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Riverscape Analysis of Nushagak & Kvichak Watersheds

A Collaboration of The Nature Conservancy and the Bristol Bay Heritage Land Trust

Final Report

Grantee: The Nature Conservancy
Grant start date: February 1, 2013 Grant end date: December 31, 2013

We are pleased to report the successful completion of Grant # AKFO – 020113 – LH, a sub-grant agreement between the Bristol Bay Heritage Land Trust and the Alaska Chapter of The Nature Conservancy. This funding for the grant was provided to the Bristol Bay Heritage Land Trust by the Bristol Bay Regional Seafood Development Association. The general goal of the project is to more clearly identify essential salmon habitat in the headwaters of the Nushagak and Kvichak watersheds in support of local and regional planning. This document serves to fulfill the reporting requirements listed under the initial contract and includes a financial summary (Attachment A) and description final objectives and deliverables (Attachment B). We have also included our summary report "A coarse-scale riverscape analysis of the Nushagak and Kvichak watersheds" (Attachment C), and a copy of TNC's comments for the public record on the Draft Bristol Bay Area Plan (Attachment D) which was made possible by this foundational effort to improve salmon habitat mapping in the region. Please let us know if you have any questions or would like further discussion regarding this work.

Best Regards,

Randall H. Hagenstein
Alaska State Director

Attachment A: Financial Summary:

These figures are preliminary; exact numbers will be provided with final invoice.

Personnel			
	Senior Scientist	~ 0.25 months at $5,686/month	$1,422
	Spatial Ecologist	~ 3.3 months at $4,242/month	$14,158
	Fringe Benefits		$6,944
Total Personnel			$22,513
Travel			
	Travel and lodging to Anchorage for Senior Scientist and Spatial Ecologist to present at the Southwest Alaska Salmon Habitat Partnership Annual Science Workshop		$1,063
	Travel and lodging to San Jose, California for Spatial Ecologist to present at The Nature Conservancy All-Science Symposium		$1,000
Total Travel			$2,063
Indirect			$4,424
Total			$29,000

Attachment B: Objectives and Deliverables:

Objective 1: Compilation of GIS data to support ecological analyses and help develop habitat monitoring systems.

Deliverable: All GIS data collected and created and the associated metadata is described in attached draft report, "A Coarse-scale Riverscape Analysis of the Nushagak & Kvichak Watersheds". The geodatabase housing all final data layers is available upon request from Christine Woll (cwoll@tnc.org), and will soon be available online to the public. This new geodatabase is currently being used or under discussion for use for the following applications by the following partners:

1) Analysis of impacts of hydrologic change on fish habitat near the Pebble mine deposit (TNC).
2) Analyses of land use designations in Bristol Bay Area Plan by TNC, The Citizen's Alternative Bristol Bay Area Plan, and the Alaska Department of Natural Resources.
3) Site selection for Proposed Long Term Monitoring of Salmon Headwaters in the Lime Hills Ecogreion (UAA; CSP2).
4) Site selection and landscape modelling for a proposed stream temperature monitoring network for Bristol Bay (BBNA; Cook Inlet Keeper).
5) Habitat analysis associated with identifying natal origins of Chinook salmon in the Nushagak River using Stronium Isotopes (UAF).
6) Updating the National Hydrography Dataset (Western Alaska LCC; USGS).
7) Various applications for the Southwest Alaska Network Inventory and Monitoring Program (NPS).
8) Expanded habitat analysis of the Nushagak-Kvichak watersheds using high-resolution multispectral satellite imagery (Flathead Lake Biological Station, University of Montana).
9) Fish sampling site selection on the Mulchatna River (University of Washington).
10) Fish distribution modelling in Bristol Bay (University of Washington).

Objective 2: Ecological mapping of hydrologic conditions relevant to salmon.

Deliverable: The draft report, "A Coarse-scale Riverscape Analysis of the Nushagak & Kvichak Watershesheds" detailing all data, methods, and maps, is attached. The results of this project were also presented for the Southwest Alaska Salmon Habitat Partnership Science Symposium in Anchorage, Alaska on December 5, 2013 (powerpoint available at http://www.southwestsalmon.org/) and at The Nature Conservancy All-science Symposium in San Jose, California on December 11, 2013.

Objective 3: Application of these data to evaluate alternatives for protection of salmon habitat in the Bristol Bay Area Plan.

Deliverable: Preliminary datasets were used to provide analysis associated with *The Citizen's Alternative Bristol Bay Area Plan* (http://www.bristolbaylandtrust.org/citizens-bristol-bay-area-plan/)

as well as public comment from TNC to Alaska Department of Natural Resources on the 2012 Bristol Bay Area Plan revision (attached).

January 2014

A Coarse-scale Riverscape Analysis of the Nushagak & Kvichak Watersheds

A Preliminary Draft

The Nature Conservancy

Alaska Field Office

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Juneau, Alaska 99801

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Executive Summary

The purpose of this project was to use novel approaches to improve mapping of salmon habitat across the Nushagak and Kvichak watersheds. We began by compiling the best available geospatial data on physical and biological characteristics of freshwater habitats within these watersheds. In addition, we reviewed the best available scientific literature on habitat characteristics that support salmon species freshwater life history needs. Once these data sources were compiled, we developed methods and models to use remote-sensing and GIS coupled with available field data to map salmon habitat characteristics across the watersheds. These methods proved robust in predicting a suite of habitat characteristics important for describing salmon habitat suitability. Using these mapped habitat characteristics, we offer exploratory hypothesis regarding habitat suitability distribution throughout the landscape, based on salmon-habitat relationships from the published literature. These habitat suitability maps only corresponded well to expert knowledge of salmon distribution for some species and life stages; the next step is to test and refine these hypotheses using site-specific fisheries data in the future. The database resulting from this compilation and analytical effort is available to support a range of research, conservation planning, resource management and educational needs to better understand and protect salmon in this critical region.

Background

Bristol Bay in Southwest Alaska provides more than half of the world's sockeye salmon, and supports substantial commercial, sport, and subsistence fisheries in the region (Ruggerone et al. 2010). The five species of Pacific Salmon (*Oncorhynchus* spp.) that spawn and rear in the freshwater rivers and lakes of Bristol Bay are keystone species, supporting the entire ecosystem of the Bay, as well as providing tremendous cultural and historical value to local residents. The headwaters of two large watersheds in the region, the Nushagak and Kvichak Rivers (Figure 1), are largely unprotected and face potential mining activities and other land uses in the near future.

The sockeye populations of the Nushagak and Kvichak and the Chinook populations of the Nushagak are actively counted and managed by the Alaska Department of Fish and Game every year (Dye & Schwanke 2012; Sands 2012). However, beyond how many fish escape into the freshwater watersheds every year, little is known about the spawning and rearing distribution of all five species within these watersheds. Field surveys for anadromous fishes are cataloged in Alaska's Anadromous Waters Catalog (AWC; ADFG 2013c), but due to the remoteness of these watersheds, these surveys are often opportunistic and do not represent the true breadth of anadromous fish distribution; furthermore, they only represent presence of anadromous fish, and do not illustrate which portions of the watershed are most productive. In order to effectively make land-use decisions that account for effects on the entire fish populations of the Nushagak and Kvichak and their associated fisheries, better understanding of the relative contribution of certain areas to overall productivity is necessary.

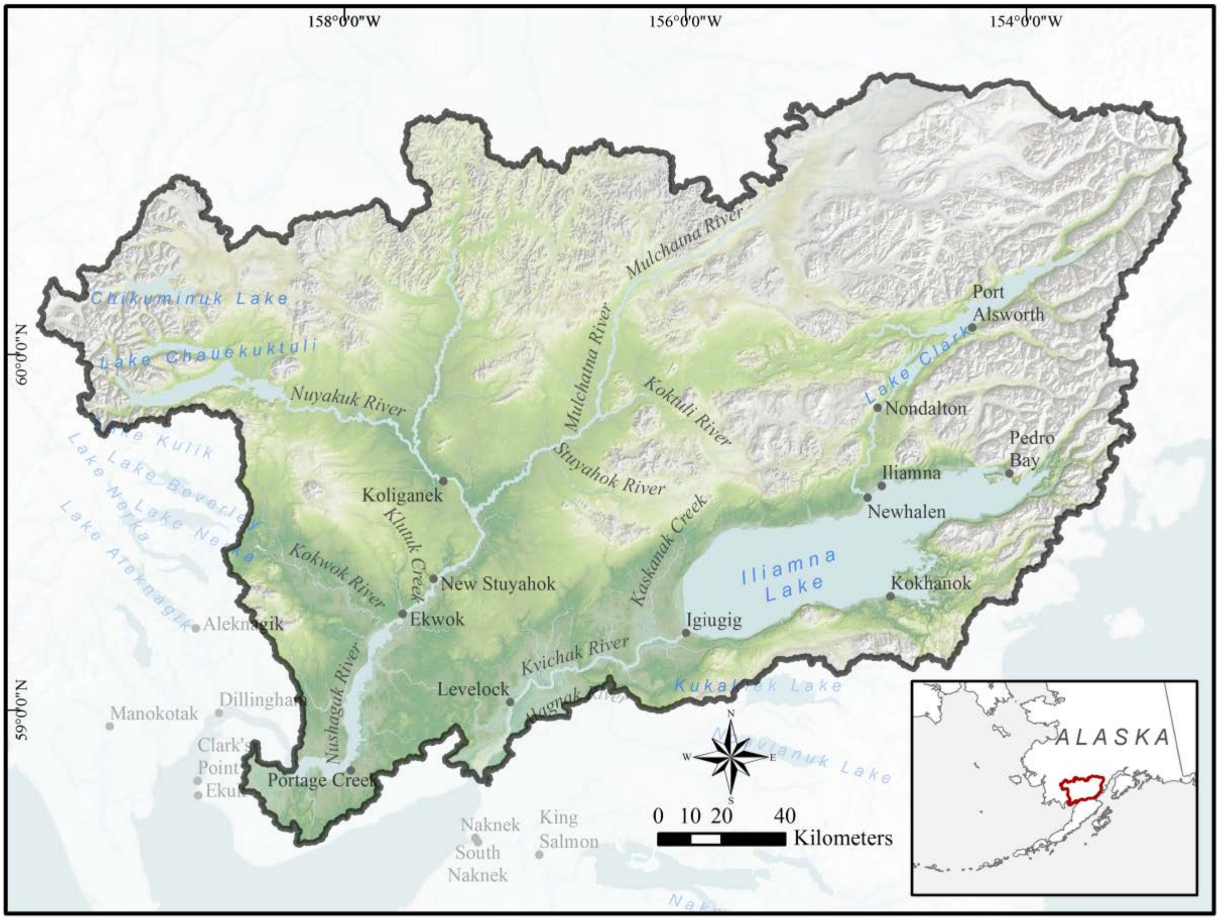

Figure 1. The project study area encompasses the Nushagak and Kvichak watersheds. The Wood River and Alagnak River systems are excluded from the study area.

Unfortunately, monitoring in-stream fish populations at the reach or sub-basin scale for watersheds of this size and remoteness is impossible. However, mapping of fish habitat quality has been used for many years as a proxy for understanding relative productivity (e.g., Hankin & Reeves 1988). For juvenile salmon, reach scale habitat characteristics such as slope, large woody debris, riparian cover, substrate composition, habitat complexity, channel size and geomorphology, water velocity, water depth, and water temperature have all been suggested as appropriate variables to describe habitat quality (e.g., McMahon 1983; Hillman et al. 1987; Bisson et al. 1988; Taylor 1988; McMahon & Hartman 1989; Bjornn & Reiser 1991; Groot & Margolis 1991; Quinn & Peterson 1996; Sharma & Hilborn 2001; Beecher et al. 2002; Ebersole et al. 2003; Quinn 2005; Burnett et al. 2007; Ebersole et al. 2009; Wissmar et al. 2010).

However, collecting habitat data in a spatially continuous manner across large watersheds is also prohibitive (Fausch et al 2002). Researchers interested in large-scale riverine habitat mapping have begun to recognize the value of remote-sensing applications in solving these problems. Using Digital Elevation Models (DEMs), satellite imagery, and aerial imagery, studies have looked at the abilities of remote sensing sources to predict both landscape scale (Lunetta et al. 1997; Thompson & Lee 2000; Sharma & Hilborn 2001; Burnett et al. 2003; Bartz et al. 2006; Burnett et al. 2007; Ebersole et al. 2009; Jorgensen et al. 2009; Luck et al. 2010; Shallin Busch et al. 2011; Whited et al. 2011; Whited et al. 2012) and reach-level (Winterbottom & Gilvear 1997; Torgersen et al. 1999; Wright et al. 2000; Marcus 2002; Marcus et al. 2003; Smikrud & Prakash 2006; Marcus & Fonstad 2008; Smikrud et al. 2008; Woll et al. 2011; Wirth et al. 2012) habitat characteristics, and map them in a spatially continuous way.

In order to help inform land-use decisions to better account for salmon habitat and populations in the Nushagak and Kvichak, this project sought to use remote-sensing approaches to improve mapping of salmon habitat in these critical watersheds. We hope that these datasets can serve as a tool to support a range of applications including research, conservation and resource planning in this landscape. We view this as a modest contribution to improve available information with current technology. Ultimately higher resolutions DEMs, such as those developed under the Alaska Statewide Digital Mapping Initiative (SDMI), will provide the basis for next-generation habitat mapping in southwest Alaska.

