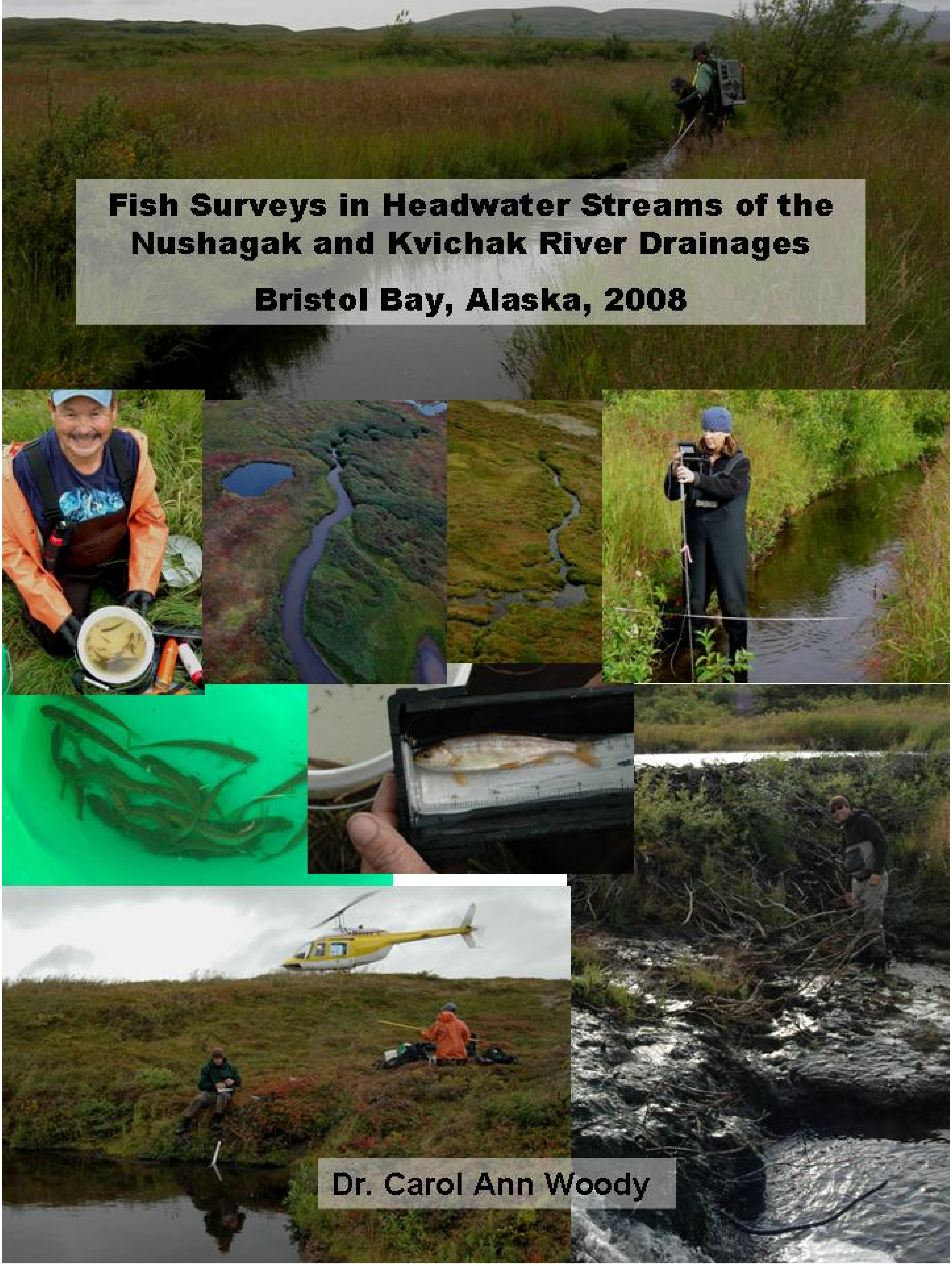
# Fish Surveys in Headwater Streams of the Nushagak and Kvichak River Drainages

## Bristol Bay, Alaska, 2008



Dr. Carol Ann Woody

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Acknowledgements

This work would not have been possible without the expertise of volunteer Alaskan scientists who opted to spend their holiday chasing fish: Daniel Rinella, Nicky Szarzi, and Steve Baird. The Bristol Bay Native Association contributed the fishing skills and bush know-how of Daniel Chythlook. The Cook Inlet Keeper contributed their cheery hydrology expert, Sue Mauger. Marcus Geist of The Nature Conservancy is responsible for both the amazing maps in this report and long term GIS database development. The Rainbow King Lodge, located on the shores of Lake Iliamna, Alaska, provided warm rooms, transport and delicious meals to the field crew. The University of Washington loaned both their vehicle and bunkhouse to the effort and Dan Young of the National Park Service provided a backup electroshocker and valuable logistical support. The Alaska Department of Fish and Game and Mike Weidmer provided valuable study plan input and ongoing technical advice. A special thanks to our patient and extremely capable helicopter pilot, “no stress” Bill **(get last name)** of Coastal Helicopters. Funding and logistical support for this study was provided by The Nature Conservancy.

# Fish Surveys in Headwaters of the Nushagak and Kvichak River Drainages, Bristol Bay, Alaska, 2008

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## Abstract

In 2008, over 42 million salmon returned to Bristol Bay, Alaska, site of the world's largest sustainable wild sockeye salmon fishery. Proposed development of a massive porphyry copper-sulfide deposit there heightened concerns regarding fish conservation and underscored the need for basic fish distribution data. Such information is important for two reasons: 1) collectively, small streams can be a major source of salmon production, and 2) in Alaska, explicit documentation of fish in a water body is required to trigger application of fish conservation statutes and regulations to guide development. To improve state fish distribution databases for Bristol Bay, single pass electrofishing surveys were conducted in both the North and South Fork Koktuli Rivers (Nushagak) and in Upper Talarik Creek (Kvichak) during 29 August to 2 September, 2008. Basic water quality and stream mophometry data were also documented.

A total of 35 headwater streams were surveyed. Electrofishing revealed anadromous salmon in 20 tributaries, resident fish in 23 tributaries, and no fish in two tributaries. Seven selected survey streams were dry, two were unfishable, and one was nonexistent during this study.

Diurnal water quality parameters during this study averaged: 7.7˚C (n = 24; SD = 2.1); pH 7.3 (n = 23; SD = 0.2); conductivity 58.0 µS/cm (n = 23; SD = 26.5) and dissolved oxygen 11.1 mg $O_2$/L (SD = 1.3). Morphometry of headwater streams averaged 1.9 m wide (n = 23; SD = 0.88) by 25.7 cm deep (n = 23; SD = 13.5) with mean flows of 1.5 cfs (n = 23; SD = 1.3). Dominant substrate composition in survey streams primarily consisted of fine to coarse (>2 mm dia < 64 mm dia) gravel.

About 47 kilometers (28 miles) of essential salmon rearing habitat was documented in 2008 and nominated for the first time to the state Anadromous Waters Catalogue. Data on both anadromous salmon and resident fish species distributions were mapped into a GIS database and submitted to Alaska State fisheries databases. Surveyed reaches were generally clear, cold, of neutral pH and very low conductivity indicating very pure dilute waters. This study provides Bristol Bay resource managers more complete information upon which to make fish conservation decisions. However, many small streams that likely support salmon and resident fish species in regions slated for development remain unsurveyed.

## Introduction

Over 42 million wild salmon returned to Bristol Bay, Alaska, in 2008 (ADFG 2008). Athabaskan, Aleut, and Yupik peoples have relied on this annual return for subsistence for thousands of years, and today salmon still comprise 60% to 80% of their total subsistence harvest (Fall 2006). The commercial sockeye salmon fishery that began in 1893 is the world's largest and is recognized as a rare example of a sustainable commercial fishery. Since 1987, commercial sockeye salmon harvests averaged 30 million from an average run of 37 million sockeye (ADFG 2007). Hilborn *et al*. (2003) attribute this sustainability, in part, to high salmon stock diversity, a limited number of fishers, and enlightened management by the Alaska Department of Fish and Game.

