ASSESSMENT OF THE SUBSISTENCE FISHERY AND BIOLOGICAL DATA FOR ARCTIC CISCO IN TUKTOYAKTUK HARBOUR, NT, CANADA, 1997-1999

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ABSTRACT

Harwood, L.A., Pokiak, F., and Walker-Larsen, J. 2008. Assessment of subsistence fishery and biological data for Arctic cisco in Tuktoyaktuk Harbour, NT, Canada, 1997-1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2845: ix + 31 p.

Tuktoyaktuk Harbour provides habitat for at least 19 species of fish, represented by anadromous, freshwater and marine species. The community of Tuktoyaktuk requested this study, the purpose of which was to assess the diversity of the fish community in three seasons (spring, summer and fall), and obtain baseline information on Arctic cisco (*Coregonus autumnalis*), their life history and the associated subsistence fishery in particular. The Arctic cisco fishery is important to the community of Tuktoyaktuk, although variable (range 5,000-35,000 fish annually; average annual harvest 14,000 fish). The majority of the subsistence catch was caught during July (16.6%), August (18.6%) and September (52.6%).

During April and May of 1998 and 1999, a single 25 m, 63 mm (1998) and 76 mm (1999) mesh gillnet was set vertically in the water column at five known deep locations in Tuktoyaktuk Harbour, to determine the types of fish that might be using the area for over-wintering. In July and September 1997, 1998 and 1999, four local fish harvesters were hired as fish monitors for five days in each month to sample and measure their own catches during the peak of the Arctic cisco subsistence fishery in Tuktoyaktuk Harbour. The test netting program consisted of standard gang mono-filament gillnet sets, set perpendicular to shore, for 7 days in each of July and September 1997, 1998, and 1999 (3 sites in Tuktoyaktuk Harbour). Finally, in each of July and September 1997-1999, Arctic cisco were caught in seine nets in Tuktoyaktuk Harbour, tagged and released (n=1835).

This study revealed that Tuktoyaktuk Harbour is used by Arctic cisco for over-wintering but not for spawning: (1) there was a total absence of current year spawners in any of the September catches as cisco entered the harbour for over-wintering; (2) one Arctic cisco was tagged moving into Tuktoyaktuk Harbour in September 1998, and then was recaptured in July 1999 moving out of the harbour; and (3) catches of Arctic cisco, least cisco (*Coregonus sardinella*) and inconnu (*Stenodus leucichthys*) were made through holes drilled in the sea ice in spring 1998 and 1999. The size and age distributions of Arctic cisco caught in the subsistence fishery versus the test nets were statistically different, due to the selectivity of the different gear types. The size and age distributions, patterns of growth, prey selection, and migration patterns found in this study were similar to that found 18-20 years earlier by Bond (1982).

An important issue facing the community of Tuktoyaktuk, government regulators and industry is the assurance and maintenance of the quality and quantity of fish over-wintering habitat in Tuktoyaktuk Harbour. Fish populations could be negatively impacted if over-wintering habitat is compromised by anthropogenic activity.

Key Words: Arctic cisco, *Coregonus autumnalis*, over-wintering, subsistence fishery, age and length distribution, catch-per-unit effort, fish diversity.

RÉSUMÉ

Harwood, L.A., Pokiak, F., et Walker-Larsen, J. 2008. Étude des données sur la pêche de subsistance et des données biologiques du cisco arctique dans la baie de Tuktoyaktuk, T.N.-O., Canada, de 1997 à 1999. Rapport manuscrit canadien des sciences halieutiques et aquatiques 2845: ix + 31 p.

La baie de Tuktoyaktuk constitue l'habitat d'au moins 19 espèces halieutiques, un nombre comprenant à la fois des espèces anadromes et marines. La communauté de Tuktoyaktuk a commandé cette étude qui visait à évaluer la diversité de la population de poissons durant trois saisons (printemps, été et automne) et à obtenir des données de référence sur le cisco arctique (*Coregonus autumnalis*), sur son cycle biologique et plus particulièrement sur la pêche de subsistance qui lui est associée. La pêche du cisco arctique est importante pour la communauté de Tuktoyaktuk, bien qu'elle ne représente que 5 000 à 35 000 prises par année (soit une récolte moyenne annuelle de 14 000 poissons). La majorité des prises de subsistance ont été capturées durant les mois de juillet (16,6 %), août (18,6 %) et septembre (52,6 %).

Durant les mois d'avril et de mai 1998 et 1999, un seul filet maillant de 25 m de longueur, dont le maillage était de 63 mm en 1998 et de 76 mm en 1999, a été installé verticalement dans la colonne d'eau à cinq endroits profonds connus de la baie de Tuktoyaktuk afin de déterminer les types de poissons utilisant ces zones pour leur hivernage. En juillet et septembre de 1997, 1998 et 1999, on a embauché quatre pêcheurs professionnels de la région à titre de surveillants des stocks pour une période de cinq jours chaque mois afin de recueillir des échantillons et de mesurer leurs propres prises au plus fort de la pêche du cisco arctique dans la baie de Tuktoyaktuk. Le programme de filets d'échantillonnage comprenait des jeux standards de filets maillants à filament simple installés perpendiculairement au rivage durant une période de 7 jours à chacun des mois de juillet et de septembre de 1997, 1998 et 1999 (dans 3 sites de la baie de Tuktoyaktuk). Enfin, au cours de chacun des mois de juillet et septembre 1997, 1998 et 1999, le cisco arctique était capturé au moyen de sennes, marqué, puis remis à l'eau dans la baie de Tuktoyaktuk (n = 1835).

Cette étude a démontré que le cisco arctique se sert de la baie de Tuktoyaktuk comme zone d'hivernage, mais pas comme zone de frai : 1) absence totale d'individus reproducteurs de l'année courante dans les prises de septembre au moment où le cisco faisait son entrée dans la baie pour sa période d'hivernage; 2) un spécimen de cisco arctique a été marqué lors de son entrée dans la baie en septembre 1998, puis il a été capturé de nouveau à sa sortie en juillet 1999; et 3) des spécimens de cisco arctique, de cisco sardinelle (*Coregonus sardinella*) et d'inconnu (*Stenodus leucichthys*) ont été capturés dans des trous forés dans la glace de mer au printemps de 1998 et de 1999. La distribution selon la taille et selon l'âge des prises de cisco arctique dans la pêche de subsistance par rapport à celles des filets d'échantillonnage était statistiquement différente en raison de la sélectivité de différents types d'engin de pêche. Les conclusions sur la distribution selon la taille et selon l'âge, les profils de croissance, la sélection des proies et les comportements migratoires de cette étude sont semblables aux conclusions de l'étude de Bond effectuée il y a 20 ans (1982).

L'assurance et le maintien de la qualité et de la quantité des habitats pour l'hivernage du poisson dans la baie de Tuktoyaktuk représentent un enjeu important pour la communauté de Tuktoyaktuk, les organismes gouvernementaux de réglementation et l'industrie de la pêche. Il pourrait y avoir des répercussions négatives sur les populations halieutiques si l'habitat d'hivernage était détruit par l'activité anthropique.

Mots clés: cisco arctique, *Coregonus autumnalis*, hivernage, pêche de subsistance, distribution selon l'âge et selon la taille, prise par unité d'effort, diversité des poissons.

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INTRODUCTION

In North America, Arctic cisco (*Coregonus autumnalis*) are found along the Arctic coast, from Point Barrow, Alaska, to Bathurst Inlet (Scott and Crossman 1973). They are common along the Yukon coast and at Herschel Island, throughout coastal waters of the Mackenzie Delta, in Tuktoyaktuk Harbour and in other locations such as Kugmallit Bay and along the Tuktoyaktuk Peninsula, in Liverpool Bay and Husky Lakes, and in Franklin and Darnley Bays (Bond 1982).

Major summer feeding and rearing areas for Arctic cisco are located in bays and lagoons along the Beaufort Sea coast (Lawrence et al. 1984). During late summer and fall, large numbers of mature coregonids including Arctic cisco pass through the Mackenzie River delta, migrating upstream to over-wintering sites located throughout the Mackenzie system. Extensive movements of coregonids also occur along the coast of the Tuktoyaktuk Peninsula, as fish migrate between over-wintering sites and summer feeding areas.

Arctic cisco occupy a variety of coastal near shore habitats, but seldom enter freshwater except for spawning and over-wintering (Craig and Mann 1974). They are generally more tolerant of saline water than other coregonid species found in the area (Galbraith and Hunter 1975). Spawning takes place during fall in the major tributaries of the Mackenzie River such as the Peel, Arctic Red, and Great Bear rivers, and in the Liard River upstream of Fort Simpson (Bond 1982). While some Arctic ciscoes mature at 6 y, most mature at 7 or 8 y.

Subsistence fish harvesters catch anadromous coregonids during their migrations. Arctic cisco is known locally as "herring", different from "blue herring" which is the local term for Pacific herring (*Clupea harengus pallasi).* In the Tuktoyaktuk Harbour area, Arctic cisco harvesting takes place primarily during their out-migration in July, and then later in September when they return for over-wintering (Bond 1982). In addition, residents of Tuktoyaktuk harvest Arctic cisco through the ice in the harbour during October. Some residents of Tuktoyaktuk had raised the question as to whether or not Arctic cisco actually spawn in Tuktoyaktuk Harbour.

The purpose of this study was to document the type and relative abundance of fishes in Tuktoyaktuk Harbour in three seasons (spring, summer and fall), focusing on Arctic cisco, their life history and the associated subsistence fishery. This study builds on similar work completed in Tuktoyaktuk Harbour in 1979-1981 (Bond 1982).

