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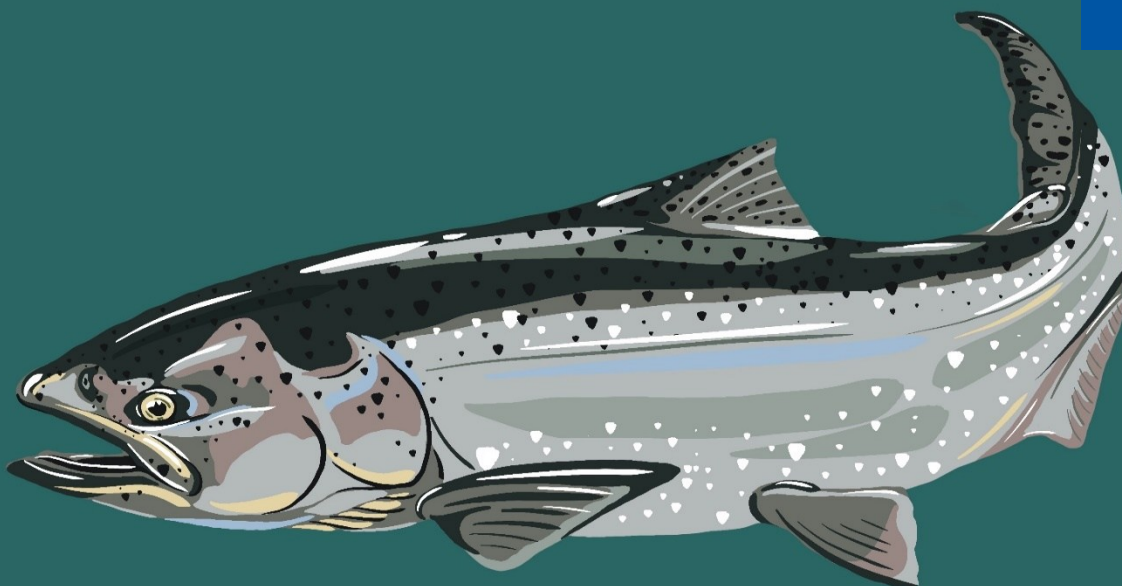


Gulf of Alaska Chinook Salmon Status Review

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

May 2026



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Gulf of Alaska Chinook Salmon Status Review

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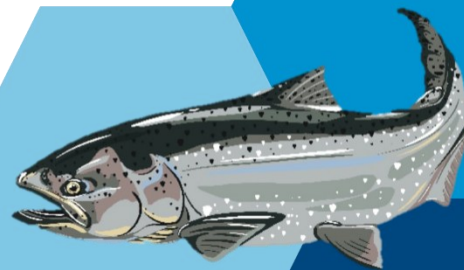
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PLAIN LANGUAGE SUMMARY

Background

Chinook salmon¹ (*Oncorhynchus tshawytscha*), also commonly referred to as king salmon, and less commonly as spring, winter, quinnat, black mouth, Sacramento, California, tule, or tyee salmon, are the largest of the Pacific salmon². Adult Chinook salmon spawn in rivers where their offspring hatch and rear before migrating to the sea. After one to five years of living and growing in the ocean, the grown fish return to their home rivers to spawn and then die.

Populations of Chinook salmon return to spawn in many rivers along the U.S. West Coast, from California to Alaska. Nine Evolutionarily Significant Units (ESUs)³ of Chinook salmon are currently protected under the Endangered Species Act (ESA)^{4,5}. An ESU is a group of Pacific salmon populations that is distinct from other groups based on key biological criteria. ESUs also meet the definition of a “species” under the ESA, and are the units the National Marine Fisheries Service (NMFS) considers for listing as threatened or endangered. All existing ESUs for Chinook salmon occur in Washington, Oregon, California, and Idaho, with none in Alaska. Established ESUs have been evaluated according to risks to population sustainability based on demographic analyses and assessment of potential threats to those populations (e.g., habitat degradation, over-utilization, inadequate regulations, disease and predation, hatcheries, or other relevant concerns).

On January 11, 2024, NMFS received a petition from the Wild Fish Conservancy to delineate and list one or more ESUs of Gulf of Alaska (GOA) Chinook salmon as threatened or endangered under the ESA (“Listing Petition” or “petition”). NMFS’ Alaska Regional Office concluded that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted (89 FR 45815) and initiated a status review⁶.

¹ NOAA Fisheries. Chinook Salmon. Available at <https://www.fisheries.noaa.gov/species/chinook-salmon>. Accessed June 20, 2025.

² NOAA Fisheries. Pacific Salmon and Steelhead. Available at <https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead>. Accessed June 20, 2025.

³ NOAA Fisheries. Glossary: Endangered Species Act, Evolutionarily Significant Unit. Available at <https://www.fisheries.noaa.gov/laws-and-policies/glossary-endangered-species-act#evolutionarily-significant-unit>. Accessed June 20, 2025.

⁴ NOAA Fisheries. Laws & Policies: Endangered Species Act. Available at <https://www.fisheries.noaa.gov/topic/laws-policies/endangered-species-act>. Accessed June 20, 2025.

⁵ NOAA Fisheries. Pacific Salmon and Steelhead: ESA Protected Species. Available at <https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead/esa-protected-species>. Accessed June 20, 2025.

⁶ NOAA Fisheries. Petition to List Gulf of Alaska Chinook Salmon as Threatened or Endangered under the Endangered Species Act – Comment Period Extended to September 6, 2024. Available at <https://www.fisheries.noaa.gov/action/petition-list-gulf-alaska-chinook-salmon-threatened-or-endangered-under-endangered-species>. Accessed June 20, 2025.

This report contains the results of that review. The goals of this Status Review were to:

- Identify appropriate ESUs for GOA Chinook salmon.
- Analyze the current status of population viability within these ESUs.
- Conduct an analysis of potential threats to GOA Chinook salmon.
- Complete an extinction risk evaluation.

The purpose of this report is to synthesize information regarding the species' status and to evaluate its extinction risk.

Key Takeaways

The report compiled detailed information on GOA Chinook salmon and the factors that may threaten them. After carefully considering this information, the authors of the report made the following conclusions:

- The best available information suggests that three ESUs can be defined for GOA Chinook salmon: Southeast GOA (all populations in Alaska east of Cape Fairweather), Central GOA (populations from Cape Fairweather through Cordova) and Northwest GOA (populations from Cook Inlet, the Kenai Peninsula, and the South Alaska Peninsula).
- All three GOA Chinook salmon ESUs are at low risk of extinction.
- GOA Chinook salmon populations fluctuate in abundance and productivity levels (a common occurrence in salmon), with current levels trending low for many GOA stocks, while remaining within the scope of historical variability.
- In evaluating individual stocks within the three ESUs, only one attribute (abundance) for one stock was determined to pose a moderate level of risk; however, in the absence of elevated risk in any other attributes or risk factors, the stock was found to be at low risk overall.
- Increasing environmental variability was considered to be the most significant threat to these ESUs.

EXECUTIVE SUMMARY

This Status Review Report contains a status assessment of three newly defined evolutionarily significant units (ESUs) for Chinook salmon populations in the Gulf of Alaska (GOA): (1) the Southeast Gulf of Alaska ESU, (2) the Central Gulf of Alaska ESU, and (3) the Northwest Gulf of Alaska ESU. The report was prepared by the Status Review Team (SRT) in response to a petition to define ESUs in the GOA, and list one or more GOA Chinook ESUs as threatened or endangered under the Endangered Species Act (ESA). The SRT comprised NMFS scientists with diverse backgrounds in salmon biology, oceanography, policy, and genetics. Two ADF&G scientists and a Tribal liaison were also included on the SRT as non-voting, advisory positions.

The goals of the report were to:

1. Define ESUs for GOA Chinook stocks.
2. Conduct a demographic risk analysis for each ESU.
3. Conduct an analysis of threats to each ESU.
4. Evaluate extinction risk of the ESUs, based on information in (2) and (3).
5. Depending on the outcome of (4), evaluate whether any ESU is at risk of extinction in a significant portion of its range.

ESU Configuration

The ESA allows the listing of "distinct population segments" of vertebrates, as well as named species and subspecies. The policy of the NMFS on this issue for anadromous Pacific salmonids is that a population will be considered "distinct," and hence a "species," for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the species as a whole. To be considered an ESU, a population or group of populations must (1) be substantially reproductively isolated from other populations, and (2) contribute substantially to the ecological or genetic diversity of the biological species (56 FR 58612). The ESU Policy is consistent with the DPS Policy (61 FR 4722, February 7, 1996) and used exclusively for evaluating whether a population unit of Pacific salmon qualifies as a DPS under the ESA. Once an ESU is identified, a variety of factors related to population abundance are considered in determining whether a listing is warranted. ESUs have not been previously defined for Chinook salmon in the Gulf of Alaska. Neutral genetic data analyzed for spawning populations in this region were considered for the reproductive isolation criterion, supplemented by inferences about barriers to migration created by habitat differences and habitat breaks. We also considered information on ocean distribution and, to a lesser extent, information on life history variation. Based on this information, we defined the following three ESUs (Figure 1).

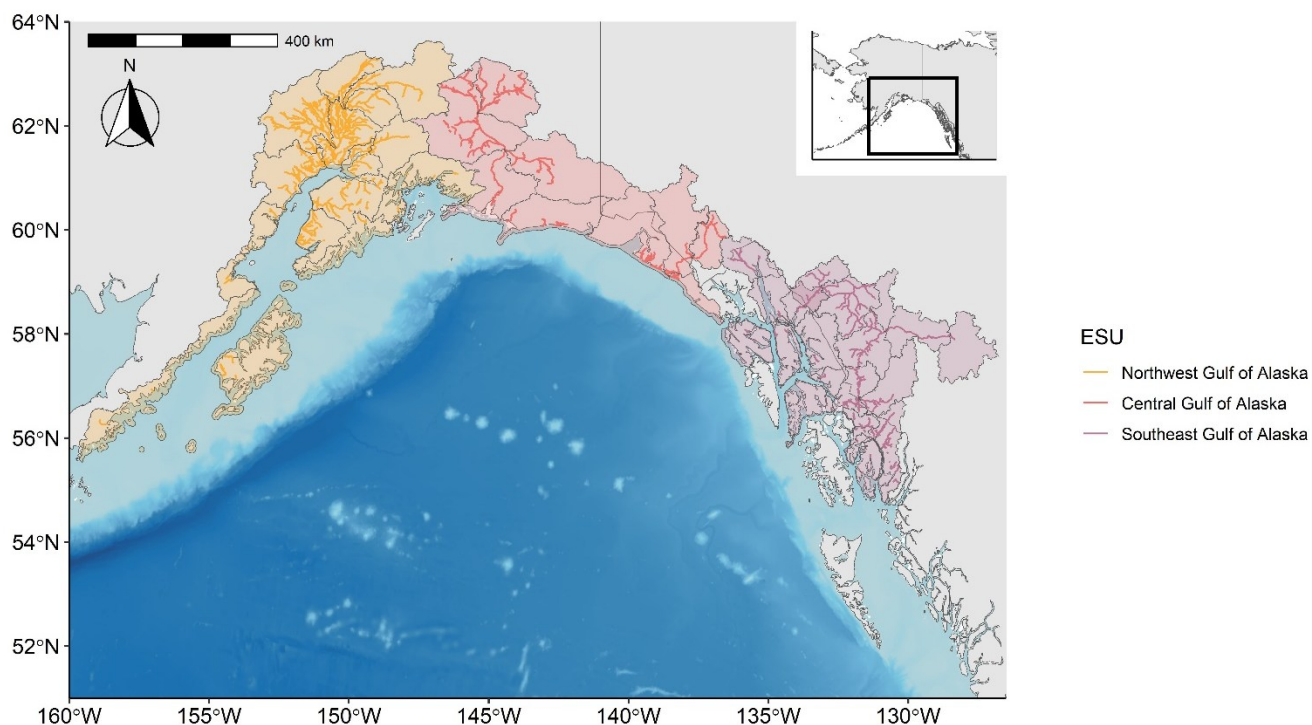


Figure 1. -- Boundaries of Evolutionarily Significant Units (ESUs), displaying anadromous waters bearing Chinook salmon in each ESU surrounded by shading displaying watershed boundaries.

Southeast Gulf of Alaska ESU

The Southeast Gulf of Alaska (SEGOA) ESU includes populations from the Chilkat River in northern Southeast Alaska to the Keta and Blossom Rivers entering Behm Canal in southern Southeast Alaska near the northern coastal border of British Columbia (Figure 2). Populations in SEGOA are part of the eastern genetic lineage, and are highly genetically diverged from the closest populations to the north (Alsek River), which are part of the western lineage. Populations from SEGOA and the Alsek River are also separated by a large geographic distance (350 km waterway distance). Populations at the southern end of this ESU (Keta and Blossom Rivers) are separated from the nearest populations to the south in Portland Inlet across the U.S. border in British Columbia by approximately 150 km. Southern Southeast Alaska populations are somewhat genetically similar to a small number of populations in Portland Inlet, but substantially diverged from the more productive populations in the Nass and Skeena Rivers to the south. Fish from the Taku and Stikine Rivers, classified as “outside rearing,” primarily rear in the GOA and Bering Sea, and are not caught frequently in inside waters as immatures. Contrastingly, other stocks in SEGOA are classified as “inside rearing,” and a portion of them

rear in SEGOA inside waters and are caught as immatures in this region; some also use the GOA and Bering Sea as rearing habitat.

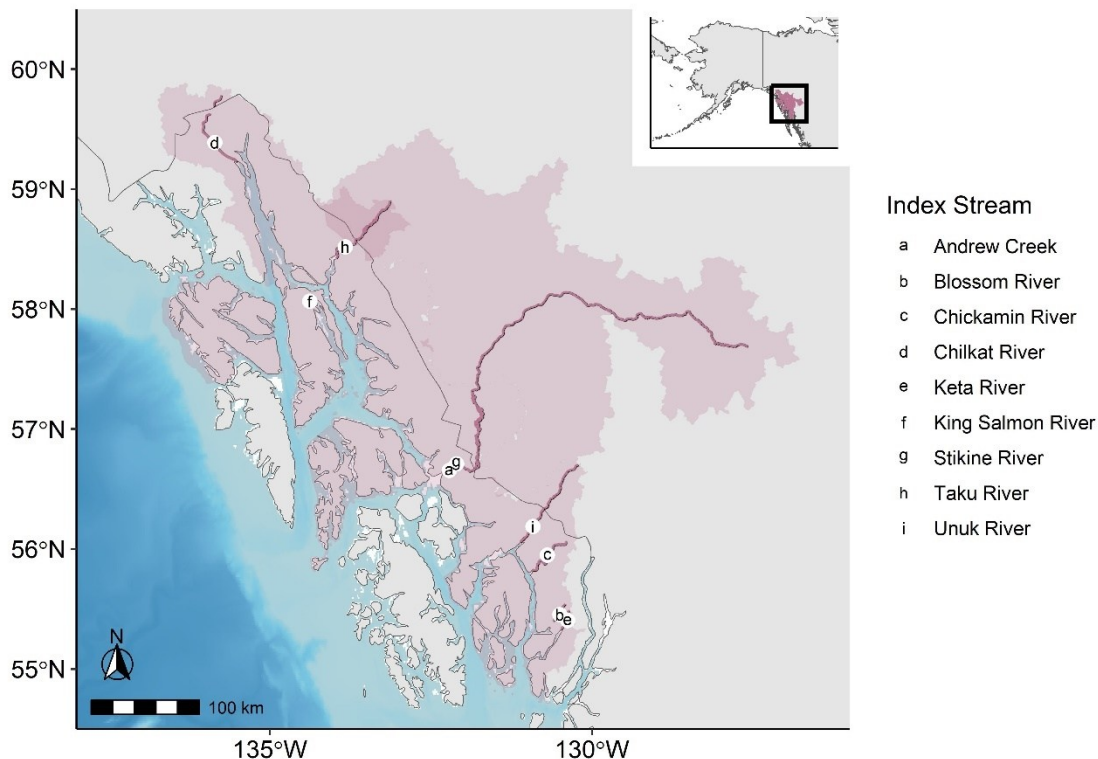


Figure 2. -- Index streams (Chinook systems with escapement monitored by ADF&G) in the Southeast Gulf of Alaska ESU.

Central Gulf of Alaska ESU

The Central Gulf of Alaska (CGOA) ESU includes populations from the Copper, Situk, and Alsek Rivers (Figure 3). Populations from the Copper River are highly genetically differentiated from Cook Inlet populations to the north, and from Southeast Alaska populations to the south. Copper River populations are also isolated by major habitat breaks. To the north, populations from the Copper River are separated from the closest populations on the Kenai Peninsula (~500 km away) by Prince William Sound, a rugged, mountainous region that does not contain any self-sustaining Chinook salmon populations. To the south, Copper River populations are separated from the Situk and Alsek Rivers by an area of rugged coastline containing glacially influenced rivers that do not contain any large, known populations of Chinook salmon, although there may be some small populations in this region. The Situk and Alsek Rivers are the only two rivers monitored by ADF&G with self-sustaining Chinook salmon in an 800 km region that spans from the Copper River to the Chilkat and Taku Rivers in Southeast Alaska. Both populations appear to be recently colonized based on genetic data, which is unsurprising given the dynamic

nature of this landscape characterized by shifting glaciers. The Situk River is the only known population in the GOA that is composed primarily of ocean-type individuals.

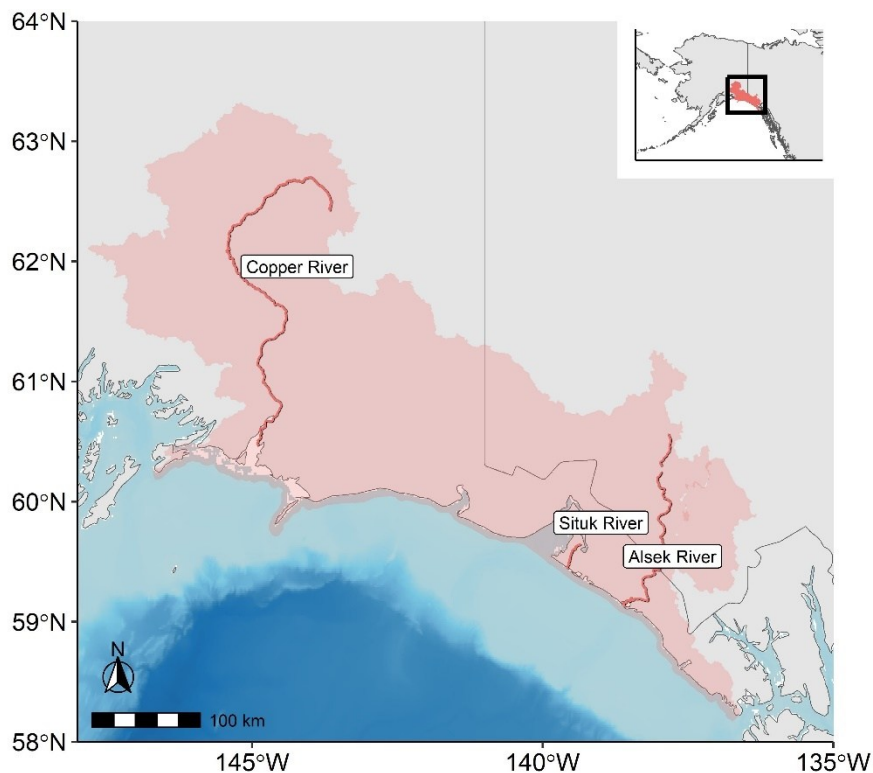


Figure 3. -- Index streams (Chinook systems with escapement monitored by ADF&G) in the Central Gulf of Alaska ESU.

Northwest Gulf of Alaska ESU

The Northwest Gulf of Alaska (NWGOA) ESU includes populations from the Chignik River on the South Alaska Peninsula, Kodiak Island (Ayakulik and Karluk Rivers), and Cook Inlet (includes the Susitna drainage and populations on the Kenai Peninsula) (Figure 4). Populations from this ESU rear in the GOA and the eastern Bering Sea to the best of our knowledge. This ESU is bounded by genetic breaks on both sides. Chignik River and populations on Kodiak are genetically diverged from populations on the North Alaska Peninsula, and populations on the western Kenai Peninsula are diverged from populations in the Copper River. The ESU boundaries also correspond to habitat breaks. Populations from the North Alaska Peninsula inhabit relatively low gradient coastal tributaries that drain flat tundra areas, whereas the South Alaska Peninsula is much more rugged and mountainous. Populations in Cook Inlet at the other margin of the ESU are separated from populations in the Copper River by Prince William Sound, which

contains steep mountains and glaciers that do not provide suitable habitat for self-sustaining populations of Chinook salmon.

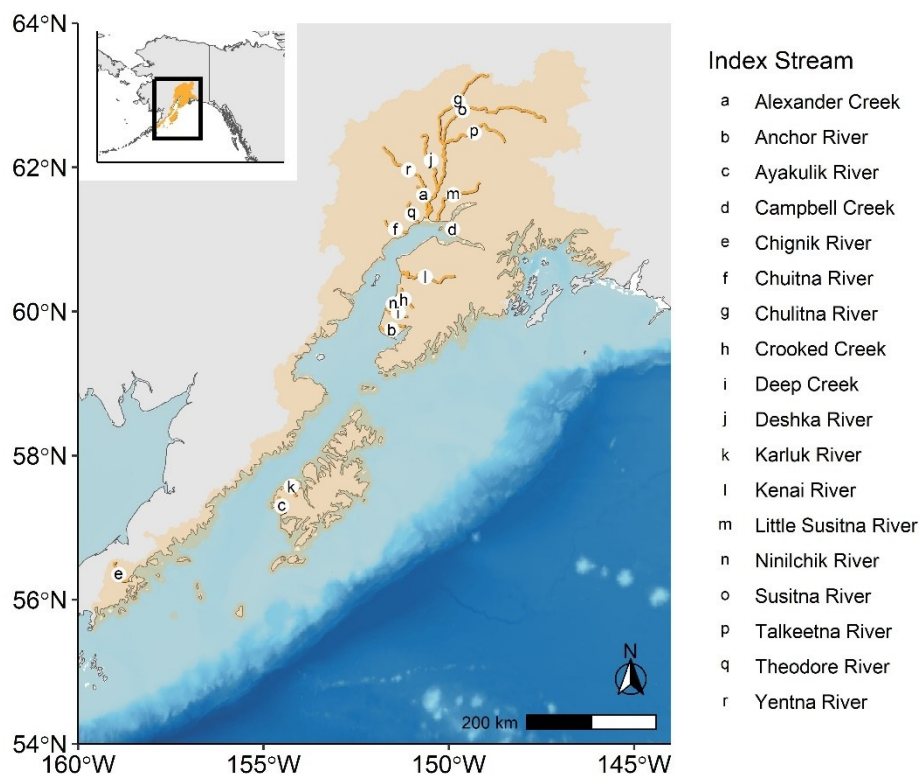


Figure 4. -- Index streams (Chinook systems with escapement monitored by ADF&G) in the Northwest Gulf of Alaska ESU.

Demographic Risk Analysis

Southeast Gulf of Alaska ESU

Short-term analyses highlight recent declines in estimated total run size and spawning escapements for several stocks within the Southeast Gulf of Alaska ESU, particularly since the early 2000s and 2010s. Escapement has decreased in systems such as the Chilkat, Unuk, King Salmon, Stikine, and Taku Rivers, but these declines generally remain within the scope of historical variability. Some stocks, including King Salmon, Taku, and Chilkat Rivers, have shown early signs of recovery in recent years. Run size trends follow a similar trajectory, with notable reductions in the past 15 years but some signs of stabilization or increase in specific stocks, particularly in the most recent 5-year period. Despite evidence of declines in the short term, long-term trend estimates indicate that observed changes largely fall within the range of historical variability. Some stocks, such as the Unuk River, have exhibited more persistent declines in escapement and run size, yet the overall trend across the ESU does not strongly support a conclusion of long-term decline. Stocks that experienced short-term reductions, such

as the Taku and King Salmon Rivers, have shown recent increases. However, the persistence of such increases remains uncertain, as short-term improvements may be temporary fluctuations rather than indicators of sustained recovery. Escapement trends exhibit clear clustering in the degree of synchrony among stocks, with stocks such as Blossom, Keta, Chickamin, and Unuk Rivers, and Andrew Creek demonstrating correlated trends, while Chilkat, Stikine, and Taku Rivers form a second, distinct group. In contrast, run size trends display weaker coherence among stocks, suggesting variable effects of harvests on spawning escapements.

Central Gulf of Alaska ESU

Short-term and long-term analyses of estimated total run size and spawning escapements for the Central Gulf of Alaska ESU of Chinook salmon indicate an overall stable population trajectory, with no strong evidence of sustained declines across the ESU. However, short-term analyses highlight more recent declines in specific stocks, particularly the Alsek and Situk Rivers, where both escapement and run size have decreased since the early 2000s. While these declines were initially pronounced, recent abundance levels in both rivers have been near long-term median values. In contrast, the Copper River has exhibited a long-term pattern of increasing escapement over multiple decades. This divergence in trends underscores the variability among stocks within the ESU, where some systems have shown short-term reductions while others have remained stable or increased. Indeed, a notable characteristic of the Central Gulf of Alaska ESU is the lack of strong interannual synchrony among stocks for both escapement and run size. This is particularly evident when comparing the distinct trajectories of the Alsek and Situk Rivers, which experienced mid-period declines, to the Copper River, which has exhibited consistent positive trends over time. Run size trends similarly lack strong coherence.

Northwest Gulf of Alaska ESU

Short-term and long-term analyses of estimated total run size and spawning escapements trends for the Northwest Gulf of Alaska ESU of Chinook salmon reveal moderate evidence of declines across multiple stocks, with patterns of decline generally beginning in the early 2000s. Short-term analyses indicate that many stocks, including Alexander Creek, Deshka River, Theodore River, Ninilchik River, and Karluk River, have experienced significant reductions in escapement in recent decades. Similarly, declines in run size have been observed in several stocks, including the Anchor River, Kenai River (early and late runs), East Susitna, Talkeetna, and Yentna Rivers. While these declines have persisted over multiple periods, some stocks show signs of stabilization, though at lower abundance levels than historical averages. The degree of decline varies by system, with some stocks exhibiting gradual reductions while others have shown more abrupt decreases, particularly in the early 2000s. A distinguishing characteristic of this ESU is the broad-scale coherence in interannual abundance trends across multiple stocks. Unlike other ESUs, where stock dynamics appear more independent, the Northwest Gulf of Alaska ESU demonstrates moderate-to-strong synchrony among stocks, particularly within certain regional groupings. For example, some stocks (e.g., Karluk and Ayakulik Rivers) show

strong correlations in both escapement and run size trends, suggesting shared environmental drivers or population dynamics. Similarly, the Kenai and Northern Cook Inlet stock groups exhibit moderate-to-strong coherence in both escapement and run size, indicating that population fluctuations may be influenced by large-scale environmental factors rather than localized conditions alone.

Summary of Threats

The status review team (SRT) evaluated a number of potential threats to GOA Chinook salmon, including habitat concerns, potential overutilization, disease, predation, adequacy of existing regulatory mechanisms, environmental conditions, invasive species, interactions with hatchery-origin salmon, and urban impacts. Additionally, the SRT discussed potential threats identified in the Listing Petition that NMFS, through its 90-day finding, deemed likely to lead a reasonable person to believe that the petitioned action may be warranted: “missed escapement goals in recent years for many stocks in the petitioned area, and evidence of decreasing size and age at maturity” (NMFS 2024d). While the topics raised in the Listing Petition are addressed throughout the document, they are not specifically singled out in this review because they are indicative of a lower productivity regime, but not diagnostic for population viability (extinction risk). Escapement goals in Alaska are not designed as thresholds for population viability, but rather to support sustained yield^{7,8}. When possible, these escapement goals are designed to support maximum sustained yield. Therefore, missed escapement goals should not be interpreted as a threat to population viability. Instead, they are useful for understanding productivity regimes and whether abundances are consistently available at levels that can provide for reliable harvest opportunities. Section 1.5 describes how GOA Chinook salmon fisheries management responds to missed escapement goals by taking action, such as reducing harvest, prior to stock abundance reaching levels low enough to present a risk to population viability. The SRT developed the demographic analysis section of this report (Section 6) to focus on population characteristics that are more informative for extinction risk than an assessment of escapement goals can provide. Similarly, reduced size and age at maturity may lead to reduced productivity when reproductive output also declines, but that characteristic is not diagnostic of population viability in isolation. Age and size diversity persists in these populations even if the mean has declined. Age and size at maturity attributes observed for GOA Chinook salmon remain well within the range for viable populations for this species: the mean size and age at maturity for GOA Chinook salmon remain larger and older than means for stocks further south in the species range. Consequently, the SRT has developed a more comprehensive review of the life history portfolio and ecology of GOA Chinook salmon (Section 2.2) to evaluate extinction risk.

⁷ Cornell Law School. 5 AAC 39.223 - Policy for statewide salmon escapement goals. Available at <https://www.law.cornell.edu/regulations/alaska/5-AAC-39.223>. Accessed September 11, 2025.

⁸ Cornell Law School. 5 AAC 39.222 - Policy for the management of sustainable salmon fisheries. Available at <https://www.law.cornell.edu/regulations/alaska/5-AAC-39.222>. Accessed September 11, 2025.

Overall, the SRT found threats due to habitat degradation, overutilization, inadequate regulations, disease and predation, hatchery salmon interactions, and increased environmental variability to be low or very low across all three ESUs (See risk matrix in Table 23). Increased environmental variability was identified as the most concerning threat for GOA Chinook salmon ESUs, although still considered a low risk. Analysis of this threat included increased prevalence and frequency of marine heatwaves, changing hydrology in freshwater systems, and increased temperatures, which were widely viewed as the most significant challenges for GOA Chinook salmon (Section 7.7.1). Some threats evaluated were deemed to have localized impacts, but were not a threat across an ESU. For example, predation was most notable for Alexander Creek stocks where invasive northern pike have become problematic. Of all the ESUs evaluated, habitat degradation due to urbanization was most notable for NWGOA ESU, though these impacts were not pervasive across the entire ESU or to a degree that the SRT determined would lead to risk of extinction in the foreseeable future.

Extinction Risk Assessment

The team's determination of overall risk to the Gulf of Alaska Chinook salmon ESUs used the categories of "high risk" of extinction, "moderate risk" of extinction, or "low risk" of extinction. The NMFS has defined these levels of risk in: "Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act"⁹. These risk levels have been used in prior Pacific Northwest salmonid species reviews with minor wording changes (Stout et al. 2012, Ford 2022, OC and SONCC Status Review Team 2024). They are defined as follows:

- **High Risk:** A species or ESU with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species or ESU at such a high level of risk may be highly uncertain and strongly influenced by stochastic or compensatory processes. Similarly, a species or ESU may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.
- **Moderate Risk:** A species or ESU is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "High risk" above). A species or ESU may be at moderate risk of extinction due to current and/or projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or ESU is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors. For example, the time horizon may reflect

⁹ NOAA Fisheries. Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act [hereinafter *Listing Guidance*]. Available at https://media.fisheries.noaa.gov/2021-02/Final%20Listing%20Guidance_%202017%20over_revisions_02012021_external.pdf?null. Accessed June 20, 2025.

certain life history characteristics (e.g., long generation time or late age-at-maturity) and should also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or ESU (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. The biologist (or Team) should, to the extent possible, clearly specify the time horizon over which it has confidence in evaluating moderate risk.

- **Low Risk:** A species or ESU is at low risk of extinction if it is not at moderate or high level of extinction risk (see “Moderate risk” and “High risk” above). A species or ESU may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species or ESU at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

The extinction risk determination reflects the informed professional judgment of each SRT member, based on a synthesis of best available information. This assessment was structured around a risk matrix framework that integrated demographic risk indicators with anticipated interactions among threats and other relevant factors. For the purpose of this review, the foreseeable future was defined as a period of 25 to 40 years, corresponding to approximately 5 to 8 generations of GOA Chinook salmon. Comprehensive demographic data across all ESUs were only available beginning in 1980, providing a 45-year historical baseline. The team could not make reasonably reliable projections farther into the future than the length of the available time series. Additionally, the projected impacts of environmental variability, ocean conditions, and freshwater habitat trends on GOA Chinook salmon viability become uncertain beyond this time frame.

