Fairbanks Fishery Resources Progress Report Number FY86-4

BASELINE HISTOPATHOLOGICAL AND CONTAMINANT STUDIES OF FOUR ARCTIC FISH SPECIES IN BEAUFORT LAGOON, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

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Key Words
Arctic char, Arctic cisco, Arctic flounder, fourhorn sculpin, parasites, histopathology, contaminants, Beaufort Lagoon, Arctic National Wildlife Refuge

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15 April 1986

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Baseline histopathological and contaminant studies of four Arctic fish species in Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska.

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Abstract:

Four Arctic fish species were studied at Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska in 1984 and 1985 as part of baseline fish and wildlife studies prior to potential oil and gas development. Arctic char (*Salvelinus alpinus*), Arctic cisco (*Coregonus autumnalis*), Arctic flounder (*Liopsetta glacialis*), and fourhorn sculpin (*Myoxocephalus quadricornis*) were examined for histopathological abnormalities and parasites and were analyzed for 10 heavy metals, and 16 aliphatic and 15 aromatic hydrocarbons. Overall condition and health of the fish were good and disease rates appeared low. Arctic flounder were found to be the least infected of the 4 species with histopathological lesions and parasites. Contaminant levels were generally low or below detection except for arsenic which was elevated in all 4 species. The most common parasite observed was a cestode *Bothrimonus sturionis* which was found in the digestive tract of specimens in all species examined and occurred in 100% of the Arctic char and 96% Arctic cisco samples.

Introduction

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 provided for inventory and assessment of fish and wildlife on the coastal plain of the Arctic National Wildlife Refuge (ANWR). Section 1002(c) of the ANILCA specifically required baseline studies to assess fish and wildlife population sizes and distribution, determine location and carrying capacity of habitats, and assess impacts of human activities, especially those related to oil and gas exploration and development. As part of other coastal fish investigations (West and Wiswar 1984) a baseline health study was initiated in 1984 and continued through 1985. The objectives of this study were to examine common fish species for parasites, histological abnormalities, overall condition, and background levels of selected heavy metals and hydrocarbons. This information was deemed important both in assessing existing population health and as a base to measure effects of future development in the area. Similar investigations have been conducted in recent years: diseases (McCain et al. 1978); parasites (Mudry and McCart 1976; Craig and Haldorson 1980); contaminants (West 1982).

Four of the most common species found in the ANWR coastal lagoons were chosen for study. These include Arctic char (Salvelinus alpinus), Arctic cisco (Coregonus autumnalis), Arctic flounder (Liopretta glacialis), and fourhorn sculpin (Myoxocephalus quadricornis). The Arctic char and Arctic cisco are anadromous species important to the local subsistence fishery. They are mid-water column feeders; whereas, the Arctic flounder and fourhorn sculpin, both of which inhabit brackish or nearshore marine waters year around, are primarily bottom feeders (Morrow 1980).

Study Area

The study was conducted at Beaufort Lagoon (Figure 1) approximately 60 km southeast of Barter Island, Alaska (Lat. 69° 52'N, Long. 142° 15'W). A field camp was established at Nuvagapak Point, the location of an abandoned military Distant Early Warning (DEW) Line Camp.

Beaufort Lagoon is described as a limited exchange lagoon (Hachmeister and Vinelli 1983) where the flow of nearshore waters is restricted due to the barrier island system. The lagoon is ice-covered much of the year with break-up evident usually in late June and new ice formation beginning in late September to early October. During the ice-free months the water is brackish but is influenced greatly by the large freshwater input from major rivers to the east. Salinities are low in June, 2 to 3 ppt, increasing as the summer progresses, reaching approximately 12 to 15 ppt by late August (West and Wiswar 1984).

Arctic char and Arctic cisco enter the lagoon system in mid- to late June to begin feeding intensively on epibenthic invertebrates along the open leads. Fourhorn sculpin are abundant throughout the thaw season but Arctic flounder tend only to become abundant as summer progresses (Griffiths 1983; West and Wiswar 1984). The amphipod Gammus setosus appears to be the most important single prey species to Arctic char and Arctic flounder in Beaufort Lagoon and were also found to be important, to a lesser degree, in the diet of Arctic cisco and fourhorn sculpin, (West and Wiswar 1984; Wiswar 1985).

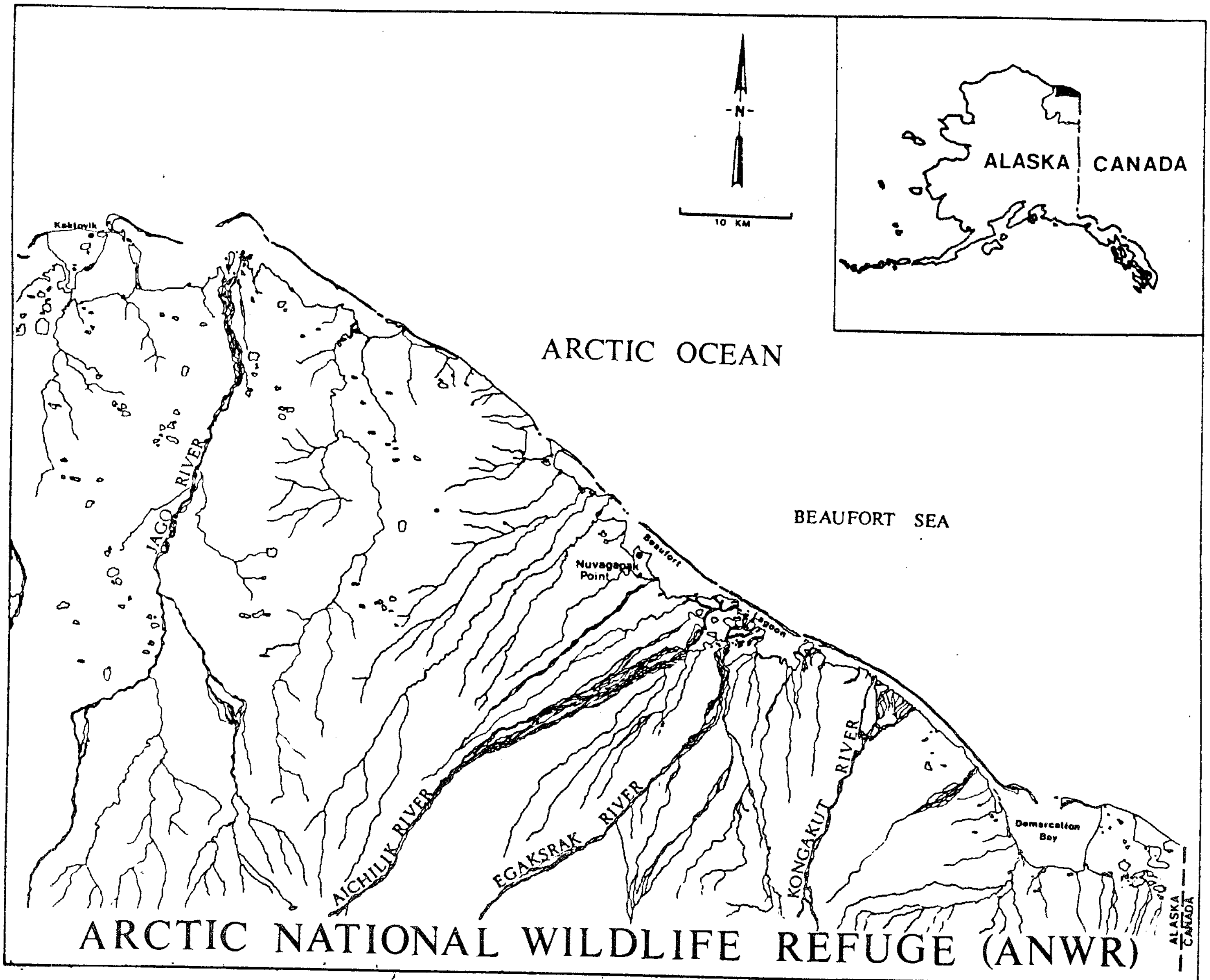

Figure 1. Location of Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska.

Arctic waters such as Beaufort Lagoon typically have short food chains and low species diversity. Schell (1983) describes Beaufort Sea estuarine food webs as dependent on allochthonous carbon from ice algae and phytoplankton supplemented by peat and vegetative detritus, an ecosystem which may have delays of several thousand years between primary production and consumer use. The most abundant wildlife species found at Beaufort Lagoon in summer are oldsquaw ducks (Clangula hyemalis) which use the area for feeding on the abundant epibenthic invertebrates and as a refuge for molting (Spindler and Meehan 1984).

Human use of the Beaufort Lagoon area is limited. The military no longer uses the facilities at Nuvagapak Point, but since a landing strip and buildings remain, the area has been used in recent years for staging for oil and gas exploration activities and biological studies. The area has also been used by Native people for traditional subsistence hunting and fishing activities (Jacobson and Wentworth 1982).

Methods

Fish were caught by either directional fyke nets or experimental gill nets. The fyke nets employed were shore-based with a 61.00 m lead, 15.25 m wings, and dual 1.22 m by 1.53 m traps. Gill nets were 38.13 m long by 1.83 m deep with equal lengths of 1.27, 2.54, 3.81, 5.08, and 6.35 cm bar mesh. Only live fish freshly removed from the nets were used for all health study examinations.

Samples for histopathological and contaminant analyses were collected between July 23 and August 28, 1984. Parasite examinations were made between July 7 and August 9, 1985.

Histopathological

A sample size of 30 fish per species was chosen based on the method described by Ossiander and Wedemeyer (1973) to detect at least a 10% disease incidence in a population of 100,000 or more fish with a 95% confidence level. Tissues were excised in the field using surgical instruments. Samples were taken of gill, heart, skin, muscle, kidney, spleen, liver, gonad, and digestive tract and preserved in Bouin's solution. The samples were then sent to the U.S. Fish and Wildlife Service National Fishery Research Center, Seattle, Washington where they were transferred to histological grade alcohol. The tissues were then embedded in paraffin, sectioned, and stained with Harris' hematoxylin and eosin and May-Grunwald Giemsa (Yasutake and Wales 1983). Gram and periodic acid Schiff stains were used when needed. Photomicrographs were taken of the prepared tissues using a Zeiss Photomicroscope III.

Contaminants

Five each of Arctic char, Arctic cisco, Arctic flounder, and fourhorn sculpin were collected for analysis of 10 heavy metals and five of each species (except 3 fourhorn sculpin) were collected for analysis of 16 aliphatic and 15 aromatic hydrocarbons. Fish were killed using a teflon-coated scalpel by making a single incision in the head while removing otoliths for ageing. After weighing and measuring the fish, they were carefully wrapped in non-annealed aluminum foil, tagged, placed in clean zip lock plastic bags, and put on ice. All samples were frozen within 3 days of the time of capture. Frozen samples were then shipped with dry ice to Analytical Bio-Chemistry

Laboratories, Inc., Columbia, Missouri for heavy metals analysis and to Hazleton Laboratories America, Inc., Madison, Wisconsin for hydrocarbons analysis.

Fish were ground whole for all determinations. Individual preparation and digestion techniques are available upon request.

Heavy metals analyzed for included lead, barium, cadmium, chromium, copper, zinc, arsenic, mercury, nickel, and vanadium. Atomic absorption spectroscopy was employed in the determinations of lead, cadmium, nickel, vanadium, arsenic, and mercury. A graphite furnace was used for lead, cadmium, nickel, and vanadium; whereas, hydride generation was used for arsenic and an automated cold vapor technique was employed for mercury. Instrumentation included a Perkin-Elmer 305B spectrophotometer with background correction, an HGA-2100 graphite furnace accessory, an MHS-10 hydride generation system, and a Technicon Auto-Analyzer. Table 1 summarizes the various instrumental parameters used for the atomic absorption spectroscopy.