Objectives

The objectives of this project were to:

- Assemble best available spatial data on the physical landscape, climate, and fish and fish habitat surveys within the Nushagak and Kvichak watersheds.
- Develop methodologies to use remote-sensing and GIS to map salmon habitat across the watersheds.
- Propose reach-level classification of physical salmon habitat and likely salmon habitat distribution across the watersheds.

Data Sources

Best-available comprehensive data sources on the physical and biological attributes of these watersheds were surveyed and compiled in a geodatabase. These included:

(1) **Biophysical template:** In order to best characterize the physical landscape, DEMs of the area were examined. Available sources include the National Elevation Dataset (NED), as well as the satellite-derived ASTER and SRTM DEMs. Other physical landscape features include geology mapping and climate mapping. In addition, remotely-sensed information on vegetation and hydrology were included.

(2) **Fish and fish habitat field data:** Ground-based sampling within the Nushagak and Kvichak included the Anadromous Waters Catalog (ADFG 2013), the Alaska Freshwater Fish Inventory (AFFI, ADFG 2013), fish and fish habitat data associated with the Pebble Partnership's Environmental Baseline Document (EBD; Pebble Limited Partnership 2012), as well as other adult salmon surveys in the watersheds. In addition, expert knowledge and literature review helped define fish and fish habitat relationships in the region.

Table 1. A summary of data sets and sources that reflect best-available data related to fish and fish habitat in the Nushagak and Kvichak watersheds

System	Data Type	Data Source
Biophysical template		
	Elevation	National Elevation Dataset
	Elevation	ASTER DEM
	Elevation	SRTM DEM
	Historic Precipitation	Scenarios for Arctic Planning (SNAP)
	Historic Air Temperature	Scenarios for Arctic Planning (SNAP)
	Multipsectral satellite imagery	SPOT imagery (2.5m)
	Multispectral satellite imagery	RapidEye Imagery (5m)
	Stream network	National Hydrography Dataset (USGS)
	Soil types	NRCS
	Vegetation	LANDFIRE
	Glaciers	USGS
Fish and Fish Habitat Field Data		
	Anadromous Waters Catalog	Alaska Department of Fish and Game (ADFG 2013c)
	Primary substrate	Alaska Freshwater Fish Inventory (AFFI; ADFG 2013b)
	Channel width	AFFI (ADFG 2013b)
	Channel depth	AFFI (ADFG 2013b)
	Freshwater Fish Presence	AFFI (ADFG 2013b)
	Fish Migration Barriers	AFFI (ADFG 2013a)
	Fish Migration Barriers	Alaska Fish Passage database (ADFG 2013a)
	Spawning surveys	Pebble EBD (PLP 2012); digititzed by TNC
	Juvenile fish counts	Pebble EBD(PLP 2012)
	Aquatic habitat surveys	Pebble EBD (PLP 2012); digitized by TNC
	Sockeye aerial surveys	ADFG (Salomone et al. 2009); digitized by TNC
	Chinook aerial surveys	ADFG (Dye & Schwanke 2012); digitized by TNC
	Chinook and Sockeye Telemetry data	Link et al 2007

Estimates of Freshwater Habitat Characteristics

Using these datasets, we evaluated which habitat characteristics that are known to be important to salmon could be mapped and modelled across the study area. All attributes successfully mapped and modelled are described below.

Stream network

The current best available stream network layer is from the National Hydrography Dataset (NHD). This dataset was derived from historic aerial photographs current in the 1950's and often lacks positional accuracy; furthermore, many smaller streams are not included. Nonetheless, this is the best available dataset for the entire region and provided the initial basis for the mapping described in this report. In order to improve these data and allow estimation of DEM-derived attributes such as contributing watershed area and stream gradient, we used the surface hydrology tools of ArcMap

10.1 (ESRI, Redlands CA) (Figure 2). As inputs, we used the existing NHD along with a mosaic of best-available DEMs derived from the Shuttle Radar Topography Mission (SRTM) and National Elevation Database (NED). According to this approach, elevation values were decreased along mapped segments of the NHD so that surface-derived flow direction would be relatively consistent with the NHD. Sinks were filled in the DEM so continuous flow paths could be maintained, and then flow direction was determined for each cell. A flow-accumulation threshold value of 0.25 km^2 was used to determine the point of initiation for headwater streams.

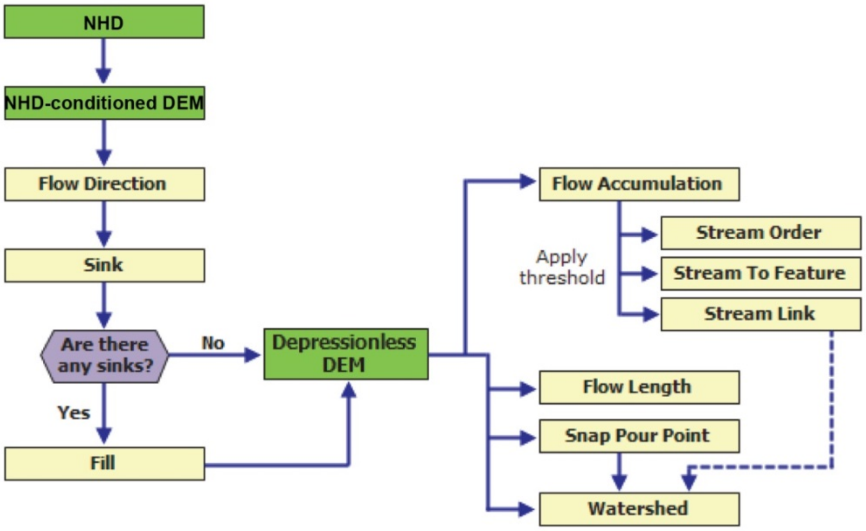

Figure 2. Process to merge the National Hydrography Database and the best available DEMs to produce a surface flow network that is relatively consistent with locational accuracy of NHD, but also includes DEM-derived attributes such as stream gradient and contributing watershed area for all stream features.

In addition, methods developed by the Flathead Lake Biological Station at the University of Montana (Luck et al. 2010) were adapted to classify bankfull channels using NDVI values and to delineate mid-channel lines on many large channels within the Lower Nushagak and Mulchatna drainages using the RapidEye and SPOT multispectral satellite imagery. These lines were also incorporated into the stream network as they captured the sinuosity and braiding associated with these mainstems.

This final stream layer was converted to a geometric network that assigned all lines a flow direction for further network-based analysis. The union of all of these datasets into a final stream network produced a superior network than any of the datasets individually (Figure 3).

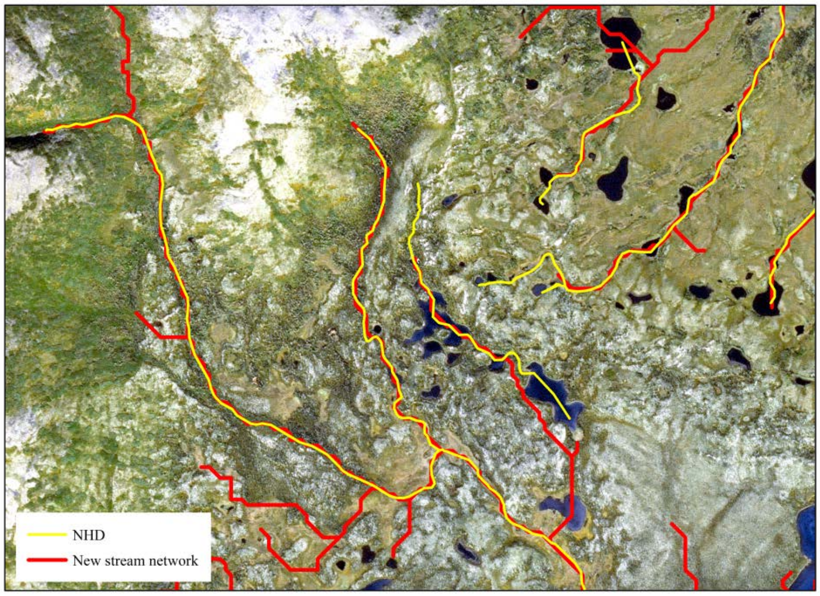

Figure 3. The NHD (in yellow) often contains unconnected lines, lacks positional accuracy, and omits smaller streams. The newly derived stream network generated by this project (in red) is an improvement in all three areas, and now represents the best available synthesis of existing hydrography and elevation datasets

Stream Order

Stream order is an indicator of stream size, and various species of salmon and life stages have stream size preferences. Stream order is frequently mapped and measured in order to better understand salmon habitat suitability.

Strahler stream order (Strahler 1964) was calculated for each stream reach in ArcMap 10.1 (Environmental Systems Research Institution, Inc. [ESRI], Redlands, California).

Elevation

Elevation is also often used to better understand salmon distribution (Jorgensen et al. 2009; Luck et al. 2010). Average elevation was calculated for each stream reach using the final conditioned DEM in ArcMap 10.1.

Slope

Reach slope often determines many habitat characteristics included substrate, water velocity, and mesohabitat distribution. Stream order is frequently mapped and measured in order to better understand salmon habitat suitability (e.g., Bradford et al. 1997; Lunetta et al. 1997; Sharma & Hilborn 2001; Burnett et al. 2003; Davies et al. 2007; Dietrich & Ligon 2008; Jorgensen et al. 2009; Shallin Busch et al. 2011).

Average slope was calculated for each stream reach using the final conditioned DEM in ArcMap 10.1 (Figure 4).

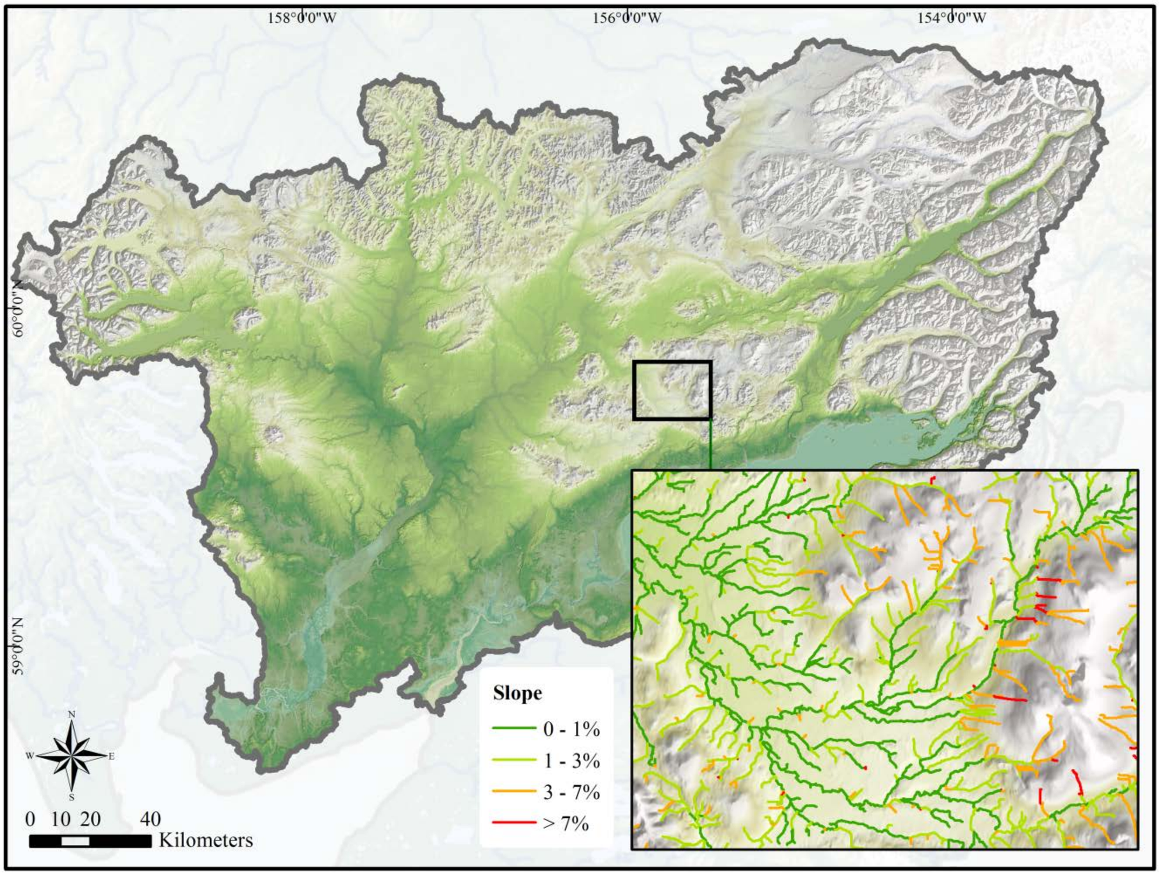

Figure 4. The reconditioned DEM allows for calculations of such physical stream attributes such as elevation, gradient and contributing watershed area.

Glacial influence

Glacial streams often have highly turbid water that can influence salmon distribution (Lloyd et al. 1987; Murphy et al. 1989; Reeves 2011), and thus it is important to take into account glacial influence on each stream reach. In order to characterize glacial influence, all streams upstream of areas known to have glacially turbid water were characterized as being glacially influenced.

