

**FISH SURVEYS IN HEADWATER STREAMS
OF THE
NUSHAGAK AND KVICHAK RIVER DRAINAGES**

BRISTOL BAY, ALASKA, 2008



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Prepared for



by

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PREFACE

The Nature Conservancy is an international organization with a mission to preserve the biodiversity of the earth. Several years ago the Conservancy asked its chapters to review programs and refocus direction to advancing local conservation efforts that contribute most to protecting globally significant natural resources. The Alaska Chapter determined that loss of wild Pacific salmon productivity in Alaska would have a global impact because so much of that productivity has been compromised in other parts of the world. A focus on wild salmon in Alaska inevitably leads to Bristol Bay – home to the largest remaining runs of sockeye salmon.

In the late 1990s the Conservancy began developing partnerships with local organizations to protect the long term viability of Bristol Bay's salmon resource. A partnership with the Curyung Tribe of Dillingham, the Bristol Bay Native Association and the Nushagak-Mulchatna Watershed Council led to the development and the publication in 2007 of the *The Nushagak River Watershed Traditional Use Area Conservation Plan*. During the time the Conservancy was working with this partnership, the discovery of a rich and large ore body on state lands in the headwaters of the Nushagak and Kvichak Rivers was announced. A flurry of new mining claims followed. The discovery, now known as the Pebble prospect, is under active exploration and environmental assessment by a consortium of mining interests.

Although development of the Pebble Prospect is uncertain, the Conservancy and its partners, nevertheless, determined the possibility of large open-pit mining in headwaters of its largest rivers raised the greatest potential threat to wild salmon habitat in Bristol Bay. Accordingly, a key strategic action outlined in the *Nushagak River Watershed Traditional Use Area Conservation Plan* is to determine if potential mining areas contain salmon habitat. If so, then action should be taken to give that habitat all protections available under the law prior to mining.

The most basic legal protection afforded in Alaska to a stream or lake containing salmon is to include it in Alaska's Anadromous Waters Catalog, as described in A.S. 16.05.871 (Anadromous Fish Act). Once included, a waterbody cannot be disturbed without prior notice to and a permit from the Alaska Department of Fish and Game. Exploration and related activity at the Pebble prospect over the last several years produced no new nominations to the Catalog and very little information was available to the public regarding the extent of salmon distribution, if any, in the vicinity of the prospect. Because Bristol Bay is a priority conservation area for the Conservancy, a team was assembled in the summer of 2008 to undertake a pilot survey of streams in the Pebble prospect area. The results of that survey are the subject of this report.

In short, our team found salmon rearing habitat throughout the area surveyed, including directly above the Pebble ore body. Streams in which salmon were found have been nominated for inclusion in the Anadromous Waters Catalog. Our findings remove any doubt that the construction of a mine will destroy salmon and salmon rearing habitat. Our findings also suggest salmon are distributed widely throughout the Pebble claim and other adjacent mineral claims. A more extensive survey should be undertaken to include all eligible streams within the Anadromous Waters Catalog before any permit to mine the Pebble Prospect is issued.

Tim Troll
SW Alaska Program Director
The Nature Conservancy



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Daniel Chythlook and a bucket of coho salmon.
Photo © Carol Ann Woody

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Photo © Bridget Besaw TNC

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

Abstract

In 2008, over 40 million salmon returned to Bristol Bay, Alaska. Commercial fishermen set their nets for the 124th consecutive year harvesting 27.7 million sockeye salmon. Native Alaskans harvested more than a hundred thousand salmon which they smoked, salted, canned and stored for subsistence, as they have for thousands of years. The Bristol Bay sockeye salmon run is the largest in the world and the fishery is certified as sustainable by the Marine Stewardship Council.

Proposed development of a massive copper-sulfide mine in Bristol Bay headwaters recently heightened fish conservation concerns 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 Kaktuli Rivers (Nushagak River drainage) and in Upper Talarik Creek (Kvichak River drainage) during 29 August to 2 September 2008. Basic water quality and stream morphometry data were also documented.

A total of 37 first- and second-order streams were surveyed. Seven selected survey streams were dry, two were unfishable, and one did not exist as mapped. Electrofishing of the remaining 27 streams revealed anadromous salmon in 20 tributaries, resident fish in 23 tributaries, and no fish in two tributaries. Water quality parameters measured on-site in fish bearing reaches 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 O₂/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 generally consisted of fine to coarse (>2 mm dia < 64 mm dia) gravel.

About 47 km (28 miles) of salmon rearing habitat was documented in 2008 and nominated for the first time to the State of Alaska Anadromous Waters Catalog. The peer reviewed literature indicates a linear relationship exists between coho salmon production and stream length; as many as 1,952 coho salmon may be produced per kilometer of stream (Bradford *et al.* 1997). Assuming a similar relationship, over 91,000 coho smolt could be produced from salmon streams documented in this study. Data on both anadromous salmon and resident fish species distributions were mapped into a GIS database and submitted to State of Alaska fisheries databases. Surveyed reaches were generally clear, cold, near neutral pH, and very low conductivity indicating very pure 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 proposed for development remain unsurveyed.

Introduction

Over 40 million wild salmon returned to Bristol Bay, Alaska, in 2008 (ADFG 2008a). Athabaskan, Aleut, and Yup'ik 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 1884 is the world's largest (Burgner 1991) and is a rare example of a certified sustainable commercial fishery. Since 1987, commercial sockeye salmon harvests averaged 30 million from an average run of 37 million sockeye (Sands et al. 2008). Hilborn *et al.* (2003) attribute this sustainability, in part, to high salmon stock diversity, a limited number of fishers, and rigorous management by the Alaska Department of Fish and Game.

