than M for most of the species and stocks and suggested a strategy of using FMSP = 0.5*M. They suggested that any fishery that results in levels of FMSP above 0.5*M needs to be very carefully justified by clear demonstration that higher fishing mortality rates have been sustained for several generations. Using FMSP = 0.5*M approach (Walters and Martell 2002), 0.5 value in the Cadima equation can be replaced with 0.33

MSP = 0.33*Z*B

Janjua and Tallman (Freshwater Institute, Winnipeg Unpublished data) found a strong correlation between harvest level and fishing mortality (R = 0.743). Therefore we can assume that the fishing mortality factors represent the stock situation and these data can be used to predict biomass using Gulland's (1971) equation (B = Y/F), and for further stock assessment analysis.

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## APPENDIX I: LIST OF PARTICIPANTS

| Name | Organization |
| --- | --- |
| Sarah Arnold | Government of Nunavut, Rankin Inlet |
| Chris Cahill | University of Alberta, Edmonton |
| Theresa Carmichael | DFO Science, Winnipeg |
| Colin Gallagher | DFO Science, Winnipeg |
| Darren Gillis | University of Manitoba, Winnipeg |
| Les Harris | DFO Science, Winnipeg |
| Kevin Hedges | DFO Science, Winnipeg |
| Yamin Janjua | DFO Science, Winnipeg |
| Tyler Jivan | DFO Fisheries Management, Winnipeg |
| Mike Jones | Michigan State University, East Lansing, USA |
| Allison MacPhee | DFO Fisheries Management, Winnipeg |
| Zoya Martin | DFO Science, Iqaluit |
| John Post | University of Calgary, Calgary |
| Ross Tallman | DFO Science, Winnipeg |
| Melanie VanGerwen-Toyne | DFO Science, Winnipeg |
| Simon Wiley | DFO Science, Winnipeg |
| Sally Wong | DFO Fisheries Management, Iqaluit |

## APPENDIX II: AGENDA FOR WORKSHOP

Char Optimizing Harvest Workshop Agenda June 12-14, 2014

| | |
|---|---|
| Jun-12, 2014 | |
| 9:00 | Opening remarks by Rob Young |
| 9:30 | General Problem with Arctic Char and Maximum Sustainable Yield (MSY)- Ross Tallman |
| 10:15 | Break |
| 10:30 | Cumberland Sound Experimental Fishery- Zoya Martin |
| 11:00 | Cambridge Bay Case Study- Les Harris |
| 11:30 | Sylvia Grinnell Case Study- Melanie VanGerwen-Toyne |
| 12:00 | Lunch |
| 13:30 | Presentation of experimental designs and general discussion |
| 14:30 | Break out groups to discuss pro and cons of experimental design |
| 16:00 | Adjourn |

| | |
|---|---|
| Jun-13, 2014 | |
| 9:00 | Plenary- group presentation of scientific design |
| 10:15 | Break |
| 10:30 | Breakout groups-feasibility (time and money) of design options |
| 12:00 | Lunch |
| 13:30 | Plenary-design presentation and discussion |
| 16:00 | Adjourn |

| | |
|---|---|
| Jun-14, 2014 | |
| 9:00 | Opening remarks to client groups- Ross Tallman |
| 9:30 | Fish Management presentation- |
| 10:15 | Break |
| 10:30 | General problems of assessing MSY for Nunavut Arctic Char- Ross Tallman |
| 11:15 | Summary of the processes to evaluate experimental designs and conclusions of the designs-Ross Tallman |
| 12:00 | Lunch |
| 13:30 | Discussion with clients |
| 15:15 | Conclusion of the client discussions |
| 14:00 | Adjourn |

# APPENDIX III: NOTES ON DAILY PROGRESS

**Recap of Day 1**

- Introduction to species
- Introduction to systems
- Cumberland Sound
- Cambridge Bay
- Sylvia Grinnell
- In most cases, no signs of fishery-induced demographic changes
- Few cases of overfishing, but it can be done
- *Salvelinus* generally susceptible to overfishing
- Workshop Goal
- Develop a research plan that optimizes the Total Allowable Harvest of Arctic Char while ensuring long term sustainability of stocks
- Workshop Outcome
- A research plan to test the impact of fishing intensities and varying environmental conditions on char productivity
- Scoping Questions
- What is our dream assessment method?
- Need to develop a Precautionary Approach framework with reference points?
- CSAS requests refer to abundance and stock status
- What do we need?
- Population estimate
- Estimate of harvest level to results MSY
- How could we better quantify the risk associated with a range of harvest levels?
- Need to include variation across the geographic range
- What data are needed from individual fisheries to apply this? (Minimum data requirements, do/can we use proxies?)
- How do we apply this risk analysis to individual stocks, specifically in the absence of population estimates?

**Recap of Day 2**

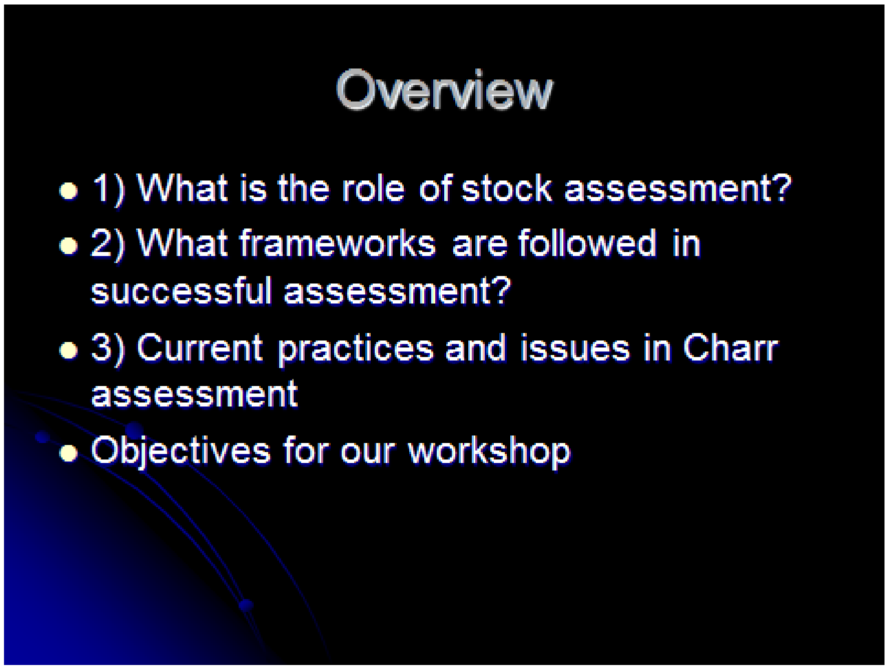
- General suggestions: Sampling opportunities
- Pay for index netting during subsistence fishing
- Use systems that have been fished in the past
- Examine systems that have been closed by communities because of overfishing concerns
- Cambridge Bay mainland stocks have historic data (good candidates for study)
- Subsistence fishing involves both gillnets and jigging
- General suggestions: Buy-in
- Focus on exploratory fisheries with strong/active proponents
- During experimental fisheries, need to balance increases and decreases in harvest within communities
- Be VERY clear about duration of experimental quotas (both increases and decreases)
- General suggestions: Indices and data gaps
- Develop indices of juvenile recruitment
- Catch per unit effort (CPUE) validation
    - Fish weirs and gillnets concurrently
- Determine natural mortality

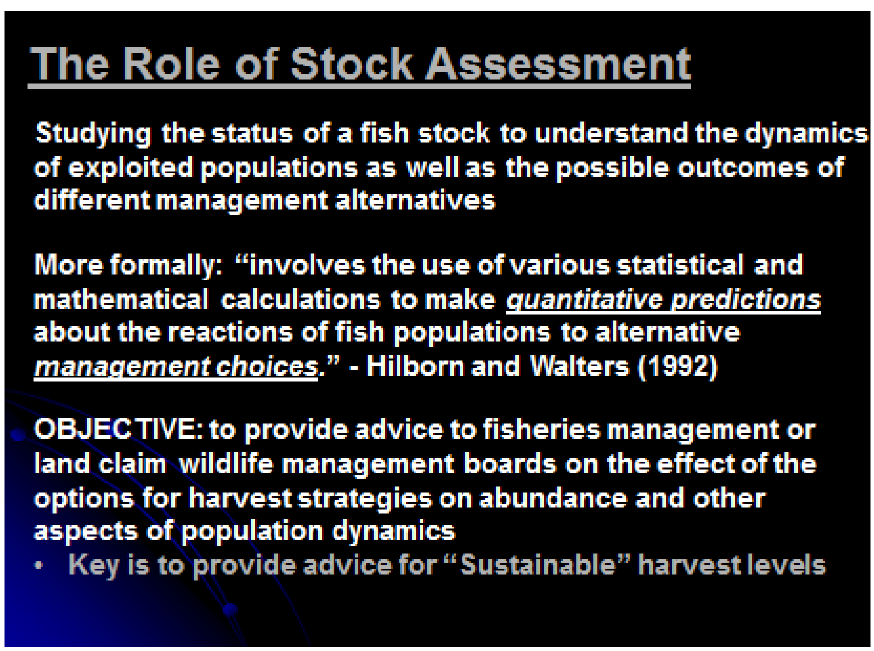
- Use existing data to quantify age distributions typical of low, medium and high risk groups
- Determine ratio between CPUE and abundance
- Quantify relationships between stock productivity and environmental characteristics
- Fill in life history data gaps
- Trophic analyses
- General suggestions: Study planning
- Table of candidate populations with estimated population size, general environmental characteristics and fishing history
- Population model to forecast experimental outcomes
- Select study sites to provide environmental and life history contrasts
- Consider geographic patterns in presence of other species.
- Identify populations that are most likely to show fishing effects
- Use staircase design to deal with time-treatment effects
- Use crossover design for fishing treatments
- Increase sample size for length frequency
- Study Design 1
- Weir sampling of entire population
- 3 areas x 3 populations per area
- Standard biological data (length, age, sex, maturity, fecundity, weight)
- 5 years pre-manipulation
- 5 years of experimental fishing (5%, 15%, 25% exploitation rates)
- 5 years post-fishing (all stocks fished at 5%)
- Study Design 2
- Create process model before fieldwork to test expectations
- Use existing fisheries from 2 or 3 areas (3 year study)
    - Double harvest rate treatment
    - Half harvest rate treatment
    - Use size-structured models
- Find 25 stocks with 5 years of data that provide environmental contrast
    - 5 groups of 5 from high to nil exploitation
    - May increase weight in middle groups
- Fit initial process model using study data
- Research program
- Process model
- Age structured model
- Age-stage structure
- Vital rates from meta-analysis
- Environmental correlates
- Life history
- Sensitivity analysis
- Outcomes
    - Predictions of how Arctic Char population respond to exploitation rates
    - How this changes across pops/regions
    - Define hypotheses and identify discrepancies in data
- Existing Modelling
- Bull Trout (John Post)
- PSA
- Stage-based matrix

- Landscape-based population
- Data poor methods (DCAC)
- Life history invariance
- Next Steps
- Workshop report
    - Draft by mid-July?
    - Appendix of available data (metadata summary)
    - Bibliography
- Data inventory
    - Data compilation lead – (To Be Decided)
        - Through report determine if casual or contract needed
    - Metadata compilation - by early July
    - DFO, Nunavut Government (GN) test fisheries, Parks Canada
    - Data from outside Nunavut: NWT, Labrador, international?
    - DFO biologists compile data for individual fisheries
- Next Steps
- Database creation
    - Database manager start in October
    - 6 month timeframe for compilation of DFO C&A data
    - Subsequent incorporation of other datasets
    - Next Steps
- Synthesis
    - Broad-scale mega-analysis
    - Formal meta-analysis (funnel plots, etc.)
- Initial process model
    - Presentation of draft model in September 2015
- Preliminary design for field study
    - Before 2016
        - Budget and value of outcomes
    - Need to factor in time for consultations
        - Determine tractability within DFO by September 2015. Discussions with GN, Department of Economic Development and Transportation (EDNT) about existing projects that can be used to leverage data (e.g. Nunavut Community Aquatic Monitoring Program (N-CAMP), subsistence harvest programs)
        - Community consultations Fall 2015
        - The Nunavut Wildlife Management Board NWMB proposal January 2016 Canadian Northern Economic Development (CanNor) proposal winter/spring 2016

## APPENDIX IV: PRESENTATIONS

### PRESENTATION 1- INTRODUCTORY PRESENTATION
**By Ross Tallman**



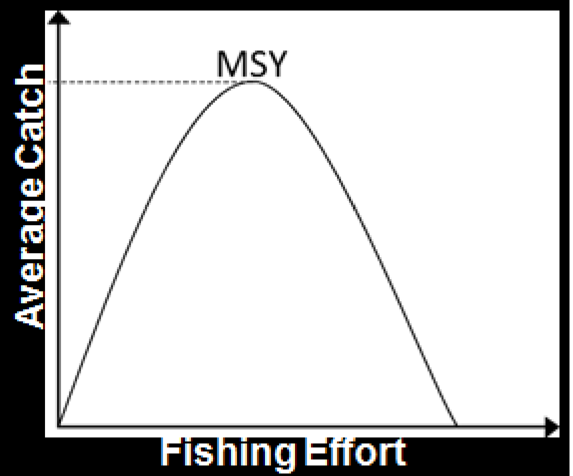
## Maximum Sustainable Yield (MSY)

Ultimate goal?
- Initially the holy grail

As fishing effort increases, catch will increase up to a maximum, and if effort continues to grow then catches (also known as yield) will decrease.

Be aware!

Presently used for resolving biological reference points



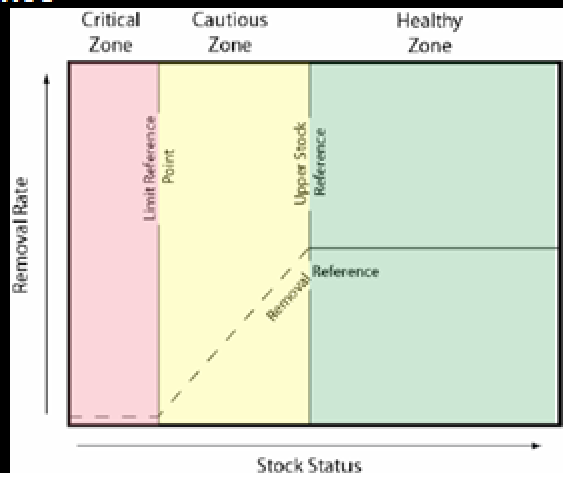

## Precautionary Approach

- applicable to all fish mgnt strategies.
- What are the minimal elements a harvest strategy must have to comply with the Precautionary Approach?
- The application of harvest strategies compliant with the Precautionary Approach will require the development of risk-based decision frameworks for each stock within a species.

