Technical Report No. 16-08

Fish and Aquatic Habitat Surveys in Drainages of Wainwright Inlet and Peard Bay, 2010–2015

by

Parker Bradley, William Morris, and Lawrence Moulton

June 2016

Alaska Department of Fish and Game **Division of Habitat**

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TECHNICAL REPORT NO. 16-08

FISH AND AQUATIC HABITAT SURVEYS IN DRAINAGES OF WAINWRIGHT INLET AND PEARD BAY, 2010–2015

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Abstract

Drainages discharging into Wainwright Inlet and Peard Bay were sampled for fish and aquatic habitat characteristics from 2010 through 2014. Fish were captured using fyke nets, set gillnets, and hoop traps. The most commonly captured fish species in Wainwright Inlet drainages were least cisco (*Coregonus sardinella*) followed by Arctic flounder (*Liopsetta glacialis*), Arctic grayling (*Thymallus arcticus*), fourhorn sculpin (*Myoxocephalus quadricornis*), ninespine stickleback (*Pungitius pungitius*), and rainbow smelt (*Osmerus mordax*). In the Kugrua River drainage, the main drainage into Peard Bay, rainbow smelt was the most commonly captured species followed by fourhorn sculpin, threespine stickleback (*Gasterosteus aculeatus*), and ninespine stickleback. Rainbow smelt were captured in both pre and post-spawning condition suggesting that they spawn in the Kugrua drainage. Additionally, pre- and post-spawning Pacific herring (*Clupea pallasii*) were captured in the Kungok River, a drainage in Wainwright Inlet, which we believe is the first documentation of spawning Pacific herring in Wainwright Inlet, and may be the northern-most spawning population in Alaska. The lack of freshwater fish species along with water quality data collected in the Kugrua River suggests there is not sufficient freshwater habitat to support substantial numbers of freshwater species. In 2011, pink salmon (*Oncorhynchus gorbuscha*) (n=13), chum salmon (*O. keta*) (n=11), and Chinook salmon (*O. tshawytscha*) (n=1) from the Kungok River were tagged with radio transmitters and relocated to identify spawning habitat. Pink salmon and chum salmon were relocated in September 2011 in various locations throughout the Kuk River, another drainage in Wainwright Inlet, which extended the range of known salmon spawning habitat. Additionally, burbot (*Lota lota*) from the upper Kuk River were tagged with radio transmitters in 2012 (n=29) and 2014 (n=50) and Arctic grayling were tagged in 2012 (n=12). Results indicate the lower Avalik River, a Kuk River tributary, provides feeding habitat for both species, while the upper Avalik River provides spawning and overwintering habitat for burbot. Growth rates for least cisco in the Kuk River drainage were lower than those for least cisco in other rivers on the North Slope, although their condition was slightly higher. Arctic grayling growth was higher in the Ivisaruk River compared to other areas including the upper Kuk River and Teshekpuk Lake.

Introduction

The Kuk and Kugrua rivers are two large drainages along the Chukchi Sea Coast on the North Slope of Alaska (Figure 1). The Kuk River discharges into Wainwright Inlet, while the Kugrua discharges into Peard Bay. The village of Wainwright is located at the mouth of Wainwright Inlet and its residents participate in subsistence fishing activities year round. However, even with this consumptive use, the fish resources of Wainwright Inlet and Peard Bay represent a major data gap with respect to our understanding of fish use within larger North Slope drainages. Prior to this study, systematic fish and aquatic habitat sampling of these Chukchi Sea drainages had not been conducted to a level adequate to make fish or fish habitat management determinations or an evaluation as to their significance to fish. If oil and gas development proceeds in this region, these rivers are likely to be crossed by pipelines connecting any Chukchi Sea development to the Trans-Alaska Pipeline System (TAPS) and are in the area identified for placement of Outer Continental Shelf related onshore facilities. These rivers have extensive estuarine lagoon-type habitats that could be impacted directly in the case of a product spill that reaches the coast.

The objectives of this study were to collect fish presence and population structure data as well as aquatic habitat data to begin to characterize fish use of these systems and their habitats. The baseline surveys were conducted to:

- Document occurrence and relative abundance by species,
- Determine size distributions by species,
- Document age, growth, body condition and age at maturity for dominant species,
- Tag numerically abundant subsistence fish species, including radiotagging and relocating burbot (*Lota lota*), Pacific salmon (*Oncorhynchus* spp.) and Arctic grayling (*Thymallus arcticus*), and
- Collect basic water quality information (temperature, specific conductance, turbidity, and pH)

An additional objective was to identify any potential rainbow smelt (*Osmerus mordax*) spawning areas within the study region as Wainwright Inlet is a well-known local resource for its abundant rainbow smelt population, which is a prized subsistence resource. Smelt are harvested under the ice in late winter and are especially sweet at that time of year; they are locally known as “sugar fish”. Rainbow smelt are an anadromous fish that spawn in the spring shortly after break-up.

New and expanded fish distribution data will be prepared and submitted for inclusion in the Alaska Department of Fish and Game Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes, the basis for Alaska fish habitat permitting under Alaska Statute 16.05.871, and the Alaska Freshwater Fish Inventory Database as appropriate.

Methods

The drainages of Wainwright Inlet and Peard Bay, which include the Kuk and Kugrua River drainages, were sampled from 2010[1] to 2015, during seven sampling events (Figure 1; Table 1). The Kungok River, which drains into eastern Wainwright Inlet, was sampled in 2011. In 2012, sampling focused on the Kaolak, Avalik, and Ketik tributaries in the upper Kuk River region of Wainwright Inlet. The Kugrua River, which flows into Peard Bay, was sampled in 2013. Finally, the upper Kuk River was sampled again in 2014, with the primary goal of deploying radio tags in burbot for determining seasonal habitat use and movement patterns. Detailed dates are provided in Table 1.

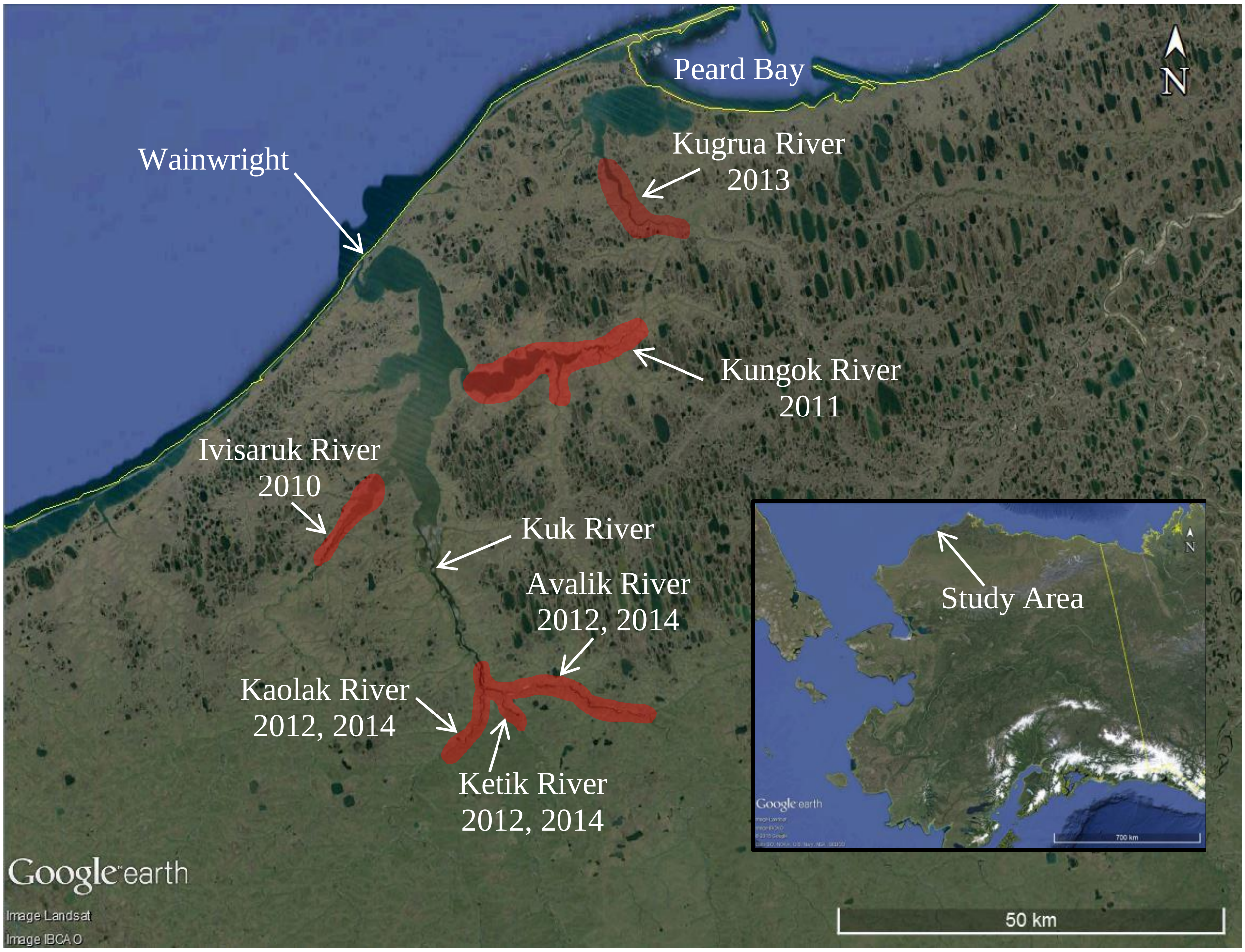


Figure 1. Sampling areas and years sampled in the Kuk and Kugrua River drainages from 2010 through 2014

[1]In 2010, the Ivisaruk River, which drains into the western portion of Wainwright Inlet, was sampled but was not part of this CIAP funded project. The results are included in this report for comparative purposes.

Table 1. Summary of sampling events in the Kuk and Kugrua River drainages 2010–2014.

River	2010	2011	2012	2013	2014
Ivisaruk	Aug. 4–Aug. 9	-	-	-	-
Kungok	-	June 27–July 9 Aug. 4–Aug. 13	-	-	-
Upper Kuk	-	-	June 17–July 6 July 31–Aug. 14	-	June 22–June 27
Kugrua	-	-	-	July 23–July 31	

Fish Sampling

Fyke nets were deployed at a variety of locations in the Ivisaruk, Kungok, upper Kuk, and Kugrua rivers. Fyke nets were comprised of two 4 X 4 ft. aluminum frames with 5 hoops and two throats and were capable of capturing all sizes of fish (Figure 2). Depending on the habitat type, they were typically set with two wing nets and a center lead going to shore ranging in length from 25–100 ft. Nets were checked daily on an approximately 24 hour schedule.

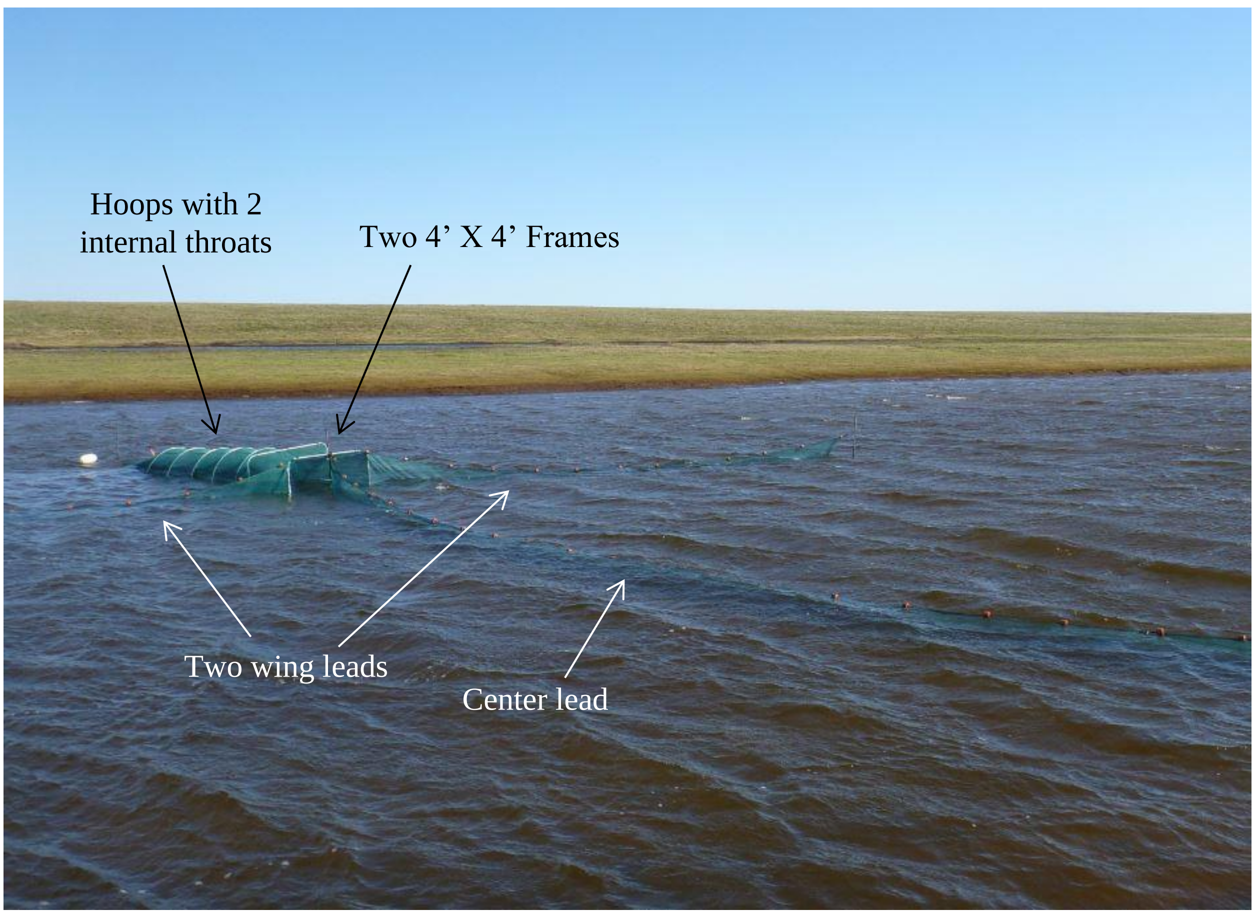


Figure 2. Fyke net set in the Kungok River 2011.

Station number, set number, and set end time were recorded prior to fish processing. Captured fish were emptied from the cod end of the fyke net into a floating net pen. The following data were recorded for each fish before releasing: species, fork length (FL) to the nearest mm or total length (TL) to the nearest mm; (burbot, fourhorn sculpin (*Myoxocephalus quadricornis*), slimy sculpin (*Cottus cognatus*), threespine stickleback (*Gasterosteus aculeatus*), and Arctic flounder (*Liopsetta glacialis*)) to the nearest millimeter, and abnormalities or presence of parasites. Pacific salmon were measured for mid-eye fork length (MEFK) to the nearest mm.

Some species were tagged with unique numbered tags to reveal fish movements within the drainage system. Floy® (FD-94) T-bar Anchor Tags were applied to least cisco (*Coregonus sardinella*) and Arctic grayling >180 mm, and burbot >330 mm. Tag numbers were recorded upon release and recapture.

Set gillnets with a variety of mesh sizes were used to obtain fish for stomach sample analysis and to capture Pacific salmon for genetic sampling. Fish for stomach samples were obtained from short-duration set gillnet sets to minimize digestion of prey items prior to removing the stomach. The abdominal cavity was opened and a small piece of twine was tied around both the esophagus and small intestine to prevent contents from leaking when placed in preservative. Stomachs were preserved in 70% ethanol and contents identified by a private laboratory. Fish obtained from fyke nets are not suitable for stomach analysis because the fish may have been in the net for up to 24 hours. Salmon for genetic sampling were captured through closely monitored set gillnet sets to minimize damage to the fish.

Hoop traps 0.53 m in diameter and 1.4-m long containing four hoops and two throats were fished only in few locations in the Kungok and upper Kuk rivers (Figure 3). Traps were baited with fish and set in deep pools near meander bends or in the main channel.

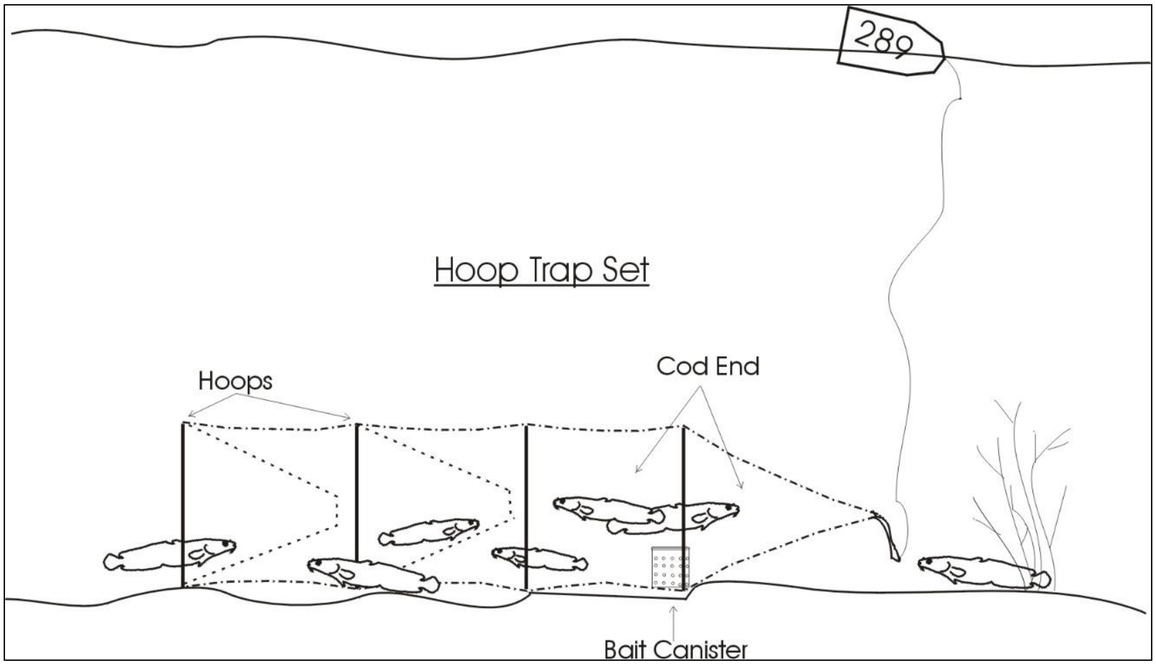


Figure 3. Diagram of a typical hoop trap set used in this study.

Fish Lab Analysis

Some captured fish were retained for analysis of length-weight, age-length, state of maturity, and to determine stomach contents. For evaluating fish age, the sampling objective was to obtain 15 fish for each 50 mm length interval beginning at 50 mm for most species of fish in each study area. Otoliths were retained and aged using the standard break and burn or cross section method (Chilton and Beamish 1982).

Sex and maturity were determined for each fish retained using the following maturity scale (Moulton 2010).

1. Immature: young individuals that have not engaged in reproduction: gonads very small, may be hard to sex.
2. Mature: non-spawners, eggs are distinguishable, ovary pink or orange, sex easy to identify. Testes light brown or ivory, but not enlarged.
3. Mature: pre-spawners, likely to spawn this year, ovaries large, individual eggs easy to see, may be 0.5 to 1.0 mm in diameter. Testes white and enlarged.
4. Spawning condition: ripe, eggs or milt extruded when light pressure is applied to the belly.
5. Spent: sex products are discharged leaving the gonads appearing like deflated sacs, residual eggs and sperm may be present.
6. Recovering: ovaries or testes empty, flaccid; fish likely spawned during the previous season.

Radiotelemetry

Pacific salmon, burbot, and Arctic grayling were targeted for surgical or esophageal radio tag implantation. All radio tags used for salmon were Lotek MCFT2-3A and were 16 mm in diameter, 46 mm in length, and weighed 16 g (6.7 g in water). All salmon were radiotagged by inserting the transmitter into their esophagus. Transmitter antennas were multi-stranded stainless steel, 1.02 mm diameter, and 45.5 cm long. Antennae were Teflon coated and covered with shrink wrap tubing to increase rigidity. In 2012, Lotek MCFT2-3BM radio tags were surgically implanted in burbot and Arctic grayling. These tags were 11 mm in diameter, 43 mm in length, and weighted 8 g (3.7 g in water). In 2014, Lotek MCFT2-3FM radio tags were surgically implanted in burbot. These tags were 11 mm in diameter, 59 mm in length, and weighed 10 g (4.6 g in water).

Fish selection for transmitter implantation was based on three major criteria; fish size, fish condition, and water temperature. Only fish caught in good condition, in water temperatures less than 15ºC, and large enough to survive with the added weight of the transmitter were considered as candidates. We computed minimum fish size, based on known length-weight relationships, considering only air weights for both the fish and the transmitters and a 2% of body weight maximum to ensure that fish would be able to handle the increased load. Only Arctic grayling ≥350 mm and burbot ≥500 mm were radiotagged.

Fish selected for surgical implantation were anesthetized in water with a diluted eugenol solution (clove oil or Aqui-S-20E) at an approximate concentration of 60 mg/L until they lost equilibrium and did not respond to handling (Anderson et al. 1997; Peake 1998; Klefoth et al. 2008). Radio tags were surgically implanted through an incision made along the centerline of the abdomen and approximately 4 cm anterior to the vent (Breeser et al. 1988, Evenson, 1993). To insert the antenna, a groove director was placed into the abdominal cavity and oriented towards the rear of the fish where it directed a 14-gauge catheter inserted from approximately 4 cm posterior of the initial incision. Once in place, the antenna was fed through the catheter and the groove director and then the catheter was removed from the fish. The incision was closed with three to five 3-0 monofilament sutures. After closing the incision, Vetbond™ surgical adhesive (3M™, St. Paul, Minnesota) was applied to further secure the sutures. During the surgical procedure, fresh water was continuously applied to the gills to prevent suffocation. Following surgery, radiotagged fish were placed into a holding pen until they could maintain equilibrium, at which time they were released.

Aerial Relocation

Surveys to relocate radiotagged fish were conducted with a Cessna 182 using two Lotek SRX-600 receivers. One receiver was connected to two antennas attached to each wing strut; the antennae were aimed down and outward at approximately 20 degrees. The second receiver was attached to a single antenna attached to the belly of the plane; this antenna was aimed straight down. Locations of fish were determined by evaluating each receiver for the highest signal strength between the two receivers for a given tag and selecting that as the most accurate position. In 2011, all the major rivers and tributaries in the Kuk River drainage were flown to locate the radiotagged salmon (Figure 4). From 2012 through 2015, only the upper Kuk River was flown to locate the radiotagged Arctic grayling and burbot (Figure 5).

Minimum movement rates were calculated for burbot and Arctic grayling when detected in two successive relocation flights. Minimum distance traveled was calculated by measuring the river kilometers between the two relocations.

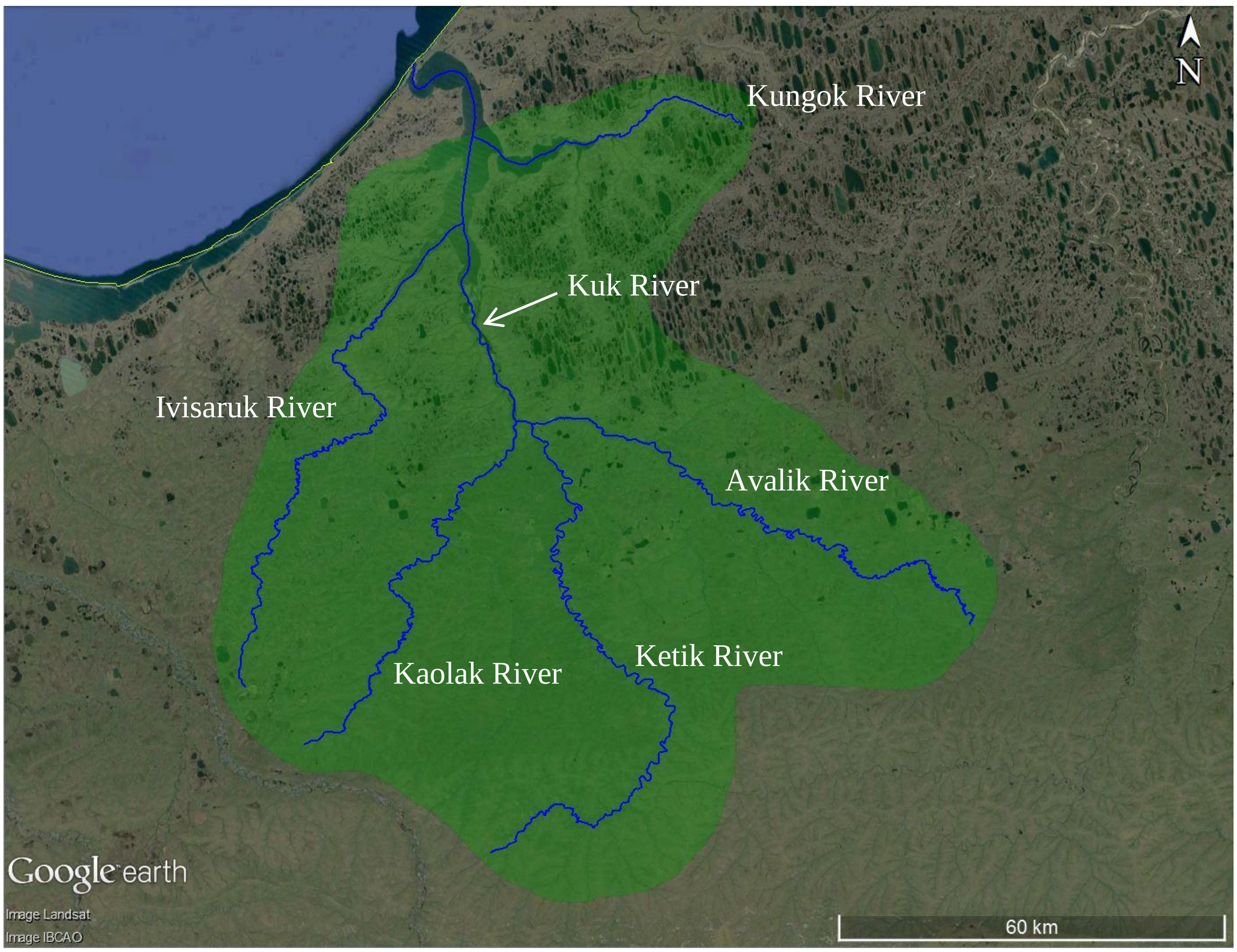


Figure 4. General aerial survey area covered during Pacific salmon relocation flights, 2011.

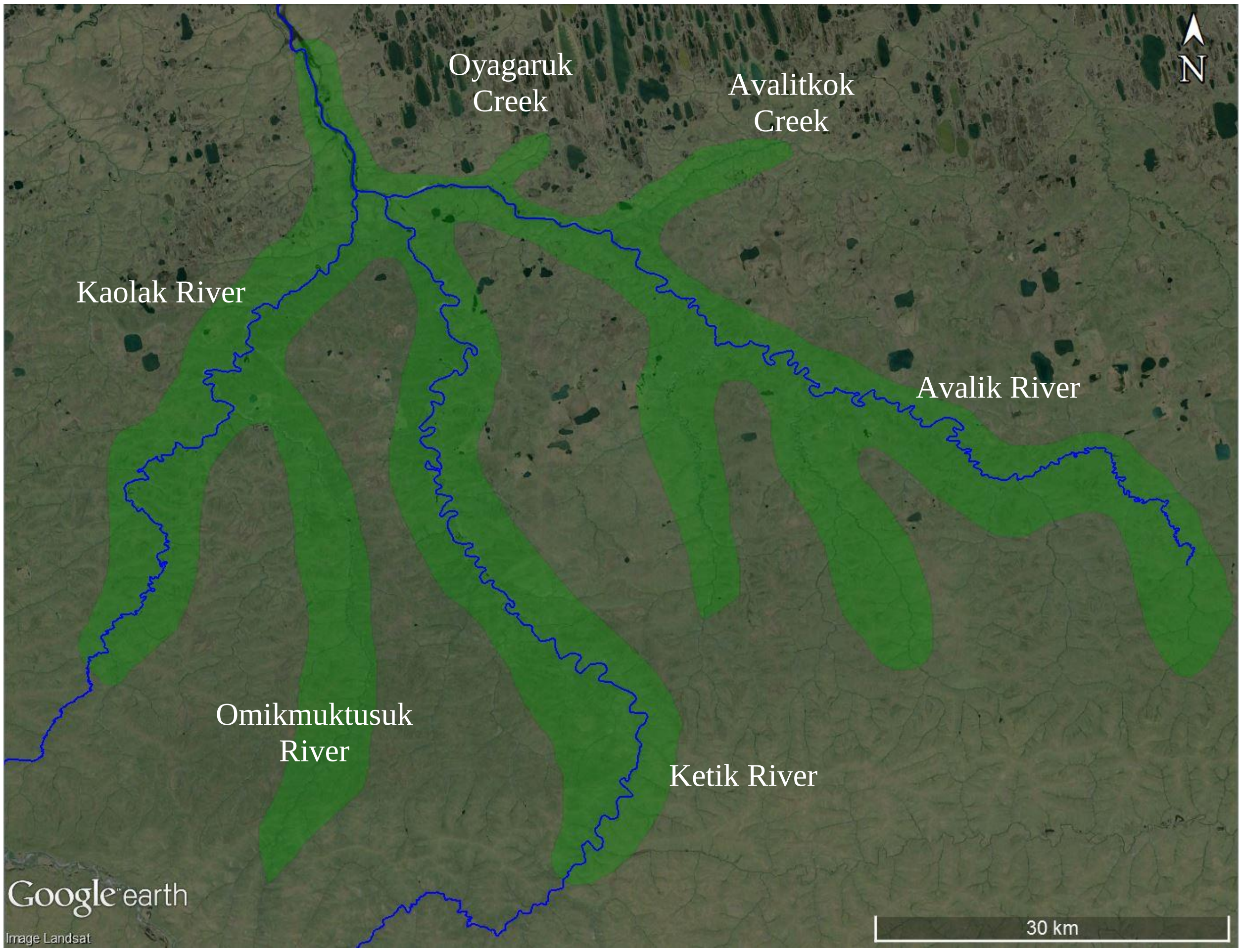


Figure 5. General survey area covered during burbot and Arctic grayling relocation flights, 2012–2015.

Macroinvertebrate Sampling

A Wildco Petite Ponar dredge was used to collect benthic (i.e., bottom) macroinvertebrate samples in proximity to fish sampling sites. At each site, three bottom grabs were taken, rinsed through a 500-µm mesh sieve, composited, and preserved with 95% ethanol. Samples were processed and invertebrates identified by a private laboratory following procedures recommended by the United States Geological Survey (Cuffney et al. 1993) and described following Vinson and Hawkins (1996).

A D-frame kick net (500 µm mesh) was used to collect macroinvertebrate samples from vegetated habitat in the vicinity of fyke net sets. A sweep sampling technique was used with each sample consisting of three parallel sweeps through macrophytes. Three approximately 1-m long sweep samples were collected at each location, composited, and preserved with 95% ethanol. Samples were processed and invertebrates identified by a private laboratory following procedures used for dredge samples (Cuffney et al. 1993; Vinson and Hawkins 1996).

An 80 µm mesh Wisconsin zooplankton net with a 30-cm (12 in) opening was used to collect invertebrates at all of the sites where the Petite Ponar dredge was used. Three 1-m vertical tows were conducted with the net typically starting just above the substrate. Samples were preserved with 95% ethanol and composited prior to analysis. Zooplankton were identified by a private laboratory.

Phytoplankton

Phytoplankton (free-floating algae) were collected at various locations as a means of establishing a baseline for lower trophic level organisms. Chlorophyll-a concentration of phytoplankton provides an estimate of algal biomass in the water column and serves as an indicator of primary productivity. Phytoplankton was collected by pumping two liters of water through a 0.7-µm glass fiber filter and adding magnesium carbonate ($MgCO_3$) to prevent degradation of chlorophyll. Samples were placed in plastic sealable bags with desiccant, wrapped in foil, and placed in a portable freezer until they were transported back to the laboratory. Three to six samples were collected at each location and frozen until they were processed by ADF&G, Division of Habitat personnel at the department laboratory in Fairbanks. Samples were analyzed for chlorophyll-a concentration with a spectrophotometer after extracting pigments with aqueous acetone (Clesceri et al. 1998).

Water Quality

In situ water quality parameters were measured to assess general fish habitat conditions. At the end of each fyke net check, a Hach HQ40D multi-parameter meter was used to collect basic ambient water quality information including temperature, specific conductivity, and pH at each fyke net location. Measurements were taken at a depth of approximately 0.5 m (1.5 ft) near the trap end of the net. A surface grab sample was obtained for field laboratory determination of turbidity using a Hach 2100P turbidimeter.

Data Analysis

Catch-per-unit-effort (CPUE) was calculated for each species for each net set by dividing the number of fish captured by duration in days (#fish/24 hrs). Mean CPUE for each species at each sampling site was calculated.

Age-length relationships, which are measures of growth rates, by fish species, were determined using linear regression analysis of age versus log transformed FL data. Length-weight relationships, which are measures of fish conditions, were determined using linear regression analysis of log transformed length versus log transformed weight data. Analysis of covariance (ANCOVA) was used to examine differences in the slopes and intercepts of the linear growth and length-weight relationships between sexes, age classes, and sampling drainages where appropriate. In addition, growth rates and length-weight relationships calculated in the current study were compared to growth rates obtained from historical sampling within the region. All ANCOVA tests for slopes and intercepts were deemed significant at alpha less than or equal to 0.05.

Results and Discussion

Results and major trends will be presented by drainage; starting with sampling dates and locations followed by fish catch data, fish length frequencies, aquatic invertebrate composition, chlorophyll-a concentrations, water quality parameters, and radiotelemetry results (if applicable). Finally, length-weight, growth, age and size at maturity will be presented for least cisco, Arctic grayling, burbot, Pacific herring (*Clupea pallasii*), and rainbow smelt.

Ivisaruk River

Sampling of the Ivisaruk River was conducted from August 4–9, 2010. Six locations were sampled for fish using fyke and set gillnets (Figure 6; Appendix 1).

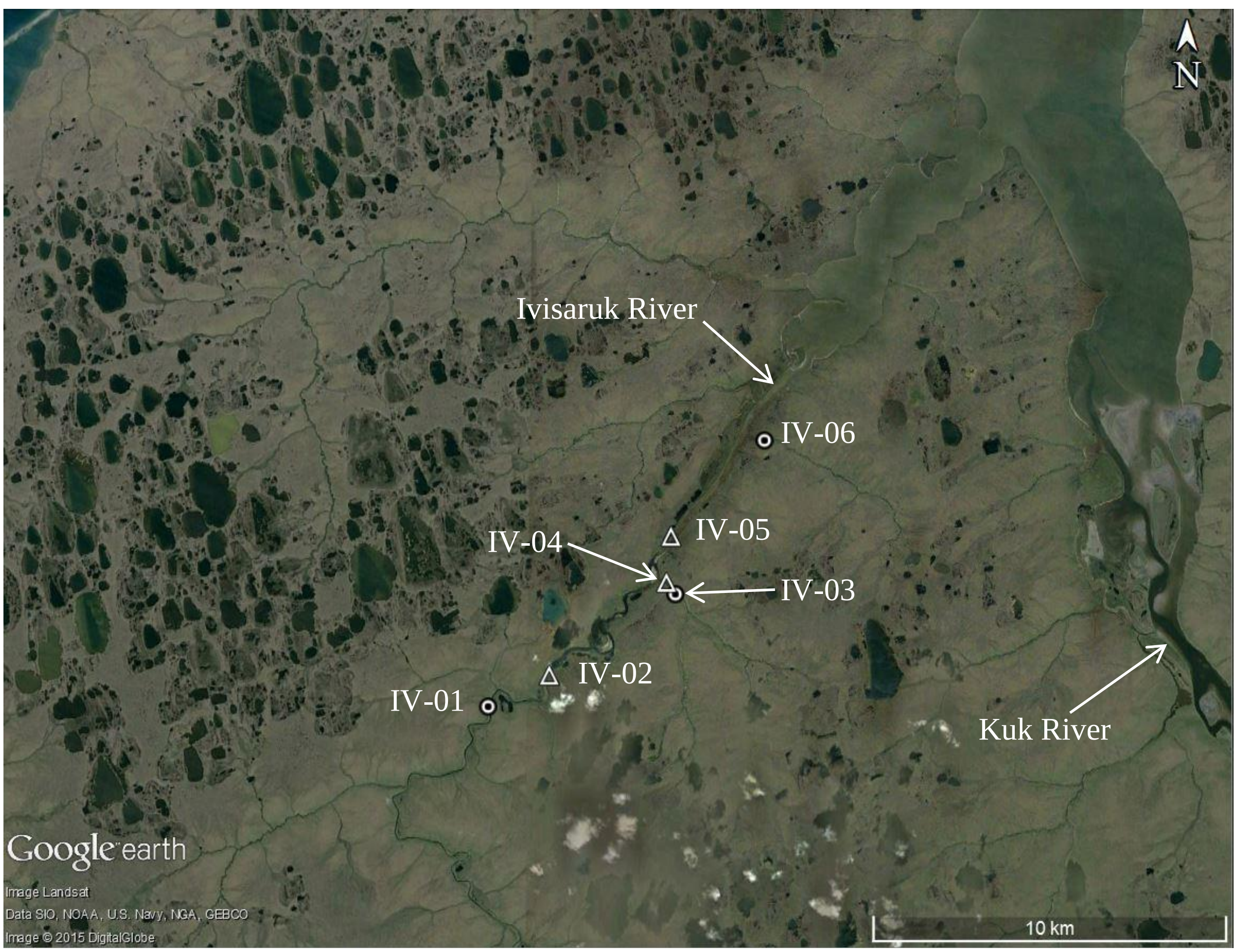


Figure 6. Sites sampled on the Ivisaruk River, 2010. Dots represent fyke net locations, triangles represent both fyke net and set gillnet locations.

