FISH SURVEYS IN HEADWATER STREAMS OF THE NUSHAGAK AND KVICHAK RIVER DRAINAGES BRISTOL BAY, ALASKA, 2008 - 2010

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Prepared for

The Nature Conservancy

Protecting nature. Preserving life.™

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PREFACE

The Nature Conservancy is an international not-for profit organization with a mission to preserve the biodiversity of the earth. Several years ago the Conservancy refocused programs to advancing local conservation efforts that contribute most to protecting globally significant strongholds of biodiversity. The Alaska Chapter determined that the loss of wild Pacific salmon productivity in Alaska would have a global impact because wild salmon have been severely compromised in other parts of the world. A focus on wild salmon in Alaska inevitably leads to Bristol Bay – home to the world's largest remaining salmon runs.

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 Nushagak River Watershed Traditional Use Area Conservation Plan.* During the time the Conservancy was working with this partnership, the discovery of a large copper and gold ore body on state lands in the watersheds 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.

The Anadromous Fish Act (AS 16.05.871) is the key State of Alaska statutory protection for freshwater habitats of fish in Alaska. The act requires the Alaska Department of Fish and Game to "specify the various rivers, lakes and streams or parts of them" of the state that are important to the spawning, rearing or migration of anadromous fishes. The Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes (AWC) and its associated Atlas are the media used to fulfill this directive, and are adopted as regulation under 5 AAC 95.011. Once included in the AWC, a person cannot "use, divert, obstruct, pollute, or change the natural flow or bed of a specified river, lake, or stream" without prior notice to and a permit from the Alaska Department of Fish and Game.

Although development of the Pebble Prospect is uncertain, the Conservancy and its partners, nevertheless, determined the possibility of a large mining effort in the watersheds of Bristol Bay's largest rivers raised a significant threat to wild salmon habitat. Although the extent of salmon habitat had been documented in some of the larger stream systems in the vicinity of the Pebble Prospect, salmon distribution in many smaller streams was not fully documented, nor did there appear to be any ongoing effort to survey these smaller streams. Consequently, the Conservancy assembled a team in 2008 to undertake a pilot fish distribution survey of headwater tributaries to the Koktuli River, Stuyahok River, Kaskanak Creek, Upper Talarik Creek and the Chulitna River that originate in or near the Pebble Prospect. All of these rivers and creeks are tributaries of the Nushagak and Kvichak Rivers. Our purpose was to determine whether salmon habitat could be affected by potential mining activity in areas currently subject to mining claims. The results of that survey were the subject of a report published in 2008. The findings from that effort led to more comprehensive fish distribution surveys in 2009 and 2010. This report combines the data and findings of all three surveys.

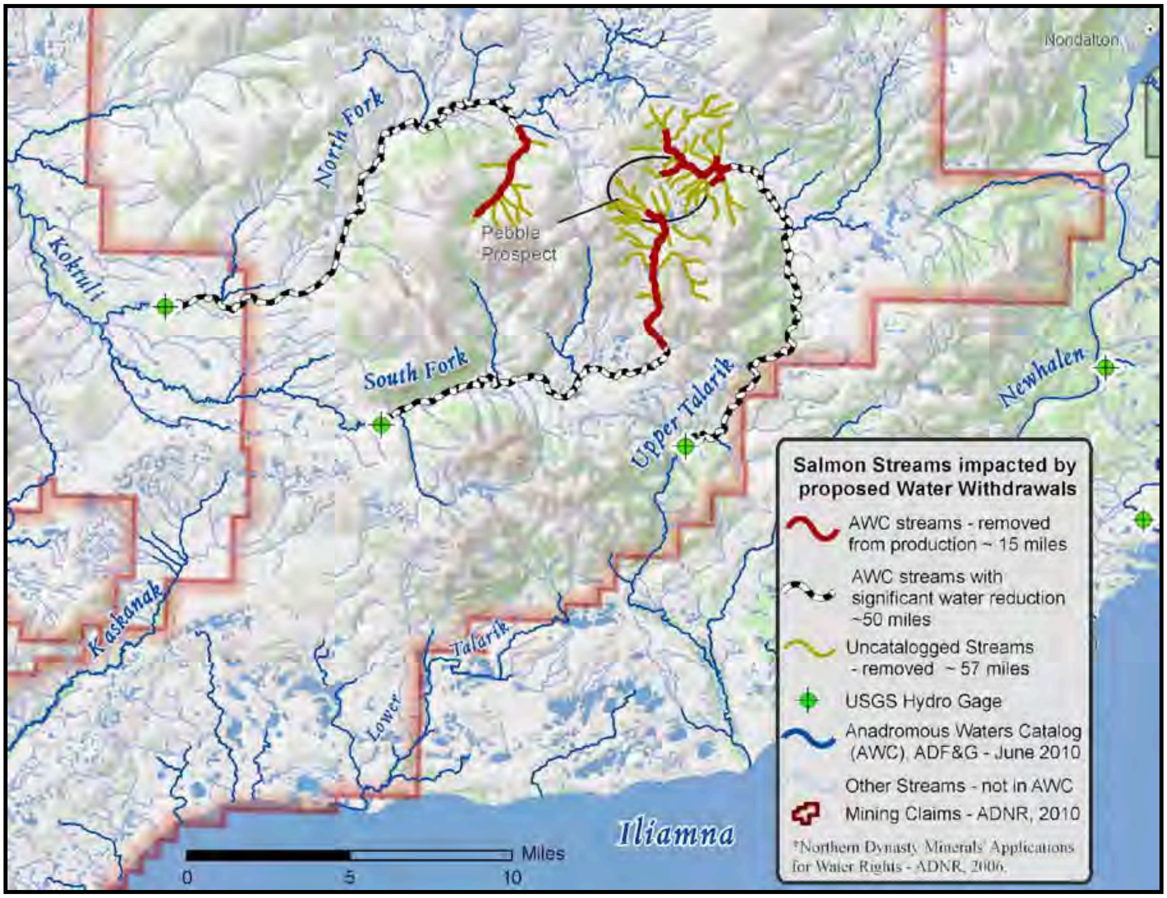
In short, our team found salmon rearing in streams throughout the Pebble Prospect and adjacent areas. Salmon were found directly above the projected Pebble ore body. Streams in which salmon were found in 2008 and 2009 are now included in the AWC. Nominations to the AWC have been submitted for streams in which salmon were found during the 2010 field surveys. The effort over these three years still fell short of surveying every potential steam that likely would qualify for the protections afforded by the AWC. However, the data we collected in 2008, 2009 and 2010 supports a hypothesis that nearly every stream in these headwater areas will contain fish, and seven out of ten streams with less than a 10% gradient will contain rearing salmon.

Under current Alaska law, however, there is no presumption that a stream is eligible for the protections of the Anadromous Fish Act. In order for a stream to be eligible for protection there must be site-specific, direct, unambiguous observations of anadromous fish by a qualified observer. The results of our surveys strongly suggest that unambiguous observation of salmon will be made in almost any headwater stream within the Pebble Prospect and nearby mining claims. Accordingly, The Conservancy makes the following recommendations:

1. Exhaustive fish distribution surveys should be undertaken by the State of Alaska to document all anadromous waters within the Pebble Prospect and adjacent leased areas that may become economically viable to develop if the Pebble Prospect is permitted.

2. Fish distribution surveys should also include any stream that will be crossed by an access road or potentially affected by any other project related infrastructure including slurry or water pipelines, power transmission lines, material sites, port sites, water withdrawal or disposal sites and any stream that may be stressed by other mining related impacts such as dewatering or windblown dust.

The import of these recommendations is readily apparent from the following map developed from information provided by Northern Dynasty Minerals in its 2006 application for permits to the Alaska Department of Natural Resources to withdraw water from the Koktuli River and Upper Talarik Creek to support a mine for the removal of 2.5 billion tons of mineral resources.* (Northern Dynasty is a partner in the Pebble Limited Partnership.)



The information provided in those applications is preliminary. The mine plan that may eventually be proposed by the Pebble Limited Partnership could differ significantly from that submitted by Northern Dynasty Minerals. However, at the time of this report, the scenario presented by Northern Dynasty in its water withdrawal application remains the only official public expression of what a mine could look like if the Pebble Prospect is developed. If this scenario, or something similar, is developed then it can be expected that 15 miles of streams currently listed in the AWC will be destroyed by the mine and associated tailing storage facilities. Another 57 miles of streams that are likely to be destroyed have not been adequately surveyed for fish distribution. Based upon the results of our fish distribution surveys in the area, approximately 70% of these streams, or another 40 miles, are likely to be eligible for inclusion in the AWC. Even if these streams do not qualify for inclusion in the AWC our findings suggest there is near certainty these streams harbor resident fish.

According to the water withdrawal application, another 50 miles of streams currently listed in the AWC are projected to experience significant water reductions of 10% of stream flow or greater. These reductions could isolate anadromous fish habitat in many more miles of smaller tributary streams that are currently unsurveyed.

These projections of impact to habitat are illustrative; the projections must be considered preliminary because the only mine scenario publically available is preliminary. However, it is probable that a large mine will be required to eventually remove the mineral resources the Pebble Limited Partnership has indicated are available on the Pebble Prospect site. Such a mine, if developed, will destroy or significantly impact large areas of anadromous fish habitat that to date remain undocumented.

THE NATURE CONSERVANCY IN ALASKA

Tim Troll
Southwest Alaska Program Director

*Pebble Project Surface Water Right Applications: Alaska Department of Natural Resources; Division of Mining, Land & Water; Land Administration System (LAS).

LAS 25874 South Fork Koktuli River
LAS 25871 Unnamed Tributary (NK1.190) North Fork Koktuli River
LAS 25876 Upper Talarik Creek

http://dnr.alaska.gov/mlw/mining/largemine/pebble/waterapp htm

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Arctic grayling (*Thymallus arcticus*) are in the same family as salmon and trout. This one was captured in the North Fork Koktuli during 2008 fish surveys. Photo © Brigit Besaw/TNC.

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A Dolly Varden char (*Salvelinus malma*) captured during fish surveys in 2009. The otoliths or earbones of this fish will be removed and examined to determine if this fish or its mother went to sea.

ACKNOWLEDGEMENTS

Many talented people contributed to the success of this project including: Stan Hermens R-44 pilot and owner of Hermens Helicopters; Daniel Chythlook of The Bristol Bay Native Association; Kristy Jeffries of the Nondalton Tribal Council; Steve Baird of the Kachemak Bay Research Reserve; Sue Mauger of Cook Inletkeeper; Justin Arnold and Dan Prince of the U.S. Fish and Wildlife Service; J. Johnson and Nicky Szarzi of the Alaska Department of Fish and Game; Jane Whitsett and Jason Gray of the Pebble Limited Partnership; Dan Bogan, Dan Rinella and Dustin Merrigan of the University of Alaska Anchorage Environment and Natural Resources Institute; Jason Everett of the U.S. Fish and Wildlife Service, Conservation Genetics Laboratory and Helen Keeling, John Campbell and Dan Young of the National Park Service. Marcus Geist of The Nature Conservancy assisted with fieldwork and produced the Geographic Information System (GIS)-based maps and data layers for nominations to Alaska's Anadromous Waters Catalog; Joel Reynolds assisted with statistical analysis, data visualization, and field work. June and Bob Tracey of Chada and Chida Bed & Breakfast in Nondalton provided valuable logistical support; Laura Sorensen assisted with data proofing and quality assurance. Tom Robinson, owner of The Rainbow King Lodge in Iliamna, provided room, board and transport for the field crew. The University of Washington graciously contributed both a vehicle and bunk space. Funding and logistical support were provided by The Nature Conservancy; The Gordon and Betty Moore Foundation; The Southwest Alaska Salmon Habitat Partnership with the U.S. Fish and Wildlife Service; The National Fish and Wildlife Foundation with the Bureau of Land Management; the Wallace Research Foundation, Mr. and Mrs. John Lovelace, Bristol Bay Regional Seafood Development Association and the National Parks Conservation Association. Peer review conducted by Dr. Cecil Rich of the Alaska Department of Fish and Game, Dr. Peter Rand at Wild Salmon Center and Dr. Robert Hughes of the University of Oregon. A special thanks to the people of Nondalton and the Nondalton Tribal Council for their ongoing support.