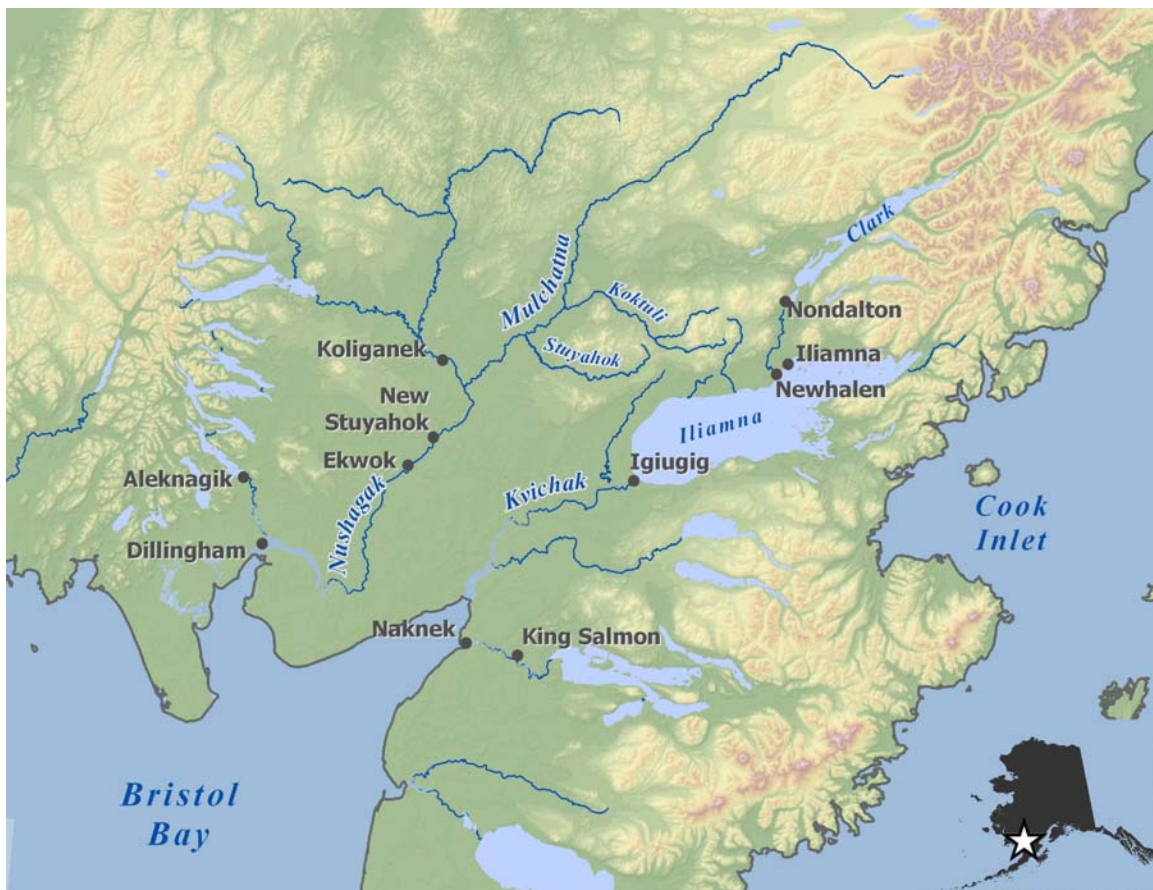


Figure 1. Map of the Bristol Bay watershed depicting major salmon producing rivers.

Salmon Stocks and Biodiversity

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 2) 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 commercial fish stock is a “portfolio” of smaller subpopulations and is more stable or resilient to change due to high biodiversity (Hilborn *et al.* 2003).

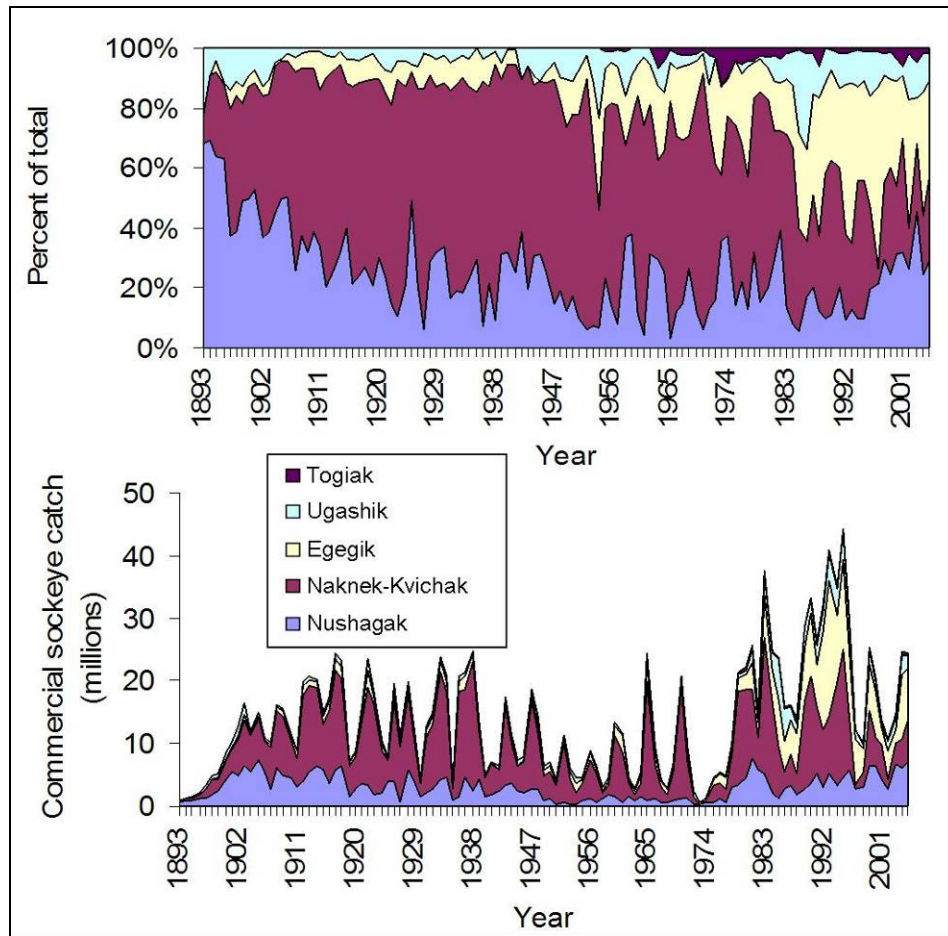


Figure 2. Upper graph depicts variation in percent contribution of each major river system to the total Bristol Bay harvest since 1893. Note the variation in contribution of each major stock over time and the long term sustainability of the fishery and harvest (lower graph). Stocks originating from each watershed are actually comprised of a “portfolio” of smaller distinct spawning subpopulations which contributed to the Bristol Bay being branded as a “sustainable fishery” by the Marine Advisory council. 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".

Available Data

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 documented (ADFG 2008b). Small headwater streams are not generally a high priority for fish surveys although, collectively, they can account for the majority of essential coho salmon rearing habitat and provide high quality spawning habitat.