Fish Catch Data

A total of 586 fish were captured with fyke nets in 334.6 total effort hours (Table 2). Least cisco were the most commonly captured species followed by Arctic grayling, ninespine stickleback (*Pungitius pungitius*), and threespine stickleback (Table 2). A total of 22 fish were captured with set gillnets in 9 hours of sampling effort with least cisco (n=16) being the most common species captured, followed by Arctic grayling (n=5) and chum salmon (*Oncorhynchus keta*) (n=1).

Table 2. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch of each species captured with fyke nets in the Ivisaruk River, August 4–9, 2010.

Species	Number of Fish	Mean CPUE	Percent of Catch
Least cisco	234	18.12	39.9
Arctic grayling	171	10.34	29.2
Ninespine stickleback	64	5.63	10.9
Threespine stickleback	62	4.65	10.6
Fourhorn sculpin	48	3.32	8.2
Arctic flounder	7	0.45	1.2
Total catch	586		
Total effort (hrs.)	334.6		

Least cisco

Least cisco ranged from 35 to 335 mm with a majority (59%) ranging from 35 to 63 mm (Figure 7).

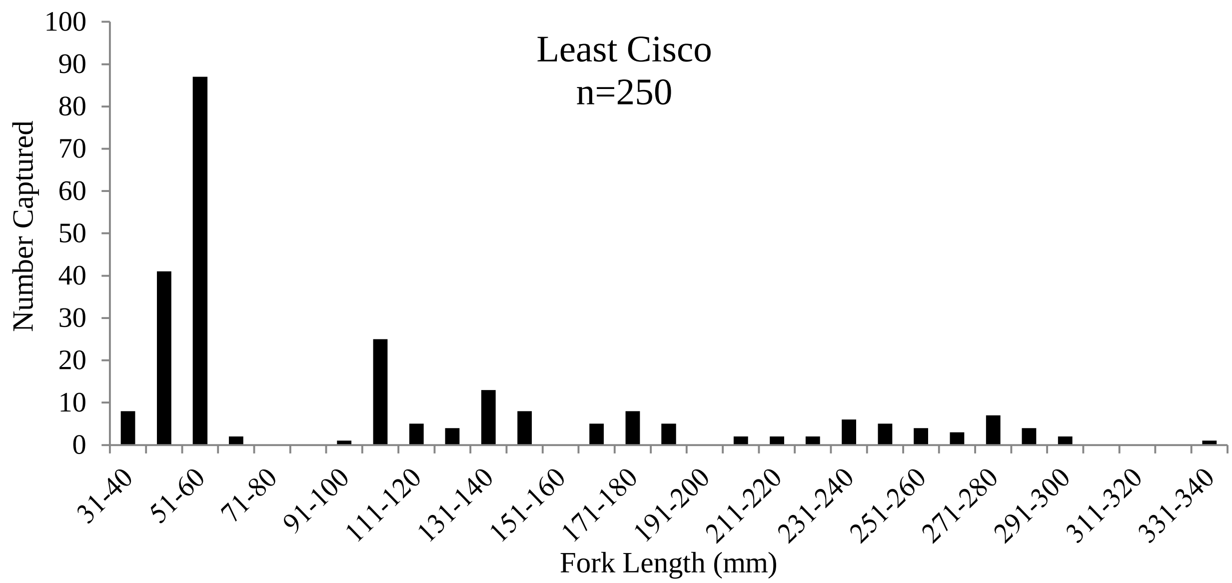


Figure 7. Length frequency distribution of least cisco captured with fyke nets and set gillnets in the Ivisaruk River, 2010.

Arctic grayling

Arctic grayling ranged from 82 to 381 mm with 40% less than 125 mm (Figure 8).

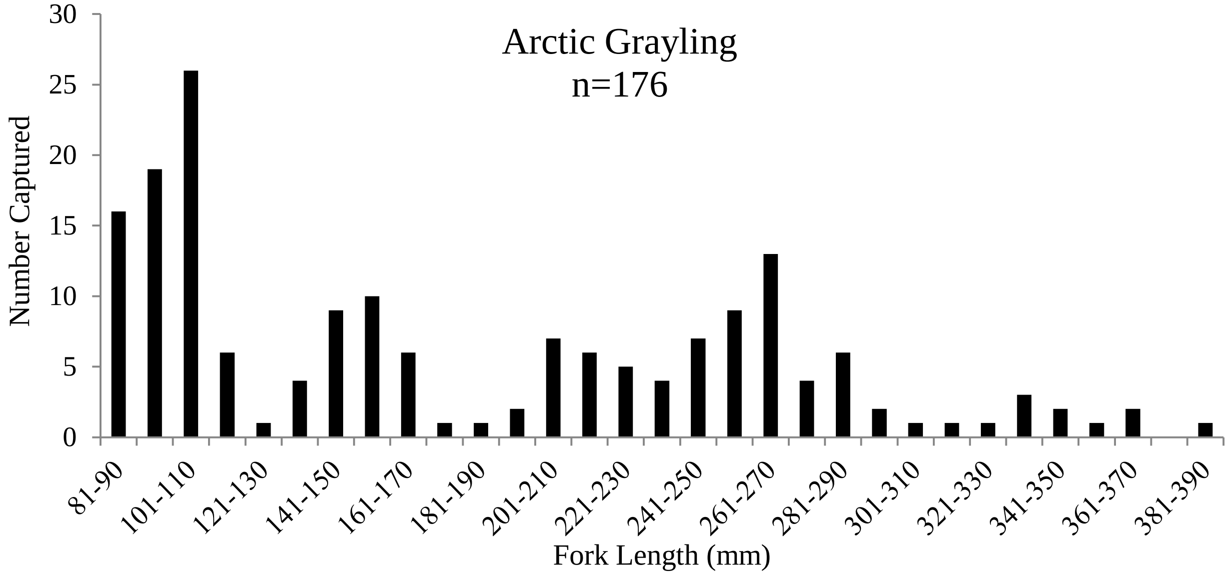


Figure 8. Length frequency distribution of Arctic grayling captured with fyke nets and set gillnets in the Ivisaruk River, 2010.

Chlorophyll

Mean chlorophyll-a concentrations measured at stations IV-02 and IV-04 were identical at 2.05 mg/m^3 (Figure 9).

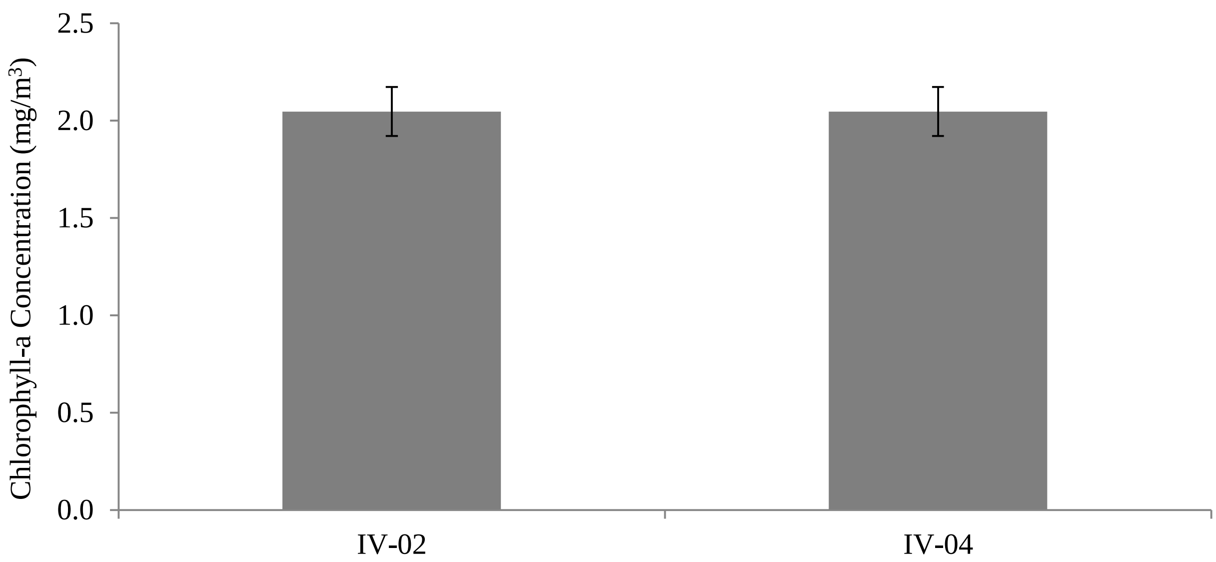


Figure 9. Mean chlorophyll-a concentrations (± 1SD) at two sample sites in the Ivisaruk River 2010.

Water Quality

Water temperature measured at the various sample sites steadily decreased over the six day sampling event from an average of 15.4ºC on August 4 to 7.7ºC on August 9, 2010 (Appendix 2). This coincided with an increase in pH over the sampling period from an average of 7.17 to 7.77. Turbidity was variable and ranged from 1.89 to 46.9 NTU (Figure 10). Specific conductance was also variable and ranged from 291 to 500 µS/cm at the predominantly freshwater stations IV-01 and IV-02, and varied from 7,285 to 13,869 µS/cm at the remaining brackish water sampling stations (Figure 10).

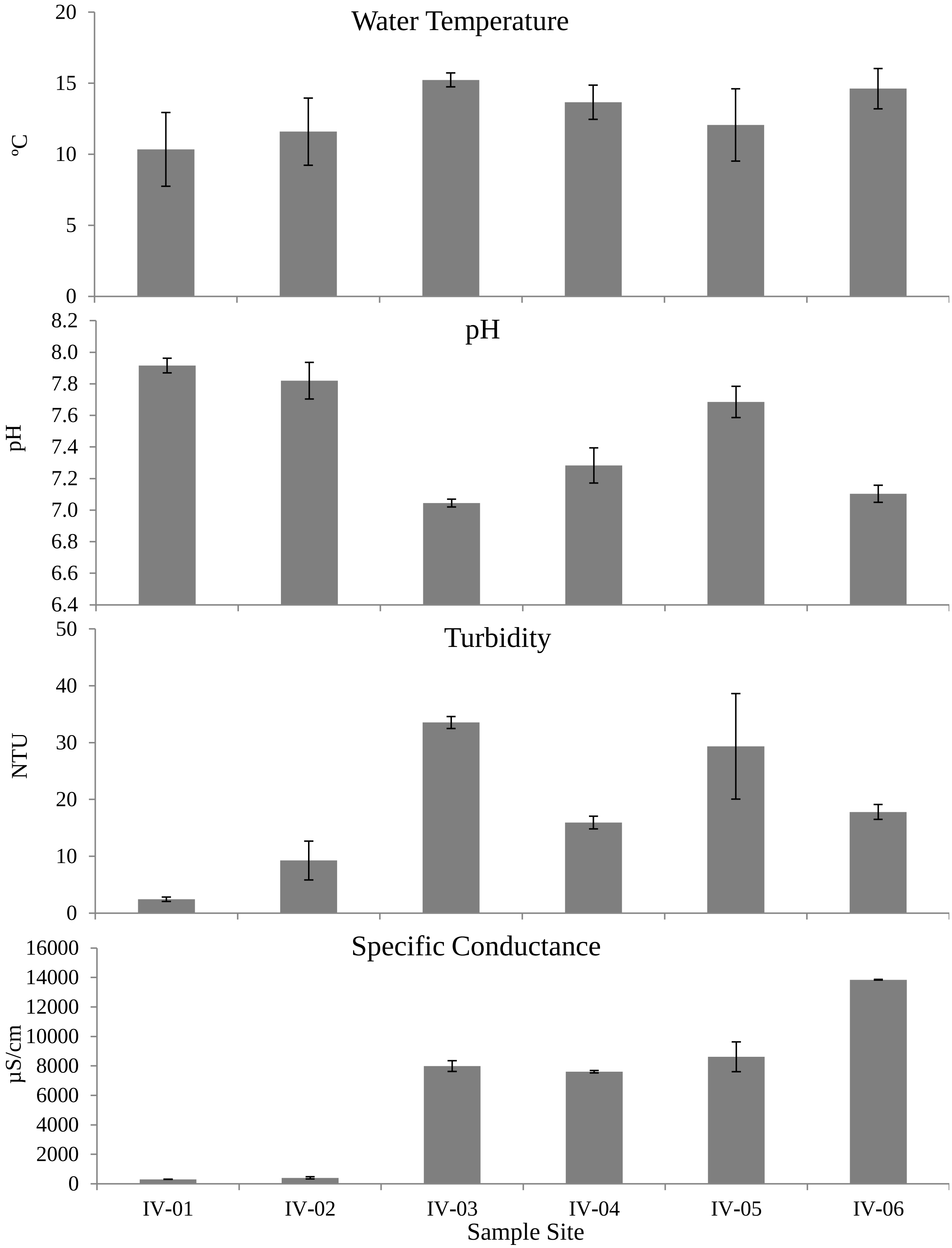


Figure 10. Mean (±1 SD) water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) for each sample site in the Ivisaruk River drainage, August 2010.

Kungok River

Sampling of the Kungok River was conducted during the periods June 27–July 9, 2011 and August 4–13, 2011. A total of 34 locations divided into three geographic regions were sampled for fish using fyke nets, set gillnets, hoop nets, and seine nets (Figure 11, Appendix 3). The Upper Arm was defined as stations 1 to 10, the Middle Arm stations 11 to 22, and the Outer Arm stations 23 to 34 (Figure 11). Aquatic invertebrates were sampled at 9 locations and phytoplankton samples were collected at 8 locations.

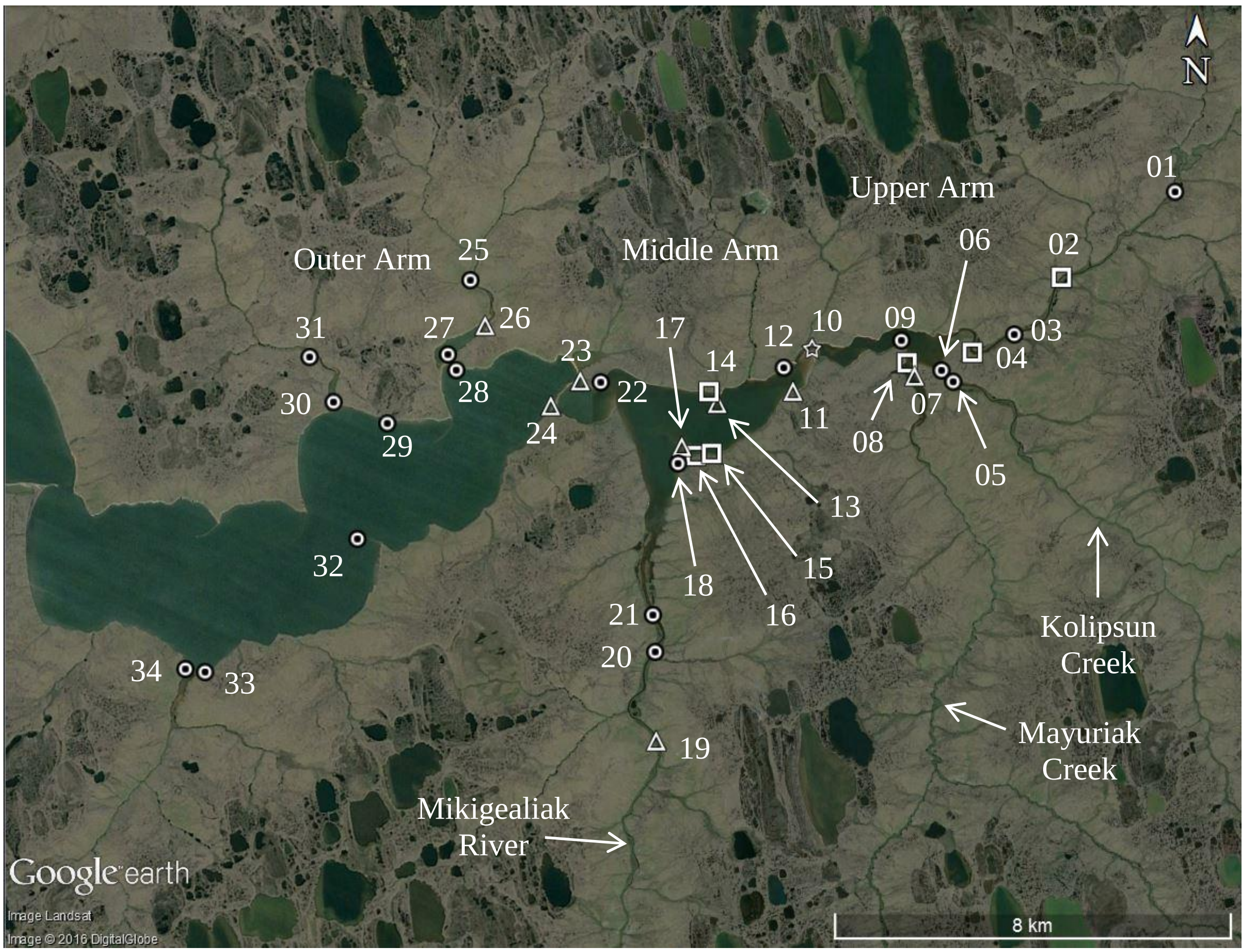


Figure 11. Sites sampled on the Kungok River (KN-##), 2011. Dots represent fyke net locations, squares represent set gillnet locations, stars represent hoop net locations, and triangles represent sample sites where multiple gear types were used. Upper Arm was defined as stations 01 to 10, the Middle Arm stations 11 to 22, and the Outer Arm stations 23 to 34.

Fish Catch Data

A total of 14,623 fish comprised of 12 fish species were captured in 2,595 fyke net effort hours in the Kungok River drainage with least cisco making up a majority of the catches followed by Arctic flounder, fourhorn sculpin, rainbow smelt, ninespine stickleback, Pacific herring, threespine stickleback, pink salmon (*Oncorhynchus gorbuscha*), saffron cod (*Eleginus gracilis*), Bering cisco (*Coregonus laurettae*), Arctic grayling, and Arctic cod (*Boreogadus saida*) (Table 3). A total of 155 fish comprised of 7 species were captured in 350 set gillnet effort hours in the Kungok River. Pink salmon made up a majority of the catches followed by least cisco, fourhorn sculpin, chum salmon, Arctic flounder, Chinook salmon (*Oncorhynchus tshawytscha*), and Bering cisco (Table 4). During set gillnet sampling in June/July, only multi-mesh set gillnets were used whereas during the August sampling, a variety of set gillnets were used from multi-mesh to 5.8 inch mesh. Fish species captured were indicative of the mixed brackish and freshwater habitats sampled in the river.

Table 3. Number of fish, mean CPUE (#fish/24 hrs), and percent of catch of each species captured with fyke nets in the Kungok River, 2011.

	Number of Fish			Mean CPUE		Percent of Catch		
Species	June 27–July 7	Aug 4–Aug 13	Total	June 27–July 7	Aug 4–Aug 13	June 27–July 7	Aug 4–Aug 13	Total
Least cisco	7,092	4,094	11,186	126.69	80.27	75.9	77.5	76.5
Arctic flounder	962	511	1,473	17.30	10.25	10.3	9.7	10.1
Fourhorn sculpin	720	316	1,036	12.94	6.37	7.7	6.0	7.1
Rainbow smelt	201	202	403	3.49	4.08	2.2	3.8	2.8
Ninespine stickleback	206	54	260	2.99	1.07	2.2	1.0	1.8
Pacific herring	105	2	107	1.77	0.03	1.1	<0.1	0.7
Threespine stickleback	3	42	45	0.05	0.87	<0.1	0.8	0.3
Pink salmon	0	41	41	0	0.82	0	0.8	0.3
Saffron cod	11	16	27	0.20	0.31	0.1	0.3	0.2
Bering cisco	22	2	24	0.38	0.04	0.2	<0.1	0.2
Arctic grayling	19	1	20	0.35	0.02	0.2	<0.1	0.1
Arctic cod	0	1	1	0	0.02	0	<0.1	<0.1
Total catch	9,341	5,282	14,623					
Number of species	10	12	12					
Total effort (hrs.)	1,380	1,215	2,595					

Table 4. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch of each species captured with set gillnets in the Kungok River, 2011.

Species	Number of Fish			Mean CPUE		Percent of Catch		
	June 27–July 7	Aug 4–Aug 13	Total	June 27–July 7	Aug 4–Aug 13	June 27–July 7	Aug 4–Aug 13	Total
Pink salmon	0	58	58	0	6.05	0	46.8	37.4
Least cisco	26	25	51	25.62	4.47	83.9	20.2	32.9
Fourhorn sculpin	1	23	24	0.80	2.12	3.2	18.5	15.5
Chum salmon	0	15	15	0	1.18	0	0.8	9.7
Arctic flounder	3	2	5	3.33	0.12	9.7	1.6	3.2
Chinook salmon	0	1	1	0	0.09	0	0.8	0.6
Bering cisco	1	0	1	1.2	0	3.2	0	0.6
Total catch	31	124	155					
Number of species	4	6	7					
Total effort (hrs.)	25	325	350					

Least Cisco

During the June/July sampling, least cisco CPUE in fyke nets was highest in bay habitats in the Upper Arm of the Kungok River, specifically at KN-09 and KN-07 (Appendix 4). Catches were also high at other bay habitats in the Middle and Outer Arm main channel habitats (KN-13, 11, 17, 22, and 33). A slightly different pattern was reflected in the set gillnet catches of least cisco with catch rates highest in the main channel of the Upper Arm (KN-04) and bay habitats in the Upper (KN-07) and Middle Arm (KN-11) (Appendix 5). Captured least cisco ranged from 82 to 354 mm during the June/July sampling event (Figure 12).

Catches of least cisco were lower in August, but catches were still highest in bay habitats with fyke nets, particularly at KN-11, 09, 23, and 28 (Appendix 4). Catches with set gillnets primarily occurred at one sample site (KN-26) in the Outer Arm bay habitat (Appendix 5). During the August sampling event, small least cisco were the more dominant size class as a result of a large catch of fish in the 101–130 mm size class. The increased catches of age-1 least cisco in August indicates that least cisco probably do not overwinter in the Kungok River, rather overwintering likely occurs upstream in the Kuk River. Captured least cisco in August ranged from 63 to 370 mm (Figure 12).

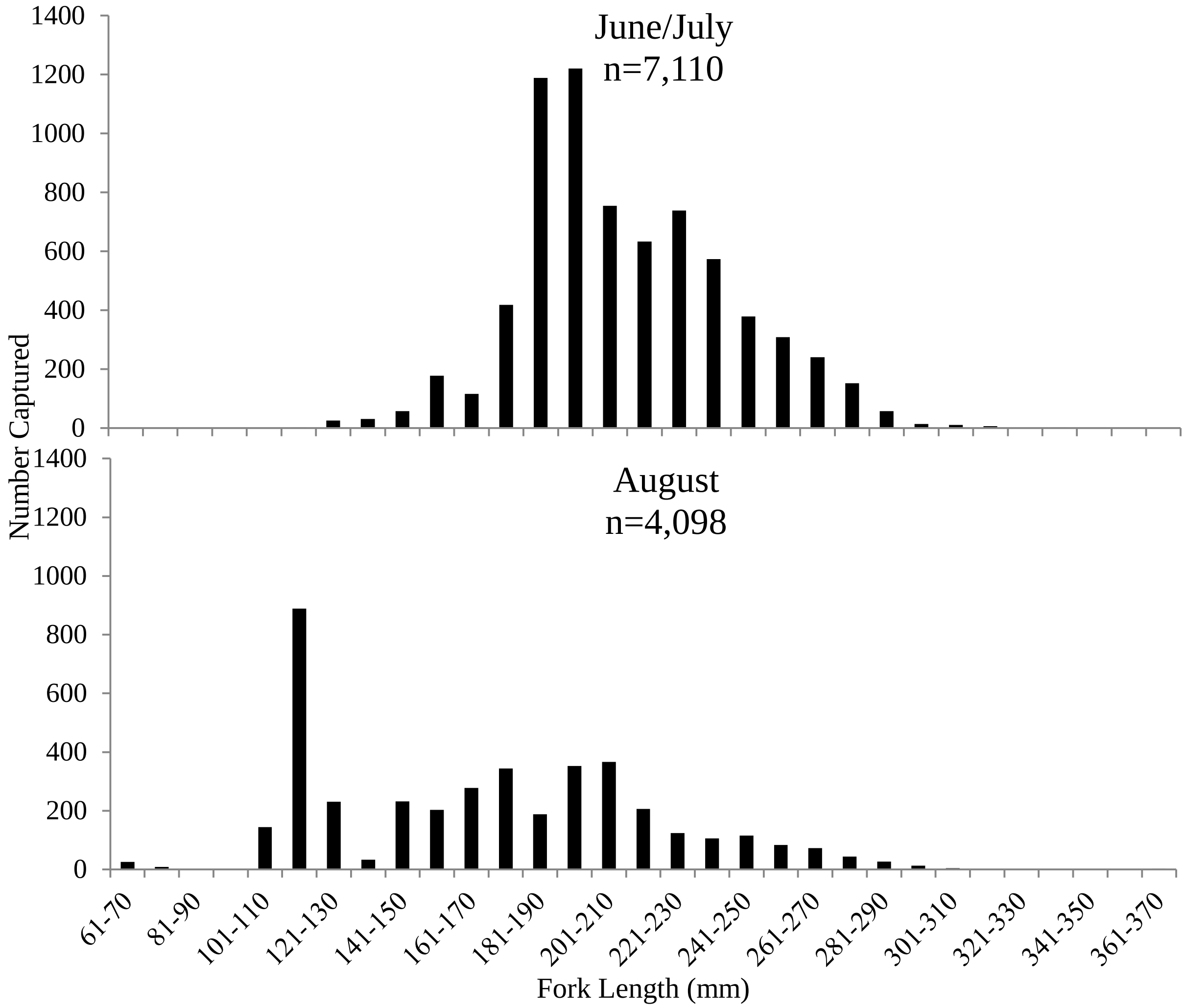


Figure 12. Length frequency distribution of least cisco captured in all gear types in the Kungok River, 2011.

Anchor tags were applied to 2,502 least cisco (≥180 mm) at 19 fyke net stations. Forty-eight tagged fish were recovered at 10 stations for an overall recovery rate of 1.92%. The tag recovery rate of tags released in the Upper Kungok Arm, 3.2%, was over twice as high as the recovery rate of tags released in the Middle (1.5%) and Outer Arm (1.2%).

Most recaptured fish were recovered in the Middle Arm, which produced 52% of the recoveries. Station KN-11 accounted for 35% of the recoveries. The remaining recaptured fish were evenly split between the Upper and Outer Arms.

Length-frequency data indicated that many of the least cisco within the tagging size range (≥180 mm) left the Kungok Arm following the June/July sampling period; thus many of the fish tagged during the first sampling period had likely moved to other portions of the inlet and were not available for capture during the second sampling period in August. Of the 27 tagged fish recovered from June/July releases, 70% were recaptured during the same time period. Recapture rates for tagged fish released within the same sampling period were similar; 1.5% in the June/July sampling and 1.7% in the August sampling. Of the recaptured least cisco, minimum distance traveled averaged 1.20 km/d (range: 0.07–5.29 km/d). Low recapture rates suggest a very large population of least cisco in this system.

Bering Cisco

Bering cisco were present in the Kungok Arm of the Wainwright Inlet, but were not abundant. Fyke nets captured 24 of the 27 Bering cisco, with the remaining 3 caught in set gillnets. Captured Bering cisco ranged from 146 to 340 mm, with 25 of the 27 fish being in excess of 230 mm.

The low catch rates and larger sizes are not surprising given the distance from known rivers of origin. It is thought that Bering cisco in this region originate in the Yukon River, the nearest known spawning location, although there may be a population associated with the Kobuk River.

Arctic Grayling

Arctic grayling contributed 0.1% of the total catch and most were juveniles, with 19 individuals ranging from 98 to 197 mm. One mature fish was caught (276 mm). This contrasts with 2010 sampling in the Ivisaruk Arm, where Arctic grayling composed 29% of the total catch and mature fish were a large part of the catch (Figure 8). In 2010, the catch rate of Arctic grayling in fyke nets in the Ivisaruk Arm was 10.3 fish per day, compared to 0.19 fish per day in 2011 Kungok Arm fyke nets. This result is not surprising because little freshwater habitat is available in the Kungok River, especially for overwintering.

Arctic Flounder

Arctic flounder were second in overall abundance, comprising 10.1% of the catch and being caught in over 65% of the net sets. Their abundance was greatest in the Middle and Outer portions of the Kungok Arm where specific conductance was higher, with lesser abundance in the Upper Arm. Arctic flounder caught during both sampling periods covered a similar range of sizes, while numbers were generally greater in the June/July period than during August (Figure 13).

Catches of Arctic flounder primarily occurred in fyke nets, and during the June/July sampling event, CPUE was generally higher at the lower sample sites in bay habitats (KN-33, 23, 17, 28, 26) (Appendix 4). During this time, Arctic flounder ranged from 25 to 275 mm. The most abundant size class ranged from 31 to 60 mm (Figure 13), which were primarily captured at KN-23.

Catch rates were lower in August, but still highest in Outer Kungok Arm sample sites (KN-23 and KN-28), similar to the June/July event (Appendix 4). During the August sampling event, Arctic flounder total length ranged from 31 to 294 mm (Figure 13). Length-frequencies were similar to the June/July event, except very few fish were captured in the 31–60 mm size class. Seasonal growth was apparent in the smaller length modes.

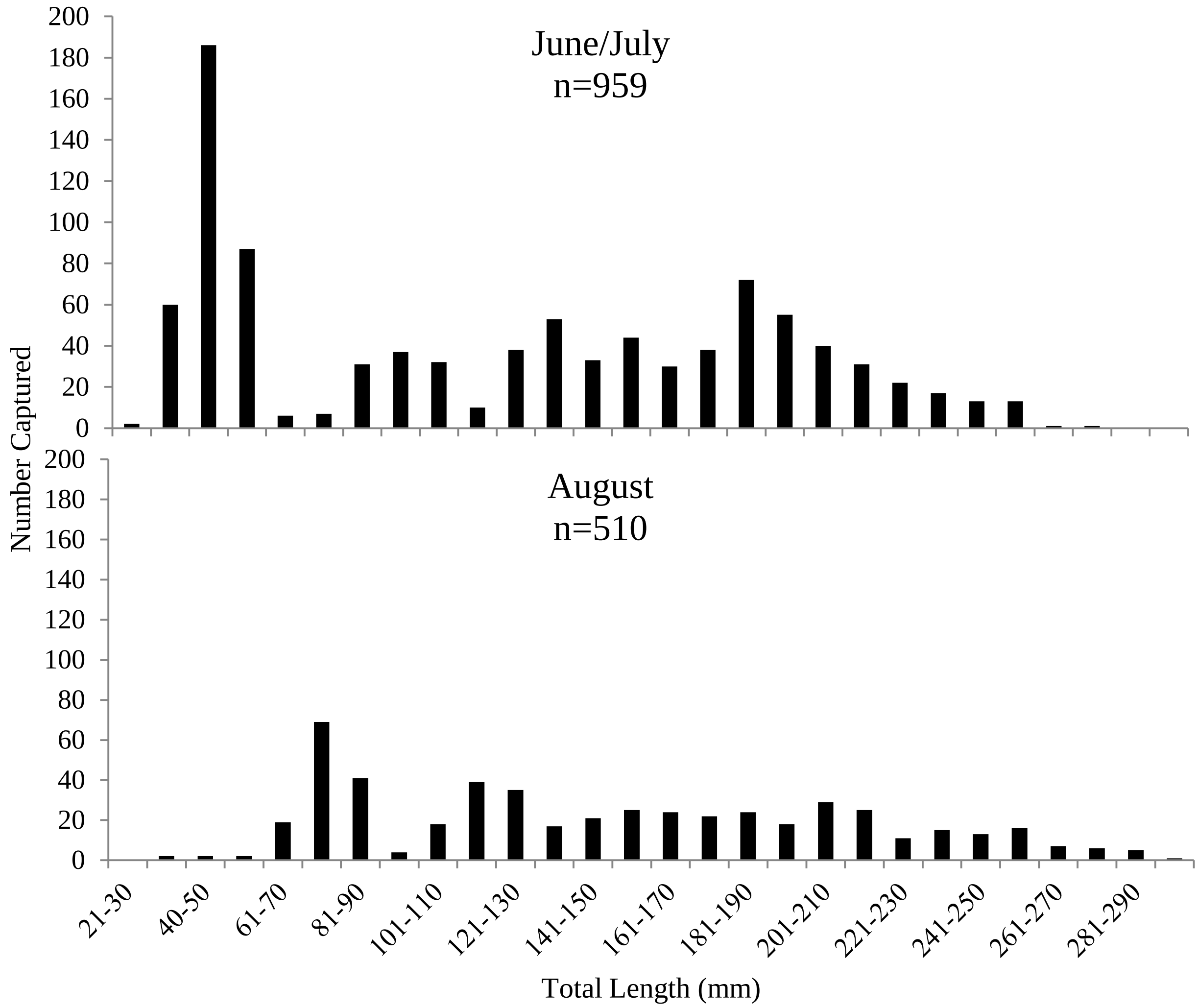


Figure 13. Length frequency distribution of Arctic flounder captured in all gear types in the Kungok River, 2011.

Rainbow smelt

Rainbow smelt were captured in bay habitats with CPUE values highest at KN-17, 13, 33, and 18 during June/July sampling (Appendix 4). During this time, rainbow smelt ranged from 45 to 250 mm. A majority of the rainbow smelt (77%) were less than 100 mm (Figure 14). All rainbow smelt over 163 mm were mature fish either in spawning or in spent condition indicating active spawning was occurring during sampling. Ovaries of ripe females averaged 25.2% of the somatic weight (range: 19-34%). Over half of the mature females and males caught in the

June/July sampling were classified as spent, indicating that spawning season was past the peak. Spawning by rainbow smelt is typically in freshwater during spring, thus it is likely that spawning is in the lower reaches of streams emptying into Kungok Arm.

Rainbow smelt catch rates were similar during the August sampling event, with CPUE highest at site KN-28 (Appendix 4). Fish ranged from 59 to 259 mm during August sampling (Figure 14). The range of lengths was similar during both sampling periods, although a length mode around 150 mm was more abundant during the August sampling (Figure 14). Mature females and males present during June/July were of similar size, with 12 females averaging 210.2 mm (range: 165–249) and 10 males averaging 210.9 mm (range: 175–232 mm).

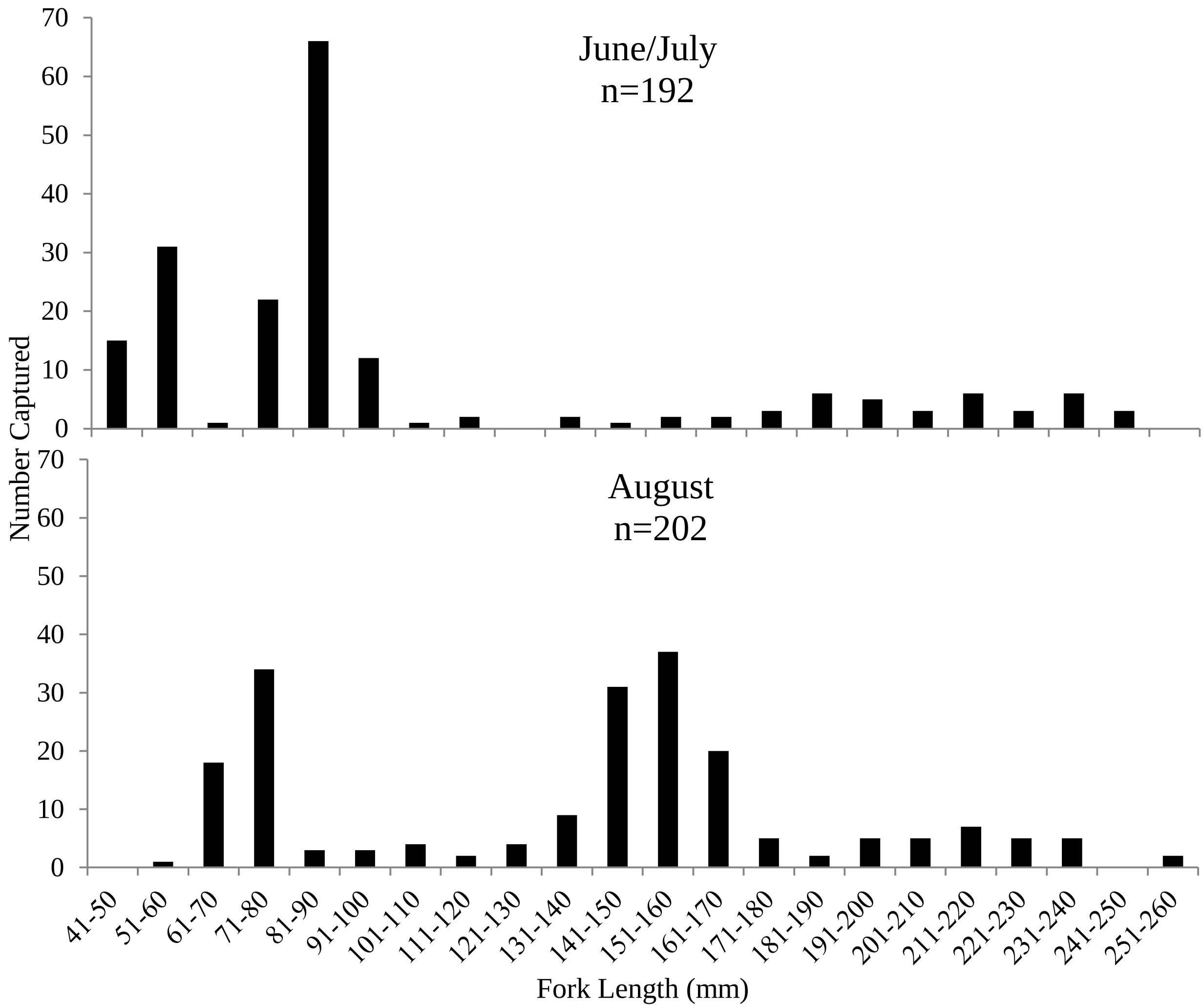


Figure 14. Length frequency distribution of rainbow smelt captured in all gear types in the Kungok River, 2011.

