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Central and Arctic **Stock Status Report 2004/010**

Cambridge Bay Arctic Char

Background

The Arctic char, Salvelinus alpinus (L.) *is distributed across the Canadian Arctic, including the islands of the Arctic Archipelago. It occupies many rivers and lakes on Victoria Island, near the Community of Cambridge Bay, as well as on the mainland to the south of this island. It is the anadromous (searun) Arctic char that is most sought after for food and commercial use.*

Commercial fishing first began at Cambridge Bay in 1960, with a gillnet operation on Freshwater Creek. In 1962, the commercial fishery was relocated to the mouth of the Ekalluk River, where it empties into Wellington Bay. As the fishery developed, other sites were utilized, including the Paliryuak (Surrey) River, the Halovik (Thirty Mile) River and the Lauchlan (Byron Bay) River, the Jayco River, and the Ellice and Perry rivers. Initially, an "area" quota was established for Wellington Bay, but the decline in the fishery at Ekalluk River, where most of the fishing took place, necessitated the establishment of "river-specific" quotas to distribute fishing effort.

This fishery is being evaluated to determine the current effects of fishing on stocks of Arctic char in this area. Recent studies have revealed that discrete stocks exist not only between river systems, but also within river systems (Kristofferson 2002). Therefore, the current fishing strategy may be impacting individual stocks within river systems to an unknown degree. An Integrated Fishery Management Plan (IFMP) is now required to ensure that this resource is exploited in a sustainable manner, given current knowledge.

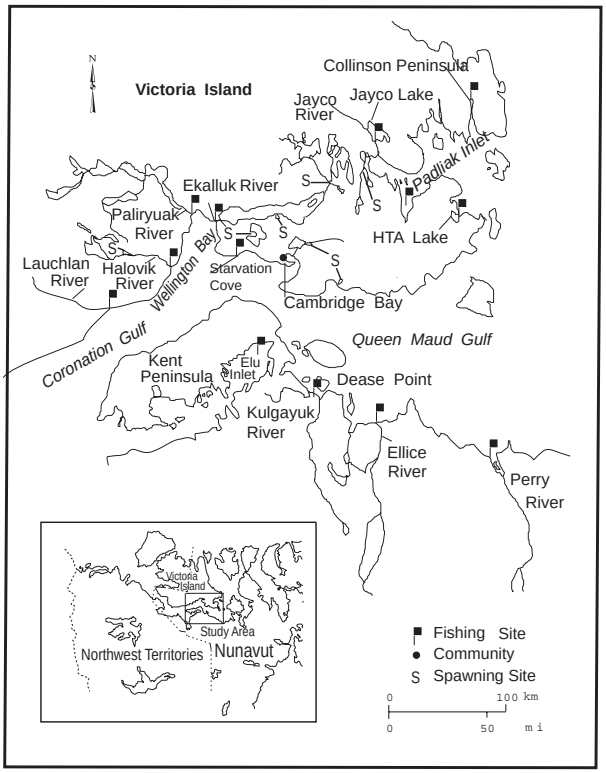

Figure 1. Map of Cambridge Bay area and commercial fisheries.

Summary

- Discrete stocks of anadromous Arctic char inhabit many river systems within the Cambridge Bay area on southern Victoria Island.
- Stocks can be differentiated from one another on the basis of significant differences in morphology and, in some cases, on the mean strontium concentration in the early growth zones of their otoliths.
- Evidence exists to show that differences among stocks have a genetic basis (electrophoresis – Malic enzyme).
- There is also evidence that anadromous Arctic char spawn with non-anadromous char in some river systems.
- Upstream runs of Arctic char often support commercial fisheries. Fisheries,

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therefore, target multiple stocks, the relative contribution of which is not known at present.

- There is evidence from age data for samples of spawning char that some stocks could be exploited to a greater degree than others.
- Trends in age data from commercial fish plant samples indicate that the commercial fishery has impacted char from several of the mixed stock fisheries of Cambridge Bay river systems but current levels of harvest are likely sustainable. Low to moderate risks of over exploitation are predicted for the next 10 years for all but the Ellice river fisheries if current rates of harvest remain stable.
- The response of char to the Ellice River fishery, as indicated by trends in age data, may indicate a moderate to high risk of over exploitation if historic rates of harvest commence. This higher level of risk is lessened by the fact that the Ellice River has only been fished once between 1999 and the present.
- Recruitment is variable and occurs in pulses which are somewhat synchronous among Cambridge Bay river systems. There is no evidence of recruitment failure.
- Coastal movements are significant during summer feeding forays, and based on tagging studies, evidence exists to show that nonspawning anadromous Arctic char may over-winter in systems other than their natal stream.
- The status of individual (discrete genetic) anadromous Arctic char stocks exploited by the fishery at Cambridge Bay, in terms of actual abundance, is largely unknown.

Species Biology

The Arctic char has a fusiform body shape typical of most salmonids but is distinguished by a rather small delicate head (Johnson 1980). It exhibits great variability in body form and colouration across its range (Johnson 1980; Nyman 1989). In the Cambridge Bay area, spawners take on an overall orange colouration, on the back, sides and belly. The intensity of colour is most pronounced in males. Fins are dusky with a bright white leading edge, particularly on spawners. Young char, or parr, have 10-15 irregularly arranged oval marks on the sides of the body.