## Precautionary Approach (PA) to Harvest

**Identify a removal reference for three stock status zones**

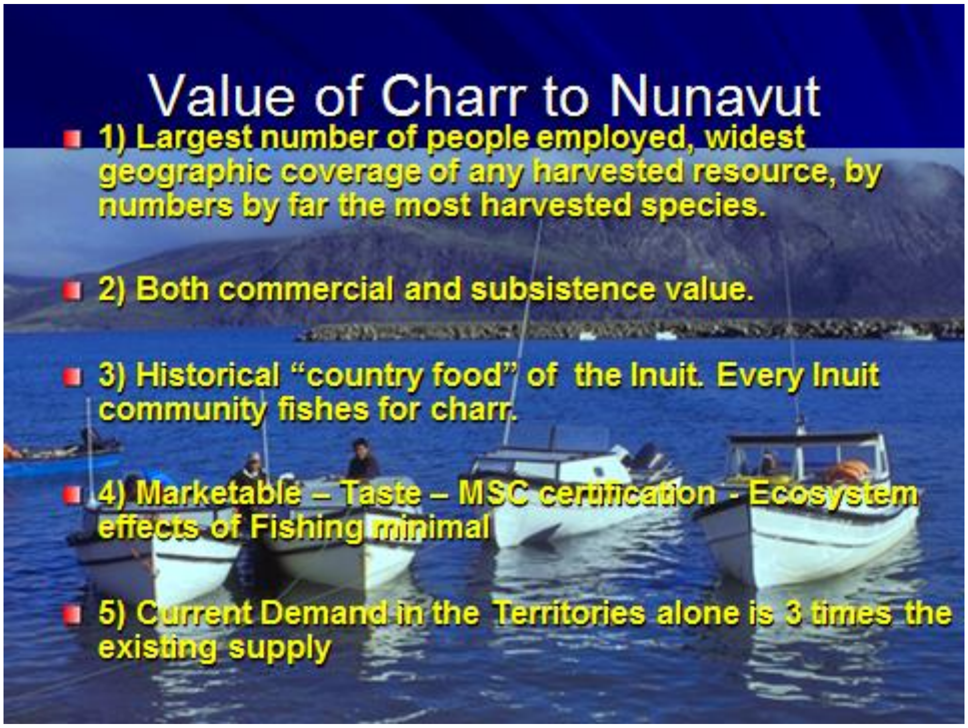
- Critical
- Cautious
- Healthy

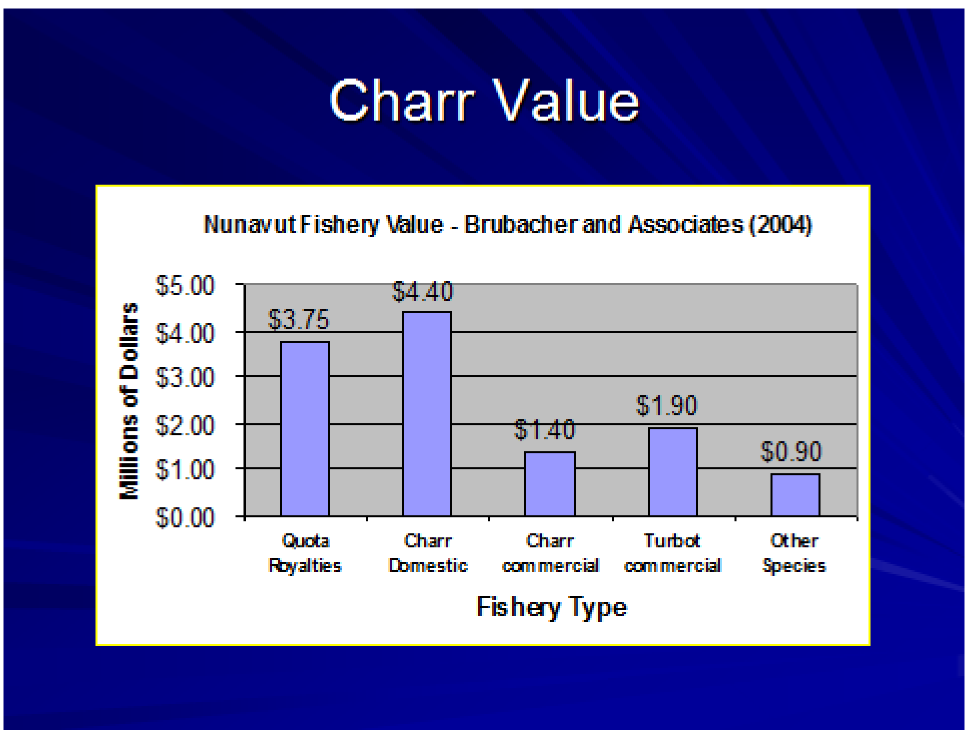



**Removal references**

- Limit
- Removal
- Upper

## Stock Assessment Arctic Charr in Nunavut

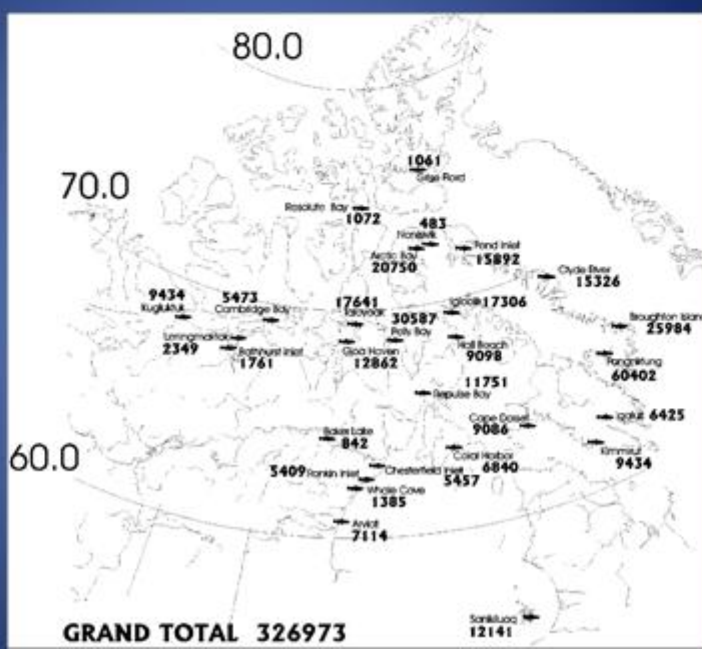

Value of Charr to Nunavut
1) Largest number of people employed, widest geographic coverage of any harvested resource, by numbers by far the most harvested species.
2) Both commercial and subsistence value.
3) Historical "country food" of the Inuit. Every Inuit community fishes for charr.
4) Marketable – Taste – MSC certification - Ecosystem effects of Fishing minimal
5) Current Demand in the Territories alone is 3 times the existing supply


Charr Value
Nunavut Fishery Value - Brubacher and Associates (2004)
Millions of Dollars
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
$3.75
$4.40
$1.40
$1.90
$0.90
Quota Royalties
Charr Domestic
Charr commercial
Turbot commercial
Other Species
Fishery Type

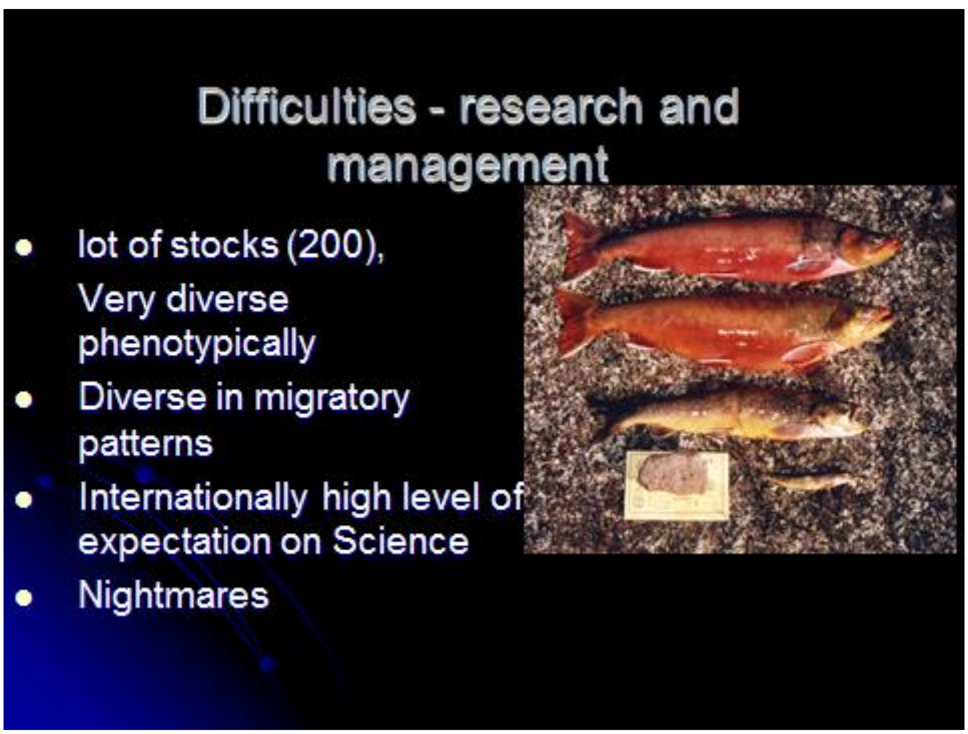
Total Weight Exploratory Fisheries =
approx. 382,942 lbs /year

$3.3million

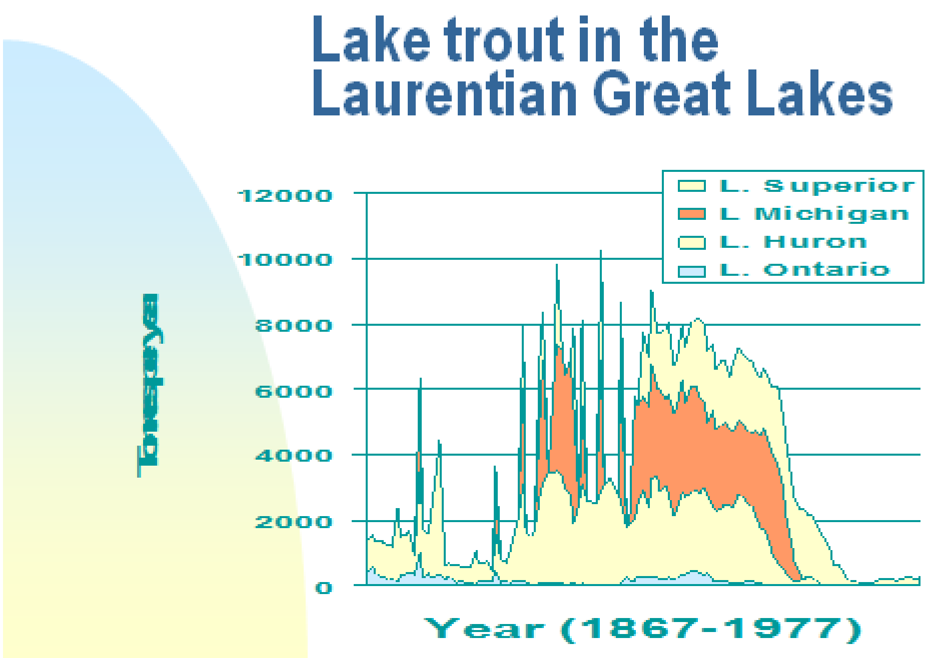
Subsistence Harvest (NWMB harvest study 1996-98).

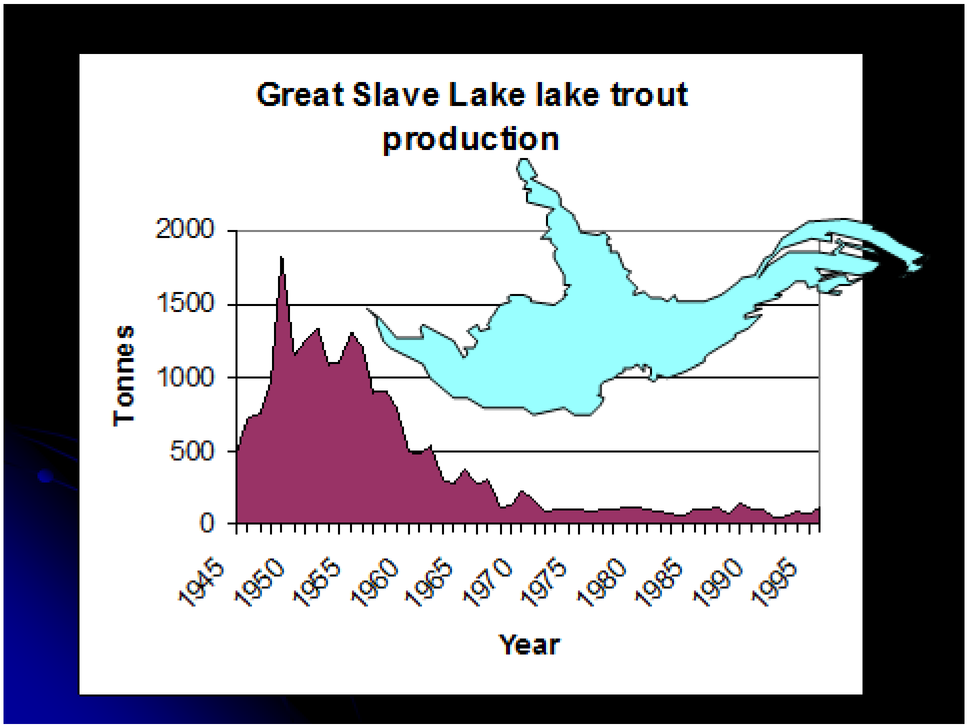


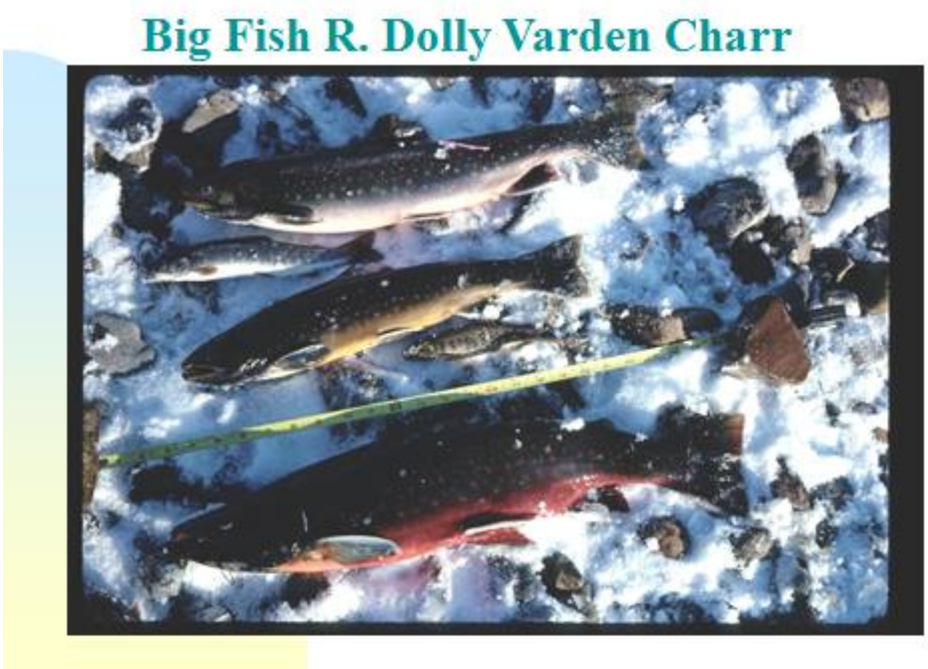

Potential Future Exploratory Fisheries
Pangnirtung – continued
• GN Coastal Resource Inventory 2013
Pond Inlet
Iglulik
Coral Harbour
ISSUE:
What is the format/process to determine initial quota?
• If historical data for stock(s) are available
• If no data is available

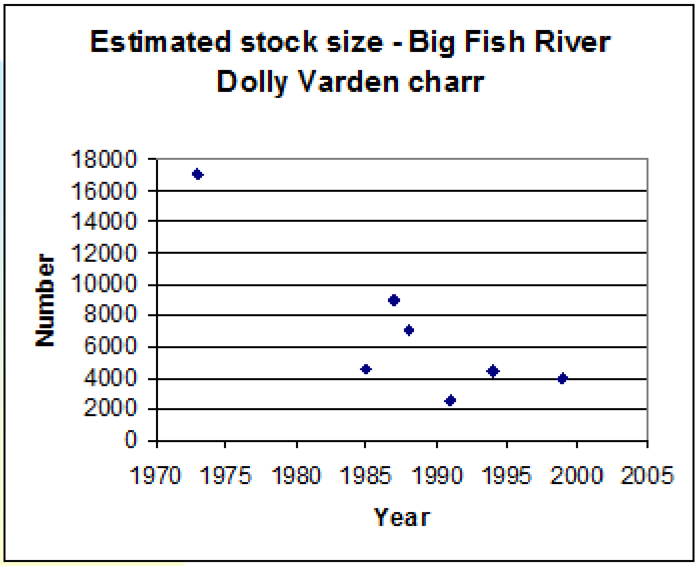

Difficulties - research and management
• lot of stocks (200), Very diverse phenotypically
• Diverse in migratory patterns
• Internationally high level of expectation on Science
• Nightmares


Lake trout variants
Northern Great Lakes
Great Slave Lake
Leans and Siscowets

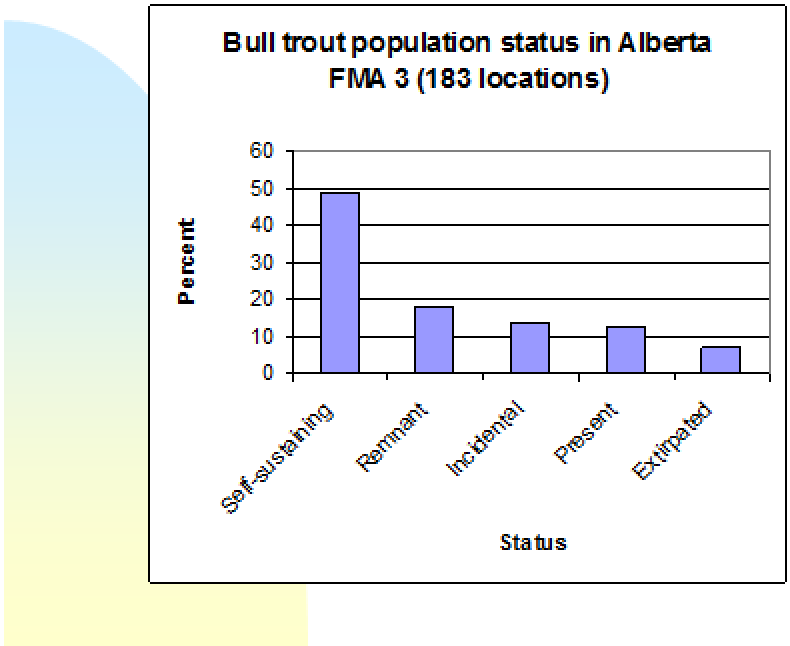

Lake trout in the
Laurentian Great Lakes
L. Superior
L Michigan
L. Huron
L. Ontario
12000
10000
8000
6000
4000
2000
0
Year (1867-1977)


Great Slave Lake lake trout production
2000
1500
1000
500
0
Tonnes
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year


Big Fish R. Dolly Varden Charr


Estimated stock size - Big Fish River
Dolly Varden charr
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Number
1970 1975 1980 1985 1990 1995 2000 2005
Year


Bull Trout


Bull trout population status in Alberta FMA 3 (183 locations)
Percent
60
50
40
30
20
10
0
Self-sustaining
Remnant
Incidental
Present
Extirpated
Status


Arctic Charr Monitoring and Research Programs
Ross Tallman
Section Head Arctic Stock Assessment and Integrated Ecosystem Research, DFO
1

# Research Plans for 2014-15 Arctic Charr in Nunavut

- Exploratory Fisheries
- Cumberland Sound commercial
- Cambridge Bay Commercial
- Kivalliq Commercial