Pacific Salmon

All Pacific salmon were captured during the August sampling. Pink salmon were the most common salmon species followed by chum salmon. Catch rates of both species were highest at KN-02 (Appendix 5). Catches that far upstream suggest that salmon use the upper Kungok River for spawning. Only one Chinook salmon was captured in the Kungok River, at site KN-15.

A total of 98 adult pink salmon were caught during 2011. Lengths of 23 females averaged 419.7 mm (range: 373–477 mm), while those of 65 males averaged 414.2 mm (range: 370–510 mm). Fifteen chum salmon were all caught by set gillnet, with 9 females averaging 571.7 mm (range: 530–607 mm) and 5 males averaging 607.6 mm (range: 595–628). The single Chinook salmon was 560 mm.

Eleven of the chum salmon, 13 pink salmon and the Chinook salmon were fitted with esophageal radio tags in an attempt to identify spawning areas.

Pacific Herring

Pre- and post-spawning Pacific herring were encountered in the June/July sampling in Kungok Arm, primarily at Station KN-11. We believe this is the first documentation of spawning Pacific herring in Wainwright Inlet, and may be the northern-most spawning population in Alaska.

Fifty-one Pacific herring were sampled, 25 females and 26 males. Females were composed of 11 in spawning condition and 14 post-spawners. Gonads of ripe females averaged 15.1% of the somatic weight (i.e., body weight – gonad weight) (range: 6.0–27.3%). A sample of 25 mature females averaged 206.9 mm (range: 171–250 mm), while 24 mature males averaged 204.0 mm (range: 151–277 mm). Two immature male herring were also identified (111 and 170 mm).

Station KN-11 produced 94% of the herring caught; it is likely that the spawning area was close to this station. Few were caught elsewhere in the sampling area.

Fourhorn Sculpin

Fourhorn sculpin composed 7.1% of the total catch (Table 3). They were widely spread through the study area, but were most abundant in the Middle and Outer Arm study areas during June/July sampling (Appendix 4). Fourhorn sculpin covered a similar size range during both sampling periods, although a small cohort (42–56 mm), probably age-0 fish were present during August.

Other Species

Saffron cod, Arctic cod, threespine stickleback, and ninespine stickleback were also caught during the 2011 sampling in the Kungok Arm of Wainwright Inlet (Table 3).

Saffron cod are a marine species that frequently enters nearshore and estuarine areas during summer for feeding. They were only caught in the Middle Arm and Outer Arm sampling areas with high specific conductance during both sampling periods. The 27 captured saffron cod ranged from 100 to 280 mm. Only 1 Arctic cod was caught (93 mm).

Threespine stickleback are a small fish that can have freshwater, anadromous, or marine populations. The population caught in Wainwright Inlet seems to be the marine variety as they were in spawning condition when caught during 2010 and 2011. They were caught throughout the sampling area, with 50% of the catch from the Upper Arm. Threespine stickleback ranged from 61 to 102 mm, with 80% between 80 and 100 mm.

Ninespine stickleback are similar to threespine stickleback, in that they also have freshwater, marine and estuarine populations. During June/July sampling, the greatest catches of ninespine stickleback were in tributary habitats (Appendix 4). By August, catches were more wide-spread.

Aquatic Invertebrates

Chironomids dominated the sweep net and ponar samples at sites KN-04 and KN-07 in July (Figure 15). Other sample sites during July were dominated by mysids, amphipods, and brackish water capitellid worms. Marine invertebrates were common in ponar samples at sites KN-11, KN-23, and KN-24 including marine bivalves (*Tellinidae*) and polychaete worms (*Spionidae, Capitellidae*), organisms often associated with fine organic rich substrates. By August, sweep net and ponar samples were dominated by chironomids and mysids. Zooplankton samples were dominated by calanoid copepods at every sample site except for KN-04 and KN-07, which were dominated by cyclopoid copepods.

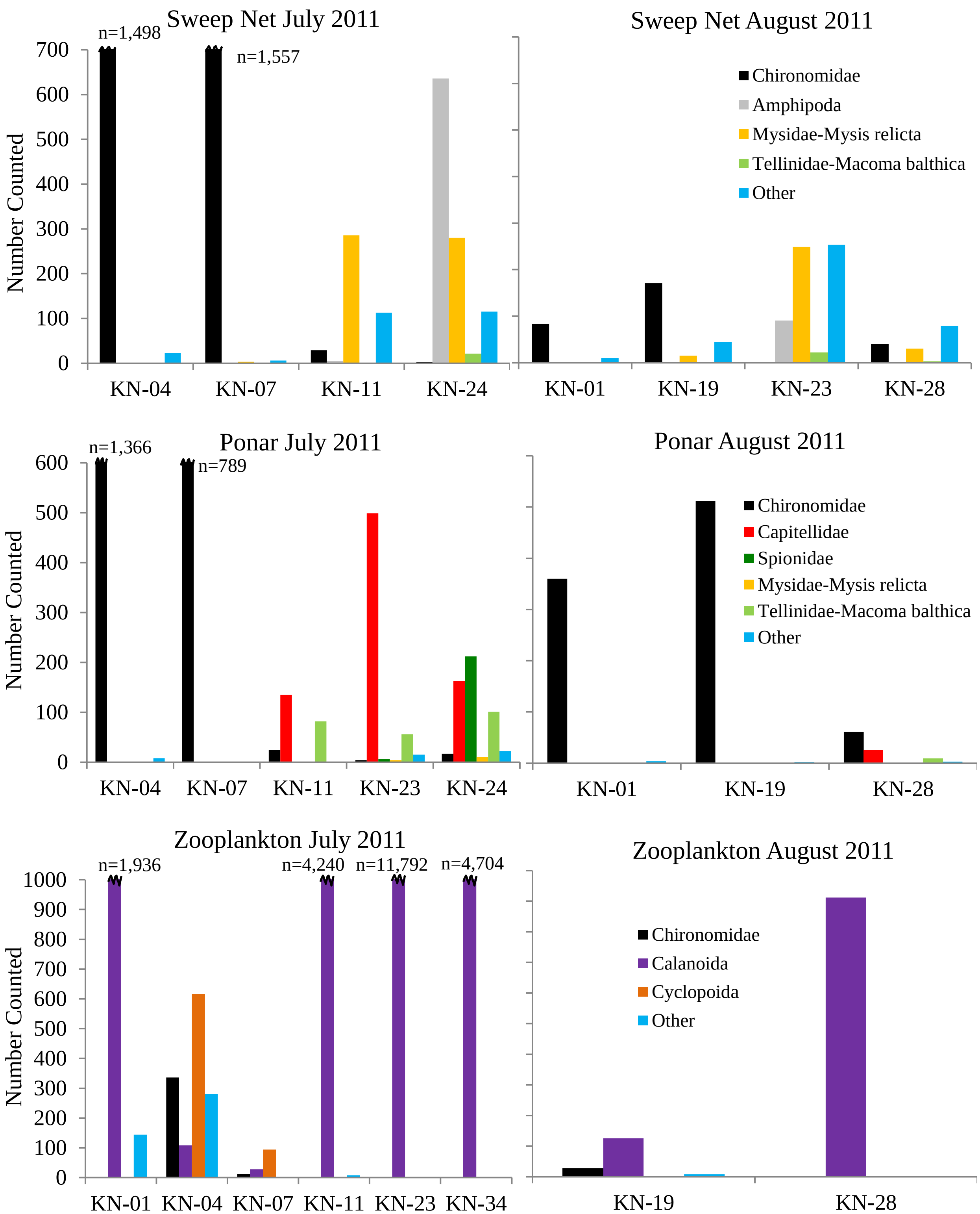


Figure 15. Invertebrates collected in the Kungok River in July and August 2011 at various sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom). Extreme values outside of the vertical axis range are shown on graphs.

Fish Diets

Least Cisco

Stomachs from 156 least cisco caught by fyke nets were examined in the field laboratory, of which 43% were empty. Chironomids and associated vegetation were identified from 56% of the stomachs that contained food. Mysids occurred in 30% and amphipods in 10% of the stomachs with identifiable food.

Stomachs from an additional 51 least cisco caught in set gillnets were retained for detailed stomach analysis in the lab, of which 10% were empty. Stomach contents retained from least cisco in July at sites KN-04 and KN-07 were dominated by chironomids (Figure 16). Sweep net and ponar sampling at those sites during July indicated that the aquatic invertebrate community was also dominated by chironomids, suggesting least cisco were taking advantage of the relatively abundant number of chironomids (Figure 15).

Stomach contents retained from least cisco caught in set gillnetsduring July at site KN-11 contained a variety of invertebrates, but were dominated by chironomids (Figure 16). Sweep net and ponar samples at KN-11 in July showed the aquatic invertebrate community to be comprised mainly of mysids, capitellids, and tellinids; capitellids and tellinids are benthic organisms not likely to be readily available in the water column. Stomach contents suggest least cisco were selecting for chironomids over mysids (Figure 16).

Stomach contents retained from least cisco caught in set gillnets during in July at sites KN-23 and KN-24 contained few aquatic invertebrates, although species richness was high (Figures 15 and 16). Chironomids made up a small percentage of the aquatic communities at these locations and if least cisco are selecting for chironomids, there would be few available at these sites.

August showed a strong shift in the stomach contents of least cisco from chironomids with small numbers of mysids and tellinids to almost strictly mysids and tellinids (Figure 16). While chironomids were relatively less abundant in August in the sweep and ponar samples, mysids and tellinids did not increase substantially during this time, suggesting least cisco may have been selecting for these invertebrates (Figure 15).

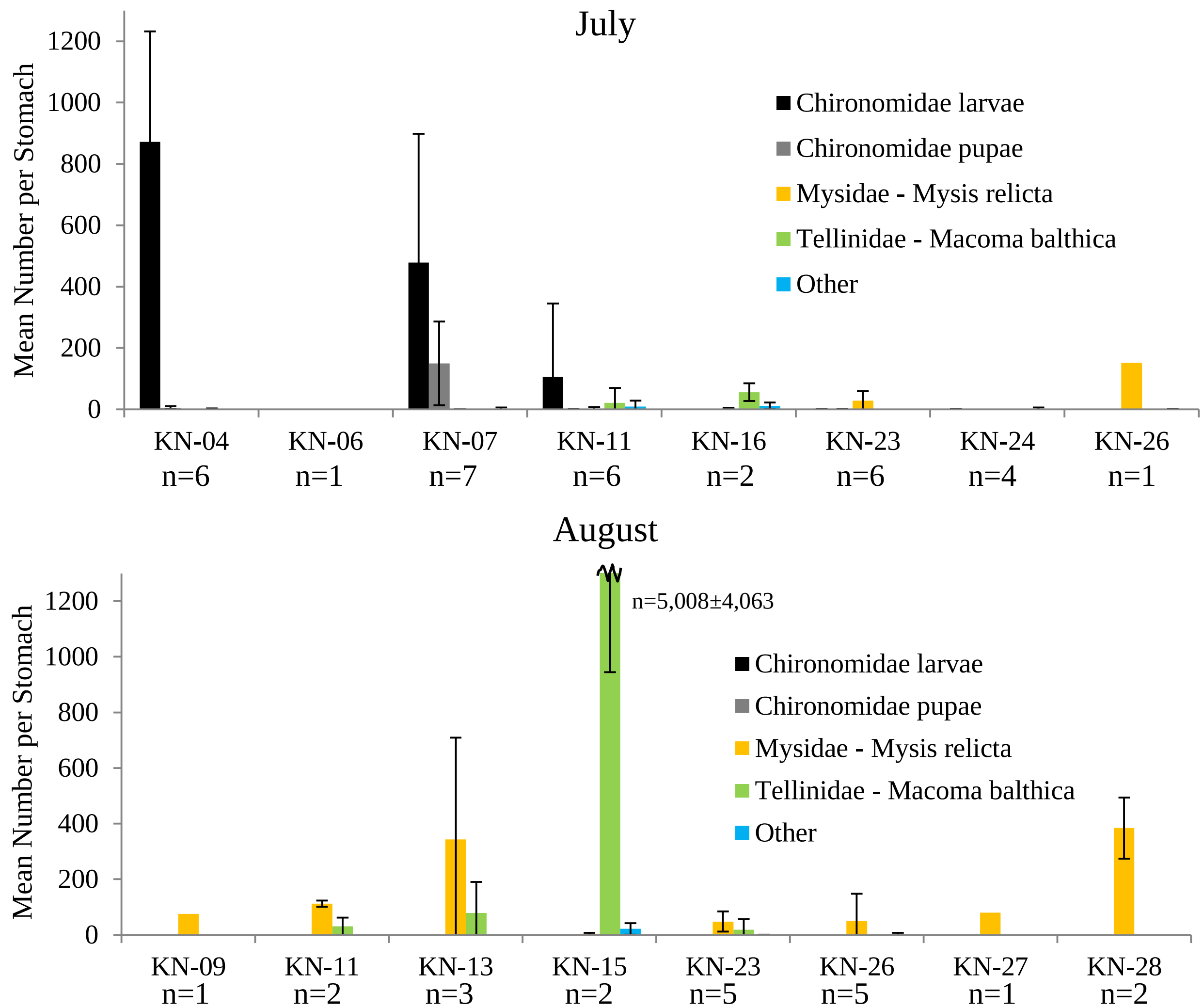


Figure 16. Mean number (±1 SD) of invertebrates in least cisco stomachs by sample site in the Kungok River, July and August 2011. Sample size per site and extreme values outside the value of the vertical are shown.

Bering Cisco

Stomachs of 23 fyke-net caught Bering cisco were examined. Of the 12 that contained identifiable food items, 7 (58%) contained mysids, 3 contained clams (likely tellinid bivalves) and one contained chironomids.

Arctic Flounder

Stomachs of 22 fyke-net caught Arctic flounder were examined. Ten of the stomach were empty or contained unidentifiable items. Twelve of the stomachs contained identifiable food, of which 8 (75%) contained clams or clam shells. Mysids were found in 2 stomachs, and amphipods were in another.

Pacific Herring

Stomachs of 51 fyke-net caught Pacific herring were examined, however, only 2 contained identifiable food items. Both had been feeding on mysids. The remaining stomachs were empty or contained unidentifiable food items.

Chlorophyll

Mean chlorophyll-a concentrations ranged from 0.13 mg/m^3 at KN-11 to 3.43 mg/m^3 at KN-04 (Figure 17). Only the tributary and main channel habitats (KN-01, KN-04, and KN-19) exceeded 1 mg/ m^3 chlorophyll a, suggesting the freshwater creek sites were relatively higher in phytoplankton productivity than were the more brackish water dominated sites.

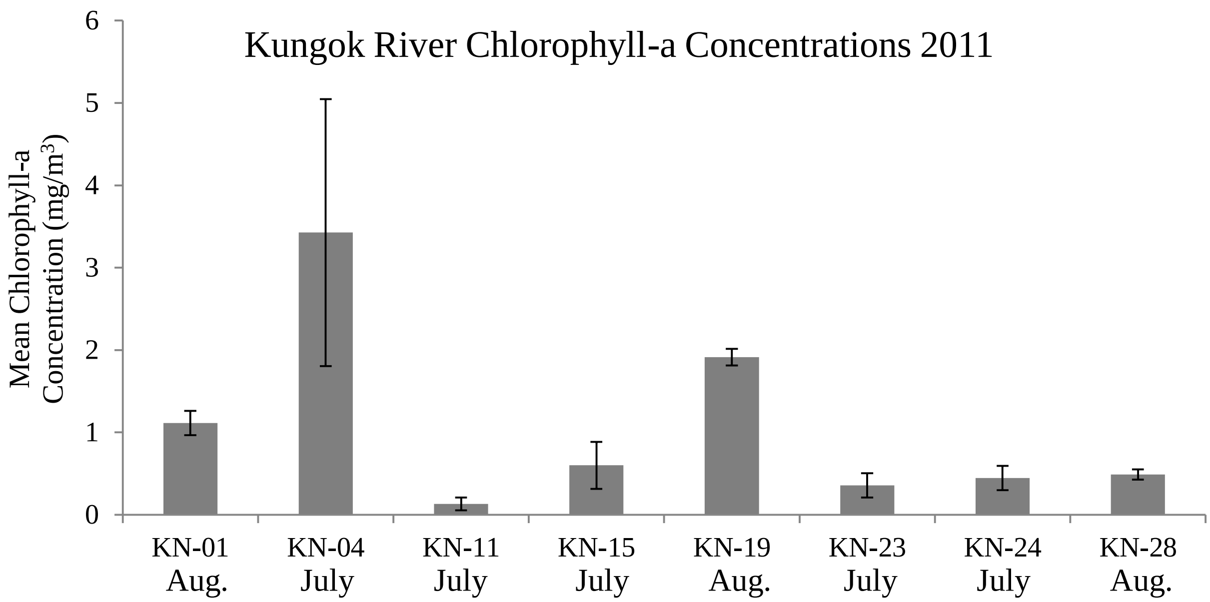


Figure 17. Mean chlorophyll-a concentrations (mg/m^3) for 8 sample sites in the Kungok River in July and August 2011.

Water Quality

Water quality data was divided into three habitat types: main channel, tributaries, and bay habitats. Main channel habitats were sample sites located in the upper Kungok River where specific conductance was less than 300 µS/cm (KN-01, 02, 03, and 04). Tributary habitats consisted of sample sites located in any of the small tributaries to the Kungok Arm. Bay habitats consisted of the remainder of the sample sites with specific conductance greater than 1,200 µS/cm suggesting a marine influence.

Water temperature was initially high when sampling began on June 27, 2011 (15ºC –19ºC), and then quickly fell to less than 10ºC by July 1, 2011 (Appendix 6). Water temperatures then steadily rose for the remainder of the sampling event. During the August sampling, water temperatures remained relatively steady between 11ºC –14ºC, but began decreasing during the last few days of sampling. Temperatures were slightly warmer in August than in June/July (Figure 18)

The pH values did not show trends and ranged from 7.01 to 8.10 (Appendix 6). With the exception of a few higher values (maximum = 103 NTU), turbidity was less than 20 NTU (Figure 18).

The majority of sites sampled were brackish water habitats while only a few sites located in the main channel of the Kungok River and its tributaries were characterized by freshwater. Specific conductance was highly variable depending on sampling location and ranged from 66.6 µS/cm at site KN-19 to 25,800 µS/cm at KN-24 (Figure 18). Sample sites with lowest specific conductance were the tributary and main channel habitats. Specific conductance increased in bay habitats from the Upper Arm to the Outer Arm due to marine influence.

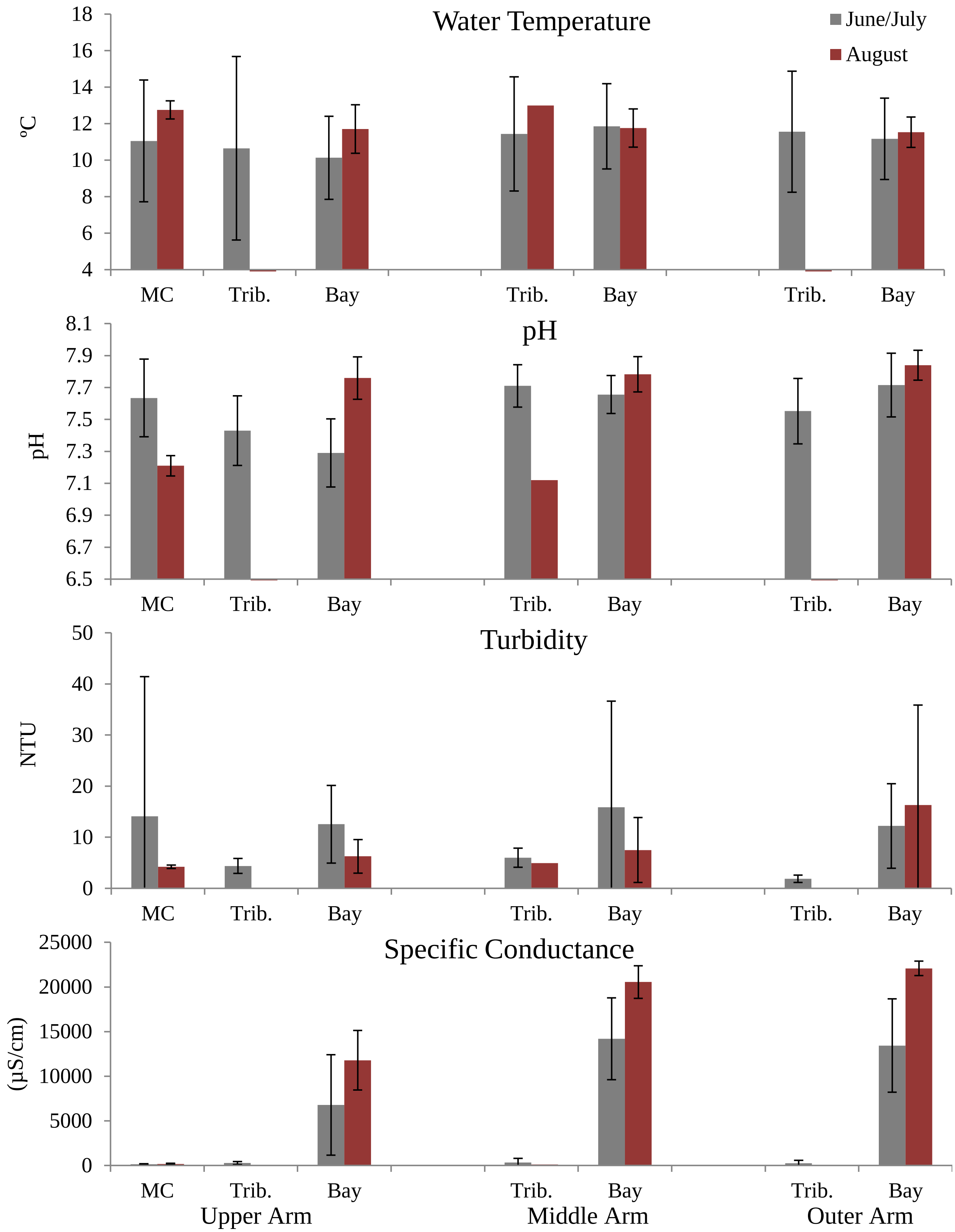


Figure 18. Mean (± 1 SD) water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) by habitat type (main channel (MC), tributary (Trib.), and Bay) in each region of the Kungok Arm, 2011.

Radiotelemetry

In August 2011, 13 pink salmon, 11 chum salmon, and one Chinook salmon were radiotagged. A relocation flight was conducted September 3, 2011 and eight pink salmon and nine chum salmon were relocated (Figure 19). Two pink salmon and four chum salmon remained in the Kungok River while one pink and one chum salmon moved into the Mikigealiak River and one pink salmon moved into Mayuriak Creek, presumably to spawn. One pink salmon and one chum salmon were found in the Ketik River while the remaining pink and chum salmon were found in the Kaolak River.

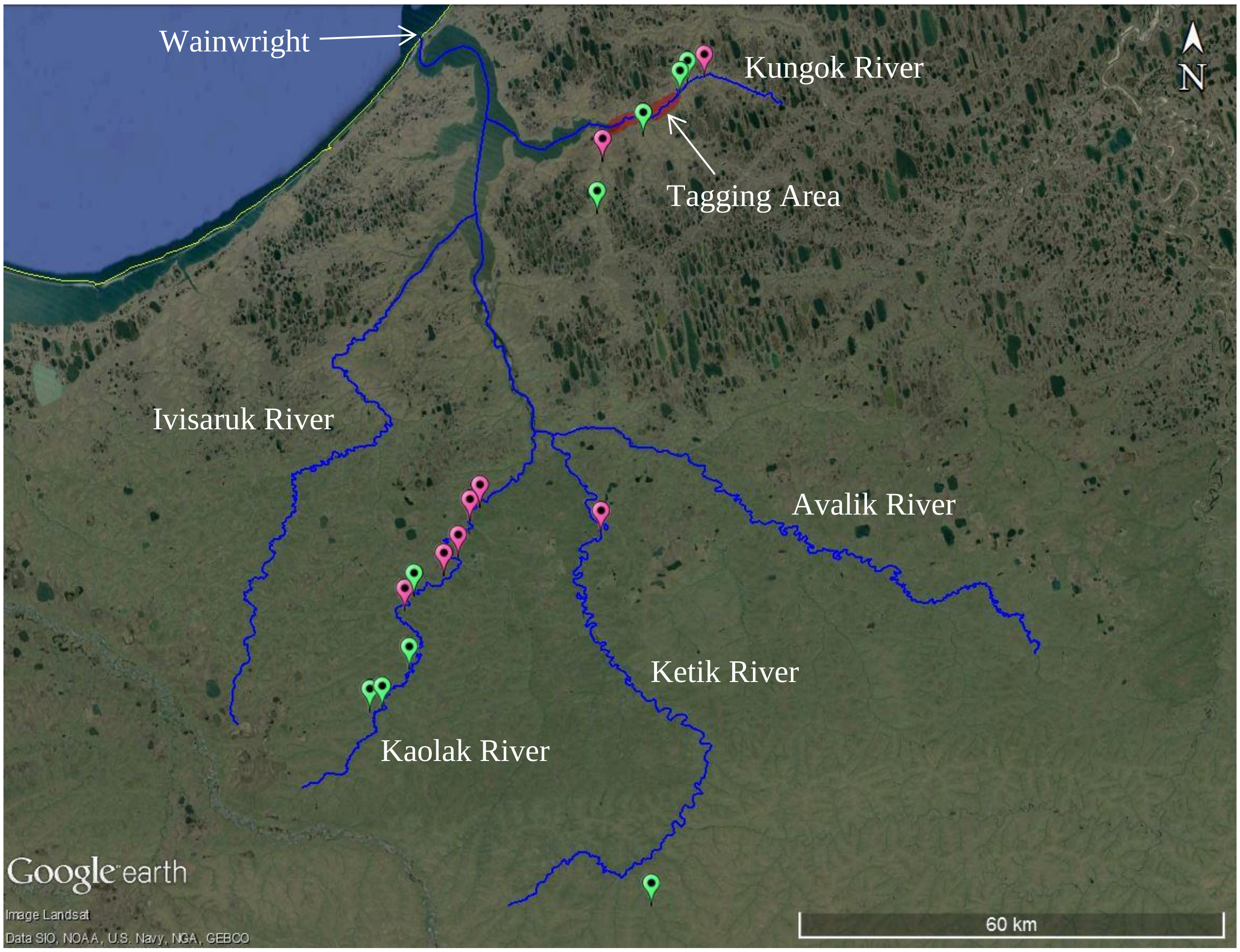


Figure 19. Relocations of 8 pink salmon (pink labels) and 9 chum salmon (green labels) in the Kuk River drainage September 3, 2011. Shaded area indicates initial tagging location for all salmon.

Upper Kuk River

Sampling of the upper Kuk River was conducted during the periods June 17–July 6, 2012, July 31–August 14, 2012, and June 22–27, 2014. A total of 28 locations were sampled for fish using fyke nets, set gillnets, hoop nets, and seine nets (Figure 20, Appendix 7). Aquatic invertebrate sweep net and ponar samples were collected at 9 locations, zooplankton samples at 7 locations, and phytoplankton samples at 7 locations.

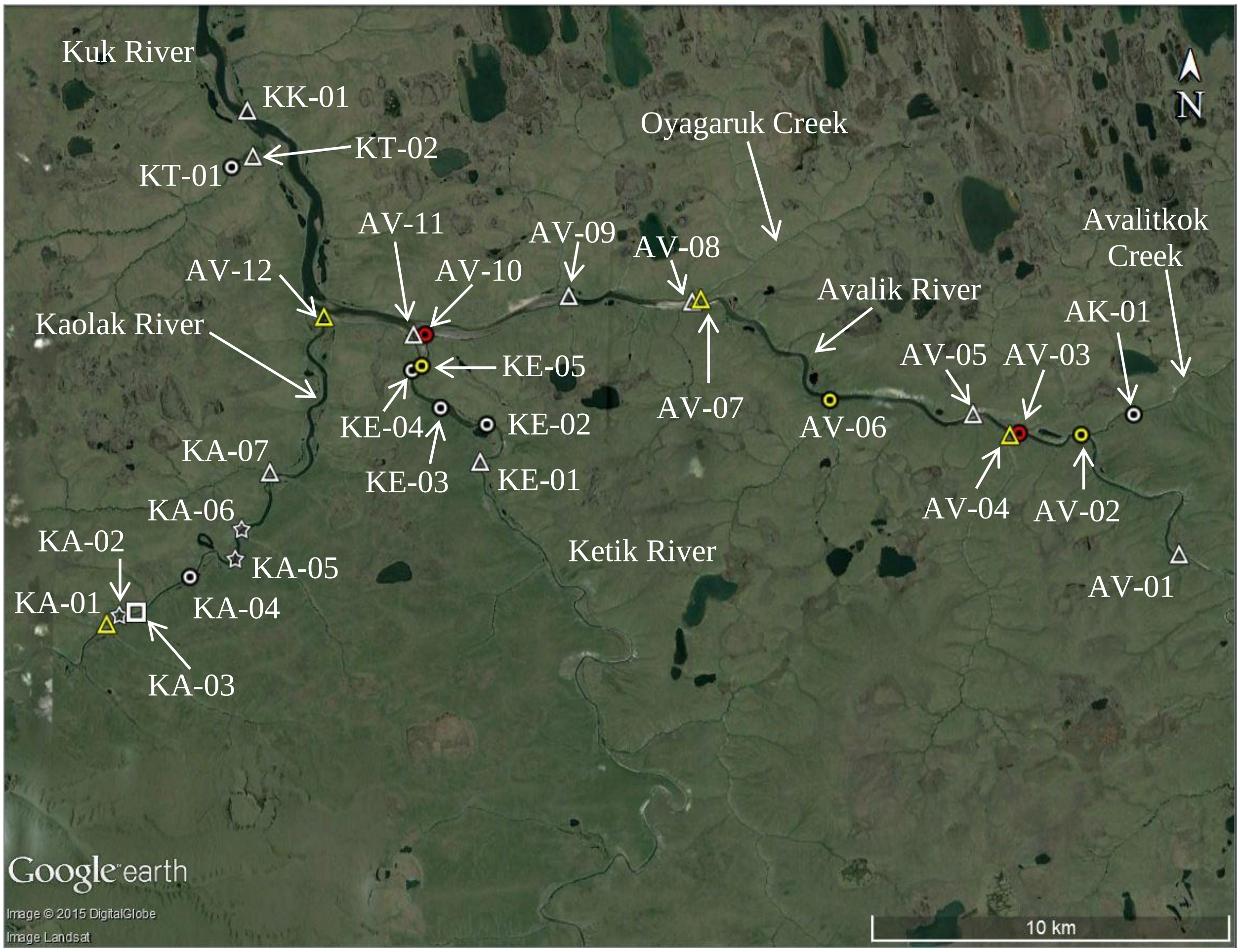


Figure 20. Sample sites in the upper Kuk River drainage in 2012 (white) and 2014 (red). Yellow symbols represent sites sampled both years. Round dots represent fyke nets, squares represent set gillnets, stars represent hoop traps, and triangles represent multiple gear types were used.

Fish Catch Data

A total of 17,720 fish comprised of 13 fish species were captured in 4,054 fyke net effort hours in the upper Kuk River drainage. Least cisco made up a majority of the catch followed by Arctic grayling, ninespine stickleback, burbot, slimy sculpin, pink salmon, fourhorn sculpin, rainbow smelt, threespine stickleback, chum salmon, Alaska blackfish (*Dallia pectoralis*), Arctic flounder, and saffron cod (Table 5).

A total of 84 fish comprised of six species were captured in 91 set gillnet effort hours in the upper Kuk River with pink salmon making up a majority of the catches followed by Arctic grayling, chum salmon, least cisco, Bering cisco, and fourhorn sculpin (Table 6).

Table 5. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch of each species captured with fyke nets in the Kuk River, 2012 and 2014.

Species	Number of Fish				Mean CPUE			Percent of Catch			
	June 17–July 6, 2012	July 31–Aug 14, 2012	June 22–June 27, 2014	Total	June 17–July 6, 2012	July 31–Aug 14, 2012	June 22–June 27, 2014	June 17–July 6, 2012	July 31–Aug 14, 2012	June 22–June 27, 2014	Total
Least cisco	9,572	783	71	10,426	137.87	10.65	4.53	65.1	28.2	28.6	58.8
Arctic grayling	4,670	931	63	5,664	63.68	12.51	5.08	31.8	33.6	25.4	32.0
Ninespine stickleback	252	811	22	1,085	260.21	10.90	1.55	1.7	29.3	8.9	6.1
Burbot	114	26	90	230	1.51	0.35	4.60	0.8	0.9	36.3	1.3
Slimy sculpin	55	51	0	106	0.70	0.70	0	0.4	1.8	0	0.6
Pink salmon	0	102	0	102	0	1.39	0	0	3.7	0	0.6
Fourhorn sculpin	21	36	2	59	0.29	0.50	0.10	0.1	1.3	0.8	0.3
Rainbow smelt	14	5	0	19	0.20	0.07	0	0.1	0.2	0	0.1
Threespine stickleback	0	18	0	18	0	0.24	0	0	0.6	0	0.1
Chum salmon	0	4	0	4	0	0.06	0	0	0.1	0	<0.1
Alaska blackfish	1	3	0	4	0.01	0.04	0	<0.1	.01	0	<0.1
Arctic flounder	1	1	0	2	0.01	0.01	0	<0.1	<0.1	0	<0.1
Saffron cod	0	1	0	1	0	0.01	0	0	<0.1	0	<0.1
Total catch	14,700	2,772	248	17,720							
Number of species	9	13	5	13							
Total effort (hrs.)	1,855	1,799	400	4,054							

Table 6. Number of fish and mean CPUE (#fish/24 hrs.) for each species captured with set gillnets in the Kuk River, 2012.

	Number of Fish			Mean CPUE	
Species	June 17–July 6	July 31–Aug 14	Total	June 17–July 6	July 31–Aug 14
Pink salmon	0	45	45	0	27.67
Arctic grayling	27	1	28	78.33	0.61
Chum salmon	0	5	5	0	3.99
Least cisco	4	0	4	11.58	0
Bering cisco	1	0	1	1.79	0
Fourhorn sculpin	1	0	1	1.79	0
Total catch	33	51	84		
Number of species	4	3	6		
Total effort (hrs.)	55	36	91		

Least cisco

Least cisco CPUE was highest in the main channel habitats, specifically at sample sites AV-09, AV-08, KK-01, and KE-04 in June/July 2012 (Appendix 8). Catch-per-unit-effort of least cisco was much lower in August 2012, but still highest in the lower sample sites (AV-11 and KK-01). In 2014, burbot were targeted and CPUE of other species, including least cisco, were low due to sampling effort being focused on tributary habitats.

In June 2012, least cisco ranged from 55 to 365 mm (Figure 21). Approximately 96% of least cisco were less than 150 mm. In August 2012, least cisco ranged from 50 to 382 mm. Only 71 least cisco were captured in June 2014, 31 of which were measured; fork length ranged from 64 to 267 mm. The dominance of small least cisco in the June catches suggests that least cisco spawning and overwintering likely occur in the upper reaches of the Kuk River drainage.