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

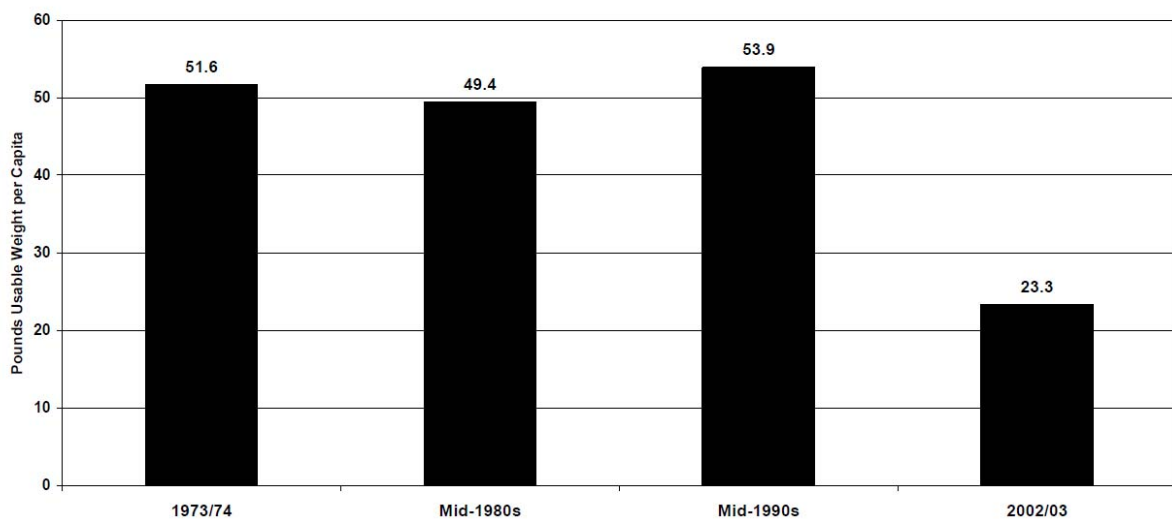


Figure 3. Estimated subsistence harvest of non-salmon freshwater fish in pounds useable weight per person, Kvichak River watershed, Bristol Bay Alaska. Graph from Krieg *et al.* 2005.

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).

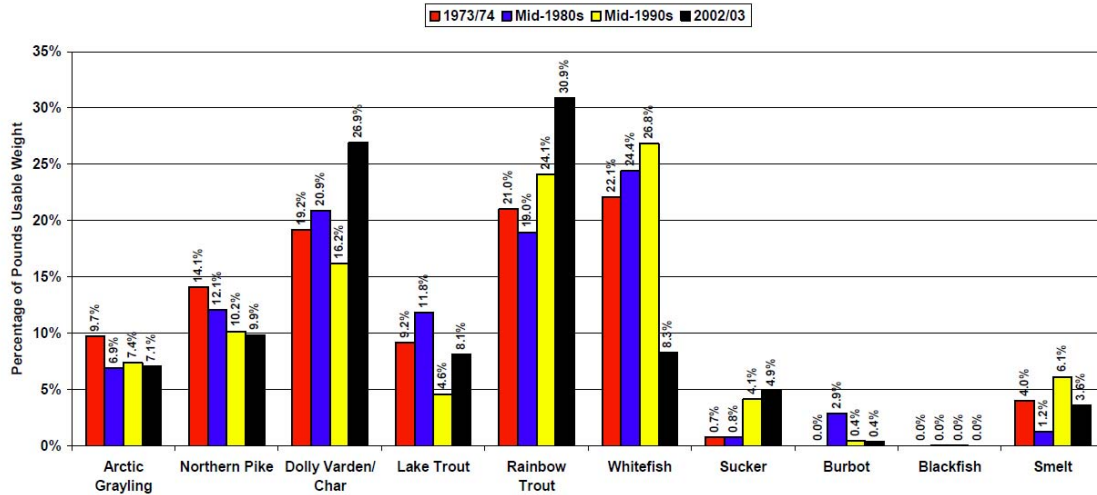


Figure 4. Composition of non-salmon freshwater fish harvest, by decade in villages of the Kvichak River watershed, Bristol Bay, Alaska. Graph from Krieg *et al.* 2005.

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	<i>Oncorhynchus nerka</i>
Chinook salmon	<i>Oncorhynchus tshawytscha</i>
coho salmon	<i>Oncorhynchus kisutch</i>
pink salmon	<i>Oncorhynchus gorbuscha</i>
chum salmon	<i>Oncorhynchus keta</i>
Resident Fishes	
longnose sucker	<i>Catostomus catostomus</i>
northern pike	<i>Esox lucius</i>
least cisco	<i>Coregonus sardinella</i>
broad whitefish	<i>Coregonus nasus</i>
humpback whitefish	<i>Coregonus pidschian</i>
round whitefish	<i>Prosopium cylindraceum</i>
Arctic grayling	<i>Thymallus arcticus</i>
lake trout	<i>Salvelinus namaycush</i>
Dolly Varden	<i>Salvelinus malma</i>
rainbow trout	<i>Oncorhynchus mykiss</i>
burbot	<i>Lota lota</i>
threespine stickleback	<i>Gasterosteus aculeatus</i>
ninespine stickleback	<i>Pungitius pungitius</i>
slimy sculpin	<i>Cottus cognatus</i>

The Nushagak River watershed produced a recent 20-year average (1987-2007) annual commercial harvest of about 4.7 million sockeye salmon, 51,000 Chinook 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 annual harvest of 8.8 million sockeye salmon. The recent 20-year average (1987-2007) annual salmon harvest for the Kvichak-Naknek district was about 3,500 Chinook salmon, 6,800 coho salmon, 193,000 chum salmon, and 137,000 pink salmon (Sands *et al.* 2008).

Although some information on presence of adult spawning salmon exists for mainstem rivers in both the Nushagak and Kvichak River watersheds, few data are available for the headwater tributaries that create them. Combined, these tributaries represent hundreds of miles of potential fish producing habitat. Future sustainability of the prolific renewable salmon resource of Bristol Bay depends, in part, on conservation of freshwater habitats essential to completion of their life cycle, including spawning, incubation, rearing, and migration habitats.