Barium, copper, chromium, and zinc were determined by inductively coupled argon plasma spectroscopy. Instrumentation used for these determinations included a Jarrell-Ash Series 800 Atom Comp equipped with a digital PDP8/a computer with dual floppy disks. A forward power of 1.0 kw was used with the emission signal taken 15 mm above the load coil. The sample was introduced into the plasma through a fixed cross-flow nebulizer at a rate of 1.4 ml/minute which was kept constant through the use of a peristaltic pump. The sample, coolant, and plasma gas flows were 250 ml, 22.5 l, and 600 ml per minute respectively. Background correction on one side of each analytical line was accomplished through the use of a spectrum shifter. A two-point standardization was employed for each element using standards of 0.0 and 10.0 ppm.

Each value reported is the average of at least 3 determinations. Metals detection limits were 0.01 μg/g.

Duplicate heavy metals analyses were conducted on randomly chosen samples and recovering information was gathered using certified value reference tissues to assume compliance with the U.S. Environmental Protection Agency Good Laboratory Practice Standards; Toxic Substances Control Act (40 CFR 792).

Analysis of fish for petroleum-derived hydrocarbons was undertaken using a modification of procedures described by Gay et al. (1980). Capillary column gas chromatography was employed in the determinations of 16 aliphatic and 15 aromatic hydrocarbons (listed in Table 2 along with information on the standards used in the analyses).

Separation of the aliphatic and aromatic hydrocarbons was performed on silicar columns. Aliphatics were eluted using 80 ml of pentane followed by elution of aromatics with 100 ml of methylene chloride. Individual fractions were reduced to 1 ml, transferred into iso-octane and analyzed on a Hewlett Packard 5730A gas chromatograph with J & W fused silica capillary columns set up as follows:

Dimensions 30 MX 0.322 mm i.d.
Liquid phase: DB-5
Film thickness: 0.25 μ
Carrier gas: helium at 1.5 to 2.0 ml/minute

Table 1. Instrumental parameters for atomic absorption spectrophotometry analysis of heavy metals in fish samples from Beaufort Lagoon.

ELEMENT:	LEAD	CADMIUM	ARSENIC	MERCURY	NICKEL	VANADIUM
Monochrometer Slit Width (nm):	0.7	0.7	0.7	0.7	0.2	0.7
Wavelength Monitored (nm):	283.3	228.8	193.7	253.7	232.0	318.4
Lamp Power or Current:	10 watts	5 watts	7 watts	15 ma	20 ma	20 ma
Signal Expansion to Recorder	3x	2x	ABS	2x	3x	10-30x
Concentration of Standards Used for Method of Additions:	0.0, 0.02, 0.04ppm	0.0, 0.002, 0.04ppm	0.0, 0.02, 0.04ppm	-	0.0,0.03, 0.06ppm	0.0, 0.03 0.06ppm
Concentration of Standards Used for Reference Curve:	-	-	-	0.20ppb	-	-
Furnace Dry Temperature and Time:	95°C 30sec	95°C 30sec	-	-	95°C 30sec	95°C 22sec
Furnace Char Temperature and Time:	700°C 30sec	250°C 30sec	-	-	1000°C 30sec	1500°C 20sec
Furnace Atomize Temperature and Time:	2700°C 4 sec	2100°C 4 sec	-	-	2700°C 5 sec	2750°C 11 sec

Table 2. Hydrocarbons analyzed for Beaufort Lagoon fish samples and information on standard source and purity used in the analyses.

Aliphatic Hydrocarbons	Source*	Lot Number	Purity (%)
Decane	EPA	E-000236	99+
Undecane	Aldrich	1528BL	99
Dodecane	Chem Service	9-30K	99
Tridecane	EPA	E-000239	99+
Tetradecane	EPA	E-000240	99+
Pentadecane	EPA	E-000241	99+
Nonylcyclohexane	Pfalty & Bauer	N13990	99
Hexadecane	EPA	E-000309	99+
Heptadecane	Aldrich	1908EL	99
Pristane	Aldrich	1922EL	96
Plytane	Aldrich	G800225	99+
Octadecane	Aldrich	2406HL	97
Nonadecane	EPA	E-000244	99+
Eicosane	EPA	EC-319-01	99+
Heneicosane	EPA	EC-386-01	99+
Docosane	EPA	E-000245	99+

Aromatic Hydrocarbons	Source*	Lot Number	Purity (%)
Naphthalene	Chem Service	6-64	99
Acenaphthylene	Chem Service	6-203	95
Acenaphthene	Chem Service	7-58E	99+
Fluorene	Chem Service	6-202	98
Phenanthene	Chem Service	9-19P	99
Anthracene	Chem Service	6-203	98+
Fluoranthene	Chem Service	10-25B	98
Pyrene	Chem Service	6-205	99+
Benzo (a) anthracene	Aldrich	1224-EL	99
Chrysene	Chem Service	4-142	97
Benzo (b) fluoranthene	Chem Service	2-40B	98
Benzo (k) fluoranthene	Chem Service	2-25B	98
Benzo (a) pyrene	Aldrich	031497	98
1,2,5,6-Dibenzanthene	Chem Service	10-25B	97
Benzo (g,h,i) Perylene	Aldrich	0421A5	98.4

*addresses of chemical standard sources available upon request.

Inlet: 18740B in splitless mode
Injection temperature: 250°C
Delay: 40 seconds
Injection volume: 4.9 µl
Pressure: 13 psi
Septum purge: 1.5 to 20 ml/minute
Detector: flame ionization
Temperature: 300°C
Range: 1
Attenuation: 16
Hydrogen flow: 30 ml/minute
Air flow: 240 ml/minute
Oven Temperature:
Initial hold: 90°C for 4 minutes
Gradient: 4°C (aromatics); 8°C (aliphatics) per minute to 300°C
Final hold: 300°C for 8 minutes

Due to variations between injections using capillary inlet systems, 20 µg of 2-fluorobiphenyl were added to each aliphatic extract and 12 µg of dotriacontane were added to each aromatic fraction as injection interval standards. Compounds detected were quantitated using a standard curve based on peak area ratios (area of compound per area of interval standard) vs. concentration. Integration and computation were performed on a Hewlett Packard 3356 Laboratory Automation System.

Detection limits for both aliphatic and aromatic hydrocarbons were 0.10 µg/g. Quality control was performed on the hydrocarbon samples by running one sample duplicate, one sample recovery, one reagent blank, one reagent method check recovery, two tuna control sample recoveries, and one tuna control sample blank. Recoveries were performed by spiking a sample with 1 ml of the 100 µg/ml mixed standard prior to the saponification step.

Because of high levels of arsenic discovered in the 1984 fish samples, 3 replicate water samples were taken each inside and outside the barrier islands at Beaufort Lagoon in 1985. These samples were taken in acid rinsed Nalgene 1-liter bottles and preserved with .2 ml of concentrated pure nitric acid. The samples were kept dark and on ice and then shipped to Northern Testing Laboratories, Inc., Fairbanks, Alaska for analysis. Procedures followed Standard Methods (APHA-AWWA-WPCF 1980). A 95% confidence interval for results was established through repetitive analyses.

Parasites

Twenty-five each Arctic char, Arctic cisco, Arctic flounder, and fourhorn sculpin were examined for macro parasites at Beaufort Lagoon in 1985. In addition, one Arctic grayling (Thymallus articus) was examined. The histopathological examinations conducted in 1984 included microscopic examination of tissues for parasites. Methods for examination and preservation of larger external and internal parasites followed Hoffman (1967).

Fish were killed by pithing. Gross examinations were made of gills, fins, skin, eyes, brain, pseudobranch, stomach, intestine, liver, gall bladder, spleen, pyloric caeca, heart, kidney, gonads, gas bladder, visceral cavity, and muscle using a Bausch and Lomb 3X hand lens. External examination was made first, followed by the viscera, and finally the muscle (accomplished by making diagonal cuts every 4 cm through the body). The lumen and gut were inverted and pyloric caeca projections individually split and inverted to make accurate counts of tapeworms.

Parasites were counted and representative specimens were weighed using a RCBS Model 505 precision scale (± 0.0065 g) and then preserved. Trematodes, cestodes, and acanthocephala were preserved in warm 10% formalin. Nematodes, copepods, and isopods were preserved in warm 70% alcohol. Identifications in the field were made under a Bausch and Lomb 10-70X dissecting microscope with the aid of host-parasite lists (Margolis and Arthur 1979; Moles 1982) and keys (Bykhouskaya-Pavlouskaya et al. 1964; Hoffman 1967). Verification of identifications and identification of unknown samples was accomplished through the assistance of several renowned fish parasitologists (See acknowledgement).

Condition and Ageing

Fish were measured using a plastic WILDCO measuring board and fork lengths were recorded to the nearest mm. Weights of fish taken in 1985 for parasite examinations were taken on an OHAUS balance (± 0.10 g) after fish were drip dried for one minute. All other weights were taken with Pesola spring scales (± 1.0g). A coefficient of condition (K) was calculated following Carlander (1969) using the equation:

$$K = \frac{\text{Weight X } 10^5 (g)}{\text{Fork Length}^3 (mm)}$$

A condition factor was determined for all fish collected for histopathological, contaminant, and parasite examination. In addition, 27 separate Arctic cisco were examined for condition in 1985. Age was determined by otoliths except for the 1984 Arctic cisco samples where scales were used. Arctic cisco otoliths were taken in 1985 and were aged by the U.S. Fish & Wildlife Service, National Fisheries Research Center in Seattle following methods similar to Williams and Bedford (1974) in which the otoliths are broken and burned. Arctic char, Arctic flounder, and fourhorn sculpin otoliths were ground when necessary with 320 grit wet sandpaper and read in a solution of Photo-Flo with a Bausch and Lomb 10-40X dissecting microscope using reflected light. Hyaline zones were counted as described by Jearld (1983).

Results

Histopathological

The histopathological examinations were accomplished under contract to the Seattle National Fisheries Research Center. A complete account of the histopathological survey was compiled in an unpublished report (Goldberg et al. 1985). The results are summarized in Table 3.

Arctic flounder was the "cleanest" fish of the four species examined. Small aneurisms in the gill lamellae were observed in 27% of the flounder samples. The gill epithelium was separated from the lamellae in 10% of the 30 fish in the sample. Congested spleens were observed in 6% of the flounder examined. Excess mucus, hyperplasia of the gill epithelium, inflamed stomach tissue, and a skin ulcer were each found in separate single cases. The skin ulcer was localized but had extended invasion with collagenous connective tissue and

Table 3. Histopathological abnormalities and percent of occurrence in four fish species from Beaufort Lagoon, Alaska.

Arctic Flounder	
*Gill aneurisms	27%
*Excess mucus in gills	3%
Hyperplasia of gill epithelium	3%
*Congested spleen	6%
Hermaphroditism	3%
Localized inflammation, stomach	3%
Skin ulcer	3%
*Gill epithelium separated from lamellae	10%

Arctic Char	
*Gill aneurisms	13%
Gill edema	3%
Helminth, trematode in gill	3%
*Congested spleen	13%
*Congested liver	3%
Helminth, cestode in digestive tract	30%
Helminth, trematode in digestive tract	10%
Nematode in digestive tract	3%
Intestine, granuloma	3%
Hypoplasia of spleen	3%
Fatty liver	3%

*Possible artifact caused during sampling

Table 3. Continued.