STUDY AREA

Tuktoyaktuk Harbour is located on the Tuktoyaktuk Peninsula, in the eastern Mackenzie River delta in the Northwest Territories (NT). The Harbour is approximately 6.5 km long and up to 1.8 km wide. Maximum water depth is 26 m, but is less than 10 m in most areas. The shoreline consists of medium to fine sandy sediments, and the landscape surrounding the Harbour consists of tundra vegetation over permafrost. There are numerous bays in the Harbour and there are three sources of freshwater to the Harbour: Freshwater Creek, Mayogiak Inlet, and Reindeer Creek (Fig. 1).

THE FISHERY

Many residents of the Inuvialuit community of Tuktoyaktuk, NT, with an estimated human population of 943 (www.statscan.ca), continue to pursue a subsistence lifestyle which includes fishing, hunting and trapping. Residents actively fish in Tuktoyaktuk Harbour for subsistence purposes, primarily during the summer and early fall months when the Harbour is free of ice. Fish harvesters use primarily 89 mm and 102 mm gillnets, set perpendicular to the shore in the Harbour. The subsistence catch of Arctic cisco is substantial and fluctuates considerably among years, with an annual average catch of 13,828 fish from 1987-2003 (Appendix A).

MATERIALS AND METHODS

SUBSISTENCE FISHERY ASSESSMENT

Each year from 1997 to 1999, four local fish harvesters were hired as fish monitors for five days in both July and September, to sample and measure their catches during the peak of the subsistence fishery for Arctic cisco (Table 1). They kept detailed records of number of nets, mesh size, net length, fishing locations and times, and number and type of fish caught. The monitors fished at 14 neighboring but different sites in Tuktoyaktuk Harbour throughout the three years of the study (Fig. 1).

Nine different fish harvesters participated in the study. The monitors were selected by the Tuktoyaktuk Hunters and Trappers Committee (HTC) and were trained by Fisheries and Oceans (DFO) technicians. Frank Pokiak was the project coordinator in all years, and worked with the community fish harvesters at all times to monitor the quality of the data collected.

Each day, each fish monitor randomly selected ten Arctic cisco for dead sampling from the subsistence catches. Sex was determined, gonads were weighed, and the fish were measured for fork length, round weight, and gonad weight, and aging structures were removed. The fish monitors retained their fish after sampling for subsistence use.

TEST NETTING ASSESSMENT

Spring

During April 27-May 4, 1998 and May 18-21, 1999, a single 25 m gillnet (mesh 63 mm in 1998 and 76 mm in 1999) was set vertically in the water column at known deep locations in Tuktoyaktuk harbour (5 sites in 1998, 2 sites in 1999 (Fig. 1)), to determine if and what type of fish were using the Harbour for over-wintering. The net was checked every 6-12 hours, usually in the late morning and late evening. Angling through holes drilled in the ice (known locally as jiggling or hooking) was also conducted at these locations for a total of 17.5 h in 1998. The test net was set at sites where fish were caught in earlier studies in Tuktoyaktuk Harbour (Bond 1982), including the deepest area of the central Harbour (Fig. 1).

Summer and fall

One or two standard gang monofilament gillnets, each with 1.5 m or 3.0 m panels (meshes 38 mm, 64 mm, 89 mm, 114 mm, 140 mm) and a total length of either 23 or 46 m, were set perpendicular to shore, 24 h per day, for up to 7 d in each of July and September 1997, 1998, and 1999 (Table 1). The test nets were set at three different sites, two of these in the central area of the Harbour and one in the West Entrance area (Fig. 1, Table 1). Nets were checked twice per day, late morning and late evening.

Fish that were caught in the test nets were identified to species, sexed and measured for fork length (±1.0 mm) and round weight (±25 g). In addition, gonad weight was measured for Arctic cisco (±1 g). Otoliths were removed for aging purposes from all Arctic cisco. Otoliths were also removed from broad whitefish (*Coregonus nasus*) and inconnu (*Stenodus leucichthys*) caught in the test nets, but these data will be reported separately. Food habits were examined by a gross examination of the stomachs of Arctic cisco in the field to determine if there were contents present or not. A sub-sample of stomachs from Arctic cisco caught in July 1997 was frozen for later identification of contents in the laboratory.

Most fish caught in the test nets were sacrificed for life history analyses. After sampling, all of the fish captured in the test nets were distributed amongst community members for use as human or dog food. If a catch was particularly large, a representative sub-sample was taken and the remainder returned to the water after their numbers were estimated.

Tagging

Arctic cisco were captured specifically for tagging purposes using a beach seine net, cast in the east entrance of Tuktoyaktuk Harbour during each of July and September in 1997, 1998 and 1999. The Arctic cisco were marked with green KR series (1997), pink TH series (1997 and 1998) and yellow TH series (1999) plastic Floy ('spaghetti') tags. Tags were inserted with a Dennison tagging gun between the basal pterygiophores below the posterior portion of the dorsal fin. Tags and the tagging gun and needle were sterilized in Betadyne solution between tagging of each fish, to prevent the spread of disease and bacteria. Tagged fish were measured for fork length before they were released.

LABORATORY ANALYSIS

Sagittal otoliths were removed for aging purposes, from all Arctic cisco, inconnu and broad whitefish caught in the test nets and from the fish monitor's daily sample of Arctic cisco. The otoliths were placed in a scale envelope for later age determination. Age determinations were made by the Inuvik Aging Lab according to Nordeng (1961).

Frozen stomachs were thawed in warm water, washed with cold water over a 250 μm sieve that was stacked on a 63 μm sieve. Contents were flushed into a glass tray and viewed with a magnifying lens. Food items were identified to Class, enumerated, and wet weight recorded. Percent occurrence of the various taxa was determined as the number of individuals of a given prey type/total number of prey items in the stomach overall x 100.

DATA ANALYSIS

Catch-per-unit-effort (CPUE) was calculated for both the test netting and the subsistence fishery as the number of fish caught/100 m net/24 h, for each species by month, year, and overall.

Frequency distributions for Arctic cisco length and age were calculated for each gear type (subsistence gillnet versus experimental net), separately for the sexes, and by year and month of the study.

Comparisons between the age and fork length of Arctic cisco caught in the subsistence fishery and caught by the test nets were done (separately for each sex) using a Kolmogorov-Smirnov (K-S) two sample test for equality of distributions (SAS 1990; Sokol and Rohlf 1981).

Mean fork length-at-age, for each year class, by sex, was calculated for Arctic cisco captured in the test nets and in the gillnet subsistence fishery in 1997, 1998 and 1999, and plotted to depict annual growth.

Fulton's condition factor (K) was calculated according to the formula (Anderson and Gutreuter 1983), for each age class and sex:

$$K = \frac{W \times 10^5}{L^3}$$

, where W = round weight (g) and L = fork length (mm).

Gonad weight was determined to quantify gonad development using the gonadosomatic index (GSI). Gonads were removed from the fish in the field and weighed fresh to the nearest g. GSI values were calculated as: GSI = Gonad Weight / Fish Round Weight x 100. GSI values were plotted against fork length for July and September, separately for each sex. Mean GSI was calculated for the entire sample, for each sex. The GSI values that were used to classify Arctic cisco as mature or immature were determined from visual examination of the plots described above. Threshold GSI values were used to determine the percent of mature males and mature females in the samples, for each of July and September.

A catch curve was constructed by plotting the running average of three age frequencies against log age using SAS (1990). Instantaneous mortality rate (Z), was then calculated using a least squares regression on the descending limb of the catch curve. Only age groups that were fully recruited into the catch were used (9-14 y 1997; 8-12 y 1998; 6-9 y 1999) following Ricker (1975). Annual survival rate (S) and annual mortality rate (A) were also calculated.

RESULTS AND DISCUSSION

TIMING AND COMPOSITION OF THE CATCH

A total of 19 species were captured in Tuktoyaktuk Harbour during the three years of the study (Table 2, Appendix C). During spring, netting effort was undertaken at five sites in Tuktoyaktuk Harbour in 1998 (26 sets, 151 h using 63 mm mesh gillnet, set vertically plus 17.5 h jiggling) and at two sites in 1999 (13 sets, 127 h, using 76 mm mesh gillnet, set vertically). Species that were caught in the spring sets were Arctic cisco (n = 5), least cisco (n = 2), Pacific herring (n =

4), inconnu (n = 6), burbot (*Lota lota*) (n=1) and one unidentified flounder. All fish were caught in the deepest parts of the net sets.

During July and September, the total test netting catch for all three study years combined was 5867 fish (Table 3, Appendix D). Approximately half of the catch consisted of marine species (48.2%) and the other half anadromous coregonids (51.8%). The most abundant species in the test net catches were rainbow smelt (34.5%), Arctic cisco (18.1%), broad whitefish (14.7%), and least cisco (12.5%). Bond (1982) reported Arctic cisco comprised 19.2% of their combined catches in Tuktoyaktuk Harbour, similar to the findings of this study.

The majority of the subsistence catch was caught during July (16.6%), August (18.6%) and September (52.6%). The average number of fishermen (in a given month) reporting catches from Tuktoyaktuk Harbour during July, August and September was 12.3, but ranged from 0 to 39 (Appendix B; Joint Secretariat 2003; Stephenson 2004).

The total subsistence fishery for all years (7458 fish) consisted of primarily anadromous coregonids (89.6%), with only 10.4% of the catch comprised of marine species (Table 3). Arctic cisco dominated the catch (51.4%) followed by broad whitefish (27.4%) and inconnu (9.6%). Rainbow smelt and least cisco were rarely captured by the subsistence fishery despite being frequently captured by test nets (Table 3).

The species composition of July test netting catches was different than July subsistence fishery catches each year (Fig. 2), owing to the difference in gear type used. Test net catches were generally more diverse than subsistence fishery catches and large numbers of marine species were captured in 1997 (57% of catch) and 1999 (78% of catch). The timing, gear and location of the July subsistence fishery tended to target Arctic cisco in both July and September.

Test net catches were more similar to subsistence fishery catches in September than in July (Fig. 3), because more anadromous fish were present in the Harbour prior to over wintering and thus available for capture by the test nets. Fewer marine fish were captured by test nets in September (14-25% of catch) and migratory coregonids dominated both catches.