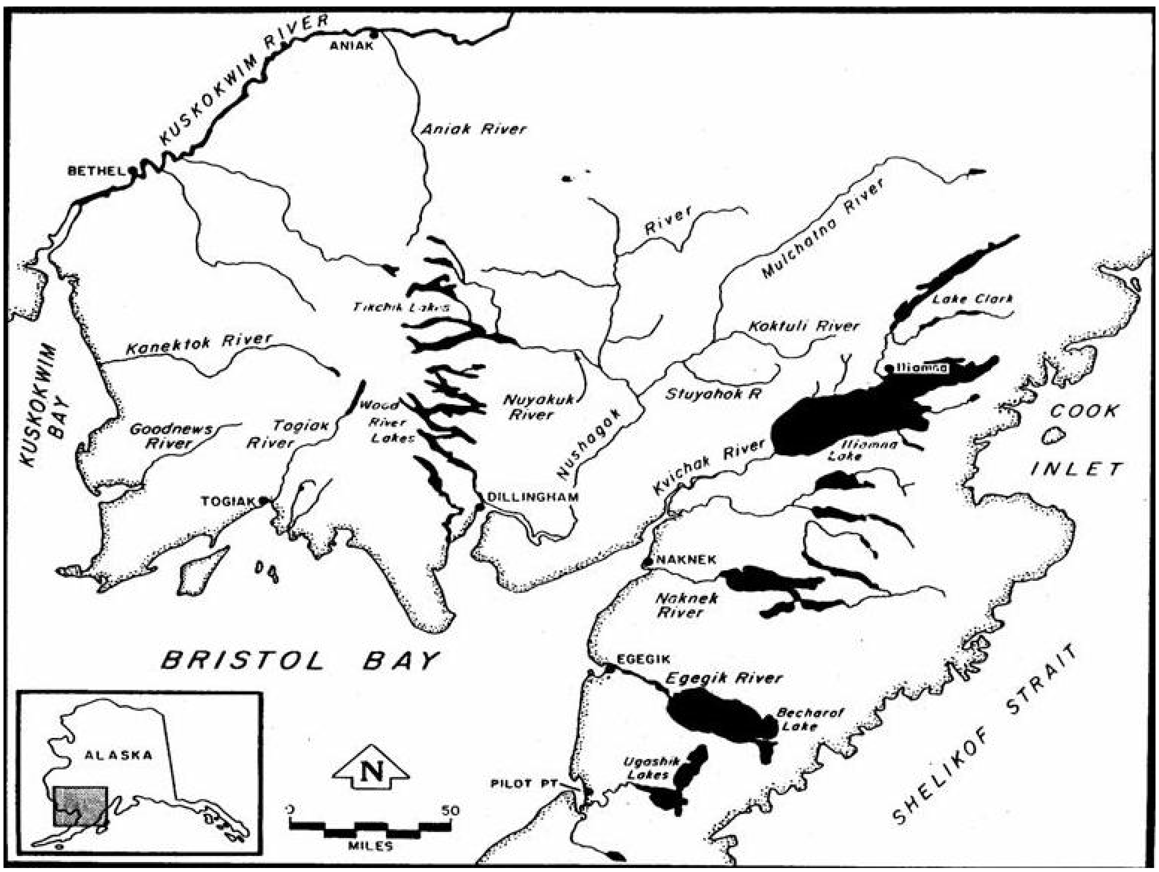


**Figure 1.** Schematic map of the Bristol Bay watershed depicting major salmon producing rivers.

Managers of the Bristol Bay fishery refer to fish that spawn in each Bristol Bay river watershed as a stock (Figure 1). However, many small unique spawning populations comprise each larger stock. These smaller subpopulations generally differ from each other in adaptations to their spawning habitats, phenotypes and genotypes (Blair *et al.* 1993, Hilborn *et al.* 2003, Ramstad *et al.* 2004, Lin *et al.* 2008). Productivity among subpopulations varies among years such that declines in production of some subpopulations tend to be counterbalanced by increased productivity in other subpopulations (Hilborn *et al.* 2003). This biodiversity helps ameliorate adverse effects of environmental change on the larger Bristol Bay stocks (Figure 1) and is considered a major reason Bristol Bay salmon production has remained stable over time despite changing environmental conditions and heavy exploitation. This stability is termed the "portfolio effect" whereby the larger fish stock is a "portfolio" of smaller subpopulations and is more stable or resilient to change due to this high local biodiversity (Hilborn *et al.* 2003).

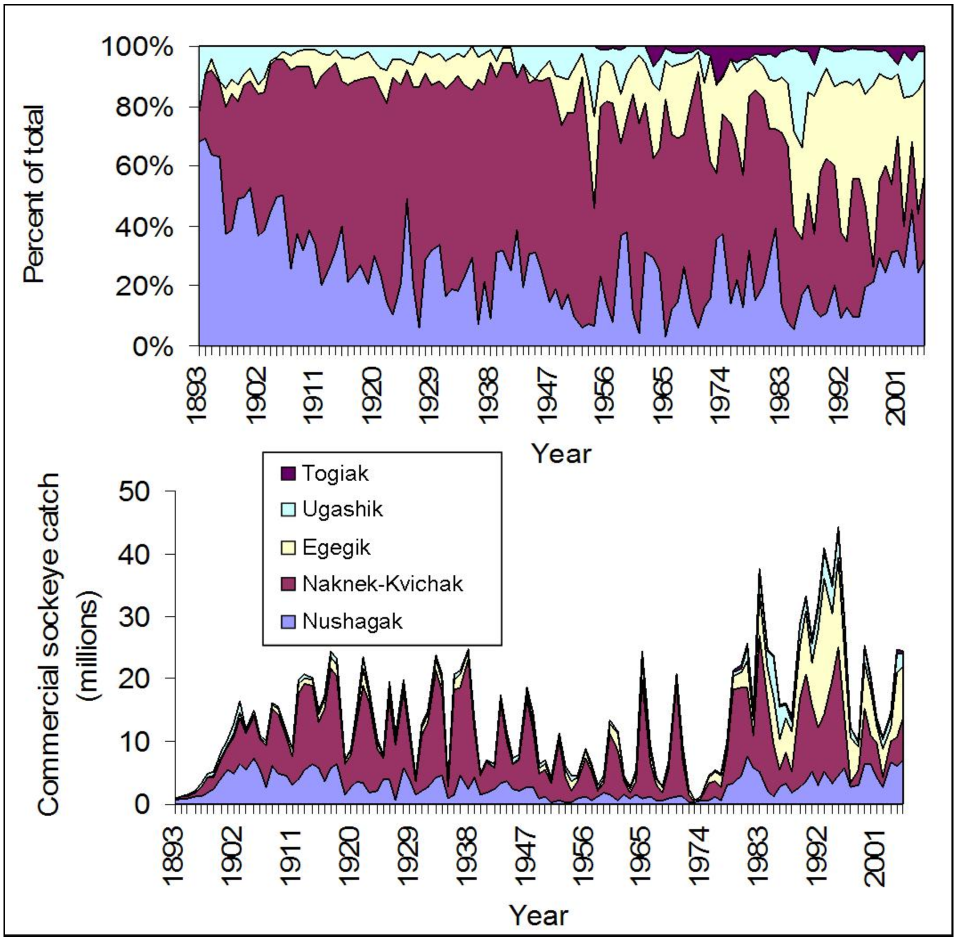


**Figure 2.** Upper graph depicts variation in percent contribution of each major river system to the total Bristol Bay harvest since 1983. Note the variation in contribution of each major stock over time and the long term sustainability of the fishery and harvest (lower graph). Stocks originating from each watershed are actually comprised of a "portfolio" of smaller distinct spawning subpopulations which contributed to the Bristol Bay being branded as a "sustainable fishery" a coveted brand that few fisheries attain. Data from ADFG, graphs modified and updated from Hilborn *et al.* 2003.

Conversely, the loss of biodiversity, i.e., loss of smaller subpopulations, can lead to declines in resiliency, overall fish production, and even extinction (Allendorf *et al.* 1997, Gustafson *et al.* 2007, Bilby 2008). For example, Gustafson *et al.* (2007) estimated losses of salmon and steelhead diversity from the Pacific Northwest and California, "…collectively, 29% of nearly 1,400 historical populations of these six species have been lost… since Euro-American contact".

Resource managers often make important regulatory decisions on fish conservation relative to resource development. However, in Alaska it is estimated that less than half of essential salmon freshwater habitats are even documented (ADFG 2008). Small salmon streams are not generally a high priority for presence absence surveys although collectively, they can account for the majority of essential coho salmon rearing habitat.

Compared to salmon, even less information is available on freshwater resident fish use of headwater tributaries, although these species are an important protein resource for local subsistence users (Figures 3 and 4; Krieg 2005). This dearth of information on essential habitat use by fish throughout Alaska, makes informed decisions on fish conservation relative to development difficult.

