Landscape-scale mapping of Pacific salmon and their freshwater habitats in the Mat-Su Basin

By

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Acknowledgements

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Executive Summary

A better understanding of the distribution and relative abundance of salmon by species and life stage is vital to support landscape-scale planning that seeks to prioritize protection of salmon habitats and salmon populations within the Matanuska and Susitna watersheds (the "Mat-Su" Basin). The first objective of this study was to use previously completed studies to map patterns of adult salmon relative abundance throughout the Mat-Su Basin. Using data from research efforts including annual escapement or escapement index data, annual harvest data, mark recapture studies, and spawning surveys, watersheds were ranked by relative abundance for each species, and known areas of spawning aggregations were mapped. The second objective was to map reach-scale freshwater habitat characteristics across the Mat-Su Basin in order to develop conceptual models to map the intrinsic potential of stream reaches to support juvenile salmon rearing. This was accomplished by using a NetMap digital hydrography platform to develop a reach-scale database of freshwater habitat characteristics that were used to map conceptual intrinsic potential models for juvenile salmon rearing, by species and season, using known regional and local research on salmon-habitat relationships. Both of these objectives showcased particular watersheds and reaches that have a high value for particular species, while also highlighting the full diversity of habitats that support salmon productivity across the basin. This study also pointed out the need to continue annual monitoring of target species, perform analyses that utilize recent telemetry studies to better understand reach-level spawning habitat associations, better understand winter habitat use by juvenile salmon, and develop field-based quantitative models that predict salmon abundance and survival by species and life stage. We hope that the methodologies utilized in this study, as well as those proposed as potential new research avenues, will provide a platform to support prioritization of salmon habitat protection in the Mat-Su Basin.

Introduction

Landscape-scale planning and prioritization for sustainable development, conservation, and restoration activities requires spatially explicit landscape-scale information on the distribution and abundance of resources. Likewise, landscape-scale planning that seeks to prioritize protection of salmon habitats and salmon populations seeks spatially explicit information detailing the quality and quantity of these habitats and the distribution of fish abundance by species and life stage.

The Matanuska and Susitna watersheds (the "Mat-Su" Basin) boasts abundant populations of coho, Chinook, sockeye, chum, and pink salmon that together provide robust economic, cultural, and recreational values to tens of thousands of residents and visitors. The Mat-Su Borough has one of the fastest growing human populations in Alaska; it increased 50 percent from 2000 to 2010 and nearly 100 percent from 1990 to 2010. This has resulted in increasing pressure on freshwater habitats associated with a growing human population and demand for resources in this region, which will likely continue into the future (Mat-Su Basin Salmon Habitat Partnership 2013). Maintaining diverse and productive salmon populations with increasing human populations is known to be difficult (Lackey 2003). A better understanding of the relative distribution and abundance of salmon by species and life stage is vital to support basin-wide decision-making and evaluate potential effects of changes in land-use in the Mat-Su Basin.

In Alaska, statewide distribution of anadromous salmon is documented in the Alaska Department of Fish and Game (ADFG)'s Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes and the Atlas to the Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes, referred to collectively as the "Anadromous Waters Catalog" (AWC; Johnson 2014). However, this data source lacks relative abundance information and is confined to ground-verified datasets; it is estimated that less than 50% of the state's anadromous waters are currently cataloged. Studies on salmon habitat quality and salmon abundance in the state are often implemented on either a coarse scale (such as adult salmon catch and escapement data) or fine scale (such as juvenile salmon habitat studies), not allowing for landscape-scale prioritization with high-resolution data.

The Mat-Su Basin Salmon Habitat Partnership, in their strategic plan, identifies science projects used to "identify important habitats for salmon and other fish species in the Mat-Su Basin" as an essential conservation strategy (Mat-Su Basin Salmon Habitat Partnership 2013). Specifically, the partnership is interested in science that helps identify critical habitat for salmon at each life stage (Objective 1.2: Habitat quality). Likewise, this science strategy is important for prioritizing conservation actions of The Nature Conservancy.

With these goals in mind, The Nature Conservancy began an effort to better understand the distribution and relative abundance of salmon and their habitats across the Mat-Su Basin beginning in 2012. As a first step towards this goal, The Nature Conservancy began by working with partners and contractors to improve the hydrologic mapping of the entire basin, as well as commissioning a terrain model that allows for a suite of analyses of aquatic and terrestrial ecosystems, also known as the NetMap platform. Building off this work, we now wish to use NetMap and its suite of products and tools, combined with previously conducted local research and expert knowledge, to quantify and map estimated salmon habitat values across the entire basin. The objectives of this part of the effort are:

1) Use previously completed studies to map patterns of relative adult salmon abundance, by species, throughout the Mat-Su Basin
2) Map reach-scale freshwater habitat characteristics across the Mat-Su Basin and conceptual intrinsic potential models for juvenile salmon by species
3) Identify information gaps and describe potential future research activities that will further understanding of landscape-scale patterns of salmon abundance and habitats by species and life stage.

Objective 1: Mapping adult salmon relative abundance

Methods

In order to map important adult salmon habitats by species in the Mat-Su Basin, watersheds were first ordinally ranked according to likely relative adult abundance. Rankings of 1-4 were chosen to represent 4 separate quantiles of relative abundance, with watersheds ranked 1 representing 0-25% of the watershed with the highest relative abundance. Watersheds were defined as hydrologic areas that drain to a common outlet, but watershed boundaries differed in scale between species depending on the finest-scale data available. Rankings were determined by first surveying all available data sources, including annual escapement index surveys (aerial and foot), annual escapement surveys (weir and sonar), periodic escapement estimates (mark recapture; traditional tagging or radio telemetry), annual harvest surveys (sport and commercial), and radio telemetry-based spawning surveys. Data sources were compared by 1) perceived reliability of methods, 2) recentness of data 3) number of years of data available for estimation and 4) spatial scale, and these comparisons were used to select which datasets were used as the primary source for watershed rankings. Additional datasets were used as comparisons, and rankings were annotated if there were discrepancies in ranking results between the primary data source and the comparison data source. Rankings were also annotated when there was less than 5 years of data and when temporal trends suggested that ranking results did not hold true over time, such as in the event of hatchery enhancement, or predation by invasive species.

Although relative abundance rankings at the finest available scale is a useful dataset, in order to compare watersheds by species, as well as build relationships between relative abundance and habitat variables, relative abundance rankings were summarized for Hydrologic Unit Code 10 (HUC10) watersheds from the National Hydrography Dataset (NHD). This was done calculating the spatial average of the ordinal rank of all waterbodies within each HUC10, and then re-ranking HUC10 on the ordinal 1-4 ranking scale.

Finally, known spawning aggregation areas were mapped in areas where telemetry data was available.

Chinook salmon

Data sources

Annual aerial escapement index surveys have been conducted annually on Willow Creek, Deception Creek, Little Willow Creek, Sheep Creek, Goose Creek, Montana Creek, Clear Creek, Prairie Creek, Chulitna River, Portage Creek, Indian River, Kashwitna River, Alexander Creek, Deshka River, Peters Creek, Lake Creek, Talachulitna River, Cache Creek, and the Little Susitna River since 1979 (Oslund et al. 2013). Aerial surveys are notoriously subject to bias and are not replacements for full escapement counts; however, they are performed in a way to minimize bias and challenging conditions are noted annually. In addition, aerial counts have been found to be correlated with escapements estimated from the only weir on the Susitna (the Deshka), averaging 40% of the escapement, and provide the basis for Sustainable Escapement Goals (SEGs) for Alexander Creek, Clear Creek, Deshka River, Little Susitna River, Little Willow Creek, Montana Creek, Peters Creek, Prairie Creek, Sheep Creek, Talachulitna River, and Willow Creek (Oslund et al. 2013). Escapement to the Deshka River has been estimated using a weir since 1995. It is considered a reliable estimate of escapement to the Deshka and indicator of annual Susitna River run strength and timing (Oslund et al. 2013).

Annual sportfish harvest of Chinook salmon is estimated by major watershed from ADFG sportfish surveys (Oslund et al. 2013). Genetic baselines have been developed for Upper Cook Inlet Chinook salmon (Barclay et al. 2012), and ADFG is currently sampling Chinook salmon harvested in the Tyonek subsistence and Northern District commercial marine fisheries in order to apportion these fish into more specific stocks of origin (St. Saviour et al. 2016).

Mark recapture studies to estimate abundance of Chinook salmon on the Susitna River were completed in 1982, 1983, 1984, 1985, 2013, and 2014. Results from the 1980s allow for estimation of total abundance in each year above the middle Susitna River (above Sunshine station), to the Talkeetna drainage, and to the upper River (above Curry Station) (Alaska Department of Fish and Game 1981, 1982, 1984; Barrett 1985; Thompson et al. 1986). Results from 2013 and 2014 used radio tags to estimation of total abundance of Chinook Salmon to the Deshka River, the Talkeetna River, the Chulitna River, the mainstem Susitna from above the Yentna to the Chulitna River Confluence, the eastside Susitna River drainages, and the mainstem Susitna above the Chulitna River confluence, although Chinook salmon it was found that fish above 50 cm were overrepresented in tagging (LGL Alaska Research Associates Inc. & A.D.F.G 2014, 2015). Abundance of Chinook salmon was also estimated during the 2014 study for the Yentna River drainage, including estimations of escapement to the Lake Creek, Kahiltna, Talachulitna, and Skwentna drainages (LGL Alaska Research Associates Inc. & A.D.F.G 2015). In addition, aerial surveys and a weir were used to estimate escapement to Indian River in 2013 and 2014, and inferences about relative abundance of adult Chinook migrating above Devi's Canyon were made using radio tag detection rates and sonar counts in 2013 and 2014 (LGL Alaska Research Associates Inc. & A.D.F.G 2015).

Radio telemetry studies on Chinook salmon spawning distribution in the Susitna watershed were completed in 2012 - 2014 (LGL Alaska Research Associates Inc. & A.D.F.G 2015; Link et al. 2013; Yanusz et al. 2013). Assumptions about fish being tagged in proportion to apparent abundance and capture selectivity were only tested in 2013, and in that year radio tags were adjusted in-season to reflect abundance over time and no evidence was found to suggest that Chinook salmon were bank-oriented (LGL Alaska Research Associates Inc. & A.D.F.G 2015).

Ranking and mapping

All aerial escapement index counts that were annotated as compromised by poor survey conditions or alternative methods (i.e., foot counts) were removed from analysis. Average annual escapement indices were used as the primary data source to separate most watersheds into rank quantiles 1-4; recent mark recapture studies in the Susitna watershed were used as comparison datasets and as primary data sources for several Yentna watersheds not included in aerial surveys. Rankings were also annotated when there was less than 5 years of data and when temporal trends suggested that ranking results did not hold true over time, such as in the event of hatchery enhancement, or predation by invasive species. More details on how watersheds were ranked is found in Appendix A.

Streams within watersheds were mapped according to the 2014 Anadromous Waters Catalog for streams documented as Chinook salmon spawning areas. In addition, specific areas of known spawning "aggregations" were digitized using documented spawning locations as recorded in the telemetry studies from 2012 and 2013 (LGL Alaska Research Associates Inc. & A.D.F.G 2014; Yanusz et al. 2013).

Sockeye salmon

Data sources

Annual escapement estimates for sockeye salmon in the Mat-Su have been obtained using weirs for the following drainages: the little Susitna River (1988, 1989, 1994, and 1995), Fish Creek (1969-present), Cottonwood Creek (1997-2004), Wasilla Creek (1993, 1994, and 1998-2003), Jim Creek (1997 and 1998), Larson Lake (1984-1987, 1990-2000, and 2005-present day, Stephen Lake (1993-1998, 2007, and 2008), Chelatna Lake (1990, 2006-present day), Judd Lake (1991-1998, 2006-present day), Shell Lake (1986, 1990-1998, and 2006-present day), Byers Lake (2006-2008), Swan Lake (2007 and 2008) and Bodenburg Creek in the Knik drainage (1968-present) (Oslund et al. 2013). In addition, escapement counts using sonar are available for the Yentna River (1981-1989 and 1998-present day) but these estimates are likely biased very low (Yanusz et al. 2007, 2009; Yanusz et al. 2011) These escapement estimates form the basis of sustainable escapement goals for the Chelatna, Fish Creek, Judd Lake, and Larson Lake (Fair et al. 2013).

Annual sportfish harvest of sockeye salmon is estimated by major watershed from ADFG sportfish surveys (Oslund et al. 2013). Commercial harvest for sockeye salmon by stock of origin has been calculated based on genetic analysis of mixtures of sockeye salmon harvested in the Upper Cook Inlet since 2005; estimates of this harvest are available for the Judd Lake, Chelatna Lake, and Larson Lake complex; for the rest of the Susitna and Yentna drainage, for Fish Creek, and for the Knik/Turnagain/Northeast Cook Inlet producers (Barclay et al. 2010).

Mark recapture estimates were performed to estimate abundance of sockeye salmon on the Yentna and Susitna River (above Sunshine) from 2006-2008 (Yanusz et al. 2007, 2009; Yanusz et al. 2011). On the Matanuska, mark recapture estimates were used to estimate sockeye abundance in 2009 (Sethi & Tanner 2013). In 2006, weighted estimates of percentages representing final spawning locations were calculated for Larson Lake, Judd Lake, Shell Lake, Chelatna Lake, other small lakes, and other streams above the Yentna (Yanusz et al. 2007). Weighted terminal distribution of sockeye salmon was estimated for Larson Lake, the Tokositna River, Swan Lake, Byers Lake, Chulitna River, Stephan Lake, the Talkeetna River, and the mainstem Susitna River in 2007(Yanusz et al. 2011). Weighted terminal distribution of sockeye salmon was estimated for Larson Lake, the Talkeetna River, the mainstem Susitna River, the Chulitna River, the Tokositna River, Byers Lake, Bunco Lake, Swan Lake, Stephan Lake, the Talachulitna River, the Skwentna River, Lake Creek, Kichatna River, Kahilitna River, Hewitt Lake, Movie Lake, Trinity Lake, Swan Lake, Shell Lake, Judd Lake, Chelatna Lake, and the mainstem Yentna River in 2008 (Yanusz et al. 2009).

Telemetry studies looking at distribution of spawning within the Susitna River were completed in 2006-2008 (Yanusz et al. 2007, 2009; Yanusz et al. 2011) and 2012-2014 (LGL Alaska Research Associates Inc. & A.D.F.G 2015). In addition, telemetry work on the Matanuska River in 2008 and 2009 identified important spawning aggregates for sockeye salmon (Anderson & Bromaghin 2009; Sethi & Tanner 2013; Tanner & Sethi 2015). Finally, telemetry work on Fish Creek in 2009 also identified important spawning aggregates in this system (J. Gerken, U.S. Fish and Wildlife Service (USFWS), unpublished data).

Ranking and mapping

Annual catch and escapement estimates were used as the primary data source to separate most watersheds into rank quantiles 1-4; recent mark recapture studies in the Susitna watershed were used as comparison datasets and as primary data sources for several Yentna watersheds not included in aerial surveys. Rankings were also annotated when there was less than 5 years of data and when temporal trends suggested that ranking results did not hold true over time, such as in the event of hatchery enhancement, or predation by invasive species. More details on how watersheds were ranked is found in Appendix A.

Watersheds were mapped according to the 2014 Anadromous Waters Catalog for streams documented as sockeye salmon spawning areas. In addition, specific areas of known spawning “aggregations” were digitized using documented spawning locations as recorded in the telemetry studies from the Susitna, Matanuska, and Fish Creek (Anderson & Bromaghin 2009; Tanner & Sethi 2015; Yanusz et al. 2007; J. Gerken, USFWS, unpublished data; 2009; Yanusz et al. 2011).

Coho salmon

Data sources

Annual escapement estimates for coho salmon in the Mat-Su have been collected using a variety of methods. Partial and full weir counts are available for various ranges of years for the Deshka River, the Little Susitna River, Cottonwood Creek, Fish Creek, Wasilla Creek, Spring Creek, and Jim Creek (Oslund et al. 2013). Partial and full sonar counts are available for various years for the Yentna River drainage (Oslund et al. 2013). Sustainable escapement goals are set for Fish Creek, Jim Creek, and the Little Susitna using these annual escapement estimates (Fair et al. 2013). Index escapements are available for various years on Rabideux Creek, Birch Creek, Question Creek, Answer Creek, Cottonwood Creek, Wasilla Creek, Spring Creek (upper and flats), Yellow Creek, Wolverine Creek, Bartko side channel, McRoberts Creek, and Upper Jim Creek (Oslund et al. 2013).

Annual sportfish harvest of coho salmon is estimated by major watershed from ADFG sportfish surveys (Oslund et al. 2013). Commercial harvest for coho salmon occurs in Upper Cook Inlet and is reported by fishing district, but no study to date has apportioned this fishery into stocks of origin (Shields & Dupuis 2013).

Mark recapture estimates of coho salmon were performed on various parts of the Susitna, including the Yentna, from 1981-1985 (Barrett 1985; Thompson et al. 1986), in 2002 (Willette et al. 2003), 2010 (Cleary et al. 2013), and 2012-2014. The mark recapture study of 2002 looked at estimating total escapement to many other Upper Cook Inlet streams, including the Little Susitna, Cottonwood creek, Eagle River, Fish Creek, the Knik River, the Matanuska River, and Rabbit Slough (Willette et al. 2003). The studies completed in 2010, 2013, and 2014 were able to estimate weighted spawner abundance by major tributaries (LGL Alaska Research Associates Inc. & A.D.F.G 2015). In addition, a study on the Matanuska River in 2009 estimated coho salmon abundance (Sethi & Tanner 2013).

Telemetry studies looking at distribution and abundance of coho spawning within the Susitna River were completed in 1998 (Todd et al. 2001), 2009 (Merizon 2010), 2010 (Cleary et al. 2013), and 2012-2014 (LGL Alaska Research Associates Inc. & A.D.F.G 2015). In addition, telemetry work on the Matanuska River in 2008 and 2009 identified important spawning aggregates for coho salmon (Anderson & Bromaghin 2009; Sethi & Tanner 2013; Tanner & Sethi 2015).

Ranking and mapping

Annual catch and escapement estimates were used as the primary data source to separate most watersheds into rank quantiles 1-4. Recent mark recapture studies in the Susitna watershed were used as comparison datasets and as primary data sources for several Yentna watersheds not included in aerial surveys. The Upper Cook Inlet (UCI) mark recapture study was also used as a comparison dataset, and as a primary dataset for several watersheds outside of the Susitna. Rankings were also annotated when there was less than 5 years of data and when temporal trends suggested that ranking results did not hold true over time, such as in the event of hatchery enhancement, or predation by invasive species. More details on how watersheds were ranked is found in Appendix A.

Watersheds were mapped according to the 2014 Anadromous Waters Catalog for streams documented as coho salmon spawning areas. In addition, specific areas of known spawning "aggregations" were digitized using documented spawning locations as recorded in the telemetry studies from 2008, 2009, 2010, and 2013 (Anderson & Bromaghin 2009; Cleary et al. 2013; LGL Alaska Research Associates Inc. & A.D.F.G 2014; Merizon 2010).

Chum salmon

Data sources

The only annual escapement counts for chum salmon are escapement index surveys done on Bodenburg creek in the Knik drainage (Oslund et al. 2013). Annual sportfish harvest of chum salmon is estimated by major watershed from ADFG sportfish surveys (Oslund et al. 2013). Commercial harvest for chum salmon occurs in Upper Cook Inlet and is reported by fishing district, but no study to date has apportioned this fishery into stocks of origin (Shields & Dupuis 2013). Mark recapture estimates for chum salmon in Upper Cook Inlet were completed in 2002 (Willette et al. 2003), and in 2010, a mark recapture study estimated escapement to the Susitna drainage, above Flathorn (Cleary et al. 2013). This study used telemetry to describe spawning areas, as well as provide estimates of escapement by major watershed in the Susitna drainage. From 2012-2014, telemetry study was used to describe chum salmon spawning areas in the Susitna drainage, although fish were not tagged in proportion to their abundance and thus do not offer an accurate estimate of overall spawning abundance (LGL Alaska Research Associates Inc. & A.D.F.G 2015). In addition, telemetry work on the Matanuska River in 2008 and 2009 identified important spawning aggregates for chum, as well as an estimated escapement in 2009 (Anderson & Bromaghin 2009; Sethi & Tanner 2013; Tanner & Sethi 2015).

Ranking and mapping

The 2010 mark recapture study in the Susitna was the primary data source to separate all watersheds into rank quantiles 1-4. More details on how watersheds were ranked is found in Appendix A.

Watersheds were mapped according to the 2014 Anadromous Waters Catalog for streams documented as chum salmon spawning areas. In addition, specific areas of known spawning "aggregations" were digitized using documented spawning locations as recorded in the telemetry studies from 2010 and 2012-2013 (Cleary et al. 2013; LGL Alaska Research Associates Inc. & A.D.F.G 2014).

Pink salmon

Data sources

No annual escapement studies exist for pink salmon. Annual sportfish harvest of pink salmon is estimated by major watershed from ADFG sportfish surveys (Oslund et al. 2013). Commercial harvest for pink salmon occurs in Upper Cook Inlet and is reported by fishing district, but no study to date has apportioned this fishery into stocks of origin (Shields & Dupuis 2013). The only abundance estimate for pink salmon was for all of Upper Cook Inlet in 2002 (Willette et al. 2003). From 2012-2014, telemetry projects were used to investigate pink salmon spawning habitat distribution within the Susitna drainage; however, in both studies fish were not tagged in proportion to their abundance, and therefore final results do not represent likely spawning abundance patterns for pink salmon (LGL Alaska Research Associates Inc. & A.D.F.G 2015; Yanusz et al. 2013). More details on how watersheds were ranked is found in Appendix A.