CATCH PER UNIT EFFORT

Arctic cisco and least cisco were captured by test nets more frequently in September than July (Fig. 4). CPUE for Arctic cisco was generally higher than most other species at all times of the year for the subsistence fishery, and this was the case for most of the fishing locations when they were examined separately.

On average, broad whitefish catches ranked second or third in importance in both the subsistence and test net catches, in both July and September (Fig. 4). CPUE for rainbow smelt was higher in July than September for all years, particularly in July 1999 when large numbers were captured (Fig. 4). CPUE for all other species was generally low for both test netting and the subsistence fishery (Fig. 4).

Tagging

Over a three year period, 1997-1999, 1835 Arctic cisco were tagged. One Arctic cisco that was tagged moving into Tuktoyaktuk Harbour in September 1998, was recaptured the following July in the subsistence fishery in the Harbour, during it's out migration following break up.

BIOLOGICAL ASSESSMENT

Length, age and growth

Arctic cisco caught in test nets ranged in size from 180-500 mm, with a mean overall fork length of 356.6 ± SE 1.3 mm (n = 564) for females and 333.6 mm ± SE 1.47 mm (n = 466) for males (Fig. 5). Size of Arctic cisco captured in the subsistence fishery ranged from 240-450 mm with a mean fork length of 367.3 mm ± SE 0.9 mm (n = 672) for females and 353.0 mm ± SE 0.95 mm (n = 406) for males (Fig. 5).

The subsistence fishery tends to target larger Arctic cisco than the test netting, due to differences in gear type. The length frequency distributions of Arctic cisco caught in the subsistence fishery were statistically different from the test net (KS_a = 5.087647; $p>KS<0.001$) for males and (KS_a = 3.4985280, $p>KS_a<0.0001$) for females. This is due to differences in selectivity between the fishing gear.

A total of 2039 Arctic cisco were aged as part of this study, averaging 7.9 y (SD 1.6) and ranging from 5-4 y. The majority (90.3%) were in the range from 6-10 y. The Arctic cisco subsistence catch (n = 1087) ranged in age from 5-14 y with three peak age classes (7, 8, 9 y; mean 8.1 ± SE 0.05 y; median 8.0 y (Fig. 6) being targeted by this fishery. Arctic cisco caught in the test nets (n = 1001) had a similar age range of 4-14 y, and a mean age of 7.7 ± SE 0.05 y. However, there was only one peak age class in the test net catches (7 y) (Fig. 6). These differences among the age distributions between the test netting and the subsistence fishery were statistically significant for both females (KS_a = 2.189977, $p>KS_a$ = 0.0001) and for males (KS_a = 3.009618, $p>KS_a<0.0001$).

Instantaneous mortalities (Z) calculated from the catch curves for 1997-1999 ranged from 0.918 (1997), to 0.615 (1998) to 1.162 (1999). The annual mortality rate was similar among all three years of the study, lowest in 1998 (Table 4).

Arctic cisco from Tuktoyaktuk Harbour grew at a rapid, almost constant rate through age 7 y (Fig. 7, Appendix E and F), by which age a mean fork length of 362 mm was reached for females and 348 mm for males (Table 5). Beyond age 7, little increase in mean fork length occurred in either sex. Females were generally larger than males, as has also been reported by Bond (1982) and Griffiths et al. (1975, 1977).

Sex ratio and maturity

Female Arctic cisco outnumbered males in all age classes of 7 y and greater (Table 5). The percentage of females in the catch was 55% for the test netting, and 62% for the subsistence fishery. Similar results skewed toward females in the catches were reported by Bond (1982) for Tuktoyaktuk Harbour, and by Craig and Mann (1974) for Alaskan waters. The opposite has been reported by other authors in other areas (Griffiths et al. 1975, 1977; Percy 1975). The variation in observed sex ratios suggests that male and female Arctic cisco may differ in their coastal migration patterns (Bond 1982).

Mean GSI ranged from 0.01-10.48 for female Arctic cisco and from 0 to 3.2 for male Arctic cisco. Scatter plots of GSI against fork length (Fig. 8) suggest thresholds for maturity of GSI 3.0 for females and GSI 0.25 for males. Given these thresholds, the proportion of mature fish was 21.5% for females and 29.9% for males in the July samples, and 0% and 7%, respectively for the September samples (Table 6). The lower GSI values for the month of September reflect the fact that the current year spawners had by then left the Harbour to return to the Mackenzie River for spawning.

Food habits

A total of 2026 Arctic cisco stomachs were examined during this study, of which 84.5% were empty. Bond (1982) also found most Arctic cisco had empty stomachs during his 1979-1981 studies in Tuktoyaktuk Harbour, reporting that they do not feed at the time of migration. However, the trend was not consistent among years in this study, with more than half of the cisco having food in their stomachs in July and September of 1998 (Table 7), and with virtually all stomachs in 1997 and 1999 being empty. The year 1998 appeared to be one of unusually high productivity in the Western Arctic. This may have been caused by El Nino conditions that year which lead to light sea ice conditions and break-up occurring 3 weeks earlier than usual (Skinner et al. 1998; Harwood et al. 2000). This appeared to have enhanced the productivity of the ecosystem, although the mechanism is not clear.

The more detailed analysis of stomach contents from 210 Arctic cisco sampled in July 1997 revealed nematodes, bivalves, acanthocephalans, and copepods were common prey items. Of the stomachs examined (n = 210), 68% had trematode parasites and 21.5% of these were classified as being heavily parasitized ($\geq$20 trematodes). Bond (1982) reported a smaller proportion of stomachs with trematode parasites (52%) in the 35 Arctic cisco stomachs they examined.

SUMMARY

Tuktoyaktuk Harbour provides habitat for at least 19 species of fish, including anadromous, freshwater and marine species. During July and September, the total test netting catch for all three study years combined was 5867 fish. Approximately half of the catch consisted of marine species, and the other half anadromous coregonids. The most abundant species in the test net catches were rainbow smelt, Arctic cisco, broad whitefish, and least cisco. The subsistence fishery consisted of primarily anadromous coregonids, with only 10.4% of the catch comprised of marine species. Arctic cisco dominated the subsistence catch, followed by broad whitefish and inconnu (9.6%).

Test net catches were generally more diverse than subsistence fishery catches owing to a different gear type. Marine species were well represented in the July test net catches. The timing, gear and location of the July subsistence fishery tended to target anadromous coregonids in both July and September.

Our study provides additional baseline information about the timing and type of use of Tuktoyaktuk Harbour by Arctic cisco. The absence of current year spawning Arctic cisco in the September catches reaffirms the conclusions in Bond (1982) that Arctic cisco do not spawn in the Harbour, but rather use it for over-wintering during non-spawning years. Further evidence of over-wintering was found with the tag return data. Catches of Arctic cisco, least cisco and inconnu through the ice in spring indicated these anadromous species were using the harbour for over-wintering during 1998 and 1999. Our results also showed that Arctic cisco size, age, growth, food habits, and migration patterns in 1997-1999 were similar to that found in 1979-1981 (Bond 1982).

The annual subsistence fishery for Arctic cisco is very important to the community, although highly variable. The average annual take is approximately 14,000 fish, but has varied from 4,500 fish to 34,300 fish. Researchers have suggested that the availability of Arctic cisco to the fishery appears linked to prevailing wind conditions at the time when young of the year are dispersed to either the east or the west (Bond and Erickson 1997). They speculate that summer winds play an important role in the dispersal of age-0 Arctic cisco along the Beaufort Sea coast, which in turn may be reflected in the strength of the fishery in Tuktoyaktuk Harbour 7-8 y later.

An important issue facing communities and regulators is the maintenance of the quality and quantity of over-wintering habitat in the Tuktoyaktuk Harbour area. The harbour is used by a wide variety of marine and anadromous species, supports a large subsistence fishery, and yet is vulnerable to degradation as it is the only deep water harbour in the vicinity of the Mackenzie River delta. Extensive dredging in the 1980's was reported by community residents to have led to the temporary degradation of over-wintering habitat and a downturn in fish populations was observed for several years following (F. Pokiak, pers. comm.).

Fish populations could be negatively impacted again in the future if over-wintering habitat is compromised by anthropogenic activity. The presence and abundance of fish in the Harbour may be an indicator of habitat quality. Fisheries monitoring (CPUE, biological parameters) provides a mechanism by which use of the Harbour by over-wintering fish can be determined.

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Table 1: Summary of sampling periods in Tuktoyaktuk Harbour, 1997-1999.

Year	Month	Location[2]	Sampling Period	Number of sets	Number of hours fished[1]
Test Netting					
1997	July	58	July 15-28	25	296
1997	September	52	September 16-21	6	111
1998	July	58	July 13-19	14	135
1998	September		September 15-20	5	103
1999	July	58	July 12-18	9	125
1999	September	61	September 16-21	6	79
Subsistence Fishery					
1997	July	33, 52, 53, 62	July 14-20	47	467
1997	September	22, 30, 52, 53, 54, 55, 56, 62, 63	September 16-21	42	423
1998	July	7, 52, 55, 57, 66	July 13-17	33	431
1998	September	7, 33, 52, 54	September 15-19	29	507
1999	July	52, 53, 54, 59	July 13-17	21	246
1999	September	53, 54, 59, 62	September 17-21	23	418

[1]Time rounded to the nearest hour.
[2]Locations shown Fig. 1

Table 2: Scientific and common names of all fish species caught in Tuktoyaktuk Harbour during this project, 1997-1999.