Proposed Industrial Development

Headwaters of the North and South Fork Koktuli Rivers (Nushagak) and Upper Talarik Creek (Kvichak) are in a region proposed for industrial sulfide mineral development by the State of Alaska (see: <http://www.dnr.state.ak.us/mlw/mining/largemine/pebble/>). Sulfide minerals of interest, primarily copper, gold and molybdenum are located under currently productive fish habitat upstream of the Nushagak and Kvichak rivers and Iliamna Lake. Iliamna Lake is Alaska's largest, ~2,600 km² (~1,000 mi²), and is the world's largest sockeye salmon rearing lake where millions of salmon fry from over a hundred different spawning populations rear one to two years before migrating to sea. Although mining exploration and scientific studies are ongoing, many tributaries have never been surveyed to verify the presence or absence of salmon or fishes important to subsistence.

Applicable Statutes

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, on spawning or incubating fish. Anadromous fish, like salmon, are afforded some statutory protection under State of 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 potentially slated for extensive mineral development which could cause both direct and indirect impacts to fish habitat. To improve coverage of the State of 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

The study focused on first and second order wadeable streams (n = 47; Figure 5) with gradients less than 10%, and no known geologic barriers to fish passage. Selected streams were not listed as anadromous in Alaska State databases, and were located in the North Fork Kaktuli River and South Fork Kaktuli River of the Nushagak River drainage, and in Upper Talarik Creek of the Kvichak River drainage. All sites were within or near the proposed mining district near the town of Iliamna. Specific survey Geographic Positioning System (GPS) coordinates were determined using 2008 AWC data in combination with geospatial data layers from the National Hydrography Dataset and the National Elevation Dataset. Because these 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 survey.

Methods

Fish Surveys

Surveys were conducted during 29 August to 2 Sept. 2008; a time during which rearing fish were expected to be widely distributed as it was prior to both fall floods and

migration to deeper overwintering areas. Two teams of three people worked simultaneously at different tributaries within a single watershed. Sampling generally began at the confluence of two first or second order headwater streams (Figure 5) nearest the selected GPS survey coordinates. If fish were documented at the confluence, then the field crew electrofished each fork upstream, discontinuously sampling all habitat types. Because dense willow growth prevented surveying a consistent length reach, fishing effort was standardized using catch per unit effort (CPUE), with effort measured as the number of fish captured per number of seconds (s) electrofished.

Single pass backpack electrofishing was conducted using pulsed direct current (DC) (Bateman *et al.* 2005). 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 $\mu\text{S}/\text{cm}$). 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 the high density of rearing coho led us to decrease fishing time in order to minimize unnecessary impact on the resource. All captured fish were held in a bucket of fresh stream water during the survey, after which, salmon were measured; a voucher photo taken, then fish were released. No anesthetic was used as handling time per fish was generally less than 10 s. If time permitted, resident species were measured prior to release. Sampling protocols were coordinated with ADFG (Buckwalter 2008) to facilitate the State AWC expansion effort.

Habitat Measurements

Habitat measures were based on McCormick and Hughes (1998) and Kaufmann and Robison (1998). 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) were measured. 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 stream reach.

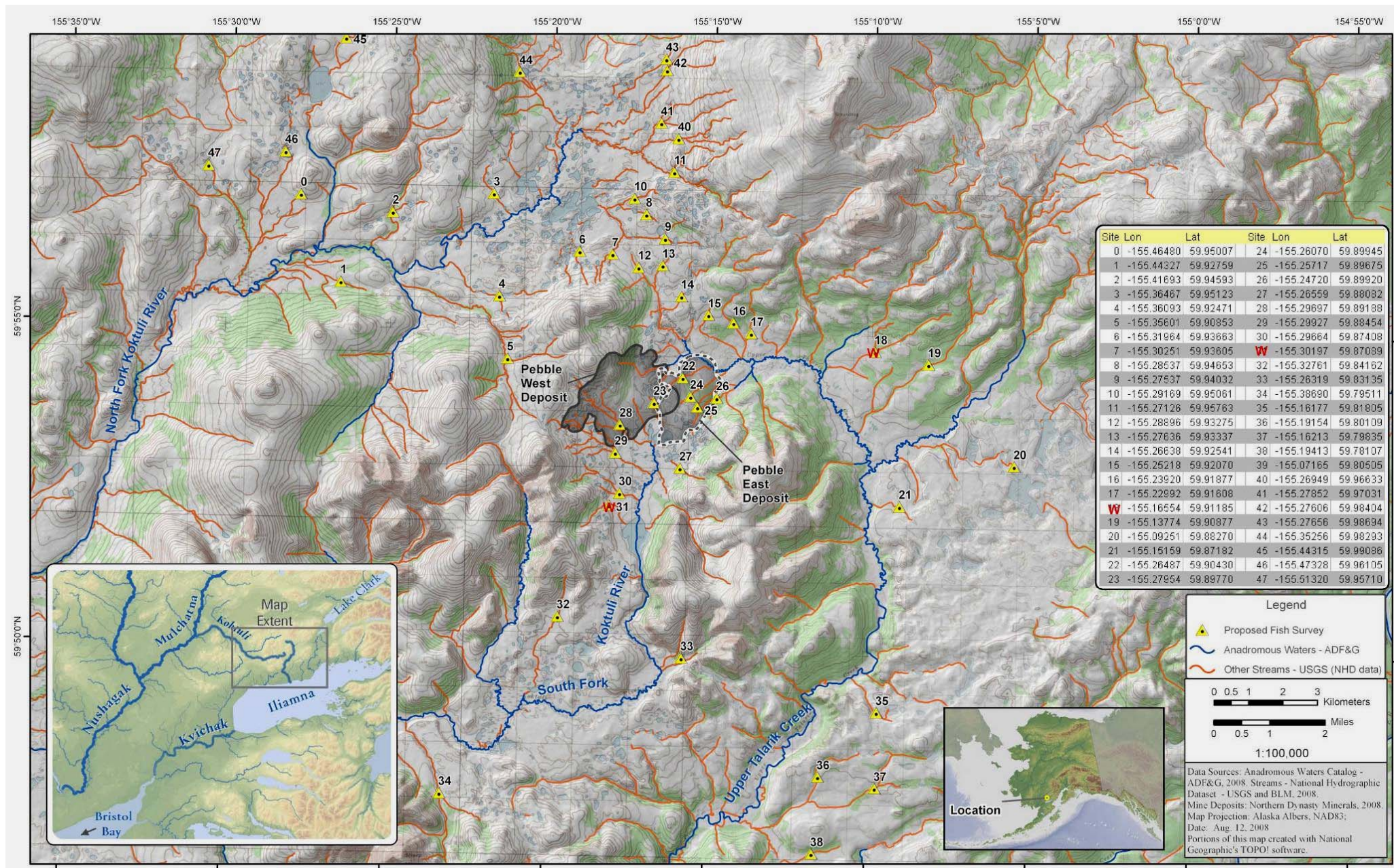


Figure 5. Numbers indicate selected survey sites in the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 2008. Blue streams are documented anadromous salmon streams in the Alaska Department of Fish and Game’s Anadromous Waters Catalogue. Orange streams lack any fish presence or absence data. **W** indicates streams dropped from survey due to dense willow growth.