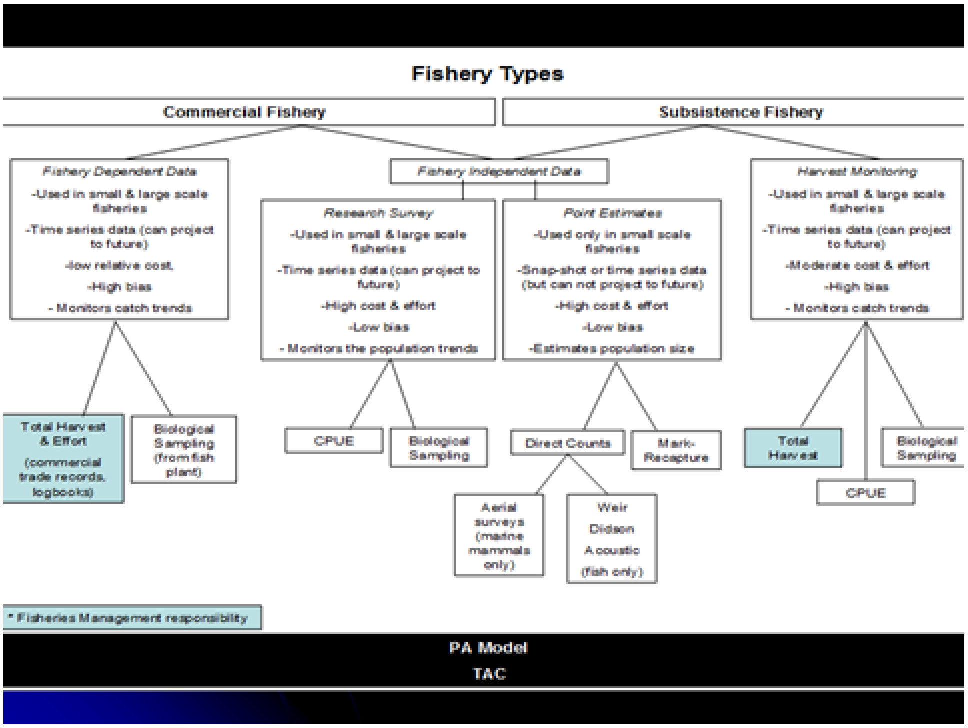
- 2 protocols

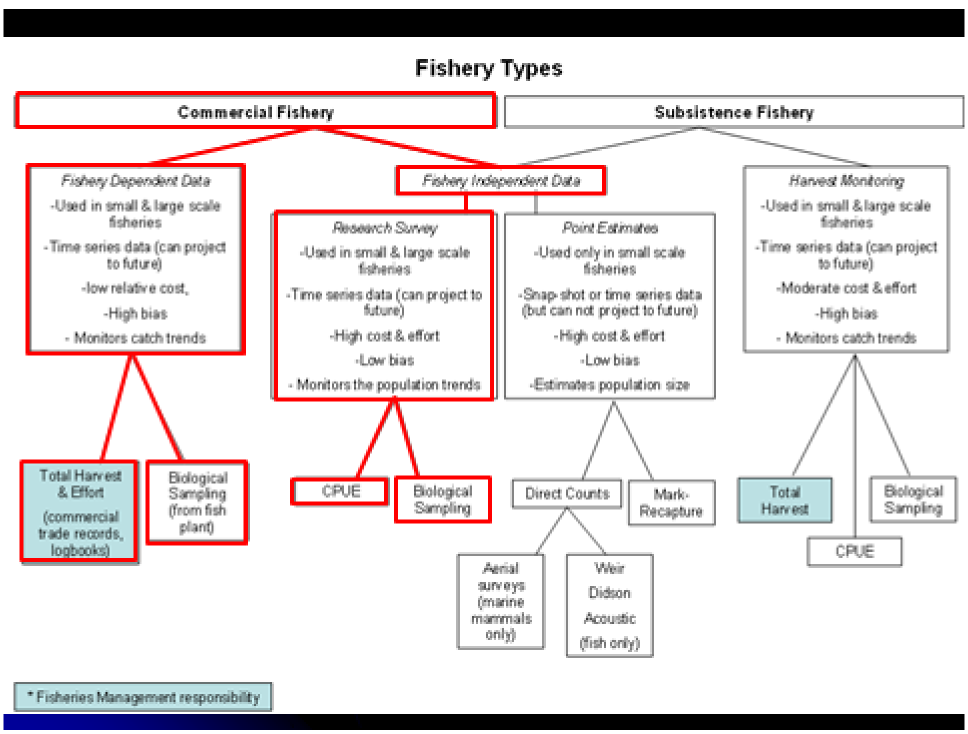
- What about the rest (up to 195 stocks on record)

CUMBERLAND SOUND

## Multi-Year Science Research Plan for Cumberland Sound Exploratory Arctic Char

| *Lake Name* | *Water-body code* | *Season Sampled* | *Years Sampled* | *Years to be sampled* | *Assessment Year (RAP)* |
|---|---|---|---|---|---|
| Iqaluit Lake | PG001 | Winter | 2000/2001/ 2005/2011 | 2012 - 2013 | 2014 |
| Naulinarvik | PG008 | Winter | 2002/2007/ 2010 | 2013 - 2014 | 2015 |
| Anaktuajuit | PG010 | Winter | 2002 | 2014 - 2017 | 2017 |
| Millut Bay | PG081 | Summer? | 2008? | 2013 - 2017 | 2018 |
| Arvituajuk | PG013 | ? | | 2014 - 2018 | 2019 |
| Kanayuktuk/ Ikpit | PG041 | Summer | 2003 | 2013 - 2017 | 2018 |
| Qasigialimiq Lake | PG068 | Summer? | | 2015 - 2019 | 2020 |
| Tagioyuk Lake | PG055 | ? | | 2015 - 2019 | 2020 |


Fishery Types
Commercial Fishery
Subsistence Fishery
Fishery Dependent Data
-Used in small & large scale fisheries
-Time series data (can project to future)
-low relative cost
-High bias
- Monitors catch trends
Fishery Independent Data
Research Survey
-Used in small & large scale fisheries
-Time series data (can project to future)
-High cost & effort
-Low bias
- Monitors the population trends
Point Estimates
-Used only in small scale fisheries
-Snap-shot or time series data (but can not project to future)
-High cost & effort
-Low bias
-Estimates population size
Harvest Monitoring
-Used in small & large scale fisheries
-Time series data (can project to future)
-Moderate cost & effort
-High bias
- Monitors catch trends
Total Harvest & Effort
(commercial trade records, logbooks)
Biological Sampling (from fish plant)
CPUE
Biological Sampling
Direct Counts
Mark-Recapture
Total Harvest
Biological Sampling
CPUE
Aerial surveys (marine mammals only)
Weir
Didson
Acoustic
(fish only)
* Fisheries Management responsibility
PA Model
TAC


Fishery Types
Commercial Fishery
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Direct Counts
Mark-Recapture
Total Harvest
Biological Sampling
CPUE
Aerial surveys (marine mammals only)
Weir
Didson
Acoustic
(fish only)
* Fisheries Management responsibility

# CUMBERLAND SOUND

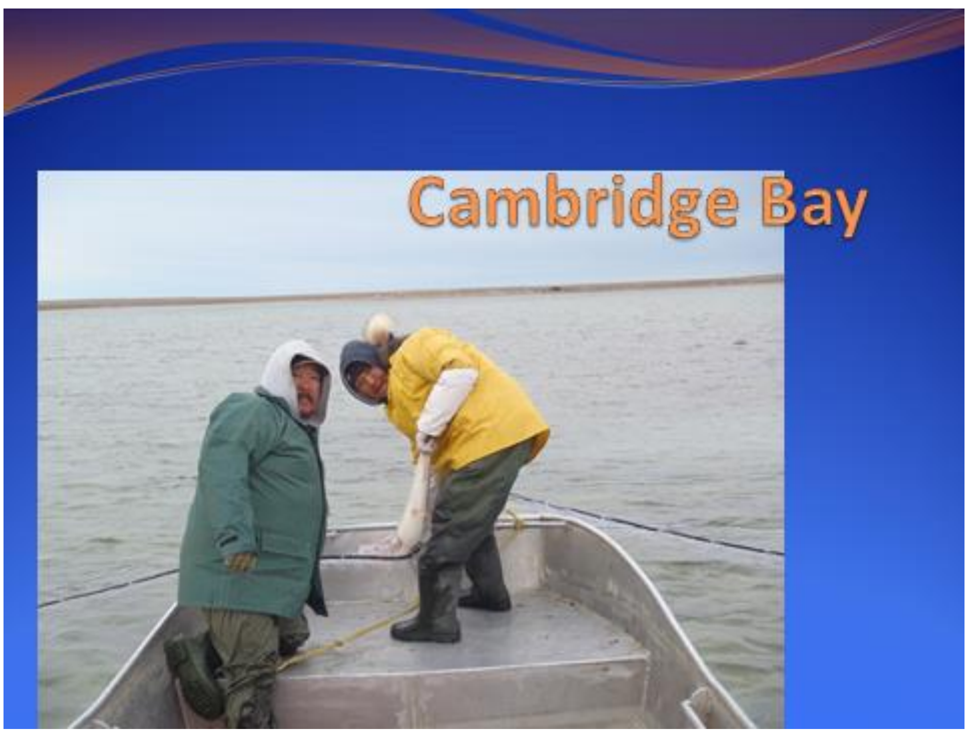
## Science Achievements

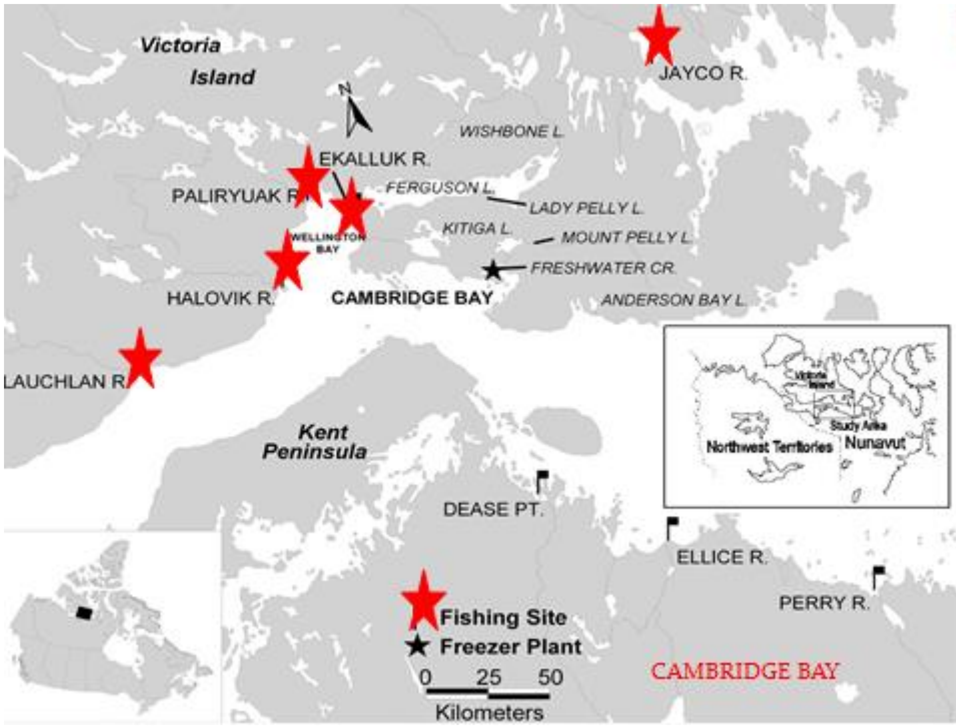
*Fishery-independent sampling:

| Study Year | PG003 | PG018 | PG027 |
|---|---|---|---|
| 2010 | Ijaruvung Lake | Irvine Inlet ✓ | Iqalujjuaq Fiord ✓ |
| 2011 | ✓ | ✓ | ✓ |
| 2012 | ✓ | ✓ | ✓ |
| 2013 | now | August | now |
| 2014 | March | August | March |
| 2015 | March | | |

*Data can be used to monitor relative abundance (CPUE) and biological indicators for changes in the <u>whole</u> stock.

*Possibly use VPA to estimate abundance.