Ranking and mapping

Because no studies to date can be used to compare relative spawning abundance between basins, we were unable to rank watersheds by pink salmon abundance. Watersheds were mapped according to the 2014 Anadromous Waters Catalog for streams documented as pink salmon spawning areas. In addition, specific areas of known spawning "aggregations" were digitized using documented spawning locations as recorded in the telemetry studies from 2012 and 2013 (LGL Alaska Research Associates Inc. & A.D.F.G 2014; Yanusz et al. 2013). More details on how watersheds were ranked is found in Appendix A.

Results

Chinook salmon

The most highly ranked watershed for Chinook salmon in the Mat-Su was the Deshka River (Figure 1). The ranking of the Chulitna watershed is uncertain due to discrepancies between the primary data source and the comparison data source. The Willow Creek, Alexander Creek, and Talachulitna watersheds were found to have inconsistent temporal trends; these inconsistent temporal trends are likely due to hatchery production (Willow Creek) and predation from invasive pike (Alexander Creek). In addition, 2 watersheds had less than 5 years of data.

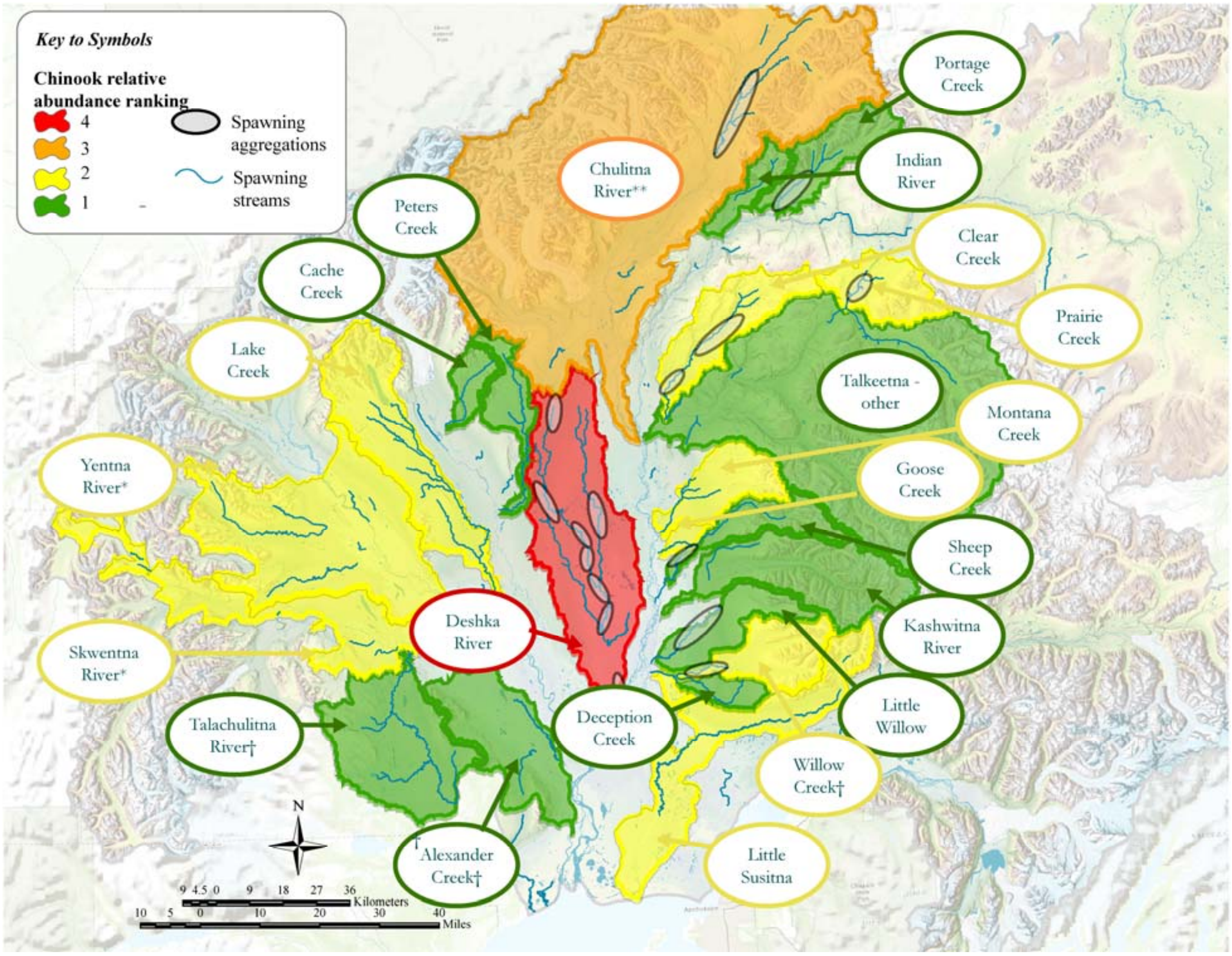

Figure 1. Adult Chinook salmon abundance rankings by watershed. Watersheds with an * represent areas that have five or less years of data, watersheds with an ** represent areas with discrepancies in ranking results between primary and comparison data sources, and watersheds labeled with a † represent those with an alternative temporal patterns than the majority of the watersheds.

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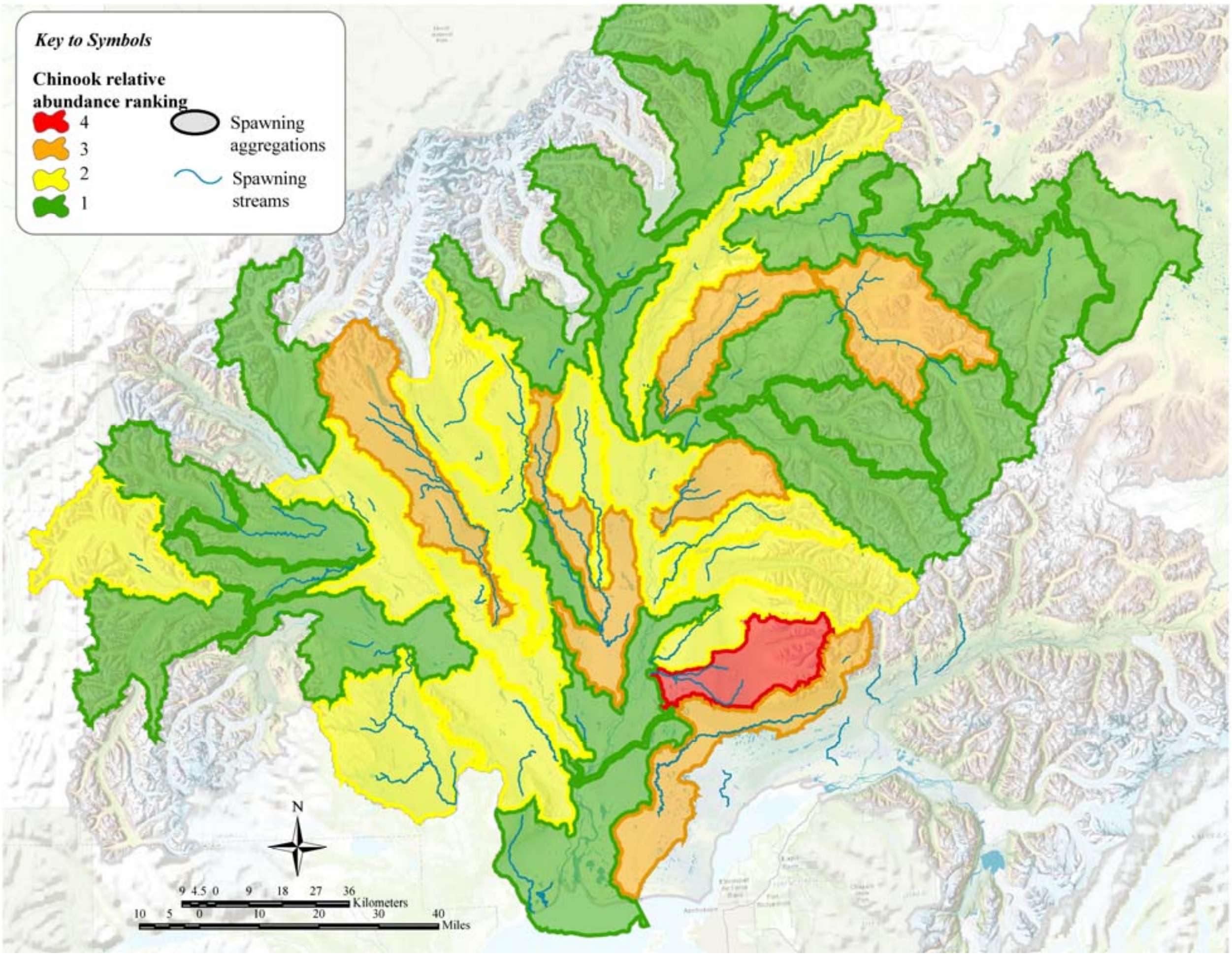

Figure 2. Adult Chinook salmon abundance rankings normalized by HUC10 watersheds.

Sockeye salmon

The most highly ranked watersheds for sockeye salmon in the Mat-Su were Larson Lake, the Skwentna River, and the mainstem Yentna (Figure 3; Figure 4). Most watersheds within the Yentna drainage have five or less years of data to support these estimates; in addition, 6 other watersheds also have less five years of data to support these estimates. Shell Lake and Fish Creek have inconsistent temporal trends, likely due to hatchery production (Fish Creek) and predation from invasive pike (Shell Lake).

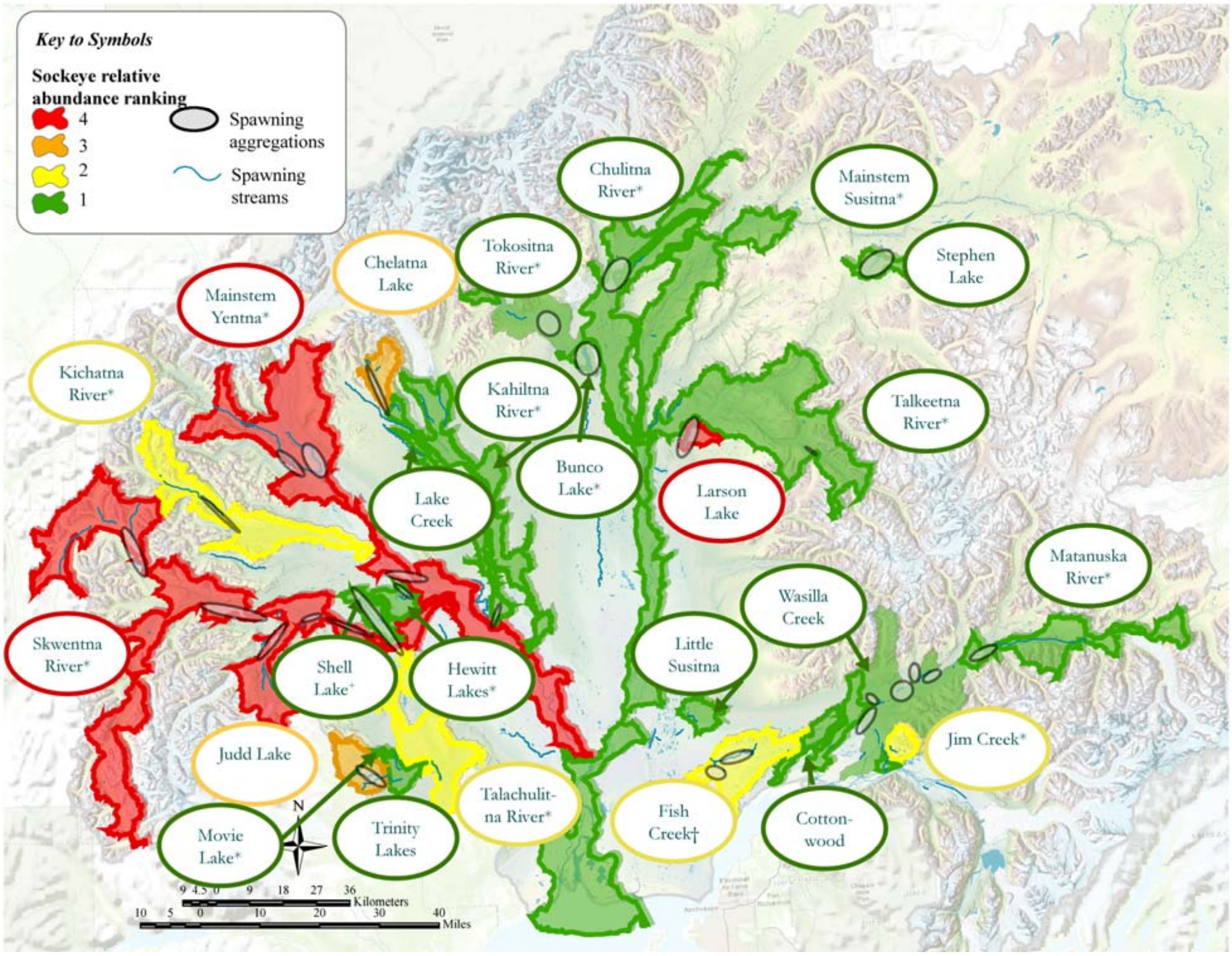

Figure 3. Adult sockeye salmon abundance rankings by watershed. Watersheds with an * represent areas that have five or less years of data, watersheds with an ** represent areas with discrepancies in ranking results between primary and comparison data sources, and watersheds labeled with a † represent those with an alternative temporal patterns than the majority of the watersheds.

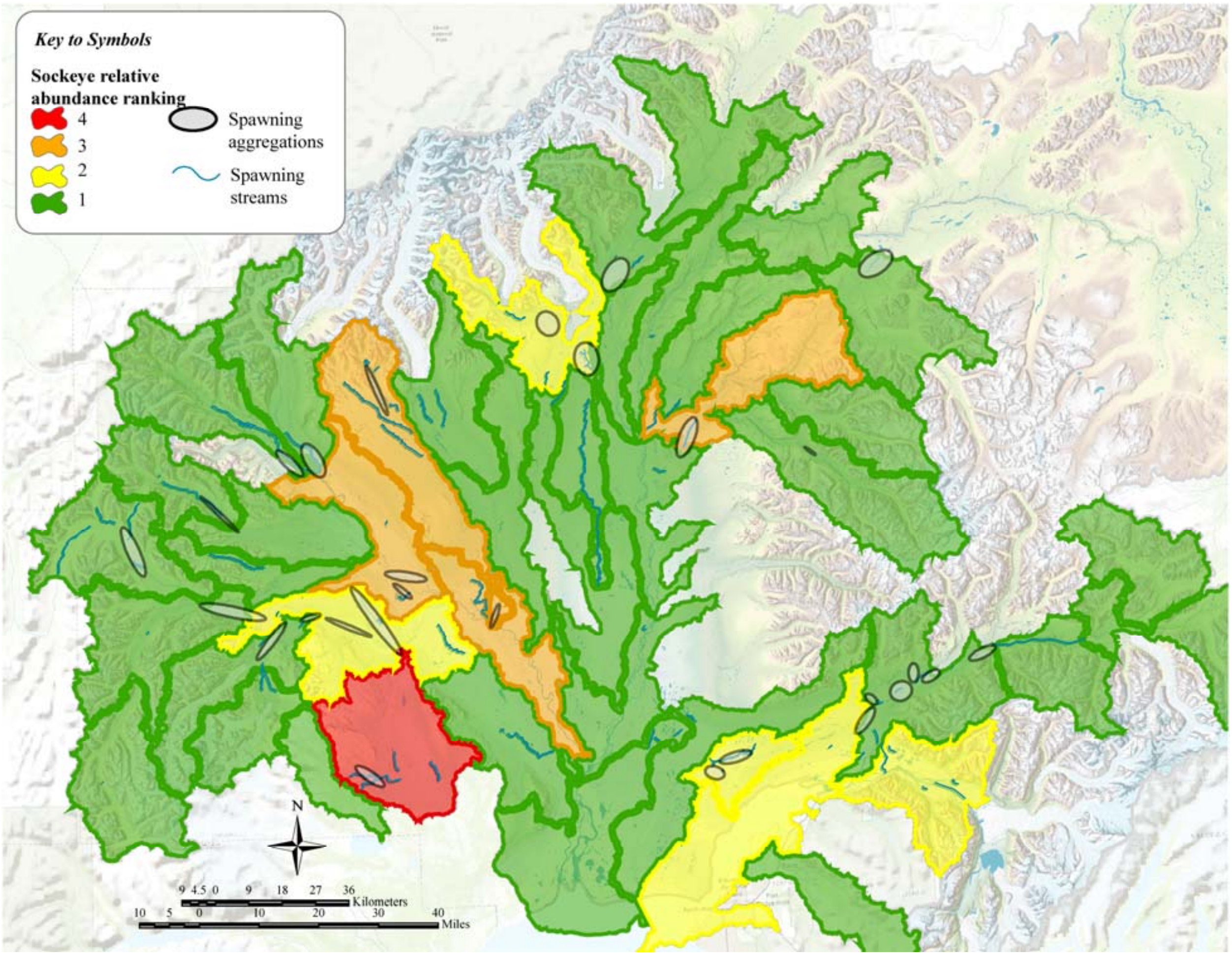

Figure 4. Adult sockeye salmon abundance rankings normalized by HUC10 watersheds.

Coho salmon

The most highly ranked watersheds for sockeye salmon in the Mat-Su were Larson Lake, the Skwentna River, and the mainstem Yentna (Figure 3; Figure 4). Most watersheds within the Yentna drainage have five or less years of data to support these estimates; in addition, 6 other watersheds also have less five years of data to support these estimates. Shell Lake and Fish Creek were found to have inconsistent temporal trends, likely due to hatchery production (Fish Creek) and predation from invasive pike (Shell Lake).

The most highly ranked watersheds for coho salmon in the Mat-Su were the Chulitna River and the Little Susitna River (Figure 5, Figure 6). Most watersheds, with the exception of the Deshka River, the Little Susitna River, Fish Creek, Cottonwood Creek, and Wasilla Creek, have five or less years of data to support these estimates. The ranking of the Talkeetna watershed is uncertain due to discrepancies between the primary data source and the comparison data source. The Little Susitna watershed was annotated as having inconsistent temporal trends due to a release of hatchery fish from 1988 – 1995 (Oslund et al. 2013).

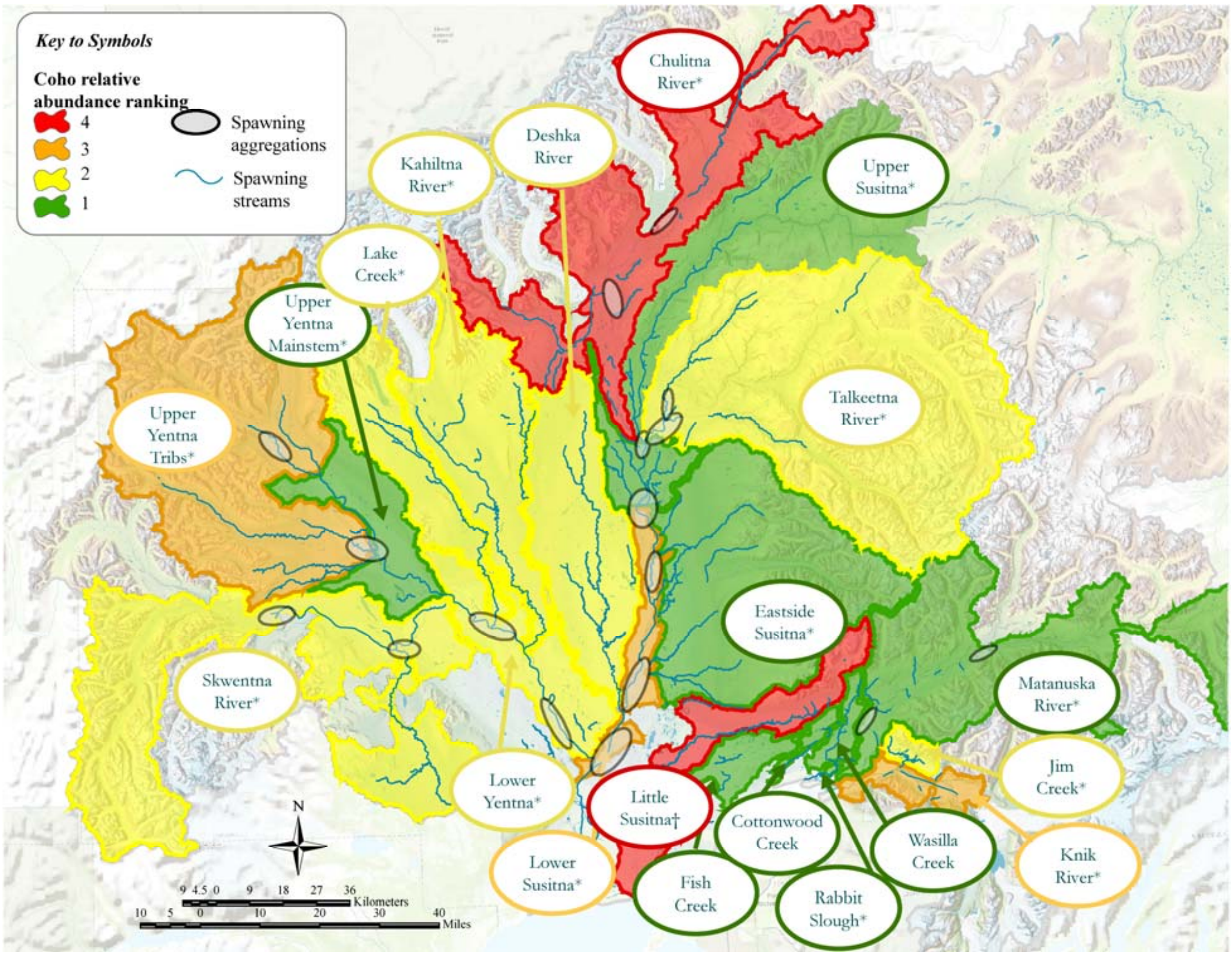

Figure 5. Adult coho salmon abundance rankings by watershed. Watersheds with an * represent areas that have five or less years of data, watersheds with an ** represent areas with discrepancies in ranking results between primary and comparison data sources, and watersheds labeled with a † represent those with an alternative temporal patterns than the majority of the watersheds.