As part of the ESA status review process, the SRT must perform a Significant Portion of the Range (SPR) analysis that serves as a distinct, but conceptually linked, evaluation of extinction risk within geographically or biologically discrete subsets of a species’ range. For salmonids and other species with strong population structure, the status review includes detailed population- or subpopulation-level assessments to inform the range-wide extinction risk determination. In these cases, the SPR analysis draws directly from that foundational work, using population-level data to assess whether any portion of the range may independently meet the criteria for listing as threatened or endangered. Our team took guidance for this process from other recent NMFS salmon status reviews, and the Listing Guidance (OC and SONCC Status Review Team 2024).

While the SPR analysis may incorporate elements of the prior risk matrix and demographic evaluation, it is guided by a different core question. Rather than asking whether the species is at risk of extinction across its entire range, the SPR framework evaluates whether the species is at risk within any particular portion, and whether that portion is significant to the species’ overall viability. An affirmative answer to both these questions provides the basis for further SPR analysis. This includes assessing whether the species is in danger of extinction, or likely to

become so in the foreseeable future, within the portion of interest, and whether that portion contributes meaningfully to the long-term persistence of the species. This shift in analytical lens distinguishes the SPR analysis from the range-wide assessment, even when the underlying biological data are shared.

Southeast Gulf of Alaska ESU

Rangewide Extinction Risk Assessment

The SRT concluded that the Southeast Gulf of Alaska Chinook salmon ESU is most likely to be at low risk of extinction in the foreseeable future. SRT members consistently cited the absence of significant long-term declines in abundance or productivity, the relatively pristine condition of freshwater and estuarine habitats, and the diversity and connectivity among populations as key factors supporting a low-risk determination. Many emphasized that although short-term declines have been observed in certain stocks, these patterns are highly variable, but are within the historical variability, and have either stabilized or begun to rebound in recent years. The risk matrix evaluations across the four viability attributes (abundance, productivity, spatial structure, and diversity) were uniformly low, with no indication of critical population-level failures.

While the overall risk was low, several SRT members acknowledged environmental variability as the most pressing emerging threat to this ESU. Concerns included shifts in streamflow patterns, reduced snowpack, increased peak flows, and marine heatwaves, all of which could negatively impact key life stages. However, these climate-related risks were generally viewed as insufficient, in isolation, to drive the ESU toward extinction within the next 25–40 years. Some SRT members assigned a small portion of likelihood points to the moderate risk category to reflect uncertainty about future environmental impacts, particularly in glacially influenced systems such as the Taku and Stikine. Nonetheless, SRT members agreed that current management actions, low levels of other threats (e.g., hatchery influence, predation, overutilization), and ecological resilience reduce the likelihood that this ESU is in danger of extinction in the foreseeable future.

SPR Extinction Risk Assessment

Following the determination of the overall ESU level risk for Southeast Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU's stock level threats, the SRT determined that each stock's risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

Central Gulf of Alaska ESU

Rangewide Extinction Risk Assessment

The SRT concluded that the Central Gulf Alaska Chinook salmon ESU was most likely to be at low risk of extinction within the foreseeable future. Most SRT members agreed that there is

little evidence of long-term declines in abundance or productivity and that habitat conditions remain largely intact, particularly in the Situk and Alsek Rivers. While some systems have experienced periods of reduced productivity, recent escapement trends have been stable or increasing, especially in the Copper River. SRT members also highlighted the presence of genetic structure within the Copper watershed and some evidence of connectivity between populations, suggesting that demographic and spatial diversity is sufficient to support viability.

A few SRT members expressed caution regarding emerging threats, particularly related to environmental variability and potential ecological isolation among populations. Environmental-related concerns included altered hydrology, warming stream temperatures, and changing marine conditions, which may impact key life stages and reduce productivity over time. Some SRT members assigned some points to the moderate-risk category, citing environmental variability and past declines as justification for acknowledging uncertainty about the ESU's long-term trajectory. Additionally, concerns were noted about limited buffering capacity due to the isolation of populations and potential ecological risks from hatchery programs. However, these factors were generally not considered sufficient to elevate the extinction risk above the low category due to low levels of all threats. Within this ESU, high levels of diversity and habitat intactness, combined with recently stable or increasing trends in abundance and productivity, reduce the likelihood of extinction in the foreseeable future.

SPR Extinction Risk Assessment

Following the determination of the overall ESU level risk for Central Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU's stock level threats, the SRT determined that each stock's risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

Northwest Gulf of Alaska ESU

Rangewide Extinction Risk Assessment

The SRT concluded that the Northwest Gulf of Alaska (NWGOA) Chinook salmon ESU was most likely to be at low risk of extinction. The conclusion of low extinction risk was supported by the ESU's broad geographic distribution, evidence of population connectivity, and generally robust spatial structure and diversity. The SRT noted significant long-term and short-term declines in abundance and productivity in multiple populations, with some stocks exhibiting signs of demographic stress. Additionally, environmental variability was identified as the most prominent overarching threat to the ESU, with additional cumulative stressors including predation by invasive northern pike, habitat impacts associated with urban development, and ecological risks from hatchery interactions, particularly in Cook Inlet and other road-accessible watersheds.

While these risks warrant continued attention within the NWGOA ESU, there are numerous measures in place to mitigate these concerns. Within Cook Inlet, the state has management strategies for controlling the expansion of the northern pike, an escapement-based management approach for addressing demographic stress, and habitat protections for urbanization impacts. These risks, mitigated by current actions, do not rise to a level that would place the ESU beyond the low-risk category. The SRT’s inclusion of moderate-risk points was intended to acknowledge demographic stress and the potential for cumulative threats to influence long-term outcomes; however, given the time horizon chosen by the SRT, no members felt that assigning high-risk points was warranted for any of these threats. Overall, the SRT’s assessment reflects a low extinction risk profile for the NWGOA Chinook salmon ESU, as it is not facing threats in abundance, productivity, spatial structure, or diversity that will lead to a risk of extinction in the foreseeable future. The SRT was also in broad agreement that continued monitoring, threat mitigation, and proactive management will help maintain population viability.

SPR Extinction Risk Assessment

Following the determination of the overall ESU level risk for Northwest Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU’s stock level threats, the SRT determined that each stock’s risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

ACKNOWLEDGMENTS

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1 INTRODUCTION

On January 11, 2024, the National Marine Fisheries Service (NMFS) was petitioned by the Wild Fish Conservancy (WFC) to delineate and list one or more evolutionarily significant units (ESUs) of Chinook salmon (*Oncorhynchus tshawytscha*) in southern Alaska—which the petition states “encompasses all Chinook populations that enter the marine environment of the Gulf of Alaska”—as threatened or endangered under the Endangered Species Act (ESA), and to designate critical habitat concurrently with the listing (Wild Fish Conservancy 2024). Hereafter, we will refer to the petitioned stocks of Chinook salmon in the Gulf of Alaska (GOA) as “GOA Chinook salmon.” On May 24, 2024, NMFS Alaska Regional Office (AKR) announced a “90-day” finding on the petition, determining that the petition presented sufficient scientific information to indicate that the petitioned action may be warranted (NMFS 2024d).

On June 12, 2024, the NMFS Alaska Fisheries Science Center (AFSC) initiated and led a status review team (SRT) to review and synthesize the best available scientific and commercial information, render expert opinion, and prepare a written report to inform AKR’s determination as to whether listing any GOA Chinook salmon ESU(s) as threatened or endangered under the ESA is warranted. Because the ESA stipulates that listing determinations should be made on the basis of the best scientific information available, NMFS AKR and AFSC formed an SRT of scientists with diverse backgrounds in genetics, oceanography, policy, and salmon biology to conduct this review. Additionally, two scientists from the Alaska Department of Fish and Game (ADF&G) and a Tribal liaison were included on the SRT as non-voting, advisory positions.

The SRT’s objective was to prepare a Status Review Report that identifies whether there are ESUs in the area covered by the petition, and provides thorough, science-based analyses regarding the demographic risks, the five section 4(a)(1) factors under the ESA, and extinction risk to the GOA Chinook salmon, in consideration of applicable laws and policies. The SRT used the best available scientific and commercial information including, but not limited to, published and unpublished literature, reports, models, traditional knowledge, and other data. The specific tasks of the SRT included the following:

- Configure and evaluate GOA ESUs.
- Complete a demographic risk analysis.
- Conduct a threats analysis.
- Complete the extinction risk synthesis.
- Conduct a Significant Portion of its Range (SPR) analysis.

This status review report is the result of the comprehensive ESA status review of GOA Chinook salmon by the SRT. This report was peer reviewed by four external salmon experts. A summary of the peer reviews will be published in parallel with this report.

1.1 ESU Policy

The ESA allows listing of species, subspecies, and distinct population segments (DPS) of vertebrates. The ESA as amended in 1978, however, provides no specific guidance for determining what constitutes a DPS. Waples (1991b) developed the concept of an ESU for identifying a DPS of Pacific salmon. This concept was subsequently adopted by NMFS in applying the ESA to anadromous salmon species (56 FR 58612). The NMFS ESU policy stipulates that a salmon population or group of populations is considered a DPS if it represents an ESU of the biological species (NMFS 1991). An ESU is defined as a population or group of populations that 1) is substantially reproductively isolated from conspecific populations, and 2) represents an important component in the evolutionary legacy of the species.

Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. The second criterion would be met if the population contributed substantially to the ecological or genetic diversity of the species as a whole (Waples 1991b). Information that can be useful in determining the degree of reproductive isolation¹⁰ includes incidence of straying, rates of dispersal, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance or discreteness can be provided by data on genetic and life-history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts on historical patterns of diversity (Waples 1991b).

The term "evolutionary legacy" is used in the sense of "inheritance," that is, something received from the past and carried forward into the future. Specifically, the evolutionary legacy of a species is the genetic variability that is a product of past evolutionary events, and that represents the reservoir upon which future evolutionary potential depends. Conservation of these genetic resources should help to ensure that the dynamic process of evolution will not be unduly constrained in the future.

The NMFS ESU policy identifies several types of evidence that should be considered in the species determination. For each of the criteria, the NMFS ESU policy advocates a holistic approach that considers all types of available information as well as their strengths and limitations.

ESUs have not previously been identified for GOA Chinook salmon (or any salmonid) in Alaska. Sections 3 and 4 of this document describe our methods for identifying ESUs within the GOA.

Throughout this document, we will refer to the distinct populations of Chinook salmon in the GOA that have been identified by the SRT as ESUs, because we determined that they meet the

¹⁰ Note that the ESU policy was developed and applied to salmon populations of the same species that are physiologically capable of interbreeding. The term reproductive isolation therefore refers to restricted gene flow for any reason, including, for example, geographic isolation or temporal differences in spawn timing.

criteria described by Waples (1991a). These criteria, and our rationale for our determinations, are described in the ESU Configuration sections of this report.

1.2 Background of Chinook Salmon under the ESA

Seventeen Chinook salmon ESUs¹¹ are currently identified in the portion of the species' range that includes California, Oregon, Idaho, and Washington (Figure 5). Hereafter, we will refer to these ESUs as "West Coast ESUs" because they are managed by the NMFS West Coast Region, and to distinguish them from our proposed GOA ESUs. Over the years, the boundaries of some ESUs have been modified as new information has become available. For example, the Southern Oregon and California Coastal ESU proposed by Myers et al. (1998) was split into the Southern Oregon Northern California Coastal ESU and the California Coastal ESU with the listing of the California Coastal ESU in 1999 (64 FR 50394, September 16, 1999). In 1999, NMFS concluded that the Deschutes River summer/fall run should be considered its own ESU, rather than part of either the Snake River fall-run ESU or the Upper Columbia River summer/fall-run ESU (WCCSBRT 1999).

¹¹ Technically, a population segment of Pacific salmon is not considered an ESU unless it is listed under the ESA. However, for convenience, we refer throughout this document to population segments of Chinook salmon that NMFS has previously determined met the ESU Policy criteria, but did not warrant listing under the ESA, as "unlisted ESUs." The number seventeen includes both listed and unlisted ESUs.

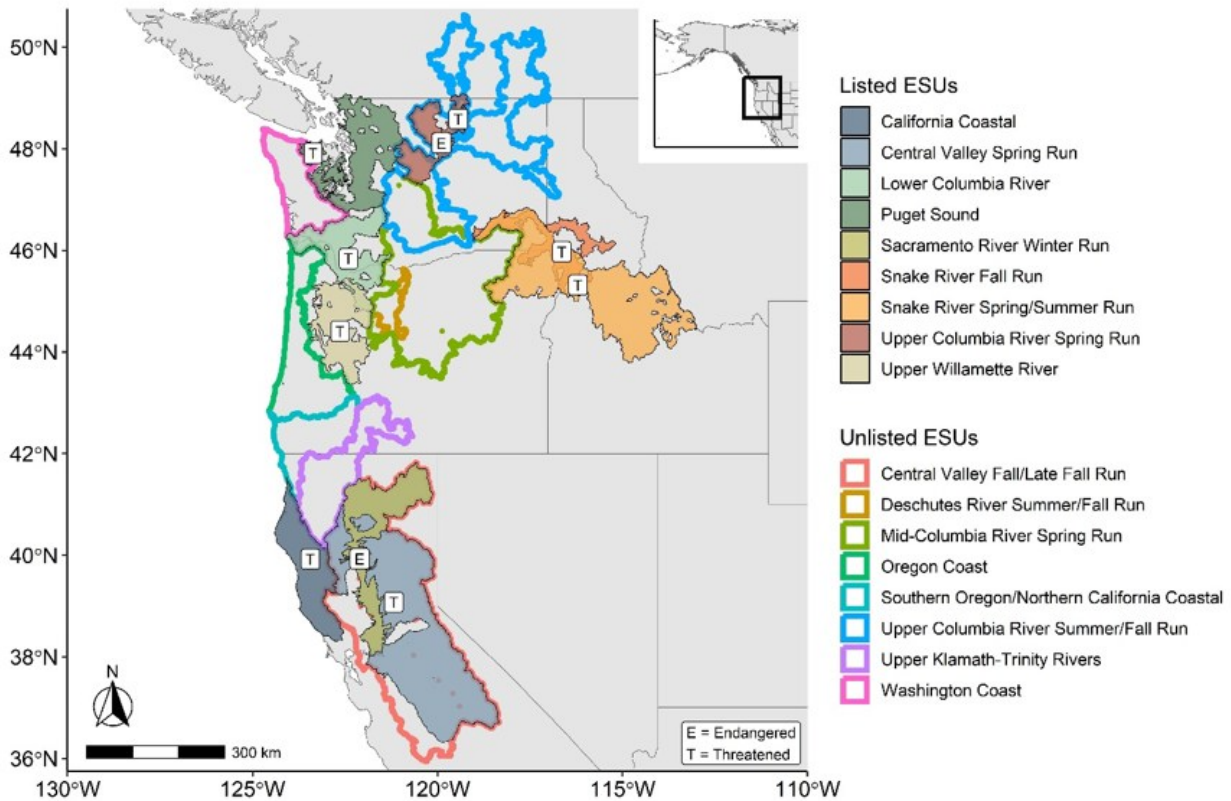


Figure 5. -- West Coast Chinook ESUs. Filled polygons represent listed ESUs; outlined polygons represent unlisted ESUs. ESUs marked with "T" are listed as threatened and those marked with "E" are listed as endangered under the Endangered Species Act.

1.2.1 Unlisted ESUs

Several West Coast Chinook population segments have been identified as meeting the ESU Policy criteria, but not warranted for listing (Figure 5). These unlisted ESUs include the following:

- Washington Coast.
- Middle Columbia River spring-run.
- Deschutes River summer/fall-run.
- Upper Columbia River summer/fall-run.
- Oregon Coast.
- Southern Oregon/Northern California Coastal.
- Upper Klamath-Trinity Rivers.
- Central Valley fall-run.

At the time the SRT was developing this report, the NMFS West Coast Region was reviewing the status of the Oregon Coast, Washington Coast, Southern Oregon/Northern California Coasts, and Upper Klamath-Trinity Rivers ESUs of Chinook salmon to determine if listings are warranted.

1.2.2 History of listed ESUs

Nine West Coast ESUs are currently listed under the ESA: two as endangered and seven as threatened (Table 1, Figure 5). All the listed ESUs were reaffirmed in 2005 (70 FR 37160) and updated in 2014 (79 FR 20802). Critical habitat has been designated and recovery plans have been developed for all listed ESUs of Chinook salmon (Table 1). A full list of species under NMFS jurisdiction is available at 50 CFR 223.102(e) (threatened species) and 50 CFR 224.101(h) (endangered species).

Under section 4(c)(2) of the ESA, the U.S. Secretary of Commerce (through NMFS) is required to review the status of threatened and endangered species at least once every 5 years to determine whether reclassification or delisting may be warranted. Table 1 provides details on the most recent 5-year status review for each Chinook salmon ESU. Notably, the Sacramento River winter-run ESU was uplisted from threatened to endangered in 1994, shortly after its initial listing in 1989. No other Chinook salmon ESU has experienced a change in ESA classification since listing.

Table 1. -- ESA-listed Chinook salmon ESUs, current listing status, dates and Federal Register citations for original listing and critical habitat designation, year and citation for recovery plan, and year and citation for most recent 5-year review. Listing statuses are E=endangered, T=threatened.

Chinook Salmon ESU	Current Listing Status	Original Listing*	Critical Habitat	Recovery Plan	Most Recent 5-Year Review and Viability Assessment
Puget Sound	T	64 FR 14308 March 24, 1999	70 FR 52630 Sept. 2, 2005	NMFS (2006), SSPS (2007)	5-year Review: NMFS (2016a) Viability Assessment: Ford (2022)
Upper Columbia River spring-run	E	64 FR 14308 March 24, 1999	70 FR 52630 Sept. 2, 2005	UCSRB (2007)	5-year Review: NMFS (2022d) Viability Assessment: Ford (2022)
Lower Columbia River	T	64 FR 14308 March 24, 1999	70 FR 52630 Sept. 2, 2005	NMFS (2013)	5-year Review: NMFS (2022a) Viability Assessment: Ford (2022)
Snake River spring/summer-run	T	57 FR 23458 June 3, 1992	58 FR 68543 Dec. 28, 1993 Revised 64 FR 57399 Oct. 25, 1999	NMFS (2017b)	5-year Review: NMFS (2022c) Viability Assessment: Ford (2022)
Snake River fall-run	T	57 FR 14653 April 22, 1992	58 FR 68543 Dec. 28, 1993 Revised 64 FR 57399 Oct. 25, 1999	NMFS (2017a)	5-year Review: NMFS (2022b) Viability Assessment: Ford (2022)
Upper Willamette River	T	64 FR 14308 March 24, 1999	70 FR 52630 Sept. 2, 2005	ODFW and NMFS (2011)	5-year Review: NMFS (2024c) Viability Assessment: Ford (2022)
California Coastal	T	64 FR 50394 Sept. 16, 1999	70 FR 52630 Sept. 2, 2005	NMFS (2016c)	5-year Review: NMFS (2024a) Viability Assessment: NMFS (2023)
Sacramento River winter-run	E	54 FR 32085 Aug. 4, 1989	58 FR 33212 June 16, 1993	NMFS (2014)	5-year Review: NMFS (2024b) Viability Assessment: NMFS (2023)
Central Valley spring-run	T	64 FR 50394 Sept. 16, 1999	70 FR 52630 Sept. 2, 2005	(NMFS 2014)	5-year Review: NMFS (2016b) Viability Assessment: NMFS (2023)

*The ESA listing status was reaffirmed in 2005 for all ESUs listed in the table above (70 FR 37160, June 28, 2005), and in 2014 the Code of Federal Regulations was updated to correct errors, update cross-references and provide consistent language for each listed species (79 FR 20802, April 14, 2014).

1.3 Summary of Petition

This section briefly summarizes the information presented by the petitioner (WFC) to support their assertion that GOA Chinook salmon warrant listing as threatened or endangered under the ESA.

On January 11, 2024, NMFS AKR received a petition from the WFC to delineate and list one or more ESUs of Chinook salmon in southern Alaska, which the petition states “encompasses all Chinook populations that enter the marine environment of the Gulf of Alaska” as threatened or endangered under the ESA, and to designate critical habitat concurrently with the listing. The petition indicates that this “includes all populations on the southern side of the Aleutian Peninsula, Cook Inlet, and the coast of Alaska south of Cook Inlet to the southern end of the Alaska/British Columbia border.” The petition asserts that GOA Chinook salmon are threatened by all of the ESA section 4(a)(1) factors: (1) the present or threatened destruction, modification, or curtailment of habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms to address identified threats; and (5) other natural or manmade factors affecting its continued existence (16 U.S.C. 1533(a)(1), 50 CFR 424.11(c)). In addition to requesting that we analyze whether GOA Chinook salmon warrant listing, the petition requested that we analyze whether any ESU of GOA Chinook salmon in the petitioned area warrants listing. The petition is available online at <https://www.fisheries.noaa.gov/action/petition-list-gulf-alaska-chinook-salmon-threatened-or-endangered-under-endangered-species>.

1.3.1 Evaluation of the petition and information readily available in NMFS' files

WFC requested that NMFS delineate and list one or more ESUs of Chinook salmon in southern Alaska as threatened or endangered under the ESA, and to designate critical habitat concurrently with the listing. The petition indicated that this “includes all populations on the southern side of the Aleutian Peninsula, Cook Inlet, and the coast of Alaska south of Cook Inlet to the southern end of the Alaska/British Columbia border.” NMFS interpreted WFC’s request as asking NMFS to consider populations of Chinook salmon on the southern side of the Alaska Peninsula, including Kodiak Island, Cook Inlet, Prince William Sound, and the Gulf of Alaska coastline and inside waters of Southeast Alaska to the United States/Canada border at approximately 54°45’ N. latitude. The petition was accompanied by literature citations and electronic copies of supporting material, including published scientific literature and unpublished reports.

In the sections that follow, we provide a synopsis of the assertions made in the petition for each of the factors identified in section 4(a)(1) of the ESA. Our analysis and conclusions follow in subsequent sections of this review.

1.3.2 Population status and trends

The petition asserted that since at least 2007, all populations of GOA Chinook salmon have experienced significant declines in abundance compared to levels exhibited in the previous two or more decades. The petition provided as evidence examples of missed escapement goals for some stocks. Additionally, the petition asserted that size and age at maturity have been decreasing across most populations for more than two decades. The petition noted that seven stocks have action plans developed in response to their designations by the State of Alaska as stocks of management concern.

1.3.3 Analysis of ESA Section 4(a)(1) factors for GOA Chinook salmon

The petition asserted that GOA Chinook salmon are experiencing threats under each of the categories listed under section 4(a)(1)(A) of the ESA and listed below:

- The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range.
- Overutilization for Commercial, Recreational, Scientific, or Educational Purposes.
- Disease or Predation.
- Inadequacy of Existing Regulatory Mechanisms.
- Other Natural or Manmade Factors Affecting Its Continued Existence.

Regarding Factor 1 (habitat), the petition asserted that GOA Chinook salmon habitat is degraded by clear-cut logging, erosion and sedimentation, elevated stream temperatures, habitat fragmentation, chemical run-off, road building, fish passage barriers, and mining.

Regarding Factor 2 (overutilization), the petition asserted that overharvest by directed commercial fisheries and bycatch in other commercial fisheries threatens the continued existence of GOA Chinook salmon and cites missed escapement goals in recent years to support this assertion. The petition asserted that reduced recreational harvest in 2021 relative to harvest levels in 2005 and 2006 indicates overharvest by the recreational sector.

Regarding Factor 3 (disease), the petition asserted that diseases originating in hatcheries (e.g., furunculosis, piscine reovirus, bacterial gill and kidney disease, and others) have been transmitted to wild populations, driving mortality of all life stages of GOA Chinook salmon. Specific examples of disease outbreaks in the petitioned area were not provided.

Regarding Factor 3 (predation), the petition asserted that predation pressure on adult GOA Chinook salmon is increasing as a result of growing populations of killer whales (*Orcinus orca*), and that humpback whales (*Megaptera novaeangliae*) may be learning to target hatchery releases of Chinook salmon in Southeast Alaska.

Regarding Factor 4 (inadequate regulations), the petition asserted that Federal regulatory mechanisms such as the National Environmental Policy Act (NEPA), ESA, National Forest Management Act, and Clean Water Act are failing to provide adequate protection to GOA

Chinook salmon. The petition broadly stated that the State of Alaska's management of salmon fisheries has been inadequate and that the state has not implemented sufficient corrective actions to address missed escapement goals.

Regarding Factor 5 (other factors), the petition asserted that artificial propagation of pink salmon increases competition for prey with wild Chinook salmon and has led to decreased rates of growth and survival of Chinook salmon. The petition asserted that changes in patterns of ocean productivity combined with climate change may be threatening GOA Chinook salmon. The petition listed numerous potential effects of climate change to freshwater, estuarine, and marine habitats, and assumed that nearly all will have negative effects on GOA Chinook salmon.

1.3.4 90-day finding on the petition

NMFS reviewed the petition, the literature cited in the petition, and other literature and information available in our files. NMFS identified numerous factual errors, omissions, incomplete references, and unsupported assertions and conclusions within the petition. However, NMFS found that some information presented in the petition, in particular the missed escapement goals in recent years for many stocks in the petitioned area, and evidence of decreasing size and age at maturity, would lead a reasonable person to believe that the petitioned action may be warranted. Additionally, it is likely that more than one ESU exists within the petitioned area and without delineating the boundaries of those ESUs, it would be challenging, if not impossible, to assess the status and trends of subpopulations. Therefore, in accordance with section 4(b)(3)(A) of the ESA and NMFS' implementing regulations (50 CFR 424.14(h)(2)), NMFS published a positive 90-day finding (NMFS 2024d) and commenced a status review of this species. The goal of the status review is to identify ESUs and determine whether any ESU of GOA Chinook salmon is in danger of extinction (endangered) or likely to become so within the foreseeable future (threatened) throughout all or a significant portion of its range.

1.4 Sources of Information

Information used to inform NMFS review of the petition and 90-day finding was limited to the literature cited in the petition and other literature and information available in our files. For this status review report, we gathered information from a wide variety of sources, described below.

1.4.1 Public comment period

To ensure that our status review was informed by the best available scientific and commercial data, NMFS opened a 60-day public comment period to close on July 23, 2024 to solicit information on GOA Chinook salmon. NMFS requested information from the public, governmental agencies, Alaska Native organizations, the scientific community, conservation groups, fishing groups, industry, or any other interested parties concerning the current and/or historical status of GOA Chinook salmon. Specifically, we requested information regarding:

1. species abundance;

2. species freshwater and saltwater productivity;
3. species distribution or population spatial structure;
4. patterns of phenotypic, genotypic, and life history diversity;
5. habitat conditions and associated limiting factors and threats;
6. information on the adequacy of existing regulatory mechanisms, whether protections are being implemented, and whether they are proving effective in conserving the species;
7. data concerning the status and trends of identified limiting factors or threats to population persistence;
8. information on targeted harvest (commercial and non-commercial) and bycatch of the species;
9. information to evaluate the ESU factors, specifically,
 - a. whether any populations are substantially reproductively isolated from other conspecific populations; and
 - b. whether any population represents an important component in the evolutionary legacy of the species;
10. other new information, data, or corrections including, but not limited to, taxonomic or nomenclatural changes; and
11. information concerning the impacts of environmental variability and climate change on survival, growth, age, fecundity, recruitment, distribution, and/or extinction risk.

At the request of Tribes, the State of Alaska, and the North Pacific Fishery Management Council, NMFS extended the public comment period for an additional 45 days until September 6, 2024. NMFS received more than 174 public comments during the extended comment period. These comments may be viewed online at www.Regulations.gov (enter NOAA-NMFS-2024-0042 in the search box). Relevant information provided in these comments was incorporated into our analysis.

1.4.2 Tribal outreach and engagement

NMFS engaged with Alaska Native Tribes and Alaska Native Corporations (Tribal Officials) throughout the status review process. Per Executive Order (EO) 13175, *Consultation and Coordination with Indian Tribal Governments*, agencies shall “have an accountable process to ensure meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications.” Additionally, E.O. 13175 states that, “no agency shall promulgate any regulation that has tribal implications and that preempts tribal law unless the agency, prior to the formal promulgation of the regulation, consulted with tribal officials early in the process of developing the proposed regulation.” Additionally, Secretarial Order 3206, *American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*, describes the “unique government-to-government relationship between Indian Tribes and the United States, the Departments and affected Indian Tribes and the need to establish and maintain effective working relationships and mutual partnerships to promote the conservation of

sensitive species (including candidate, proposed and listed species) and the health of ecosystems upon which they depend. Such relationships should focus on cooperative assistance, consultation, the sharing of information, and the creation of government-to-government partnerships to promote healthy ecosystems.” Secretarial Order 3206 recognizes the right of Indian Tribes to participate fully in the listing process by providing timely notification to, soliciting information and comments from, and utilizing the expertise of, Indian Tribes.

The SRT acknowledges the vast traditional knowledge and expertise in biology and sustainable salmon management held by Alaska Natives since time immemorial. *NOAA’s Guidance and Best Practices for Engaging and Incorporating Indigenous Knowledge in Decision-Making* states: “Bringing forward equitable engagement practices for the involvement of Indigenous Knowledge will inform and enrich many aspects of NOAA’s work, allowing us to better understand Earth and ocean systems and fulfill our management responsibilities.” As such, we upheld this directive and sought to incorporate traditional knowledge into this status review through tribal outreach and engagement, as well as including a tribal liaison on the SRT.

The 90-day finding included an announcement of a public comment period to gather information to inform the status review. During the extended public comment period, NMFS received seventeen comments from Tribal Officials (some representing a large number of member tribes and individuals) and individuals. These comments (1) provided thoughtful histories of the importance of salmon to native cultures, (2) expressed opinions and concerns regarding a potential ESA listing, (3) requested greater transparency and inclusion in the status review process, (4) requested tribal consultations and informal informational sessions, and (5) identified threats to Chinook salmon and data sources to inform the status review.

Under our federal trust responsibility, NMFS provided additional direct outreach and opportunities for Tribal Officials to participate in the status review process. NMFS sent two letters to the 176 Alaska Native Tribes and eight Alaska Native Corporations that reside in the petitioned geographic area. The first letter informed Tribal Officials that a petition had been received. The second letter (1) announced our positive 90-day finding and intent to proceed with a status review, (2) requested information to inform the status review, (3) communicated our openness and desire to meet and/or consult with interested Alaska Native Tribes and Corporations, and (4) encouraged interested tribes to share information through the government-to-government process. These letters offered participation to all Alaska Native Tribes and Corporations within the geographic range of the petition. Once requested, NMFS participated in tribal consultation with the following Tribal Officials:

- Central Council of Tlingit and Haida Indian Tribes of Alaska (representing Southeast Alaska Tribes).
- Chugach Regional Resources Commission (representing Central Gulf of Alaska Tribes).

- Doyon Corporation.
- Calista Corporation.
- Chickaloon Native Village.
- Eyak Native Village.

During these consultations, NMFS answered questions about the status review process, heard testimony from tribes about the importance of Chinook salmon to their communities, listened to concerns regarding management, gleaned sources of additional data to be incorporated into analyses, and discussed threats unique to each region. For example, during consultation with the Central Council Tlingit and Haida Indian Tribes of Alaska, tribal concerns were raised regarding the presence of federal and state representation, but the lack of tribal representation, on the SRT. In response to tribal concerns, NMFS added a tribal representative (Clinton Cook) as an advisor to the SRT.