Arctic Cisco	
*Gill aneurisms	6%
Hyperplasia of gill epithelium	3%
*Gill epithelium separated from lamlelae	6%
Fatty liver	3%
Helminth, cestode in digestive tract	17%
Helminth, trematode in digestive tract	3%
Granuloma, kidney	6%
Granuloma, spleen	3%
Coccidian protozoan, testis	3%
Localized inflammation, gut mesentery	3%
Fourhorn Sculpin	
*Gill aneurisms	3%
Trichodina in gill	43%
Ichthyophthirius - like protozoan in gills	3%
Epitheliocystis in gill	3%
Fatty liver	3%
*Congested liver	3%
*Congested heart	3%
*Congested kidney	3%
Megalocytic Hepatosis, liver	40%
Helminth, trematode in digestive tract	3%
Helminth, cestode in digestive tract	6%
Kidney tubule degeneration	3%
Kidney tubules swollen	3%
Localized inflammation between muscle bundles	3%
*Congested spleen	3%
Granuloma, kidney	3%

*Possible artifact caused during sampling numerous inflammatory cells underneath, but it did not exhibit any etiological agent. One hermaphroditic flounder was also discovered (Goldberg et al. 1986).

Thirty percent of the Arctic char examined contained cestodes in the lumen tissue sections where they caused no apparent histological damage to the digestive tract. Other parasites observed in char during histopathological examinations included small trematodes in the digestive tract of 10% of those examined, 1 trematode in the gill of a single fish, and 1 nematode in the muscularis of the intestine of another fish. The trematodes caused no apparent histological damages but the nematode was surrounded by an inflammed tissue area. Congested spleens were observed in 13% of the Arctic char examined. Gill aneurisms were also noted in 13% of the samples. Single cases were observed each for gill edema, congested liver, granuloma in the intestine, hypoplasia of the spleen, and a fatty liver.

As with Arctic char, Arctic cisco were found to possess cestodes (17%) and a trematode (3%) in the digestive tracts causing no apparent harm. Gill aneurisms and gill epithelium separated from lamellae were observed in 2 cases but may have been artifacts caused during sampling. A granuloma was seen in the kidney of each of 2 Arctic cisco and in the spleen of one fish. One example each of fatty liver, localized inflammation in the gut mesentery, and hyperplasia of gill epithelium was also observed. A single cisco was found to have a coccidian protozoan parasite infection in the testis. The parasite consisted of a basophilic body with a nucleus containing a single round basophilic nucleolus. The parasite displaced the germinal cysts within the seminiferous tubule thereby sterilizing the fish in those tubules posessing the parasite. In the single case examined, however, the density of the parasite did not appear sufficient to influence the fertility of the fish.

Fourhorn sculpin appeared to be relatively free of helminth parasites. Helminth infections were seen in two separate fishes. Fourhorn sculpin, however, were heavily parasitized on the gill by Trichodina. A single Ichthyophthirius - like protozoan was also seen in the gills. One observation of possible epitheliocystis was made. This disease is caused by rickettsiae, encompassing the orders Rickettsiales and Chlamydiales (Buchanan and Gibbons 1974). Gill aneurisms were found in one sculpin. An idiopathic lesion was found in a single fourhorn sculpin kidney. In another sample some of the kidney tubules were swollen; the kidney from another fish was congested. A granulomatous area on the periphery of the kidney was seen in 1 sculpin. Single cases of congested heart, congested spleen, fatty liver, congested liver, and inflammation between muscle bundles were also observed. Forty-three percent of the fourhorn sculpins examined displayed signs of Megalacytic Hepatosis (MH) with pleomorphic nuclei. This is a liver condition characterized by an increase in hepatocyte diameters and their nuclei.

Contaminants

Mean concentrations, range of values, and standard deviations for contaminants found in the fish tissues are reported by species for heavy metals, aliphatic hydrocarbons, and aromatic hydrocarbons in Tables 4 to 6, respectively.

Arctic char had the lowest overall metal concentrations but the highest total tissue hydrocarbon levels of the 4 species analyzed (Table 7). Fourhorn sculpin displayed just the opposite, having the highest heavy metal concentrations and the lowest hydrocarbon levels. Arctic cisco ranked second for both metals and hydrocarbons of the 4 species and Arctic flounder ranked

Table 4. Concentrations of heavy metals in whole ground fish from Beaufort Lagoon, Alaska, 1984. Results are expressed as micrograms of contaminant per gram of tissue (µg/g).

	Lead	Barium	Cadmium	Chromium	Copper
Arctic Char (n=5)					
Mean Value	*0.01	0.21	*0.02	*0.01	1.50
Range	*0.01-0.02	0.14-0.25	*0.01-0.03	*0.01-0.02	1.30-1.70
Std. Deviaiton	0.004	0.043	0.008	0.004	0.158
Arctic Cisco (n=5)					
Mean Value	0.03	0.51	*0.01	*0.01	1.01
Range	0.01-0.04	0.42-0.67	*0.01-0.02	*0.01-0.03	0.92-1.10
Std. Deviation	0.011	0.102	0.004	0.009	0.083
Arctic Flounder (n=5)					
Mean Value	*0.03	0.41	*0.01	0.13	1.10
Range	*0.01-0.07	0.21-0.66	*0.01-0.02	0.06-0.20	0.92-1.30
Std. Deviation	0.024	0.187	0.004	0.051	0.152
Fourhorn Sculpin (n=5)					
Mean Value	0.07	1.42	0.04	0.16	2.64
Range	0.06-0.09	0.69-2.80	0.02-0.04	0.08-0.22	1.90-3.90
Std. Deviation	0.011	0.843	0.009	0.058	0.792

Table 4. Continued.

	Zinc	Arsenic	Mercury	Nickel	Vanadium
Arctic Char (n=5)					
Mean Value	20.94	0.92	0.04	0.06	0.10
Range	16.40-22.80	0.50-1.40	0.03-0.05	0.01-0.13	0.04-0.14
Std. Deviation	2.589	0.448	0.008	0.055	0.042
Arctic Cisco (n=5)					
Mean Value	26.48	1.01	0.03	0.06	0.11
Range	20.70-34.80	0.74-1.40	0.02-0.05	0.01-0.14	0.05-0.16
Std. Deviation	5.893	0.261	0.013	0.049	0.040
Arctic Flounder (n=5)					
Mean Value	22.12	0.75	0.02	0.11	*0.09
Range	19.80-23.80	0.51-1.10	0.02-0.04	0.03-0.20	*0.01-0.17
Std. Deviation	1.678	0.240	0.009	0.070	0.074
Fourhorn Sculpin (n=5)					
Mean Value	23.92	0.71	0.02	0.14	*0.19
Range	20.10-27.70	0.54-0.84	0.01-0.03	0.08-0.23	*0.01-0.60
Std. Deviation	3.216	0.113	0.007	0.067	0.240

*Means "less than" where the true value is below the normal detection limit. Mean values and standard deviations were calculated using values at the detection limit; therefore, in cases where one or more replicate sample(s) were below detection, the reported mean values are slightly high and standard deviations are slightly low.

Table 5. Concentrations of aliphatic hydrocarbons in whole ground fish from Beaufort Lagoon, Alaska, 1984. Results are expressed as micrograms of contaminant per gram of tissue (µg/g).

	Decane	Undecane	Dodecane	Tridecane	Tetradecane
Arctic Char (n=5)					
Mean Value	0.28	1.53	*0.10	*0.10	*0.10
Range	*0.10-0.67	0.69-3.19	*0.10	*0.10	*0.10
Std. Deviation	0.232	1.016	0	0	0
Arctic Cisco (n=5)					
Mean Value	0.25	1.45	*0.10	*0.10	*0.10
Range	*0.10-0.57	*0.10-3.29	*0.10	*0.10-0.12	*0.10
Std. Deviation	0.190	1.225	0	0.009	0
Arctic Flounder (n=5)					
Mean Value	0.54	2.71	*0.10	*0.10	*0.10
Range	*0.10-0.77	*0.10-4.19	*0.10	*0.10	*0.10
Std. Deviation	0.261	1.579	0	0	0
Fourhorn Sculpin (n=5)					
Mean Value	0.17	1.05	*0.10	*0.10	*0.10
Range	*0.10-0.30	0.47-1.89	*0.10	*0.10	*0.10
Std. Deviation	0.115	0.745	0	0	0

Table 5. Continued.

	Pentadecane	Nonylcyclohexane	Hexadecane	Heptadecane	Pristane
<u>Arctic Char</u> (n=5)					
Mean Value	0.15	*0.10	*0.10	0.12	14.52
Range	*0.10-0.19	*0.10	*0.10	*0.10-0.18	7.01-27.43
Std. Deviation	0.036	0	0	0.36	7.815
<u>Arctic Cisco</u> (n=5)					
Mean Value	0.31	*0.10	*0.10	0.13	4.05
Range	0.17-0.56	*0.10	*0.10	*0.10-0.22	0.37-6.34
Std. Deviation	0.149	0	0	0.053	2.261
<u>Arctic Flounder</u> (n=5)					
Mean Value	*0.10	*0.10	*0.10	0.12	0.11
Range	*0.10	*0.10	*0.10	*0.10-0.18	*0.10-0.14
Std. Deviation	0	0	0	0.036	0.018
<u>Fourhorn Sculpin</u> (n=5)					
Mean Value	0.12	*0.10	*0.10	*0.10	0.38
Range	*0.10-0.17	*0.10	*0.10	*0.10	0.11-0.91
Std. Deviation	0.040	0	0	0	0.456

Table 5. Continued.

	Octadecane	Phytane	Nonadecane	Eicosane	Heneicosane	Docasane
Arctic Char (n=5)						
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0	0
Arctic Cisco (n=5)						
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0	0
Arctic Flounder (n=5)						
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0	0
Fourhorn Sculpin (n=5)						
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0	0

*Means "less than" where the true value is below the normal detection limit. Mean values and standard deviations were calculated using values at the detection limit; therefore, in cases where one or more replicate sample(s) were below detection, the reported mean values are slightly high and standard deviations are slightly low.

Table 6. Concentrations of aromatic hydrocarbons in whole ground fish from Beaufort Lagoon, Alaska, 1984. Results are expressed as micrograms of contaminant per gram of tissue (µg/g).

	Naphthalene	Acenaphthylene	Acenaphthene	Flurorene	Phenanthrene
Arctic Char (n=5)					
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0
Arctic Cisco (n=5)					
Mean Value	-	-	-	-	-
Range	-	-	-	-	-
Std. Deviation	-	-	-	-	-
Arctic Flounder (n=5)					
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0
Fourhorn Sculpin (n=5)					
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0

Table 6. Continued.

	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Arctic Char (n=5)					
Mean Value	*0.10	0.13	0.31	*0.10	*0.10
Range	*0.10	*0.10-0.18	0.12-0.63	*0.10	*0.10
Std. Deviation	0	0.044	0.197	0	0
Arctic Cisco (n=5)					
Mean Value	-	-	-	-	-
Range	-	-	-	-	-
Std. Deviation	-	-	-	-	-
Arctic Flounder (n=5)					
Mean Value	0.19	0.12	0.45	*0.10	*0.10
Range	*0.10-0.29	*0.10-0.17	0.28-0.55	*0.10	*0.10
Std. Deviation	0.088	0.032	0.115	0	0
Fourhorn Sculpin (n=5)					
Mean Value	*0.10	*0.10	*0.10	*0.10	*0.10
Range	*0.10	*0.10	*0.10	*0.10	*0.10
Std. Deviation	0	0	0	0	0

Table 6. Continued.