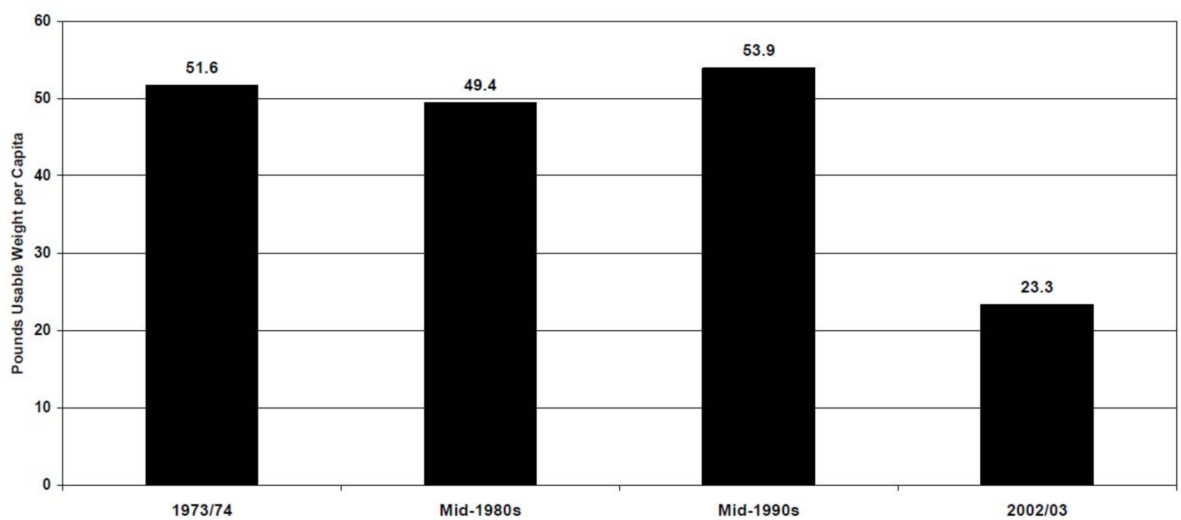


**Figure 3.** Estimated subsistence harvest of non-salmon freshwater fish in pounds useable weight per person, Kvichak River watershed, Bristol Bay Alaska. Graph from Krieg *et al.* 2005.

The Nushagak and Kvichak River watersheds are the largest in Bristol Bay and they provide essential spawning, incubation and rearing habitats for all five species of North American salmon and at least 14 resident fish species (Table 1).

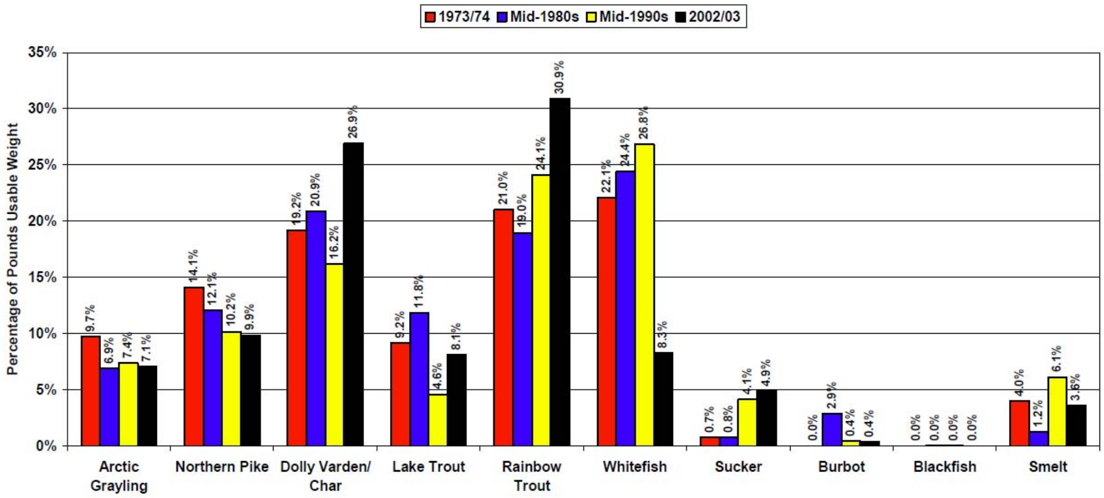


**Figure 4.** Composition of non-salmon freshwater fish harvest, by decade in villages of the Kvichak River watershed, Bristol Bay, Alaska. Graph from Krieg *et al*. 2005.

**Table 1.** Common and scientific names of fish species known to occur in the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska.

| Common name | Scientific name |
|---|---|
| **Anadromous Salmon** | |
| sockeye salmon | *Oncorhynchus nerka* |
| Chinook salmon | *Oncorhynchus tshawytscha* |
| coho salmon | *Oncorhynchus kisutch* |
| pink salmon | *Oncorhynchus gorbuscha* |
| chum salmon | *Oncorhynchus keta* |
| **Resident Fish** | |
| longnose sucker | *Catostomus catostomus* |
| northern pike | *Esox lucius* |
| least cisco | *Coregonus sardinella* |
| broad whitefish | *Coregonus nasus* |
| humpback whitefish | *Coregonus pidschian* |
| round whitefish | *Prosopium cylindraceum* |
| Arctic grayling | *Thymallus arcticus* |
| lake trout | *Salvelinus namaycush* |
| Arctic char | *Salvelinus alpinus* |
| Dolly Varden | *Salvelinus malma* |
| rainbow trout | *Oncorhynchus mykiss* |
| burbot | *Lota lota* |
| threespine stickleback | *Gasterosteus aculeatus* |
| ninespine stickleback | *Pungitius pungitius* |
| slimy sculpin | *Cottus cognatus* |

The Nushagak River watershed produced a recent 20-year average (1987-2007) commercial harvest of about 4.7 million sockeye salmon, 51,000 king salmon, 28,000 coho salmon, 450,000 chum salmon, and 61,000 pink salmon (Sands *et al.* 2008). The Kvichak River watershed alone has produced over 50% of all sockeye salmon harvested from Bristol Bay since 1893 (Fair 2003) with a recent 20-year average harvest of 8.8 million sockeye salmon. The recent 20-year average (1987-2007) salmon harvest for the Kvichak-Naknek district was about 3,500 king salmon, 6,800 coho salmon, 193,000 chum salmon, and 137,000 pink salmon (Sands *et al.* 2008). Future sustainability of such a prolific renewable resource depends, in part, on conservation of habitats essential to completion of their life cycle, including freshwater spawning, incubation, rearing, and migration habitats.

Headwaters of the North and South Fork Koktuli Rivers (Nushagak) and Upper Talarik Creek (Kvichak) are in a region slated by the state of Alaska for mineral development (see: http://www.dnr.state.ak.us/mlw/mining/largemine/pebble/). Minerals of interest, primarily copper, gold and molybdenum are located under currently productive fish habitat and upstream of the Nushagak and Kvichak rivers and Iliamna Lake. Iliamna Lake is ~2,600 $km^2$ (~1,000 $mi^2$), Alaska's largest lake, and is the world's largest sockeye salmon rearing lake where millions of salmon fry rear one to two years before migrating to sea. Although some information on presence of adult spawning salmon exists for mainstem tributaries of the North and South Fork Koktuli Rivers and Upper Talarik Creek, little empirical data is available on presence of rearing salmon and resident fishes in the smaller tributaries that drain into these mainstem rivers. Combined, these tributaries represent hundreds of miles of potential fish producing habitat.

Explicit documentation of fish species within a water body, their life stage (spawning, rearing, smolt etc.) and time of year present, aids regulators in application of fish conservation statutes and regulations. For example, construction of stream crossings, such as culverts or bridges, is often constrained temporally to minimize adverse effects of increased sediment, caused by construction, on spawning or incubating fish. Anadromous fish, like salmon, are afforded some statutory protection under Alaska Statutes, specifically:

1) Alaska Statute 16.05.871 (Anadromous Fish Act) which requires prior notification and permit approval from the Alaska Department of Fish and Game Habitat Division(ADFG) "to... use, divert, obstruct, pollute, or change the natural flow or bed" of a specified waterbody (Quoted portions from AS 16.05.871 (b)). All activities within documented anadromous waterbodies require ADFG approval, including construction; road crossings; gravel removal; mining; water withdrawals; the use of vehicles or equipment in the waterway; stream realignment or diversion; bank stabilization; blasting; and the placement, excavation, deposition, or removal of any material.

2) Alaska Statute 16.05.841 (Fishway Act) requires prior notification and permit approval from ADFG for activities within or across a stream used by fish when such uses represent an impediment to fish passage.

Activities that impact documented fish habitat can also be subject to state compensatory measures which may be monetary or restorative.

### *Study Rationale*

Documentation of fish use of headwater streams draining into the Nushagak and Kvichak Rivers is incomplete. These headwaters are now slated for extensive mineral development which will cause both direct and indirect impacts to fish habitat. To improve coverage of the Alaska Anadromous Waters Catalogue (AWC) and Fish Distribution Database (FDD), which define waterways subject to fish conservation statutes and regulations, surveys were conducted in tributaries of the state designated mining district in Bristol Bay (Figure 5).

## Study Sites

Headwater streams (n = 47) in the State designated mining district without geologic barriers to salmon migration and undocumented in the Anadromous Waters Catalogue (AWC) or Fish Distribution Database (FDD) maintained by the ADFG were selected for survey (Figure 5). Specific survey GPS coordinates were determined using the most recent AWC data in combination with geospatial data layers from the National Hydrography Dataset and the National Elevation Dataset; selected streams were generally less than 10% gradient (Figure 5). Because these GIS hydrography data sets are sometimes inaccurate e.g., mapped streams may not exist, final stream selections were determined in the field by project leaders during low-level helicopter reconnaissance or foot surveys.