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

FISH SURVEYS IN HEADWATER STREAMS OF THE NUSHAGAK AND KVICHAK RIVER DRAINAGES BRISTOL BAY, ALASKA, 2008 - 2010

EXECUTIVE SUMMARY

The persistence of North American wild salmon in the Lower 48 and Canada is uncertain due primarily to habitat loss and degradation. In contrast, over 42 million wild salmon returned to pristine habitats in Bristol Bay, Alaska in 2010. Commercial fishers set their nets for the 126th consecutive year harvesting over 30 million salmon. Alaska Natives harvested over a hundred thousand salmon, which they smoked, salted, canned and stored for winter subsistence, as they have for thousands of years. Sport fishers trekked across the globe to ply Bristol Bay's rivers for abundant salmon, trout, and char.

Bristol Bay is the most valuable commercial salmon fishery in the U.S. and is one of its few remaining salmon strongholds—a place where wild salmon are abundant, highly diverse and benefit from intact essential habitats. However, over 2,054 km^2 (~793 mi^2) of contiguous mining claims are now staked on the watershed divide of two of Bristol Bay's largest salmon producers- the Nushagak and Kvichak River drainages. Development of claims would have both direct and indirect impacts on fish habitat and ecosystem function.

The risks industrial mining present to Bristol Bay salmon raised conservation concerns, foremost being a lack of available salmon distribution and other data throughout the area proposed for mining. Fish distribution data are important because 1) collectively, the hundreds of small unstudied streams are a major source of salmon production and diversity, providing essential habitat to both young salmon and fish that subsistence users rely on, and 2) in Alaska, salmon and fish must be explicitly documented in a water body for certain State protections and permitting requirements to apply.

Single pass electrofish surveys, minnow trapping and aerial surveys conducted in and near mining claims and along proposed roads improved state fish distribution databases for Bristol Bay headwaters during August and September 2008, 2009 and 2010. A total of 105 streams were sampled for fish and basic habitat parameters. In addition, over 400 kilometers of aerial surveys were flown to document adult salmon presence in rivers during 2009.

Combined stream survey data for 2008 - 2010 indicated salmon presence in 3 of every 4 headwater streams of less than 10% gradient draining to an anadromous river, including streams on top of the Pebble Prospect. Rearing salmon were documented above dry stream reaches and in waters disconnected from rivers suggesting salmon access such sites during annual floods or via subsurface groundwater channels. Non-salmon species important to subsistence, such as Dolly Varden char, were found in 96% of streams surveyed. A total of 168 km (104.3 miles) of previously undocumented salmon streams, were nominated for the first time to the State's Anadromous Water Catalog. The State accepted all 2008 and 2009

new salmon stream nominations, available at (http://www.sf.adfg.state.ak.us/SARR/AWC/index.cfm) and 2010 nominations are currently under review. Aerial survey data verified adult salmon presence in an additional 358 km (253 miles) of streams and rivers that needed confirming data.

Basic water quality data collected during fish surveys indicated reaches were generally clear (means in 2009 = 1.6 NTU; 2010 = 2.36 NTU), cold (means in 2008 = 7.7^{o}C; 2009 = 8.8^{o}C); 2010 = 8.8°C), near neutral pH (means 2008 = 7.3; 2009 = 7.1; 2010 = 7.2), saturated oxygen conditions (> 11 mg/L), with very low conductivity (means 2008 = 58 µS/cm; 2009 = 44 µS/cm; 2010 = 57 µS/cm). These data indicate pure waters with low suspended solids and high water quality for fish production.

In addition to providing baseline habitat information, inclusion of these 168 kilometers (104.3 miles) of newly documented salmon streams the State's Anadromous Water Catalog triggers state permitting under the Anadromous Fish Act. This study underscores both the importance of headwater streams as essential rearing habitat for salmon and the lack of basic ecological information for two of the world's most productive salmon systems, the Nushagak and Kvichak River watersheds.

It is important to note that these surveys represent only three brief snapshots in time of fish resources in these headwaters; it is highly probable that both the number and species present vary through time. More comprehensive study is recommended to thoroughly document fish use and timing of use in this region.

Rearing rainbow trout (lower fish) and coho salmon (upper fish) were newly documented in an unnamed headwater lake system that drains to Upper Talarik Creek in 2009. Photo C. Woody.

INTRODUCTION

Basic fish distribution data is lacking for most headwater streams draining into the Nushagak and Kvichak rivers in Bristol Bay, Alaska, site of the world's largest most valuable wild salmon fisheries. Extensive mineral development is proposed (Figure 1) which would cause both direct and indirect impacts to fish habitat. To improve coverage of the State of Alaska Anadromous Waters Catalog (AWC) and the AWC Database, which define waterways subject to fish conservation statutes and regulations, surveys were conducted in tributaries in and around the area proposed for mining and road development in Bristol Bay. The conservation context of Bristol Bay salmon stocks is reviewed prior to presenting study methods and results.

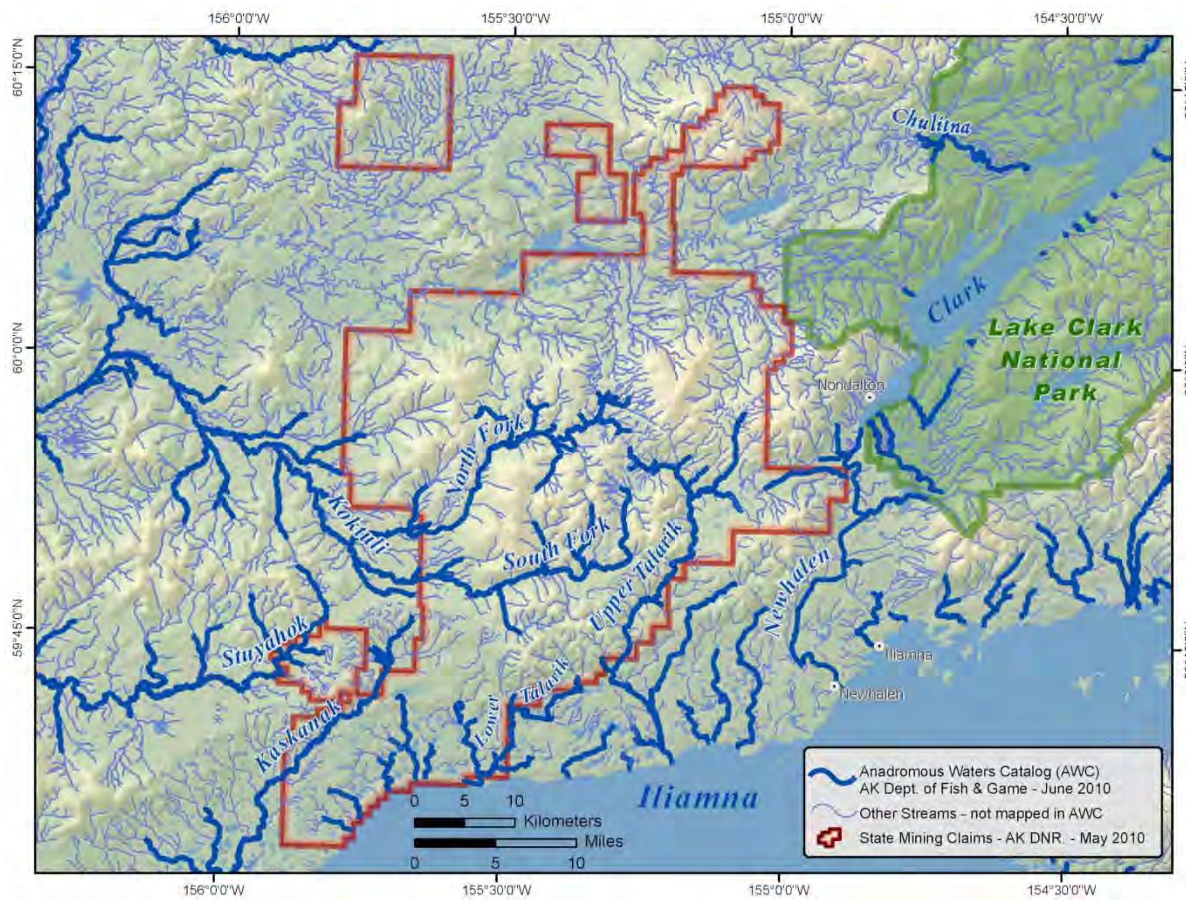


Figure 1. Mining claims in Bristol Bay headwaters as of May 2010. Data from Alaska Department of Natural Resources.

Status of North American Salmon

Atlantic salmon (*Salmo salar*) on the east coast of North America once sustained viable fisheries, but now populations are less than 2% of historic abundance (Parrish *et al.* 1998, USFWS and NOAA 2000, Amiro 2003). Pacific salmon are also in decline. About a third of 1,400 Pacific salmon (*Oncorhychus* spp.) populations along the western contiguous U.S. are now extinct, representing at least 40% of their freshwater range (National Research

Council 1996). A third of remaining populations are threatened or endangered with extinction, and 28 distinct population segments are now listed as endangered or threatened in the U.S. (Figure 2; NOAA 2008). In response, commercial, aboriginal, and sport fisheries have experienced frequent closures in recent years (PFMC 2009). Sockeye and Chinook salmon populations are suffering proportionally higher losses compared to other salmon species (Gustafson *et al.* 2007, IUCN 2008).

British Columbia (B.C.) salmon stocks are declining as well. An assessment of 5,487 B.C. and Yukon salmon stocks, including all large commercially important stocks, listed 142 as extirpated, 624 at high risk of extinction, 78 at moderate risk of extinction, and 230 of special concern (Slaney *et al.* 1996). The continued dramatic decline of Canada's largest salmon system, the Fraser River, is now the subject of a Federal inquiry (CBC News 2009).

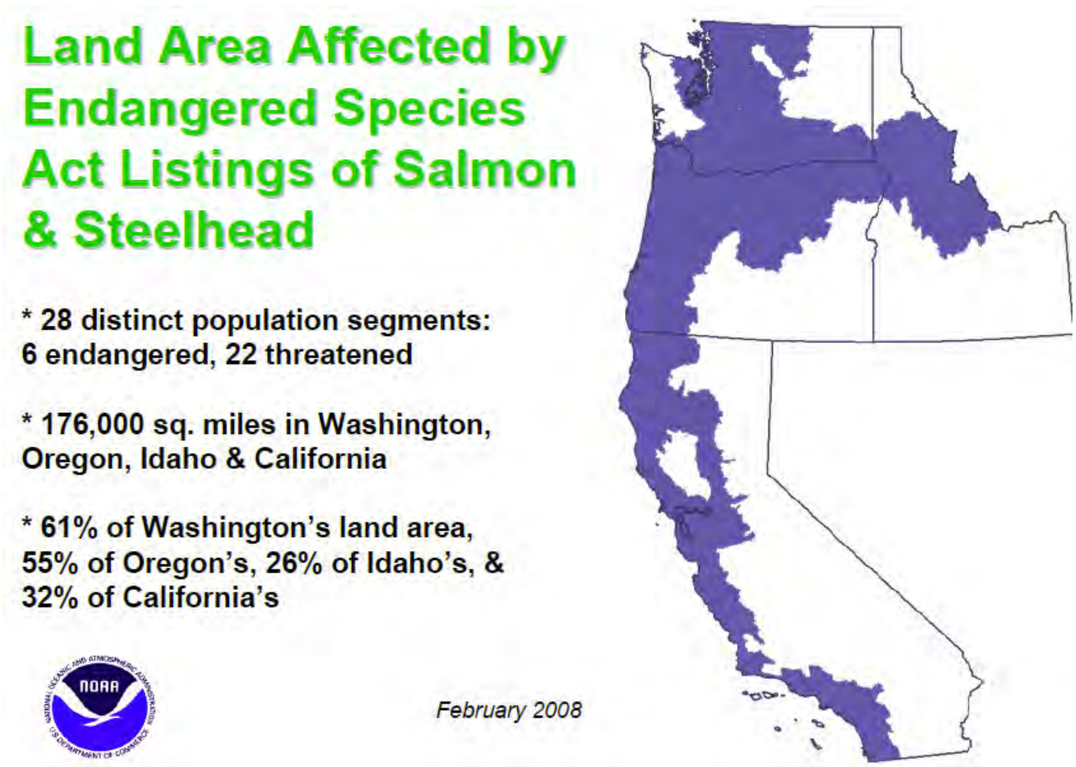


Figure 2. Area of the contiguous U.S. supporting endangered and threatened salmon runs. Map produced by the National Atmospheric and Oceanic Administration (NOAA) available from: http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Maps/Index.cfm.