	Benzo (b) fluoranthene	Benzo (k) fluoranthene	Benzo (a) pyrene	Dibenz (a,h) anthracene	Benzo (g,h) perylene
Arctic Char (n=5)					
Mean Value	0.12	0.11	*0.10	*0.10	0.24
Range	*0.10-0.18	*0.10-0.16	*0.10	*0.10	*0.10-0.81
Std. Deviation	0.036	0.027	0	0	0.318
Arctic Cisco (n=5)					
Mean Value	-	-	-	-	-
Range	-	-	-	-	-
Std. Deviation	-	-	-	-	-
Arctic Flounder (n=5)					
Mean Value	*0.10	0.12	*0.10	*0.10	*0.10
Range	0.09-*0.10	*0.10-0.18	*0.10	*0.10	*0.10
Std. Deviation	0	0.036	0	0	0
Fourhorn Sculpin (n=5)					
Mean Value	*0.10	0.11	*0.10	*0.10	*0.10
Range	0.09-*0.10	*0.10-0.12	*0.10	*0.10	*0.10
Std. Deviation	0.006	0.012	0	0	0

*Means "less than" where the true value is below the normal detection limit. Mean values and standard deviations were calculated using values at the detection limit; therefore, in cases where one or more replicate sample(s) were below detection, the reported mean values are slightly high and standard deviations are slightly low.

third for both. Considering total aromatic hydrocarbons alone, however, flounder had the highest concentrations (although not significantly different from char, $p < 0.05$) (see Table 7).

Arsenic was the only contaminant that appeared high relative to results of similiar recent studies of various fish species in Northern Alaska (Table 8). The only results that were similar were for those of Arctic grayling taken in the Kantishna Hills mining area of Denali National Park which had high levels of arsenic in many of the mined streams (West and Deschu 1984).

Analysis of seawater samples from Beaufort Lagoon showed a significant difference ($p < 0.05$) for total arsenic concentration inside the barrier islands compared to just outside the barrier islands (mean value inside was 27.333 µg/l, n=3; mean value outside was 9.33 µg/l, n=3; individual sample standard deviations ranged from 0.002 to 0.005).

Nevertheless, arsenic concentrations within Beaufort Lagoon were still far below what is normally considered toxic to saltwater aquatic life (EPA 1980). The arsenic levels found in the fish, however, are high enough to be considered as an increased health risk if consumed in quantity. EPA (1980) provides that the following concentrations of arsenic when consumed in aquatic organisms will result in incremental increase of cancer risk over the individuals lifetime: 0.175 µg/l = 10^{-5} increased risk, 0.01 µg/l = 10^{-6} increased risk, and 0.002 µg/l = 10^{-7} increased risk. Such values are approximate and dependent on a number of factors; however, a further examination of arsenic concentration in Beaufort Sea fishes, especially those of value to subsistence, sport, and commercial fisheries, may be warranted.

Macro-Parasites

Arctic char generally had more taxa and numbers of macro-parasites than the other fish species examined. Arctic cisco were second, followed by fourhorn sculpin. Sculpins had more variety of parasites than ciscos but these parasites were found much less frequently. Arctic flounder rarely were observed to be a host to parasites and had only two identified taxa present.

The most common parasite observed in the Beaufort Lagoon fish samples was the adult cestode (tapeworm) Bothrimonus sturionis. These cestodes were observed in 25 (100%) of the Arctic char examined and 24 (96%) of the Arctic cisco. Only 4 (16%) of the fourhorn sculpin and 3 (12%) of the Arctic flounder possessed Bothrimonus sturionis.

The average number of B. sturionis found in Arctic char was 96 worms with a range of 1 to 685. For Arctic cisco, the average was 38 with a range of 0 to 270 worms. The size of these cestodes varied greatly but the average wet weight of 1,053 taken from char was 0.012 g/worm and 0.008 g/worm from a sample of 539 B. sturionis taken from cisco.

The second most commonly observed parasites were copepods attaching to the fins, gills, mouth, or pseudobranch. All of the parasitic copepods observed were of the genus Salmincola, but several species appeared to be present and were difficult to identify. Salmincola edwardsii was positively identified in char, but other copepods observed in char more commonly resembled S. carpionis or S. extensus. Those in Arctic cisco appeared to be primarily S. extensus but a positive identification was not made. Attachment in char was observed primarily in gills or mouth while fins were the most common attachment site in

Table 7. Ranking of metal and hydrocarbon contaminant levels among four fish species from Beaufort Lagoon, Alaska. Contaminant concentrations are expressed in µg/g.

	Arctic Char	Arctic Cisco	Arctic Flounder	Fourhorn Sculpin
Total *Mean Heavy Metal Concentration and 95% Confidence Intervals (All 10 Metals Combined)	23.81 ±4.03	29.26 ±7.76	24.77 ±2.99	29.31 ±6.41
Total *Mean Heavy Metal Concentration and 95% Confidence Intervals (Less Zinc and Copper)	1.37 ±.73	1.77 ±.59	1.55 ±.79	2.75 ±1.60
Total *Mean Heavy Metal Concentration and 95% Confidence Intervals (Less Zinc)	2.87 ±.92	2.78 ±.69	2.65 ±.97	5.39 ±2.55
Ranking for Mean Heavy Concentrations (1 is high)	4	2	3	1
Total *Mean Hydrocarbon Concentrations and 95% Confidence Intervals (Aliphatics and Aromatics)	19.61 ±11.71	-	6.66 ±2.60	4.18 ±3.44
Total *Mean Aromatic Hydrocarbon Concentration and 95% Confidence Interval	1.91 ±.75	-	1.98 ±.33	1.51 ±.05
Total *Mean Aliphatic Hydrocarbon Concentration and 95% Confidence Interval	17.70 ±10.96	7.29 ±4.66	4.68 ±2.27	2.67 ±3.39
Ranking for Mean Hydrocarbon Concentration (1 is high)	1	2	3	4

*Total mean concentrations were calculated using values at detection limits although many actual values were below detection; therefore, the totals given above are higher than actual total concentrations and the confidence limits are narrower than the true, unknown limits. Refer to Tables 1 and 2 for a complete listing of metals and hydrocarbons in the analyses.

Table 8. Total arsenic levels in whole fish from Northern Alaska.

Species	Location	Sample Size	Mean Total Arsenic (µg/g)	Reference
Broad Whitefish (*Coregonus nasus*)	Teshekpuk Lake	6	0.05	West 1982
Arctic Grayling	Teshekpuk Lake	5	< 0.05	West 1982
Longnose Sucker (*Catastomus catastomus*)	Colville River	7	0.10	West 1982
Arctic Grayling	Itkalukrok Cr.	5	0.01	Metsker et al. 1984
Arctic Grayling	Kantishna Area	9	0.73	West and Deschu 1984
Arctic Grayling	Canning River	5	0.05	Metsker et al. 1984
		- Results This Study -		
Arctic Char	Beaufort Lagoon	5	0.92	-
Arctic Cisco	Beaufort Lagoon	5	1.01	-
Fourhorn Sculpin	Beaufort Lagoon	5	0.71	-
Arctic Flounder	Beaufort Lagoon	5	0.75	-

cisco. Nine (36%) of the char examined had Salmincola and 19 (76%) of the cisco; whereas, none were observed in Arctic flounder or fourhorn sculpin. Two parasitic isopods were found in a single fourhorn sculpin attached to the gills.

The most common parasites observed in fourhorn sculpin were nematodes (*Anisakis simplex*) attached to the viscera of 7 (28%) of the sculpins examined. Three cases each (12%) of adult cestodes (*Eubothrium crassum* and *Bothriocephalus scorpii*) in the lumen or intestine were also observed.

The only parasites found in Arctic flounder other than *Bothrimonus sturionis* were juvenile Acanthocephala found loosely attached to the liver in 3 (12%) of the fish sampled. This parasite appeared to be *Corynosoma* sp. The adults of this organism are found in pinnipeds.

Many of the small cysts observed on char and cisco viscera appeared to be *Diphyllobothrium* sp. plerocercoids (intermediate stages) but species identification was not possible.

Appendix 1 provides a complete account of numbers and species of macro-parasites identified for each fish sample in Beaufort Lagoon. Table 9 is a summary of the macro-parasites observed.

Of the Arctic grayling captured at Beaufort Lagoon in 1985, one was examined for parasites. The fish was a 359 mm (FL), 420 g female with good physical apearance. She was feeding on amphipods and mysids. She had three copepods (*Salmincola* sp.) attached to gill filaments, 89 small *Bothrimonus sturionis* in the lumen, and an additional 23 *B. sturionis* in the intestine.

Condition

Sample numbers, dates of collection, fork lengths, weights, condition values, ages, and sex of all fish samples are provided in Appendix 2. The mean condition value for Arctic char was 0.875 (n = 65, S.D. = 0.143). For Arctic cisco the mean condition value was 1.089 (n = 65, S.D. = 0.145). Arctic flounder and fourhorn sculpin had mean condition values of 1.334 (n = 69, S.D. = 0.241) and 0.920 (n = 63, S.D. = 0.187) respectively.

Condition in all species was highly variable, possibly in response to a wide variety of environmental and physiological factors such as length of active feeding period in the lagoon system, age, and reproductive status. Multiple regression (Zar 1974) analyses demonstrated no significant correlations ($p < 0.01$) between combinations of contaminant levels, numbers of parasites, and condition factors (dependent variable). Significance was based on the slope of the regression line. Sampling date and condition factors were significantly correlated ($r = 0.75$, $p < 0.01$) for Arctic cisco, but not for the other species examined. Figure 2 illustrates the trend in increasing condition for Arctic cisco throughout the summer sampling periods.

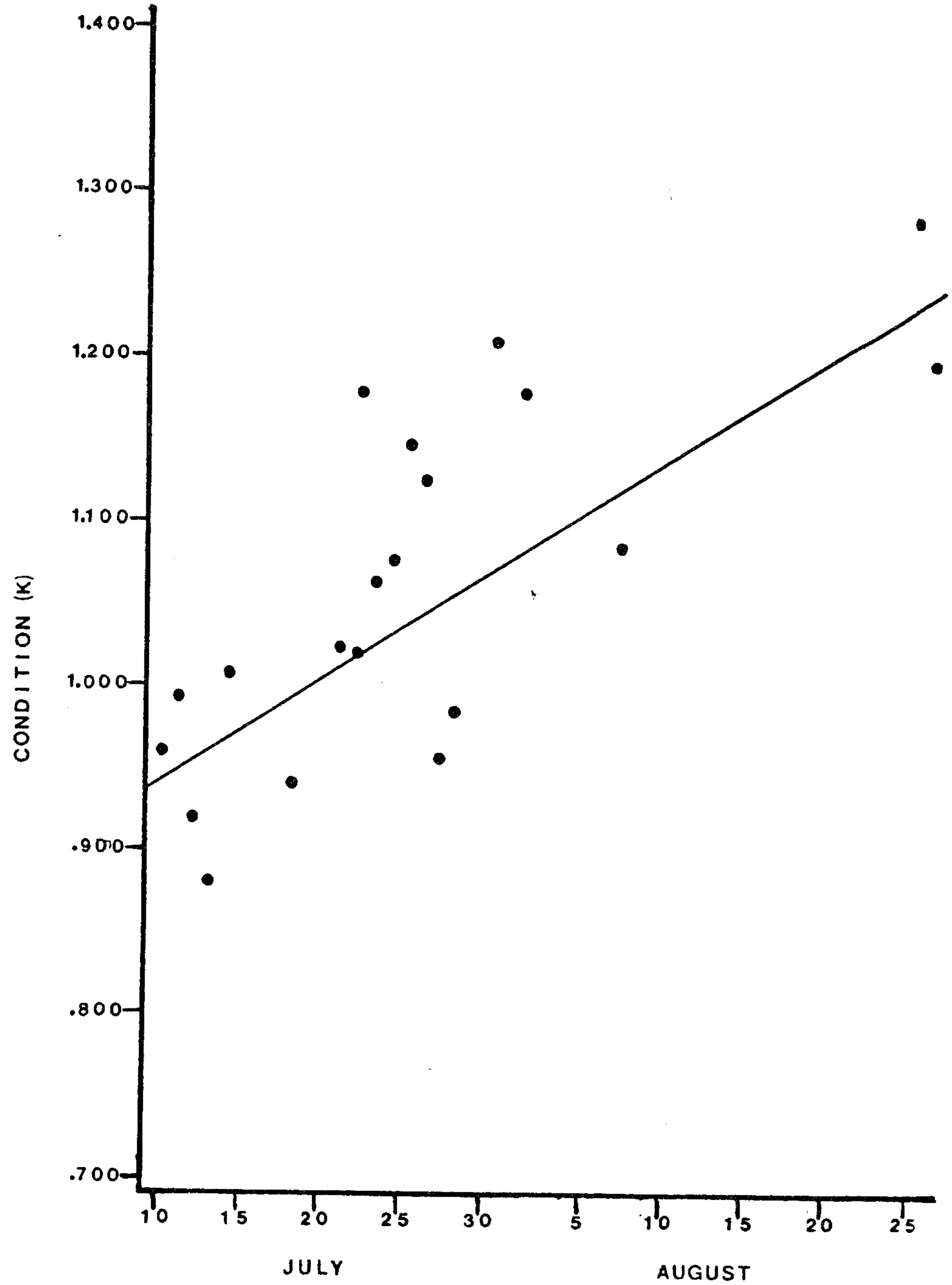

Figure 2. Mean condition values (K) for Arctic cisco by time, Beaufort Lagoon, Alaska (n = 93).