NMFS also participated in informational meetings with several Subsistence Regional Advisory Councils including the Southeast, Southcentral, and Kodiak/Aleutian Islands Regional Advisory Councils.

Information gathered from tribal participants during tribal consultations and Subsistence Regional Advisory Council meetings informed this status review report.

1.4.3 Alaska Department of Fish and Game

As the primary managers of salmon and salmon fisheries in Alaska, the Alaska Department of Fish and Game (ADF&G) has the most comprehensive monitoring data for Chinook salmon in the region. It was imperative that NMFS collaborate with ADF&G and use their data for this review. Two senior scientists from the department were invited to join the SRT in a non-voting role as technical advisors. These advisors provided the team with the data and context needed for many analyses. These data included the most up-to-date escapement and/or run size estimates and brood tables that were available for all stocks within this region (including unpublished estimates for recent years). In addition, ADF&G provided references to published reports documenting the methods used to collect these data and derive estimates were provided. ADF&G also submitted an informative report during the public comment period (available at [www.Regulations.gov](https://www.regulations.gov); enter NOAA-NMFS-2024-0042 in the search box) and granted NMFS permission to use sections of that report to inform this status review.

1.5 Overview of Chinook Salmon Management

Authority to manage salmon populations and fisheries within the Gulf of Alaska was granted by the federal government to the State of Alaska in 1960, one year after statehood. Since then, the State of Alaska has implemented strategies that utilize spawning escapement goals as the primary management targets for major salmon stocks (ADF&G 2023b). Escapement goals are based on the principle of sustained yield; that is, adhering to these goals will support sustainable salmon yields into the future in terms of escapement and harvest. This

management approach is stipulated in Article VIII, Section 4 of the Alaska Constitution and in state statute (AS 16.05.050). Other notable policies that guide salmon management in Alaska include the Policy for Statewide Salmon Escapement Goals (5 AAC 39.223), the Policy for the Management of Mixed Stock Fisheries (5 AAC 39.220), and local fishery management plans (5 AAC 39.200; ADF&G 2023b).

Additionally, the Policy for the Management of Sustainable Salmon Fisheries (5 AAC 39.222) calls for the conservative management of salmon populations, fisheries, essential habitats, and hatchery enhancement efforts (5 AAC 39.222(c)(5)). This policy outlines the different types of escapement goals to which salmon stocks can be managed. The biological escapement goal (BEG), specified as a range, is the escapement that provides the greatest potential for maximum sustained yield (MSY). In situations where a BEG cannot be estimated or implemented, the sustainable escapement goal (SEG) is used, which is the escapement known to provide for sustained yield over a 5- to 10-year period. The SEG is typically expressed as a range or a lower bound. BEG and SEG escapement goals are developed by ADF&G based on the best available biological information and are scientifically defensible. Other goals include the optimal escapement goal (OEG) and in river run goal, which are allocative in nature and may be established by the Alaska Board of Fisheries for a given stock to meet specific management objectives (ADF&G 2023b).

Escapement goals are identified by ADF&G and presented to the Alaska Board of Fisheries and the public for consideration every 3 years at board meetings. The Alaska Board of Fisheries is responsible for making allocative and regulatory decisions to both conserve and develop the fisheries resources of Alaska, including setting seasons, bag limits, and allocations across commercial, sport, subsistence, and personal use fisheries. The board comprises seven members with diverse perspectives, who are appointed by the governor for 3-year terms and confirmed by the state legislature. Any escapement goals identified by ADF&G and the Board of Fisheries must then be approved for management by the directors of the Divisions of Commercial Fisheries and Sport Fish. The State of Alaska currently has 232 active salmon stock escapement goals across all species, including 31 escapement goals for GOA Chinook salmon (A. Munro, ADF&G, personal communication, March 7, 2025).

ADF&G and the Alaska Board of Fisheries are also responsible for identifying salmon stocks that fail to meet escapement and/or harvest goals consistently across a period of 4-5 years (average generation time of Chinook salmon). A stock can be designated a stock of concern in one of three categories based on yield concerns, management concerns, or conservation concerns. At the time a stock is designated a stock of concern, ADF&G and the Alaska Board of Fisheries develop an action plan with management actions to achieve identified rebuilding goals and objectives, identify measures to restore and protect salmon habitat, and develop performance measures for monitoring and gauging effectiveness of the action plan. The department then implements regulatory actions (e.g., harvest restrictions) for this stock, and the stock's status is reviewed every 3 years (ADF&G 2023b).

Additional details regarding the management of GOA Chinook salmon in three proposed ESUs -- Southeast Gulf of Alaska, Central Gulf of Alaska, and Northwest Gulf of Alaska -- are described below.

1.5.1 Chinook salmon management in the Southeast Gulf of Alaska

The Southeast Gulf of Alaska (SEGOA) ESU comprises 32 known stocks of Chinook salmon, of which nine stocks -- Chilkat, Taku, King Salmon, Stikine, Unuk, Chickamin, Blossom, and Keta Rivers, and Andrew Creek -- produce a majority of all Chinook salmon in the region (Munro and Brenner 2022, ADF&G 2023b, Munro and Chenoweth 2025). These nine stocks are managed according to State of Alaska Management Plans to achieve escapement goals and are designated as escapement indicator stocks by ADF&G. Escapement for each stock is estimated annually using various methods including weir counts, mark-recapture studies, and observer counts (ADF&G 2023b, Munro and Chenoweth 2025). Escapement goals for these nine stocks were developed by ADF&G, adopted by the Alaska Board of Fisheries, and also approved by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC), which implements the bilateral Pacific Salmon Treaty (PST) between the United States and Canada. Escapement goals for the Taku and Stikine Rivers (transboundary rivers) were further approved by the Transboundary Technical Committee of the PSC.

Escapement goals for Chinook stocks in the SEGOA pertain to “large” fish that have mid-eye fork lengths greater than 660 mm, which typically correspond to Chinook that have spent at least three years in the ocean (Mecum 1990, McPherson et al. 1996). Smaller Chinook (i.e., those that spend only 1 or 2 years at sea) are considered by the ADF&G to be surplus to spawning escapement needs, as these are predominantly early-maturing males. In addition, small Chinook cannot be accurately distinguished from other species during aerial and foot surveys (Mecum 1990, McPherson et al. 1996). Notably, four of the nine escapement indicator stocks (King Salmon, Taku, Stikine, and Andrew Creek) are currently designated as stocks of management concern by the State of Alaska, which signifies a chronic inability to meet escapement goals despite the use of specific management measures.¹² Action plans were developed by the Alaska Board of Fisheries in cooperation with ADF&G when the stocks were listed and are periodically reviewed.

Four of the nine ADF&G escapement indicator stocks - Chilkat, Taku, Stikine, and Unuk -- are also currently considered escapement indicator stocks by the CTC (CTC 2024). Notably, these four stocks have full stock assessment programs in place. Each year, a number of juvenile Chinook salmon in these systems are captured, marked with adipose fin-clips, and tagged with coded-wire tags (CWT) before being released back into the wild. The marking and tagging of these wild stocks enable managers to estimate metrics such as smolt abundance and marine harvest by gear, area, and time in mixed-stock commercial and sport fisheries (ADF&G 2023b).

¹² ADF&G, State of Alaska Special Status Species, Fish Stocks of Concern. Available at <https://www.ADF&G.alaska.gov/index.cfm?ADF&G=specialstatus.akfishstocks>, accessed March 11, 2025.

When paired with other data including spawning abundance and age, sex, and length composition estimates, information from the CWT programs allows for estimates of marine (smolt-to-adult) survival, total return, and exploitation rates. These data are presented each year by the Chinook Technical Committee in their Annual Report on Catch and Escapement (e.g., CTC 2024).

The Pacific Salmon Treaty, first established in 1985, aims to maximize the long-term sustainability of wild salmon stocks and allocate harvest between the two countries based on relative productivity. As such, Chinook salmon harvests in SEGOA must not exceed the annual catch limit established by the PSC (e.g., CTC 2023, CTC 2024). Of the annual catch limit set by the PSC, regulations established by the Alaska Board of Fisheries allocate catches among troll, net, and sport fisheries, although harvests of Chinook salmon in net fisheries are primarily incidental to harvest of other species. Currently, 4.3% of the annual catch limit is allocated to purse seine fisheries, 2.9% to drift gillnet fisheries, and 1,000 fish for set gillnet fisheries. Historically, 80% of the remaining catch limit is allocated to the commercial troll fishery and 20% to sport fisheries, although new allocations of 77% and 23% will take effect in 2025. Bag and possession limits for the sport fisheries are established prior to the season. Importantly, the estimated incidental mortality of Chinook salmon each year across all of these SEGOA fisheries cannot exceed 59,400 Chinook salmon per Chapter 3, Paragraph 4(f) of the 2019 PST.

Fisheries are managed in-season by ADF&G according to State Fishery Management Plans to ensure the PSC catch and incidental mortality limits are not exceeded; commercial fisheries are managed using a fish ticket reporting system while sport harvests are monitored using integrated data from port sampling (creel) and charter logbook reporting programs. ADF&G port sampling programs are in place for all fisheries to recover CWTs from tagged Chinook salmon to assess catch composition, as well as to collect biological samples and other fishery information. Chinook salmon fisheries in SEGOA are sampled at a minimum rate of 20% of the total harvest for CWTs stratified by gear, fishing area, and statistical week. Sampling data is crucial to the management of fisheries, as the data enables managers to analyze stock contributions, create brood tables, generate run forecasts, determine migratory patterns and routes, determine size-at-age relationships, and fulfill international harvest sharing agreements outlined in the PST (ADF&G 2023b). Data on catch, escapement, and exploitation rates for SEGOA Chinook by fishery are summarized annually by the PSC Chinook Technical Committee in their reports on Annual Catch and Escapement (e.g., CTC 2023, CTC 2024).

Approximately 7-8 million hatchery Chinook salmon smolt are released into the marine environment each year in SEGOA to support commercial and recreational fisheries (Wilson 2022, Wilson 2023, Wilson 2024). Importantly, most hatchery Chinook salmon harvested in SEGOA - the “Alaska hatchery add-on” - do not count towards the annual catch limit set by the PSC. The Alaska hatchery add-on is the total estimated catch of Alaska hatchery-origin fish, minus a base Alaska hatchery catch of 5,500 fish, and minus the risk adjustment (product of

standard error for the total estimated Alaska hatchery catch and a risk factor of 1.282; CTC 1992). In 2023, the Alaska hatchery add-on was 32,423 Chinook (CTC 2024).

Additionally, there are State and Federal personal use or subsistence fisheries in designated areas of SEGOA. State personal use and subsistence permit holders in the Ketchikan management area are allowed to harvest Chinook salmon from Herring Bay terminal harvest area, while permit holders in the Petersburg-Wrangell management area are allowed to harvest Chinook in the Anita Bay terminal harvest area¹³

Federal subsistence fisheries are regulated by a Federal Subsistence Board, which is established by the U.S. Secretary of the Interior and Secretary of Agriculture. According to 36 CFR 242.10, the Board comprises, a Chair to be appointed by the Secretary of the Interior with the concurrence of the Secretary of Agriculture; five public members who possess personal knowledge of and direct experience with subsistence uses in rural Alaska to be appointed by the Secretary of the Interior with the concurrence of the Secretary of Agriculture; the Alaska Regional Director, U.S. Fish and Wildlife Service; Alaska Regional Director, National Park Service; Alaska Regional Forester, U.S. Forest Service; the Alaska State Director, Bureau of Land Management; and the Alaska Regional Director, Bureau of Indian Affairs. Each Federal agency member of the Board may appoint a designee. Liaisons to the board (i.e., consultants) include a state liaison and the chair of each regional council. The board is empowered to issue regulations for the management of federal subsistence fisheries, including harvest limits, permit restrictions, fishing seasons, and harvest reporting. Regulations are specified in the Code of Federal Regulations (36 CFR Part 242). In SEGOA, there is a limited federal subsistence fishery for Chinook in the Stikine River in which permit holders are allowed to harvest up to five Chinook salmon between May 15 and June 20 (2023-2025 federal subsistence management regulations for the harvest of fish and shellfish on the federal public lands and waters in Alaska). Additionally, there is a federal subsistence fishery that was established in 2024 on the Taku River. This fishery mirrors the State of Alaska personal use fishery; it does not directly target Chinook salmon, but allows for incidental take of up to two individuals.

Southeast Gulf of Alaska has the only federally recognized Indian reservation in Alaska: the Metlakatla Indian Community (MIC) Annette Islands Reserve. In 1916, the Annette Islands Fishery Reserve was created, which established an exclusive fishing zone (3,000 feet wide) around the Annette Islands for the Metlakatla Indian Community (25 CFR Part 241; MIC 2022, NPFMC 2024). Fisheries within this reserve are regulated by the U.S. Department of the Interior and are managed by the U.S. Fish and Wildlife Service and the Metlakatla Community in cooperation with the ADF&G (NPFMC 2024). Each year, a Salmon Fishery Management Plan is developed by the Metlakatla Indian Community and authorized by the Bureau of Indian Affairs (on behalf of the Secretary of the Interior; MIC 2022). The Metlakatla Indian Community has a Fisheries Management Board (FMB), which is responsible for enacting the Management Plan.

¹³ ADF&G, Southeast Alaska/Yakutat Area, Subsistence Fishing. Available at <https://www.adfg.alaska.gov/index.cfm?adfg=ByAreaSubsistenceSE.fishingInfo>.

Fisheries are managed in-season by the FMB using fish tickets, port sampling for CWT recoveries, regular escapement surveys, and consistent communication with other fishery management entities such as ADF&G (MIC 2022). Chinook salmon harvest within the Annette Islands Reserve accounts for approximately 0.5-1% of the total Chinook salmon harvest within SEAK (e.g., CTC 2022, CTC 2023, CTC 2024).

1.5.2 Chinook salmon management in the Central Gulf of Alaska

The Central Gulf of Alaska (CGOA) ESU includes Chinook populations from the Alsek, Situk, and Copper Rivers. These Chinook stocks, as in SEGOA, are managed according to State of Alaska Management Plans to achieve escapement goals that have been identified by ADF&G and adopted by the Alaska Board of Fisheries (Munro and Brenner 2022, ADF&G 2023b).

Escapement in the Alsek is estimated each year using a weir installed on the Klukshu River, a tributary of the main salmon producing system in the Alsek (ADF&G 2023b). Escapement in the Alsek has also been estimated in some years using drainage-wide mark-recapture studies. Escapement in the Situk River is estimated annually using a weir installed across the lower river. Escapement goals for the Alsek and Situk Rivers were developed by ADF&G and approved by the CTC of the PSC. As a transboundary river, the escapement goal for the Alsek was also approved by the Transboundary Technical Committee of the PSC. Goals for the Alsek and Situk pertain to Chinook salmon greater than 660 mm mid-eye fork length, the same as SEGOA stocks. The Alsek and Situk Rivers are located within the geographic bounds encompassed by the Pacific Salmon Treaty. As such, these stocks are managed in the same way as the SEGOA stocks described in the previous section (i.e., PSC catch and incidental mortality limits, State Fishery Management Plans, fishery allocations, and in-season management). Listing of Alsek or Situk Chinook salmon stocks as stocks of concern has not been warranted.

The Copper River drainage comprises six major spawning populations of Chinook salmon: Chitina, Gulkana, Klutina, Tazlina, Tonsina, and Upper Copper. Chinook escapements to the Copper River drainage have been estimated using multiple methods (Botz and Somerville 2021, ADF&G 2023b). With the exception of 1993–1995, Chinook escapement was estimated by aerial surveys from 1966 to 2021. Since 2003, the Native Village of Eyak has also conducted a mark-recapture fish wheel study to estimate drainage-wide escapement of Chinook salmon greater than 500 mm snout-to-fork length. Further, ADF&G and the Bureau of Land Management have estimated escapement above the West Fork of the Gulkana River each year since 2002 by jointly operating a salmon counting tower (ADF&G 2023b). Listing of Copper River Chinook salmon as a state stock of management concern has not been warranted.

The Copper River is outside the geographic bounds of the Pacific Salmon Treaty. Therefore, most Copper River Chinook salmon fisheries and Chinook incidental catch in other salmon fisheries are solely governed by State of Alaska Management Plans, including the Copper River King Salmon Management Plan (5 AAC 24.361), the Copper River Subsistence Salmon Fisheries Management Plan (5 AAC 01.647), and the Copper River Personal Use Dip Net Salmon Fishery Management Plan (5 AAC 77.591; Botz and Somerville 2021). These management plans,

developed by ADF&G and adopted by the Alaska Board of Fisheries, establish fishing seasons, open areas, and gear and bag limits for the following fisheries: (1) a commercial gillnet fishery at the mouth of the Copper River; (2) a subsistence gillnet fishery at the mouth of the Copper River, a subsistence dipnet and fish wheel fishery in the Copper River between Chitina and the Slana River confluence, and a subsistence fish wheel, dip net and spear fishery in Tanada Creek and the Copper River near the traditional village site of Batzulnetas; (3) a personal use dip net fishery in the Copper River near Chitina; and (4) sport fisheries that occur in various tributaries (ADF&G 2023b). These fisheries are administered by ADF&G and managed in-season using escapement estimates, weekly harvest forecasts, and environmental conditions such as river height (Botz and Somerville 2021).

Additionally, federal subsistence fisheries have occurred within the Copper River drainage since 1999, specifically in the Glennallen and Chitina Subdistricts and the Batzulnetas area (these were considered state fisheries prior to 1999; Botz and Somerville 2021). For the Copper River drainage, regulations are administered by the Superintendent of the Wrangell-St. Elias National Park and Preserve. Specific Federal subsistence regulations are outlined in the 2023-2025 federal subsistence management regulations for the harvest of fish and shellfish on the federal public lands and waters in Alaska.

1.5.3 Chinook salmon management in the Northwest Gulf of Alaska

The Northwest Gulf of Alaska (NWGOA) ESU includes Chinook salmon populations from the Chignik River on the South Alaska Peninsula, the Ayakulik and Karluk Rivers on Kodiak Island, and those within Cook Inlet, including the Susitna drainage and populations on the Kenai Peninsula. As in the other ESUs, Chinook salmon stocks in the NWGOA ESU are predominately managed according to State of Alaska Management Plans and approved escapement goals (ADF&G 2023b, Munro 2023b).

Escapement of Chignik River Chinook salmon is assessed each year using a weir located about halfway between Chignik Lagoon and Chignik Lake. The Chignik Chinook population is designated as a stock of management concern by the State of Alaska and is not targeted by commercial fisheries; commercial harvest is mostly incidental to sockeye salmon (*Oncorhynchus nerka*) fisheries (Burnside 2023). There are also state and federal subsistence fisheries for Chignik Chinook in years of sufficient returns, although they have been highly restricted or closed in recent years. The state and Federal subsistence fisheries are managed by ADF&G and USFWS under direction from the Alaska Board of Fisheries and the Federal Subsistence Board, respectively.

Escapements of Chinook to the Ayakulik and Karluk Rivers on Kodiak Island are also enumerated using weirs. These Chinook populations are managed according to escapement goals, and there are no directed commercial fisheries. However, a certain number of Chinook may be harvested incidentally during pink (*Oncorhynchus gorbuscha*) and sockeye salmon fisheries (Jackson and Dorner 2024). The annual incidental Chinook harvest limits are established by ADF&G and the Alaska Board of Fisheries. Sport and subsistence fisheries for

Chinook on Kodiak Island also occur in years of sufficient return. However, as with Chignik Chinook, these fisheries have been severely restricted or closed in recent years by the authority of ADF&G and the Federal Subsistence Board. Both the Ayakulik and Karluk River Chinook salmon stocks are listed as stocks of management concern by the state of Alaska; each has an associated action plan.

Cook Inlet is divided into two management areas, Upper Cook Inlet (UCI) and Lower Cook Inlet (LCI). UCI includes many stocks of Chinook salmon, including 13 that currently have escapement goals identified by ADF&G and adopted by the Alaska Board of Fisheries: Alexander Creek, Campbell Creek, Chuitna River, Chulitna River, Crooked Creek, Deshka River, Eastside Susitna River, Kenai River early run (fish >34 inches or ~864 mm), Kenai River late run (fish > 34 inches or 864 mm), Little Susitna River, Talkeetna River, Theodore River, and Yentna River (Munro and Brenner 2022, Munro 2023b). LCI contains three Chinook stocks with escapement goals: Anchor River, Deep Creek, and Ninilchik River (Munro 2023a). Methods to assess escapement on these systems vary but include weirs, sonar, and aerial surveys (ADF&G 2023b, Munro 2023b). Five stocks within Cook Inlet (Alexander Creek, Chuitna River, Eastside Susitna River, Kenai River late run, and Theodore River) are currently listed as stocks of management concern by the State of Alaska and have associated action plans.

Commercial, sport, personal use, and subsistence fishing occurs on Cook Inlet Chinook salmon. Several salmon management plans - developed by ADF&G and adopted by the Alaska Board of Fisheries - are employed to regulate many of these fisheries (e.g., Northern District King Salmon Management Plan (5 AAC 21.366)). Federal subsistence fisheries in this region (e.g., those within the Kasilof and Kenai River drainages), including harvest limits, permit restrictions, fishing seasons, and harvest reporting, are administered by the Federal Subsistence Board.

Additionally, drift gillnet (commercial) and recreational fishing occurs within the Cook Inlet Exclusive Economic Zone (EEZ), an area of Federal waters located in Cook Inlet north of a line at 59°46.15' N. Until 2024, all commercial salmon fishing in Cook Inlet was managed by the State of Alaska, in both State and Federal waters. Since 2024, NMFS has managed the salmon fishery in the Cook Inlet EEZ. For the commercial drift gillnet fishery, the catch limits and total allowable catch for Chinook salmon will be established annually by NOAA Fisheries.¹⁴ For recreational fishing in the EEZ, Chinook fishing is open year-round, but bag and possession limits may vary temporally.

¹⁴ NMFS, Cook Inlet Small Entity Compliance Guide. Available at <https://www.fisheries.noaa.gov/resource/document/cook-inlet-small-entity-compliance-guide>.

2 OVERVIEW OF THE GULF OF ALASKA AND CHINOOK SALMON

2.1 Ecological Features of the Gulf of Alaska

In this section, we summarize biological and environmental information and consider the relevancy of each in determining the nature and extent of GOA Chinook salmon ESUs. ESU boundaries were determined by the SRT on the basis of the team's professional opinion of the degree to which environmental and biological attributes exhibited significant changes with respect to the reproductive isolation and ecological or genetic diversity of GOA Chinook salmon.

2.1.1 Geologic events

During the Last Glacial Maximum (LGM), a period during which the maximum extent of most global ice sheets occurred around 26.5 to 19 thousand years ago (kiloannum; ka), most of the landmass surrounding the GOA was covered by the Cordilleran Ice Sheet (Clark et al. 2009) (Figure 6). At this time, the North Pacific was mostly free of sea ice and sea level was significantly lower than at present, leaving large portions of the continental shelf in the Bering and Chukchi Seas exposed (Mann and Hamilton 1995). During this period of Pleistocene glaciation, there were two main refugia for Pacific salmon: Beringia, unglaciated areas of western Alaska and Russia, and Cascadia, unglaciated areas of North America south of the Cordilleran Ice Sheet and west of the Continental Divide. Potential refugia in Beringia included areas around Bristol Bay and the North Slope of the Alaska Peninsula, portions of Kodiak Island, areas near Cook Inlet northwest of the Kenai Mountains, part of the Copper River basin, areas in the Queen Charlotte Islands, and portions of Southeast Alaska, such as areas near Glacier Bay (McPhail and Lindsey 1970, Lindsey and McPhail 1986, Mann and Hamilton 1995). Potential refugia in Cascadia included the southern two-thirds of the Columbia River system and areas near Queen Charlotte Sound (Lindsey and McPhail 1986, McPhail and Lindsey 1986).

The Cordilleran Ice Sheet began to retreat from its maximum between 19 and 20 ka (Clark et al. 2009). This allowed populations previously isolated in ice-free refugia to begin to recolonize newly habitable areas. Many genetic studies have established Southeast Alaska as a contact zone for colonization from Beringia versus Cascadia lineages of Chinook salmon (Gharrett et al. 1987, Guthrie and Wilmot 2004, Moran et al. 2013). Additional changes in glaciation continued to occur during the Holocene, with alternating cold and warm intervals lasting several hundred to a thousand years causing multiple periods of glacial expansion and retreat (Mann et al. 1998, Calkin et al. 2001). The majority of Alaska glaciers reached their Holocene maxima during the Little Ice Age (ca. AD 1350-1900), during which salmon populations experienced significant fluctuations in abundance in response to local glaciation, as well as changes in oceanographic and atmospheric conditions (Mann et al. 1998, Calkin et al. 2001). Salmon populations and habitats were also impacted by “watershed capture” as some drainages changed direction in post-glacial periods due to both changing physical obstructions and rising water levels (Lindsey

and McPhail 1986). For example, numerous lakes and streams that previously drained into the Alsek River and Stikine River now drain into the Yukon River (Lindsey and McPhail 1986). In some cases, stream capture was likely detrimental to local fish populations; in other cases, it likely provided increased passageways for colonization (Lindsey and McPhail 1986).

Other geologic events, such as volcanic eruptions and earthquakes, have also impacted salmon populations and spawning habitats. The Gulf of Alaska is an area of high tectonic activity, experiencing both volcanic eruptions and large earthquakes, with impacts from these including tsunamis and changes in sea level (Mann et al. 1998). During the Holocene, 80 volcanoes in Alaska have erupted, with 41 of these leading to more than 265 eruptions in more recent history (post-1760) (Miller et al. 1998). Volcanic eruptions and their aftermath have played a significant role in shaping the ecosystems and landscapes of southern and southwestern Alaska and the Aleutian Islands, with some of the largest Holocene eruptions on Earth occurring in the Aleutian arc (Waythomas 2015). The strength of volcanic eruptions can be categorized by the Volcanic Explosivity Index (VEI) scale, a logarithmic scale ranging from VEI 0 to VEI 8. A VEI 0-1 is categorized as “non-explosive” to “small,” with the eruption described as “gentle,” consisting of lava flows with a low eruptive height (< 1 km above crater) and a low volume of ejecta (< 10^6 m³) (Newhall and Self 1982). Anything above a VEI 5 is categorized as “very large,” with the eruption described as “colossal” and “violent,” consisting of large explosions with a high eruptive height (> 25 km above sea level) and a large volume of ejecta (> 10^{12} m³ for a VEI 8) (Newhall and Self 1982). Over the past 300 years, 20% of volcanic eruptions in Alaska have been between a 0 and 1 on the Volcanic Explosivity Index (VEI) scale, with 50% a VEI 2, 25% a VEI 3, 5% a VEI 4, and only one larger than a VEI 4: the Novarupta-Katmai eruption in 1912 that reached a VEI 6. Volcanoes in Alaska are typically covered in glacial ice, seasonal snow, or both, making lahars (a flowing mixture of sediment and water) common after volcanic eruptions, in addition to volcanic flow (Waythomas 2015). These lahars can be a significantly larger flow than any meteorologically generated flooding, leading to significant watershed impacts, including flow diversion, blockage, and habitat destruction, as well as changes in sedimentation, temperature, and acidity (Zimmerman et al. 2008, Waythomas 2015). Volcanic ash can also impact food availability and spawning habitat for fishes (Zimmerman et al. 2008). Major volcanic eruptions that have negatively impacted fish populations and fish habitat in Alaska include Aniakchak around 1645 BC, Novarupta-Katmai in 1912, Redoubt in 1989-1990, and Chiginagak in 2004 (Schaefer et al. 2008, Zimmerman et al. 2008). There are two main areas in Alaska where earthquakes are generated. Earthquakes along the Aleutian Trench, between the Copper River delta and the western Aleutian Islands, are generated by the subduction of the Pacific Plate under Alaska and the Bering Sea shelf (Mann et al. 1998, Zimmerman et al. 2008). Earthquakes in Southeast Alaska are generated at the Queen Charlotte-Fairweather Fault, an area where the Pacific Plate moves north-northwest relative to the North American Plate (Zimmerman et al. 2008). In addition to the mechanical shock from earthquakes potentially damaging salmonid eggs in spawning habitats, earthquakes may also impact fish habitat through submarine landslides and tsunamis (Zimmerman et al. 2008).

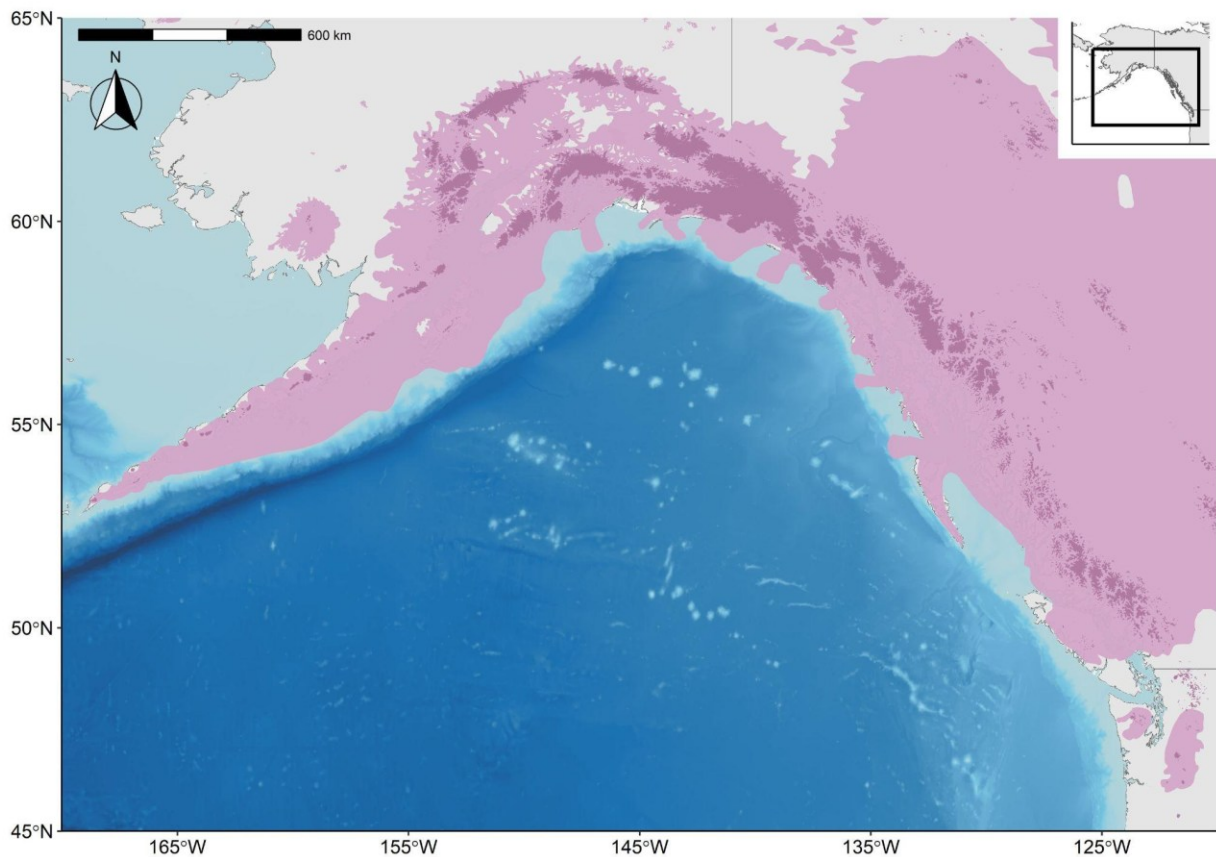


Figure 6. -- Ice extent during Last Glacial Maximum in light purple, and current glaciation in dark purple.