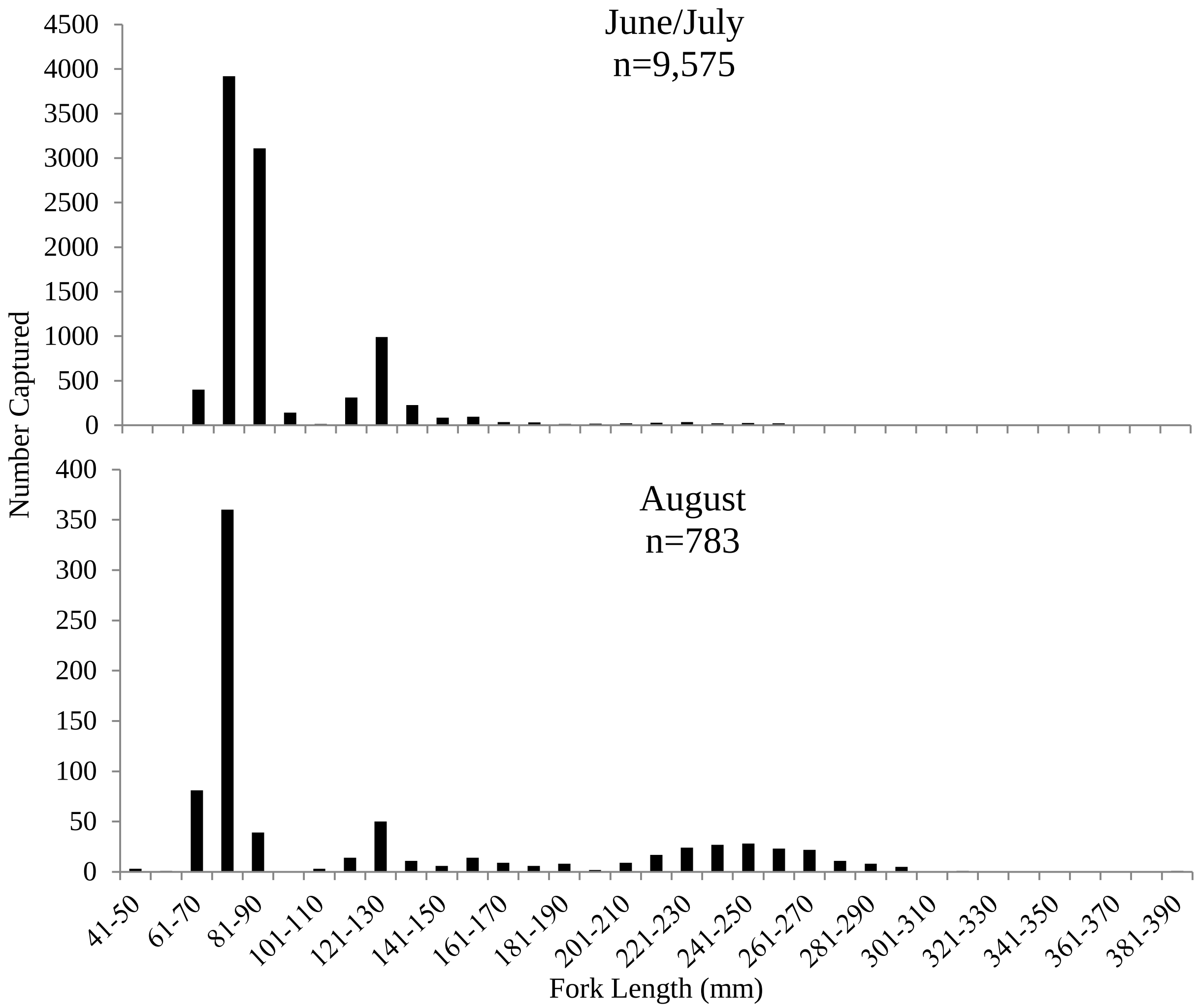


Figure 21. Length frequency of least cisco captured with all gear types in the upper Kuk River, 2012. Note: scale of y-axes are not the same.

A total of 294 least cisco were floy tagged in 2012, none of which were recaptured.

Arctic grayling

In June/July 2012, Arctic grayling CPUE was generally highest in creek habitats, specifically at sites AK-01 in Avalitkok Creek, AV-02 where Avalitkok Creek flows into the Avalik River, AV-09 which is the main channel of the Avalik River, and KT-02 and KA-07 which are small tundra drainage (Appendix 8).

In June 2012, Arctic grayling ranged from 38 to 415 mm (Figure 22). The most common size class was fish 61–90 mm, likely age-1 fish. In August 2012, fork length ranged from 41 to 394 mm. The most common size class was fish 91–120 mm, which is likely the same age-1 cohort of fish captured in June/July plus seasonal growth (Figure 22). A few fish in a smaller size class were also captured in August, ranging 41 to 61 mm, likely age-0 fish. These fish were captured at KA-01, KA-04, and AV-07 suggesting Arctic grayling spawn in the Kaolak River and Oyagaruk Creek. Few Arctic grayling were captured in June 2014 and ranged from 57 to 324 mm.

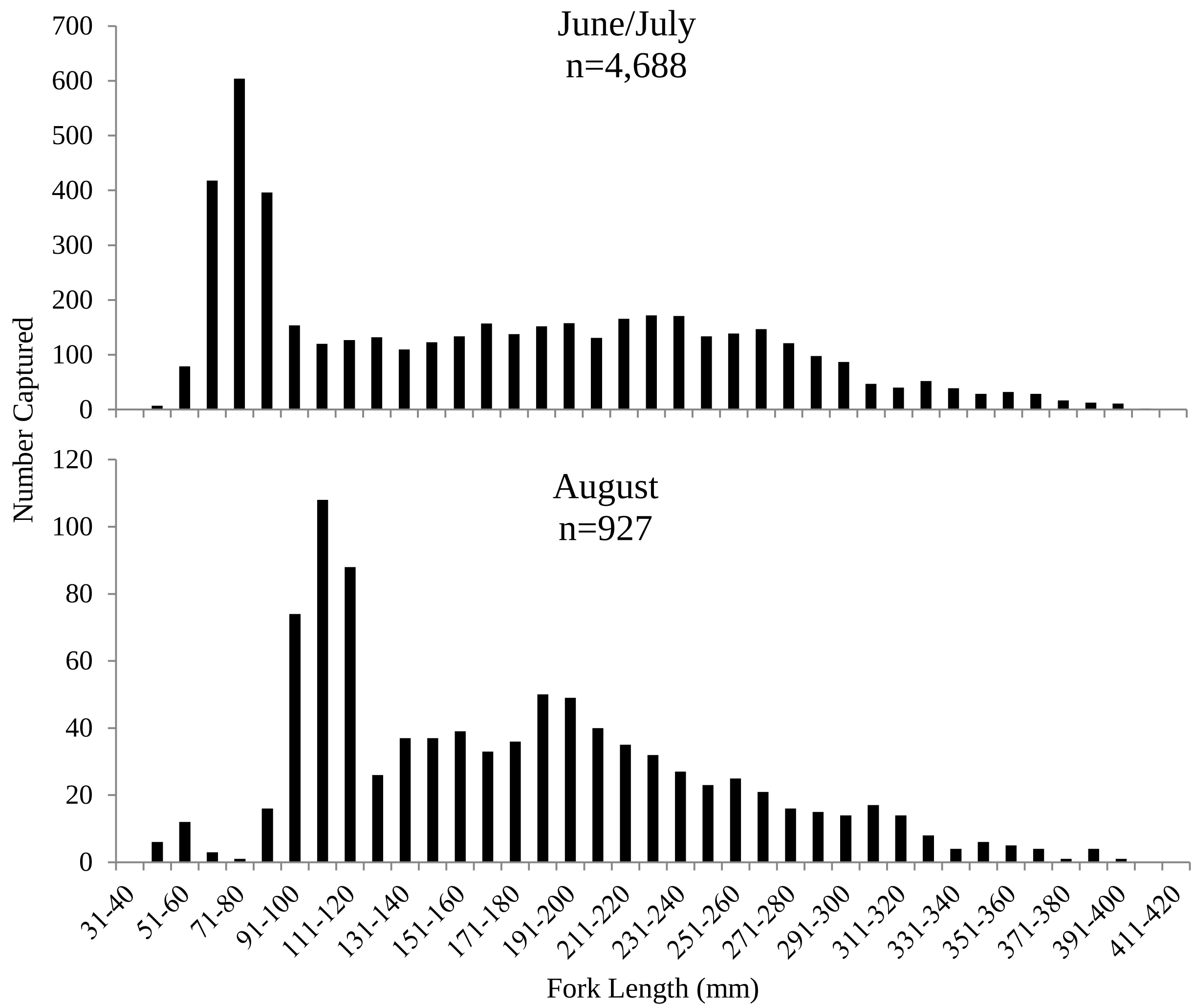


Figure 22. Length frequency of Arctic grayling captured with all gear types in the upper Kuk River, 2012. Note: scale of y-axes are not the same.

A total of 1,286 Arctic grayling were tagged with uniquely numbered anchor tags in 2012. Recaptures of 121 of those fish occurred later in the summer, 61 of which were recaptured at different stations than their release point (Appendix 9). Days between tagging and recapture ranged from 1 to 53 days. Minimum distance traveled per day of recaptured Arctic grayling ranged from 0.04 to 13.4 km/d. One interesting movement was from 13 Arctic grayling tagged at AV-02 that moved to AV-07. Twelve of those fish swam the 12.4 km between those two locations in only one day from July 2 to July 3, 2012.

Burbot

Burbot catches were highest in creek habitats, particularly at creek mouths where the drainages discharged into the Avalik River (AV-06, 08, 07, and 02) (Appendix 8). Catches of burbot were relatively low in the Ketik and Kaolak rivers during each sampling period.

Burbot captured in June 2012 had total lengths ranging from 97 to 996 mm (Figure 23). Approximately 94% of captured burbot were greater than 500 mm. In August 2012, burbot ranged from 79 to 853 mm. The length frequency distribution for captured burbot in June 2014 was similar to that of June 2012 with burbot ranging from 455 to 1,025 mm.

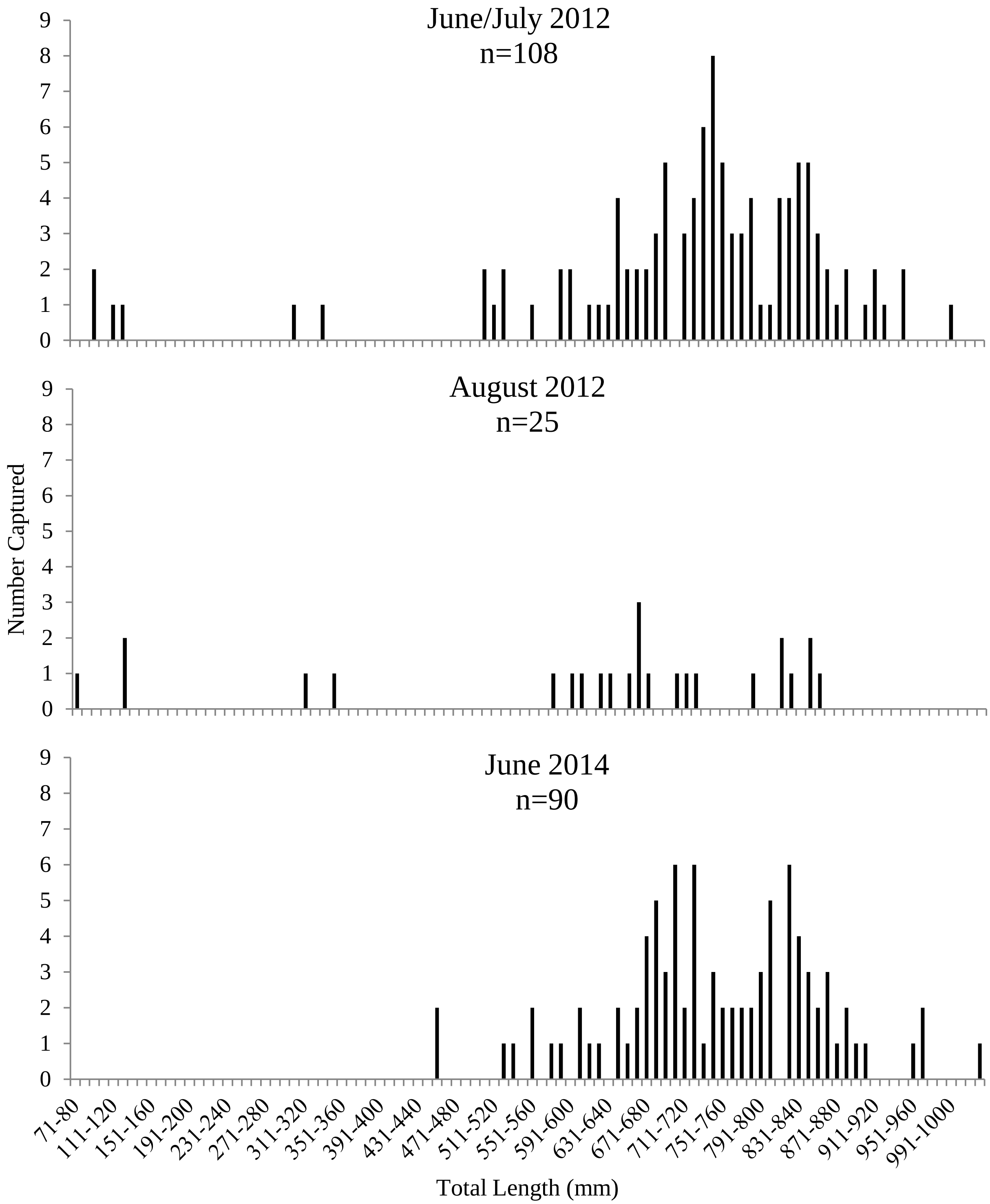


Figure 23. Length frequency of burbot captured in the upper Kuk River 2012 and 2014.

In 2012, 99 burbot were tagged with uniquely numbered anchor tags; 84 during June sampling and 15 during August sampling. Of the 84 burbot tagged in June, three were recaptured in August: one which moved 5.3 km from AV-06 to AV-08, one moved 20.3 km from AV-09 to KA-01, and another 24 km from AV-08 to KA-01. In 2014, eight burbot were recaptured from the 2012 tagging. Of those, 4 were recaptured at their tagging location nearly 2 years to the date later. The other 4 were tagged at various stations in the Avalik River and were recaptured in the Avalik River. Between 2012 and 2014, recaptured burbot grew an average of 17 mm.

Pacific Salmon

Pink salmon have not been documented in the Avalik River above the Ketik River, yet the highest CPUE for pink salmon occurred at the mouth of Oyagaruk Creek, approximately 8 km above the Ketik and Avalik River confluence (AV-07) (Appendix 8). Catches of ripe pink salmon were also recorded at AK-01 in Avalitkok Creek. This suggests pink salmon spawn in these creeks. Additionally, two ripe male chum salmon were captured at the mouth of Oyagaruk Creek, which had not been previously documented as a spawning area for chum salmon.

Aquatic Invertebrates

Aquatic invertebrate samples in the upper Kuk River drainage were dominated by freshwater organisms; however, spionid marine worms were present in ponar samples collected in August at several of the sites furthest downstream (Figure 24). Sweep net samples collected in June were dominated by chironomids at AK-01 and AV-09, while gastropod snails dominated sweep net samples at AV-07. Cladocerans, dipterans, and nematodes made up a large portion of the "other" category of invertebrates identified at AV-09. Sweep net sampling in June at all other sites captured low numbers of invertebrates. By August, taxa richness in sweep net samples had increased substantially at most sites, with chironomids dominating samples at AV-09, KA-01, and KT-01. Gastropod snail numbers were lower than in June, but snails were detected at more sites than in June. Mysids and cyclopoid copepods were present at several sites in August whereas they were absent in June sampling.

Ponar benthic samples were dominated by chironomids in both June and August sampling (Figure 24). Zooplankton samples indicated relatively low numbers of zooplankton in June with the exception of site KT-02 which was dominated by copepods (Figure 24). By August, zooplankton numbers had increased substantially with all sites except KA-01 being dominated by copepods. Site KA-01 was dominated by cladocerans which were also present at other sites in August.

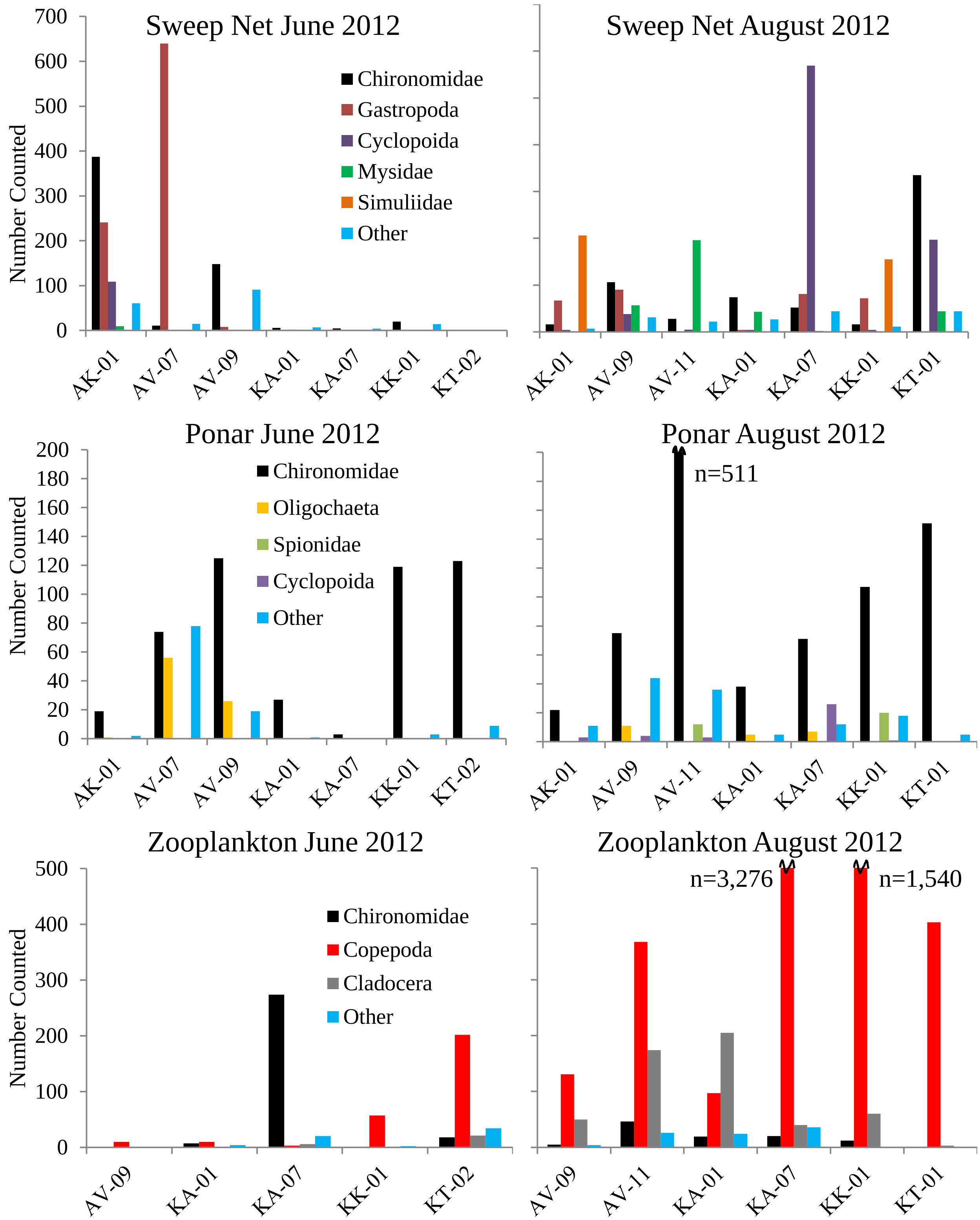


Figure 24. Invertebrates collected in the upper Kuk River in June and August 2012 at various sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom). Extreme values outside of the vertical axis range are shown on graphs.

Fish Diets

Arctic grayling stomachs were retained from a variety of locations in June 2012. Stomach contents from Arctic grayling in Avalitkok Creek (AK-01) were dominated by terrestrial flies (Dipterans) (Figure 25). Only a few dipterans were present in invertebrate samples at that site suggesting they were selecting for terrestrial dipterans over other available food items. Stomach contents of Arctic grayling from the remaining sample sites were dominated by chironomid larvae and pupae.

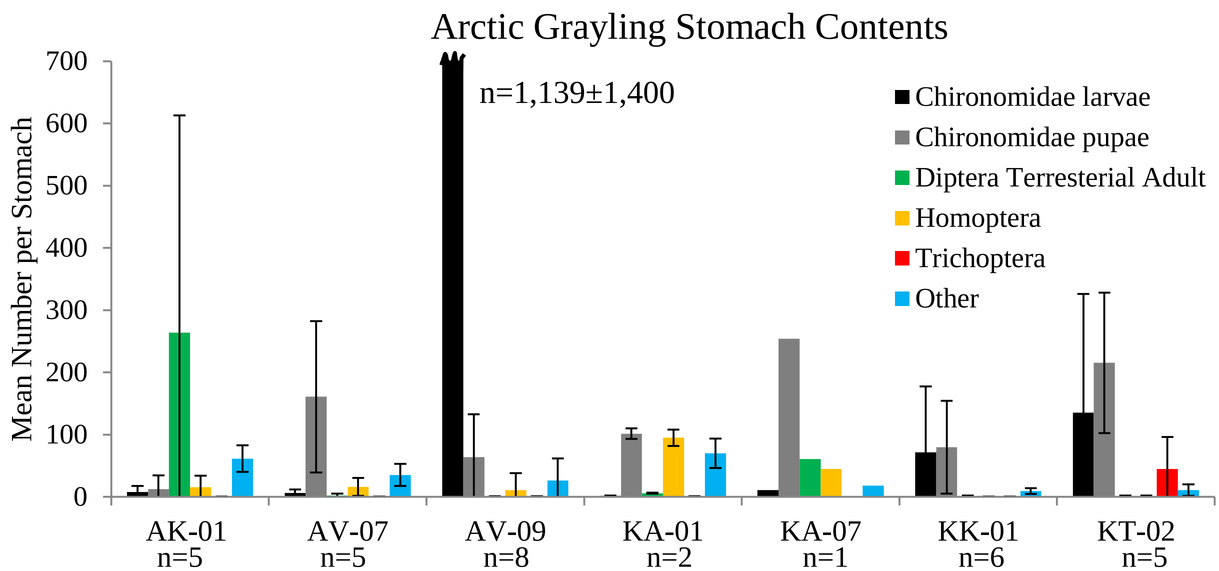


Figure 25. Mean number (±1 SD) of various invertebrates in Arctic grayling stomachs by sample site from the Kuk River drainage, June 2012. Sample size per site and extreme values outside of the vertical axis range are shown.

Stomach contents from three Arctic grayling from the Kaolak River (KA-01 and KA-07) were dominated by chironomid pupae and invertebrates in the terrestrial suborder Homoptera (leafhoppers and aphids). Eleven of the samples from Arctic grayling from two of the furthest downstream sample sites (KT-02 and KK-01) were dominated by chironomid larvae and pupae.

One Bering cisco was retained for quantitative examination of diet and its stomach contained 16 chironomid larvae and 70 adult mysids. Three least cisco stomachs were retained from site KT-02 and contained an average of 81% chironomid pupae, 17% chironomid larvae, and 2% other species by number.

Chlorophyll

On average, chlorophyll-a concentrations were higher in June than in August in various locations in the upper Kuk River drainage (Figure 26). Phytoplankton standing crops were likely lower in

August because water temperatures had dropped between June and August sampling but also because zooplankton populations had substantially increased possibly decreasing phytoplankton populations via direct predation.

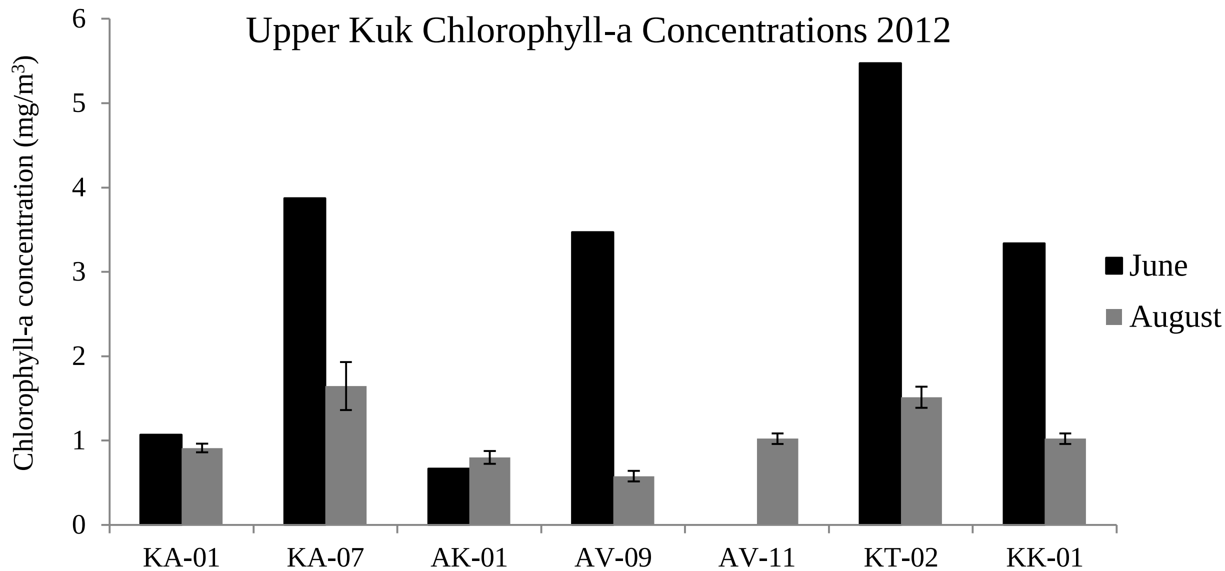


Figure 26. Chlorophyll-a concentrations in June and August at various sites in the upper Kuk River, 2012.

Water Quality

Water temperature averaged 15.2ºC (range: 11.4ºC –18.8ºC) during June 2012 sampling (Figure 27). By August, water temperatures were cooler, averaging 12.3ºC (range: 9.4ºC –15.7ºC). During the 2014 sampling, temperatures averaged 11.7ºC (range: 6.6ºC –15.5ºC). These cooler temperatures during the June 2014 sampling were likely a result of fish sampling being focused in small tributaries which were more influenced by spring melt as compared to the main river (Figure 27).

Values for pH averaged 7.75 (range: 6.23–8.44) during June 2012 sampling and followed a similar pattern as water temperature with values initially decreasing for the first half of sampling, then increasing later in sampling (Figure 27; Appendix 10). Averages were slightly higher during the August event at 8.12 (range: 7.09–8.65). In 2014, pH values averaged 7.4 (range: 6.94–7.83).

Turbidity averaged 8.17 NTU (range: 1.95–58.90 NTU) during the June 2012 sampling and was more variable than the August sampling, likely a result of spring runoff (Figure 27; Appendix 10). During August, turbidity averaged 5.51 NTU (range: 1.70–22.20 NTU). In 2014, turbidity averaged 9.2 NTU (range: 2.26–50.30 NTU).

Specific conductance was low at all sample sites in June 2012 where values averaged 156.5 µS/cm (range: 20.7–462.0 µS/cm) and low in June 2014 when values averaged 69.4 µS/cm (range: 31.1–132.5 µS/cm) (Figure 27; Appendix 10). During the August 2012 sampling, values were much higher, averaging 2,423 µS/cm (range: 109.2–12,240 µS/cm). Highest specific conductance values in August 2012 were primarily from the sample sites in the lower river where there was brackish water influence from Wainwright Inlet. These same sites had lower specific conductance in the spring when increased flow from spring melt prevented brackish water intrusion into the sampling area.

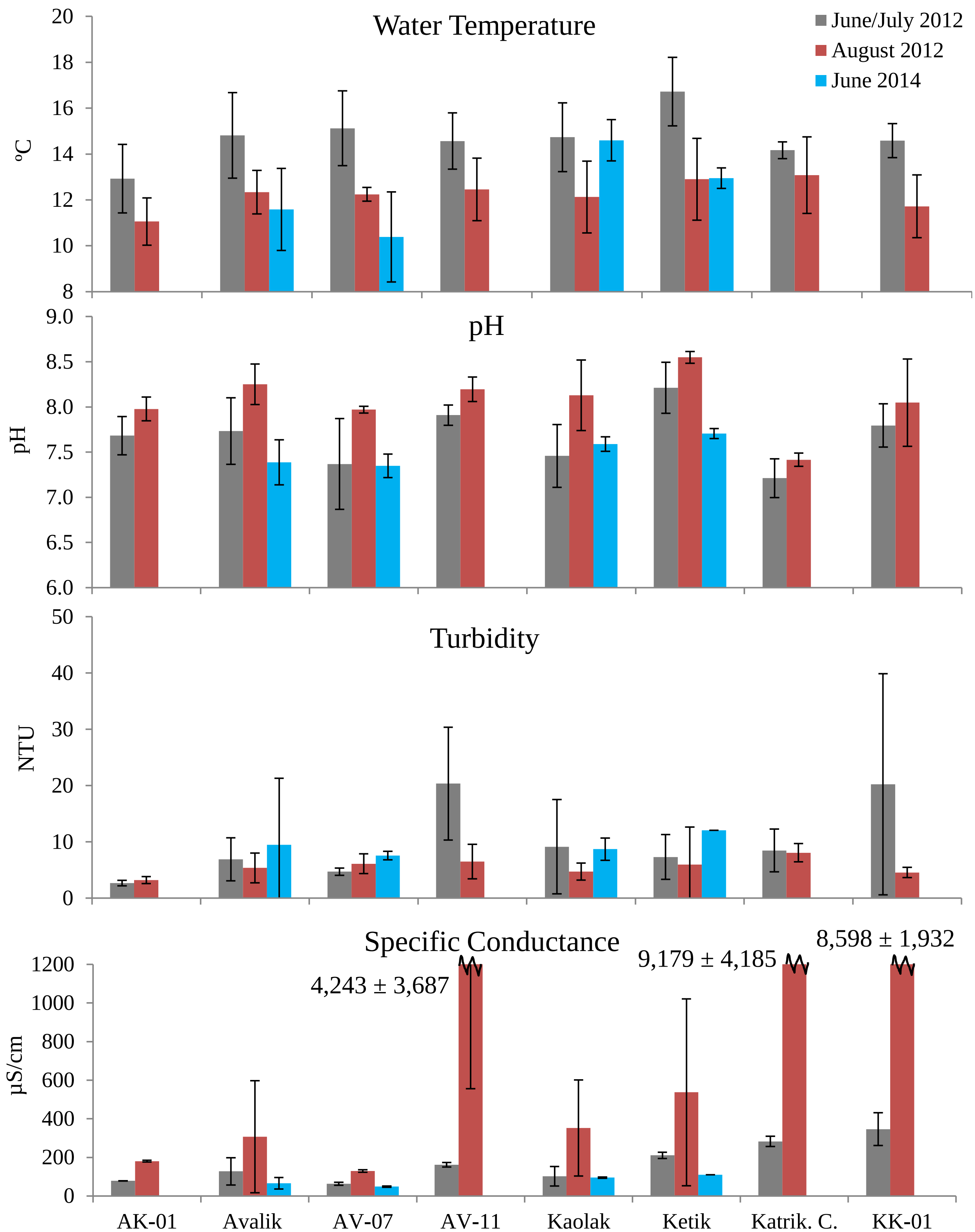


Figure 27. Mean (± SD) water temperature (ºC), pH, turbidity (NTU) and specific conductance (µS/cm) for AK-01, the Avalik River (AV-01, 02, 03, 04, 05, 06, 08, 09, 10, 12), AV-07, AV-11, the Kaolak River (KA-01, 02, 03, 04, 05, 06, 07), the Ketik River (KE-01, 02, 03, 04, 05), Katrikiorak Creek (KT-01, 02), and KK-01. Values outside of the y-axis range are shown.

Radiotelemetry

A total of 29 burbot were radiotagged in the upper Kuk River drainage in 2012, 20 in June/July sampling and 9 in August sampling. Burbot were caught in a variety of locations in the Kaolak, Ketik, and Avalik rivers, but were transported to one of three tagging locations near the confluence of these three rivers for tag implantation and release (Figure 28). In addition, 12 Arctic grayling were also radiotagged, five in June/July sampling and seven in August sampling.

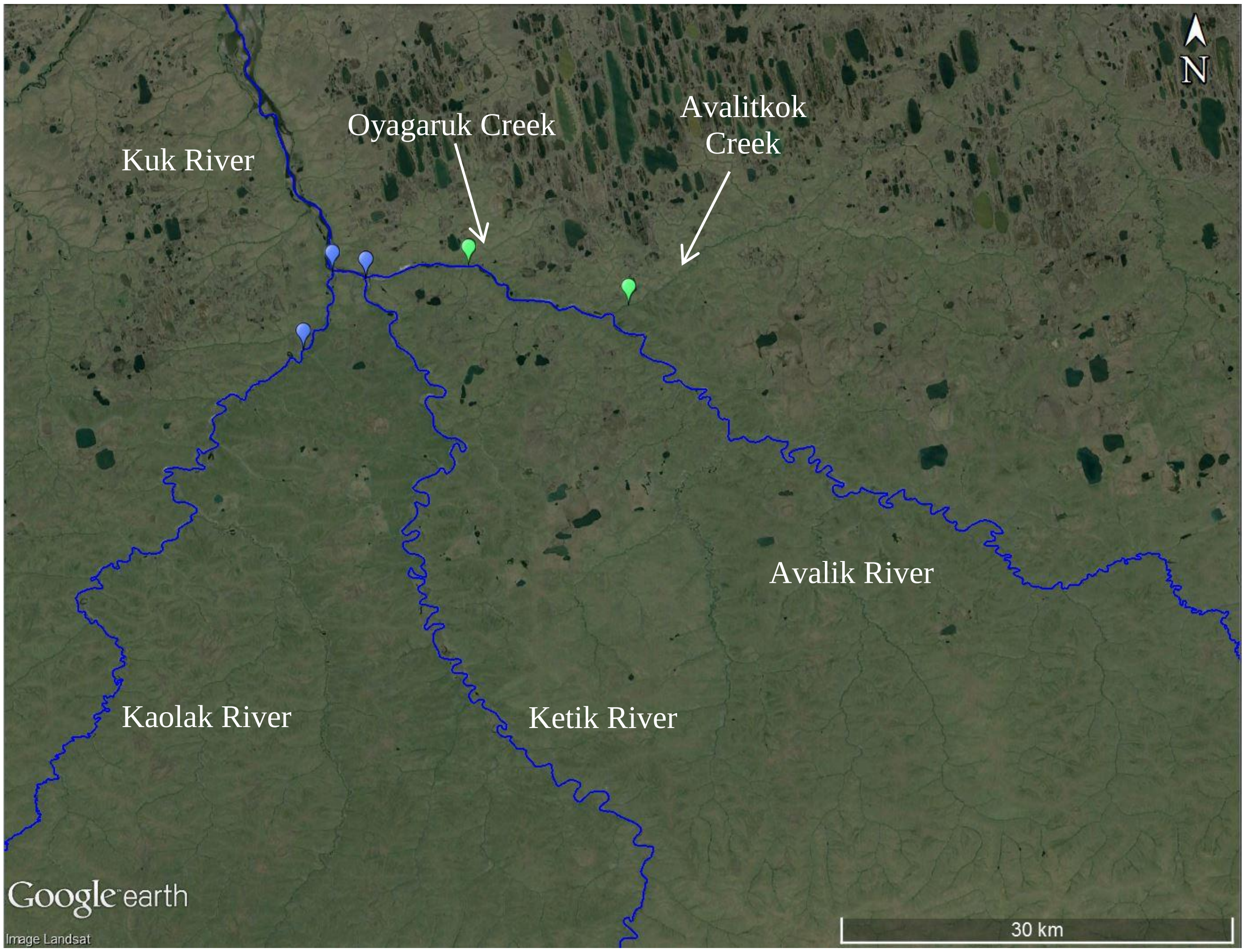


Figure 28. Burbot (blue marks) and Arctic grayling (green marks) tagging locations in the upper Kuk River drainage June 17–July 6, 2012 and July 31–August 14, 2012.

The first relocation flight was conducted on November 5, 2012 and 24 of the 29 (83%) radiotagged burbot were relocated (Figure 29). Three of the fish were relocated in the Kaolak River while the remaining fish were relocated in the Avalik River. All relocated fish had moved upstream from their tagging location. The average upstream movement was 48.2 km (range: 8–108 km). Eight of the 12 (67%) radiotagged Arctic grayling were also relocated during this flight. Five Arctic grayling had moved upstream from their tagging locations. The average upstream movement was 14.8 km (range: 3–45 km). One fish moved downstream 8 km, then 3 km upstream in the Ketik River, one moved downstream 4 km, and one did not move from the tagging location.

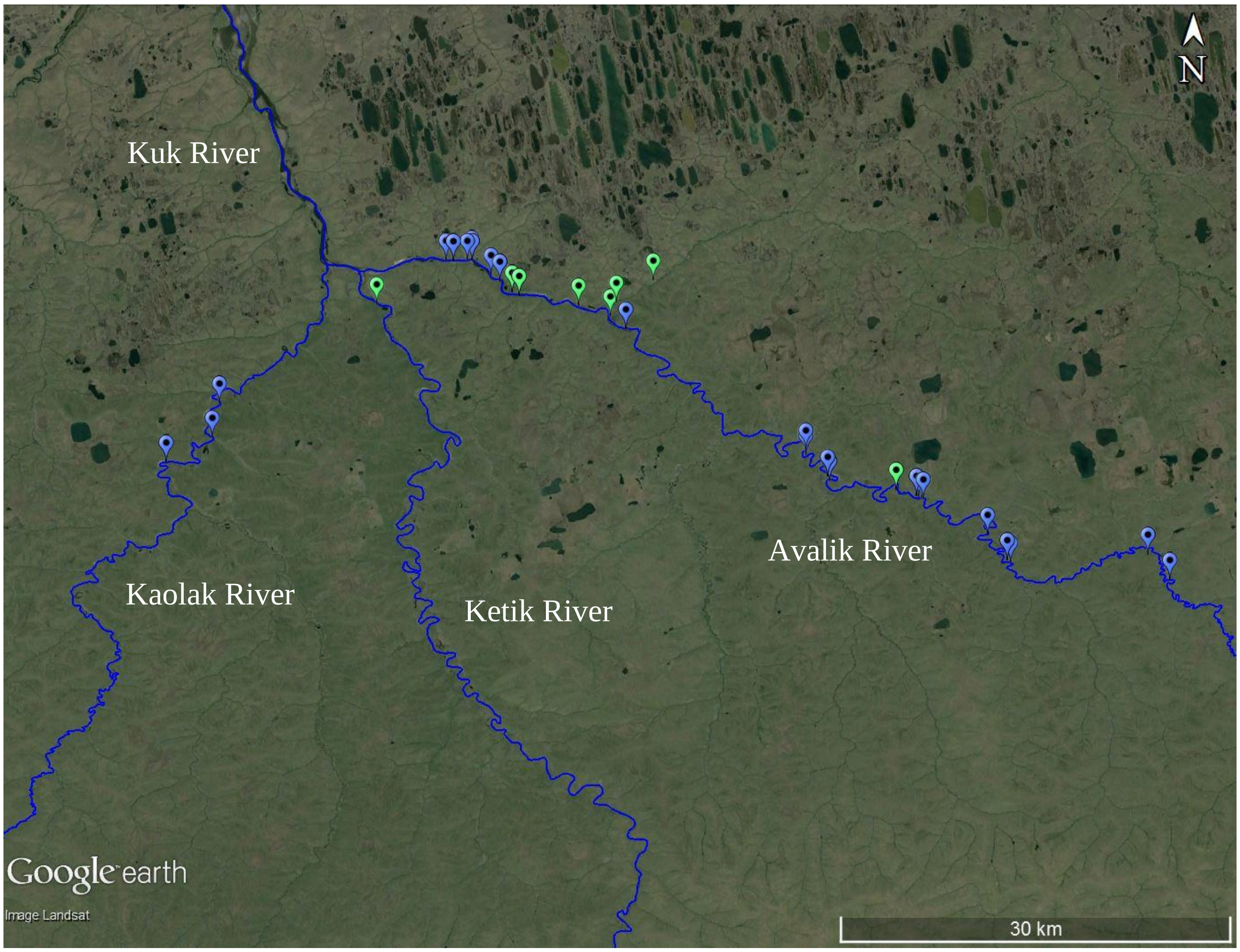


Figure 29. Relocations for 24 of the 29 radiotagged burbot (blue marks) and 8 of the 12 radiotagged Arctic grayling (green dots) in the upper Kuk River drainage; November 5, 2012.