Distance upstream

Some species of salmonids, such as pink salmon, tend to only spawn in lower portions of watersheds (Groot & Margolis 1991). Network analyst (ArcMap 10.1) was used to determine the distance upstream from the outlet of the Nushagak or Kvichak Rivers for each stream reach.

Lake influence

Because sockeye salmon tend to spawn and rear in or near lakes, it is important to determine whether streams are joined to large lakes. Each stream reach was attributed based on the size of the lake it overlapped or was upstream of, according to the NHD Waterbodies dataset.

Barriers

Natural and man-made migration barriers exist in all salmon ecosystems, and identifying them is important to understanding fish distribution. Although no natural or man-made barriers have been recorded in the Alaska Fish Passage database (ADFG 2013), several entries in the AFFI (ADFG 2013b) note barriers that were used in this analysis. In addition, network analyst (ArcMap 10.1) was used to identify all reaches above reaches with slopes > 12%, and these reaches were assumed to be unavailable to salmon migration.

Flow accumulation

Flow accumulation is a relative measure of channel size, and is often mapped and measured in order to better understand salmon habitat suitability (Sharma & Hilborn 2001; Ebersole et al. 2009; Luck et al. 2010)

For each cell, the flow receiving area, based on the direction of flow, was determined in ArcMap 10.1. The maximum flow accumulation for each reach was then summarized.

Mean annual precipitation

Precipitation is a primary determinate of flow and channel size, and has been used as an indicator of fish habitat in previous studies (Thompson & Lee 2000; Jorgensen et al. 2009). Mean annual precipitation was calculated as the mean annual precipitation of a reach between 1971 and 2000 Scenarios Network for Alaska and Arctic Planning data (Figure 5; SNAP 2012).

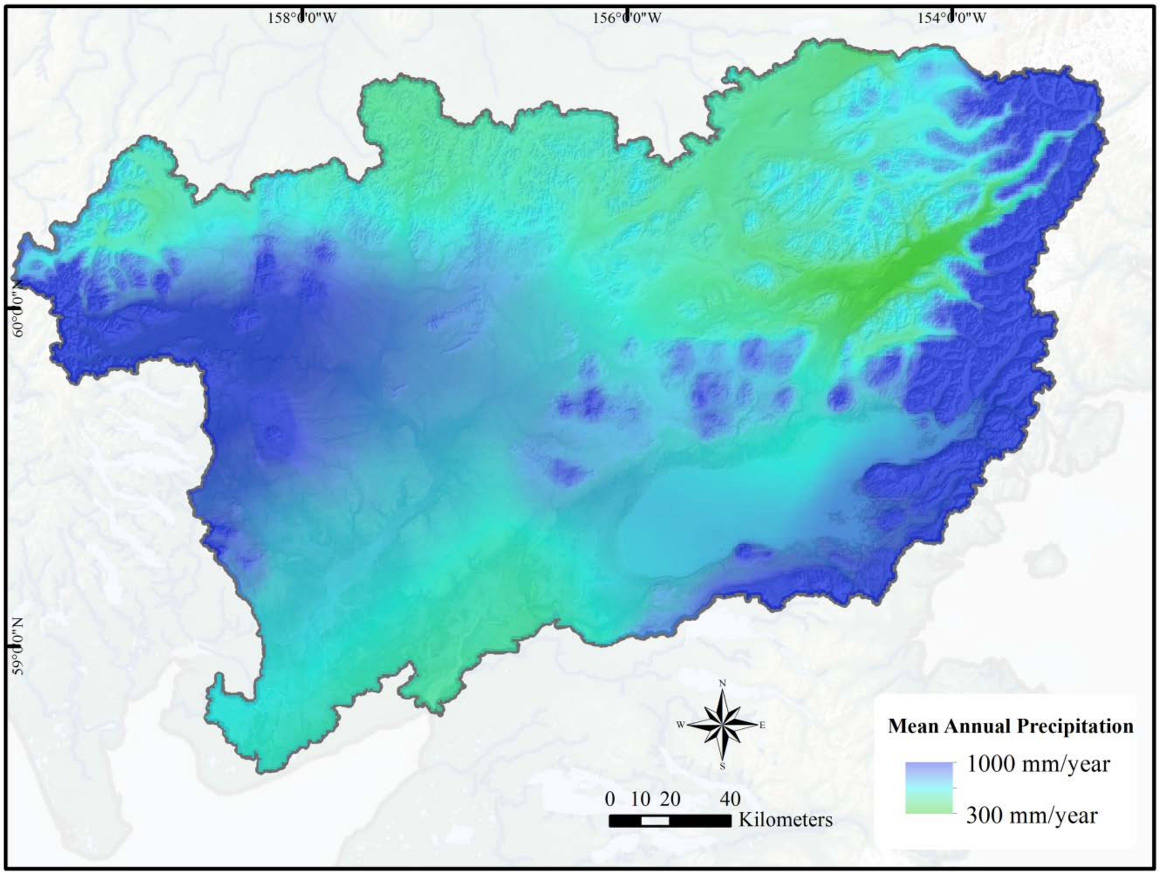

Figure 5. Mean annual precipitation across the study area from 1971-2000.

Mean annual flow

Mean annual flow is a primary determinate of channel size, and has been used as an indicator of fish habitat in previous studies (Bradford et al. 1997; Burnett et al. 2003; Bartz et al. 2006). Mean annual flow was calculated from a regression equation developed by Parks and Madison (1985) for southwestern Alaska:

$$Q = 9.55*(FA)*(P)$$

Where Q is mean annual flow in cubic feet per second, FA is flow accumulation in square miles, and P is mean annual precipitation in inches per year.

Estimated channel width

Channel width is an indicator of stream size, and various species of salmon and life stages have stream size preferences. Channel widths are frequently mapped and measured in order to better understand salmon habitat suitability (Davies et al. 2007; Dietrich & Ligon 2008; Shallin Busch et al. 2011).

Empirical support (e.g., Leopold & Maddock 1953; Leopold & Leopold 1995) have suggested that channel width increases according to power law functions:

$$w = aQ^{b}$$

where w is width, Q is discharge, and a and b are coefficients. In order to parameterize this equation, channel width measurements taken in the field throughout the Nushagak and Kvichak watersheds, and recorded in the AFFI (ADFG 2013), were used to develop power relationships between width and mean annual flow, using the often-applied linear regression of log-transformed variables (Leopold et al. 1964). The following equation:

$$w = 0.0585\ Q^{\ 0.4625}$$

was found to significantly predict channel width in the study area ($p<0.05$; Figure 6).

Estimated channel depth

Understanding channel depth helps understand certain geomorphologic conditions important for mapping salmon habitat (see below); in addition, both spawning and rearing salmon exhibit water depth preferences (McMahon 1983; Bisson et al. 1988; Bjornn & Reiser 1991). Thus, it is important to map and model channel depth (Dietrich & Ligon 2008).

Like channel width, it has been shown (Leopold & Maddock 1953; Leopold & Leopold 1995) that channel depth also increases according to power law functions:

$$h = cQ^{d}$$

where h is depth, Q is discharge, and c and d are coefficients. In order to parameterize this equation, channel depth measurements taken in the field throughout the Nushagak and Kvichak watersheds and recorded in the AFFI (ADFG 2013) were used to develop power relationships between channel depth and mean annual flow, using the often-applied linear regression of log-transformed variables (Leopold et al. 1964).. The following equation:

$$h = 0.0876\ Q^{\ 0.1937}$$

where h is channel width and Q is mean annual discharge was found to significantly predict channel width in the study area ($p<0.05$; Figure 6).

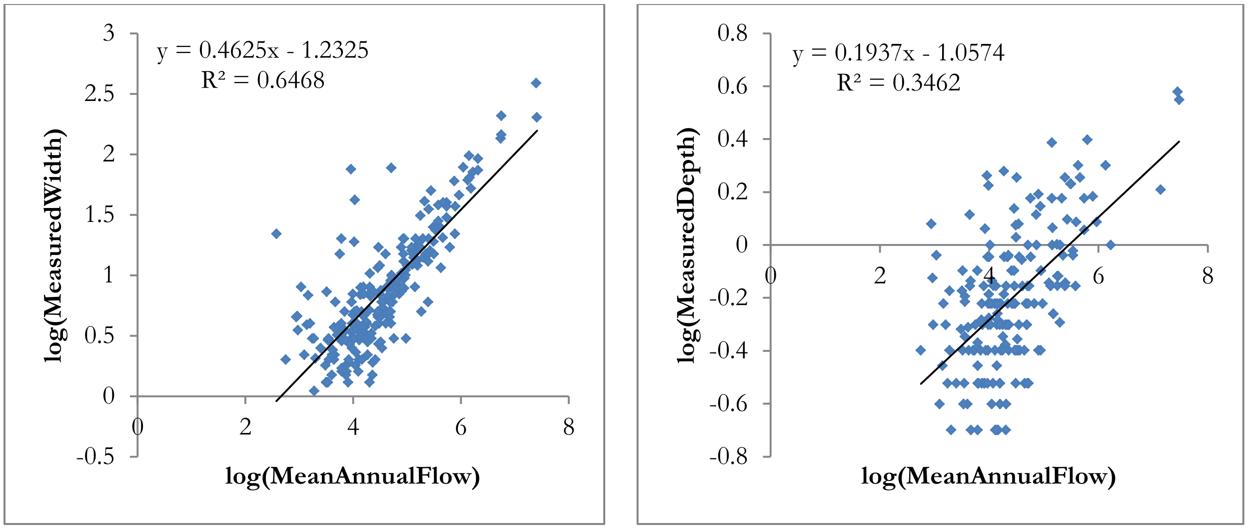

Figure 6. Relationships between annual flow and field-based width and depth measurements show that estimated annual flow can help predict these channel characteristics.

Estimated substrate size

Substrate size has an important effect on salmon egg survival as well as salmon spawning site selection (Quinn 2005). Thus, it is an important habitat variable to model and map, and has been done in several similar studies (Buffington et al. 2004; Dietrich & Ligon 2008).

Substrate size in rivers is controlled by both channel hydraulics and sediment supply. In theory, a river's bank full flow is the major channel hydraulic feature that will influence sediment transport and grain size (Buffington & Montgomery 1999). Thus, the median surface grain size (D$_{50}$) that can be transported by the bank-full flow can be predicted from the Shields (1936) equation

$$D_{50} = \frac{\tau}{(\rho_s - \rho)g\tau^*{}_c} = \frac{\rho h S}{(\rho_s - \rho)\tau^*{}_c}$$

where τ is the bank-full shear stress as dictated by depth (h) and slope (S), ρ_s is sediment density (2650 kg•m^{-3}•s^{-1}), ρ is water density (1000 kg•m^{-3}•s^{-1}), g is gravitational acceleration and t^*_c is the critical Sheild's stress for the movement of the median grain size (Buffington et al. 2004). This would allow one to predict median grain size based on bank-full depth, slope, and Shield's critical stress alone. Buffington et al (2004) note that one can approximate the true critical shield's stress by incorporating channel roughness, which will vary with channel type. Thus, they developed relationships to predict Shield's stress from channel type, slope, and depth, using field data for different channel types (plane-bed, pool-riffle, step-pool and cascades).

Although having pebble count data throughout the Nushagak and Kvichak watershed would have allowed for derivation of these relationships specific for the watershed, that type of field data was not available. Thus, Buffington et al (2004)'s formula was adopted for predicting substrate size throughout the watershed.

However, these equations do not account for sediment supply (Buffington et al 2004). After examining the results from the application of Buffington et al (2004)'s equations, it was clear that in areas without a supply of large substrate, substrate size was being over predicted. Thus, we modified the results so that all reaches that were not downstream of any reaches with slopes > 2% were assumed to have a substrate size of > 2mm (Figure 7).

Although pebble counts were not available on a large enough scale to develop site-specific relationships, there were a large number of recorded primary substrate information for sites across both watersheds, as recorded in the Alaska Freshwater Fish Inventory (ADFG 2013). In order to validate our predicted substrate results, we compared our predicted substrate size to our primary substrate classes and found that predicted substrate size differed significantly between primary substrate classes (P<0.5; Figure 7).