Scientific Name	Common name	Code
Family Clupeidae		
Clupea harengus pallasi Valenciennes	Pacific herring (blue herring)	PCHR
Family Salmonidae		
Coregonus autumnalis (Pallas)	Arctic cisco	ARCS
Coregonus sardinella Valenciennes	least cisco	LSCS
Coregonus clupeaformis (Mitchill)	lake whitefish (crooked back)	LKWT
Coregonus nasus (Pallas)	broad whitefish	BDWT
Coregonus artedi (Lesueur)[1]	lake herring	LKCS
Stenodus leucichthys (Guldenstadt)	inconnu (coney)	INCO
Family Gadidae		
Lota lota (Linnaeus)	burbot (loche)	BRBT
Eleginus gracilis (Tilesius)	saffron cod	SFCD
Boreogadus saida	Arctic cod	ARCD
Family Cottidae		
Myoxocephalus quadricornis (Linnaeus)	fourhorn sculpin	FHSC
Family Esocidae		
Esox lucius (Linnaeus)	northern pike	NRPK
Family Osmeridae		
Osmerus mordax dentex (Mitchill)	rainbow smelt	SMLT
Hypomesus olidus (Pallas)	pond smelt	PDSM
Family Gasterosteidae		
Pungitius pungitius (Linnaeus)	ninespine stickleback	NSSB
Family Pleuronectidae		
Liopsetta glacialis (Pallas)	Arctic flounder	ARFL
Platichthys stellatas (Pallas)	starry flounder	STFL
Family Catostomidae		
Catostomus catostomus (Forster)	longnose sucker	LNSK
Family Stichaeidae		
Acantholumpenus mackayi	blackline prickleback[2]	BLPR

[1] Lake herring reported by McPhail and Lindsay (1970) to occur in the Mackenzie system only to Great Bear Lake. Only 1 fish captured in September 1998.

[2] Designated as a vulnerable species under Canada's Species at Risk Act (SARA) and by COSEWIC (Committee on Status of Endangered Wildlife in Canada)

Table 3: Total catch and catch location for the test netting and subsistence fishery in Tuktoyaktuk Harbour, 1997-1999

	Test Netting		Subsistence Fishery	
Species	**n**	**% Total Catch**	**n**	**% Total Catch**
Marine				
Pacific herring (blue herring)	315	5.4	239	3.2
saffron cod	2	0.0	3	0.0
Arctic cod	17	0.3	4	0.1
fourhorn sculpin	239	4.1	332	4.5
rainbow smelt	2025	34.5	14	0.2
pond smelt	16	0.3		
Arctic flounder	85	1.4	1	0.0
starry flounder	126	2.1		0.0
Unidentified	5	0.1	182	2.4
Total Marine	2830	48.2	775	10.4
Anadromous/Freshwater				
Arctic cisco	1060	18.1	3837	51.4
least cisco	732	12.5	1	0.0
broad whitefish	864	14.7	2041	27.4
inconnu (coney)	283	4.8	717	9.6
lake whitefish (crooked back)	89	1.5	74	1.0
burbot (loche)	2	0.0		0.0
northern pike	3	0.1	13	0.2
ninespine stickleback	2	0.0		0.0
longnose sucker	1	0.0		0.0
lake herring	1	0.0		0.0
Total Anadromous	3037	51.8	6683	89.6
Total Catch (All species)	5867		7458	

Table 4: Instantaneous mortality, annual survival rate, and annual mortality rate for Arctic cisco taken in the Tuktoyaktuk Harbour subsistence harvests, 1997-1999.

Year	ages used in analysis	Intercept	slope	Instantaneous mortality (Z)	Annual survival rate	Annual mortality rate
1997	9-14	13.5334	-0.91872	0.91872	0.39903	0.60097
1998	8-12	10.4118	-0.61596	0.61596	0.54012	0.45988
1999	6-9	14.3634	-1.16228	1.16228	0.31277	0.68723

Table 5: Mean length at age for Arctic cisco captured in Tuktoyaktuk Harbour, 1997-1999.

	females N=1200								males n=839							sex ratio
age	N	Mean	SD	min	max	K		age	N	Mean	SD	min	max	K		F/M
						July	Sept							July	Sept	
4	0							4	5	281	12.8	265	300		0.89	
5	31	333	33.6	225	382	1.19	1.32	5	60	305	34.4	229	355	1.04	1.14	0.5
6	98	349	15.1	300	390	1.21	1.31	6	154	337	23.4	228	385	1.19	1.21	0.6
7	328	362	23.6	181	440	1.24	1.27	7	212	348	22.6	245	390	1.31	1.29	1.5
8	281	367	26.6	264	441	1.33	1.39	8	169	350	27.6	237	437	1.64	1.31	1.7
9	245	364	31.2	245	504	1.43	1.41	9	130	346	23.4	298	415	1.60	1.46	1.9
10	151	363	25.4	302	446	1.66	1.42	10	74	355	23.6	267	398	2.04	1.56	2.0
11	45	374	26.1	297	420	1.36	1.42	11	28	347	30.5	228	389	1.73	1.53	1.6
12	13	376	37.7	314	438	1.38	1.28	12	7	357	8.5	342	371		1.13	1.9
13	5	385	23.4	353	410	1.27	1.19	13	0							
14	3	447	30.6	414	474	1.26	1.27	14	0							

Table 6: Proportion of mature Arctic cisco sampled from Tuktoyaktuk Harbour, July and September 1997-1999.

	females			males		
	N	mean GSI (range)	% mature*	N	Mean GSI (range)	% mature**
July	454	2.44 (0.2-10.48)	21.50	229	0.44 (0-2.32)	29.90
Sept	326	0.30 (0.1-2.98)	0.00	233	0.21 (0-3.20)	6.70

* GSI > 3.0 for mature females, Fig. 8
** GSI of >0.25 for mature males, Fig 8

Table 7: Proportion of Arctic cisco stomachs with contents

	N	percent with contents
July		
1997	208	0.48
1998	194	59.79
1999	482	0.21
Sept		
1997	236	0.85
1998	350	52.57
1999	551	0.73

Figure 1: Map of sampling sites fished during this study in Tuktoyaktuk Harbour 1997-1999.

