Technical Report No. 16-07

Fish and Aquatic Habitat Surveys in the Topagoruk, Chipp, and Meade Rivers, 2012–2016

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. 16-07

FISH AND AQUATIC HABITAT SURVEYS IN THE TOPAGORUK, CHIPP, AND MEADE RIVERS, 2012–2016

By
Parker Bradley
Division of Habitat, Fairbanks

William Morris
and Lawrence Moulton
Owl Ridge Natural Resource Consultants, Inc.

In cooperation with

Matthew Whitman, Bureau of Land Management
Craig George, North Slope Department of Wildlife Management:

Alaska Department of Fish and Game
Division of Habitat
1300 College Rd, Fairbanks, Alaska, 99701

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Abstract

The Topagoruk, Chipp, and Meade rivers were sampled for fish and aquatic habitat characteristics from June 2012 through September 2015. Fish were captured using fyke and set gillnets. Most commonly captured fish included least cisco (*Coregonus sardinella*) broad whitefish (*C. nasus*), Arctic grayling (*Thymallus arcticus*), humpback whitefish (*C. pidschian*), longnose sucker (*Catostomus catostomus*), ninespine stickleback (*Pungitius pungitius*), burbot (*Lota lota*), and rainbow smelt (*Osmerus mordax*); with least cisco being the most abundant species in general. Pre-spawning rainbow smelt caught in the Meade River was the first documentation of potential spawning areas for this species in the Meade River. Least cisco, broad whitefish, and Arctic grayling were sampled for stomach content analysis (n=10). Broad whitefish (n=62) from the Topagoruk River in 2013 were tagged with radio transmitters and relocated multiple times to identify spawning, overwintering, and summer feeding areas. There was considerable movement of fish among the Ikpikpuk, Oumalik, Chipp, Topagoruk, Meade, and Inaru River drainages. An additional 57 broad whitefish were radiotagged from the lower Meade River in 2014 and 2015. Relocations showed a majority of fish remained in the Meade River, with a few moving to the Inaru, Topagoruk, and Chipp rivers. Growth rates, condition, length-at-maturity, and age-at-maturity were calculated for broad whitefish, least cisco, Arctic grayling, and humpback whitefish. The age at maturity for humpback whitefish appeared to be earlier than previously reported. Aquatic invertebrates and water quality data were collected from all fish sampling locations.

Introduction

The Topagoruk, Chipp, and Meade rivers are located within the National Petroleum Reserve-Alaska on the North Slope of Alaska (Figure 1). All three rivers flow north into Admiralty Bay approximately 55 km southeast of Barrow, Alaska and are only accessible by air or water during the open water season (Figure 1). These three rivers, and associated smaller drainages, support vigorous subsistence fisheries from ice-out through freeze-up (Brewster et al. 2009). The Meade River flows approximately 380 km from its headwaters in the western foothills of the Brooks Range, north to Admiralty Bay. The village of Atqasuk is located approximately 100 km from Admiralty Bay on the Meade River. The Meade River is comprised of a single channel until the delta, where the river splits into four main channels. The Topagoruk River flows approximately 280 km north into the south end of Admiralty Bay. The Chipp River flows approximately 100 km from the Ikpikpuk River north into the south end of Admiralty Bay. There are many fishing and hunting camps located along these rivers.

Broad whitefish (*Coregonus nasus*) are the primary target of the open-water subsistence fishery and are caught throughout the season; females captured just prior to spawning in the fall are especially desired (Brewster et al. 2009). The riverine fishery usually ends by early October as spawning progresses and gravid females are no longer available, however fishing for broad whitefish in lakes continues well into November. The subsistence fishery was studied in the 1970’s and 1980’s with reported annual broad whitefish harvests approaching 30,000 kg (Underwood et al. 1978, Braund et al. 1988). Somewhere between 20,000 and 30,000 broad whitefish may be harvested during the summer and fall fisheries in some years (Craig 1989, Braund 1993). The current broad whitefish harvest level appears sustainable based on biological data, harvest records, and interviews with elders (Braund 1993; Fuller and George 1997; Morris et al. 2006).

Other species typically harvested in the Meade, Chipp and Topagoruk subsistence fisheries include: Arctic grayling (*Thymallus arcticus*), burbot (*Lota lota*), lake trout (*Salvelinus namaycush*), humpback whitefish (*C. pidschian*), pink salmon (*Oncorhynchus gorbuscha*), and chum salmon (*O. keta*). Occasionally sockeye (*O. nerka*) and Chinook salmon (*O. tshawytscha*) are captured during the summer fishing season.

Fish populations in this region of the North Slope have been assessed since the mid-1970’s (Netsch et al. 1977, Bendock and Burr 1985, Philo et al. 1993, Moulton et al. 2011). Early studies were exploratory, describing species presence and basic life history information. These studies found least cisco (*C. sardinella*), broad whitefish, humpback whitefish, and Arctic grayling to be widespread and abundant in the streams and lakes between the Meade and Ikpikpuk rivers (Netsch et al. 1977, Bendock and Burr 1985). More recent studies have focused specifically on the life history, habitat characterization, and movements of broad whitefish because of their importance to the subsistence fishery.

Sampling with fyke nets in the coastal region of Dease Inlet from 1988 to 1990 revealed a high abundance of least cisco followed by broad whitefish and humpback whitefish (Philo et al. 1993). Broad whitefish caught in the coastal region during summer were primarily juvenile fish between 80 and 220 mm fork length (FL), which likely represented ages 1 through 3. Larger fish between 280 and 370 mm were also present, while few fish greater than 400 mm were caught. Broad whitefish caught during 1993-1995 in fyke nets within the middle Chipp River were not abundant and were primarily juvenile fish less than 350 mm (Moulton et al. 2011). They were more abundant and covered a wide range of sizes within a large tapped lake (Tasiqpatchiaq Lake) in the lower river. In 2008, a wide range of sizes of broad whitefish was caught in the lower Chipp River and associated tapped lakes. Broad whitefish were third in abundance during sampling within the Chipp River, following least cisco and humpback whitefish.

Broad whitefish radiotagged in 1994 and 1995 by the North Slope Borough moved extensively within the Chipp River, with some movement observed upstream into the Ikpikpuk River to presumed spawning areas (Moulton et al. 2011). Broad whitefish radiotagged in 2003 and 2004 in the Mayoriak River, the outlet to Teshekpuk Lake, moved extensively into the upper Ikpikpuk River, with some entering the Chipp River, demonstrating a high degree of interchange between the connected river systems (Morris et al. 2006). In 2005, ten broad whitefish were radiotagged in the lower Meade River (Morris et al. 2006). By 2006, one fish from this tag release had moved into the upper Topagoruk River while another had moved into the upper Ikpikpuk River with several of the fish that had been tagged in the Mayoriak River. The overall results of radiotagging indicate some degree of intermixing of fish from all of the Dease Inlet and Ikpikpuk River drainages.

Objectives

The primary objective of this study was to describe the fish and aquatic resources of the Chipp, Topagoruk, and Meade River systems using both qualitative and quantitative metrics to establish a baseline. The results of this study will provide information that may be used to assess future impacts to fish and/or their habitats from development activities and/or natural stressors. Additionally, results may assist in developing measures to ensure the protection of coastal areas and mitigate impacts to fish and/or their habitats prior to development activities.

Fish and aquatic habitat data from multiple locations within the Chipp, Topagoruk, and Meade rivers were collected and analyzed; the results of that work are summarized within this document. Additionally, 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 Topagoruk, Chipp, and Meade River drainages were sampled for a total of seven sampling events from 2012 to 2015 (Figure 1; Table 1). There were two sampling events in 2012, one in the Topagoruk River June 26–July 2 and another in the Chipp River August 11–20. These two rivers were sampled again in 2013; the Topagoruk River June 27–July 2 and the Chipp River August 23–31. Beginning in 2014, sampling efforts focused on the Meade River, which was sampled in three events: July 16–25, 2014, June 17–26, 2015, and August 26–September 4, 2015.

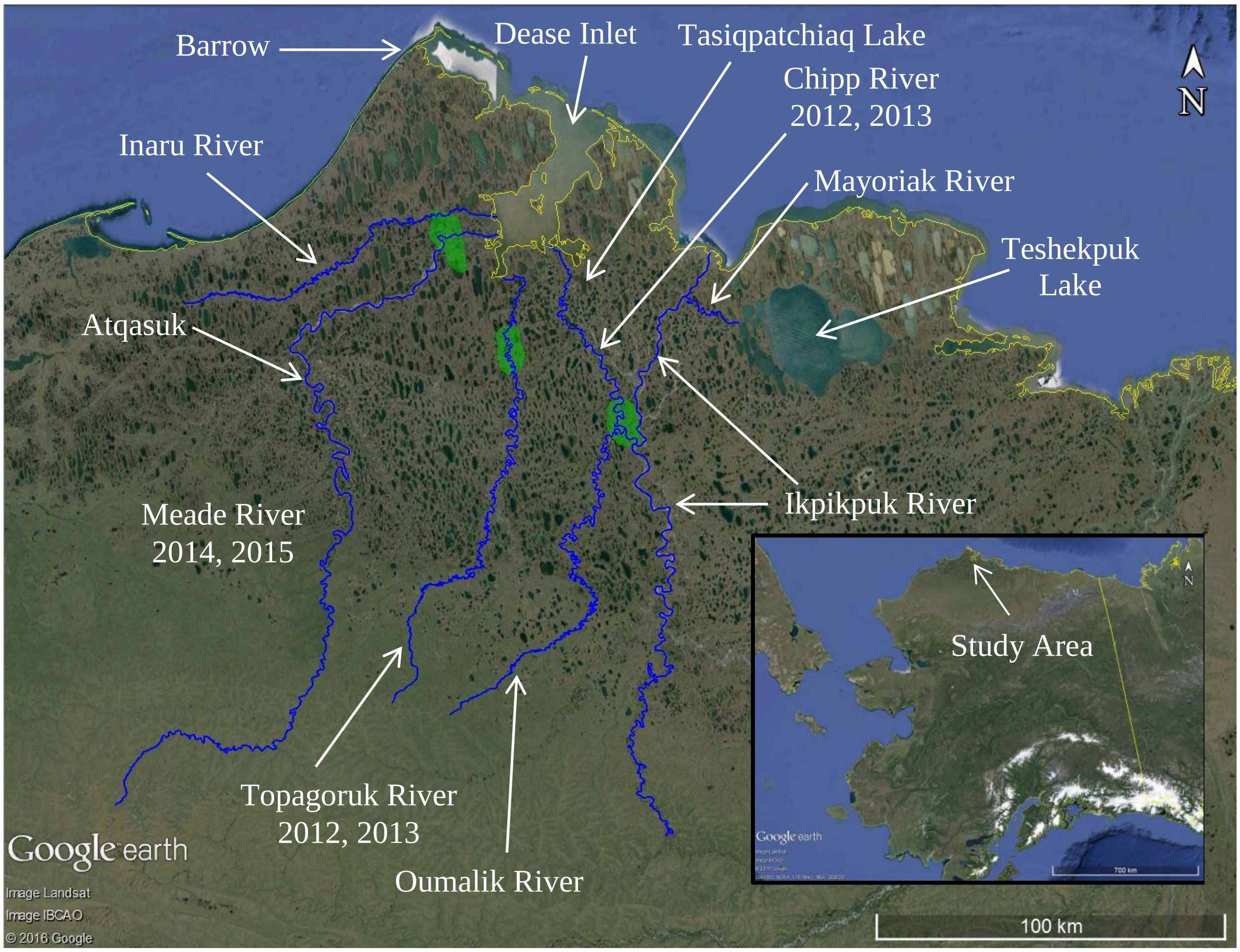

Figure 1. Map of the main river drainages (blue) and areas sampled for fish (green) from 2012–2015.

Table 1. Summary of sampling events in the Topagoruk, Chipp, and Meade rivers 2012–2015

River	2012	2013	2014	2015
Topagoruk	June 26–July 2	June 27–July 2	-	-
Chipp	Aug. 11–Aug. 20	Aug. 23–Aug. 31	-	-
Meade	-	-	July 16–July 25	June 17–June 26 Aug. 26–Sept. 4

Fish Sampling

Fyke nets were fished at a variety of locations in the Topagoruk, Chipp, and Meade rivers. Fyke nets were comprised of two 1.2-m x 1.2-m aluminum frames with five hoops and two throats and were capable of capturing all sizes of fish (Figure 2). Depending on the habitat type, they were typically set so that the channel was blocked with two nets facing opposite directions (Figure 2), or with two wing nets and a center lead going to shore ranging in length from 7.6 to 30.5 m (Figure 3). Nets were checked once each day on an approximately 24 hour set schedule.

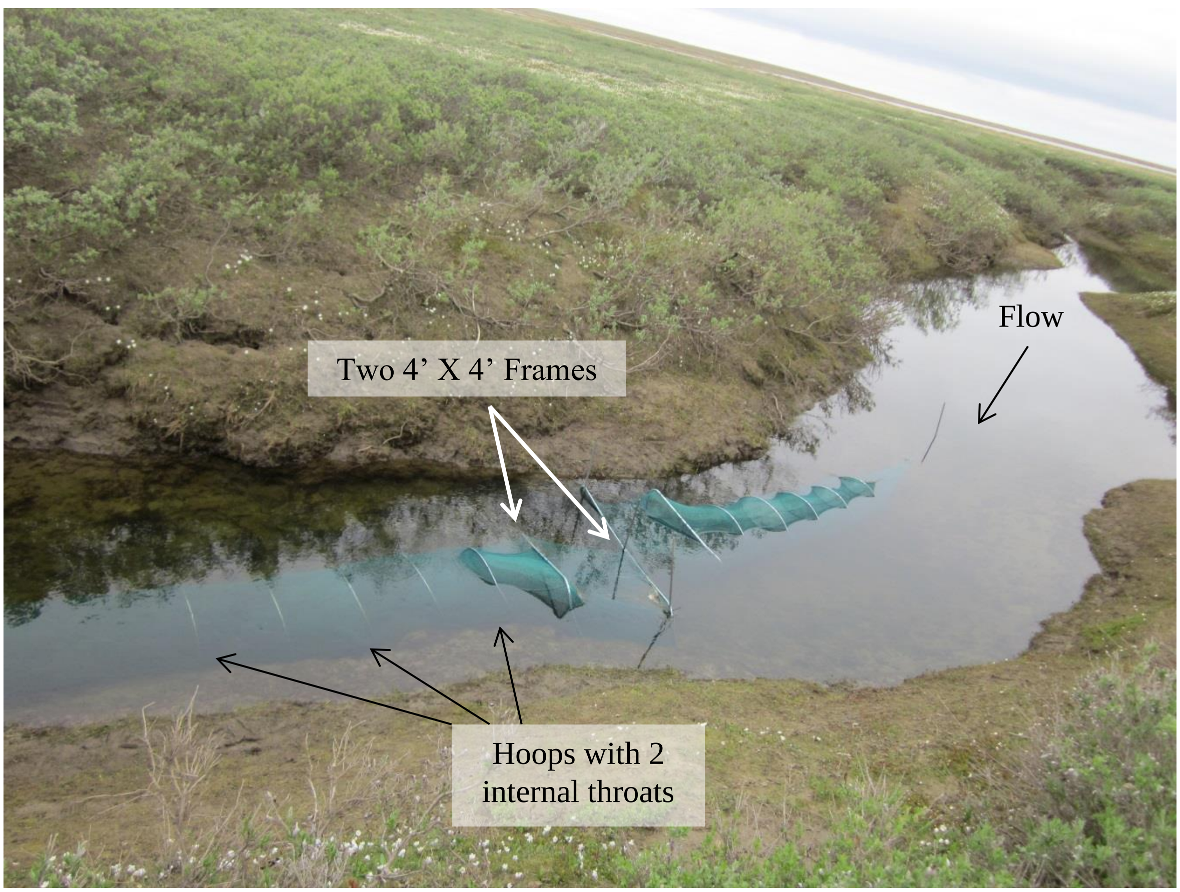

Figure 2. Two fyke net sets in a tributary to the Topagoruk River (Station TP-04), one facing upstream, one facing downstream, 2012.

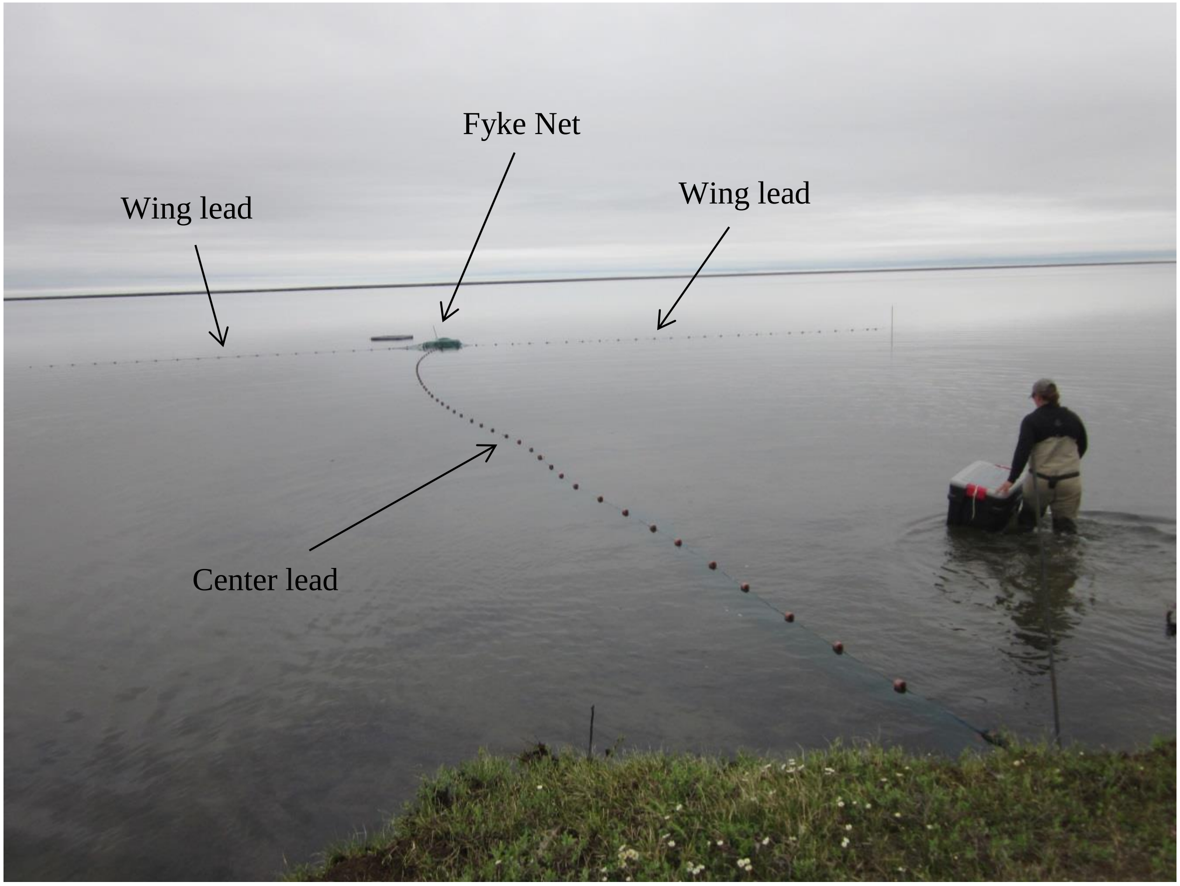

Figure 3. Fyke net set in an off channel lake near the Topagoruk River (Station TP-05), 2012.

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. Each fish captured was identified to species and measured for fork length to the nearest millimeter, except for slimy sculpin (*Cottus cognatus*), burbot, Alaska blackfish (*Dallia pectoralis*), and saffron cod (*Eleginus gracilis*) which were measured for total length to the nearest millimeter. Any abnormalities or presence of parasites were also noted.

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 (approximately one hour) set gillnet sets to minimize digestion prior to removing the stomach. Once the fish was euthanized, 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 gillnets to minimize injury 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 the Chipp River at one station. Traps were baited with fish and set in deep pools near meander bends or in the main channel.

Field Lab Analysis

Some captured fish were retained for analysis of length-weight relationships, age-at-length relationships (growth rates), state of maturity, and to determine general stomach contents. The sampling design 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 for later analysis using the break and burn method or cross section method (Chilton and Beamish 1982).

Sex and maturity were determined for each fish retained using the following maturity scale (Moulton et al. 2007).

1. Immature: young individuals that have not engaged in reproduction: gonads very small, may be hard to determine 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

Broad whitefish were targeted for surgical implantation of Lotek MCFT2-3FM radio tags. These tags were 11 mm in diameter, 59 mm in length, and weighed 10 g (4.6 g in water). Transmitter antennas were multi-stranded stainless steel, 1.02-mm diameter, and 45.5-cm long. Antennas were Teflon coated and covered with shrink wrap tubing to increase rigidity.

Surgical implantation of radio tags 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. Generally, broad whitefish over 350 mm in fork length were large enough to be outfitted with the 10-g tags. One 375-mm long broad whitefish was implanted with a 10-g transmitter in the Meade River; the remaining radiotagged fish were over 400 mm.

Once fish were selected for tagging they 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 a 3 to 4-cm incision made along the ventral side of the fish into the peritoneal cavity (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 posterior of the pelvic girdle (Morris et al. 2011). Once in place, the antenna was fed through the catheter and the groove director and catheter were removed from the fish. The incision was closed with three to five 3-0 monofilament sutures. After closing the incision, Vetbond™ (3M™, St. Paul, Minnesota) surgical glue was applied to further secure the sutures. During the surgical procedure, fresh water was continuously applied to the gills of the fish to prevent suffocation. Following surgery, radiotagged fish were placed into a holding pen until they could maintain equilibrium, at which time they were released.

Surveys to relocated radiotagged fish were conducted with a Cessna 182 and generally took 2-3 days and encompassed the major river drainages in the area (Figure 4). There were many tributaries and lakes between the major river drainages that could not be flown due to time and budget constraints; however, when time and weather allowed, as much area between the river drainages was flown as possible. Two Lotek SRX-600 receivers were utilized relocating radiotagged fish. One receiver was connected to two antennae 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 selecting the point with the highest signal strength between the two receivers.

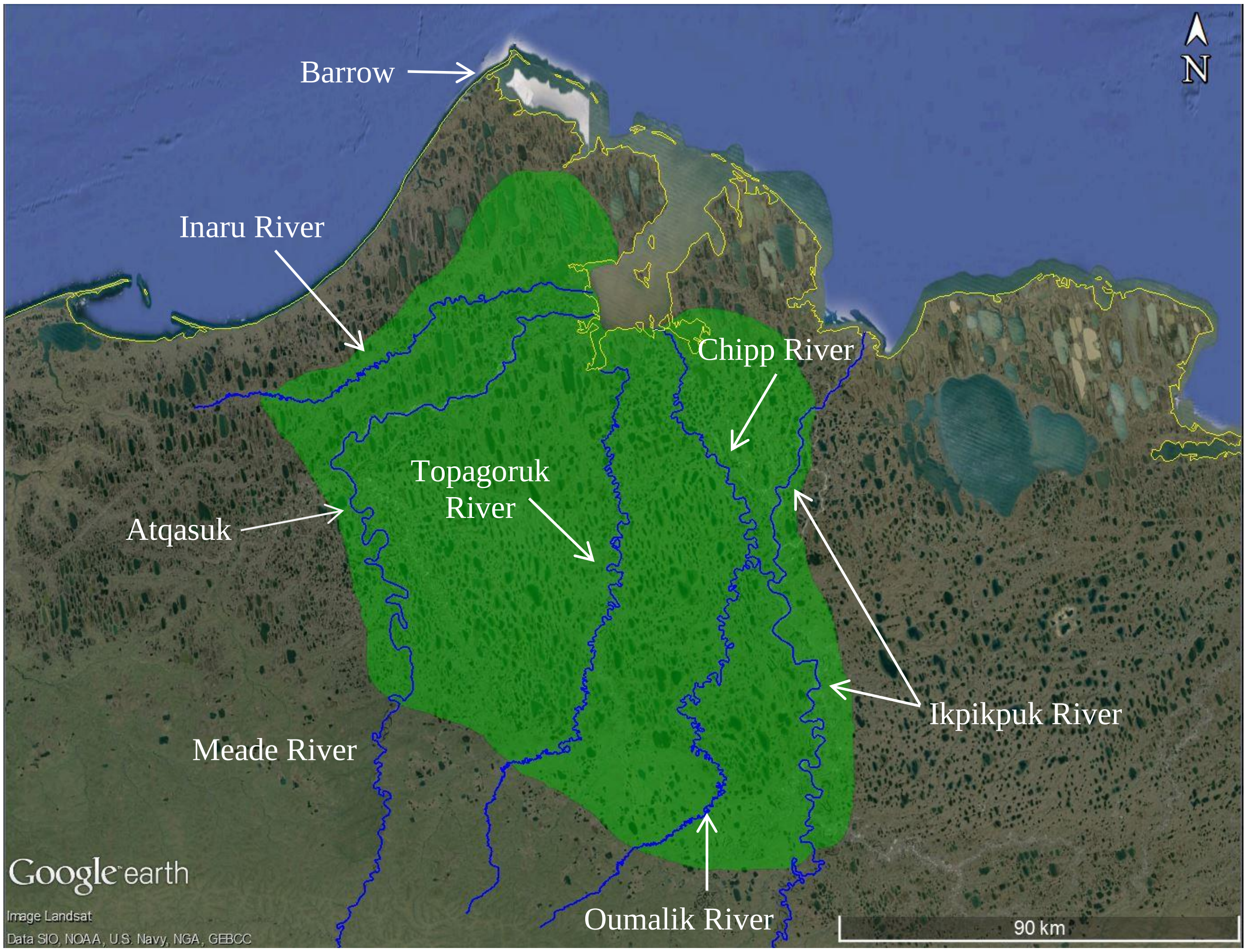

Figure 4. Major drainages (blue) and relocation survey area (green) flown during aerial relocation surveys 2013–2016.

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 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 utilized 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. These were processed 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 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. These were processed 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. The concentration of chlorophyll-a 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 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 (Froese 2006). Length-weight relationships for female least cisco, broad whitefish, and humpback whitefish in pre-spawning condition were significantly different from remaining fish, so they were removed from analysis because a significant portion of their mass consists of eggs. 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 when comparable datasets were available. All ANCOVA tests for slopes and intercepts were deemed significant at alpha less than or equal to 0.05.

Results

Catch Summary

Topagoruk River

Sampling of the Topagoruk River was conducted during the periods June 26–July 2, 2012 and June 27–July 2, 2013. The purpose of the first sampling event in 2012 was to document species present, relative abundance, classify the aquatic invertebrate community, and establish a baseline of phytoplankton concentrations. Seven locations were sampled for fish using either fyke nets or set gillnets (Figure 5; Appendix 1). In 2013, the primary goal was to surgically implant radio tags in large broad whitefish to better understand seasonal movements and important habitats. Three locations were sampled with fyke nets in 2013 (Figure 5; Appendix 1).

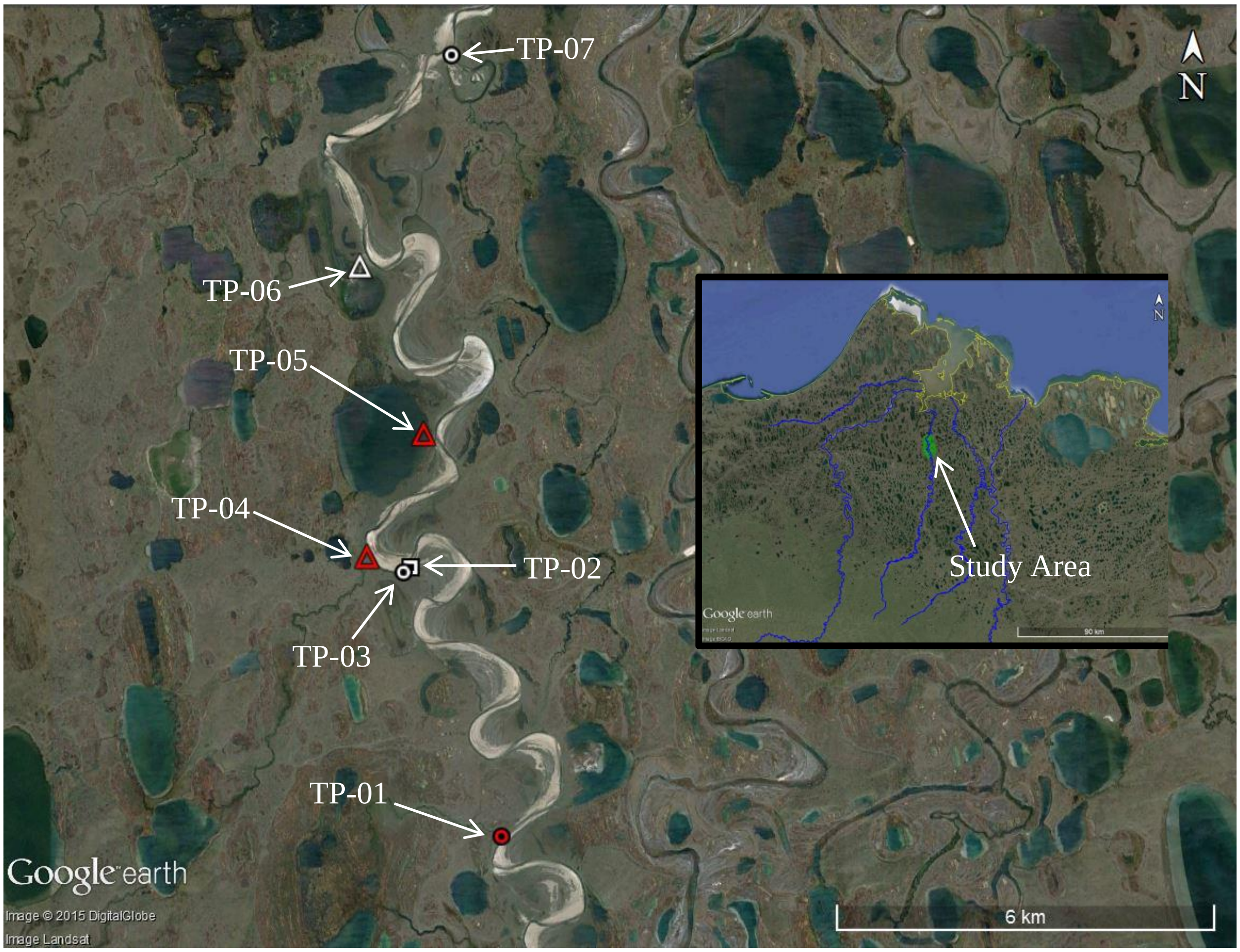

Figure 5. Sampling sites along the Topagoruk River. White symbols represent sites sampled only in 2012 and red symbols represent sites sampled in 2012 and 2013. Round dots represent fyke net sites, square dots represent set gillnet sites, and triangles represent both gear types used.

A total of 2,633 fish comprised of at least six species were captured with fyke nets in 599 total effort hours (Table 2). Least cisco were the most commonly captured species followed by broad whitefish, Arctic grayling, slimy sculpin, ninespine stickleback (*Pungitius pungitius*), unidentified whitefish (*Coregonus* sp.), and humpback whitefish. The unidentified whitefish were age-0 fish, less than 30 mm that could not be positively identified to species. A total of 13 fish were captured with set gillnets in 15 hours of sampling effort in 2012 with broad whitefish (n = 5), Arctic grayling (n = 4), and least cisco (n = 4) making up the catches (Table 3).

Table 2. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch of each species captured with fyke nets in the Topagoruk River, 2012 and 2013.

	Number of Fish			Mean CPUE		Percent of Catch		
Species	June 26–July 2, 2012	June 27–July 2, 2013	Total	June 26–July 2, 2012	June 27–July 2, 2013	June 26–July 2, 2012	June 27–July 2, 2013	Total
Least cisco	283	1,561	1,844	19.36	146.99	33.0	87.9	70.0
Broad whitefish	272	162	434	16.31	18.69	31.7	9.1	16.5
Arctic grayling	247	47	294	19.08	4.98	28.8	2.6	11.2
Slimy sculpin	35	1	36	2.04	0.11	4.1	0.1	1.4
Ninespine stickleback	12	3	15	0.78	0.33	1.4	0.2	0.6
Unidentified whitefish	7	0	7	0.56	0	0.8	0	0.3
Humpback whitefish	2	1	3	0.11	0.10	0.2	0.1	0.1
Total catch	858	1,775	2,633					
Number of species	6	6	6					
Total effort (hrs.)	380	219	599					

Table 3. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch of each species captured with set gillnets in the Topagoruk River, 2012.