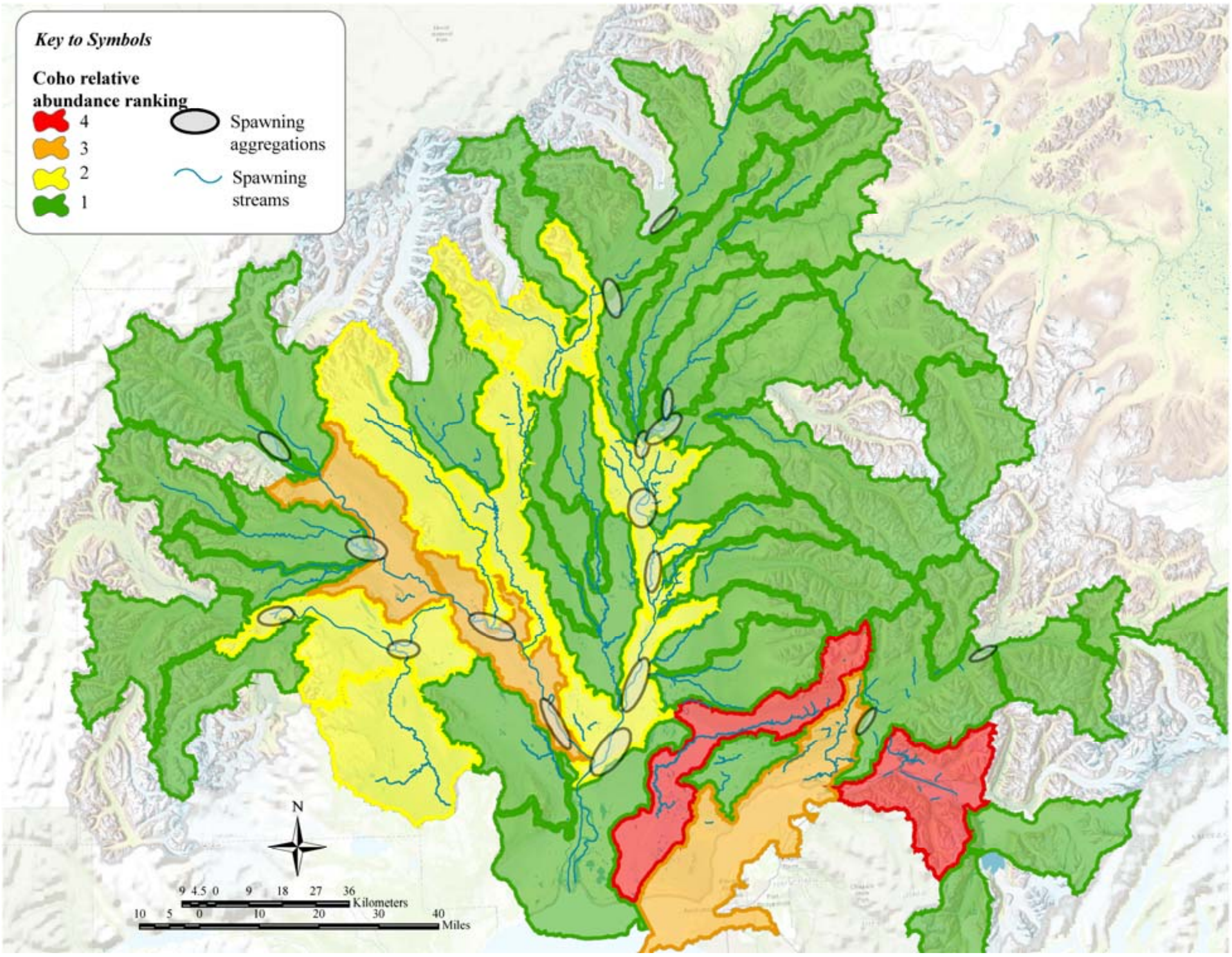

Figure 6. Adult coho salmon abundance rankings normalized by HUC10 watersheds.

Chum salmon

The most highly ranked monitored watershed for chum salmon in the Mat-Su Basin is the Skwentna River (Figure 7). However, all data presented is only based on one year of data collection (Cleary et al. 2013), and no data is available for drainages outside of the Susitna drainage. No watershed has been influenced by hatchery production.

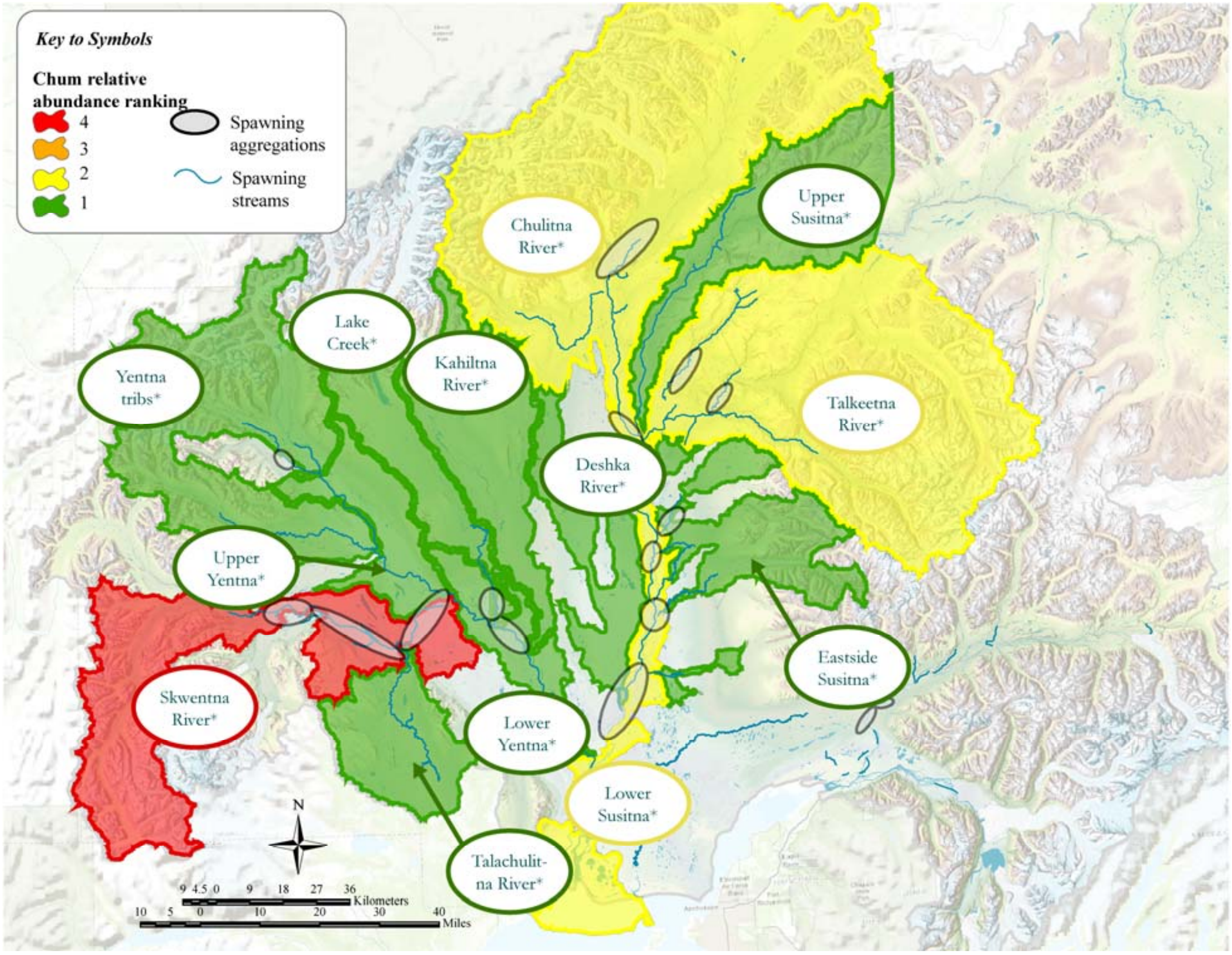

Figure 7. Adult chum salmon abundance rankings by watershed Watersheds with an * represent areas that have five or less years of data, watersheds with an ** represent areas with discrepancies in ranking results between primary and comparison data sources, and watersheds labeled with a † represent those with an alternative temporal patterns than the majority of the watersheds.

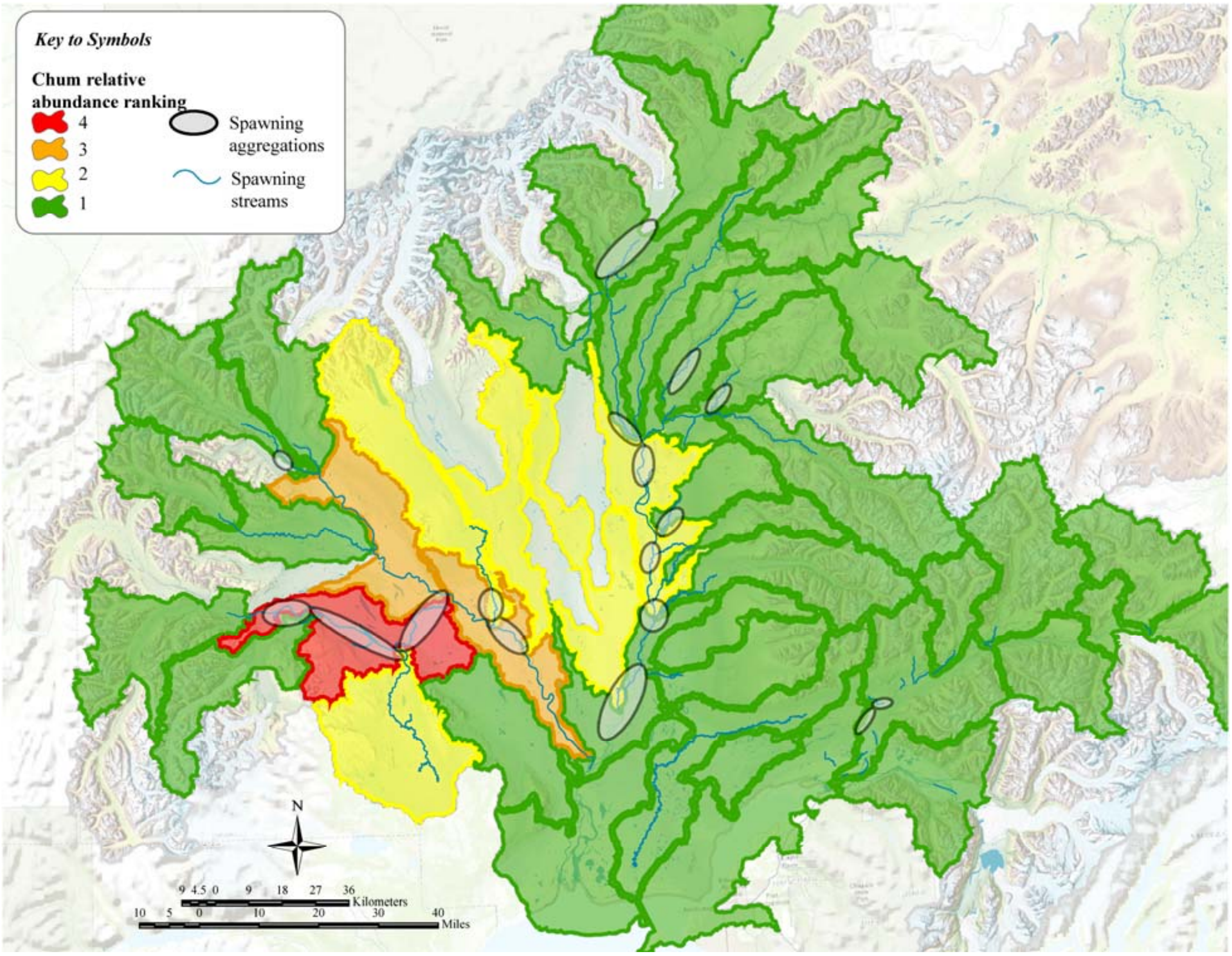

Figure 8. Adult chum salmon abundance rankings normalized by HUC10 watersheds.

Pink salmon

Although watersheds were not ranked by abundance, distribution patterns show pink salmon to mainly spawn in medium to large, clear-water tributaries (Figure 9).

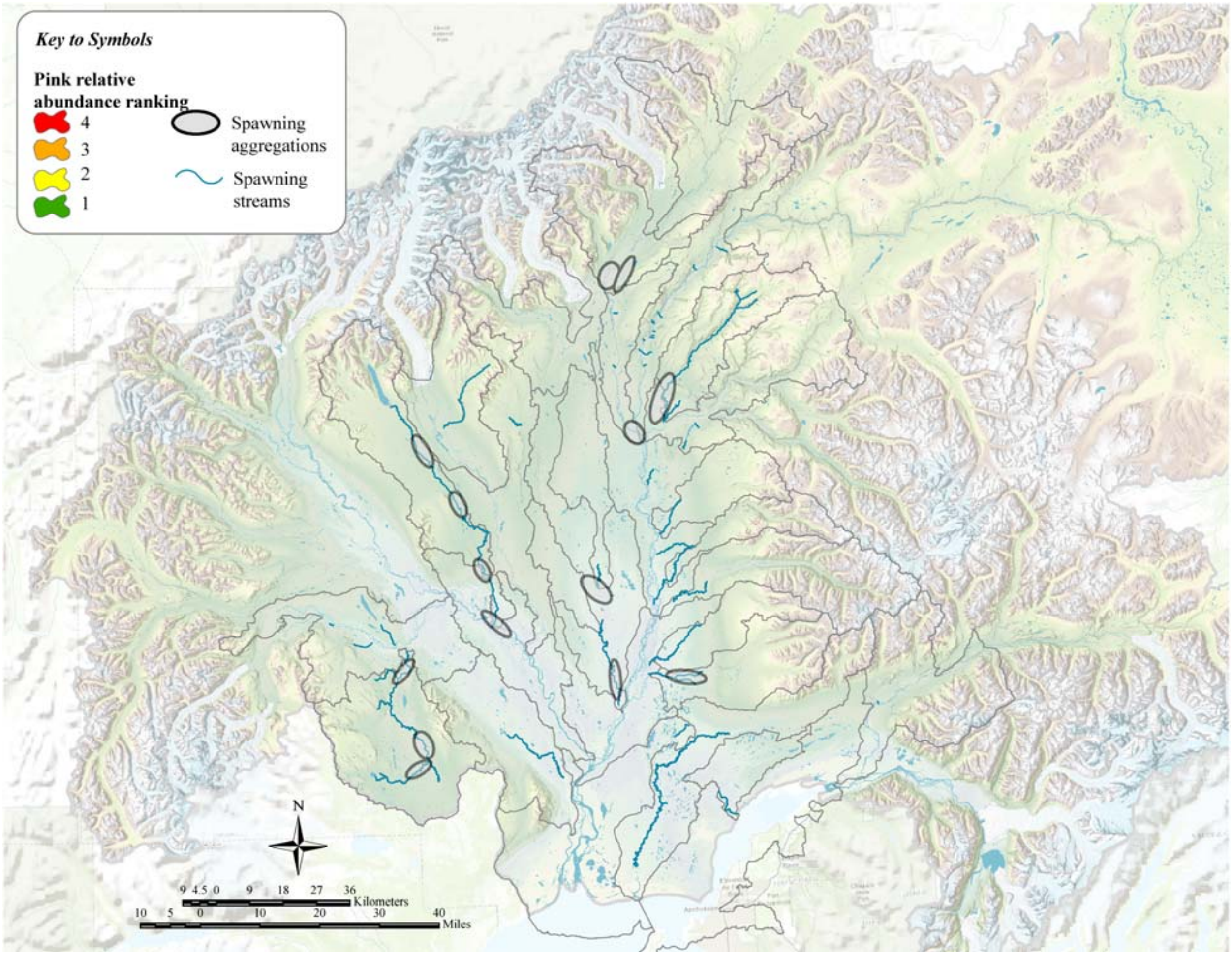

Figure 9. Because of limited datasets, pink salmon abundance by watershed was not ranked. Spawning streams and spawning aggregations are shown instead.

All species

A final dataset showcasing the average rank for all species for each HUC 10 watershed shows that rankings are fairly evenly distributed, with no watershed having an average ranking of 4 (Figure 10). The highest ranked watersheds were the Little Susitna, the Talachulitna, the lower Yentna, and the Lake Creek drainages.

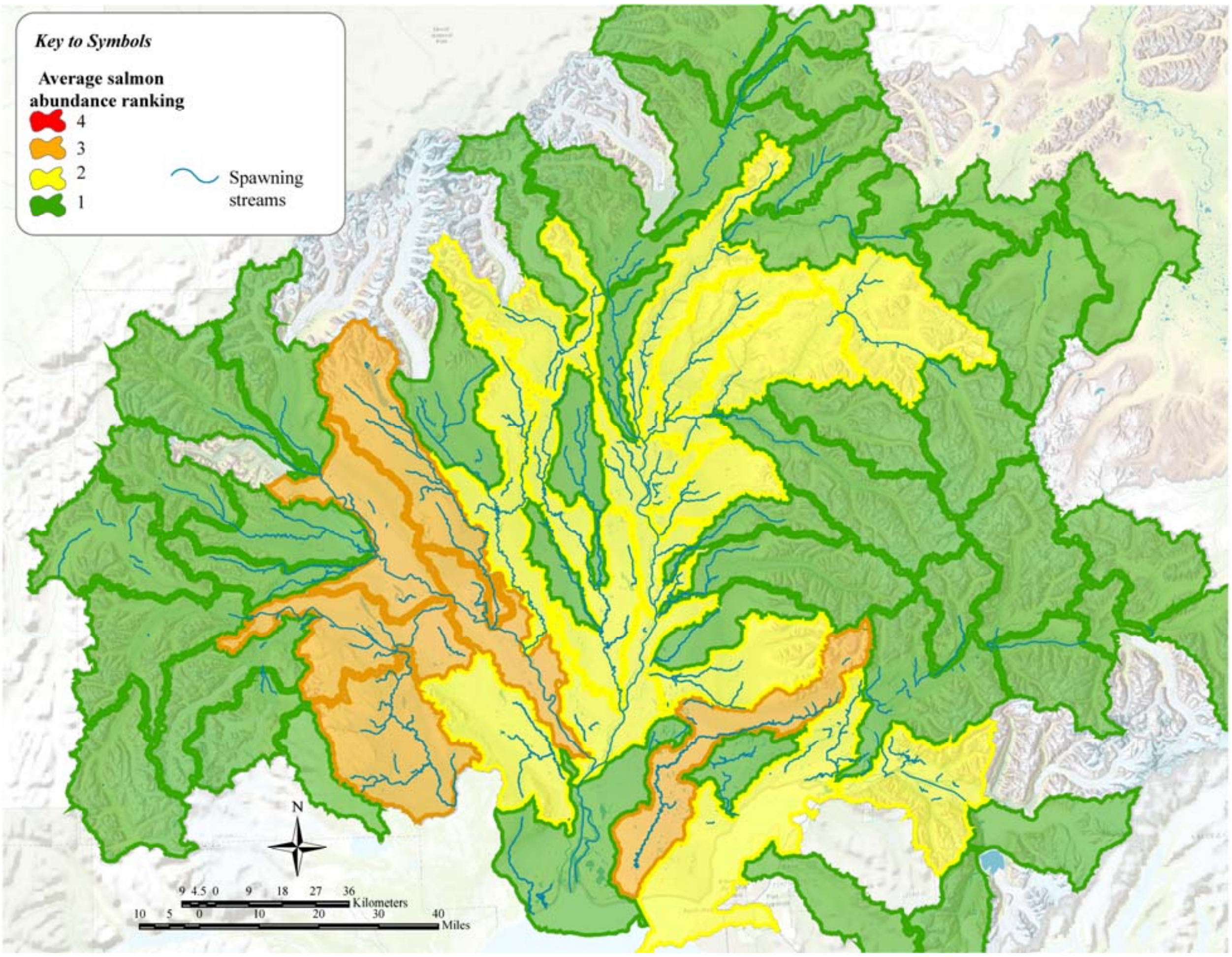

Figure 10. Average salmon abundance ranking by HUC 10 watershed.

Objective 2: Mapping freshwater habitat and intrinsic potential to support juvenile salmon

Methods

Freshwater habitat mapping

In order to map important salmon habitats, we first created a GIS database to characterize freshwater habitat characteristics. Table 1 describes the attributes included in this database, and detailed description of the methods used to derive these characteristics can be found in Appendix A: Mapping Freshwater Habitat Characteristics in the Mat-Su Basin.