2.1.2 Ecoregions

Pacific salmon exhibit a high degree of site fidelity, utilizing homing mechanisms to return to natal streams for spawning (Dittman and Quinn 1996). Therefore, localized environmental conditions and landscape heterogeneity can significantly impact spatial genetic structure (Ackerman et al. 2013). One approach for categorizing these local environments is “ecoregions,” a categorization generated to aid in resource management based on regional patterns in factors such as climate, terrain, land use, vegetation, and soils (Omernik 1987, Gallant et al. 1995). There are 32 Level III ecoregions in Alaska, mapped by Gallant et al. 1995, building upon the ecoregion map for the contiguous United States developed by (Omernik 1987, Gallant et al. 1995) (Figure 7). Seven of these ecoregions are utilized by Gulf of Alaska Chinook salmon: Alaska Peninsula Mountains (113), Cook Inlet (115), Alaska Range (116), Copper Plateau (117), Wrangell Mountains (118), Pacific Coastal Mountains (119), and Coastal Western Hemlock-Sitka Spruce Forests (120). There are 217 ecoregions in Canada, mapped by the Ecological Stratification Working Group 1996 (Ecological Stratification Working Group 1996) (Figure 7). Five of these ecoregions are utilized by GOA Chinook salmon: St. Elias Mountains (173), Yukon-Stikine Highlands (179), Boreal Mountains and Plateaus (180), Northern Coastal

Mountains (185), and Skeena Mountains (198). The SEGOA ESU inhabits Pacific Coastal Mountains (119), Coastal Western Hemlock-Sitka Spruce Forests (120), Yukon-Stikine Highlands (179), Boreal Mountains and Plateaus (180), Northern Coastal Mountains (185), and Skeena Mountains (198); the CGOA ESU inhabits Alaska Range (116), Copper Plateau (117), Wrangell Mountains (118), Pacific Coastal Mountains (119), Coastal Western Hemlock-Sitka Spruce Forests (120), St. Elias Mountains (173), Yukon-Stikine Highlands (179), and Northern Coastal Mountains (185); and the NWGOA ESU inhabits Alaska Peninsula Mountains (113), Cook Inlet (115), Alaska Range (116), Pacific Coastal Mountains (119), and Coastal Western Hemlock-Sitka Spruce Forests (120) (Figure 7). All information on these 12 ecoregions provided below is summarized from Gallant et al. (1995) for U.S. ecoregions and from Ecological Stratification Working Group (1996) for Canadian ecoregions.

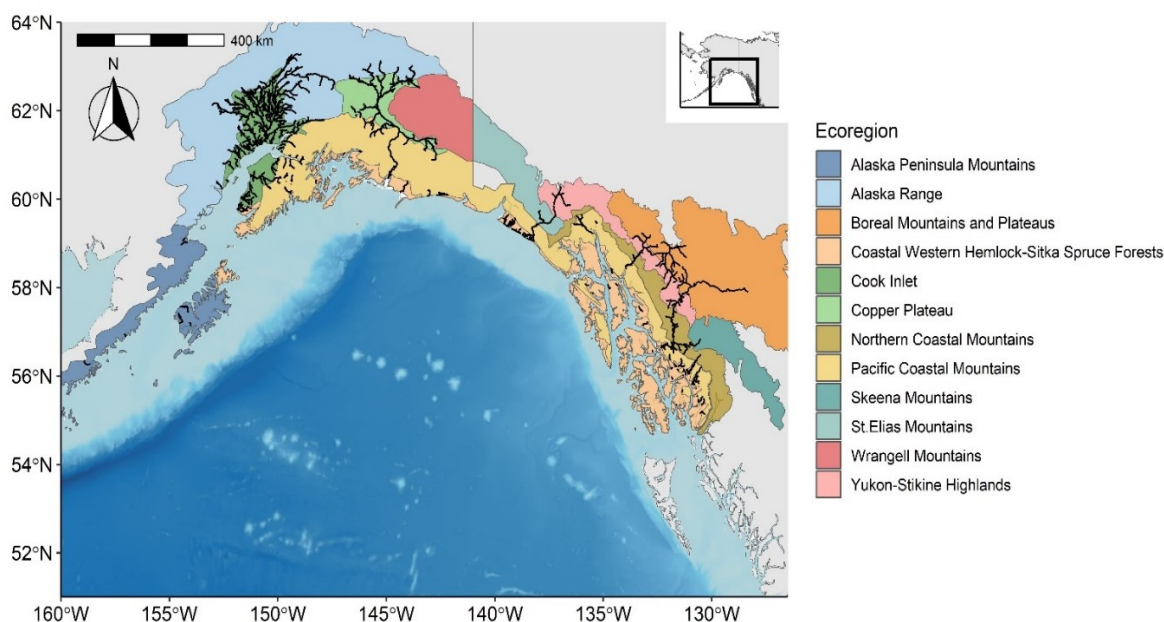


Figure 7. -- Ecoregions in Alaska and Canada encompassing Gulf of Alaska Chinook salmon habitats. Anadromous waters supporting Chinook are shown in black.

2.1.2.1 Ecoregion descriptions

2.1.2.1.1 113: *Alaska Peninsula Mountains*

The Alaska Peninsula Mountains ecoregion is a 48,000 km² U.S. ecoregion encompassing the south side of the Alaska Peninsula and Kodiak Island. Kodiak, Alaska (population = 5,354) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include the Chignik, McNeil, and Little Kamishak on the Alaska Peninsula, and the Ayakulik and Karluk on Kodiak Island. The Alaska Peninsula Mountains were glaciated during the Pleistocene epoch, and are primarily sedimentary ridges 300-1,200 m high, with some volcanic peaks 1,400-2,600 m high. Most slopes are gradual, but there are steeper slopes in 7%

of the ecoregion. It experiences a maritime climate, with precipitation between 600 and 3,300 mm per year in coastal areas and more than 4,060 mm per year at higher elevations; snowfall ranges from 55-160 cm on the coast to greater than 510 cm at higher elevations. Winter temperatures range from an average daily low between -11°C and -6°C to an average daily high between -2°C and 1°C, while summer temperatures range from an average daily low of 6°C to an average daily high of 15°C. The ecoregion is mostly free from permafrost, and primary soils present are Typic Haplocryands and Typic Viticryands, with soils influenced by glacial deposits and volcanic ash. Vegetation is primarily dwarf scrub communities at higher elevations and in exposed areas, low scrub at lower elevations and in protected areas, and tall scrub at some lower elevations and hill-slope drainages. Broadleaf forests are also present on floodplains and south-facing slopes, with scrub bog communities and mesic graminoid herbaceous communities in poorly drained areas. Settlements in this area are mostly restricted to the coastline, with land uses including commercial fishing and processing, subsistence and recreational hunting, fishing, and gathering, and extraction of metals (gold, silver, lead, and copper) and energy resources (coal and petroleum).

2.1.2.1.2 115: Cook Inlet

The Cook Inlet ecoregion is a 28,000 km² U.S. ecoregion encompassing the area surrounding Cook Inlet on both the mainland and the northwest side of the Kenai Peninsula. Anchorage, Alaska (population = 286,075) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include the Chickaloon, Kenai, Kasilof, Ninilchik, and Deep Creek on the Kenai Peninsula, and the Big, Kustatan, McArthur, Nikolai Creek, Chuitna, Beluga, Theodore, Lewis, Ivan, Susitna, Little Susitna, Wasilla Creek, and Matanuska on the mainland. The Cook Inlet ecoregion was glaciated during the Pleistocene epoch, and experiences both maritime and continental influences to climate. Elevations vary from sea level to 600 m, with rolling topography and gentle slope gradients less than 5.24%. Precipitation ranges from 380 to 680 mm across the region, with snowfall ranging from 160 to 255 cm. Winter temperatures range from an average daily low around -15°C to an average daily high around -5°C, with temperature inversions common; summer temperatures range from an average daily low of around 5°C to an average daily high around 18°C. The ecoregion is mostly free from permafrost, and primary soils present are Haplocryands, Sphagnic Borofibrists, Terric Borosaprists, Typic Borohemists, Andic Haplocryands, and Andic Humicryods, with soils formed from loess, volcanic ash, glacial deposits, and peat. Needleleaf, broadleaf, and mixed forests are the most widespread form of vegetation. Mesic graminoid, graminoid herbaceous, and low scrub graminoid are also present over a range of areas, with tall scrub along floodplains, streambanks, and drainageways, low scrub in poorly drained lowlands, and tall scrub swamp, low scrub bog, wet forb herbaceous, and wet graminoid herbaceous in the wettest areas. Cook Inlet is the most populated ecoregion in Alaska. While ecoregions do not align perfectly with census areas, the Cook Inlet ecoregion crosses over the first, second, and fourth most populated census areas in Alaska, as of 2019: the Municipality of Anchorage (40% of Alaska's population), Matanuska-Susitna Borough (15%), and Kenai Peninsula Borough (8%) (ADLWD

2020). It experiences heavy recreational use year-round, as well as agricultural activities in some areas, subsistence hunting and gathering, timber production, gas and oil wells, sand and gravel operations, shipping activities, military operations, and extraction of metals (gold, silver, platinum, tin, copper, and tungsten) and energy resources (coal and uranium).

2.1.2.1.3 116: Alaska Range

The Alaska Range ecoregion is a 117,000 km² U.S. ecoregion encompassing a mountainous area surrounding Southcentral Alaska. Healy, Alaska (population = 865) is the largest community in this ecoregion, which also includes Denali National Park. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include upper tributaries of the Copper, Susitna, Little Susitna, Beluga, McArthur, and Big Rivers, as well as the entirety of the Crescent River. The Alaska Range was heavily glaciated during the Pleistocene epoch, and valley glaciers are still present at higher elevations. Elevation ranges from sea level in the southwest portion of the ecoregion, to 600 m in lower valleys, to greater than 3,900 m for some of the peaks. The ecoregion experiences a continental climate. Average annual precipitation is around 380 mm for much of the ecoregion, with snowfall ranging from 150 to 305 cm; on higher peaks, precipitation averages 2,030 mm and snowfall averages 1,015 cm. Winter temperatures range from an average daily low around -25°C to an average daily high of around -3°C, with summer temperatures averaging around 2°C for the low and 18°C for the high. Permafrost is discontinuous throughout the ecoregion. Much of the ecoregion consists of rocky slopes, icefields, and glaciers, so soil formation is minimal. Where soil does occur, primary soils are Lithic Cryothents, Pergelic Cryaquepts, Pergelic Ruptic-Histic Cryaquepts, Typic Cryochrepts, Pergelic Cryumbrepts, and Typic Cryumbrepts. Dwarf scrub communities are the dominant form of vegetation where vegetation does occur, but much of the ecoregion is barren. Some protected sites are vegetated by low or tall scrub communities, with needleleaf forest and woodlands in some valleys and on lower slopes. The Alaska Range has few permanent settlements, with land uses including recreational and subsistence hunting, fishing, and gathering, and extraction of metals (gold, silver, lead, copper, tungsten, platinum, zinc, chromium, mercury, and tin), energy resources (coal and uranium), and non-metallic elements (antimony, bismuth, and molybdenum).

2.1.2.1.4 117: Copper Plateau

The Copper Plateau ecoregion is a 17,000 km² U.S. ecoregion in Southcentral Alaska. Glennallen, Alaska (population = 522) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the Copper River, with the majority of the Copper River watershed lying within this ecoregion. This ecoregion was the location of a large lake during Pleistocene glaciation, and now consists of rolling terrain between 420 and 900 m in elevation, with gentle slope gradients less than 3.49%, and many lakes and wetlands. The ecoregion experiences a continental climate, and receives 250-460 mm of precipitation, with 100-190 cm of snowfall. Winter temperatures range from an average daily low of -27°C to an average daily high of -16°C; summer temperatures range from an average daily low of 4°C to an average daily high of 21°C. Permafrost is continuous, and primary soils are Histic Pergelic Cryaquepts, Aquic Cryochrepts, Typic Cryochrepts, Pergelic

Cryaquolls, and Typic Cryobrolls. Needleleaf forest and woodlands are the dominant vegetation types, although broadleaf forests, tall scrub communities, and wetlands with scrub bogs and graminoid herbaceous communities are also common. The Copper Plateau has a few small settlements, with land uses including subsistence hunting, fishing, and gathering, as well as some mining (gold and selenium).

2.1.2.1.5 118: Wrangell Mountains

The Wrangell Mountains ecoregion is a 29,000 km² U.S. ecoregion in Southcentral Alaska that borders the Yukon. McCarthy, Alaska (population = 107) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include a few upper tributaries of the Copper River. The Wrangell Mountains were glaciated during the Pleistocene epoch, and extensive glaciation persists, with many icefields and glaciers. Elevations typically range from 600 to 3,900 m, with some volcanic peaks over 4,880 m. The ecoregion experiences a continental climate, receiving 410-2,030 mm of precipitation and 175-255 cm of snow. Winter temperatures range from an average daily low of -34°C to an average daily high of -9°C; summer temperatures range from an average daily low of 3°C to an average daily high of 22°C. Permafrost is discontinuous and soil is influenced by volcanic and glacial deposits, with primary soils being Lithic Cryothents, Typic Cryothents, Pergelic Cryochrepts, and Pergelic Cryumbrepts. Dwarf scrub communities are the dominant form of vegetation where vegetation occurs, but most slopes are barren. Tall scrub is also present along drainages and floodplains, as well as some needleleaf forests at lower elevations. There are only a few small settlements in this ecoregion, and land uses include subsistence hunting, fishing, and gathering, as well as some mining (copper, silver, gold, lead, and zinc).

2.1.2.1.6 119: Pacific Coastal Mountains

The Pacific Coastal Mountains ecoregion is a 106,000 km² U.S. ecoregion that covers a large portion of Southcentral and Southeast Alaska. Juneau, Alaska (population = 31,555) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the Kenai River, tributaries of the Chickaloon River, and some other smaller rivers in Southcentral Alaska; portions of the Copper River and its tributaries; and portions of the Alsek, Chilkat, Taku, Stikine, Unuk, and Chickamin Rivers and their tributaries, as well as some smaller rivers, in Southeast Alaska. The Pacific Coastal Mountains were glaciated during the Pleistocene epoch, and glaciers and icefields persist in most of the region. Mountains in this ecoregion are steep, and elevations range from sea level to over 4,500 m. Climate in this ecoregion is transitional between maritime and continental influences. It has high precipitation, ranging from 2,030 mm to over 7,000 mm, with snowfall between 510 and 2,030 cm. There are no long-term weather stations in this ecoregion, so average temperatures were not provided in Gallant et al. (1995). Permafrost is present in the Chugach Mountains, but absent farther south in the ecoregion. Primary soils are Lithic Cryothents, Andic Cryumbrepts, Pergelic Cryumbrepts, Typic Cryumbrepts, Typic Haplocryods, Andic Humicryods, Lithic Humicryods, and Typic Humicryods. Where vegetation does occur, dwarf and low scrub communities are dominant, but alpine slopes are mostly barren of vegetation. Needleleaf forests are present at lower

elevations along drainageways. Although there are a few larger communities, much of the ecoregion is free of permanent settlements. Land uses include recreational and subsistence hunting, fishing, and gathering, and extraction of metals (gold, silver, copper, zinc, lead, tungsten, iron, nickel, platinum, barium, chromium), energy resources (coal, petroleum, and uranium), and non-metallic elements (antimony, arsenic, and molybdenum).

2.1.2.1.7 120: Coastal Western Hemlock-Sitka Spruce Forests

The Coastal-Western Hemlock-Sitka Spruce Forests ecoregion is a 61,000 km² U.S. ecoregion encompassing much of Southeast Alaska and some coastal areas in Southcentral Alaska. Sitka, Alaska (population = 8,282) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include portions of the Anchor and Resurrection Rivers and their tributaries, as well as some smaller rivers, in Southcentral Alaska; portions of the Copper River and its tributaries; and portions of the Alsek, Stikine, Unuk, and Chickamin Rivers and their tributaries, as well as some smaller rivers, in Southeast Alaska. This ecoregion was intensely glaciated during the Pleistocene epoch, and now consists of sea cliffs leading to mountains and valleys. Elevations generally range from sea level to 500 m, with some mountains up to 1,000 m, and a wide range of slope gradients is present. The climate is maritime, with the mildest temperatures and highest precipitation of all Alaska ecoregions. Precipitation ranges from 1,350 to 3,900 mm, with snowfall from 80 to 600 cm. Winter temperatures range from an average daily low of -3°C to an average daily high of 3°C, and summer temperatures range from an average daily low of 7°C to an average daily high of 18°C. The ecoregion is generally free from permafrost, and primary soils are Terric Cryohemists, Andic Cryaquods, Andic Humicryods, Lithic Humicryods, and Typic Humicryods. There is a wide variety of vegetation, including coastal forest, scrub, and wetland communities. Forests consisting of needleleaf, broadleaf, or both are the dominant form of vegetation, with other vegetation types including tall shrub, low shrub, dwarf shrub, wetland tall scrub swamp, low scrub bog, wet graminoid herbaceous, and wet forb herbaceous. Most of the ecoregion's population is concentrated in relatively flat, coastal areas, and land uses include recreational and subsistence hunting, fishing, and gathering, timber harvest, and extraction of metals (gold, copper, silver, zinc, lead, iron, platinum, titanium, barium, nickel, cobalt, and chromium), energy resources (coal, uranium, and petroleum), and non-metallic elements (antimony, arsenic, calcium, molybdenum, and sulfur).

2.1.2.1.8 173: St. Elias Mountains

The St. Elias Mountains ecoregion is a Canadian ecoregion encompassing the St. Elias Mountains and Kluane Ranges in the Yukon. There are no permanent communities in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the transboundary Alsek River. This ecoregion comprises icefields and glaciers, with some of the highest mountains in Canada reaching peaks up to 6,000 m. Precipitation ranges from 300 to 1,000 mm. The mean annual temperature is -1.5°C, with a winter mean of -14°C and a summer mean of 9.5°C. Much of the ecoregion is devoid of vegetation, but there are some

areas of alpine tundra, as well as grasses in wetter areas. Land use is mainly recreational, with a significant amount of protected land in this ecoregion.

2.1.2.1.9 179: Yukon-Stikine Highlands

The Yukon-Stikine Highlands ecoregion is a Canadian ecoregion encompassing mountainous areas leeward of the St. Elias Mountains and a portion of the Kluane Ranges in northwestern British Columbia and southern Yukon. There is only one small permanent community in this ecoregion: Telegraph Creek, British Columbia (population = 51). Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the transboundary Alsek, Taku, and Stikine Rivers. Lying in the rain shadow of the Coast Mountains, this ecoregion consists of smaller mountains and large valleys and represents a climate transition from coastal to interior. Precipitation ranges from 500 to 600 mm. The mean annual temperature is -1°C, with a winter mean of -13°C and a summer mean of 10°C. Primary soils are Brunisolic and Regosolic, with some Dystric and Eutric Brunisols in subalpine and boreal habitat, and some Cryosolic in alpine regions. Permafrost is sporadic and discontinuous. There are three primary vegetation types: closed boreal forests, subalpine forests, and alpine tundra. Land uses include hunting, recreation, mining, and mineral exploration.

2.1.2.1.10 180: Boreal Mountains and Plateaus

The Boreal Mountains and Plateaus ecoregion is a Canadian ecoregion encompassing a large area of northwestern British Columbia and a small portion of southern Yukon. Atlin and Dease Lake, British Columbia (population = 477 and population = 229, respectively) and Carcross, Yukon Territory (population = 317) are the largest communities in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the transboundary Taku and Stikine Rivers. This ecoregion consists of mountains, plateaus, and lowlands, with glaciers and volcanoes present. Some volcanic peaks reach over 2,000 m. Precipitation ranges from 400 to 700 mm. The mean annual temperature is -2°C, with a winter mean of -15°C and a summer mean of 10°C. Primary soils are Humo-Ferric Podzolic, Gray Luvisolic, and Dystric Brunisolic, with sporadic permafrost in the northern portion of the ecoregion and isolated patches of permafrost in the southwest portion. Boreal forests are the dominant vegetation type at lower elevations, with lichen alpine vegetation and bare rock at higher elevations. Land uses include hunting, trapping, and recreation, with forestry and forage-crop based agriculture in boreal areas.

2.1.2.1.11 185: Northern Coastal Mountains

The Northern Coastal Mountains ecoregion is a Canadian ecoregion encompassing the Fairweather Ranges and Boundary Ranges. Stewart, British Columbia (population = 517) is the largest community in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the transboundary Alsek, Chilkat, Taku, Stikine, Unuk, and Chickamin Rivers. Mountain peaks range from 2,100 to 3,050 m, with many icefields and large glaciers present. Precipitation ranges from 1,000 to 2,400 mm. The mean annual temperature is -0.5°C, with a winter mean of -11.5°C and a summer mean of 10°C. Primary soils are Humo-

Ferric Podzolic and Gleysolic at lower elevations, Podzolic and Brunisolic in the subalpine, and Brunisolic and Regosolic in the alpine. There are three vegetation zones: closed forests at lower elevations, subalpine forests at mid-elevations, and alpine tundra above tree line. Land uses include recreation, mining, and mineral exploration.

2.1.2.1.12 198: Skeena Mountains

The Skeena Mountains ecoregion is a Canadian ecoregion encompassing the western portion of the Skeena Mountains. There are no major communities in this ecoregion. Rivers supporting Gulf of Alaska Chinook salmon in this ecoregion include tributaries of the transboundary Stikine and Unuk Rivers. Extensive glaciers are present in mountain ranges above 2,000 m.

Precipitation ranges from 600 to 1,200 mm. The mean annual temperature is 0.5°C, with a winter mean of -11°C and a summer mean of 11°C. Primary soils are Gray Luvisolic and Dystric Brunisolic in montane areas, Brunisolic and Podzolic in the subalpine, and Regosolic and Sombric in the alpine. Vegetation is mainly boreal forests at lower elevations and in subalpine areas, with alpine tundra at higher elevations. Land uses include recreation, hunting, and forestry at lower elevations.

2.1.3 Multivariate environmental analysis

To better assess broader environmental patterns across ecoregions and to aid in ESU determination, we performed multivariate analysis on select environmental variables. The variables included were elevation, annual precipitation, annual average snow water equivalent (SWE; a measurement of the amount of water contained in snowpack), annual average minimum temperature, and annual average maximum temperature. These variables were averaged across a 15-year time period from 2008 to 2022. This temporal scale was chosen for consistency with our demographic analyses, which also span a 15-year time period, and to select the most recent years for which complete data are available (i.e., some datasets did not contain complete data for 2023 and 2024 at the time of analysis).

Elevation data (m) at a 30 s (~1 km²) resolution were downloaded from WorldClim 2.1 (Fick and Hijmans 2017). All time series data (precipitation in mm, SWE in kg/m², and minimum and maximum temperature in °C) were downloaded as 1 km grids for 2008-2022 from Daymet Version 4 (Thornton 2022). Precipitation is an annual total, and all other variables are annual averages.

These datasets were read into R as either a raster object for elevation data or a RasterBrick object for all other variables using the “raster” and “brick” functions from the “raster” package in R (Hijmans 2023, R Core Team 2024). All data were then extracted for the GOA Chinook population location coordinates used in the “AK_248” Chinook genetic baseline dataset (see section 3.2.1 for details on these data) using the “extract” function from the “raster” package in R, and then averaged across 2008-2022 for each variable at each coordinate (see Figure 8A for these locations). These baseline coordinates can be considered approximate to the central spawning locations for these populations. Once this dataframe with locations, coordinates, and

averaged environmental variables was generated, data were normalized in preparation for principal component analysis (PCA) using the “scale” function in base R (R Core Team 2023). PCA was performed using the “prcomp” function in the “stats” package, and PCA results were visualized using the “factoextra” package (Kassambara 2020, R Core Team 2023).

Principal component 1 (PC1) explained 62.3% of the variance in the dataset, and principal component 2 (PC2) explained 30.7% of the variance, for a cumulative 93.0% of the variance explained by the first two components (Figure 8). PC1 was primarily a temperature-elevation gradient with average maximum temperature as the largest contributor to PC1 (30.8%), followed closely by average minimum temperature (28.8%) and elevation (25.1%). Snow water equivalent and precipitation provide smaller contributions to PC1, at 8.8% and 6.4%, respectively. PC2 was dominated by a precipitation-snowfall gradient, largely driven by precipitation (48.1%), and SWE also contributing significantly (39.1%). Elevation (7.9%), minimum temperature (4.4%), and maximum temperature (0.5%) were minor contributors (Table 2; Figure 9). Although PC3 was not included in visualizations, it explained additional variation (dominated by SWE at 50.2% and elevation at 28.4%), indicating that snow-related conditions represent a secondary but potentially important environmental axis beyond the first two components. Grouping the results into the following 12 locations was found to be most informative for visualizing PCA results: Chignik, Kodiak, Northern Cook Inlet, Kenai Peninsula, Upper Copper, Middle Copper, Lower Copper, Situk, Alsek, Chilkat, Taku and Stikine, and Southeast Coastal. These groups are displayed on the map in Figure 8A.

Table 2. -- Contributions to PC1 through PC5 of each variable: elevation (m), annual average total precipitation (mm), annual average snow water equivalent (SWE; kg/m²), annual average minimum temperature (°C), and annual average maximum temperature (°C).

Variable	PC1	PC2	PC3	PC4	PC5
Elevation	25.1%	7.9%	28.4%	31.9%	6.7%
Precipitation	6.4%	48.1%	16.7%	28.5%	0.4%
SWE	8.8%	39.1%	50.2%	1.5%	0.4%
Max. Temperature	30.8%	0.48%	3.6%	8.5%	56.5%
Min. Temperature	28.8%	4.4%	1.2%	29.7%	36.0%

One pattern that emerges in the PCA is a strong split between SEGOA and the remainder of the GOA populations along PC2 (Figure 8). Within SEGOA, there is also a split between coastal locations, which cluster tightly and also group with the Situk, and the transboundary Taku and Stikine Rivers, which show a larger spread, along PC1. The Alsek locations also show a large spread. This pattern of a split between coastal versus inland locations along PC1 repeats elsewhere, including Northern Cook Inlet versus Kenai Peninsula locations, and Lower Copper versus Upper and Middle Copper. Upper and Middle Copper are tightly clustered and distinct from Lower Copper, which clusters with Northern Cook Inlet. Kenai Peninsula also clusters with Northern Cook Inlet, but does not overlap at all with Lower Copper, split along PC1. Although Kodiak and Chignik only consist of a few locations, they cluster on their own, close to the Chilkat locations. All outlier points differ significantly in multiple ways from other points in that area (e.g., higher elevation with higher precipitation and snow water equivalent, and lower maximum temperature) and most outliers are more inland sites. This could indicate that some populations that migrate farther distances upstream to more inland locations may experience very different environmental conditions than other nearby populations with shorter upriver migrations, which could have implications for life-history expression, smolt timing, or freshwater survival. While PCA cannot directly test these biological hypotheses, the environmental structure it reveals provides a framework for evaluating how landscape heterogeneity may influence Chinook salmon population dynamics.

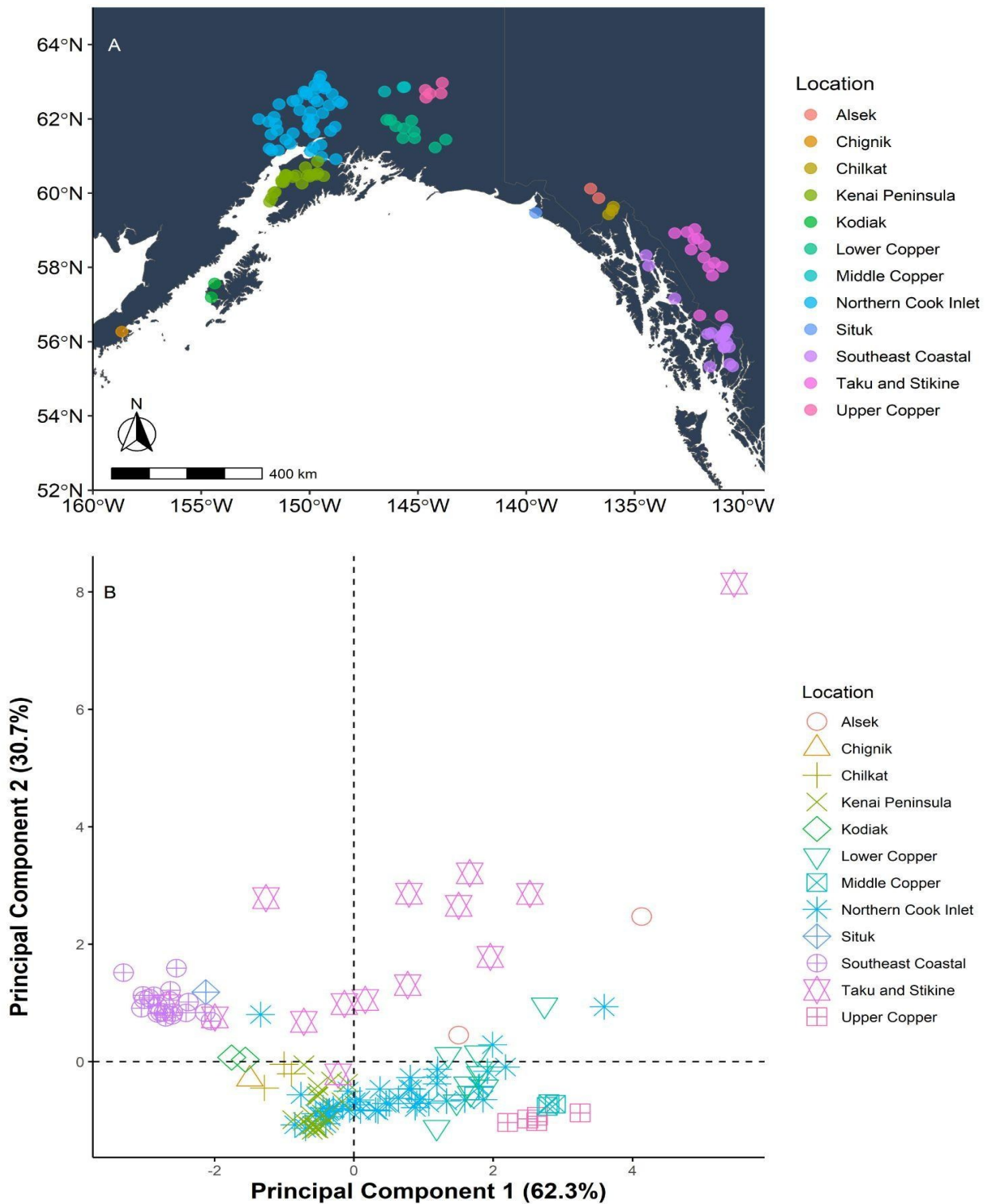


Figure 8. -- Principal component analysis scores for PC1 and PC2 (B) for environmental variables at Gulf of Alaska locations (A).