## Methods

### *Fish Surveys*

Protocols were coordinated with ADFG (Buckwalter 2008) to facilitate the State AWC expansion effort. Surveys were conducted during 29 August to 2 Sept. 2008. Two teams of 3 people worked simultaneously at different tributaries within a single watershed. Sampling generally began at the confluence of two first order headwater streams (Figure 5) nearest the selected GPS survey coordinates. If salmon were documented there, the field crew moved upstream and sampled in an attempt to determine upper extent of salmon habitat use. All habitat types were sampled and electrofishing was discontinuous to avoid fish herding.

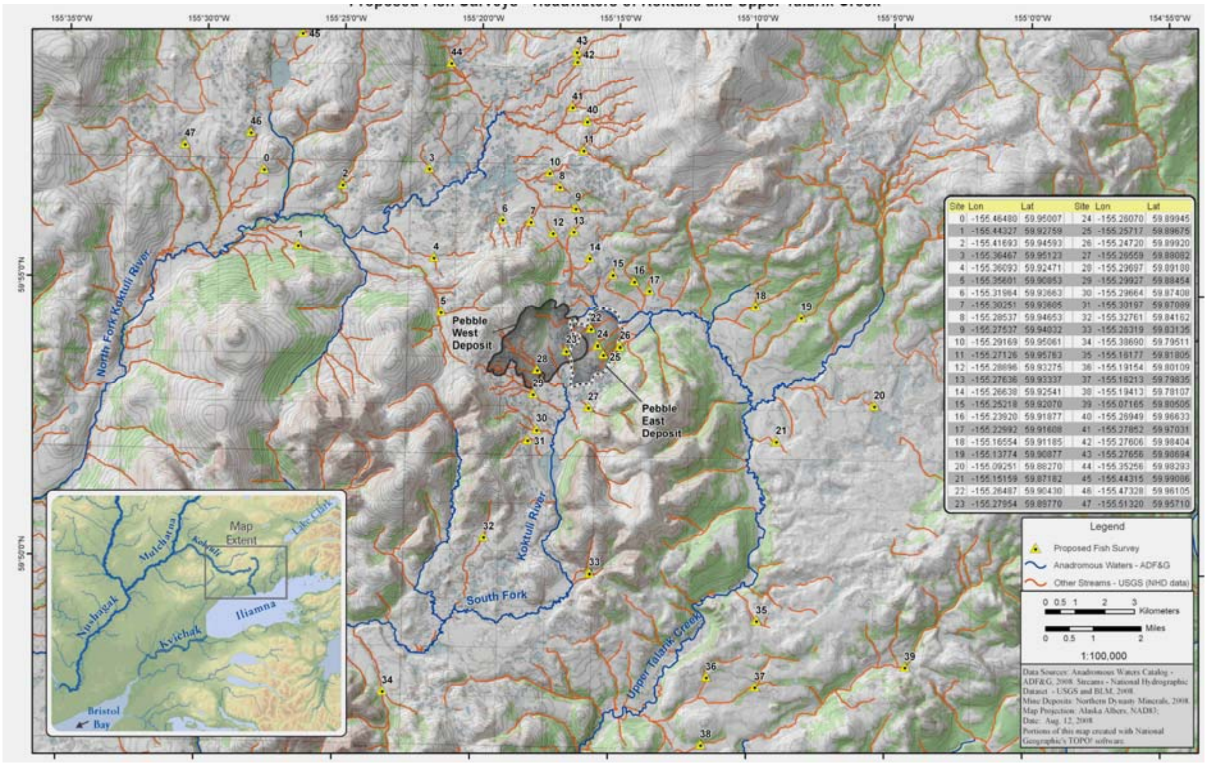


**Figure 5.** Numbers indicate headwater tributaries selected for survey in the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 2008. Blue streams are documented anadromous salmon streams in the Alaska Department of Fish and Game's Anadromous Waters Catalogue. Orange streams lack any fish presence or absence data.

Single pass backpack electrofishing was conducted using pulsed direct current (DC). Pulse frequencies used ranged from 30 to 40 pps based on Meador *et al.* (1993) and Reynolds (1996). Electrofishers were programmed for 30 pulses/sec DC and an initial voltage of 800 V due to low measured conductivities (<150 µS/cm). When fish were not attracted to the anode, voltage was increased. If fishing efficacy remained low at high voltage, voltage was decreased to 800V, and pulse frequency was increased by 10 pps. Total fishing time generally exceeded 300 s, except at site number 47 (Figure 5) where fishing time was decreased due to ADFG permit stipulations indicating catch was not to exceed 25 anadromous salmon per site (Piorkowski 2008). Captured fish were held in a bucket of fresh stream water during the electrofishing survey, after which, salmon were measured; a voucher photo taken, then fish were released. If time permitted, resident species were measured prior to release.

### *Habitat Measurements*

One transect was established in a run within each surveyed tributary; GPS coordinates were recorded. Basic water quality was measured in the thalweg with a Hydrolab: temperature, pH, conductivity, and dissolved oxygen (DO). Discharge (cfs) was measured following USGS protocols (Rantz 1982). Stream stage was categorized (dry, low, medium, or high water). Morphometric measures included channel width and thalweg measured at both wetted and ordinary high water (OHW) (Kaufman *et al*.1999). Channel slope was measured by taking multiple readings over the reach using a handheld clinometer and a graduated pole. Visual categorizations were made for both water color (clear, ferric, glacial-high turbidity, glacial-low turbidity, humic, or muddy) and substrate composition (mm dia): Category 1: < 2mm; Category 2: >2-16 mm; Category 3: >16-64; Category 4: >64-128 and Category 5: >128 mm. Upstream and downstream photographs were made from ~ 50 m in the air above each reach.

## Results

### *Fish Surveys*

A total of 37 streams were surveyed by air or foot out of 47 preselected sites. Of the 37 sites, one had no discernable stream channel (Site 46; Figure 5), 7 were dry (Sites 1, 6, 8, 10, 32-34; Figure 5), and two sites proved unsuitable for electrofishing due to dense willow growth (18 and 31); baited minnow traps left overnight would be a more effective sampling tool in these habitats. Electrofishing time at each site averaged 665 s/site and ranged from 230 s to 1838 s. Due to permit stipulations (Piorkowski 2008) and the difficulty of sampling a contiguous run due to dense riparian vegetation, standardized survey reach lengths, e.g., 40 times the stream width, were difficult to attain. Therefore, Catch Per Unit Effort (CPUE) is a more appropriate measure to standardize our fishing effort and results.

Of the 27 electrofished streams, anadromous rearing king and coho salmon were documented in 20 streams (Appendix I, III-V). Coho were captured at 18 sites while both king and coho salmon were captured at 2 additional sites. Catch Per Unit Effort (CPUE) for anadromous rearing salmon in these 20 streams averaged 1 salmon per 63 seconds of electrofishing effort. One channel surveyed was dry near the confluence with the North Fork Koktuli (Site 5); however, coho salmon were captured in the upper reaches above the dry section. Since our survey was conducted during low flow conditions, salmon must access this, and potentially similar sites, at higher flow regimes.

Coho salmon (n = 203) averaged 68.3 mm and ranged in size from 42 mm to 136 mm (Figure 6). Three king salmon were captured and averaged 80 mm fork length; all king salmon captured were beginning to turn silver and parr marks were fading, coho salmon larger than 91 mm showed similar coloration (Appendix III; survey site 7 & 9 confluence king salmon voucher; sites 1, 4, 5, and other coho salmon vouchers see Appendicies III-V). Salmon size data suggest some coho salmon may remain in fresh water for three years based on the discontinuous size distributions (Figure 6) which show distinct first and second year coho age classes, then a gap with no overlap in sizes before the last size class- indicative of another age class. This large coho salmon was collected at the stream confluence of survey sites 7 and 9 near a large lake system that the Pebble Limited Partnership refers to as “Big Wiggly Lake”, and which local Yupik Natives in the region refer to as “qagiiyayagaat irrvia”, which translates to “a hiding place for young coho” (Daniel Chythlook, Bristol Bay Native Association, Personal Communication).