	Number of Fish	Mean CPUE	Percent of Catch
Species	June 26–July 2	June 26–July 2	June 26–July 2
Broad whitefish	5	8.5	38.5
Arctic grayling	4	18.3	30.8
Least cisco	4	8.0	30.8
Total catch	13		
Number of species	3		
Total effort (hrs.)	15		

Chipp River

A total of 21 sites were sampled in the Chipp River during the periods August 11–20, 2012 and August 23–31, 2013 for fish using fyke nets, set gillnets, and hoop traps (Figure 6; Appendix 2). Aquatic invertebrate and phytoplankton samples were collected at four of those sites.

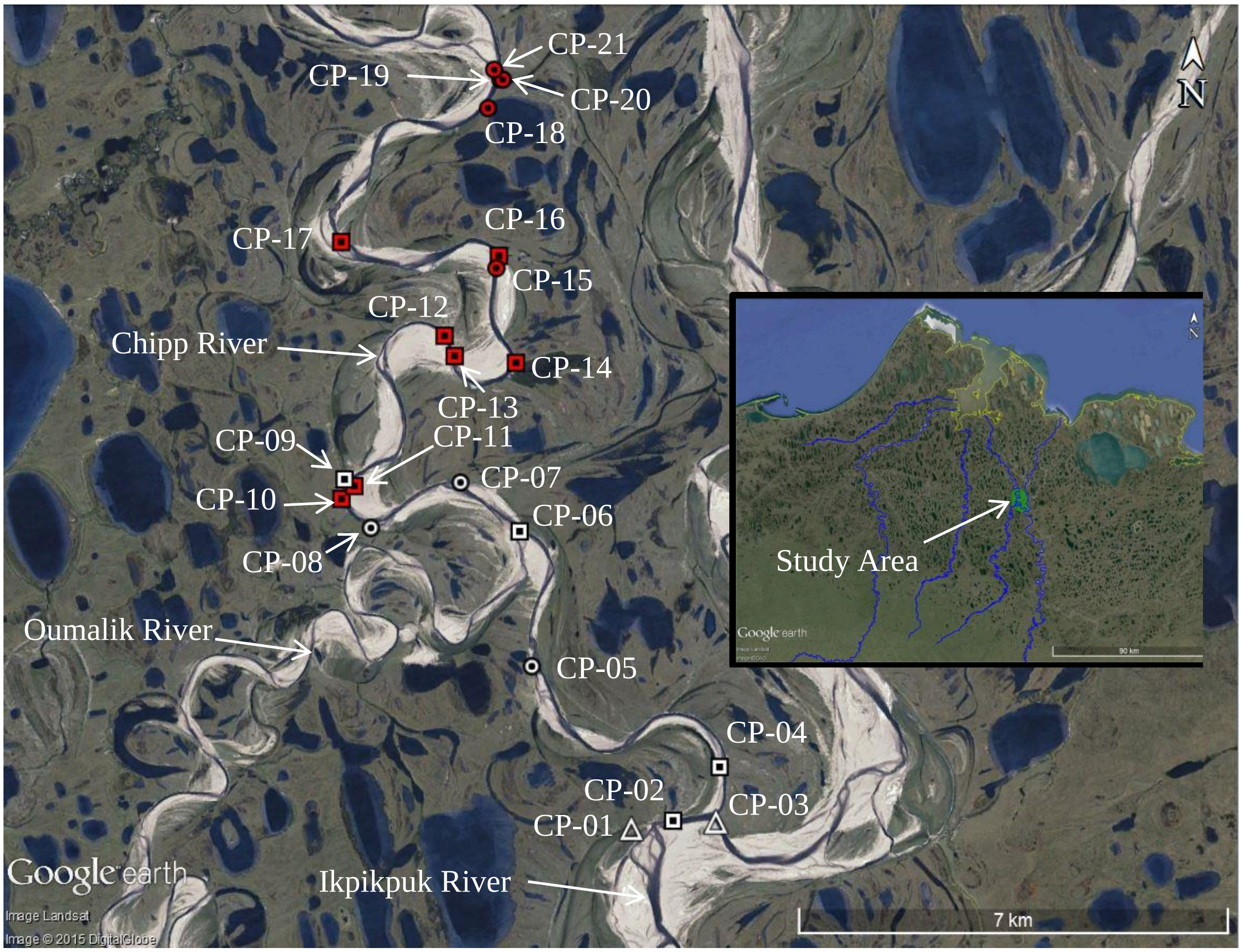

Figure 6. Sampling sites along the Chipp River in 2012 (white symbols) and 2013 (red symbols). Square symbols represent set gillnet sites, round symbols represent fyke net sites, and triangles represent multiple gear types used.

A total of 1,044 fish representing 12 species were captured in the Chipp River with fyke nets; 871 fish in 2012 and 173 in 2013 (Table 4). The most commonly captured species was broad whitefish, followed by least cisco, longnose sucker (*Catostomus catostomus*), Arctic grayling, humpback whitefish, slimy sculpin, Alaska blackfish, burbot, ninespine stickleback, northern pike (*Esox lucius*), rainbow smelt (*Osmerus mordax*), and round whitefish (*Prosopium cylindraceum*).

A total of 268 fish comprised of seven species were captured in a total of 592 set gillnet effort hours in the Chipp River in 2012 and 2013 with broad whitefish making up a majority of the catches followed by humpback whitefish, chum salmon, pink salmon, Arctic grayling, least cisco, and northern pike (Table 5).

Table 4. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch for each species captured with fyke nets in the Chipp River, 2012 and 2013.

	Number of Fish			Mean CPUE		Percent of Catch		
Species	Aug 11–20, 2012	Aug 23–31, 2013	Total	Aug 11–20, 2012	Aug 23–31, 2013	Aug 11–20, 2012	Aug 23–31, 2013	Total
Broad whitefish	669	9	678	40.53	0.60	76.8	5.2	64.9
Least cisco	49	54	103	3.10	4.58	5.6	31.2	9.9
Longnose sucker	69	9	78	5.23	0.81	7.9	5.2	7.5
Arctic grayling	20	22	42	1.37	1.54	2.3	12.7	4.0
Humpback whitefish	36	0	36	2.06	0	4.1	0	3.4
Slimy sculpin	13	22	35	0.70	1.67	1.5	12.7	3.4
Alaska blackfish	1	30	31	0.08	2.17	0.1	17.3	3.0
Burbot	7	10	17	0.50	0.78	0.8	5.8	1.6
Ninespine stickleback	5	8	13	0.39	0.60	0.6	4.6	1.2
Northern pike	0	9	9	0	0.72	0	5.2	0.9
Rainbow smelt	1	0	1	0.06	0	0.1	0	0.1
Round whitefish	1	0	1	0.07	0	0.1	0	0.1
Total catch	871	173	1,044					
Number of species	11	9	12					
Total effort (hrs.)	371	318	689					

Table 5. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch for each species captured with set gillnets in the Chipp River, 2012 and 2013.

	Number of Fish			Mean CPUE		Percent of Catch		
Species	Aug 11–20, 2012	Aug 23–31, 2013	Total	Aug 11–20, 2012	Aug 23–31, 2013	Aug 11–20, 2012	Aug 23–31, 2013	Total
Broad whitefish	159	62	221	12.33	6.52	79.5	91.2	82.5
Humpback whitefish	24	4	28	1.70	0.40	12.0	5.9	10.4
Chum salmon	7	0	7	0.51	0	3.5	0	2.6
Pink salmon	3	2	5	0.16	0.21	1.5	2.9	1.9
Arctic grayling	3	0	3	0.16	0	1.5	0	1.1
Least cisco	2	0	2	0.02	0	1.0	0	0.7
Northern pike	2	0	2	0.02	0	1.0	0	0.7
Total catch	200	68	268					
Number of species	7	3	7					
Total effort (hrs.)	362	230	592					

Meade River

Sampling of the Meade River was in three periods: July 16–25, 2014, June 17–26, 2015, and August 26–September 4, 2015. A total of 19 locations were sampled for fish using fyke nets (Figure 7; Appendix 3). One sample site (MD-19) was located on the Inaru River. Aquatic invertebrates and phytoplankton samples were collected at six locations.

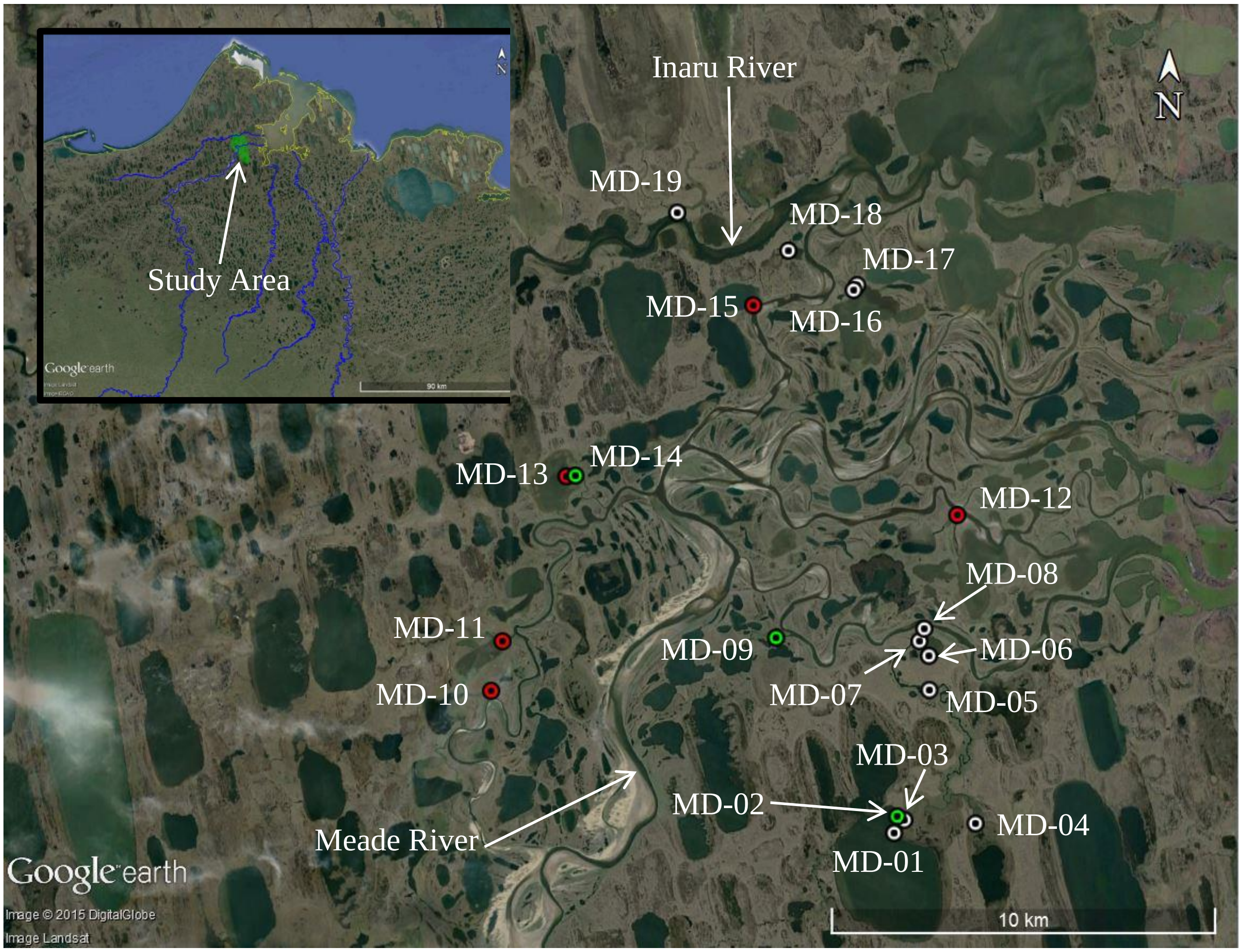

Figure 7. Sampling sites in the lower Meade and Inaru rivers 2014 (red) and 2015 (white). Green dots represent sites sampled both years.

A total of 9,749 fish comprised of 11 species were captured in 2,613 fyke net effort hours in the Meade River drainage with least cisco making up a majority of the catches followed by broad whitefish, Arctic grayling, humpback whitefish, ninespine stickleback, burbot, rainbow smelt, longnose sucker, threespine stickleback (*Gasterosteus aculeatus*), slimy sculpin, and saffron cod (Table 6).

Table 6. Number of fish, mean CPUE (#fish/24 hrs.), and percent of catch for each species captured with fyke nets in the Meade River, 2014 and 2015.

Species	Number of Fish				Mean CPUE			Percent of Catch			
	July 16–25, 2014	June 17–26, 2015	Aug 26–Sept 4, 2015	Total	July 16–25, 2014	June 17–26, 2015	Aug 26–Sept 4, 2015	July 16–25, 2014	June 17–26, 2015	Aug 26–Sept 4, 2015	Total
Least cisco	204	3,318	1,619	5,141	6.45	81.68	49.08	14.8	67.5	46.8	52.7
Broad whitefish	337	703	1,391	2,431	10.69	16.47	45.13	24.4	14.3	40.2	25.0
Arctic grayling	630	634	207	1,471	20.36	17.05	5.74	45.7	12.9	5.9	15.1
Humpback whitefish	39	154	122	315	1.06	3.97	3.84	2.8	3.1	3.5	3.2
Ninespine stickleback	125	42	78	245	4.31	0.84	2.68	9.1	0.9	2.3	2.5
Burbot	21	9	34	64	0.66	0.21	1.04	1.5	0.2	0.9	0.7
Rainbow smelt	6	34	6	46	0.17	0.78	0.18	0.4	0.7	0.2	0.5
Longnose sucker	9	18	0	27	0.28	0.44	0	0.7	0.4	0	0.3
Threespine stickleback	6	0	0	6	0.24	0	0	0.4	0	0	0.1
Slimy sculpin	2	0	0	2	0.04	0	0	0.1	0	0	0.02
Saffron cod	1	0	0	1	0.02	0	0	0.1	0	0	0.01
Total catch	1,380	4,912	3,457	9,749							
Number of species	11	8	7	11							
Total effort (hrs.)	838	992	783	2,613							

CPUE, Length-Weight, Growth, and Maturity Patterns

Least Cisco

Topagoruk River

During the 2012 Topagoruk River sampling, least cisco CPUE was highest in the unconnected lake at TP-05 (Figure 5; Appendix 4). Captured least cisco ranged from 27 to 376 mm, with the most common size class ranging 151 to 200 mm (Figure 8). During the 2013 sampling, least cisco CPUE was highest at the furthest upstream site (TP-01) (Figure 5; Appendix 4). Although more least cisco were captured during this sampling event, only 5% of the captured fish were measured and remaining fish were counted; of those measured, lengths ranged from 109 to 348 mm (Figure 8).

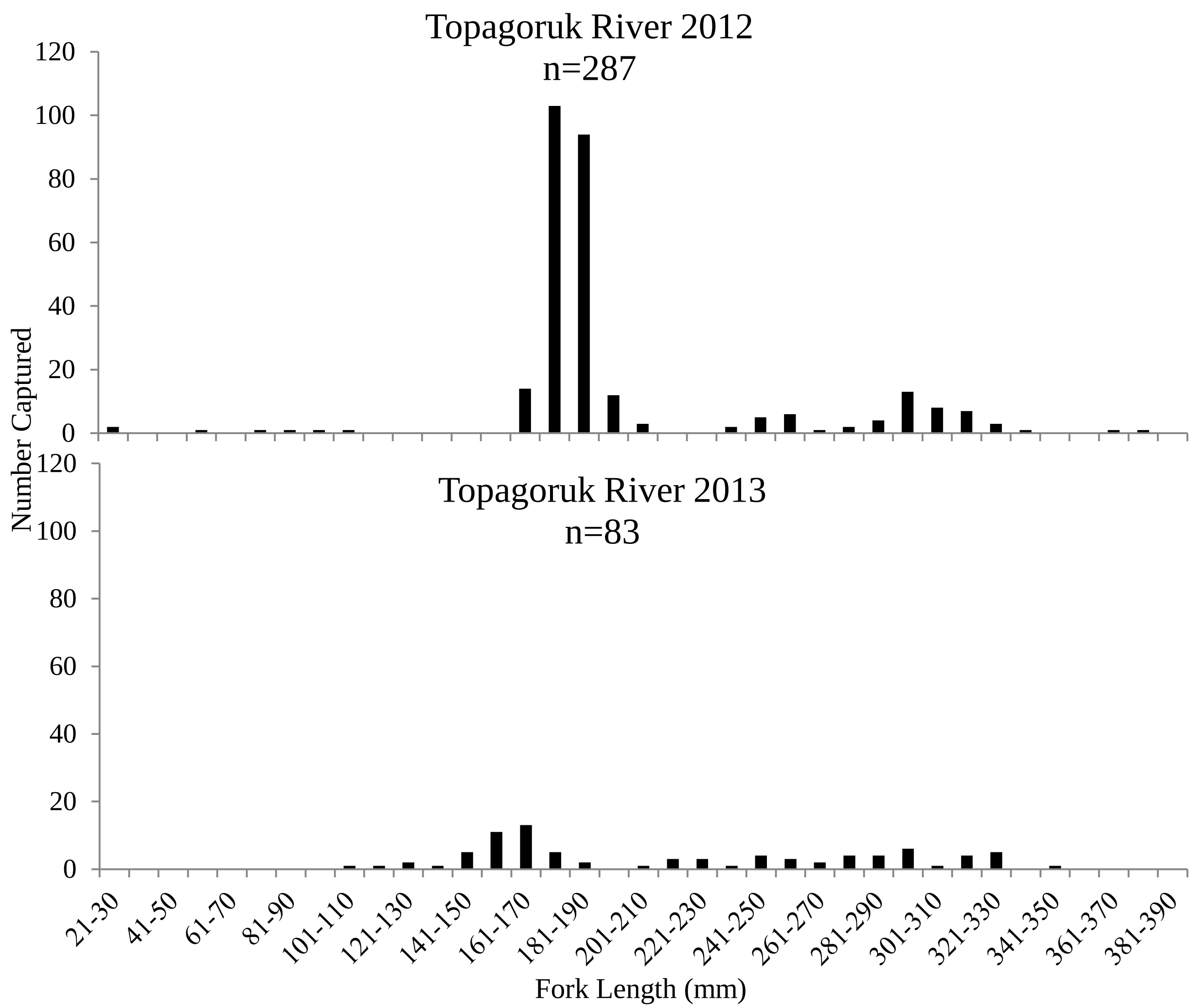

Figure 8. Length frequency distribution of least cisco captured in the Topagoruk River in 2012 and 2013 with fyke nets and set gillnets.

Chipp River

In 2012, catches of least cisco in the Chipp River were highest at CP-01 in a small unnamed creek, and at CP-03 (Figure 6; Appendix 5). Captured least cisco ranged from 55 to 353 mm (Figure 9). Least cisco < 80 mm, which were likely age 0, were captured at each fyke net location except CP-08.

In 2013, catch rates of least cisco were highest at CP-18, which is in a lake without an obvious surface water connection to other bodies of water (Figure 6; Appendix 5). All least cisco captured at this location were age-0 fish ranging in length from 58 to 77 mm. Among all the sample sites, least cisco ranged from 56 to 365 mm (Figure 9).

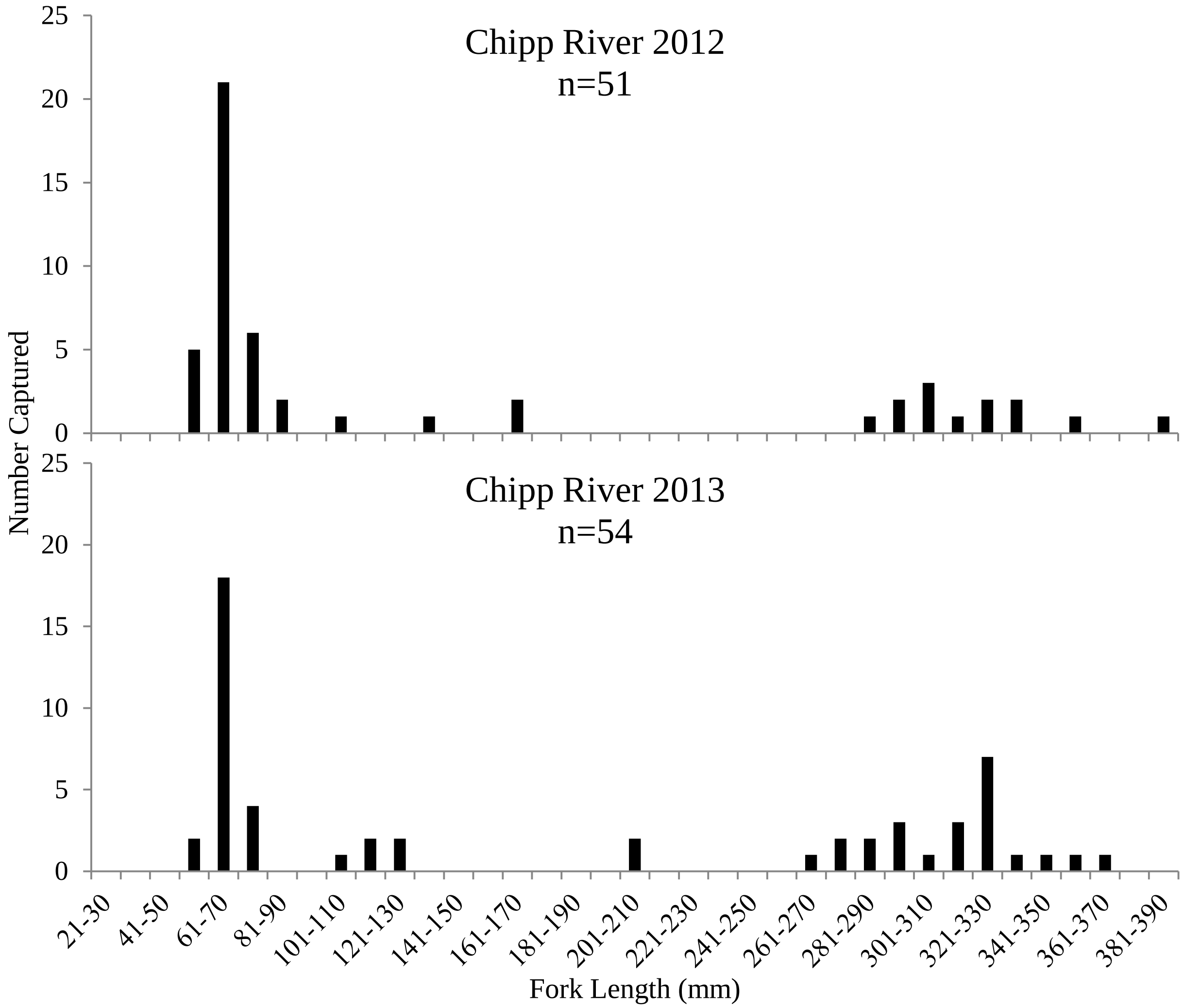

Figure 9. Length frequency distribution of least cisco captured in the Chipp River 2012 and 2013 with fyke nets and set gillnets.

Meade River

During the 2014 Meade River sampling, least cisco CPUE was highest in a connected lake at MD-13 (Figure 7; Appendix 6). Catch rates were also relatively high in a backwater slough (MD-11) and another connected lake (MD-02) (Figure 7). Captured least cisco ranged from 68 to 375 mm (Figure 10).

Catches in June 2015 increased with highest CPUE occurring in the connected lake habitats (MD-06, MD-18, MD-16, MD-17, and MD-01) and a lake outlet (MD-14) (Figure 7; Appendix 6). Captured least cisco ranged from 48 to 385 mm (Figure 10). Very few fish captured were ≤125 mm, while a large number of fish captured were in the next size class 126–150 mm (Figure 10). Based on age-length relationships of least cisco from this area, fish ≥126 mm were likely age 3+.

In August 2015, CPUE was also highest in a few connected lake habitats (MD-07, MD-17, and MD-07) and an unnamed creek (MD-08) (Figure 7; Appendix 6). Captured least cisco ranged from 40 to 390 mm (Figure 10). The most abundant size class was fish 51–75 mm, which were likely age-0 fish.

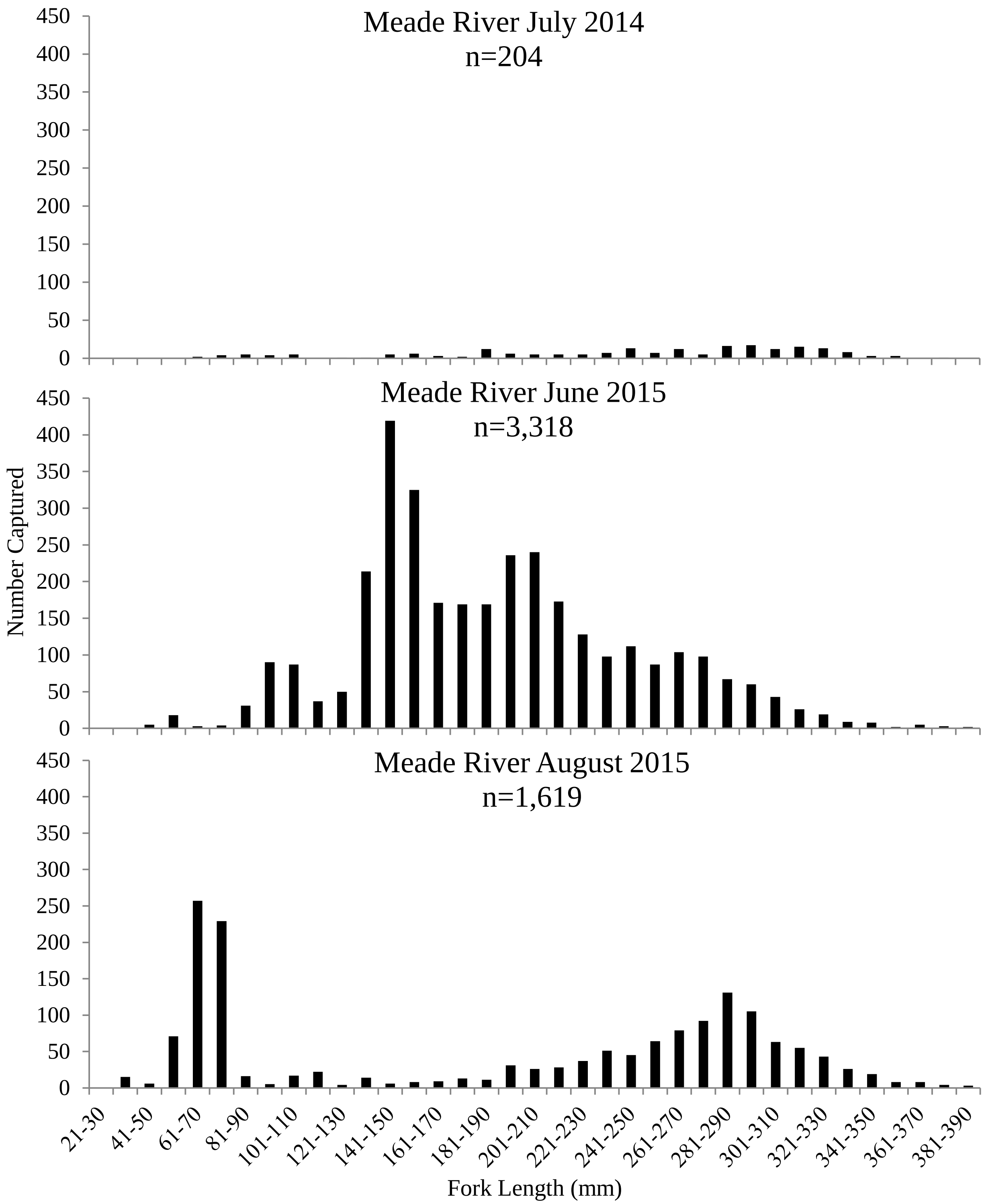

Figure 10. Length frequency distribution of least cisco captured in the lower Meade River July 2014, June 2015, and August 2015 with fyke nets.

Length-weight

Length-weight relationships for least cisco were established to allow for comparison of body condition among drainages in the current study area and for future comparisons of the same populations. Comparisons of fish condition can also be conducted among other populations in the region or previous length-weight curves. Differences in body condition may be indicative of habitat quality and feeding conditions and can be used to make relative comparisons of populations both over time and geographically.

Length and weight data from the Meade River least cisco were log-transformed. Data from the Chipp and Topagoruk rivers were combined due to low sample size and subsequently log transformed. An ANCOVA was used to compare the slope and intercept of the regression line between mature least cisco from the Meade River and mature least cisco from the Chipp and Topagoruk rivers. With pre-spawning females removed, length-weight relationships did not differ between these rivers (Figure 11; Table 7). Length weight relationships were similar between least cisco in the current study and a prior study in the lower Chipp River in 2008. Least cisco from the Chipp, Topagoruk, and Meade rivers had a higher weight at a given length than least cisco from Teshekpuk Lake 2003-2007 (Table 7). Data from prior research conducted in Dease Inlet/Admiralty Bay includes pre-spawning females which is likely why least cisco from that region have a higher weight for a given length compared to the current study (Table 7).

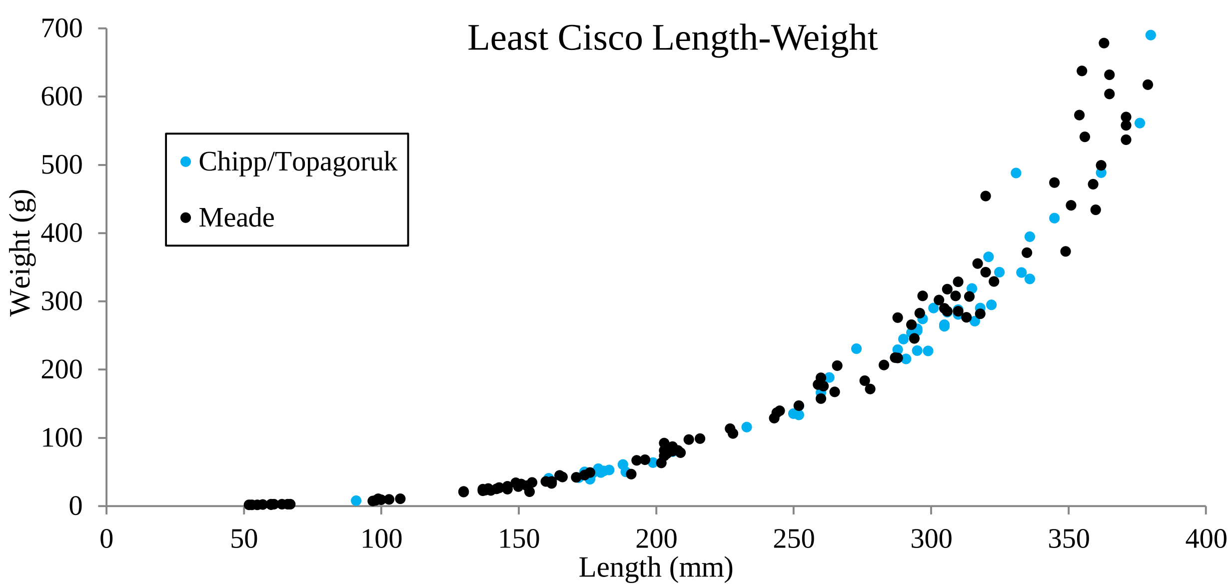

Figure 11. Length-weight relationships for least cisco captured in the Meade River 2015 (black dots), Chipp River 2012 (blue dots), and Topagoruk River 2012 (blue dots).