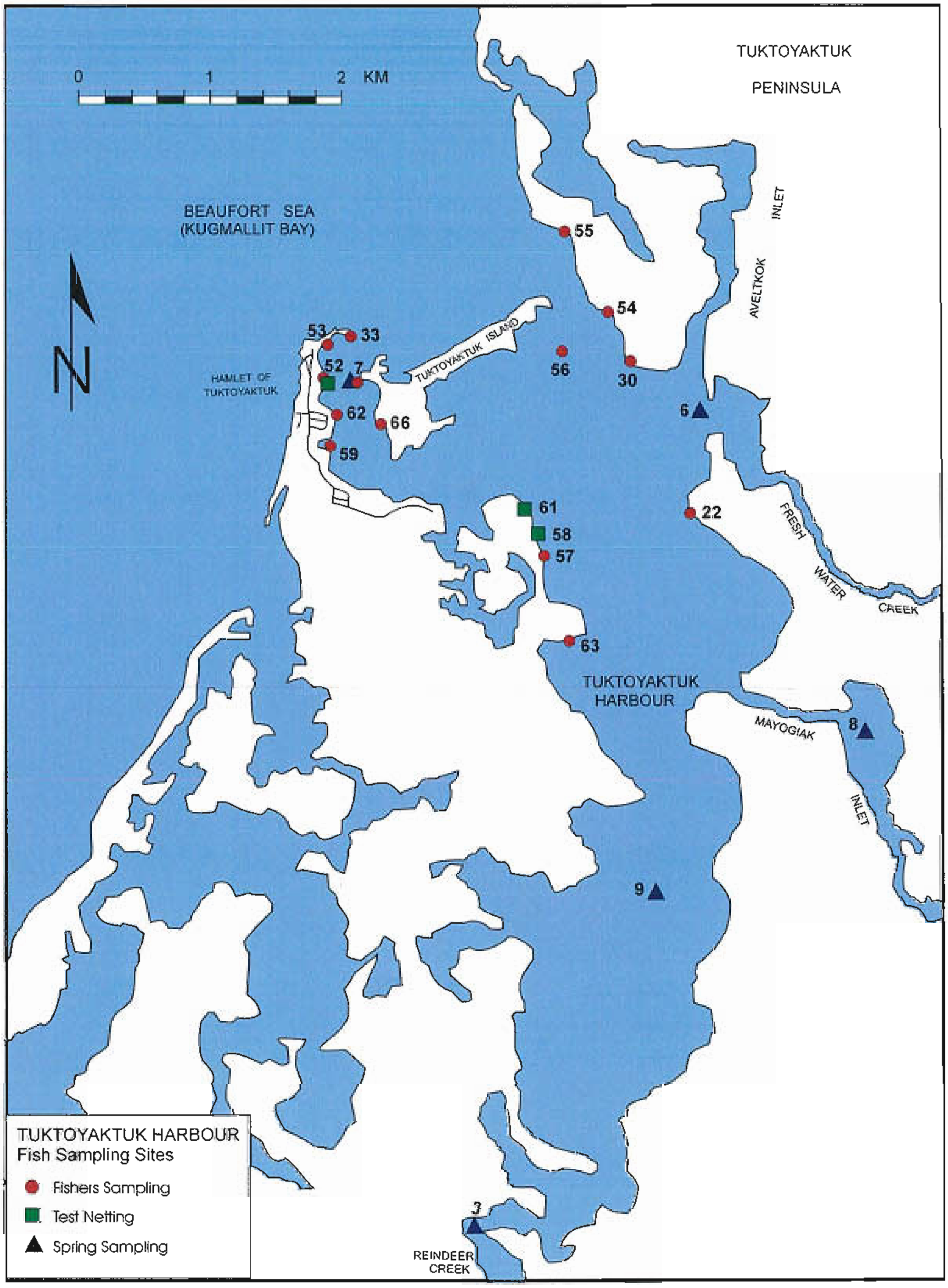
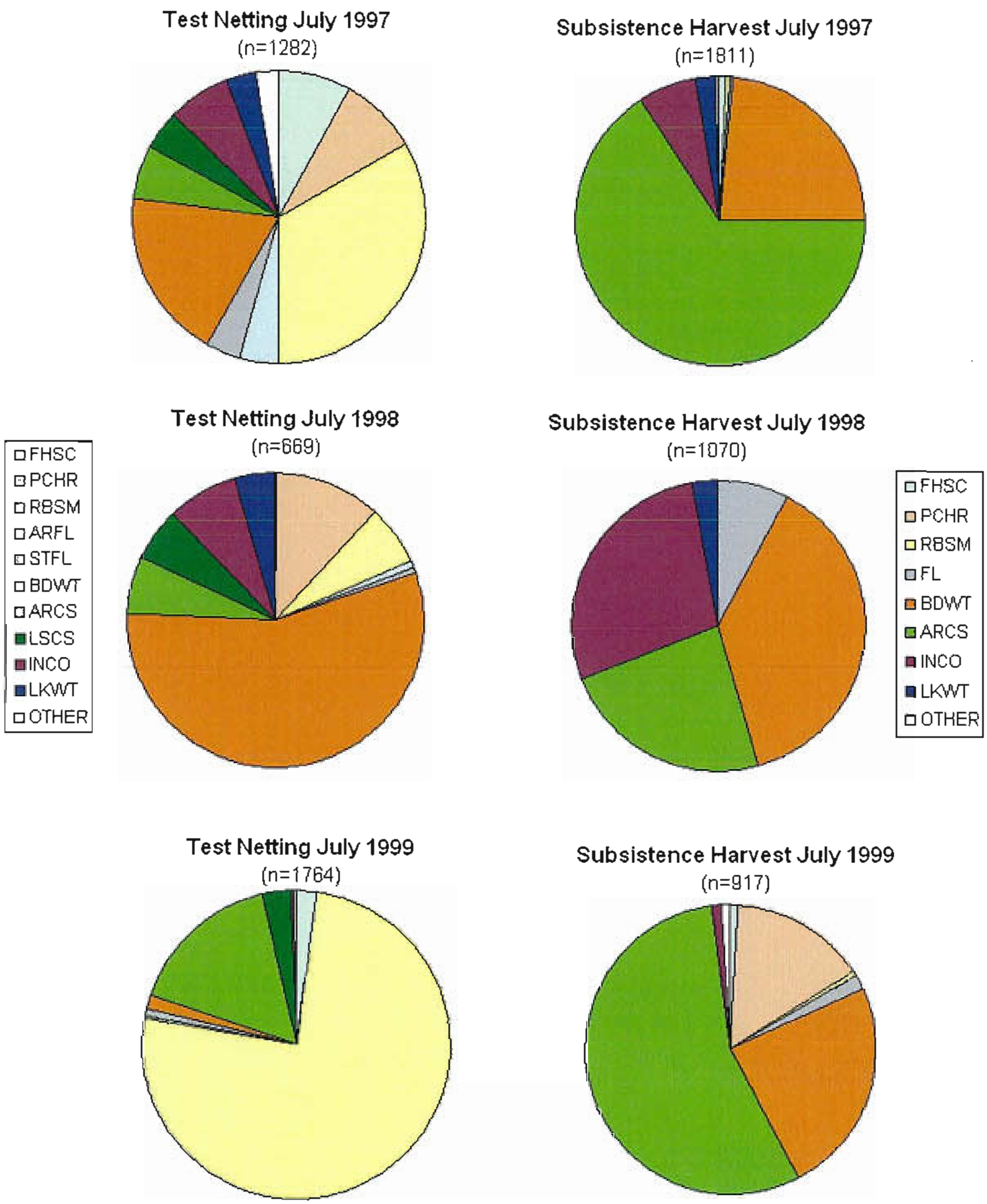
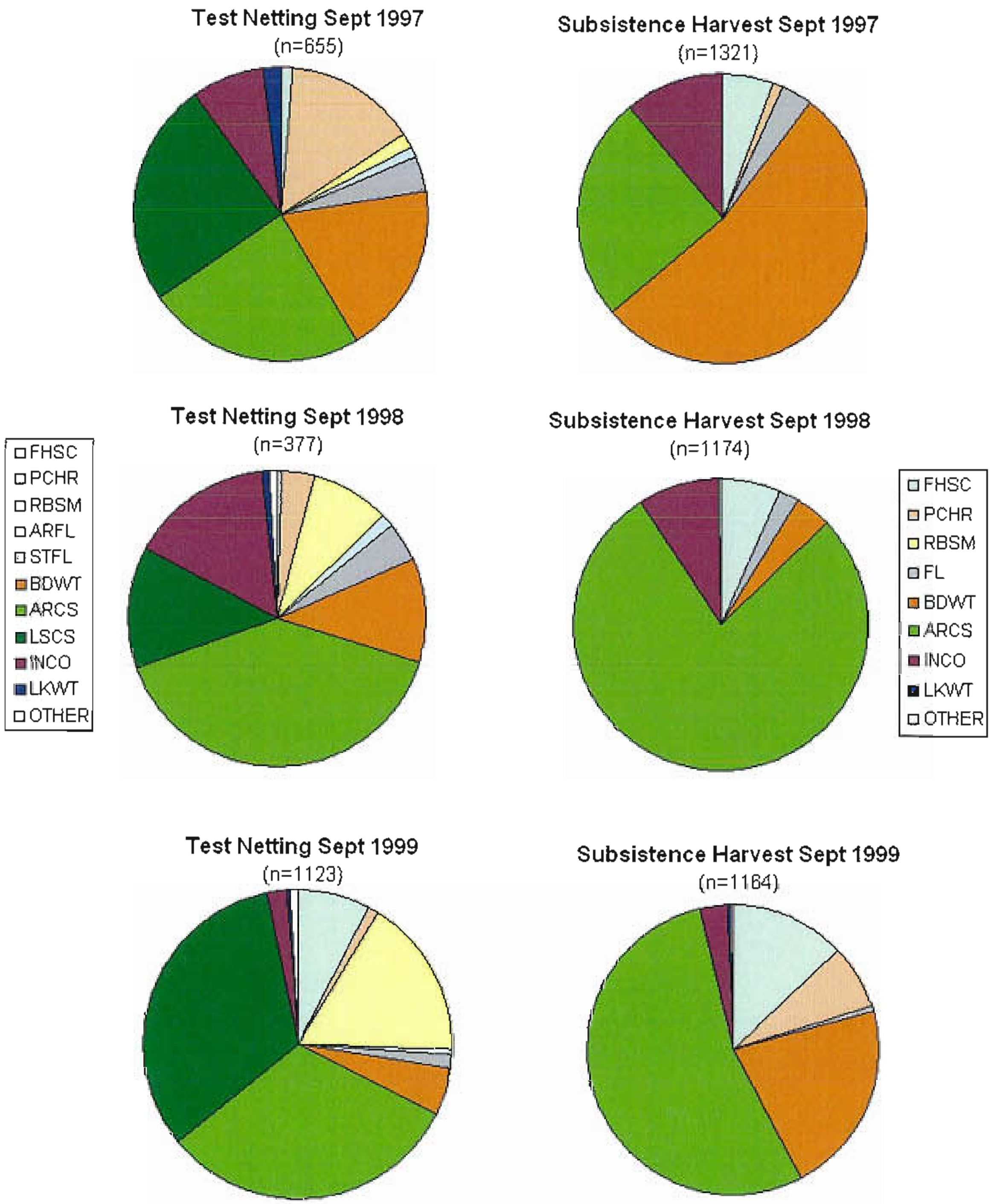


Figure 2: Species composition of the July catch each year for the test netting and subsistence harvest in Tuktoyaktuk Harbour, 1997-1999 (refer to Table 2 for species codes).



*Other includes SFCD, unidentified cod, NRPK LSCS, and ARFL

Figure 3: Species composition of the September catch each year for the test netting and subsistence harvest in Tuktoyaktuk Harbour, 1997-1999 (refer to Table 2 for species codes).



*Other includes SFCD, unidentified COD, NRPK, LSCS, and ARFL

Figure 4: Seasonal changes in CPUE for the test netting and the subsistence fishery in Tuktoyaktuk Harbour, 1997-1999. CPUE is expressed as a proportion of the maximum calculated CPUE for a single month in either fishery and for any species except rainbow smelt which were captured in very high numbers in 1999 (refer to Table 2 for species codes)