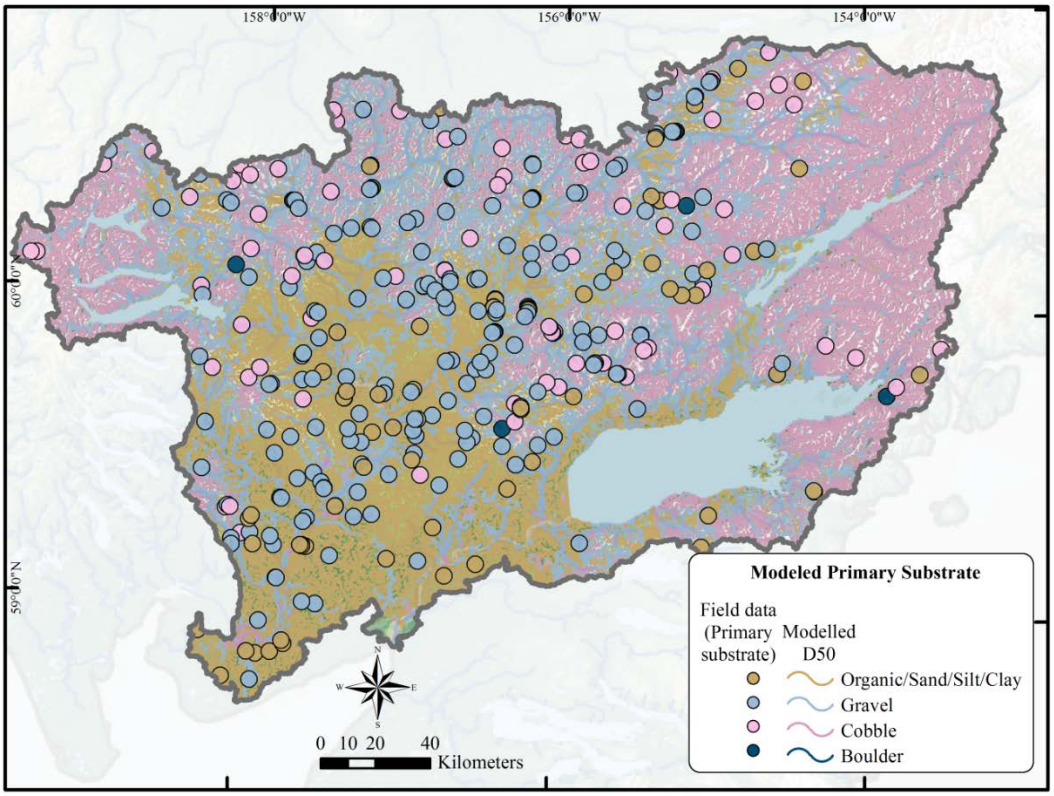

Figure 7. We estimated median substrate size (D50) using channel type, gradient and bank-full depth (Buffington et al. 2004) in comparison with observations of substrate size in the ADF&G Freshwater Fish Inventory Database.

Valley confinement

An important geomorphic feature of a river valley is its degree of confinement. Unconfined valleys and large floodplains tend to contain more complex channels with features desirable for both spawning and rearing salmon, including pools, off-channel habitats, areas of hyporheic exchanges, and spring brooks. Several studies have mapped or modelled valley bottoms or similar features in order to examine salmon habitat distribution (Bradford et al. 1997; Sharma & Hilborn 2001; Burnett et al. 2003; Dietrich & Ligon 2008; Shallin Busch et al. 2011; Whited et al. 2011). Ongoing research with the University of Montana Flathead Lake Biological Stations and multispectral satellite imagery of selected portions of the study area suggests that valley confinement and floodplain width is directly linked to various important channel types including off-channel habitats, spring brooks, and shallow shore areas, as well as observed salmon spawning areas (Figure 8).

In order to map valley floors and determine confinement, a version of the valley confinement algorithm (Nagel et al., unpublished data) adapted to use reach-scale bankfull-depth estimates was applied to the DEM. Once valley floors were mapped (Figure 7), the valley confinement ratio, defined as the bankfull width divided by the valley width, was used to characterize every reach as confined or unconfined (Figure 8).

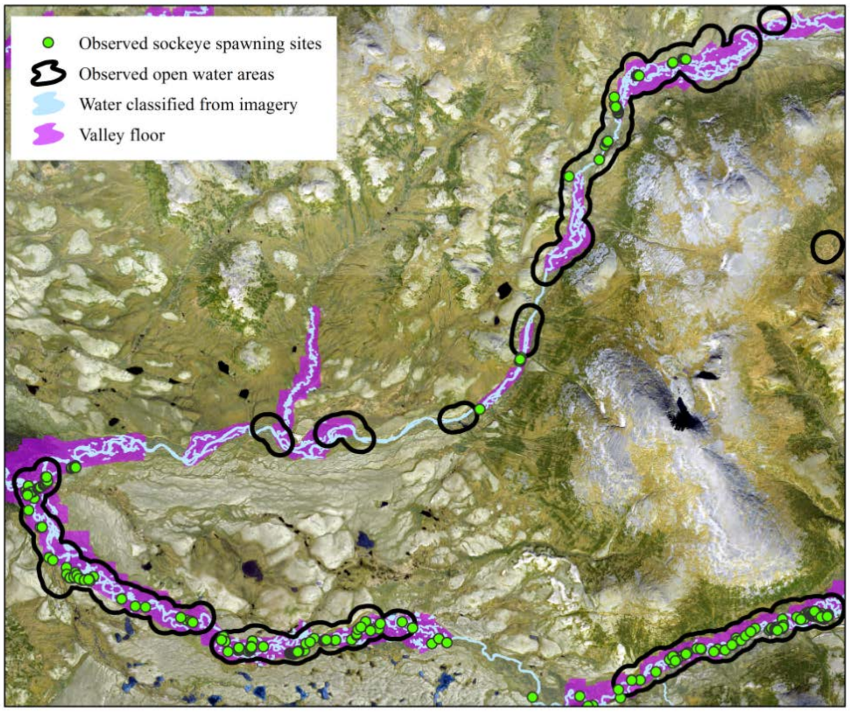

Figure 8. Floodplains mapped using the DEM seem to correlate with the complex water areas classified from the multispectral satellite imagery, as well as to open water areas and sockeye spawning sites observed on the Koktuli Rivers as part of the Pebble Partnership's Environmental Baseline Document . This indicates that valley confinement is a useful indicator of salmon habitat.

A Preliminary Index of Salmon Habitat Suitability

The above-described habitat characterization of all reaches lends itself to describing reach-specific suitability to all species of salmons during both their spawning and rearing lifestages. Based on a literature review, we developed simple qualitative models for each species and life stage to predict where the most productive habitats may be within the Nushagak and Kvichak. However, it should be noted that these models represent testable hypothesis and it is understood that quantitative models between fish and fish habitat using site-specific data would provide better modeling results, and is planned for the future. TNC and BBHLT are currently collaborating on a project that will result in site-specific data for improved modeling results.

Coho salmon rearing

Coho salmon prefer to rear in pool, off-channel, and beaver pond habitats particularly in smaller streams (McMahon 1983; Groot & Margolis 1991; Nickelson et al. 1992; Quinn & Peterson 1996; Pollock et al. 2004; Quinn 2005). In addition, they tend to avoid glacial systems in Bristol Bay (ADFG 2013). Thus, our model assumed that the best coho rearing habitat would be in small streams with gradients below 3% (which tend to be pool-riffle channels) that are in unconfined valleys likely to contain complex, off-channel habitats.

Table 2. Habitat quality assignments for coho salmon rearing habitat model.

4	**Highest quality**	Unconfined and stream order 1-4;
3		Confined and stream order 1-4; unconfined and stream order 5-9;
2		Confined and stream order 5-9
1		Gradient 3-7%; Upstream gradient never exceeds 2%
0	**Not Suitable**	Gradient >7%; Glacial; Reaches upstream of barriers

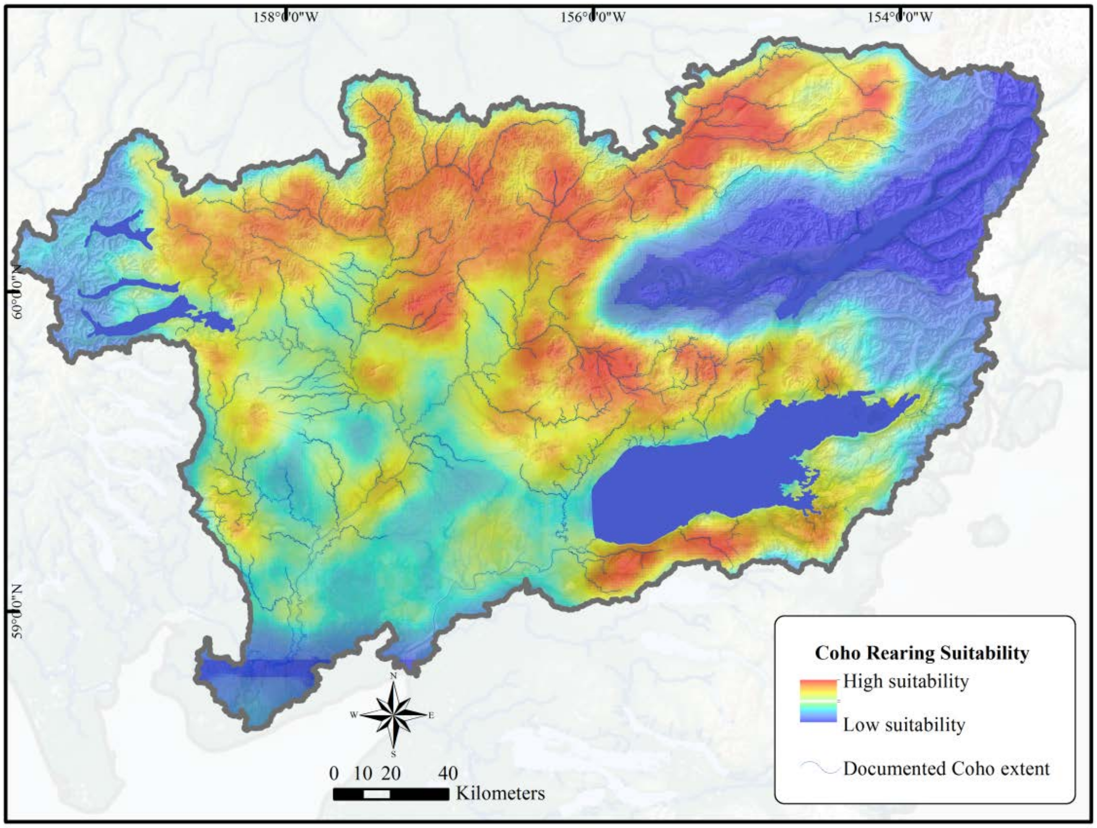

Figure 9. Habitat suitability index for coho salmon rearing habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented coho salmon extent.

Coho salmon spawning

Coho salmon have the widest range of spawning habitat preference, using channels of all sizes (Groot & Margolis 1991). We used the substrate criteria described for coho salmon in Kondolf and Wolman (1993), as well as the assumption that unconfined channels would provide more hyporheic activity, which coho salmon seek when looking for spawning sites (Groot & Margolis 1991; Quinn 2005; Mull & Wilzbach 2007). Again, coho salmon tend to avoid glacial systems in Bristol Bay (ADFG 2013).

Table 3. Habitat quality assignments for coho salmon spawning habitat model.

4	**Highest quality**	14mm < Substrate < 30 mm; Unconfined
3		14mm < Substrate < 30 mm; Confined
2		14mm > Substrate > 5 mm; 36mm > Substrate > 30 mm; Unconfined
1		14mm > Substrate > 5 mm; 36mm > Substrate > 30 mm; Confined
0	**Not Suitable**	5mm > Substrate > 36 mm; Glacial; Channel size < 2m; Reaches upstream of barriers

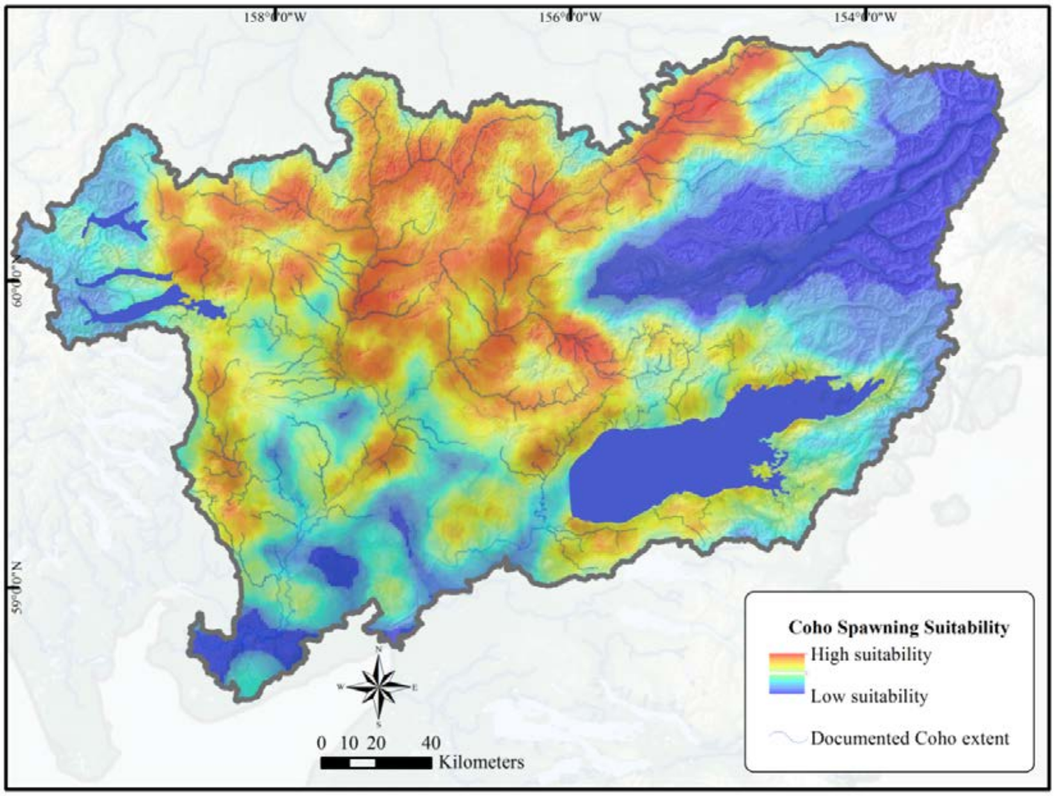

Figure 10. Habitat suitability index for coho salmon spawning habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius

The suitability map appears to correspond with the Anadromous Waters Catalog's documented coho salmon extent.