Table 7. 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	Length-Weight Relationship Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 175	250	325
Chipp, Topagoruk, Meade Rivers[1]								
	all groups except ripening females	3.16	-5.413	0.99	71	47.3	145.9	334.4
Lower Chipp River, June 2008[1, 5]								
	all groups except ripening females	3.285	-5.720	0.99	75	44.5	143.6	340.0
Teshekpuk Lake, 2003-2007[1, 4]								
	all groups except ripening females	3.297	-5.768	0.99	160	42.4	137.4	326.3
Elson Lagoon, 2010[1, 6]								
	all groups except ripening females	3.435	-6.099	0.99	66	40.3	137.4	338.3
Dease Inlet/Admiralty Bay 1988[3]								
	Immature	3.101	-5.294	0.99	67	45.9	-	-
Dease Inlet/Admiralty Bay 1989[3]								
	Immature	3.118	-5.349	0.99	71	44.1	-	-
Dease Inlet/Admiralty Bay 1990[3]								
	Immature	2.915	-4.877	0.99	76	45.9	-	-
Dease Inlet/Admiralty Bay 1988[2, 3]								
	Mature	3.353	-5.873	0.94	59	-	147	354.2
Dease Inlet/Admiralty Bay 1989[2, 3]								
	Mature	3.079	-5.175	0.92	202	-	161.5	362.3
Dease Inlet/Admiralty Bay 1990[2, 3]								
	Mature	3.588	-6.466	0.96	47	-	137.3	352.1

[1] excludes pre-spawning females
[2] includes pre-spawning females
[3] Philo et al. 1993
[4] Moulton et al. 2007
[5] Moulton et al. 2011
[6] Morris et al. 2012

Growth

Age-length relationships were established for least cisco to allow comparisons of growth rates among sampling areas, regions, and over time. Least cisco retained for analysis ranged in age 1-24 in the Chipp/Topagoruk rivers and age 0-25 in the Meade River. No differences in growth among the Chipp, Topagoruk, and Meade rivers for least cisco ages 2-7 were detected. Growth rates were the same between least cisco age 2-7 in this study and fish from the Chipp River 2008, but fish were larger at a given age in the current study (Figure 12; Appendix 7). In contrast, growth rates and size at age were larger in the current study when compared to least cisco captured in the Chipp River in 1993-1994.

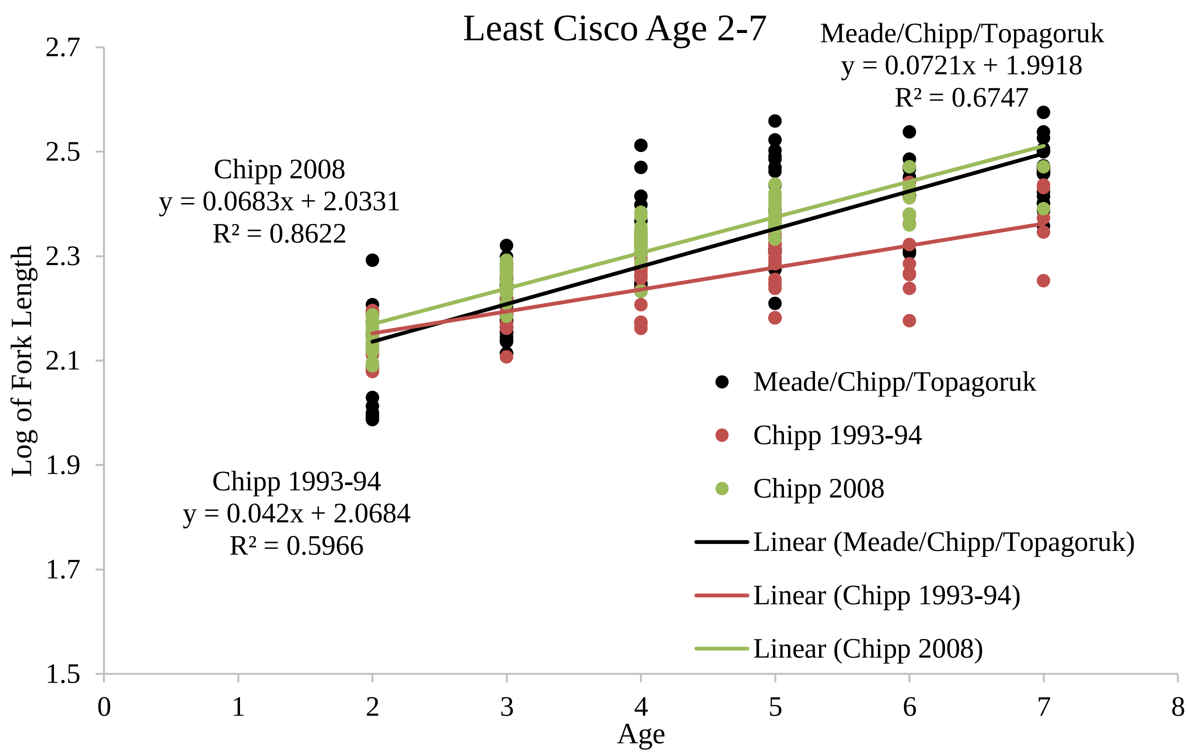

Figure 12. Age-log fork length relationships for least cisco captured in the Topagoruk River in 2012, Chipp River in 2012, and Meade River in 2015, Chipp River in 2008 (Moulton et al. 2011), and Chipp River 1993-1994 (Moulton et al. 2011).

Maturity

The reproductive characteristics for least cisco are listed in Appendix 8. Both male and female least cisco began maturing at age 4 with 100% of males mature and by age 7 and 100% of females were mature by age 8 (Figure 13). All least cisco < 171 mm were immature while fish > 243 mm were mature (Figure 14). Of all the mature least cisco caught, 45% of the males and 52% of the females were pre-spawners suggesting many fish spawn every other year. The sex ratio (female: male) for least cisco was 1.76:1, which is slightly higher than other studies conducted in this region (Philo et al. 1993; Bradley et al. 2016)

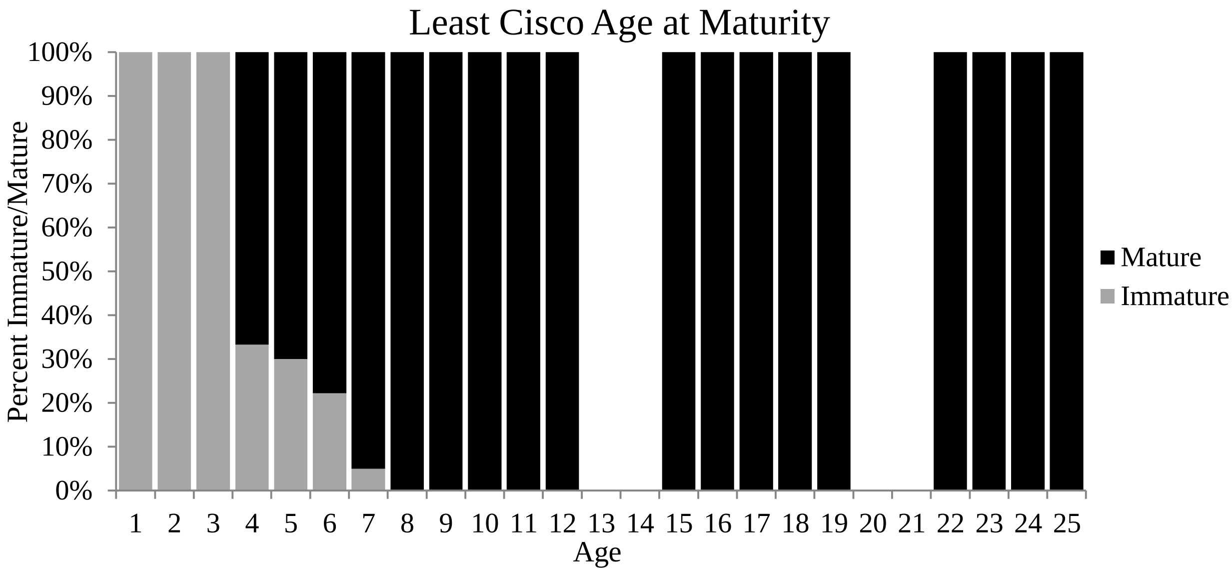

Figure 13. Percent maturity by age class for least cisco captured in the Topagoruk River in 2012 (n = 39), the Chipp River in 2012 (n = 15), and the Meade River in 2015 (n = 113).

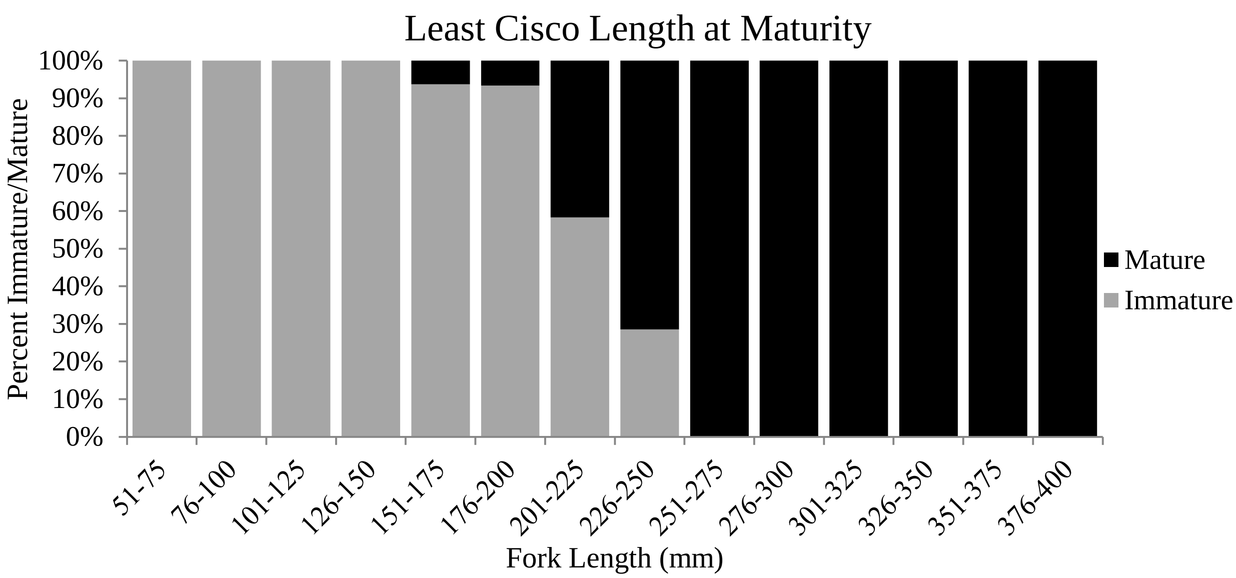

Figure 14. Percent maturity by size class for least cisco captured in the Topagoruk River in 2012 (n = 39), the Chipp River in 2012 (n = 15), and the Meade River in 2015 (n = 113).

Broad Whitefish

Topagoruk River

During the 2012 sampling, broad whitefish CPUE in fyke nets was highest in the unconnected lake (TP-05) and in a small creek (TP-04) (Figure 5; Appendix 4). Captured broad whitefish ranged from 372 to 611 mm with a majority of captured fish > 500 mm (Figure 15).

The following year in 2013, CPUE was highest at TP-05 (Figure 5; Appendix 4). A similar length frequency distribution was seen in 2013 as in 2012 with captured broad whitefish ranging from 125 to 591 mm (Figure 15). The few smaller broad whitefish (< 150 mm) captured at TP-04 were likely age 1 or age 2. The presence of large mature adults and lack of age-0 fish suggests the Topagoruk River provides important rearing and recovery habitat for post-spawning adults.

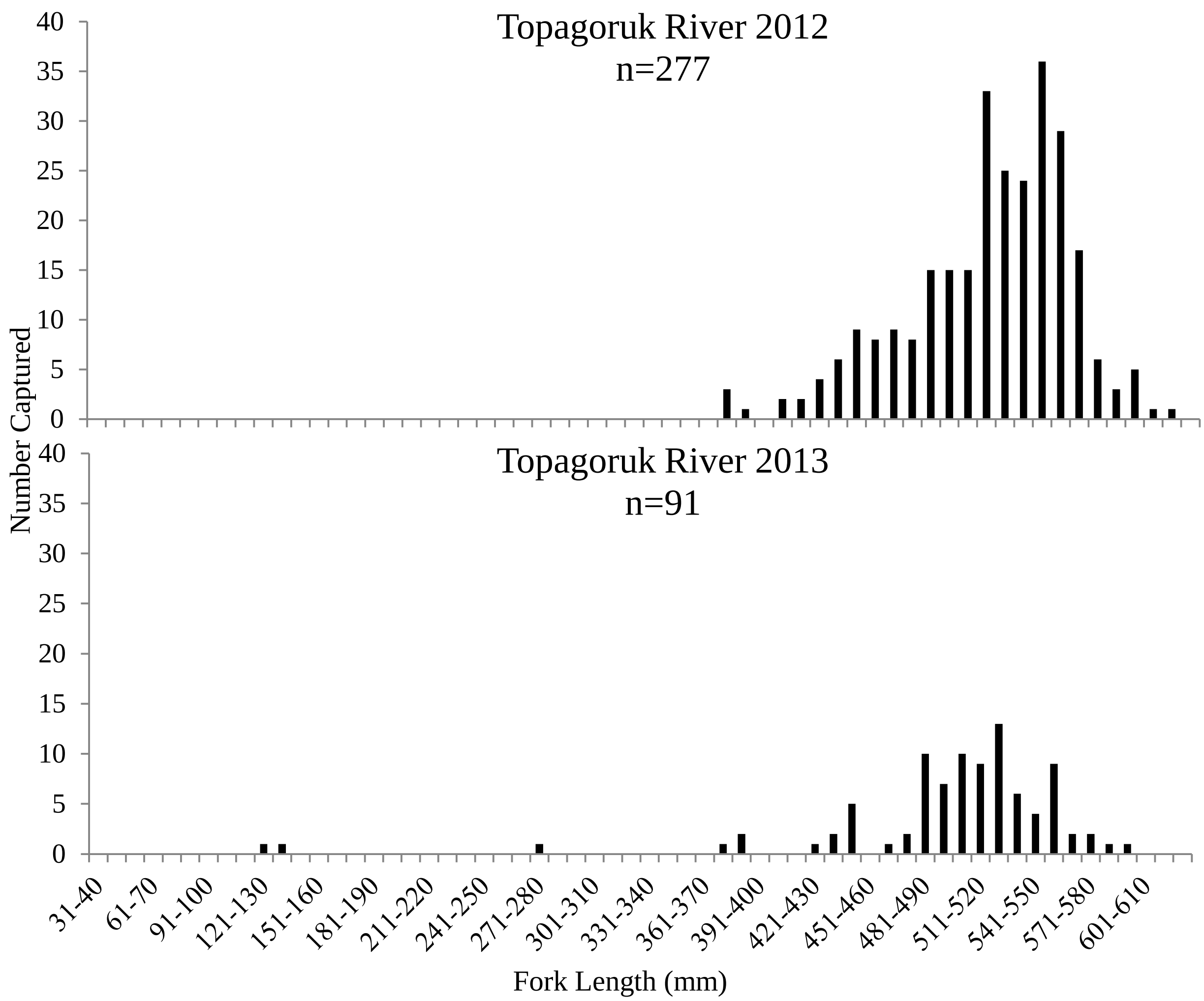

Figure 15. Length frequency distribution of broad whitefish captured in the Topagoruk River, 2012 and 2013 with fyke nets and set gillnets.

Chipp River

In 2012, broad whitefish CPUE in fyke nets was highest at CP-03 where the Chipp River starts at the Ikpikpuk River (Appendix 5). Approximately 97% of the broad whitefish catches in fyke nets at this site were comprised of juveniles < 100 mm suggesting spawning occurs upstream of this location (Figure 16). Broad whitefish captured in fyke nets ranged from 63 to 522 mm in 2012. Sample sites CP-02 and CP-09 had the highest catch rates of broad whitefish with set gillnets in 2012 (Figure 6; Appendix 9). Captured broad whitefish in set gillnets ranged from 466 to 624 mm.

In 2013, broad whitefish CPUE in fyke nets was much lower than in 2012, likely the result of different sites being sampled and more effort being placed on set gillnets. The nine broad whitefish captured in fyke nets ranged from 62 to 546 mm (Figure 16). The juvenile broad whitefish were captured at three locations; CP-15, CP-18, and CP-19. Set gillnet catch rates were comparable to those in 2012, with highest catches occurring at CP-13 and CP-17 (Figure 6; Appendix 9). Broad whitefish captured in set gillnets ranged from 445 to 624 mm. Based on known age-length relationships for broad whitefish in the region, all fish captured < 100 mm during these two sampling events in August were presumed age 0. The presence of large mature adults and age-0 fish suggests this region provides important spawning habitat.

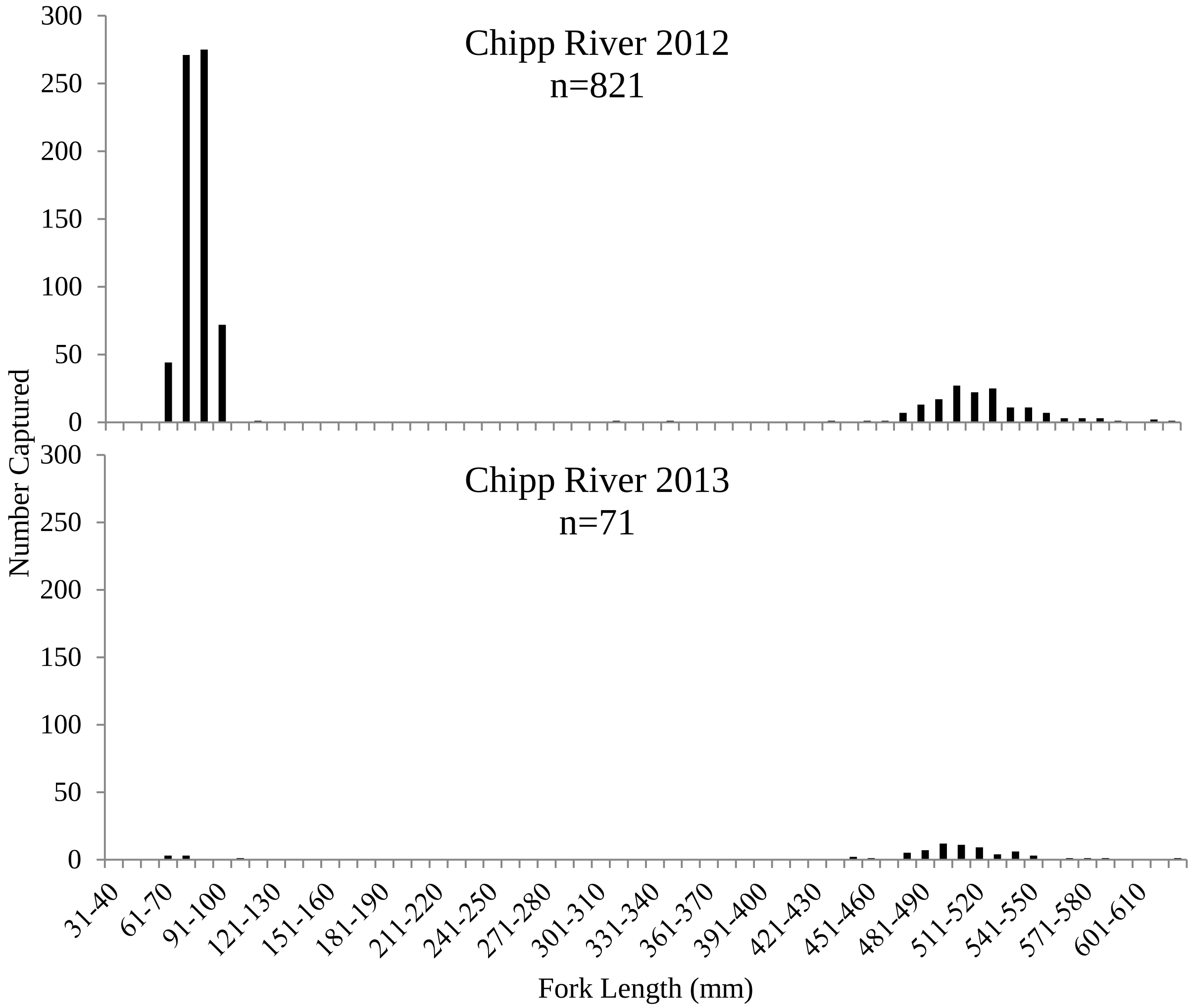

Figure 16. Length frequency distribution of broad whitefish captured in the Chipp River, 2012 and 2013 with fyke nets and set gillnets.

Meade River

During the July 2014 sampling event, broad whitefish CPUE was highest in a connected lake (MD-13), a backwater slough (MD-11), and a lake outlet (MD-14) (Figure 7; Appendix 6). Captured broad whitefish ranged from 75 to 515 mm (Figure 17).

In June 2015, the highest catch rates were in a connected lake at MD-06 (Figure 7; Appendix 6). Captured fish were larger than the prior sampling event, and ranged from 60 to 546 mm (Figure 17). The most abundant size class ranged from 176 to 225 mm.

In August 2015, catch rates were highest in a connected lake at MD-07 (Figure 7; Appendix 6). Moderate catches of broad whitefish were also recorded at MD-08, MD-17, and MD-16. Captured broad whitefish ranged from 40 to 567 mm (Figure 17). The most abundant size class was fish 76–100 mm. Based on age-length relationships of broad whitefish captured during this sampling event, these were likely all age 0 or age-1 fish. More mature adult fish were also captured during this sampling event as compared to the prior sampling events.

When compared to the Topagoruk and Chipp rivers, catches of broad whitefish in the Meade River were comprised primarily of immature fish, with a few mature non-spawners and mature spawners. In contrast, nearly all broad whitefish captured in the Topagoruk River were large mature fish and while many age-0 fish were captured in the Chipp River, the remaining broad whitefish were all large mature adults.

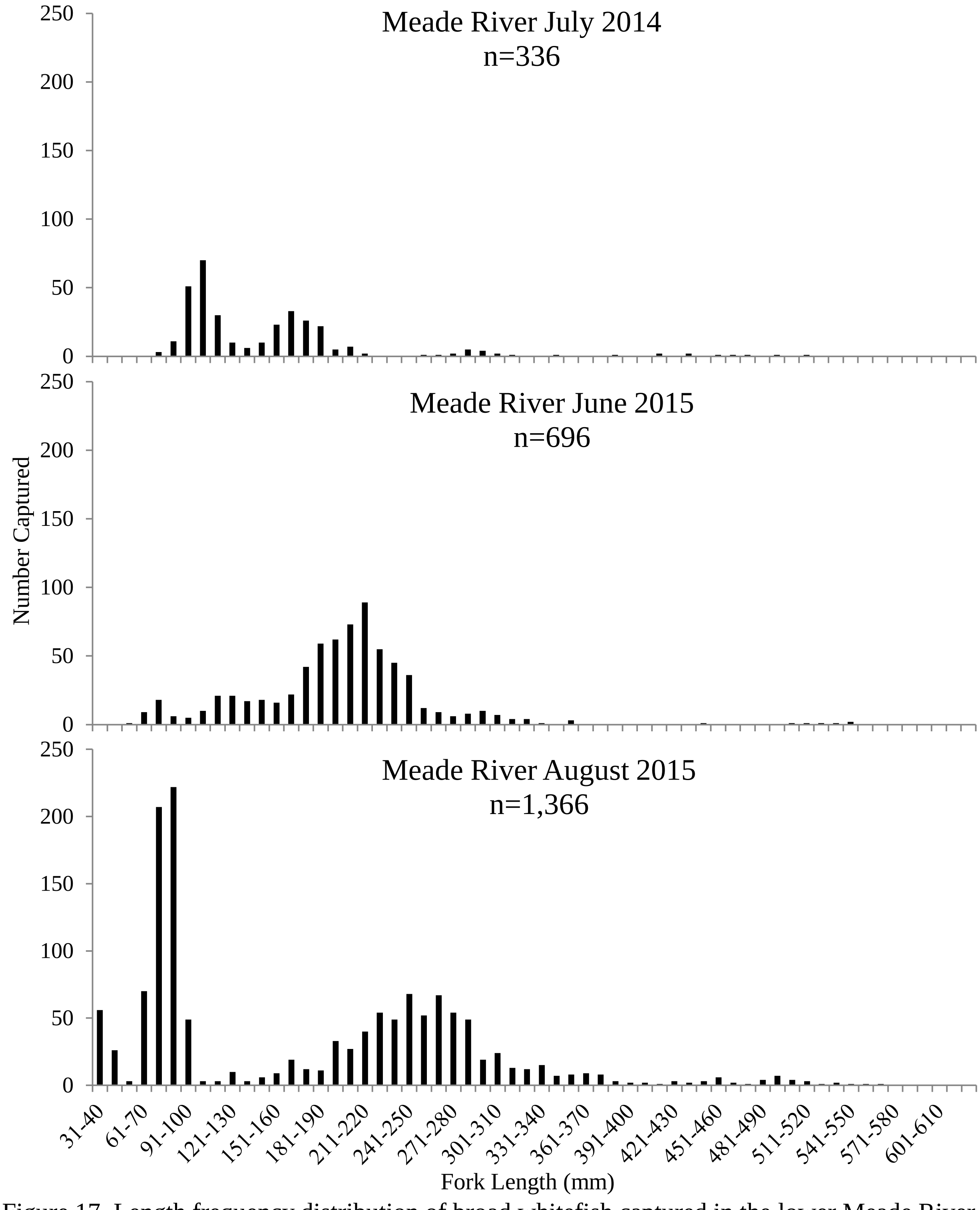

Figure 17. Length frequency distribution of broad whitefish captured in the lower Meade River July 2014, June 2015, and August 2015 with fyke nets.

Length-weight

The majority of broad whitefish captured in the Meade River were < 400 mm whereas in the Chipp and Topagoruk rivers, the majority were > 400 mm (Figure 18). For broad whitefish ages 1-8, no statistical differences were detected in weight at a given length between the Meade River and fish captured in the Chipp River during 1993-94 (Table 8). For broad whitefish age 9+, fish had a larger weight at a given length in the Chipp River 1993-94 when compared to fish in the Chipp and Topagoruk rivers in the current study (Table 8; Appendix 10). Broad whitefish from the Meade River had a larger weight at a given length than fish from Dease Inlet/Admiralty Bay (Table 8).

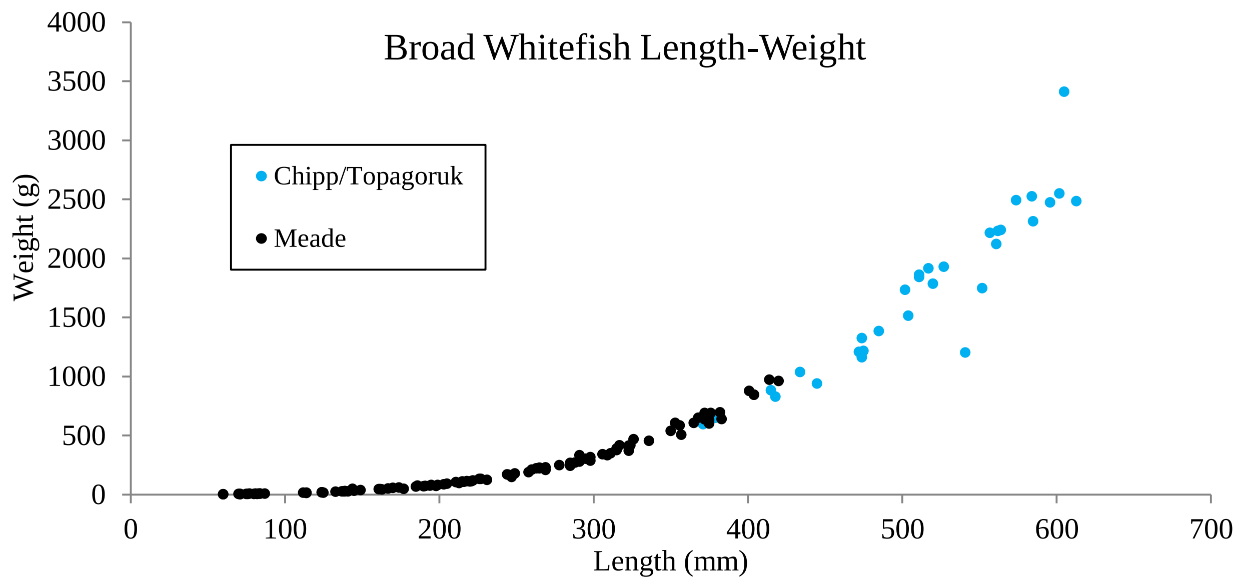

Figure 18. Length-weight relationship for broad whitefish captured in the Chipp River in 2012 (blue dots), Topagoruk River in 2012 (blue dots), and Meade River in 2014 (black dots).

Table 8. Weights at given lengths for broad whitefish caught in the current study compared to other North Slope areas.

Area	Sample Group	Length-Weight Relationship Slope	Length-Weight Relationship Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 200	400	600
Meade River[1]								
	Immature (Age 1-8)	3.202	-5.431	0.99	113	86.5	795.8	-
Chipp River 1993-94[1, 4]								
	Immature (Age 1-8)	3.153	-5.327	0.99	70	84.8	753.9	-
Chipp and Topagoruk Rivers[1]								
	Mature (Age 9+)	3.026	-4.994	0.92	25	-	-	2,586
Chipp River 1993-94[1, 4]								
	Mature (Age 9+)	3.645	-6.625	0.97	67	-	-	3,172
Dease Inlet/Admiralty Bay 1988[2, 3]								
	Immature	3.122	-5.278	0.99	95	80.5	700.9	-
Dease Inlet/Admiralty Bay 1989[2, 3]								
	Immature	3.182	-5.422	0.99	77	79.4	720.7	-
Dease Inlet/Admiralty Bay 1990[2, 3]								
	Immature	3.117	-5.261	0.99	81	81.5	707.3	-

[1]excludes pre-spawning females
[2] includes pre-spawning females
[3]Philo et al. 1993
[4]Moulton et al. 2011

Growth

Captured broad whitefish retained for analysis ranged in age from 0 to 23 years. Broad whitefish from the Meade River age 1 to 8 years had higher growth rates than broad whitefish from the Chipp River 1993-94 (Figure 19; Appendix 7). Broad whitefish age 9+ had similar growth rates between fish captured in the current study and in the Chipp River 1993-94.

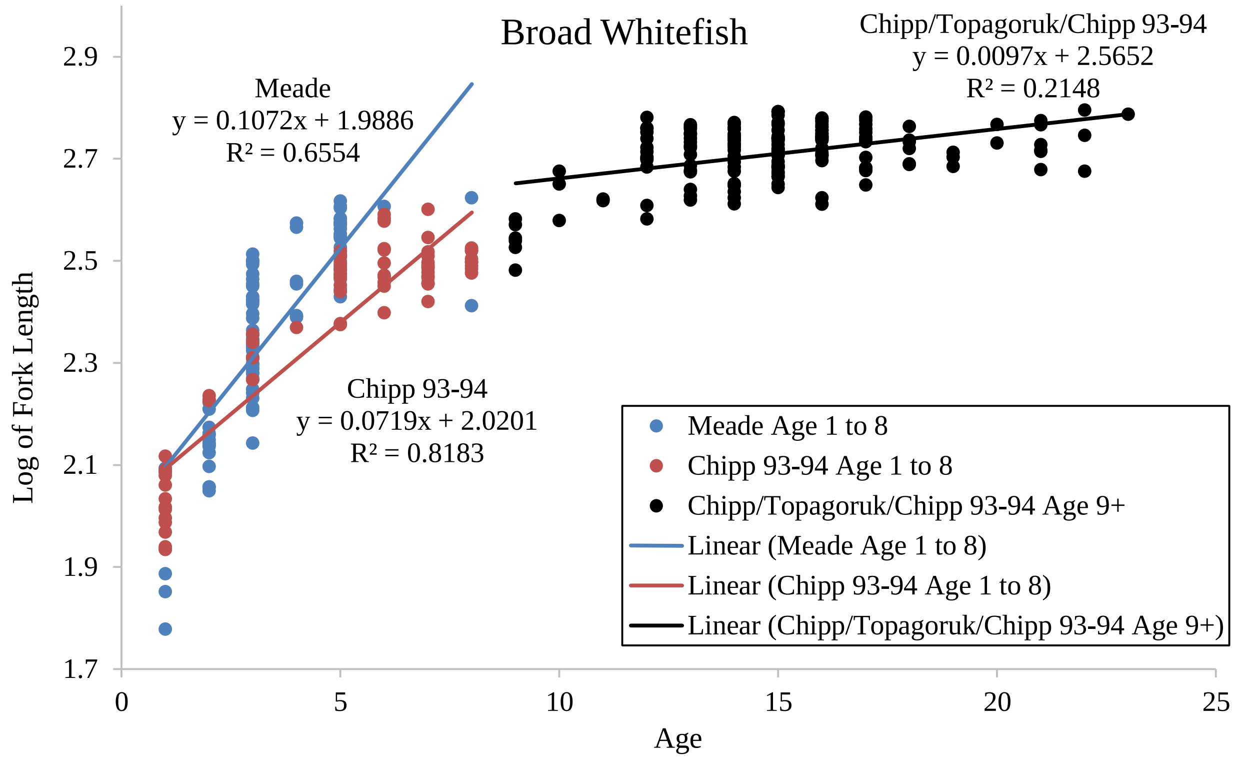

Figure 19. Age-log fork length relationships for broad whitefish from the Meade River 2015, Chipp River 2012, and Chipp River 1993-1994.