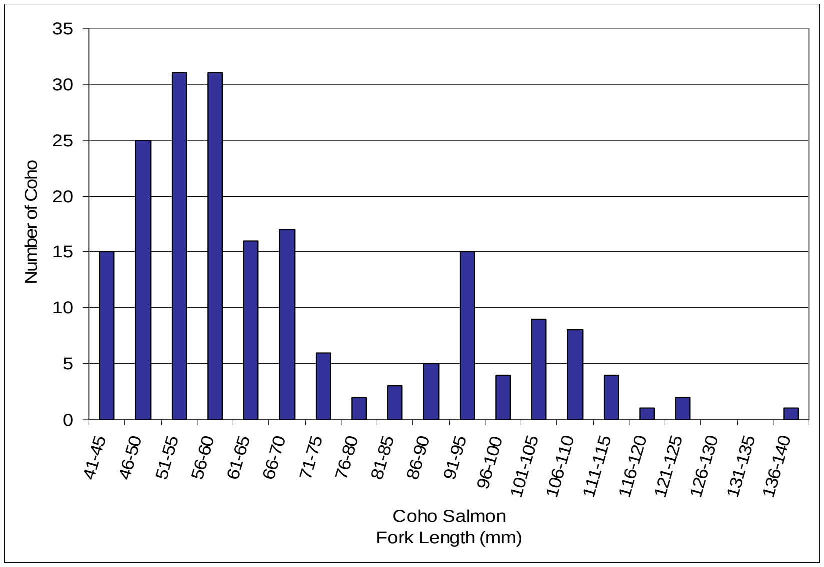


**Figure 6.** Size distribution of coho salmon (n = 203) rearing in 20 headwater tributaries of the N. and S. Fork Koktuli rivers (Nushagak drainage) and Upper Talarik Creek (Kvichak drainage), Bristol Bay, Alaska, 29 Aug. to 2 Sept. 2008.

Resident fish, including: Dolly Varden, grayling, nine spine stickleback, northern pike, round whitefish, slimy sculpin, and three spine stickleback, were documented in 23 streams (Appendix II); no fish were captured in two streams. Field crews identified and enumerated all fish encountered; resident species were measured if time permitted. Data on resident species distributions were mapped into a GIS database and shapefiles were provided to ADFG for inclusion in the ADFG Fish Distribution database. Thousands of tiny (<2 mm) sculpin fry, were observed concurrent with adult female sculpin that appeared gravid at sites 2, 7, 9 (Figure 5; Appendix II).

### *Habitat Surveys*

Surveyed headwater tributaries were generally first or second order streams, with cold, clear water of neutral pH and very low conductivity (Table 1). Dissolved oxygen levels were at or near saturation for recorded temperatures (Table 2).

**Table 2.** Summary of basic water quality parameters measured in headwater tributaries of the North and South Fork Koktuli Rivers and Upper Talarik Creek, Bristol Bay, Alaska, 2008.

| **Statistic** | ***Water temp (°C)*** | ***Air temp (°C)*** | ***pH*** | ***Conductivity* µS/cm** | ***DO (mg/L)*** |
|---|---|---|---|---|---|
| n | 24 | 22 | 23 | 23 | 23 |
| Mean | 7.7 | 14.2 | 7.3 | 58.0 | 11.1 |
| Standard Deviation | 2.1 | 3.4 | 0.2 | 26.5 | 1.3 |
| Minimum | 3.3 | 8.9 | 6.8 | 22.6 | 8.2 |
| Maximum | 11.5 | 20.0 | 7.9 | 128.0 | 13.1 |
| CI 95% | 7.7 ± 0.9 | 14.2 ± 1.5 | 7.3 ± 0.1 | 58.0 ± 11.5 | 11.1± 0.6 |

Surveyed headwaters were generally low gradient palustrine or wetland channel types (Paustian 1992) including groundwater fed mossy streams; beaver ponds; and narrow placid flow channels (Appendices III-V). Many streams were associated with off-channel and beaver ponds which, similar to willow encased streams, were difficult to sample with the electroshocker. In both these situations (ponds and dense riparian cover) baited minnow traps set for 12 – 24 hours would be a more appropriate sampling tool. During this survey, streams were categorized as low (n = 16) or medium flow (n = 8).

Wetted widths averaged 1.9 m wide by 25.7 cm deep compared to ordinary high water (OHW) which averaged 2.2 m wide by 35.8 cm deep measured at the thalweg. Discharge averaged 1.5 cfs at the low to medium flows encountered in this study (Table 3). Substrate composition of streams varied from 100% sand and silt (< 2mm dia) to one that was comprised of up to 20% boulders (> 128 mm dia). However, substrates in 14 of the 23 streams had ≥ 50% substrates comprised of fine to coarse gravel (≥2mm dia to < 64 mm dia) (Figure 7).

**Table 3.** Stream mophometry parameters measured for surveyed headwater streams of the North and South Fork Koktuli rivers, Nushagak River watershed, and Upper Talarik Creek, Kvichak River watershed, Bristol Bay, Alaska. Surveys conducted during 29 August to 2 Sept 2008.

| **Statistic** | ***OHW (m)*** | ***OHW thalweg (cm)*** | ***Wetted Width (m)*** | ***Wetted Thalweg (cm)*** | ***Discharge (cfs)*** |
|---|---|---|---|---|---|
| n | 23 | 23 | 23 | 23 | 23 |
| Mean | 2.2 | 35.8 | 1.9 | 25.7 | 1.5 |
| SD | 0.98 | 14.51 | 0.88 | 13.47 | 1.32 |
| Range | 4.57 | 73.15 | 4.27 | 57.91 | 5.46 |
| Minimum | 0.91 | 6.10 | 0.61 | 3.05 | 0.14 |
| Maximum | 5.49 | 79.25 | 4.88 | 60.96 | 5.60 |
| CI (95%) | 2.2 ±0.42 | 35.8 ± 6.27 | 1.9 ±0.38 | 25.7 ± 5.8 | 1.5 ± 0.57 |

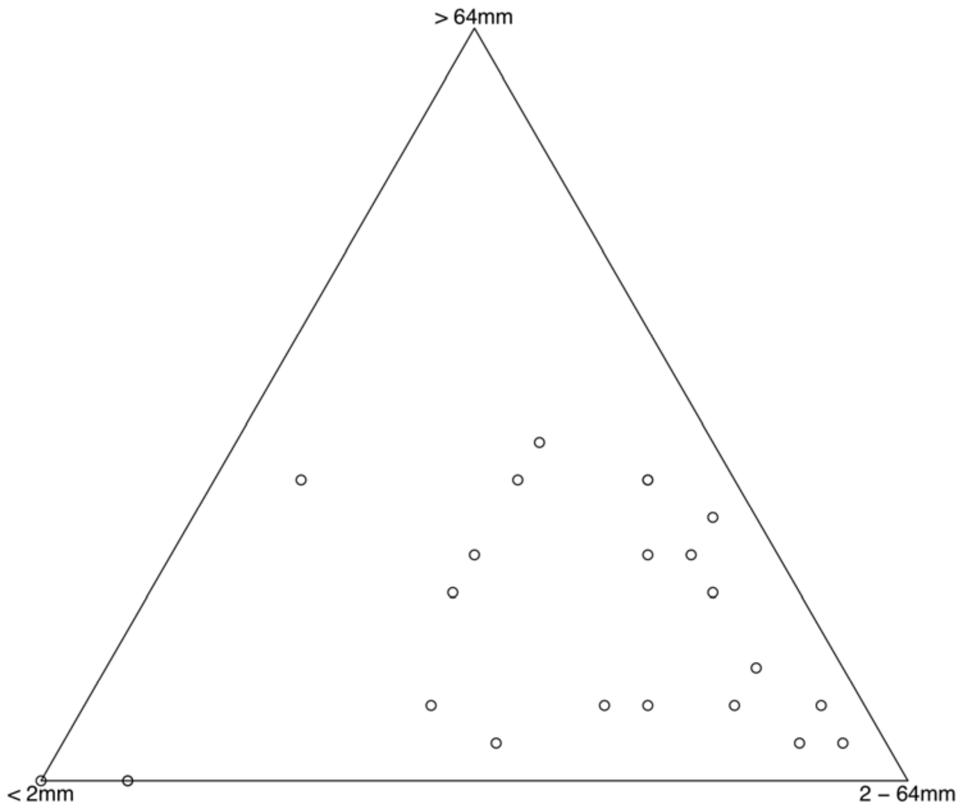


**Figure 7.** Ternary plot of stream substrate composition. One site had 100% of substrate in the fine sand and silt (< 2 mm dia) category as indicated by the dot on the lower left corner. Some sites contained only substrates <64 mm dia (points along bottom edge), and all other sites exhibited all three size classes. The largest size classes (≥64 mm dia) commonly termed cobble (64 – 128 mm dia) and boulder (>128mm dia) were least common (only two sites had >5% boulders; substrate category 5).

## Conclusions

Approximately 47 kilometers (28 miles) of previously undocumented salmon rearing habitat were mapped in 2008 and nominated for the first time to the State AWC; a length greater than the Upper Talarik Creek mainstem. A literature review by Marshall and Britton (1990) indicated a positive linear relationship exists between stream length and the number of coho smolts produced. Further study of this relationship by Bradford et al. (1997) of 86 Alaskan, Canadian and Washington streams corroborated the relationship of increasing smolt with increasing stream length, with an average of 1952 smolts produced per stream kilometer. Assuming a similar coho smolt productivity relationship here, the 47 km of anadromous streams documented in this study could produce over 91,000 coho smolt.