Factors in Salmon Population Declines

Salmon require diverse habitats to complete their complex lifecycles, including spawning, incubation, rearing and migration. Since Euro-Americans arrived in North America, salmon habitats have diminished in quantity and quality and as a result support fewer salmon. Salmon waters and habitats have also been co-opted for uses other than salmon production. Decline of salmon populations has tracked the extent and intensity of human development: mining, agriculture, urbanization, roads, dams, pollution, overfishing and forestry all being contributing factors (Elson 1974, Nehlsen 1991, NRC 1996, Gresh *et al.* 2000, USEPA 2002, Montgomery 2003, Augerot 2005, USEPA 2007).

Bristol Bay Salmon Fisheries

In sharp contrast to salmon declines elsewhere, over 40 million wild salmon returned to Bristol Bay, Alaska in 2010. Commercial fishers have harvested five species of Pacific salmon from Bristol Bay for 126 years, and in 2010 over 30 million salmon were netted, 29 million of which were sockeye salmon (ADFG 2010a). Bristol Bay is one of the most valuable commercial fisheries in the U.S. (Burgner 1991, NMFS 2010) and is one of the few certified as sustainable (MSC 2009). During 1950 to 2008, U.S. commercial sockeye salmon landings were valued at about $7.9 billion dollars with about half that value attributed to Bristol Bay stocks (NOAA 2010); sockeye salmon harvests alone have averaged about 26 million annually since 1989 (Morstad *et al.* 2010). Bristol Bay also supports a thriving sport fish industry attracting thousands of fishers who generally spend over 90 thousand angler days and millions of dollars to catch wild salmon, trout and char from pristine Bristol Bay rivers (Duffield *et al.* 2007, Dye *et al.* 2008).

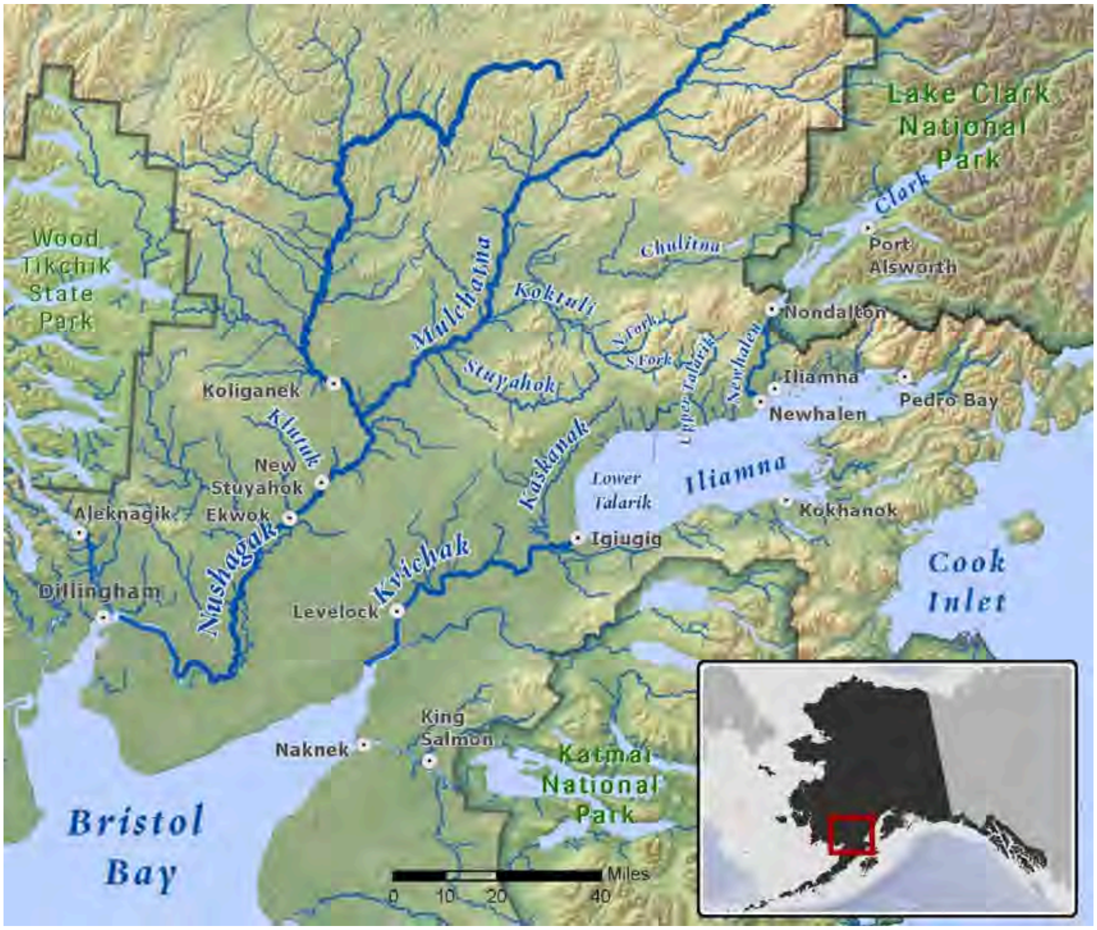


Figure 3. Watersheds and communities (white dots) of Bristol Bay, Alaska.

Noncommercial fishing figures prominently in Bristol Bay communities. Athabaskan, Aleut, and Yup'ik peoples annually harvest over 100 thousand salmon, which they dry, smoke, pickle, salt, can and store for winter sustenance, as they have for thousands of years. Sockeye salmon are their most important food resource and comprise 60% to 80% of annual subsistence harvests (Fall *et al.* 1996, Fall *et al.* 2006). Non-salmon fish, such as Dolly Varden, rainbow trout, and whitefish, also comprise a significant part of people's diets (Figures 4 and 5).

A rearing round whitefish captured in headwaters of the Kvichak River watershed; whitefish are an important subsistence species in the region.

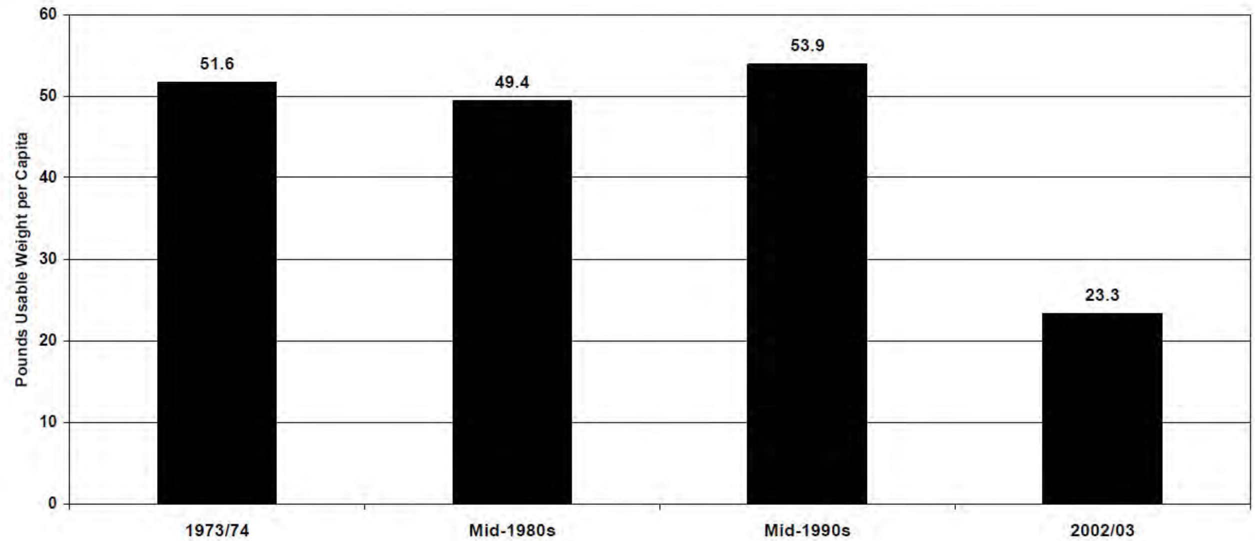


Figure 4. Estimated subsistence harvest of non-salmon freshwater fish in pounds useable weight per person, Kvichak River watershed, Bristol Bay, Alaska. Graph from Krieg *et al.* 2005.

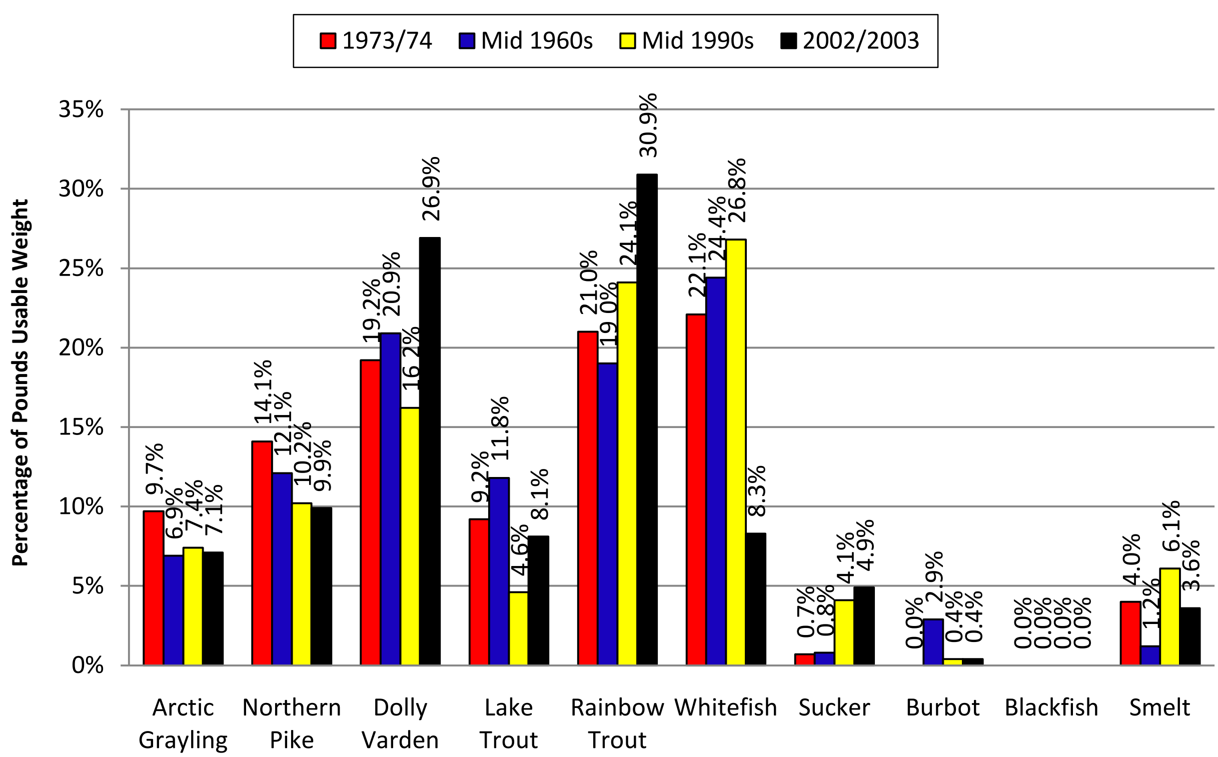


Figure 5. Composition of non-salmon freshwater fish harvest, by decade in villages of the Kvichak River watershed, Bristol Bay, Alaska. Graph from Krieg *et al.* 2005.

Bristol Bay, Alaska is recognized as one of the world's few remaining Pacific salmon strongholds (Figure 6) because wild salmon remain abundant, highly diverse, and their genetic integrity and essential habitats remain intact. Each river watershed can contain hundreds of distinct spawning populations that differ from each other in behavior, appearance, and genetic makeup (Hilborn 2003, Ramstad *et al.* 2004, Habicht *et al.* 2007). This high biodiversity helps ameliorate adverse effects of environmental stressors on salmon production and is considered a major reason Bristol Bay salmon production has remained stable over time despite changing environmental stressors and heavy exploitation (Hilborn *et al.* 2003). This stability is termed the "portfolio effect" since the larger commercial fish stock is a "portfolio" of many small spawning stocks: although production of each spawning group varies annually, production of the whole remains relatively stable, e.g. the more diverse the salmon "stock portfolio," the higher the probability of its persistence into the future (Giesel 1974, Altukhov 1981, Hilborn *et al.* 2003, Schindler *et al.* 2010).