The second relocation flight was conducted just over one year later on November 27, 2013, and seven of the 29 (24%) radiotagged burbot were relocated (Figure 30). Poor weather prevented a complete survey so most of the area was not flown. However, of the seven fish that were relocated, four were in the same location as the prior relocation flight, one had moved 26 km down the Kaolak River, and then 87 km up the Avalik River, one moved 26 km down the Avalik River and one moved 21 km up the Avalik River. No Arctic grayling were relocated during this flight.

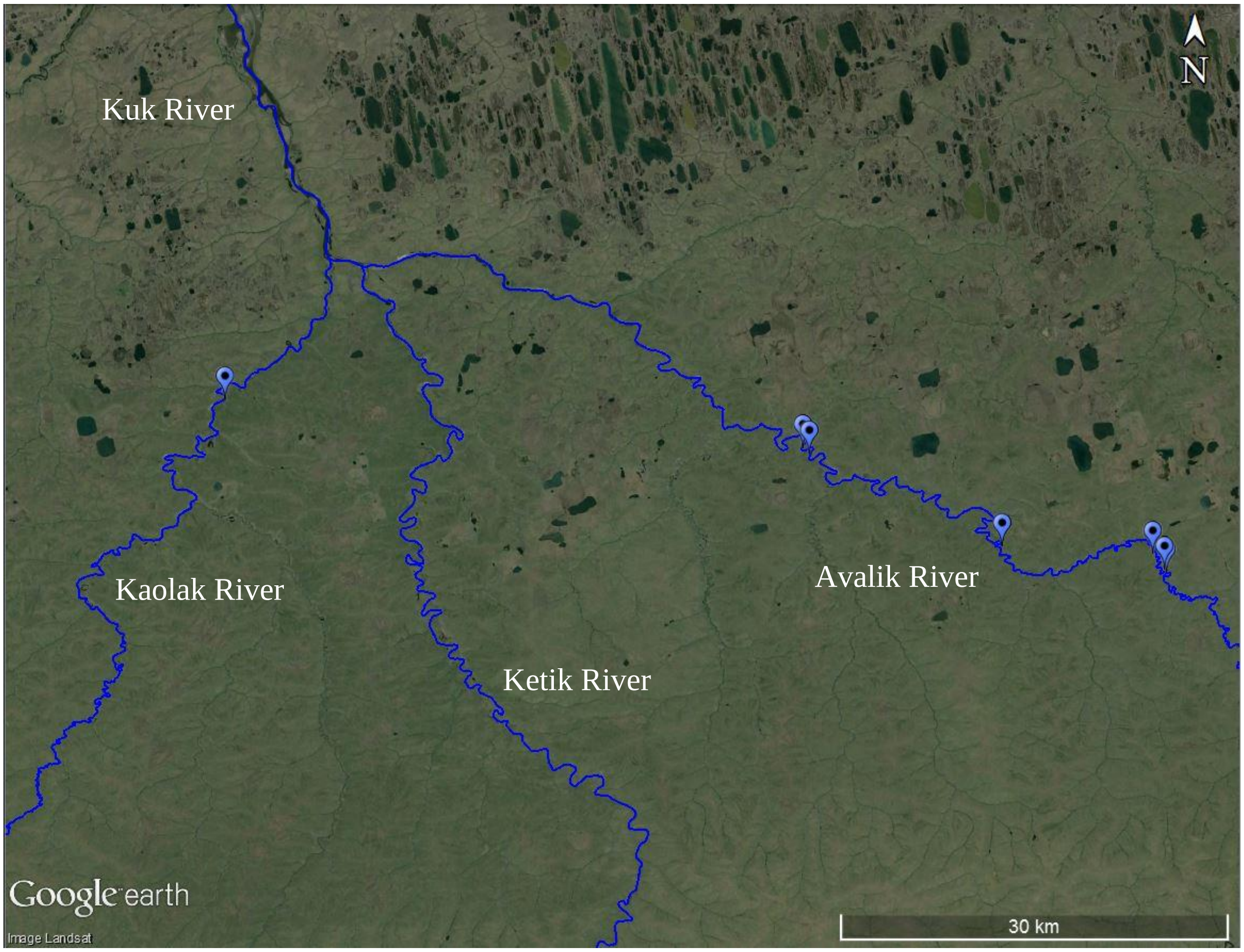


Figure 30. Relocations for 7 of the 29 radiotagged burbot in the upper Kuk River drainage; November 27, 2013.

In 2014, 50 burbot were radiotagged at six locations in the lower Avalik and Ketik rivers (Figure 31). All 50 fish were relocated at least once during five subsequent relocation flights. Based on relocation and movement rates, we believe that only one fish died after transmitter insertion indicating 98% surgery survival. One fish was captured by a fisherman. Eight fish (16% of radiotagged fish) showed some site fidelity by moving back to their tagging location; their movements may be tracked in figures 32, and 34-37 as numbers 1–8.

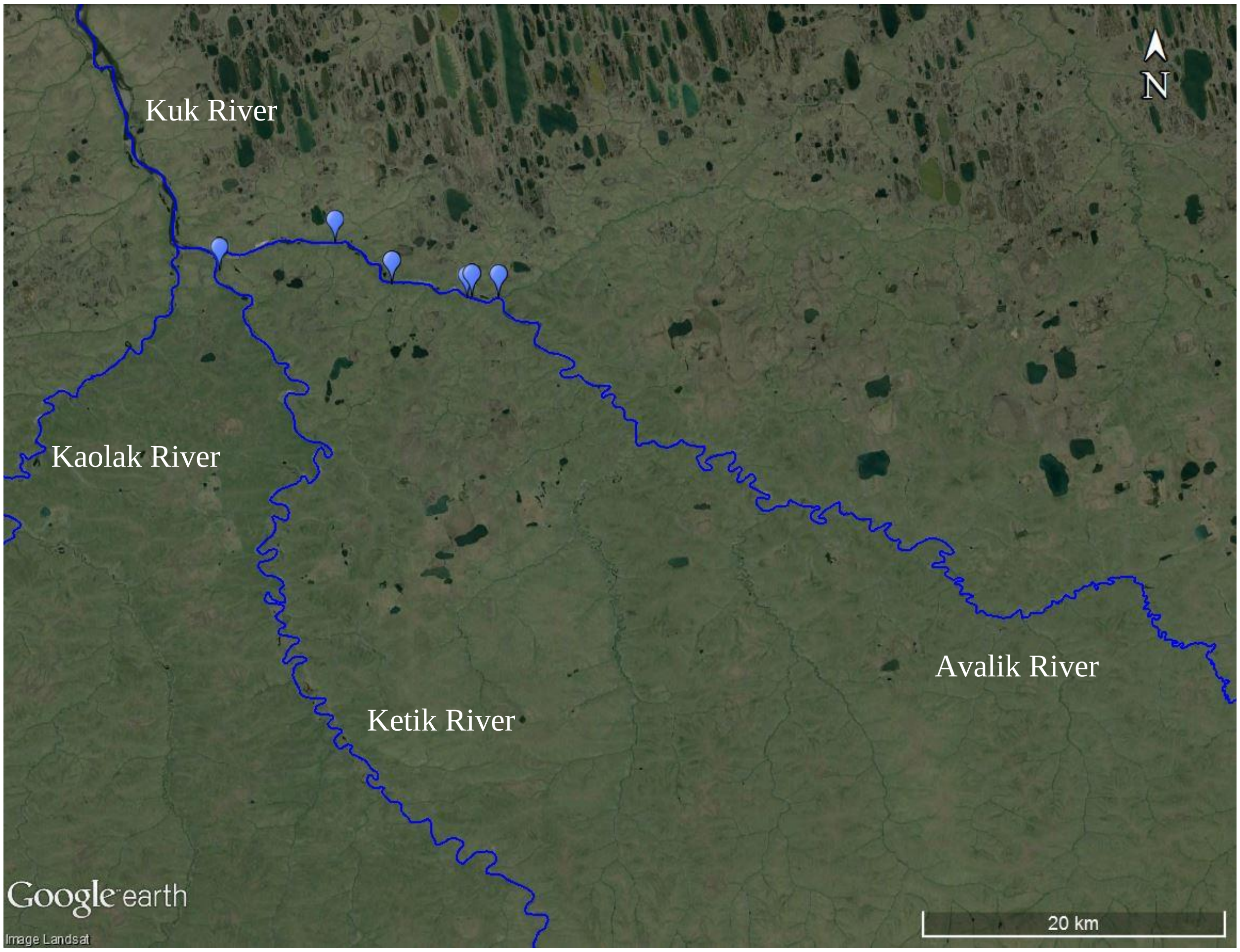


Figure 31. Burbot tagging locations in the upper Kuk River drainage; June 23–27, 2014.

The first 2014 relocation flight was on July 26, approximately one month after tagging. A total of 35 of the 50 (70%) radiotagged burbot were relocated (Figure 32). Sixteen (46% of relocated fish) of the burbot moved upstream from the tagging location, averaging 8.7 km (range: 1.6–28.2 km), 7 (20% of relocated fish) moved downstream averaging 10.4 km (range: 4.0–15.4 km), and 12 (34% of relocated fish) did not move from their tagging locations (Figure 33). Fish #'s 1, 2, 4, and 5 remained close to their tagging locations while fish #'s 3, 6, 7 and 8 were not located (Figure 32).

Figure 32. Relocations for 35 burbot, including fish #'s 1, 2, 4, and 5, in the upper Kuk River drainage; July 26, 2014. Green shading represents tagging area.

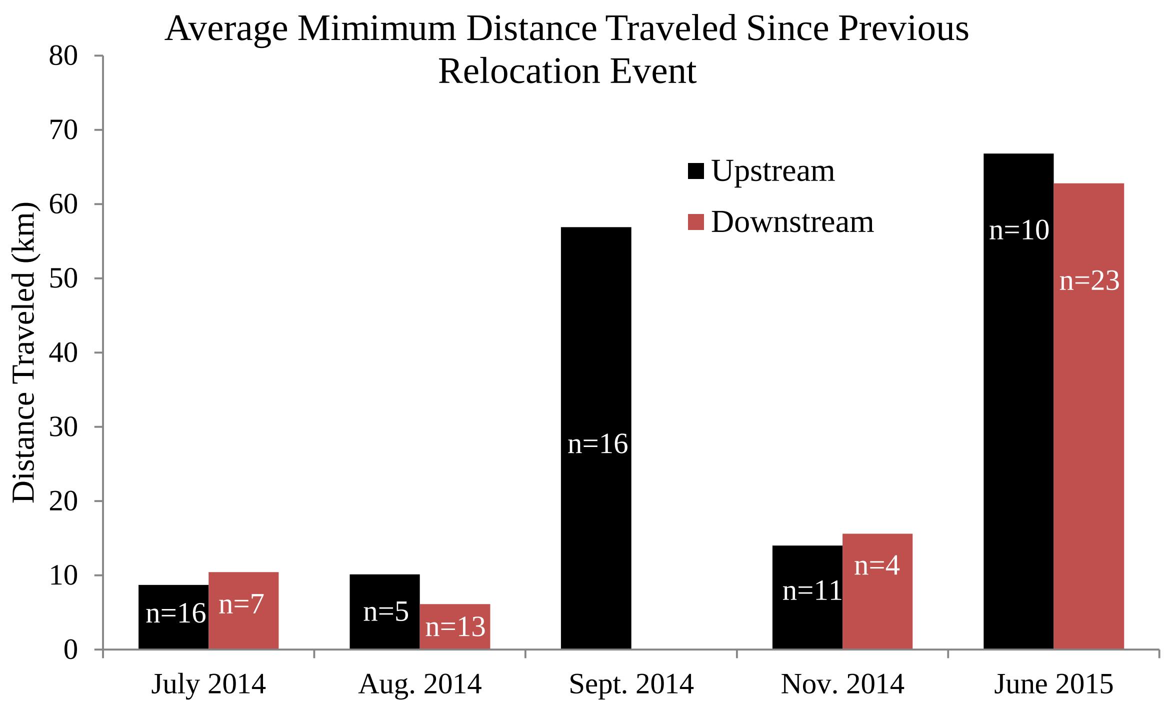


Figure 33. Average minimum distance (km) and direction traveled for burbot radiotagged in the upper Kuk River drainage in 2014. Only burbot that were detected in the prior relocation event are included. Number of burbot used in analysis for each relocation event is included.

The second relocation flight was on August 30, 2014. A total of 29 of the 50 (58%) radiotagged burbot were relocated during this flight (Figure 34). All fish were relocated in the Avalik River, except for one that was found 11.2 km upstream in an unnamed tributary flowing into the Avalik River from the south. Of the 21 fish relocated both in July and August, 5 (17%) had moved upstream averaging 10.1 km (range: 1.6–27.4 km), 13 (45%) had moved downstream averaging 6.1 km (range: 1.6–12.8 km), and 3 (10%) had not moved (Figure 33). Fish #'s 3 and 8 had moved downstream from their tagging location, fish #'s 4 and 6 remained in the vicinity of their tagging locations, and fish #'s 1, 2, 5, and 7 were not relocated (Figure 34).

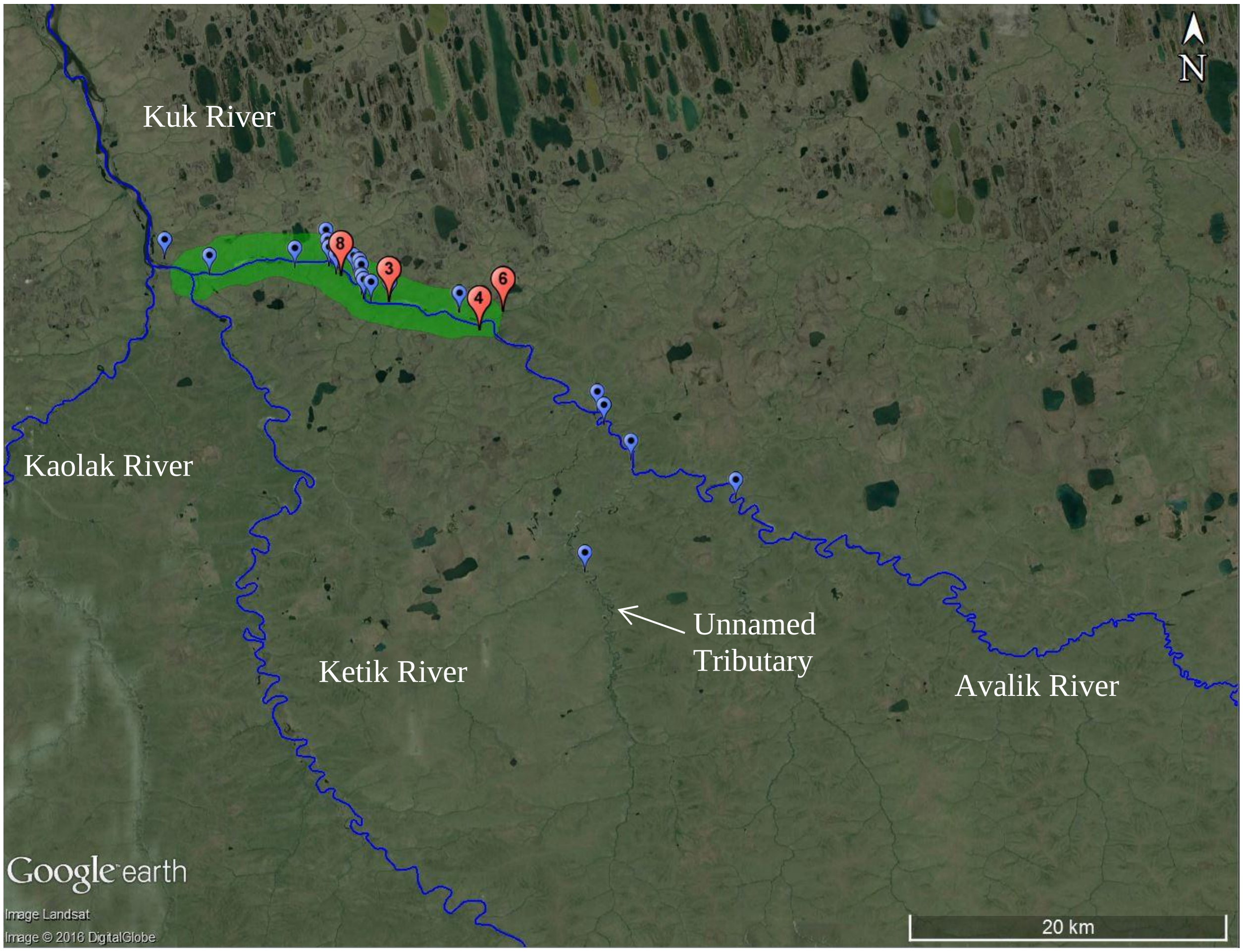


Figure 34. Relocations for 29 burbot, including fish #'s 3, 4, 6, and 8, in the upper Kuk River drainage; August 30, 2014. Green shading represents tagging area.

The third relocation flight was conducted September 26, 2014 and 33 of the 50 radiotagged burbot were relocated (Figure 35). All were relocated in the Avalik River, except for 5 that were found in the small unnamed tributary to the Avalik River. One of those fish had moved 32 km upstream in the unnamed tributary. Of the 18 consecutively relocated fish between August and September, 16 (89%) fish had moved upstream averaging 56.9 km (range: 17.7–90.1 km), none had moved downstream, and 2 (11%) did not move (Figure 33). Fish #'s 1, 4, 5, 6, and 7 showed significant upstream movements from their prior known locations (Figure 35).

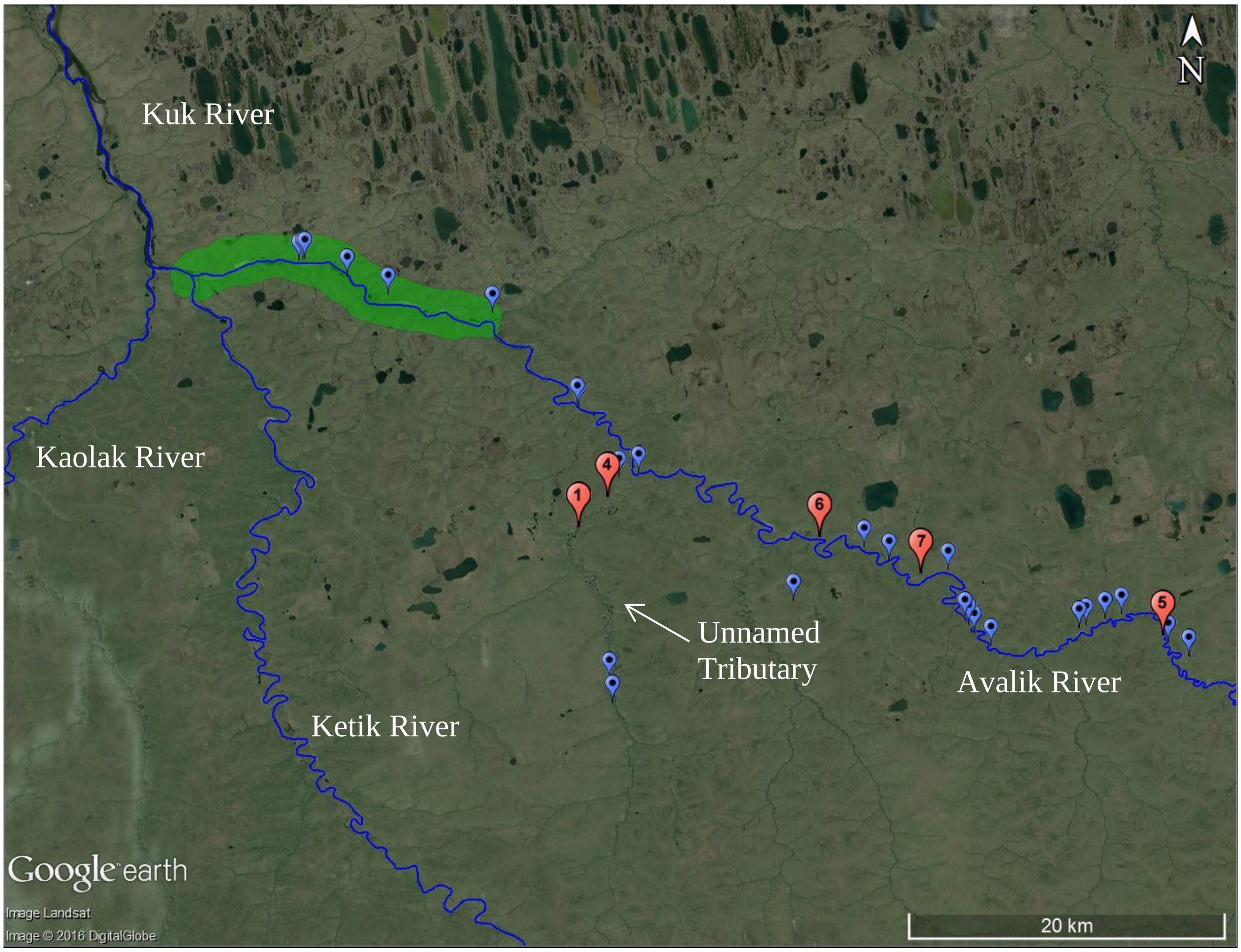


Figure 35. Relocations for 33 burbot, including fish #'s 1, 4, 5, 6, and 7 in the upper Kuk River drainage; September 26, 2014. Green shading represents tagging area.

The fourth relocation flight was on November 12, 2014 and 41 of the 50 (82%) radiotagged burbot were relocated (Figure 36). Thirty-seven (90% of relocated fish) fish were relocated in the Avalik River, and 4 (10% of relocated fish) were in the unnamed tributary to the Avalik River. Three of those 4 fish were relocated there in September as well. Of the 28 consecutively relocated fish between September and November, 11 (39%) had moved upstream an average of 14 km (range: 6.4–29.0 km), four (14%) had moved downstream an average of 15.6 km (range: 3.1–29.0 km), and 13 (46%) had not moved (Figure 33). Fish #'s 1–8 were substantially upstream from their tagging location. Fish #4 had moved from the small unnamed tributary to further upstream in the Avalik River (Figure 36).

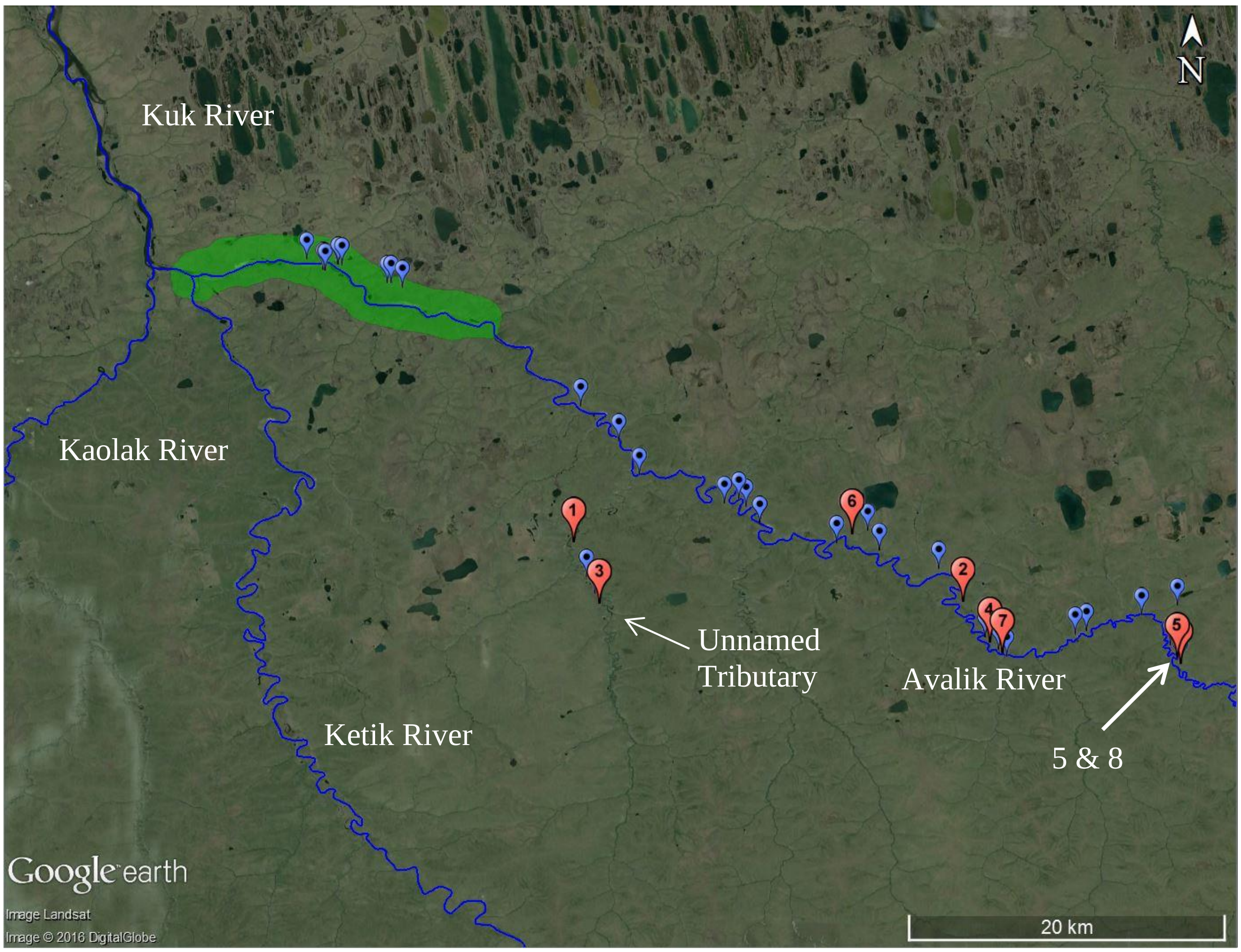


Figure 36. Relocations for 41 burbot, including fish #'s 1–8, in the upper Kuk River drainage; November 12, 2014. Green shading represents tagging area.

The final relocation flight was on June 13, 2015 and 45 of the 50 (90%) radiotagged burbot were relocated (Figure 37). A majority of the burbot remained in the Avalik River, with one fish being relocated in the Kaolak River and one in the Kuk River. Fish #'s 1–8 were relocated in the same location where they were radiotagged, and many others had moved from the upper Avalik River to the general vicinity of their tagging location (Figure 37). Of the 37 consecutively relocated fish between November 2014 and June 2015, 10 (27%) had moved upstream averaging 66.8 km (range: 16–96.6 km), 23 (62%) had moved downstream averaging 62.8 km (range: 2.4–107.8 km), and 4 (11%) had not moved (Figure 33).

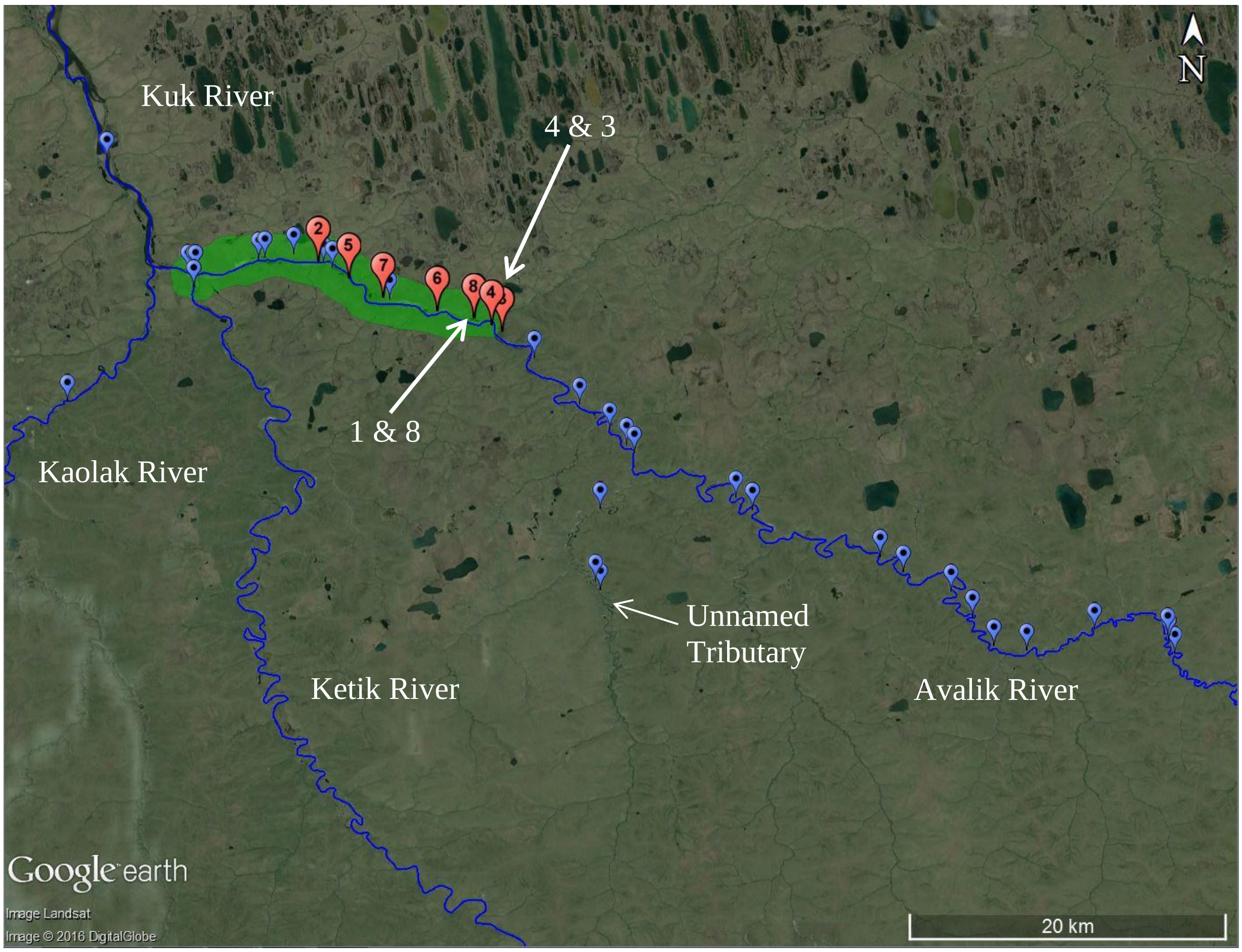


Figure 37. Forty five of 50 burbot relocations June 13, 2015 with fish #'s 1–8 occurring back at their tagging locations. Green shading represents tagging area.

The Avalik River is important for burbot that reside in the upper Kuk River drainage. Movement patterns suggest that the upper Avalik River provides overwintering and likely spawning habitat for burbot since they spawn under the ice in late winter (Scott and Crossman 1973). The unnamed tributary likely provides important habitat as well since multiple burbot made extensive movements up the tributary at various times of the open water season. June 2015 relocations suggest that burbot show site fidelity for feeding locations where specific tributaries flow into the

Avalik River. Based on these telemetry results and fish capture data, it appears that some burbot utilize the Kaolak River during summer, but likely not for overwintering. No burbot were located in the Ketik River suggesting that neighboring drainages provide more suitable habitat.

Kugrua River

Sampling of the Kugrua River was conducted July 23–July 31, 2013. A total of 12 locations were sampled for fish using fyke nets and set gillnets (Figure 38; Appendix 11). Aquatic invertebrate and phytoplankton samples were collected at 6 of these locations.

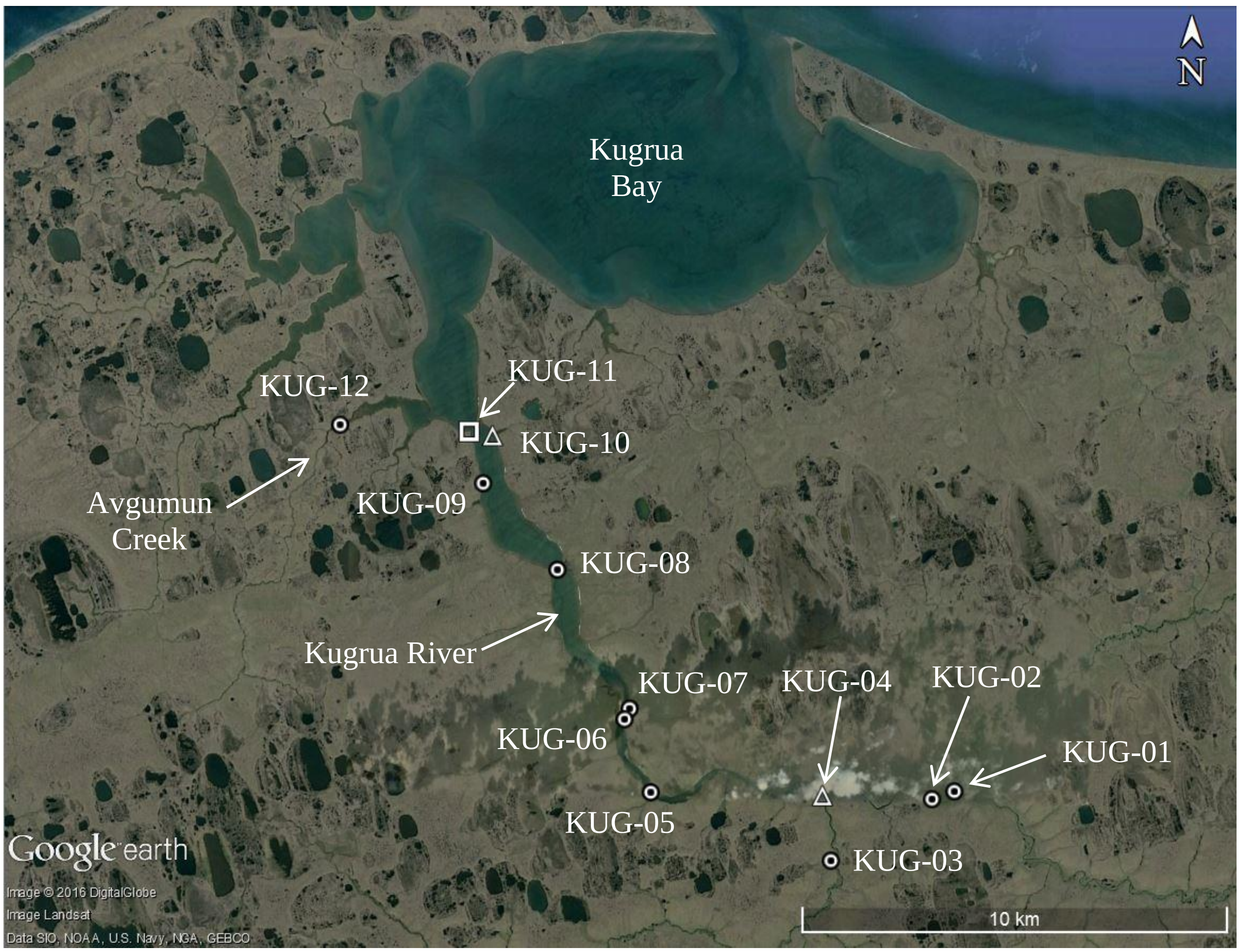


Figure 38. Kugrua River sites sampled in 2013 with fyke nets (round dots) and set gillnets (squares). Triangles represent sites where both gear types were used.

Fish Catch Data

A total of 1,926 fish comprised of 8 species were captured in 666 fyke net effort hours in the Kugrua River drainage. Rainbow smelt were the most abundant species followed by fourhorn sculpin, threespine stickleback, ninespine stickleback, Arctic flounder, saffron cod, pink salmon, and least cisco (Table 7).

Table 7. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch for each species captured with fyke nets in the Kugrua River, 2013.

Species	Number of Fish	Mean CPUE	Percent of Catch
Rainbow smelt	600	22.01	31.2
Fourhorn sculpin	538	19.91	27.9
Threespine stickleback	333	12.02	17.3
Ninespine stickleback	250	9.47	13.0
Arctic flounder	123	4.50	6.4
Saffron cod	74	2.77	3.8
Pink salmon	6	0.22	0.3
Least cisco	2	0.08	0.1
Total catch	1,926		
Total effort (hrs.)	666		

A total of 26 fish comprised of two species were captured in 74 set gillnet effort hours in the Kugrua River with chum salmon and pink salmon making up the catches (Table 8).