Table 1. Freshwater habitat characteristics within the GIS database

Attribute class	Attribute	Definition
Basic characteristics	Elevation	The elevation (m) of downstream end of reach
	Distance to outlet	The distance (km) from the downstream end of reach to the basin outlet
	Distance to upstream end of channel	The distance (km) from the downstream end of the reach to the upstream end of the upstream-most reach on the same channel
	Distance to downstream end of channel	The distance (km) from channel mouth to downstream end of reach.
	Gradient	The slope gradient of each reach
	Maximum gradient downstream	The maximum reach gradient downstream of the reach
	Lake	Whether a reach intersects a lake feature
	Glacier	Whether a reach intersects a glacier feature
Stream size and flow	Strahler stream order	The stream order of the reach using the Strahler method (1964)
	Drainage area	The drainage area (km^2) of the watershed located above each channel segment

	Mean annual precipitation	The mean annual precipitation (m) within the local contributing area located on either side of an individual reach.
	Mean annual flow	The estimated mean annual flow (cms) for an individual reach
	Bankfull width	The estimated bankfull width for an individual reach
	Bankfull depth	The estimated bankfull depth for an individual reach
	Bankfull flow velocity	The estimated flow velocity (m/s) at bankfull depth
	Bankfull discharge	The estimated bankfull discharge (m3/s) of an individual reach
	Stream power	The estimated stream power of an individual reach, which is a measure of the energy of a stream channel including that which is related to the ability to transport sediment
Other fluvial processes	Bed shear stress	The bed shear stress of an individual reach
	Median substrate size	The estimated median substrate size (d50) in an individual reach
	Substrate class	The estimated Wentworth substrate class based on d50
	Sinuosity	The measure of deviation of a channel between two points from the shortest possible path
	Floodplain width	The width of the floodplain, as mapped as contiguous polygons two bankfull depths above the channel
	Valley width	The width of the floodplain, as mapped as contiguous polygons five bankfull depths above the channel
	Valley constraint	The ratio of the valley width to the estimated channel width
	Channel confinement	The degree to which channels are limited in their ability to move laterally
	Rosgen channel classification	The estimated Rosgen channel class, according to the Rosgen stream classification system (Rosgen & Silvey 1996).

	Tributary confluence effect probability	The probability of a reach segment having a tributary confluence effect, based on the estimated probability of tributary effects (Benda et al. 2004a; Benda et al. 2004b)
Other stream habitat characteristics	Beaver habitat	Whether a reach is a potential location of beaver habitat based on an empirical model of beaver dams based on data from the Stilliguamish River basin, Washington (Pollock et al. 2004).
	Invasive pike locations	Whether a reach is documented or susceptible to invasive pike (K. Dunker, ADFG, unpublished data)
	Debris flow effects	The relative potential for landslide-triggered debris flow effects (including scour, traversal, or deposition) within the reach
	Lake size	The size of the lake (km^2) intersected by a reach
	Glacial coverage	The percentage of the watershed above a reach that is covered by glaciers
	Glacier influence	The class of glacial influence for a reach
	Large woody debris type	The type of wood accumulation likely to be found in an individual reach
	Waterfall	Whether a reach is upstream of potential waterfall locations that would serve as salmon migration barriers
	Salmon barrier	Whether a reach is upstream of potential gradient-based salmon migration barriers.
	Natural barrier	Whether a reach is upstream of either potential waterfall locations or potential gradient-based salmon migration barriers.
	Wetland	Whether a reach is intersected by wetland areas
	Wetland class	The wetland type for reaches that intersect wetland areas

Human impacts	Road crossings	Whether roads, as delineated in the Mat-Su borough roads layer cross a reach
	Road density upstream	The road density (road length (km)/sq km) for the contributing area to the downstream end of an individual reach
	Road density downstream	The road density (road length per unit area) for the adjacent contributing area to all reaches downstream.
	Red pipe	Whether a reach has a red pipe on it, as documented in the state of Alaska's fish passage dataset (Alaska Department of Fish and Game 2013)
	Gray pipe	Whether a reach has a gray pipe on it, as documented in the state of Alaska's fish passage dataset (Alaska Department of Fish and Game 2013).

In order to better choose likely explanatory variables, we calculated correlation coefficients between a subset of these characteristics, as we thought it was likely that several variables would be highly correlated.

Rearing habitat model development

To identify relevant habitat characteristics for mapping, we first summarized known salmon-habitat relationships by species for coho, Chinook, and sockeye salmon. We included literature from across the full extent of Pacific salmon distribution and, where available, studies specific to salmon and freshwater habitat in the Mat-Su Basin, as salmon are known to be highly adaptive to local conditions. Next, we proposed conceptual models that used independent habitat characteristics to rank stream reaches from low to high intrinsic potential to support summer and winter rearing. Ranking criteria were developed from known information on salmon-habitat relationships from regional and local studies.

Results

Freshwater habitat mapping

The correlation matrix comparing selected habitat characteristics is shown in Table 2. Correlation coefficients greater than 0.4 or less than -0.4 were found for gradient and elevation, stream order and gradient, valley width and stream order, floodplain width and mean annual flow, valley width and floodplain width, valley width and sinuosity, and probability of tributary effects and stream order.

Table 2. Correlation coefficients between habitat characteristics

	Elevation	Gradient	Stream order	Mean annual flow	Sinuosity	Floodplain width	Valley width	Debris flow effects	Probability of tributary	Wetland coverage
Elevation	1									
Gradient	0.57	1								
Stream order	-0.24	-0.43	1							
MAF	-0.11	-0.08	0.30	1						
Sinuosity	-0.26	-0.32	0.36	0.08	1					
Floodplain width	-0.21	-0.26	0.34	0.41	0.30	1				
Valley width	-0.30	-0.38	0.45	0.28	0.42	0.72	1			
Debris flow effects	0.32	0.38	-0.09	-0.05	0.16	-0.19	-0.26	1		
Probability of tributary	-0.07	-0.19	0.41	-0.02	0.12	0.13	0.11	0.3	1	
Wetland coverage	-0.27	-0.17	-0.00	-0.09	0.15	0.05	0.17	-0.12	-0.01	1

Chinook salmon

Salmon habitat relationships

Across their range, Chinook salmon spend between 3 months and 2 years rearing in freshwater as juvenile fish. Juvenile Chinook salmon have been found in a wide variety of habitats including pools, off-channel habitats, shallow shore habits, springbrooks, and runs; preferences between habitat types are usually found to be related to body size and season (Bjornn & Reiser 1991; Groot & Margolis 1991; Hillman et al. 1987; Holecek et al. 2009; Murphy et al. 1989; Murray & Rosenau 1989; Stanford et al. 2005). In general, Chinook salmon seek out higher velocity instream habitats and larger stream channels than coho salmon due to their larger body size, and mean velocity tends to increase as Chinook salmon grow larger and older (Groot & Margolis 1991; Hillman et al. 1987; Murphy et al. 1989; Taylor 1988). Chinook salmon are also known to seek protective cover using instream features such as large woody debris, overhanging vegetation, and undercut banks (Hillman et al. 1987; Mossop & Bradford 2004; Siedelman & Kissner 1988). Chinook salmon have also been found to respond to water temperature, seeking out thermal refugia in both winter and summer months (Bjornn & Reiser 1991; Ebersole et al. 2003; Taylor 1988). Finally, adequate water quality, including sufficient dissolved oxygen levels and low levels of contaminants, are necessary for juvenile Chinook salmon similarly to other juvenile salmonids (Bjornn & Reiser 1991).

Within the Mat-Su Basin, nearly all of the salmon exhibit a stream-type life history pattern, spending a year rearing in freshwater before outmigrating to the ocean (Alaska Department of Fish and Game 1981, 1982, 1984; Barrett 1985; Delaney et al. 1981; Thompson et al. 1986). Studies within the Susitna watershed as part of the Susitna Hydro project in the 1980s (Delaney et al. 1981; Schmidt & Bingham 1983; Schmidt et al. 1984) on juvenile Chinook salmon habitat utilization patterns during the open water period ("summer") suggest that juvenile Chinook salmon rear in their natal tributaries or in tributary mouths during summer months, seek more cover when found in clear streams versus turbid streams, prefer stream velocities between 0.2 and 0.6 feet per second, and are found in a wide variety of habitat types. Results from summer habitat utilization studies in the mainstem Middle Susitna as part of the recent Susitna Hydropower project (R2 Resources Consultants Inc. 2015) found Chinook salmon fry at depths ranging from 0.2-3.6 feet (highest frequency: 0.6 feet), velocities of 0.2-2.6 feet per second (fps; highest frequency: 0.2 fps), and all substrate sizes (highest frequency: small cobble). Results from summer habitat utilization studies in the mainstem Middle Susitna as part of the recent Susitna Hydropower project (R2 Resources Consultants Inc. 2015) found juvenile Chinook salmon at depths ranging from 0.4-4.2 feet (highest frequency: 1.0 feet), velocities of 0.2-2.4 feet per second (fps; highest frequency: 0.2 fps), and all substrate sizes (highest frequency: small cobble). They were observed during all season in a variety of habitats including tributaries, main channel Susitna River, and off-channel Susitna River, with highest densities being found in upland slough beaver complexes, tributaries, clearwater plumes, and side channels and slow water mesohabitats including beaver ponds, glides, and pools. Initial results from summer juvenile Chinook salmon distribution in Upper Susitna tributaries as part of the recent Susitna Hydropower project (R2 Resources Consultants Inc. 2014) found juvenile Chinook salmon in fast water habitats, including boulder, riffle, and run habitats. These studies also found the highest abundance of juvenile Chinook salmon in spawning tributaries. Juvenile Chinook salmon sampled during winter months were found in shallower and slower water than those sampled in the summer (R2 Resources Consultants Inc. 2015). Studies conducted by the Aquatic Restoration & Research Institute (ARRI) looking at juvenile Chinook salmon within small upland and wetland streams found a much higher abundance of Chinook salmon in upland streams than wetland streams in spring, summer, and fall sampling periods (Davis & Davis 2009; Davis et al. 2015; Miller et al. 2011). A study looking at juvenile Chinook salmon distribution throughout the Mat-Su drainages during summer months found that juvenile Chinook salmon were more likely to be in found in larger streams, and in streams with gradients of less than 3% (Kirsch et al. 2014).

Studies within the Susitna watershed as part of the Susitna Hydropower project in the 1980s on juvenile migration (Roth et al. 1986; Schmidt et al. 1985; Schmidt et al. 1984) suggest that in late summer, many Chinook salmon migrate downstream to tributary mouths or to the mainstem Susitna River, although some remain in their natal tributaries. According to these studies, juvenile Chinook salmon seek out side sloughs and side channels with upwelling as over-wintering habitat. Winter habitat utilization studies in the mainstem Middle Susitna as part of the recent Susitna Hydro project found juvenile Chinook salmon at depths ranging from 0.3-4.1 feet (highest frequency: 0.9 feet), velocities of 0.1-2.3 fps (highest frequency: 0.1 fps), and all substrate sizes (highest frequency: small cobble). A study conducted by ARRI looking at winter habitat utilization by Juvenile Chinook on the Susitna River found the highest concentrations in upland slough and side channels, and no

Chinook in beaver pond habitats; however, habitat variables were unable to explain the variability in sampling, suggesting that fall low flows and ice development may exclude juvenile salmon from overwintering locations, even if habitats are suitable for rearing (Davis & Davis 2015).

Invasive pike in the Mat-Su Basin have been cited as an important top-down influence on salmonid populations where pike are present (Rutz 1999). Pike have been documented consuming large quantities of salmonids, including Chinook juveniles, in select Susitna drainages (Rutz 1999; Sepulveda et al. 2015; Sepulveda et al. 2013), and are assumed to be the reason for significant Chinook salmon declines in Alexander Creek (Oslund et al. 2013).

Distribution data for juvenile Chinook salmon, as described in the AWC (Figure 11; Johnson 2014) shows that juvenile Chinook salmon have been documented in most large systems and tributaries throughout the Mat-Su Basin, with the exception of the Knik River.

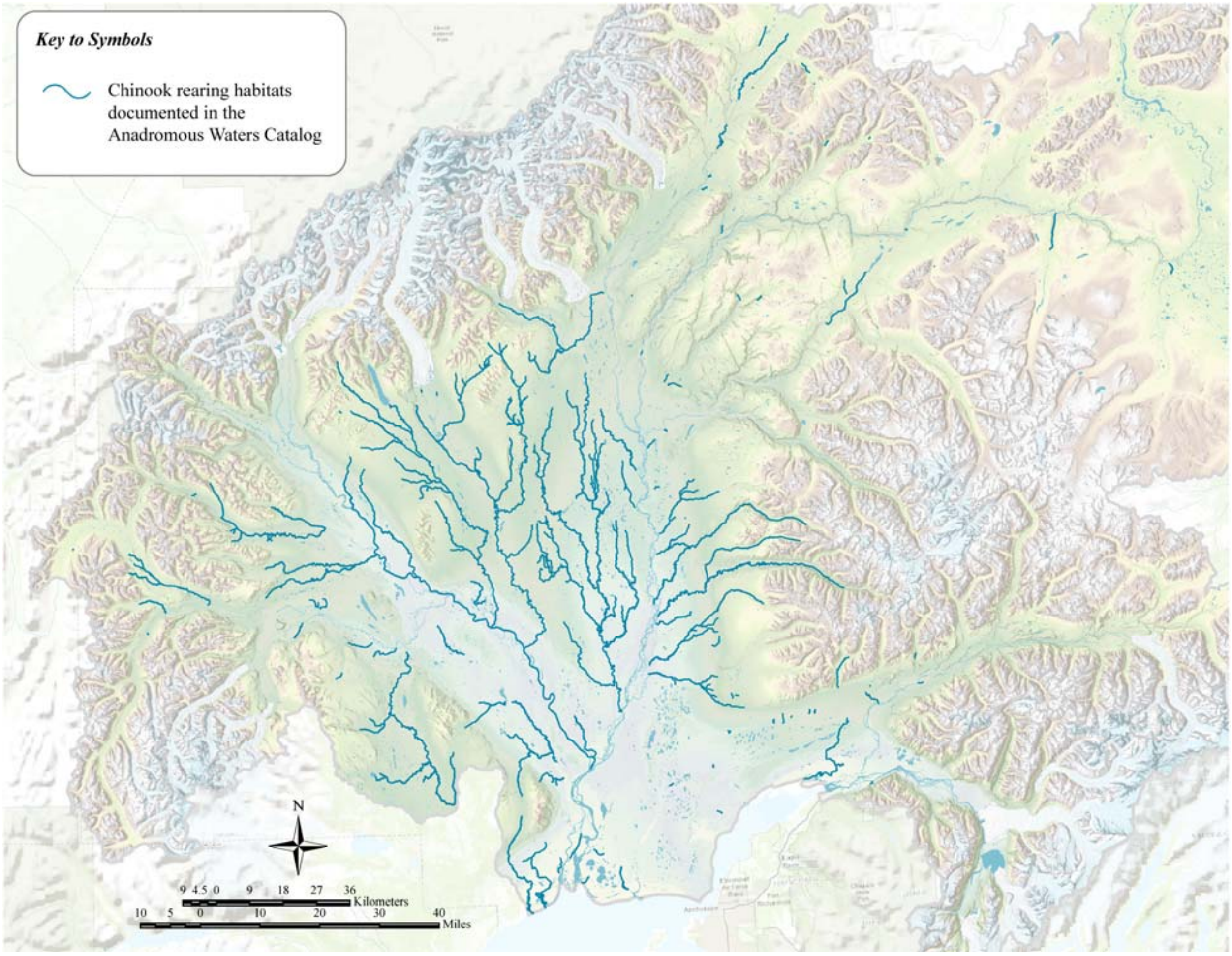

Figure 11. Distribution of Chinook salmon rearing habitats as documented in the AWC (Johnson 2014).

Model selection

A conceptual intrinsic potential model for juvenile Chinook salmon during summer months was created by ranking reaches according to the following criteria (Table 3) based on previously described local and regional research on juvenile Chinook salmon habitat preferences.

Table 3. Stream reach criteria for ranking juvenile Chinook salmon intrinsic potential during summer months.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 5% gradient; streams < 0.5 cubic meters per second (cms) mean annual flow values
Negligible	Streams with gradients of 3-5%; streams considered highly turbid; streams outside of high-ranked Chinook salmon spawning watersheds
Low	Streams with gradients of 0 – 0.5% and 1.5% to 3%
Moderate	Streams with gradients 0.5% - 1.5% and low likelihood of tributary effects (< 0.1)
High	Streams with gradients 0.5% and 1.5% and high likelihood of tributary effects (> 0.1).

A conceptual intrinsic potential model for juvenile Chinook salmon during winter months was created by ranking reaches according to the following criteria (Table 4) based on previously described local and regional research on juvenile Chinook salmon habitat preferences.

Table 4. Chinook salmon winter rearing habitat intrinsic potential ranking criteria.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 5% gradient; streams < 0.5 cms mean annual flow values
Negligible	Streams with gradients > 1.5%; streams considered highly turbid; streams not downstream of high-ranked Chinook salmon spawning watersheds
Low	Highly confined and low probability of tributary effects
Moderate	High probability of tributary effects and high confined
High	Low confinement

Model mapping

Mapping of stream reach intrinsic potential for juvenile Chinook in summer rankings show that highest rankings are in many of the small Eastside Susitna drainages and the Deshka (Figure 12). Mapping of stream reach intrinsic potential for juvenile Chinook in winter rankings show that highest rankings are in mainstem habitats throughout the Susitna Basin (Figure 13).

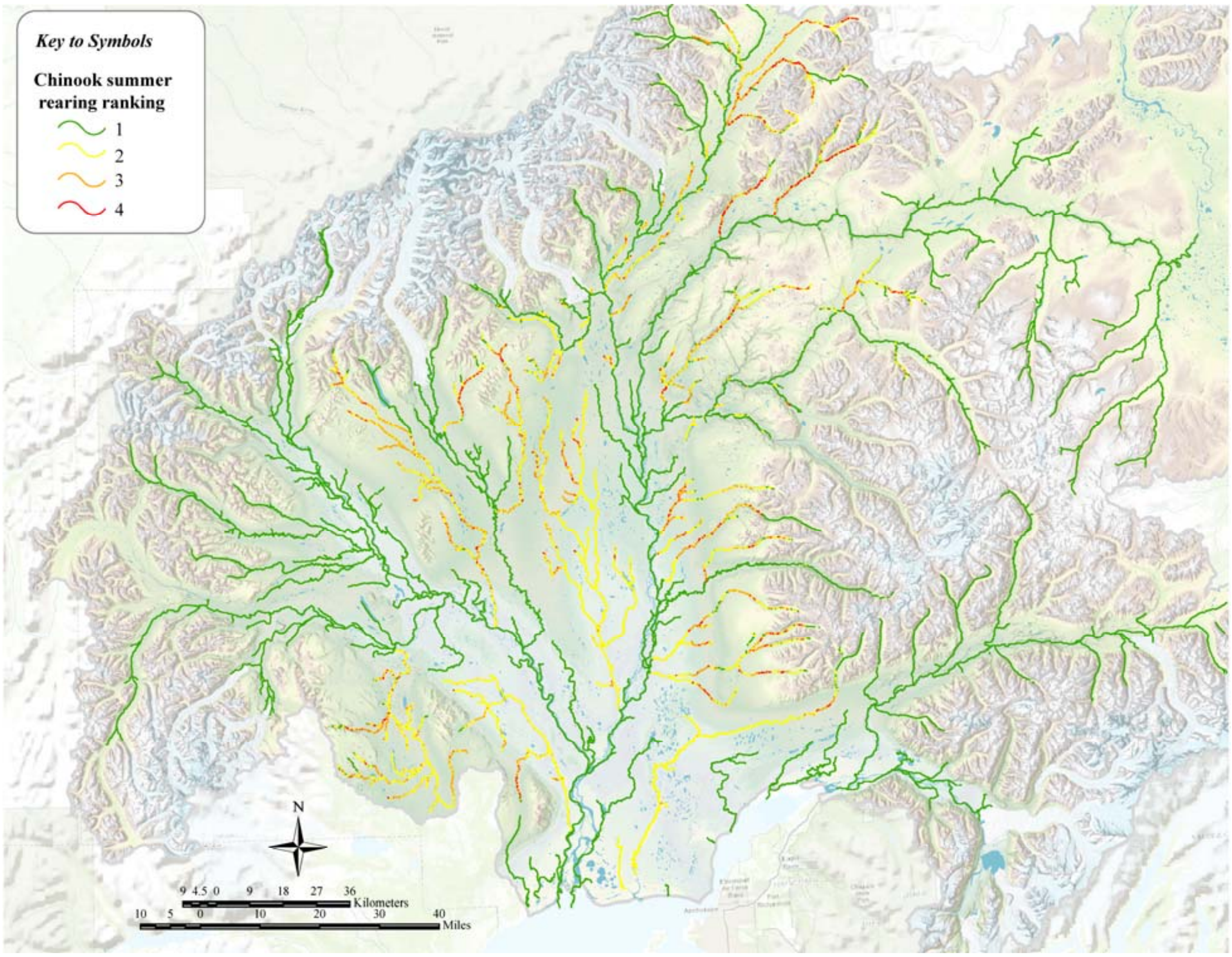

Figure 12. Stream reach intrinsic potential ranking for juvenile Chinook salmon in summer. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