Spawning takes place in freshwater in the fall, usually September or October, over gravel beds. In the Cambridge Bay area in particular, and the central Canadian Arctic in general, spawning takes place in lakes, because most rivers freeze completely in winter (Johnson 1980). Males arrive first on the spawning grounds and establish and defend territories. Females are “courted” by males as they arrive later. The female digs a nest or “redd”, 2-3 m in diameter, in water 3-6 m deep, and deposits the eggs there during the spawning act. The males continue to defend the “territory” for some time, even after spawning has taken place. Fights with other males sometimes occur. The eggs incubate under ice for about six months.

In most systems char are ready to take their first migration to sea at age 4-5 years and a size of 150-250 mm (Johnson 1980). The young Arctic char feed on freshwater shrimp (amphipods) and insect larvae, and the adults feed on small fish and bottom organisms including snails, clams and insect larvae. Initially, they do not venture much past the brackish water of the river estuaries, but as they grow, they are able to tolerate full strength sea water. They feed in nearshore areas along the coast for the duration of the summer which may last from 5 to 8 weeks depending on geographic location and local environmental conditions (Moore 1975; Sekerak *et al*. 1976; Johnson 1980; Dempson and Kristofferson 1987). Access to more abundant food resources allows the anadromous Arctic char to grow faster and, ultimately, larger than the freshwater form. At sea, char feed mainly upon invertebrates and fishes. In the fall, all char return to freshwater to overwinter to escape freezing in the sea (Johnson 1980). Nonanadromous Arctic char

are also found in systems inhabited by the anadromous form.

Kristofferson (unpublished) found that the mean length of spawners in the Cambridge Bay area was 657 mm and ranged from 459 mm to 850 mm, and first maturity was reached at an age of about 9 or 10 years. Mean age of these spawners was 14.5 years and ranged from 9 to 21 years (Kristofferson 2002). Females generally carry 3000 to 5000 eggs (Scott and Crossman 1973). Arctic char are iteroparous (capable of spawning more than once in a lifetime). In this area, they do not appear to spawn in consecutive years.

After spawning, the char remain in freshwater for another winter before resuming their feeding migration to the sea the next spring. This behaviour results in a loss of 30-40% of their body weight, so they are often in very poor condition at this time (Dutil 1986). Therefore, some anadromous Arctic char may spawn only once or twice in their lifetime (Sprules 1952; Johnson 1980).

Description of Habitat

Historically, eight river systems in the Cambridge Bay area were fished commercially (Kristofferson *et al*. 1984). These included the Ekalluk, Paliryuak, Halovik and Lauchlan rivers flowing into Wellington Bay, Freshwater Creek flowing into Cambridge Bay, the Jayco River flowing into Albert Edward Bay, and the Ellice and Perry rivers, located southeast on the mainland. (Figure 1). Headwaters range from 60 km to 250 km from the sea at elevations of 15 m to 235 m above sea level (Kristofferson 2002). The surface topography is relatively flat except where eskers, moraines and drumlins exist. It is dotted with many small lakes and streams as well as some lakes of considerable size, including Ferguson Lake (Johnson 1962). The surface is primarily covered with unconsolidated glacial drift. Vegetation is predominantly sedges, grasses and lichens (Peterson *et al*. 1981).

Most of this area was ice covered during the last glacial period and is believed to have become ice free between 8 500 and 12 500 years ago. Subsequently, much of the southeast corner of Victoria Island was inundated by sea water following glacial retreat (Wilson *et al*. 1958). Over time, the land rose at a uniform rate estimated at about 1 to 2 m per 100 years. Thus, the area near Cambridge Bay appears to have risen above the sea within the last 1 300 years (Johnson 1962).

Overwintering habitat for anadromous Arctic char likely exists in the many lakes on each system that do not freeze to the bottom in winter.

The Fishery

Historical Fishery

Prior to the onset of the commercial fishery (1960) it is likely that all river systems in this area were fished for food. The early history of this fishery is described in Abrahamson (1964), and Barlishen and Webber (1973). Commercial fishing sites were located at the mouths of various rivers in the area, and targeted either the downstream run in spring or the upstream run in fall. Initially, gillnets of various mesh sizes were used but, ultimately, the minimum mesh size allowable was established as 139 mm.
Harvest statistics for the Cambridge Bay commercial fishery (given as round weight in kilograms) are shown in Appendix 1 and are described below.

Freshwater Creek

The first commercial effort, at Freshwater Creek (which flows by the community of Cambridge Bay) in 1960, produced a harvest of about 2 000 kg of Arctic char and in 1961, 7 550 kg were harvested from a quota of 10 500 kg. Due to evidence of a declining stock at that location, and its importance as a subsistence fishery, commercial fishing ceased there and resumed at the Ekalluk River in 1962.