Maturity

The reproductive characteristics for broad whitefish are listed in Appendix 11. In the Meade River, all of the 110 fish that were retained for analysis were immature. In contrast, of the 13 broad whitefish retained from the Chipp River, all were mature in pre-spawning condition, 77% of which were males. In the Topagoruk River, of the 24 broad whitefish retained for analysis, five were immature and the remaining 19 were mature. In the Topagoruk River, males and females began maturing at 10 and 11 years, respectively (Figure 20). In the Topagoruk River, all male fish were mature by age 10 and all female fish were mature by age 12. All retained broad whitefish less than < 415 mm were immature (Figure 21).

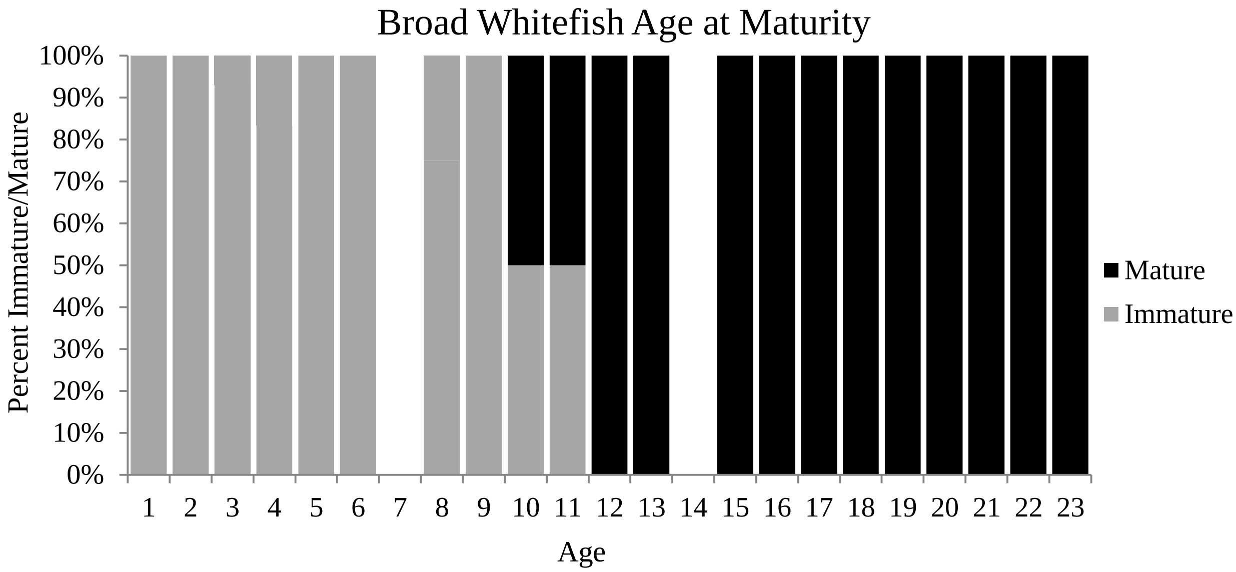

Figure 20. Percent maturity by age class for broad whitefish captured in the Topagoruk River in 2012 (n = 24), the Chipp River in 2012 (n = 13), and the Meade River in 2015 (n = 110).

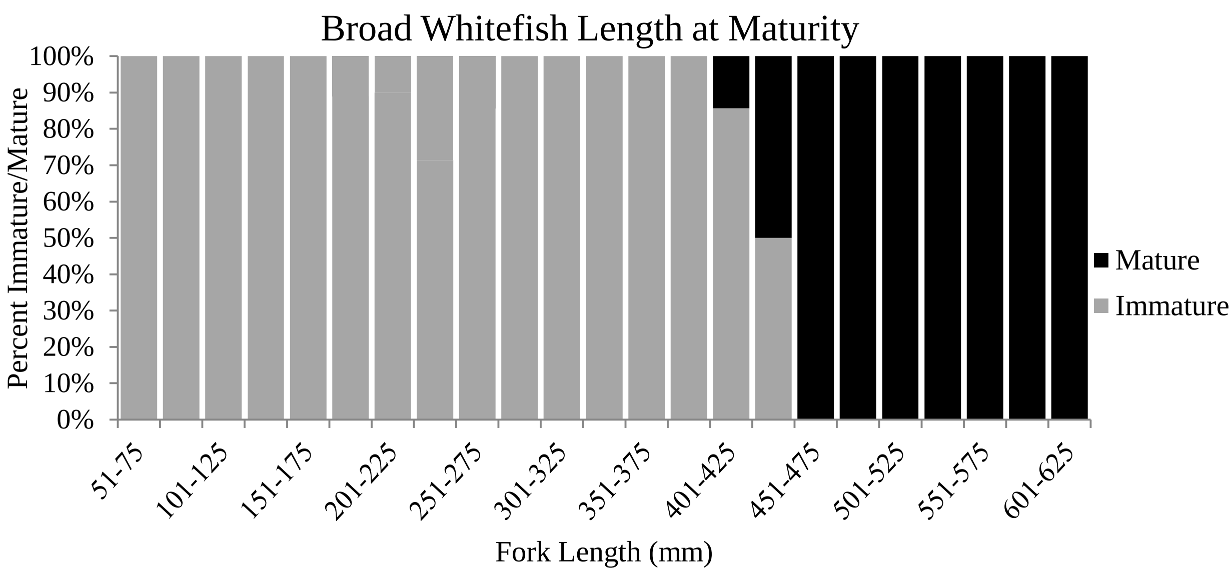

Figure 21. Percent maturity by size class for broad whitefish captured in the Topagoruk River in 2012 (n = 24), the Chipp River in 2012 (n = 13), and the Meade River in 2015 (n = 110).

Humpback Whitefish

During Meade River July 2014 sampling, humpback whitefish were captured in relatively low numbers in a variety of habitats with catch rates highest in a backwater slough (MD-11) (Appendix 6). Captured humpback whitefish ranged from 178 to 435 mm (Figure 22). Length frequency distributions were relatively normally distributed with fish 301–325 mm being the most common size class.

In June 2015, catches of humpback whitefish in the Meade River were highest at lake/lake outlet sites, MD-16, MD-17, MD-14, MD-18, and relatively low at other locations (Appendix 6). Captured humpback whitefish ranged from 55 to 408 mm (Figure 22).

During August 2015 sampling, catches in the Meade River were highest at the lake site MD-07 and relatively low at other locations (Appendix 6). Captured humpback whitefish were larger in size during this sampling and ranged from 57 to 436 mm (Figure 22). The larger average size may be a result of mature adults returning to the Meade River for spawning.

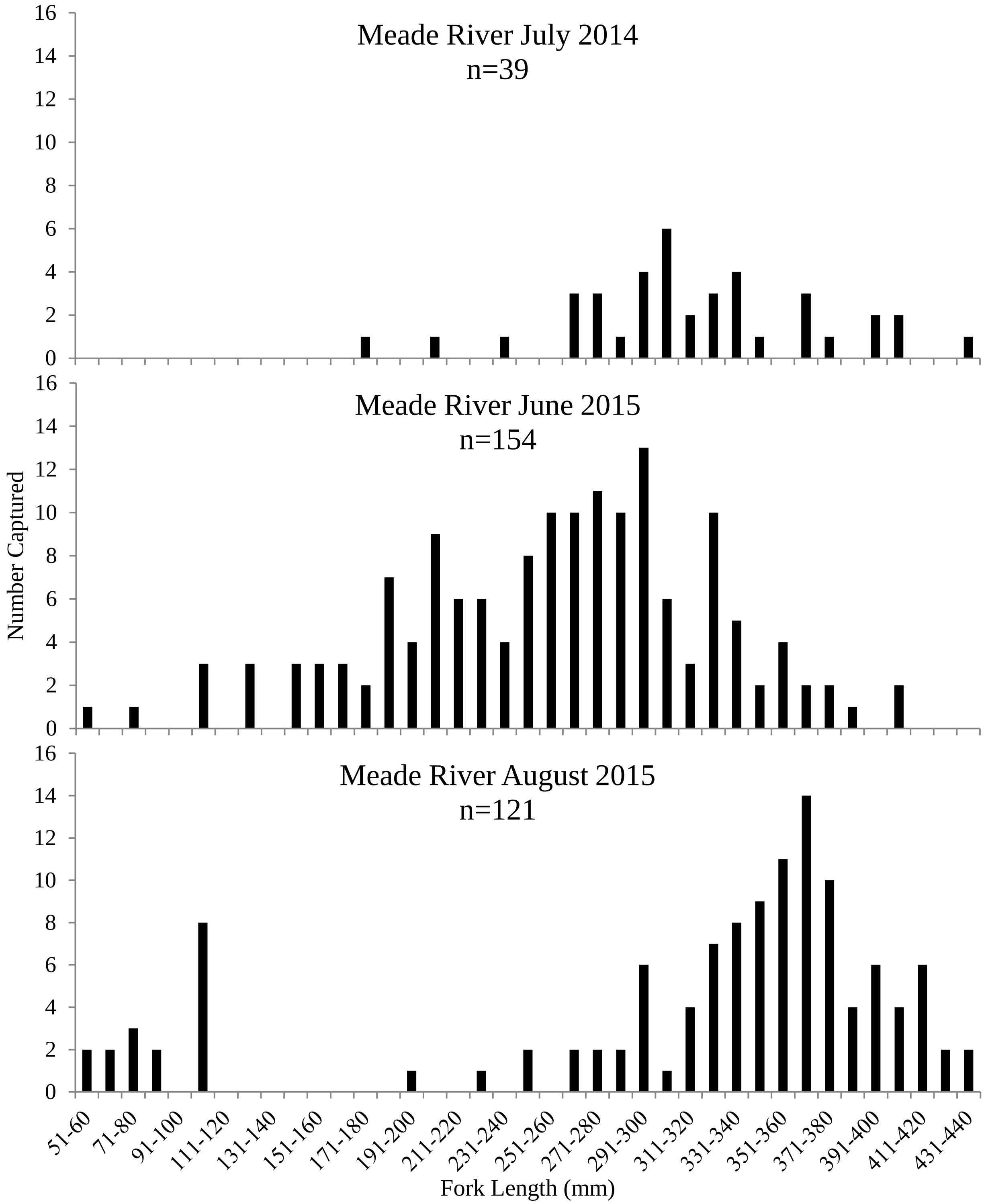

Figure 22. Length frequency distribution of humpback whitefish captured in the lower Meade River in July 2014, June 2015, and August 2015 with fyke nets.

Length-weight

Length-weight relationships for Meade and Chipp River humpback whitefish are presented in Figure 23. Detailed area-wide length-weight analyses included only humpback whitefish from the Meade River because of low sample sizes from other rivers in the current study (Table 9; Appendix 10). Pre-spawning females were removed from the Meade River, Chipp River 2008, and Chipp River 1993-94 data sets for these analyses. Length-weight relationships differed for humpback whitefish between the Meade River and prior research conducted in the Chipp River (Table 9; Appendix 10). For humpback whitefish age <10, length-weight slopes were significantly higher for fish in the Meade River than both the Chipp River 2008 and Chipp River 1993-94 (Table 9; Appendix 10). For humpback whitefish age 10+, ANCOVA results suggest fish have higher weights at a given length in the Meade River compared to prior research in the Chipp River (Table 9; Appendix 10). Length weight relationships are similar between immature humpback whitefish from the Meade River and Dease Inlet/Admiralty Bay (Table 9).

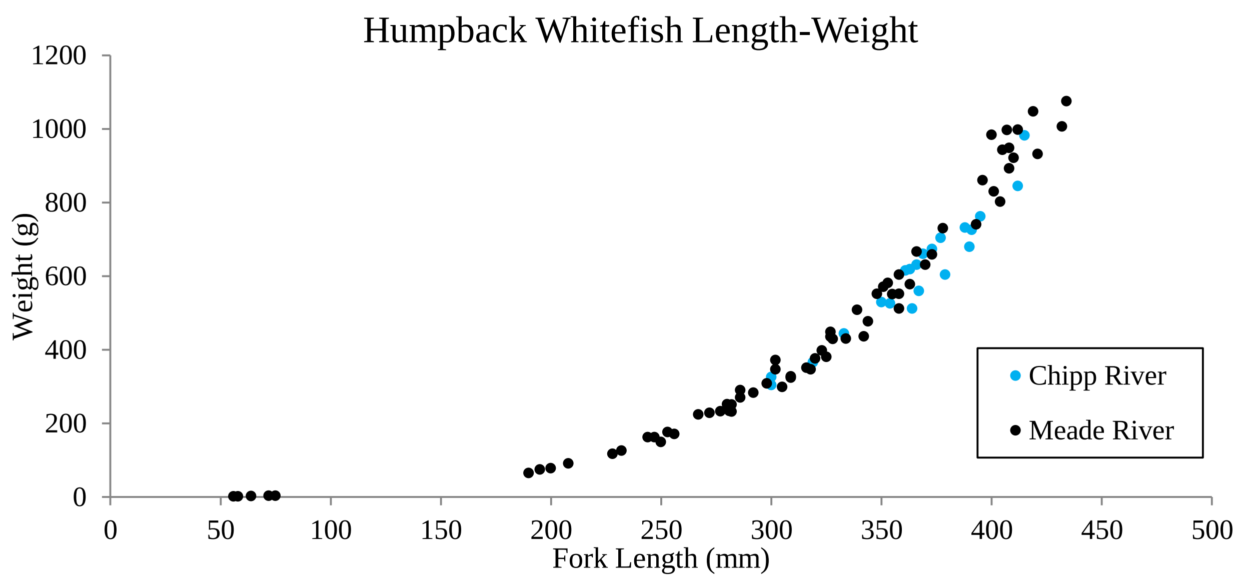

Figure 23. Length-weight relationships for humpback whitefish captured in the Chipp River in 2012 (blue dots) and Meade River in 2015 (black dots).

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

Area	Sample Group	Length-Weight Relationship Slope	Length-Weight Relationship Intercept	r^2	Sample Size	Weight (g) at Comparison Fork Length (mm) 175	250	400
Meade River 2015[1]								
	Immature (Age <10)	3.425	-5.991	0.99	51	49.1	166.7	-
Chipp River 2008[1, 4]								
	Immature (Age <10)	3.107	-5.219	0.99	43	56.2	170.4	-
Chipp River 1993-94[1, 4]								
	Immature (Age <10)	3.182	-5.415	0.99	37	52.8	164.2	-
Meade River 2015[1]								
	Mature (Age 10+)	2.881	-4.565	0.91	12	-	-	854.2
Chipp River 2008[1, 4]								
	Mature (Age 10+)	3.194	-5.425	0.95	29	-	-	769.1
Chipp River 1993-94[1, 4]								
	Mature (Age 10+)	3.335	-5.785	0.92	22	-	-	781.4
Dease Inlet/Admiralty Bay 1988[2, 3]								
	Immature	3.256	-5.586	0.99	62	52.2	166.6	-
Dease Inlet/Admiralty Bay 1989[2, 3]								
	Immature	3.611	-6.439	0.97	62	45.8	165.9	-
Dease Inlet/Admiralty Bay 1990[2, 3]								
	Immature	3.165	-5.379	0.99	83	52.5	162.4	-
Dease Inlet/Admiralty Bay 1988-90[2, 3]								
	All Mature	2.927	-4.741	0.89	61	-	-	750.3

[1]excludes pre-spawning females
[2] includes pre-spawning females
[3]Philo et al. 1993
[4]Moulton et al. 2011

Growth

Growth rates were higher for humpback whitefish age <10 in the Chipp River compared to the Meade River, but did not differ for fish age 10 and older (Figure 24; Appendix 7). Compared to prior studies in the Chipp River, humpback whitefish from the current study in the Chipp and Meade rivers had higher growth rates for all ages (Figure 25; Appendix 7).

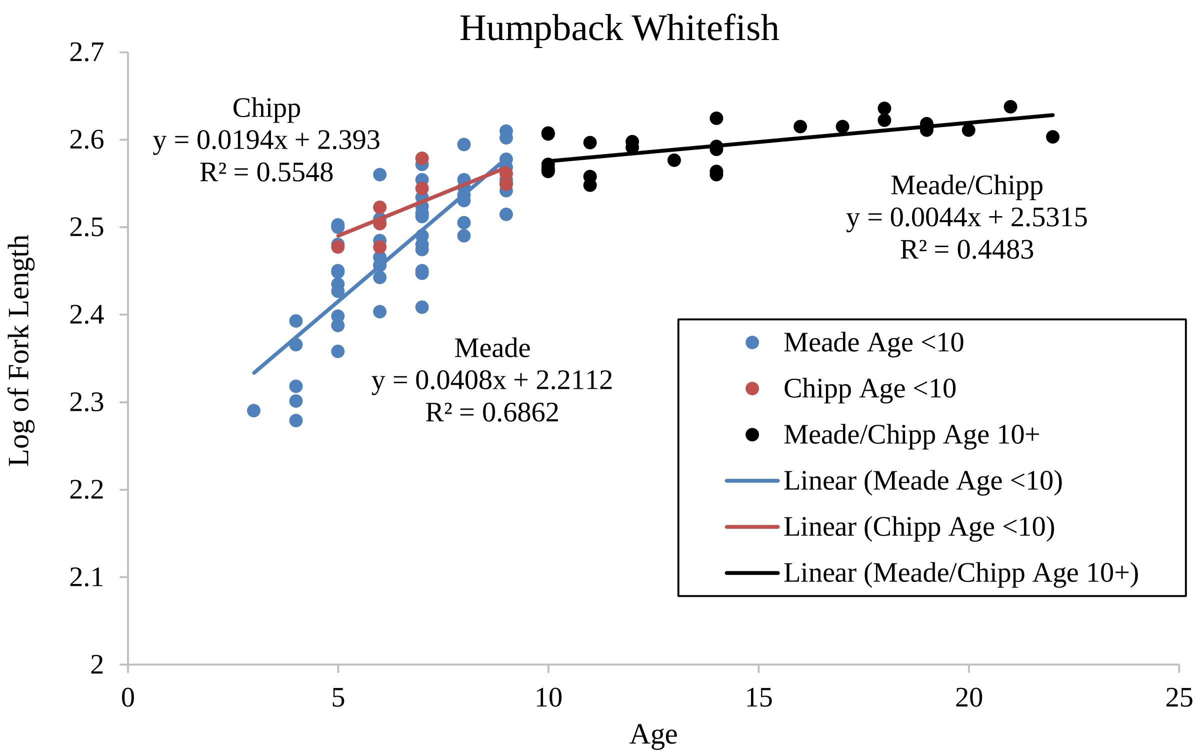

Figure 24. Age-log fork length relationships for humpback whitefish age 10+ for Chipp River 2012 and Meade River 2015 combined, and age <10 for Chipp River 2012 and Meade River 2015.

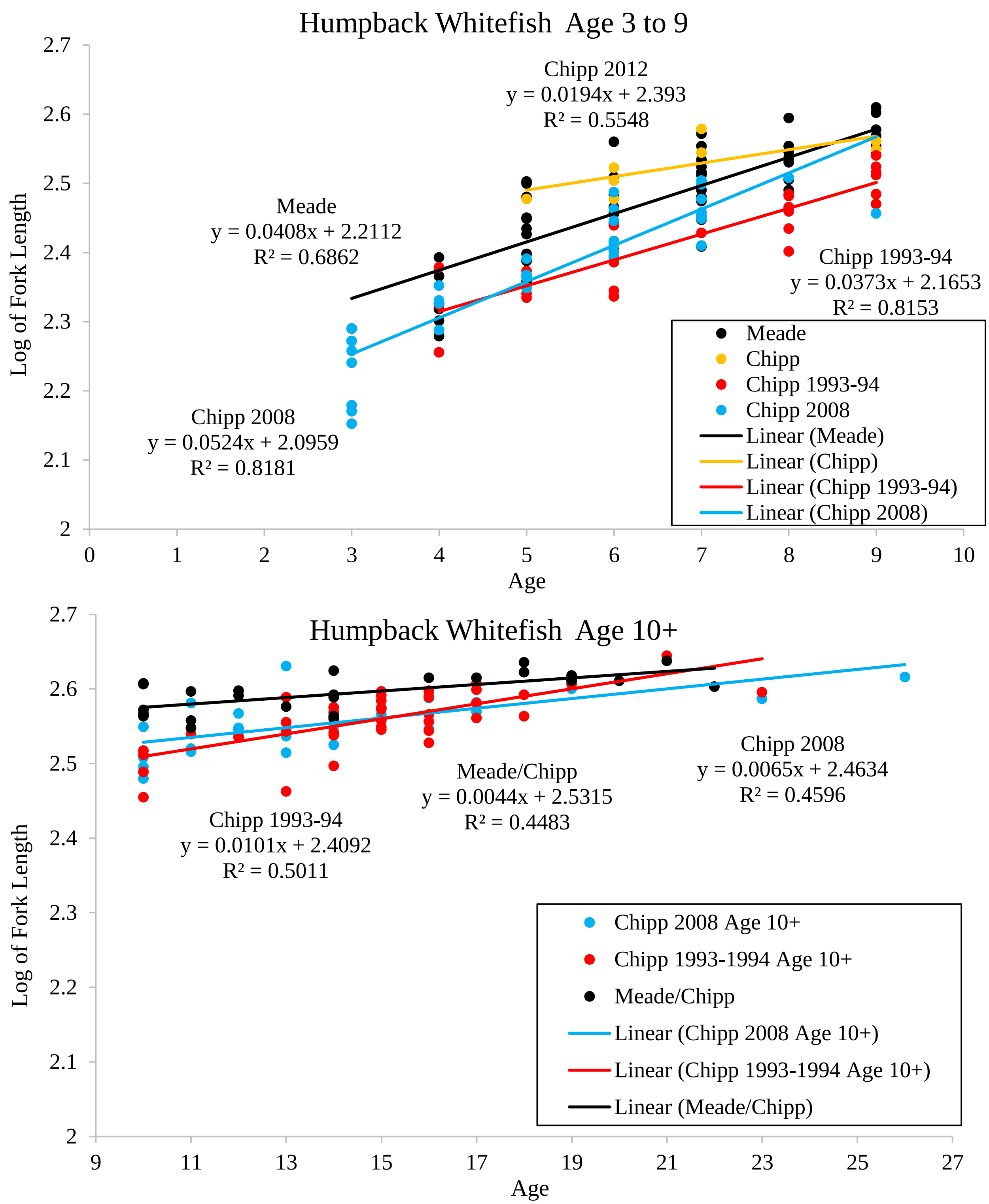

Figure 25. Age-log fork length relationships for humpback whitefish ages 3-9 (top) and age 10+ (bottom) from the Meade River 2015/Chipp River 2012, Chipp River 2008, and Chipp River 1993-1994.

Maturity

The reproductive characteristics for humpback whitefish are listed in Appendix 12. Humpback whitefish in this study first began maturing at age 5 and were 100% mature by age 9 (Figure 26). Fifty percent maturity was obtained between ages 7 and 8. In contrast, humpback whitefish captured in Dease Inlet from 1988–1990 obtained 50% maturity at age 14 for males and age 11 for females (Philo et al. 1993). The percentage of pre-spawners of all mature fish was 58% for males and 29% for females, which are similar percentages to fish captured in Dease Inlet (Philo et al. 1993). The oldest immature fish was age 8 for males and age 7 for females, whereas in Dease Inlet, the oldest immature fish was age 13 for both sexes (Philo et al. 1993). All fish < 298 mm were immature whereas all fish > 350 mm were mature (Figure 27).

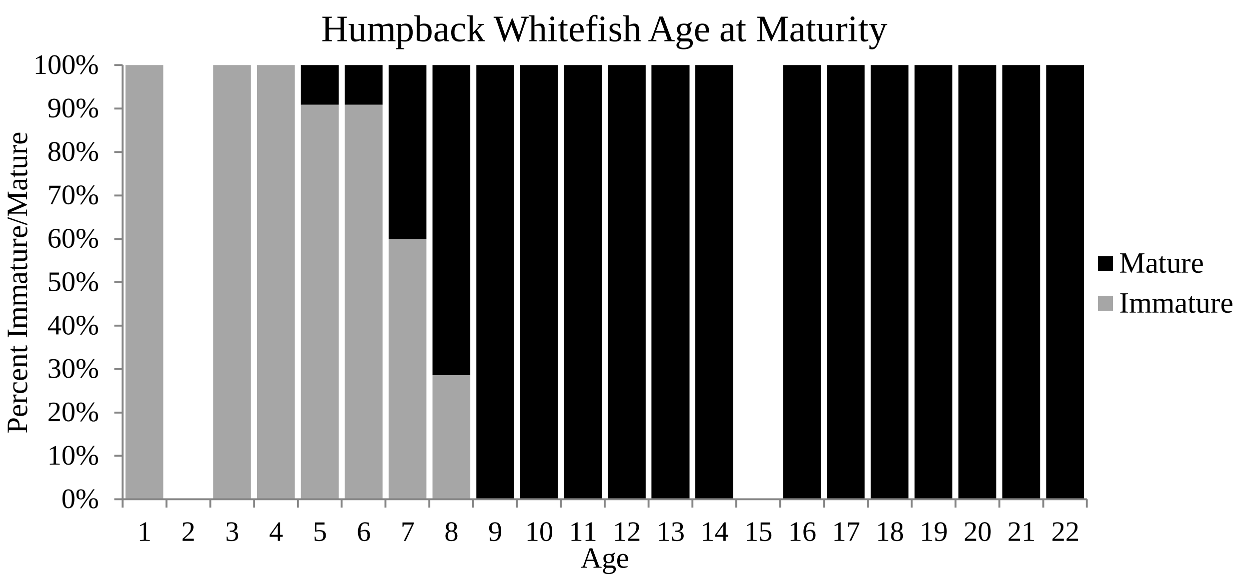

Figure 26. Percent maturity by age class for humpback whitefish captured in the Chipp River in 2012 (n = 21) and Meade River in 2015 (n = 71).

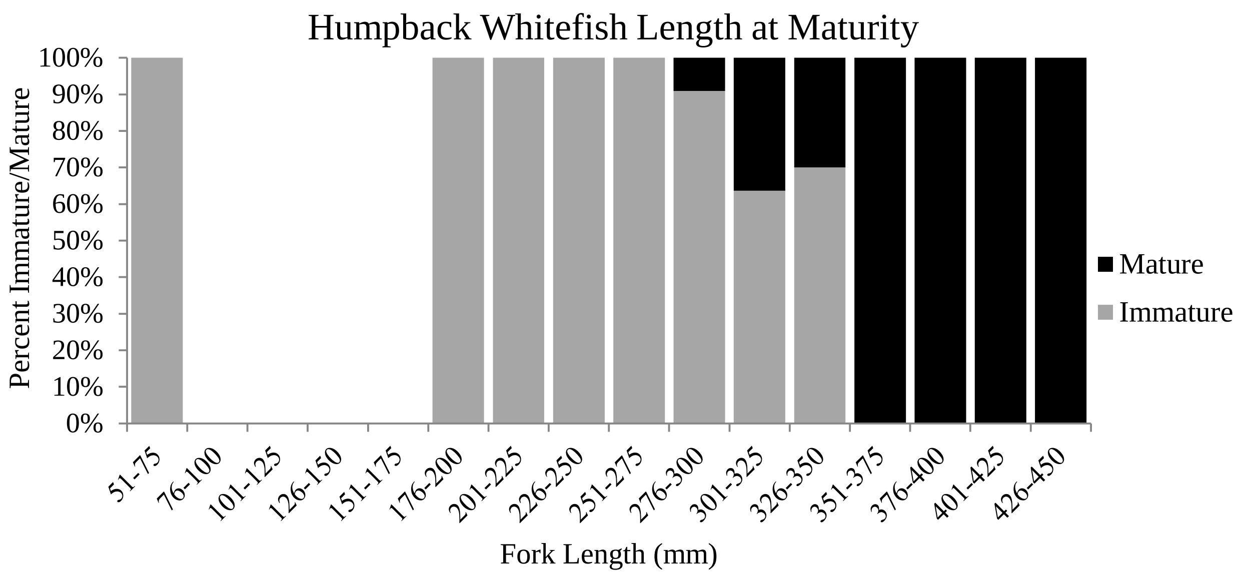

Figure 27. Percent maturity by size class for humpback whitefish captured in the Chipp River in 2012 (n = 21) and Meade River in 2015 (n = 71).

Arctic Grayling

Topagoruk River

The majority of Arctic grayling were captured at TP-06 in 2012 (Figure 5; Appendix 4). Fork lengths ranged from 55 to 432 mm with approximately 84% of the Arctic grayling less than 100 mm (Figure 28).

Site TP-06 was not sampled in 2013 so catches of Arctic grayling only occurred at TP-01 and TP-04 (Figure 5; Appendix 4). Catch rates at those locations in 2013 were similar to catch rates in 2012. Fork length ranged from 70 to 395 mm.

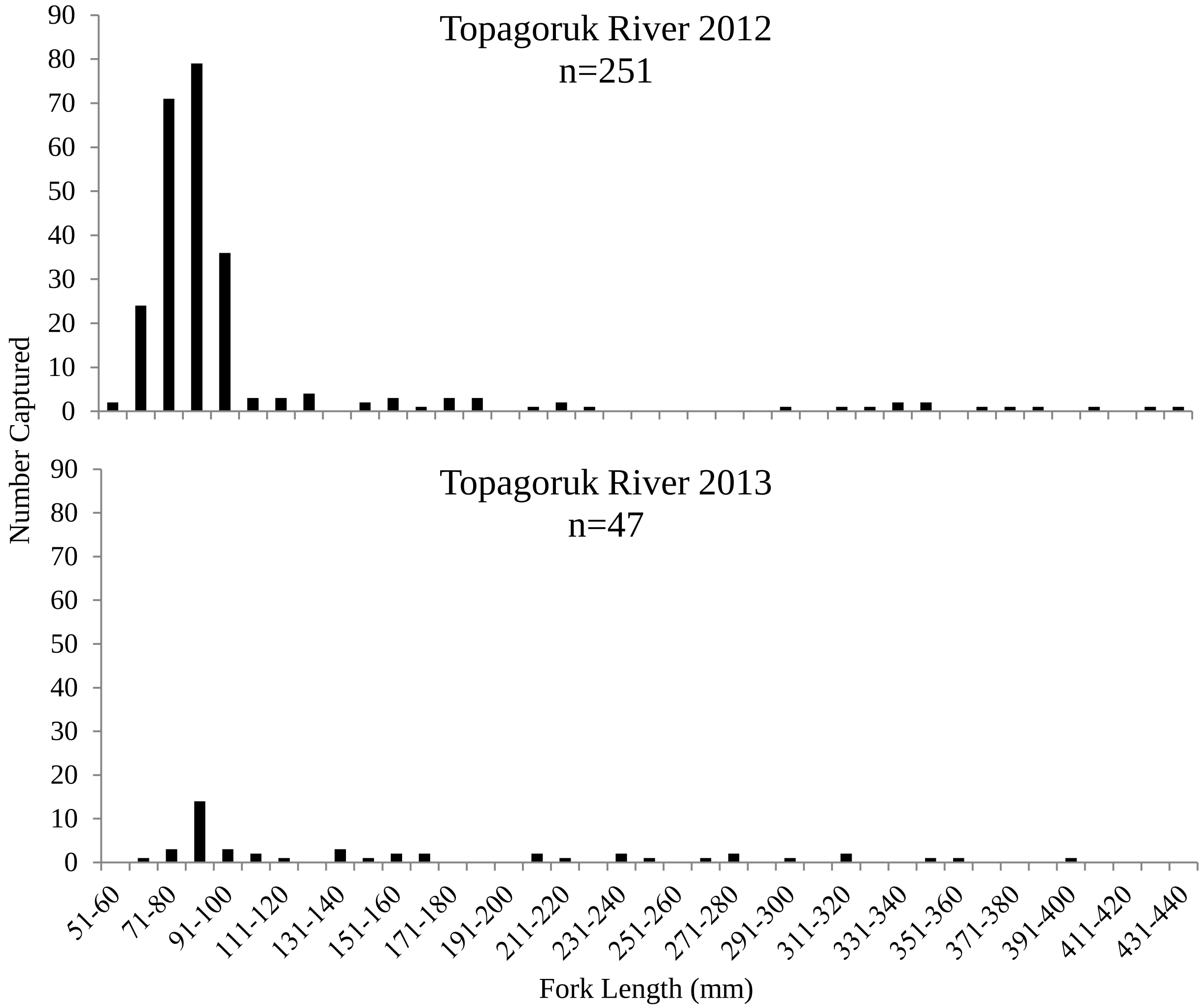

Figure 28. Length frequency distribution of Arctic grayling captured in the Topagoruk River, 2012 and 2013 with all gear types.