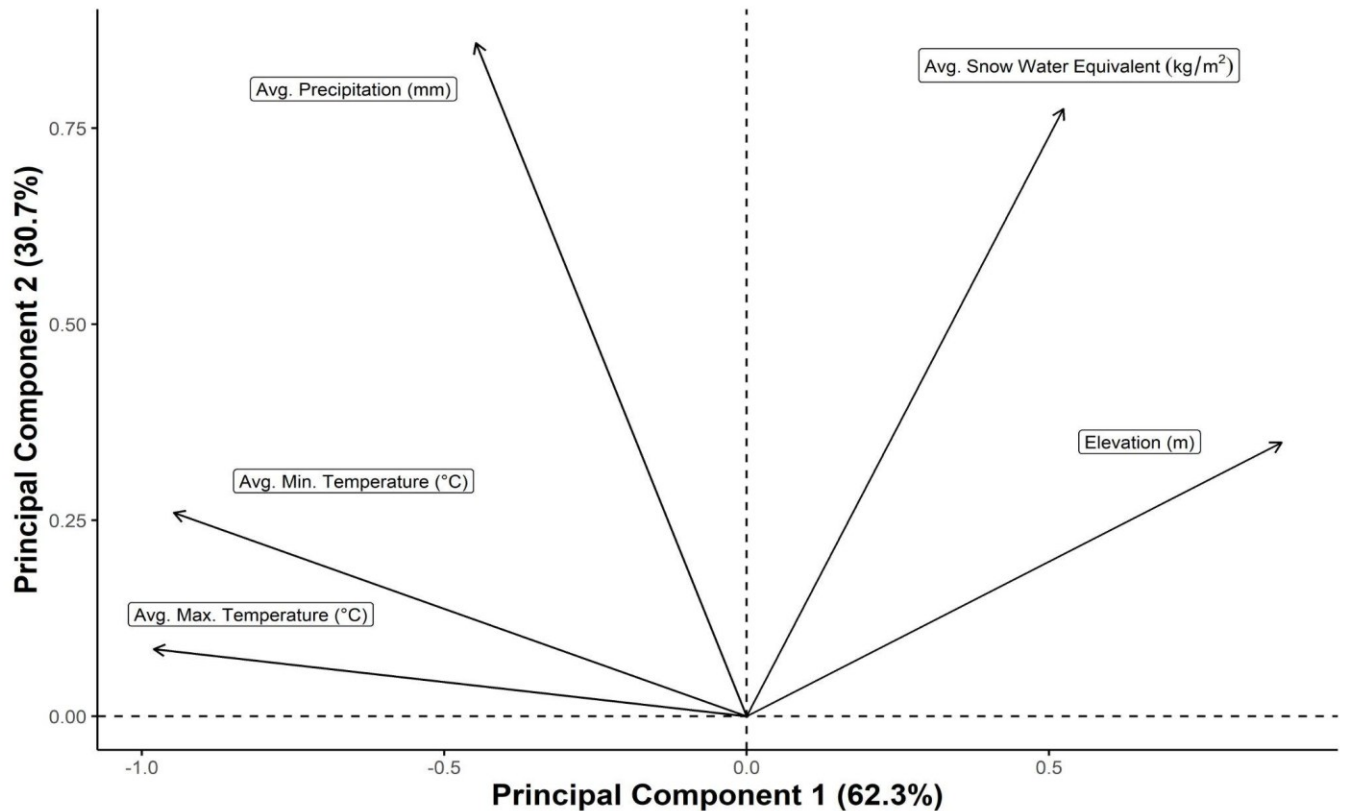


Figure 9. -- Principal component analysis contribution vectors along PC1 and PC2 for each environmental variable.

2.1.4 Ocean ecosystem

Chinook salmon ocean life history occurs in three general phases: (1) a juvenile seaward migration phase after smolting, spanning the first months of ocean life until winter, (2) an immature rearing phase in coastal and oceanic waters, lasting up to 7 years of ocean life, and (3) a final adult return migration phase to natal streams, spanning the last 4 to 10 months of ocean life (Riddell et al. 2018). Because Chinook salmon spend the majority of their life history in the marine environment, a general understanding of the ocean habitat and processes in the GOA is needed.

2.1.4.1 Gulf of Alaska physical oceanography

Mundy (2005) describes the GOA region as bounded on the east and north by tall, rugged mountains that are separated by a continental shelf from abyssal depths more than 3,000 m in the eastern GOA to more than 7,000 m in the Aleutian Trench. The continental shelf has a total area of approximately 370,000 km² and ranges from 5 to 200 km in width. Islands, banks, ridges, and numerous troughs and gullies cut across the shelf, resulting in a complex bathymetry that promotes an exchange between the shelf water and deeper waters. The coastal mountain range captures large amounts of precipitation from low pressure systems

originating in the west, resulting in large volumes of nutrient-poor freshwater runoff into coastal areas.

The GOA coastal area comprises the shoreward Alaska Coastal Current (ACC), the offshore Alaska Current (AC) and Alaska Stream, and the eddies and meanders that cross them (Mundy 2005). The currents may extend along the continental shelf and shelf break as far south as the mouth of the Columbia River in Washington State and as far west as the Aleutian Islands.

The ACC, AC, and Alaska Stream all flow counterclockwise within the shelf and slope regions of the GOA. Therefore, these currents bring warm waters from the North Pacific Current and subarctic plankton communities to the slope and shelf regions and into protected inside waters such as Prince William Sound and Southeast Alaska. Due to their counterclockwise flow, the currents also create downwelling along the shelf, where surface waters are entrained and directed downward. The surface waters are replenished by offshore water moving across the shelf toward shore. All these dynamic processes help to move nutrients, zooplankton, and small fishes onto the shelf and around the GOA.

The speed at which these currents flow around the GOA is dependent on large- and small-scale atmospheric forcing that, in turn, impacts sea surface temperatures, formation of eddies, and lower and upper trophic level production. For example, for small-scale forcing, freshwater buoyancy and local winds drive the nearshore ACC (Stabeno et al. 2004, Stabeno et al. 2016). Frequent gap winds, defined as offshore-directed flow channeled through mountain gaps, can decrease the flow of the ACC within Shelikof Strait (Kodiak region), which has implications for freshwater transport in the region (Ladd et al. 2016). In addition, model experiments suggest that gap winds may enhance primary production in the eastern GOA through formation of eddies and changes in circulation (Ladd and Cheng 2016). These small eddies that form in the GOA also concentrate plankton and small fishes for foraging fishes, birds, and marine mammals.

Large-scale atmospheric forcing can also affect circulation speed, transport of nutrients and prey, sea temperatures, and other biophysical oceanographic characteristics encountered by Chinook salmon in the GOA. Many of these large-scale forcing processes, such as the Aleutian Low (AL), a semi-permanent low-pressure system located near the Aleutian Islands, are described by indices that reflect spatio-temporal changes in biophysical oceanographic characteristics of the GOA. For instance, the Pacific Decadal Oscillation (PDO), which is defined as the leading pattern of variability of North Pacific sea surface temperature anomalies, is qualitatively consistent with the atmospheric forcing associated with fluctuations of position and strength of the AL (Schneider and Cornuelle 2005). Other forcing mechanisms influencing the PDO include the El Niño southern oscillation (ENSO) index and oceanic changes in the Kuroshio-Oyashio Extension. Positive values for the PDO indicate warm coastal sea surface temperatures throughout the northeast Pacific Ocean, stronger downwelling, and increased precipitation in the ACC (Mantua et al. 1997, Royer 2005). Negative values indicate the presence of La Niña conditions, with cool sea surface temperatures along the Pacific coast, but warm anomalies in the interior of the North Pacific. The North Pacific Index (NPI) is the area-

weighted sea level pressure over the North Pacific (including the GOA) and defined to measure interannual to decadal variations in the atmospheric circulation (Trenberth and Hurrell 1994). These variations depict changes in the intensity of the Aleutian Low-pressure system where negative NPI values indicate that the Aleutian Low is stronger than normal, leading to increased circulation speed for the various currents along the GOA shelf. The interplay of climate indices, such as the PDO, NPI, NPGO, and ENSO, has significant implications for Chinook salmon habitats in the Gulf of Alaska. Figure 10 illustrates trends in these indices from 1995 to 2024, highlighting inter-annual variability and broader patterns that correlate with ecosystem changes. For example, positive PDO phases, as shown in the figure, align with warmer sea surface temperatures and stronger downwelling conditions, which can influence salmon productivity (Mantua et al. 1997).

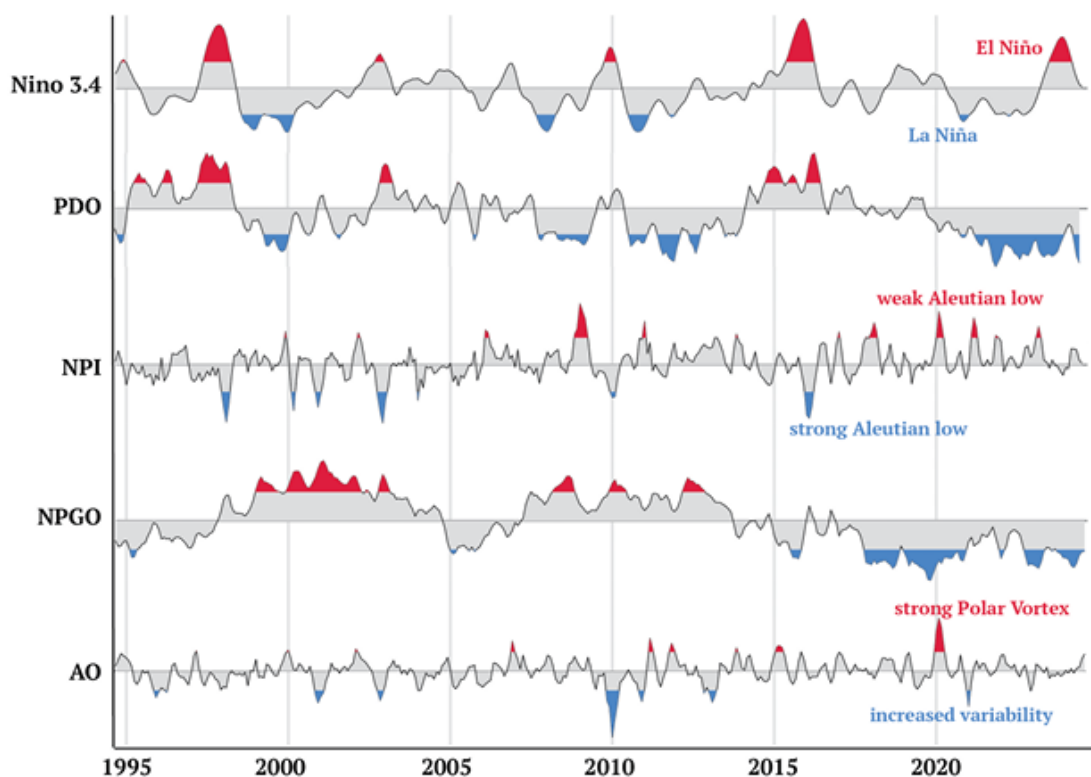


Figure 10. --Time series of five commonly used indices for relating patterns across the Alaska marine ecosystem, including the NINO3.4 index for the state of the El Niño/Southern Oscillation, the Pacific Decadal Oscillation (PDO), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO), and the Arctic Oscillation (AO) indices for 1995-2024 (through August 31, 2024). Each monthly index is normalized using a 30-year climatology from 1991 to 2020 and smoothed using a 3-month running mean. Red and blue shading indicates positive and negative values, respectively. Lighter shaded areas are within one standard deviation of the 30-year climatology. Figure excerpted from Ferris (2024).

The western GOA exhibits seasonal variability and responds to weak decadal signals, particularly the Pacific Decadal Oscillation (PDO) (Hare and Mantua 2000). The PDO's

autocorrelation (0.55) aligns with previous findings (Newman et al. 2016), though it explains little variance in sea surface temperature and freshwater runoff, suggesting local influences like winds are more significant (Bond et al. 2003, Stabeno et al. 2004, Weingartner et al. 2005).

Other indices include the North Pacific Gyre Oscillations (NPGO) and the Pacific North American Pattern (PNA). The NPGO is a climate pattern that can be used as an index to measure changes in ocean circulation and currents in the GOA and California Current (Di Lorenzo et al. 2008). The NPGO is linked to fluctuations in salinity, chlorophyll-a, and nutrients in these areas. The NPGO is also a strong indicator of changes in the mechanisms that drive planktonic ecosystem dynamics. The PNA is a large-scale weather pattern that relates the atmospheric circulation of the North Pacific Ocean to the North American continent. A positive phase of the PNA is associated with anomalously high precipitation over the GOA and Pacific Northwest.

2.1.4.2 Primary production

The GOA is a highly dynamic and productive marine ecosystem where primary production and chlorophyll levels are shaped by complex interactions between physical and biological factors. Wind patterns during winter and spring play a crucial role in cross-shelf nutrient exchange, the Alaska Coastal Current transport, and the timing of spring phytoplankton blooms (Weingartner et al. 2002, Stabeno et al. 2004, Ladd et al. 2005, Coyle et al. 2013).

It is well documented that marine ecosystems can, and have been, affected by perturbations in atmospheric forcing and changing physical conditions (Rallu De Malibran et al. 2024). Environmental variation has led to longer, more intense, and more frequent heat exposure in the upper ocean, often coinciding with other environmental extremes, exacerbating the effects on sensitive marine organisms. Short-term extreme events, such as marine heatwaves, can push conditions beyond the tolerance levels of some species (Janout et al. 2010, IPCC 2014).

The Northeast Pacific and Coastal GOA regions are influenced by strong baroclinic forces and mesoscale physical variability, which disrupt alongshore transport and promote nutrient-rich water movement across the shelf (Okkonen et al. 2003, Royer 2005). During winter, storm-driven mixing deepens the upper ocean, which brings nutrients to the surface but limits primary production due to low light availability. However, between March and May, longer days and increased sunlight result in significant phytoplankton blooms. The timing and strength of these blooms depend on factors such as cloud cover and stratification (Napp et al. 2000).

By late spring and early summer, chlorophyll blooms are observed across the GOA shelf, especially in coastal areas where nutrient-rich waters from the Alaska Coastal Current interact with central GOA waters. Satellite images from 1997 to 1999 show that these blooms are patchy and concentrated in specific regions, such as the shallower banks south of Kodiak Island and Shelikof Strait, while other areas exhibit lower chlorophyll levels (Martin et al. 1989). During summer, strong stratification separates nutrient-depleted surface waters from nutrient-rich waters below, resulting in the formation of a subsurface chlorophyll maximum where phytoplankton thrive at the base of the euphotic zone (Whitney et al. 1998, Sharples et al.

2001). Chlorophyll levels vary significantly across the GOA, with the highest concentrations found in regions influenced by local mixing processes, such as Kennedy Entrance and lower Cook Inlet, which remain productive even in late summer. The transport of nutrients by the ACC into Shelikof Strait also contributes to high chlorophyll concentrations there.

Changes in primary production and chlorophyll levels have important implications for the GOA ecosystem. For example, the 2014-2019 marine heatwave altered the timing and magnitude of phytoplankton blooms, potentially disrupting predator-prey relationships and affecting fishery yields (Ware and Thomson 2005). These alterations in primary production cascade through the food web, significantly impacting zooplankton populations, which are crucial intermediaries in the marine ecosystem.

2.1.4.3 Zooplankton

Zooplankton are important components of the GOA ecosystem, acting as intermediaries between primary producers and higher trophic levels. Their populations are responsive to environmental variability, making them useful indicators of ecosystem changes due to environmental conditions (Beaugrand et al. 2003, Hays et al. 2005, Chiba et al. 2006, Steinberg and Landry 2017).

A long-term study by Kimmel and Duffy-Anderson (2020) found a strong correlation between climatic variability and the May zooplankton community in Shelikof Strait. Temperature, salinity, and timing were identified as the most influential factors. The recent North Pacific warming event (1990–2017) significantly affected zooplankton, with large-bodied copepods like *Neocalanus* spp. potentially entering diapause earlier and an increase in the less lipid-rich *C. pacificus*. These changes could lead to mismatches between zooplankton and their predators, particularly juvenile fish that rely on larger zooplankton in the spring.

The spring zooplankton community in the coastal western GOA and Shelikof Strait is predominantly composed of calanoid copepods, including *Neocalanus plumchrus*, *N. flemingeri*, and *Calanus marshallae* (Cooney 1986, Incze et al. 1997, Napp et al. 2000). Additionally, significant species such as euphausiids, pteropods, and appendicularians play an essential role in the region's intricate food web (Coyle and Pinchuk 2003, Coyle and Pinchuk 2005, Sousa et al. 2016). Zooplankton abundance tends to be higher in nearshore areas and exhibits considerable interannual variability. This variability is influenced by both abiotic factors, such as wind and upwelling, and biotic factors, including primary production (Napp et al. 2000, Coyle and Pinchuk 2005, Sousa et al. 2016).

Zooplankton, including calanoid copepods and euphausiids, are positioned near the base of the GOA's marine food web and may indirectly influence the foraging success of Chinook salmon. Because GOA Chinook salmon are predominantly stream-type individuals, they are fairly piscivorous even as juveniles (Weitkamp and Sturdevant 2008). Zooplankton community dynamics, inclusive of species composition and energetic content, may influence the forage fish prey base available to Chinook salmon.

2.1.4.4 Forage fish

Forage fish, which are important for transferring energy from plankton to predators, exhibit cyclical population patterns marked by frequent collapses and recoveries (McClatchie et al. 2017). The diversity within forage fish communities provides stability to ecosystem services, akin to a diversified financial portfolio, by lessening the impact of fluctuations in individual species (Figge 2004, Schindler et al. 2010). Asynchronous dynamics within these communities enhance stability by decreasing interspecific competition and promoting niche differentiation (Loreau and De Mazancourt 2008). Portfolio effects offer insights into long-term ecosystem stability (Schindler et al. 2015, Thorson et al. 2018). The diversity and varied life-history strategies of forage fish contribute to the resilience of marine food webs by alleviating bottlenecks at middle trophic levels (Kondoh 2003, Perry et al. 2010).

In the Gulf of Alaska, the life histories of key forage species like capelin (*Mallotus villosus*), Pacific herring (*Clupea pallasii*), and Pacific sand lance (*Ammodytes personatus*) are well documented. Capelin migrate from the continental shelf to spawn along beaches from spring through fall, with larvae overwintering and developing during spring's peak productivity (Brown 2002, Arimitsu et al. 2008, Doyle et al. 2019). Herring follow a different pattern, migrating inshore as juveniles and offshore as adults, with rapid larval development crucial for overwintering (Sewall et al. 2019). Sand lance, which are non-migratory and associated with nearshore sandy habitats, spawn from fall to winter, with temperature influencing hatch timing and growth (Ostrand et al. 2005, Baker et al. 2019).

2.2 Chinook Salmon Life History and Ecology

Chinook salmon were historically distributed from the Ventura River in California to Point Hope, Alaska, in North America, and in northeastern Asia from Hokkaido, Japan to the Anadyr River in Russia (Healey 1991). Additionally, Chinook salmon have been reported in the Mackenzie River area of northern Canada (McPhail and Lindsey 1970). Of the Pacific salmon, Chinook salmon exhibit arguably the most diverse and complex life history strategies across their range. Healey (1986) described 16 age categories (combinations of freshwater and saltwater ages) for Chinook salmon: 7 total ages, with 3 possible freshwater ages. Two generalized freshwater life-history types were initially described by Gilbert (1912): "stream-type" or "yearling" Chinook salmon reside in freshwater for a year or more following emergence, whereas "ocean-type" or "sub-yearling" Chinook salmon migrate to the ocean within their first year. According to the best available data, nearly all populations of Chinook salmon in Alaska comprise individuals from the stream-type life history (Taylor 1990, Lewis et al. 2015). However, one population (Situk River) contains primarily ocean-type individuals (Johnson et al. 1992), and other populations (e.g., Keta River, Blossom River) contain some proportion of ocean-type individuals (Pahlke 2001, Fleischman et al. 2011). While there have also been some historical observations of ocean-type individuals in the Deshka River (Delaney 1982), more recent data (2005-2014) show no sub-yearlings observed based on scale data from returning adults (Lescanec 2017).

The generalized life history of Pacific salmon involves incubation, hatching, and emergence in freshwater, migration to the ocean, and subsequent initiation of maturation and return to freshwater for completion of maturation and spawning (Figure 11). Additionally, some young male Chinook salmon mature in freshwater (minijacks), thereby foregoing emigration to the ocean. Minijacks have only been documented through hatchery work in Alaska but have been anecdotally observed in some wild populations in Southeast Alaska (C. Waters, NOAA, personal communication, June 17, 2025; N. Frost, ADF&G, personal communication, June 17, 2025). Salmon exhibit a high degree of variability in life-history traits, which are determined by a combination of genetic and environmental factors. Many of these traits appear to have a substantial genetic component (Carlson and Seamons 2008) and some appear to be largely controlled by variation at a few or single genomic regions (Barson et al. 2015, Pearse et al. 2019, Thompson et al. 2020, Barry et al. 2024).

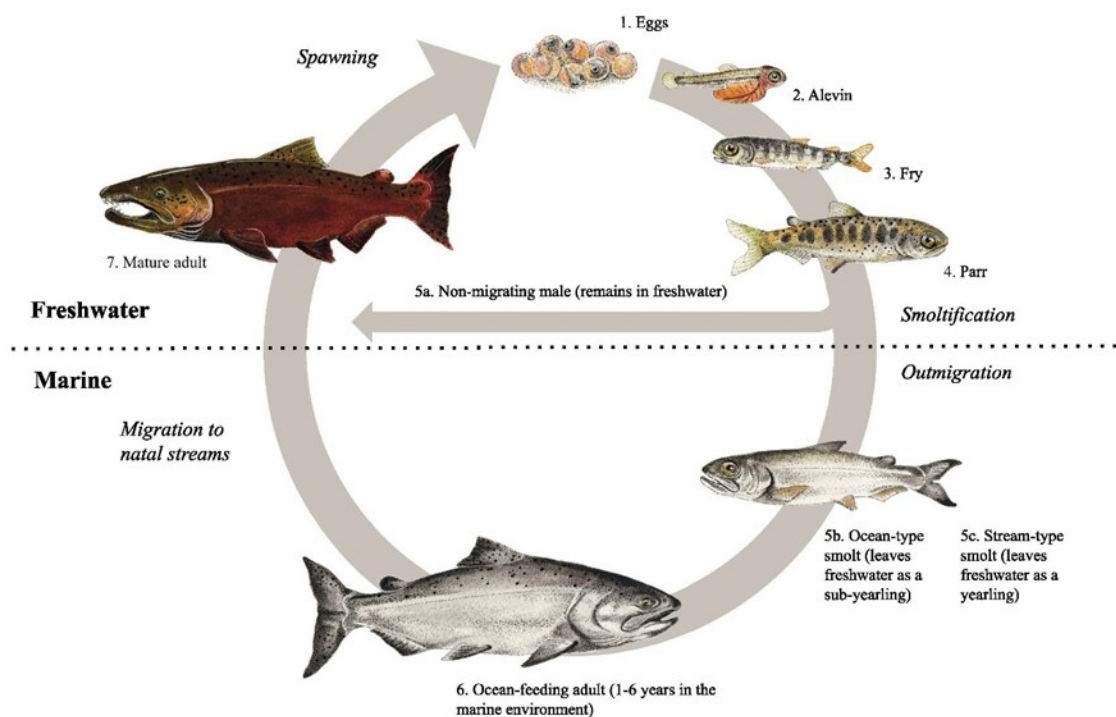


Figure 11. -- Generalized Chinook salmon life history. (Illustrations by Juliana Cornett).

Several types of biological evidence were considered in evaluating the contribution of GOA Chinook salmon to ecological and genetic diversity of the biological species under the ESA. Life-history traits examined for naturally spawning Chinook salmon populations included freshwater life history, age and size at spawning, river-entry timing, spawn timing, and ocean migration. These traits are believed to have both a genetic and environmental basis, and similarities among populations could indicate either a shared genetic heritage or similar responses to shared environmental conditions.

The analysis of life-history trait information is complicated by several factors. Data collected from different locations during different years are confounded by spatial and temporal environmental variability. This variability creates considerable "noise," which may be as large among geographically proximate locations as differences between geographically distant populations, and may mask subtle regional patterns. High interannual variability also complicates the comparison of results from studies conducted during different time periods. For Chinook salmon, for which a single brood year may return from the ocean over a 5- or 6-year period, variations in ocean productivity due to events such as El Niño (Johnson 1988) may bias estimates of age distribution, age-size relationships, and/or age and size-related fecundity estimates (Oke et al. 2020). Direct comparisons of Chinook salmon life-history traits between stocks under controlled conditions are limited in number, and the extent to which inference can be made to wild populations is uncertain.

Because of these potential sources of variability, we determined that statistical analyses of life history trait variability would not yield robust conclusions. Instead, data were collected from as many sources as possible for each system to give some indication of the mean and range in character traits.

2.2.1 Spawning distribution and habitat selection

The GOA region contains a range of river systems from large rivers to short, coastal streams that sustain Chinook salmon populations extending from the Alaska Peninsula through Southeast Alaska. These watersheds may be predominantly glacial, snow-fed, or rain-fed in nature. The spawning distribution of Chinook salmon is dictated by several key environmental factors, including water temperature, flow regimes, substrate composition, and the availability of cover. Within this region, Chinook salmon exhibit adaptability in selecting their spawning sites to match the varying environmental conditions.

Chinook in the GOA region typically spawn from late summer through fall, with the exact timing varying depending on the river system, local conditions, and latitude (e.g., Richards et al. 2022). Water temperature plays a crucial role in determining when spawning begins. Ideal spawning water temperatures range from 6°C to 14°C, as these temperatures optimize egg incubation and survival (Reiser and Bjornn 1979, Piper et al. 1982, McCullough 1999). When environmental conditions vary, such as fluctuating river flows and corresponding temperatures due to snowmelt, rain events, or glacial runoff, spawning times can shift accordingly (Keefer et al. 2008).

A key element of spawning habitat selection for Chinook salmon is the type of substrate in which they build their redds (spawning nests). The size of substrate selected for redd construction typically ranges from gravel to small cobble and may depend on water velocity (Healey 1991, Moir and Pasternack 2010). This range of substrate size is crucial for maintaining the proper water flow through the gravel, which helps prevent sediment from clogging the

redds and ensures that eggs receive sufficient oxygen. Chinook salmon often build their redds in areas of moderate flow velocity, where the water is fast enough to prevent sediment buildup, but not so fast as to wash away eggs or displace newly hatched alevin and fry. Ideal spawning sites are typically located in riffles or pool tailouts, where water depth ranges between 0.05 and 1.5 m, and the flow velocity is between 30 and 100 cm per second (Bjornn and Reiser 1991, Healey 1991). These conditions create a stable environment that provides the necessary oxygenation for eggs while also protecting them from predators and environmental disturbances. While the substrate size, water velocity, and water depth utilized by spawning Chinook are variable, the need for adequate subsurface flow is constant. The large size of Chinook eggs relative to other salmonids makes them more sensitive to low oxygen levels and increases the subsurface flow required for proper development (Healey 1991).

In addition to water temperature, substrate, and flow that influence spawning habitat selection, Chinook salmon also seek out areas with habitat complexity, such as submerged logs, large boulders, and undercut banks. These features provide essential cover from predators and help reduce the energy expenditure of adult salmon during spawning. In rivers with high habitat complexity, Chinook salmon are more likely to construct redds in areas where there is protection from strong currents and predators. Large woody debris, in particular, plays an important role in creating these protected areas by slowing down water flow and creating deep pools (Keller and Swanson 1979). These pools not only serve as spawning sites but also offer refuge for adult salmon before and after spawning, reducing stress and energy expenditure (Quinn 2004). In systems with low habitat complexity, such as rivers that have been channelized or logged, Chinook salmon may have fewer suitable sites for spawning. In contrast, rivers with natural flow regimes and abundant cover provide a wider range of high-quality spawning sites, supporting higher reproductive success. Additionally, the size and connectivity of these habitat types can greatly influence Chinook productivity (Isaak et al. 2007).

2.2.2 Juvenile habitat use, life history, and feeding ecology

The habitat use of Chinook salmon is intricately tied to their life cycle, with different habitats serving distinct roles during various stages of development. From their early rearing phase in freshwater rivers and streams to their eventual migration to estuarine and marine environments, Chinook salmon are able to adapt to and utilize a wide range of habitats. These habitats provide shelter and protection from predators along with a supply of food resources that support early growth and development.

During their freshwater life stages, Chinook salmon utilize a variety of habitats. Main river channels, side channels, and smaller tributaries all play roles in the rearing of juvenile Chinook. Main channel habitats are typically colder and less productive than shallower off-channel habitats (Limm and Marchetti 2009, Huntsman and Falke 2019); therefore, access to off-channel or complex habitats is important for Chinook salmon fry and parr. Off-channel areas,

such as side channels and sloughs offer slower-moving, warmer water, which reduces the energy expenditure required for the juvenile salmon to maintain their position in the water column. Additionally, warmer conditions promote increased energy conversion from consumed prey. The complexity of these habitats, often enhanced by the presence of large woody debris, submerged vegetation, and root wads, provides cover from predators and creates an ideal environment for foraging. These sheltered areas are critical during early development, as they allow the fry and parr to feed extensively on macroinvertebrates and small fish species (Wipfli and Baxter 2010).

The diet of juvenile Chinook salmon shifts seasonally and as the fish grow, reflecting changes in habitat use and prey availability. During their early freshwater phase, young Chinook are primarily insectivorous, feeding on aquatic insects such as mayflies, stoneflies, and caddisflies. These prey items can be abundant in the riffles and shallow stream margins where juvenile Chinook typically reside during their first few months of life (Healey 1991). As the juveniles grow larger and alternative prey items become available, they begin to diversify their diet to include terrestrial invertebrates. This shift in feeding behavior is closely linked to their increasing body size and ability to capture larger prey and the increased availability of terrestrial invertebrates during summer. Later in the year, juvenile Chinook are able to take advantage of marine-derived prey in off-channel habitats in the form of salmon eggs (Quinn 2004, Rine et al. 2016). Feeding behavior is also influenced by habitat complexity and water velocity. In slower-moving water, such as side channels and backwaters, juvenile Chinook can feed more efficiently on drifting prey, allowing them to maximize their energy intake while expending minimal effort. Conversely, in faster-flowing sections of rivers, Chinook must expend more energy to capture drifting prey, but those prey may be more frequently available (Everest and Chapman 1972). Additionally in faster flowing water, it is harder for juvenile Chinook to distinguish between prey, and non-prey items (Neuswanger et al. 2014). This dietary flexibility is a key factor in the success of Chinook salmon, allowing them to exploit a wide range of habitats and prey types during their freshwater rearing phase.

As juvenile Chinook salmon grow and prepare for their migration to the ocean, they undergo a physiological transformation known as smoltification, which allows them to survive in saltwater environments. During this stage, Chinook salmon gradually shift from freshwater habitats to estuarine environments, where they acclimate to the changing salinity levels and continue to feed extensively in preparation for their ocean migration. Estuaries serve as critical transitional zones for Chinook salmon, providing abundant food resources and protection from predators during this vulnerable period. A study in the Skeena River in British Columbia found that 25% of outmigrating Chinook individuals spent at least 33 days in the estuary, with the estuarine environment providing an opportunity for growth at an estimated rate of 0.55 mm per day (Moore et al. 2016). The brackish waters of estuaries can be highly productive, supporting dense populations of larval fish, marine invertebrates, and invertebrates that have drifted from the freshwater or terrestrial environment; all of which can become prey for juvenile Chinook

(Healey 1991, Moulton 1997, Hillgruber and Zimmerman 2009). Within estuarine habitats, Chinook salmon exhibit habitat selectivity based on factors such as water depth, salinity, and temperature. Shallow, vegetated areas in estuaries offer ideal foraging grounds, as they provide protection from larger predators and support high densities of prey (Davis et al. 2019). Estuaries also serve as a buffer, helping juvenile Chinook gradually acclimate to the increasing salinity of ocean waters, which reduces the physiological stress of the transition from freshwater to marine environments.

Juvenile Chinook salmon display two primary life history strategies related to timing of smoltification, stream-type and ocean-type. Ocean-type juveniles generally enter the marine environment soon after hatching, whereas stream-type juveniles spend at least a year rearing in freshwater before smoltification. Much of what is known about the juvenile life history of Chinook salmon in Alaska has been summarized by Healey (1991) and Morrow (1980) and was briefly summarized by ADF&G as part of the Chinook Salmon Research Initiative (ADF&G 2013). With rare exceptions, Chinook salmon from the GOA exhibit a stream-type life history, with the majority of juveniles spending two winters (one winter as eggs in gravel, one winter in freshwater as a juvenile) in freshwater before smolting. Stream-type juveniles are highly dependent on freshwater stream ecosystems because of their extended residence in these areas. A stream-type life history may be adapted to those watersheds, or parts of watersheds, that are more consistently productive and less susceptible to dramatic changes in water flow, or which have environmental conditions that would severely limit the success of subyearling smolts (Miller and Brannon 1982, Healey 1991). Recent research has shown that productivity of juvenile habitat varies widely across years, emphasizing the importance of preserving intact watersheds (Brennan et al. 2019).