Ekalluk River

In 1962, a quota of 18 160 kg was set for the Ekalluk River. This site has been traditionally fished in the fall. During the years 1962-66, the average annual harvest at the Ekalluk River was 14 570 kg. The annual quota was increased to 45 400 kg in 1967, and was issued for the Wellington Bay area, in an attempt to spread fishing effort to the other systems flowing into this bay. However, all fishing was concentrated at the Ekalluk River that year, with a harvest of 27 700 kg. In 1968, fishing took place at the Ekalluk, Paliryuak and Halovik rivers, again under the 45 400 kg area quota. The reported harvest for Ekalluk River that year was 34 300 kg. In 1969, 22 700 kg was harvested at the Ekalluk River. The average annual harvest at the Ekalluk River over this three year period was 28 200 kg, but the average weight of Arctic char taken at the Ekalluk River was reported to have declined from 3.0 kg in 1967 to 1.4 kg in 1969. In comparison, the average weight of Arctic char taken at Halovik River in 1969 was 3.2 kg. Consequently, the commercial fishery at Ekalluk River was closed in 1970 and remained so until 1973 when the average weight was 2.7 kg. The original quota of 18 160 kg was set for 1973, and 9 630 kg were harvested that year. The quota was reduced to 11 350 kg in 1974 and an average of 13 790 kg were harvested over the years 1974-78. The quota was increased to 14 500 kg in 1979, and the average harvest at this site over the years 1979-90 was 14 290 kg.

The Ekalluk River was not fished in 1991 or 1992, due to a variety of reasons including declining size of Arctic char in the catch the previous years and declining prices for the product. A small harvest of 1 480 kg was taken in 1993 under a quota of 7 500 kg, and 1 640 kg were harvested in 1994, under an increased quota of 20 000 kg. An experimental weir, located at the outlet of Ferguson Lake, was used during both years. The plan was to hold char alive in a pen until transport to market could be assured. There was some success in getting a fresh product to market using this technique. Although the fishery was opened in 1995 with the 20 000 kg quota, only 4 665 kg were harvested that year. However, in 1996, 10 210 kg were harvested using the traditional gillnets set near the mouth of the river, 14 328 kg were taken in 1997, and 19 825 kg were taken in 1998. Annual harvest for the period 1999 to 2002 averaged 16 072 kg, under the 20 000 kg quota. However, harvest at Paliryuak River averaged 6 217 kg over that same period. Tagging studies indicated that most of the Arctic char taken by the fishery at Paliryuak River were from Ekalluk River stocks, therefore, the actual harvest of Ekalluk River char could have been about 22 200 kg over that time period.

Paliryuak River (Surrey River)

Commercial fishing first took place here in 1968 in the spring. The harvest that year was 6 470 kg, under the Wellington Bay area quota of 45 400 kg. It was not fished in 1969, but a harvest of 5 880 kg was reported for 1970. Fishing ceased here until 1977, when a harvest of 3 260 kg was reported under a quota of 4 500 kg assigned specifically to this site. The quota was increased to 6 800 kg in 1978, with a reported harvest that year of 8 420 kg. The quota was once again increased in 1979, this time to 9 100 kg. The average harvest at this site from 1979-93 was 8 880 kg. In 1994 the quota was rationalized with the Ekalluk River quota, based on the results of tagging studies that indicated most char taken there were from Ekalluk River stocks. No fishing took place at this site from 1994 to 1998 inclusive. The average annual harvest from 1999 to 2002 inclusive was 6 217 kg.

There appears to be no fall upstream migration at this site but harvesters report that there are large red char in the system.

Halovik River (Thirty Mile River)

Commercial fishing began here in 1968, and took place in fall, similar to the fishery at Paliryuak River. An average harvest of 16 290 kg was reported taken there from 1968 to 1971, under the Wellington Bay area quota of 45 400 kg. In 1972, a quota of 9 100 kg was assigned to this specific location and average

harvest there from 1972-73 was 4 200 kg. Due to declining catches and size of Arctic char in the catch, the fishery was closed for the period 1974-75, inclusive. The fishery resumed in 1976 under the 9 100 kg quota, and 2 780 kg were harvested that year. In 1977, the quota was reduced to 4 500 kg, and the average catch for 1977-78 was reported to be 5 179 kg. The quota was increased in 1979 to 6 800 kg, and catches averaged 6 850 kg for the period 1979-93. The quota was reduced to 5 000 kg in 1994, and 3 859 kg were harvested by weir during the fall upstream run. No fishing took place in 1995, but 4 909 kg were reported taken by the weir in 1996, 4 995 kg in 1997, and 5 143 kg in 1998. Average annual harvest for the period 1999 to 2002 inclusive was 5 130 kg.

Lauchlan River (Byron Bay)

The Lauchlan River was first fished for commercial purposes in 1970, although a harvest of 2 270 kg was reported in 1963 with no quota assigned. This site was also included under the Wellington Bay area quota of 45 400 kg, and during the years 1970-71, an average of 10 736 kg of Arctic char was taken there. This fishery also took place in spring, and it was assigned a site-specific quota of 18 160 kg in 1972. Average harvest for 1972-73 was 15 326 kg. The quota was reduced to 11 350 kg in 1974, and harvest fell to 8 125 kg that year. As a consequence, the fishery was closed during 1975 and 1976. It opened again in 1977 under a reduced quota of 6 800 kg, and average harvest for 1977-78 was 5 028 kg. The quota was increased to 9 100 kg in 1979, and average catch from 1979-93 was 9 230 kg. This site was not fished in 1994 but was opened in 1995 under a reduced quota of 2 400 kg. Harvest for 1995 to 1999 inclusive averaged 1 772 kg. No fishing took place in 2000 but 436 kg were harvested in 2001. No fishing took place in 2002.