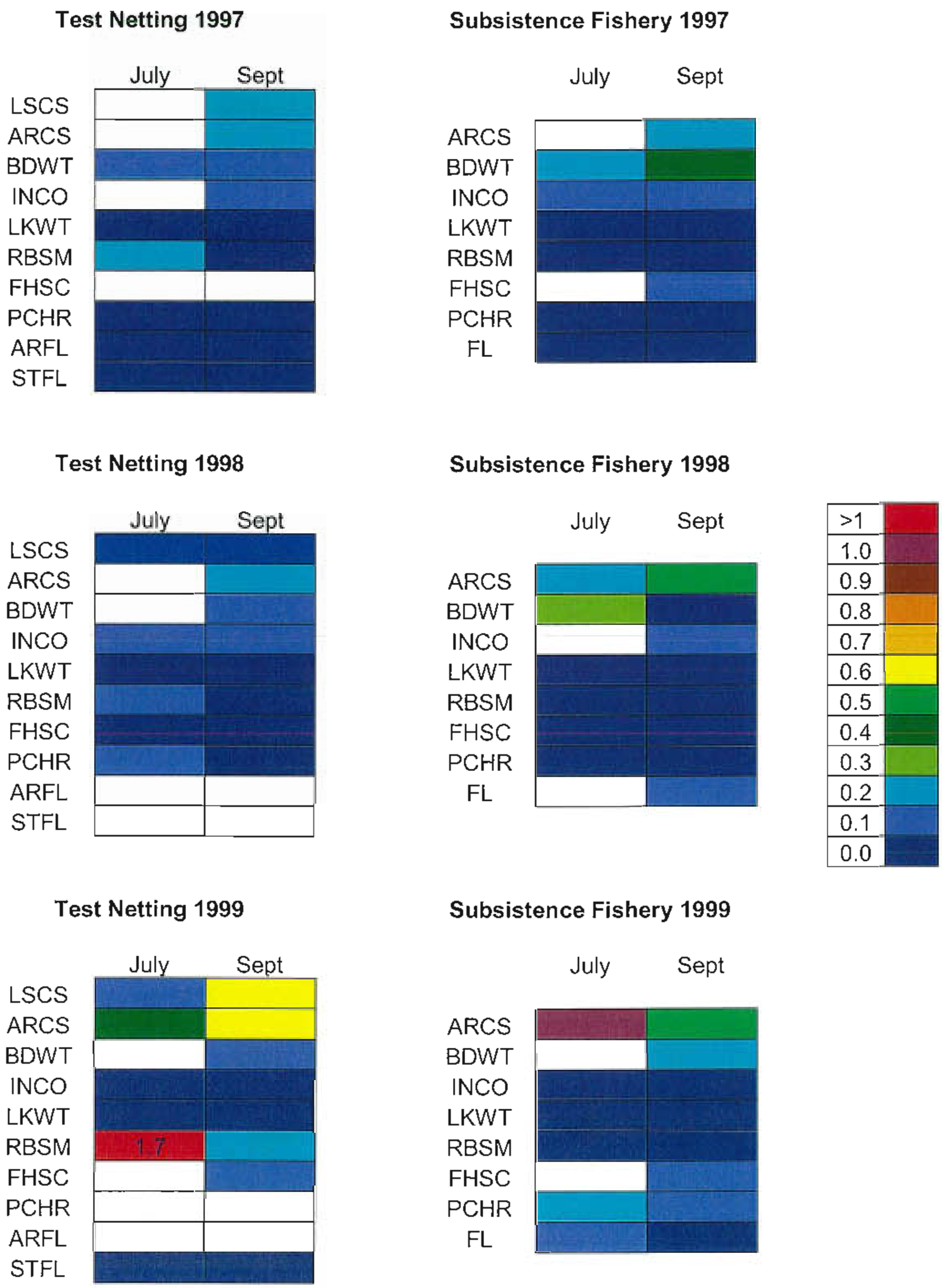


Figure 5: Mean, SE, median and frequency distribution of fork lengths for male and female Arctic cisco caught in the test netting and subsistence fishery in Tuktoyaktuk Harbour, 1997-1999.

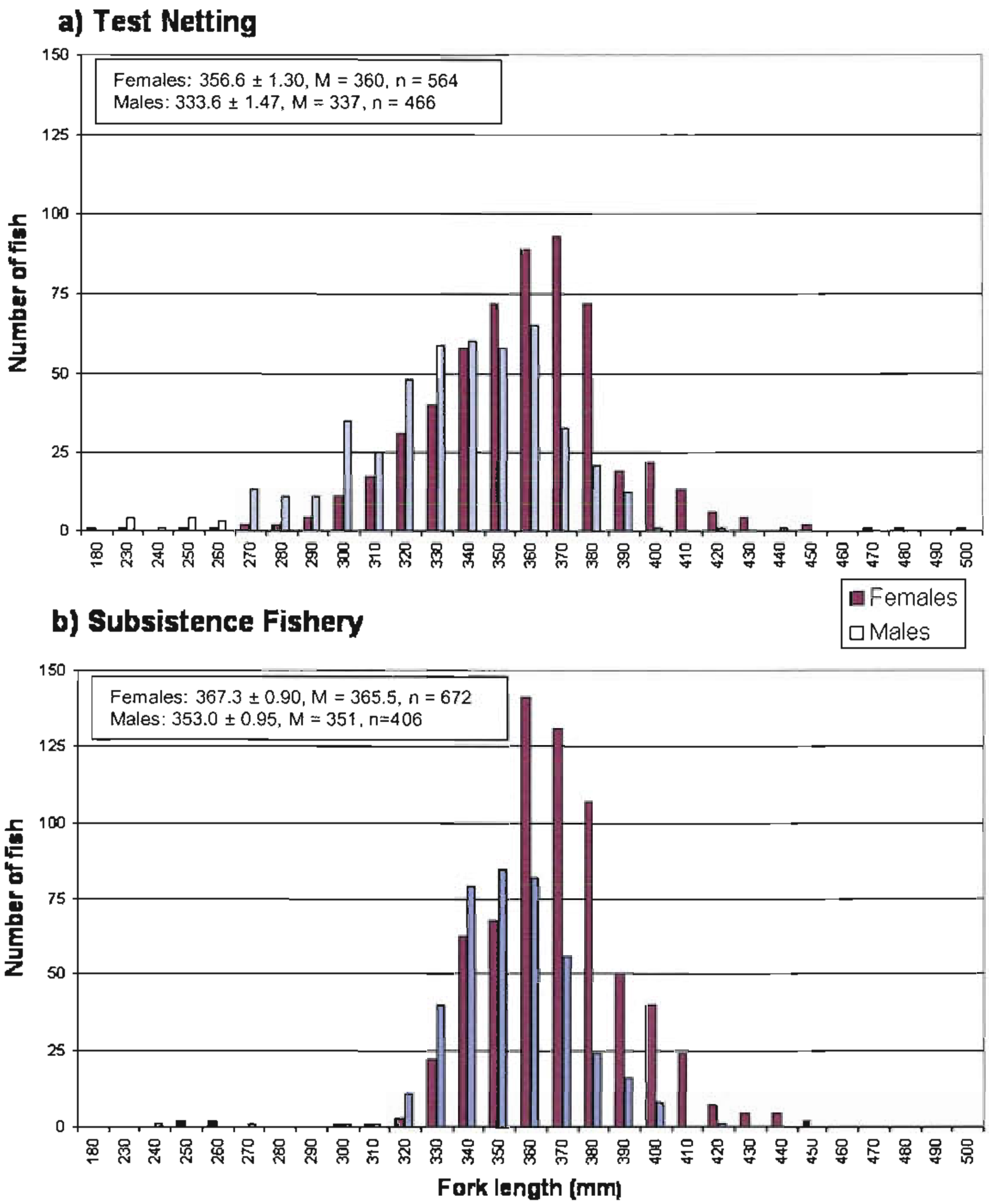


Figure 6: Mean, SE, median and frequency distribution of ages of male and female Arctic cisco caught in the test netting and subsistence fishery in Tuktoyaktuk Harbour, 1997-1999.

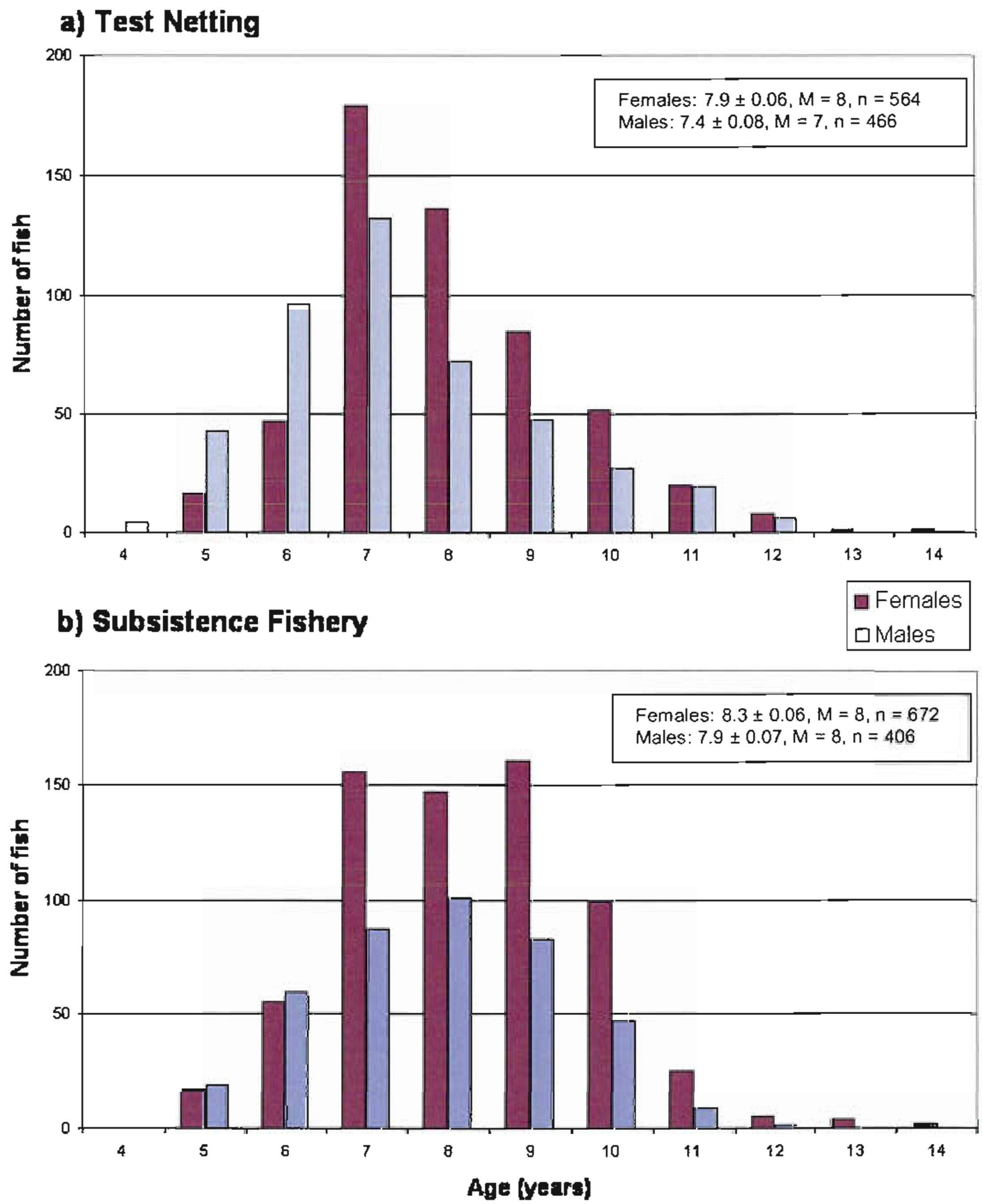
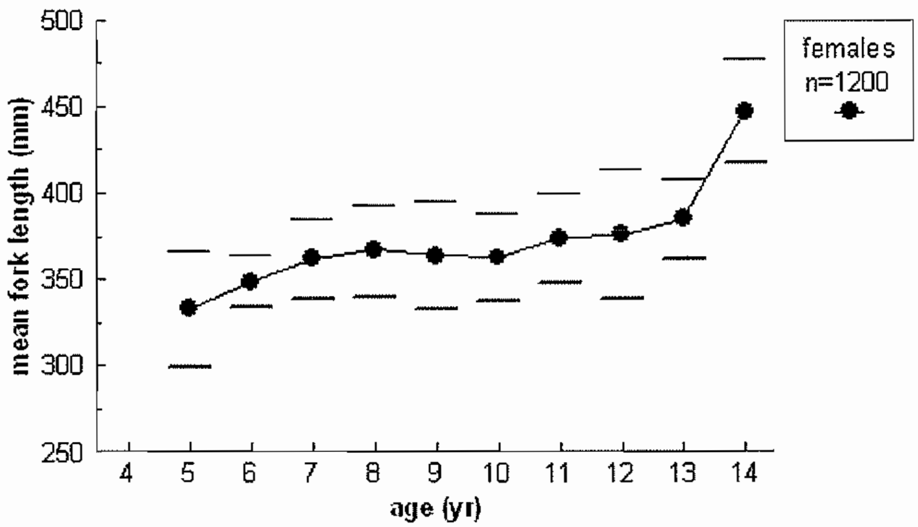