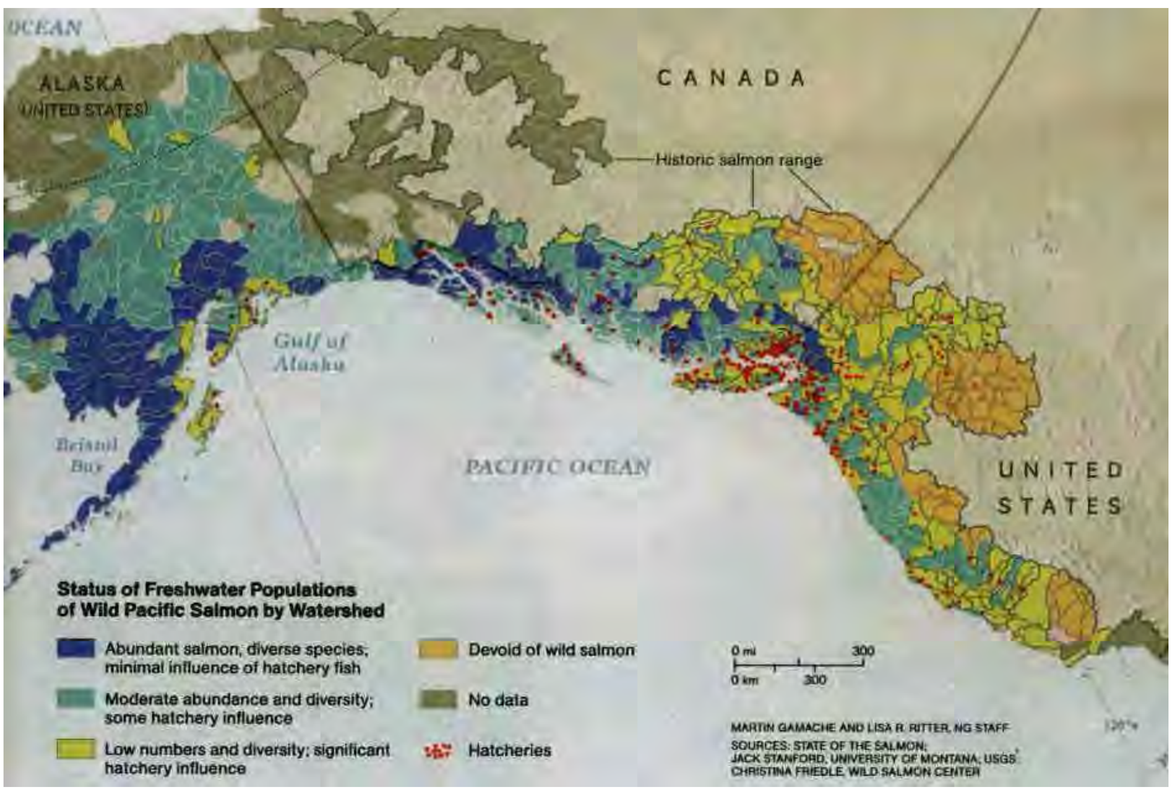


Figure 6. Bristol Bay is considered North America's premier wild salmon stronghold. Note the absence of hatcheries (red dots) in Bristol Bay, which can cause detrimental genetic and ecological changes in wild salmon populations. (Map courtesy of National Geographic).

Available Data on Bristol Bay Fish Populations

Bristol Bay contains thousands of headwater streams from which all major salmon rivers originate. These small streams are not a high priority for fish studies although, collectively, they can account for the majority of essential salmon and non-salmon rearing, spawning and incubation habitat (Beechie *et al.* 1994). Resource managers are required to make critical regulatory decisions regarding fish habitat in response to resource development. However, in Alaska, less than half of essential freshwater salmon habitats are documented (ADFG 2010b). This lack of basic fisheries information—what species and life stage are where at what time of year—makes informed regulatory decisions difficult at best. Effective conservation of salmon resources in regards to development requires detailed knowledge of the spatial distribution, ecology and timing of stocks that comprise the larger salmon stock portfolio. Compared to the salmon resource, less information is available on non-salmon fish habitat use, although such species are an important year round food resource for subsistence users (Krieg *et al.* 2005). Limited data exists on the timing, duration and extent of habitat use by salmon and non-salmon subsistence species in the Nushagak and Kvichak River watersheds. Future sustainability of Bristol Bay salmon and subsistence fisheries depends, in part, on documenting and conserving essential fish habitats including spawning, incubation, rearing, feeding and migration habitats.

Applicable Statutes

Explicit documentation of salmon and other fish and their life stage (spawning, rearing, migrating, etc.) is required for certain state permitting requirements to apply. For example, construction of stream crossings, such as culverts or bridges, can be temporally constrained to minimize adverse effects of increased sediment on spawning or incubating fish. Salmon and other anadromous fish, are afforded some statutory protection, specifically:

> Alaska Statute 16.05.871 (Anadromous Fish Act) 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.

Whereas non-anadromous fish receive some protection of migration corridors under:

> 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.

Unpermitted activities that impact documented fish habitat can be subject to state compensatory measures, which may be monetary or restorative.

Study Rationale

Documentation of essential fish habitats is lacking for headwater streams draining into the Nushagak and Kvichak rivers. Recent changes by the State to the Bristol Bay Area Plan (ADNR 2005) made mineral development a "designated use" to be encouraged or protected on about 12 million acres of State land, and an exclusive designated use on about 9.4 million of those acres. These 9.4 million acres contain a significant proportion of Bristol Bay headwaters and extensive mineral development would cause direct and indirect impacts to fish habitat. To improve coverage of the State of Alaska AWC, which defines waterways subject to fish conservation statutes and regulations, surveys were conducted in and near the area proposed for mine development (Figure 7).

Burbot (*Lota lota*) captured in a small pond associated with the Stuyahok River. Although this pond was not connected to the Stuyahok River during surveys, fish likely move in and out of such habitats during spring and fall floods.

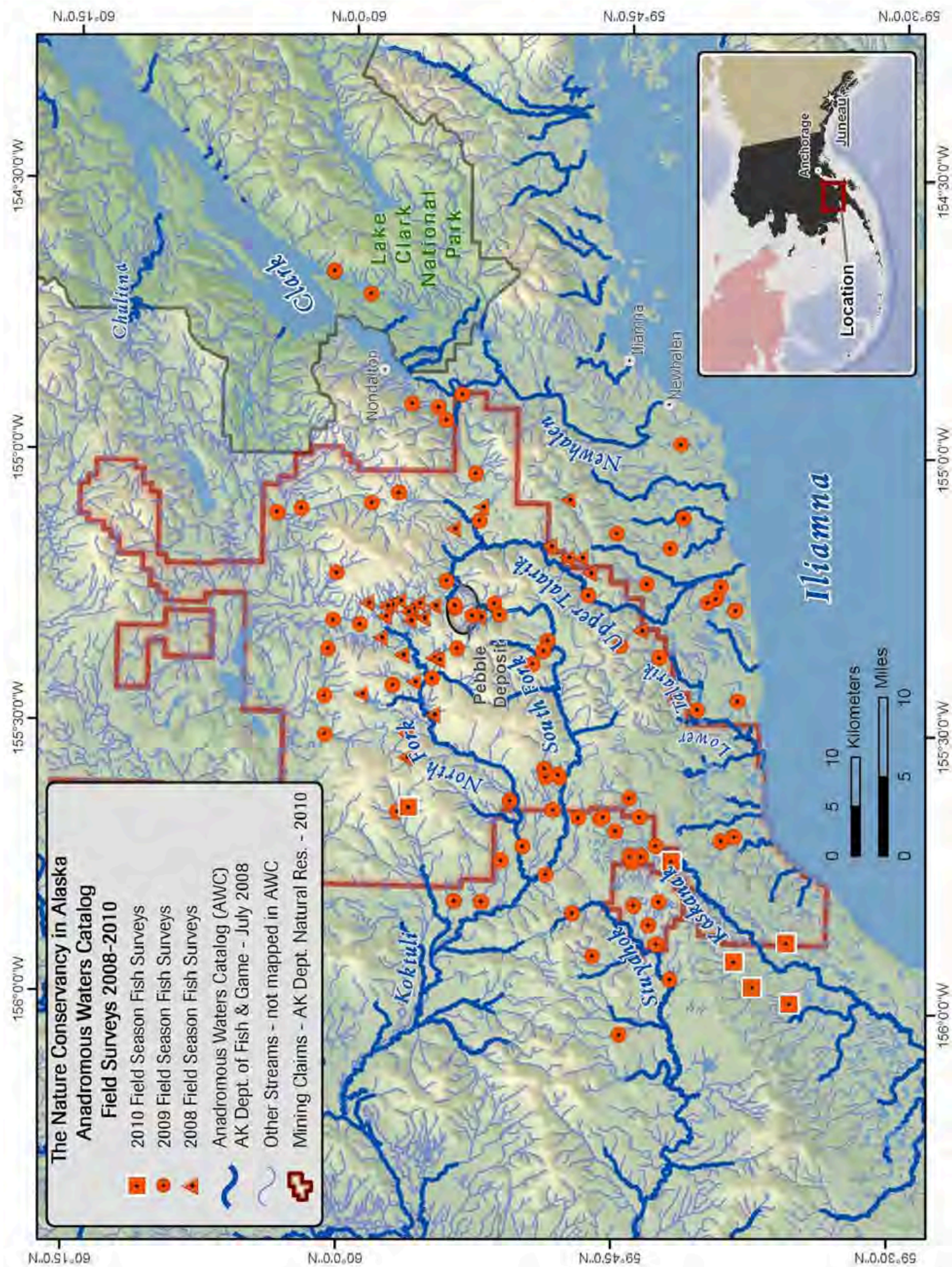


Figure 7. Fish survey sites (red dots, triangles and squares) for 2008—2010, Bristol Bay, Alaska. Mine claims as of May 2010 are outlined in red. Approximate Pebble deposit is outlined in black.

STUDY SITES

The study focused primarily on first and second order wadeable streams with gradients less than 10%. Selected streams were not listed as anadromous in Alaska State databases, and were generally located in or near mining claims on State land and along proposed mine road corridors in the Nushagak and Kvichak River drainages. Geographic Positioning System (GPS) coordinates for survey sites were determined using geospatial data layers from the National Hydrography Dataset and the National Elevation Dataset. Because hydrography data sets are sometimes inaccurate (e.g., mapped streams may not exist) final stream selections were determined in the field during low-level helicopter reconnaissance or foot survey. Aerial surveys for adult and spawning salmon were conducted along mainstem tributaries (non-wadeable) in mining leases and along proposed road lines where contemporary survey information was lacking for State fishery databases.

METHODS

Fish Surveys

Headwater stream surveys were conducted during 29 August to 2 September 2008, 13 August to 4 September 2009 and 16 August to 1 September 2010 prior to fall floods. Fish were sampled using single pass backpack electrofishing set for pulsed (30-40 pps) direct current (Meador *et al.* 1993, Reynolds 1996, Bateman *et al.* 2005). Voltages were set using the following conditions: 150-400 V for high conductivity waters of $>$ 300 μS/cm; 500-800 V for medium conductivity waters of 100 to 300 μS/cm, and $\geq$ 800 V for low conductivity waters of $<$ 100 μS/cm. Initial pulse frequency was set at 30 pps and duty cycle was set at 25 percent. If effectiveness was low at high voltage, voltage was decreased to the initial setting, and pulse frequency was increased by an increment of 10 pps. Voltage was increased until fish response improved, or pulse frequency reaches 50 pps. A pulse frequency of 50 pps was not exceeded. Total electrofishing time generally exceeded 300 seconds at each survey site.

Fish sampling began by measuring water conductivity, setting appropriate electrofisher parameters, then moving downstream measuring either 150 m or 40 times the stream width whichever was greater. Survey crews electrofished upstream, discontinuously sampling all habitat types. If salmon were captured at the study site, the crew attempted to document uppermost distribution of salmon by flying upstream and electrofishing at the highest accessible fishable site within that tributary. If salmon were captured at this higher site, GPS coordinates were recorded and noted as the upper extent of documented salmon presence. Sites not amenable to electrofishing, e.g., beaver ponds, deep spring fed pools, or dense willows, were sampled by deploying minnow traps for 12 to 24 hours. Traps were baited with commercially prepared, sterilized salmon eggs.

All captured fish were held in a bucket of fresh stream water, identified, and enumerated. All salmon were measured and a voucher specimen photographed for any newly documented salmon streams. Up to 20 non-salmon species were also measured at each site, time permitting. All fish were returned to the stream with a few exceptions. If positive species identification was not possible, then fish were taken back to the field station for identification. Approximately 60 Dolly Varden samples were collected for an interagency study to verify species and to examine otoliths for evidence of anadromy.