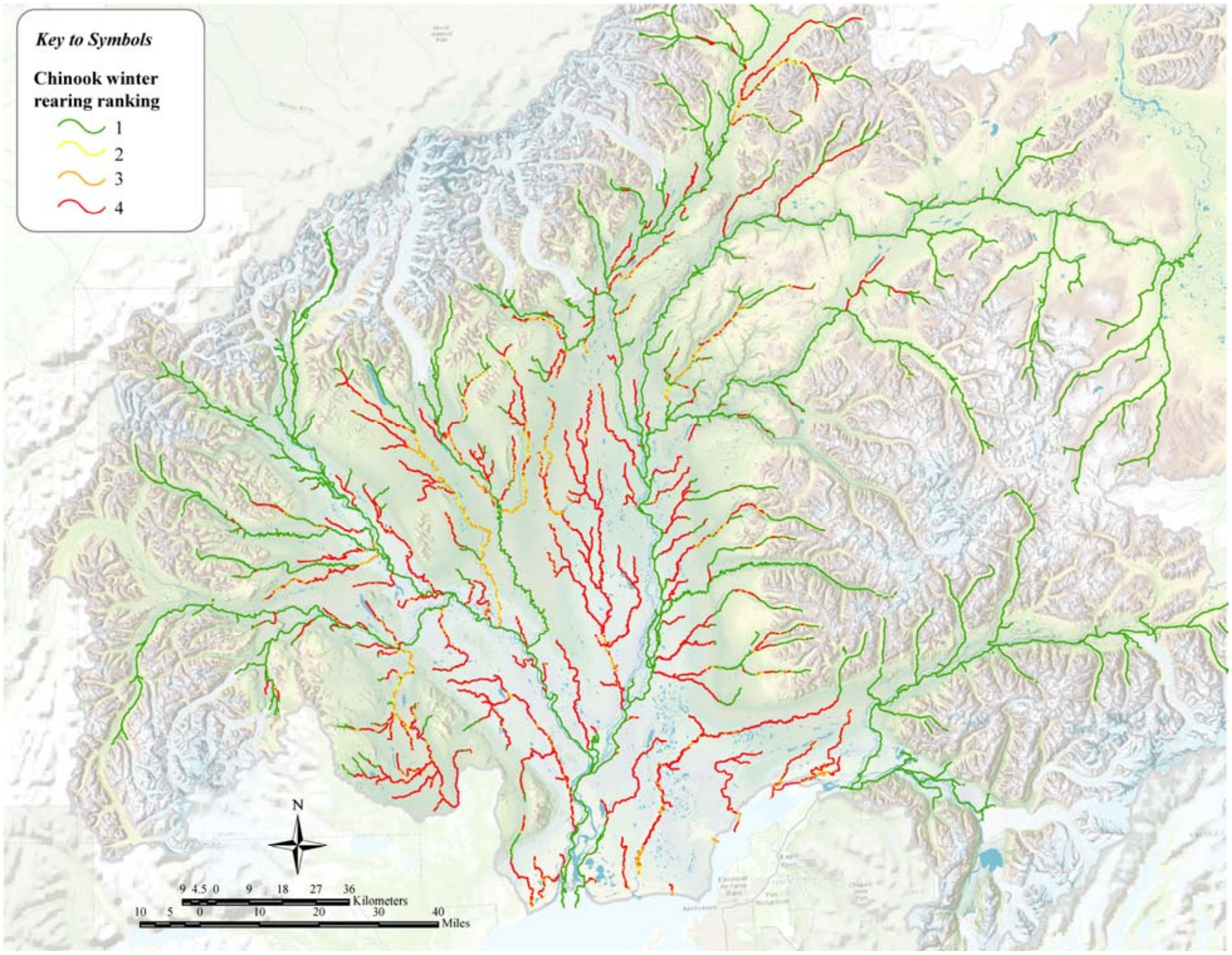

Figure 13. Stream reach intrinsic potential ranking for juvenile Chinook salmon in winter. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

Sockeye salmon

Salmon habitat relationships

The majority of sockeye salmon rear in lakes. They spend most of their time in the limnetic zone, and population productivity tends to be related to growth factors related to water temperature, nutrients, prey availability, lake size, competition, and predator abundance (Groot & Margolis 1991). Because characterization of lake habitats was not part of this analysis and we did not evaluate habitat factors that influence lake-rearing sockeye salmon, for the purpose of this study we simply acknowledge that lake habitats are by far the most productive habitats for juvenile sockeye salmon. Further work in the Mat-Su investigating causes of productivity of sockeye salmon in lake systems can be found in a variety of sources (Edmundson et al. 2000; King & Walker 1997; Litchfield & Willette 2002; Willette & Fandrei 2013).

An alternative life history strategy for sockeye salmon involves river rearing associated with sockeye salmon that spawn in rivers not associated with lakes, also known as "river-type" or "stream type" sockeye salmon (Groot & Margolis 1991). These are often associated with glacial-fed systems (Gustafson & Winans 1999). Juvenile river-type sockeye salmon are not well studied but it has been suggested that they use side-channel and off-channel river habitat for one or two years of rearing (Gustafson & Winans 1999; Murphy et al. 1989).

Scale samples of outmigrating Susitna River salmon have demonstrated that the majority of these fish had a stream-type life history pattern, with most (90%) of these fish exiting during their second year, and the rest outmigrating as fry or during their third year (R2 Resources Consultants 2013). These scale samples only represent the successful life history patterns of adults returning from sea.

Local studies looking at habitat utilization of juvenile sockeye salmon are mostly confined to those conducted in the Lower and Middle Susitna River as part of the Susitna River Hydropower studies of the 1980s and recent years. During the open water season, sockeye salmon were most abundance in low velocity backwater and sloughs of turbid mainstem water (R2 Resources Consultants Inc. et al. 2014; Schmidt & Bingham 1983; Schmidt et al. 1985; Schmidt et al. 1984). In 2014, sockeye fry were found most frequently at velocities of 0.1 fps (range 0.1-7 fsp) and of depths at 0.7 feet (range 0.1 – 3.3 feet), whereas juvenile sockeye salmon were found most frequently at velocities of 0.1 fps (range 0.1-0.5 fsp) and of depths at 1.3 feet (range 0.7 – 3.3 feet; (R2 Resources Consultants Inc. 2015). Sockeye fry and juveniles were found in a wide range of substrate types, but most frequently associated with fine substrates (R2 Resources Consultants Inc. 2015). A study looking at juvenile sockeye salmon distribution throughout the Mat-Su drainages during summer months found that juvenile sockeye salmon were more likely to be in found at lower elevations, more turbid streams, and in streams with gradients of less than 2% (Kirsch et al. 2014). Studies have also documented pike predation on sockeye salmon in large numbers (Rutz 1999) where pike and sockeye salmon are present.

Studies that look at river-type juvenile sockeye salmon during winter periods within the drainage are even scarcer. All studies that looked at juvenile sockeye salmon habitat use in the winter found them to be most abundance in upland and side sloughs (R2 Resources Consultants Inc. et al. 2014; Schmidt & Bingham 1983; Schmidt et al. 1985).

Sampling of outmigrating smolt at various locations during 1984 and 1985 (Roth et al. 1986; Schmidt et al. 1985; Schmidt et al. 1984) do not necessarily provide robust information on patterns of habitat-related or spatially explicit growth and survival, although it was suggested that growth potential for fry overwintering in the Middle and Lower Susitna River was low compared to fry that rear in lake systems (Roth et al. 1986).

Distribution data for juvenile sockeye salmon, as described in the AWC (Figure 14; Johnson 2014) shows sockeye salmon rearing in the western drainages of the Susitna and the Knik watershed. Very little abundance information is available for river-type sockeye salmon in the Mat-Su Basin, although there has been estimation of juvenile and smolting sockeye salmon from numerous lake systems over the years including Big Lake (Chlupach & Kyle 1990; Litchfield & Willette 2002; Shields & Dupuis 2013; Weber 2009), Swan Lake (Weber 2013c), Byers Lake (King & Walker 1997; Kyle et al. 1994; Weber 2013a), Stephan Lake (Cook Inlet Aquaculture Association 2013d), Judd Lake (Cook Inlet Aquaculture Association 2013b; King & Walker 1997; Kyle et al. 1994), Larson Lake (Cook Inlet Aquaculture Association 2013c; King & Walker 1997; Kyle et al. 1994), Shell Lake (King & Walker 1997; Kyle et al. 1994; Weber 2013b), Chelatna Lake (Cook Inlet Aquaculture Association 2013a; King & Walker 1997; Kyle et al. 1994), Hewitt Lake (King & Walker 1997; Kyle et al. 1994), and Redshirt lake (Kyle et al. 1994).

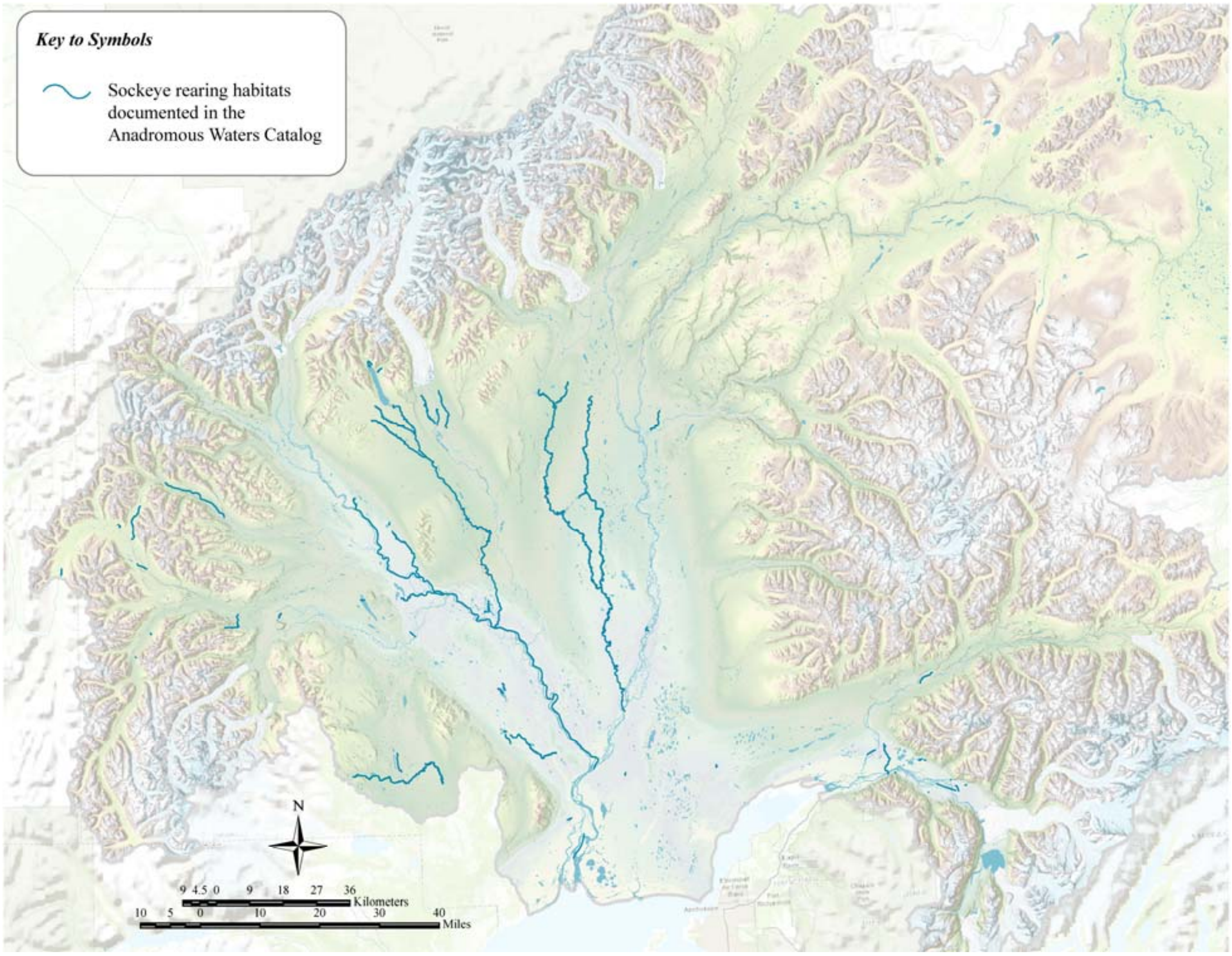

Figure 14. Distribution of sockeye salmon rearing habitats as documented in the AWC (Johnson 2014).

Model selection

A conceptual intrinsic potential model for juvenile sockeye salmon was created by ranking reaches according to the following criteria (Table 5) based on previously described local and regional research on juvenile sockeye salmon habitat preferences. No distinction was made between summer and winter seasons as it is likely that these habitats are similar.

Table 5. Sockeye salmon rearing habitat intrinsic potential ranking criteria.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 2% gradient; streams < 0.5 cms mean annual flow values; streams that are both not wetlands and not glacially influences
Negligible	Wetland streams
Low	Glacially influenced streams
Moderate	Lakes > 1.5 km^2
High	Judd, Larson, and Chelatna Lakes

Model mapping

Mapping of stream reach intrinsic potential for juvenile sockeye salmon rankings show that highest rankings are in large lakes, but also highlight the importance of mainstem habitats in glacial and wetland streams.

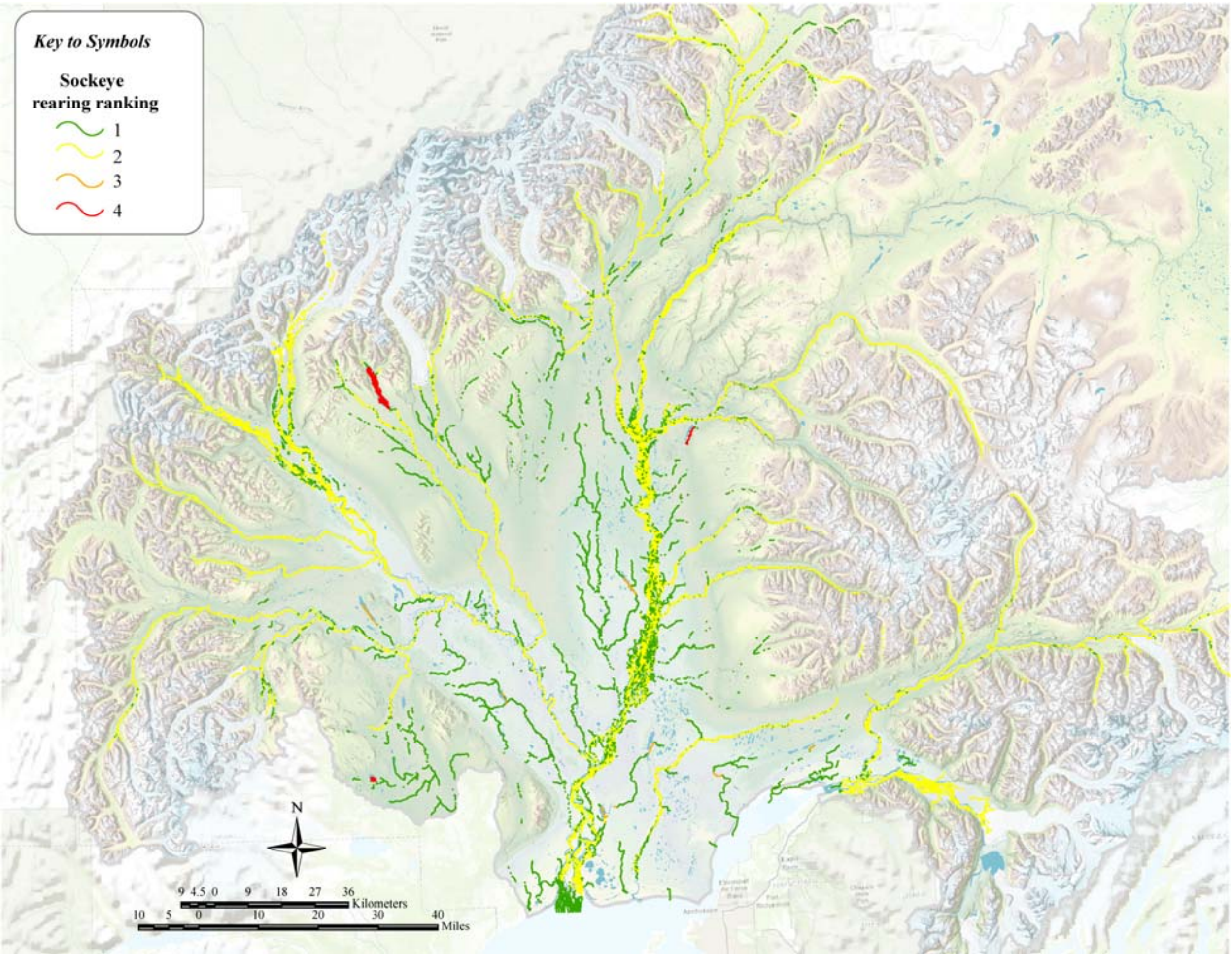

Figure 15. Stream reach intrinsic potential ranking for juvenile sockeye salmon in summer. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

Coho salmon

Salmon habitat relationships

Freshwater habitat selection by juvenile coho salmon has been the subject of studies across their range. Coho salmon prefer to rear in pool, off-channel, shallow shore, springbrook, and beaver pond habitats particularly in smaller streams (Beechie et al. 1994; Bisson et al. 1988; Bjornn & Reiser 1991; Brown et al. 2011; Bugert et al. 1991; Bustard & Narver 1975; Groot & Margolis 1991; Heifetz et al. 1986; McMahon 1983; Nickelson et al. 1992; Nickelson & Lawson 1998; Pollock et al. 2004; Quinn & Peterson 1996; Quinn 2005; Reeves et al. 1989; Rosenfeld et al. 2000; Sharma & Hilborn 2001; Solazzi et al. 2000; Stanford et al. 2005). Water temperature is an important habitat feature, both during winter and summer months (Holtby 1988; Konecki et al. 1995; Madej et al.

2006; Power et al. 1999). Depth and velocity preferences have been established for various coho populations, with coho tending towards slower water velocities than Chinook salmon, and faster velocities as they grow older (Beecher et al. 2002; Bjornn & Reiser 1991; Taylor 1988). Cover provided by overhanging vegetation, undercut banks, and large woody debris is also a well-studied habitat feature (Bjornn & Reiser 1991; Bugert et al. 1991; Heifetz et al. 1986; McMahon & Hartman 1989; Reinhardt & Healey 1997). Food availability associated with habitat features including overhanging vegetation and substrate are also important (Allan et al. 2003). Finally, adequate water quality, including sufficient dissolved oxygen levels and low levels of contaminants, are necessary for juvenile coho salmon similarly to other juvenile salmonids (Bjornn & Reiser 1991).

Within the Mat-Su Basin, it is estimated that 50-60 % of coho salmon migrate from freshwater after their third year, and 30-45% after their second (Delaney et al. 1981; Roth et al. 1986; Schmidt & Bingham 1983; Schmidt et al. 1985; Schmidt et al. 1984). Several studies within the Basin have looked at juvenile coho summer rearing preferences. Studies within the Susitna watershed as part of the Susitna Hydro project in the 1980s (Delaney et al. 1981; Roth et al. 1986; Schmidt & Bingham 1983; Schmidt et al. 1984) found the highest densities of juvenile coho salmon near clear water tributary mouths in the mainstem, as well as side sloughs, upland sloughs, and tributaries. In addition, these studies suggested that juvenile coho prefer debris, undercut banks, and beaver habitats to turbid water or substrate for cover purposes. Summer juvenile coho salmon sampling in the Susitna River drainage as part of the recent Susitna Hydro project (R2 Resources Consultants Inc. 2015) found similar results. Coho fry microhabitat depth measurements were shallower than those of coho juvenile, with fry utilization ranged from 0.2-3.2 feet with the highest frequency occurring at a depth of 0.8 feet, and juvenile utilization ranging from 0.4-4.6 feet with highest frequency occurring at depths from 1.6-2.0 feet. Both fry and juvenile coho velocity ranged from 0.2 – 1.8 fps, with the highest frequency occurring at velocities of 0.2 fps. This study found the highest counts of juvenile coho in slow water, including pools, beaver habitats, side sloughs, and upland sloughs. A study looking at juvenile coho salmon distribution throughout the Mat-Su drainages during summer months found that juvenile coho salmon were more likely to be in found in smaller, warmer, less turbid streams, and in streams with gradients of less than 3% (Kirsch et al. 2014). Studies conducted among several tributaries within the Matanuska-Susitna Basin by ARRI found more biomass and higher growth rates for coho salmon in wetland streams than in upland streams (Davis & Davis 2009, 2010; Davis et al. 2015). A 2-year study conducted on upland tributaries of the Little Susitna River found that upstream extent of juvenile coho was limited by elevation and generally by a gradient of 5% (Foley 2014). Finally, studies looking at juvenile coho in the Big Lake watershed found that coho prefer mainstem and tributary habitats in the summer (Gerken & Sethi 2013).

Studies from the Susitna drainage suggest that most, but not all, juvenile coho emigrate from their natal tributaries after their first summer, and there is no evidence that these fish move into new tributaries (Delaney et al. 1981; Roth et al. 1986; Schmidt & Bingham 1983; Schmidt et al. 1985; Schmidt et al. 1984). Instead, they were found most often in sloughs and side channels during winter months. Juvenile coho salmon sampled during winter months were found in shallower and slower water than those sampled in the summer (R2 Resources Consultants Inc. 2015). Studies looking at juvenile coho in watersheds outside the Susitna River drainage suggest that coho can move into lake or wetland habitats during winter months (Benolkin & Sethi 2012; Gerken & Sethi 2013).

Distribution data for juvenile coho salmon, as described in the AWC (Figure 16; Johnson 2014) shows that juvenile coho have been documented in most low-gradient streams throughout the basin.