Table 8. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch for each species captured with set gillnets in the Kugrua River, 2013.

Species	Number of Fish	Mean CPUE	Percent of Catch
Chum Salmon	13	4.66	50
Pink Salmon	13	3.18	50
Total catch	26		
Total effort (hrs.)	74		

Rainbow smelt

Catches of rainbow smelt were primarily dominated by age-0 fish, with only two larger individuals captured (Figure 39). Fork lengths ranged from 44 to 230 mm. The presence of age-0 fish suggests that the Kugrua River serves as spawning habitat for rainbow smelt. They likely spawn in or near the mouths of the few freshwater tributaries near sample sites KUG-01, 02, 03, or 12.

The highest CPUE for rainbow smelt was at KUG-08 (Appendix 12) where the river narrows from approximately 700 to 100 m wide. The constriction of the channel funnels fish into a smaller area as they are moving up or downstream making this an especially effective sampling location.

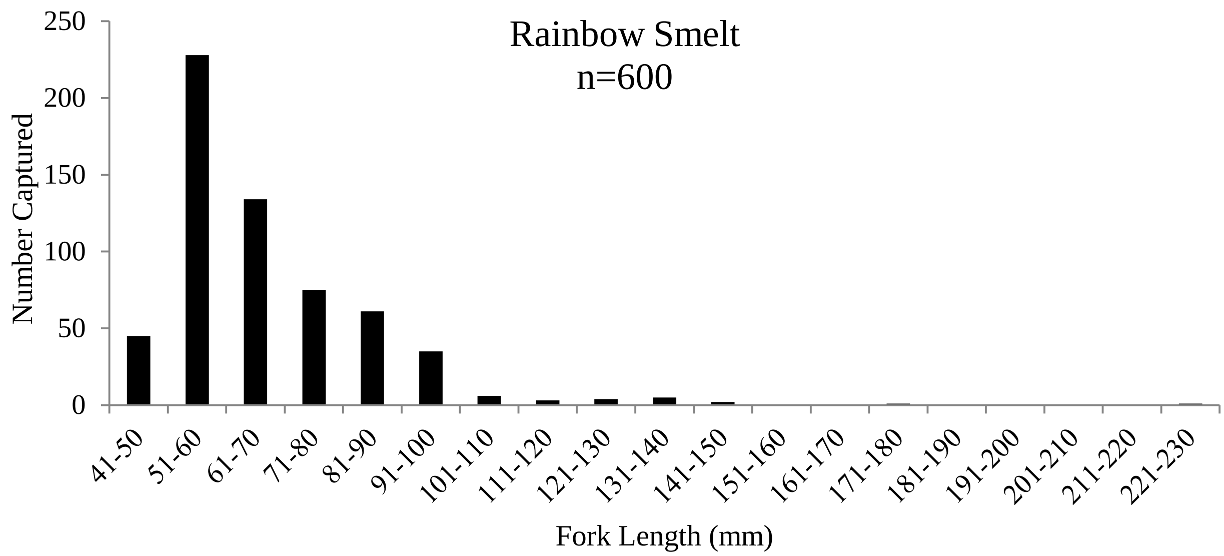


Figure 39. Length frequency distribution of rainbow smelt captured in the Kugrua River, 2013.

Fourhorn sculpin

Catches of fourhorn sculpin were dominated by juveniles; total length ranged from 22 to 251 mm (Figure 40). The most common size class was 61–70 mm. Similar to rainbow smelt catches, the highest CPUE for fourhorn sculpin occurred at KUG-08 (Appendix 12). Fourhorn sculpin were captured at every fyke net location except KUG-01 and KUG-02.

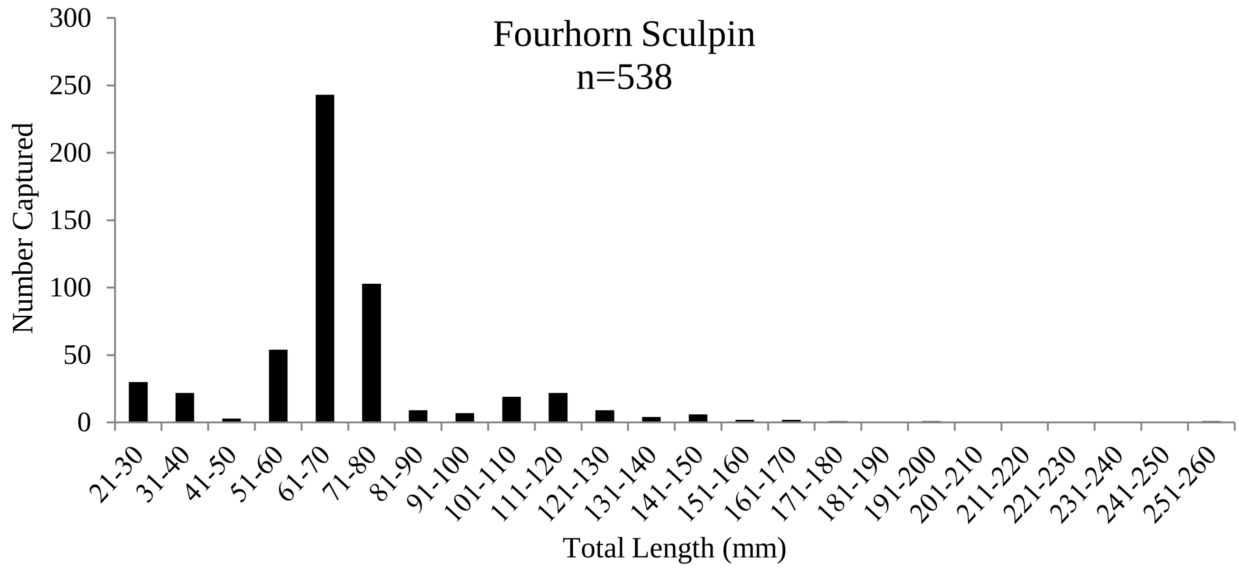


Figure 40. Length frequency distribution of fourhorn sculpin captured in the Kugrua River, 2013.

Aquatic Invertebrates

Chironomids dominated the sweep net and ponar aquatic invertebrate samples at a majority of the sample sites with nematodes, ostracods, mysids, and tellinids being common at many sample sites (Figure 41). Copepods and cladocerans dominated the zooplankton samples.

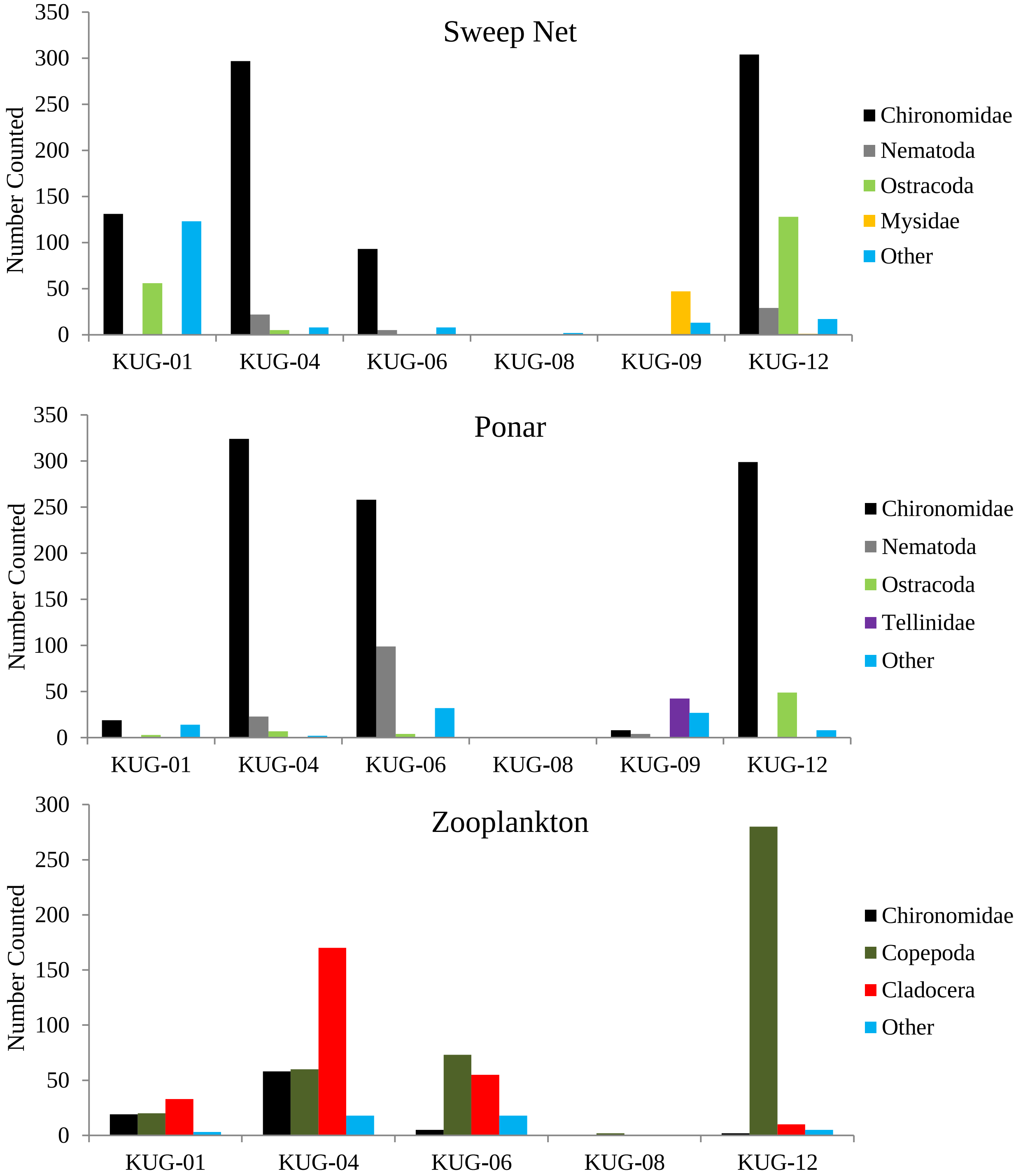


Figure 41. Invertebrates collected in the Kugrua River at various sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom), 2013.

Chlorophyll

Chlorophyll-a values were low, but relatively similar among all sample sites, with average values ranging from 0.49 mg/m^3 at KUG-01 to 0.85 mg/m^3 at KUG-04 (Figure 42).

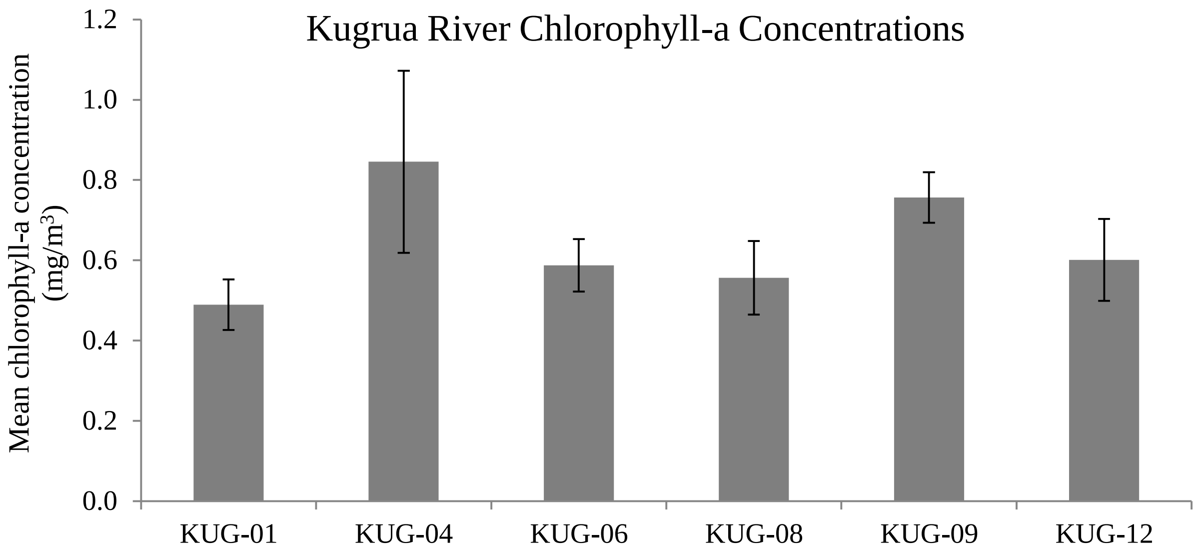


Figure 42. Mean chlorophyll-a concentrations (mg/m^3) ± 1 SD at six sample sites in the Kugrua River, 2013.

Water Quality

Mean water temperatures were similar among sample sites with mean temperatures ranging from 9.4ºC at site KUG-08 to 11.9ºC at site KUG-07. Mean specific conductance was lowest at sample sites KUG-01, 02, 03, 04, and 12 indicating these sites contained freshwater. Beginning at KUG-05 and sites further downstream, conductivity values increased indicating a saltwater influence. Sample site KUG-07 was at the mouth of a small tributary and had some freshwater influence compared to the surrounding sample sites. Mean pH values were also similar among sample sites and ranged from 7.06 at KUG-12 to 8.15 at KUG-08. Turbidity values were lowest at the furthest upstream sample sites and highest at the downstream sites. This is likely a result of high winds and tidal influence that increased sediments in the water column at these lower river sites.

CPUE, Length-Weight, Growth, and Maturity Patterns

Least Cisco

Length-Weight

Least cisco retained for length-weight analysis ranged from 70 to 381 mm (Figure 43). Weights were calculated at three comparison lengths (175, 250 and 325 mm) to evaluate differences among areas (Table 9). Least cisco from the upper Kuk River had greater weights at a given length than least cisco from other rivers in the Kuk River drainage and fish from other studies in the Chipp River in 1993-94 and 2008, Teshekpuk Lake in 2003-2007, and Elson Lagoon in 2010 (Figure 43; Table 9; Appendix 13). Least cisco from the Ivisaruk River had the second greatest weights at a given length.

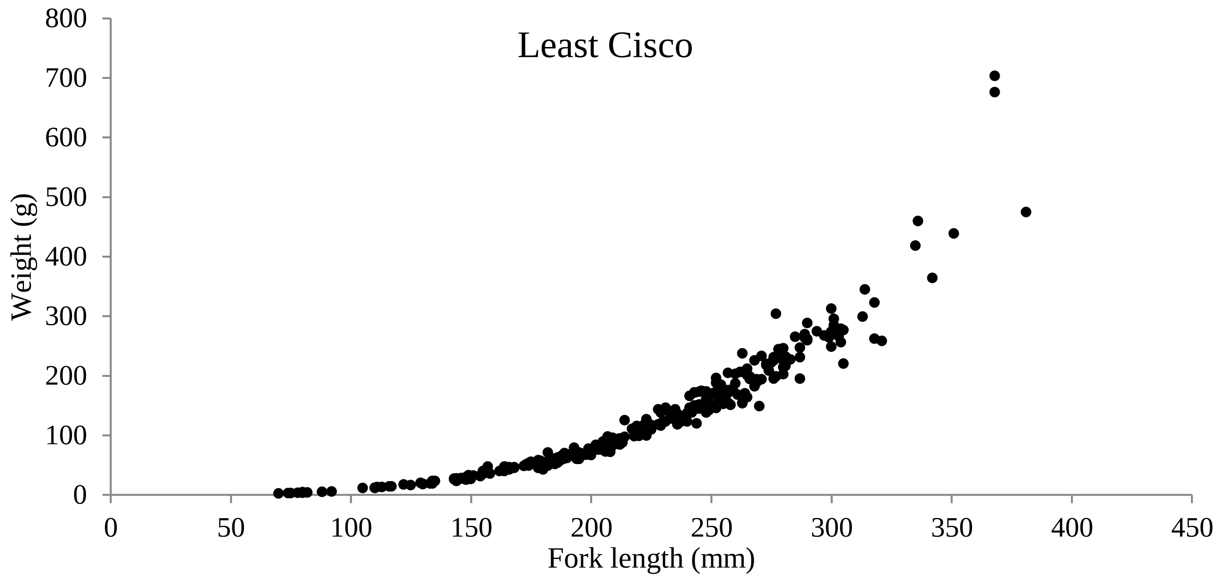


Figure 43. Length-weight relationship for least cisco captured in the Ivisaruk River in 2010 (n=50), the Kungok River in 2011 (n = 191), and the upper Kuk River in 2012 (n = 58).

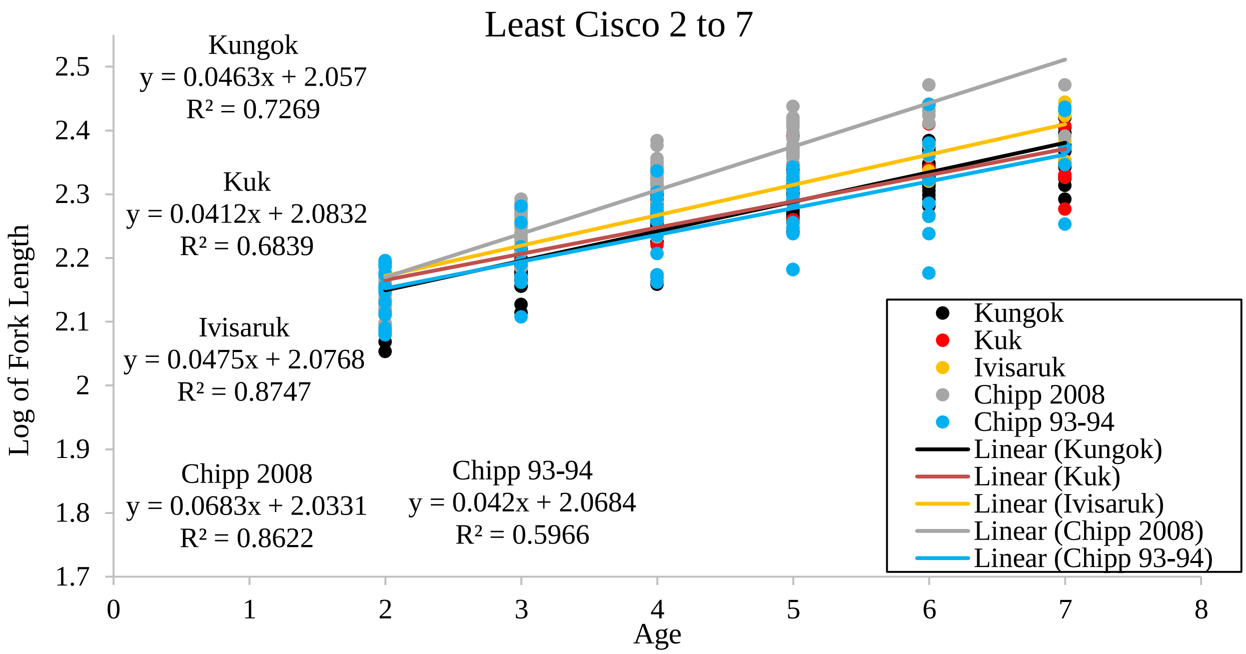
Table 9. Weights at given lengths for least cisco caught in the current study compared to other North Slope areas.

Area	Sample Group	Length-Weight Relationship Slope	Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 175	250	325
Ivisaruk River[1]								
	all groups except ripening females	3.153	-5.359	0.99	34	51.7	159.1	363.9
Kungok River[1]								
	all groups except ripening females	3.125	-5.327	0.99	142	48.1	146.7	333.1
Kuk River[1]								
	all groups except ripening females	3.410	-5.964	0.99	33	48.4	163.3	399.5
Chipp River 1993-94[1,2]								
	all groups except ripening females	3.164	-5.412	0.98	171	48.4	149.7	343.2
Chipp River 2008[1,2]								
	all groups except ripening females	3.285	-5.720	0.99	75	44.5	143.6	340.0
Teshekpuk Lake 2003-2007[1,3]								
	all groups except ripening females	3.297	-5.768	0.99	160	42.5	137.7	327.1
Elson Lagoon 2010[1,4]								
	all groups except ripening females	3.435	6.099	0.99	66	40.2	137.0	337.4

[1] groups included: immatures, ripening males, mature non-spawning females and males
[2] Moulton et al. 2007
[3] Moulton et al. 2011
[4] Morris et al. 2012

Age-Length

Least cisco retained for analysis ranged from age 2 to age 25. Growth rates of least cisco ages 2 to 7 from the Ivisaruk, Kungok, and Kuk rivers were lower compared to least cisco from the Chipp River 2008 (Figure 44, Appendix 14). Growth rates were similar between least cisco ages 2 to 7 between the Ivisaruk and Kungok rivers; however, least cisco in the Ivisaruk River were larger at a given age. Growth rates of least cisco ages 8 and older were similar between the Ivisaruk, Kungok, and Kuk rivers; however, fish in the Kungok River were larger at a given age than least cisco from the Kuk River (Figure 44; Appendix 14).



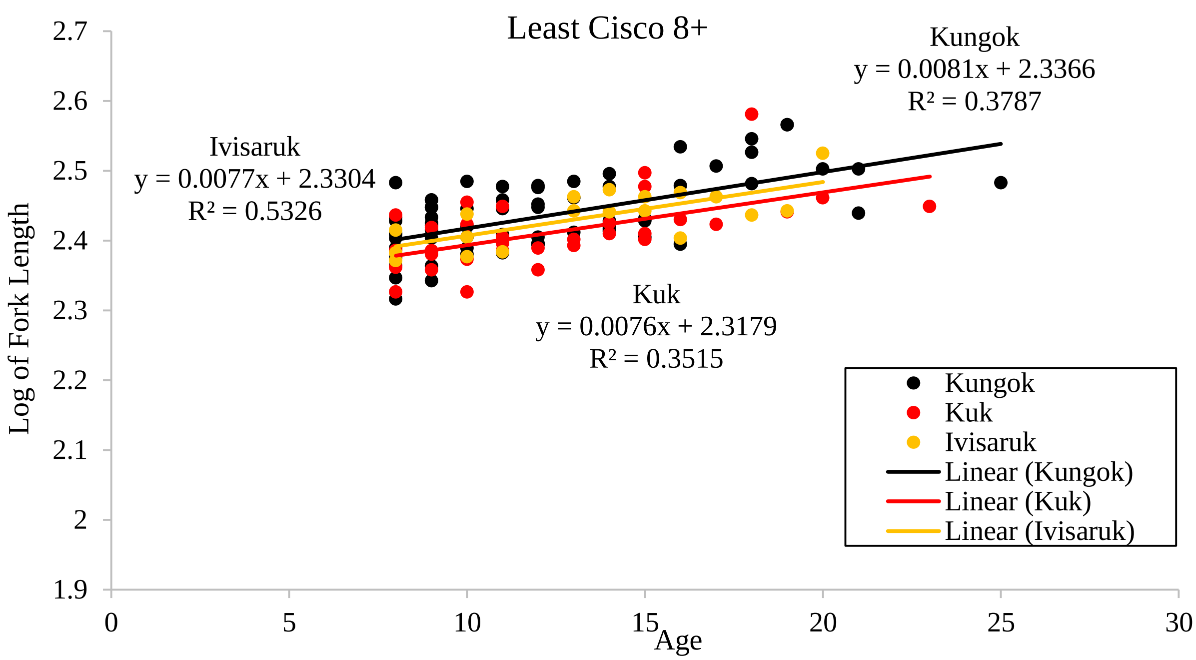


Figure 44. Age-log fork length relationships for least cisco ages 2-7 (top) from the Ivisaruk River 2010, Kungok River 2011, Kuk River 2012, Chipp River 1993-94, and Chipp River 2008 (Moulton et al. 2011) and ages 8+ (bottom) from the Ivisaruk River 2010, Kungok River 2011, Kuk River 2012.

Maturity

The reproductive characteristics for least cisco are listed in Appendix 15. Male least cisco began maturing at age 3 while female least cisco began maturing at age 4. By age 5, 85% of all least cisco were sexually mature and by age 6, 100% of least cisco were sexually mature (Figure 45).

All least cisco less than 150 mm were sexually immature while 100% of least cisco over 210 mm were sexually mature (Figure 46). Of all the mature least cisco caught, 47% of the males and 67% of the females were pre-spawners suggesting many fish spawn every other year. The sex ratio (female: male) for least cisco was 1.46:1, which is similar to other studies further north in the Dease Inlet region (Philo et al. 1993).

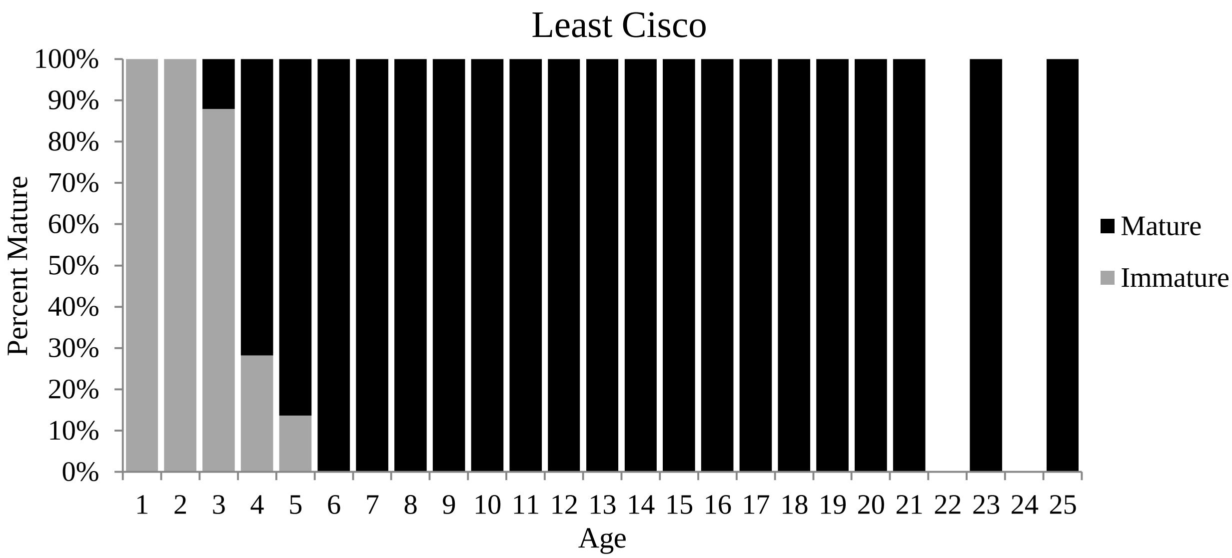


Figure 45. Percent maturity by age class for least cisco captured in the Ivisaruk River in 2010 (n=50), the Kungok River in 2011 (n = 191), and the upper Kuk River in 2012 (n = 58).

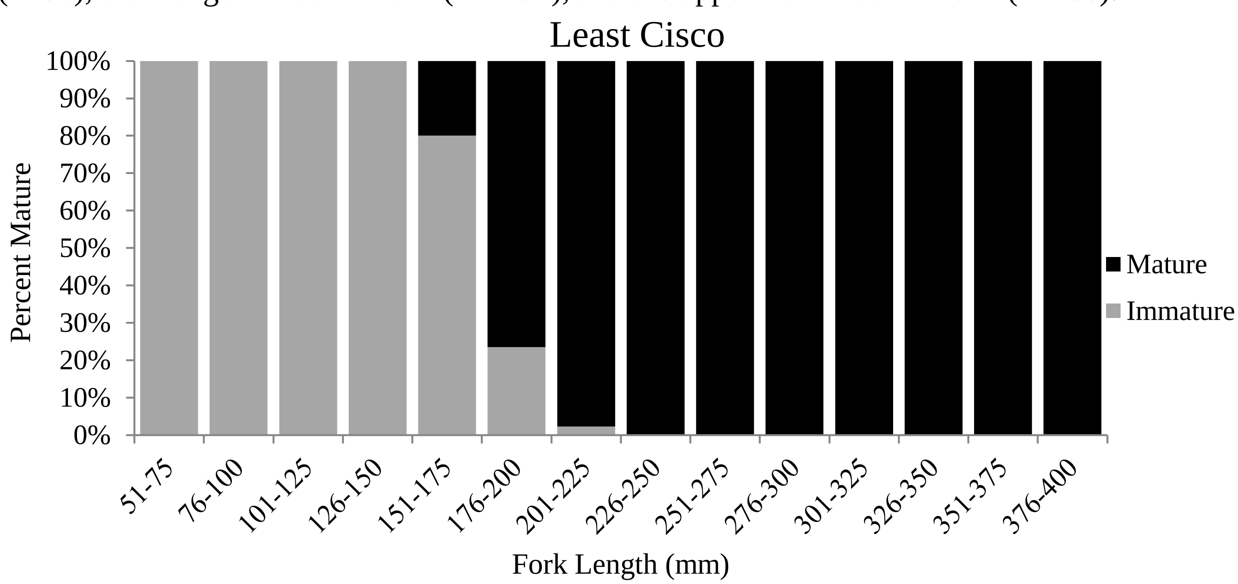


Figure 46. Percent maturity by size class for least cisco captured in the Ivisaruk River in 2010 (n=50), the Kungok River in 2011 (n = 191), and the upper Kuk River in 2012 (n = 58).

Length-Weight

Arctic grayling retained for length-weight analysis ranged from 91 to 383 mm (Figure 47). Weights were calculated at three comparison lengths (150, 225 and 350 mm) to evaluate differences among areas (Table 10). Arctic grayling from the Ivisaruk and Kuk rivers compared to fish caught in the Teshekpuk Lake area in 2004 had greater weights at 150 mm and 225 mm, but smaller at the larger size class (Table 10; Appendix 13).

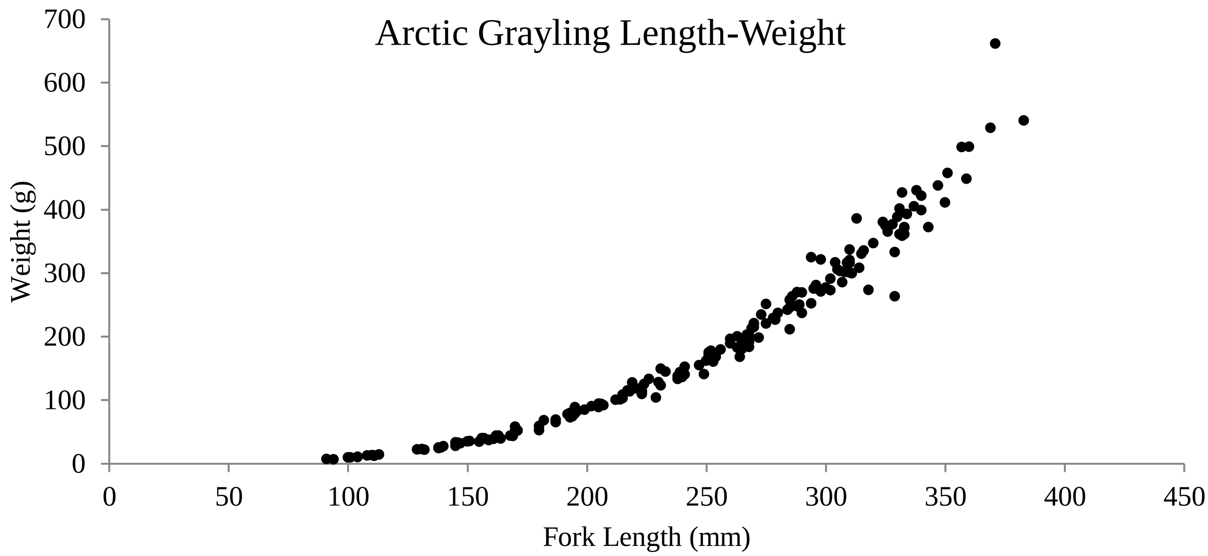


Figure 47. Length-weight relationship for Arctic grayling captured in the Ivisaruk River in 2010 (n = 37), Kungok River in 2011 (n = 1), and upper Kuk River in 2012 (n = 150).

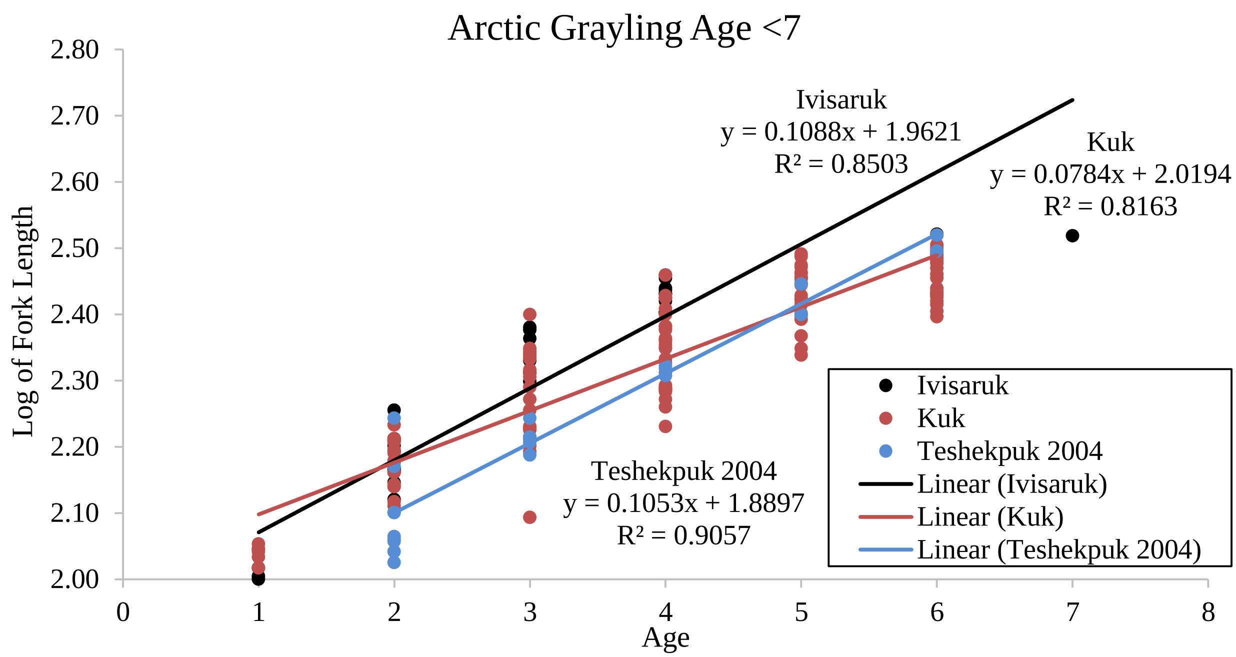
Table 10. Weights at given lengths for Arctic grayling caught in the Ivisaruk and Kuk rivers and Teshekpuk Lake 2004.

Area	Sample Group	Length-Weight Relationship Slope	Length-Weight Relationship Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 150	225	350
Ivisaruk/Kuk								
	All fish	3.079	-5.174	0.99	200	33.6	117.0	456.2
Teshekpuk Lake 2004[1]								
	All fish	3.209	-5.499	0.99	31	30.5	111.9	462.3

[1] Moulton et al. 2007

Age-Length

Arctic grayling retained for analysis ranged in age from 1 to 15 years. Arctic grayling <7 years of age retained from the Ivisaruk River had higher growth rates than fish from the Kuk River and Teshekpuk Lake 2004 (Figure 48; Appendix 14). For Arctic grayling age 7+, no differences in growth were detected between the Kuk and Ivisaruk Rivers so those data were combined. When compared to Teshekpuk Lake 2004 data, Arctic grayling age 7+ from the Kuk and Ivisaruk rivers had lower growth rates (Figure 48; Appendix 14).



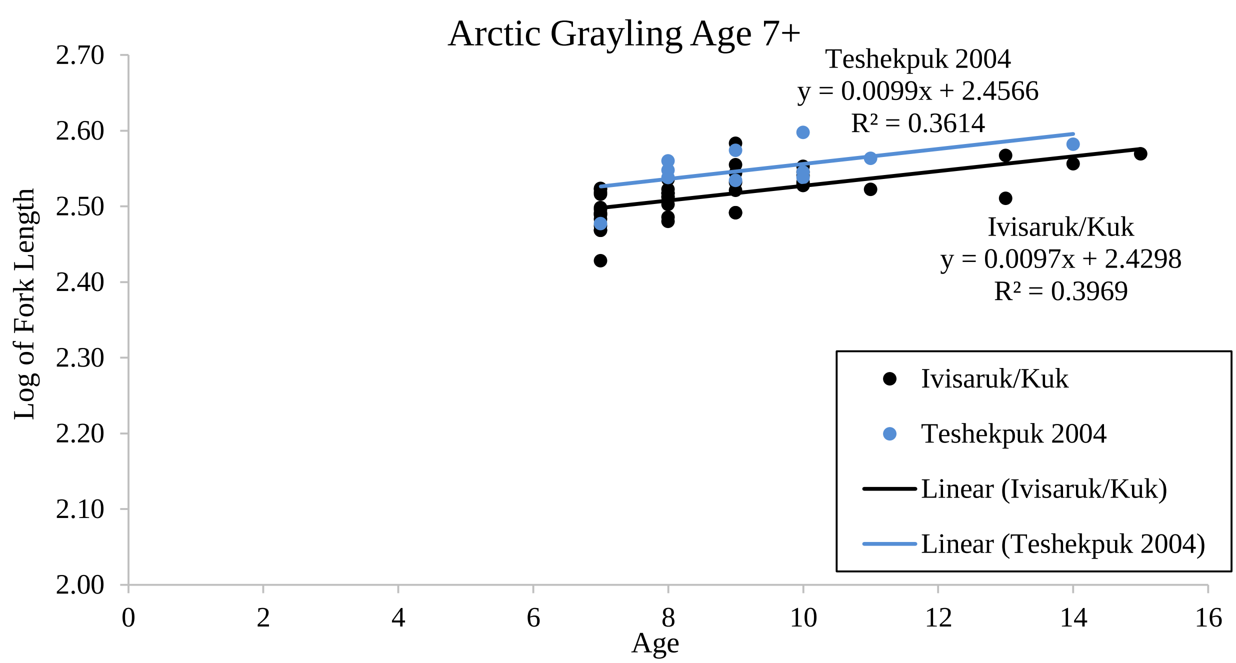


Figure 48. Age-log fork length relationships for Arctic grayling ages <7 (top) and 7+ (bottom) from the Ivisaruk River 2010, Kuk River 2012, and Teshekpuk Lake 2004 (Moulton et al. 2007).