Chinook salmon rearing

Like coho salmon, Chinook prefer to rear in pool and off-channel habitats although they tend to prefer larger mainstem rivers (Hillman et al. 1987; Murphy et al. 1989; Groot & Margolis 1991). Thus, our model assumed that the best Chinook rearing habitat would be in large streams with gradients below 3% (which tend to be pool-riffle channels) that were in unconfined valleys likely to contain complex, off-channel habitats.

Table 4. Habitat quality assignments for Chinook salmon rearing habitat model.

4	**Highest quality**	Unconfined, stream order 5-9;
3		Confined and stream order 5-9; Unconfined and stream order 1-4;
2		Confined and stream order 1-4;
1		Gradient 3-7%; Upstream gradient never exceeds 2%
0	**Not Suitable**	Gradient >7%; Reaches upstream of barriers

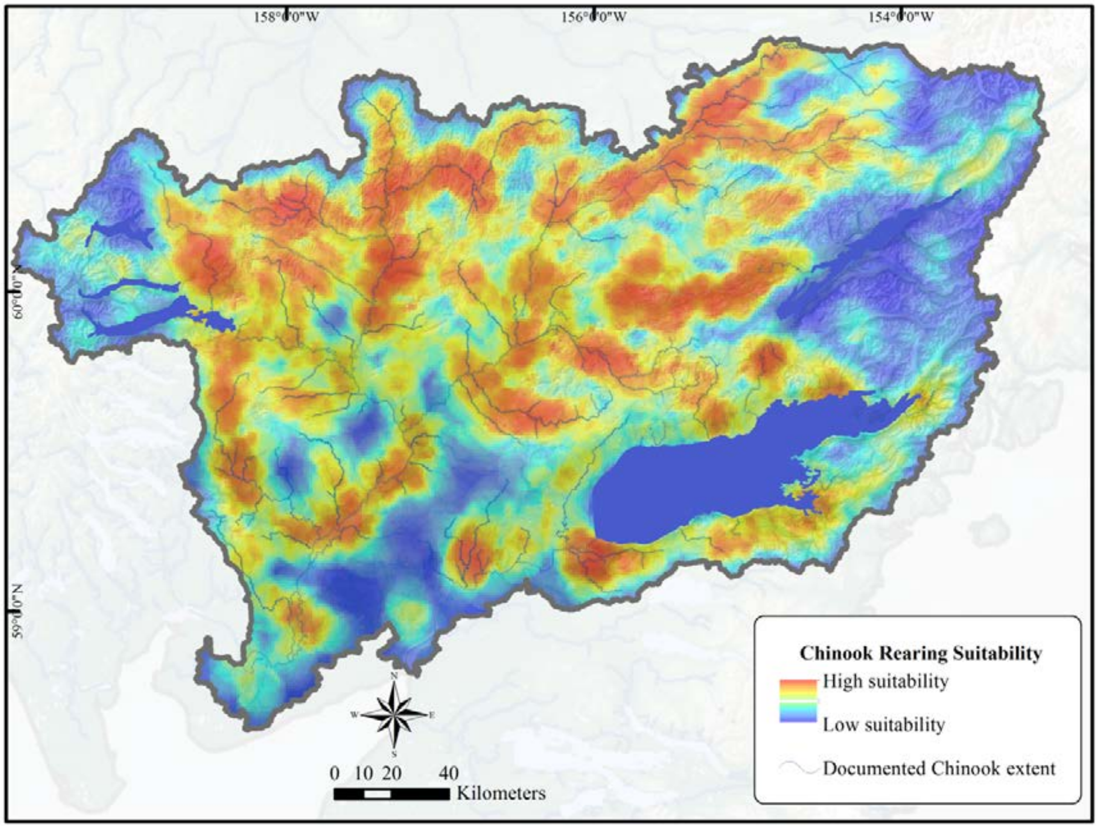

Figure 11. Habitat suitability index for Chinook salmon rearing habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented chinook salmon extent, with the exception of the Chulitna river drainage upstream of Lake Clark.

Chinook salmon spawning

Chinook salmon prefer to spawn in larger channels (Groot & Margolis 1991). We used the substrate criteria described for Chinook salmon in Kondolf and Wolman (1993), as well as the assumption that unconfined channels would provide more hyporheic activity, which Chinook salmon seek when looking for spawning sites (e.g., Geist & Dauble 1998; Geist et al. 2002; Isaak et al. 2007).

Table 5. Habitat quality assignments for Chinook salmon spawning habitat model.

4	**Highest quality**	23mm < Substrate < 47 mm; Unconfined
3		23mm < Substrate < 47 mm; Confined
2		23mm > Substrate > 11 mm; 80mm > Substrate > 47 mm; Unconfined
1		23mm > Substrate > 11 mm; 80mm > Substrate > 47 mm; Confined
0	**Not Suitable**	11mm > Substrate > 80 mm; Channel size < 4m; Reaches upstream of barriers

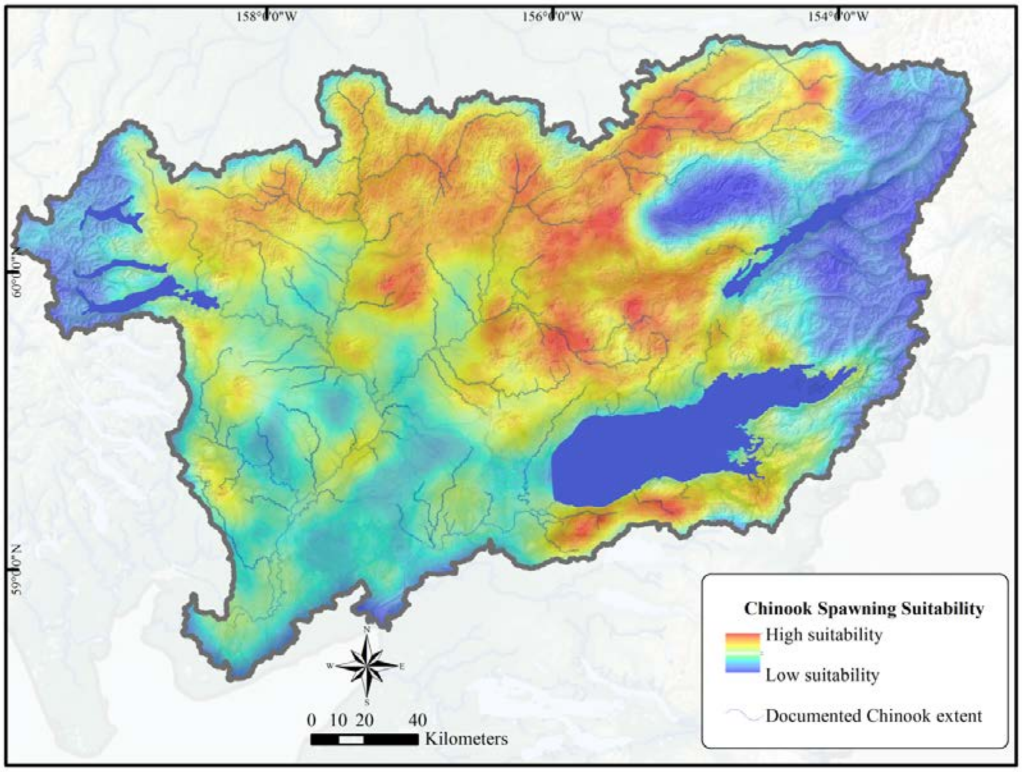

Figure 12. Habitat suitability index for Chinook salmon spawning habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented chinook salmon extent, with the exception of the Chulitna river drainage upstream of Lake Clark. Observations that chinook salmon often use the lower Mulchatna mainstems and upper Nushagak mainstems (Link et al. 2007; Dye and Schwanke 2012) indicates that substrate spawning suitability may be slightly different in the Nushagak watersheds than it is in the literature.

Sockeye salmon rearing

Sockeye salmon prefer to rear in large lakes (Groot & Margolis 1991; Quinn 2005). However, there are river-rearing sockeye in the Nushagak and Kvichak systems (PLP 2012). Very little is known about the habitat preferences of river-rearing sockeye, but one study by Murphy et al. (1989) and an unpublished dataset from Bristol Bay (J. Coleman, unpublished data) suggested that riverine sockeye prefer off-channel habitats.

Table 6. Habitat quality assignments for sockeye salmon rearing habitat model.

4	**Highest quality**	Lakes bigger than 2 km^2
3		
2		Unconfined streams
1		Confined streams; Upstream gradient never exceeds 2%
0	**Not Suitable**	0% > Gradient >7%; Reaches upstream of barriers

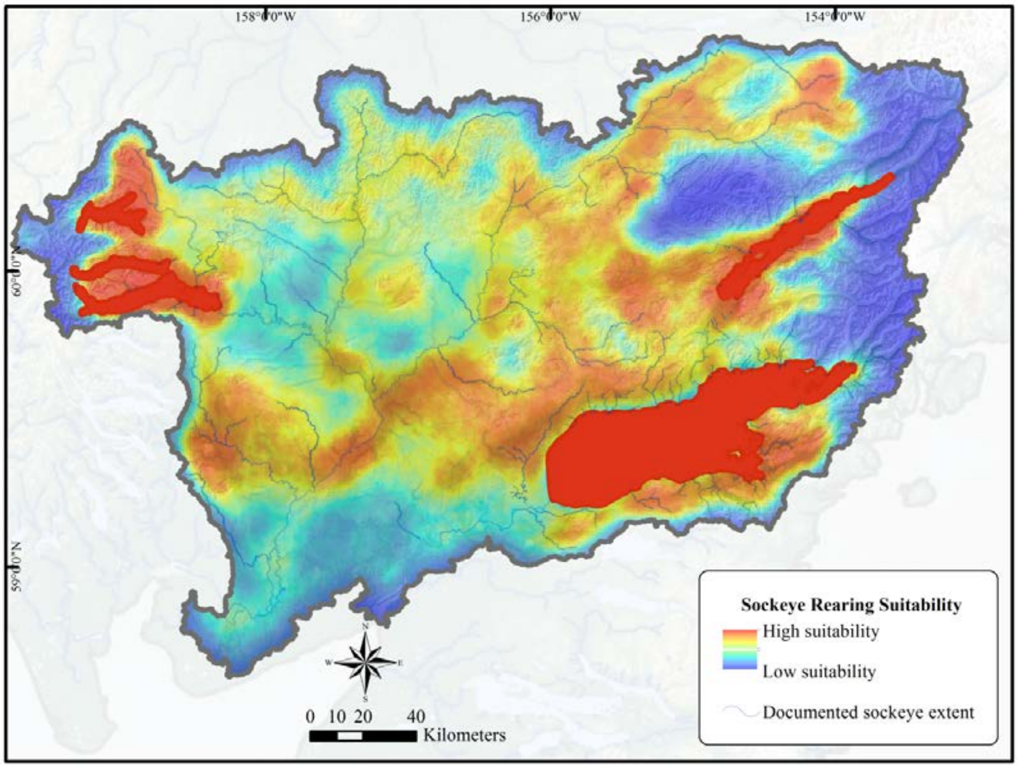

Figure 13. Habitat suitability index for sockeye salmon rearing habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented sockeye salmon extent, with the exception of the Chulitna river drainage upstream of Lake Clark, as well as Chikuminuk Lake and Upnuk Lake in the Tikchik lake system, which have not been documented as sockeye lakes.

Sockeye salmon spawning

Sockeye salmon prefer to spawn on lake beaches and in lake tributaries, usually in gravel substrates (Groot & Margolis 1991). In general, they tend to prefer unconfined channels would provide more hyporheic activity (e.g., Lorenz & Filer 1989; Hall & Wissmar 2004).

Table 7. Habitat quality assignments for sockeye salmon spawning habitat model.