In some instances, Alaska stocks can exhibit a combination of stream-type and ocean-type behavior with a portion of the fish spending one winter in the gravel as eggs and then emigrating to sea as 1-year-old fish. Situk River is one such example wherein the Chinook are predominately ocean-type fish (Thedinga et al. 1998, McPherson et al. 2005); scale age analysis since 1978 indicates 40%–95% of the returning adults are ocean-type fish (E. Jones, ADF&G, personal communication). Seaward emigration of smolt generally occurs between May and July (King and Breakfield 2002), with smolt ranging in length from approximately 50-100 mm (Pahlke et al. 2010).

2.2.3 Predation and competition in freshwater environments

Chinook salmon interact with various aquatic and terrestrial species through predation and competition. As both predator and prey, Chinook salmon are integral components of freshwater and marine food webs. Their interactions with other species, particularly during critical life stages such as juvenile development and adult spawning migrations, shape the structure and function of the ecosystems they inhabit. Predation is discussed in Section 7.5 of this document and competition is discussed below.

Chinook salmon compete for limited resources such as food, spawning habitat, and rearing space with other salmonids (Healey 1991, Quinn 2004). Competition is most pronounced during the juvenile stages, when multiple species of salmonids may occupy the same habitats at the same time (Miller and Simenstad 1997, Moore et al. 2016). During their juvenile rearing phase, Chinook salmon sometimes overlap in habitat use with coho (*Oncorhynchus kisutch*) and sockeye salmon (Quinn 2004). Juvenile Chinook salmon may compete with other salmonids for food resources, especially in nutrient-limited systems where prey availability is low (Clitherow et al. 2024). However, Chinook salmon have evolved to occupy slightly different ecological niches than their competitors, which reduces direct competition. For example, when Chinook and coho juveniles share similar habitats, Chinook are more likely to use faster-flowing stream reaches, while coho make use of deeper pools with reduced flow (Taylor 1991a).

2.2.4 Winter ecology and survival in freshwater

Winter during freshwater residency presents a period in the life cycle of Chinook salmon when survival is heavily dependent on the ability to find suitable habitats that allow for the conservation of energy in harsh environmental conditions. For Chinook salmon fry/parr in Alaska, winter conditions are characterized by low water temperatures, reduced food availability, changes in habitat structure due to ice formation and fluctuating water levels, and the potential for deoxygenation. As water temperatures drop and food becomes scarce, Chinook seek out low-velocity habitats that provide both thermal refuge and protection from predators (Cunjak 1996). Winter habitats are typically found in deep pools, side channels, backwaters, and off-channel areas. These areas offer more stable environmental conditions and reduce the energy expenditure needed to hold position in the water column, which is important during the winter months when metabolic rates are lower (Cunjak 1988). Large numbers of overwintering Chinook on the Kenai River were found to use Skilak Lake as overwintering habitat; some traveling as much as 56 km upstream to reach the lake (Bendock 1989). Winter habitats often have slightly warmer microclimates where groundwater influx can create pockets of warmer water within the streambed, providing Chinook with thermally favorable environments (Bradford et al. 2001). These thermal refugia help buffer the fish against extreme cold and can increase the chances of overwinter survival (Bjornn and Reiser 1991).

Juvenile Chinook salmon exhibit several physiological adaptations during the winter that enable them to maximize their survival in challenging conditions. One of the most important physiological changes is reduced activity levels. Lower water temperatures lead to reduced metabolic rates, resulting in reduced foraging activity. Fat reserves, primarily accumulated during the summer and fall when food availability is higher, are metabolized during late fall and winter to sustain basic physiological functions. Lowered metabolic rates during the winter reduce the demand for oxygen, which is particularly important in habitats where ice cover or reduced water flow can limit oxygen availability. As the fish expend less energy on swimming,

feeding, and other activities, they are able to devote more energy to essential physiological processes such as maintaining cellular function and repairing damaged tissues. Chinook diel activity can also switch from diurnal or arrhythmic activity to primarily nocturnal behavior (Hillman et al. 1992, Bradford and Higgins 2001).

2.2.5 Ocean distribution and migration

Salmon species are distributed in different parts of the water column, with Chinook typically found deeper than other species, and juvenile (first year at sea) Chinook found shallower than older immature Chinook (Walker et al. 2007). Very little is known about habitats occupied by juvenile (first year at sea) Chinook salmon as they first enter nearshore marine waters of Alaska, particularly in coastal transition zones where early marine survival may be strongly influenced by temperature, salinity, and prey availability. As with other populations of stream-type Chinook salmon, it is thought that after leaving their natal river estuaries, juvenile GOA Chinook salmon move into the coastal currents along the shoreline, which remain poorly sampled in most monitoring programs and limited biological sampling has been done to date. It has been hypothesized that the first year at sea is a critical period of growth and survival for juvenile Chinook salmon, a period that is modulated by climatic conditions (Beamish and Mahnken 2001, Fergusson et al. 2022).

After leaving their freshwater and nearshore environments, immature Chinook salmon from Gulf of Alaska stocks typically migrate farther offshore into the shelf areas of the Gulf of Alaska and Bering Sea. These fish spend from one to five years in the marine environment feeding predominately on fish, squid, and euphausiids.

Chinook salmon distribution varies seasonally and by stock across the marine environment. Differences in the ocean distribution of specific stocks may be indicative of resource partitioning and may be important to the success of the species as a whole. Current migratory patterns may have evolved as a balance between the relative benefits of accessing specific feeding grounds and the energy expenditure necessary to reach them. If the migratory pattern for each population is, in part, genetically based, then the efficiency with which subsequent generations reach and return from their traditional feeding grounds will be increased. Ocean migration patterns represent an important form of resource partitioning and are important to the evolutionary success of the species; therefore, differences in ocean migratory pattern were an important consideration in the determination of ESU boundaries.

Transplantation studies conducted in Washington and Oregon suggest a strong influence of genetic factors on oceanic migratory patterns of Chinook salmon. Recoveries of CWT-marked fish from ocean fisheries indicate that fish stocks follow predictable ocean migration patterns, and that these are based on "ancestral" feeding routes (Brannon and Setter 1989, Orsi et al. 2009). For example, Chinook salmon from some populations such as those found on the west coast of Vancouver Island are consistently found farther inshore than those from other neighboring stocks (Weitkamp 2010).

What is known about stock distribution is based on genetic and coded wire tag analyses of samples gathered from commercial and sport fisheries, catches in various research cruises and in bycatch from federal groundfish fisheries. Therefore, the relative intensity and other characteristics of each fishery (e.g., location, season, gear type) may introduce biases into stock distribution estimates due to variability in sampling effort and gear selectivity.

Stock composition estimates from immature Chinook salmon caught as bycatch in federal groundfish fisheries are one of the best sources of data on stock-specific distribution patterns (Larson et al. 2013, Guthrie et al. 2022b, Guthrie et al. 2022a). Figure 12 presents hypothesized seasonal distributions for each ESU. Chinook salmon caught in the Bering Sea pollock fishery from 2011 to 2023 comprised 2.71% SEGOA fish, 2.72% NWGOA fish, and 0.17% CGOA fish on average from 2011 to 2023. Chinook salmon from GOA populations are mostly encountered in the Bering Sea in summer but are found in lower proportions in the winter. Chinook salmon caught in GOA federal groundfish fisheries were comprised of 14.83% SEGOA fish, 5.46% NWGOA fish, and 1.34% CGOA fish on average from 2011 to 2023. These samples primarily come from NOAA fishing districts 610, 620, and 630 which span from Prince William Sound to Kodiak, and are taken in federal fisheries outside of the three nautical mile state fishery zone. Stock composition data from 2014 to 2016 are also available for this region from Chinook salmon harvested closer to shore in state fisheries, where Chinook salmon from SEGOA comprise 4.83% of estimates, and Chinook salmon from the NWGOA comprise 3.63% of estimates (Shedd et al. 2016). The lower proportion of SEGOA fish in these estimates may indicate that these stocks prefer more offshore habitats. Less than 1% of the fish in these samples originated from the CGOA.

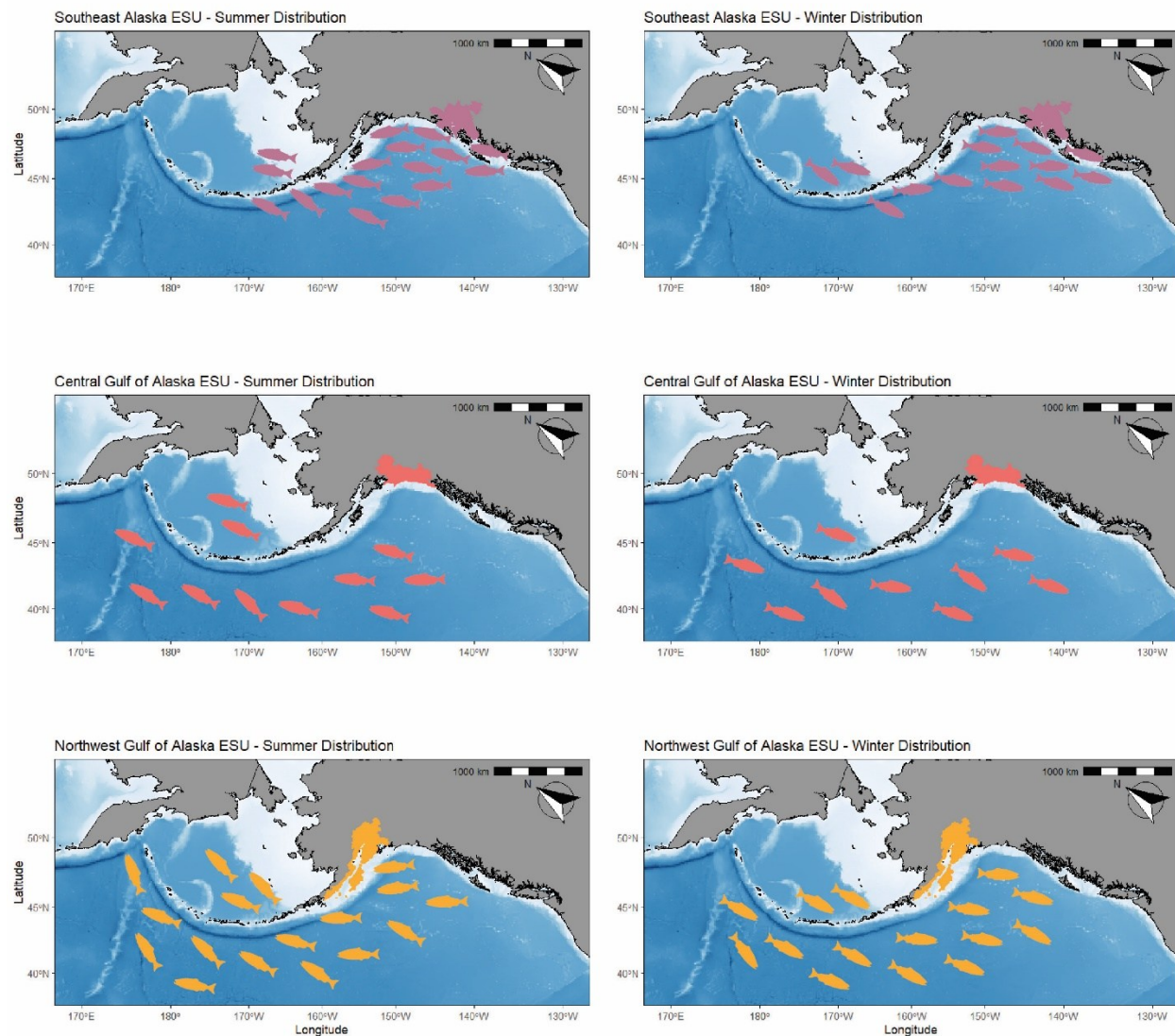


Figure 12. --Hypothesized seasonal distributions for each ESU. This conceptual diagram is adapted from Larson et al. (2013) and partitioned by ESU rather than the stock groups used in Larson et al. (2013). It also integrates additional data collected over the last decade. The diagram is conceptual and is based on best available data for stock-specific distributions, which is sparse, especially in offshore regions.

Stock composition data from directed salmon fisheries is also available from Cook Inlet, the Copper River, and Southeast Alaska. Analyses from Cook Inlet indicate that most of the fish harvested in this region are from stocks outside of Cook Inlet (stocks outside of Cook Inlet were collapsed into one reporting group for this analysis) (Barclay et al. 2019b). Notably, contributions from NWGOA stocks were near zero in the winter, indicating that these stocks rarely use Cook Inlet for rearing when they are of harvestable size. Unlike in Cook Inlet, most of the fish harvested in fisheries near the Copper River are of Copper River origin (Barclay et al. 2022). On average, 3.47% of fish harvested in Copper River fisheries were from the NWGOA and

2.14% were from the SEGOA. This suggests that at least some portion of fish from NWGOA and SEGOA stocks use Prince William Sound for rearing. Upper river stocks from the Copper River migrate through the fishery first, followed by middle then lower river stocks (Barclay et al. 2022). For example, the contributions of up-river stocks can exceed 60% in early to mid-May strata, but decrease quickly to under 1% in later strata by mid-June. The extremely low proportions of upper Copper River fish in later samples suggests that Copper River populations likely do not use Prince William Sound as a primary rearing habitat. Similarly, Chinook salmon from the NWGOA and CGOA areas are generally absent in catches from the Southeast Alaska troll and sport fisheries. These fish are caught so infrequently that the baseline used to generate stock composition estimates does not include populations north of the Alsek River (Shedd et al. 2022). In contrast, fish from SEGOA are caught in relatively high numbers in the Southeast Alaska troll fishery, including in winter when they are not returning to spawn (average = 17.69% from 2009-2019, Shedd et al. 2022).

Data from coded wire tags (CWTs), which are mostly employed for hatchery stocks but also some wild stocks in the SEGOA, can also provide information on stock-specific distribution patterns. CWT data generally support the genetic stock composition data and indicate that Chinook salmon from Cook Inlet and Southeast Alaska are encountered in the Bering Sea and central/northern Gulf of Alaska, fish from Southeast Alaska are encountered in Southeast Alaska, but fish from Cook Inlet are rarely encountered in Southeast Alaska (Celewycz et al. 2008, Weitkamp 2010). CWTs also support the hypothesis that GOA Chinook stocks are found more frequently in the Bering Sea in the summer. Tag recoveries have been rare outside of terminal areas. However, it is notable that eight CWTs from the Copper River and one from the Situk were recovered in the Southeast Alaska troll fishery (K. Shedd, ADF&G, personal communication, September 16, 2024).

Within Southeast Alaska, stocks from the Taku and Stikine Rivers are thought to primarily migrate northwards to the central Gulf of Alaska and Bering Sea to rear (termed outside rearing), whereas all other stocks are thought to primarily rear in Southeast Alaska waters including inside waters (termed inside rearing; Geiger and McPherson 2004). Genetic and CWT data generally support these patterns. For example, fish from the Taku and Stikine rivers, which are the most productive rivers in Southeast Alaska, are rarely encountered in the Southeast Alaska troll fishery or in recreational catches, whereas fish from other populations in Southeast Alaska are much more common (Shedd et al. 2022). For management, genetic stock composition estimates from outside Southeast Alaska do not differentiate among inside and outside rearing groups due to lack of resolution. In Southeast Alaska, CWTs are recovered from both outside-rearing (Taku and Stikine River stocks) and inside-rearing (Chilkat and Unuk River stocks); however, outside of the mature-run period (essentially February to mid-July, annually), recoveries are mostly from the inside-rearing stocks. Although outside-rearing fish are very strict in their far north migrating behavior, inside-rearing fish represent a mix of behavior with CWTs from these stocks also recovered in the GOA and Bering Sea.

Contextualizing data from various sources to investigate stock-specific distribution patterns can be difficult. One way to approach this is to compare the relative abundance of different stocks among areas by scaling the proportion of each stock from a mixed stock sample to the overall abundance of that stock. Larson et al. (2013) coarsely estimated stock sizes as follows: Northwest Gulf of Alaska (includes South Peninsula and Cook Inlet) 131,000, Copper River and Northeast Gulf of Alaska (includes Copper, Situk, and Alsek Rivers) 89,000, and Southeast Alaska and Northern British Columbia 181,000 (Northern British Columbia was grouped with Southeast Alaska in this study due to poor genetic resolution). While these numbers are rough estimates, for the purposes of this report, we assume the Northwest Gulf of Alaska and Southeast Alaska have relatively similar abundances, with the Copper River and Northeast Gulf of Alaska having roughly two-thirds the abundance of the other two stock groups.

Distribution patterns for NWGOA and SEGOA stocks differ markedly in shelf usage and spatial extent, although there are some areas of overlap. Based on stock composition estimates, NWGOA and SEGOA stocks are found in similar abundances in the Bering Sea and inshore in the GOA (near Kodiak and near the Copper River). However, fish from SEGOA are found at much higher frequencies than NWGOA fish on the continental shelf in the central/western GOA (~ 15% vs. ~ 5%) and in SEGOA, where SEGOA fish comprise ~ 18% of catches but NWGOA fish are virtually absent. Both Weitkamp (2010) (based on CWTs) and Larson et al. (2013) (based on genetics) hypothesize that NWGOA and SEGOA fish have different distributions. Larson et al. (2013) discussed this topic in depth and hypothesized that stocks from Southeast Alaska generally follow the migration patterns of more southern stocks (but do not frequently travel south), and are usually found close to the continental shelf, whereas NWGOA stocks are more patchily distributed over a wider area. CWTs from Cook Inlet stocks have been recovered from the middle of the GOA and as far south as Oregon, suggesting the area of distribution for this stock may be quite large. It is possible that the central GOA off the continental shelf is an area of high abundance for this stock but data from this region is too sparse to provide a definitive conclusion. However, the available data provide strong support for the hypothesis that NWGOA and SEGOA stocks have different distribution patterns.

Measurable contributions from Copper River fish to mixed-stock samples from the Bering Sea and GOA are extremely rare. Given that this stock is roughly two-thirds the size of the NWGOA and SEGOA stocks, if Copper River fish shared the same distributions as these stocks, we would expect to see stock composition estimates that were generally similar for the three stocks. However, estimates for Copper River fish are consistently much smaller (often by an order of magnitude) than estimates for the other two groups. The largest contribution to any mixture in our literature was 4% from the GOA federal groundfish fishery bycatch in 2011. CWT recoveries for this stock are also extremely sparse because there are no hatcheries in the system, but the few tags that were recovered from this stock were found in the Southeast Alaska troll fishery (n = 8), British Columbia troll fishery (n = 6) and off the Washington Coast (n = 1). Given that at least some data from most nearshore areas along the coast exists, and Copper River fish are rarely found in these datasets, we hypothesize that Copper River fish may be distributed more

offshore than other stocks and potentially across a wider area. While the NWGOA stock appears to be distributed both onshore and offshore, it is possible that the Copper River stock is more consistently distributed offshore. It is impossible to make definitive conclusions about the distribution of the Copper River stock given the sparse available data but the data that are available seem to indicate a different distribution pattern for Copper River stocks compared to others in the NWGOA.

2.2.6 Size and age at maturity

The age at which Chinook salmon begin sexual maturation and undertake their spawning migration is dependent on multiple factors. Maturation rate tends to be sex- and population-specific, with males maturing earlier than females, and more northerly populations maturing later than more southerly populations. Chinook salmon in Alaska return primarily at age 3 to 6 years (ocean-age-1 to ocean-age-4 fish); 7-year-olds (ocean-age-5 fish) are rare for most stocks. Age composition, body size, and fecundity traits in salmonids have all been shown to be partially under genetic control (Ricker 1972, Carlson and Seamons 2008) and genetically and phenotypically correlated (Gall 1975). Because of genetic correlations between these traits, natural selection on one or more of these traits may affect the expression of other traits. The confounding effects of correlated traits make it difficult to identify specific selective (ecologically important) criteria that influence size and age at maturity.

An alternative reproductive strategy for Chinook salmon is for males to mature at an early age. In Alaska, "minijack" and "jack" Chinook salmon males mature after a few months or after their first year at sea, respectively (different terminology is used in areas like the Columbia River). Early maturation offers a reduced risk of mortality, but younger (smaller) males may be at a competitive disadvantage in securing a mate (Gross 1987). The incidence of jack males has underlying genetic determinants and appears to be, in part, a response to growing conditions (Siegel et al. 2017, Willis et al. 2025). For example, minijack rates varied approximately 10-fold across different integrated and segregated hatchery release groups of spring and summer Chinook salmon throughout the Columbia River basin, and cumulative growth (size at release) affected rates in some programs (Harstad et al. 2014). The location and physical characteristics of each river may also influence the expression of this life-history trait. For example, sockeye salmon streams with certain characteristics, such as cut banks, seem to select for higher proportions of jacks (DeFilippo et al. 2018).

The heritability of body size and age has been more extensively studied in Chinook salmon than other traits. Crosses between different aged parents have demonstrated that the ages of maturity for parents and progeny were strongly correlated (Donaldson and Bonham 1970, Withler et al. 1987, Hankin et al. 1993). The expression of early maturation in Chinook salmon was found to have a significant genetic component; moreover, different stocks exhibited different levels of early maturation in response to environmental changes (Heath et al. 1994). The positive response of Chinook salmon to selective breeding experiments is indicative of a significant genetic component to body size (Donaldson and Menasveta 1961). Chinook salmon

stocks exhibit considerable variability in size and age of maturation, and at least some portion of this variation is genetically determined.

More recent genomic studies have revealed specific regions of the genome that strongly influence age-at-maturity. This is most clear in Atlantic salmon, where two small genomic regions (six6 and vgll3) influence age-at-maturity in both males and females (Ayllon et al. 2015, Barson et al. 2015). Six6 has also been found to influence age-at-maturity in steelhead (Willis et al. 2020, Waters et al. 2021). In Chinook salmon, strong associations between variation on the sex chromosome and age-at-maturity have been documented in males but not in females (McKinney et al. 2020b). Additional research would be useful to understand the strength of these relationships within populations and across the range and to further investigate the genetic basis of age-at-maturity in females.

The mean age and size-at-age of Chinook salmon populations has declined significantly across Alaska over the past 20-25 years (Lewis et al. 2015, Ohlberger et al. 2018, Oke et al. 2020). In particular, the abundance of the oldest age classes has declined. Additionally, the size-at-age of older age classes (ocean ages 3-5) has decreased while sizes of younger age classes (ocean ages 1-2) has increased (Ohlberger et al. 2018). Reductions in size and the abundance of the oldest age classes are concerning because reductions in size can potentially reduce productivity through decreases in fecundity and/or egg quality (Oke et al. 2020, Malick et al. 2023). Additionally, smaller females may not be able to dig deep enough redds to reduce susceptibility to scouring (Healey 1991), and reduction of age diversity could increase variation in abundance and decrease portfolio effects and population stability (Schindler et al. 2010).

Hypotheses to explain these observed declines in size and age-at-maturity include size-selective harvest, environmental changes, increased competition with wild and hatchery salmon, and size selective predation by marine mammals and sharks (Ohlberger et al. 2018, Seitz et al. 2019). While it is challenging to definitively rule out any of these potential mechanisms, Ohlberger et al. (2018) noted that the temporal signature of the observed declines in size and age-at-maturity are not consistent with trends in harvest. Moreover, harvest patterns have varied greatly among individual river systems, while the observed declines in size and age-at-maturity for Chinook salmon are coherent over comparatively broad spatial scales. While increased competition at sea, particularly driven by increased hatchery production of pink salmon and chum salmon (*Oncorhynchus keta*), has been implicated in shifts in the age composition of some salmon populations (Ruggerone and Connors 2015), such competition is expected to reduce marine growth rates and thereby delay age-at-maturity (Cline et al. 2019), in contrast to the patterns observed for some Chinook salmon populations (Lewis et al. 2015, Ohlberger et al. 2018). While temperature and oceanography can impact salmon growth and marine survival, patterns of variability in marine environmental conditions have fluctuated considerably over the period in which Chinook salmon demography has shown comparatively consistent shifts. Conversely, increasing abundance of mammalian predators - such as resident killer whales (*Orcinus orca ater*) is spatially and temporally consistent with the observed

demographic patterns of Chinook salmon (Ohlberger et al. 2018). Killer whales preferentially feed on larger and older Chinook salmon, and eco-evolutionary simulations indicate that such size-selective predation could potentially drive the observed declines in Chinook size and age (Ohlberger et al. 2019). However, it is important to note that the data on killer whale abundance available for this study were limited in Alaska. Additionally, recent diet data indicates that killer whales feed on other salmon species (particularly chum salmon) when they are available (Van Cise et al. 2024). Tagging studies indicate that predation by salmon sharks (*Lamna ditropis*) on older age classes of Chinook salmon may also be substantial, potentially contributing to size-selective predation pressure (Seitz et al. 2019). Regardless of the underlying mechanisms, the demographic shifts in Chinook salmon populations likely have negative consequences for population productivity (Ohlberger et al. 2020, Ohlberger et al. 2025).

2.2.7 Run timing

The timing of migration and spawning is an important life-history trait in salmon that varies among and within populations. Variation in spawn timing is an integral component of the portfolio of salmon diversity that buffers against environmental variation and contributes to resilience (Schindler et al. 2010). Freshwater entry and spawning timing are generally thought to be related to local temperature and water flow regimes (Miller and Brannon 1982). Temperature has a direct effect on the development rate of salmonids (Alderdice and Velsen 1978). Seasonal (e.g., spring vs. fall run Chinook) run timing in salmon has generally been found to be highly heritable (Carlson and Seamons 2008) and has been shown to be controlled by variation in a few or single genomic regions in some cases (Waples et al. 2022, Barry et al. 2024). In particular, seasonal run timing phenotypes of Chinook salmon and steelhead in the Pacific Northwest and California appear to be largely controlled by variation at a single genomic region (Greb1l, Waples et al. 2022).

Chinook salmon populations in the GOA generally spawn in the summer, mostly July and August, with fish entering freshwater as early as April or as late as August depending on the population. In general there is less diversity in spawn timing in Chinook populations from Alaska than those found in the Pacific Northwest and California (Myers et al. 1998). It is likely that this is a function of the reduced growing season in Alaska and generally cooler temperatures that eliminate the need for migration strategies to avoid high summer temperatures, such as premature migration (Burger et al. 1985).

The largest run timing and spawn timing diversity for GOA Chinook salmon occurs in large river systems such as the Copper and Kenai Rivers. These differences are likely due to variation in distances fish must migrate to disparate spawning areas and/or the temperature of the water their embryos experience. In the Copper River, upriver populations enter the lower river around the last week of May, with middle river (Gulkana River) populations entering a few days later, and lower river populations entering between the second and third weeks of June (Schwanke and Piche 2023). In the Kenai River, fish that spawn in tributaries to the main river without large lakes enter the river in May and June and spawn in July, whereas fish that spawn in the

mainstem or in tributaries with large lakes enter the river from June through August and spawn approximately a month later (Burger et al. 1985). These spawn timing differences are likely due to different thermal regimes, with later spawning in areas fed by glacial lakes due to the fact that they are warmer in the winter, leading to more rapid development (Burger et al. 1985). The Kenai River is the only river in the GOA where early and late runs of Chinook salmon are managed separately and have separate escapement goals. There are also smaller differences in spawn timing among various Chinook populations in Southeast Alaska, where peak spawn timing can differ by 4-6 weeks (Richards et al. 2022). Although variation in run timing is not as extreme for GOA Chinook as it is in other areas of the range, even relatively small differences in run timing contribute to ecologically meaningful diversity that can influence population dynamics and ecosystem services (Schindler et al. 2013).

2.2.8 Straying

The high degree of fidelity with which Chinook salmon return to their natal stream has been shown in a number of studies (Rich and Holmes 1928, Quinn and Fresh 1984, McIsaac and Quinn 1988). Fish returning to their natal stream may have evolved as a method of ensuring an adequate incubation and rearing habitat. It also provides a mechanism for reproductive isolation and local adaptation. Conversely, returning to a non-natal stream is important in colonizing new areas and responding to unfavorable or perturbed conditions at the natal stream (Quinn 1993). Straying Chinook, coho, sockeye, pink, and chum salmon have colonized newly deglaciated habitat across Alaska (Milner and Bailey 1989, Pitman et al. 2020, Pitman et al. 2021). The degree of straying in wild populations determines the extent of reproductive isolation and the potential for the formation of ESUs.

Available information on straying rates primarily involves hatchery-reared, transplanted, or transported fish. Rich and Holmes (1928), in one of the earliest studies of homing, released marked Chinook salmon juveniles from a number of hatcheries along the lower Columbia River. Of the 104 Chinook salmon that were recovered in spawning areas or at hatchery racks, only 5 (4.8 %) had strayed to areas other than their release sites (Rich and Holmes 1928). Quinn and Fresh (1984) reported that only 1.4% of the returning spring-run Chinook salmon from the Cowlitz River Hatchery in Washington state were recovered outside of their natal watershed, and it was suggested that straying was more frequent in older fish and in years when the run-size was low. More recently, Westley et al. (2013) evaluated rates of Chinook salmon straying in the Columbia River basin and found that ocean-type Chinook strayed more on average than stream-type (5.2–18.6% strays for ocean-type vs. 0.11–10% for stream-type).

Olfactory cues provided by conspecifics on spawning grounds, especially large aggregations, may be a powerful attractant to returning salmon (Duker 1981). If these spawning aggregations are an attractant, it may explain the negative correlation between run-size and straying as well as explaining the observed straying of naturally-produced salmon into hatcheries. Additionally, the adult returning migratory process has been shown to be under a significant genetic influence. In one experiment in the Columbia Basin, “upriver bright” (i.e., spring type) Chinook

salmon were captured, spawned, and the subsequent progeny reared and released from a downriver site (McIsaac and Quinn 1988). A significant fraction of the returning adults from the upriver bright progeny group bypassed their rearing site and returned to their "traditional" spawning ground 370 km farther upriver.

Hatchery rearing and release procedures may increase the rate of straying. Wild Chinook salmon had significantly lower straying rates than did hatchery-reared fish from the Lewis River (McIsaac 1990). Releasing fish even a short distance from the hatchery can dramatically increase the straying rate (Quinn 1993, Heard 1996). Straying rates as high as 86% resulted from the long-distance transportation and release of fall Chinook salmon in the Sacramento River (Cramer 1991). Unfavorable conditions (high water temperature and low flow) at hatchery return facilities may further increase straying rates (Quinn 1993). The use of hatchery stocks founded from a composite of wild stocks (e.g., upriver bright fall Chinook salmon) may increase straying if the genetic component to homing is more important than the olfactory (learned) component. Chapman et al. (1994) indicated that Columbia River fall Chinook salmon upriver bright hatchery stocks did have a relatively high straying rate. However, Pascual and Quinn (1994) found similar homing success rates for local and introduced stocks of Chinook salmon released in the Columbia River.

Much of the data on stray rates of Chinook salmon in Alaska comes from Southeast Alaska, as Southeast Alaska contains most of the hatchery production in the GOA and straying is much simpler to quantify for hatchery fish where at least a portion of the fish are tagged. Hard and Heard (1999) examined hatchery straying from fish produced at NOAA's Little Port Walter Research Station in Southeast Alaska from adult recoveries at 25 locations in Alaska and British Columbia between 1981 and 1989. Of the over 22,000 Little Port Walter-origin fish recovered, 98.8% were collected at Little Port Walter. Of 264 fish recovered elsewhere, 64.4% were within 25 km of the facility. No Little Port Walter-origin fish were recovered from the ancestral rivers, but nine fish were recovered from rivers supporting wild Chinook salmon. Following up on previous work (Heard et al. 1995), Heard (2012) summarized the incidence of hatchery strays in ten wild stock rivers in Southeast Alaska from 1983 to 2007. Out of the 180,260 fish examined, only 493 were estimated to be hatchery fish from coded wire tag expansions for an overall stray rate of 0.3%. Hatchery proportions were generally under 1% across all rivers and years except the Farragut River where the portion of hatchery strays was 8.5% over the 8 years (1983–1985; 1989; 1991–1993, 2007) for which data were available (Heard 2012).