Headwater tributaries in this region are mostly low gradient (<5%) and many are associated with off channel ponds, beaver ponds and lakes. Sharma and Hilborn (2001) reviewed the number of coho smolt produced by different rivers and found an increase in smolt production per kilometer of stream as gradient declined and as the number of ponds associated with the streams increased. Such ponds and pools are likely important winter refuge. Coho that rear in this region would find suitable winter refugia in the numerous lakes, such as "qagiiyayagaat irrvia", beaver ponds and spring fed pools observed throughout this survey.

Of the selected survey sites 22% were dry or nonexistent, 57% contained anadromous fish and 69% contained resident fish. Although no fish were captured at 6% of the sites it should not be concluded that they do not support fish, but that none were captured during our survey. Additional surveys of similar headwaters in this region can provide similar useful estimates of the number of ephemeral and non-existent channels, anadromous and resident fish streams which could be applied at a broader scale to the thousands of yet unsurveyed streams in this region.

Surveys were conducted in late August in an effort to coincide with maximum upstream distributions of rearing coho and king salmon. Coho were found in a majority of streams surveyed, but few rearing king salmon were observed despite the previous year's strong adult escapement. The lack of king salmon observations in this study may be because our survey timing was off temporally or geographically or because they had low overwinter survival. We likely did not sample sufficient habitats king salmon prefer based on prior studies focused on habitat segregation between coho and king salmon. A study in the Taku River, Alaska, found coho in sloughs, off channel or beaver ponds and kings found were mainly in riverine habitat (Murphy 1989). In the Big Quallicum River, coho were found more frequently in lower velocity sites than king salmon (Lister and Genoe 1970). Scarnecchia and Roper (2000) found coho essentially absent from a mainstem river, but at high densities in low-elevation tributaries, compared to kings which were found at highest densities in the mainstem and mid-elevation tributaries. Because our study was limited to small headwater tributaries during low flow, more kings might be encountered in deeper higher velocity habitats than observed during this study.

Resident fish are an important subsistence food resource for people of this region (Figures 3 and 4). The last non-salmon subsistence use survey conducted by Krieg *et al.* (2005) for the Kvichak watershed indicated use of Dolly Varden has increased over the last decade from about 16% to 27%. Little is known about the life history of Dolly Varden in this region including whether they are anadromous, their movement patterns within and among drainages and their abundance. In this study, Dolly Varden were the second most abundant species encountered next to sculpin. They were found in the higher gradient habitats and were most abundant (136) in a small (< 2 m) shallow (< 0.5 m) spring fed tributary (Site 42) with rooted aquatic plants and mosses. Further information on this species, especially regarding anadromy would provide valuable information to both subsistence managers and regulators.

Small headwater streams are not afforded the same conservation considerations as large mainstem rivers they create. However, as illustrated here, small headwater tributaries can comprise a significant amount of essential salmon and resident fish habitat. The conservation of sustainable salmon and resident fish resources depends on conserving essential habitats. The information gathered here on headwater stream basic chemistry, channel morphology and fish communities will provide more complete and accurate information upon which to base future fish conservation decisions.

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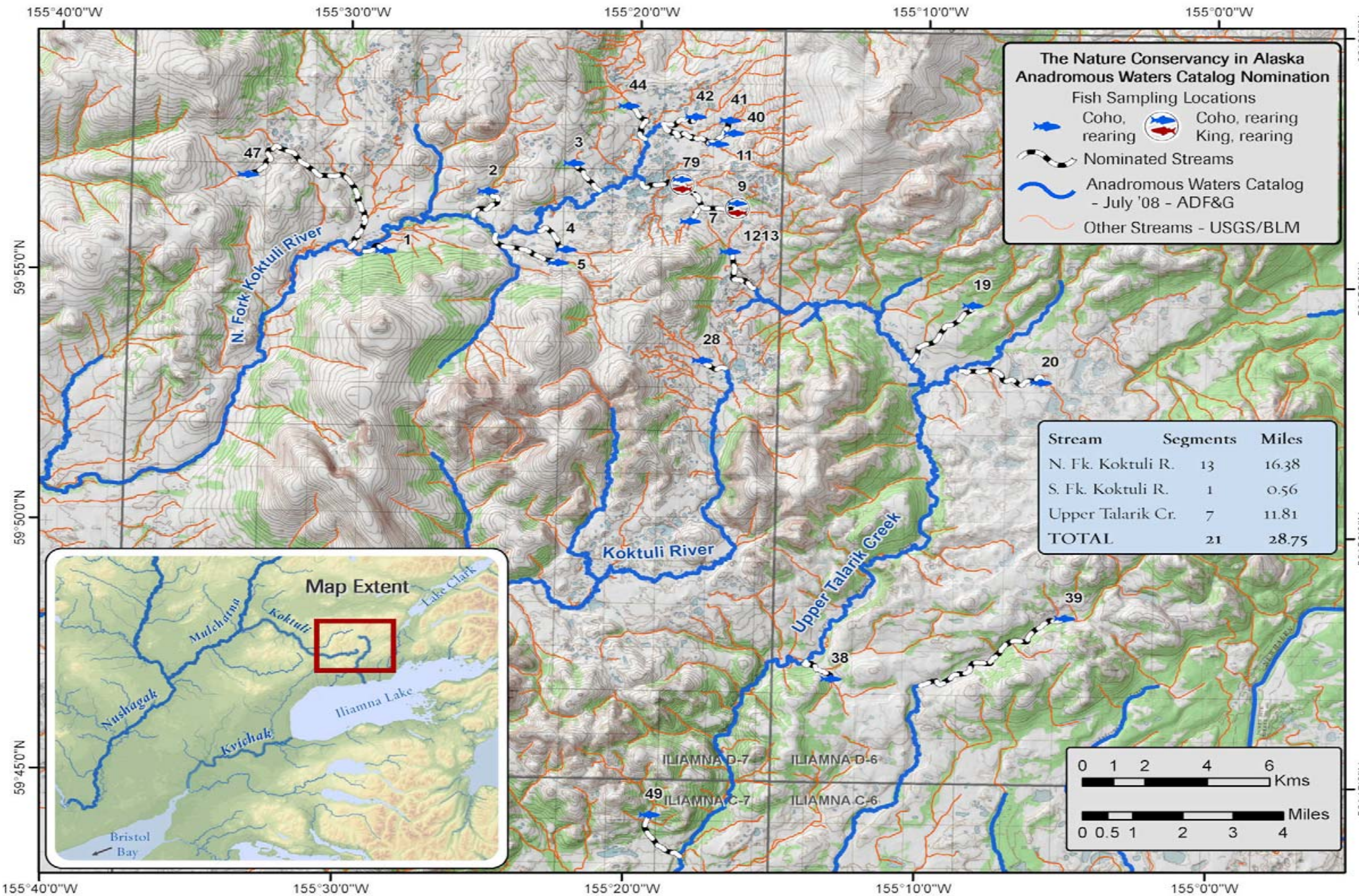
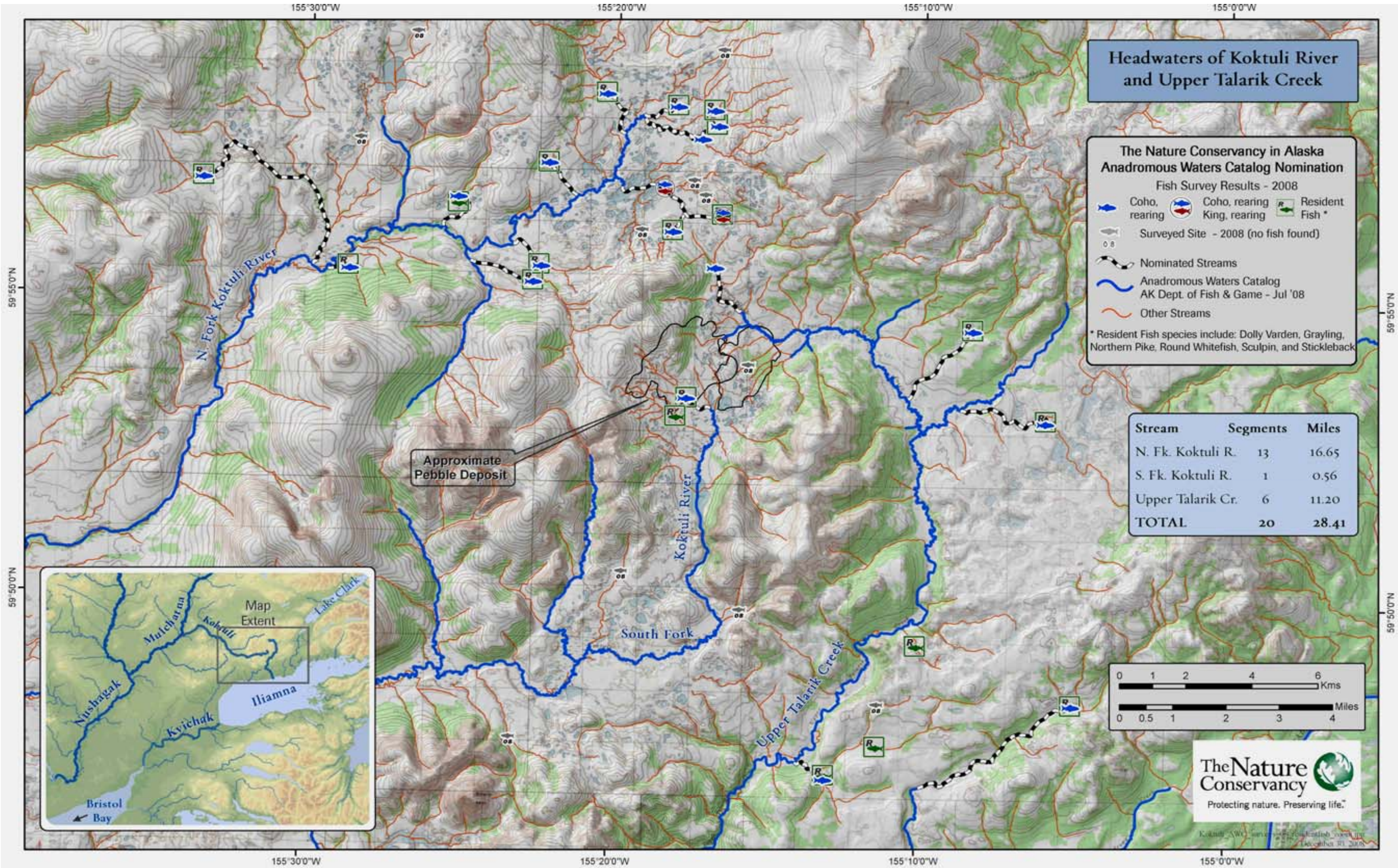
**Appendix I.** Hatched lines show tributaries where anadromous salmon were newly documented during 2008 electrofishing surveys; North and South Fork Koktuli rivers and Upper Talarik Creek, Bristol Bay, Alaska.