Aerial surveys to substantiate presence of adult or spawning salmon were conducted from a helicopter during September and October 2009 in the North and South Fork Koktuli Rivers, Upper Talarik Creek, tributaries draining to Lake Iliamna, and along proposed road corridors. Surveys were conducted from 10 to 20 meters above the stream. When adult salmon were observed, GPS coordinates were marked and a voucher photo taken.

Habitat Measurements

Habitat measures were based on McCormick and Hughes (1998) and Kaufmann and Robison (1998). One transect was established across a run within each tributary; GPS coordinates were recorded. Basic water quality was measured in the thalweg with a YSI 556 Multi Probe System (YSI Incorporated, Yellow Springs, Ohio, USA) in 2008 and 2009 and with an Oakton model PC 10 meter in 2010 (Oakton, Vernon Hills, Illinois, USA) for temperature, pH, conductivity, specific conductance, and dissolved oxygen (DO). Turbidity was measured using a Hach 2100P Portable Turbidimeter (Hach Company, Loveland, Colorado, USA) and air temperature was measured using a standard alcohol thermometer.

Meters were checked for accuracy on a regular basis using standard calibration solutions, and calibrated when not compliant with data quality objectives. Manufacturer's instructions were followed for pH and conductivity calibration, using pH 4, 7 and 10 buffer solutions and 1413 µS/cm conductivity standard solution. The DO sensor was pre-calibrated daily to saturated conditions in accordance with manufacturer's instructions. Data produced from meters that failed to meet post-calibration data quality objectives were qualified and excluded from analyses.

Dr. Dan Rinella collects fish habitat data on an unnamed tributary to the North Fork Koktuli River. Photo C. Woody.

Discharge (cfs) was measured following USGS protocols (Rantz 1982) using Marsh-McBirney Flo-Mate Model 2000 portable meters (Hach Company, Loveland, Colorado, USA) that were calibrated at each study site. Stream stage was categorized (dry, low, medium, or high water). Morphometric measures were made at the upstream end of the sampling reach, including channel width and thalweg measured at both wetted and ordinary high water (OHW) (Kaufman *et al*. 1999). Channel slope was estimated to the nearest 0.5% by taking one or multiple readings from the top to the bottom of the reach using a handheld clinometer and a pole held at the water surface. Visual categorizations were made for both water color (clear, ferric, glacial, humic, muddy, or, in one case yellow) and substrate composition (mm diameter) at the downstream end of the reach: Category 1: < 2 mm; Category 2: > 2-16 mm; Category 3: > 16-64 mm; Category 4: > 64-128 mm; and Category 5: >128 mm. Upstream and downstream photographs were taken at each transect as well as from ~50 m in the air.

Low ionic strength of study area waters presented some difficulty in measuring habitat parameters (namely pH and conductivity) during 2009. Consequently, 24 sites sampled in 2009 were revisited in 2010 for the sole purpose of verifying water quality data using equipment better suited to site characteristics.

RESULTS

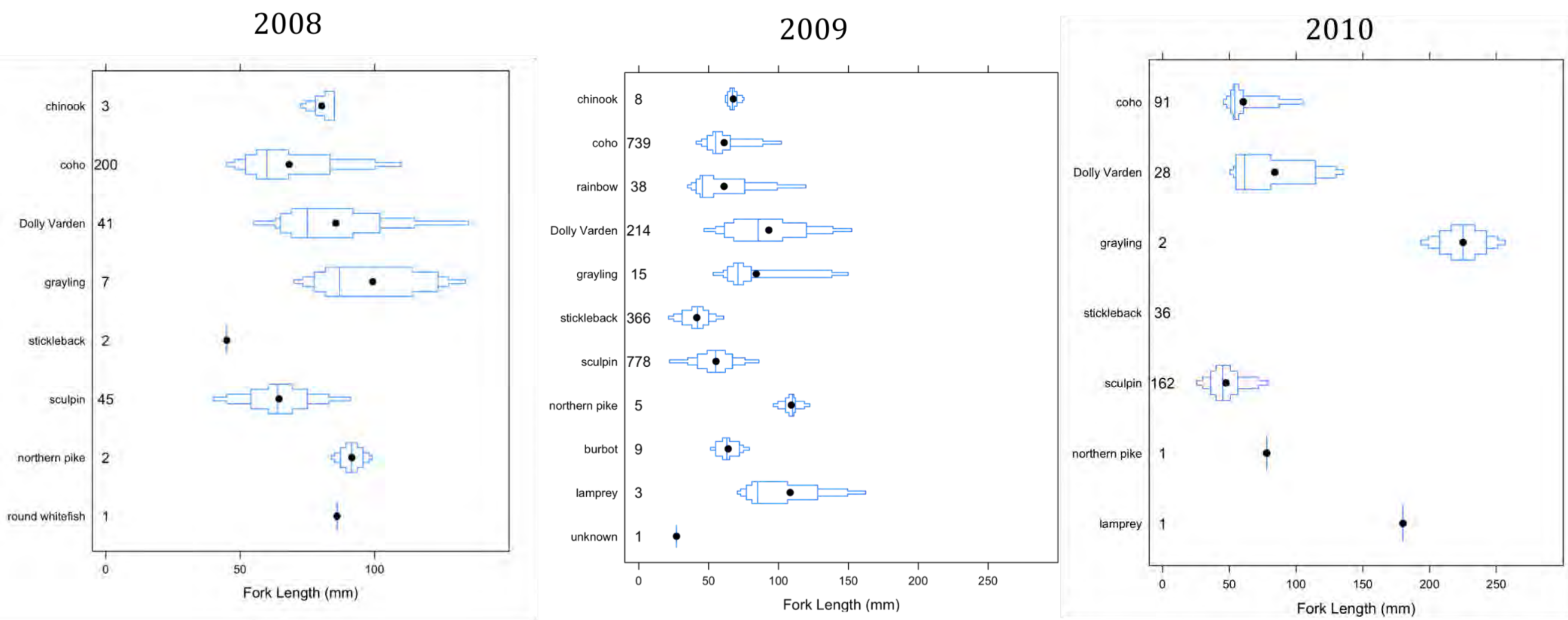
Fish Surveys

A total of 108 sites were electrofished or trapped during mid-August to the first week of September, 2008 through 2010 (Appendix I). Fish were captured in 104 of 108 streams or in 96% of sites. Surveys revealed headwaters support:

- 3 salmon species and at least two life stages: rearing coho and Chinook salmon, and adult coho and sockeye salmon;
- 6 non-salmon species important to subsistence: rainbow trout, Dolly Varden, grayling, round whitefish, burbot, Northern pike, and pond smelt; and
- 4 species important to ecosystem function: lamprey, slimy sculpin, ninespine and threespine stickleback; and
- many small (<150 mm) and rearing fish (Figure 8).

A total of 168 km (104.3 miles) of essential salmon rearing habitat was nominated for the first time to the State's Anadromous Waters Catalog (Appendices I – VI). The State accepted all 2008 and 2009 nominations and is currently reviewing 2010 nominations. An additional 408 km (253 miles) of waters were documented as supporting adult or spawning coho and sockeye salmon; the majority of these observations were to update current AWC databases although some sites were nominated for the first time to the AWC.

Figure 8. Box-percentile plots of fish fork length distributions for 2008, 2009 and 2010; all sample sites combined. Sample sizes are along y axis. Mean fork length denoted by a dot, median fork length by a central vertical line. The tallest central section encompasses the central 25% of observed fork lengths; the next tallest section encompasses the central 50%; the next section 75%, and the shortest box the central 90% of observed fork lengths. Unknown fish documented in 2009 was later determined to be a pond smelt (*Hypomesus olidus*).



A total of 97 sites were electrofished or minnow trapped in 2008 through 2010 excluding dry, unsurveyed, and Chulitna River survey sites (The Chulitna drainage is a Northern pike and humpback whitefish ecosystem). Of those 97 sites, 74% (72) contained anadromous salmon, 96% (93) contained resident fish, and no fish were captured in 3% (4). Of the 10 non-salmon species documented, two new species were observed, an anadromous lamprey (*Lampetra camtschatica*) and a potentially anadromous pond smelt (*Hypomesus olidus*).

During 2008, coho salmon were documented at a channel within the North Fork Koktuli watershed that had no surface connection to an anadromous stream. During 2009, several similar sites within the South Fork Koktuli and Stuyahok watersheds also contained coho salmon and non-salmon species. Disconnection of those sites to an anadromous stream may be due to low water in August and resulting downwelling of surface water into the water table, as well as channel constriction creating tunnels covered by dense Sphagnum moss. Field observations indicate fish are able to exploit hyporheic corridors for extended distances due to the large alluvial substrates and copious groundwater in the study region (Boulton *et al.* 1998).

Aerial surveys in September and October of 2009, to substantiate presence of adult or spawning salmon in the North and South Fork Koktuli Rivers, Upper Talarik Creek, tributaries draining to Lake Iliamna, and along proposed road corridors, resulted in documentation and verification of an addition 407 km (253 miles) of anadromous rivers (Appendices II – IV). Some evidence of spawning was documented during those surveys as well.

Habitat Measurements

Surveyed headwater tributaries in both years were generally first or second order streams, with cold, clear water, nearly neutral pH and very low conductivity (Tables 1 through 3). Dissolved oxygen levels were at or near saturation for recorded temperatures (Tables 1 and 2).

Table 1. Summary of basic water quality parameters measured in headwater tributaries of the Nushagak and Kvichak watersheds, Bristol Bay, Alaska, 29 August to 2 September 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
SD	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

Table 2. Summary of basic water quality parameters measured in headwater tributaries of the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 13 August to 4 September 2009.

Statistic	*Water temp (°C)*	*Air temp (°C)*	*pH*	*Conductivity (µS/cm)*	*Dissolved Oxygen (mg/L)*	*Dissolved Oxygen % saturation*	*Turbidity (NTU)*
N	67	54	37	62	62	62	60
Mean	8.8	14.2	7.1	44	11.4	97.6	1.6
SD	2.8	3.6	0.3	20	1.6	11.6	1.3
Minimum	4.0	6.0	6.3	16	6.3	56.1	0.2
Maximum	15.5	21.0	8.0	125	14.6	120.5	5.5
CI 95%	8.8 ± 0.7	14.2 ± 1.0	7.09 ± 0.11	44 ± 5	11.42 ± 0.40	97.55 ± 2.86	1.58 ± 0.33

Table 3. Summary of basic water quality parameters measured in headwater tributaries of the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 16 August to 1 September 2010.

Statistic	*Water temp (°C)*	*Air temp (°C)*	*pH*	*Conductivity (µS/cm)*	*Turbidity (NTU)*
N	30	30	30	30	30
Mean	8.8	15.6	7.2	57	2.4
SD	2.0	3.4	0.4	35	2.4
Minimum	5.7	11.1	6.2	23.8	0.3
Maximum	13.4	23	7.9	186.7	10.4
CI 95%	8.8 ± 0.7	15.6 ± 1.2	7.2 ± 0.14	57 ± 13	2.4 ± 0.87

In 2008, wetted stream 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 2008 (Table 4).

Sockeye salmon can exploit spawning habitat upstream of beaver dams. Photo © Craig Coray.

Table 4. Stream morphometry parameters measured for surveyed headwater streams of the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska. Surveys conducted during 29 August to 2 September 2008. OHW is ordinary high water, thalweg is the deepest part of stream on transect.

Statistic	***OHW width, m (ft)***	***Thalweg OHW, cm (ft)***	***Wetted Width, m (ft)***	***Thalweg Wetted Depth, cm (ft)***	***Discharge (cfs)***
N	23	23	23	23	23
Mean	2.2 (7.4)	35.8 (1.2)	1.9 (6.3)	25.7 (0.8)	1.5
SD	0.98 (3.2)	14.5 (0.5)	0.9 (2.9)	13.5 (0.4)	1.32
Minimum	0.9 (3)	6.1 (0.2)	0.6 (2)	3.1 (0.1)	0.14
Maximum	5.5 (18)	79.3 (2.6)	4.9 (16)	61.0 (2)	5.6
CI (95%)	2.2 ±0.4 (7.4 ± 1.4)	35.8 ± 6.3 (1.2 ± 0.2)	1.9 ±0.4 (6.3 ± 2.9)	25.7 ± 5.8 (0.8 ± 0.2)	1.5 ± 0.57

Substrate composition varied from 100% sand and silt (< 2 mm dia) to one comprised of up to 20% boulders (> 128 mm dia). However, 14 of 23 streams had ≥ 50% substrates comprised of fine to coarse gravel (≥ 2 mm dia to < 64 mm dia) (Figure 9).