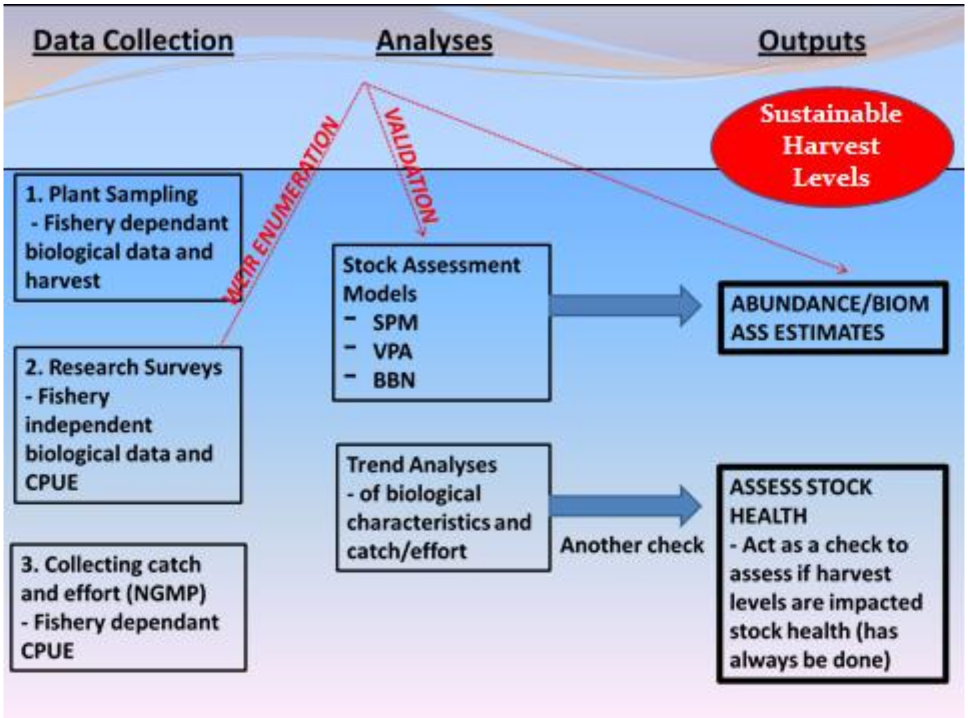


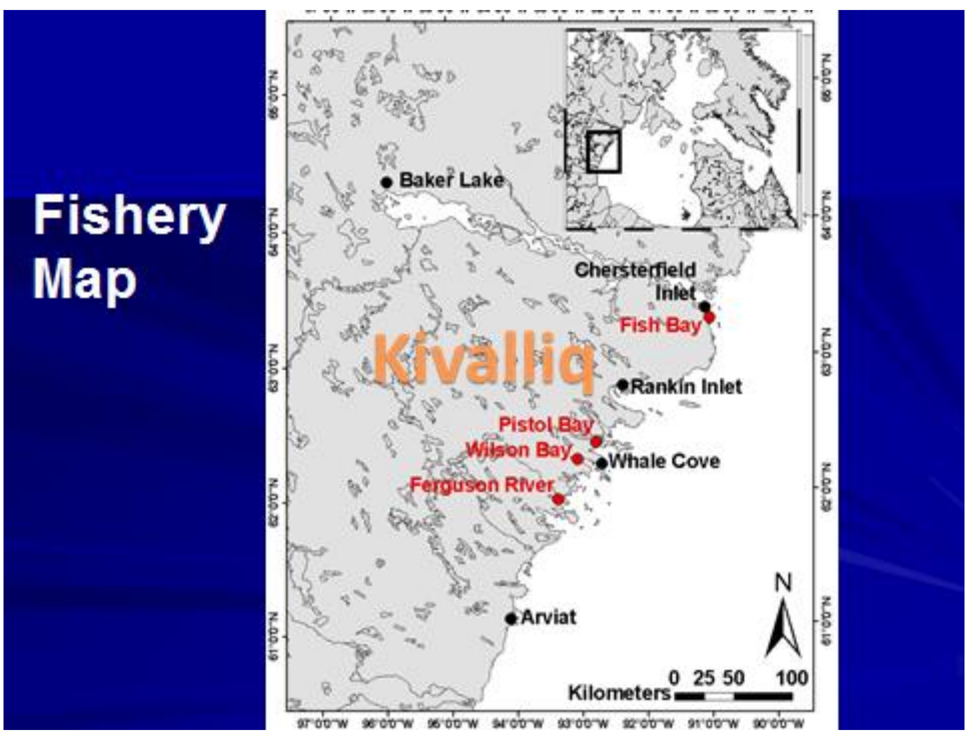


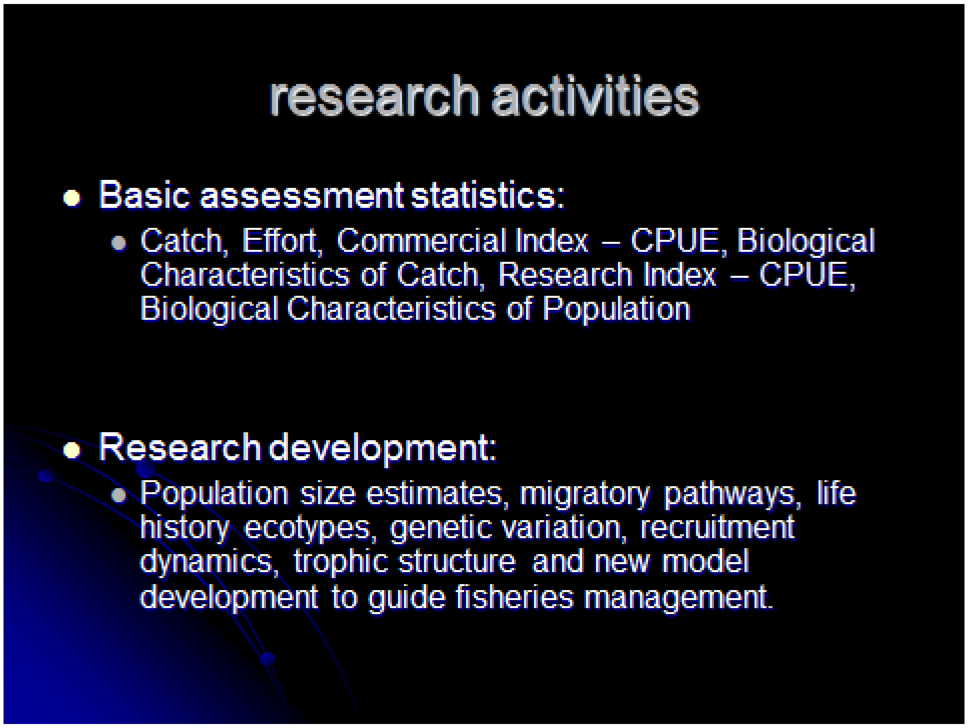

# Science Action Plan - Year 2 (2014)

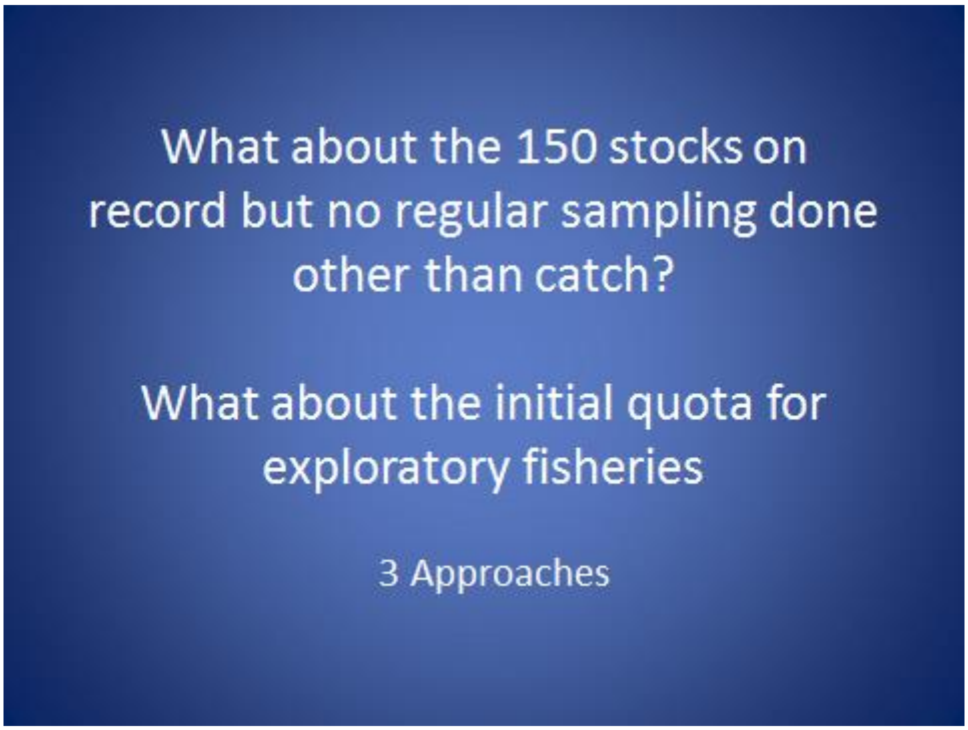
## 1. Continue the plant sampling program

- Facilitates the collection of fishery independent data
- Has allowed for establishment of a long-term time series of biological data
- Inexpensive ("best bang for the buck")
- Has been the backbone of assessment for Cambridge Bay


Data Collection
Analyses
Outputs
WEIR ENUMERATION
VALIDATION
Sustainable Harvest Levels
1. Plant Sampling - Fishery dependant biological data and harvest
2. Research Surveys - Fishery independent biological data and CPUE
3. Collecting catch and effort (NGMP) - Fishery dependant CPUE
Stock Assessment Models - SPM - VPA - BBN
Trend Analyses - of biological characteristics and catch/effort
ABUNDANCE/BIOMASS ESTIMATES
Another check
ASSESS STOCK HEALTH - Act as a check to assess if harvest levels are impacted stock health (has always be done)


Fishery Map
Baker Lake
Chersterfield Inlet
Fish Bay
Kivalliq
Rankin Inlet
Pistol Bay
Wilson Bay
Whale Cove
Ferguson River
Arviat
N
Kilometers
0 25 50 100


research activities
Basic assessment statistics:
Catch, Effort, Commercial Index – CPUE, Biological Characteristics of Catch, Research Index – CPUE, Biological Characteristics of Population
Research development:
Population size estimates, migratory pathways, life history ecotypes, genetic variation, recruitment dynamics, trophic structure and new model development to guide fisheries management.


What about the 150 stocks on record but no regular sampling done other than catch?
What about the initial quota for exploratory fisheries
3 Approaches

## Data Poor Methods

- Catch Based methods (eg. Depletion Corrected Average Catch)
- Landscape Assessments
- Experimental Harvesting (to estimate MSY)

## 6 Methods for Cambridge Bay Arctic charr

- Cadima's Method (FAO)
- Hierarchical Bayesian Approach
- Depletion Corrected Average Catch
- Long-term average catch
- Pope's (1973) Method
- Status Quo TAC

## Data limited assessment of selected North American anadromous charr stocks.

Ross F. Tallman[1], , Xinhua Zhu[1], Yamin Janjua[1], Les Harris[1], Colin Gallagher[1] Marie-Julie Roux[2], Kimberly L. Howland[1] & Melanie Toyne[1]

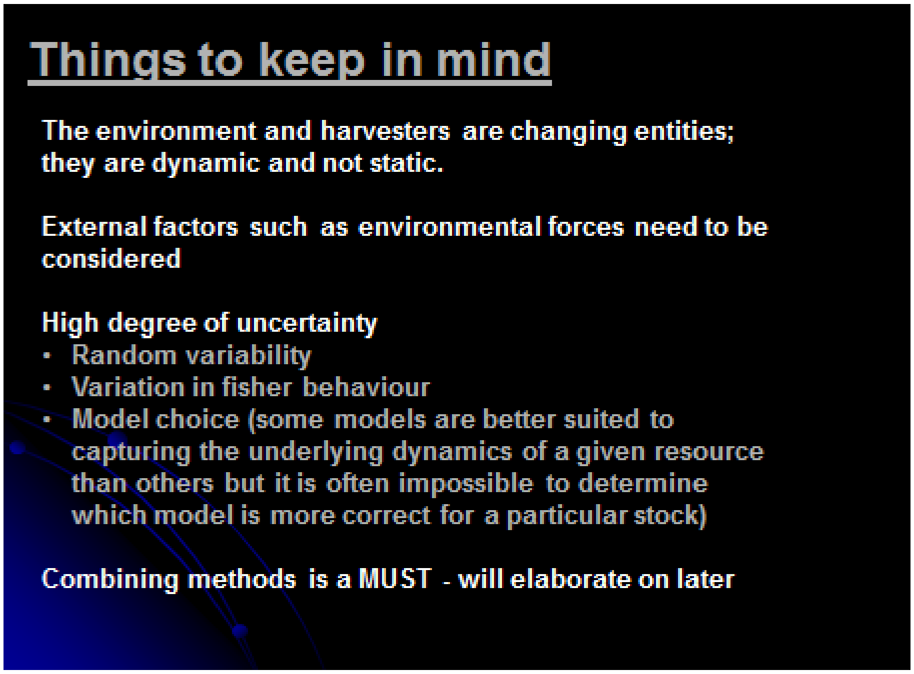
Journal of Ichthyology 2013

## Landscape Assessment

- Consider available limiting habitat (freshwater and/or marine habitat )
- Develop relationship between landscape features and stock size/production
- Calculate total allowable harvest

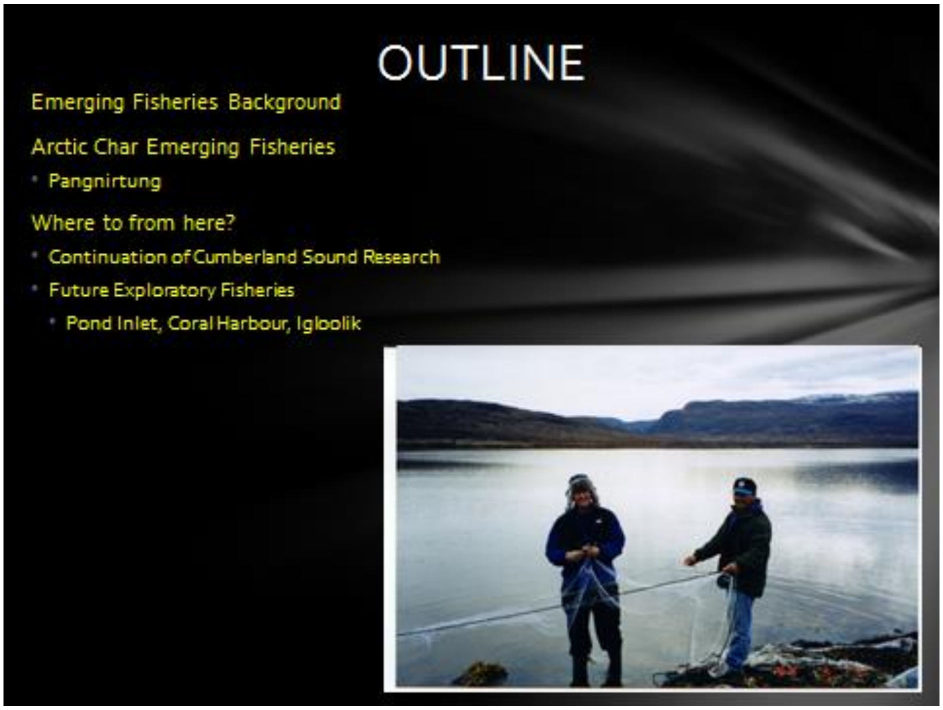
## Estimating maximums and minimums

- Difficult to determine MSY and reference points because fisheries are managed so well for conservation that there is no contrast in the data.
- Tallman's Rule – 5% harvest rate applied in most cases as a precautionary approach.
- Propose a controlled harvesting experiment – harvest a number of stocks to determine if a higher harvest rate could be used to approximate MSY.


Things to keep in mind
The environment and harvesters are changing entities; they are dynamic and not static.
External factors such as environmental forces need to be considered
High degree of uncertainty
• Random variability
• Variation in fisher behaviour
• Model choice (some models are better suited to capturing the underlying dynamics of a given resource than others but it is often impossible to determine which model is more correct for a particular stock)
Combining methods is a MUST - will elaborate on later


Take Home
• The domestic (territorial) market currently exceeds the production.
• Markets for pristine wild char – as produced in Nunavut – will continue.
• Arctic char may be a candidate for eco-certification, which would open up specialty markets (Used as MSC test example).
• The success of these enterprises will depend on sound scientific stock assessment of char resources
• Must have multi-year studies of stock dynamics and ecosystem interactions
27

**PRESENTATION 2:**
**EXPLORATORY/ EMERGING FISHERIES (CUMBERLAND SOUND)**
**by Zoya Martin**


Sampling
4 pillars –
1) Fishery Dependent
Catch and Effort
Demographics of the Catch (Plant Sampling)
2) Fishery Independent
Catch and Effort
Population Demographics eg. age and size structure


Emerging Fisheries Background
Developed in 1996
Revised in 2008
"A cornerstone of the new policy is provision for the establishment of a scientific base with which stock responses to new fishing pressures can be assessed"
"The objective is to diversify fisheries and increase economic returns while ensuring conservation of the stocks and realizing the sustainable use of fisheries resources."

## Emerging Fisheries Background

Developed in 1996

Revised in 2008

"A cornerstone of the new policy is provision for the establishment of a scientific base with which stock responses to new fishing pressures can be assessed"

"The objective is to diversify fisheries and increase economic returns while ensuring conservation of the stocks and realizing the sustainable use of fisheries resources."

## Emerging Fisheries Background

"In undertaking new fisheries, DFO will work with appropriate Boards or other bodies established under Land Claims Agreements."

- Nunavut Land Claim Agreement (NLCA), Aboriginal Land Claims in NWT.

"DFO has a policy of promoting increased Aboriginal participation in the management of fisheries, especially through co-management agreements, as well as providing economic development opportunities in existing and new fisheries."

## For Example: Arctic charr assessment problem in the Canadian Territories

Geography

# Arctic charr assessment problem in the Canadian Territories

Geography

No infra-structure – collection of data logistically difficult

# Research History Cumberland Sound

1997 Gary Weber – NIF - Someone to work in Pangnirtung

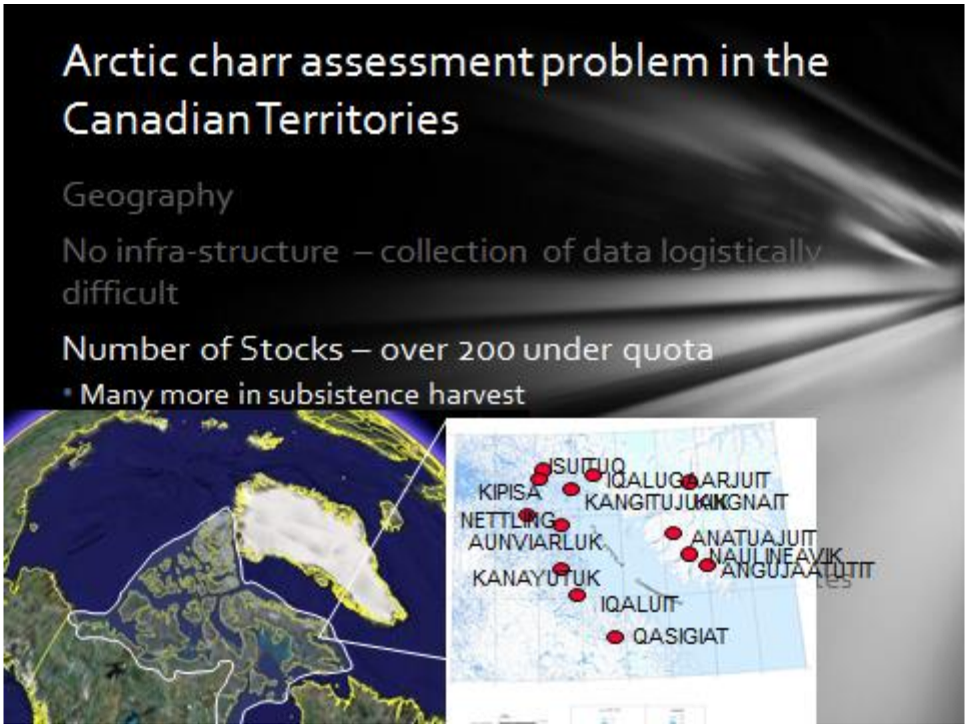
Research project was to treat Cumberland Sound as a microcosm of the general problem of developing a model for all charr stocks in Nunavut under quota (NIF support then NWMB)

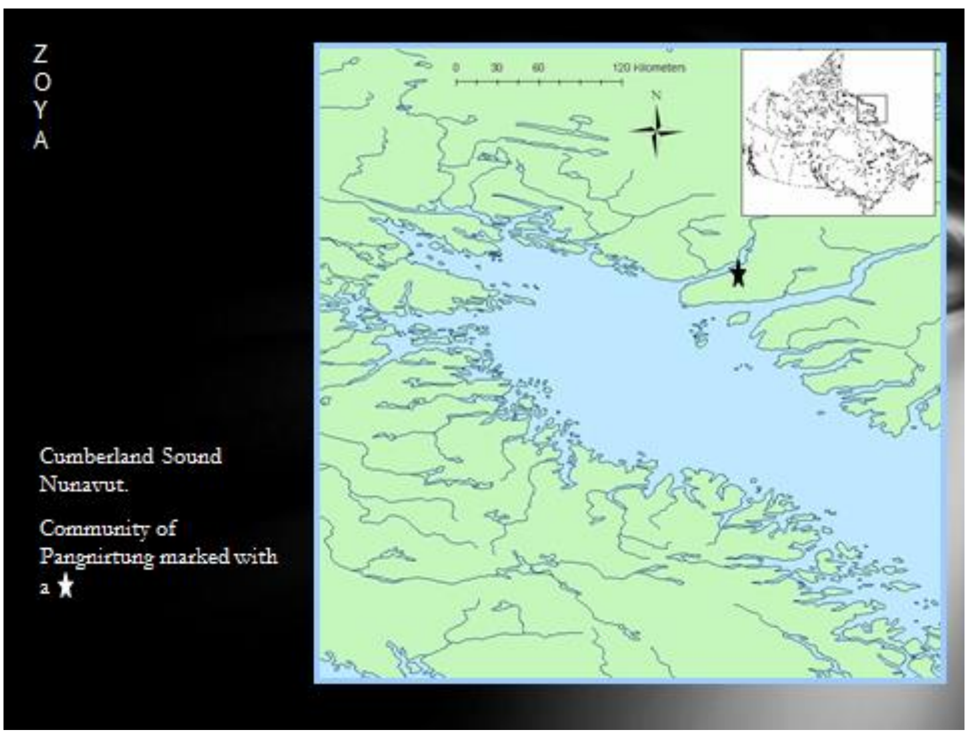
1999-2000 Leesee Papatsie NIF Want project to be relevant to the desires of the community of Pangnirtung

Research was to help Pangnirtung Exploratory Stocks be moved to commercial status (NIF and NWMB support)

2004- Investment by GN greatly increased capacity (Tracey Loewen, Melanie Toyne and so on)

2007-2008 GN push for infrastructure development results in DFO SCH to propose 7 ports – awarded 1 in Pangnirtung (only) - Emerging fisheries resources from Ottawa to support increased fishing (expansion of existing commercial licences and exploratory licences – changing fishing patterns in Cumberland Sound due to harbour development


Arctic charr assessment problem in the Canadian Territories
Geography
No infra-structure – collection of data logistically difficult
Number of Stocks – over 200 under quota
Many more in subsistence harvest
KIPISA
AUNVIARLUK
KANAYUTUK
IQALUIT
QASIGIAT
ANATUAJUIT


0 30 60 120 Kilometers
N
Cumberland Sound Nunavut.
Community of Pangnirtung marked with a ★