Ellice River

Commercial fishing began at this mainland site in the fall of 1971. The quota that year was set at 22 700 kg and a harvest of 12 820 kg was reported. The quota was reduced to 11 350 kg for 1972, and catches for 1972-75 averaged 9 269 kg. In 1976, the quota was increased to 13 600 kg. and the average catch from 1976-78 was 14 199 kg. The quota was reduced to 9 100 kg in 1979, due to a decline in the size of Arctic char in the catch. The average harvest from 1979-84 was 7 736 kg. The quota was further reduced to 4 500 kg in 1985 and the average catch from 1985-87 was 4 768 kg. The quota was then increased to 6 000 kg in 1988 and average annual catch for 1988-90 was 6 295 kg. The quota was increased again in 1991, to 8 000 kg and average harvest from 1991-96 was 7 040 kg, although no fishing took place there in 1992. With the exception of 1999, when 4 497 kg of char were harvested, there has been no fishing at this site since 1997.

Perry River

Perry River, located on the mainland east of Ellice River, was first fished commercially in fall of 1977. Average harvest from 1977-1980 was 6 724 kg, under a quota of 11 350 kg. In 1981, the quota was reduced to 6 800 kg, due to declining size of Arctic char in the catch. Harvest that year was reported to be 2 836 kg. The quota was further reduced to 4 500 kg in 1985 but no fishing took place under that quota. In 1991, the quota was increased to 6 500 kg and a harvest of 600 kg was reported. The site has not been fished since, primarily due to the cost of transporting the catch to the community of Cambridge Bay, and inclement weather often experienced there in fall.

Jayco River

Jayco River was first fished commercially in 1975. Average catch from 1975-77 was 8 410 kg, under a quota of 6 800 kg. The quota was increased in 1978 to 11 350 kg and harvest that year was reported to be 13 414 kg. The quota was increased to 13 600 kg in 1979, and catches averaged 12 045 kg from 1979-90. This location was occasionally fished in spring and fall, with the quota being shared between the fishing seasons. However, in 1980, the harvest was taken by experimental

weir (Kristofferson *et al*.1986) during the fall upstream run, and, for the most part, harvest since then has been by weir. In 1991, the quota was increased to 15 600, but harvest, by gillnet that year, was only 2 226 kg. Ice forming on the weir caused it to collapse. No fishing took place in 1992 due to low prices, but resumed in 1993 with 15 411 kg harvested. The quota was increased to 17 000 kg in 1994, during which time 16 290 kg were harvested. The average annual harvest at this site over the years 1994 to 2002 inclusive was 15 656 kg.

Other Fishing Sites

Over the years, other sites were periodically fished, including Dease Point (Kulgayuk River) on the mainland for 8 890 kg (9 100 kg quota) in 1972, 3 020 kg (22 700 kg quota) in 1974, and 1 170 kg (20 400 kg quota) in 1976. A harvest of 3 853 kg was reported in 1991 under a 4 000 kg quota and a harvest of 3 120 kg was reported in 1993. Padliak Inlet was fished in 1977 for 880 kg (2 270 kg quota). Elu Inlet, on the mainland, was fished for 2 620 kg in 1977 and 260 kg in 1978, under a quota of 2 270 kg. Starvation Cove, on the south coast of Victoria Island, west of Cambridge Bay, was fished for 6 370 kg of Arctic char in 1977, although no quota was assigned for that location. More recently, an experimental fishery has taken place for a number of years at a site called HTA Lake (Takyoknitok), on the southeast coast of Victoria Island. A weir is used there and the average harvest for the period 1988 to 1991 inclusive was 1 558 kg under a quota of 1 500 kg. This quota was increased to 2 500 kg in 1993, and 3 000 kg in 1999. No fishing was reported for 1992 but the average harvest for 1993 and 1994 was 2 302 kg. No fishing was reported in 1995 but the harvest in 1996 was 2 685 kg. No fishing was reported for 1997 or 1998, but the 1999 harvest was 2 847 kg. No fishing was reported for 2000 but the 2001 harvest was 2 988 kg. Fishing did not take place there in 2002.

Current Harvest

In 2003, most fishing is still by gillnet although weirs are used on an experimental basis at some sites (Halovik and Jayco rivers and HTA Lake). Six sites were fished in 2003. Harvest at the Ekalluk River (20 000 kg quota) was reported to be 15 842 kg. Harvest at Halovik River (5 000 kg quota) was 5 478 kg. The harvest at Lauchlan River (2 400 kg quota) was 1 519 kg. At Jayco River (17 000 kg quota) the harvest was reported to be 17 174 kg. Kulgayuk River harvest (4 000 kg quota) was reported to be 1 842 kg. The harvest at HTA Lake (Takyoknitok) (3 000 kg quota) was 1 278 kg. No fishing took place at Paliryuak, Ellice and Perry rivers in 2003.