Figure 7: Mean fork length at age for Arctic cisco caught in Tuktoyaktuk Harbour, 1997-1999.



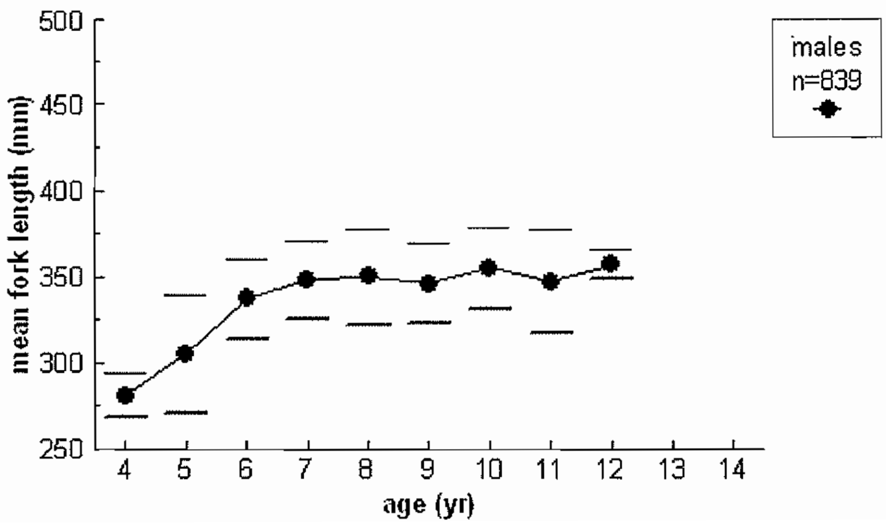
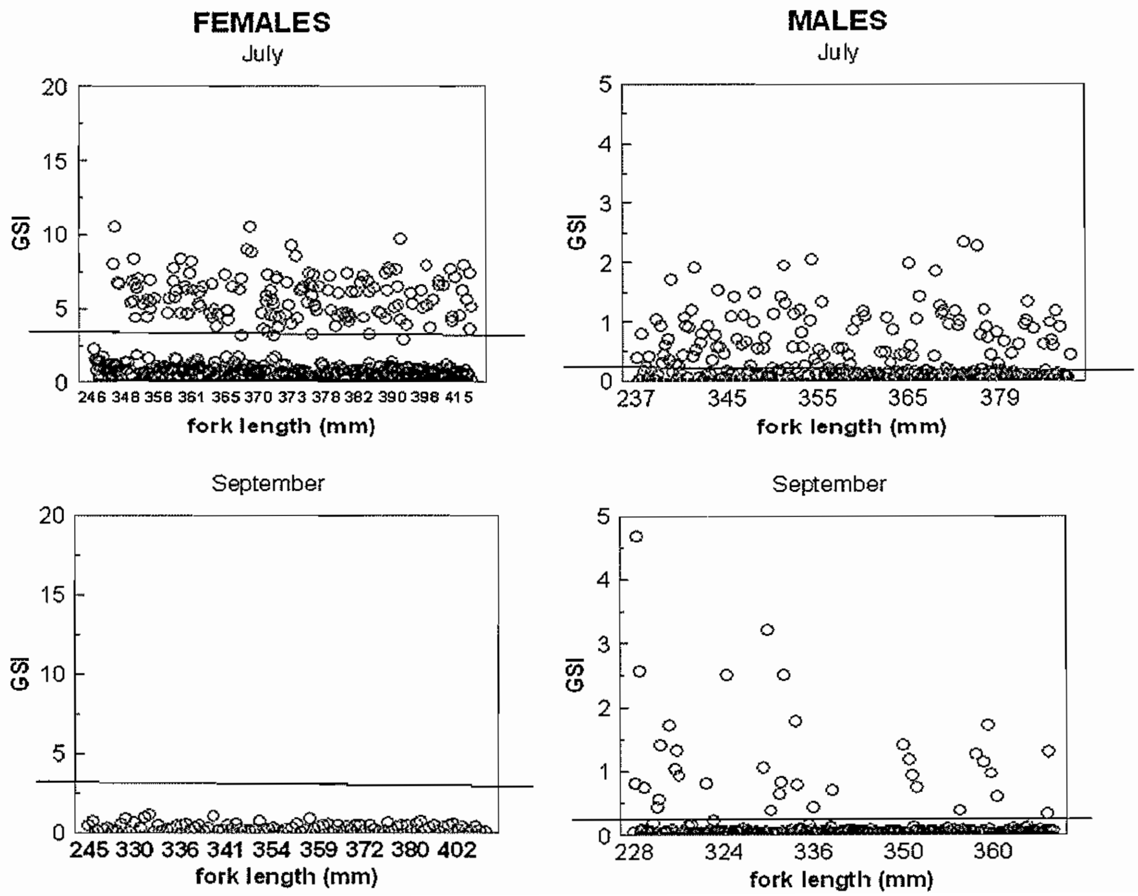


Figure 8: Gonadosomatic indices for male and female Arctic cisco caught in Tuktoyaktuk Harbour, 1997-1999 (horizontal lines indicate thresholds for maturity assumed for this study).



Appendix A: Monthly reported subsistence harvests of Arctic cisco by residents of Tuktoyaktuk, NT, 1987-2003.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yearly Total
1987	0	0	0	0	0	0	4,188	10,672	11,999	3,382	1,808	0	32,049
1988	0	0	0	0	0	0	2,100	650	31,602	0	0	0	34,352
1989	0	0	0	0	0	30	1,228	768	6,663	0	0	0	8,689
1990	0	0	0	0	0	0	1,600	2,260	6,750	3,011	2,900	0	16,521
1991	0	0	0	0	0	0	3,276	3,495	4,441	3,435	0	0	14,647
1992	0	0	0	0	0	250	2,033	1,730	1,330	110	0	0	5,453
1993	0	0	0	0	0	10	1,403	670	4,043	2,530	250	0	8,906
1994	0	0	0	0	0	0	0	740	7,390	520	0	0	8,650
1995	0	0	0	0	0	60	140	3,640	1,406	180	0	0	5,426
1996	0	0	0	0	0	110	120	2,500	1,820	0	0	0	4,550
1997	0	0	0	0	0	40	2,795	3,095	4,530	1,360	0	0	11,820
1998	0	0	0	0	0	320	2,610	3,294	4,420	3,190	0	0	13,834
1999						260	6,453	0	14,843	0			21,556
2000						500	4,153	2,452	593	622			8,320
2001													
2002													
2003						0	1,570	2,555	859	7,660	0	0	12,644
Mean	0	0	0	0	0	105	2,245	2,568	6,846	1,733	331	0	13,828
SE	0	0	0	0	0	40	454	654	2057	557	219	0	2,351
Mean % of total catch	0	0	0	0	0	0.8	16.6	18.6	52.6	9.5	2.6	0.0	

[1] Data from the Inuvialuit Harvest Study (1987-1998; Joint Secretariat, 2003) and Stephenson (2004; for 1999, 2000, and 2003)

Appendix B: Number of Tuktoyaktuk fishers reporting fish harvests to the Inuvialuit Harvest Study each month, 1987-1997.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yearly Total
1988	0	0	0	0	0	0	4	3	39	0	0	0	46
1989	0	0	0	0	0	1	5	3	4	0	0	0	13
1990	0	0	0	0	0	0	2	4	7	4	2	0	19
1991	0	0	0	0	0	3	13	14	14	10	0	0	31
1992	0	0	0	0	0	1	12	11	12	1	0	0	24
1993	0	0	0	0	0	1	14	11	13	8	2	0	31
1994	0	0	0	0	0	0	0	5	21	2	0	0	20
1995	0	0	0	0	1	2	3	32	23	3	0	0	40
1996	0	0	0	0	0	3	2	20	15	0	0	0	29
1997	0	0	0	0	0	1	27	29	19	7	0	0	40
1999						2	17	0	18	0	0	0	27
2003							13	6	8	19			28
Mean	0	0	0	0	0	1.2	8.2	13.2	16.7	3.5	0.4	0	29.3
SE	0	0	0	0	0	0.36	2.63	3.37	3.09	1.16	0.27	0.00	3.33

[1] Data from the Inuvialuit Harvest Study (1987-1998; Joint Secretariat, 2003) and Stephenson (2004; for 1999, 2000, and 2003)

Appendix C: Catch summary for test netting by year, month, and sampling location for Tuktoyaktuk Harbour, 1997-1999 (see Table 2 for species codes).