Meade River

Arctic grayling were the only fish species captured at every sample site in the Meade River. During July 2014, Arctic grayling were captured in a variety of habitats with highest catch rates at MD-11, MD-15, and MD-09 (Figure 7; Appendix 6). Captured Arctic grayling ranged from 62 to 370 mm (Figure 29). The most common size class was 76–100 mm which was likely age-1 or age-2 fish.

In June 2015, highest catches occurred at the mouth of a small unnamed creek (MD-19) that flows into the Inaru River (Figure 7; Appendix 6). Catches were also high in lakes (MD-18, MD-06, and MD-01) and a lake outlet (MD-03) (Figure 7). Captured Arctic grayling ranged from 59 to 456 mm (Figure 29). Besides the smallest and largest size classes, all of the size classes were captured in relatively equal proportions suggesting a complete population lives in this area with good recruitment and reproductive success.

In August 2015, catch rates were highest at lake MD-18 and relatively low at other locations (Figure 7; Appendix 6). Captured Arctic grayling ranged from 88 to 375 mm (Figure 29).

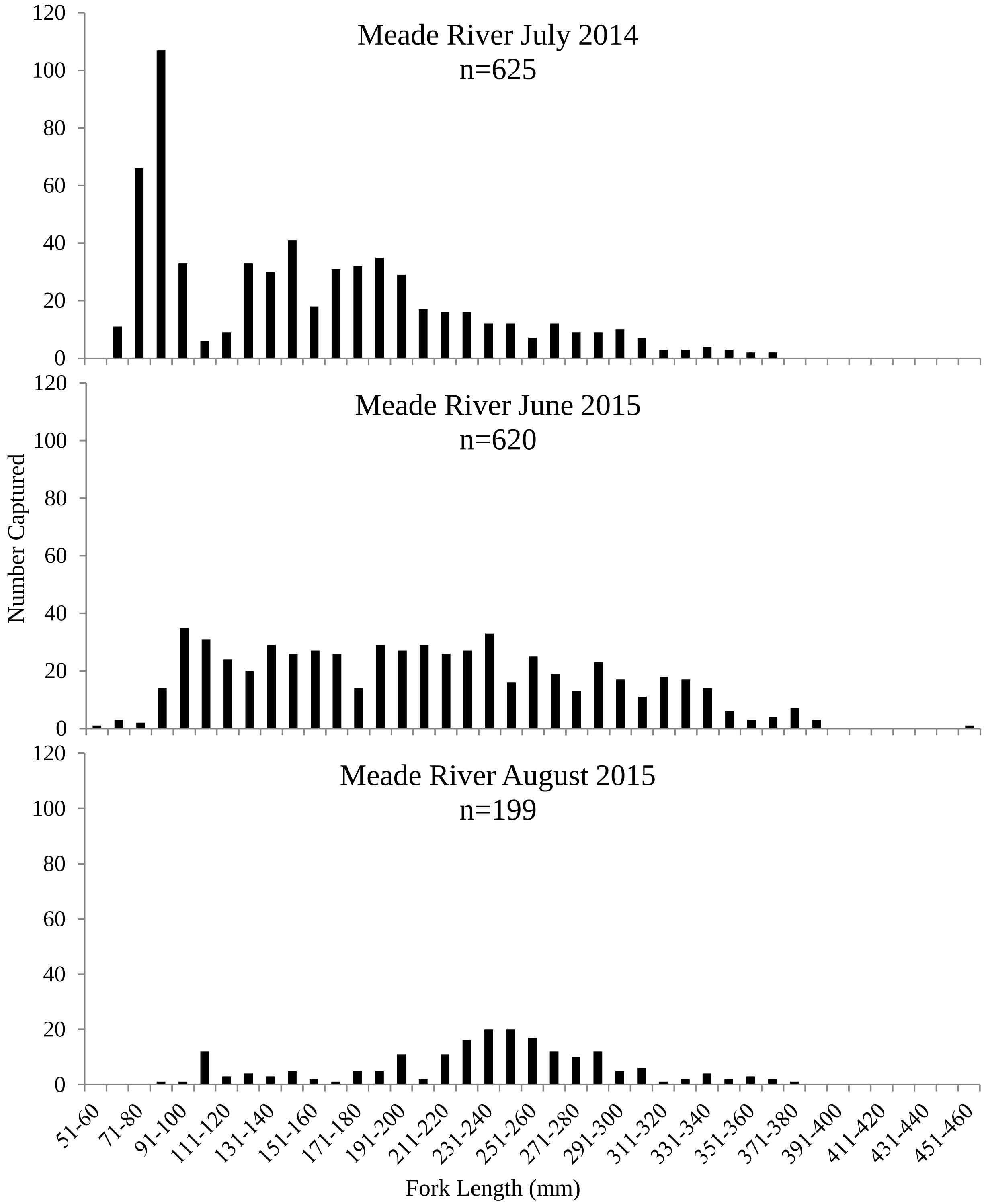

Figure 29. Length frequency distribution of Arctic grayling captured with fyke nets in the lower Meade River in July 2014, June 2015, and August 2015.

Length-weight

Unlike broad whitefish, Arctic grayling have not been studied as extensively on the North Slope so there was minimal historical data for comparisons. Arctic grayling in the Meade and Topagoruk rivers had greater weights at a given length than Arctic grayling from Teshekpuk Lake in 2004 (Figure 30; Table 10; Appendix 10).

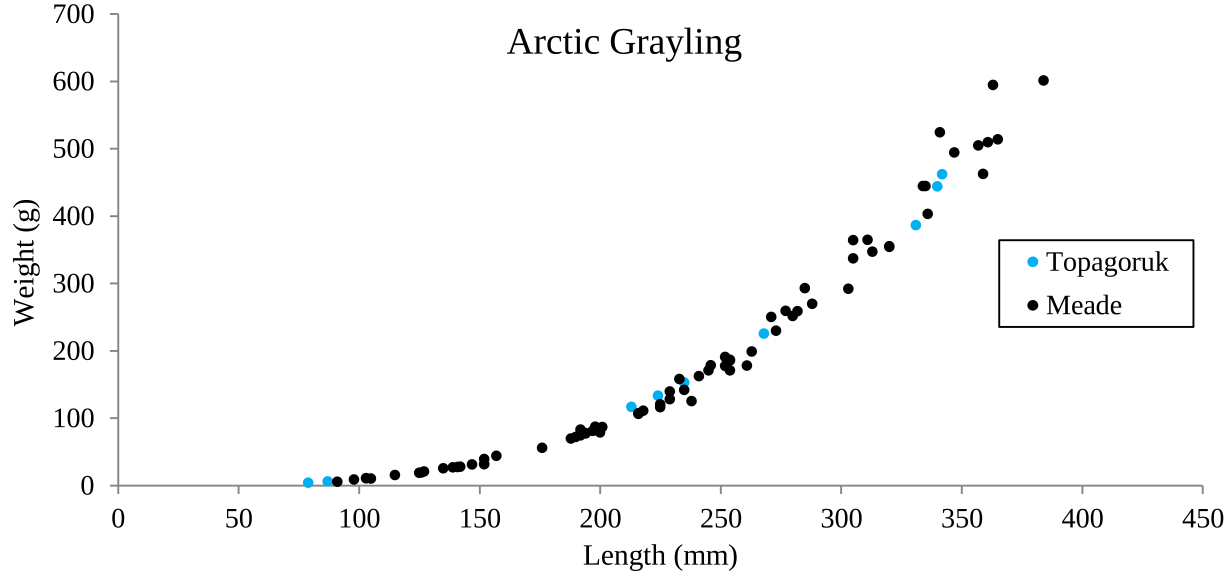

Figure 30. Length-weight relationships for Arctic grayling captured in the Topagoruk River in 2012 (blue dots) and Meade River in 2015 (black dots).

Table 10. Weights at given lengths for Arctic grayling caught in the Topagoruk/Meade rivers and Teshekpuk Lake 2004 age <11.

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
Topagoruk and Meade Rivers								
	All fish	3.183	-5.396	0.99	92	33.9	123.3	503.2
Teshekpuk Lake 2004[1]								
	All fish	3.209	-5.499	0.98	32	30.5	111.9	462.3

[1] Moulton et al. 2007

Growth

In the Chipp and Topagoruk rivers, Arctic grayling ranged in age from 1 to 6 years. In the Meade River, Arctic grayling ranged in age from 2 to 10 years. Growth rates for Arctic grayling ages 2-5 were higher in the Meade River than Teshekpuk Lake, but similar for fish 6+ years (Figure 31; Appendix 7).

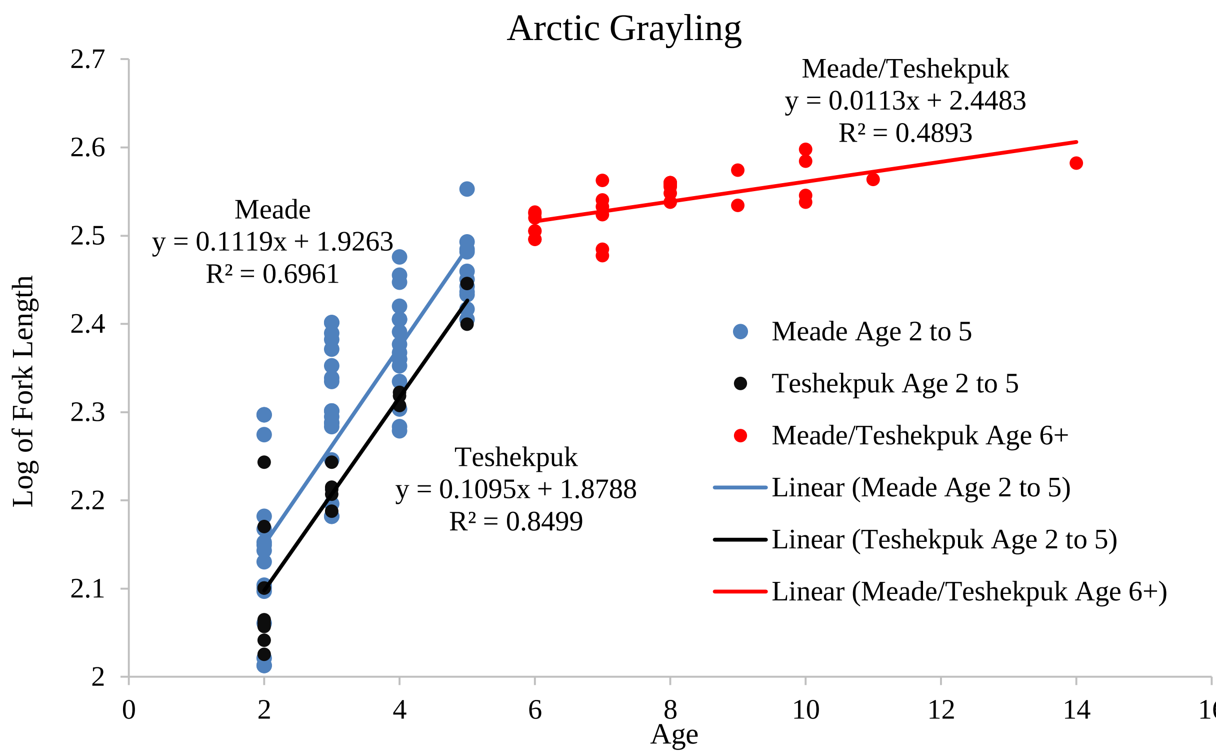

Figure 31. Age-log fork length relationships for Arctic grayling captured in the Meade River in 2015 and Teshekpuk Lake in 2004.

Maturity

The reproductive characteristics of Arctic grayling are listed in Appendix 8. The male Arctic grayling in this study first began maturing at age 4 and female Arctic grayling first began maturing at age 3, with all fish being mature by age 6 (Figure 32). All fish < 233 mm were immature while all fish > 300 mm were mature (Figure 33).

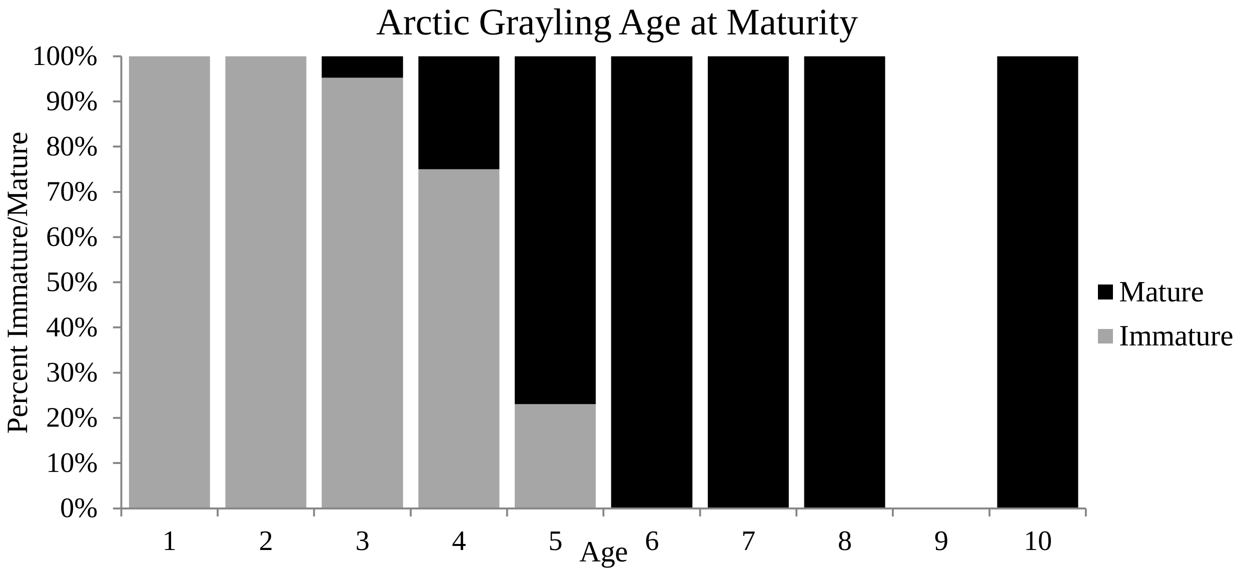

Figure 32. Percent maturity by age class for Arctic grayling captured in the Topagoruk River in 2012 (n = 7), Chipp River in 2012 (n = 2), and Meade River in 2015 (n = 77).

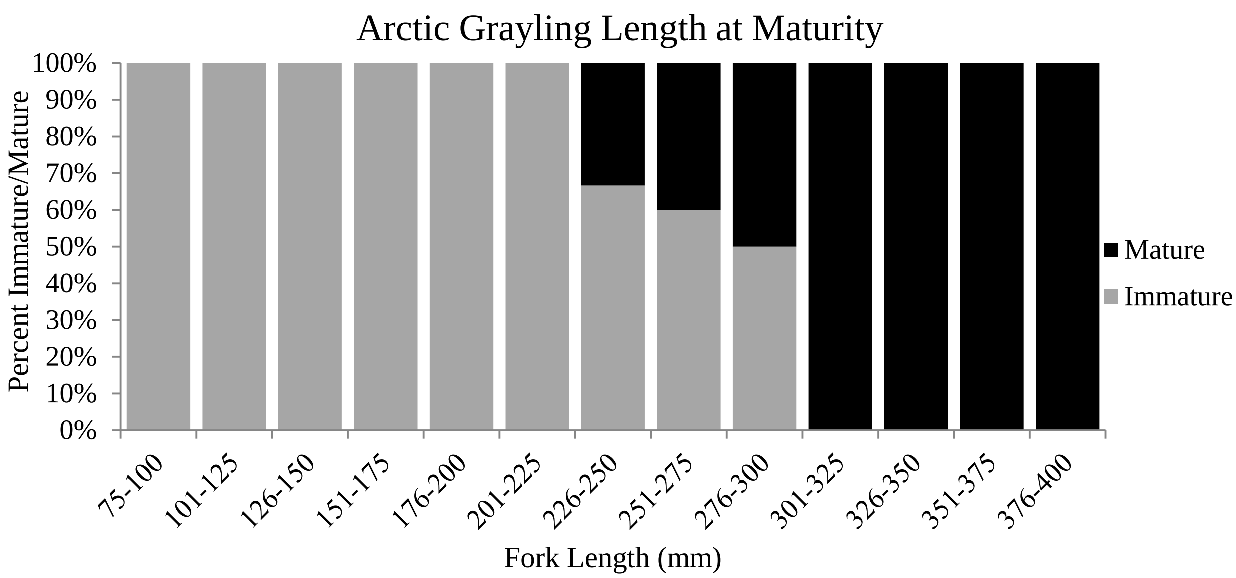

Figure 33. Percent maturity by size class for Arctic grayling captured in the Topagoruk River in 2012 (n = 7), Chipp River in 2012 (n = 2), and Meade River in 2015 (n = 77).

Other species

Topagoruk River

Relatively few other species were captured in the Topagoruk River. Slimy sculpin were the fourth most common species captured in the Topagoruk River with catches highest in small creek at TP-07 (Figure 5; Appendix 4). Ninespine stickleback were also captured at a majority of the sample sites. Only three humpback whitefish were captured in the Topagoruk River, two adults and one juvenile, likely age 1.

Chipp River

Longnose sucker were the third most commonly captured species in 2012 with catch rates highest in a backwater slough at CP-08 (Figure 6; Appendix 5). Approximately 94% of all longnose sucker between both years were ≤76 mm and were likely age-0 or age-1 fish.

Humpback whitefish were captured at every fyke net location in 2012 except at CP-01 and were not captured in 2013 in fyke nets (Appendix 5). Humpback whitefish captured in fyke nets ranged from 61 to 425 mm) with 95% ≤80 mm. Humpback whitefish captured in set gillnets between 2012 and 2013 ranged from 302 to 454 mm.

Seven chum salmon were captured with set gillnets in 2012 at one location in the Chipp River (CP-02) (Figure 6; Appendix 9). Five pink salmon were captured with set gillnets during 2012 and 2013 in the Chipp River. Low catches of salmon suggest either timing of sampling did not coincide with the peak migration, or the runs of chum and pink salmon are relatively small within this drainage.

Slimy sculpin were captured in a variety of habits in 2012 and 2013 including the Chipp River main channel (CP-03), a backwater slough (CP-08), a lake (CP-20), and lake outlet (CP-19) (Figure 6; Appendix 5). Alaska blackfish were captured in a backwater slough in 2012 and in relatively high numbers in a lake (CP-18) in 2013.

Two northern pike (564 mm and 582 mm) were captured in 2012 in set gillnets at CP-03 (Figure 6; Appendix 9). Fyke net catches of northern pike only occurred in 2013 in a lake (CP-20) and the lake outlet (CP-19) and fork length ranged from 80 to 211 mm.

Burbot were captured at each fyke net location in 2012 and 2013 except CP-01 and CP-05. In 2012, burbot ranged from 122 to 720 mm. In 2013, burbot ranged from 71 to 690 mm. The 71 mm juvenile was captured in the isolated lake at CP-18 (Figure 6).

Ninespine stickleback were only captured in the backwater slough (CP-08) in 2012 and in a connected lake (CP-20), its outlet (CP-19), and an isolated lake (CP-18) in 2013 (Figure 6).

In 2012, one 84 mm rainbow smelt and one 74 mm round whitefish were captured in a fyke net at CP-03 (Figure 6).

Meade River

Ninespine stickleback were captured at every location except MD-02 in July 2014, with highest catches occurring at MD-11 (Figure 7; Appendix 6). During the June 2015 sampling event, catches were much lower and only occurred at a couple locations. In August 2015, catches were highest at MD-18.

Burbot were captured at every location except MD-02 and MD-15 in July 2014 (Figure 7; Appendix 6). A total of 31 burbot were captured and ranged from 80 to 500 mm, many of which were juveniles. Nine burbot were captured at only a few locations in June 2015, but by August, catch rates increased and a total of 34 were captured and burbot occurred at every sampling location. In August, captured burbot ranged from 52 to 680 mm.

Six rainbow smelt were captured in July 2014. Of those captured, one was 210 mm and the remaining five ranged from 67 to 87 mm, which were likely age-1 fish. In June 2015, catches of the 34 rainbow smelt primarily occurred in a connected lake at two sites (MD-16 and MD-17) (Figure 7; Appendix 6). Rainbow smelt captured at those two locations ranged from 186 to 265 mm, and were in pre-spawning condition suggesting spawning would occur nearby. By August 2015, catches of rainbow smelt only occurred at MD-17 and all fish were age 0 ranging from 37 to 42 mm, confirming spawning occurred nearby.

Longnose sucker were captured in July 2014 and June 2015 in a variety of habitats (Appendix 6). Between both sampling events, longnose sucker averaged 228 mm (range: 97–295 mm). No longnose suckers were captured in August 2015.

Threespine stickleback were only captured in July 2014 at two locations (MD-09 and MD-11) (Figure 7). Two slimy sculpin were captured at MD-14 and MD-15 in July 2014. One saffron cod was captured in 2014 at MD-12 (Figure 7).

Radiotelemetry

A total of 62 broad whitefish were implanted with radio transmitters in the Topagoruk River in 2013, primarily at site TP-04 (n = 50), but also at site TP-01 (n = 2) and TP-05 (n = 10) (Figure 5). Six radio relocation flights were conducted which relocated 92% (57) of the radiotagged fish at least once.

Relocation histories for each fish were assessed for likelihood of mortality. For each individual fish, its first movement to a new location was included in the analysis. If that fish did not move from that location for multiple tracking events, particularly with a very strong signal strength that suggested the tag was out of the water, all subsequent locations for that fish after initial detection were deleted and not considered in further analyses. The likelihood of an individual being located in a nearby lake was evaluated prior to exclusion from further analysis. For example, because the main river channels were primarily flown, if weak signal strengths were recorded for a fish on multiple relocation flights and there was a well-connected lake nearby, the fish was assumed to be alive in that lake and was not excluded from analyses.

The first relocation flight was conducted on October 5, 2013 approximately 90 days post tagging and 73% (45) of radiotagged broad whitefish were relocated (Figure 34). Fish dispersed widely from the tagging location, by moving either within the Topagoruk River (60% of relocated fish); or into the Inaru (2%), Meade (7%), Chipp (9%), Oumalik (11%), and Ikpikpuk (11%) rivers. The timing of this flight corresponded to spawning timing, which suggested some of these locations may be near broad whitefish spawning areas. Broad whitefish relocated in the Ikpikpuk River, upstream from the confluence with the Chipp River, were found in an area used by broad whitefish radiotagged in 2003 in the Teshekpuk Lake outlet and Meade River presumably for spawning (Morris et al. 2006). Since broad whitefish do not spawn in consecutive years, not all of these fish were actively spawning. All of the fish radiotagged at TP-05, a lake with no surface water connection during sampling, remained in the lake. The one fish relocated in the Inaru River was later captured by a fisherman.

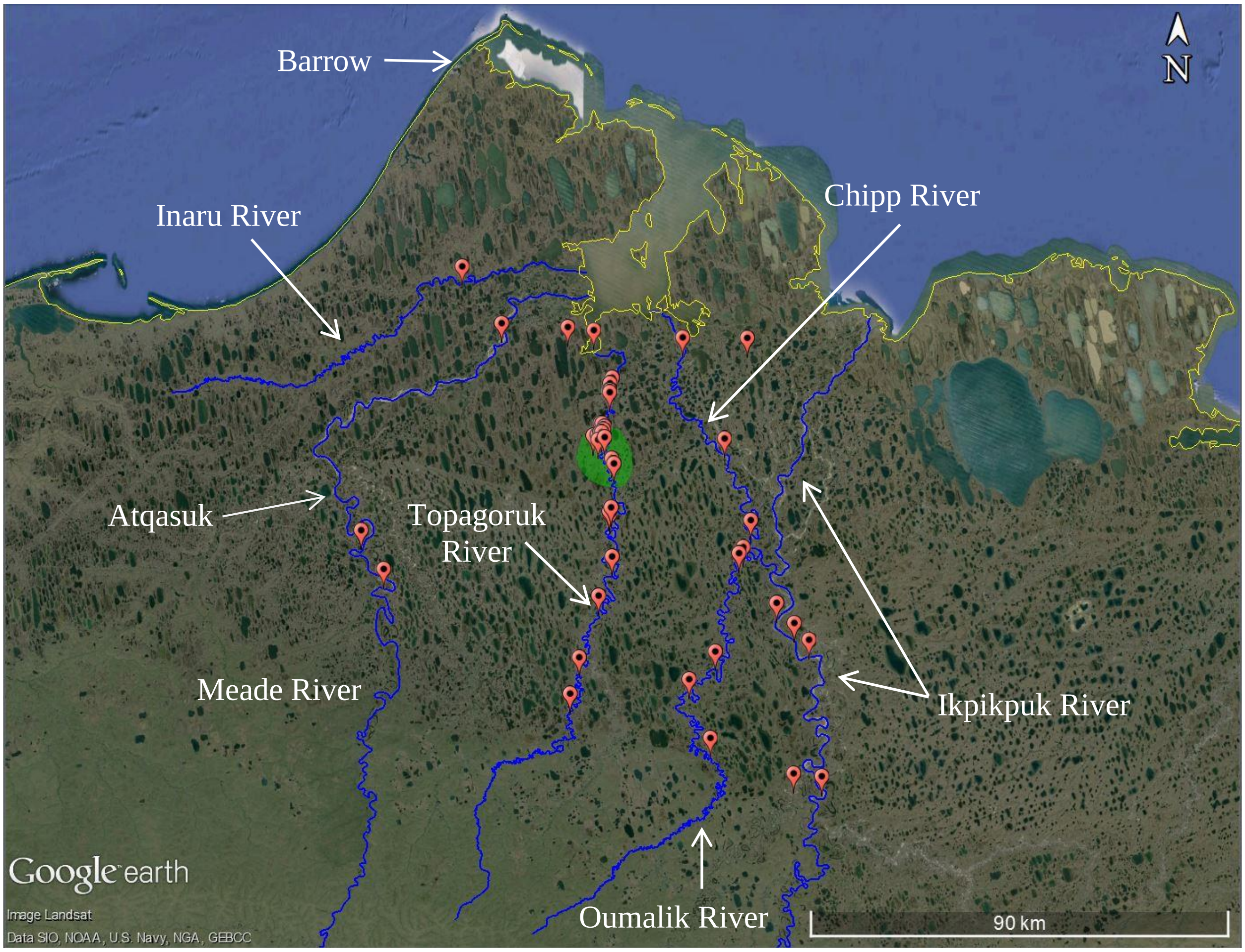

Figure 34. Relocations of 45 of 62 radiotagged broad whitefish (red dots) on October 5, 2013. The green circle on the Topagoruk River represents tagging location, June 27–July 2, 2013.

Poor weather conditions prevented relocation flights in November 2013, which would have identified overwintering locations. The next relocation flight occurred July 26, 2014, well after break-up, and identified summer distribution for feeding. All major river drainages were flown during this flight. After approximately one year post tagging, a total of 32% (20) of the radiotagged broad whitefish from the Topagoruk were relocated (Figure 35). An additional nine fish were relocated on this flight, but not included due to assumed mortality. Most of the relocated fish (70%) were still in the Topagoruk River. Of the 10 radiotagged in the perched lake, 60% of those fish were detected still in the lake and the remaining 40% were not detected during this flight. A small proportion of relocated fish were each detected in the Chipp (20%), Ikpikpuk (5%) and Meade rivers (5%).

In July 2014, an additional eight broad whitefish were radiotagged in the lower Meade River, all of which were relocated at least once. The July 26, 2014 flight relocated 75% (6) of the radiotagged broad whitefish (Figure 35). Of those, five remained close to their tagging location and one moved slightly upstream.

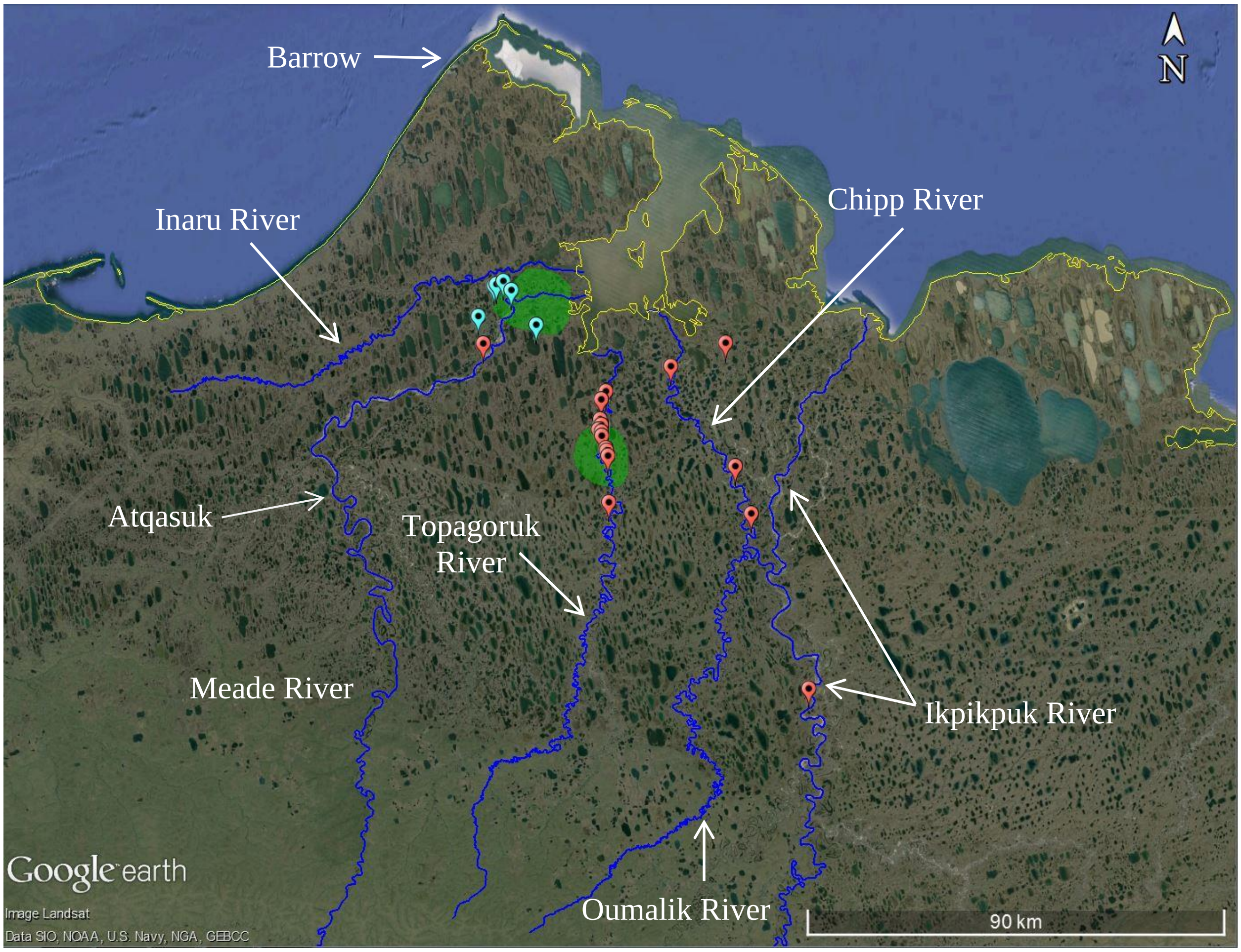

Figure 35. July 26, 2014 relocations of 20 of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 6 of 8 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 16–25, 2014.