View of Fishers

Fishers from the community of Cambridge Bay have long realized the importance of the Arctic char resource to the economy of their community, both for subsistence and commercial purposes. Fishers realized that Freshwater Creek could not support both a subsistence and a commercial fishery, hence commercial fishing operations were stopped at this location. As time passed, and the various harvest levels proved not to be sustainable at some locations, they willingly reduced harvest levels, or closed fisheries outright, in order to allow them to recover. Information arising from the Department of Fisheries and Oceans (DFO) research studies was readily accepted, and adjustments to quotas were incorporated where needed. Fishers viewed quotas as reasonable and compliance was excellent, particularly following 1979, by which time it had become apparent that individual fishing sites could be over harvested. The community support for a moratorium on gillnet fishing on Freshwater Creek, following the 1982 weir assessment of the upstream run, showed their concern and willingness to actively participate in the recovery of this important resource. Fishers have observed an improvement in size and number of char taken in Freshwater Creek. In general the harvesters feel the stocks are currently stable and productive.

There has been no perceived decline in size and catch rate.

Resource Status

Stock Delineation

Discrete stocks within and among river systems can be differentiated from one another on the basis of significant differences in morphology, genetics and, in some cases on the mean strontium concentrations in the early growth zones of their otoliths.

Kristofferson (2002) found that separate stocks of anadromous Arctic char exist within the Ekalluk and Halovik river systems and Freshwater Creek, as well as among the Halovik, Jayco and Ellice rivers and Freshwater Creek. Samples from other sites not fished commercially also proved to support the existence of discrete stocks (Kitiga Lake, Anderson Bay Lake, Fish Trap Lake and Char Lake).

Stock Size

Attempts have been made in the past to determine the abundance of the upstream runs in a number of systems in the Cambridge Bay area (McGowan 1990; McGowan and Low 1992). This was accomplished by installing a counting weir at the mouth of these systems and directly counting all char that passed through on their way upstream. The counts differed significantly among river systems (Appendix 2), ranging from 183 203 at the Ekalluk River in 1979 to 9 961 at Freshwater Creek in 1982. However, due to the presence of multiple stocks within some river systems, counts do not represent the size of an individual stock, but rather the aggregate count of all members of all stocks returning to the river that year. A further complication is the fact that not all char return to their natal river to overwinter, particularly during years when they are not spawning (Johnson 1980). Therefore, the upstream run can consist of returning residents as well as nonresidents coming in to overwinter in a system other than their natal system during nonspawning years. Regardless, the counts do indicate that some systems provide overwintering habitat for a much greater number of anadromous Arctic char than do others. Upstream counts were the basis for a rationalization of quotas in the early 1990's. Thus, the largest quotas in effect today are at the Ekalluk and Jayco rivers.

Stock Trends

In the absence of annual counts of char entering rivers, the status is inferred from harvests in the fishery and trends in biological characteristics obtained from commercial sampling programs. With respect to the Ekalluk River plant samples, between 1972 and 2002, the number of age classes increased from 9 (9-17) to 13 (7-19) with the greater number observed between 1990 and 2002. The centre of distribution has remained stable around ages 12-13 throughout the time series. However, between 2000 and 2002 there was a bimodal distribution centered around ages 10-11 and 13-14.

In Ellice River plant samples, the number of age classes has remained constant but the modal age has declined steadily from 12 in 1971 to 8 in 1999.

In Halovik River, the catch was composed of a broad range of age classes with no pronounced mode evident. One anomaly is the strong modal representation of 15-17 year old char which occurred between 1985 and 1990.

In Jayco River there was a strong mode (15-16 years) which persisted from 1976 to 1991. In recent years modal age has shifted to ages 11 and 12. There appears to be a slight reduction in the number of age classes from 1976 to 2001.

Between 1972 and 1993 the Lauchlan River was characterized by a broad age distribution with good representation of older fish (15-18 years). No samples were available between 1994 and 1996. In 1997 a much narrower distribution, centered around ages 12 and 13, was evident.

The Paliryuak River age distribution was broad and stable between 1977 and 1993 and centered around ages 13-14 throughout the time series.

Examination of year class strengths (year of birth) revealed that there are pulses of recruitment in all river systems examined. The pulses are somewhat synchronous among river systems with regards to when they occur with no evidence of year class failure (Day 2004).

Sustainable Harvesting Rate

It is apparent from the early history of the fishery that effort was increased at different locations until some fisheries showed signs of decline, and thus had to be closed. Stocks recovered after a few years, and fishing resumed. This took place at Freshwater Creek, and later at the Ekalluk, Halovik, Ellice and Lauchlan rivers.

The history of the fisheries at these locations also shows that they were sustained for many years (1979-90) at lower levels of exploitation. For example, based on the 1979 weir count on the Ekalluk River, the current quota of 14 500 kg equates to about 6.4% of the exploitable biomass (fish greater or equal to 60 cm) or 3.5 % of the biomass of all length intervals of char which passed through the weir. The 1979 catch (15 806 kg) was equivalent to about 7.0% of the exploitable biomass or 3.8 % of the biomass of all length intervals of char which passed through the weir. If the point estimate of abundance derived from the 1979 weir assessment was representative of the run size and if annual variation in run size is relatively low, then these estimated sustainable harvest rates may represent the only information available for Arctic coast char populations. The actual effect of fishing on individual stocks, because these are, for the most part, mixed stock fisheries is unknown. It is possible that smaller more vulnerable populations of char may have been extirpated by Cambridge Bay char fisheries.