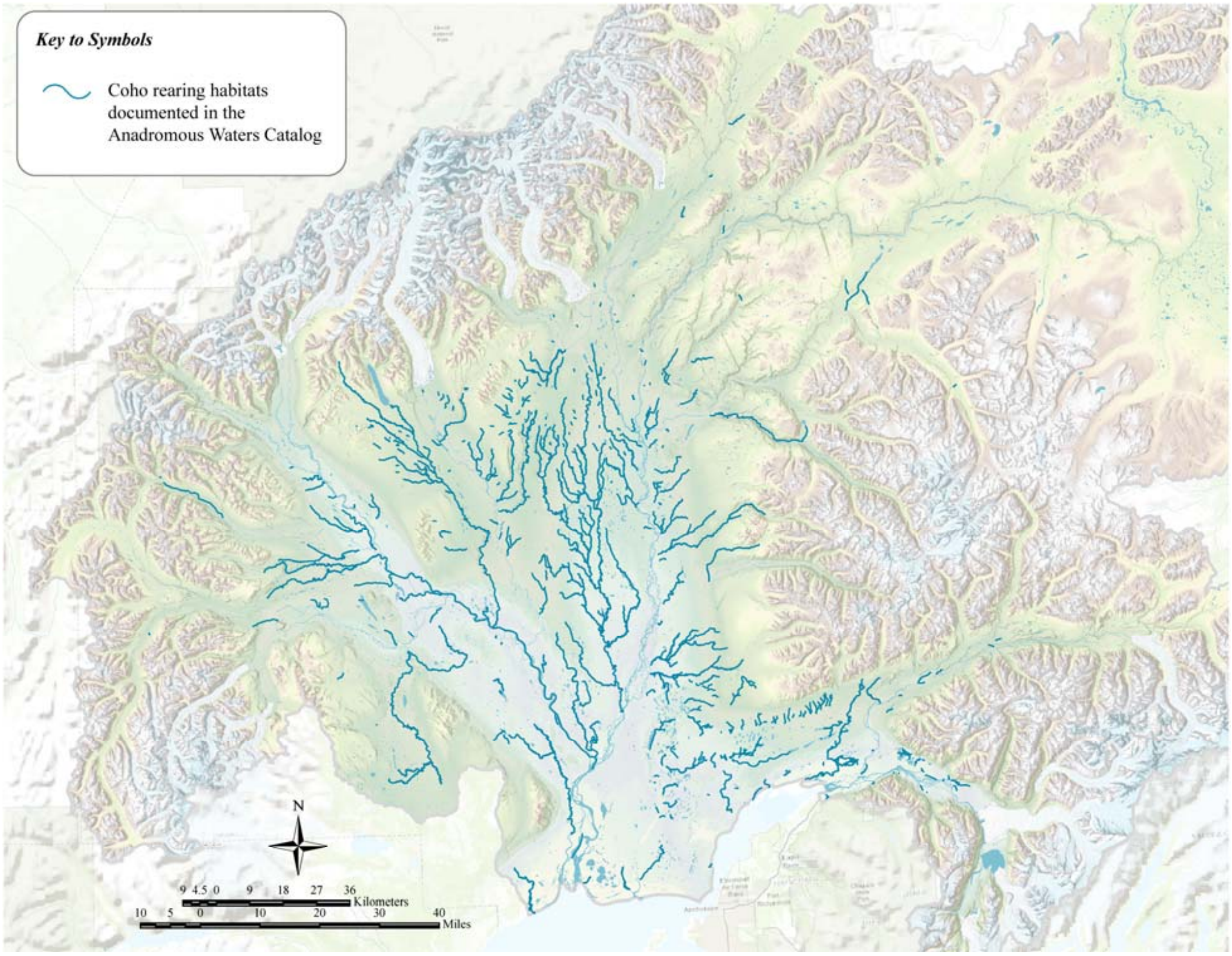

Figure 16. Distribution of coho salmon rearing habitats as documented in the AWC (Johnson 2014)

Model selection

Conceptual intrinsic potential models for juvenile coho salmon during summer (Table 6) and winter (Table 7) months were created by ranking reaches according to the following criteria based on previously described local and regional research on juvenile coho salmon habitat preferences.

Table 6. Coho salmon summer rearing habitat intrinsic potential ranking criteria.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 5% gradient; lakes
Negligible	Stream order > 7
Low	Gradient > 2%
Moderate	Confined streams
High	Unconfined and wetland streams

Table 7. Coho salmon winter rearing habitat intrinsic potential ranking criteria.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 5% gradient;
Negligible	Gradient > 2% and mean annual flow values < 0.5
Low	Confined streams
Moderate	Unconfined, not wetlands
High	Wetland streams

Model mapping

Mapping of stream reach intrinsic potential for juvenile coho in summer rankings show that abundance of high quality habitat is distributed throughout the Susitna and Matanuska watersheds (Figure 17). Mapping of stream reach intrinsic potential for juvenile coho in winter rankings show less abundant but evenly distributed winter habitats throughout the Susitna and Matanuska Basins (Figure 18).

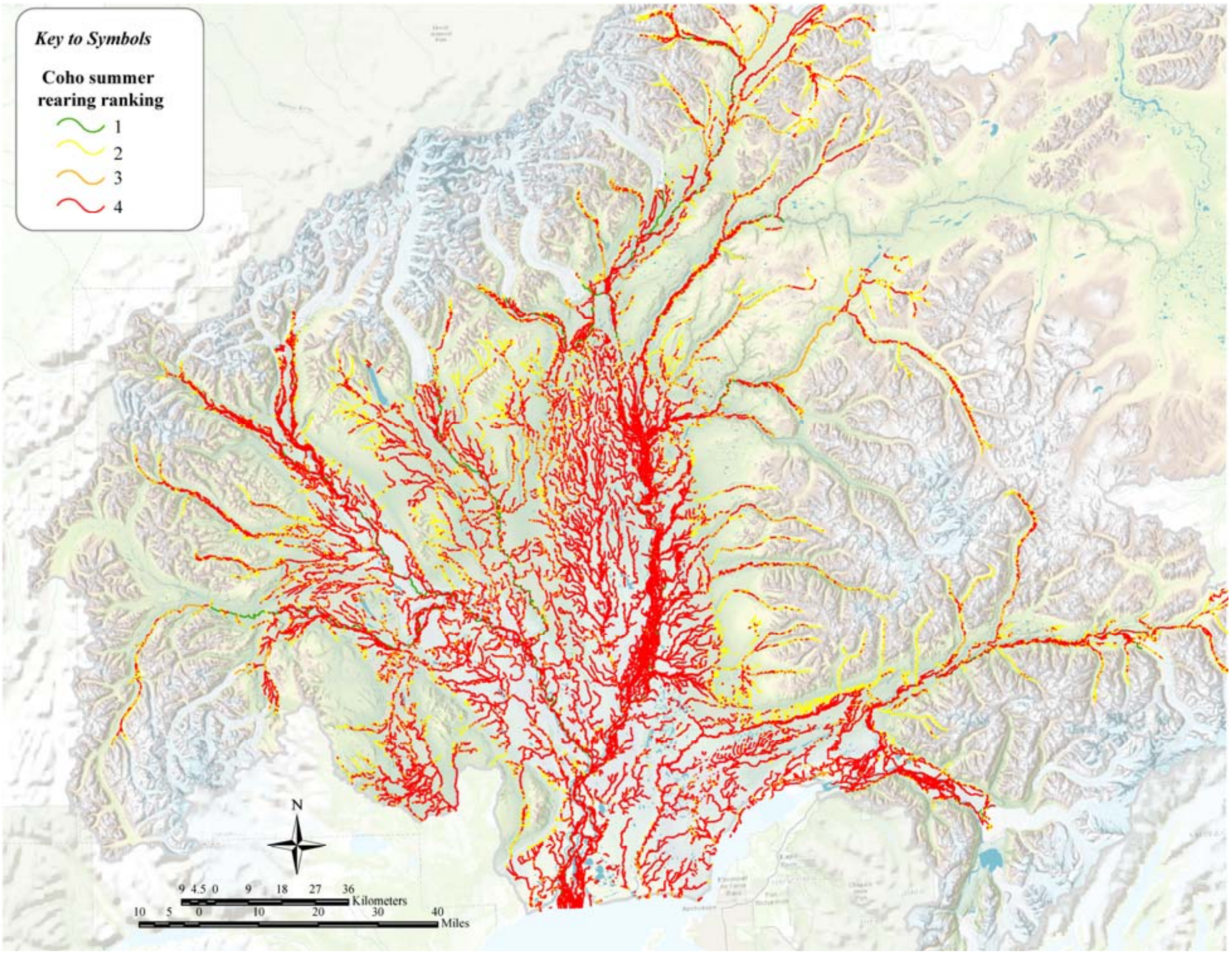

Figure 17. Stream reach intrinsic potential ranking for juvenile coho salmon in summer. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

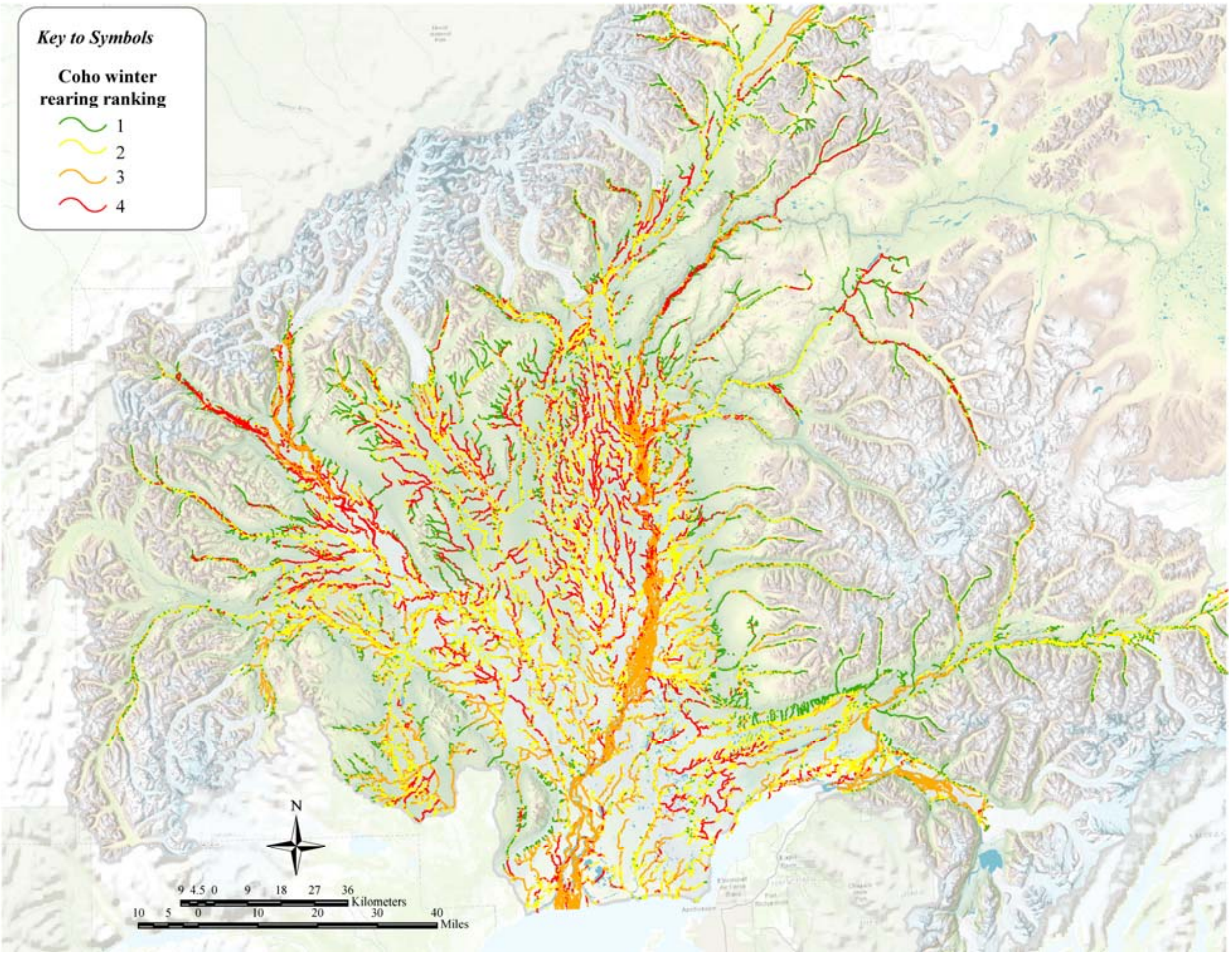

Figure 18. Stream reach intrinsic potential ranking for juvenile coho salmon in summer. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

All species

Average rearing habitat ranking for Chinook, coho, and sockeye salmon (both summer and winter) were calculated and mapped. Results showcase the wide distribution of rearing habitats across the basin (Figure 19).

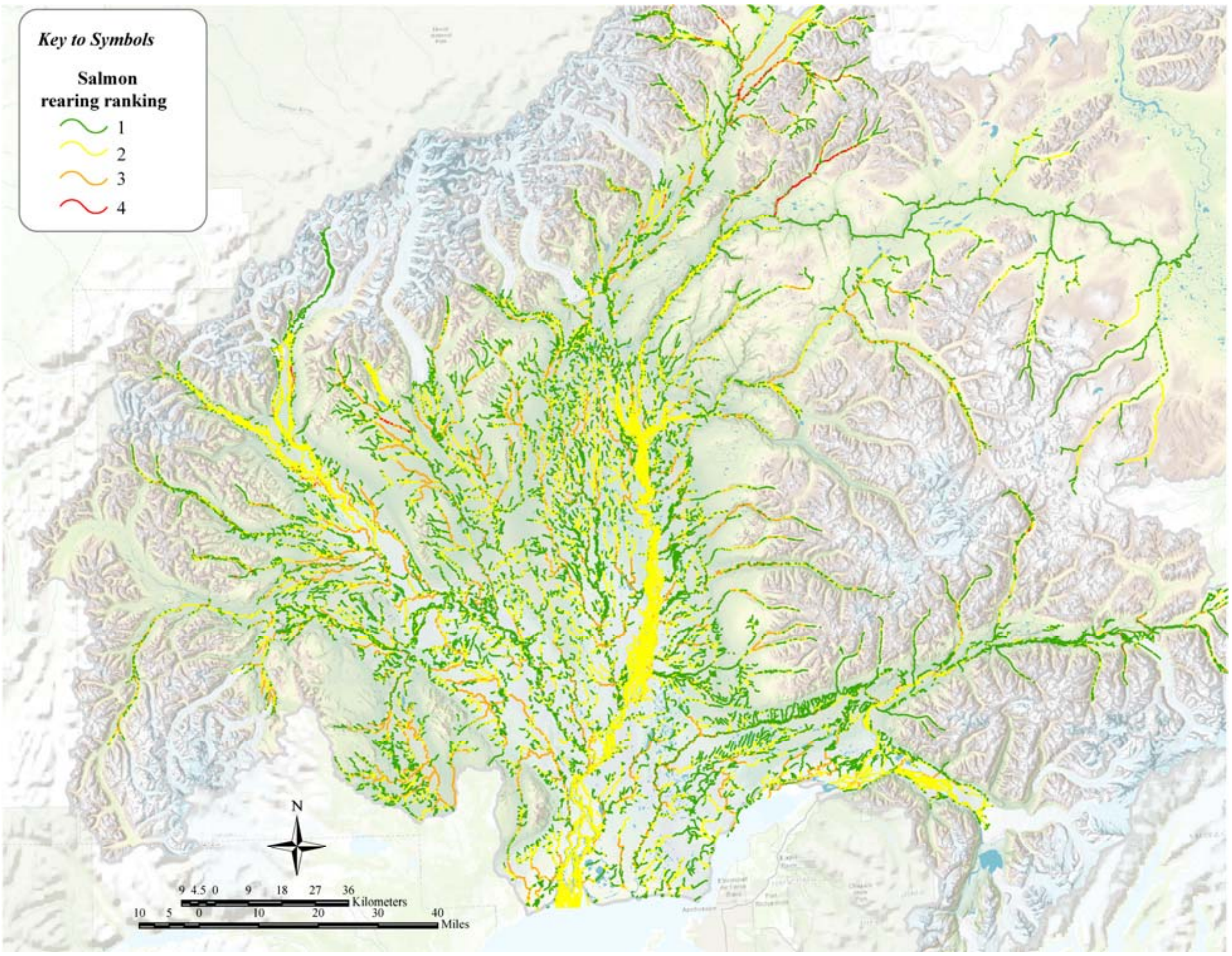

Figure 19. Average stream reach intrinsic potential ranking for all species. 1 symbolizes negligible intrinsic potential, 2 symbolizes low intrinsic potential, 3 symbolizes moderate intrinsic potential, and 4 symbolizes high intrinsic potential.

Objective 3: Limitations, Recommendations, and Conclusions

This thorough review of information available on salmon abundance and habitat distribution by species and life stage within the Matanuska-Susitna Basin provides the opportunity to reflect on the state of information for landscape-scale planning that seeks to prioritize protection of salmon habitats and salmon populations in this location. Although the methods presented above offer a novel approach to developing the datasets necessary to do this type of planning, we wish to summarize potential research directions that will allow for more accurate datasets.

Efforts by the ADFG to monitor catch and escapement annually or periodically provide useful datasets to understand consistent patterns in use of specific watersheds by species for Chinook, sockeye, and coho salmon. This type of information is lacking for chum and pink salmon, which is not surprising due to the lesser value of these species for commercial, sport, or subsistence fisheries. Likewise, the telemetry studies performed in recent years are a major step forward in understanding important spawning locations within the Susitna drainage. Several years of telemetry data are not presented in this study because the data has not yet been published, and incorporation of this data into these models at a later date will be useful. Explicit analysis of this telemetry data will present the opportunity to compare patterns in spawning to the reach-level freshwater habitat characteristics generated in this study. Better understanding of these habitat relationships may allow spawning patterns to be estimated on a finer scale, similar to the work completed in this study on rearing habitats. In addition to providing information a finer scale, similar analyses may allow for estimating of abundance and spawning patterns outside of the Susitna drainage, or within the Susitna for species that have very few years of data, i.e., pink and chum salmon.

It is widely recognized that Pacific salmon exhibit considerable life-history diversity, and that this life-history diversity contributes to the resilience of salmon populations (Hilborn et al. 2003; Schindler et al. 2010). Chinook salmon was the only salmon species in the Mat-Su for which there was enough annual data to assess whether patterns in relative abundance between watersheds changed over time. Although the data still provided valuable snapshots of the most likely current patterns in salmon abundance, and some information on the variability in abundance between systems, it is likely that some of these species may exhibit considerable variability in their relative abundance overtime, especially with sockeye salmon and their apparent life-history diversity within the Mat-Su. Only with additional studies over time can the true variability and complexity of these populations be assessed.

Although many of the habitat characteristics modeled were parameterized using local datasets, several of the characteristics could benefit from ground-truthing and localized models. Models that calculated geomorphological characteristics and substrate did not take into account the influence of glacial runoff and associated braiding, and thus are less accurate in glacial streams in the Mat-Su. Characteristics related to beaver habitat, debris flow effects, and large woody debris should be parameterized in areas more ecologically similar to the Mat-Su Basin. There are several freshwater habitat characteristics likely important to juvenile salmon that are not directly quantifiable from our elevation-derived methods. The influence of beaver activity on both spawning and rearing habitats for different species is an important issue in the Mat-Su Basin (Beamesderfer et al. 2015; HDR Alaska Inc. 2011; Oslund 2015), and is not directly quantifiable by these methods currently. Likewise, water temperature, groundwater inputs, and ice formation processes all likely have significant impacts on juvenile habitats in the Mat-Su, especially during winter months (Beamesderfer et al. 2015; HDR Alaska Inc. 2011; Mat-Su Basin Salmon Habitat Partnership 2013), and are not explicitly modeled in our study. The habitat mapping work completed as part of this project focused exclusively on characterizing river habitats. Given that salmon, especially sockeye salmon, utilize lake and wetland habitats, more habitat characterization directly focused on lake habitats would be beneficial for understanding lake productivity and its influence on salmon production.

The reach-scale habitat models developed in this study to look at rearing habitat are only conceptual, and not based in empirical data. Furthermore, summer habitat use by juvenile coho and Chinook salmon has been documented in the Mat-Su and elsewhere, but less is known about juvenile salmon habitat relationships for river-type sockeye salmon, or winter habitat use by any species. Explicit attempts to quantify the relationships between juvenile abundance and habitat characteristics that can be described over large landscapes using field-based methods will dramatically improve both the precision and accuracy of these reach-scale rearing models.

Understanding watershed-scale adult salmon abundance and reach-scale juvenile rearing habitats are only two steps crucial to being able to quantify the potential impacts of land use on salmon production. Life stage habitat requirements including those during migration as adults, juveniles, and smolts, as well as during the development of eggs in the gravel are also important. Ideally, the development of a life-stage specific survival model (e.g., Scheuerell et al. 2006) coupled with habitat mapping could provide the most useful quantification of impacts of habitat degradation on salmon populations.

This study is useful for planning and prioritization for sustainable development, conservation, and restoration activities near important salmon habitats within Mat-Su Basin. It highlights several key areas within the basin notable for high abundance of habitats for each species. However, when taken as a whole, it is clear that maintaining productivity and diversity of salmon requires attention to a broad spectrum of habitats across the landscape. Given the documented importance of this diversity to the resilience of salmon and the salmon fisheries that they support (Hilborn et al. 2003; Schindler et al. 2010), it may be worthwhile to conduct prioritization efforts in the context of this diversity.

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Appendix A

Ranking Methodologies

The Nature Conservancy
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Introduction

As described in the main document, in order to map important adult salmon habitats by species in the Mat-Su Basin, watersheds were first ordinally ranked according to likely relative adult abundance. Rankings of 1-4 were chosen to represent 4 separate quantiles of relative abundance, with watersheds ranked 1 representing 0-25% of the watershed with the highest relative abundance. Watersheds were defined as hydrologic areas that drain to a common outlet, but watershed boundaries differed in scale between species depending on the finest-scale data available. Rankings were determined by first surveying all available data sources, including annual escapement index surveys (aerial and foot), annual escapement surveys (weir and sonar), periodic escapement estimates (mark recapture; traditional tagging or radio telemetry), annual harvest surveys (sport and commercial), and radio telemetry-based spawning surveys. Data sources were compared by 1) perceived reliability of methods, 2) recentness of data 3) number of years of data available for estimation and 4) spatial scale, and these comparisons were used to select which datasets were used as the primary source for watershed rankings. Additional datasets were used as comparisons, and rankings were annotated if there were discrepancies in ranking results between the primary data source and the comparison data source. Rankings were also annotated when there was less than 5 years of data and when temporal trends suggested that ranking results did not hold true over time, such as in the event of hatchery enhancement, or predation by invasive species.