Table 9. A summary of macro-parasites observed in Beaufort Lagoon fish samples.

Arctic Char		
(Adult Cestode)	*Bothrimonus sturionis*	digestive tract
(Larval Cestodes)	*Triaenophorus crassus*	in muscle
	Triaenophorus nodulosus	pyloric caeca
	Diphyllobothrium sp.	liver and viscera
(Larval Trematodes)	unidentified intermediate stages	on viscera
(Adult Nematoda)	Cystidicola sp. (probably *C. farionis*)	swim bladder
(Copepoda)	*Salmincola edwardsii*	pseudobranch
	Salmincola sp.	fins, gills, pseudobranch, and mouth
Arctic Cisco		
(Adult Cestode)	*Bothrimonus sturionis*	digestive tract
(Larval Cestode)	*Diphyllobothrium* sp.	on pyloric caeca
(Adult Trematode)	unidentified	on gonads
(Adult Nematoda)	unidentified	in stomach
(Copepoda)	*Salmincola* sp.	fins, gills, and pseudobranch
Fourhorn Sculpin		
(Adult Cestodes)	*Eubothrium crassum*	intestine
	Bothriocephalus scorpii	digestive tract
	Bothrimonus sturionis	digestive tract
(Adult Nematoda)	*Anisakis simplex*	on stomach mesentary
	Hysterothylacium sp.	in gut
(Acanthocephala)	unidentified larvae	on stomach mesentary
(Isopoda)	unidentified adult	on gills
Arctic Flounder		
(Adult Cestode)	*Bothrimonus sturionis*	digestive tract
(Acanthocephala)	probably *Corynosoma* sp.	on liver

Discussion

Histopathological examinations resulted in observations of a number of idiopathic tissue changes present at low frequencies. These included congestion in the spleen, heart, kidney, and liver; gill aneurisms; epithelial separation from the gill lamellae, hyperplasia of the gill epithelium, and excess mucus in gills. Some of the observed changes may have resulted from trauma during capture.

The fewest lesions were found in Arctic flounder. The single skin ulcer observed had large amounts of connective tissue suggesting it was chronic in nature. No bacteria were observed and only one sample had Trichodina in the gills.

Arctic char demonstrated no histological damage in the digestive tract as result of their heavy helminth parasite infestation. There was an inflammatory tissue response to a nematode in one case. One granuloma was seen in the intestine of a single fish perhaps indicating chronic host response to parasites, bacteria, or other factors. One example of hyperplasia of the spleen was also seen for Arctic char. Malins et al. (1982) observed up to 25% of the Pacific tomcod (Microgadus proximus) and Pacific staghorn sculpin (Leptocottus armatus) in samples from Puget Sound to contain similar lesions.

No histopathological damage was associated with the cestode infestation in the digestive tract of Arctic cisco. Granulomas were found in the kidneys of two different fish but most of the lesions observed in Arctic cisco were found in a single sample.

Nearly half the fourhorn sculpins examined were infested with Trichodina; however, no histopathological damage was observed in the gills. Usually this protozoa is harmless attaching to the gill epithelial cells of marine fishes and feeding on particles in the water and cellular debris (Lom 1970). One-third of the sculpins demonstrated signs of Megalocytic Hepatosis, a lesion which has been associated with hepatotoxic changes induced in vertebrates by chemicals (McCain et al. 1982). This condition may be normal for fourhorn sculpins and samples from the species should be taken elsewhere for comparison before conclusions as to the cause of this histological "change" can be drawn. One sculpin had a highly vacuolated fatty liver. This also may be within the normal intraspecific variations to be expected. The single occurrences each of an idiopathic kidney lesion, swollen kidney tubules, and a localized inflammation between muscle bundles could not be linked to any particular cause.

The heavy metals analyses were relatively simple and the results were close to expected except for arsenic. The primary source of arsenic for fish is organoarsenic compounds synthesized lower in the food chain (Lunde 1972). Because the arsenic is most likely being picked up from feeding on zooplankton and was found at elevated levels in all the fish samples and species examined, it appears as though the arsenic "contamination" may be widespread. However, since the arsenic levels were found to be significantly higher inside the barrier island at Beaufort Lagoon compared to outside the island, the source of arsenic may be one or more of the major river drainages in the Eastern Beaufort Sea which influence the nearshore water quality.

The baseline metals values should provide good background information to monitor potential marine drilling contamination. Barium in particular has been suggested as a good indicator metal because of the high barite content in most drilling muds (Chow 1976). Other indicators such as chromium and zinc may prove valuable depending on the types of muds used.

A major interference occurred in the analysis of two aliphatic hydrocarbons, decane and undecane. Major peaks appeared for these compounds in all samples analyzed, including the blank, indicating reagent-associated contamination. All sample values were corrected for this contamination, but due to the large amount of contamination relative to the amount present in the samples, the values obtained are of questionable accuracy.

The analysis showed pristane as the largest and most frequent aliphatic contaminant. Pristane was present in all char samples at levels ranging from 7 to 27 µg/g, all but one cisco between 3.5 and 6.3 µg/g, and all fourhorn sculpins between 0.11 and 0.91 µg/g. The flounder were "clean" except for one sample which contained pristane at 0.14 µg/g. Gay et al. (1980), noted that pristane accumulated more than any other compound in their study and also pointed out that branched aliphatics have been demonstrated to selectively accumulate in marine organisms.

Pentadecane was the second most common aliphatic hydrocarbon compound. It appeared in all Arctic cisco samples at levels between 0.17 and 0.56 µg/g and all but one char between 0.14 and 0.19 µg/g. The tuna used for the laboratory control contained more aliphatic compounds than any of the arctic species and all of the levels in the control, except pristane, were higher than in the study samples.

Analysis of the aromatic fractions were more difficult than the aliphatics. All but one cisco sampled contained large interference that rendered analysis by capillary gas chromatograph impossible. It is likely that this interference was due to biogenic compounds such as carotenoids and steroids which will elute with polycylic aromatic compounds during the silicar separation. The one cisco that had little interference associated with it was captured in July. The remaining samples were captured in August and had noticeably increased their body condition (Figure 2) which was evident in the large deposits of visceral fat. Future efforts may need to be modified to include a sample cleanup by gel permeation chromatography to eliminate interference of this nature.

The fish samples overall were relatively free of most aromatic hydrocarbons. Pyrene was shown to be the largest and most frequent aromatic contaminant and was confirmed by mass spectroscopy. It appeared in all char and flounder samples at levels between 0.12 and 0.63 µg/g. All fourhorn sculpin were "clean". Anthracene and fluoranthene were found in 4 of the 5 flounder samples at levels ranging from 0.10 µg/g to 0.29 µg/g while 2 of 5 char contained fluoranthene at this level.

Chromatograms of the fish hydrocarbon samples showed a large number of unidentified peaks eluting with the aromatic fraction. These peaks could have been due to pesticide compounds, PCBs, polycyclic aromatic sulfur heteracycles, or low-level biogenic compounds. None of these compounds were analyzed for in this study. Nitrogen heterocycles were removed by washing the extracts with 3N HCI, but this would not affect the sulfur compounds. Vassilaros et al. (1982) found fairly high levels of sulfur heterocycles in the fish they studied and suggested from the data some degree of sulfur-selective accumulation in the fish or the aquatic ecosystem. Recent analyses of water and soil around Beaufort Lagoon and other abandoned military sites on the North Slope have evinced high levels of PCBs. U.S. Army Corp of Engineers data show up to 19.7 μg/g as AROCLOR 1254 in a soil sample near the facility at Beaufort Lagoon. A liquid sample from the facility at Bullen Point (approximately 210 km west of Beaufort Lagoon along the coast) contained 136.6 μg/g as AROCLOR 1254. The possibility of PCB contamination may therefore be high and sampling of this contaminant in local fish should be undertaken.

Many documents of parasite infestation records for various fish species exist for Arctic areas in Alaska, Canada, and the U.S.S.R. Some of the parasites found in this study appear to be new accounts of fish hosts or range extensions for parasites. Mudry and McCart (1976) in studying Metazoan parasites of Arctic char from the North Slope of Canada and Alaska, found 14 species consisting of 1 monogean, 4 degeneans, 4 cestodes, 2 nematodes, 1 acanthocephalan, and 2 copepods. One parasite was described as a new species (Bulbodacnitis alpinus; Mudry and McCart 1974), 3 were new North American host records, and all of the localities sampled were range extensions of the parasites found. Of note is their identification of parasites also found in char at Beaufort Lagoon in this study, Bothrimonus sturionis at 1 site and Salmincola edwardsii and/or S. carpionis infecting char at 5 of the 11 sites they sampled.

Craig and Haldorson (1981) found 3 parasites in Arctic cisco in their studies in Simpson Lagoon, near Prudhoe Bay. The primary species present was Diplocotyle olrikii, a species considered to be synonymous with Bothrimonus sturionis by some researchers (Margolis and Arthur 1979). It appears likely that the two are indeed the same species, at least as considered in the Simpson Lagoon work and this study. Craig and Haldorson (1981) found the cisco captured in mid to late summer in the lagoon had 84-92% infection rates with D. olrikii/B. sturionis; whereas none were found in the November samples. This indicates an annual cycle of infection in lagoons initiated in the spring by fish feeding on infected zooplankton. This thought is reinforced by Bauer (1970) who reported that this species infected fish in marine waters but died once the host entered freshwater. This short infection period may help explain why the parasite appears to do no long term harm to its host species. Burt and Sandeman (1969) provide a good summary of B. sturionis/D. olrikii taxonomy and biology and list other Alaska host records. Other host records provided by Margolis and Arthur (1979) for this species include Arctic char from the Eastern Arctic, Labrador, and Manitoba and fourhorn sculpin from the Eastern Arctic.

Copepod infestations have been reported by Margolis and Arthur (1979) in Arctic char in Labrador, Northwest Territories, and Yukon Territory (Salmincola edwardsii) and in Labrador, Northwest Territories, Quebec, and Yukon Territory (S. carpionis). Alaskan records include S. edwardsii in Arctic char (Dunagan 1957), S. extensus in Coregonus sp. (Wilson 1908), and S. carpionis in Arctic char (Mudry and McCart 1976).

The cestodes Bothriocephalus scorpii and Eubothrium crassum have both been reported in fourhorn sculpins from Canada (Margolis and Arthur 1979) and the nematode Cystidicola farionis has been identified in Arctic char from Alaska (Pennell et al. 1973).