Information from wild stock tagging programs in Southeast Alaska provide some context for the observed hatchery-wild stray proportions. A portion of smolt from four wild stock rivers (Chilkat, Taku, Stikine and Unuk Rivers) have been externally marked with adipose fin clips and coded-wire-tagged for many years by ADF&G as part of long-term stock assessment programs. Carcass recovery efforts in two of these rivers documented straying between wild rivers. In the Taku River, 4 out of 606 tags (0.7%) recovered over the period 1994 through 2013 were wild strays (E. Jones, ADF&G, personal communication, October 15, 2024). Likewise, eight out of 872

tags (0.9%) recovered from the Unuk River between 1996 and 2014 were wild strays (P. Richards, ADF&G, personal communication). It is difficult to compare stray rates between wild and hatchery Chinook salmon in Southeast Alaska because not all are coded-wire tagged and marked fractions vary. Likewise, straying information in the Cook Inlet area has been limited because not all hatchery Chinook released at sites throughout this area are externally marked (refer to Table 4 in section 5.3.3). However, data collected between 2014 and 2023 from the Anchor River weir, in lower Cook Inlet, suggest a hatchery stray rate of 3% into this system. Similarly, data collected between 1997 and 2000 and again from 2018 through 2020 at the Deep Creek weir, also in lower Cook Inlet, suggest an average hatchery stray rate of 6% into this system (B. Templin, ADF&G, personal communication, November 7, 2024).

In general, stray rates for GOA Chinook salmon are relatively low (near or below 1% in wild populations with higher stray rates up to 6% in hatchery populations). This is unsurprising given that nearly all populations are stream-type (which stray less than ocean-type), and that hatchery influence is generally low (Westley et al. 2013). Therefore, it is unlikely that strays would be able to colonize new habitats quickly, especially if those habitats are not proximate to existing populations. However, it does appear that some populations in the CGOA (Alsek and Situk Rivers) have been founded recently, presumably through straying from other populations. This indicates that recolonization from straying is possible, however the specific time scales over which this recolonization occurred are unknown.

2.2.9 Fecundity and egg size

The anadromous life history of salmon is thought to be a response to the relatively poor productivity of glacially influenced or unstable freshwater environments relative to the nearby marine habitat (Neave 1958, Miller and Brannon 1982). In order to maximize the success of their emigration to saltwater, salmon juveniles must obtain a relatively large size in productivity-limited freshwater environments. One strategy for accomplishing this is through the production of large eggs (Taylor 1991b, Kreeger 1995). Larger eggs produce larger fry (Fowler 1972), which may be more successful at migrating to saltwater than smaller fry (Kreeger 1995). In general, stream-type stocks of Chinook salmon have smaller eggs than ocean-type stocks. However, there is no apparent latitudinal cline in egg size among stream-type nor ocean-type stocks. In general, the number of eggs produced by Chinook females, as well as egg size, increases with body size (Healey and Heard 1984, Beacham and Murray 1993). Similarly, fecundity tends to increase, while egg size decreases, as latitude increases (Healey and Heard 1984, Kaev and Kaeva 1987, Fleming and Gross 1990). Variability in egg size within populations appears to be most directly related to fish size and, to a lesser extent, age (Healey and Heard 1984, Hankin and McKelvey 1985), whereas between-population differences may represent an adaptation to regional environmental and geographic conditions.

Variation in fecundity and egg size among different stocks of Chinook salmon appears to be related to geography and life-history strategy. Chinook salmon females sampled from the Sacramento River had 68% more eggs than females from the Klamath River, after adjusting for

differences in body size (Snyder 1931, Healey and Heard 1984). The relationship between fecundity and body size is also dependent on a number of other factors such as age, migration distance, and latitude, and varies between stocks (Healey and Heard 1984, Kaev and Kaeva 1987, Fleming and Gross 1990). Galbreath and Ridenhour (1964) found that linear length-fecundity regressions for the Columbia River Chinook salmon stocks were not significantly different when compared on a seasonal (monthly) run timing, total age, or smolt age basis; however, differences in body size and a small sample size may have obscured racial differences in fecundity. Similarly, ocean-type Chinook salmon stocks in British Columbia were reported to have larger eggs than stream-type stocks (Lister 1990). Beacham and Murray (1993) found that some Chinook salmon returning to streams on Vancouver Island had larger eggs than fish returning to proximate populations on the mainland. In general, Smirnov (1975) suggested that latitudinal differences existed in egg size, with southern stocks having larger eggs. Furthermore, he speculated that this was because embryonic development at higher temperatures is less efficient; southern stocks need more energy stores (larger eggs) to complete development. Alternatively, this trend may be related to the need for more southerly, predominantly ocean-type, Chinook salmon to produce larger-sized fry for migration to estuary areas.

Correlations between fecundity and body size and age, in addition to environmental fluctuations over several years, complicate the interpretation of fecundity differences. For example, one complication in the analysis of fecundity traits is the difference in body weight devoted to gonadal tissue between coastal and inland populations. Populations which undertake extended migrations may not be able to devote the same percentage of body weight toward gonad (especially ovary) development (Lister 1990). Linley (1993) found a significant negative correlation for adult sockeye salmon between the percentage of body weight devoted to gonads and the length and duration of the freshwater migration. Ivankov (1983) determined that differences in the fecundity of masu salmon (*Oncorhynchus masou*) females within and among rivers were correlated with juvenile growth rate and the rate of gonadal development prior to saltwater emigration, although he did not specifically evaluate the relative contributions of genetic and environmental effects.

A second potential complication is that the majority of fecundity information comes from hatchery populations. Differences in selection on fecundity and egg size traits under hatchery conditions relative to the natural environment may limit the representative value of hatchery populations for their wild counterparts (Fleming and Gross 1990). There is very little information on fecundity of Chinook salmon populations in Alaska, with the most data available for the Yukon River and for three hatchery stocks propagated at NOAA's Little Port Walter Research Station in Southeast Alaska. In the Yukon River, fecundity varies by population and is related to migration distance, with populations that migrate further containing fewer eggs (Bromaghin et al. 2011). At Little Port Walter, fecundity varies between stocks and has shown to be reduced by hatchery rearing (Joyce et al. 2004; C. Waters, NOAA, personal communication, January 2025).

It should be noted that physiological and biological factors have been identified that may limit the potential minimum and maximum egg sizes of 0.12 and 0.47 g, respectively (Quinn and Bloomberg 1992). Maximum egg size may be limited by a reduced surface area-to-volume ratio and the generally high physiological oxygen demands of salmonids. Stream flow, gravel quality, and silt load all significantly influence the survival of developing Chinook salmon eggs. Therefore, behavioral traits such as spawning site selection would need to be correlated with physical fecundity traits. Healey (1991) showed that suboptimal habitat conditions delay or discourage spawning at a specific site.

Changes in fecundity and egg size related to decreases in age-at-maturity and size-at-age are a concern for Chinook salmon from the Gulf of Alaska. Oke et al. (2020) estimated that age and size reductions have resulted in a median reduction in egg production of 15% in Chinook salmon populations across Alaska. Malick et al. (2023) investigated fecundity in hatchery populations from Washington state and found that fecundity in most populations decreased over the 25-year study period, with 62% of the variation in fecundity attributed to decreases in mean length. Ohlberger et al. (2025) discussed the importance of integrating information on fecundity into management and recommended conducting stock-recruit analyses based on egg mass instead of spawner abundance.

2.2.10 Other life history traits

Information concerning the variability, adaptiveness, and heritability of other life-history traits in salmon is limited. Genetically based differences in the rate of Pacific salmon embryonic and alevin development between run times in the same river (Tallman 1986), and between rivers (Iwamoto 1982, Beacham and Murray 1987, Beacham and Murray 1989), represent important adaptations to ensure emergence occurs at a time for optimal survival. The heritability estimates for embryonic development to hatch in Chinook salmon range from 0.25 to 0.40 (Hickey 1983). Smirnov (1975) suggested significant differences in the embryonic development exist between Asian and North American stocks of Chinook salmon.

Pathogen resistance is another locally adapted trait (Beacham and Evelyn 1992). Chinook salmon from the Columbia River drainage exhibited reduced susceptibility to *Ceratomyxa shasta*, an endemic pathogen, relative to stocks from coastal rivers where the disease is not known to occur (Zinn et al. 1977). Differences in susceptibility to the infectious hematopoietic necrosis virus (IHNV) were detected between Alaskan and Columbia River stocks of Chinook salmon (Wertheimer and Winton 1982). Variability in temperature tolerance between populations is also probably due to adaptation to local conditions; however, information on the genetic basis of this trait is lacking (Levings 1993).

2.2.11 Regional variation in life history traits

Variation in life history traits across Chinook salmon populations in the GOA was discussed in the sections above. This information is important for defining ESUs and understanding potential threats to Chinook salmon populations across the GOA. We summarize differences in life

history traits among populations and regions here. It is also important to emphasize that regional differences in life history traits may be present but we may currently lack the data to detect any differences. Chinook salmon are locally adapted to the streams and rivers they inhabit, but much of this local adaptation is difficult to observe and document. Genetic data are helpful as a proxy for local adaptation, especially in areas like the GOA where data on life-history variation is generally sparse.

2.2.11.1 Juvenile life history

Chinook populations across the GOA primarily comprise the “stream-type” life-history strategy, in which juveniles spend two winters in freshwater before outmigrating to the ocean. The Situk River near Yakutat is the only population that contains primarily “ocean-type” Chinook salmon that migrate to sea after one winter.

2.2.11.2 Ocean distribution and migration

Chinook salmon populations across the GOA display differences in migration and distribution patterns. These data are primarily based on genetic stock composition estimates from various fisheries standardized by approximate relative productivity of ESUs. Chinook salmon from SEGOA appear to behave like more southern stocks and are found from Southeast Alaska to the Bering Sea. Within SEGOA, some stocks primarily rear in inside waters (Chilkat, King Salmon, Unuk, Chickamin, Blossom, and Keta Rivers, and Andrew Creek) while others make longer migrations to the open ocean (Taku, Stikine; ADF&G 2023b). Chinook salmon populations from the CGOA (Copper, Situk, and Alsek Rivers) are rarely encountered in the marine environment. We hypothesize that they may be distributed more offshore than other stocks and potentially across a broader area. Chinook salmon populations from the NWGOA (Cook Inlet, Kodiak, and Chignik River) are encountered more frequently than Copper River populations in fishery samples from the GOA and Bering Sea but are still relatively rare. We hypothesize that some Chinook from this area may stay closer to shore, where they are encountered in fisheries, while others have a more offshore distribution. In general fish from the three regions appear to have different migration patterns.

2.2.11.3 Size and age-at-maturity

Variation in age-at-maturity and size exists among populations across the GOA, but this variation does not appear to be associated with regions. Chinook salmon across the GOA are returning at younger ages and are getting smaller by age (Lewis et al. 2015). This trend seems relatively consistent across GOA populations, with no apparent variation across regions.

2.2.11.4 Run timing

Run timing is generally similar for Chinook populations across the GOA, with no consistent regional differences. Diversity in migration and/or spawn timing exists in some large river systems in the GOA such as the Copper and Kenai. Among SEGOA stocks, peak spawn date varies by 4-6 weeks among populations (Richards et al. 2022).

2.2.11.5 Straying

Data on straying is very limited outside of a few hatchery and wild populations in Southeast Alaska.

2.2.11.6 Fecundity and egg size

Fecundity and egg size can be highly variable among populations as well as among years. As with size and age-at-maturity, no apparent variation exists among regions.

2.2.11.7 Other life history traits

To the best of our knowledge, no other regional variation in life-history characteristics has been documented across the GOA.

3 GENETIC INFORMATION

3.1 Introduction to Population Genetic Methods and the Types of Genetic Data Used in this Document

In this section, we consider molecular genetic evidence used to define reproductively isolated populations or groups of populations of Chinook salmon. We focus on genetic markers that have been shown to follow, or are assumed to follow, Mendelian inheritance and are not under selection (i.e., presumed to be selectively neutral), so that an analysis of the geographical distributions of these markers can reveal historical levels of gene flow and isolation. The bulk of this evidence consists of allele frequencies of single-nucleotide polymorphisms (SNPs). SNPs are single base pair changes in the DNA sequence; variation at SNPs due to genetic drift within populations can be used to infer the degree of reproductive isolation among populations. Many statistical methods have been used to analyze molecular genetic data to test various hypotheses of reproductive isolation, understand genetic diversity, and infer evolutionary history. In this report we quantify and analyze patterns of reproductive isolation using estimates of genetic differentiation based on fixation index (F_{ST}), neighbor-joining trees to visualize patterns of F_{ST} , and multidimensional scaling plots. Genetic diversity was quantified using estimates of observed heterozygosity (H_O) and allelic richness (A_R). There are many types of analyses that can be conducted with genetic data. We chose these analyses and metrics because they are commonly used and do not rely on model fitting; therefore, they are not influenced by analytical choices. For example, models exist to estimate parameters such as divergence time and migration rates using genetic data, but their reliability is highly uncertain so we have decided not to use them here. However, the metrics presented here are influenced by the number of individuals sampled, the number of genetic markers used, and the allele frequencies of those markers (Willing et al. 2012, Kardos et al. 2015).

The primary metric that we use to understand genetic differentiation is F_{ST} . Genetic differentiation between populations at various hierarchical levels has been estimated in many studies with F_{ST} analyses (Hedrick 2005), which apportions allele-frequency variability among

populations into its geographical or temporal components. For example, the proportion of genetic subdivision among populations may be estimated with $F_{ST} = (HT - HS)/HT$, where HS is the average within-population heterozygosity and HT is the total heterozygosity disregarding geographical subdivision. In this document, we use the formula for F_{ST} from Weir and Cockerham (1984), which includes corrections for varying sample sizes.

Most genetic variability in salmonids occurs as genotypic differences among individuals within a population (Ryman 1983). A smaller proportion of the total variability is due to hierarchical differences between regions, river systems, tributaries and streams within a river system, years, or run types. Estimates of F_{ST} among natural populations (averaged across many loci and assumed to be representative of the genome-wide average) range from 0.0 (no genetic differentiation among populations) to about 0.25 (strong differentiation among populations). These statistics facilitate comparisons among groups of populations that can be used to analyze regional differences in gene flow between populations. However, coming up with specific cutoffs for interpreting F_{ST} values is challenging, as F_{ST} can be influenced by marker sets and marker types and varies widely among species.

In this document, we generally compare F_{ST} s estimated from the same SNP markers or subsets of the same marker panel, which largely removes the confounding variables of different marker panels and types. However, it is still difficult to contextualize F_{ST} values in this document with those of other species. Additionally, tests for significant F_{ST} between populations are not particularly useful because the levels of F_{ST} observed for GOA Chinook salmon and the number of markers used mean that nearly all tests will produce significant results (Waples 1998). In this document, we therefore focus on using F_{ST} s as a metric to compare genetic differentiation among and between groups of populations and to identify genetic breaks.

F_{ST} values for GOA Chinook populations calculated with the 248 SNP dataset (see Section 3.2.1) range from 0 to 0.23, with a mean of 0.10. In general, we considered population comparisons with F_{ST} s < 0.04 as genetically similar, population comparisons with F_{ST} values between 0.04 and 0.08 as moderately diverged, and populations with F_{ST} values > 0.08 as highly diverged. These are not steadfast rules and were constructed solely to assist with interpretation of the genetic data. We also did not base our definition of ESUs solely on these rules. For example, there are isolated examples of populations within ESUs with F_{ST} s > 0.08 and populations that span ESUs with F_{ST} s < 0.08. Many of the population comparisons with F_{ST} s > 0.08 found within ESUs include a small population that has likely diverged due to genetic drift but was not deemed to be evolutionarily distinct. More broadly, after we identified hierarchical clusters using genetics, we incorporated additional data, such as data on ecology, abundance trends, and habitat characteristics to evaluate which level of the cluster hierarchy meets the criteria for being evolutionarily significant.

It is also important to note that recent research has shown that salmon populations with small F_{ST} s < 0.01 can accumulate important adaptive differences (Larson et al. 2017, Tigano and Russello 2022). However, when defining ESUs, considerations beyond genetic differentiation

are important for making appropriate distinctions. Therefore, even if populations are statistically, genetically differentiated, that criterion alone does not warrant ESU designation.

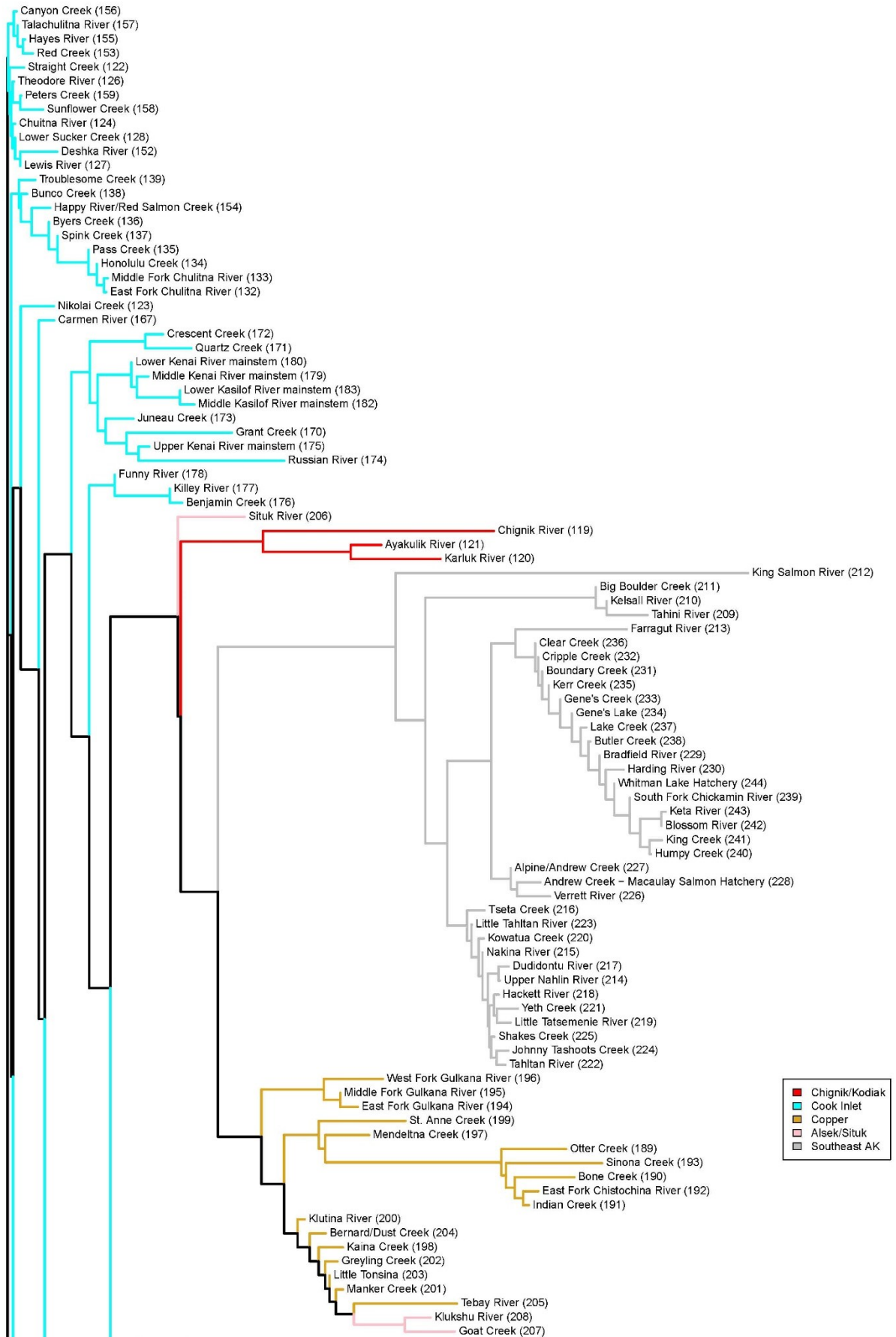
We also used visual tools to quantify the degree of reproductive isolation based on the pattern of genetic distances between populations. Clustering methods, such as the neighbor-joining method (Saitou and Nei 1987), produce hierarchical groupings of genetically similar populations. Multivariate methods, cluster populations in multiple dimensions. When the geographical distribution of genetic variability is continuous and not hierarchical or disjunct, such as in a clinal or reticulate pattern, multivariate cluster analysis more accurately depicts relationships among samples than does agglomerative clustering such as the neighbor-joining method (Lessa 1990). Since the latter algorithm compares the genetic distance of an incoming sample to the average genetic distance between samples already in a cluster, the information about the relationship between the incoming sample and the samples already in the cluster is lost. Multivariate cluster analysis, on the other hand, is a non-metric ordination technique that minimizes the distortion of the order of pairwise genetic distances between samples in n -dimensional space without relying on variance-covariance decomposition. The relative degree of reproductive isolation between populations was inferred from a visual examination of these plots.

Levels of genetic variability within populations were also considered, because the level of within-population variability may reflect evolutionary or historical differences in population size and migration patterns between populations. In general, estimates of diversity were used to identify whether genetic outlier populations based on analyses of population structure also displayed patterns of genetic diversity that were not consistent with other populations in the dataset. For example, populations with high genetic differentiation and low diversity are typically small and have probably diverged from other populations due to genetic drift. Additionally, populations with unusually high genetic diversity could indicate that a given sample is composed of multiple populations or contains mixed ancestry. Regional patterns of diversity were also assessed, but these were not heavily integrated into the ESU designation process. We estimated observed heterozygosity (H_o) and allelic richness (A_R). Observed heterozygosity is the number of heterozygous individuals observed at a given locus in a given population sample divided by the number of individuals in the sample and is averaged across loci. Allelic richness is the number of alleles observed at each locus averaged across loci. As with F_{ST} , there are no consistent rules for interpreting these metrics. Instead, it is more common to compare values within a dataset; this is the approach that we took. Specifically, we noted when diversity metrics for certain populations differed from surrounding populations and used those data to provide more information on potential population histories.

3.2 Genetic Structure of Chinook Salmon within and outside Alaska

3.2.1 Overview of available data that includes populations from Alaska

Over the past four decades, multiple studies have examined the genetic structure of Chinook salmon in Alaska with allozymes (Gharrett et al. 1987, Guthrie and Wilmot 2004), microsatellites (Beacham et al. 2006b, Seeb et al. 2007, Olsen et al. 2011, Moran et al. 2013), SNP panels (Templin et al. 2011, Larson et al. 2014a, Barclay et al. 2019a) and thousands of SNPs genotyped using genomic techniques (Larson et al. 2014b, Hecht et al. 2015, McKinney et al. 2020a). Many of these studies are regional and focus on specific areas such as western Alaska and the Yukon River, or Southeast Alaska. Other studies genotype populations from a large portion of the range, but only include a few populations from across Alaska, or genotype a large number of populations in Southeast Alaska and southward, but very few northward of this area. The only available published study with adequate coverage for assessing population structure across Alaska is Templin et al. (2011), which genotyped 172 populations from across the range of Chinook salmon, including 99 populations in Alaska, with 43 SNPs. However, ADF&G has recently genotyped 260 populations of Chinook salmon from Russia, Alaska, the Yukon Territory, and British Columbia with a panel of 248 SNPs developed by Idaho Department of Fish and Game and the Columbia River Intertribal Fish Commission (Hess et al. 2016). This dataset was assembled to enable stock identification of Chinook harvested in Pacific Salmon Treaty fisheries or as bycatch in groundfish fisheries in the GOA and Bering Sea. Unless otherwise specified, the genetic analyses presented in this document are based on data from the 248 SNP panel (Figure 13 and Figure 14).



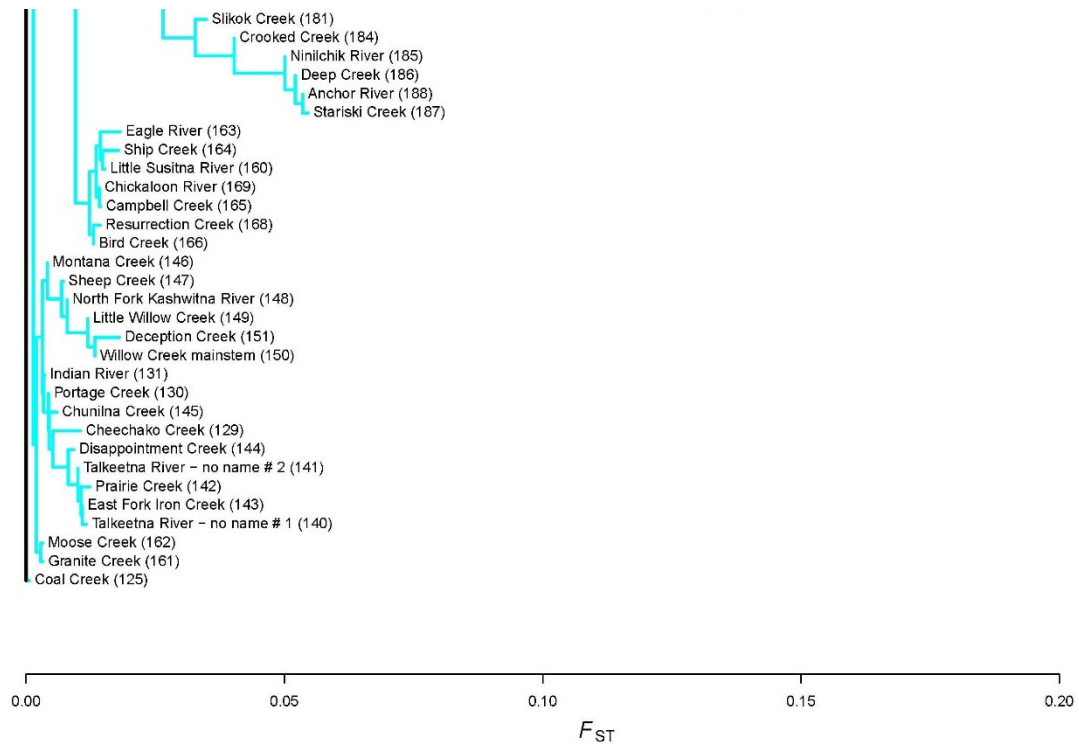


Figure 13. -- Phylogenetic tree based on F_{ST} of 139 Chinook salmon populations that spawn in the Gulf of Alaska from Chignik River to Keta River genotyped with the 248 SNP panel.

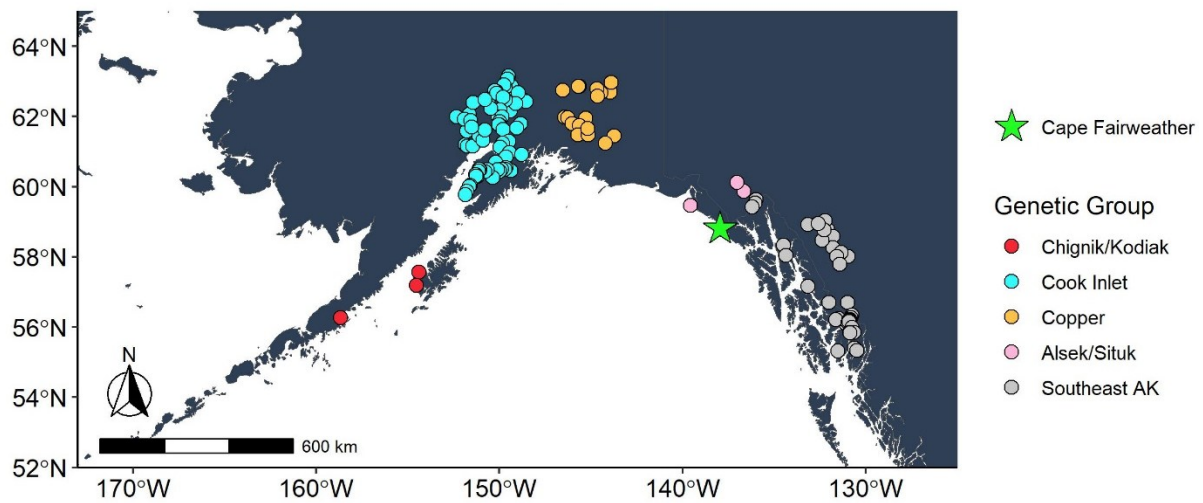


Figure 14. --Map of 139 Chinook salmon populations that spawn in the Gulf of Alaska from Chignik River to Keta River genotyped with the 248 SNP panel.

Understanding the genetic basis of adaptive variation and identifying adaptive genetic variants has become much more feasible over the last decade as genomic data has become more widely available (Allendorf 2017). It is becoming clear that variation in multiple important life history

traits in salmon, such as run timing and age at maturity, is at least partially controlled by large effect loci (Waples et al. 2022). However, there is still much uncertainty regarding the extent to which information from these loci should be integrated into conservation planning (Funk et al. 2012, Waples and Lindley 2018).

Genomic studies revealed a large effect locus associated with seasonal run timing in Chinook salmon and steelhead from California and the Pacific Northwest (Greb1l) that explains > 50% of the variation in this trait in certain populations (Waples et al. 2022). However, the degree to which data from adaptive loci such as Greb1l have been integrated into conservation and management of salmon has varied widely, with some entities placing much more emphasis on these data than others.

Genomic data and data from adaptive loci in general, including run timing loci, are rare or unavailable for Chinook salmon populations in Alaska. Genomic studies using restriction site associated DNA (RAD) sequencing to genotype thousands of loci have either been conducted on single geographic regions with low structure in western Alaska (Larson et al. 2014b, McKinney et al. 2020a) and northern Cook Inlet (Dann et al. 2018), or have surveyed populations across the range, but only included a few populations from Alaska (Hecht et al. 2015). These studies did not identify strong signals of adaptive variation. Whole genome sequencing represents a major advance over RAD, and studies using this technique generally genotype millions rather than thousands of markers (Lou et al. 2021). However, there is only one published whole-genome sequencing study on Chinook salmon in Alaska, and this study focused on genetic differences between hatchery and wild populations in Southeast Alaska (Howe et al. 2024).

The only strong evidence of adaptive genetic variation that has been identified in populations of Chinook salmon from Alaska is from loci in the major histocompatibility complex (MHC). The MHC complex, which is involved in immune system function, is encoded by one of the most highly polymorphic DNA sequences in vertebrates and has been shown to be involved in local adaptation in a large number of animals including multiple species of salmon (Pirotney and Oliver 2006). Two MHC loci were included in the 43 SNP (Templin et al. 2011) and AK_248 SNP panels. The *OTS_MHC2* locus has the highest F_{ST} of any non-mitochondrial locus in the 43 SNP dataset ($F_{ST}=0.42$). Additionally, the *OTS_MHC2* locus was found to have significantly elevated F_{ST} consistent with putative adaptive divergence in populations of Chinook salmon from the Copper River (Ackerman et al. 2013). Given that genomic data and data on adaptive loci are generally scarce for Chinook salmon populations from Alaska, we focus the majority of our discussion of population structure on data from putatively neutral loci included in the three SNP datasets outlined above.

3.2.2 Overview of Chinook salmon population structure

Population structure of Chinook salmon across their range is influenced by a number of factors, including geographic distance, colonization from different glacial refugia after the last glacial maximum, and ecological differences such as spawn timing and juvenile life-history type (e.g.,

ocean vs. stream-type populations) (Waples et al. 2004, Templin et al. 2011, Moran et al. 2013). During the last glacial maximum, which ended approximately 10,000 years ago, Chinook salmon are hypothesized to have inhabited multiple refugia. These included at least one refugium in the northern part of their range (potentially in coastal western Alaska in the lower parts of the contemporary Kuskokwim and Yukon drainages, and multiple refugia in the southern part of their range (e.g., Puget Sound and the Snake River Basin, Waples et al. 2008). As the glaciers receded, Chinook salmon colonized the newly available habitats and locally adapted to fill available niches (Waples et al. 2004, Moran et al. 2013). Higher levels of gene flow among proximate populations led to a signal of isolation by distance. Additionally, isolation driven by biological factors such as spawn timing and juvenile life history type also led to genetic differences among populations.