The purpose of this appendix is to describe in detail the data sources used for creating watershed rankings, and how they were used to create final rankings.

Chinook Salmon

Table 1. Available data sources for understanding relative Chinook salmon abundance estimates across the Mat-Su Basin.

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
Escapement index surveys						
	ADFG (Oslund et al. 2013)	1979-present	Northern Cook Inlet (NCI)	All major clear water spawning streams; Willow Creek, Deception Creek, Little Willow Creek, Sheep Creek, Goose Creek, Montana Creek, Clear Creek, Prairie Creek, Chulitna River, Portage Creek, Indian River, Kashwitna River, Alexander Creek, Deshka River, Peters Creek, Lake Creek, Talachulitna River, Cache Creek, and the Little Susitna River	Single pass helicopter aerial counts at peak spawning time	Aerial surveys are notoriously subject to bias; however, they are performed in a way to minimize bias and challenging conditions are noted annually. Aerial counts have been found to be correlated with escapements estimated from the only weir on the Susitna (the Deshka), averaging 40% of the escapement, and provide the basis for Sustainable Escapement Goals.
Escapement surveys						
	ADFG (Oslund et al. 2013	1995-present	Deshka River		Weir counts	

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	ADFG (ADFG 1982, 1984; Barret 1985; Thompson et al. 1986)	1982-1985	Susitna River	Above Sunshine station, Talkeetna River drainage, Upper River (above Curry)	Mark recapture	
	LGL and ADFG (LGL Alaska Research Associates Inc. and ADFG 2014, 2015)	2013 – 2014	Susitna River	Deshka River, Talkeetna River, the Chulitna River, the mainstem Susitna from above the Yentna to the Chulitna River Confluence, the eastside Susitna River drainages, and the mainstem Susitna above the Chulitna River confluence; in 2014, included Yentna River drainage, with Kahiltna, Talachulitna, and Skwentna drainages	Mark recapture using radio telemetry	Fish above 50 cm were overrepresented in tagging
Harvest surveys						

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	ADFG (Oslund et al. 2013)	1997-present	Statewide; Includes Eastside Susitna, Westside Susitna, and Knik Arm watersheds	Willow Creek, Little Willow Creek, Kashwitna River, Caswell Creek, Sheep Creek, Goose Creek, Montana Creek, Birch Creek, Sunshine Creek, Talkeetna River, Alexander Creek, Deshka River, Rabideux Creek, Peters Creek, Yentna River, Lake Creek, Fish Creek, Talachulitna River, Little Susitna River, Jim Creek, Wasilla Creek, Cottonwood Creek, and Fish Creek	Mail survey estimates statewide sport fish harvest	The Statewide Harvest Survey is designed to provide estimates of effort, harvest, and catch by site but is not designed to provide effort estimates towards a single species at any given site.
	ADFG (Shields and Dupuis 2013)	1966-present	Upper Cook Inlet (UCI)	Northern District	Estimation of commercial fishery harvest	
Spawner distribution						

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	LGL and ADFG (LGL Alaska Research Associates Inc. & ADFG 2015; Link et al. 2013; Yanusz et al. 2013)	2012-2014		Tracked to final spawning location; reported by stream	Radio telemetry	Assumptions about fish being tagged in proportion to apparent abundance and capture selectivity were only tested in 2013, and in that year radio tags were adjusted in-season to reflect abundance over time, no evidence was found to suggest that Chinook salmon were bank-oriented, and that larger fish were overrepresented

Table 2. Description of how the selected data sources were used in ranking methodologies for individual watersheds for Chinook salmon.

Watershed	Data source					
	Escapement Index Surveys (NCI; annual aerial index)			Escapement surveys (Susitna; 2013-2014 mark recapture)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Alexander	x	Primary		x	Comparison	
Little Susitna	x	Primary		x	Comparison	
Susitna above Yentna						
Mainstem Susitna				x	Primary	
Talkeetna	x	Comparison		x	Primary	
Clear	x	Primary		x	Comparison	
Sheep				x	Primary	
Iron				x	Primary	
Prairie	x	Primary		x	Comparison	
Cache	x	Primary		x	Comparison	
Deception	x	Primary				
Goose	x	Primary		x	Comparison	
Indian	x	Primary		x	Comparison	
Kashwitna	x	Primary		x	Comparison	
Little Willow	x	Primary		x	Comparison	
Montana	x	Primary		x	Comparison	
Other Eastside Susitna	x	Primary				
Portage	x	Primary		x	Comparison	
Sheep	x	Primary		x	Comparison	

Watershed	Data source					
	Escapement Index Surveys (NCI; annual aerial index)			Escapement surveys (Susitna; 2013-2014 mark recapture)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Willow	x	Primary		x	Comparison	
Yentna						
Lak	x	Primary		x	Comparison	
Other	x	Primary				
Westside						
Susitna						
Peters	x	Primary		x	Comparison	
Talachulitna	x	Primary		x	Comparison	
Skwentna				x	Primary	
Upper Yentna				x	Primary	

Sockeye Salmon

Table 3. Available data sources for understanding relative sockeye salmon abundance estimates across the Mat-Su Basin

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
Escapement surveys						
	ADFG and Cook Inlet Aquaculture Association (CIAA) (Oslund et al. 2013)	Varies by river system;	Upper Cook Inlet	Little Susitna River, Fish Creek, Cottonwood Creek, Wasilla Creek, Jim Creek, Larson Lake, Stephen Lake, Chelatna Lake, Judd Lake, Shell Lake, Byers Lake, Swan Lake and Bodenburg Creek	Weir	
	ADFG (Oslund et al. 2013)	1981-1989 and 1998-present	Yentna		Sonar	Likely biased very low
	ADFG (Yanusz et al. 2007; 2009, 2011)	2006-2008	Yentna and Susitna (above Sunshine)	Larson Lake, the Talkeetna River, the mainstem Susitna River, the Chulitna River, the Tokositna River, Byers Lake, Bunco Lake, Swan Lake, Stephan Lake, the Talachulitna River, the Skwentna River, Lake Creek, Kichatna River, Kahilitna River, Hewitt Lake, Movie Lake, Trinity Lake, Swan Lake, Shell Lake, Judd Lake, Chelatna Lake, and the mainstem Yentna River	Mark recapture using radio telemetry	

	USFWS (Sethi & Tanner 2013)	2009	Matanuska River		Mark recapture using radio telemetry	
Harvest surveys						
	ADFG (Oslund et al. 2013)	1997-present	Statewide; Includes Eastside Susitna, Westside Susitna, and Knik Arm watersheds	Willow Creek, Little Willow Creek, Kashwitna River, Caswell Creek, Sheep Creek, Goose Creek, Montana Creek, Birch Creek, Sunshine Creek, Talkeetna River, Alexander Creek, Deshka River, Rabideux Creek, Peters Creek, Yentna River, Lake Creek, Fish Creek, Talachulitna River, Little Susitna River, Jim Creek, Wasilla Creek, Cottonwood Creek, and Fish Creek	Mail survey estimates statewide sport fish harvest	The Statewide Harvest Survey is designed to provide estimates of effort, harvest, and catch by site but is not designed to provide effort estimates towards a single species at any given site.
	ADFG (Barclay et al. 2010)	2005-Present	Upper Cook Inlet	Judd Lake, Chelatna Lake, and Larson Lake complex; Remainder of the Susitna drainage; Fish Creek; Knik/Turnigan/Northeast Cook Inlet	Genetic sampling of commercial harvest	
	ADFG (Shields and Dupuis 2013)	1966-present	Upper Cook Inlet	Northern District	Estimation of commercial fishery harvest	
Spawner distribution						

LGL and ADFG (LGL Alaska Research Associates Inc. & ADFG 2015)	2012-2014	Susitna River	Tracked to final spawning location; reported by stream	Radio telemetry
USFWS (Anderson & Bromaghin 2009; Sethi & Tanner 2013; Tanner & Sethi 2015)	2008-2009	Matanuska River	Tracked to final spawning location	Radio telemetry
USFWS (J. Gerken, unpublished data)	2009	Fish Creek	Tracked to final spawning location	Radio telemetry

Table 4. Description of how the selected data sources were used in ranking methodologies for individual watersheds for sockeye salmon.

Watershed	Data Sources					
	Escapement estimates (NCI; Annual weir and sonar counts)			Escapement estimates (Mark recapture using radio telemetry)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Fish	x	Primary				
Little Susitna	x	Primary				
Cottonwood	x	Primary				
Wasilla	x	Primary				
Jim	x	Primary				
Bodenburg	x	Primary				
Matanuska				x	Primary	
Susitna River						
Mainstem				x	Primary	
Susitna						
Talkeetna				x	Primary	
Larson Lake	x	Primary		x	Comparison	
Stephan Lake	x	Primary		x	Comparison	
Byers Lake	x	Primary		x	Comparison	
Swan Lake	x	Primary		x	Comparison	
Chulitna				x	Primary	
Tokositna				x	Primary	
Bunco Lake				x	Primary	
Chelatna Lake	x	Primary		x	Comparison	
Judd Lake	x	Primary		x	Comparison	
Shell Lake	x	Primary		x	Comparison	
Hewitt Lake	x	Primary		x	Comparison	
Talachulitna				x	Primary	

Watershed	Data Sources					
	Escapement estimates (NCI; Annual weir and sonar counts)			Escapement estimates (Mark recapture using radio telemetry)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Skwentna				x	Primary	
Lake Creek				x	Primary	
Kichatna				x	Primary	
Kahiltna				x	Primary	
Movie Lake				x	Primary	
Trinity Lake				x	Primary	
Mainstem				x	Primary	
Yenta						

Coho Salmon

Table 5. Available data sources for understanding relative coho salmon abundance estimates across the Mat-Su Basin

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
Escapement index surveys						
	ADFG (Oslund et al. 2013)	Various by stream	Upper Cook Inlet	Rabideux Creek, Birch Creek, Question Creek, Answer Creek, Cottonwood Creek, Wasilla Creek, Spring Creek (upper and flats), Yellow Creek, Wolverine Creek, Bartko side channel, McRoberts Creek, and Upper Jim Creek	Foot counts	
	ADFG (Oslund et al. 2013)	1981-2008	Yentna		Side-scan sonar and fish wheels	Considered index counts for coho because not operational for full coho run
Escapement surveys						
	ADFG (Oslund et al. 2013)	Varies by stream	Upper Cook Inlet	Deshka River, the Little Susitna River, Cottonwood Creek, Fish Creek, Wasilla Creek, Spring Creek, and Jim Creek	Weir	Partial and full
	ADFG (Barret 1985; Thompson et al. 1986;)	1981-1985	Susitna	Yentna and Susitna	Side-scan sonar on Yentna; mark recapture on Susitna	Considered minimum based on sonar underestimating returns; but operational for full coho run
	ADFG (Willette et al. 2003)	2002	Upper Cook Inlet	Little Susitna River, Cottonwood Creek, Eagle River, Fish Creek, the Knik River, the Matanuska River, and Rabbit Slough	Mark recapture using radio telemetry	

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	ADFG and LGL (Cleary et al. 2013; LGL Alaska Research Associates Inc. & ADFG 2015)	2010, 2013, 2014	Susitna	Yentna mainstem, Kahiltna River, Lake Creek, Skwentna River, Talachulitna Tiver, Upper Yentna tributaries, Mainstem Susitna, Eastside Susitna, Talkeetna River, Chulitna River, Deshka River	Mark recapture using radio telemetry	
	USFWS (Sethi & Tanner 2013)	2009	Matanuska River		Mark recapture using radio telemetry	
Harvest surveys						
	ADFG (Oslund et al. 2013)	1997-present	Statewide; Includes Eastside Susitna, Westside Susitna, and Knik Arm watersheds	Willow Creek, Little Willow Creek, Kashwitna River, Caswell Creek, Sheep Creek, Goose Creek, Montana Creek, Birch Creek, Sunshine Creek, Talkeetna River, Alexander Creek, Deshka River, Rabideux Creek, Peters Creek, Yentna River, Lake Creek, Fish Creek, Talachulitna River, Little Susitna River, Jim Creek, Wasilla Creek, Cottonwood Creek, and Fish Creek	Mail survey estimates statewide sport fish harvest	The Statewide Harvest Survey is designed to provide estimates of effort, harvest, and catch by site but is not designed to provide effort estimates towards a single species at any given site.
	ADFG (Shields and Dupuis 2013)	1966-present	Upper Cook Inlet	Northern District	Estimation of commercial fishery harvest	
Spawner distribution						

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	LGL and ADFG (LGL Alaska Research Associates Inc. & ADFG 2015; Todd et al. 2001; Merizon 2010; Cleary et al. 2013)	1998, 2009, 2010, 2012-2014	Susitna	Tracked to final spawning location; reported by stream	Radio telemetry	
	USFWS (Sethi & Tanner 2013)	2009	Matanuska River		Radio telemetry	

Table 6. Description of how the selected data sources were used in ranking methodologies for individual watersheds for coho salmon.

Watershed	Data Sources								
	Escapement estimates (UCI; Mark recapture)			Escapement estimates (UCI; Weir and sonar)			Escapement estimates (Susitna; Mark recapture using radio telemetry)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Cottonwood	x	Comparison		x	Primary				
Little Susitna	x	Comparison		x	Primary				
Rabbit Slough	x	Primary							
Wasilla Creek	x	Comparison		x	Primary				
Fish Creek	x	Comparison		x	Primary				
Matanuska	x	Comparison		x	Primary				
Knik River	x	Primary							
Jim Creek				x	Primary				
Deshka River	x	Comparison		x	Primary				
Susitna above Yentna									
Mainstem Susitna									
RM 24-97							x	Primary	
RM 97-152							x	Primary	
Eastside Susitna							x	Primary	
Talkeetna							x	Primary	
Chulitna							x	Primary	
Yentna	x			x			x	Primary	
Yentna mainstem									
Below Skwentna							x	Primary	

Watershed	Data Sources								
	Escapement estimates (UCI; Mark recapture)			Escapement estimates (UCI; Weir and sonar)			Escapement estimates (Susitna; Mark recapture using radio telemetry)		
	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison	Used in ranking?	How?	Comparison
Above Skwentna							x	Primary	
Talachulitna							x	Primary	
Kahiltna							x	Primary	
Lake Creek							x	Primary	
Upper Yentna							x	Primary	

Chum Salmon

Table 7. Available data sources for understanding relative chum salmon abundance estimates across the Mat-Su Basin

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
Escapement index surveys						
	ADFG (Oslund et al. 2013)	1968-Current	Bodenburg Creek		Foot survey	
Escapement surveys						
	ADFG (Cleary et al. 2013)	2010	Susitna above Flathorn	Mainstem Susitna, Deshka River, Eastside Susitna River, Talkeetna River, Chulitna River, Mainstem Yentna, Kahiltna River, Lake Creek, Skwentna River, Talachulitna River, Upper Yentna	Mark recapture using radio telemetry	
	USFWS (Sethi & Tanner 2013)	2009	Matanuska River		Mark recapture using radio telemetry	
	ADFG (Willete et al. 2003)	2002	Upper Cook Inlet		Mark recapture using radio telemetry	
Harvest surveys						

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	ADFG (Oslund et al. 2013)	1997-present	Statewide; Includes Eastside Susitna, Westside Susitna, and Knik Arm watersheds	Willow Creek, Little Willow Creek, Kashwitna River, Caswell Creek, Sheep Creek, Goose Creek, Montana Creek, Birch Creek, Sunshine Creek, Talkeetna River, Alexander Creek, Deshka River, Rabideux Creek, Peters Creek, Yentna River, Lake Creek, Fish Creek, Talachulitna River, Little Susitna River, Jim Creek, Wasilla Creek, Cottonwood Creek, and Fish Creek	Mail survey estimates statewide sport fish harvest	The Statewide Harvest Survey is designed to provide estimates of effort, harvest, and catch by site but is not designed to provide effort estimates towards a single species at any given site.
	ADFG (Shields and Dupuis 2013)	1966-present	Upper Cook Inlet	Northern District	Estimation of commercial fishery harvest	
Spawner distribution						
	LGL and ADFG (LGL Alaska Research Associates Inc. & ADFG 2015)	2012-2014		Tracked to final spawning location; reported by stream	Radio telemetry	

Table 8. Description of how the selected data sources were used in ranking methodologies for individual watersheds for chum salmon.

Watershed	Data Source		
	Escapement estimates (Susitna and Matanuska; Mark recapture using radio telemetry)		
	Used in ranking?	How?	Comparison
Susitna above Yentna			
Mainstem Susitna			
RM 24-97	x	Primary	
RM 97-152	x	Primary	
Talkeetna River	x	Primary	
Deshka River	x	Primary	
Eastside Susitna	x	Primary	
Chulitna	x	Primary	
Yentna			
Lake Creek	x	Primary	
Mainstem Yentna			
Below Skwentna	x	Primary	
Above Skwentna	x	Primary	
Kahiltna	x	Primary	
Talachulitna	x	Primary	
Skwentna	x	Primary	
Upper Yentna	x	Primary	

Pink Salmon

Table 9. Available data sources for understanding relative pink salmon abundance estimates across the Mat-Su Basin

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
Escapement surveys						
	ADFG (Willette et al. 2003)	2002	Upper Cook Inlet		Mark recapture using radio telemetry	
Harvest surveys						
	ADFG (Oslund et al. 2013)	1997-present	Statewide; Includes Eastside Susitna, Westside Susitna, and Knik Arm watersheds	Willow Creek, Little Willow Creek, Kashwitna River, Caswell Creek, Sheep Creek, Goose Creek, Montana Creek, Birch Creek, Sunshine Creek, Talkeetna River, Alexander Creek, Deshka River, Rabideux Creek, Peters Creek, Yentna River, Lake Creek, Fish Creek, Talachulitna River, Little Susitna River, Jim Creek, Wasilla Creek, Cottonwood Creek, and Fish Creek	Mail survey estimates statewide sport fish harvest	The Statewide Harvest Survey is designed to provide estimates of effort, harvest, and catch by site but is not designed to provide effort estimates towards a single species at any given site.
	ADFG (Shields and Dupuis 2013)	1966-present	Upper Cook Inlet	Northern District	Estimation of commercial fishery harvest	
Spawner distribution						

Method	Implementer (Citations)	Year(s)	Spatial extent	Spatial scale	Specific methods	Notes
	LGL and ADFG (LGL Alaska Research Associates Inc. & ADFG 2015)	2012-2014		Tracked to final spawning location; reported by stream	Radio telemetry	

Appendix B

Mapping Freshwater Habitat Characteristics in the Mat-Su Basin

Methods and Data Dictionary

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TerrainWorks (NetMap)

Contents

Introduction

A better understanding of the relative distribution and abundance of salmon by species and life stage is vital to support landscape-scale planning that seeks to prioritize protection of salmon habitats and salmon populations within the Matanuska and Susitna watersheds (the "Mat-Su" Basin). Unfortunately, monitoring in-stream fish populations at the reach or sub-basin scale for watersheds of this size and remoteness is not practical. However, mapping of fish habitat characteristics has been used for many years as a proxy for understanding salmonid relative productivity (e.g., Hankin & Reeves 1988).

Habitat requirements for Pacific salmon can be shown to be linked in a spatial hierarchy at local micro-habitat and reach scales with broader patterns and drivers within the stream system and watershed. Because collecting such data in a spatially continuous manner across large watersheds is also prohibitive, a multiscale approach that uses landscape (or, "riverscape") processes to predict fish habitat is necessary (Fausch et al 2002). Landscape processes and habitat features that influence life history requirements necessary for salmon survival and productivity can be mapped as broad-scale patterns of climate, geology, topography and land use and related to specific life-history requirements for successful reproduction and survival.

The objectives of this project were to leverage the best available data on landscape features and processes in the Mat-Su Basin in order to develop a spatially explicit, reach-scale database of freshwater habitat characteristics. The mapping of these freshwater habitat characteristics will provide a useful tool to support a range of research, conservation planning, resource management and educational needs to better understand and protect salmon in this critical region.

Database Design

The first steps to building a database on freshwater habitat characteristics was update the Mat-Su Basin hydrographic information and incorporate it into an integrated platform that allowed for landscape-based analysis on this hydrographic dataset.

Basin hydrography was updated for the entire Mat-Su Basin using high-resolution elevation data available including the Alaska Statewide Digital Mapping Initiative's collection of interferometric synthetic aperture radar (IfSAR) digital elevation models (DEMs; 5m) and 1-m LiDAR bare-earth DEMs. Methods for updating hydrography are described in detail in Miller et al. (2015), but involved augmenting tools available in ArcGIS to create elevation-derived digital hydrography with more accurate and complete channel networks. These augmented method included those designed to merge disparate elevation data sources into contiguous DEMs with minimal artifacts at seams, to utilize the open-water breaklines derived from the IfSAR (and LiDAR) orthorectified intensity imagery to guide flow paths through areas where topographic relief is insufficient to resolve channel courses, to calibrate channel initiation criteria to local conditions, to obtain optimal flow paths that preserve all topographic information when creating hydrologically conditioned DEMs, to breach road crossings, and to smooth DEM-derived channel courses to provide improved estimates of channel length and gradient.

Upon this updated hydrologic database, a Mat-Su Basin-wide suite of hydrogeomorphic data, models and software, collectively known as the NetMap application, was built. NetMap consists of a group of software programs with numerous analytic tools and modeling capabilities coupled with a set of custom GIS databases upon which the models are calculated. The goal this application is to provide watershed modelling and analysis. Using the NetMap tool suite, as well as additional processing in ArcGIS, a freshwater habitat dataset was created. Freshwater habitat data was represented on a reach scale, with reaches delineated by confluences or by 100-m breaks if no confluences were present. For each reach, a series of attributes were assigned. Attribute definitions and methodologies associated with this database are described below.