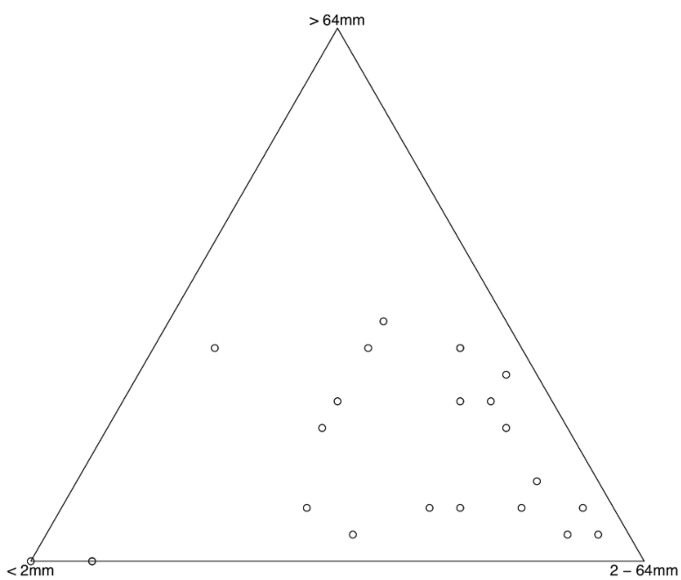


Figure 9. Ternary plot of stream substrate composition for surveyed headwater streams in the Nushagak and Kvichak River drainages, 2008. One site had 100% of substrate in the fine sand and silt (< 2 mm dia) category as indicated by the dot on the lower left corner. Some sites contained only substrates < 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 (> 128 mm dia) were least common (only two sites had >5% boulders; substrate category 5).

In 2009, wetted widths averaged 4.1 m wide by 30 cm deep; ordinary high water (OHW) averaged 5.0 m wide by 50 cm deep measured at the thalweg (Table 5). Discharge averaged 11.6 cfs (Table 5).

Table 5. Stream morphometry parameters measured for surveyed headwater streams of the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 2009. Surveys were conducted during 13 August to 4 September 2009. OHW is ordinary high water, thalweg is the deepest part of stream on transect.

Statistic	***OHW width, m (ft)***	***Thalweg OHW depth cm (ft)***	***Wetted Width, m (ft)***	***Thalweg Wetted Depth cm (ft)***	***Discharge (cfs)***
N	61	60	63	62	57
Mean	5.0 (16.5)	50 (1.7)	4.1 (13.6)	30 (1.1)	11.6
SD	5.8 (18.9)	30 (0.9)	4.5 (14.7)	20 (0.6)	20.4
Minimum	0.3 (0.9)	20 (0.5)	0.8 (2.6)	10 (0.3)	0.0
Maximum	37.6 (123.4)	190 (6.1)	26.0 (85.4)	110 (3.4)	126.9
CI (95%)	5.0 ± 1.4 (16.5 ± 4.7)	50± 10 (1.7 ± 0.2)	4.1 ± 1.1 (13.6 ± 3.6)	30 ± 0 (1.1 ± 0.2)	11.6 ± 5.3

Substrate composition varied from 100% sand and silt (< 2 mm dia) to one comprised of 100% cobble and boulders (> 64 mm dia). However, substrates in most streams had ≥ 50% substrates comprised of fine to coarse gravel (≥ 2 mm dia to < 64 mm dia) (Figure 10).

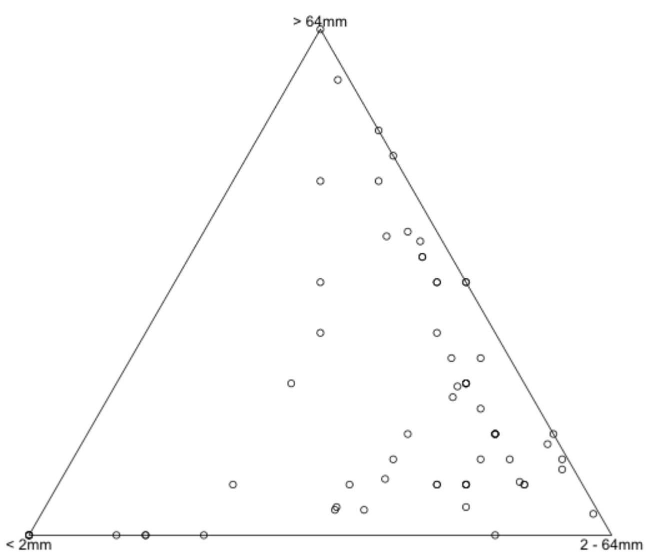


Figure 10. Ternary plot of stream substrate composition for surveyed headwater streams in the Nushagak and Kvichak River drainages, 2009. One site had 100% fine substrate (< 2 mm dia) as indicated by the dot on the lower left corner. Some sites contained 100% cobble and boulder substrates (> 64 mm dia) as indicated by dot on top of triangle, while most sites were a mix of small to medium gravel (2 - 64 mm).

In 2010, wetted widths averaged 2.9 m wide by 34 cm deep; ordinary high water (OHW) averaged 3.0 m wide by 40 cm deep measured at the thalweg (Table 6). Discharge averaged 16.6 cfs (Table 6).

Table 6. Stream morphometry parameters measured for surveyed headwater streams of the Nushagak and Kvichak River watersheds, Bristol Bay, Alaska, 2010. Surveys were conducted during 15 August to 4 September 2010. OHW is ordinary high water, thalweg is the deepest part of stream on transect.

Statistic	***OHW width, m (ft)***	***Thalweg OHW depth cm (ft)***	***Wetted Width, m (ft)***	***Thalweg Wetted Depth cm (ft)***	***Discharge (cfs)***
N	28	27	30	30	30
Mean	3.0 (9.7)	40 (1.3)	2.9 (9.6)	34 (1.1)	16.6
SD	2.0 (6.5)	13 (0.4)	2.3 (7.4)	16 (0.5)	29.1
Minimum	0.3 (1.0)	15 (0.5)	0.3 (1.0)	13 (0.5)	0.7
Maximum	7.6 (25.0)	70 (2.3)	26.0 (85.4)	9.3 (30.4)	113.7
CI (95%)	3.0 ± 0.7 (9.7 ± 2.4)	40 ± 5 (1.3 ± 0.2)	2.9 ± 0.8 (9.6 ± 2.7)	34 ± 6 (1.1 ± 0.2)	16.6 ± 10.4

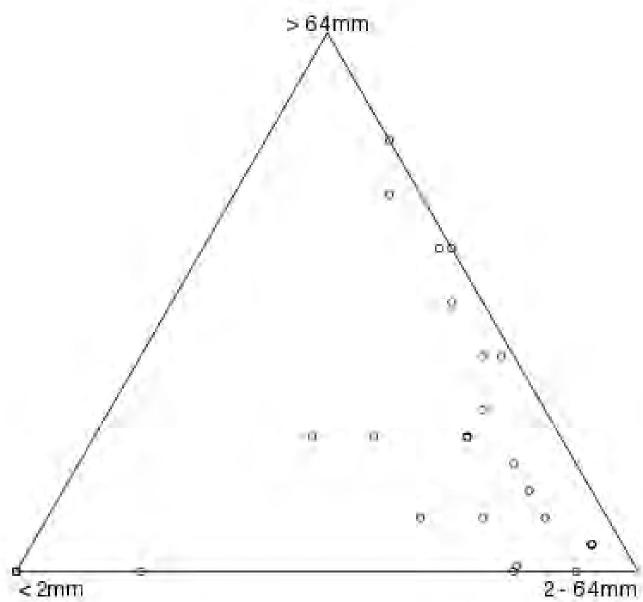


Figure 11. Ternary plot of stream substrate composition for surveyed headwater streams in the Nushagak and Kvichak River drainages, 2010. Two sites had 100% fine substrate (< 2 mm dia) as indicated by the dot on the lower left corner. Some sites were dominated by cobble substrates as indicated by dots in the upper right of the plot. Most sites were a mix of small to medium gravel (2 - 64 mm).

CONCLUSION

The 2008 - 2010 surveys documented over 168 km (104.3 miles) of essential salmon rearing habitats, which were subsequently nominated for the first time to the State of Alaska Anadromous Waters Catalog (AWC). All 2008 and 2009 survey nominations were accepted by the State for inclusion in the AWC. The 2010 nominations are currently under review. Combined results from both years showed 96% of all surveyed streams contained fish, and anadromous salmon presence in 74% of headwater tributaries, excluding the Chulitna River. Our surveys within the Chulitna River watershed did not reveal salmon presence, possibly due to habitat factors including slow-moving water, fine sediments, and presence of large, abundant, predacious Northern Pike. A total of thirteen species were documented during 2008 through 2010 surveys, including lamprey and pond smelt.

In addition to juvenile fish surveys, aerial surveys for spawning adults resulted in documentation and verification of another 408 km (253 miles) of anadromous rivers. Although it was not always possible to verify spawning, evidence of redds was apparent in drainages surveyed. Telemetry studies in Lake Clark, in the Kvichak drainage, show the presence of adult sockeye salmon in a tributary indicate spawning will occur in that tributary (Young and Woody 2007). A report by HDR (2008) also documented the presence of juvenile salmon in the upper reaches of the North and South Fork Koktuli rivers and Upper Talarik Creek during winter surveys, indicating that spawning occurs in these systems. Additional adult surveys to verify spawning and winter studies focused on juvenile presence in these systems would provide additional insight.

A literature review by Marshall and Britton (1990) documented a positive linear relationship between stream length and coho smolt production. 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 (Table 7). They also demonstrated a relationship between latitude and smolt abundance, though the study lacked sufficient streams of comparable latitude to those in Bristol Bay. Further studies to verify the production relationship would be useful for Bristol Bay streams.

Table 7. Summary statistics of coho salmon smolt production rates (smolts/km of stream) estimated by the nonparametric density estimation procedure of Rice (1993), by latitude, showing the median and the interquartile and 5, 95% ranges. From Bradford *et al.* 1997.

Latitude (˚N)	Smolts/km Median	Percentile ranges 25, 75	Percentile ranges 5, 95
45	457	291, 868	124, 2,849
47	642	419, 1,198	161, 2,259
49	1,476	823, 2,849	435, 3,650
51	924	664, 3,129	186, 3,286
53	902	787, 1,642	345, 3,286

These surveys were conducted during periods of summer low flows. Thus fishless survey sites may support fish at periods of higher flow. As evidenced by the presence of salmon in sites disconnected from surface water flow in this study, groundwater supplied refuge during periods of low flow and may also provide subsurface migration corridors to fish. Annual floods during spring and fall in Bristol Bay, likely reconnect such refugia allowing salmon to move among ephemeral habitats. The lack of information on salmon use of ephemeral habitats and the critical role of groundwater warrants further investigation. Improved information on the functional significance, flow patterns, and vulnerability of the hyporheic zone to proposed mining would provide insight into potential impacts groundwater contamination could have on salmon production.

Initial survey sites were selected using geospatial data layers from the National Hydrography Dataset and the National Elevation Dataset (n=135), 16% (21) of these sites proved dry or nonexistent, 53% (72) contained anadromous fish and 66% (89) contained resident fish and 3% (4) had no fish at the time of sampling. Lacking additional information, these percentages could be used to estimate the number of non-existent channels, and anadromous and resident fish streams among the thousands of yet unsurveyed headwater streams in Bristol Bay. However, additional surveys of similar headwaters should be considered to assess and further refine estimates.

Combined data show two sites where both rearing coho and Chinook salmon occurred together (a lake complex draining to the North Fork Koktuli River, and a tributary to the Stuyahok River). The lack of more Chinook salmon observations is likely due to habitat segregation. For example, in Alaska's Taku River, coho salmon were found more often in sloughs and ponds compared to Chinook salmon, which were more often found in riverine habitat (Murphy 1989). In British Columbia's Big Quallicum River coho salmon were captured more often in lower velocity sites than Chinook salmon (Lister and Genoe 1970). And a study in Oregon's upper South Umpqua River, found coho absent from a mainstem river, but at high densities in low-elevation tributaries, in contrast to Chinook which were found at highest densities in the mainstem and mid-elevation tributaries (Scarnecchia and Roper 2000). Because our study was generally limited to small, shallow, headwater tributaries during low flow, Chinook salmon may have been more abundant in deeper higher velocity habitats that were not targeted for survey in this study.