Age structure of spawners captured in the Halovik River system and Freshwater Creek system in 1993 showed few spawners older than 14 years of age compared to other locations where spawners as old as 20 years were observed (Kristofferson 2002). This could be evidence of heavier exploitation on these specific stocks.

Tagging studies carried out over many years in the Cambridge Bay area suggest that, at some fishing sites, exploitation exceeded 5 % per year. Exploitation rates calculated for those fisheries that appeared to have been sustained for many years was at or less than 5 % Johnson (1980) found that exploitation of 10-11 % per year led to a decline in the numbers of upstream migrants in Nauyuk River, located nearby on the mainland south of Cambridge Bay

Sources of Uncertainty

Currently, there is no information on the size or level of exploitation on genetically discrete stocks of anadromous Arctic char in the Cambridge Bay fishery. There is, at present, no way of determining the relative contribution of discrete stocks to these mixed stock fisheries, and therefore, the effects of fishing on discrete stocks. Random samples of the catch, presumed to be representative of the fishery are an admixture of samples from many stocks. Therefore, such samples may not provide timely information on the status of discrete stocks, whether in decline or not. Modeling the response of anadromous Arctic char to exploitation is very difficult as a consequence. However, 1) similarity among river systems with regards to the synchronous occurrence of strong year classes and 2) a positive age and size response to quota adjustments observed within river systems suggests that discrete stocks may respond in a similar manner to variation in environmental conditions and fishing mortality. It follows then, that mixed stock samples may in fact reflect the response of discrete stocks to exploitation even if the individual identity of stocks is unknown.

Estimates of subsistence harvests are not available at this point in time. There are data available from the Nunavut Wildlife Harvest Study report through the Nunavut Wildlife Management Board (NWMB) but there was concern expressed by the Ekaluktutiak Hunters and Trappers Association (HTO) that this is probably an underestimate of the actual harvest. A preliminary draft of the unpublished NWMB Harvest Study indicated that subsistence harvests are substantial and, for the period 1997 to 2001, may have equaled those of the commercial harvest.

Outlook

Levels of the risk of over exploitation were assigned subjectively to each river system based on temporal trends in age class distribution described in the section "Stock Trends". The assignment of these levels is based on the assumption that current levels of exploitation will remain relatively constant for the next 10 years (Appendix 3). Levels were also assigned in light of the observation that although anadromous char from the Cambridge Bay area begin maturing at age 9, the percentage of mature char in samples does not approach 100% until age 13 or 14.

Based on trends in the age structure the Ekalluk River fishery has a low to moderate risk of overexploitation due to an observed slight decline in modal ages. The Halovik and Paliryuak rivers have low levels of risk as indicated by stable and broad age distributions which contain large proportions of older age fish. Based on the assumptions that age at maturity is age 9 and that the age distribution has remained stable since 1999, the Ellice River may have a moderate to high risk of overexploitation should harvest resume because recent catches have contained a large proportion of immature char and ages have declined steadily throughout the history of the fishery. The assumption of stable age distribution is questionable because there has been no fishing on this stock for five years. This cannot be resolved without further sampling. The Jayco and Lauchlan rivers have moderate levels of risk of exploitation as indicated by a decline in modal age from 15-16 to 12-13. However, in both systems recent samples still contain a large proportion of older mature char.

Although there are indications of changes in the age distribution, the commercial quotas are considered to be sustainable for all rivers with the possible exception of the Ellice. However the HTO representative stated "… the fishing has always been good. The only reason we did not fulfill our quota is because we did not have enough manpower". To obtain a more precise estimation of the risk further research will be required. If harvests are maintained at or below current levels, the long-term outlook for the fishery is likely to be positive.

Research Recommendations

- Continue plant sampling for tracking response of char to exploitation.
- Expand sampling program to include spring fisheries (Paliryuak and Lauchlan rivers).
- Obtain current estimates of abundance for one index river via weir enumeration to establish the effects of exploitation on abundance.
- Investigate the utility of aerial visual counts as estimator of spawning char abundance.
- Obtain estimates of life history parameters such as fecundity, age at maturity, and natural mortality for stocks of concern.
- Explore the development of biological reference points specific to Arctic char in this area.
- Gather traditional ecological knowledge for spawning locations of char among Cambridge Bay area stocks.
- Collect information on catch per unit of fishing effort as an index of abundance.
- Incorporate subsistence harvest statistics into the scientific assessment of this fishery.

Management Considerations

Jurisdiction

The Cambridge Bay commercial fishery is jointly managed by DFO and the Nunavut Wildlife Management Board (NWMB) and HTO under legislated co-management. The DFO is responsible for stock assessment and recommendation of harvest levels to the NWMB, which then approves fishing plans. An Integrated Fishery Management Plan (IFMP) is required for this fishery. Perhaps the best approach to consider for this fishery is an "Adaptive Co-management" approach.