The third relocation flight was on August 30, 2014 and 32% (20) of radiotagged broad whitefish from the Topagoruk River were relocated. Of the 10 radiotagged in the perched lake, 60% of those fish were detected in the lake, 30% were not detected, and 10% (1 fish) was detected in a lake connected to the lower Inaru River (Figure 36). This shows that lake TP-05 had a seasonal connection to the river during high water in spring 2014 so that fish were able to leave the lake. This fish remained at the lake location in the lower Inaru River for the next two flights. A majority of relocated fish were still found in the Topagoruk River (70%) while 20% were detected in the Chipp River drainage, 5% in the Inaru River, and 5% in a lake on the north side of Admiralty Bay not connected to any river drainage. An additional 18 fish were relocated on this flight, but not included due to assumed mortality.

A total of 63% (5) of radiotagged broad whitefish from the Meade were relocated August 30, 2014, four of which were also relocated in the prior relocation flight (Figure 36). Three of those fish had not moved, and one moved slightly upstream. The fifth fish was relocated in the lower Inaru River.

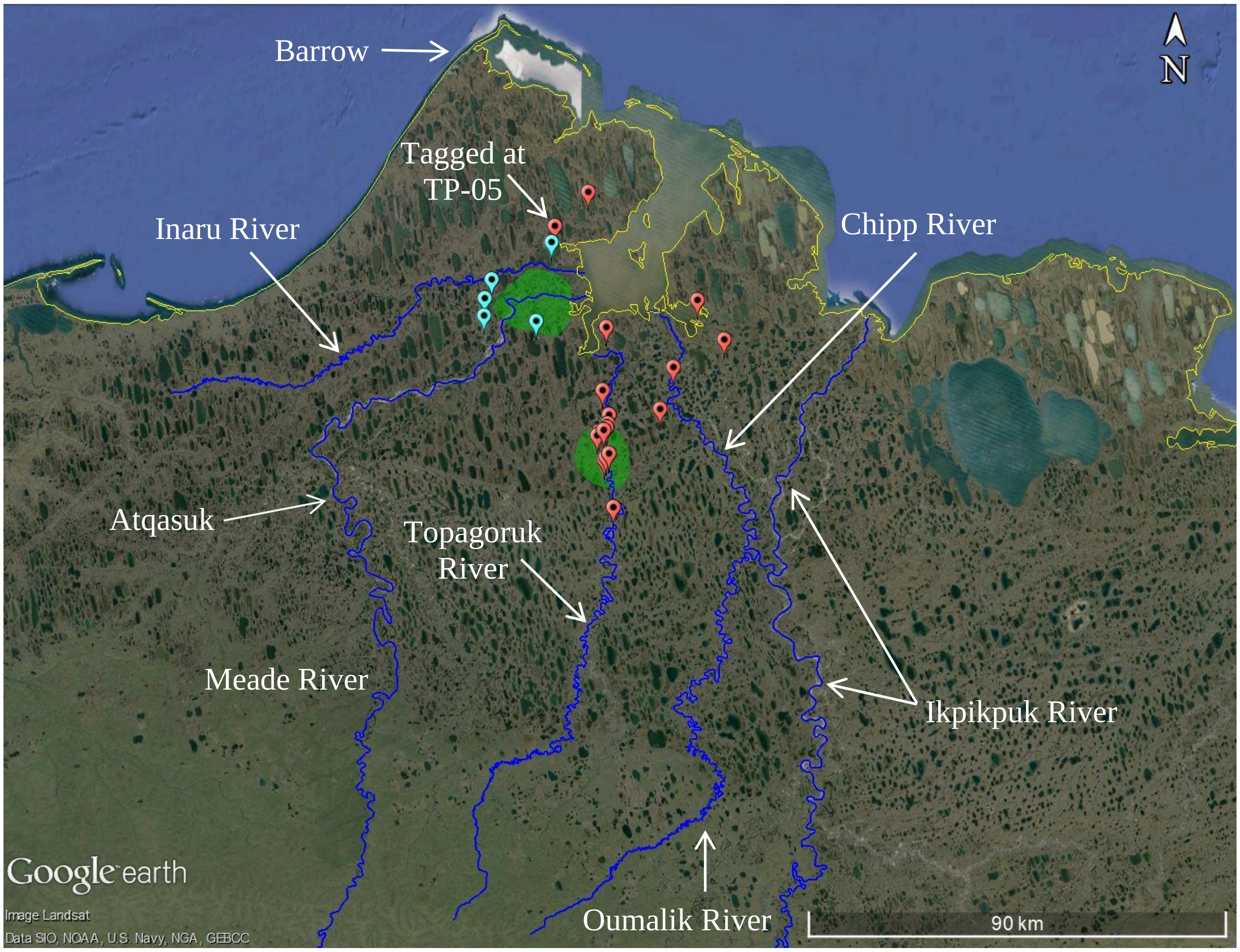

Figure 36. August 30, 2014 relocations of 20 of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 5 of 8 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 16–25, 2014.

The fourth radio relocation flight was conducted September 27, 2014 and all of the major river drainages were flown along with some lakes between the lower Ikpikpuk, Chipp, Topagoruk and Meade rivers. A total of 37% (23) of the radiotagged broad whitefish from the Topagoruk River were relocated (Figure 37). Of the 10 radiotagged in the perched lake, 80% of those fish were detected still in the lake, and 10% (1 fish) was detected again in a lake connected to the lower Inaru River, 10% were not detected. A total of 74% of the relocated fish were detected in the Topagoruk River drainage, 9% in the Chipp River drainage, 9% in the delta region between the lower Chipp and Ikpikpuk rivers, including the Alaktak and Piasuk River drainages, 4% in the Inaru River, and 4% in a lake on the north side of Admiralty Bay not connected to any river drainage. An additional 16 fish were relocated on this flight, but not included due to assumed mortality.

Of the Meade River radiotagged fish, 63% (5) of radiotagged broad whitefish were relocated, four of which had prior relocations (Figure 37). Of those four fish, three remained in the general tagging area vicinity and one had moved upstream in the Meade River to about 22 km below Atqasuk. The last fish with no prior locations had moved upstream in the Meade River approximately 20 km from the tagging area.

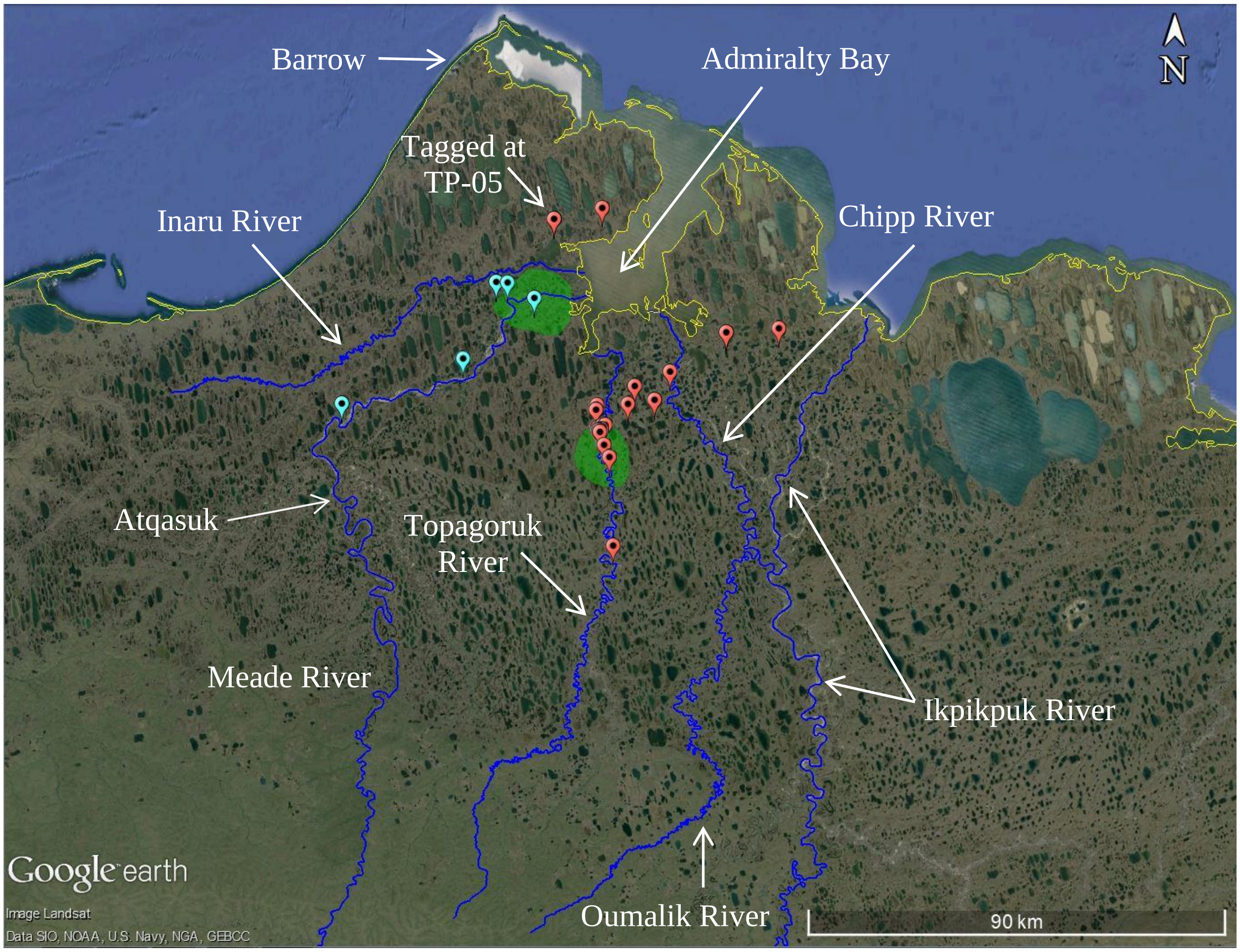

Figure 37. September 27, 2014 relocations of 23 of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 5 of 8 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 16–25, 2014.

The fifth flight occurred on October 8, 2014 and 48% (30) of radiotagged broad whitefish were relocated. Some additional areas were flown between the Meade and Topagoruk rivers and seven fish (11% of radiotagged fish) were located in two lakes not previously documented as containing broad whitefish (Figure 38). Of those, three had not been located prior to this flight and one fish was located in the Oumalik River the prior October in 2013, probably spawned in 2013, and was there unlikely to spawn in 2014. Additionally, three fish were detected during this flight in the lake upstream from TP-04 where they were radiotagged moving downstream in the spring of 2013. This suggests lake overwintering site fidelity for some fish. Of those three fish, one fish was detected in the Oumalik River the prior October in 2013, likely spawned in 2013, and then returned to the lake upstream from TP-04 (where it had been radiotagged) during fall 2014 to overwinter. Of all relocated fish, 87% were detected in the Topagoruk River, 7% in the Chipp River, 3% in a tributary to the Meade River, and 3% in the Inaru River. Of the 10 radiotagged in the perched lake, 90% of those fish were detected still in the lake and 10% (1 fish) was still located in the lower Inaru River. An additional 16 fish were relocated on this flight, but not included due to assumed mortality.

Of the Meade River radiotagged fish, 50% (4) of radiotagged broad whitefish were relocated (Figure 38). Three of those fish remained in the general vicinity from their prior relocations, and one fish moved upstream in the Meade River approximately 15 km.

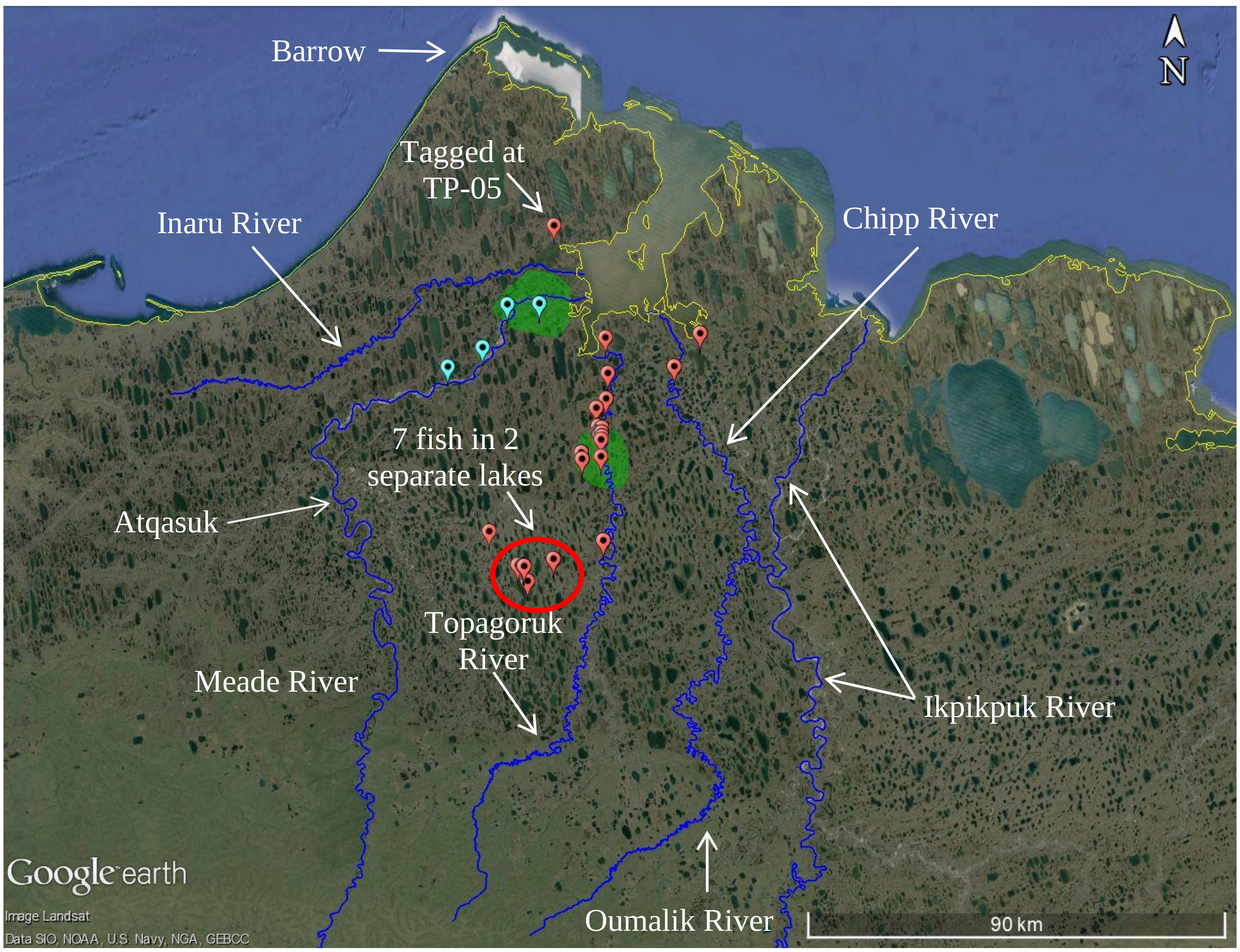

Figure 38. October 8, 2014 relocations of 30 of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 4 of 8 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 16–25, 2014.

The last relocation flight of 2014 was on November 13 and 47% (29) of radiotagged broad whitefish from the Topagoruk River were relocated (Figure 39). The fish located in the lakes west of the Topagoruk River were still in the same location as the prior relocation flight, suggesting these are overwintering locations. Many of the fish were likely overwintering in the rivers or in nearby lakes as radio signals could be detected from a few miles away. Of all the relocated fish, 80% were detected in the Topagoruk River drainage, 7% in the Chipp River drainage, 3% in the delta between the lower Chipp and Ikpikpuk rivers, 7% in the Meade River drainage, and 3% in a lake north of the Inaru River that is heavily fished by Barrow residents. An additional 17 fish were relocated on this flight, but not included due to assumed mortality.

Of the broad whitefish radiotagged in the Meade River, 63% (5) of radiotagged broad whitefish were relocated (Figure 39). Only one fish, located 22 km downstream of Atqasuk in September, did not move from that location. The remaining four fish showed some upstream movement from their prior locations, both in the Meade and Inaru rivers indicating both rivers are used by broad whitefish for overwintering in these reaches, and likely also for spawning.

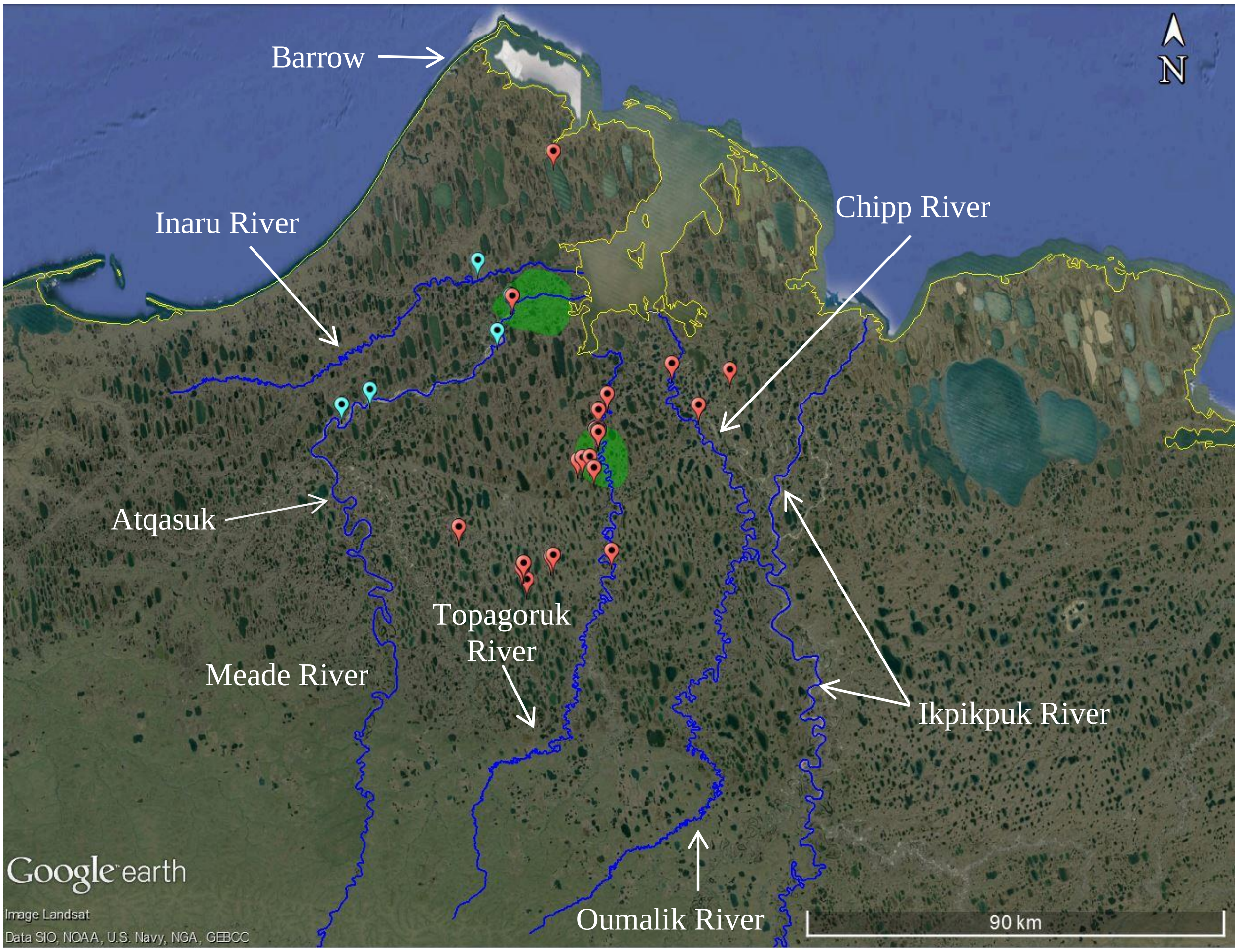

Figure 39. November 13, 2014 relocations of 29 of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 5 of 8 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 16–25, 2014.

In June 2015, an additional nine broad whitefish were radiotagged and in August 2015, an additional 40 were radiotagged resulting in a total of 57 broad whitefish radiotagged from the lower Meade River. A relocation flight on October 10, 2015, relocated 54% (31) of radiotagged broad whitefish from the Meade River (Figure 40). Weather was poor during this flight, preventing relocations the Ikpikpuk and Oumalik Rivers. Of all the relocated fish, 74% remained in the Meade River, 19% were in the Inaru River, and 3% in the Topagoruk River. During tagging in August, some female fish were full of eggs, suggesting they would be spawning in the fall. Four of those fish were relocated, one of which remained in the tagging area, two went up the Meade River upstream from Atqasuk, and one was located in the Topagoruk River near prior broad whitefish radiotagging sites in 2013. With the presence of two ripe females in the upper Meade River, along with two broad whitefish from the Topagoruk River being located in the same area on October 5, 2013 (Figure 34), this suggests this area may be a spawning location for broad whitefish.

Most of the batteries in the tags deployed in 2013 in the Topagoruk River had died by October 2015; however, two of those fish were still detected, one occurring in the Topagoruk River and the other near the Chipp River. Of the three total fish detected in the Topagoruk River, all three occurred together near TP-04, and based on relatively weak signal strengths, they likely were in the lake just upstream of TP-04.

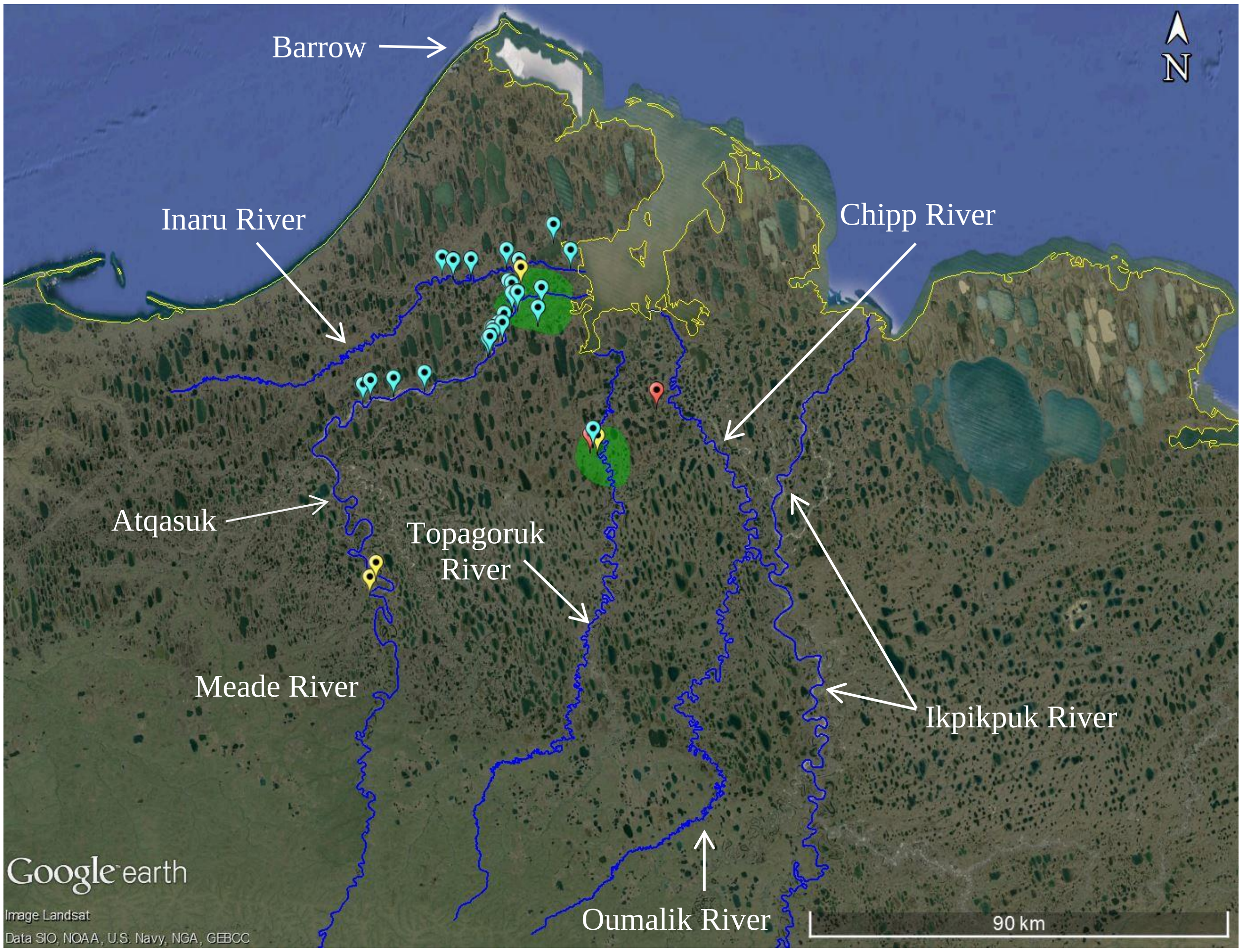

Figure 40. October 10, 2015 relocations of two of 62 broad whitefish radiotagged in the Topagoruk River (red dots) and 31 of 57 broad whitefish radiotagged in the Meade River (light blue dots). Green circles represent tagging locations on the Topagoruk River June 27–July 2, 2013 and Meade River July 2014, and June/August 2015. Yellow symbols represent ripe females at time of tagging August 2015.

The final relocation flight was on May 12, 2016, before spring break up, and relocated 58% (33) of radiotagged broad whitefish from the Meade River (Figure 41). Of all the relocated fish, 67% remained in the Meade River, 12% were relocated in the Inaru River, 12% in the Chipp River, and 9% in the Topagoruk River. The Mayoriak River and Teshekpuk Lake were also flown over during this flight; no fish were detected. The purpose of this flight was to document overwintering locations for broad whitefish. Of all the relocated fish, 42% were detected in an 11-km stretch of the Meade River, suggesting this is an important overwintering area (Figure 41). It is likely that the locations where other fish were detected also provide suitable overwintering habitat in the form of isolated deep water pools, a habitat type identified as important, but limited in availability, on the North Slope of Alaska.

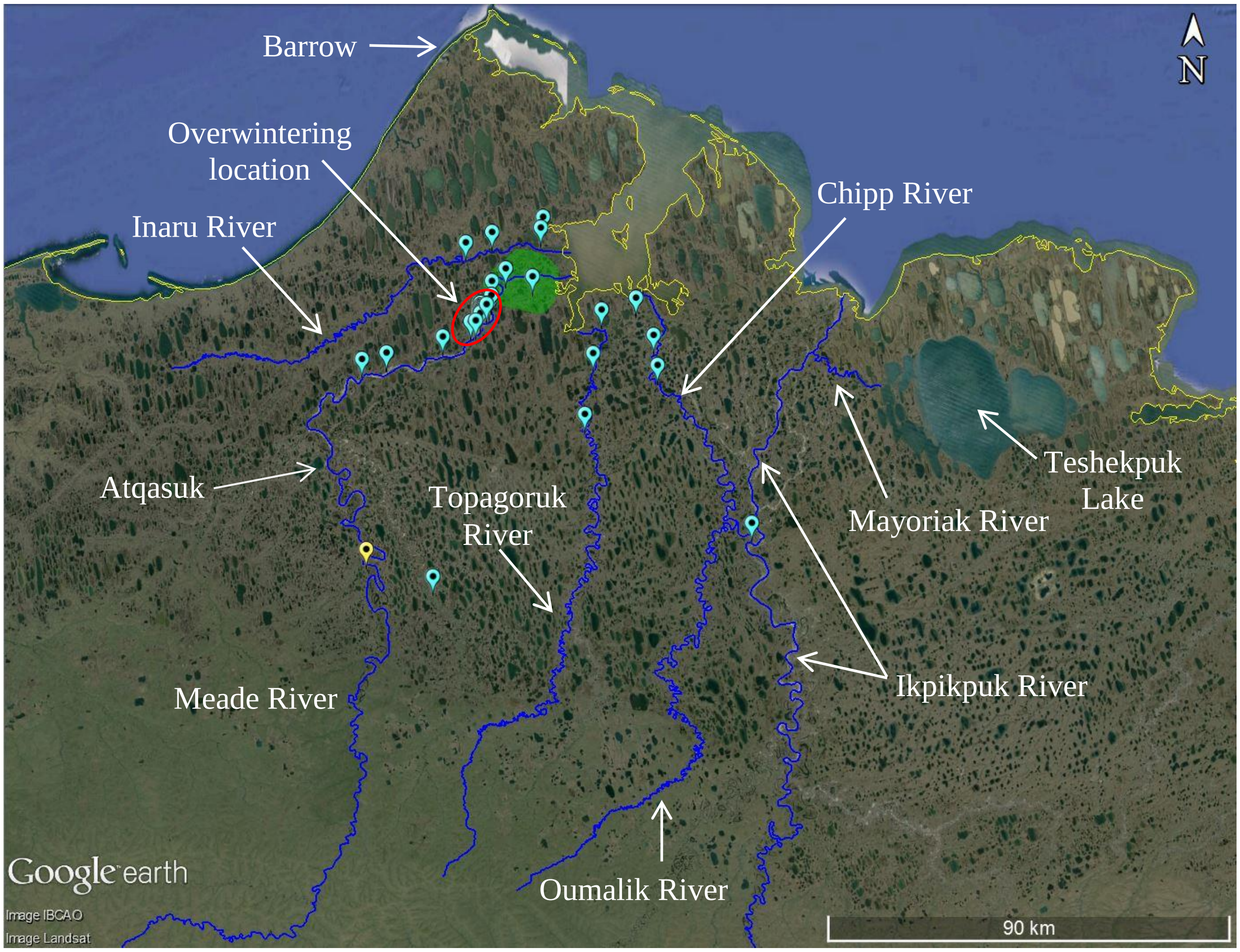

Figure 41. May 12, 2016 relocations of 33 of 57 broad whitefish radiotagged in the Meade River July 2014, and June/August 2015. Green circle represent tagging location. Yellow symbols represent ripe females at time of tagging August 2015. Red circle represents likely overwintering location where 42% of relocated fish were detected.

Invertebrates, Stomach Contents, and Chlorophyll

Macroinvertebrates

Sweep net samples at TP-04 (Figure 5) were dominated by aquatic invertebrates in the family Valvatidae (small freshwater snails) while ponar samples showed a mix of chironomids (non-biting midges), oligochaetes (worms), valvatids, sphaeriids (small to minute freshwater bivalve molluscs), and other invertebrates (Figure 42). Sweep net and ponar samples at TP-01 and TP-03 contained relatively few aquatic invertebrates. Zooplankton samples at TP-05 and TP-06 were dominated by copepods whereas samples from the remaining locations were not dominated by any particular group of invertebrates.