4	**Highest quality**	Lakes; unconfined lake tributaries
3		Confined lake tributaries
2		
1		Streams that are not lake tributaries
0	**Not Suitable**	2mm > Substrate > 64mm; Reaches upstream of barriers; Channel size < 2m

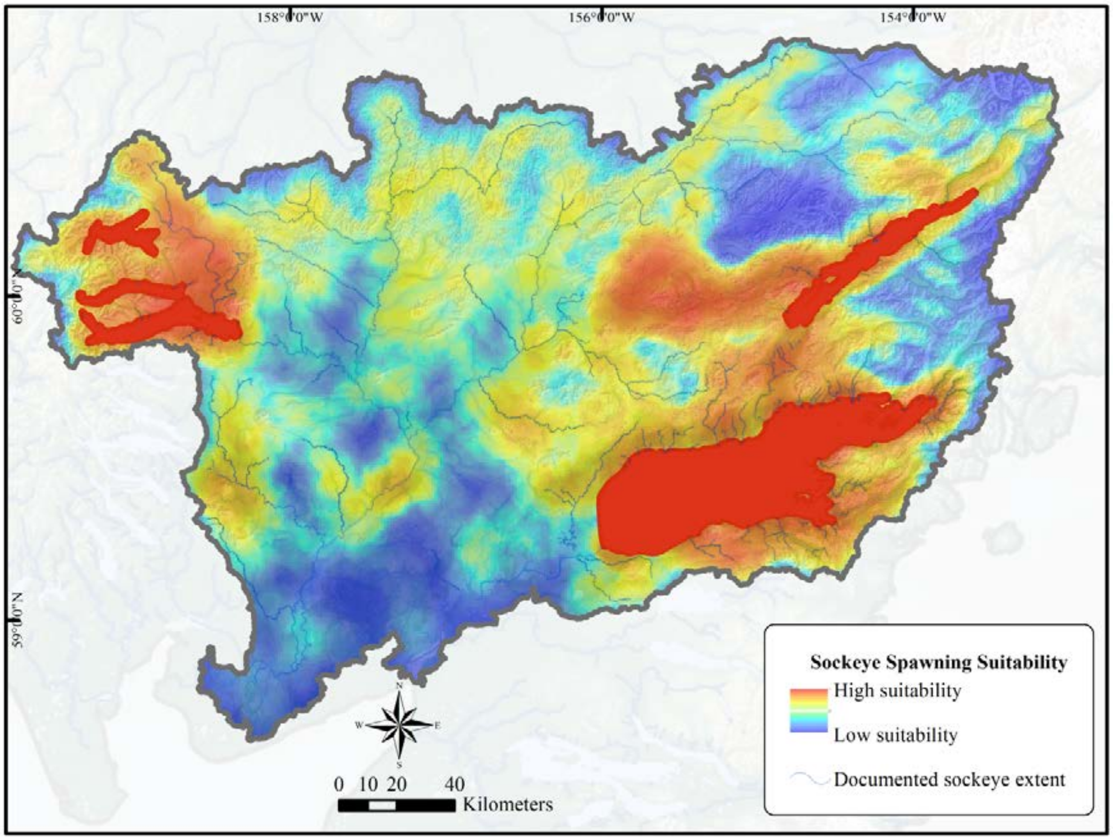

Figure 14. Habitat suitability index for sockeye salmon spawning habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented sockeye salmon extent, with the exception of the Chulitna river drainage upstream of Lake Clark, as well as Chikuminuk Lake and Upnuk Lake in the Tikchik lake system, which have not been documented as sockeye lakes.

Chum salmon spawning

We used the substrate criteria described for Chum salmon in Kondolf and Wolman (1993), as well as the assumption that unconfined channels would provide more hyporheic activity, which Chum salmon seek when looking for spawning sites (e.g., Geist et al. 2002; Wirth et al. 2012).

Table 8. Habitat quality assignments for Chum salmon spawning habitat model.

4	**Highest quality**	15mm < Substrate < 40 mm; Unconfined
3		15mm < Substrate < 40 mm; Confined
2		15mm > Substrate; 62mm > Substrate > 40 mm; Unconfined
1		15mm > Substrate; 62 mm > Substrate > 40 mm; Confined
0	**Not Suitable**	Substrate > 62 mm; Channel size < 4 m; Reaches upstream of barriers; Glacial

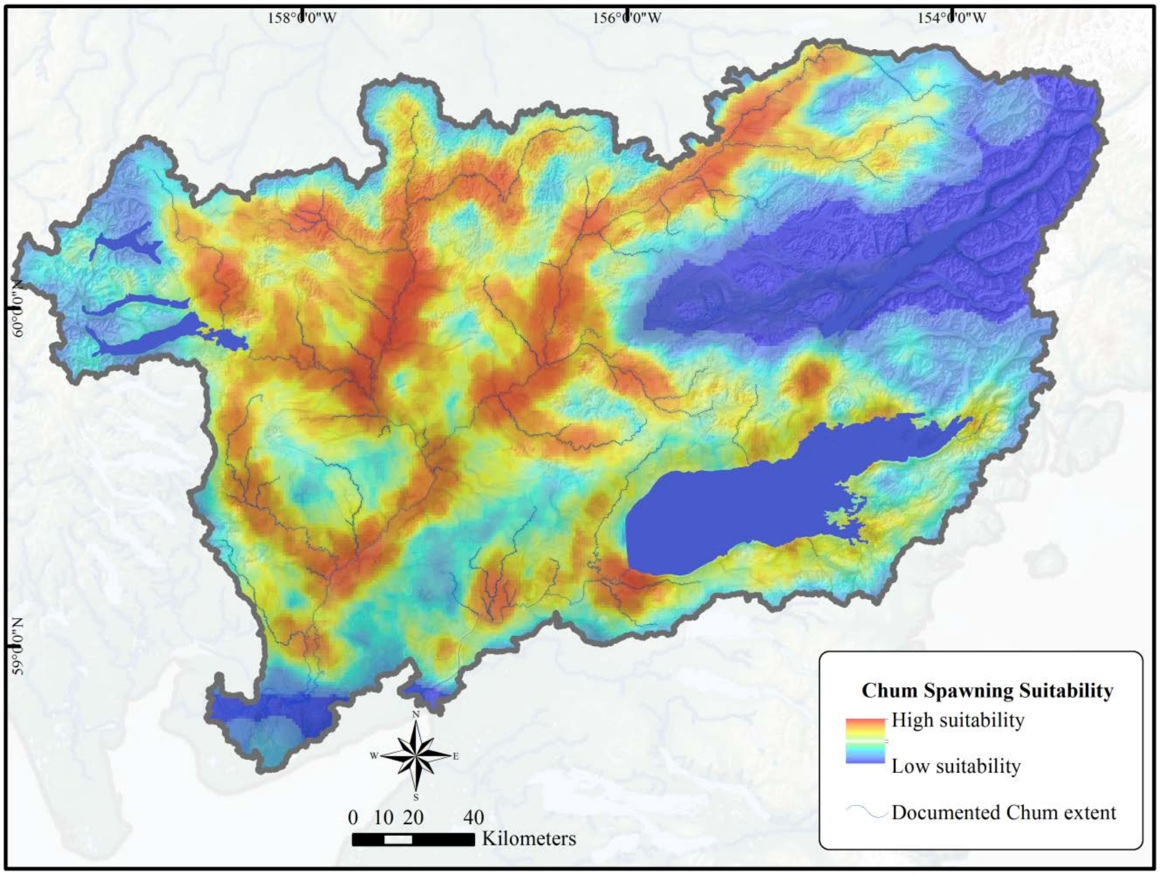

Figure 15. Habitat suitability index for chum salmon spawning habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented chum salmon extent.

Pink salmon spawning

Pink salmon prefer to spawn lower in the watershed (Groot & Margolis 1991). We used the substrate criteria described for Pink salmon in Kondolf and Wolman (1993).

Table 9. Habitat quality assignments for pink salmon spawning habitat model.

4	**Highest quality**	7mm < Substrate < 11 mm; Distance < 300rkm
3		7mm < Substrate < 11 mm; Distance > 300rkm
2		7mm > Substrate > 2 mm; 64mm > Substrate > 11 mm; Distance < 300rkm
1		7mm > Substrate > 2 mm; 64mm > Substrate > 11 mm; Distance > 300rkm
0	**Not Suitable**	2 mm > Substrate > 64 mm; Glacial; Channel size < 2m; Reaches upstream of barriers

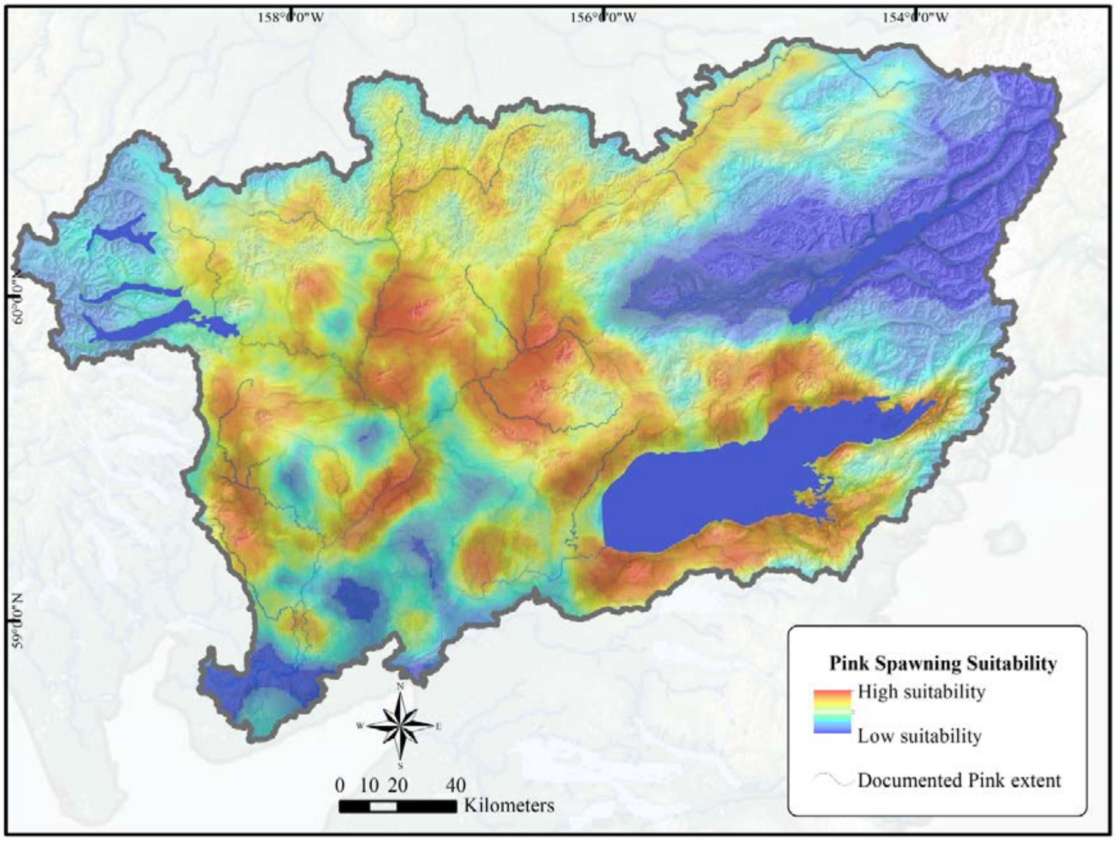

Figure 16. Habitat suitability index for pink salmon spawning habitat, summarized at a landscape scale by averaging suitability indices for all reaches within an 8-m radius.

The suitability map appears to correspond with the Anadromous Waters Catalog's documented pink salmon extent. However, it does not in general reflect local traditional ecological knowledge and other expert opinion that the Nuyakuk river system is more heavily used by pink salmon than the Mulchatna River (T. Troll, personal communication), indicating that the substrate suitability for pink salmon in these systems may differ from the literature.

Conclusions

This project presents a survey and database of best-available information on freshwater salmon habitat distribution in the Nushagak and Kvichak watersheds. Using these datasources, it effectively models and maps the likely distribution of various habitat characteristics across the watersheds. This toolset provides a physical template for better predictions of abundance and distribution trends across freshwater habitats for all species and life stages of salmon.

This tool does not come without it suite of limitations. There are many other habitat characteristics important to spawning and rearing salmonids that were not mapped here; variables including beaver dams, water temperature, channel entrenchment, large woody debris and other cover, and microhabitat distributions were not explicitly modelled. With more field data and more highly resolute remote sensing sources, habitat modelling in these landscapes could be improved. With the increased activities of Alaska's Statewide Digital Mapping Initiative, these high-resolution satellite images as well as higher-resolution DEMs will offer the opportunity for continued exploration of these habitat mapping and modelling efforts. More importantly, habitat suitability models based on qualitative literature-based models seem to only compare well to expert knowledge and field data concerning fish distributions for some species and life stages; it is clear that habitat suitability models will need to be refined with more information on site-specific fish and habitat relationships.

The ultimate goal of this tool and dataset is to inform scientists and decision-makers about the relative value of certain areas within these large and remote areas. We believe that this watershed scale information, previously unavailable, will lend itself well to several upcoming decision-making processes regarding land use near freshwater salmon habitats in the Nushagak and Kvichak watersheds in the near future.

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April 30, 2013

Alaska Department of Natural Resources
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550 West 7th Ave, Suite 1050
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SUBJ: Comments on Determination of Reclassification and Plan Amendment to the 2005 Bristol Bay Area Plan

Thank you for the opportunity for The Nature Conservancy to provide input to the recently released *Determination of Reclassification and Plan Amendment to the 2005 Bristol Bay Area Plan (*BBAP*)*. The mission of The Nature Conservancy is to conserve the lands and waters on which all life depends. We have operated an Alaska Chapter for 25 years, bringing a science-based, non-confrontational, and results oriented approach to conservation. Our Alaska Board of Trustees includes business, civic, and conservation leaders from around the state.

Over the past several years The Nature Conservancy has made considerable efforts to better understand salmon distribution and habitat use in the Bristol Bay region. Our recent efforts to improve mapping of freshwater habitats that support salmon have been designed to assist in decision-making regarding land use and development activities. Thus, we appreciate this opportunity to share conclusions from our current habitat modeling in the Nushagak and Kvichak watersheds.

Our comments are related to the methods used to identify anadromous habitats for designation as Wildlife Habitat. In the majority of lands included in the BBAP, criteria used to designate land as Wildlife Habitat included: (1) navigability; and (2) listing in the Anadromous Waters Catalog.