Adaptive management recognizes the existence of complex ecological relationships and the biological uncertainty associated with them (McDonald 1988). This approach emphasizes the need to synthesize ideas, experience and experimentation to deal effectively with this uncertainty (Walters 1986). Co-management is flexible and participatory and relies on systematic feedback learning between resource users and assessors (Berkes *et al*. 2001). This approach was used for research conducted on Cambridge Bay Arctic char spawning site fidelity (Kristofferson 2002) when local traditional knowledge was used to locate char spawning grounds so that scientific sampling could be conducted. Also, fishers are often aware of stock declines and are able to inform researchers of perceived problems.

Other considerations

Habitat alteration and/or degradation of spawning and overwintering sites does not appear to be a problem in this area at this time. However, there is a ford across Freshwater Creek that is sometimes used by heavy vehicles in the process of recovering gravel and sand from the far side. This practice must be eliminated during the downstream and upstream migrations of Arctic char in this system. The downstream migration takes place from ice break-up until about July 15. The upstream migration usually takes place from August 15 to September 15 (McGowan and Low 1992).

For more Information

Contact: A. Chris Day
Or
Dr. Al Kristofferson
Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
Canada
R3T 2N6

Tel: Day (204) 983-5158
Kristofferson (204) 983-5159
Fax: (204) 984-2403
E-Mail: dayc@dfo-mpo.gc.ca
kristofa@dfo-mpo.gc.ca

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Central and Arctic Region
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Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6

Telephone: (204) 983-8838
Fax: (204) 984-2403
email: Cosenss@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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Appendix 1. Quota and harvest (kilograms (kg) round weight) history of the Cambridge Bay commercial Arctic char (*Salvelinus alpinus*) fishery.

Year	Wellington Bay Area									Queen Maud Gulf Area					Albert Edward Bay Area	
	Ekalluk R.		*Paliryuak R.*		*Halovik R.*		*Lauchlan R.*		Harvest Area Total	*Ellice R.*		*Perry R.*		Harvest Area Total	*Jayco R.*	
	Quota	Harvest	Quota	Harvest	Quota	Harvest	Quota	Harvest		Quota	Harvest	Quota	Harvest		Quota	Harvest
1960	NQ	15876	NQ	NF	NQ	NF	NQ	NF	15876	NQ	NF	NQ	NF	0	NQ	NF
1961	NQ	NF	NQ	NF	NQ	NF	NQ	NF	0	NQ	NF	NQ	NF	0	NQ	NF
1962	18160	5765	NQ	NF	NQ	NF	NQ	NF	5765	NQ	NF	NQ	NF	0	NQ	NF
1963	18160	13875	NQ	NF	NQ	NF	NQ	2270	16145	NQ	NF	NQ	NF	0	NQ	NF
1964	18160	15504	NQ	NF	NQ	NF	NQ	NF	15504	NQ	NF	NQ	NF	0	NQ	NF
1965	18160	20865	NQ	NF	NQ	NF	NQ	NF	20865	NQ	NF	NQ	NF	0	NQ	NF
1966	18160	16783	NQ	NF	NQ	NF	NQ	NF	16783	NQ	NF	NQ	NF	0	NQ	NF
1967	AQ	27700	AQ	NF	AQ	NF	AQ	NF	27700	NQ	NF	NQ	NF	0	NQ	NF
1968	AQ	34300	AQ	6470	AQ	2614	AQ	NF	43384	NQ	NF	NQ	NF	0	NQ	NF
1969	AQ	22700	AQ	NF	AQ	25855	AQ	NF	48555	NQ	NF	NQ	NF	0	NQ	NF
1970	Closed	0	AQ	5880	AQ	26203	AQ	2420	34503	NQ	NF	NQ	NF	0	NQ	NF
1971	Closed	0	AQ	NF	AQ	10433	AQ	19051	29484	22700	12820	NQ	NF	12820	NQ	NF
1972	Closed	0	NQ	NF	9100	6477	18160	20994	27471	11350	12524	NQ	NF	12524	NQ	NF
1973	18160	9630	NQ	NF	9100	1918	18160	9657	21205	11350	7239	NQ	NF	7239	NQ	NF
1974	11350	12540	NQ	NF	Closed	0	11350	8125	20665	11350	6956	NQ	NF	6956	NQ	NF
1975	11350	12261	NQ	NF	Closed	0	Closed	0	12261	11350	10357	NQ	NF	10357	6800	8231
1976	11350	13628	NQ	NF	9100	2780	Closed	0	16408	13600	12679	NQ	NF	12679	6800	9437
1977	11350	15897	4500	3260	4500	4624	6800	1519	25300	13600	20796	11350	13649	34445	6800	7563
1978	11350	14585	6800	8420	4500	5734	6800	8536	37275	13600	9118	11350	8135	17253	11350	13414
1979	14500	15806	9100	11816	6800	7316	9100	10845	45783	9100	7177	11350	1736	8913	13600	12235
1980	14500	10519	9100	7497	6800	7481	9100	9151	34648	9100	6629	11350	3377	10006	13600	14471
1981	14500	14283	9100	8638	6800	7009	9100	8724	38654	9100	5744	6800	2836	8580	13600	13320
1982	14500	14234	9100	9045	6800	6848	9100	8918	39045	9100	8864	6800	NF	8864	13600	5711
1983	14500	14840	9100	8831	6800	6825	9100	9106	39602	9100	9046	6800	NF	9046	13600	12966
1984	14500	14500	9100	8814	6800	7306	9100	9876	40496	9100	8953	6800	NF	8953	13600	13515

Key
NQ = No Quota
AQ = Wellington Bay Area Quota (45 400 kg)
NF = Not Fished
E= Experimental
(s)= Shared quota with Ekalluk River

Appendix 1. Continued. Quota and harvest (kilograms (kg) round weight) history of the Cambridge Bay commercial Arctic char (Salvelinus alpinus) fishery.