Database attributes

For many attributes, including those automatically generated in the NetMap Platform, attribute definitions come directly from the NetMap technical help menu available at www.NetMaptools.org.

Identification attributes

Reach ID (attribute: ID)

This attribute is automatically generated in the NetMap Platform. It represents the ID of the collection of individual channel reaches.

Downstream ID (attribute: DOWN_ID)

This attribute is automatically generated in the NetMap Platform. It represents the ID of the downstream reach.

Channel ID (attribute: CHAN_ID)

This attribute is automatically generated in the NetMap Platform. It represents the ID of the collection of individual channel reaches beginning at a tributary junction and continuing upstream to the maximum headwater extent. At confluences, the "channel" follows the reach with the largest drainage area with the smaller tributary then initiating a new channel ID.

Basin ID (attribute: Basin_ID)

This attribute is automatically generated in the NetMap Platform. It represents the HUC Code from the National Hydrography Dataset (NHD; U.S.G.S. & D.O.I. 2015).

Feature Name (attribute: Feature_name)

Name of the feature according to the Geographic Names Information System (U.S.G.S. & D.O.I. 2015).

Basic characteristics

Reach length (attribute: LENGTH_M)

This attribute is automatically generated in the NetMap Platform. It represents the length of the reach (m).

Elevation (attribute: ELEV_M)

This attribute is automatically generated in the NetMap Platform. It represents the elevation (m) of downstream end of reach. Elevation values are derived from the digital elevation models described above (see “Database design”).

Distance to outlet (attribute: OUT_DIST)

This attribute is automatically generated in the NetMap Platform. It represents the distance (km) from the downstream end of reach to the outlet of the entire dataset.

Distance to upstream end of channel (attribute: SRC_DIST)

This attribute is automatically generated in the NetMap Platform. It represents the distance (km) from the downstream end of the reach to the upstream end of the upstream-most reach on the same channel.

Distance to downstream end of channel (attribute: FROM_DIST)

This attribute is automatically generated in the NetMap Platform. It represents the distance (km) from channel mouth to downstream end of reach.

Gradient (attribute: GRADIENT)

This attribute is automatically generated in the NetMap Platform. It represents the slope gradient of each reach. Gradient is calculated for every node in the linked-node channel data structure. Reach gradients are estimated as the mean gradient of all nodes contained in the reach. The gradient at each node is iteratively calculated by fitting a 2nd-order polynomial over a window centered on the node. Window length varies linearly with gradient, from 50m for gradients of 0.2 or greater to 500m for gradients of 0.001 or less.

Maximum gradient downstream (attribute: MAX_GRAD_D)

This attribute is automatically generated in the NetMap Platform. It represents the maximum reach gradient downstream of the reach.

Azimuth (attribute: AZIMTH_DEG)

This attribute is automatically generated in the NetMap Platform. It represents the average downstream flow direction (degrees) for a reach.

Lake (attribute: Lake)

This attribute represents whether a reach intersects a lake feature. If a reach intersects a lake, it is given a value of 1. All other reaches are given a value of 0.

Glacier (attribute: Glacier)

This attribute represents whether a reach intersects a glacier feature. If a reach intersects a glacier, it is given a value of 1. All other reaches are given a value of 0.

Stream size and flow

Strahler stream order (attribute: STRM_ORDER)

This attribute is automatically generated in the NetMap Platform. It represents the stream order of the reach using the Strahler method (1964). The confluence of two first-order channels creates a second-order stream. Two second-order streams create a third-order channel, and so forth. The intersection of lower order channels to a higher-order stream does not change the downstream order.

Drainage area (attribute: AREA_SQKM)

This attribute is automatically generated in the NetMap Platform. It represents the drainage area (km^2) of the watershed located above each channel segment.

Mean annual precipitation (attribute: MNANPRC_M)

This attribute is automatically generated in the NetMap Platform. It represents the mean annual precipitation (m) within the local contributing area located on either side of an individual reach. Precipitation data is obtained from the PRISM climate data (Prism Climate Group 2015).

Mean annual flow (attribute: MEANANNCMS)

This attribute represents the mean annual flow (cubic meters per second; cms) for an individual reach. Mean annual flow was calculated according to a regional regression equation developed for southcentral Alaska (Parks & Madison 1985):

$$Q = (10^{-1.33})(FA^{0.96})*(P^{1.11})$$

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.

Bankfull width (attribute: WIDTH_M)

This attribute represents the estimated bankfull width for an individual reach. Empirical evidence (e.g., Leopold & Maddock 1953; Leopold et al. 1964) suggests 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. Channel width measurements from studies throughout the Mat-Su watersheds recorded in the Alaska Freshwater Fish Inventory (AFFI; Alaska Department of Fish and Game 2013b) were used to develop power relationships between width and mean annual flow, using a linear regression of log-transformed variables (Leopold et al. 1964). The following equation:

$$w = 11.3\ Q^{0.48}$$

where Q is mean annual flow (cms) was found to significantly predict channel width (m) in the study area ($p<0.05$; Figure 1).

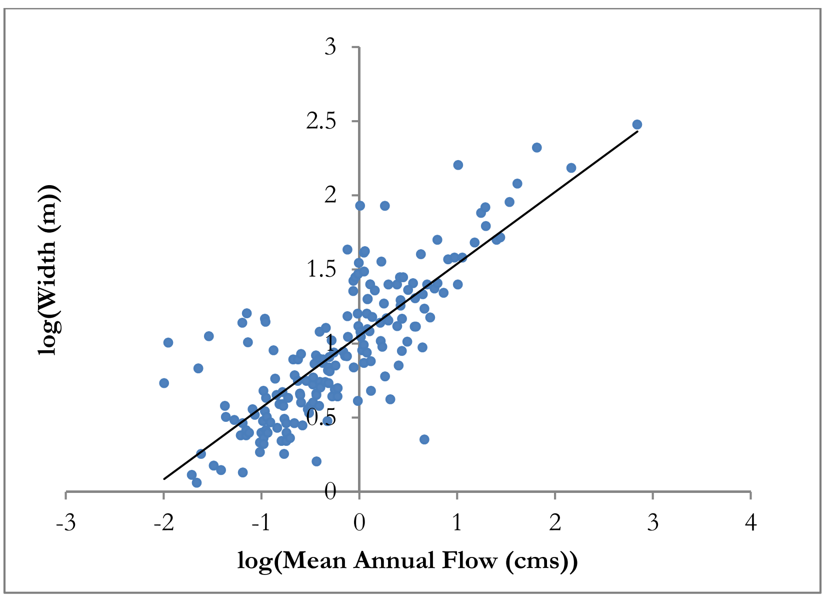

Figure 1. Relationships between mean annual flow and field-based width measurements show that estimated annual flow can help predict these channel characteristics.

Predictions of bankfull width are likely not representative of highly braided channels in glacial systems.

Bankfull depth (attribute: DEPTH_M)

This attribute represents the estimated bankfull depth for an individual reach. Like channel width, it has been shown (Leopold & Maddock 1953; Leopold et al. 1964) 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 Mat-Su 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:

$$h = 0.98\ Q^{0.20}$$

where h is channel depth (m) and Q is mean annual discharge (cms) was found to significantly predict channel depth in the study area ($p<0.05$; Figure 2).

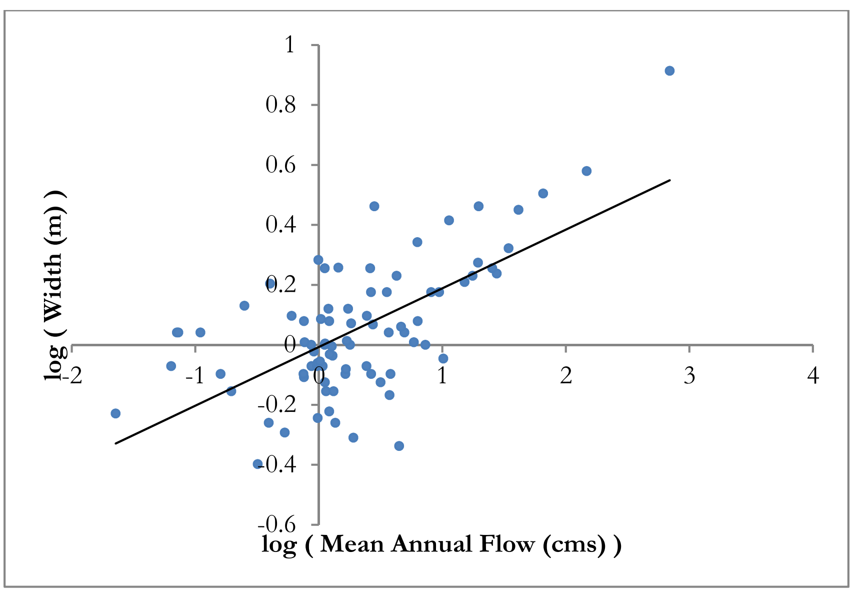

Figure 2. Relationships between mean annual flow and field-based width measurements show that estimated annual flow can help predict these channel characteristics

Predictions of bankfull depth are likely not representative of highly braided channels in glacial systems.

Bankfull flow velocity (attribute: FlowVel)

This attribute is automatically generated in the NetMap Platform. This attribute represents estimate flow velocity (m/s) at bankfull depth. NetMap contains a tool for predicting flow velocity based on the Manning equation. The Manning equation uses the hydraulic radius (R), channel slope (S), and a roughness coefficient (η) to predict flow velocity (v; m/s):

$$v = (R^{0.66} * S^{0.5}) / \eta$$

The hydraulic radius (R) can be calculated as a function of estimated channel depth (h) and channel width (w):

$$R = (h * w) / (2h + w)$$

For this project, we set the roughness coefficient (η) as a function of channel slope (S) and channel width (w), so that η =0.05 when S>0.08; η = 0.03 when S > 0.08 and w < 30 m; and η = 0.025 when S > 0.08 and channel width > 30 m.

Predictions of flow velocity are likely not representative of highly braided channels in glacial systems.

Bankfull discharge (attribute: BFQ)

This attribute is automatically generated in the NetMap Platform. It represents the estimated bankfull discharge (m^3/s) of an individual reach. It is a function of bankfull depth (h), width (w), and flow velocity (v):

$$BFQ = hwv$$

Stream power (attribute: StrmPow)

This attribute is automatically generated in the NetMap Platform. It represents the estimated stream power of an individual reach, which is a measure of the energy of a stream channel including that which is related to the ability to transport sediment. Stream power (calculated as a function of the density of water (ρ; 1000 kg/m^3), acceleration due to gravity (g; 9.8 m/s^2), the bankfull discharge (BFQ), and channel slope (S):

$$\text{Stream power} = \rho g(BFQ)S$$

Other fluvial processes

Bed shear stress (attribute: Shear)

This attribute is automatically generated in the NetMap Platform. It represents the bed shear stress of an individual reach. Bed shear stress provides an index of fluid force per unit area on a stream bed, and is related to sediment mobilization and transport. Bed shear stress (τ) is a function of density of water (ϱ; 1000 kg/m^3), acceleration due to gravity (g; 9.8 m/s^2), the bankfull depth (h; m) and channel slope (S):

$$\tau = \varrho g h S$$

Median substrate size (attribute: d50)

This attribute is automatically generated in the NetMap Platform. It represents the estimated median substrate size (d50) in an individual reach. In the Pacific Northwest (Buffington et al. 2004), the relationship between shear stress (τ) and substrate D_{50} was found to be:

$$d50 = 2.6\ \tau^{0.64}$$

Although there are many departures from this average relationship, and d50 values were not available across the Mat-Su Basin, substrate class information collected as part of the AFFI (Alaska Department of Fish and Game 2013b) was used to adjust the relationship between shear stress (τ) and substrate D_{50} to:

$$d50 = 3.3\ \tau^{0.68}$$

Substrate class (attribute: Substrate)

This attribute is automatically generated in the NetMap Platform, and represents the estimated Wentworth substrate class based on d50. In this classification, substrate over 256 mm are considered boulders, over 64 mm cobbles over 16 mm pebbles, over 2 mm gravel, and below 2 mm, sand.

Sinuosity (attribute: SINUOSITY)

This attribute is automatically generated in the NetMap Platform. It represents the measure of deviation of a channel between two points from the shortest possible path and is calculated as the ratio of actual channel path length divided by shortest path length.

Floodplain width (attribute: FP_WIDTH)

This attribute is automatically generated in the NetMap Platform. It represents the width of the floodplain, as mapped as contiguous polygons two bankfull depths above the channel.

Valley width (attribute: VAL_WIDTH)

This attribute is automatically generated in the NetMap Platform. It represents the width of the floodplain, as mapped as contiguous polygons five bankfull depths above the channel.

Valley constraint (attribute: ValCnstrnt)

This attribute is automatically generated in the NetMap Platform. It represents the ratio of the valley width to the estimated channel width.

Channel confinement (attribute: CCON)

This attribute is automatically generated in the NetMap Platform. It represents the degree to which channels are limited in their ability to move laterally. Confinement can result from bedrock walls, closely spaced hillslopes, or by entrenchment into a floodplain (channels entrenched into floodplains are difficult to detect using digital elevation models).

Channel confinement is defined by the valley constraint. Numerical values of channel confinement are classified on the following thresholds: valley width < 4; confined, 4 < valley width < 6; intermediate, valley width > 6 unconfined.

Rosgen channel classification (attribute: Rosgen)

This attribute is automatically generated in the NetMap Platform. It represents the estimated Rosgen channel class, according to the Rosgen stream classification system (Rosgen & Silvey 1996). Rosgen stream classification system (Rosgen 1996) requires information on: 1) entrenchment ratio (valley width/channel width), 2) channel width to depth ratio, 3) sinuosity, 4) channel gradient and 5) substrate size (gravel, cobbles etc.). For classification of this dataset, reaches were classified at

Level 1 as Rosgen divisions A, B, C, and E based on entrenchment ratio, channel width to depth ratios, and channel gradient. Sinuosity was not included because results are likely too approximate to inform the Rosgen classification system. Divisions F and G were not included because they can only be defined in the field, and categories D and DA were not included because braiding was not estimated.

Tributary confluence effect probability (attribute: p_trib)

This attribute is automatically generated in the NetMap Platform. It represents probability of a reach segment having a tributary confluence effect, based on the estimated probability of tributary effects (Benda et al. 2004a; Benda et al. 2004b) For each tributary junction, the probability of effects in the mainstem channel is calculated as a function of the ratio of tributary to mainstem channel contributing area. This probability is assumed to decrease linearly from a maximum at the junction to zero at a distance from the junction dependent on mainstem size. The modeled probability for each tributary is calculated for each node within this patch-length distance, and the conditional probability of effects at the node is determined accounting for all nearby tributaries. The reach value is the mean probability of tributary effects for all nodes within the reach.

Other stream habitat characteristics

Beaver habitat (attribute: BeavHAB)

This attribute is automatically generated in the NetMap Platform. It represents potential locations of beaver habitat is predicted based on an empirical model of beaver dams based on data from the Stilliguamish River basin, Washington (Pollock et al. 2004). The model uses a slope-area threshold of 0.3 km2, corresponding to a value of 2,000 Joules per second per meter for stream power at bankfull discharge. Areas with drainages areas smaller than 0.1 km^2 and reaches with gradients greater than 0.04 are also excluded.

Invasive pike locations (attribute: Pike)

This attribute represents waterbodies documented or susceptible to invasive pike (K. Dunker, ADFG, unpublished data). Waterbodies are coded as "Known" if they have been documented as containing pike, "Probable" if they are likely to contain pike, "Vulnerable" if they are likely vulnerable to an invasion, "Eradicated" if pike have been eradicated from the waterbody, or "Control" if there are currently efforts to control pike populations in these waterbodies.

Debris flow effects (attribute: P_DF_AVE)

This attribute is automatically generated in the NetMap Platform. It represents the relative potential for landslide-triggered debris flow effects (including scour, traversal, or deposition) within the reach. This value takes into account the number of upslope landslide sources, the potential for landsliding from each source, and the potential for a debris flow to travel from the source to the reach. Values are based on empirical models described in Miller and Burnett (Miller & Burnett 2007, 2008) which were calibrated to data from the Oregon Coast Range following the large storm of 1996. The values indicate the spatial density of modeled debris flow potential - the model indicates, for example, that we expect to find evidence of debris flows twice as often in reaches with a value of two than in reaches with a value of one, but it does not provide information on what the actual frequency is.

Lake size (attribute: Lake_size)

This attribute represents the size of the lake (km^2) intersected by a reach. Values were attained from the NHD (U.S.G.S. & D.O.I. 2015).

Glacial coverage (attribute: Glac_cov)

This attribute represents the percentage of the watershed above a reach that is covered by glaciers.

Glacier influence (attribute: Glac_inf)

This attribute represents categorization of reaches by their amounts of glacial influence. Reaches are defined as "Clear", "Semi-glacial: moderately turbid", or "Glacial: highly turbid" based on the percentage of the watershed above a reach that is covered by glaciers (or the "glacial coverage"). Thresholds are shown in Table 1 and were determined by comparing glacial coverage values to data from the AFFI (Alaska Department of Fish and Game 2013b).

Table 1. Threshold values for determining glacier influence classes from glacial coverage.

Category	Glacial coverage
Clear	0%
Semi-glacial: moderately turbid	>0 % and < 5%
Glacial: highly turbid	> 5%

Large woody debris type (attribute: LWD_TYPE)

This attribute is automatically generated in the NetMap Platform. It represents the type of wood accumulation type likely to be found in an individual reach. Wood accumulation types include: 1) individual spanning logs, 2) spanning and partial stream-spanning jams (30 – 70% of the channel is spanned), or 3) scattered accumulations on lateral bars. Streams with too high energy and likely no wood accumulation are represented by the value 0.

The model uses a few factors (stream power, riparian tree height [e.g., log size], and channel width) to estimate spatial patterns of different wood accumulation types at the scales of watersheds. For instance, large, channel-spanning logs in small streams tend to stay where they fall. If the channel has sufficient power to transport wood, channel-spanning logs can form. Larger and more powerful channels will favor the formation of partial jams, scattered bar accumulation, or no accumulations at all. Based on field surveys and observations, different wood accumulation types fall into relatively distinct fields in a plot of drainage area (surrogate for stream size and stream power) against tree height scaled by channel width. The average height of riparian trees is used as a relative measure of log length, since piece sizes should correlate with the height of streamside trees (i.e., tall trees should break into longer pieces than short trees).

Tree height data for the Mat-Su Basin was derived from the Landscape Fire and Resource Management Planning Tools (LANDFIRE) dataset (U.S.G.S. & D.O.I. 2015).

Scattered accumulation probability (attribute: PSCATTERED)

This attribute is automatically generated in the NetMap Platform. It represents the probability of a reach containing scattered accumulation of wood on lateral bars (see “Large woody debris type”).

Individual spanning logs probability (attribute: PSINGLE)

This attribute is automatically generated in the NetMap Platform. It represents the probability of a reach containing individual spanning logs (see “Large woody debris type”).

Spanning jams probability (attribute: PSPANNING)

This attribute is automatically generated in the NetMap Platform. It represents the probability of a reach containing spanning and partial stream-spanning jams (30 – 70% of the channel is spanned) (see “Large woody debris type”).

Waterfall (attribute: Waterfal)

This attribute represents reaches upstream of potential waterfall locations that would serve as salmon migration barriers. These waterfalls are mapped as reaches upstream of 4-m changes in elevation between contiguous pixels.

Salmon barrier (attribute: Sal_Bar)

This attribute represents reaches upstream of potential gradient-based salmon migration barriers. They are identified by locating reaches that contain gradients above 8% over 1200-foot windows.

Natural barrier (attribute: Nat_Bar)

This attribute represents reaches upstream of either potential waterfall locations or potential gradient-based salmon migration barriers.

Wetland coverage (attribute: Wet_cov)

This attribute represents the percentage of the watershed above a reach that is covered by wetland areas, as defined as areas categorized in the National Wetlands Inventory dataset (U.S.F.W.S 2015) as "Freshwater emergent wetlands". Reaches downstream of areas that did not have available National Wetlands Inventory datasets were populated with "Null" values.

Human impacts

Road crossings (attribute: roadX)

This attribute represents reaches where roads, as delineated in the Mat-Su borough roads layer cross.

Road density upstream (attribute: RdDensUp)

This attribute represents the road density (road length (km)/sq km) for the contributing area to the downstream end of an individual reach.

Road density downstream (attribute: RdDensDown)

This attribute is automatically generated in the NetMap Platform. It represents road density (road length per unit area) for the adjacent contributing area to all reaches downstream.

Local road density (attribute: RdDensLoc)

This attribute is automatically generated in the NetMap Platform. It represents road density (road length per unit area) for the adjacent contributing area to all reaches downstream. The adjacent contributing area is delineated in NetMap as a pair of "drainage wings", one on each side of the reach, and is typically about 0.1 km^2 in area.

Red pipe (attribute: Red_pipe)

This attribute reaches that have red pipes on them, as documented in the state of Alaska's fish passage dataset (Alaska Department of Fish and Game 2013a). Red pipes are culverts that are likely to impact fish passage.

Gray pipe (attribute: Gray_pipe)

This attribute represents reaches that have gray pipes on them, as documented in the state of Alaska's fish passage dataset (Alaska Department of Fish and Game 2013a). Gray pipes are culverts that may impact fish passage.

Upstream from red pipe (attribute: US_Red_pip)

This attribute represents reaches that are upstream of reaches with red pipes on them.

Upstream from gray pipe (attribute: US_Gry_pip)

This attribute represents reaches that are upstream of reaches with gray pipes on them.

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