All the other parasites besides those specifically mentioned that were identified to species from this study are found in parasite-host records from Alaska or Canada, but were generally found in different fish species than this study (Moles 1982; Margolis and Arthur 1979).

Conclusions

The histopathological examinations indicated that parasite and pathological tissue changes occur in at least 10% of the general population of each of the four species (Arctic char, Arctic cisco, Arctic flounder, and fourhorn sculpin). A number of the observed changes (e.g. gill epithelial separation, aneurisms, and liver and spleen congestion) could have resulted from trauma associated with capture. Arctic flounder had the least number of abnormalities of the 4 species examined. Fourhorn sculpin had heavy infestations of the protozoan *Trichodina*. Although this parasite is generally harmless, high infestations have been reported to cause mortalities in fish (Sindermann 1980).

Further histological examinations focusing on fish reproduction may prove useful in monitoring should oil development occur in the area in the future. Scott et al. (1980) and Scott et al. (1981) in histopatholocial studies of fish gonads near petroleum production sites and control sites in the Gulf of Mexico found little evidence morphologically of toxic effects from exposure to petroleum. The researchers did find, however, acidophilic cells, chromatophores, and leucocytic foci more often in fish ovaries from specimens collected in the vicinity of petroleum production platforms than in those from control sites. A baseline study of the reproductive cycle of the four species examined in this study in Beaufort Lagoon might also be valuable for future monitoring to help identify changes as result of development.

Futher sampling is also recommended for contaminants. Sampling for arsenic should be undertaken to determine its source(s) by sampling water in lagoons along the coast and from major rivers entering the Beaufort Sea. Testing for arsenic in fish muscle tissues rather than whole ground fish should also be undertaken to determine the level of arsenic normally available when consumed. Accompanying these analyses should be a chemical analysis of the arsenic to determine if it is in a form readily absorbed by man. Analysis of fish tissues for PCBs and pesticides is also recommended to determine if these contaminants are present.

The heavy metal and hydrocarbon tissue analyses should be repeated periodically if development begins in the area. Every third year during exploration and every second year during production should be adequate to monitor the contaminant levels in the local fish populations.

The overall health of the Beaufort Lagoon fish appears good. The parasite infestations seem to be in the range of what normally might be expected for a wild fish population. The parasites for the most part don't appear to be adversely affecting fish health. The most commonly found parasite, *Bothrimonis sturionis* is also probably the most aesthically displeasing as these tapeworms were quite obvious and often filled much of the digestive tract of their hosts. There is no indication, however, that *B. sturionis* can be transmitted to man. Some of the other parasite species present less frequently may be of concern to public health. The *Diphyllobothrium* sp. may be transmittable to man. Hoffman (1967) reports *D. latrum* has developed in man in the United States and Canada. Bauer (1970) reports *D. dendriticum*, a species also known to infect man, is present in cisco in the U.S.S.R. Larval *Anisakis* nematodes, found in the fourhorn sculpin, have also been reported to cause acute abdominal syndrome in man (Hoffman 1967). To avoid risk of any parasite infections, the viscera should be discarded and the meat thoroughly cooked. Smoking or freezing may kill the parasites depending on temperature and the particular parasite species tolerance.

Acknowledgements

U.S. Fish and Wildlife Service employees David Wiswar and Barbara Mahoney spent countless hours preparing field samples for histopathological examinations. Stephen Goldberg of the Department of Biology at Whittier College, under the direction of William Yasutake of the Seattle National Fishery Research Center, examined the histopathological samples and prepared a report of findings. The histological preparations were made by D.W. Eib. Others at the Seattle National Fishery Research Center who helped in interpretations and recommendations for this portion of the report include D.G. Elliot, Dr. A.G. Sparks, J.F. Morado, L.D. Rhodes, M.S. Myers, and Dr. G.A. Wedemeyer. Scott Corley assisted in Arctic cisco ageing.

The contaminants analyses were organized by Howard Metsker, U.S. Fish and Wildlife Service, Anchorage. Special thanks are also due the laboratory staffs at Analytical Bio-Chemistry Laboratories, Inc., Columbia and Hazleton Laboratories America, Inc., Madison.

Dr. Glenn Hoffman provided invaluable assistance in the identification and verification of parasites. His many hours of sharing his expertise in parasistology are greatly appreciated.

Dr. Leo Margolis and staff at the Fish Health and Parasitology Section of the Pacific Biological Station in Nanaimo, B.C. also deserve special credit in their help in verifying parasite identifications. Dr. Jeffrey Bier of the Public Health Service also helped in parasite identification.

Finally, I wish to thank Reed Glesne and Tonya Stevens for their review of the manuscript and Susan Mang for help with figures and typing.

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Appendix 1. Results of individual fish examinations for parasites at Beaufort Lagoon, Alaska.

Sample Number*	Date	Number, Location, and Identification of Parasites**
AC-373-BL85	7/11/85	(8) *Salmincola* sp. on gills; (1) *Salmincola* sp. on vomer; 5 cysts attached to visceral mesentary; (61) *Bothrimonus sturionis* in lumen.
AC-599-BL85	7/13/85	(51) Cysts on pyloric caeca; (96) *B. sturionis* in lumen; (34) *B. sturionis* in intestine
AC-771-BL85	7/15/85	(2) *Salmincola* sp. on gills; (2) *Salmincola* sp. on pseudobranch; (1) *Salincola* sp. on tongue; (1) *Triaenophorous nodulosus* in stomach; (65) B. sturionis in lumen and intestine
AC-772-BL85	7/15/85	(5) *Salmincola* sp. on gills (217) cysts on pyloric caeca; (1) *Triaenophorus nodulosus* in stomach; (70) *B. sturionis* in digestive tract
AC-780-BL85	7/15/85	(1) *Cystidicola* sp. in swim bladder; (3) *B. sturionis* in intestine; (157) *B. sturionis* in lumen
AC-781-BL85	7/15/85	(3) *Salmincola* sp. on gills; (1) *Salmincola edwardsii* on pseudobranch; (2) cestodes in stomach; (264) *B. sturionis* in lumen
AC-782-BL85	7/15/85	(72) *B. sturionis* in lumen
AC-798-BL85	7/16/85	(1) *Salmincola edwardsii* on pseudobranch; (126) cysts on pyloric caeca; (4) *B. sturionis* in lumen
AC-800-BL85	7/16/85	(2) *Diphyllobothrium* sp. in liver; (2) cysts in kidney; (215) *B. sturionis* in digestive tract
AC-801-BL5	7/16/85	(1) cyst in kidney; (116) cysts on pyloric caeca; (81) *B. sturionis* in lumen; (4) *B. sturionis* in intestine
AC-802-BL85	7/16/85	(3) *Salmincola edwardsii* on pseudobranch; (3) *Salmincola* sp. on gills; (39) *B. sturionis* in lumen
AC-820-BL85	7/16/85	(33) *B. sturionis* in lumen
AC-821-BL85	7/16/85	(26) *B. sturionis* in lumen
AC-822-BL85	7/16/85	(53) *B. sturionis* in lumen
AC-823-BL85	7/16/85	(3) *B. sturionis* in lumen
AC-838-BL85	7/17/85	(19) *B. sturionis* in lumen
AC-839-BL85	7/17/85	(2) cysts in kidney; (18) *B. sturionis* in lumen
AC-840-BL85	7/17/85	(18) *Triaenophorus crassus* in muscle; (16) *B. sturionis* in lumen
AC-847-BL85	7/17/85	(1) Nematode loose in viscera; (2) cysts in kidney; (26) *B. sturionis* in intestine; (93) *B. sturionis* in lumen
AC-852-BL85	7/17/85	(1) *B. sturionis* in lumen
AC-1841-BL85	8/6/85	(1) *Salmincola* sp. on vomer; (1) cyst on stomach; (12) *B. sturionis* in intestine; (81) *B. sturionis* in lumen
AC-1842-BL85	8/6/85	(119) cysts on pyloric caeca; (1) *Triaenophorus crassus* in muscle; (1) cyst in kidney; (13) *B. sturionis* in lumen

Appendix 1. Continued.

Sample Number*	Date	Number, Location, and Identification of Parasites**
AC-1843-BL85	8/6/85	(1) Salmincola sp. on tongue; (5) Salmincola sp. on gills; (56) cysts on pyloric caeca; (1) cyst in kidney; (74) B. sturionis in digestive tract
AC-1844-BL85	8/6/85	(1) Salmincola edwardsii on pseudobranch; (27) B. sturionis in lumen
AC-1845-BL85	8/6/85	(16) B. sturionis in lumen; (112) B. sturionis in intestine
ACi-057-BL85	7/10/85	(2) Salmincola sp. on pelvic fins; (1) encapsulated egg case on ova; (4) Bothrimonus sturionis in lumen
ACi-067-BL85	7/11/85	(14) B. sturionis in intestine; (5) B. sturionis in lumen
ACi-077-BL85	7/11/85	(1) cyst on pyloric caeca; (7) Salmincola sp. on pelvic dorsal, and pectoral fins; (5) B. sturionis in lumen
ACi-095-BL85	7/12/85	(3) Salmincola sp. on dorsal, pelvic, and pectoral fins; (6) B. sturionis in intestine; (9) B. sturionis in lumen
ACi-096-BL85	7/12/85	(1) Salmincola sp. on pelvic fin; (39) B. sturionis in lumen; (94) B. sturionis in intestine
ACi-097-BL85	7/12/85	(36) cysts on pyloric caeca; (107) B. sturionis in intestine; (163) B. sturionis in lumen
ACi-098-BL85	7/12/85	(1) Salmincola sp. on pelvic fin; (31) B. sturionis in lumen; (88) B. sturionis in intestine
ACi-099-BL85	7/13/85	(1) cyst on pyloric caeca; (1) Salmincola sp. on dorsal fin; (5) B. sturionis in lumen
ACi-100-BL85	7/13/85	(2) Salmincola sp. on pelvic fin
ACi-101-BL85	7/13/85	(2) Salmincola sp. on pectoral and pelvic fins; (29) B. sturionis in intestine; (52) B. sturionis in lumen
ACi-102-BL85	7/13/85	(1) B. sturionis in lumen; (1) B. sturionis in intestine
ACi-104-BL85	7/14/85	(6) cysts on pyloric caeca; (16) B. sturionis in digestive tract; (1) nematode in stomach
ACi-105-BL85	7/14/85	(11) B. sturionis in lumen; (1) B. sturionis in intestine

Appendix 1. Continued.

Sample Number*	Date	Number, Location, and Identification of Parasites**
ACi-106-BL85	7/14/85	(2) Salmincola sp. on dorsal and pelvic fins; (4) cysts on pyloric caeca; (24) B. sturionis in lumen; (18) B. sturionis in intestine
ACi-107-BL85	7/14/85	(1) cyst on spleen; (1) B. sturionis in lumen
ACi-174-BL85	7/18/85	(1) Salmincola sp. on pelvic fin; (14) cysts on pyloric caeca; (3) cysts on gall bladder; (11) B. sturionis in lumen
ACi-175-BL85	7/18/85	(12) cestodes encysted in liver, pyloric caeca, and stomach wall; (1) Salmincola sp. on dorsal fin; (4) B. sturionis in digestive tract
ACi-176-BL85	7/18/85	(3) Salmincola sp. on pelvic, dorsal, and pectoral fin; (1) B. sturionis in intestine
ACi-357-BL85	8/7/85	(1) Trematode on gonads; (1) Salmincola sp. on pelvic fin; (3) cysts on pyloric caeca; (2) tiny unidentified parasites on liver; (32) B. sturionis in digestive tract
ACi-358-BL85	8/7/85	(1) Salmincola sp. on pelvic fin; (6) B. sturionis in intestine; (18) B. sturionis in lumen
ACi-359-BL85	8/7/85	(1) Salmincola sp. on pelvic fin; (40) B. sturionis in lumen; (13) B. sturionis in intestine
ACi-360-BL85	8/7/85	(2) Salmincola sp. on pelvic fin; (3) cysts in kidney; (3) cysts on intestine; (34) B. sturionis in digestive tract
ACi-361-BL85	8/7/85	(3) cysts in kidney; (12) B. sturionis in lumen; (1) B. sturionis in intestine
ACi-362-BL85	8/7/85	(1) Salmincola sp. on pelvic fin; (2) B. sturionis in lumen; (16) B. sturionis in intestine
ACi-363-BL85	8/7/85	(1) Salmincola sp. on pelvic fin; (17) B. sturionis in lumen; (22) B. sturionis in intestine
AF-001-BL85	7/8/85	"clean"
AF-002-BL85	7/8/85	"clean"
AF-004-BL85	7/9/85	(7) loose egg sacs on intestine from unidentified parasite
AF-005-BL85	7/9/85	"clean"
AF-006-BL85	7/9/85	"clean"

Appendix 1. Continued.