Year	Wellington Bay Area									Queen Maud Gulf Area					Albert Edward Bay Area	
	Ekalluk R.		*Paliryuak R.*		*Halovik R.*		*Lauchlan R.*		Harvest Area Total	*Ellice R.*		*Perry R.*		Harvest Area Total	*Jayco R.*	
	Quota	Harvest	Quota	Harvest	Quota	Harvest	Quota	Harvest		Quota	Harvest	Quota	Harvest		Quota	Harvest
1985	14500	14524	9100	9286	6800	6448	9100	9056	39314	4500	5598	4500	NF	5598	13600	11584
1986	14500	14349	9100	9123	6800	6830	9100	8243	38545	4500	4180	4500	NF	4180	13600	12076
1987	14500	14661	9100	8668	6800	6875	9100	9553	39757	4500	4525	4500	NF	4525	13600	13686
1988	14500	14834	9100	8570	6800	6808	9100	9425	39637	6000	6544	4500	NF	6544	13600	11820
1989	14500	13565	9100	9176	6800	6858	9100	9184	38783	6000	5969	4500	NF	5969	13600	10293
1990	14500	15294	9100	9318	6800	6971	9100	8938	40521	6000	6371	4500	NF	6371	13600	12865
1991	1500 E	NF	9100	8953	6800	6354	9100	8807	24114	8000	7971	6500	600	8571	15600	2226
1992	7500	NF	9100	8884	6800	6872	9100	9320	25076	8000	NF	6500	NF	0	15600	NF
1993	7500	1480	9100	6579	6800	5939	9100	9306	23304	8000	8016	6500	NF	8016	15600	15411
1994	20000	1640	(s)	NF	5000	3859	9100	NF	5499	8000	7175	6500	NF	7175	17000	16290
1995	20000	4665	(s)	NF	5000	4269	2400	1439	10373	8000	7536	6500	NF	7536	17000	12556
1996	20000	10210	(s)	NF	5000	4909	2400	2352	17471	8000	4502	6500	NF	4502	17000	16914
1997	20000	14328	(s)	NF	5000	4995	2400	900	20223	8000	NF	6500	NF	0	17000	10585
1998	20000	19825	(s)	NF	5000	5143	2400	1430	26389	8000	NF	6500	NF	0	17000	17070
1999	20000	14581	(s)	5677	5000	5120	2400	2740	28118	8000	4497	6500	NF	4497	17000	17094
2000	20000	16932	(s)	5808	5000	5205	2400	NF	27948	8000	NF	6500	NF	0	17000	17312
2001	20000	16548	(s)	5766	5000	5428	2400	436	28178	8000	NF	6500	NF	0	17000	16374
2002	20000	16225	(s)	7618	5000	4769	2400	NF	28612	8000	NF	6500	NF	0	17000	16709
2003	20000	15842	(s)	NF	5000	5478	2400	1519	22839	8000	NF	6500	NF	0	17000	17174

Key
NQ = No Quota
AQ = Wellington Bay Area Quota (45 400 kg)
NF = Not Fished
E= Experimental
(s)= Shared quota with Ekalluk River

Appendix 2. Weir enumerations of fall upstream Arctic char (Salvelinus alpinus)migrations in the Cambridge Bay area.

Year	Location				
	Ekalluk [a] River	**Jayco [a] River**	**Halovik [a] River**	**Lauchlan [a] River**	**Freshwater [b] Creek**
1979	183,203	.	.	.	.
1980	.	33,388 [c]	.	.	.
1981	.	138,795	21,214	.	.
1982	.	.	.	.	9,961
1983	.	.	.	10,850	.
1984	.	.	.	.	.
1985	.	.	.	.	.
1986	.	.	.	.	.
1987	.	.	.	.	.
1988	.	.	.	.	*36,933*
1989	.	.	.	.	.
1990	.	.	.	.	.
1991	.	.	.	.	39,559

[a] from McGowan (1990), [b] from McGowan and Low (1992), [c] incomplete count

Appendix 3. Cambridge Bay Arctic char (Salvelinus alpinus) fisheries risk levels. Strong modal ages by year and fishery with a level of risk of overexploitation if harvest rates continue at present level.

Fishery	**Year**	**Strong Modal Age Classes**	**Year**	**Strong Modal Age Class**	**Risk Level (over 10 years)**
Ekalluk River	1972	12, 13	2002	10, 11-13, 14	Low to Moderate
Ellice River	1971	12, 13	1999	7, 8	Moderate to High
Halovik River	1972	8 to 14	2002	8 to 15	Low
Jayco River	1976	15, 16	2001	11, 12	Moderate
Lauchlan River	1972	15 to 17	1997	12, 13	Moderate
Paliryuak River	1977	13 to 15	1993	13 to 15	Low