**Appendix II.** Tributaries where resident and anadromous fish presence were documented during 2008 electrofishing surveys; North and South Fork Koktuli rivers and Upper Talarik Creek, Bristol Bay, Alaska, 2008. Streams where no fish were found are delineated by a grey fish shape and represent: nonexistent channels or dry streams (8), unfishable streams (2) and surveyed streams where no fish were detected (2).



**Appendix III.** North Fork Koktuli River tributary study site photos and salmon vouchers, 2008.

Site 1.


Site 1. North Fork Koktuli tributary looking downstream.


Site 1. Looking upstream from ~50m in the air.

Site 1. Coho salmon voucher.

Site 2.


Site 2.  North Fork Koktuli River tributary looking downstream.


Site 2. Looking upstream from ~ 50m in air.


Site 2.  North Fork Koktuli coho salmon.

Site 3.

Site 3.  North Fork Koktuli tributary looking downstream.

Site 3.  Looking upstream from ~ 50 m in air.

Site 3. Coho voucher.

Site 4.


Site 4. North Fork Koktuli tributary looking upstream.


Site 4. Looking upstream from ~ 50 m in air. Note pond in upper left.


Site 4. Coho salmon voucher.

Site 5.

Site 5.  North Fork Koktuli looking upstream.  Lower reach of this stream was dry.

Site 5.  Looking upstream from ~ 50 m in air.

Site 5.  Coho salmon voucher.

Confluence of Sites 7 and 9.

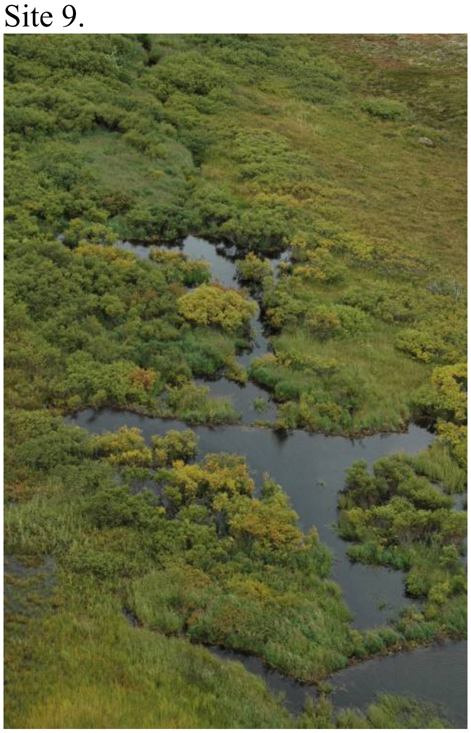
Sites 7 and 9. North Fork Koktuli tributary and lake system. Aerial view from ~ 50 m taken just below confluence of study sites 7 and 9. Some refer to the lake into which both drain “Big Wiggly Lake”, however, the Yupik name for this system is “qagiiyayagaat irrvia “. Upper reaches of each fork were surveyed the next day.

Sites 7 and 9. Coho and king salmon vouchers from fork. Note king silver coloration.

Site 7.

Site 7. North Fork Koktuli tributary looking upstream from ~50 m in air. Coho salmon, grayling, slimy sculpin and northern pike observed in this small spring fed tributary.

Site 9.



Site 9. North Fork Koktuli tributary looking downstream from ~ 50m in air. Chinook and coho salmon, grayling, and sculpin observed.

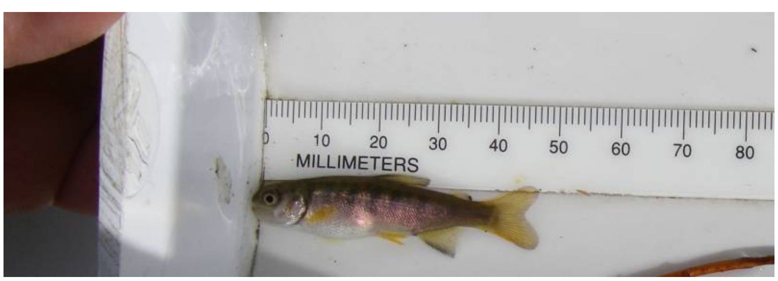
Site 11.


Site 11.  North Fork Koktuli tributary coho salmon voucher.  No site photos available.

Site 40.


Site 40.  North Fork Koktuli tributary looking downstream.

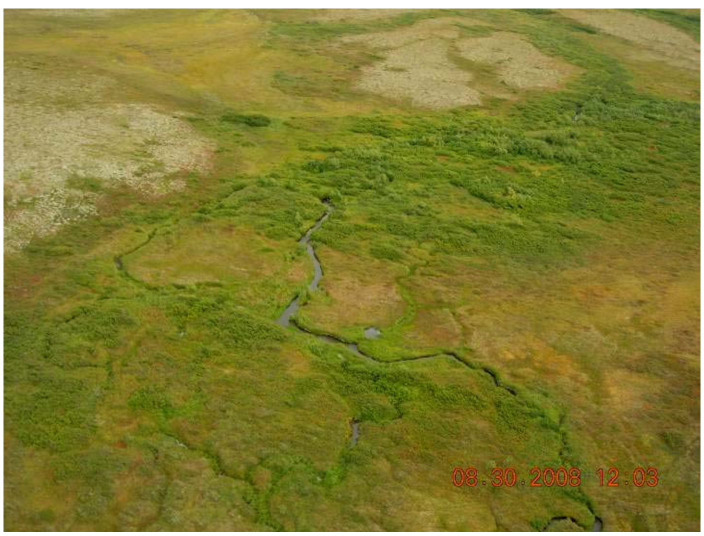

Site 40.  North Fork Koktuli aerial from ~ 50m, looking upstream.




Site 40.  Coho salmon voucher.

Site 41.


Site 41.  North Fork Koktuli tributary looking downstream.




Site 41.  North Fork Koktuli tributary, aerial from ~ 50 m, looking upstream.

Site 41.  Coho salmon voucher.

Site 42.

Site 42.  North Fork Koktuli, tributary uppermost reach, spring fed system.  Moss and aquatic plants observed.  One fork of this ended in a rock wall and the other fork disappeared into cobble substrate.

Site 42.  Aerial view from ~50m looking upstream.

Site 42.  Coho salmon voucher.