# PANGNIRTUNG

*47* exploratory Arctic Char stocks

- Many of these stocks have been stuck in the exploratory stages for 20+ years

2012 – 16 exploratory licences issued

Science has completed 5 Stock Assessments (RAP): *Kingnait, Kipisa, Isuituq, Qasigiyat and Emerging Fisheries Exploratory Protocol*

Science plan 8 more Stock Assessment (RAP) requests by 2020 (CSAS request) – sustainable harvest level

**Multi-Year Science Research Plan for Cumberland Sound Exploratory Arctic Char**

| *Lake Name* | *Water-body code* | *Season Sampled* | *Years Sampled* | *Years to be sampled* | *Assessment Year (RAP)* |
|---|---|---|---|---|---|
| | PG001 | Winter | 2000/2001/ 2005/2011 | 2012 - 2013 | 2014 |
| Naulinarvik | PG008 | Winter | 2002/2007/ 2010 | 2013 - 2014 | 2015 |
| Anaktuajuit | PG010 | Winter | 2002 | 2014 - 2017 | 2017 |
| Millut Bay | PG081 | Summer? | 2008? | 2013 - 2017 | 2018 |
| Arvituajuk | PG013 | ? | | 2014 - 2018 | 2019 |
| Kanayuktuk/ Ikpit | PG041 | Summer | 2003 | 2013 - 2017 | 2018 |
| Qasigialimiq Lake | PG068 | Summer? | | 2015 - 2019 | 2020 |
| Tagioyuk Lake | PG055 | ? | | 2015 - 2019 | Iqaluit Lake |

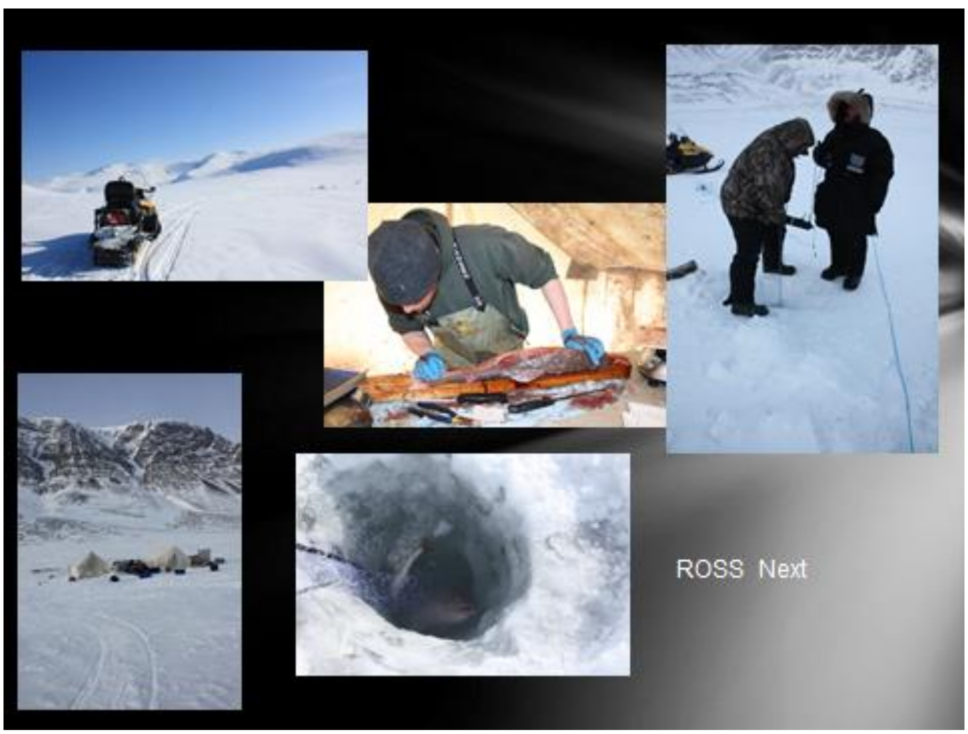
## Meetings with Pangnirtung HTA

There are at least 2 DFO – HTA meeting annually

- December
- May
- Updates, including post-field season reports

Community Open Houses have been planned and will continue to be planned

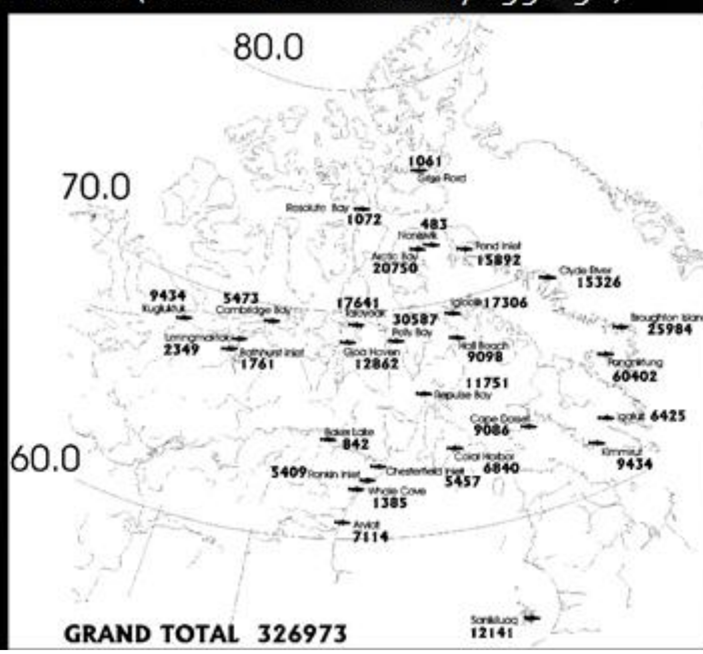
DFO Science attends and presents summary at Pangnirtung HTA AGM



# Total Weight Exploratory Fisheries = approx. 382,942 lbs /year

# $3.3million

Subsistence Harvest (NWMB harvest study 1996-98).



## Potential Future Exploratory Fisheries

Pangnirtung – continued

- GN Coastal Resource Inventory 2013

Pond Inlet

Iglulik

Coral Harbour

*ISSUE:*

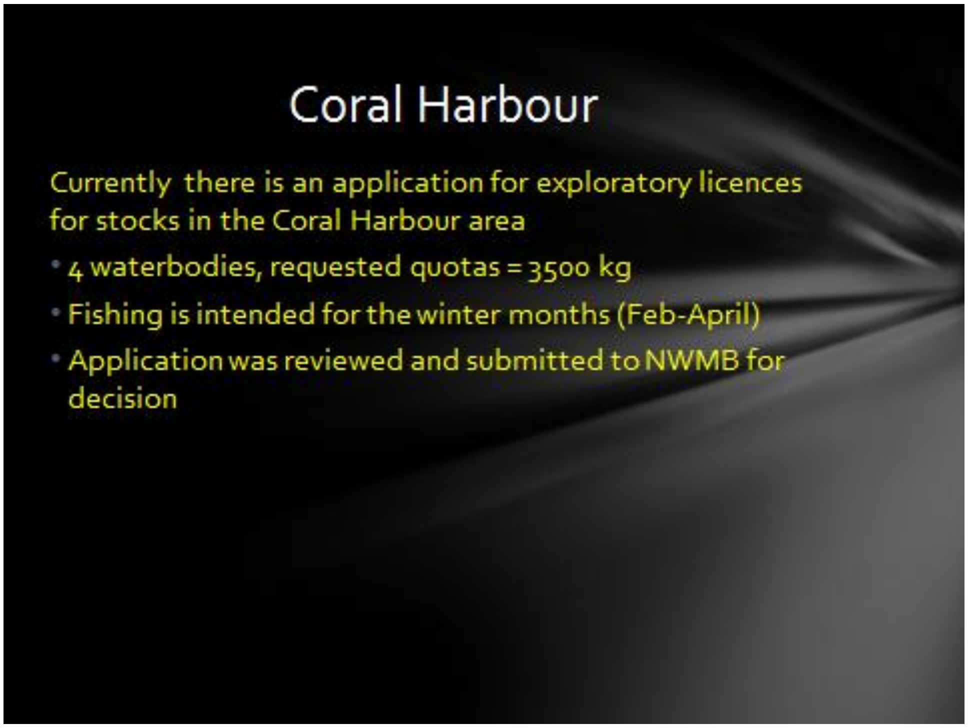
What is the format/process to determine initial quota?

- If historical data for stock(s) are available
- If no data is avaliable

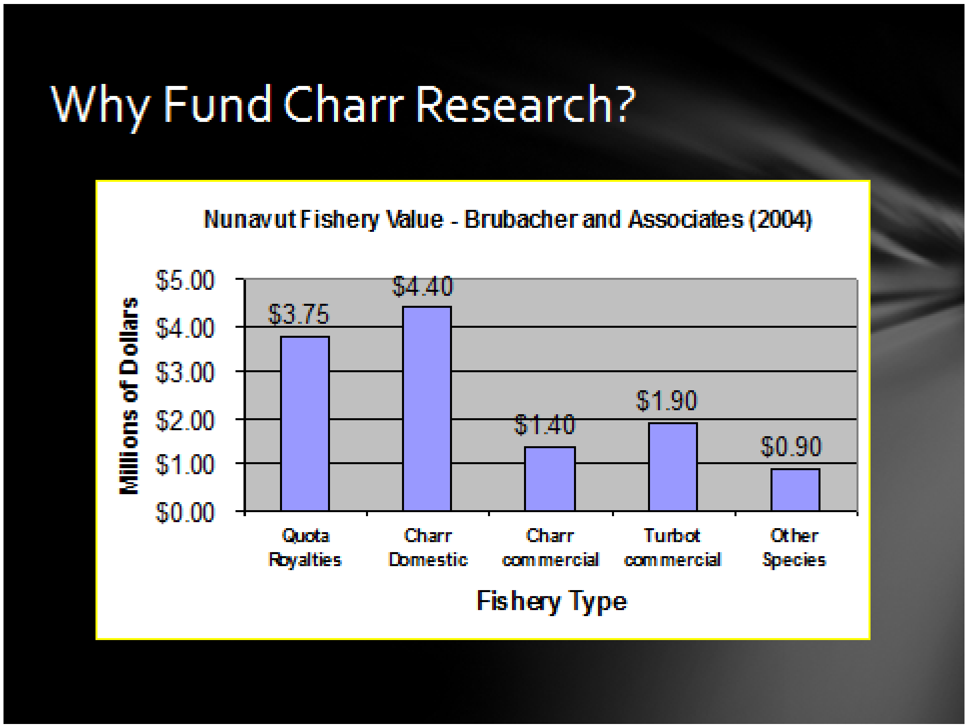
## Pond Inlet

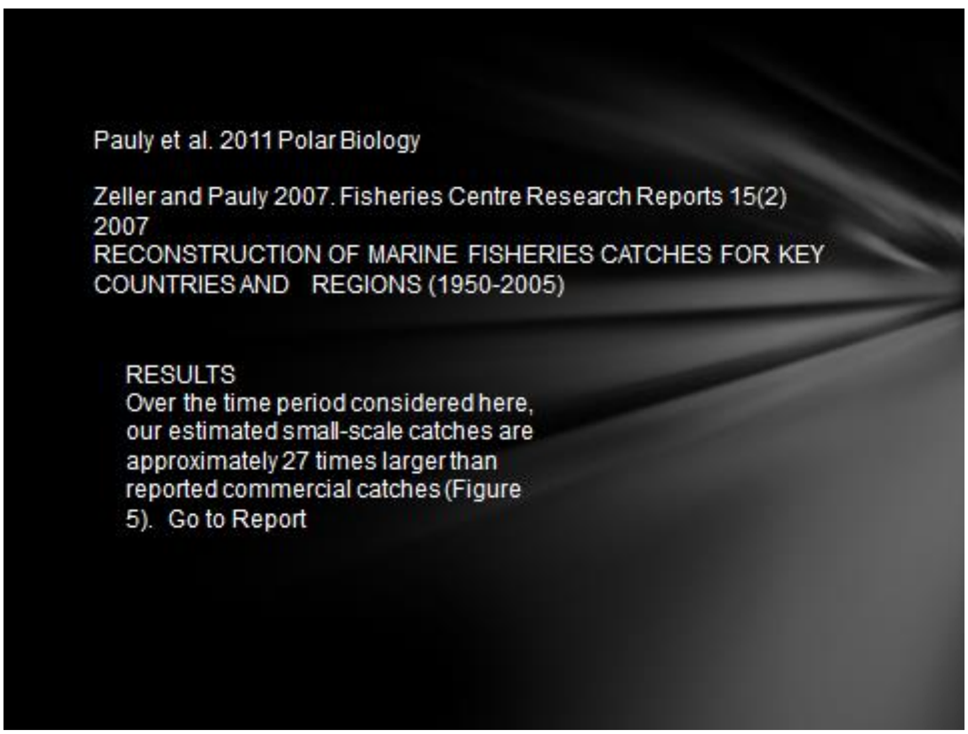
Currently there is an application for exploratory licences for stocks in the Pond Inlet area

- 17 waterbodies, requested quotas = 46,750 kg
- Fishing intended for August/September
- Application is currently under review

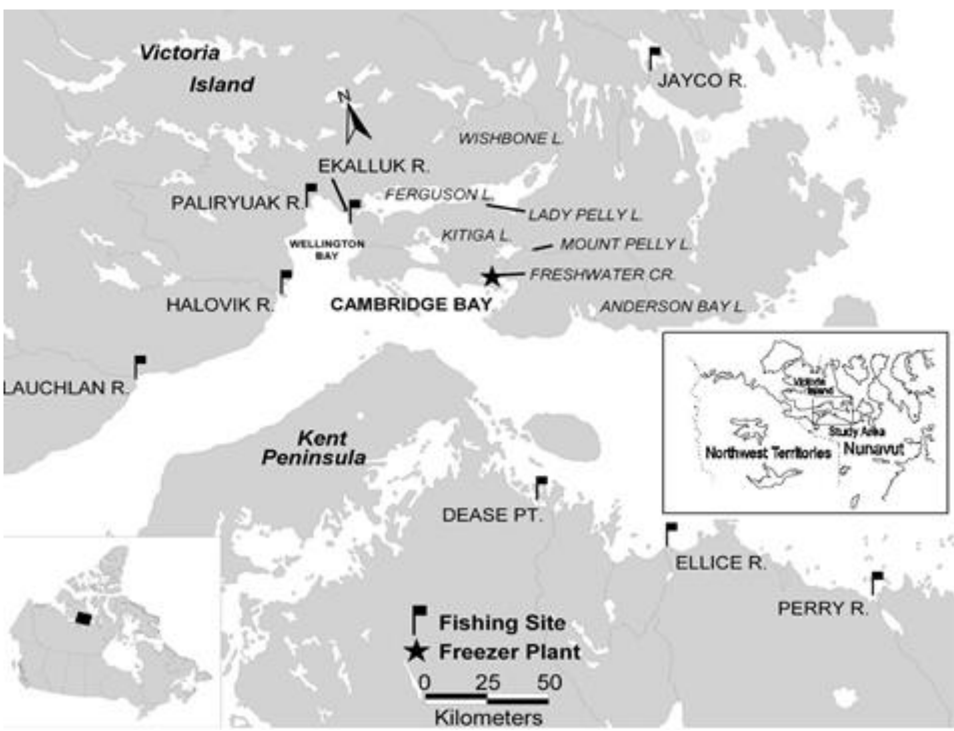

Coral Harbour
Currently there is an application for exploratory licences for stocks in the Coral Harbour area
4 waterbodies, requested quotas = 3500 kg
Fishing is intended for the winter months (Feb-April)
Application was reviewed and submitted to NWMB for decision


Iglulik
Currently there is an application for exploratory licences for stocks in the Iglulik area
1 waterbody, requested quota =1000 kg
Fishing is intended for the winter months (February – April)
Application is currently under reviewed


Why Fund Charr Research?
Nunavut Fishery Value - Brubacher and Associates (2004)
Millions of Dollars
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
$3.75
$4.40
$1.40
$1.90
$0.90
Quota Royalties
Charr Domestic
Charr commercial
Turbot commercial
Other Species
Fishery Type


Pauly et al. 2011 Polar Biology
Zeller and Pauly 2007. Fisheries Centre Research Reports 15(2) 2007
RECONSTRUCTION OF MARINE FISHERIES CATCHES FOR KEY COUNTRIES AND REGIONS (1950-2005)
RESULTS
Over the time period considered here, our estimated small-scale catches are approximately 27 times larger than reported commercial catches (Figure 5). Go to Report

**PRESENTATION 3:**
**THE COMMERCIAL FISHERY FOR ARCTIC CHAR IN CAMBRIDGE BAY REGION**
By Les Harris

## Background: Cambridge Bay Fisheries

**Initiated at Freshwater Creek (1960)**

**Relocated to Ekalluk River (1962)**

**Extended to other water bodies:**

- Paliryuak (Surrey) River - 1968
- Halokvik River (30 Mile) - 1968
- Lauchlan River (Byron Bay) - 1970
- Jayko River - 1975
- Ellice River - 1971
- Perry River - 1977

Victoria Island (Paliryuak, Halokvik, Lauchlan, Jayko)

Mainland (Ellice, Perry)

**Other location were explored**

- Dease Point, Padliak Inlet, Elu Inlet, Starvation Cove and HTA Lake

## Quotas

**Initially an "area" quota for Wellington Bay - 45,400 kg (1962)**

**"River-specific" quotas were established in 1973**

**Presently 4 waterbodies are fished with gillnets or conduit weir**

**Quotas variable among and within waterbodies**

- Ekalluk River: 7500 - 20,000 kg (20,000 kg)
- Paliryuak River: 4500 - 9100 kg (9100 kg)
- Halovik River: 4500 - 9100 kg (5000 kg)
- Jayco River: 6800 - 17,000 kg (17,000 kg)