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; Figure 5); baited minnow traps left overnight would be a more effective sampling tool in these habitats. Electrofishing time at 27 sites averaged 665 s/site and ranged from 230 s to 1838 s. Due to the difficulty of sampling a contiguous run in sites with dense riparian vegetation, standardized survey reach lengths, e.g., 40 times the stream width, were sometimes difficult to attain. Therefore, Catch Per Unit Effort (CPUE) was considered is a more appropriate measure to standardize our fishing effort and results.

Of the 27 electrofished streams, anadromous rearing Chinook and/or coho salmon were documented in 20 streams (Appendix I, III-V). Coho were captured at 18 sites while both Chinook and coho salmon were captured at 2 additional sites. The CPUE for anadromous rearing salmon in these 20 streams averaged 1 salmon per 63 seconds of electrofishing effort. One channel surveyed was dry (losing reach) 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 and exit this, and potentially similar sites, at higher flow regimes.

Coho salmon ($n = 203$) averaged 68.3 mm (SD = 22.9) and ranged in size from 42 mm to 136 mm (Figure 6). Three Chinook salmon were captured and averaged 80 mm fork length; all Chinook 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 and Chinook salmon voucher; also, sites 1, 4, 5, and other coho salmon vouchers; Appendices 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 (Figure 6) was collected at the confluence of survey sites 7 and 9 near a large lake system used by the Pebble Limited Partnership for a fueling area.

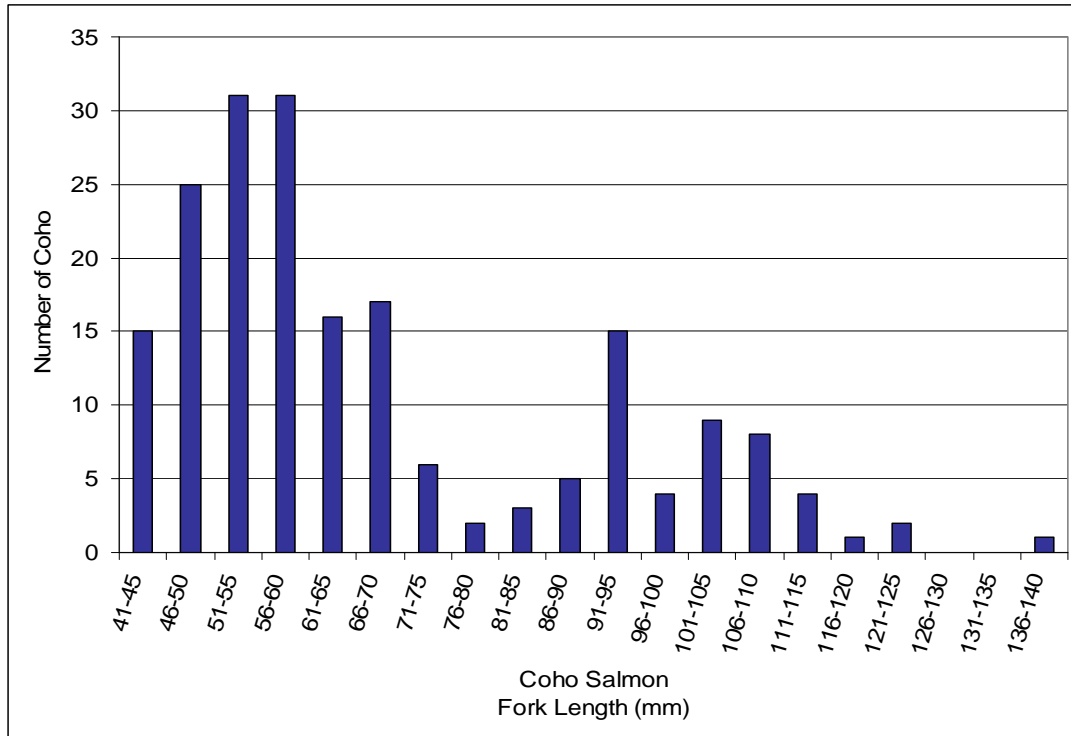


Figure 6. Size distribution of coho salmon (n = 203) rearing in 20 headwater tributaries of the N. and S. Fork Kaktuli rivers (Nushagak drainage) and Upper Talarik Creek (Kvichak drainage), Bristol Bay, Alaska, 29 Aug. to 2 Sept. 2008.

Resident fish, including Dolly Varden, grayling, ninespine stickleback, northern pike, round whitefish, slimy sculpin, and threespine stickleback, were documented in 23 streams (Appendix II); no fish were captured in two streams. Not all captured resident fish were measured however subsampled Dolly Varden (n = 41) average fork length was 85.5 mm (SD = 26.5) and ranged from 38-148 mm; grayling (n = 7) average fork length was 99.2 mm (SD = 28.2) and ranged from 68 to 138 mm, and sculpin (n = 45) averaged 64.4 mm (SD = 16.3) and ranged from 25 to 95 mm. 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). The two measured threespine stickleback were both 45 mm fork length, while the two northern pike captured were 100 and 83 mm; the single round whitefish captured was 86 mm. All fish captured were under 150 mm fork length suggesting that these small shallow headwaters are essential rearing habitat to a wide diversity of small rearing Arctic fishes. 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.

Habitat Measurements

Surveyed headwater tributaries were generally first or second order streams, with cold, clear water, nearly neutral pH and very low conductivity (Table 2). 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 electrofisher. In such 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 varied from 100% sand and silt (< 2 mm dia) to one comprised of up to 20% boulders (> 128 mm dia). However, substrates in 14 of 23 streams had ≥ 50% substrates comprised of fine to coarse gravel (≥ 2 mm dia to < 64 mm dia) (Figure 7).