1) While navigability is a useful indicator of recreation and/or subsistence use, it is not related to the extent or quality of habitat for anadromous fish. This criteria eliminates 49% of cataloged anadromous waters from designation as Wildlife Habitat, and it is not clear that the navigable sub-set of anadromous waters are equally important for salmon productivity than many others.
2) The extent of the anadromous waters catalog is most likely a significant underrepresentation of water bodies actually used by salmon for spawning and rearing. Our preliminary estimates suggest that only 22% of streams containing anadromous fish within the planning boundaries in the Nushagak and Kvichak drainages are included in the Anadromous Waters Catalog. Of these potentially anadromous waters, only 31% are included within lands designated as Wildlife Habitat. This analysis suggests that a majority of the regions anadromous waters are currently excluded from the catalog and from the lands designated as Wildlife Habitat in the draft plan.

The significant under-representation of salmon habitat within lands designated Wildlife Habitat is inconsistent with the very high value of salmon production in this region to Alaska’s communities and economy. We recommend that DNR revisit the anadromous fish habitat criteria that DNR uses to classify Wildlife Habitat using more biologically relevant methods; a more justifiable approach may be to assume that all water bodies support anadromous fish unless evidence to the contrary is available. We hope that the review, analysis, and data that we have provided here will assist DNR in improving these criteria.

Thank you again for the opportunity to provide input to the 2005 BBAP and 2012 amendment.

Sincerely,

Randall H. Hagenstein
Alaska State Director

Attachments:

Comments on Anadromous Habitat Classification in the 2005 Bristol Bay Area Plan (The Nature Conservancy, 2013)

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Comments on Anadromous Habitat Classification in the 2005 Bristol Bay Area Plan

Summary

This review has been prepared as a response to the public review draft of the *Determination of Reclassification and Plan Amendment to the 2005 Bristol Bay Area Plan* (BBAP; ADNR 2012), and serves to provide comments and a brief scientific analysis pertaining to the methods used to identify anadromous habitats for designation as Wildlife Habitat in the current BBAP. In the majority of lands included in the BBAP, criteria used to designate land as Wildlife Habitat included: (1) navigability; and (2) listing in the Anadromous Waters Catalog. In this review, we conclude that:

1) While navigability is a useful indicator of recreation and/or subsistence use, it is not related to the extent or quality of habitat for anadromous fish. This criteria eliminates 49% of cataloged anadromous waters from designation as Wildlife Habitat, and it is not clear that the navigable sub-set of anadromous waters are equally important for salmon productivity than many others.
2) The extent of the anadromous waters catalog is most likely a significant underrepresentation of water bodies actually used by salmon for spawning and rearing. Our preliminary estimates suggest that only 22% of streams containing anadromous fish within the planning boundaries in the Nushagak and Kvichak drainages may be included in the Anadromous Waters Catalog. Of these potentially anadromous waters, only 31% are included within lands designated as Wildlife Habitat. This analysis suggests that a majority of the regions anadromous waters are currently excluded from the catalog and from the lands designated as Wildlife Habitat in the draft plan.

The significant under-representation of salmon habitat within lands designated Wildlife Habitat is inconsistent with the very high value of salmon production in this region to Alaska's communities and economy. We recommend that DNR revisit the anadromous fish habitat criteria that DNR uses to classify Wildlife Habitat using more biologically relevant methods; a more justifiable approach may be to assume that all water bodies support anadromous fish unless evidence to the contrary is available. We hope that the review, analysis, and data that we have provided here will assist DNR in improving these criteria.

Comments on Anadromous Habitat Criteria

In the 2005 BBAP (ADNR 2005), the Habitat designation was defined as "concentrated use area for fish and wildlife species during a sensitive life history stage where alteration of the habitat and/or human disturbance could result in a permanent loss of a population or sustained yield of the species." Criteria in the BBAP to identify areas to be designated as Wildlife Habitat include waters used for spawning and rearing of anadromous fishes. However, in most areas within the BBAP boundaries, fish habitat is only designated as Wildlife Habitat if it is listed in the Alaska Department of Fish and Game's (ADFG) Anadromous Waters Catalog (AWC) and is considered navigable by boat.

Although the BBAP has recognized that spawning and rearing areas for anadromous fish is an important determinant for Wildlife Habitat designation, methods for evaluating which anadromous waters are included in this designation do not seem to be based on relevant aspects of the biology or productivity of salmon populations. It is widely recognized that the extent of waters used for spawning and rearing by anadromous fish within the boundaries of the BBAP is more extensive than reflected in the AWC. We respectfully submit two specific comments intended to strengthen methods used to designate lands and waters as Wildlife Habitat, with the ultimate goal of sustaining long-term salmon production and associated economic, cultural and social values.

Our first critique is based on the use of Navigability as a criterion in designation of Wildlife Habitat. The state defines a water body as "navigable" if it is useable as a highway for the transportation of people or goods. While navigability is a useful indicator of recreation and/or subsistence use, it is not related to the extent or quality of habitat for anadromous fish. Furthermore, it excludes small, tributary streams and off-channel habitats that play a critical role in salmon population productivity.

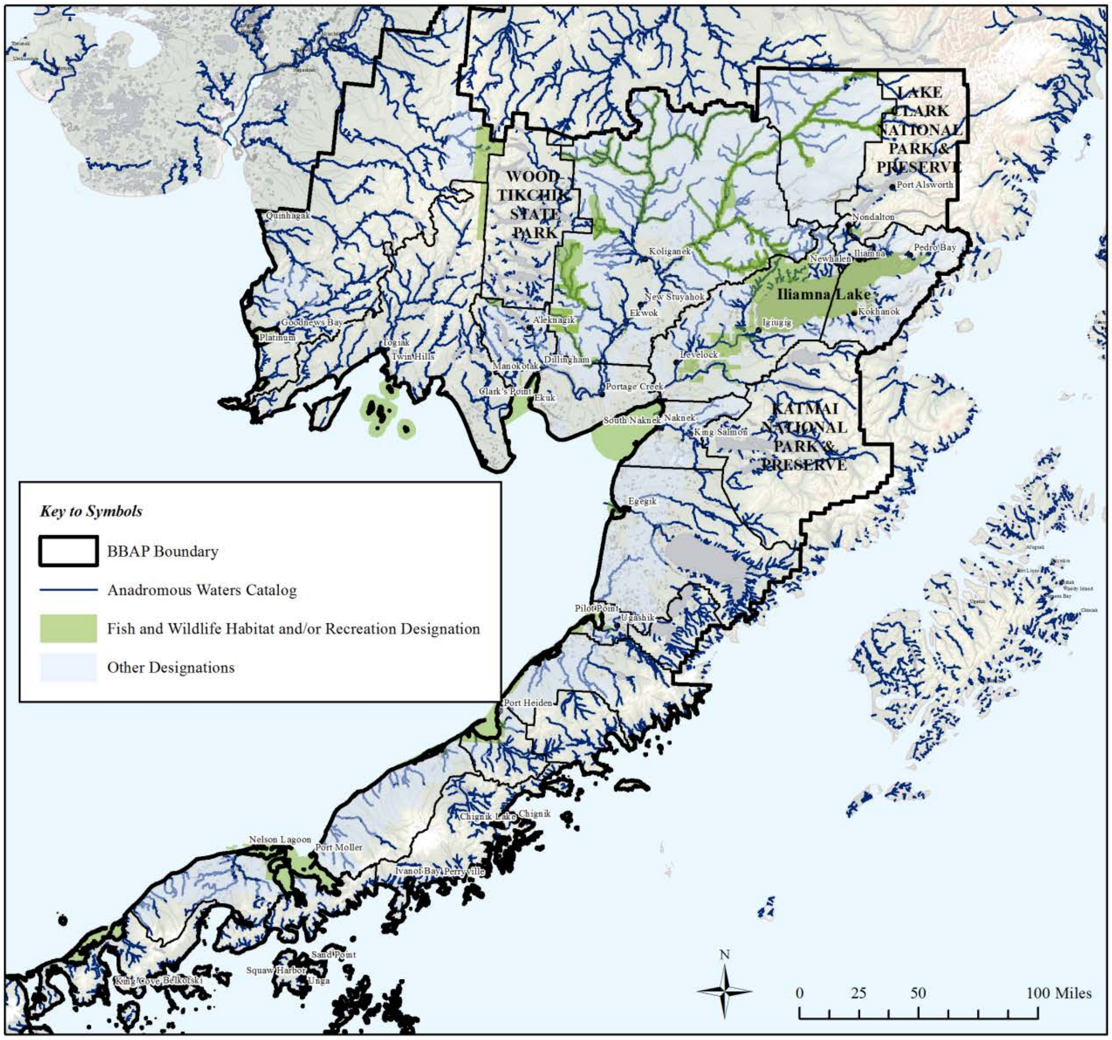

Figure 1. Areas classified as Fish and Wildlife Habitat and/or Recreation do not reflect the full extent of Anadromous Water Catalog within the boundaries of the BBAP.

Small tributary streams and off-channel habitats have actually been shown to be critical to several species and life stages of Pacific salmon (*Oncorhynchus spp.)*. Both Chinook salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*) are known to rear in both shallow, narrow tributaries (e.g., ADFG 2012; Mossop & Bradford 2004; Murray & Rosenau 1989; Rosenfeld et al. 2000) and off-channel, backwater areas. Beaver ponds typically not navigable by watercraft are recognized as essential winter habitat for juvenile coho salmon (e.g., Bustard & Narver 1975; Marshall & Britton 1990; Murphy et al. 1989; Nickelson et al.

1992; Peterson 1982; Pollock et al. 2004; Reeves et al. 1989). Even adult spawning fish utilize these shallower and narrower channels. Sockeye salmon (*O. nerka)* can be seen spawning with their backs out of the water in small streams and springbrooks, and both pink salmon (*O. gorbuscha*) and Chinook salmon can be found in shallow areas, with nests at depths as shallow as 10-30cm of water in small tributaries (Groot & Margolis 1991). Coho salmon are generally found spawning in almost all coastal streams regardless of size or remoteness (Groot & Margolis 1991).

Our second critique reflects the inadequacy of the AWC to represent the true extent of anadromous waters in this region. The extent of documentation of anadromous waters in Alaska, especially in remote areas, is mostly a product of sampling effort, and is mostly limited to areas with the easiest access or near potential development projects. Salmon have high adaptability and are considered generalists; in terms of freshwater habitat, they can be found in a very wide range of habitats across their range, and thus it is difficult to accurately document their full extent. The Alaska Department of Fish and Game acknowledges that it is likely that less than 50% of all anadromous water bodies in the state have actually been cataloged (ADFG 2012). In a study of headwater streams in the Nushagak River drainage, researchers found that 7 out of every 10 streams with less than a 10% gradient contained rearing salmon, suggesting that nearly all headwater areas will contain fish, despite the fact that these areas were previously undocumented in the AWC (Woody & O'Neal 2010).

Alternative methods for defining anadromous habitat

Because we have concluded that using navigability and the AWC to define anadromous habitat is lacking in some regards, we wish to provide an alternative method for defining anadromous habitat. We hope that this can be used to better define and apply the habitat designation within the BBAP. As an alternative method, we applied a physical habitat model to predict likely spawning and rearing habitat within the Nushagak and Kvichak drainages. We believe that this model more accurately represents spawning and rearing habitats within this area as it extends to habitats beyond those previously surveyed and does not include a navigability criteria.

In order to develop a physical habitat model, we reviewed existing literature on the habitat requirements and preferences for both spawning and rearing habitat of all five species of North American Pacific salmon. It was determined that coho salmon has the widest range of habitat preferences of any of the species. Because coho salmon had such a wide range of habitat preferences, it was determined that a physical habitat model modeling coho distribution would be the most appropriate for determining full extent of spawning and rearing habitat within our study area. It is not expected that sockeye salmon, pink salmon, Chinook salmon, nor chum salmon (*O. keta*) would be found outside of the areas predicted for coho salmon.

Coho salmon have been found in habitats as diverse as braided glacial rivers, large mainstem areas, floodplains, estuaries, and slow-moving off-channel habitats, even within the same watersheds; they have long been described as the “least particular” of all Pacific Salmon (Groot & Margolis 1991). Thus, in order to develop a physical habitat model for coho salmon, stream gradient and migration barriers were the only factor used to predict potential spawning and rearing areas. In order to identify barriers to upstream migration, two data sources were used. Included in the AWC is documentation of known physical barriers; for example, beaver dams, vertical falls, and man-made of certain proportions barriers require documentation. We intended to eliminate water bodies located upstream of documented barriers from the analysis; however, examination of the data source revealed that there are currently no documented barriers within the Nushagak and Kvichak drainages. In addition, stream reaches with gradients above 16% have been found to serve as migration barriers (USFS 2001); thus, we eliminated water bodies located upstream of stream reaches with gradients greater than 16%. It is unlikely that coho salmon will be found in streams with gradients exceeding 7% (Burnett et al. 2007); thus all water bodies with gradients exceeding 7% were also eliminated from the analysis.

Final results of potential anadromous streams are shown in Figure 2; they include all water bodies with a gradient of less than 7% and not upstream of a known or predicted barrier.