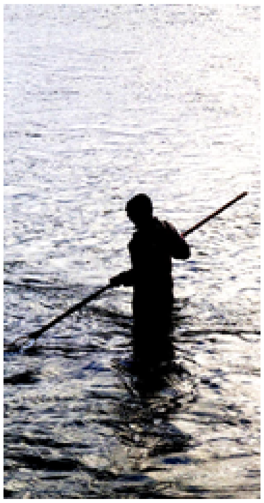
## Harvest

**Harvest has been quite variable**

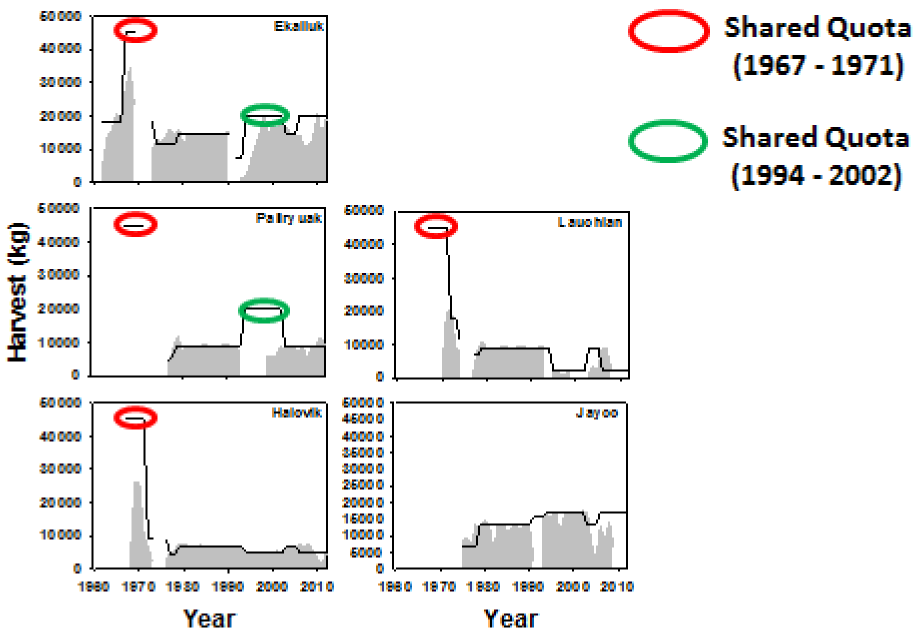
- Ekalluk River: 1480 – 33,400 kg
- Paliryuak River: 3260 – 11,816 kg
- Halokvik River: 1124 – 26,203 kg
- Lauchlan River: 0 – 20,994 kg
- Jayko River: 2226 – 17,312 kg

**Due to a variety of reasons**

- No fishing - economically not feasible
- Fishing closures
- Quota modifications
- Timing (missed runs)
- Concerns over parasites
- Camp issues/concerns



## Quota and Harvest Since 1960



# Fishery-dependant data collection

**Cambridge Bay plant sampling program**

- Facilitates the collection of fishery dependent data
- Collected form most systems starting in the early 1970's
- Has allowed for establishment of a long-term time series of biological data
- Inexpensive ("best bang for the buck")
- Has been the backbone of assessment for Cambridge Bay

# Fishery-independent data collection

**DFO research/stock assessment surveys**

- Collection of biological data independent of the fishery
- Expensive, but not biased
- Can collect additional information (sex, maturity, gonad weight, fecundity, etc.)
- Collected five consecutive years per waterbody
- Also includes additional work to understand population demographics, abundance and biology

# Fishery-independent

**Weir enumerations**

- Ekalluk River: 1979 (183,203)
- Paliryuak River: no count
- Halokvik River: 1981 (21,214)
- Lauchlan River: 1983 (10,850) - ????
- Jayko River: 1981 (138,795)

# Limited CPUE Data

**The NGMP**

**Log-book system for collecting CPUE**

**Year three of data collection**

**Extended to recreational and subsistence fisheries in 2012**

**The Nunavut General Monitoring Plan (NGMP) for Cambridge Bay Arctic Char: 2013 Update**

BACKGROUND

- Arctic char in the Cambridge Bay region have been commercially fished since the 1960's.
- There is currently very little information on catch-per-unit-effort (CPUE) for these fisheries.
- This metric is the number of fish captured in a given period of time and can provide an indicator for the number of fish in a river when population sizes are unknown.
- This NGMP for Cambridge Bay aims at collecting CPUE information for commercial, recreational and subsistence Arctic Char fisheries.
- This project is led by the Ekaluktutiak HTO with participation from community based monitors, Kitikmeot Foods, commercial fishers and Fisheries and Oceans Canada.

2013 Update

- There were 41 days of monitoring conducted by 5 monitors at 4 commercial fisheries (Halokvik, Surrey, Ekalluk and Jayko rivers).
- 4082 char were commercially harvested by weir.
- Catch from weir fisheries ranged from 26 to 573 char when the weir was emptied and averaged 549 char per 24 hours of fishing.
- 7288 char were commercially harvested by gill net.
- Catch from the gillnet fisheries ranged from 0 to 145 char per net and average 50 fish per 24 hours of fishing.
- In total 11650 char were harvested in the 2013 commercial fishery.

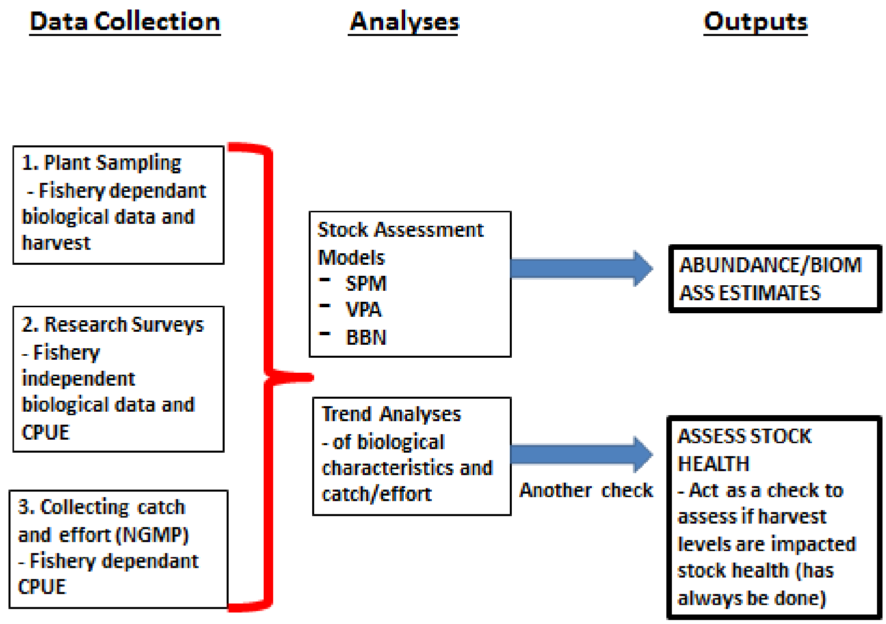
2014 Work

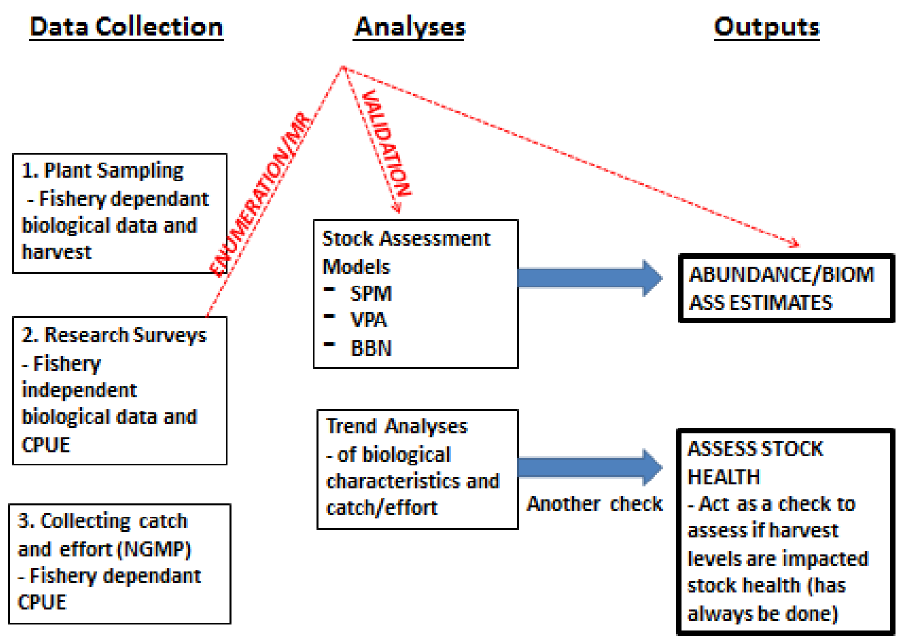
- Community-based monitors will again be hired to record CPUE information and environmental data from each commercially fished waterbody.
- Work will be extended to also include the monitoring of recreational catch and effort at Freshwater Creek.
- Work will also be extended to monitor harvest at Gravel Pit.
- Community presentations will be given in the fall after the commercial harvest is completed.

Acknowledgements

This program was made possibly by the community based monitors and commercial fishers who facilitated the collection of catch and effort data.

Questions


Data Collection
Analyses
Outputs
1. Plant Sampling
- Fishery dependant biological data and harvest
2. Research Surveys
- Fishery independent biological data and CPUE
3. Collecting catch and effort (NGMP)
- Fishery dependant CPUE
Stock Assessment Models
- SPM
- VPA
- BBN
Trend Analyses
- of biological characteristics and catch/effort
ABUNDANCE/BIOMASS ESTIMATES
Another check
ASSESS STOCK HEALTH
- Act as a check to assess if harvest levels are impacted stock health (has always be done)


Data Collection
Analyses
Outputs
ENUMERATION/MR
VALIDATION
1. Plant Sampling
- Fishery dependant biological data and harvest
2. Research Surveys
- Fishery independent biological data and CPUE
3. Collecting catch and effort (NGMP)
- Fishery dependant CPUE
Stock Assessment Models
- SPM
- VPA
- BBN
Trend Analyses
- of biological characteristics and catch/effort
ABUNDANCE/BIOMASS ESTIMATES
Another check
ASSESS STOCK HEALTH
- Act as a check to assess if harvest levels are impacted stock health (has always be done)

# Assessments using these data

## Examining Trends in Population Demographics

Day, A.C. and Harris, L.N. 2013. Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960–2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/068. v + 30 p.

DFO (Day and Harris). 2013 Update assessment of the Cambridge Bay Arctic Char Fishery, 1960 to 2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/051.

Day, A.C. and de March, B. 2004. Status of Cambridge Bay Anadromous Arctic Char Stocks. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/052.

DFO (Day). 2004. Cambridge Bay Arctic Char. DFO Can. Sci. Advis. Sec. Stock Status Rep. 2004/010 Island

## General Conclusions

- ALL STOCKS ARE CURRENTLY HEALTHY AND ARE AT A LOW RISK OF OVEREXPLOITATION IF CURRENT HARVEST LEVELS REMAIN THE SAME.
- Based primarily on trends in biological data (e.g., strong modal age classes)

# Assessments using these data

## Quantitative Stock Assessment Modelling

Zhu, Xinhua, Day, A.C., Carmichael, T.J., and Tallman, R.S., *Res. Doc. In CSAS Review*. Temporal variation in a population biomass index for Cambridge Bay Arctic Char, *Salvelinus alpinus* (L.), in relation to large-scale climate changes.

- establish individual- and weight-based catch per unit effort (CPUE) series (biomass index) from DFO-designed experimental sampling programs

Zhu, Xinhua, Day, C.A., Carmichael, T.J., Tallman, R.F., *Res. Doc. In CSAS Review*. Hierarchical Bayesian Modeling for Cambridge Bay Arctic Char, *Salvelinus alpinus* (L.), incorporated with precautionary reference points.

- employing the biomass index to resolve precautionary reference points through hierarchical Bayesian modelling.

## General Conclusions

- Limit Reference Point (LRP) = standing biomass of 208 metric tonnes
- The Upper Stock Point (USP) = standing biomass of 417 metric tonnes
- The Target Reference Point (TRP) = standing biomass of 522 metric tonnes

THESE ARE NOT WATERBODY SPECIFIC – WELLINGTON BAY

# Assessments using these data

## Quantitative Stock Assessment Modelling

### Lauchlan River Special Response

- Request for an increase in quota
- Janjua assessed VBGF parameters, natural mortality, total mortality and fisheries mortality
- Estimated maximum sustainable production

## General Conclusions

- Using biomass estimated from Gulland' equation during (2006-2007) harvest rate of 5% would be of low risk and a recommended removal of 3400kg.
- A rate of 7% would be of low-moderate risk and a recommended removal of 4741kg.
- A rate of 10% would be of moderate-hi risk and a recommended removal of 6706kg.
- The requested removal of 9100kg would be a hi risk option at 13% harvest rate

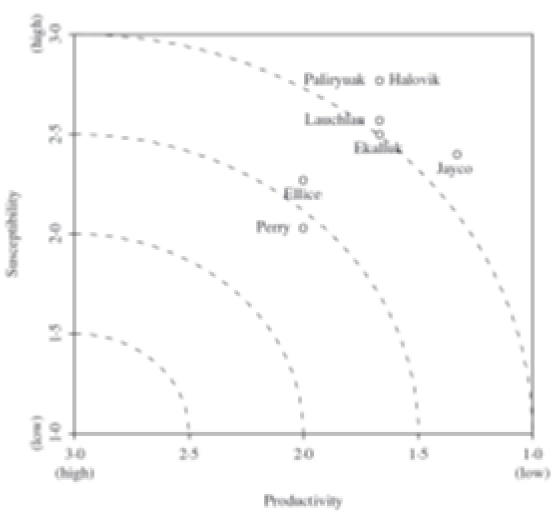
CATCH AND EFFORT INFORMATION IS REQUIRED

# Assessments using these data

## Productivity Susceptibility Analysis (PSA)

### Roux et al. 2011

- This framework combines (1) a risk assessment tool [productivity–susceptibility analysis (PSA)] to evaluate the relative vulnerability of *S. alpinus* stocks to harvest and (2) a conceptual model for quantitative assessment to determine sustainable harvest levels.




## General Conclusions

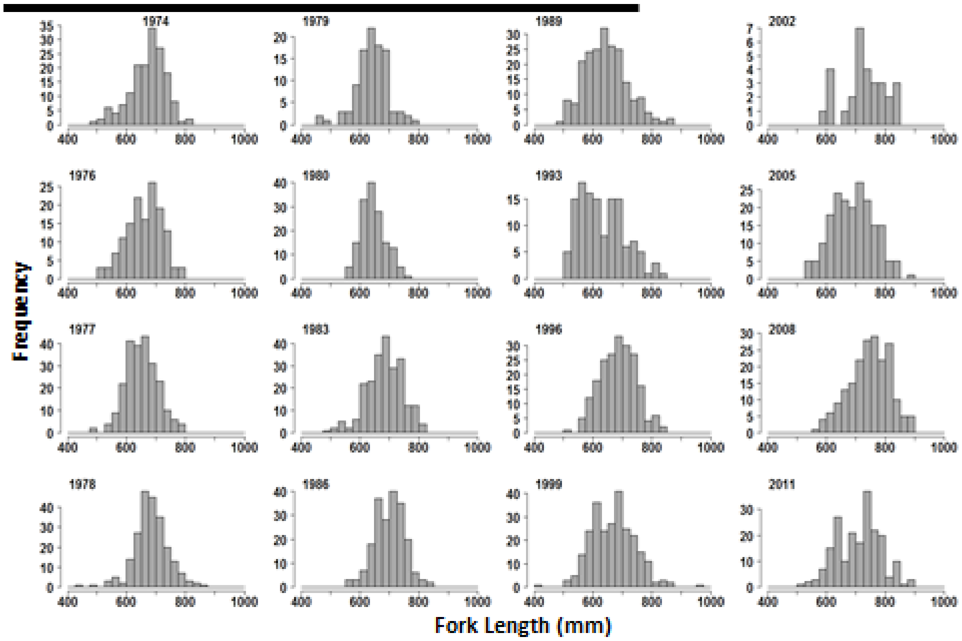
- Looked at 86 stocks
- Cambridge Bay in most detail
- Vulnerability scores ranged from 1.4 (Perry River) to 2.2 (Jayco, Halovik and Paliryuak rivers), with Halovik and Paliryuak showing overlapping scores