Year	Month	Location	Number of sets	Hours Fished	FHSC	PCHR	BDWT	ARCS	LSCS	INCO	RBSM	LKWT	ARFL	STFL	COD	PDSM	OTHER*
1997	7	58	25	296.15	103	112	244	72	59	88	427	42	53	49	6	16	11
1997	9	52	6	131	9	94	124	157	162	53	12	12	6	26	.	.	.
1998	7	58	14	135	1	79	374	39	40	52	43	29	5	4	.	.	3
1998	9	52	5	102.75	2	14	43	150	50	59	32	3	5	16	1	.	2
1999	7	58	9	139	38	3	24	289	52	5	1324	2	8	16	.	.	2
1999	9	61	6	78.5	86	13	55	353	369	26	187	1	8	15	10	.	.
		Total	65	882.4	239	315	864	1060	732	283	2025	89	85	126	17	16	18

*Includes NRPK, NNSB, BRBT, LNSK, SFCD, unidentified flounder, unidentified cisco, lake herring and unknown fish.

Year	Month	Location	Total Fish
1997	7	58	1282
1997	9	52	655
1998	7	58	669
1998	9	52	377
1999	7	58	1763
1999	9	61	1123
		Total	5869

Appendix D: Catch summary for the subsistence fishery by year, month, and sampling location for Tuktoyaktuk Harbour, 1997-1999.

Year	Month	Location	Number of sets	Hours Fished	FHSC	PCHR	BDWT	ARCS	INCO	RBSM	LKWT	FL[+]	NRPK	OTHER[*]	TOTAL
1997	7	33	13	96.5	.	.	33	529	36	11	6	2	1	0	618
1997	7	52	7	70	.	.	13	165	11	.	.	1	.	.	190
1997	7	53	14	192.5	.	.	97	421	46	0	.	.	.	.	564
1997	7	62	13	108	14	.	277	81	28	.	33	3	3	0	439
1997	9	22	1	24.5	4	15	6	6	4	.	.	.	.	.	35
1997	9	30	1	3	.	1	7	.	.	.	.	.	.	.	8
1997	9	52	7	98	.	.	128	37	14	.	.	1	.	.	180
1997	9	53	5	114	.	.	304	145	55	.	.	.	.	.	504
1997	9	54	2	37	15	.	20	5	9	.	.	14	.	.	63
1997	9	55	4	85.5	24	.	37	17	9	.	.	24	.	.	111
1997	9	56	8	91.65	11	.	24	33	6	.	.	.	.	.	74
1997	9	62	1	3	.	1	.	.	10	.	.	.	.	.	11
1997	9	63	13	113	22	.	176	91	37	.	.	8	.	1	335
1998	7	7	9	105.5	.	.	36	58	62	.	.	51	1	0	208
1998	7	52	5	124	.	.	165	83	44	.	4	15	.	.	311
1998	7	55	3	20.5	.	.	59	35	27	.	.	3	.	.	124
1998	7	57	4	62	1	.	21	7	5	.	1	3	.	.	38
1998	7	66	12	118.5	.	.	125	66	164	.	25	9	.	.	389
1998	9	7	9	168	.	.	8	333	32	.	.	18	.	.	391
1998	9	33	6	100	.	.	3	160	16	.	.	.	.	.	179
1998	9	52	6	80	1	.	11	108	14	.	.	.	.	.	134
1998	9	54	8	158.5	77	.	24	317	42	.	.	7	.	4	471
1999	7	52	6	53	.	.	66	213	4	.	.	.	.	.	283
1999	7	53	5	105	1	30	11	187	1	1	.	.	.	.	231
1999	7	54	5	56	9	.	38	110	5	.	.	15	7	0	184
1999	7	59	5	41.25	.	109	104	.	1	2	.	2	1	0	219
1999	9	53	10	178.5	26	.	177	415	23	.	5	.	.	4	650
1999	9	54	5	131	73	.	18	215	6	.	.	2	.	1	315
1999	9	59	2	41.5	17	12	18	.	2	.	.	2	.	.	51
1999	9	62	6	67	37	71	35	.	4	.	.	3	.	.	150
		Total	195	2646.9	332	239	2041	3837	717	14	74	183	13	6	7460

[+] Includes ARFL, STFL, and unidentified flounder.

[*] Includes SFCD, LSCS, and unidentified fish.

Appendix E: Fork lengths of female Arctic cisco caught by test nets and the subsistence fishery in Tuktoyaktuk Harbour, 1997-1999.

		Female Fork Length Test Netting (mm)					Female Fork Length Subsistence Fishery (mm)					Wilcoxon 2 Sample Test	
Year	**Month**	**n**	**Mean ± 1 SE**	**Median**	**Min**	**Max**	**n**	**Mean ± 1 SE**	**Median**	**Min**	**Max**	**z**	**P**
1997	7	12	351.2 ± 8.06	351.5	308	407	128	375.5 ± 1.96	373	312	433	-2.95	0.003
1997	9	87	333.1 ± 2.87	328	270	430	87	357.6 ± 3.21	356	245	454	-6.36	0.0001
1998	7	17	369.3 ± 11.69	364	260	504	89	369.1 ± 2.88	368	246	436	-0.046	0.645
1998	9	86	343.8 ± 3.68	349	181	474	114	362.2 ± 1.83	361.5	255	440	-5.35	0.0001
1999	7	187	374.9 ± 1.47	373	318	478	136	375.2 ± 1.42	373	339	415	0.424	0.671
1999	9	160	352.1 ± 2.06	350	225	415	118	360.1 ± 1.87	360	333	453	2.216	0.0267

Appendix F: Fork lengths of male Arctic cisco caught by test nets and the subsistence fishery in Tuktoyaktuk Harbour, 1997-1999.

		Male Fork Length Test Netting (mm)					Male Fork Length Subsistence Fishery (mm)					Wilcoxon 2 Sample Test	
Year	**Month**	**n**	**Mean ± 1 SE**	**Median**	**Min**	**Max**	**n**	**Mean ± 1 SE**	**Median**	**Min**	**Max**	**z**	**P**
1997	7	7	324.6 ± 7.07	320	306	360	51	361.2 ± 3.44	365	237	393	-3.45	0.0006
1997	9	70	323.1 ± 2.84	320	271	398	30	342.4 ± 2.89	342	314	375	4.58	0.0001
1998	7	21	338.0 ± 8.46	353	248	393	94	355.7 ± 2.14	355	267	418	-1.52	0.1292
1998	9	64	334.7 ± 3.51	337.5	228	385	86	347.7 ± 1.51	348	316	378	-2.83	0.0047
1999	7	111	354.4 ± 1.57	355	311	391	63	362.4 ± 1.96	360	338	400	2.76	0.0057
1999	9	193	324.9 ± 2.58	333	228	437	82	346.7 ± 1.73	343	318	400	5.08	0.0001

Appendix G: Age of female Arctic cisco caught by test nets and the subsistence fishery in Tuktoyaktuk Harbour, 1997-1999.

		Female Age Test Netting					Female Age Subsistence Fishery					Wilcoxon 2 Sample Test	
Year	Month	n	Mean ± 1 SE	Median	Min	Max	n	Mean ± 1 SE	Median	Min	Max	z	P
1997	7	12	9.4 ± 0.19	9	9	11	128	9.3 ± 0.10	9	7	14	0.65	0.5160
1997	9	87	9.2 ± 0.13	9	8	10	87	9.4 ± 0.13	9	7	14	-0.74	0.4609
1998	7	17	9.0 ± 0.32	9	7	11	89	8.9 ± 0.13	9	7	12	0.507	0.6123
1998	9	86	9.6 ± 0.15	10	7	14	114	8.6 ± 0.12	8	5	11	4.94	0.0001
1999	7	203	7.5 ± 0.06	7	5	10	136	7.2 ± 0.07	7	5	9	-3.11	0.0019
1999	9	159	6.9 ± 0.07	7	5	9	118	6.7 ± 0.09	7	5	9	-1.95	0.0508

Appendix H: Age of male Arctic cisco caught by test nets and the subsistence fishery during the Tuktoyaktuk Harbour Arctic Cisco Project, 1997-1999. A Wilcoxon Two-Sample test was used to test differences between age distributions of the monthly test netting male Arctic cisco catch and the monthly subsistence fishery male Arctic cisco catch.

		Male Age Test Netting					Male Age Subsistence Fishery					Wilcoxon 2 Sample Test	
Year	Month	n	Mean ± 1 SE	Median	Min	Max	n	Mean ± 1 SE	Median	Min	Max	z	P
1997	7	7	8.9 ± 0.26	9	8	10	51	9.2 ± 0.13	9	7	11	-1.03	0.3046
1997	9	70	9.0 ± 0.16	9	6	11	30	8.8 ± 0.18	9	7	12	-1.30	0.1949
1998	7	21	8.1 ± 0.25	8	6	10	94	8.4 ± 0.11	8	6	11	-1.12	0.2624
1998	9	64	9.5 ± 0.18	9	7	12	86	8.5 ± 0.11	8	7	11	4.40	0.0001
1999	7	111	7.0 ± 0.08	7	5	10	63	6.9 ± 0.10	7	5	9	-0.82	0.4100
1999	9	193	6.3 ± 0.07	6	4	9	82	6.2 ± 0.09	6	5	8	-0.83	0.4065