Table 3. Stream morphometry 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

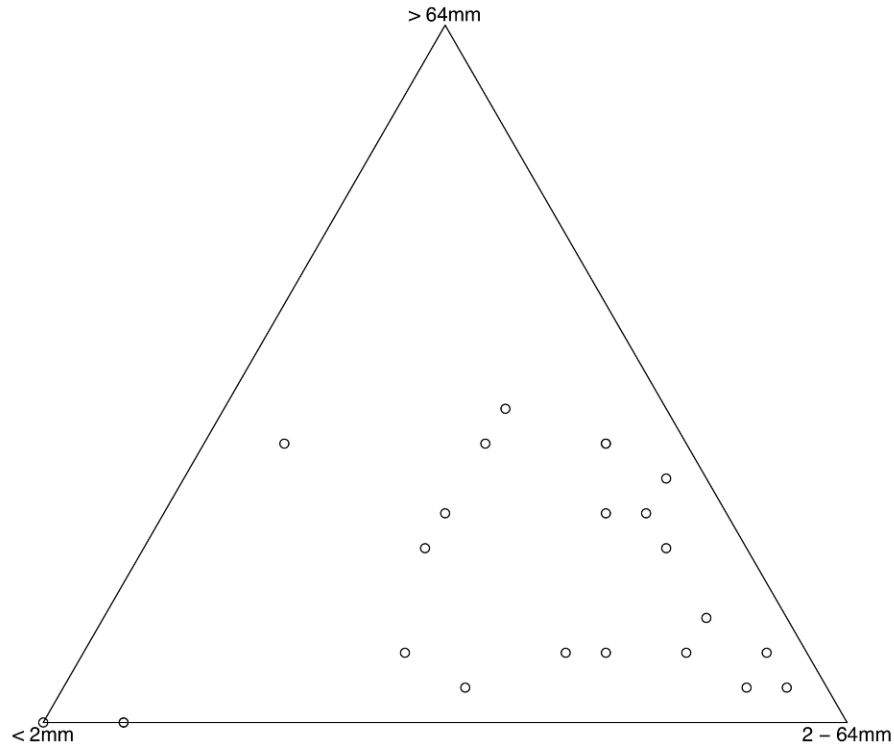


Figure 7. Ternary plot of stream substrate composition. One site had 100% of substrate in the fine sand and silt (< 2 mm dia) category as indicated by the dot on the lower left corner. Some sites contained only substrates <64 mm dia (points along bottom edge), and all other sites exhibited all three 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 km (28 miles) of previously undocumented salmon rearing habitat were mapped in 2008 and nominated for the first time to the State of Alaska 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 it produced. Further study of this relationship by Bradford *et al.* (1997) of 86 Alaskan, Canadian and Washington streams corroborated the relationship of increasing smolt abundance with increasing stream length, with an average of 1,952 smolts produced per stream kilometer. Assuming a similar coho smolt productivity relationship here, the 47 km of anadromous streams documented in this study could annually 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 the survey region would find suitable winter refuge in the numerous lakes, beaver ponds and spring fed pools observed throughout the region.

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 be noted that they may support fish at higher flows as this study was conducted at low flows. 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 wide distribution of rearing coho and Chinook salmon. Coho were found in a majority of streams surveyed, but few rearing Chinook salmon were observed despite the previous year's strong adult escapement. One reason for the lack of Chinook salmon observations in this study may be due to habitat segregation. Prior studies suggest coho and Chinook salmon prefer different habitats. A study in the Taku River, Alaska, documented coho in sloughs, off channel and beaver ponds compared to Chinook which were documented more often in riverine habitat (Murphy 1989). In the Big Qualicum River, coho were found more frequently in lower velocity sites than Chinook 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 Chinook which were found at highest densities in the mainstem and mid-elevation tributaries. Because our study was limited to small, shallow, headwater tributaries during low flow, Chinook may have been more abundant in deeper higher velocity habitats.

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 was 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 anadromous tendencies, would provide valuable information to both subsistence managers and regulators.

Small headwater streams are not assumed to be important salmon producing habitats in Alaska, even though they feed into and create salmon producing rivers. As illustrated by this and other studies such tributaries can comprise a significant amount of salmon and resident fish rearing habitat. By exploiting these headwater shallow streams, small rearing fish can avoid larger predaceous fish as illustrated by the fact no fish longer than 150 mm were captured during this study. Successful negotiation of the vulnerable

rearing life history phase increases the probability an individual will survive to reproduce- a key factor in a sustainable fishery.

Conservation of the sustainable Bristol Bay fisheries depends, in part, on conserving the diverse habitats essential to fish survival and reproduction, e.g., spawning, incubation, rearing and migration. The information presented here on rearing fish distributions, headwater stream chemistry, and channel morphology provides a more complete and accurate database upon which to base future fish conservation decisions. However, thousands of similar streams that contribute to fish production remain unsurveyed, and therefore unprotected, in regions proposed for industrialized development.



Daniel Chythlook (left) and Dan Rinella collect stream flow data for an unnamed tributary to Upper Talarik Creek, Kvichak River watershed, Alaska. Photo © Bridget Besaw/TNC.