# Example - Ekalluk River

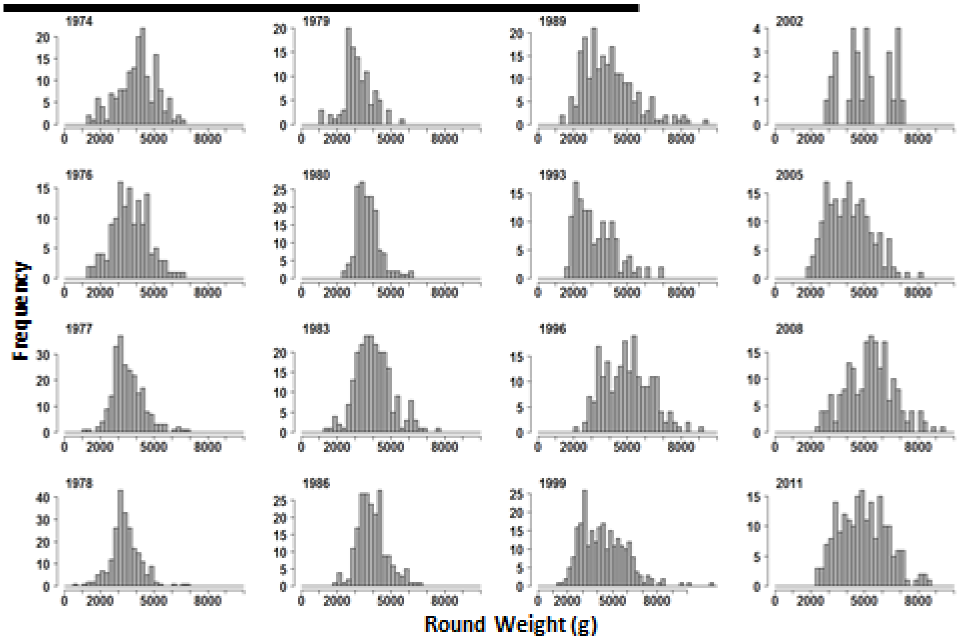
**The Ekalluk River**

- Established in 1962
- In 1967 an area quota (45,000 kg) was issued for the Wellington Bay
- The average weight of Char declined (reported in AFSAC reports) from 3.0 kg in 1967 to 1.4 kg in 1969.
- Consequently, the commercial fishery at Ekalluk River was closed in 1970 and reopened in 1973 – RIVER SPECIFIC QUOTAS ESTABLISHED
- Biological data collection initiated in 1974
- Exploitation rate (crudely calculated) = **4.1% (or 5.2 % based on current quota/harvest)**

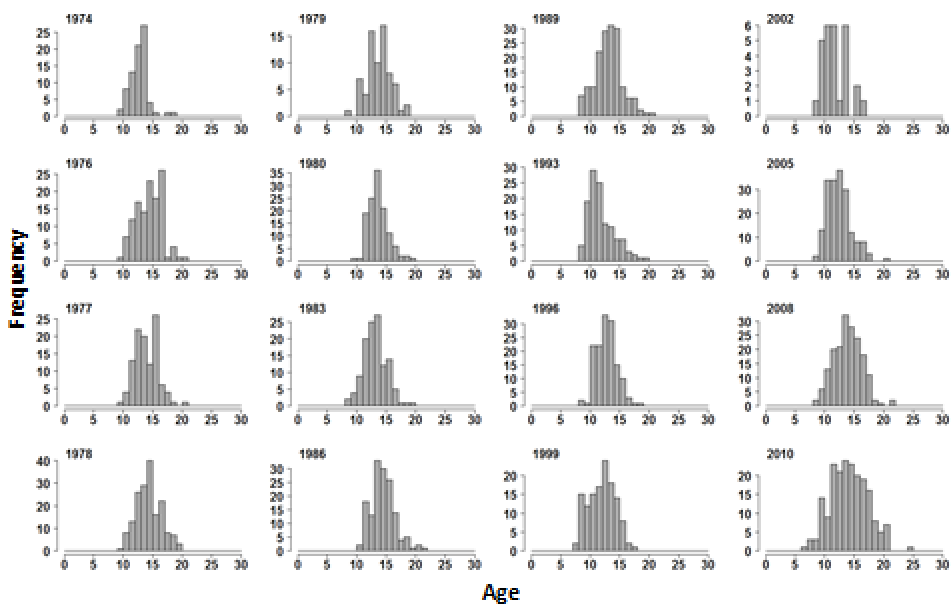
# Ekalluk River – Length Frequency



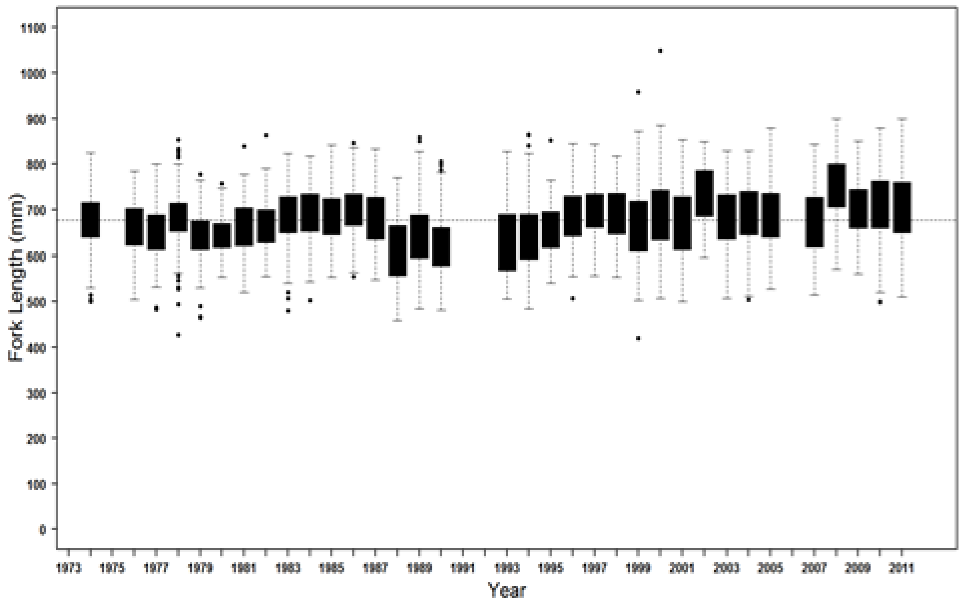
## Ekalluk River – Weight Frequency



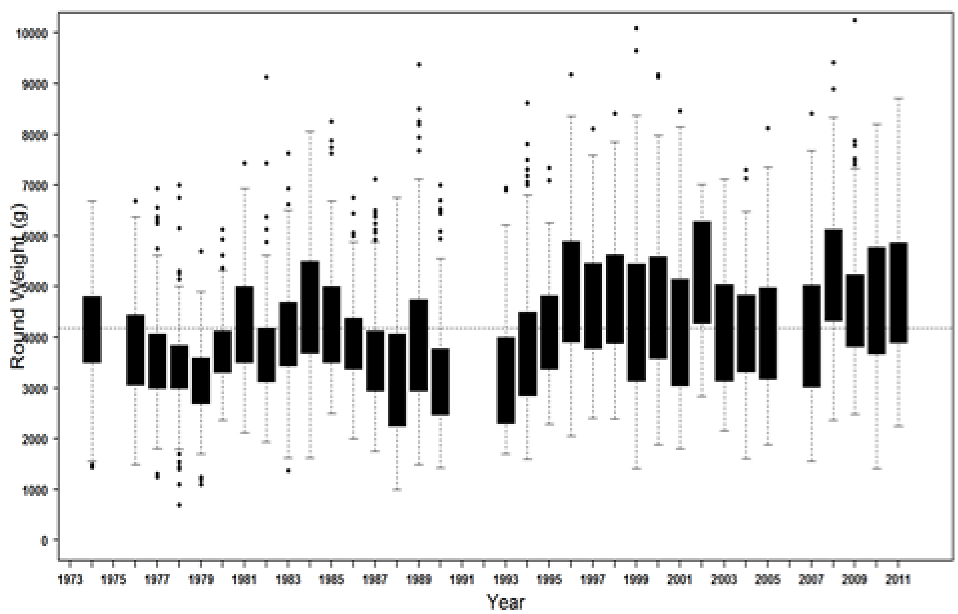

## Ekalluk River – Age Frequency



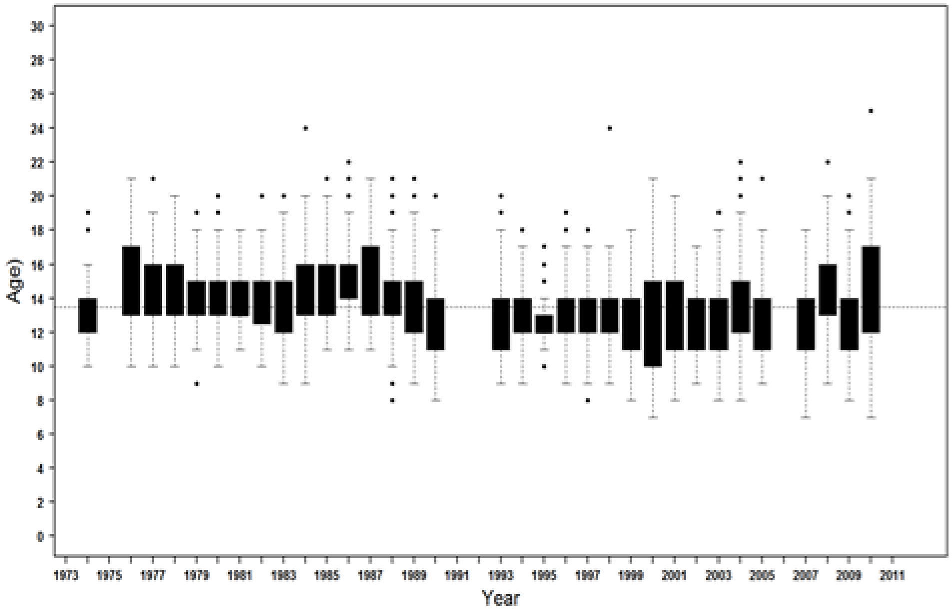
# Ekalluk Avg. Length




# Ekalluk Avg. Round Weight



# Ekalluk Avg. Age

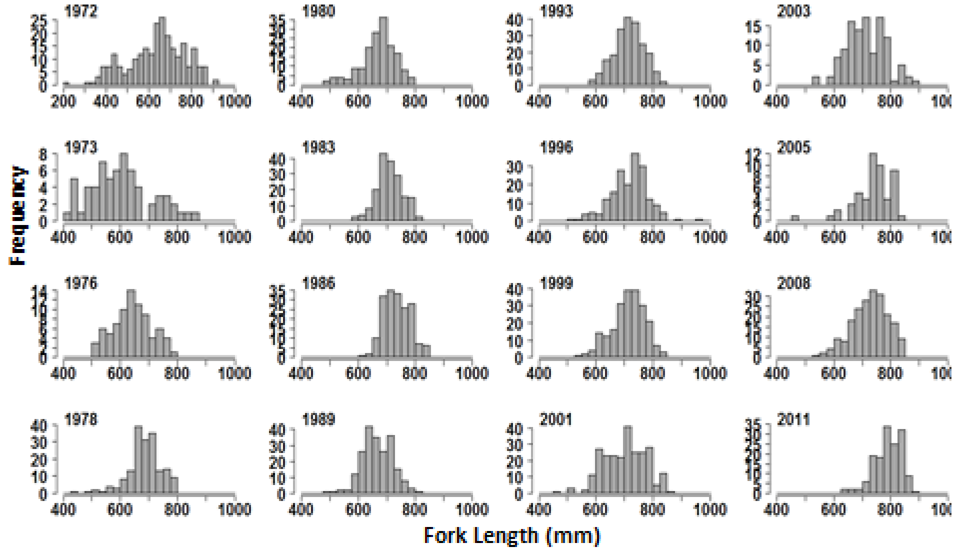



# Example - Halovik River

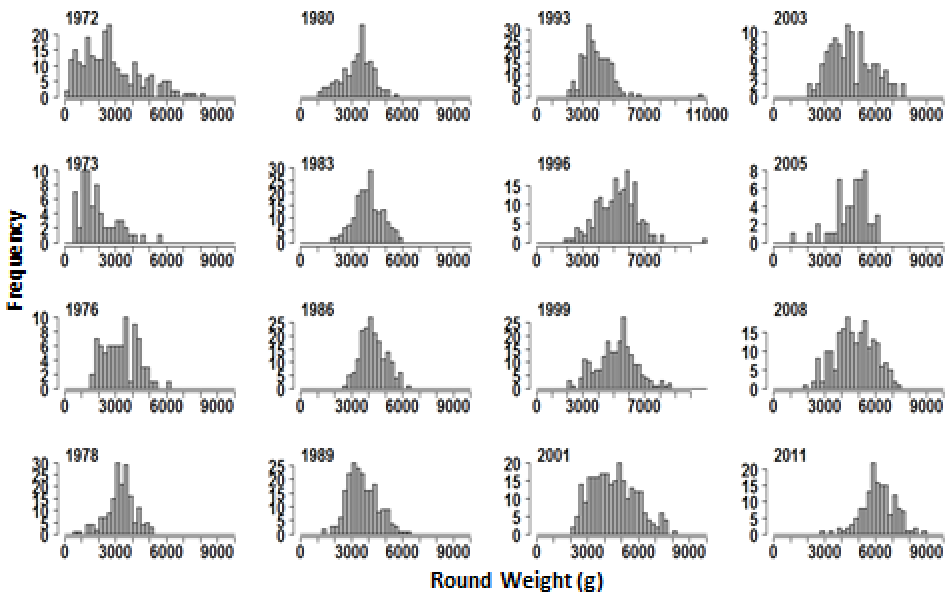
**<u>The Halovik River</u>**

- Fishing began here in 1968,
- Under the Wellington Bay quota
- In 1972, a quota of 9,100 kg was assigned to the Halovik River
- This fishery has been harvested by weir in the fall from 1994 to the present with a 5,000 kg quota.
- Exploitation rate (crudely calculated) = 11.1% (or 8.0% based on current quota/harvest)