Sample Number*	Date	Number, Location, and Identification of Parasites**
AF-007-BL85	7/9/85	"clean"
AF-008-BL85	7/9/85	"clean"
AF-009-BL85	7/9/85	"clean"
AF-010-BL85	7/9/85	"clean"
AF-025-BL85	7/10/85	"clean"
AF-030-BL85	7/10/85	"clean"
AF-032-BL85	7/10/85	"clean"
AF-036-BL85	7/11/85	"clean"
AF-054-BL85	7/12/85	"clean"
AF-059-BL85	7/13/85	"clean"
AF-118-BL85	7/18/85	(4) Bothrimonus sturionis in digestive tract
AF-119-BL85	7/18/85	(6) Acanthocephalans on liver
AF-949-BL85	8/6/85	"clean"
AF-962-BL85	8/8/85	"clean"
AF-963-BL85	8/8/85	(1) cyst on gas bladder; (2) B. sturionis in intestine
AF-965-BL85	8/8/85	(5) B. sturionis in intestine; (5) Acanthocephala on liver and viscera
AF-966-BL85	8/8/85	"clean"
AF-968-BL85	8/8/85	(1) Acanthocephalan on viscera
AF-969-BL85	8/8/85	"clean"
AF-970-BL85	8/8/85	"clean"
FS-012-BL85	7/8/85	"clean"
FS-013-BL85	7/8/85	(1) Anisakis simplex in visceral mesentary
FS-014-BL85	7/8/85	(2) A. simplex in viscera mesentary
FS-039-BL85	7/9/85	(1) A. simplex on stomach
FS-040-BL85	7/9/85	(3) cysts on pyloric caeca; (1) A. simplex on stomach; (1) Bothriocephalus scorpii in lumen
FS-041-BL85	7/9/85	(3) Isopods on gills; (1) A. simplex loose in viscera
FS-042-BL85	7/9/85	"clean"
FS-131-BL85	7/9/85	"clean"
FS-131-BL85	7/9/85	"clean"
FS-132-BL85	7/9/85	(8) Bothriocephalus scorpii in digestive tract
FS-261-BL85	7/11/85	"clean"
FS-327-BL85	7/12/85	(1) cyst on intestine; (2) Bothrimonus sturionis in lumen; (7) Hysterothylacium sp. in digestive tract
FS-388-BL85	7/13/85	"clean"

Appendix 1. Continued.

Sample Number*	Date	Number, Location, and Identification of Parasites**
FS-436-BL85	7/13/85	(22) cysts in liver; (1) *A. simplex* loose in viscera
FS-437-BL85	7/13/85	(1) cyst on pyloric caeca; (1) *Eubothrium crassum* in digestive tract
FS-607-BL85	7/17/85	"clean"
FS-610-BL85	7/17/85	(2) Acanthocephalans on stomach
FS-615-BL85	7/17/85	(6) *B. sturionis* in intestine
FS-1579-BL85	8/6/85	(2) *A. simplex* in visceral mesentary; (1) *Eubothrium crassum* in intestine; (4) *B. sturionis* in lumen; (1) *Hysterothylacium* sp. in lumen
FS-1788-BL85	8/9/85	"clean"
FS-1789-BL85	8/9/85	"clean"
FS-1790-BL85	8/9/85	"clean"
FS-1791-BL85	8/9/85	"clean"
FS-1792-BL85	8/9/85	(1) *Eubothrium crassum* in intestine
FS-1793-BL85	8/9/85	(2) unidentified parasites in pyloric caeca; (7) Acanthocephala on intestine; (2) *Eubothrium crassum* in intestine

*AC = Arctic Char; ACi = Arctic cisco; AF = Arctic flounder; FS = fourhorn sculpin

**Counts of parasites are accurate; identification of large groups of parasites (greater than 10) were based on subsamples. This only applied to *Bothrimonus sturionis* and it is likely in some cases that similar size cestodes or trematodes occasionally got overlooked when entangled with masses of *B. sturionis*.

Appendix 2. Sample numbers, dates of collection, fork lengths, weights, condition factors, ages, and sex of fish samples from Beaufort Lagoon, Alaska.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
Histopathological Samples						
AC-056-BL84	7/24/84	410	660	.958	6+	F
AC-057-BL84	7/24/84	456	860	.907	7+	F
AC-059-BL84	7/25/84	494	1150	.954	7+	F
AC-060-BL84	7/25/84	519	1125	.805	7+	F
AC-061-BL84	7/25/84	491	1125	.950	6+	F
AC-064-BL84	7/25/84	505	1300	1.009	8+	F
AC-069-BL84	7/26/84	377	475	.886	5+	M
AC-070-BL84	7/26/84	510	1265	.954	8+	F
AC-071-BL84	7/26/84	384	525	.927	6+	F
AC-072-BL84	7/26/84	468	980	.956	7+	F
AC-073-BL84	7/26/84	420	650	.877	7+	M
AC-074-BL84	7/26/84	484	875	.772	7+	F
AC-075-BL84	7/26/84	505	1200	.932	7+	F
AC-076-BL84	7/26/84	340	305	.776	5+	M
AC-077-BL84	7/26/84	328	290	.822	4+	M
AC-078-BL84	7/26/84	295	204	.787	4+	F
AC-079-BL84	7/26/84	517	1225	.886	8+	F
AC-081-BL84	7/26/84	521	1440	1.018	7+	F
AC-082-BL84	7/26/84	302	245	.889	5+	M
AC-084-BL84	7/27/84	299	230	.860	4+	M
AC-085-BL84	7/27/84	505	1150	.893	6+	M
AC-086-BL84	7/27/84	432	750	.930	7+	M
AC-087-BL84	7/27/84	445	760	.862	7+	M
AC-088-BL84	7/27/84	335	300	.798	5+	F
AC-089-BL84	7/27/84	478	950	.870	7+	F
AC-091-BL84	7/27/84	301	250	.917	4+	M
AC-092-BL84	7/27/84	367	410	.829	5+	F
AC-093-BL84	7/27/84	533	1325	.875	8+	M
AC-094-BL84	7/27/84	506	1225	.946	7+	F
ACi-016-BL84	7/24/84	399	725	1.141	7+	F
ACi-017-BL84	7/24/84	371	650	1.273	6+	M
ACi-018-BL84	7/24/84	366	585	1.193	5+	M
ACi-019-BL84	7/24/84	350	485	1.131	5+	M
ACi-020-BL84	7/24/84	378	550	1.018	6+	F
ACi-023-BL84	7/24/84	392	615	1.021	6+	F
ACi-025-BL84	7/25/84	384	630	1.113	6+	F
ACi-026-BL84	7/25/84	449	1120	1.237	8+	F
ACi-027-BL84	7/25/84	391	675	1.129	7+	M
ACi-028-BL84	7/25/84	389	690	1.172	6+	F
ACi-030-BL84	7/25/84	390	700	1.180	6+	F

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
ACi-031-BL84	7/26/84	401	640	1.070	7+	F
ACi-032-BL84	7/26/84	389	660	1.121	7+	M
ACi-033-BL84	7/26/84	420	800	1.080	8+	M
ACi-034-BL84	7/26/84	369	560	1.051	6+	M
ACi-037-BL84	7/26/84	356	500	1.108	5+	M
ACi-038-BL84	7/26/84	432	1050	1.302	8+	F
ACi-039-BL84	7/26/84	389	710	1.206	6+	M
ACi-040-BL84	7/26/84	372	460	.894	7+	M
ACi-041-BL84	7/26/84	361	550	1.170	5+	M
ACi-042-BL84	7/26/84	362	510	1.290	6+	M
ACi-048-BL84	7/26/84	379	700	1.026	6+	F
ACi-049-BL84	7/26/84	420	760	1.024	8+	F
ACi-050-BL84	7/26/84	384	580	1.175	6+	F
ACi-051-BL84	7/26/84	371	600	1.085	6+	F
ACi-052-BL84	7/26/84	381	600	1.104	7+	M
ACi-054-BL84	7/26/84	408	750	.933	7+	F
ACi-055-BL84	7/26/84	377	500	1.141	6+	F
ACi-056-BL84	7/26/84	378	665	1.231	6+	F
ACi-057-BL84	7/26/84	378	820	1.518	6+	F
AF-001-BL84	7/27/84	143	35	1.197	4+	M
AF-002-BL84	7/27/84	115	21	1.381	4+	M
AF-003-BL84	7/28/84	210	185	1.998	5+	M
AF-005-BL84	7/28/84	114	20	1.350	4+	M
AF-006-BL84	7/28/84	151	40	1.162	4+	M
AF-007-BL84	7/28/84	104	15	1.333	3+	M
AF-008-BL84	7/29/84	125	27	1.382	4+	M
AF-009-BL84	7/29/84	115	20	1.315	4+	M
AF-010-BL84	7/29/84	110	15	1.127	3+	M
AF-011-BL84	7/29/84	122	30	1.652	4+	M
AF-012-BL84	7/29/84	135	34	1.382	4+	M
AF-013-BL84	7/29/84	136	29	1.153	4+	M
AF-014-BL84	7/29/84	109	20	1.544	3+	M
AF-015-BL84	7/30/84	130	29	1.320	4+	M
AF-016-BL84	7/30/84	125	9	.461	4+	M
AF-017-BL84	8/22/84	148	48	1.141	5+	M
AF-018-BL84	8/22/84	135	32	1.301	4+	M
AF-019-BL84	8/22/84	138	39	1.484	4+	M
AF-020-BL84	8/22/84	113	21	1.455	4+	M
AF-021-BL84	8/22/84	124	28	1.469	4+	M
AF-022-BL84	8/22/84	106	13	1.092	4+	M
AF-023-BL84	8/22/84	137	33	1.283	4+	M
AF-024-BL84	8/22/84	191	97	1.392	5+	M
AF-025-BL84	8/22/84	131	48	2.135	4+	M
AF-026-BL84	8/23/84	138	34	1.294	4+	M