Maturity

The reproductive characteristics for Arctic grayling are listed in Appendix 15. Male Arctic grayling began maturing at age 3 while female Arctic grayling began maturing at age 4 (Appendix 15). By age 5, 87% of all Arctic grayling were sexually mature and by age 7, 100% were sexually mature (Figure 49). All Arctic grayling less than 200 mm were sexually immature while 100% of Arctic grayling greater than 270 mm were sexually mature (Figure 50).

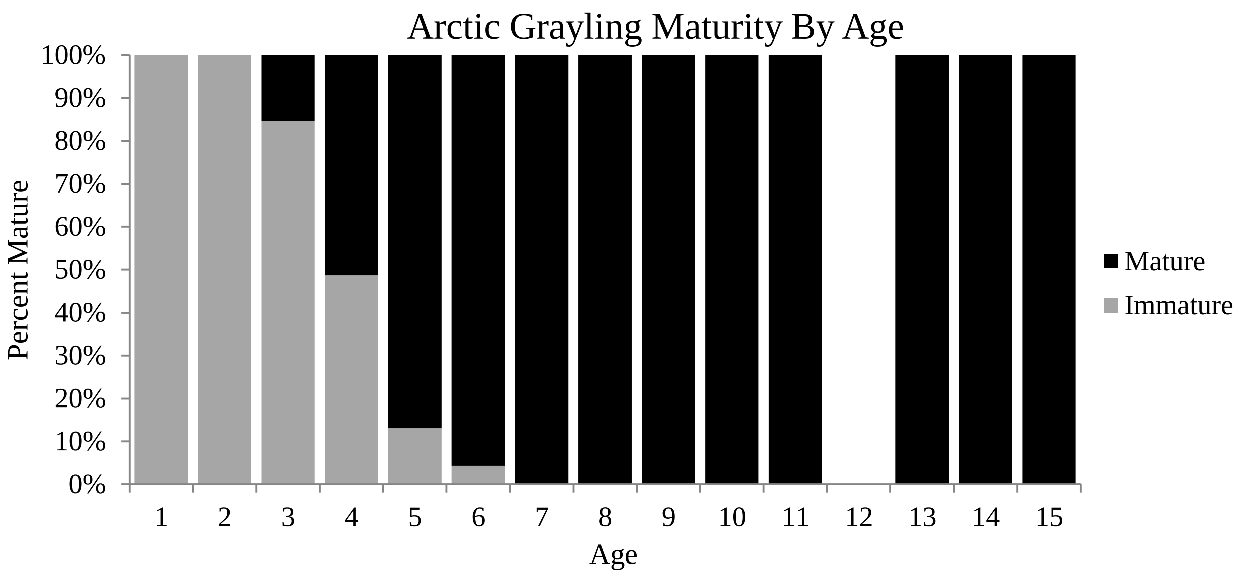


Figure 49. Percent maturity by age class for Arctic grayling captured in the Ivisaruk River in 2010 (n=37), the Kungok River in 2011 (n = 1), and the upper Kuk River in 2012 (n = 150).

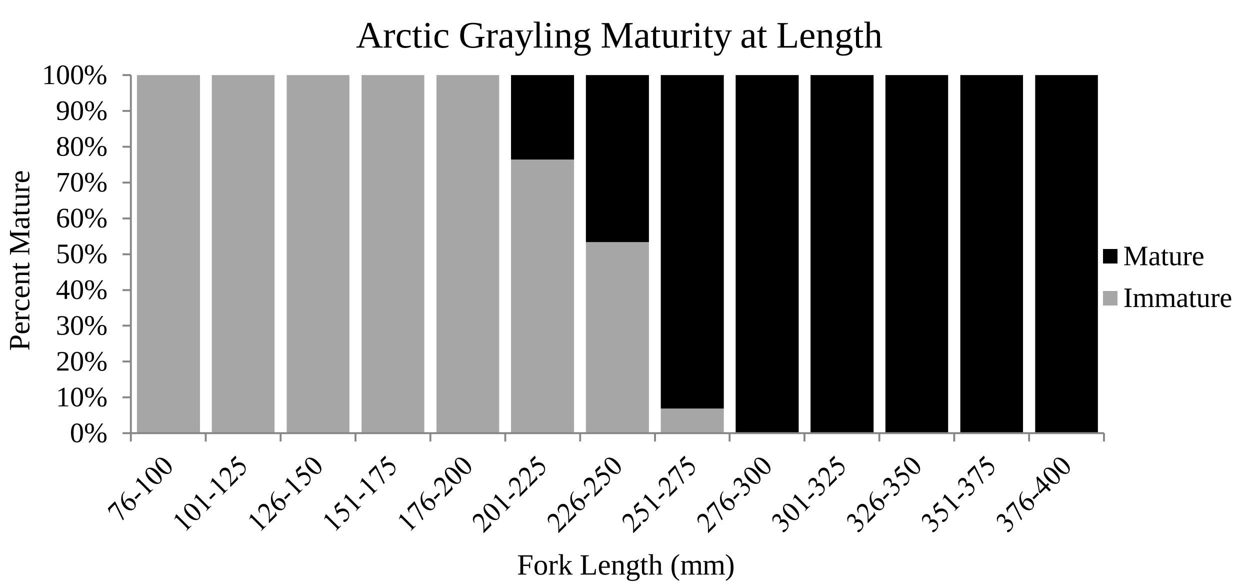


Figure 50. Percent maturity by size class for Arctic grayling captured in the Ivisaruk River in 2010 (n=37), the Kungok River in 2011 (n = 1), and the upper Kuk River in 2012 (n = 150).

Burbot

Length-Weight

Burbot retained for length-weight analysis ranged from 305 to 875 mm (Figure 51). Weights were calculated at three comparison lengths (300, 600 and 900 mm) to evaluate differences among areas (Table 11). Length-weight relationships of burbot from the Kuk River are compared to burbot populations in other rivers in Alaska and Alberta, Canada in Table 11; statistical comparisons were not possible. In general, burbot from the Kuk River had lower weights at a given length, particularly at the larger size classes than most of the other rivers.

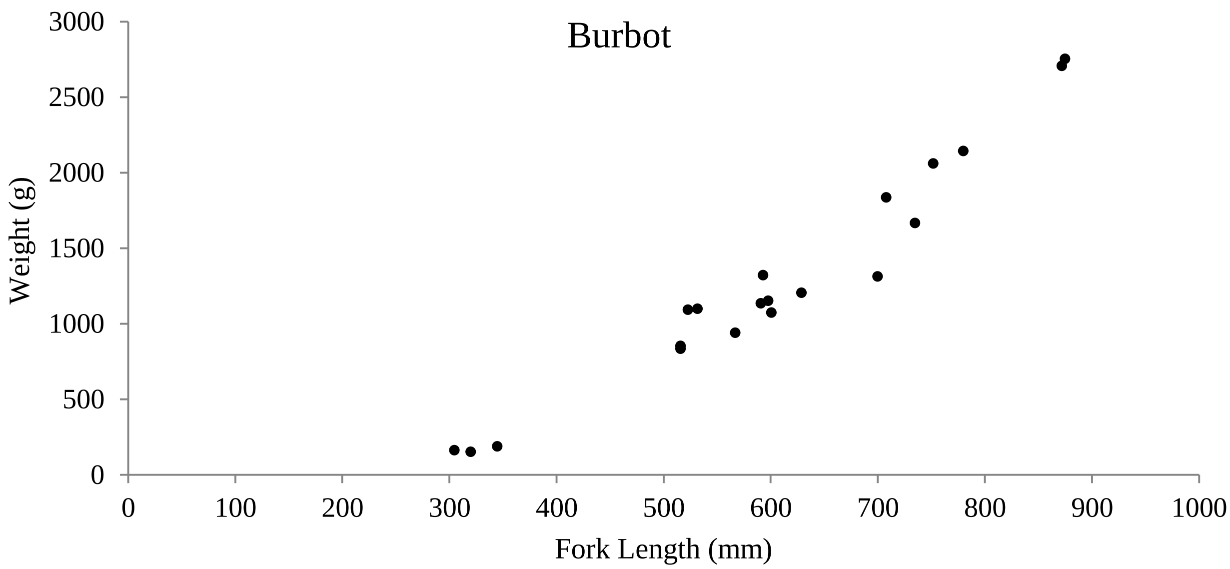


Figure 51. Length weight relationship for burbot captured in the Kuk River in 2012 (n = 20).

Table 11. Weights at given lengths for burbot caught in the Kuk River 2012 and other rivers in Alaska and Alberta, Canada.

Area	Sample Group	Length-Weight Relationship Slope	Length-Weight Relationship Intercept	r^2	Sample Size	Weight (g) at Comparison Total Length (mm) 300	600	900
Kuk River								
	All	2.766	-4.639	0.95	20	163.2	1,110	3,407
Tanana River, Alaska[1]								
	Unknown	2.993	-5.197	0.98	590	167.8	1,312	4,416
Smoky River, Alberta[1]								
	Unknown	3.109	-5.553	0.98	55	140.7	1,214	4,282
Peace River, Alberta[1]								
	Unknown	3.205	-5.828	0.98	152	129.2	1,191	4,368
Athabasca, Alberta[1]								
	Unknown	3.201	-5.835	0.99	87	124.2	1,142	4,183
Wapiti River, Alberta[1]								
	Unknown	2.773	-4.644	0.98	15	155.6	1,063	3,274
Lesser Slave River, Alberta[1]								
	Unknown	2.651	-4.355	0.98	20	162.8	1,023	2,997

[1] Fisher et al. 1996

Age-Length

Burbot retained for analysis ranged in age from 3 to 22 years. One fish was removed (22 year old) from age-length analysis (Figure 52).

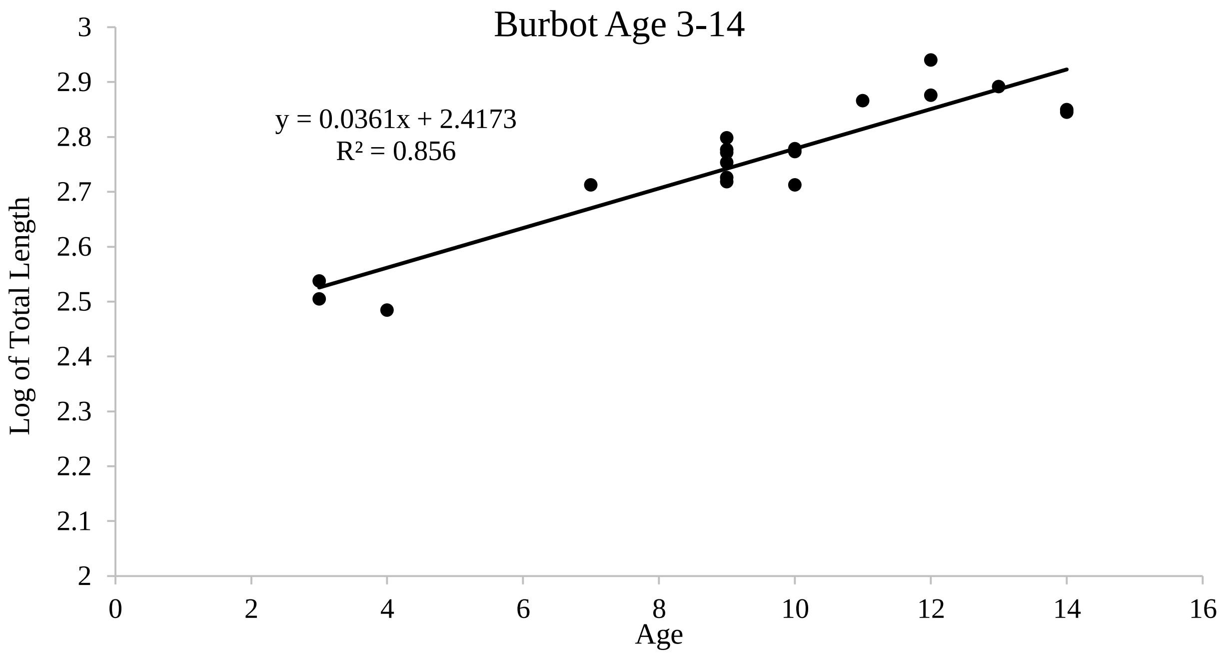


Figure 52. Age-log total length relationships for burbot ages 3-14 for burbot captured in the upper Kuk River 2012 (n=19).

Pacific Herring

Length-Weight

Pacific herring retained for analysis ranged from 111 to 277 mm (Figure 53). Weights were calculated at three comparison lengths (150, 225 and 275 mm) to evaluate differences among groups and areas (Table 12). Ripe females had the greatest weight for a given length compared to ripe males or post-spawned fish (Table 12; Appendix 13). Post spawned fish had the smallest predicted weight for a given length.

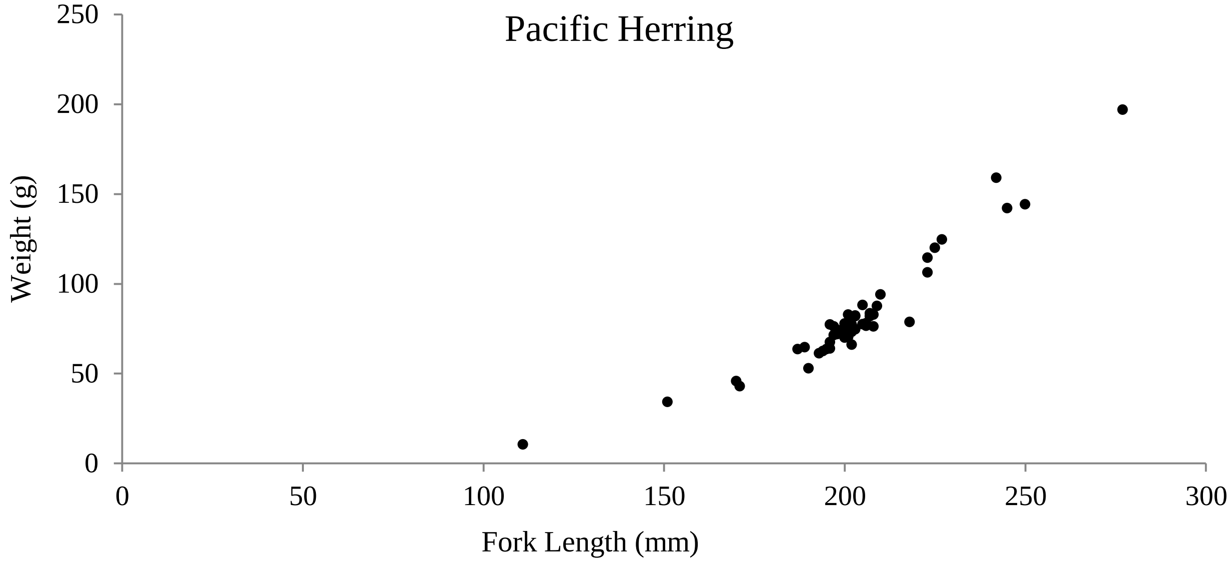


Figure 53. Length weight relationship for Pacific herring captured in the Kungok River in 2011 (n = 51).

Table 12. Weights at given lengths for Pacific herring (ripe males, ripe females, and pre-spawned male/female fish) caught in the Kungok River 2011.

Area	Sample Group	Length-Weight Relationship Slope	Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 150	225	275
Kungok River								
	Ripe Females	3.226	-5.524	0.97	11	31.3	115.9	221.5
	Ripe Males	2.981	-4.982	0.97	13	31.9	107.1	194.8
	Post-spawned Male/Female	2.925	-4.886	0.87	22	30.1	98.7	177.4

Age-Length

Pacific herring retained for analysis ranged in age from 2 to 7 years (Figure 54).

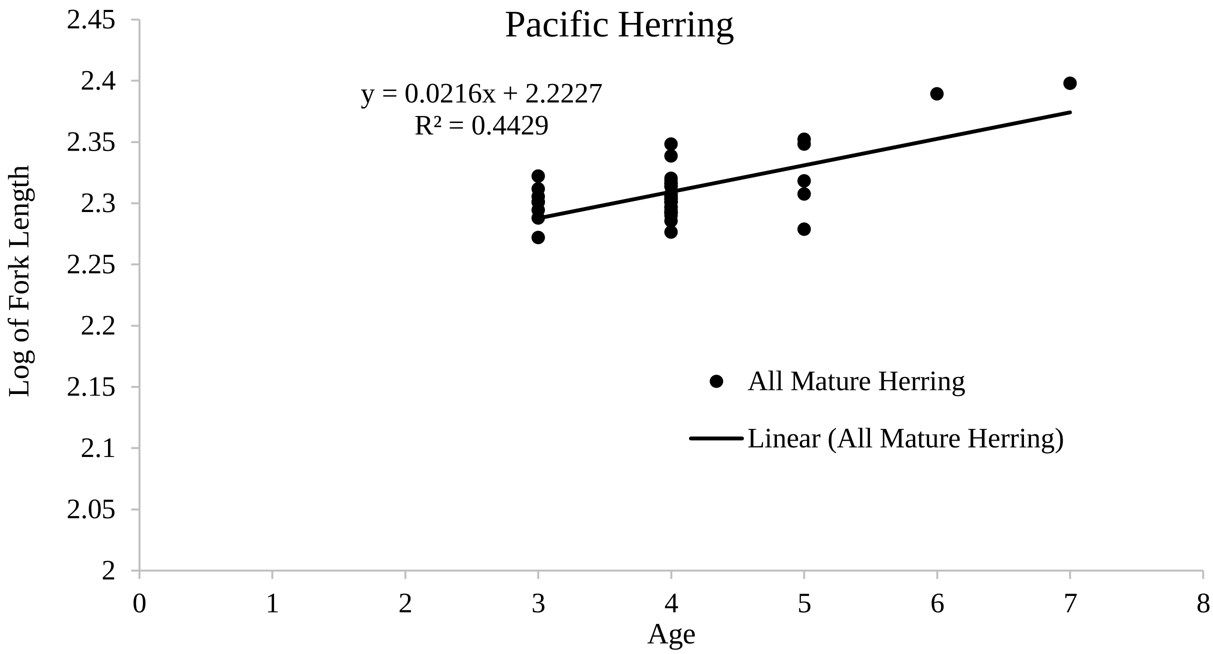


Figure 54. Age-log fork length for mature Pacific herring captured in the Kungok River in 2011 (n=41).

Rainbow Smelt

Length-weight

Rainbow smelt retained for analysis ranged from 84 to 270 mm (Figure 55). Weights were calculated at three comparison lengths (100, 175 and 250 mm) to evaluate differences among groups and areas (Table 13). Length-weight differences were analyzed through analysis of covariance among groups of rainbow smelt caught in the Kungok Arm, the Chipp River (June 2008) and Elson Lagoon (July/August 2010). As with Kungok Arm samples, rainbow smelt from the Chipp River were obtained during the spawning season, thus groups were stratified and tested based on sex and maturity stage (i.e., immature, ripe, or post-spawning). Statistical tests revealed no differences between immature fish and ripe males, thus these categories were pooled for further testing. Ripe females tested separate from other categories, while post-spawning females and males were statistically similar and were pooled.

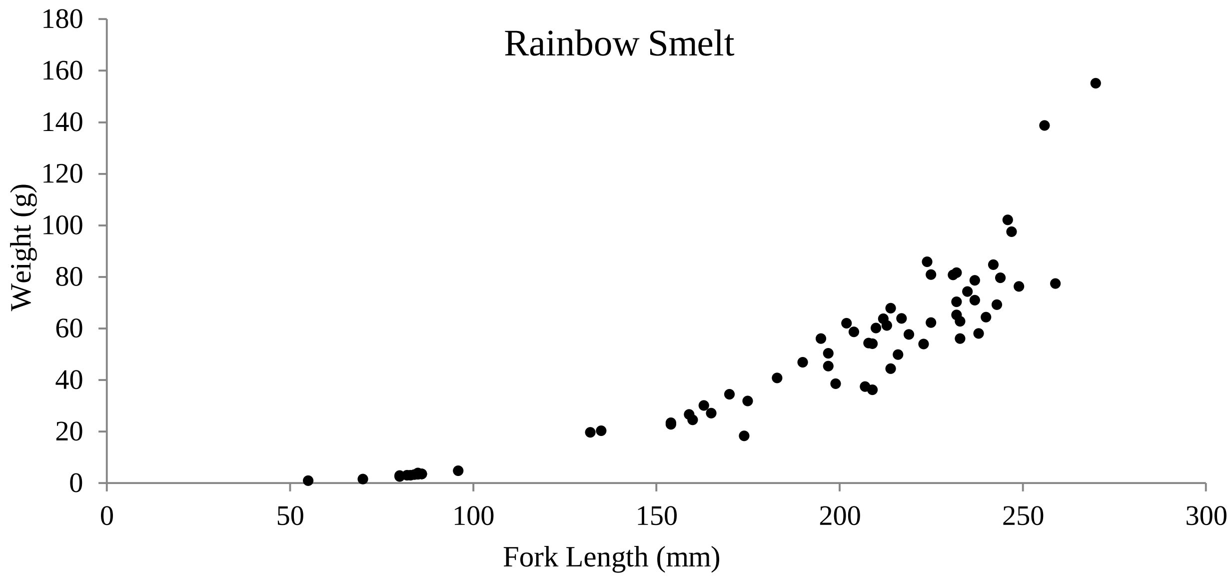


Figure 55. Length-weight relationship for rainbow smelt captured in the Kungok River in 2011 (n = 42) and upper Kuk River in 2012 (n = 15).

Table 13. Weights at given lengths for rainbow smelt caught in the Kungok River 2011 and prior studies in the Chipp River 2008 and Elson Lagoon 2010.

		Length-Weight Relationship				Weight (g) at Comparison Fork Length (mm)		
Area	Sample Group	Slope	Intercept	r^2	Sample Size	100	175	250
Kungok River								
	Immatures and ripe males	3.290	-5.831	0.99	27	5.6	35.3	114.0
	Ripe females	2.366	-3.718	0.94	5	-	38.8	90.3
	Post-spawned Male/Female	2.735	-4.685	0.86	21	-	28.2	74.9
Chipp River 2008[1]								
	Immatures and ripe males	3.369	-5.980	0.99	21	5.7	37.7	125.5
	Ripe females	2.748	-4.459	0.781	6	-	50.6	134.9
	Post-spawned male/female	3.099	-5.374	0.90	34	-	37.9	114.4
Elson Lagoon 2010[2]								
	All groups	3.492	-6.245	0.99	27	5.5	38.7	134.6

[1] Moulton et al. 2011
[2] Morris et al. 2012

Age-Length

Rainbow smelt retained for analysis ranged in age from 1 to 16 years (Figure 56). The majority of growth occurs from ages 1 to 5 years, after which growth slows.

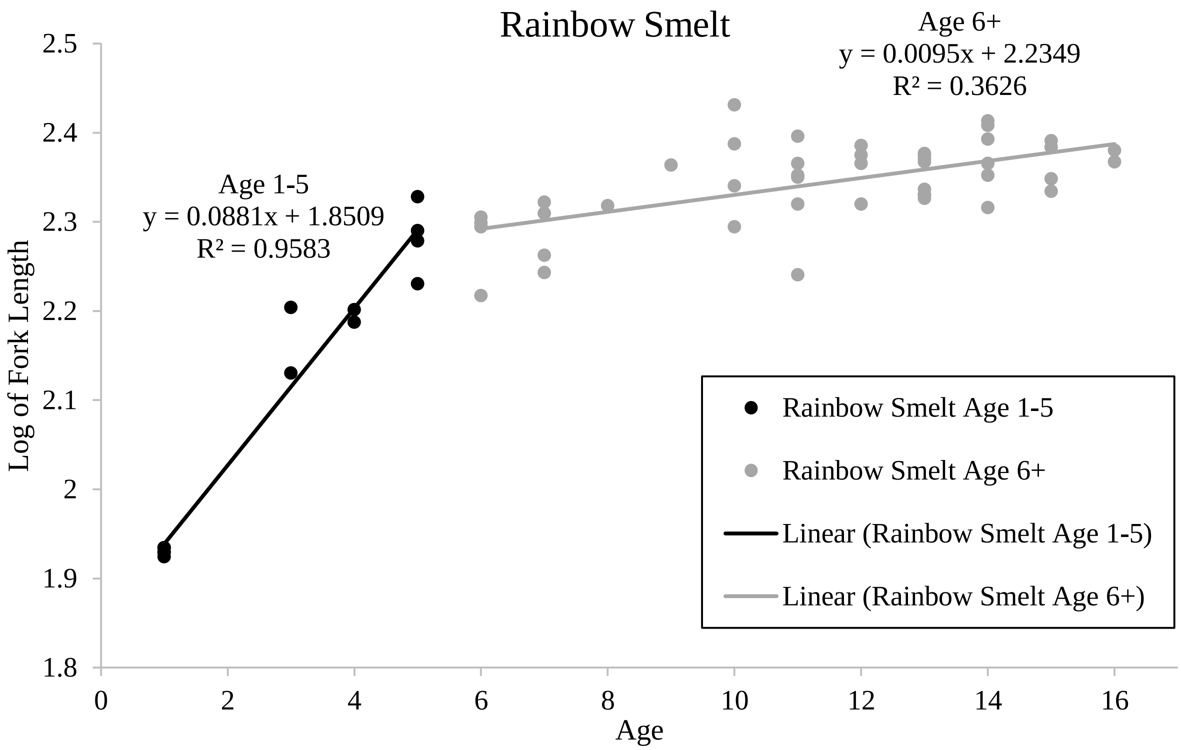


Figure 56. Age-log fork length relationships for rainbow smelt for ages 1-5 and 6+ captured in the Kungok River 2011 and upper Kuk River 2012.

Maturity

Age of youngest sexually mature for rainbow smelt was 3 years, when 50% were mature (Figure 57). However, the sample size in the 3 and 4 year old age classes was low (n=2 for each) thus the percent mature may not be representative of these ages. The low sample sizes of rainbow smelt between ages 2 and 4 during the spawning period suggests that most fish probably do not mature until age 5 and were not available for capture.

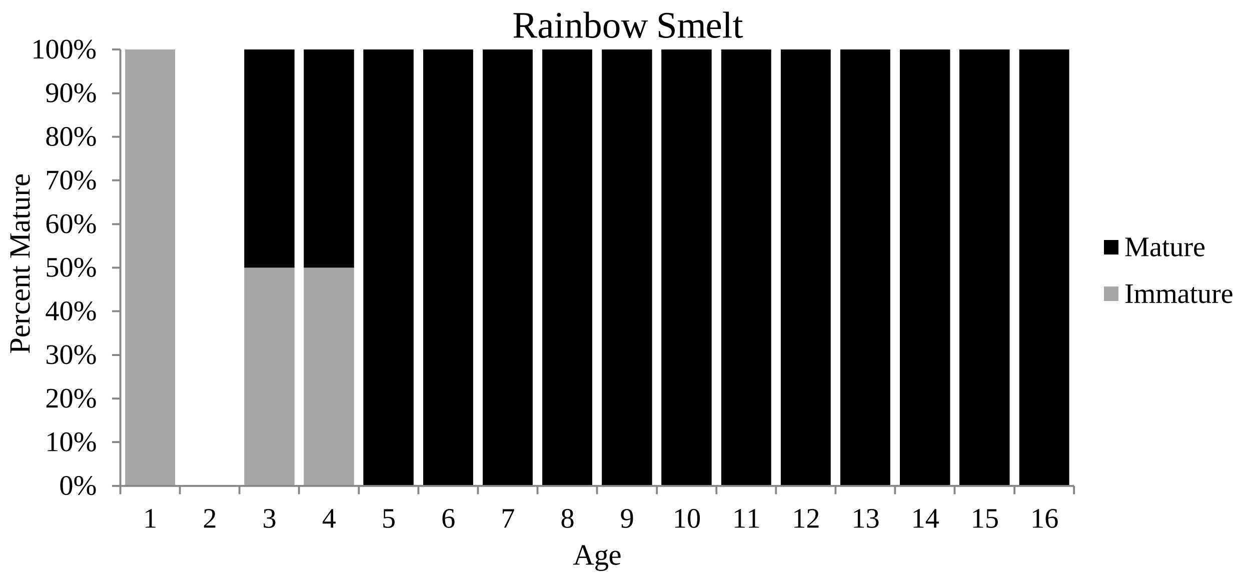


Figure 57. Percent maturity by age class for rainbow smelt captured in the Kungok River in 2011 (n = 42) and the upper Kuk River in 2012 (n = 15).

A similar pattern is seen in the percent by size class for rainbow smelt, likely as a result of low sample size in certain size classes (Figure 58). While these results suggests rainbow smelt are variable in the size at which they become sexually mature, with 100% of fish >160 mm being sexually mature, it is likely most rainbow smelt smaller than 160 mm simply were not available for capture during sampling of the spawning population of fish because most are immature.

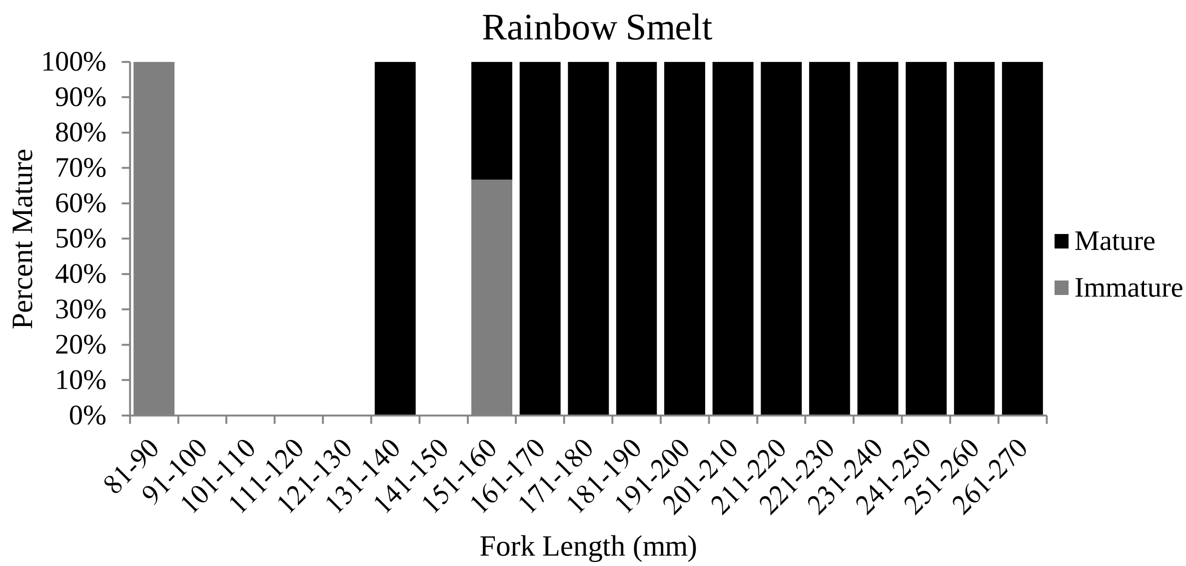


Figure 58. Percent maturity by size class for rainbow smelt captured in the Kungok River in 2011 (n = 42) and the upper Kuk River in 2012 (n = 15).

Conclusions

Species Composition of Wainwright Inlet Drainages

The freshwater and anadromous fish assemblage associated with Wainwright Inlet is relatively less diverse when compared to systems farther north and east along the North Slope.

- As with many other systems, least cisco predominated, however other common whitefishes, such as broad whitefish and humpback whitefish, were absent.
- Bering cisco were present, but in low abundance.
- Chum salmon and pink salmon spawning areas were identified in the Kungok and upper Kuk rivers.
- Arctic grayling had a patchy distribution around the inlet, with distribution apparently limited by available overwintering habitat.
- Burbot in the upper Kuk River represent a significant subsistence resource, being relatively abundant and accessible
- Mature post-spawning rainbow smelt were particularly abundant in Kungok Arm
- A probable spawning site for Pacific herring was identified in Kungok Arm.

Dominant Species

Least Cisco

On the North Slope, least cisco occur as freshwater and anadromous populations. Anadromous populations, such as the one found in Wainwright Inlet, migrate along the coast during summer to feed on marine and estuarine invertebrates and return to rivers to spend the winter. Least cisco in Wainwright Inlet were abundant during both sampling periods and across all areas of the Kungok Arm and the Kuk River. Least cisco were a dominant component of the fish catch during 2011 sampling in the Kungok Arm, being present in over 95% of the net checks. In June/July, least cisco were primarily large fish, with 89% of those caught exceeding the tagging threshold of 180 mm. In contrast, only 42% exceeded 180 mm in August, when cohorts of smaller least cisco, representing ages 0 and 1, were present. It appears as though many of the larger least cisco left the Kungok Arm between the two sampling periods.

Least cisco in the Kuk River study area were abundant in the Kuk and lower Avalik rivers during the June/July sampling, but were not abundant elsewhere, and were scarce in August. Least cisco were a dominant component of the fish catch in 2012, being 59% of the fyke net catch and present in 49% of the net checks. In June/July, least cisco were primarily age 1 and 2 fish, with 98% of those caught below the tagging threshold of 180 mm. In contrast, 24% exceeded 180 mm in August, when cohorts of smaller least cisco, representing ages 0 and 1, were less abundant. Catches of large least cisco were similar during both sampling periods. It appears many of the small least cisco left the Kuk River area between the two sampling periods.

Larger least cisco tend to move rapidly from overwintering areas into summer feeding areas along the coast, with smaller fish following later (Fechhelm et al. 1994). Sampling near an overwintering area should detect younger-aged fish early in the season. In the Kungok Arm, the occurrence of large least cisco early in the season, with smaller fish arriving later may indicate that least cisco do not overwinter in the Kungok Arm drainages. The high abundance of small least cisco early in the season in the in the Kuk and lower Avalik rivers suggests that least cisco overwinter in this region of the inlet.

Least cisco in Wainwright Inlet drainages generally exhibited higher weights per length than populations further north, however, they were shorter at a given age than populations to the north. This pattern suggests a different morphology associated with this population.

Arctic Grayling

During 2010 sampling in the Ivisaruk Arm, Arctic grayling composed 29% of the total catch and mature fish were a large part of the catch. In contrast, the few Arctic grayling caught in the Kungok Arm in 2011 were mostly juveniles, with 19 individuals averaging 142 mm (range: 98–197 mm). One mature fish was caught (276 mm). In 2010, the catch rate of Arctic grayling in fyke nets in the Ivisaruk Arm was 12.3 fish per day, compared to 0.19 fish per day in 2011 Kungok Arm fyke nets. During 2012 sampling in the upper Kuk drainages, Arctic grayling were abundant throughout the Kuk River study area during the June/July sampling, but were relatively scarce in August suggesting they had moved upstream in smaller tributaries to feed. Arctic grayling were a dominant component of the fish catch in 2012, being 32% of the fyke net catch and present in 90% of the net checks.

The catch patterns of Arctic grayling indicate that both the Ivisaruk and Kuk rivers provide wintering areas capable of supporting Arctic grayling, while the Kungok Arm does not.

Burbot

Burbot were fourth in abundance in the Kuk River study area, which is unusually high for this predatory fish; however, they were less than 1% of the catch. Highest catches were in the Avalik River and lower Ketik River.

Burbot caught in 2012 covered a wide range of sizes, from age 1 to large, mature fish, with similar size ranges during both sampling periods. Subjective comparison of burbot from the Kuk River study area to those from the Chipp River and Teshekpuk Lake region indicated differences among all three groups. Burbot from the Kuk River study area weighed considerably less at given lengths than burbot from either the Chipp River or Teshekpuk Lake region.

Relocations of radiotagged burbot revealed extensive movements in the Avalik River, indicating that the Avalik River is important for burbot that reside in the upper Kuk River. Movement patterns suggest that the upper Avalik River provides overwintering and likely spawning habitat for burbot since they spawn under the ice in late winter (Scott and Crossman 1973). An unnamed tributary entering from the south likely provides important habitat as well since multiple burbot made extensive movements up the tributary at various times. Burbot exhibited site fidelity for feeding locations where specific tributaries flow into the Avalik River. Based on these telemetry results and fish capture data, some burbot utilize the Kaolak River in the summer, but likely not for overwintering and feeding. The Avalik River and its small tributaries provide all necessary habitats to support the local burbot population and likely provides the majority of viable freshwater fish overwintering habitat associated with the Wainwright Inlet.

Rainbow Smelt

Rainbow smelt are an important subsistence resource for the village of Wainwright, located at the mouth of Wainwright Inlet, yet little is known of their local distribution and life history. During 2011 sampling in the Kungok Arm, rainbow smelt were fourth in abundance in fyke net catches, and were broadly distributed in the estuarine portion of the study area. In 2012, only 19 were caught in the Kuk River and associated drainages, with only 14 caught during June, when spawning and/or post-spawning fish would be present. Catches were scattered spatially and temporally with no apparent concentrations of fish. Spawning by rainbow smelt is typically in freshwater during spring, thus it is likely that the Kungok Arm is used more heavily for spawning rainbow smelt than is the Kuk River area. Other spawning areas for rainbow smelt are likely to be scattered around the inlet at various drainages that have not yet been sampled during spring, such as the Ivisaruk, Apikuguruak and Alataktok rivers and Omikmak Creek.