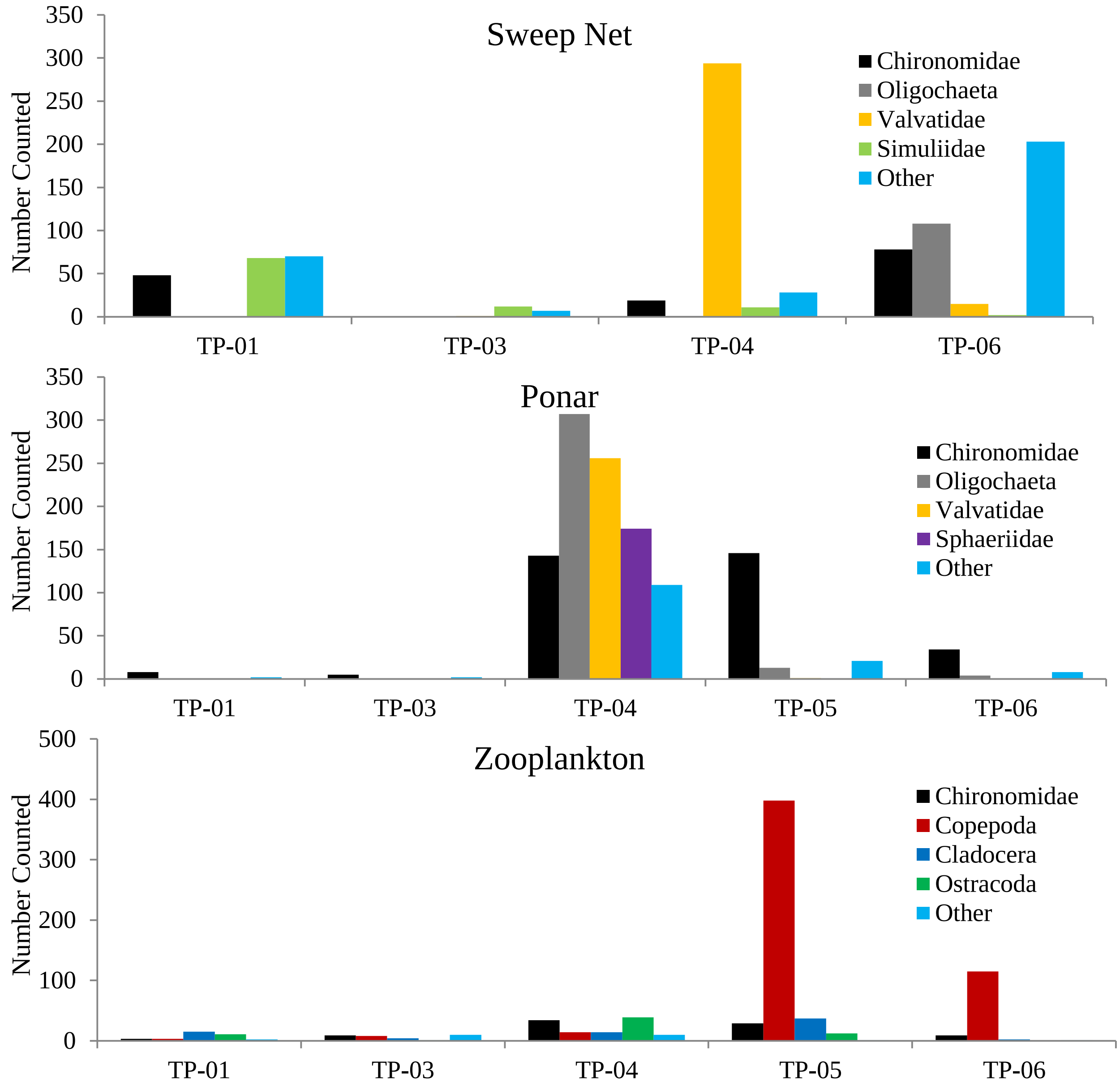

Figure 42. Number of invertebrates collected of various orders/families at five sample sites using a sweep net (top), ponar grab (middle), and zooplankton net (bottom) in the Topagoruk River 2012.

Invertebrate numbers in sweep net samples were highest in an unnamed tributary (CP-01) to the Chipp River (Figure 43). The invertebrate community was dominated by snails in the genus *Valvata* at this location. Sweep net samples at the other sample sites contained few chironomids and copepods. The second most dominant group identified in sweep net samples was categorized as “other” which was dominated by sphaeriids, arachnids (eight-legged arthropod), lymnaeids (freshwater snail), and cladocerans (water fleas).

Ponar samples at CP-01 (Figure 6) were dominated by worms in the class Oligochaeta and worms in the family Sabellidae, with relatively few chironomids compared to the other sample sites (Figure 43). Site CP-03 contained the highest values of chironomids compared to the other sample sites and contained few oligochaetes. Sample sites CP-07 and CP-08 (Figure 6) were also dominated by chironomids.

Zooplankton samples at CP-01 (Figure 6) contained few aquatic invertebrates (Figure 43). Crustaceans in the order Cladocera increased in abundance from CP-01 to the furthest downstream site at CP-08. Chironomids and copepods were present at each sample site and were relatively similar in abundance in samples between CP-03, CP-07, and CP-08.

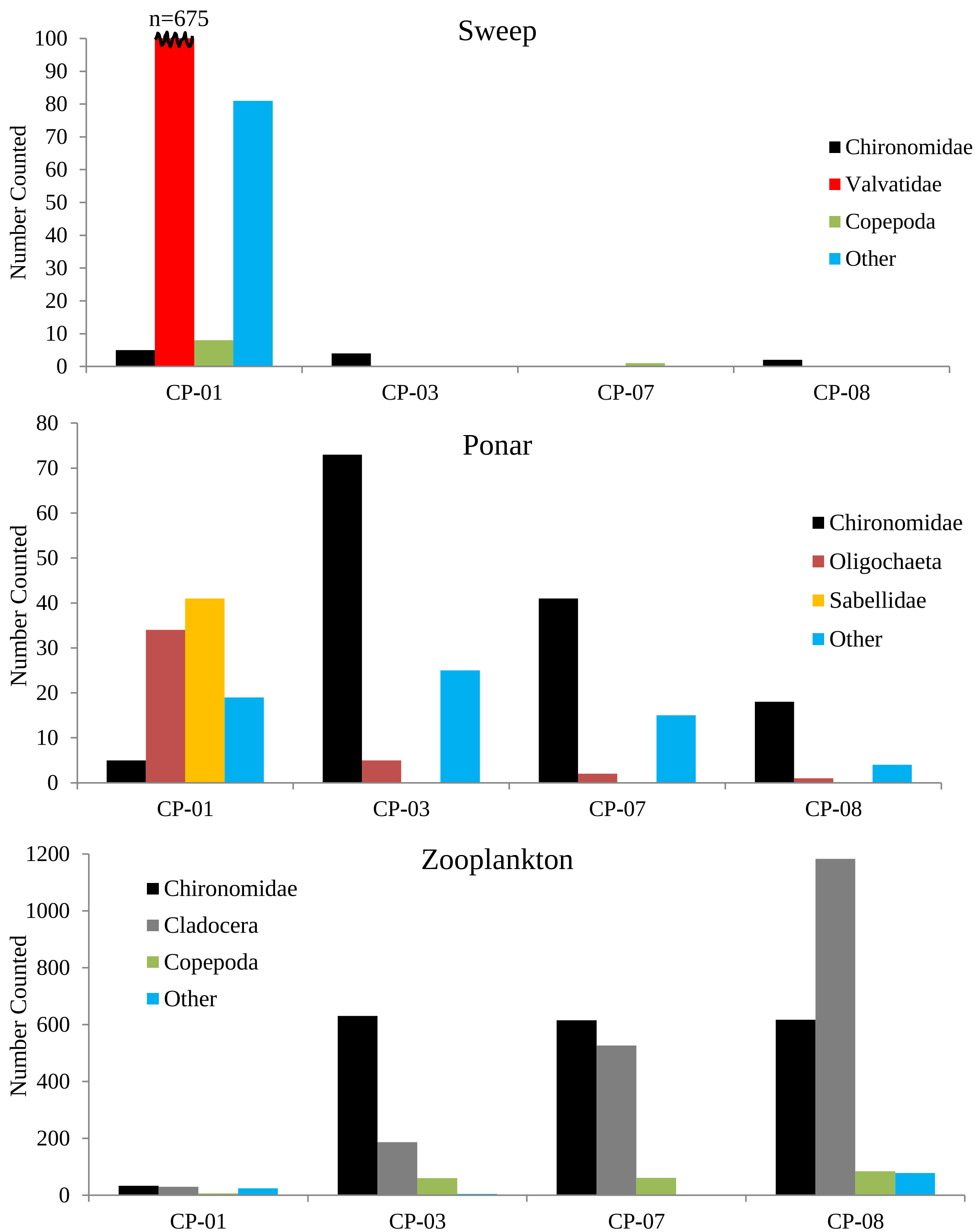

Figure 43. Invertebrates collected in the Chipp River in 2012 at four sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom). Extreme values outside of the vertical axis range are shown on the graphs.

In 2014, the invertebrate numbers from the sweep net samples were highest at tundra stream site MD-09 and lowest at the sand bed stream site MD-12 (Figure 44). Site MD-09 also had the highest species richness with a total of at least 14 different species, and was dominated by cladocerans, ostracods, and chironomids. Lake site MD-14 was dominated by oligochaetes and cladocerans. In contrast, 2015 sweep net samples at MD-14 were dominated by worms in the family Sabellidae (Figure 45). With the exception of river site MD-08, which is downstream from a series of drainage lakes, and dominated by cladocerans, remaining sample sites contained very few invertebrates.

Site MD-09 also had the highest species richness of ponar samples in 2014 and was dominated by ostracods, chironomids, and oligochaetes. Site MD-12, located downstream on a distributary channel of the Meade River near Dease Inlet, was the only sample site to contain significant numbers of amphipods in the family Gammaeridae (scuds) while MD-14 contained relatively similar proportions of chironomids, oligochaetes, and sabellids. Similar to 2014, ponar samples from MD-14 in 2015 were also dominated by those three groups of invertebrates (Figure 45). Chironomids and oligochaetes were the dominate groups of invertebrates at remaining sample sites except for MD-08, which did not contain oligochaetes.

Zooplankton samples in 2014 were comprised primarily of oligochaetes at MD-09, cladocerans and calanoids at MD-12, and calanoids at MD-14 (Figure 44). In contrast, zooplankton samples in 2015 were comprised primarily of other copepod orders, except at site MD-03 which contained very few invertebrates (Figure 45).

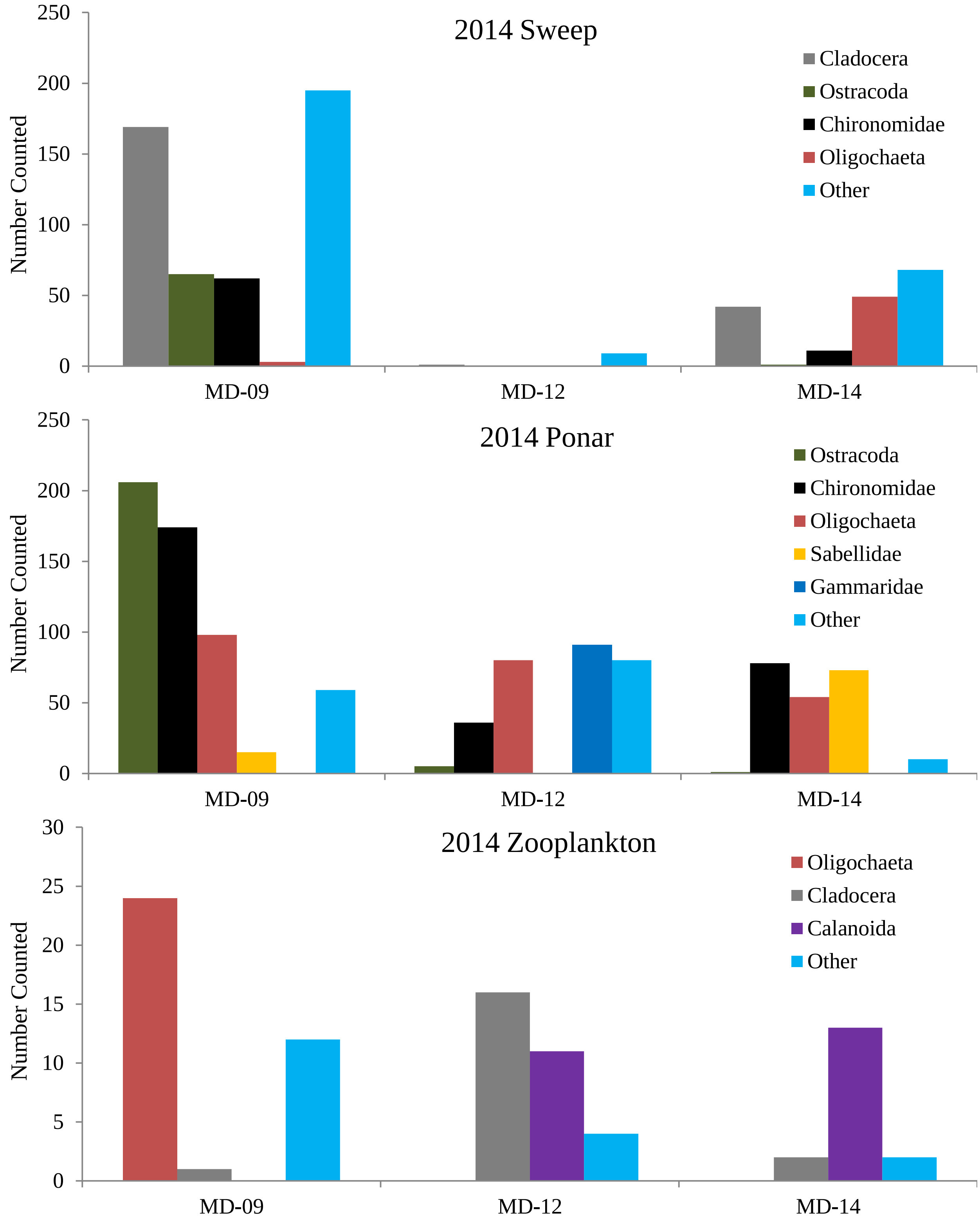

Figure 44. Invertebrates collected in the Meade River in July 2014 at three sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom).

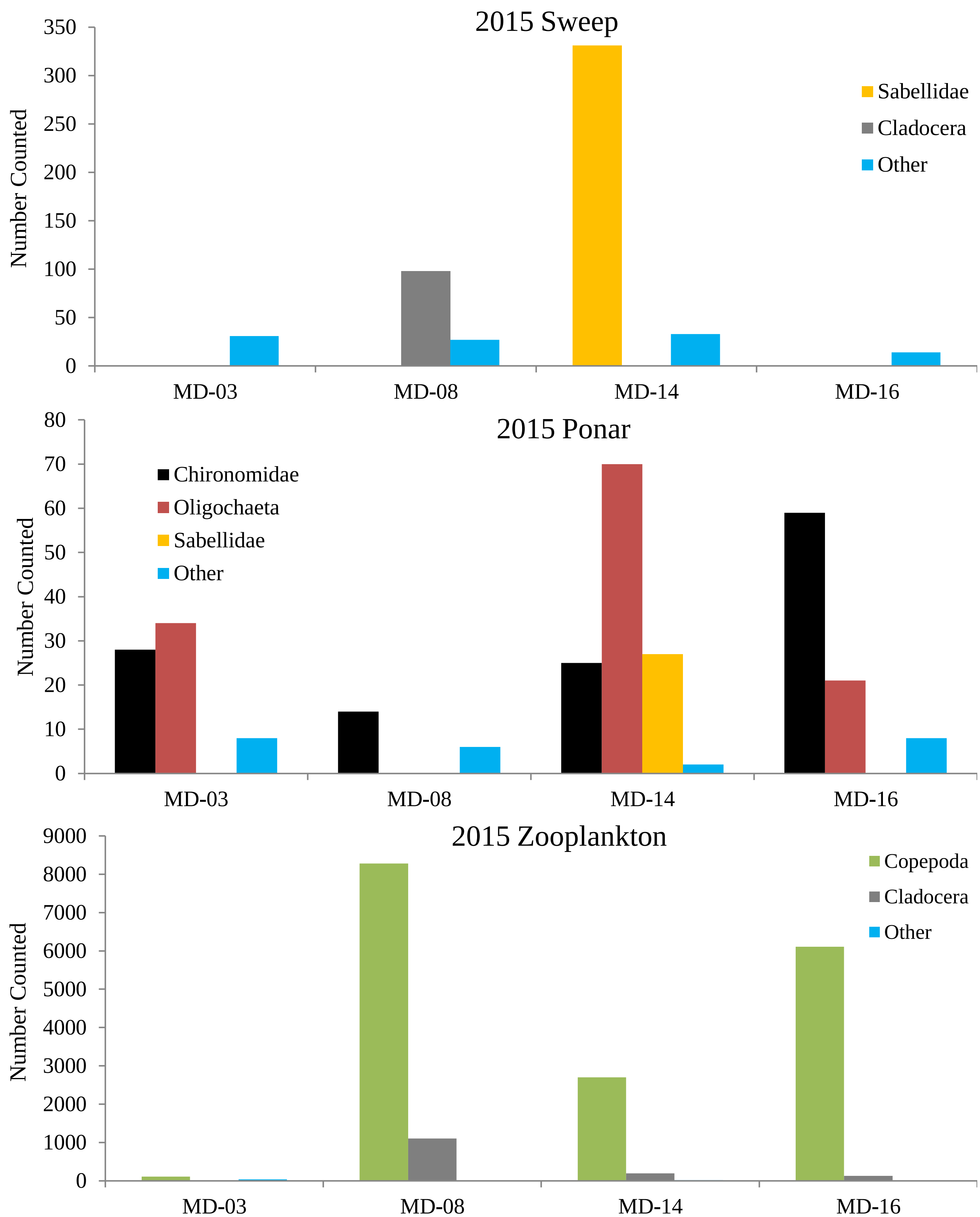

Figure 45. Invertebrates collected in the Meade River in June 2015 at four sample sites with a sweep net (top), ponar grab (middle), and zooplankton tow net (bottom).

Stomach samples retained from least cisco captured at TP-05 show they preyed primarily on chironomid pupa and arachnids (Figure 46). Broad whitefish captured at the same location preyed primarily on chironomid larva and sphaeriids. However, when combined, snails and bivalves contributed more to overall stomach composition than other invertebrates, which is consistent with observations from local fisherman (Brewster et al. 2009). Arctic grayling captured at TP-04 preyed primarily on larval dipterans (true flies); chironomids and simuliids.

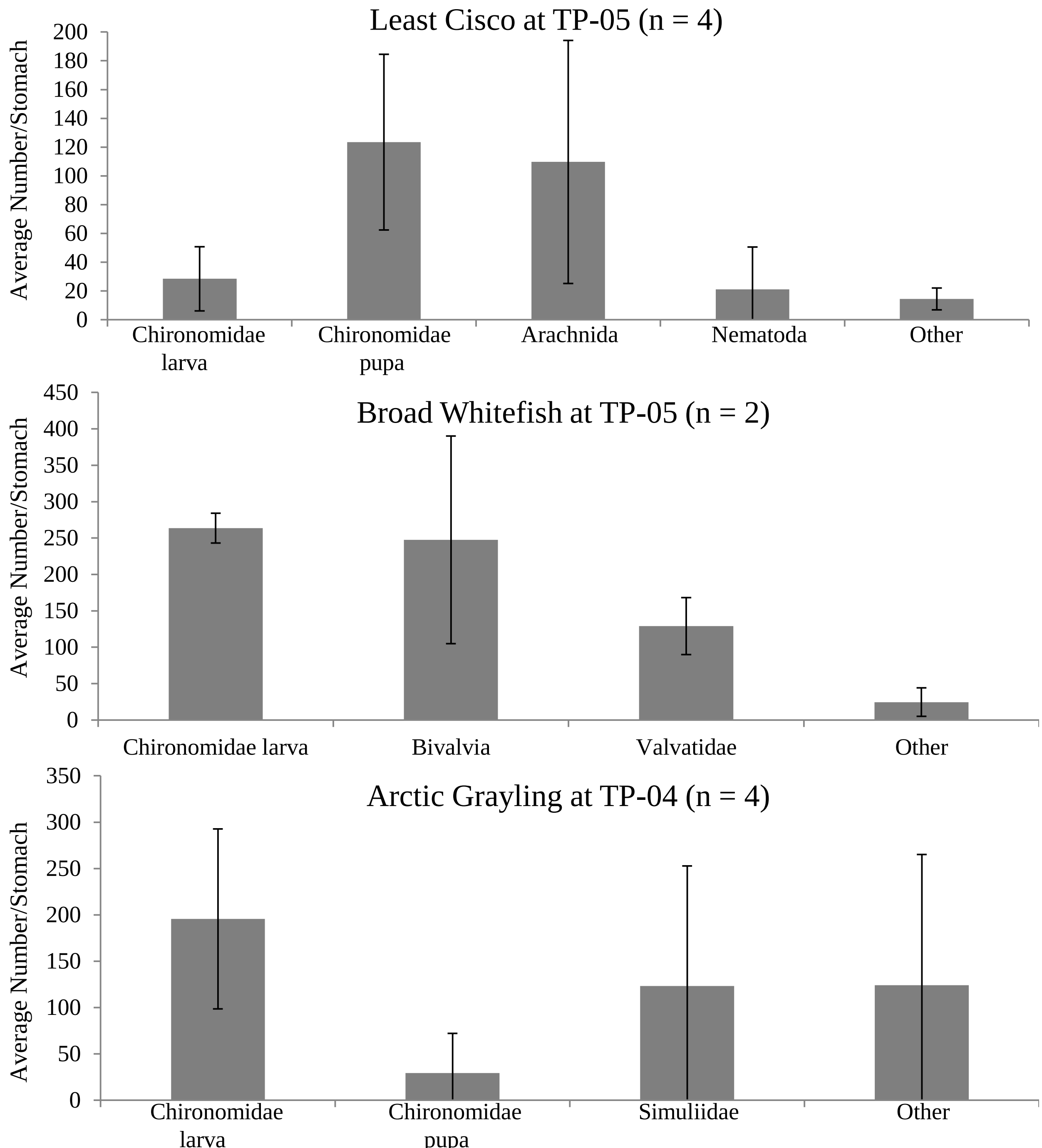

Figure 46. Average (±1 SD) stomach contents of least cisco and broad whitefish from TP-05 and Arctic grayling from TP-04 in the Topagoruk River 2012.

Chlorophyll

Mean chlorophyll-a concentrations ranged from 0.40 mg/m^3 at TP-01 to 1.36 mg/m^3 at TP-05 (Figure 47). In the Chipp River, highest mean chlorophyll-a concentrations occurred at CP-03 and were lowest at CP-01 (Figure 47). Chlorophyll-a concentrations were measured at six locations in the Meade River. Mean chlorophyll-a concentrations ranged from 0.85 mg/m^3 at MD-09 to 4.98 mg/m^3 at MD-08 (Figure 47).

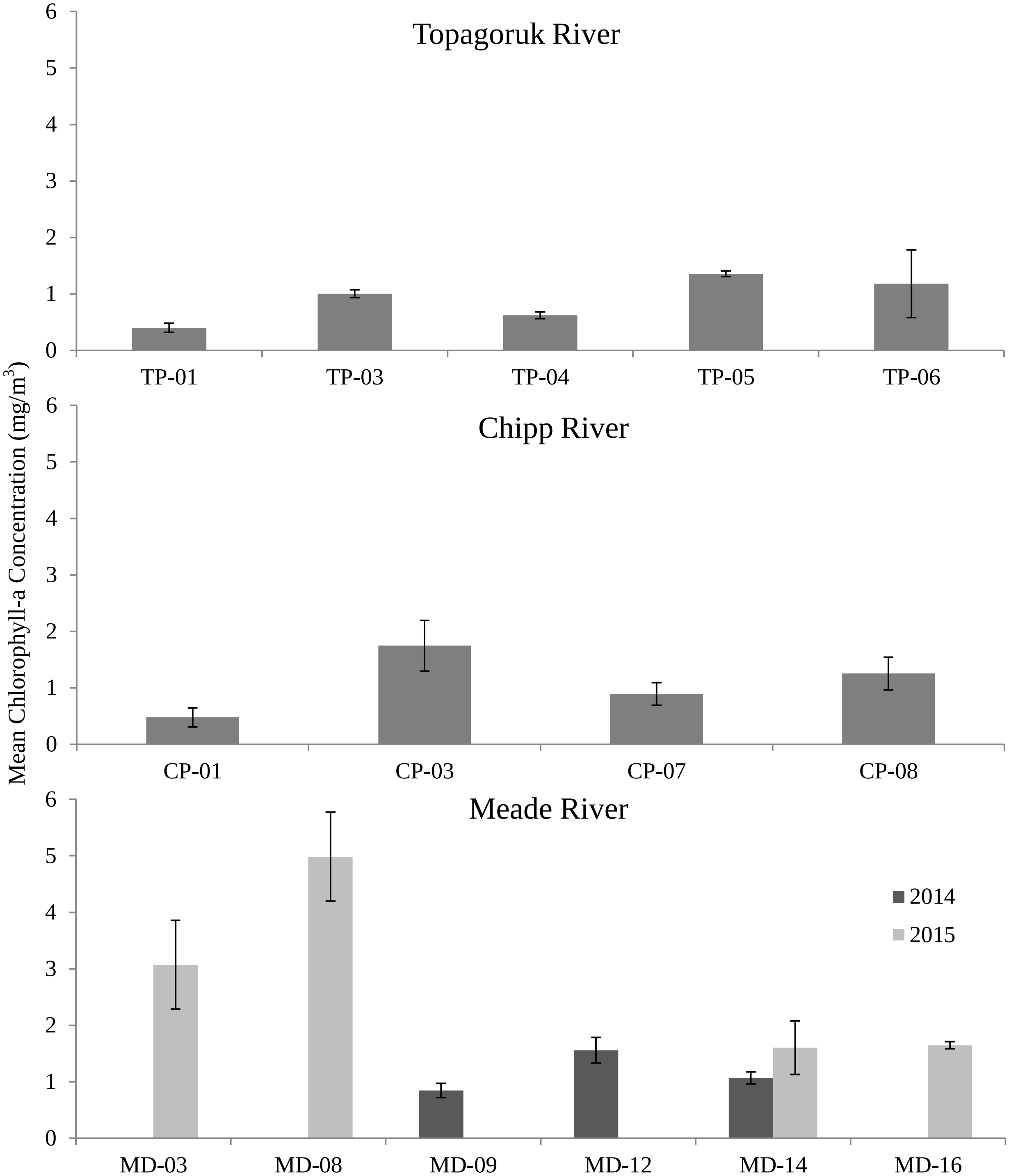

Figure 47. Mean (± 1SD) chlorophyll-a concentrations (mg/m^3) from the Topagoruk River 2012, Chipp River 2012, and Meade River July 2014 and June 2015.

Water Quality

Topagoruk River

Water temperature increased relatively quickly during the short sampling period in 2012 and 2013 (Figure 48). For example, in 2012 at TP-04, water temperature was 8.2ºC on June 27 and by July 2, water temperature was 16.1ºC. Temperatures were similar between 2012 and 2013.

The pH values also showed an increasing trend from late June through early July (Figure 48). Values ranged from 7 to 8.01 in 2012 and from 7.05 to 8.2 in 2013. Turbidity was not measured in 2013, but overall values were low in 2012 ranging from 0.77 to 6.60 NTU (Figure 48). Highest values for specific conductance in 2012 were at TP-06 and ranged from 207.9 to 241.0 µS/cm (Figure 48). Including all sample sites, specific conductance values ranged from 64.5 to 241.0 µS/cm.

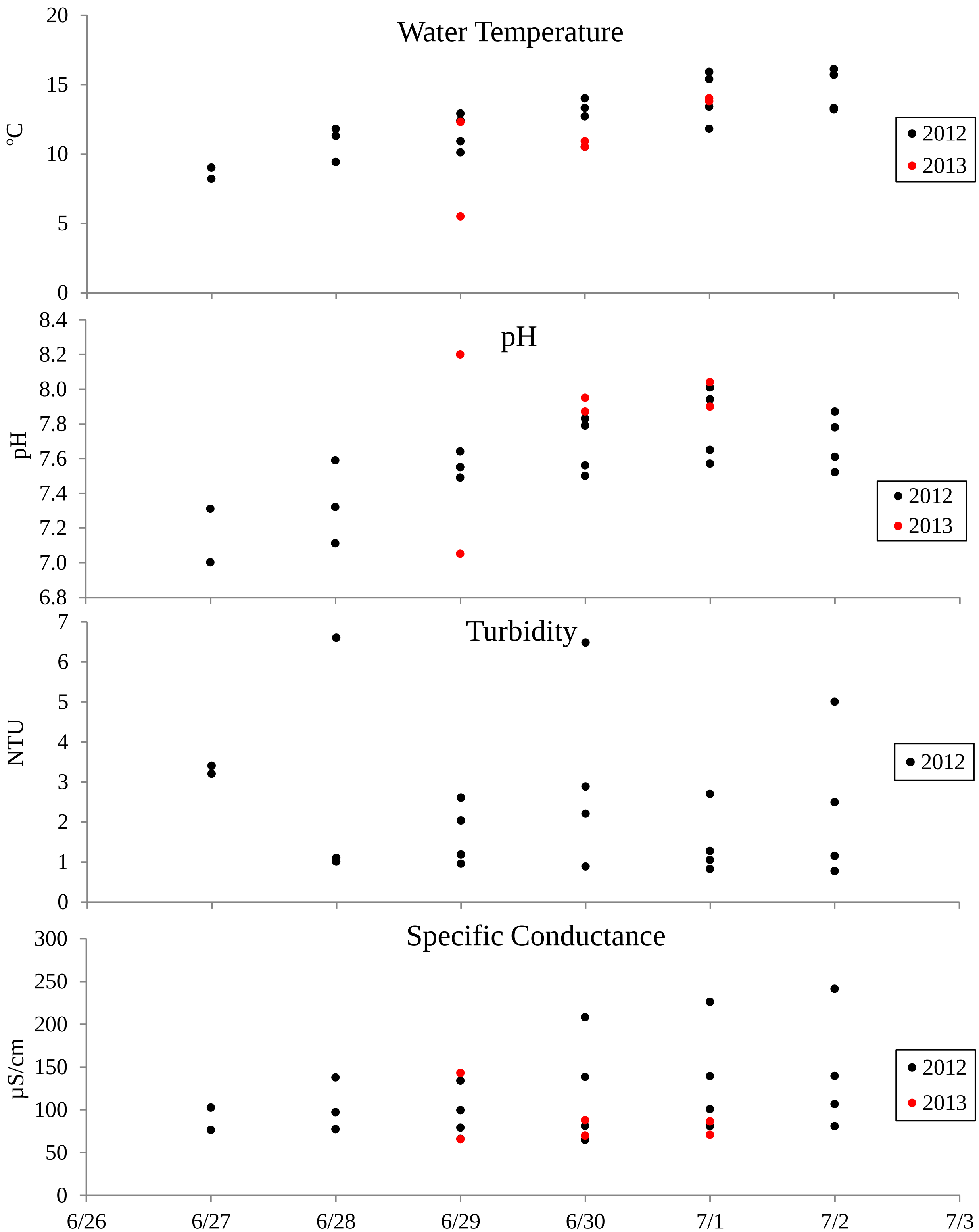

Figure 48. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the Topagoruk River drainage, 2013.

Chipp River

Water temperatures in the Chipp River showed an increasing trend during the 2012 sampling from 10.6ºC on August 11 to 14.3ºC on August 20 (Figure 49). Water temperatures in the Chipp River and nearby lakes were much cooler during 2013 sampling and showed a decreasing trend from 6.9ºC on August 23, 2013 to 4.4ºC on August 31, 2013.

Values for pH also showed an increasing trend during the 2012 sampling from 7.17 on August 11 to 8.01 on August 20 (Figure 49). Mean pH values were higher during the 2013 sampling event, but did not show any trends.

Turbidity values in 2012 ranged from 1.55 NTU at CP-01 to 14.43 NTU at CP-07 (Figure 49). In 2013, turbidity values ranged from 1.64 NTU at CP-20 to 17.53 NTU at CP-14. The lowest turbidity values in 2013 occurred primarily at sites CP-19 and CP-20, a drainage lake and its outlet.

In 2012, lowest specific conductance values occurred in the unnamed tributary at CP-01 (84.2 and 84.8 µS/cm) while the highest values occurred at the mouth of the Oumalik River at CP-06 (190.2 µS/cm) (Figure 49). Specific conductance of the main channel of the Chipp River generally ranged from 130 to 139 µS/cm. In 2013, the highest specific conductance values occurred in the connected lake (CP-20) and its outlet (CP-19) and ranged from 181 to 187 µS/cm. The main channel of the Chipp River had fairly consistent values ranging from 128 µS/cm to 136 µS/cm while the unconnected lake at CP-18 had values at 151.1 and 153 µS/cm.