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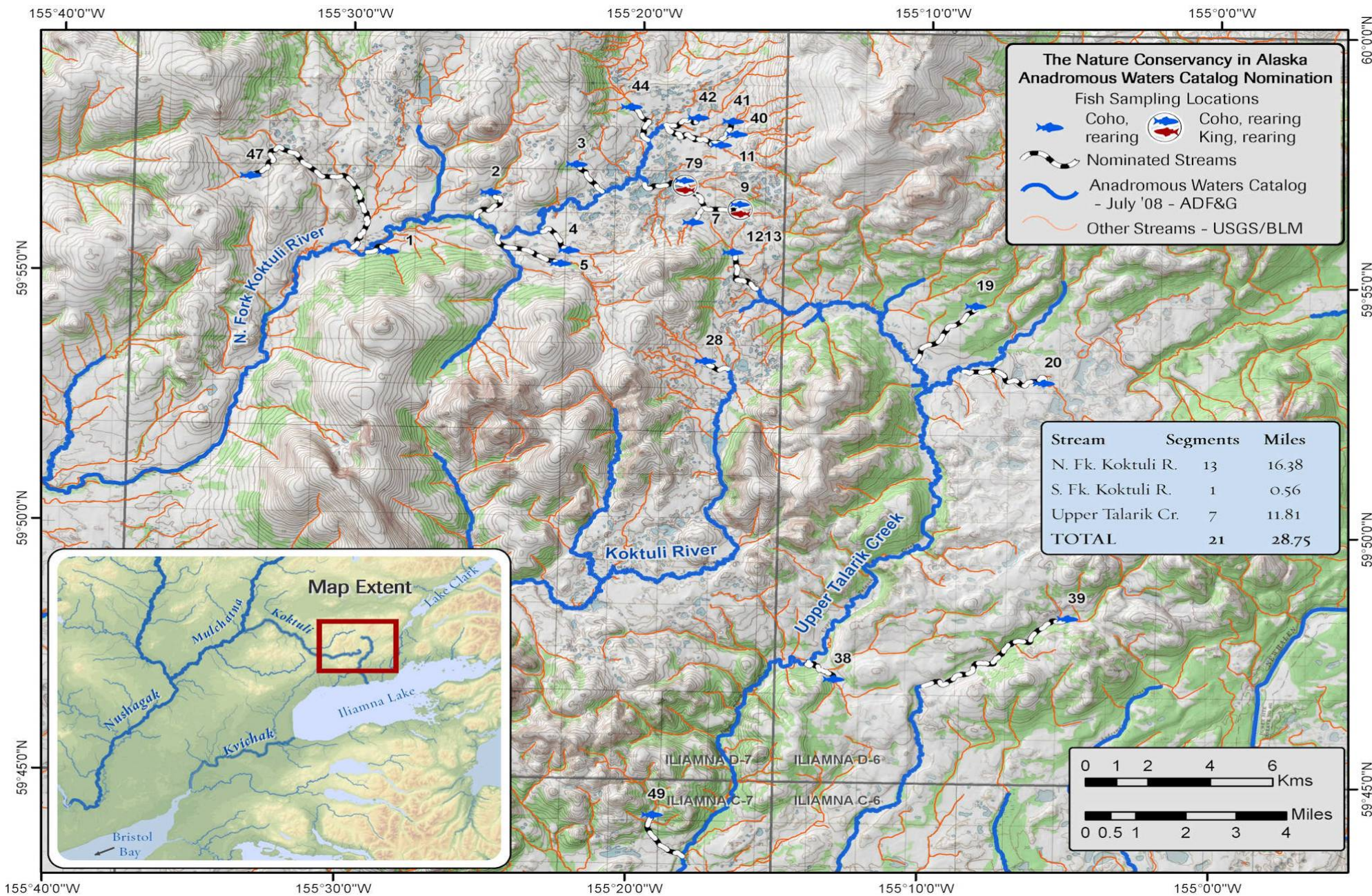
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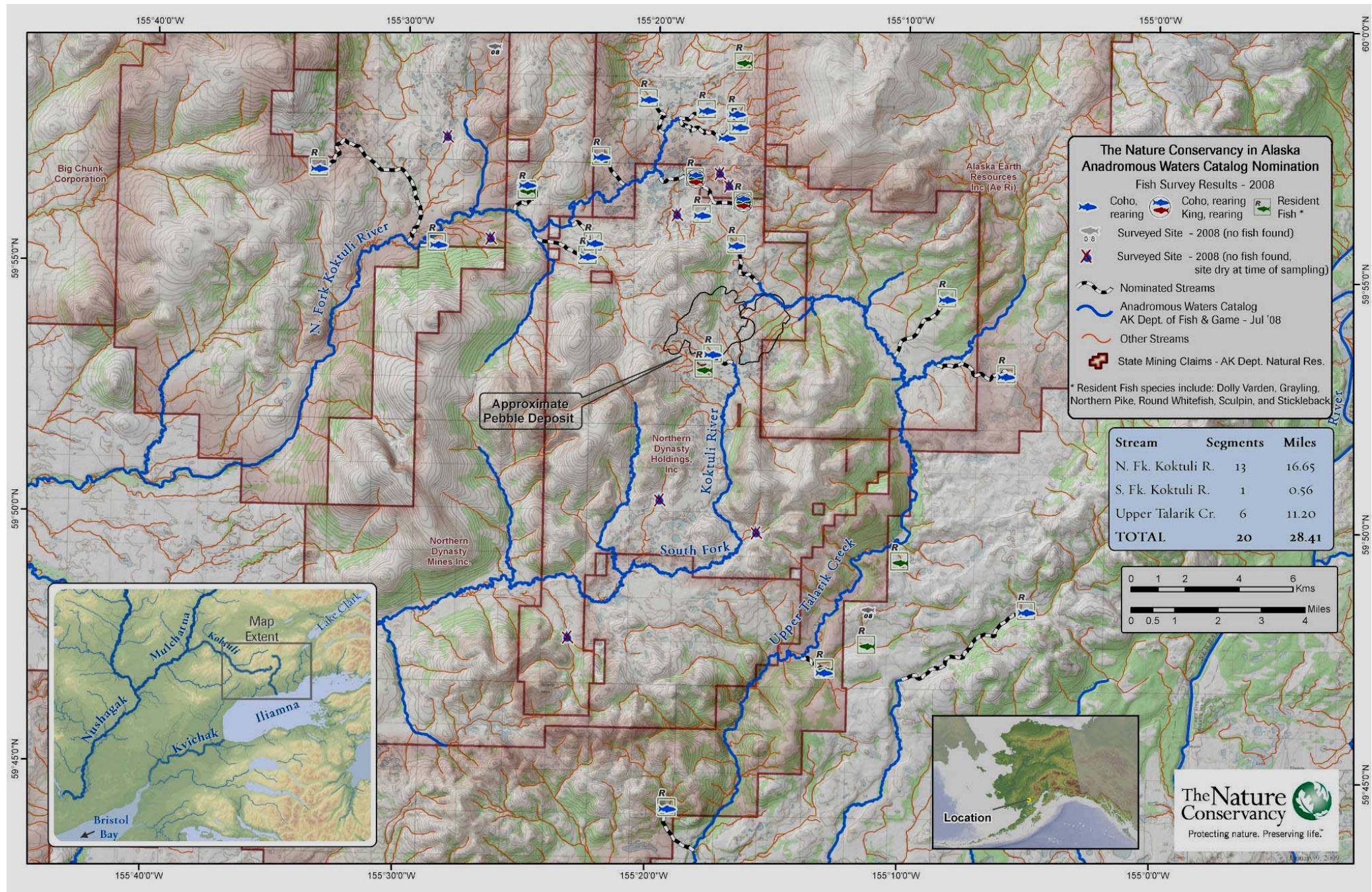
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Appendix I. Hatched lines show tributaries where anadromous salmon were documented during 2008 electrofishing surveys; North and South Fork Koktuli rivers and Upper Talarik Creek, Bristol Bay, Alaska.