Non-salmon fish species are an important subsistence food resource for people in this region (Figures 4 and 5). Subsistence use surveys for the Kvichak River watershed showed use of Dolly Varden for subsistence increased from about 16% to 27% over the last decade (Krieg *et al.* 2005). Few studies have focused on the life history of Dolly Varden in this region, including their anadromous tendencies, movement patterns, and abundance. Preliminary results of otolith microchemistry analysis for the study area, however, indicate low levels (2 of 29 samples in the North and South Fork Koktuli Rivers) of Dolly Varden anadromy (Christian Zimmerman, personal communication, July 2010). Further, recent radiotelemetry studies in the Togiak Wildlife Refuge showed that of 97 fish radiotagged during 1998 and 1999, 57 survived to the next spring and all migrated to saltwater during May and June of 1999. Thirty one radiotagged fish returned to the Togiak River during July and August 1999 after spending an average of 40.5 days at sea. Tagged Dolly Varden from the Togiak Refuge study have been captured in the Egigik, Yukon, Kanektok, and Arolik Rivers. Otolith analysis studies indicated that 54 of 55 fish subjected to microchemical analysis were anadromous and made their first trip to sea at age 0 to age 3. Because the Togiak River watershed has undergone similar geologic influences as the Nushagak and Kvichak River watersheds, it is likely that further studies of Dolly Varden in this region will reveal similar anadromous life history patterns. Because Dolly Varden was the second most abundant species encountered in this study (after sculpin), and because it is such an important subsistence species, further information on their life history patterns in the Nushagak and Kvichak River watersheds would provide valuable information toward their conservation.

Small headwater streams are often assumed not to be important salmon producing habitats in Alaska, although collectively they produce millions of salmon and determine water flow and chemistry of larger rivers. As illustrated by this and numerous other studies, headwaters comprise a significant proportion of essential spawning and rearing habitat for salmon and non-salmon species all of which are important to subsistence users in the region. Because mortality is highest during early life for fish, successful negotiation of the vulnerable juvenile life history phase increases the probability an individual will survive to reproduce—a key factor in a sustainable fishery.

In addition to documenting fish presence and absence, this study evaluated basic water quality and habitat parameters, indicating generally pristine conditions throughout the area. Temperatures were cool, well below upper tolerance limits for all species and life stages of salmon (Richter and Kolmes 2005). Oxygen levels were at or near saturation at all sites, and well above critical levels for egg incubation and juvenile rearing as well as spawning (Quinn 2005). Likewise conductivity, a function of the number of dissolved ions in the water, is very low in the region, closer to that of distilled water or melted snow than typical freshwater levels (CWT 2004, Table 8). Low conductivity is generally one coarse indication of low nutrient levels and minimal human disturbance (Dodds 2002). Finally, in sites where pH was successfully measured, values were near neutral, which is also conducive to salmon egg incubation and juvenile survival. In contrast, lower (acidic) pH increases solubility of toxic metals that can impair successful embryo development and hatching (Dodds 2002). In addition to chemical habitat parameters, physical habitat parameters suggested abundant spawning gravel, and depths appropriate for both spawning and rearing (Quinn 2005). It is important to note that all habitat measurements represent only three brief snapshots in time. A more robust dataset including diel temperature, oxygen and conductivity patterns throughout the year would be useful in understanding daily and seasonal ranges of those parameters.

Table 8. Typical ranges for conductivity in U.S. waters. From CWT 2004.

Water Type	Conductivity (umhos/cm)
Distilled water	0.5 - 3.0
Melted snow	2 - 42
Potable water in U.S.	30 - 1500
Freshwater streams	100-2000

Conservation of the world's largest, most valuable, sustainable, wild sockeye salmon fisheries in Bristol Bay depends, in part, on conserving the diverse habitats essential to fish survival and reproduction. The information presented here on fish distribution, headwater stream chemistry, and channel morphology provides more complete and accurate information for future fish conservation decisions. However, thousands of similar streams that contribute to fish production remain unsurveyed and therefore are not afforded statutory protection offered by inclusion in the AWC in regions proposed for industrial development.

Unnamed tributary and pond system to Upper Talarik Creek surveyed for the first time in 2008 and found to support rearing coho salmon, sticklebacks, and sculpin.

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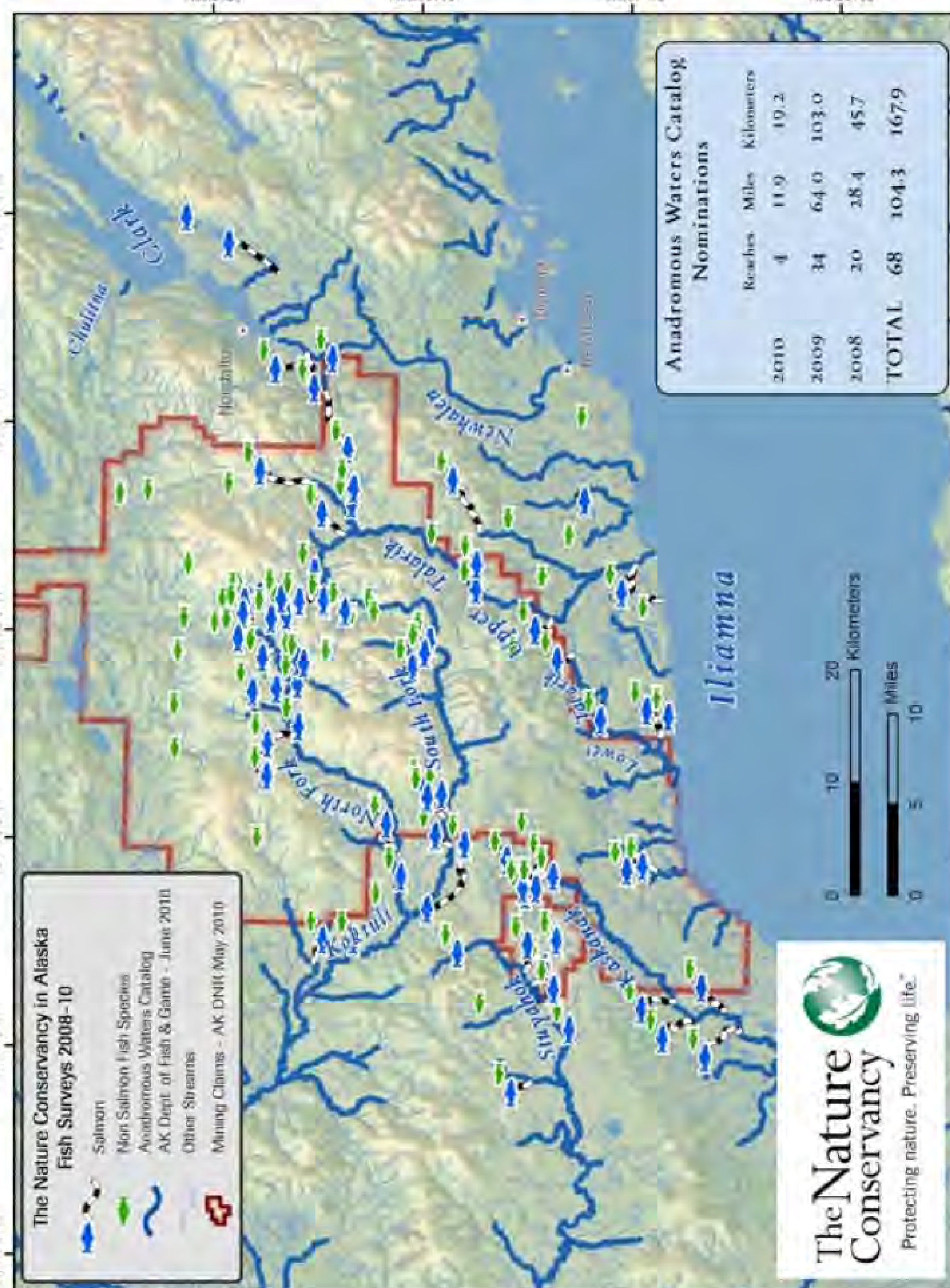
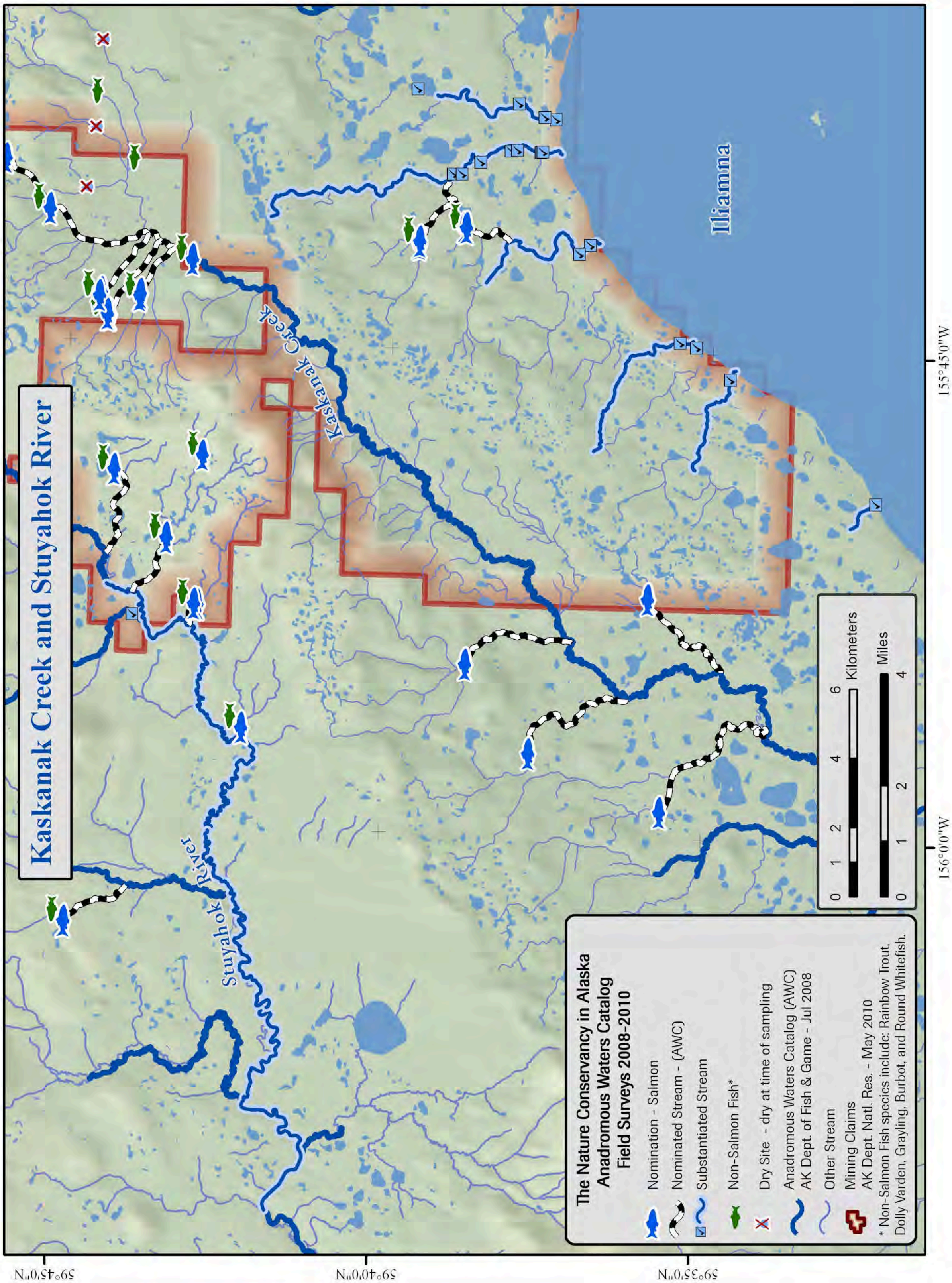
APPENDICES