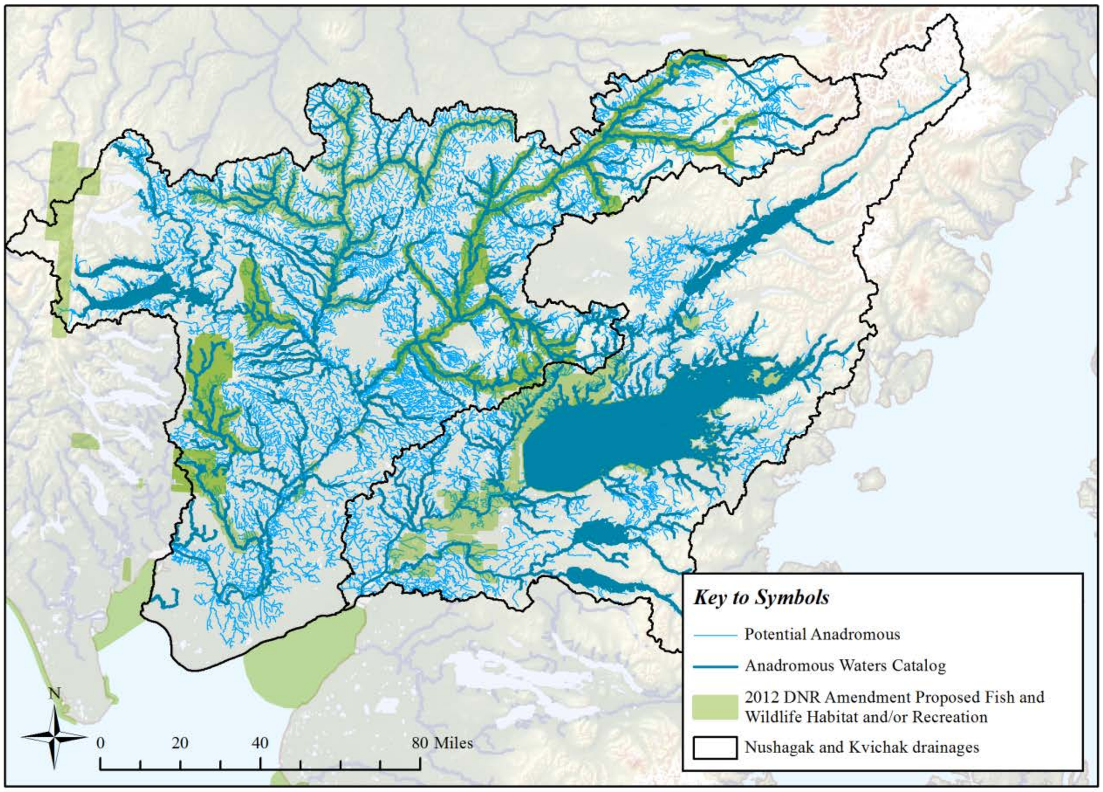

Figure 2. Potential anadromous habitat within the Nushagak and Kvichak drainages, as compared to the current AWC and areas designated as fish and wildlife habitat.

It is clear from figure 2 and from recent sampling of anadromous fish distribution, that the full extent of anadromous water bodies in the Nushagak and Kvichak drainages is likely much larger than that currently described by the AWC or by the BBAP Habitat classification. Table 1 estimates linear distance of potentially anadromous streams within each current land use designation. This analysis suggests that only 31% of all potentially anadromous water bodies are currently included within land designations of Wildlife Habitat.

Table 1. The length of anadromous streams currently cataloged, and those found to be potentially anadromous by our model, by BBAP unit designation categories. The majority of streams that we found to be potentially anadromous are currently designated as General Use, as opposed to Habitat.

Unit designation	Potential anadromous streams (% within unit designation)	Cataloged anadromous waters (% within unit designation)
General Use	12,293 rkm (55%)	1,716 rkm (36%)
Public Rec. and Tourism (Dispersed) / Habitat	6,789 rkm (31%)	2,369 rkm (49%)
Public Rec. and Tourism (Dispersed)	1,263 rkm (6%)	280 rkm (6%)
Minerals	716 rkm (3%)	215 rkm (4%)
Public Rec. and Tourism (Public Use Sites)	641 rkm (2%)	184 rkm (4%)
Settlement	459 rkm (2%)	49 rkm (1%)
Habitat	6.2 rkm (0%)	3.1 rkm (0%)
Public Facilities (Retain)	3 rkm (0%)	2 rkm (0%)
Heritage Resources	1 rkm (0%)	0 rkm (0%)
Total	22,171 rkm (100%)	4,818 rkm (100%)

Recommendations

Although TNC is not advocating for a specific methodology for assigning land use designations for given management units, it is clear that the current methods for defining the wildlife habitat designation in regard to anadromous spawning and rearing habitat is flawed in some regards. We recommend that anadromous fish habitat criteria used to designate Wildlife Habitat rely on a more biologically relevant approach with an explicit goal of maintaining diversity and productivity of regional salmon populations. We hope that the review, analysis, and data that we have provided here and in the appendix will be helpful in this process so that not only this amendment to the BBAP but also future land use decision making can better reflect life history needs and population-scale considerations for conservation of Alaska’s salmon resources.

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Appendix A: Anadromous Habitat By Management Unit

Table A1. Potential anadromous habitat, current extent of the Anadromous Waters Catalog, and current designation by management unit.

Management unit	Potential extent of anadromous habitat (km of stream)	Current extent of Anadromous Waters Catalog (km of stream)	Unit designation (Plan Amendment to the 2005 Bristol Bay Area Plan)
R05-20	102.6	23.3	General Use
R05-21	156.5	1.6	Settlement
R05-22	18.2	10.9	Public Rec. and Tourism - Dispersed, and Habitat
R05-23	110.9	4.2	General Use
R05-24	2.0	1.3	General Use
R05-26	2.4	0.3	Public Rec. and Tourism - Public Use Site
R05-27	0.8	0.2	Public Rec. and Tourism - Public Use Site
R05-28	0.7	0.3	Public Rec. and Tourism - Public Use Site
R05-29	0.9	0.3	Public Rec. and Tourism - Public Use Site
R05-30	1.1	0.0	Public Rec. and Tourism - Public Use Site
R05-31	0.3	0.0	Public Facilities - Retain
R05-32	7.5	0.0	General Use
R06-01	2049.0	179.5	General Use
R06-02	1925.1	659.2	Public Recreation and Tourism - Dispersed, and Habitat
R06-03	79.2	21.2	Minerals
R06-05	3920.6	471.6	General Use
R06-06	1.7	1.0	Public Rec. and Tourism - Public Use Site
R06-07	166.4	24.0	Public Rec. and Tourism - Dispersed
R06-08	2.7	0	Public Rec. and Tourism - Public Use Site
R06-09	2510.9	776.3	Public Rec. and Tourism - Dispersed, and Habitat
R06-11	0.3	0.1	Public Rec. and Tourism - Public Use Site
R06-12	3.2	1.7	Public Rec. and Tourism - Public Use Site
R06-13	1928.4	439.3	General Use
R06-14	1.6	1.1	Public Rec. and Tourism - Public Use Site
R06-15	0.6	0.0	Public Rec. and Tourism - Public Use Site
R06-16	1.2	0.0	General Use
R06-17	2.8	1.3	Public Rec. and Tourism - Public Use Site
R06-18	289.5	49.4	Minerals
R06-19	0.8	0.1	Heritage Resources
R06-20	1.1	0.4	Public Rec. and Tourism - Public Use Site
R06-21	0.7	0.6	Public Rec. and Tourism - Public Use Site
R06-22	2.1	0.4	Public Rec. and Tourism - Public Use Site
R06-23	99.9	25.6	Minerals

Management unit	Potential extent of anadromous habitat (km of stream)	Current extent of Anadromous Waters Catalog (km of stream)	Unit designation (Plan Amendment to the 2005 Bristol Bay Area Plan)
R06-24	174.4	92.6	Minerals
R06-25	285.1	103.5	Public Rec. and Tourism - Dispersed, and Habitat
R06-26	71.1	16.5	Public Rec. and Tourism - Dispersed, and Habitat
R06-27	3.6	2.3	Public Rec. and Tourism - Public Use Site
R06-28	0.8	0.5	Public Rec. and Tourism - Public Use Site
R06-29	1.2	0.5	Public Rec. and Tourism - Public Use Site
R06-30	105.3	51.0	Public Rec. and Tourism - Dispersed, and Habitat
R06-31	0.9	0.8	Public Rec. and Tourism - Public Use Site
R06-32	1.5	1.1	Public Rec. and Tourism - Public Use Site
R06-33	4.1	2.3	Public Rec. and Tourism - Public Use Site
R06-34	1.3	1.3	Public Rec. and Tourism - Public Use Site
R06-35	343.9	200.4	Public Rec. and Tourism - Dispersed, and Habitat
R06-36	405.1	128.3	Public Rec. and Tourism - Public Use Site
R06-37	0.7	2.1	Public Facilities - Retain
R06-38	6.2	0.0	Public Rec. and Tourism - Public Use Site
R06-39	0.9	0.0	Public Rec. and Tourism - Public Use Site
R06-40	3.4	0.0	Public Rec. and Tourism - Public Use Site
R06-41	12.9	0.0	Public Rec. and Tourism - Dispersed
R06-42	784.6	97.8	General Use
R06-43	0.8	1.0	Public Rec. and Tourism - Public Use Site
R06-45	0.5	0.0	Public Facilities - Retain
R06-48	81.0	13.3	Public Rec. and Tourism - Dispersed, and Habitat
R06-49	221.7	88.7	Public Rec. and Tourism - Dispersed, and Habitat
R06-50	0.6	0.0	Public Rec. and Tourism - Public Use Site
R06-51	3.1	2.8	Public Rec. and Tourism - Public Use Site
R06-54	2.5	0.9	Public Rec. and Tourism - Public Use Site
R06-56	130.9	66.7	Public Rec. and Tourism - Dispersed, and Habitat
R06-57	75.7	37.8	Public Rec. and Tourism - Dispersed, and Habitat
R06-58	97.6	44.5	Public Rec. and Tourism - Dispersed, and Habitat
R07-01	6.2	0.0	General Use
R07-02	1413.3	192.3	General Use
R07-03	0.8	0.8	Public Rec. and Tourism - Public Use Site
R07-04	50.7	14.6	Settlement
R07-06	922.2	300.0	Public Rec. and Tourism - Dispersed, and Habitat
R07-07	2.3	2.4	Public Rec. and Tourism - Public Use Site
R07-09	0.4	0.0	Public Rec. and Tourism - Public Use Site
R07-10	3.3	1.3	Public Rec. and Tourism - Public Use Site
R07-11	1.9	1.6	Public Rec. and Tourism - Public Use Site

Management unit	Potential extent of anadromous habitat (km of stream)	Current extent of Anadromous Waters Catalog (km of stream)	Unit designation (Plan Amendment to the 2005 Bristol Bay Area Plan)
R07-12	3.4	1.7	Public Rec. and Tourism - Public Use Site
R07-13	1.1	0.6	Public Rec. and Tourism - Public Use Site
R07-14	3.0	2.2	Public Rec. and Tourism - Public Use Site
R07-15	6.2	1.8	Public Rec. and Tourism - Public Use Site
R07-16	141.3	9.0	Public Rec. and Tourism - Public Use Site
R07-17	1.8	1.4	Public Rec. and Tourism - Public Use Site
R07-18	0.7	0.0	Public Rec. and Tourism - Public Use Site
R07-19	212.7	2.5	General Use
R07-20	13.8	0.0	Settlement
R07-21	18.5	0.0	Settlement
R07-22	18.6	0.0	Settlement
R08-01	28.5	0.0	General Use
R08-02	2.4	0.0	Settlement
R08-03	0.7	0.0	Public Facilities - Retain
R08-05	52.3	17.2	Settlement
R08-06	14.3	3.9	General Use
R08-07	0.1	0.0	Public Facilities - Retain
R08-08	0.3	0.1	Settlement
R09-01	110.3	31.9	General Use
R09-02	46.0	12.2	Settlement
R09-03	1.4	2.6	Settlement
R09-04	0.1	0.1	Public Facilities - Retain
R09-06	32.6	1.5	Public Rec. and Tourism - Dispersed
R09-07	395.3	47.9	General Use
R09-08	98.8	0.4	Settlement
R09-09	6.2	3.1	Habitat
R09-10	6.8	0.5	Minerals
R09-13	2.9	1.6	Public Rec. and Tourism - Dispersed
R09-14	0.7	0.0	General Use
R10-01	123.0	46.2	General Use
R10-02	66.5	26.1	Minerals
R10-03	543.2	184.0	Public Rec. and Tourism - Dispersed
R10-04	16.5	12.0	Public Rec. and Tourism - Public Use Site
R10-06	814.2	129.3	General Use
R10-07	494.8	68.9	Public Rec. and Tourism - Dispersed
R10-08	138.4	36.5	General Use
R10-09	10.4	0.0	Public Rec. and Tourism - Dispersed
R10-10	0.0	0.0	Settlement

Management unit	Potential extent of anadromous habitat (km of stream)	Current extent of Anadromous Waters Catalog (km of stream)	Unit designation (Plan Amendment to the 2005 Bristol Bay Area Plan)
R10-12	129.7	8.1	General Use
R10-13	0.2	0	Public Facilities - Retain