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
AF-027-BL84	8/23/84	138	33	1.256	4+	M
AF-028-BL84	8/23/84	125	28	1.434	4+	M
AF-029-BL84	8/23/84	121	23	1.298	4+	M
AF-030-BL84	8/23/84	116	20	1.281	4+	M
AF-031-BL84	8/23/84	114	17	1.147	4+	M
FS-002-BL84	7/25/84	101	8	.776	2+	M
FS-003-BL84	7/25/84	99	7	.721	2+	M
FS-004-BL84	7/26/84	119	11	.653	2+	M
FS-007-BL84	7/26/84	96	8	.904	2+	M
FS-008-BL84	7/26/84	114	8	.540	2+	M
FS-009-BL84	7/26/84	134	22	.914	3+	M
FS-010-BL84	7/26/84	219	108	1.028	4+	F
FS-013-BL84	7/27/84	230	113	.929	5+	F
FS-014-BL84	7/27/84	121	12	.677	3+	M
FS-015-BL84	7/27/84	100	8	.800	2+	M
FS-018-BL84	7/27/84	153	52	1.452	4+	M
FS-019-BL84	7/27/84	139	28	1.043	3+	M
FS-020-BL84	7/27/84	111	12	.877	2+	M
FS-021-BL84	7/27/84	88	6	.880	2+	M
FS-022-BL84	7/27/84	184	55	.883	4+	F
FS-023-BL84	7/27/84	159	38	.945	3+	M
FS-026-BL84	7/27/84	103	6	.549	2+	M
FS-029-BL84	7/28/84	122	16	.881	3+	M
FS-032-BL84	7/29/84	222	109	.996	5+	M
FS-033-BL84	7/29/84	228	104	.877	5+	M
FS-034-BL84	7/29/84	102	8	.754	2+	M
FS-039-BL84	7/29/84	79	3	.608	2+	M
FS-040-BL84	7/29/84	97	8	.877	2+	M
FS-041-BL84	7/29/84	110	11	.826	2+	M
FS-042-BL84	7/29/84	123	15	.806	3+	M
FS-043-BL84	7/29/84	206	79	.904	4+	F
FS-045-BL84	7/29/84	154	38	1.040	3+	M
FS-047-BL84	7/29/84	195	72	.971	4+	F
FS-048-BL84	7/29/84	259	180	1.036	7+	F
FS-050-BL84	7/30/84	161	40	.958	4+	M
<u>Heavy Metals Samples</u>						
AC-413-BL84	7/30/84	408	1180	1.737	7+	F
AC-414-BL84	7/30/84	489	1120	.958	7+	F
AC-415-BL84	7/30/84	381	550	.994	6+	M
AC-416-BL84	7/30/84	476	1015	.941	7+	F
AC-417-BL84	7/30/84	490	1220	1.037	7+	F

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
ACi-164-BL84	7/30/84	399	895	1.409	7+	F
ACi-165-BL84	7/30/84	389	775	1.317	6+	F
ACi-166-BL84	7/30/84	429	870	1.102	9+	F
ACi-167-BL84	7/30/84	378	562	1.041	6+	F
ACi-168-BL84	7/30/84	381	603	1.090	6+	M
AF-032-BL84	8/23/84	202	113	1.371	6+	M
AF-033-BL84	8/23/84	211	178	1.895	6+	F
*** AF-034-BL84	8/23/84	136	36	1.431	4+	M
and AF-035-BL84	8/23/84	118	24	1.460	4+	M
AF-036-BL84	8/24/84	198	118	1.520	6+	M
*** AF-037-BL84	8/24/84	131	33	1.468	4+	M
and AF-038-BL84	8/24/84	120	26	1.505	4+	M
FS-051-BL84	7/30/84	179	58	1.011	4+	F
FS-052-BL84	7/30/84	173	53	1.024	4+	F
FS-053-BL84	7/30/84	136	24	.954	3+	M
FS-054-BL84	7/30/84	179	59	1.029	4+	F
FS-063-BL84	7/30/84	169	41	.849	4+	M
Hydrocarbons Samples						
AC-425-BL84	7/30/84	350	393	.917	5+	F
AC-427-BL84	7/30/84	394	554	.906	6+	M
AC-428-BL84	7/30/84	386	507	.882	6+	F
AC-429-BL84	7/30/84	464	830	.831	7+	M
ACi-169-BL84	7/30/84	381	705	1.275	6+	M
ACi-183-BL84	8/25/84	329	464	1.303	5+	M
ACi-184-BL84	8/25/84	331	456	1.257	5+	M
ACi-186-BL84	8/26/84	294	282	1.110	4+	M
ACi-187-BL84	8/26/84	385	728	1.276	6+	F
*** AF-039-BL84	8/24/84	143	44	1.505	4+	M
and AF-040-BL84	8/25/84	108	21	1.667	3+	M
AF-041-BL84	8/25/84	180	90	1.543	5+	M
AF-042-BL84	8/25/84	176	82	1.596	5+	M
AF-043-BL84	8/25/84	186	87	1.352	5+	M
*** AF-044-BL84	8/25/84	133	35	1.488	4+	M
and AF-045-BL84	8/25/84	123	31	1.666	4+	M
FS-064-BL84	7/30/84	172	47	.924	4+	M
FS-065-BL84	7/30/84	310	279	.937	10+	F
FS-240-BL84	8/25/84	249	208	1.347	7+	F

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
Parasite Samples						
AC-373-BL85	7/11/85	817	4820	.884	15+	M
AC-599-BL85	7/13/85	481	563	.563	7+	M
AC-771-BL85	7/15/85	538	1218	.871	9+	F
AC-772-BL85	7/15/85	586	1652	.821	10+	F
AC-780-BL85	7/15/85	476	854	.791	7+	F
AC-781-BL85	7/15/85	610	2063	.909	11+	M
AC-782-BL85	7/15/85	567	1628	.893	10+	M
AC-798-BL85	7/16/85	622	2238	.930	10+	F
AC-800-BL85	7/16/85	575	1637	.861	11+	M
AC-801-BL85	7/16/85	469	702	.680	7+	M
AC-802-BL85	7/16/85	458	880	.916	8+	F
AC-820-BL85	7/16/85	211	72	.764	3+	F
AC-821-BL85	7/16/85	156	28	.740	3+	F
AC-822-BL85	7/16/85	188	50	.751	3+	M
AC-823-BL85	7/16/85	110	12	.840	2+	F
AC-838-BL85	7/17/85	184	46	.738	3+	F
AC-839-BL85	7/17/85	371	347	.679	5+	F
AC-840-BL85	7/17/85	373	374	.720	5+	M
AC-847-BL85	7/17/85	366	344	.701	5+	F
AC-852-BL85	7/17/85	117	13	.799	2+	F
AC-1841-BL85	8/6/85	610	2010	.886	10+	M
AC-1842-BL85	8/6/85	549	1317	.797	11+	F
AC-1843-BL85	8/6/85	506	1163	.898	8+	F
AC-1844-BL85	8/6/85	221	90	.829	4+	F
AC-1845-BL85	8/6/85	196	65	.869	3+	F
ACi-057-BL85	7/10/85	446	851	.959	12+	F
ACi-067-BL85	7/11/85	404	697	1.057	13+	M
ACi-077-BL85	7/11/85	430	737	.927	13+	F
ACi-095-BL85	7/12/85	411	691	.995	10+	M
ACi-096-BL85	7/12/85	404	598	.907	9+	F
ACi-097-BL85	7/12/85	374	434	.830	9+	F
ACi-098-BL85	7/12/85	358	431	.939	7+	M
ACi-099-BL85	7/13/85	377	437	.816	8+	F
ACi-100-BL85	7/13/85	387	535	.923	8+	F
ACi-101-BL85	7/13/85	407	578	.857	9+	F
ACi-102-BL85	7/13/85	376	488	.918	8+	M
ACi-104-BL85	7/14/85	415	713	.998	12+	F
ACi-105-BL85	7/14/85	400	619	.967	11+	F
ACi-106-BL85	7/14/85	388	502	.859	10+	F
ACi-107-BL85	7/14/85	377	646	1.206	7+	F
ACi-174-BL85	7/18/85	417	728	1.004	12+	F
ACi-175-BL85	7/18/85	416	675	.938	12+	M

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
ACi-176-BL85	7/18/85	382	489	.877	8+	M
ACi-357-BL85	8/7/85	408	724	1.066	12+	M
ACi-358-BL85	8/7/85	362	517	1.090	7+	M
ACi-359-BL85	8/7/85	389	654	1.111	8+	M
ACi-360-BL85	8/7/85	345	480	1.169	7+	M
ACi-361-BL85	8/7/85	419	765	1.040	12+	F
ACi-362-BL85	8/7/85	371	517	1.012	9+	M
ACi-363-BL85	8/7/85	356	498	1.104	7+	M
AF-001-BL85	7/8/85	152	44	1.256	5+	M
AF-002-BL85	7/8/85	145	35	1.145	5+	M
AF-004-BL85	7/8/85	160	49	1.206	5+	M
AF-005-BL85	7/8/85	133	24	1.033	4+	M
AF-006-BL85	7/8/85	141	28	.999	5+	F
AF-007-BL85	7/8/85	114	15	.999	4+	M
AF-008-BL85	7/8/85	125	19	.983	5+	M
AF-009-BL85	7/8/85	138	29	1.103	4+	M
AF-010-BL85	7/9/85	194	96	1.316	5+	F
AF-025-BL85	7/10/85	175	62	1.161	5+	M
AF-030-BL85	7/10/85	217	129	1.259	6+	F
AF-032-BL85	7/10/85	166	58	1.264	5+	M
AF-036-BL85	7/11/85	211	122	1.296	6+	F
AF-054-BL85	7/12/85	185	69	1.093	5+	F
AF-059-BL85	7/13/85	164	52	1.179	5+	F
AF-118-BL85	7/18/85	196	79	1.044	6+	M
AF-119-BL85	7/18/85	298	347	1.310	9+	F
AF-949-BL85	8/6/85	195	107	1.446	6+	F
AF-962-BL85	8/8/85	159	47	1.164	4+	M
AF-963-BL85	8/8/85	159	50	1.234	5+	M
AF-965-BL85	8/8/85	207	131	1.478	6+	F
AF-966-BL85	8/8/85	176	79	1.444	5+	M
AF-968-BL85	8/8/85	192	87	1.232	6+	F
AF-969-BL85	8/8/85	172	65	1.283	5+	M
AF-970-BL85	8/8/85	170	60	1.219	5+	M
FS-012-BL85	7/8/85	191	67	.967	4+	F
FS-013-BL85	7/8/85	267	168	.883	8+	F
FS-014-BL85	7/8/85	231	101	.818	6+	M
FS-039-BL85	7/9/85	207	92	1.035	4+	F
FS-040-BL85	7/9/85	264	165	.895	7+	M
FS-041-BL85	7/9/85	208	96	1.062	5+	F
FS-042-BL85	7/9/85	199	74	.933	4+	M
FS-131-BL85	7/9/85	213	91	.944	5+	M
FS-132-BL85	7/9/85	247	158	1.047	7+	F
FS-133-BL85	7/9/85	224	140	1.241	6+	F

Appendix 2. Continued.

Sample Number*	Date	Fork Length (mm)	Weight (g)	Condition (K-value)	Age**	Sex
FS-261-BL85	7/11/85	186	60	.929	4+	F
FS-327-BL85	7/12/85	243	148	1.028	7+	F
FS-388-BL85	7/13/85	155	40	1.071	3+	M
FS-436-BL85	7/13/85	182	60	.995	4+	M
FS-437-BL85	7/13/85	225	119	1.042	6+	M
FS-607-BL85	7/17/85	242	182	1.281	7+	F
FS-610-BL85	7/17/85	182	45	.750	4+	M
FS-615-BL85	7/17/85	163	35	.797	4+	F
FS-1579-BL85	8/6/85	245	165	1.123	7+	F
FS-1788-BL85	8/9/85	127	14	.659	3+	F
FS-1789-BL85	8/9/85	137	25	.972	3+	M
FS-1790-BL85	8/9/85	118	14	.840	3+	M
FS-1791-BL85	8/9/85	276	58	1.057	4+	F
FS-1792-BL85	8/9/85	211	100	1.062	5+	F
FS-1793-BL85	8/8/85	255	175	1.057	7+	M

*AC = Arctic char; ACi = Arctic cisco; AF = Arctic flounder; FS = fourhorn sculpin

**1984 Arctic cisco aged by scales; all other samples aged by otoliths.

***Pooled samples for contaminant analysis (2 fish treated as 1 sample).