Pacific Herring

Pre- and post-spawning Pacific herring were encountered in the June/July 2011 sampling in Kungok Arm, primarily at Station KN-11. We believe this is the first documentation of spawning Pacific herring in Wainwright Inlet, and may be the northern-most spawning population in Alaska.

Management Implications

The drainages of Wainwright Inlet and Peard Bay represented major data gaps in our understanding of fish use of large sized North Slope drainages. This study has filled an important information gap for these drainages by identifying fish species using the waters in these drainages, identifying habitats used for important life history stages, and providing baseline fish population structure data which will be important for use in future comparisons. Through sampling and radiotelemetry work conducted in this study, important overwintering, feeding, and spawning habitats for burbot in the Avalik River were identified. The upper Kuk River also provides important habitat for Arctic grayling and least cisco populations. Additionally, new spawning habitats for rainbow smelt, Pacific herring, chum salmon, and pink salmon were identified in the drainages of Wainwright Inlet. Results from the Kugrua River suggest there is limited fresh water to support fish species dependent on freshwater for parts of their annual life cycle. No freshwater fish populations were evident in sampling. However, tributaries to Peard Bay, including the Kugrua River provide spawning habitat for anadromous species such as rainbow smelt, chum salmon, and pink salmon. The new and expanded fish distribution data will be prepared and submitted for inclusion in the Alaska Department of Fish and Game Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes which allows for statutory protection of important anadromous fish habitats through the Anadromous Fish Act and Fish Habitat Permitting.

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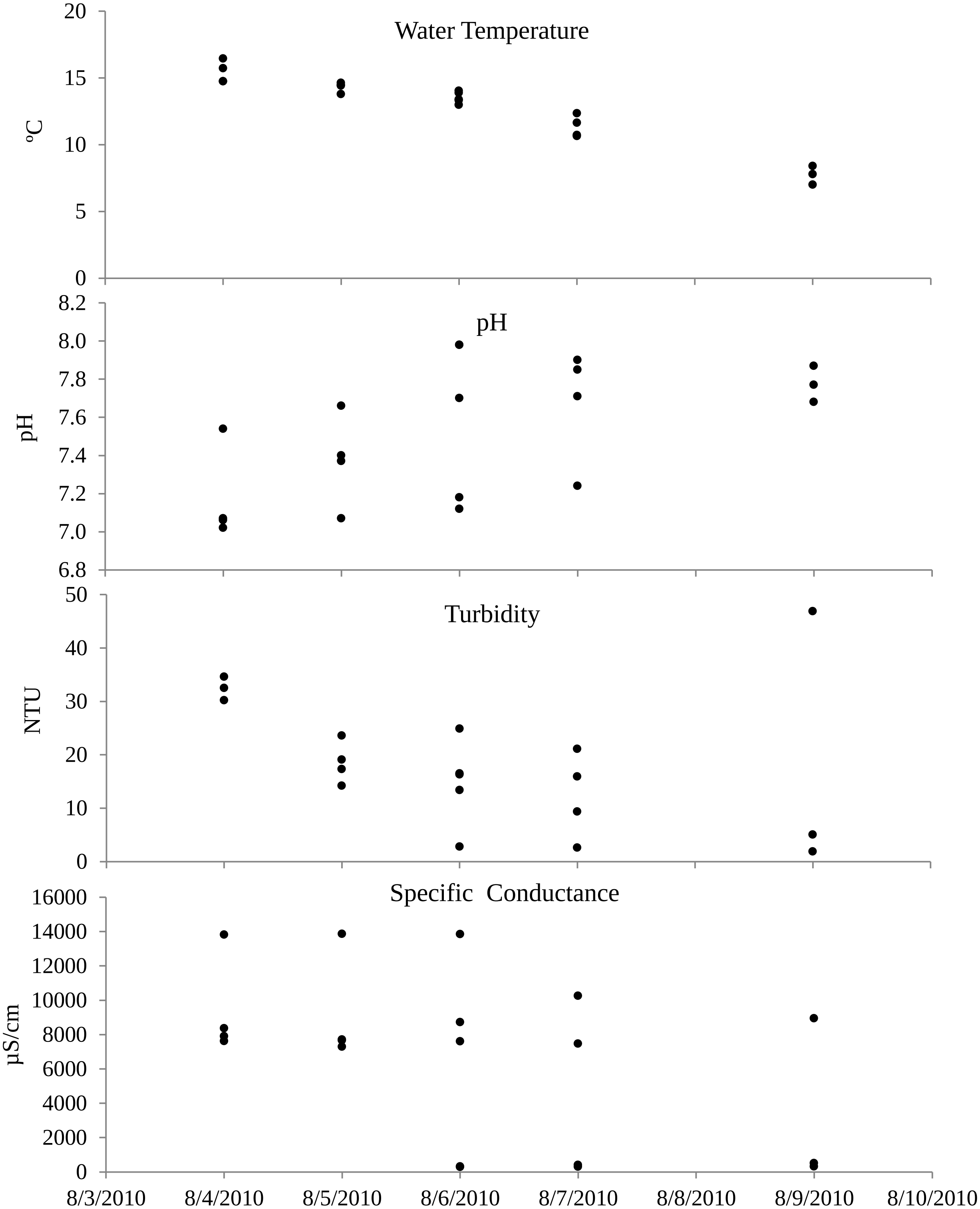
Appendix 1. Fish sampling locations (WGS84) in the Ivisaruk River and total hours sampled at each site with fyke nets and set gillnets, 2010.

			August 4–9 Total Effort (hours)	
Station	Latitude	Longitude	Fyke Net	Set Gillnet
IV-01	70.23218	-160.35334	67.8	-
IV-02	70.52791	-159.20473	73.9	4.8
IV-03	70.51787	-159.22963	2.5	-
IV-04	70.51445	-159.25299	22.1	2.6
IV-05	70.51034	-159.26529	123.7	1.7
IV-06	70.51095	-159.26566	38.6	-

Appendix 2. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the Ivisaruk River drainage, August 2010.



Appendix 3. Fish and invertebrate sampling locations (WGS84) in the Kungok River and total hours sampled at each site with fyke nets, set gillnets, hoop nets, and seine nets in 2011.

				June 27–July 9					Aug. 4–13		
				Total Effort (hours)				Invert Sampling	Total Effort (hours)		Invert Sampling
Region	Station	Latitude	Longitude	Fyke Net	Set Gillnet	Hoop Net	Seine Net		Fyke Net	Set Gillnet	
Upper	KN-01	70.54342	-159.14265	71.2	-	-	-	++	44.3	-	++
Arm	KN-02	70.52791	-159.20473	-	-	-	-	-	-	3.8	-
	KN-03	70.51787	-159.22963	69.5	-	-	-	-	-	-	-
	KN-04	70.51445	-159.25299	-	2.1	-	-	++	-	-	-
	KN-05	70.51034	-159.26529	70.4	-	-	-	-	-	-	-
	KN-06	70.51095	-159.26566	-	-	-	-	-	48.0	-	-
	KN-07	70.51022	-159.28400	45.5	2.6	-	-	++	-	-	-
	KN-08	70.5126	-159.28815	-	-	-	-	-	-	6.6	-
	KN-09	70.51685	-159.29059	45.5	-	-	-	-	190.2	-	-
	KN-10	70.51528	-159.33925	-	-	25.6	-	-	-	-	-
Middle	KN-11	70.50753	-159.34955	208.2	1.7	-	-	++	214.4	-	-
Arm	KN-12	70.51199	-159.35399	21.8	-	-	-	-	-	-	-
	KN-13	70.50657	-159.38878	70.2	-	-	1.4	-	241.1	-	-
	KN-14	70.50711	-159.38979	-	7.6	-	-	-	-	-	-
	KN-15	70.49617	-159.39586	-	-	-	-	-	-	203.1	-
	KN-16	70.49596	-159.40207	-	3.0	-	-	-	-	46.9	-
	KN-17	70.49703	-159.40710	23.9	-	-	-	-	44.6	59.7	-
	KN-18	70.49671	-159.40804	72.5	-	-	-	-	26.4	-	-
	KN-19	70.4446	-159.42337	46.0	-	-	-	-	-	2.8	++
	KN-20	70.46085	-159.42337	23.1	-	-	-	-	-	-	-
	KN-21	70.46749	-159.42461	47.0	-	-	-	-	-	-	-
	KN-22	70.50938	-159.45271	42.3	-	-	-	-	-	-	-
Outer	KN-23	70.50942	-159.46421	93.3	2.7	-	-	++	215.5	-	++
Arm	KN-24	70.50493	-159.48008	70.1	5.0	-	-	++	-	-	-
	KN-25	70.52773	-159.52301	42.7	-	-	-	-	-	-	-
	KN-26	70.51935	-159.51553	47.3	-	-	-	-	-	2.4	-
	KN-27	70.51436	-159.53506	-	-	-	-	-	95.8	-	-
	KN-28	70.51154	-159.53057	67.9	-	-	-	-	94.7	-	++
	KN-29	70.50195	-159.56770	25.8	-	-	-	-	-	-	-
	KN-30	70.50575	-159.59670	46.6	-	-	-	-	-	-	-
	KN-31	70.51386	-159.60966	45.8	-	-	-	-	-	-	-
	KN-32	70.48112	-159.58371	21.8	-	-	-	-	-	-	-
	KN-33	70.45707	-159.66546	44.6	-	-	-	-	-	-	-
	KN-34	70.4576	-159.67601	16.9	-	-	-	++	-	-	-

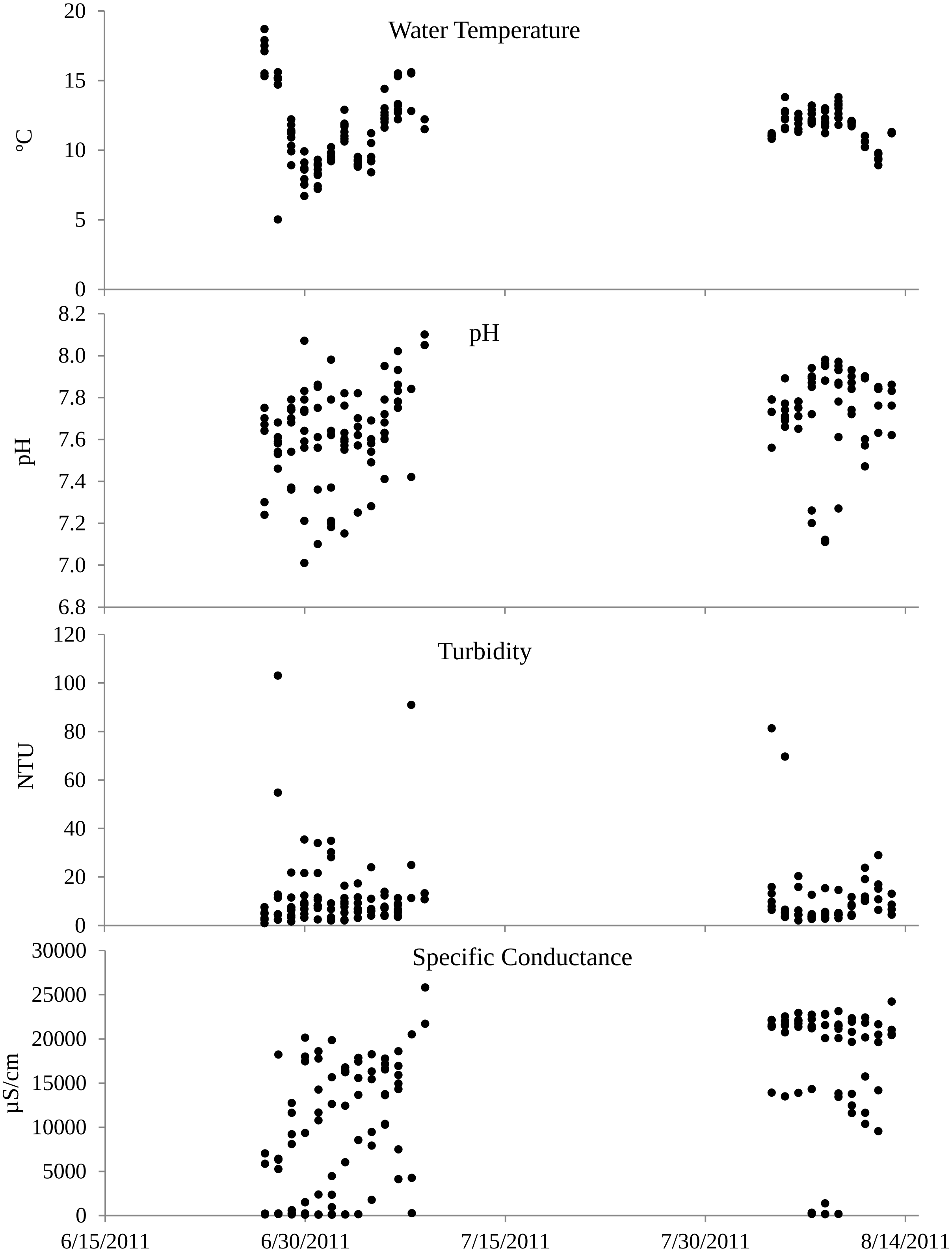
Appendix 4. Mean CPUE (#fish/24 hrs.) of least cisco (LCIS), Arctic flounder (ARFL), fourhorn sculpin (FHCS), rainbow smelt (RBSM), ninespine stickleback (NSSB), Pacific herring (HERR), threespine stickleback (TSSB), and pink salmon (PINK) in fyke net sample sites in the Kungok River, 2011. The three geographic regions are identified under habitat type (Upper Arm (UA), Middle Arm (MA), and Outer Arm (OA)).

	Station #	Habitat Type	LCIS	ARFL	FHSC	RBSM	NSSB	HERR	TSSB	PINK
June/	KN-01	UA-Main channel	7.89	0.32	3.96	-	2.77	-	0.36	-
July	KN-03	UA-Main channel	26.18	0.34	3.07	-	1.01	-	-	-
2011	KN-05	UA-Tributary	9.92	-	3.02	-	3.05	-	-	-
	KN-07	UA-Bay	426.00	0.52	-	0.54	-	-	-	-
	KN-09	UA-Bay	614.94	-	1.68	3.69	-	-	-	-
	KN-11	MA-Bay	241.08	25.63	28.07	6.88	-	11.07	-	-
	KN-12	MA-Bay	36.41	14.34	38.62	1.10	-	-	-	-
	KN-13	MA-Bay	355.88	7.42	4.38	9.75	-	1.15	-	-
	KN-17	MA-Bay	202.07	46.16	23.08	17.06	-	-	-	-
	KN-18	MA-Bay	57.84	8.13	7.20	8.00	-	-	-	-
	KN-19	MA-Tributary	28.90	-	-	-	0.94	-	-	-
	KN-20	MA-Tributary	1.04	-	1.04	-	1.04	-	-	-
	KN-21	MA-Tributary	15.10	0.48	2.12	-	0.96	-	-	-
	KN-22	MA-Bay	198.44	28.43	20.44	6.83	-	0.57	-	-
	KN-23	OA-Bay	7.78	61.86	28.74	6.50	-	-	-	-
	KN-24	OA-Bay	7.70	13.79	6.18	0.99	-	-	-	-
	KN-25	OA-Tributary	-	-	1.13	-	44.44	-	-	-
	KN-26	OA-Bay	135.93	34.50	9.80	0.54	-	-	-	-
	KN-28	OA-Bay	138.52	42.06	31.49	1.23	-	-	-	-
	KN-29	OA-Bay	1.86	11.14	13.94	-	-	-	-	-
	KN-30	OA-Bay	1.52	0.49	0.54	-	0.49	-	-	-
	KN-31	OA-Tributary	-	-	4.88	-	52.77	-	-	-
	KN-32	OA-Bay	2.20	1.10	1.10	-	-	-	-	-
	KN-33	OA-Bay	173.90	61.72	29.93	8.33	-	-	2.04	-
	KN-34	OA-Bay	28.37	1.42	-	-	-	-	-	-
Aug.	KN-01	UA-Main channel	24.58	0.55	12.92	-	3.22	-	4.34	2.17
2011	KN-06	UA-Bay	1.43	0.95	1.48	-	10.06	-	-	-
	KN-09	UA-Bay	73.12	1.09	10.32	1.66	2.69	-	5.51	1.07
	KN-11	MA-Bay	136.81	1.28	4.97	2.61	0.27	-	1.31	3.15
	KN-13	MA-Bay	27.09	-	1.01	-	1.99	-	-	-
	KN-17	MA-Bay	48.52	7.22	10.89	2.67	-	-	-	-
	KN-18	MA-Bay	2.73	6.37	3.64	-	-	-	-	-
	KN-23	OA-Bay	63.50	41.76	12.99	2.89	0.56	-	0.44	0.23
	KN-27	OA-Bay	30.48	4.63	9.47	-	-	-	-	-
	KN-28	OA-Bay	54.77	19.30	4.27	12.06	-	-	-	-

Appendix 5. Mean CPUE (#fish/24 hrs.) of the eight most commonly captured species at set gillnet location in the Kungok River, 2011. The three geographic regions are identified under habitat type (Upper Arm (UA), Middle Arm (MA), and Outer Arm (OA)).

	Station #	Habitat Type	Pink salmon	Least cisco	Fourhorn sculpin	Chum salmon
June/ July 2011	KN-04	UA-Main channel	-	69.68	-	-
	KN-07	UA-Bay	-	55.74	-	-
	KN-11	MA-Bay	-	57.60	-	-
	KN-14	MA-Bay	-	-	-	-
	KN-16	MA-Bay	-	31.82	7.96	-
	KN-23	OA-Bay	-	27.00	-	-
	KN-24	OA-Bay	-	14.40	-	-
Aug. 2011	KN-02	UA-Main channel	19.20	-	-	6.40
	KN-08	UA-Bay	7.29	-	-	-
	KN-15	MA-Bay	7.19	3.06	3.18	1.22
	KN-16	MA-Bay	0.51	-	1.02	-
	KN-17	MA-Bay	0.22	-	-	0.67
	KN-19	MA-Tributary	-	-	-	-
	KN-26	OA-Bay	-	49.66	-	-

Appendix 6. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the Kungok River drainage, 2011.



Appendix 7. Fish and invertebrate sampling locations (WGS84) in the Kuk River and total hours sampled at each site with fyke nets, set gillnets and hoop nets 2012 and 2014.

			June 17–July 6, 2012				July 31–August 14, 2012				June 22–June 27, 2014
			Total Effort (hours)				Total Effort (hours)				Trap Effort (hours)
Station	Latitude	Longitude	Fyke Net	Hoop Trap	Set Gillnet	Invert Sampling	Fyke Net	Hoop Trap	Set Gillnet	Invert Sampling	Fyke Net
AK-01	70.09814	-159.07907	95.3	-	-	++	248.6	-	-	++	-
AV-01	70.06316	-159.04590	71.9	-	-	-	-	-	2.0	-	-
AV-02	70.09326	-159.11676	120.9	-	-	-	-	-	-	-	52.6
AV-03	70.09324	-159.16300	-	-	-	-	-	-	-	-	46.2
AV-04	70.09238	-159.17170	90.9	69.3	-	-	-	-	-	-	20.0
AV-05	70.09713	-159.19751	68.2	-	-	-	-	-	4.3	-	-
AV-06	70.10107	-159.30165	120.0	-	-	-	77.1	-	-	-	47.1
AV-07	70.12494	-159.40108	184.4	-	0.5	++	187.7	-	-	-	97.7
AV-08	70.12482	-159.40202	45.6	-	-	-	-	-	2.0	-	-
AV-09	70.12592	-159.49426	42.2	-	3.9	++	-	-	4.0	++	-
AV-10	70.11606	-159.59890	-	-	-	-	-	-	-	-	18.0
AV-11	70.11579	-159.60815	66.9	-	46.3	-	433.3	-	1.0	++	-
AV-12	70.12104	-159.67462	116.6	94.0	-	-	-	-	-	-	24.1
KA-01	70.04272	-159.82155	117.2	-	1.0	++	311.5	-	9.1	++	24.8
KA-02	70.04461	-159.81996	-	94.7	-	-	-	172.3	-	-	-
KA-03	70.04500	-159.81435	-	-	-	-	-	-	9.6	-	-
KA-04	70.05462	-159.76819	-	-	-	-	78.5	-	-	-	-
KA-05	70.05917	-159.73595	-	77.5	-	-	-	213.8	-	-	-
KA-06	70.0666	-159.73164	-	169.9	-	-	-	214.2	-	-	-
KA-07	70.08037	-159.70772	117.5	-	0.8	++	182.0	-	-	++	-
KE-01	70.08434	-159.55789	111.0	-	-	-	24.3	-	4.0	-	-
KE-02	70.09387	-159.55278	133.4	-	-	-	-	-	-	-	-
KE-03	70.09782	-159.58678	118.7	-	-	-	-	-	-	-	-
KE-04	70.10747	-159.60481	119.3	-	-	-	-	-	-	-	-
KE-05	70.10826	-159.60114	-	-	-	-	66.9	-	-	-	69.8
KK-01	70.17096	-159.73309	72.6	-	1.9	++	95.3	-	-	++	-
KT-01	70.15701	-159.74318	-	-	-	-	93.8	-	-	++	-
KT-02	70.15957	-159.72835	42.2	-	1.1	++	-	-	-	-	-

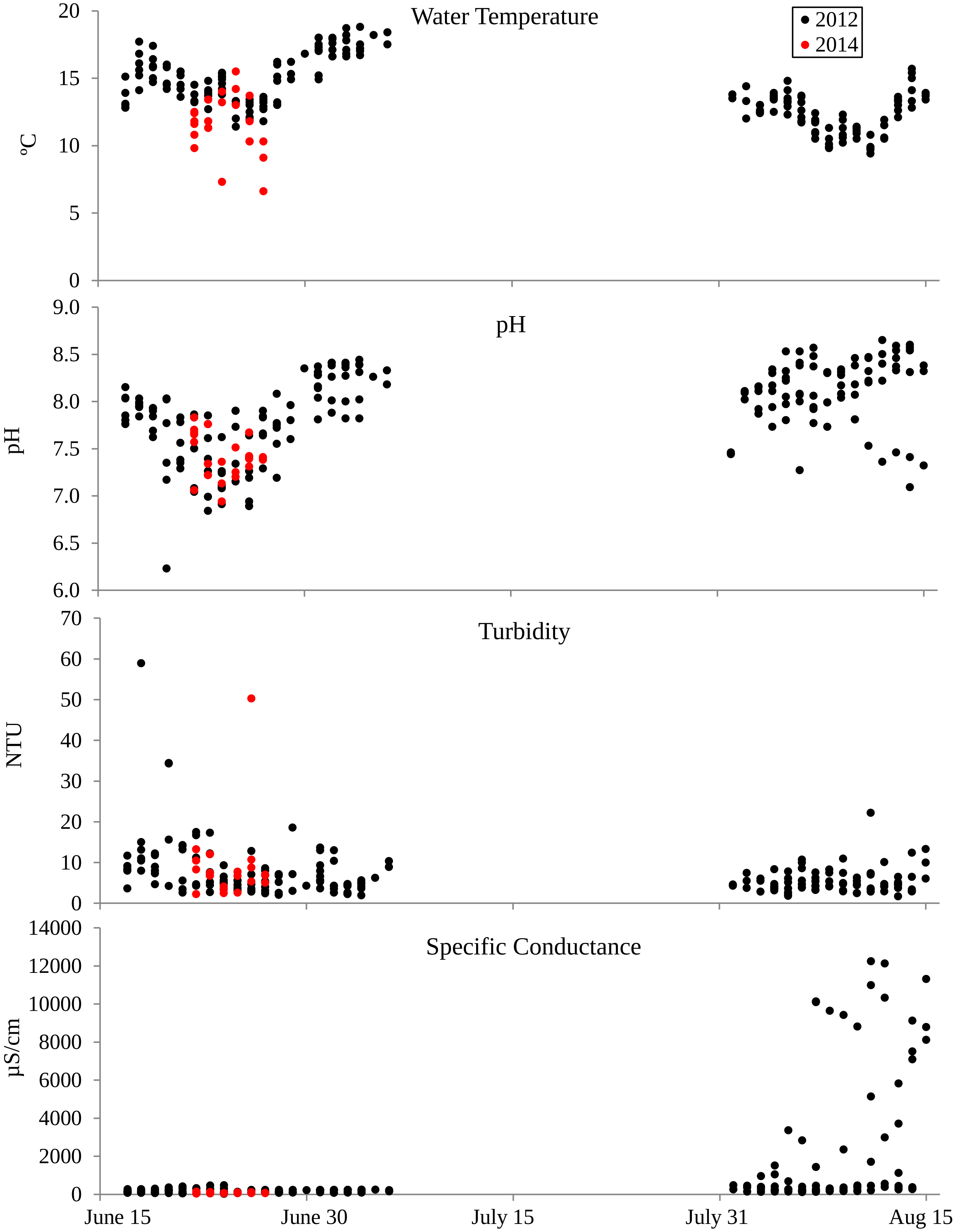
Appendix 8. Mean CPUE (#fish/24 hrs.) of least cisco (LCIS), Arctic grayling (GRAY), ninespine stickleback (NSSB), burbot (BURB), slimy sculpin (SLSC), pink salmon (PINK), fourhorn sculpin (FHSC), and rainbow smelt (RBSM) at fyke net sample sites in the upper Kuk River, 2012 and 2014.

	Station #	Habitat Type	LCIS	GRAY	NSSB	BURB	SLSC	PINK	FHSC	RBSM
June/	AK-01	Creek	0.74	201.38	-	-	0.28	-	-	-
July	AV-01	Main channel	0.32	21.25	7.83	0.68	0.65	-	-	-
2012	AV-02	Main channel	3.27	207.13	0.61	0.58	1.56	-	-	-
	AV-04	Creek	-	19.72	2.76	0.28	3.48	-	-	-
	AV-05	Main channel	8.92	42.99	0.37	-	3.38	-	-	-
	AV-06	Creek	-	8.43	0.33	7.69	0.50	-	-	-
	AV-07	Creek	0.25	92.29	-	3.58	0.25	-	-	-
	AV-08	Main channel	1258.7	48.00	2.15	5.67	-	-	0.51	-
	AV-09	Main channel	1994.9	179.16	8.17	1.02	-	-	3.46	.064
	AV-11	Main channel	72.00	7.49	1.88	2.04	-	-	-	1.21
	AV-12	Main channel	76.63	21.48	5.24	0.59	-	-	0.21	0.62
	KA-01	Main channel	10.60	32.40	1.00	1.24	1.26	-	-	0.68
	KA-07	Creek	1.05	133.17	2.23	-	-	-	-	-
	KE-01	Main channel	1.05	19.09	18.79	0.29	1.64	-	-	0.20
	KE-02	Main channel	0.42	2.67	3.92	-	-	-	-	-
	KE-03	Main channel	3.10	8.66	1.66	0.24	1.75	-	-	-
	KE-04	Main channel	174.99	0.20	1.59	2.35	-	-	-	-
	KK-01	Main channel	799.06	68.62	6.61	-	-	-	-	1.36
	KT-02	Creek	91.02	123.08	2.56	-	-	-	-	-
July/	AK-01	Creek	-	4.00	-	0.19	0.96	1.55	-	-
Aug.	AV-06	Creek	-	3.44	29.16	1.48	1.03	-	-	-
2012	AV-07	Creek	-	7.58	0.59	0.14	0.54	8.45	-	-
	AV-11	Main channel	30.03	19.33	2.56	0.16	0.79	0.11	1.25	0.23
	KA-01	Main channel	1.85	4.28	1.68	0.96	0.18	0.96	-	-
	KA-04	Main channel	0.34	9.41	23.20	-	0.26	-	-	-
	KA-07	Creek	0.17	19.02	24.50	-	-	0.34	0.52	-
	KE-01	Main channel	-	17.77	1.97	-	1.97	-	-	-
	KE-05	Main channel	1.32	3.53	3.48	1.10	4.67	-	-	-
	KK-01	Main channel	46.99	22.39	10.27	-	-	0.27	1.34	0.27
	KT-01	Creek	5.73	28.09	103.64	-	-	-	1.66	-
June	AV-02	Main channel	1.04	-	-	9.96	-	-	-	-
2014	AV-03	Creek	-	-	-	4.15	-	-	-	-
	AV-04	Creek	-	49.28	-	2.40	-	-	-	-
	AV-06	Creek	-	-	-	17.34	-	-	-	-
	AV-07	Creek	-	0.36	-	4.45	-	-	-	-
	AV-10	Main channel	6.67	1.33	-	1.33	-	-	-	-
	AV-12	Main channel	3.98	10.95	14.94	-	-	-	1.00	-
	KA-01	Main channel	38.76	-	-	-	-	-	-	-
	KE-05	Main channel	5.93	4.25	3.35	0.90	-	-	0.23	-

Appendix 9. Arctic grayling tagged and recaptured in the Kuk River 2012.

Tagging Station	Number Tags Released	Recaptures at Station													Recaptured at other stations	
		KK -01	KT -01	KT -02	AV -02	AV -04	AV -05	AV -06	AV -07	AV -09	AV -12	AK -01	KA -07	KE -01	Total	Percent
KK-01	68	2		4									1		5	7.4%
KT-01	46		5												0	0%
KT-02	113	1	1									1			3	2.7%
AV-01	2														0	0%
AV-02	156				4			1	13						14	9.0%
AV-04	32				4	1						2			6	18.8%
AV-05	10						1					1			1	10.0%
AV-06	12														0	0%
AV-07	234				7	1			5	1		5			14	6.0%
AV-08	3														0	0%
AV-09	13								1			1			2	15.4%
AV-11	22														0	0%
AV-12	107										1			1	1	0.9%
AK-01	174				9				1			7			10	5.7%
KA-01	31										1				1	3.2%
KA-04	3														0	0%
KA-07	240											2	35		3	1.3%
KE-01	12								1						1	8.3%
KE-03	8														0	0%
Total	1,286														61	4.7

Appendix 10. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the upper Kuk River drainage 2012 (black) and 2014 (red).



Appendix 11. Fish and invertebrate sampling locations (WGS84) in the Kugrua River and total hours sampled at site with fyke nets and set gillnets, 2013.

			July 23–July 31		
			Total Effort (hours)		Invert sampling
Station	Latitude	Longitude	Fyke Net	Set Gillnet	
KUG-01	70.65878	-158.9651	47.8	-	++
KUG-02	70.65717	-158.9792	49.5	-	-
KUG-03	70.64433	-159.0434	99.8	-	-
KUG-04	70.65825	-159.0480	50.2	10.7	++
KUG-05	70.65877	-159.1574	67.8	-	-
KUG-06	70.67407	-159.1739	44.3	-	++
KUG-07	70.67631	-159.1707	24.6	-	-
KUG-08	70.70544	-159.2164	47.7	-	++
KUG-09	70.72356	-159.2636	67.3	-	++
KUG-10	70.73328	-159.2583	69.3	7.7	-
KUG-11	70.73414	-159.2733	-	55.2	-
KUG-12	70.7358	-159.3546	97.6	-	++

Appendix 12. Mean CPUE (#fish/24 hrs.) of rainbow smelt (RBSM), fourhorn sculpin (FHSC), threespine stickleback (TSSB), ninespine stickleback (NSSB), Arctic flounder (ARFL), saffron cod (SFCD), pink salmon (PINK), and least cisco (LCIS) at fyke net sample sites in the Kugrua River, 2013.

Station #	Habitat Type	RBSM	FHSC	TSSB	NSSB	ARFL	SFCD	PINK	LCIS
KUG-01	Creek	-	-	5.89	1.01	-	-	-	-
KUG-02	Main channel	-	-	8.45	4.88	-	-	-	-
KUG-03	Creek	-	0.23	1.64	16.11	-	-	-	-
KUG-04	Main channel	-	0.51	10.00	10.80	-	-	-	-
KUG-05	Main channel	0.33	12.91	14.42	7.92	0.68	-	-	0.39
KUG-06	Main channel	-	2.61	3.47	2.75	-	-	-	-
KUG-07	Creek		11.70	12.67	6.82	3.90		-	
KUG-08	Main channel	225.83	127.74	-	-	21.11	21.12	-	-
KUG-09	Main channel	18.07	28.89	2.99	0.30	5.16	5.44	-	-
KUG-10	Main channel	36.43	19.82	24.22	2.57	16.24	5.90	2.09	0.38
KUG-12	Creek	-	24.59	34.21	30.68	3.39	0.29	-	-

Appendix 13. Comparison on linear relationships between log fork length (mm) and log weight (g) of least cisco and Arctic grayling between rivers in the current study (Ivisaruk 2010, Kungok 2011, Kuk 2012) and other studies. Pacific herring comparisons are made between males and females in the Kungok 2011. Only results where group compared had significant differences of slope or intercept are shown. Bold p-values indicate significant differences.

Species	Age interval (years)	Group compared	Test	F-value	p-value
Least cisco	All	Kungok vs. Kuk[1]	Slope	40.240	**<0.001**
			Intercept	0.484	0.488
		Kungok vs. Ivisaruk[1]	Slope	0.279	0.598
			Intercept	22.716	**<0.001**
		Kuk vs. Ivisaruk[1]	Slope	22.645	**<0.001**
			Intercept	7.285	**0.009**
		Ivisaruk vs. Chipp 93-94[1,3]	Slope	0.033	0.856
			Intercept	11.971	**<0.001**
		Kuk vs. Chipp 93-94[1,3]	Slope	31.112	**<0.001**
			Intercept	0.570	0.451
		Ivisaruk vs. Chipp 2008[1,3]	Slope	4.171	**0.044**
			Intercept	74.978	**<0.001**
		Kungok vs. Chipp 2008[1,3]	Slope	9.063	**0.003**
			Intercept	23.733	**<0.001**
		Kuk vs. Chipp 2008[1,3]	Slope	8.475	**0.004**
			Intercept	22.039	**<0.001**
Arctic grayling	All	Ivisaruk/Kuk vs. Teshekpuk 2004[2]	Slope	16.072	**<0.001**
			Intercept	13.004	**<0.001**
Pacific Herring	3-7	Ripe Females vs. Ripe Males	Slope	0.770	0.391
			Intercept	5.215	**0.033**
		Ripe Females vs. Post-spawned Females	Slope	0.010	0.921
			Intercept	29.713	**<0.001**
		Ripe Males vs. Post-spawned Males	Slope	1.480	0.241
			Intercept	7.201	**0.016**

[1] groups excluded: pre-spawning females
[2] Moulton et al. 2007
[3] Moulton et al. 2011

Appendix 14. Comparison of linear relationships between log fork length (mm) and age (years) of least cisco and Arctic grayling between rivers in the current study (Ivisaruk 2010, Kungok 2011, Kuk 2012) and other studies. Only results where group compared had significant differences of slope or intercept are shown. Bold p-values indicate significant differences.

Species	Age interval (years)	Group compared	Test	F-value	p-value
Least cisco	2-7	Ivisaruk vs. Chipp 93-94[2]	Slope	0.735	0.393
			Intercept	7.414	**0.008**
		Ivisaruk vs. Chipp 2008[2]	Slope	19.156	**<0.001**
			Intercept	19.922	**<0.001**
		Kungok vs. Chipp 2008[2]	Slope	32.016	**<0.001**
			Intercept	127.336	**<0.001**
		Kuk vs. Chipp 2008[2]	Slope	20.442	**<0.001**
			Intercept	42.028	**<0.001**
		Ivisaruk vs. Kungok	Slope	0.066	0.797
			Intercept	8.584	**0.004**
	8+	Kuk vs. Kungok	Slope	0.056	0.813
			Intercept	8.882	**0.004**
Arctic grayling	<7	Ivisaruk vs. Kuk	Slope	32.301	**<0.001**
			Intercept	12.656	**0.001**
		Kuk vs. Teshekpuk 2004[1]	Slope	80.77	**0.005**
			Intercept	9.320	**0.003**
		Ivisaruk vs. Teshekpuk 2004[1]	Slope	3.859	0.055
			Intercept	42.306	**<0.001**
	7+	Ivisaruk/Kuk vs. Teshekpuk 2004[1]	Slope	0.002	0.965
			Intercept	11.285	**0.002**

[1] Moulton et al. 2007
[2] Moulton et al. 2011

Appendix 15. Reproductive characteristics of least cisco and Arctic grayling caught in the Kuk River Drainage from 2010 to 2012.

	Sex	Least cisco	Arctic grayling
Age/Length[1] of Youngest Sexually Mature	Male	3 yr.	3 yr.
		181.5 ± 3.5 mm (4)	228 ± 16 mm (4)
	Female	4 yr.	4 yr.
		192.2 ± 11.8 mm (13)	258 ± 19 mm (16)
Pre-spawners % of all Mature[2]	Male	47%	NA
	Female	67%	NA
Age/Length of Oldest Mature	Male	23 yr.	14 yr.
		281 mm	360 mm
	Female	25 yr.	15 yr.
		304 mm	371 mm
Age/Length[1] of Oldest Immature	Male	5 yr.	5 yr.
		183 mm	237 ± 14 mm (2)
	Female	5 yr.	6 yr.
		170 ± 26 mm (2)	254 mm
Sex Ratio (female/male)		1.46	0.85

[1]Lengths given as mean FL ± standard deviation (sample size) where sample size >1
[2]Since Arctic grayling are spring spawners, gonads weren't developed enough at time of sampling to determine which fish would spawn the following year