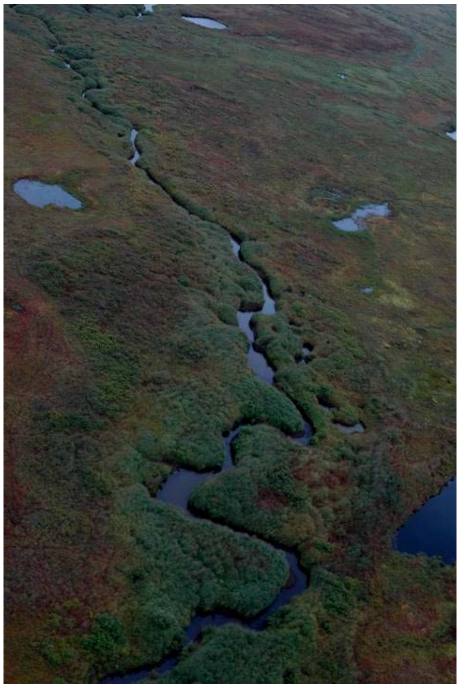
Site 44.

Site 44. North Fork Koktuli tributary aerial from ~50m, looking downstream.

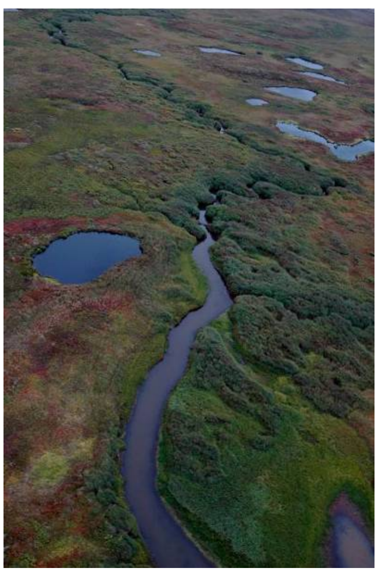
Site 44. North Fork Koktuli tributary aerial from ~50m looking upstream.

Site 44. Coho voucher specimen.

Site 47.



Site 47. North Fork Koktuli tributary, aerial from ~50 m, looking upstream.



Site 47. North Fork Koktuli tributary aerial from ~50m high, looking downstream.

Site 47. Coho salmon voucher.

Appendix IV. Upper Talarik Creek tributary study site photos and salmon vouchers, 2008.

Confluence of Sites 12 and 13.


Sites 12 and 13 confluence. Upper Talarik tributary looking downstream.


Sites 12 and 13 confluence looking upstream from 50m high.

Sites 12 and 13 coho salmon voucher.

Site 19.

Site 19. Upper Talarik Creek tributary looking downstream from ~50 m high. Highly productive site with 3 coho salmon age classes. Habitat consisted of many active and breached beaver dams.

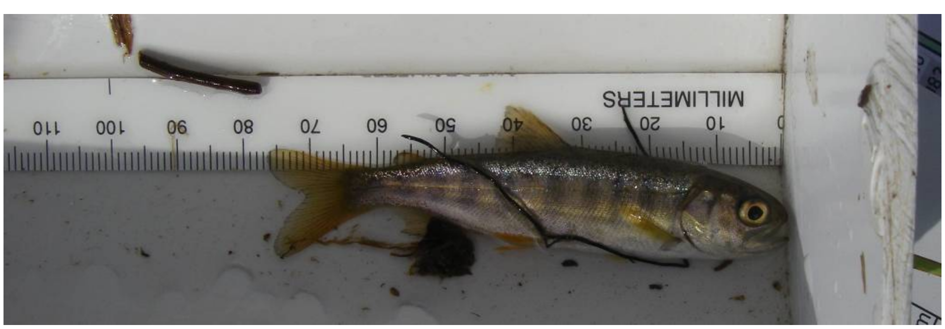
Site 19. Example of beaver dams on tributary 19, coho salmon were found above this dam.

Site 19. Bucket of coho salmon collected from site 19, Upper Talarik Creek.

Site 20.


Site 20.  Upper Talarik Creek tributary and pond system, looking downstream.


Site 20.  Upper Talarik Creek, aerial from ~50m, looking upstream.



Site 20.  Coho salmon voucher.

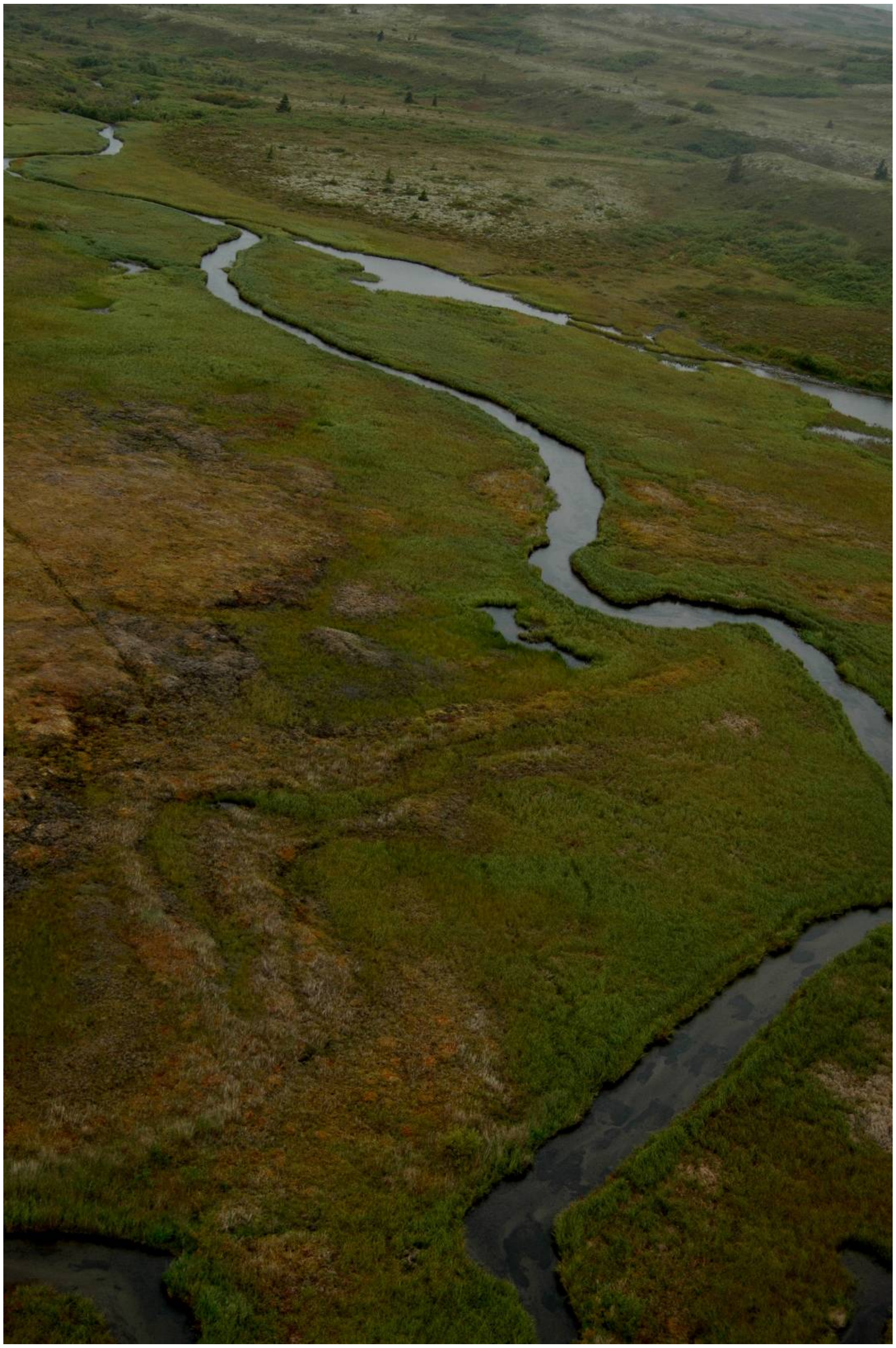
Site 38.


Site 38. Upper Talarik Creek tributary looking downstream.


Site 38. Upper Talarik Creek tributary, aerial from ~50 m, looking upstream.


Site 38. Coho salmon voucher.

Site 39.



Site 39. Upper Talarik Creek tributary. No salmon were captured in the main tributary, however, hundreds were observed in the off channel ponds in the upper right of this photo. Coho were impossible to capture in the pond via electrofishing, however, where the pond feeds into the tributary, schools of feeding coho were observed and some were captured. Voucher photos of coho salmon were taken by a Nature Conservancy photographer as fish were measured.

Site 49.


Site 49.  Upper Talarik Creek tributary, looking downstream.


Site 49.  Upper Talarik Creek tributary, aerial from ~50m, looking upstream.


Site 49.  Coho salmon voucher.

Appendix V.   South Fork Koktuli tributary study site photos and salmon vouchers.

Site 28.


Site 28. South Fork Koktuli River tributary, looking downstream.


Site 28. South Fork Koktuli tributary, from ~50m in the air, looking downstream.

Site 28. South Fork Koktuli coho salmon voucher.