Appendix II. Fish survey results from 2008 electrofishing surveys in North and South Fork Koktuli rivers and Upper Talarik Creek tributaries, Bristol Bay, Alaska, 2008.



Appendix III. Selected examples of surveyed North Fork Kaktuli River tributaries, site photos and salmon vouchers, 2008.

Site 1.



Site 1. North Fork Kaktuli tributary looking downstream.



Site 1. Coho salmon voucher.

Site 2.



Site 2. North Fork Kaktuli River tributary looking downstream.



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



Site 2. North Fork Kaktuli coho salmon.

Site 3.



Site 3. North Fork Koktuli tributary looking downstream.



Site 3. Coho voucher.

Site 4.



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 Kaktuli 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 Kaktuli tributary and lake system. Aerial view from 50 m taken just below confluence of study sites 7 and 9.



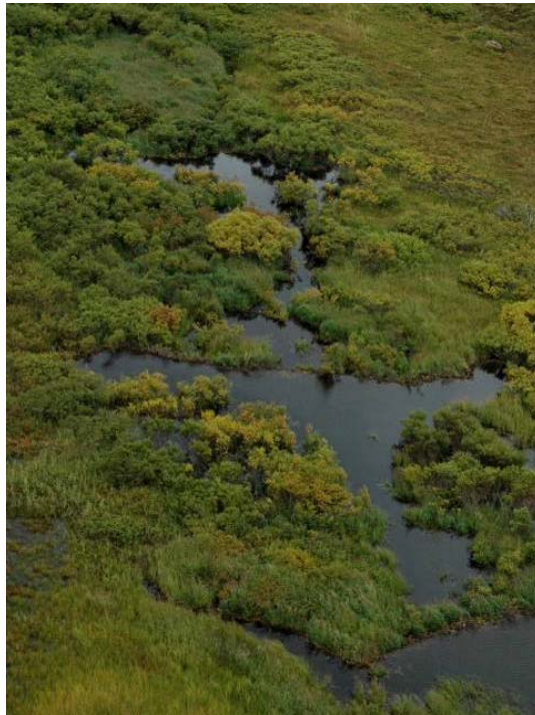
Sites 7 and 9. Coho and Chinook salmon vouchers from fork. Note Chinook silver coloration.

Site 7.



Site 7. North Fork Kaktuli 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 Kaktuli tributary looking downstream from ~ 50m in air. Chinook and coho salmon, grayling, and sculpin observed.

Site 40.



Site 40. North Fork Kuktuli tributary looking downstream.



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



Site 40. Coho salmon voucher.

Site 41.



Site 41. North Fork Kaktuli tributary looking downstream.



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



Site 41. Coho salmon voucher.

Site 42.



Site 42. North Fork Kaktuli, 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 Kaktuli tributary aerial from ~50m, looking downstream.



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



Site 44. Coho voucher specimen.

Site 47.



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



Site 47. Coho salmon voucher.

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

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. Left photo: Upper Talarik Creek tributary looking downstream from ~50 m high. Right photo: 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.

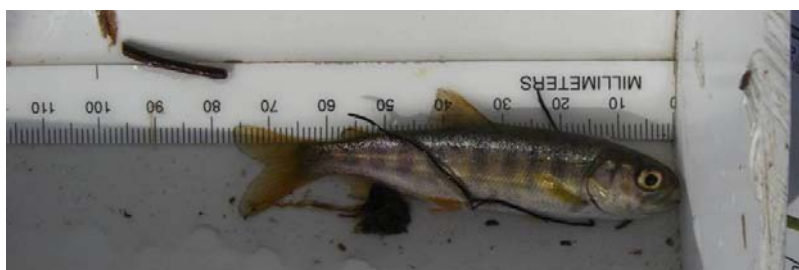
Site 20.



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.

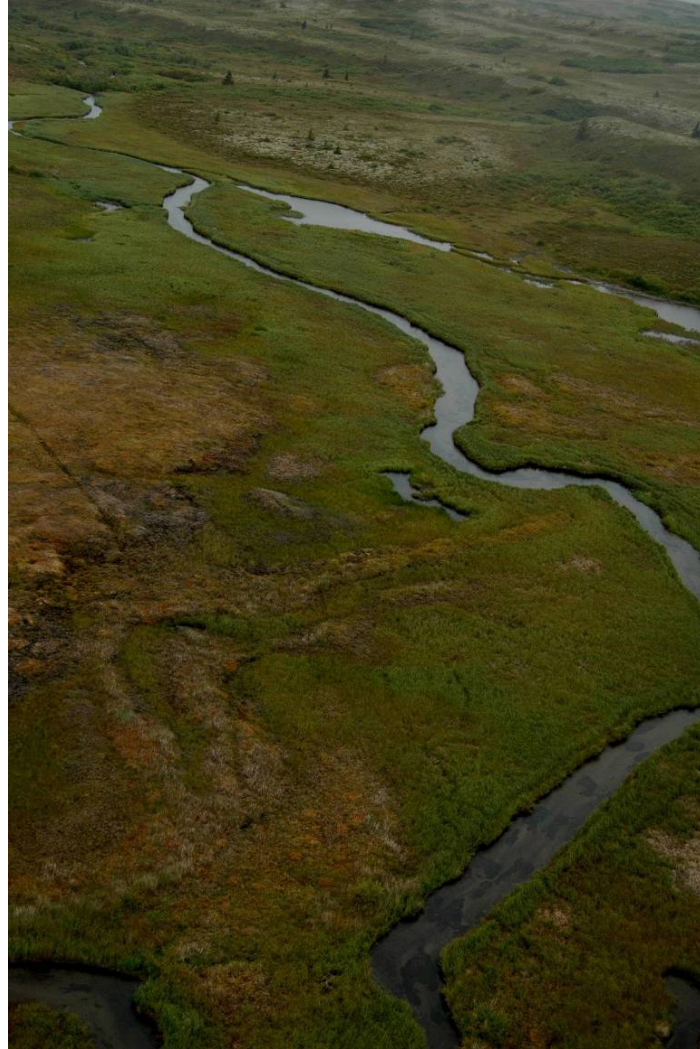


Site 38. Upper Talarik Creek tributary, aerial from ~50 m, looking upstream.



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.



Site 39. Coho salmon voucher.

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 Kuktuli tributary study site photos and salmon vouchers.

Site 28.



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



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



Site 28. South Fork Kuktuli coho salmon voucher.