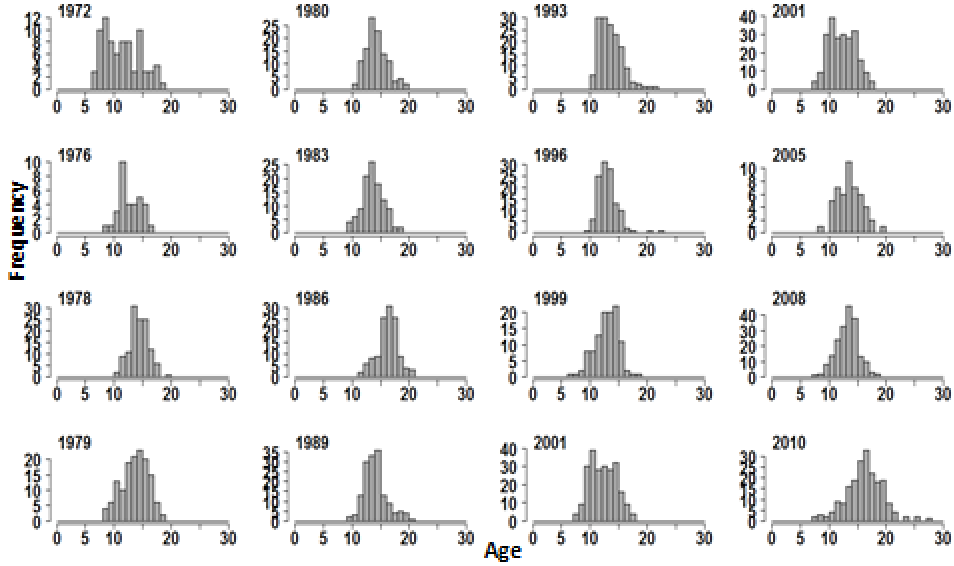
## Halovik River – Length Frequency



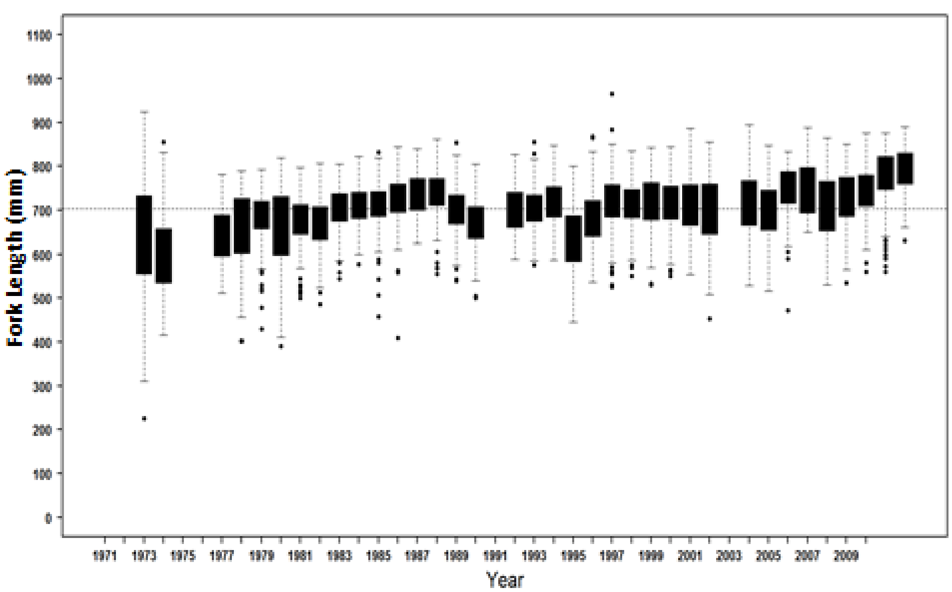

## Ekalluk River – Weight Frequency



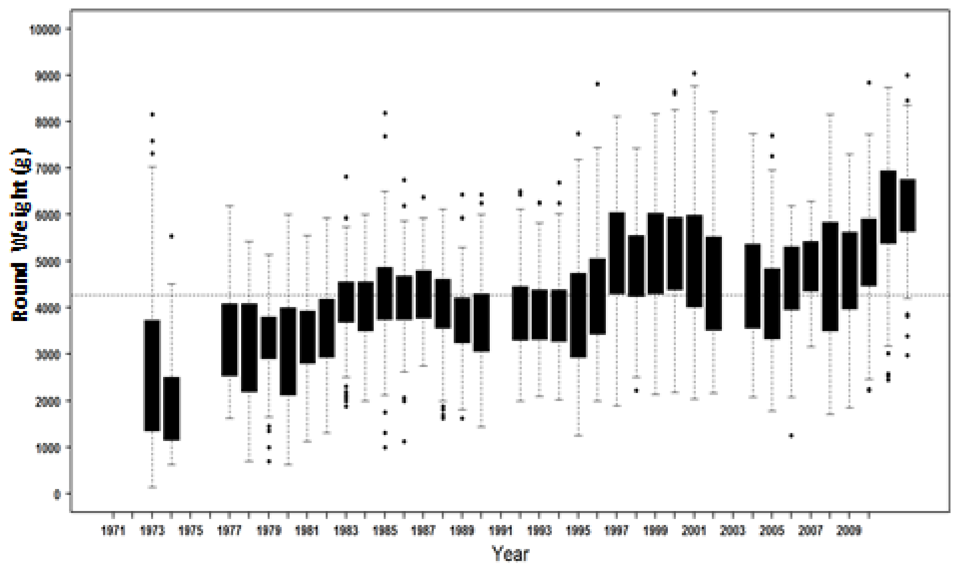
# Ekalluk River – Age Frequency



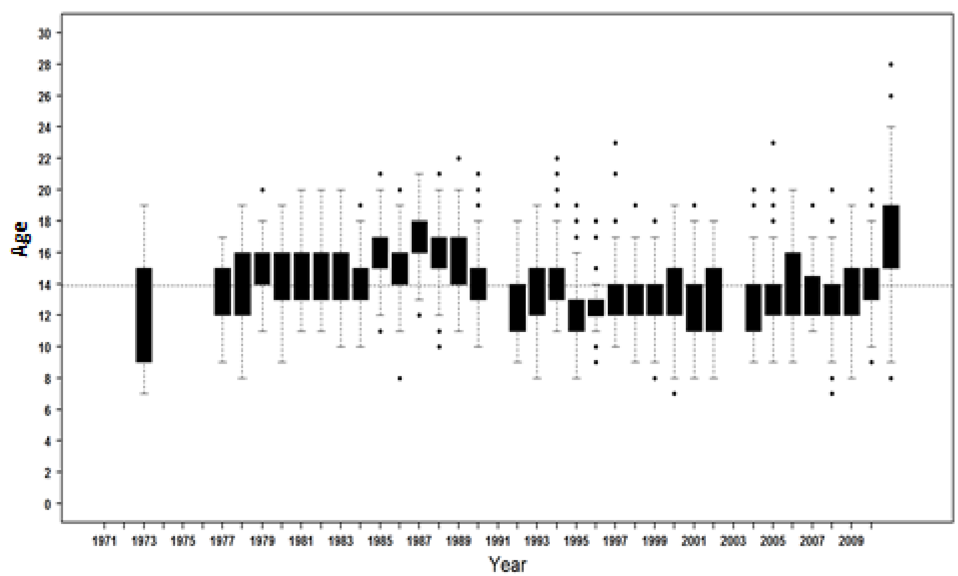

# Avg. Length



# Avg. Weight




# Avg. Age



## The Dilemma and Problems

- Fisheries appear to be healthy, and at a low risk of exploitation
- BUT, with the data we have how do we get at MSY or possibly suggestion more appropriate quotas
- Information on abundance is limited and outdated
- Very little CPUE data
- Quantitative modelling unable to provide river-specific LRP
- Sex and maturity collected only as part of sporadic stock surveys
- Char exploitation rates?

## Also …

**<u>Other things to consider</u>**

- The interesting life history of Arctic char in the region
- Straying is likely pervasive in this system
- Some areas certainly qualify as mixed stock fisheries
- Char exploitation rates?
- Subsistence and recreational harvest?

**PRESENTATION 4**
**SYLVIA GRINNELL ARCTIC CHAR**
By Melanie VanGerwen-Toyne

Fisheries and Oceans Canada | Pêches et Océans Canada

# Sylvia Grinnell Arctic Char


Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

## Fisheries

- Commercial fishery
  - 1947, 1948, 1950
  - 1958 to 1966
  - ceased due to decreasing CPUE (97.1 kg/unit effort to 21.8 kg/unit effort) and reduction in fish size (Hunter 1976).
- Subsistence fishery

Canada

Fisheries and Oceans Canada Pêches et Océans Canada

# Stock Assessment

- Biological characteristics
  - Length, age, natural mortality, size-at-age

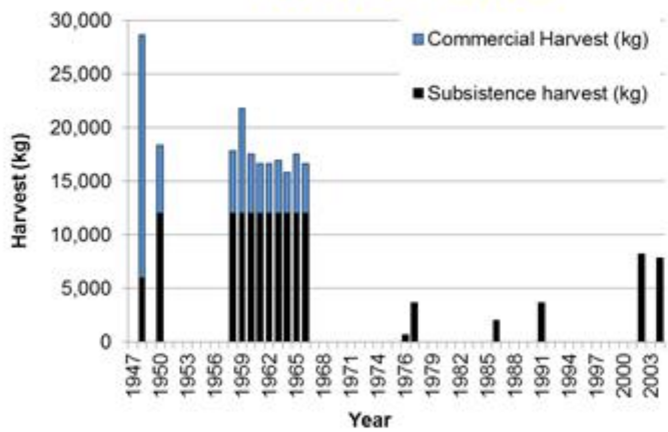
- Harvest studies
  - Commercial, subsistence, recreational

Kristofferson and Sopuck 1983; Bodaly et al. 1992; Cosens et al. 1993, Gallagher & Dick 2010, VanGerwen-Toyne et al. 2013

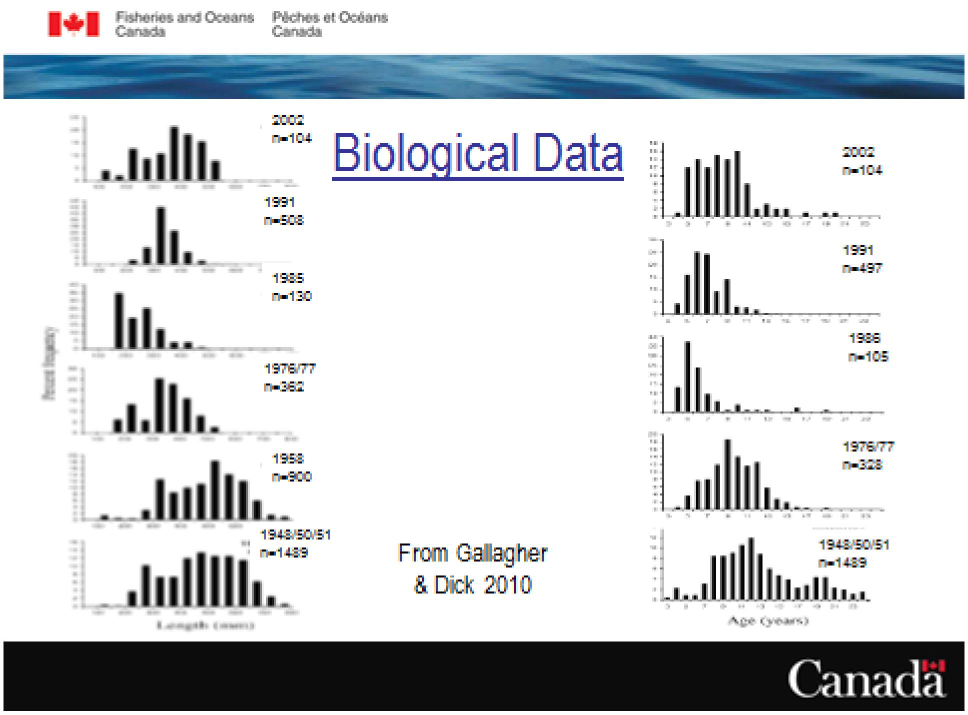
Canada

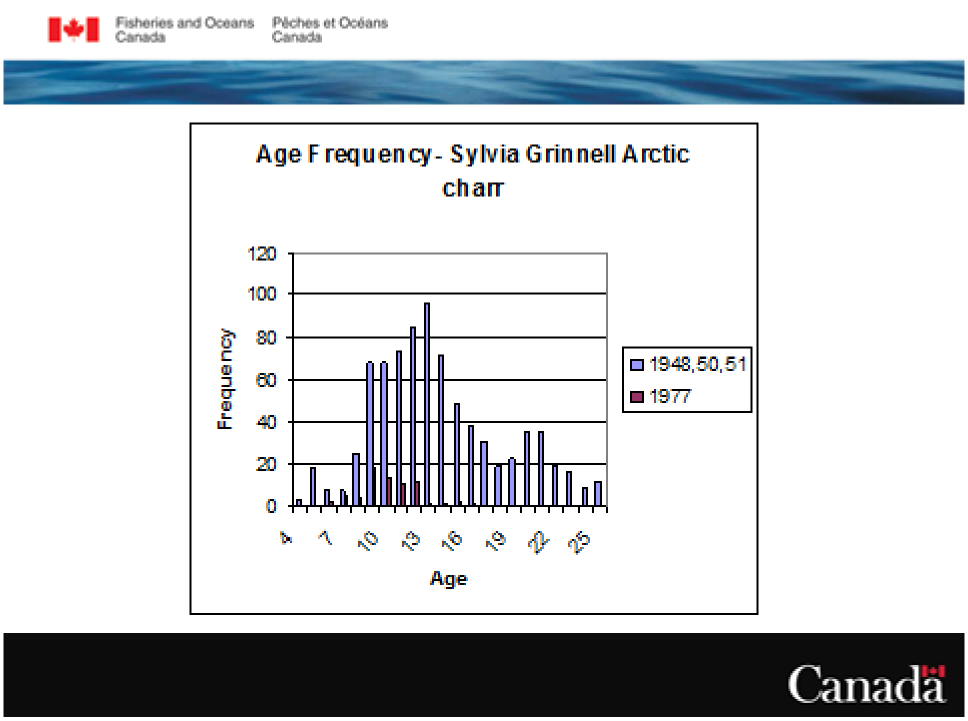
Fisheries and Oceans Canada Pêches et Océans Canada

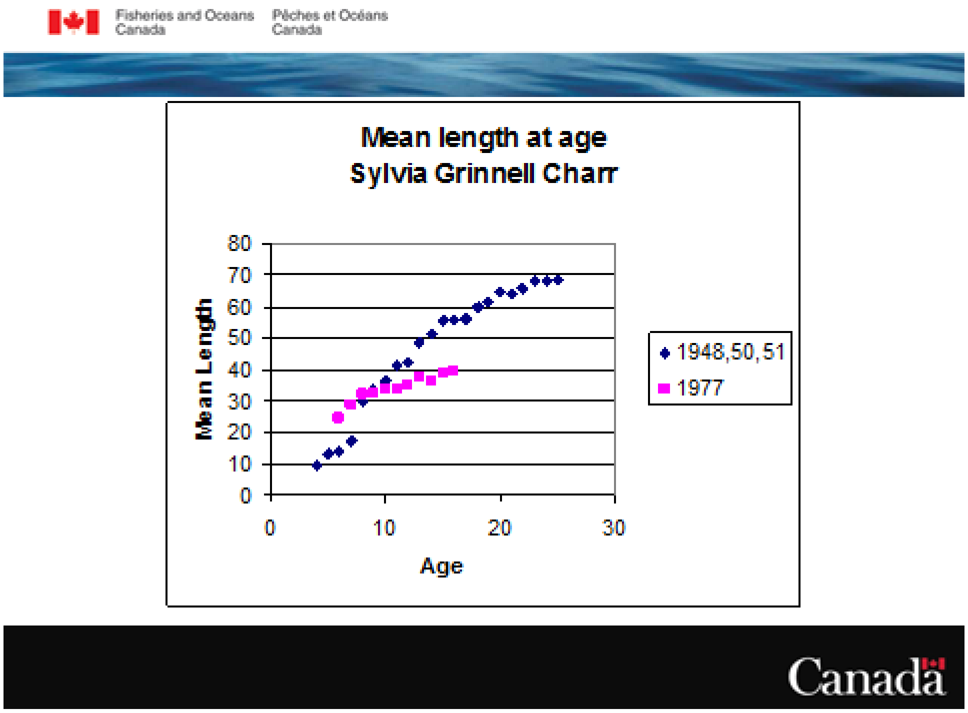
# Harvest Trends

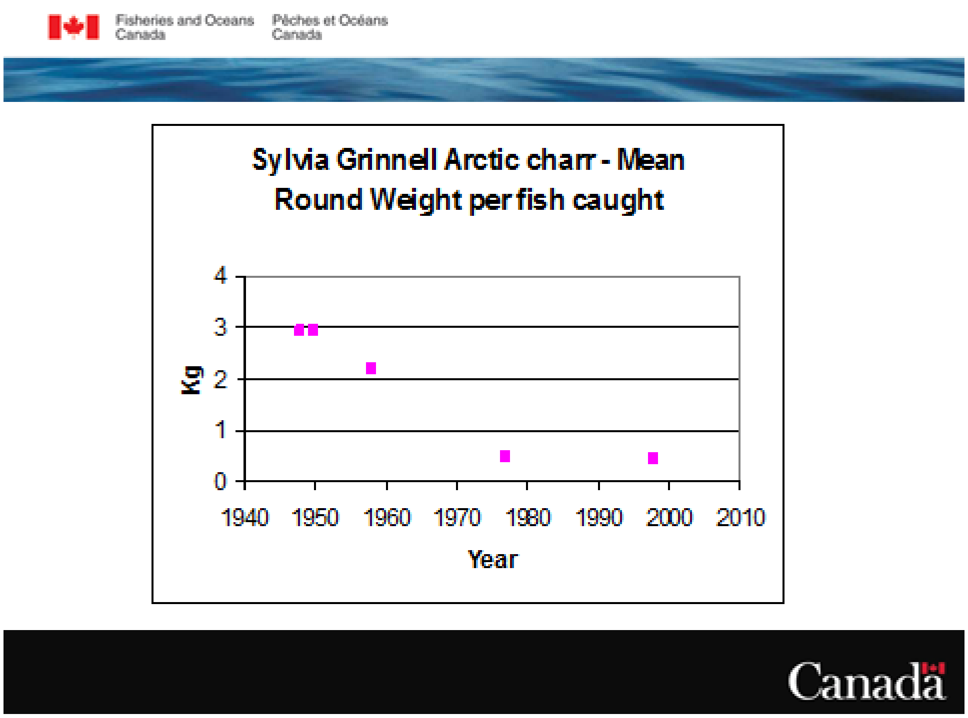



Canada


Fisheries and Oceans Canada
Pêches et Océans Canada
Biological Data
2002
n=104
1991
n=508
1985
n=130
1976/77
n=362
1958
n=900
1948/50/51
n=1489
Length (mm)
From Gallagher & Dick 2010
2002
n=104
1991
n=497
1986
n=105
1976/77
n=328
1948/50/51
n=1489
Age (years)
Canada


Fisheries and Oceans Canada
Pêches et Océans Canada
Age Frequency - Sylvia Grinnell Arctic charr
120
100
80
60
40
20
0
Frequency
4
7
10
13
16
19
22
25
Age
1948,50,51
1977
Canada


Fisheries and Oceans Canada
Pêches et Océans Canada
Mean length at age
Sylvia Grinnell Charr
Mean Length
0
10
20
30
40
50
60
70
80
0
10
20
30
Age
1948,50,51
1977
Canada


Fisheries and Oceans Canada
Pêches et Océans Canada
Sylvia Grinnell Arctic charr - Mean Round Weight per fish caught
Kg
0
1
2
3
4
1940
1950
1960
1970
1980
1990
2000
2010
Year
Canada

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## Summary

- Stock reduced after two pulses of commercial fishing.
- Not yet recovered to its pre-commercial state, even though total harvest decreased for decades.
  - but showing early stages of recovery, based on biological traits.

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## Issues

- Data collection sporadic.
- Is it realistic to expect harvest to return to pre-commercial levels?

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**PRESENTATION 5:**
**FISHERIES MANAGEMENT OF ARCTIC CHAR IN NUNAVUT**
By Tyler Jivan and Allison MacPhee

Fisheries and Oceans Canada
www.dfo-mpo.gc.ca

## Fisheries Management and the Importance of Establishing Harvest Levels of Arctic Char for Nunavut Fisheries

**Harvest Workshop for Nunavut Arctic Char**
**Freshwater Institute**
**Winnipeg, MB June 13, 2014**

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Fisheries and Oceans Canada
www.dfo-mpo.gc.ca

## The Role of Fisheries Management

Creating a credible, science-based, affordable and effective fisheries program.

**Long-term sustainability**
Enabling DFO and resource users to demonstrate the conservation of fish and the sustainability of fisheries

**Economic prosperity**
Aligning fisheries policies and decision-making processes to support economically prosperous fisheries for Canadians

**Improved Governance**
Increasing stability, transparency and accountability in fisheries management and by promoting shared stewardship

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## Supporting Fisheries Management

Science has provided integral information in support of managing Arctic Char fisheries in Nunavut.

- Main areas where stock assessment and advice continue to be needed include:
  1. Commercial fisheries
  2. Exploratory fisheries
- Science advice and recommendations have implications under the Nunavut Land Claims Agreement (NLCA)
  - Total Allowable Harvests (TAHs) and Basic Needs Levels (BNLs).

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## Commercial Fisheries

- Commercial fisheries are currently managed using waterbody-specific quotas.
- Stock assessments are required to determine maximum sustainable harvest levels (SHLs) for each commercial waterbody.
- DFO Science regularly conducts fishery-independent research which supports fishery-dependent data collection.
- Data collection is limited in most fisheries (e.g. lacks CPUE) despite some fisheries having decades of harvest and sampling data.

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# New Emerging Fisheries Policy

- New Emerging Fisheries Policy (NEFP) sets out the requirements and procedures to follow before a new commercial fishery can be established.
- NEFP requires the development of a workplan that identifies science data collection, monitoring and reporting requirements used to determine if the stock can sustain a commercial fishery.
- Proponent is required to collect scientific info (e.g. biological samples); DFO Science is responsible for the analysis of data generated and the provision of advice.
- Arctic Char exploratory fisheries are considered Stage II (new fishery development) – acknowledges the species is known to be present, gears appropriate for harvesting, and market exists.

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