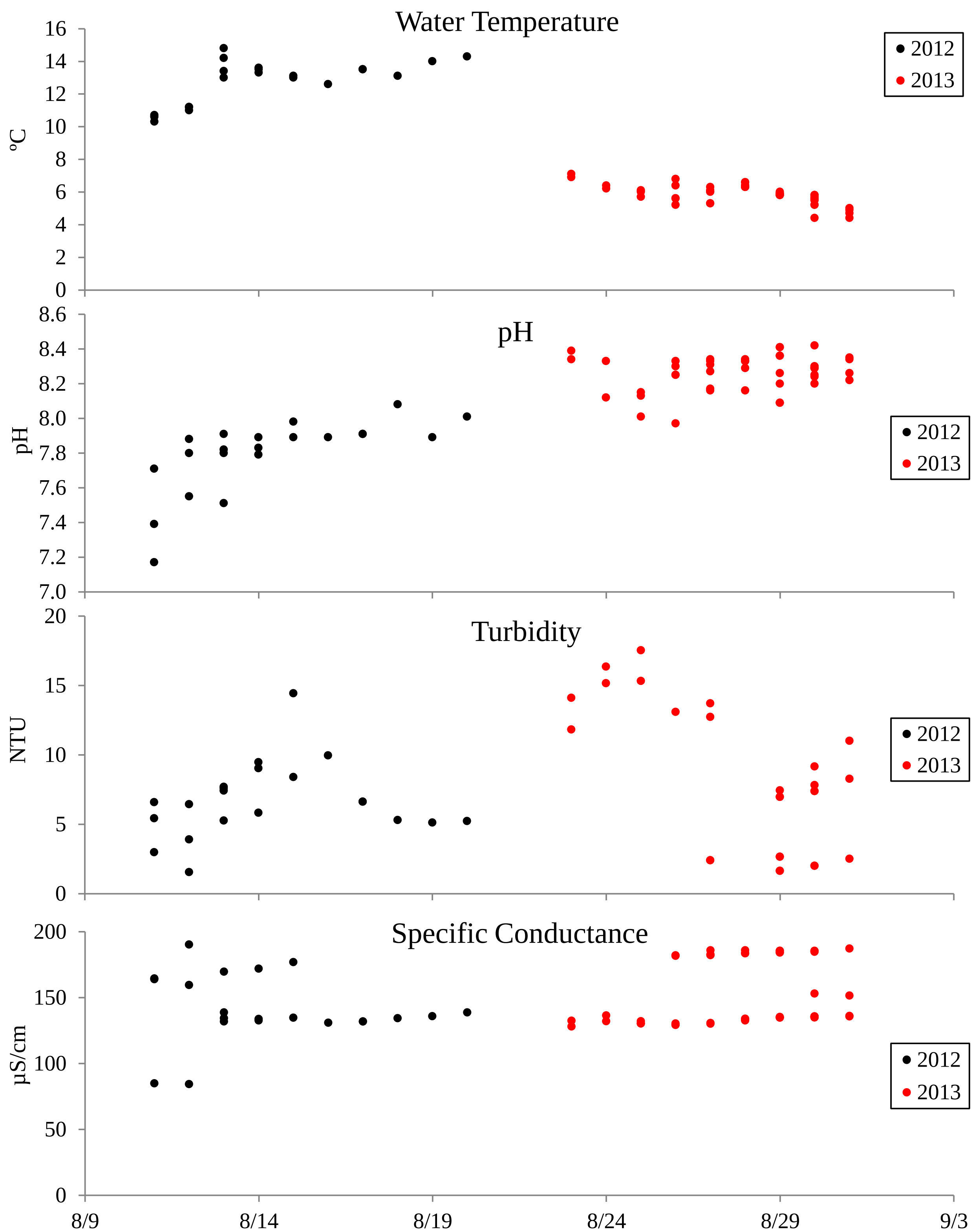

Figure 49. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the Chipp River, 2012 and 2013.

Meade River

Water temperatures in the Meade River were warmest in June 2015 and ranged from 6.4ºC at MD-02 to 20.3ºC at MD-14 (Figure 50). July 2014 temperatures were cooler, ranging from 6.4ºC at MD-15 to 12.5ºC at MD-09 whereas August and September 2015 temperatures were the coolest, ranging from 4.1ºC at MD-18 to 7.3ºC at MD-14.

Values for pH in June 2015 showed the highest variability, ranging from 7.04 at MD-02 to 8.31 at MD-09 (Figure 50). July 2014 pH values averaged slightly lower, ranging from 6.81 at MD-11 to 7.73 at MD-12. Highest mean pH values occurred in August and September 2015 where values averaged 8.15 and ranged 7.78 at MD-14 to 8.29 at MD-07.

Turbidity values slightly increased during the open water season combining both years of data (Figure 50). June 2015 turbidity values averaged 8.28 NTU and ranged from 1.72 NTU at MD-04 to 36 NTU at MD-06. July 2014 turbidity values averaged 11.2 NTU and ranged from 1.48 NTU at MD-09 to 43.8 NTU MD-12. By August and September 2015, mean turbidity values were 20.4 NTU and ranged 3.6 NTU at MD-18 to 62.6 NTU MD-14.

Mean specific conductance values increased during the open water season as well with mean values at 109 µS/cm in June 2015 and ranged from 42.6 µS/cm at MD-09 to 247 µS/cm at MD-17 (Figure 50). In July 2014, mean specific conductance was 121 µS/cm and ranged from 97.2 µS/cm at MD-13 to 187.5 µS/cm at MD-12. August and September had the highest mean specific conductance values at 223 µS/cm and ranged from 121.4 µS/cm at MD-14 to 458 µS/cm at MD-16 and MD-17.

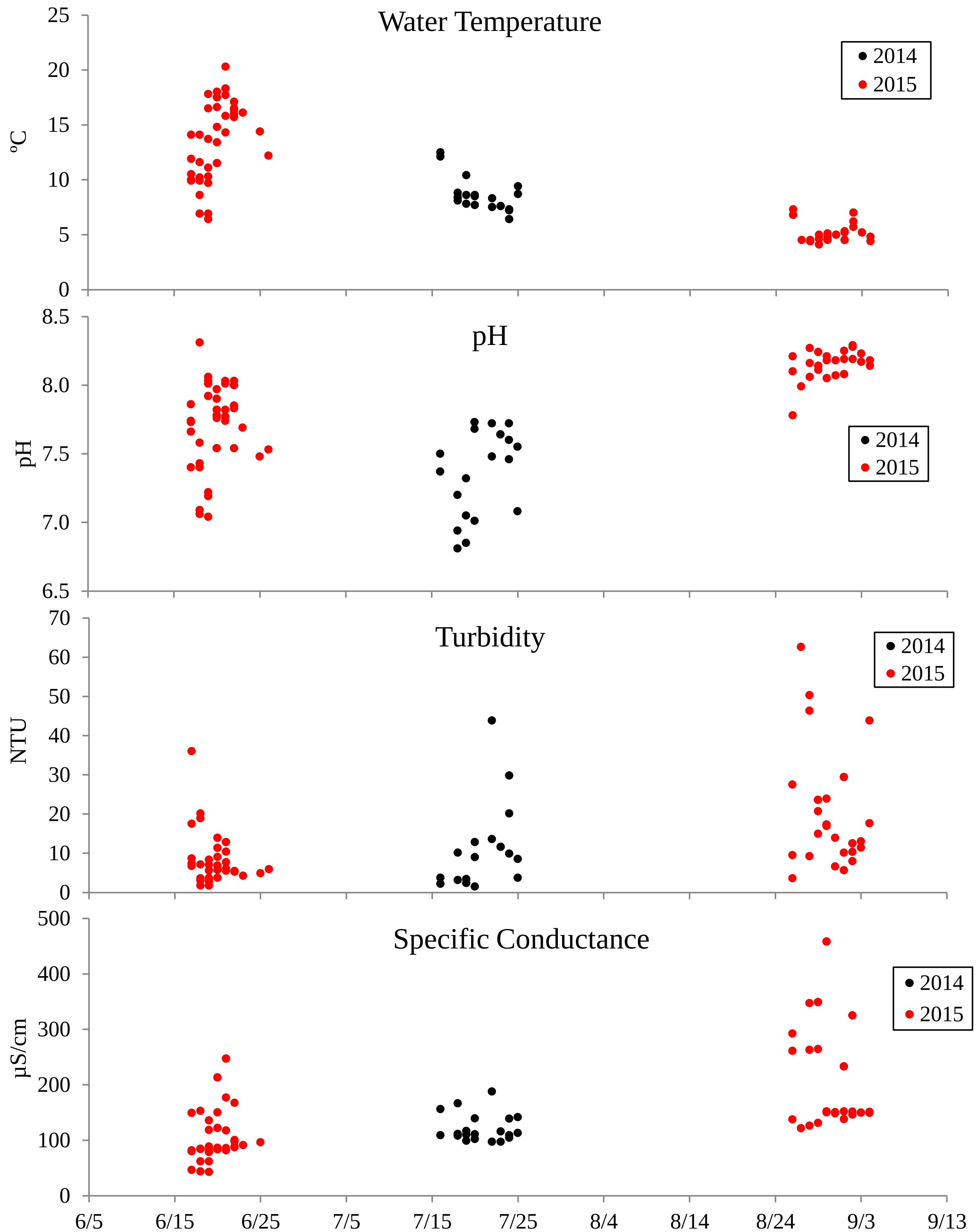

Figure 50. Water temperature (ºC), pH, turbidity (NTU), and specific conductance (µS/cm) measured at fish sample sites in the Meade River, 2014 and 2015.

Discussion

Catch Patterns

Fish sampling results were consistent with previous field work conducted in the region (Bendock and Burr 1985, Philo et al. 1993, Moulton et al. 2001) and as reported by subsistence users familiar with the area (Brewster et al. 2009). Least cisco tended to be the most abundant species in the river systems, with broad whitefish, humpback whitefish, and Arctic grayling also abundant. However, humpback whitefish were rare in fyke net catches in the Topagoruk River and were not common in catches in the Chipp River during 2012 and 2013. The apparent lower abundance in the Chipp River may be related to the fact that our sampling was farther upstream than in previous studies. Humpback whitefish appear to be more abundant in lower reaches of the study rivers.

Netsch et al. (1977) reported catching no fish in the Topagoruk River whereas Bendock and Burr (1985) reported low catch rates in the Topagoruk River and did not catch least cisco. In contrast, fish were abundant in our 2012 and 2013 sampling, with least cisco being the most numerous species. Some of the difference could be related to gear type and sampling duration; the earlier studies were based on short-term set gillnet sampling. Fish can be widely dispersed in these streams and were likely missed in the early studies.

The capture of pre-spawning rainbow smelt in the lower Meade River, while not surprising, is the first documentation of potential spawning areas in this river. Rainbow smelt are abundant in the southern portion of Dease Inlet (Brewster et al. 2009). They are known to spawn in the lower Chipp River (Moulton et al. 2011), and likely spawn in multiple Dease Inlet drainages.

Growth, Condition, and Maturity

Least Cisco

Least cisco from the Chipp/Topagoruk region in 2012 appeared to have a higher growth rate than those from other rivers and years. However, this apparent higher growth rate, at least for the Topagoruk River, is likely the result of lake-type least cisco being included in the growth curve. Least cisco from previous studies in the Dease Inlet and Colville regions represent anadromous populations, which often have lower growth rates than lake-dwelling populations (Lawrence et al. 1984, Moulton 1997). If the lake-type least cisco are removed from the analysis, the age-length relationships among the various data sets are similar.

Least cisco in the study region began maturing at age 4 and reached full maturity by age 8. These results are similar to that reported for the Chipp River, where first maturity was also age 4 and full maturity was age 6 for males, and age 9 for females (Moulton et al. 2011). In Dease

Inlet during 1988-1990, however, age at first maturity was much later: age 7 for males and age 6 for females, with age of 50% maturity being age 8 for males and age 7 for females (Philo et al. 1993). At this time, it is not apparent what may cause these differences; potential factors could be temporal differences, variation in the populations being sampled, or different portions of the population being present during sampling. Lengthening of the open water season and increased summer water temperatures may also contribute to increased growth rates and fish condition allowing for an earlier age at maturity as observed in this study.

Broad Whitefish

Comparing the growth of broad whitefish between the Meade River and Chipp/Topagoruk rivers was compromised by the lack of size overlap in samples from the different drainages. Few fish in excess of 400 mm were captured in the Meade River, whereas most of the fish from the Chipp/Topagoruk rivers exceeded 400 mm. The minimal catches of juvenile and sub-adult broad whitefish suggest this part of the Topagoruk River is primarily used by large adults for feeding and overwintering. The combined age-length curve for broad whitefish collected from 2012 and 2015 appeared to show higher growth rates than fish collected from the Colville River region in 1985 and Dease Inlet in 1988-1990; however, it is not clear if the differences are from geographic, temporal, or climatic differences.

In the Meade River, an unusually large range of fork lengths occur at a given age for certain age classes. For example, age-3 fish ranged from 139 to 326 mm, which is likely a result of different habitats being used. For example, the smaller fish may not have spent any time in brackish/salt water, leading to lower growth rates, while some of the larger fish may have at least one season of growth in the marine environment.

Broad whitefish from the Chipp/Topagoruk rivers had a similar age of first maturity to those caught in Dease Inlet in 1988-1990, however fish from the current study reached 50% maturity by age 10 and 100% maturity by age 12. Broad whitefish caught in the Chipp River during 1991 to 1993 and 2008 began maturing at ages 7 and 8, reaching full maturity around age 14 (Moulton et al. 2011). In the Teshekpuk Lake region, 50% maturity was reached by age 14 or 15, with full maturity near age 18 (Moulton et al. 2007).

Arctic Grayling

Arctic grayling captured during the 2012 and 2015 sampling reached 300 mm between ages 5 and 6. Similar growth was observed in Chipp River samples from 1990-1992 and 2008 (Moulton et al. 2011), and samples from the Teshekpuk region in 1990-1992 and 2003-2004 (Moulton et al. 2007).

Humpback Whitefish

Growth of humpback whitefish caught in the Chipp and Meade rivers during 2012 to 2015 was similar to that reported from the Colville region in 1985 (Fawcett et al. 1986), but appeared to be greater than growth rates reported for Dease Inlet in 1988-1990 (Philo et al. 1993) and Chipp River from 1993-1994 and 2008 (Moulton et al. 2011).

Humpback whitefish in the Topagoruk/Meade River region may be maturing earlier than reported in earlier studies. Humpback whitefish caught in 2012 and 2015 reached 50% maturity between ages 7 and 8, and were fully mature by age 9. This compares to humpback whitefish in Dease Inlet reaching 50% maturity by ages 14 for males and 11 for females (Philo et al. 1993). In the Chipp River, 50% of the males reached maturity by age 8, with females reaching maturity at age 9.

Movement Patterns

Identifying movement patterns of broad whitefish through radiotagging was a primary goal of this study. A total of 119 broad whitefish were fitted with radio tags between 2013 and 2015, with 62 released in the Topagoruk River and 57 released in the Meade River. Flights to relocate radiotagged fish were conducted from October 2013 through May 2016. The majority of relocations were within the river of origin; however, fish released in the Topagoruk River dispersed to the Meade, Inaru, Chipp, Oumalik and upper Ikpikpuk rivers. One entered Iqaluligauraq River, a small stream along western Dease Inlet, and moved upstream into Tusikvoak Lake. Similarly, fish that left the Meade River were relocated in the Inaru and Topagoruk rivers. When viewed with the movement of radiotagged fish reported in Morris et al. 2006 and Moulton et al. 2011, it is clear that there is substantial interchange of broad whitefish from all drainages associated with Dease Inlet and Smith Bay. While most fish remained within the river in which they were radiotagged, a substantial portion left the tagging rivers and often migrated great distances to spawning and/or wintering areas. The frequent exchange of broad whitefish among all drainages indicates that these fish may represent one population with substantial genetic exchange within the region.

Management Implications

Basic fish life history and population structure data are lacking for much of the Chipp, Topagoruk, and Meade rivers, although the area is of particular importance to subsistence fishers and portions have been leased for oil and gas exploration. This study has filled an important information gap for the Topagoruk, Chipp, and Meade rivers by identifying fish species using the waters within the region, identifying habitats used for important life history stages by key subsistence fish species, and providing baseline fish population structure data which will be important for future comparisons. Through the sampling and radiotelemetry work conducted in this study, important overwintering and rearing habitats for post-spawning adult broad whitefish in the Topagoruk were identified, along with spawning and overwintering habitats for broad whitefish in the Chipp, Ikpikpuk, Inaru, and Meade rivers. Additionally, new spawning habitats for rainbow smelt were identified in the lower Meade River. 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 and invertebrate sampling locations in the Topagoruk River and total hours sampled at each site with fyke nets and set gillnets in 2012 and 2013.

				June 26–July 2, 2012			June 27–July 2, 2013
				Total Effort (hours)		Invert Sampling	Total Effort (hours)
Station	Habitat Type	Latitude	Longitude	Fyke net	Set gillnet		Fyke net
TP-01	Creek	70.51459	-155.83698	89.6	-	++	26.4
TP-02	Main river	70.55215	-155.87915	-	10.9	-	-
TP-03	Main river	70.55206	-155.87877	14.1	-	++	-
TP-04	Creek	70.55412	-155.89479	168.1	0.6	++	174.2
TP-05	Perched lake	70.57154	-155.87067	64.6	1.3	++	18.5
TP-06	Creek	70.59535	-155.89803	17.6	2.1	++	-
TP-07	Creek	70.62546	-155.85859	26.1	-	-	-

Appendix 2. Fish and invertebrate sampling locations in the Chipp River and total hours sampled at each site with fyke nets, set gillnets, and hoop traps in 2012 and 2013.

				Aug 11–20, 2012				Aug 23–31, 2013	
				Total Effort (hours)			Invert sampling	Total Effort (hours)	
Station	Habitat Type	Latitude	Longitude	Fyke net	Set gillnet	Hoop trap		Fyke Net	Set gillnet
CP-01	Creek	70.33118	-154.93260	44.1	7.0	-	++	-	-
CP-02	Main river	70.33259	-154.91422	-	203.8	-	-	-	-
CP-03	Main river	70.33228	-154.89603	96.3	69.7	35.4	++	-	-
CP-04	Main river	70.34048	-154.89433	-	25.5	-	-	-	-
CP-05	Backwater slough	70.35482	-154.97615	95.3	-	-	-	-	-
CP-06	Main river	70.37444	-154.98215	-	37.1	-	-	-	-
CP-07	Main river	70.38144	-155.00806	93.7	-	-	++	-	-
CP-08	Backwater slough	70.37466	-155.04665	41.3	-	-	++	-	-
CP-09	Main river	70.38168	-155.05833	-	19.0	-	-	-	-
CP-10	Main river	70.37882	-155.0595	-	-	-	-	-	15.7
CP-11	Main river	70.38096	-155.0571	-	-	-	-	-	15.8
CP-12	Main river	70.40276	-155.0158	-	-	-	-	-	5.1
CP-13	Main river	70.39983	-155.0113	-	-	-	-	-	63.3
CP-14	Main river	70.39896	-154.9847	-	-	-	-	-	68.9
CP-15	Main river	70.4127	-154.9937	-	-	-	-	26.8	-
CP-16	Main river	70.4145	-154.9926	-	-	-	-	-	41.9
CP-17	Main river	70.41622	-155.0613	-	-	-	-	-	19.5
CP-18	Perched lake	70.43598	-154.9982	-	-	-	-	23.7	-
CP-19	Lake outlet	70.44022	-154.9931	-	-	-	-	113.6	-
CP-20	Drainage lake	70.44018	-154.9919	-	-	-	-	89.7	-
CP-21	Main river	70.4416	-154.9957	-	-	-	-	63.8	-

Appendix 3. Fish and invertebrate sampling locations in the lower Meade River and total hours sampled at each site with fyke nets in 2014 and 2015.

				July 16–25, 2014		June 17–26, 2015		Aug 26–Sept 4, 2015
				Total Effort (hours)	Invert Sampling	Total Effort (hours)	Invert sampling	Total Effort (hours)
Station	Habitat Type	Latitude	Longitude	Fyke net		Fyke net		Fyke net
MD-01	Drainage lake	70.77211	-156.2631	-	-	49.6	-	-
MD-02	Drainage lake	70.77598	-156.2608	38.3	-	80.4	-	-
MD-03	Lake outlet	70.77512	-156.2558	-	-	30	++	-
MD-04	Creek	70.77426	-156.2056	-	-	34.5	-	-
MD-05	Creek	70.80531	-156.2379	-	-	42.5	-	-
MD-06	Drainage lake	70.81327	-156.2381	-	-	24.7	-	-
MD-07	Drainage lake	70.81667	-156.2448	-	-	-	-	142
MD-08	Creek	70.81956	-156.2413	-	-	412.2	++	243.4
MD-09	Creek	70.81757	-156.3461	187.4	++	42.6	-	-
MD-10	Backwater slough	70.80523	-156.5474	42.9	-	-	-	-
MD-11	Backwater slough	70.81675	-156.5394	37.9	-	-	-	-
MD-12	Lake outlet	70.84595	-156.2177	186	++	-	-	-
MD-13	Drainage lake	70.85508	-156.4943	123.7	-	-	-	-
MD-14	Lake outlet	70.85516	-156.8879	160.5	++	133.1	++	63.5
MD-15	Lake outlet	70.89477	-156.3619	61.7	-	-	-	-
MD-16	Drainage lake	70.8983	-156.2907	-	-	40.9	++	167.8
MD-17	Drainage lake	70.89942	-156.2883	-	-	42.3	-	100.2
MD-18	Drainage lake	70.90744	-156.3369	-	-	23.6	-	65.7
MD-19	Creek	70.9163	-156.4157	-	-	40.8	-	-

Appendix 4. Mean CPUE (#fish/24 hrs.) of fish captured at each fyke net location in the Topagoruk River, 2012 and 2013.

	Station #	Habitat Type	Least cisco	Broad whitefish	Arctic grayling	Slimy sculpin	Ninespine Stickleback	Humpback whitefish
2012	TP-01	Creek	1.74	2.94	4.12	2.24	0.28	-
	TP-03	Main river	-	-	13.67	-	-	-
	TP-04	Creek	5.73	17.29	5.35	0.64	0.14	0.27
	TP-05	Perched lake	92.65	48.16	-	-	0.40	-
	TP-06	Creek	4.08	-	253.16	2.72	5.44	-
	TP-07	Creek	-	-	3.68	18.41	4.60	-
2013	TP-01	Creek	1070.82	1.82	5.46	-	-	-
	TP-04	Creek	49.61	9.81	5.54	0.14	0.41	0.12
	TP-05	Perched lake	2.60	106.57	-	-	-	-

Appendix 5. Mean CPUE (#fish/24 hrs.) of six of the most commonly captured species by fyke net sites in the Chipp River, 2012 and 2013.

	Station #	Habitat Type	Broad whitefish	Least cisco	Longnose sucker	Arctic grayling	Humpback whitefish	Slimy sculpin
2012	CP-01	Creek	5.31	6.43	1.68	5.97	-	-
	CP-03	Main river	188.77	5.76	0.50	0.35	6.18	3.08
	CP-05	Backwater slough	0.61	1.66	2.13	0.99	0.68	-
	CP-07	Main river	9.70	3.80	0.29	0.76	1.84	-
	CP-08	Backwater slough	-	-	29.23	1.16	1.84	0.61
2013	CP-15	Main river	3.58	4.48	2.69	6.27	-	-
	CP-18	Perched lake	1.01	21.31	1.01	-	-	-
	CP-19	Lake outlet	0.38	-	-	1.37	-	3.58
	CP-20	Drainage lake	0.46	-	-	-	-	1.37
	CP-21	Main river	-	12.77	2.53	2.83	-	-

Appendix 6. Mean CPUE (#fish/24 hrs.) of least cisco (LCIS), broad whitefish (BDWF), Arctic grayling (GRAY), humpback whitefish (HBWF), ninespine stickleback (NSSB), burbot (BURB), rainbow smelt (RBSM), and longnose suckers (LNSK) in fyke net sample sites in the Meade River, 2014 and 2015.

	Station #	Habitat Type	LCIS	BDWF	GRAY	HBWF	NSSB	BURB	RBSM	LNSK
2014	MD-02	Drainage lake	9.98	1.25	0.63	-	-	-	-	-
	MD-09	Creek	6.10	4.46	29.71	-	0.90	0.64	-	-
	MD-10	Backwater slough	-	-	14.53	-	11.18	1.12	-	-
	MD-11	Backwater slough	10.12	23.57	65.92	4.49	16.68	0.62	-	1.89
	MD-12	Lake outlet	3.75	6.39	8.45	2.35	0.64	0.25	0.12	0.38
	MD-13	Drainage lake	15.49	24.72	15.57	1.88	9.94	1.73	0.53	0.41
	MD-14	Lake outlet	2.40	17.31	7.40	0.63	2.06	0.32	0.40	0.20
	MD-15	Lake outlet	-	-	31.10	0.39	1.94	-	-	-
June 2015	MD-01	Drainage lake	112.90	2.72	29.51	0.91	-	-	-	-
	MD-02	Drainage lake	33.82	5.22	2.54	-	-	-	-	-
	MD-03	Lake outlet	20.20	-	25.97	-	-	-	-	-
	MD-04	Creek	1.39	1.39	4.87	-	-	-	-	-
	MD-05	Creek	2.65	-	6.90	-	0.98	-	-	-
	MD-06	Drainage lake	300.65	173.19	30.16	4.86	-	-	-	-
	MD-08	Creek	51.63	9.02	11.64	0.11	2.00	0.10	0.10	-
	MD-09	Creek	26.20	3.78	10.11	-	-	1.14	-	-
	MD-14	Lake outlet	125.54	36.57	12.57	11.62	-	0.90	-	2.89
	MD-16	Drainage lake	248.74	29.82	7.65	27.79	-	-	13.45	-
	MD-17	Drainage lake	230.35	18.83	19.84	17.21	-	-	2.65	1.16
	MD-18	Drainage lake	289.02	48.85	51.90	10.18	-	-	1.02	-
	MD-19	Creek	1.76	1.76	103.36	-	-	-	-	-
Aug 2015	MD-07	Drainage lake	75.65	156.36	9.91	7.33	-	1.66	-	-
	MD-08	Creek	51.25	27.02	2.13	4.27	-	0.58	-	-
	MD-14	Lake outlet	6.67	0.40	0.40	-	2.77	0.35	-	-
	MD-16	Drainage lake	49.96	25.23	3.31	3.81	1.90	0.94	-	-
	MD-17	Drainage lake	69.50	26.46	4.58	2.35	-	1.20	1.70	-
	MD-18	Drainage lake	2.64	2.44	29.28	0.98	28.63	2.84	-	-

Appendix 7. Comparison of linear relationships between log fork length (mm) and age (years) of least cisco, broad whitefish, humpback whitefish, and Arctic grayling between rivers in the current study (Chipp River 2012, Topagoruk River 2012, and Meade River 2015) 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	Meade/Chipp/Topagoruk vs. Chipp 2008[2]	Slope	0.370	0.544
			Intercept	7.812	**0.006**
		Meade/Chipp/Topagoruk vs. Chipp 93-94[2]	Slope	20.244	**<0.001**
			Intercept	18.762	**<0.001**
Broad whitefish	1–8	Meade 2015 vs Chipp 93-94[2]	Slope	16.468	**<0.001**
			Intercept	38.769	**<0.001**
Humpback whitefish	3–9	Meade 2015 vs Chipp 2012	Slope	3.151	0.081
			Intercept	4.340	**0.042**
		Meade 2015 vs. Chipp 2008[2]	Slope	3.919	0.051
			Intercept	21.444	**<0.001**
		Meade 2015 vs. Chipp 93-94[2]	Slope	0.367	0.546
			Intercept	51.059	**<0.001**
		Chipp 2012 vs. Chipp 2008[2]	Slope	8.810	**0.005**
			Intercept	18.087	**<0.001**
		Chipp 2012 vs. Chip 93-94[2]	Slope	4.185	**0.049**
			Intercept	64.781	**<0.001**
	≥10	Meade 2015 and Chipp 2012 vs Chipp 2008[2]	Slope	1.687	0.199
			Intercept	39.108	**<0.001**
		Meade 2015 and Chipp 2012 vs Chipp 93-94[2]	Slope	8.567	**0.005**
			Intercept	33.551	**<0.001**
Arctic grayling	2–5	Meade 2015 vs Teshekpuk 2004[1]	Slope	0.016	0.899
			Intercept	7.736	**0.007**

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

Appendix 8. Reproductive characteristics of least cisco and Arctic grayling caught in the Topagoruk, Chipp, and Meade River drainages from 2012 to 2015.

	Sex	Least cisco	Arctic grayling
Age/Length[1] of Youngest Sexually Mature	Male	4 y	4 y
		247.6 ± 11.1 mm (3)	258.6 ± 19.4 mm (3)
	Female	4 y	3 y
		242.2 ± 58 mm (5)	235 mm
Pre-spawners % of all Mature[2]	Male	45%	NA
	Female	52%	NA
Age/Length of Oldest Mature	Male	17 y	10 y
		318 mm	384 mm
	Female	25 y	8 y
		278 mm	361 mm
Age/Length[1] of Oldest Immature	Male	6 y	5 y
		204 mm	288 mm
	Female	7 y	5 y
		228 mm	272 ± 1 mm (2)
Sex Ratio (female/male)		1.76	1.27

[1]Lengths given as mean ± 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

Appendix 9. Mean CPUE (#fish/24 hrs.) of fish captured by set gillnet sites in the Chipp River, 2012 and 2013.

	Station #	Habitat Type	Broad whitefish	Humpback whitefish	Chum salmon	Pink salmon	Arctic grayling	Least cisco	Northern pike
2012	CP-01	Creek	-	-	-	-	-	-	-
	CP-02	Main river	14.47	-	0.69	0.20	-	-	-
	CP-03	Main river	8.02	9.03	-	-	0.90	0.13	2.29
	CP-04	Main river	-	-	-	-	-	-	-
	CP-06	Main river	0.86	-	-	-	-	-	-
	CP-09	Main river	12.63	-	-	1.26	-	-	-
2013	CP-10	Main river	7.88	-	-	-	-	-	-
	CP-11	Main river	7.89	-	-	-	-	-	-
	CP-12	Main river	-	-	-	-	-	-	-
	CP-13	Main river	11.04	1.12	-	-	-	-	-
	CP-14	Main river	4.94	0.40	-	0.72	-	-	-
	CP-16	Main river	0.62	-	-	-	-	-	-
	CP-17	Main river	10.86	-	-	-	-	-	-

Appendix 10. Comparison on linear relationships between log fork length (mm) and log weight (g) of broad whitefish, humpback whitefish, and Arctic grayling between rivers in the current study (Chipp River 2012, Topagoruk River 2012, and Meade River 2015) and other studies (Moulton et al. 2007, Moulton et al. 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
Broad whitefish	9+	Chipp/Topagoruk[1] vs. Chipp 93-94[1, 3]	Slope	12.988	**0.001**
			Intercept	12.311	**0.001**
Humpback whitefish	<10	Meade[1] vs Chipp 08[1, 3]	Slope	17.139	**<0.001**
			Intercept	2.432	0.122
		Meade[1] vs. Chipp 93[1, 3]	Slope	28.277	**<0.001**
			Intercept	0.001	0.976
	10+	Meade[1] vs. Chipp 08[1, 3]	Slope	0.947	0.337
			Intercept	17.209	**<0.001**
		Meade[1] vs. Chipp 93[1, 3]	Slope	1.060	0.312
			Intercept	7.584	**0.010**
Arctic grayling	All	Meade[1] vs. Teshekpuk[2]	Slope	0.698	0.405
			Intercept	52.585	**<0.001**

[1]excludes pre-spawning females
[2]Moulton et al. 2007
[3]Moulton et al. 2011

Appendix 11. Reproductive characteristics broad whitefish caught in the Topagoruk River in 2012, Chipp River in 2012, and Meade River in 2015.

	Sex	Chipp/Topagoruk River	Meade River
Age/Length of Youngest Sexually Mature	Male	10 y	NA
		474 mm	NA
	Female	11 y	NA
		415 mm	NA
Pre-spawners % of all Mature	Male	61%	NA
	Female	66%	NA
Age/Length of Oldest Mature	Male	23 y	NA
		613 mm	NA
	Female	22 y	NA
		474 mm	NA
Age/Length[1] of Oldest Immature	Male	8 y	6 y
		402.5 ± 31.5 mm (2)	404 mm
	Female	11 y	8 y
		418 mm	420 mm
Sex Ratio (female/male)		0.48	0.86

[1]Lengths given as mean ± standard deviation (sample size) where sample size > 1

Appendix 12. Reproductive characteristics humpback whitefish caught in the Chipp River in 2012 and Meade River in 2015.

	Sex	Humpback whitefish
Age/Length[1] of Youngest Sexually Mature	Male	5 y
		316 mm
	Female	7 y
		328 ± 30 mm (2)
Pre-spawners % of all Mature	Male	58%
	Female	29%
Age/Length of Oldest Mature	Male	22 y
		401 mm
	Female	20 y
		408 mm
Age/Length[1] of Oldest Immature	Male	8 y
		341.5 ± 2.5 mm (2)
	Female	7 y
		295.3 ± 29.8 mm (3)
Sex Ratio (female/male)		0.78

[1]Lengths given as mean ± standard deviation (sample size) where sample size > 1