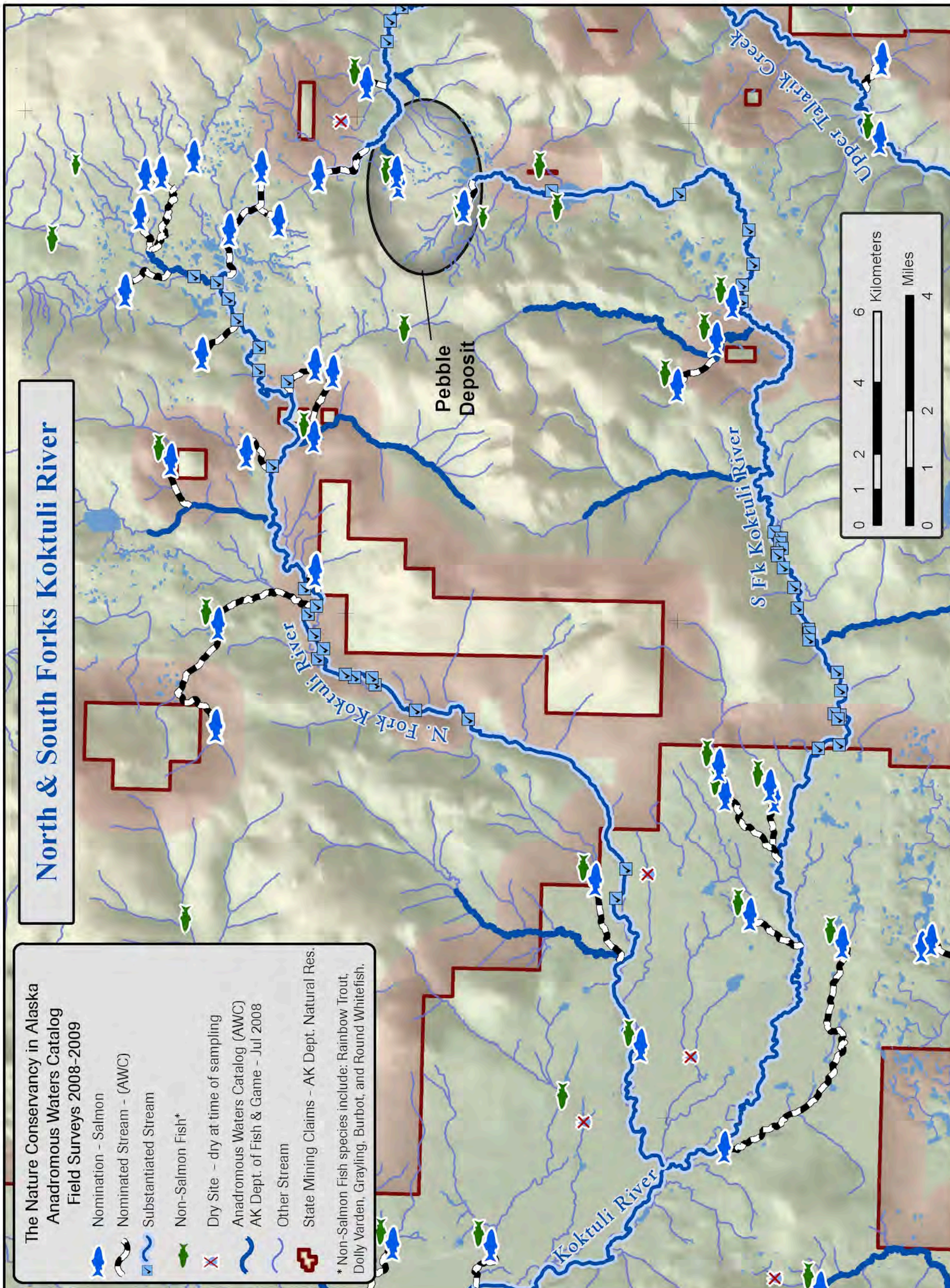
Appendix I. Fish survey results for the Nushagak and Kvichak river watersheds, Bristol Bay, Alaska, 2008 - 2010.



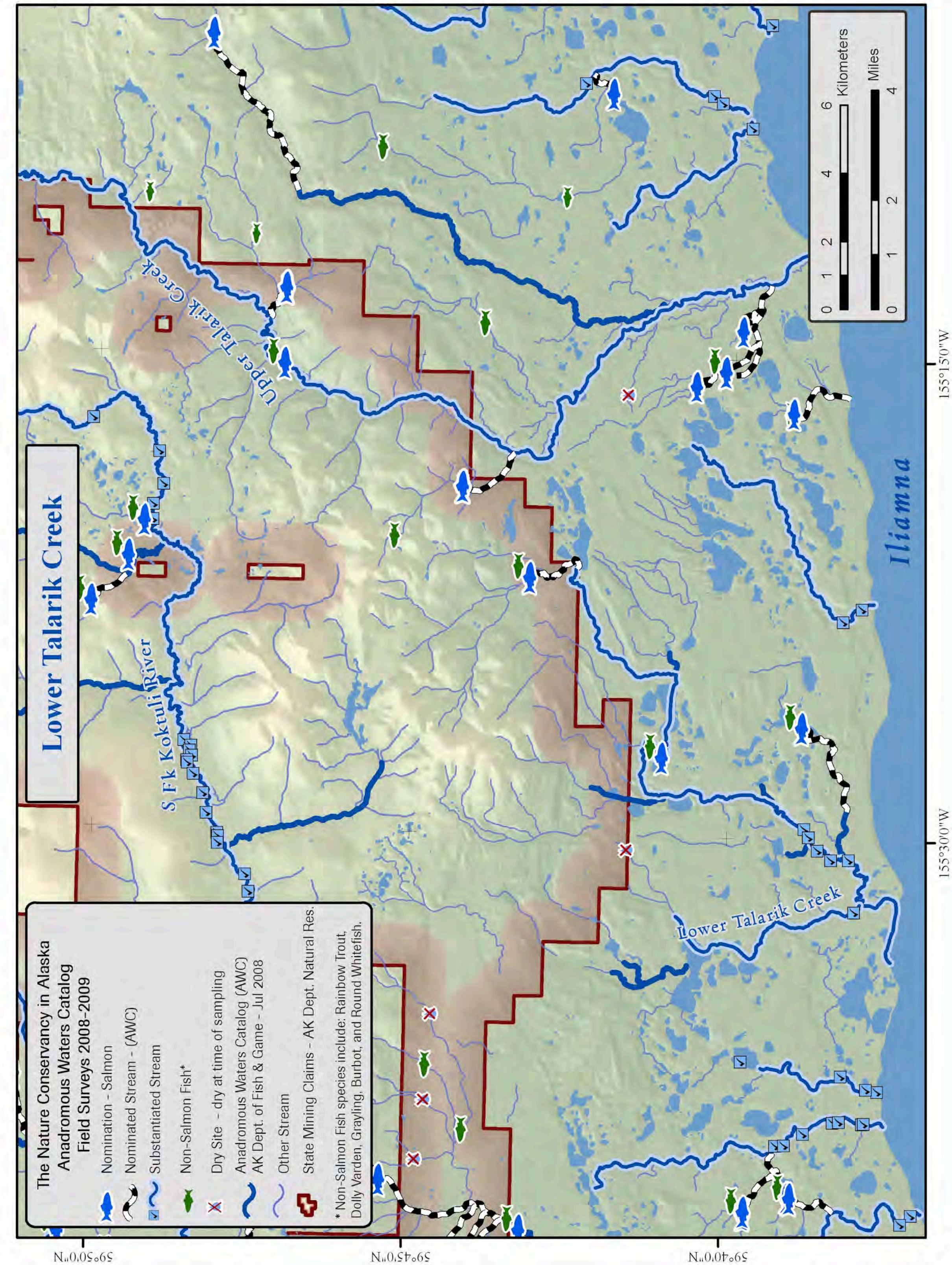
Appendix II. Fish survey results for Kaskanak Creek, Stuyahok River and unnamed tributaries to the South Fork Koktuli River and Iliamna Lake, Bristol Bay Alaska, 2008 - 2010. Adult salmon presence, indicated as substantiated streams (check marks) was verified during spawning season by helicopter surveys.



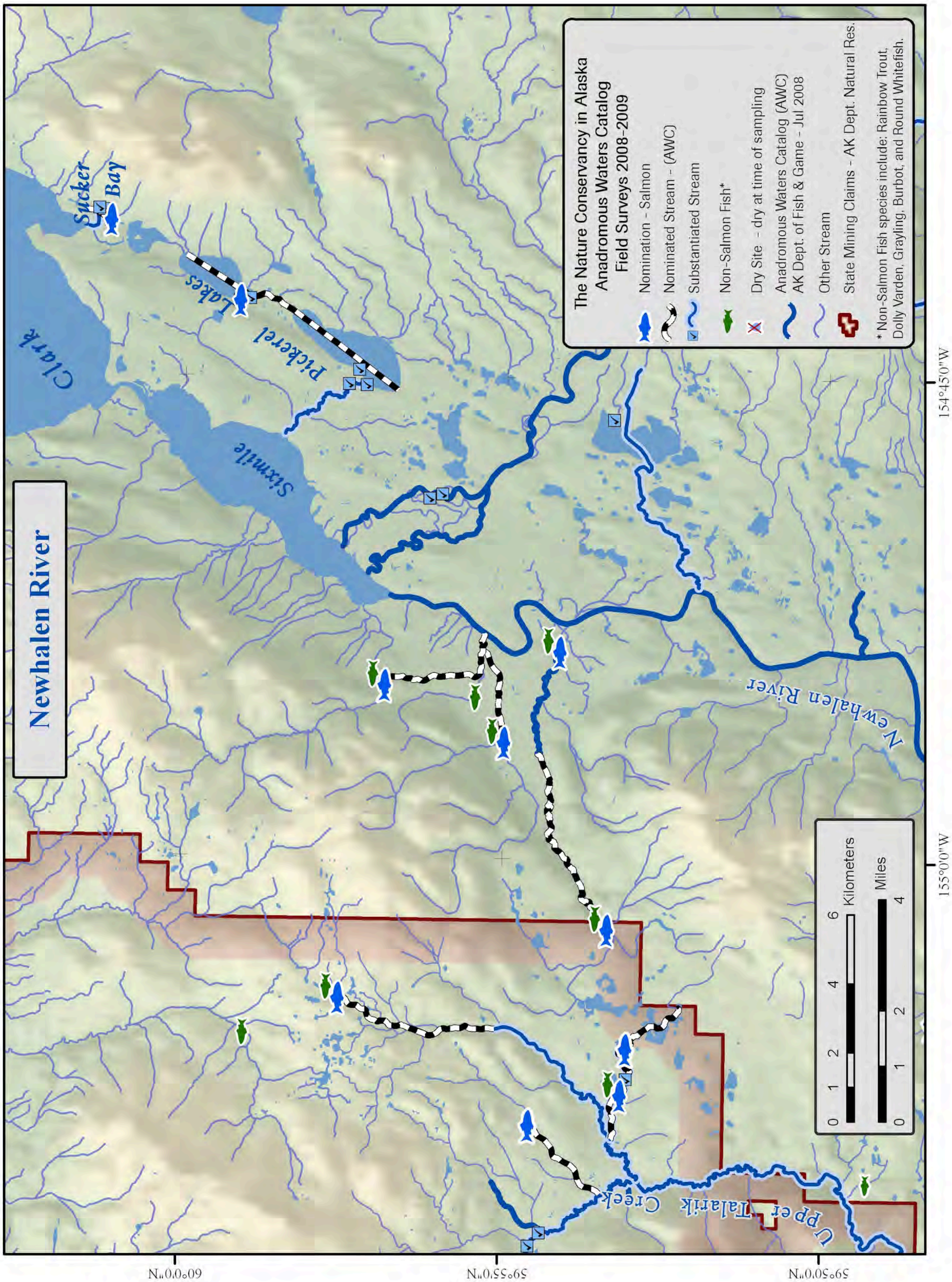
Appendix III. Fish survey results for the North and South Fork Koktuli Rivers, Nushagak River drainage, Bristol Bay, Alaska, 2008 - 2010. Note salmon presence on top of Pebble deposit. Adult salmon presence, indicated as substantiated streams (check marks) was verified during spawning season by helicopter surveys.



Appendix IV. Fish survey results for Lower Talarik Creek, a portion of Upper Talarik Creek, and unnamed tributaries to Iliamna Lake, Bristol Bay Alaska, 2008 - 2010. Adult salmon presence, indicated as substantiated streams (check marks) was verified during spawning season by helicopter surveys.



Appendix V. Fish survey results for Newhalen River drainage, Bristol Bay, Alaska, 2008 and 2009. Adult salmon presence, indicated as substantiated streams (check marks) was verified during spawning season by helicopter surveys.



Appendix VI. Fish survey results for the Chulitna River drainage, Bristol Bay Alaska, 2008 and 2009. Adult salmon presence, indicated as substantiated streams (check marks) was verified during spawning season by helicopter surveys.