In the southern range of Chinook salmon (e.g., the Fraser and Columbia Basins), it is difficult to disentangle the relative influence of recolonization from distinct glacial refugia, isolation by distance, a history of stocking and fish transfers, and isolation by time/adaptation on genetic structure (Moran et al. 2013). For example, there is evidence of two highly diverged lineages of Chinook salmon in the Columbia River (Interior Columbia spring run and Lower Columbia) that differ substantially in life histories and also were likely derived from different glacial refugia (Waples et al. 2004). Genetic structure in the northern range is generally shallower, less complex, and seems to be largely driven by isolation by distance (Myers et al. 1998). However, there are signals of genetic discontinuities that are likely due to colonization from discrete lineages after the last glaciation and other notable biogeographic boundaries that likely contribute to genetic differentiation among populations. Genetic structure in the northern range has not been comprehensively described; therefore, we attempt to describe patterns of structure in detail below with an emphasis on populations that spawn in rivers draining into the Gulf of Alaska.

3.2.3 Description of lineage break near Cape Fairweather (~latitude 59° N)

Chinook salmon in Alaska comprise two major genetic lineages, with populations from north and west of Cape Fairweather (~latitude 59° N) belonging to what we will refer to as the western lineage, and populations east and south of this point belonging to what we will refer to as the eastern lineage. The lineage split occurs between the Chilkat River, which is part of the eastern lineage, and the Situk and Alsek Rivers, which are part of the western lineage (Figure 14). It is hypothesized that Chinook salmon from a northern glacial refugia re-colonized areas from western Alaska north of latitude 59° after the last glacial maximum, whereas populations from a southern refugia colonized areas south of latitude 59°.

The precise location of the lineage split was first described by Beacham et al. (2006a), who genotyped 52,000 Chinook salmon from 320 localities from Russia to California with 13 microsatellites. This was the first study to analyze a sufficient number of populations from north and south of the lineage split to definitively identify it; however, studies before this noted that samples north of Southeast Alaska were genetically distinct, and that recolonization in

Alaska likely occurred from multiple glacial lineages (Gharrett et al. 1987, Myers et al. 1998, Guthrie and Wilmot 2004). The split is highlighted in the phylogenetic tree (Figure 13), and also evident in the PCA plot, where populations from the eastern and western lineages are separated by a large gap on axis 1 (Figure 15). Additionally, we observed lower H_O and A_R for populations in the western versus eastern lineage (average $H_O = 0.21$ for Western Lineage and $H_O = 0.28$ for the Eastern Lineage; $A_R = 1.69$ and 1.88 , respectively). Differences in diversity can be caused by ascertainment bias, which occurs when genetic markers are chosen based on polymorphisms in a certain geographic region that may not be representative of other regions (Smith et al. 2007). However, we do not believe that ascertainment bias explains the differences in within population diversity observed between lineages, as the same pattern of lower diversity was observed in the 43 SNP dataset (Templin et al. 2011), which consists of loci that are largely derived from Alaskan populations, including populations in the western lineage. Instead, the reduced diversity of the western lineage is likely a result of past demographic history (e.g., bottlenecks or reduced population sizes in glacial refugia; also hypothesized in Templin et al. (2011)). Evidence of introgression/secondary contact between the lineages (e.g., lower differentiation and increased diversity in populations near the lineage split) is not present, suggesting that gene flow between the lineages is rare.

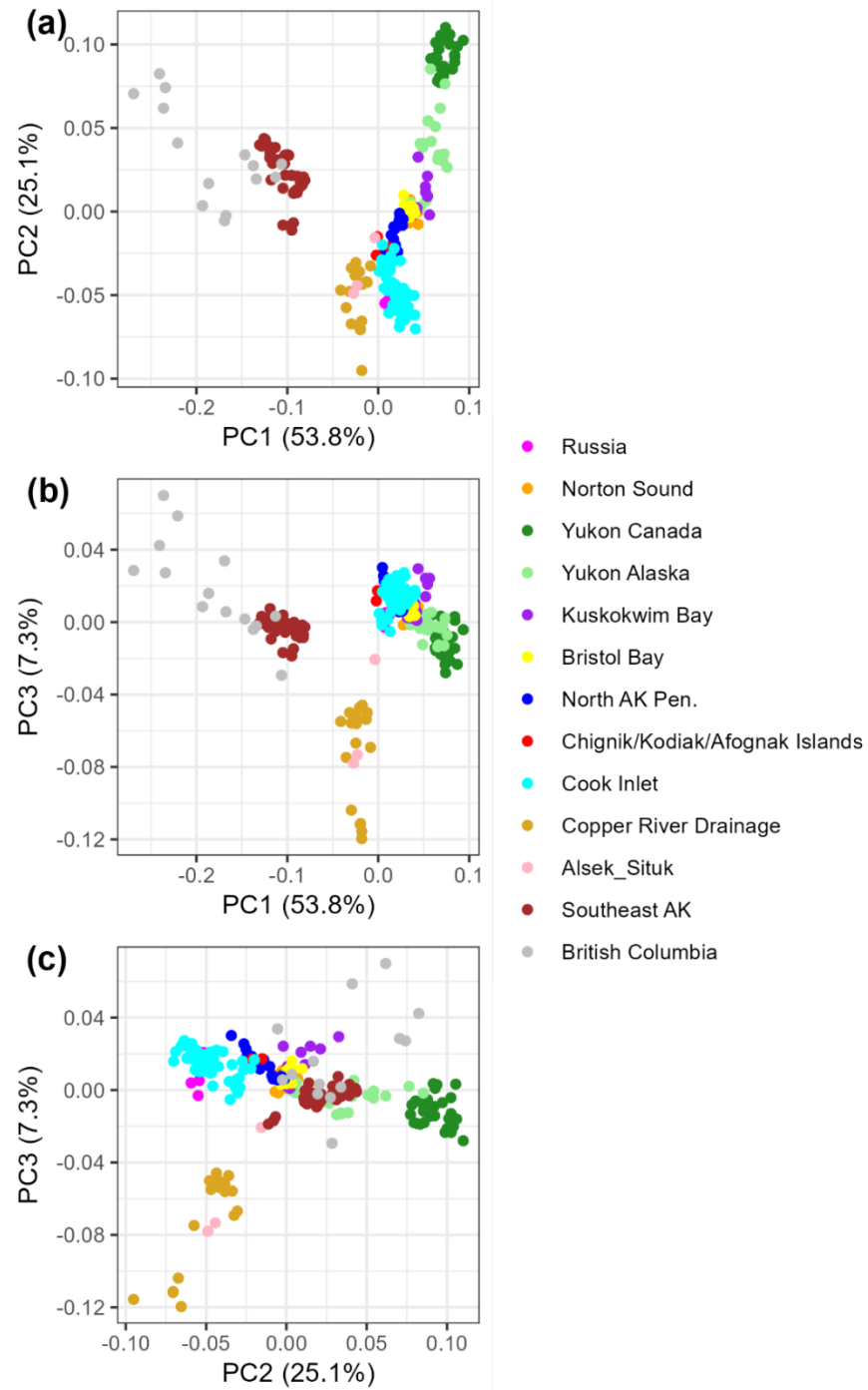


Figure 15. --PCA of all Chinook salmon populations genotyped with the 248 SNP panel. Panels a, b, and c display different PC axes.

3.2.4 Overview of genetic structure in the eastern lineage in Southeast Alaska and Northern British Columbia

Chinook salmon populations in Southeast Alaska and Northern British Columbia primarily inhabit large river systems with multiple tributaries, including the Chilkat, Taku, Stikine, Nass, and Skeena Rivers. Some populations inhabit shorter coastal rivers, with a particularly high concentration of these populations found in Behm Canal in southern Southeast Alaska. Genetic structure of populations in this region has been evaluated with allozymes (Gharrett et al. 1987, Guthrie and Wilmot 2004), microsatellites (Beacham et al. 2006a, Moran et al. 2013), SNPs (Templin et al. 2011), RAD sequencing (Hecht et al. 2015), and whole genome sequencing (Howe et al. 2024). Many of these studies did not include a sufficient number of populations to fully evaluate genetic structure in the region, but the studies generally provide support for the following primary genetic groups: (1) Chilkat River, (2) King Salmon River, (3) Taku and Stikine Rivers, (4) Southern Southeast Alaska/Behm Canal/Portland Inlet, (5) Nass and Skeena River. In general, population structure follows an isolation by distance pattern and is organized hierarchically by major river systems. Populations from the Nass and Skeena Rivers will not be discussed further, as they are located in Canada, and they are genetically differentiated from populations in Southeast Alaska (see Beacham et al. 2006a for more information on these populations).

Populations from the Chilkat River are highly genetically isolated from other populations in Southeast Alaska (average $F_{ST} = 0.08$ for comparisons between Chilkat and other Southeast Alaska populations). This genetic differentiation is somewhat expected given that the mouth of the Chilkat River is approximately 175 km from the mouth of the Taku River, which is the closest system that supports Chinook salmon. The King Salmon River is also highly isolated from other populations, both genetically and geographically. This population is separated from the closest Chinook salmon system (Taku River) by ~170 km, and displays high levels of genetic differentiation (average pairwise F_{ST} values between King Salmon River and other Southeast Alaska populations = 0.12), likely due to its small size (average escapement from 2014 to 2022 = 85) and genetic drift. Similarly, the population also contains lower genetic diversity than other populations in Southeast Alaska, which is likely a function of the small population size. See the “Genetic Diversity and Small Populations” section below for more discussion of the King Salmon River population. Notably, the King Salmon River is the only known population of Chinook salmon that spawns on an island in Southeast Alaska, although others may have existed previously (e.g., Wheeler Creek and Greens Creek also on Admiralty Island) (Guthrie and Wilmot 2004). It also may have earlier spawn timing than other populations in Southeast Alaska (McPherson and Clark 2001, Guthrie and Wilmot 2004), which could further increase genetic isolation.

Chinook salmon from the highly productive Taku and Stikine Rivers are largely genetically similar, with average pairwise F_{ST} values < 0.01 with some values as low as 0.004. The only exception is populations from the Lower Stikine River (Andrew Creek, Verrett River, Alpine

Creek), which are somewhat diverged from other populations in these two rivers (pairwise F_{ST} values ~ 0.02 between lower Stikine River populations and other populations in the Taku and Stikine Rivers). Populations from the lower Stikine River are also somewhat diverged from populations in the nearby Bradfield, Harding, and Unuk Rivers (average F_{ST} between lower Stikine populations and Bradfield, Harding, and Unuk River populations = 0.02). There are no lower river spawning populations in the Taku River, and most of the spawning in both the Taku and Stikine Rivers occurs well into Canada east of the coastal mountain range. The pattern of higher genetic differentiation in the lower portions of the rivers is inconsistent with general patterns for Chinook salmon but is likely due to the unique geologic history of this region. The spawning tributaries of the Taku and Stikine Rivers traverse the Stikine Plateau, a low-lying area that has likely experienced a large number of stream captures in the past (Guthrie and Wilmot 2004). Guthrie and Wilmot (2004) hypothesized that the genetic similarities among populations from these two rivers based on allozymes were due to these stream captures, and the SNP data analyzed here also supports this hypothesis. However, it is also important to note that coded wire tag data from wild fish indicate low levels of contemporary straying between the Taku and Stikine Rivers, suggesting that the low levels of genetic differentiation may be at least partially the result of contemporary gene flow (K. Shedd, ADF&G, personal communication).

Populations in southern Southeast Alaska largely inhabit short to medium sized rivers and display low levels of genetic differentiation (average pairwise F_{ST} between populations in this area = 0.008). This suggests that gene flow among these short and proximately located rivers is likely high enough to homogenize genetic structure. Stray rates have been shown to increase with decreasing migration distances (Keefer and Caudill 2014), which likely explains the low levels of genetic differentiation in this region compared to populations separated by similar distances in larger river systems such as the Copper or Kenai Rivers. Genetic differentiation between populations in southern Southeast Alaska and populations in Portland Inlet across the border in British Columbia is moderate; the average F_{ST} between the Kincolith River in Portland Inlet and populations in southern Southeast Alaska is 0.03. This level of genetic differentiation suggests that some straying may occur among Chinook salmon populations in southern Southeast Alaska and British Columbia, but these groups are largely genetically isolated.

3.2.5 Overview of genetic structure in the western lineage from the South Alaska Peninsula to the Alsek River

Populations of Chinook salmon occur relatively continuously across Western Alaska from the North Alaska Peninsula to the Seward Peninsula, but this is not the case for populations from the South Alaska Peninsula to the Alsek River. Instead, this region is characterized by two areas with a large number of Chinook salmon populations (Cook Inlet and the Copper River), separated by large swathes of coastline containing no or very few Chinook salmon populations. This isolation has likely led to the moderate to high genetic differentiation observed among regions.

In general, the region from the South Alaska Peninsula to the Alsek River is characterized by extremely rugged, glacial landscapes. For example, the North Alaska Peninsula contains more than 10 moderate gradient coastal rivers that can support Chinook salmon, while only three rivers support sizeable Chinook salmon populations across the much more mountainous South Alaska Peninsula. Additional large habitat breaks exist across Prince William Sound, where the rugged glacial landscape does not support any large Chinook salmon populations, and from the Copper River to the Yakutat Bay, which is also characterized by extremely rugged landscapes dominated by mountains and glaciers, with only a few small Chinook salmon populations.

Populations in this region are partitioned into three primary genetic groups based on the neighbor joining tree and PCA plots: (1) Chignik River, Karluk River, and Ayakulik River; (2) Cook Inlet; and (3) Copper and Alsek Rivers (Figure 13). In the PCA plot, the first axis differentiates Cook Inlet and South Peninsula populations from lower/middle Copper River, Alsek River populations, and Upper Copper River populations. The second PC of the PCA plot generally differentiates the South Alaska Peninsula populations from others in the western lineage, while the third PC differentiates populations within major genetic groups (e.g., middle from lower Copper River, Kenai River late from other Cook Inlet populations) (Figure 16). Notably, the Situk River appears genetically intermediate between genetic groups (discussed below). It is important to note that there is high structure within the Copper River, and Upper Copper River populations are some of the most genetically diverged populations found from the South Alaska Peninsula to the Alsek River.

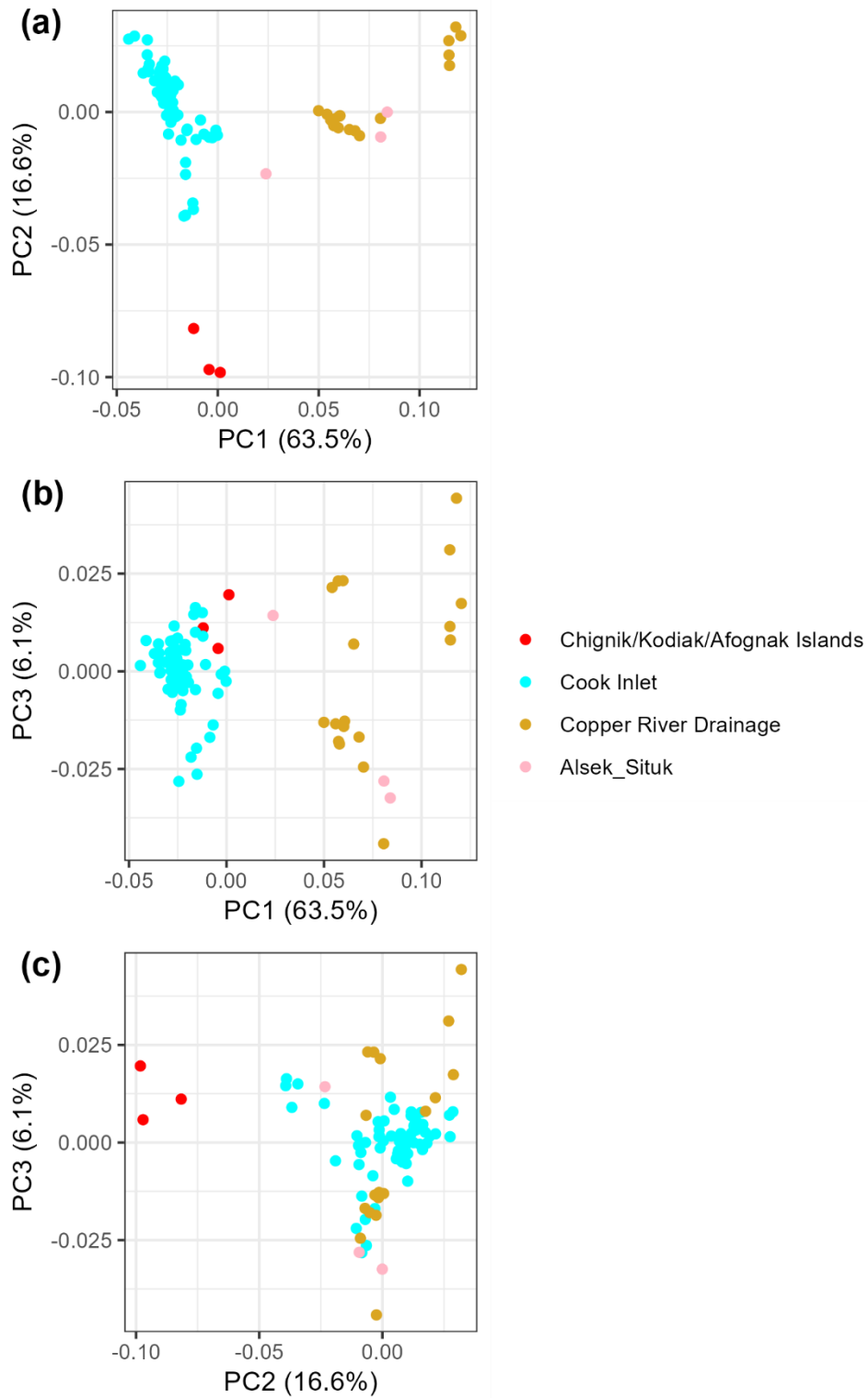


Figure 16. -- PCA of Chinook salmon populations from Chignik River to Alsek River genotyped with the 248 SNP panel. Panels a, b, and c display different PC axes.

Although populations on the South Alaska Peninsula are moderately diverged from proximate populations in Cook Inlet, there is no specific genetic break across this region; instead, the pattern of genetic structure is consistent with a signal of isolation by distance across the sparsely distributed populations from the Chignik River through Kodiak and into Cook Inlet. This signal is illustrated on PC2 of the PCA (Figure 16) and is also evident when examining pairwise F_{ST} values. For example, the F_{ST} between the Ayakulik River on Kodiak Island and the closest populations in Cook Inlet on the Southwestern Kenai Peninsula (e.g., Anchor River, Deep Creek) is 0.061, whereas F_{ST} s between the Ayakulik River and other populations in Cook Inlet are generally above 0.1. Genetic differentiation between the Chignik River and all other populations, including those found on Kodiak Island, is high. The lowest F_{ST} observed for any comparison including the Chignik River is 0.097 (comparison with the Karluk River), while F_{ST} s between Chignik River and other populations from the South Alaska Peninsula to the Alek River are generally between 0.1 and 0.15. This indicates that the Chignik River is relatively isolated and has experienced substantial genetic drift, which is unsurprising given its relatively small population size and the fact that the next closest population is over 250 km away. Pairwise F_{ST} values between populations from the Karluk and Ayakulik Rivers on Kodiak are ~ 0.03 , and these populations are separated by ~ 75 km. This level of differentiation is comparable to populations separated by similar distances on the North Alaska Peninsula.

Cook Inlet contains a large number of Chinook salmon populations distributed across multiple habitats, including major river systems and shorter coastal tributaries. Genetic structure across coastal tributaries and shorter rivers on the north and east side of Cook Inlet (e.g., Susitna and Yentna Rivers and Turnagain Arm) is relatively shallow and follows a general pattern of isolation by distance (Figure 13 and Figure 16). A genomic study (Dann et al. 2018) that genotyped thousands of loci in five populations from northern Cook Inlet also documented shallow population structure, as well as minimal evidence of putatively adaptive loci (highest F_{ST} across the $\sim 13,000$ loci was ~ 0.08). The only notable exceptions are populations from the Upper Susitna drainage, which are slightly diverged from the more coastal populations (Figure 13 and Figure 16). In contrast, there is much higher genetic structure on the Kenai Peninsula, especially in the Kenai and Kasilof Rivers. The Kenai and Kasilof Rivers each contain two spawning runs of Chinook salmon that are managed separately – an early run that enters the river in May and June and spawns in tributaries feeding into the mainstem in July, and a later run that enters the river from June through August and spawns in the mainstem river in August (Burger et al. 1985). These drainages each contain large lakes, and it is hypothesized that the mainstem populations spawn later because the water feeding the mainstem from the lakes is warmer than tributaries in the fall and winter, leading to more rapid development of juveniles (Burger et al. 1985). The early and late run populations in these systems are genetically distinct, with proximate early and late run populations separated by tens of km displaying F_{ST} values > 0.04 . A small number of tributaries also contain lakes, and fish in these tributaries also spawn later than those in tributaries without lakes (Burger et al. 1985). The hypothesized influence of lakes on spawn timing and genetic structure is best exemplified by the Russian River. This drainage

contains two large lakes, has an estimated peak spawn date similar to mainstem populations (Burger et al. 1985), and is highly genetically diverged from early run populations ($F_{ST} > 0.08$ for multiple comparisons with early run populations). Populations from coastal tributaries on the west side of the Kenai Peninsula (e.g., Ninilchik River) and small tributaries near the mouths of the Kenai and Kasilof Rivers (e.g., Slikok Creek) are diverged from all others in Cook Inlet, with F_{ST} s averaging 0.057. Notably, this average F_{ST} is only slightly lower than the average F_{ST} across comparisons that include populations from the western Kenai Peninsula and Kodiak Island, which is 0.061.

Chinook populations in the Copper River are highly diverged from those in Cook Inlet, with F_{ST} values near or above 0.1 for nearly all pairwise comparisons between Copper River and Cook Inlet populations. Additionally, Copper River populations form a discrete and highly diverged branch in the neighbor joining tree, although the branch also includes the Alsek River (Figure 13). The Copper River is a unique and isolated habitat for Chinook salmon. The closest large population to the north is approximately 500 km away (Anchor River) while the closest large population to the south is approximately 350 km away (Situk River). The Copper River and its tributaries drain two unique environments: (1) a rugged, mountainous, and forested region in the lower river that is high gradient, turbid, and largely fed by glacial meltwater, and (2) a lower gradient portion in the middle and upper river and its tributaries (including the Gulkana River) that drains large areas of low-lying tundra. Upriver populations generally enter the river earlier, but it is unclear whether differences in spawn timing exist among populations (Wuttig and Evenson 2001, Barclay et al. 2022). Populations in the Copper River are separated into three primary genetic groups that generally correspond to these habitats: (1) lower Copper River, (2) middle Copper River (Gulkana River), and (3) upper Copper River (Seeb et al. 2009, Ackerman et al. 2013). Upper Copper River populations are highly genetically distinct, displaying F_{ST} s between 0.05 and 0.11 in comparisons with other populations in the Copper River and near or above 0.15 in comparisons with populations from Cook Inlet. Additional genetic heterogeneity exists within this group. For example, the average F_{ST} value between Sinona Creek (upper Copper River) and the other upriver populations is 0.04. Three populations from the Gulkana River, which joins the Copper River mainstem near the middle of the river, are genetically similar (average pairwise $F_{ST} \sim 0.01$), but differ from populations in other reaches of the river. Specifically, F_{ST} values between the Gulkana River and the lower river populations are approximately ~ 0.04 , while F_{ST} values between the Gulkana River populations and the upper river populations are ~ 0.08 . The higher genetic divergence of middle and upper river populations is consistent with many studies in salmon that document higher differentiation in upriver populations (Olsen et al. 2008). Structure in populations from the lower river is highly variable. Populations from the Tonsina River and most populations from the Tazlina and Klutina Rivers are genetically similar. Contrastingly, St. Anne Creek in the Klutina Drainage, Mendeltna Creek in the Tazlina Drainage, and the Tebay River (tributary of the Chitina River) are more genetically unique, with F_{ST} values > 0.03 for nearly all comparisons. Ackerman et al. (2013) conducted a landscape genetic analysis of Chinook and sockeye salmon populations in the

Copper River and observed generally high heterogeneity across both species that corresponded to putative environmental breaks. Ackerman et al. (2013) also identified evidence of local adaptation at an MHC locus (*Ots_MHC2*), which displayed an F_{ST} of > 0.4 across the populations in the study. Previous studies and the data presented here highlight the fact that the unique and highly variable habitats in the Copper River have promoted local adaptation and led to a genetically diverse portfolio of populations.

Populations from the Situk and Alsek Rivers are highly, geographically isolated from other sizeable Chinook salmon populations. The closest sizeable population to the Situk is in the Copper River approximately 350 km to the north, while the closest population to the Alsek is in Southeast Alaska approximately 350 km to the south. The Situk River is a short (~30 km) river with a small lagoon that drains a low lying coastal plain near Yakutat, while the Alsek is a much longer (~300 km) river that extends through extremely rugged mountains containing a large number of glaciers. The landscape surrounding the Alsek and Situk Rivers is highly dynamic, and stream captures in this region have likely been common over geological time. Evidence of the dynamic nature of this region is common in recorded history. For example, proglacial hydrological reorganization is occurring in an area near the top of the Alsek watershed that could dramatically change the characteristics of this river (Main et al. 2023). Additionally, the Situk River has altered course several times due to multiple, geologically-recent ice damming events in Russell Fjord that temporarily created Russell Lake and occasionally redirected outflow into the Situk and Old Situk Rivers (Gubernick and Paustian 2007).

We would expect patterns of genetic structure for the Alsek and Situk to look similar to isolated populations on the South Alaska Peninsula if they had existed since the last glacial maximum. Specifically, we would expect the populations to cluster with their nearest neighboring population within the lineage (the Copper River), but to be significantly differentiated from Copper River populations. We would also expect the Situk and Alsek to be relatively genetically similar to each other, but not identical, given that spawning habitats in the two rivers are separated by hundreds of km. However, despite the proximity of their river mouths, the Alsek and Situk River stocks are not genetically similar. The only commonality between the two rivers is that they are highly isolated from populations in Southeast Alaska, and are clearly part of the western lineage.

The Situk River clusters between genetic groups in an PCA (Figure 16) and on its own relatively long branch in a neighbor joining tree (Figure 13). Pairwise F_{ST} values for comparisons that include the Situk are moderate and remarkably similar across a large geographic area. For example, pairwise F_{ST} values between the Situk and populations in coastal western Alaska (Norton Sound, the lower Yukon and Kuskokwim Rivers, and the Nushagak River), Cook Inlet, and the lower Copper River generally range from 0.045 to 0.065. Notably, the Situk River is the only known system in Alaska composed of primarily ocean type fish, which spend less than a year rearing in freshwater (Kissner 1986, Thedinga et al. 1998). A large analysis of stray rates of ocean and stream type Chinook salmon in the Columbia River revealed that stray rates are

consistently higher (and often many times higher) for ocean type compared to stream type Chinook salmon (Westley et al. 2013). While it is thought that very few populations contain a large number of ocean type Chinook salmon, it is possible that biases in aging could underestimate their prevalence (Thedinga et al. 1998). We therefore hypothesize that the Situk River was colonized by ocean-type Chinook salmon from multiple locations, but the similar values of genetic differentiation between the Situk and other populations across a large range preclude speculation about the origin(s) of colonization. This hypothesis is further supported by slightly elevated estimates of allelic richness observed in the Situk (largest values of A_R of any populations from Chignik to Cape Fairweather), providing additional evidence that it was founded by a mixture of populations. Additionally, genetic differentiation between this population and other populations throughout the Gulf of Alaska was moderate but not especially high (e.g., compared to Chignik River, which has a similar population size and a similar degree of isolation). We hypothesize based on genetic data and information on the dynamic nature of the Yakutat area, that the population was recolonized more recently than the end of the last glacial maximum.

Chinook salmon from the Alsek River are genetically similar to populations in the lower Copper River, with F_{ST} values between 0.02 and 0.03 for multiple comparisons. These F_{ST} values are extremely low given the geographic distances between these populations. For example, these F_{ST} s are lower than the F_{ST} between two populations separated by ~40 km that are both tributaries of the Chitina River ($F_{ST} = 0.046$ between Gilahina River and Tebay River). If the Alsek and lower Copper River populations had been colonized by a similar founding population after the last glacial maximum, the F_{ST} values would undoubtedly be much higher due to ~10,000 years of genetic drift. The low F_{ST} values therefore lead us to hypothesize that the Alsek populations were colonized by strays from the lower Copper River much more recently. The Alsek is an extremely dynamic environment that is continually being shaped by glaciers as they move, retreat, and advance. It is therefore likely that the main river may have been blocked recently, or that for some other reason Chinook populations went extinct, then were recolonized. Although we are not able to effectively date the timing of colonization, we hypothesize that the populations have only been isolated for up to a few thousand years given low values of genetic differentiation. Metrics of genetic diversity (heterozygosity, allelic richness) were not depressed in the Alsek, suggesting there is no strong genetic evidence of a founder event. This suggests that the Alsek was colonized by a relatively large number of fish or by multiple waves of fish. It is important to note that the hypotheses presented above to explain why the genetic structure of the Alsek and Situk does not match expected patterns of isolation by distance are speculative, and more research needs to be conducted to test them further. However, we determined that it was important to provide hypotheses about their history based on available data to inform delineation of ESUs.

3.3 Genetic Diversity and Small Populations

The most conspicuous differences in genetic diversity (H_O and A_R) exist between populations from the eastern versus the western lineage, with western lineage populations displaying lower diversity (average H_O of eastern lineage populations = 0.29 and average of western lineage populations = 0.21; average A_R s are 1.88 and 1.69, respectively). This pattern was discussed above and is likely a function of the demographic history of the two lineages. Lower diversity in populations that are higher upriver is common across the dataset and has also been observed in other systems and salmon species (Olsen et al. 2008). This pattern is especially prevalent in populations from the Upper Yukon and Upper Copper Rivers.

Lower genetic diversity is common in isolated and small populations (Amos and Harwood 1998), and this pattern is present in our dataset. For example, H_O in Chilkat River populations, which are isolated from other populations in Southeast Alaska, averages 0.25 compared to an average of 0.29 for other populations in Southeast Alaska. Additionally, H_O in the King Salmon River, which is a small population on Admiralty Island in northern Southeast Alaska, was 0.24 compared to an average of 0.29 for other Southeast Alaska populations. Similar variation in A_R was observed for these populations. Notably, we did not observe any evidence of reduced diversity in the isolated populations from the Alek, Situk, or Chignik Rivers (values of H_O were within 0.01 of the nearest large populations).

Four populations in our dataset appear to be substantially genetically isolated from all other populations, displaying minimum pairwise F_{ST} values of 0.04 or more (Chignik, Russian, Situk, and King Salmon Rivers). The genetic uniqueness of the Russian River is notable given its proximity to other populations; this pattern may be due to isolation by adaptation associated with later run timing and/or other life history characteristics such as adaptation to migrating over a waterfall (Burger et al. 1985). Despite this genetic isolation, there is limited evidence of reduced diversity in the population. The Situk River is also genetically unique (lowest pairwise F_{ST} = 0.04), but does not show evidence of reduced diversity (in fact, it displays the highest A_R of any population in western lineage, likely due to mixed origins). This population is likely unique due to its geographic isolation and ocean type life history. While the Russian and Situk Rivers are genetically unique, the similar genetic diversity to other populations indicates that concerns regarding reductions in genetic diversity of these populations due to inbreeding are likely minimal.

The minimum pairwise F_{ST} value for the Chignik River population was 0.09 and the minimum for the King Salmon River population was 0.10. Chignik River is a relatively small population (average abundance from 2019-2023 = 851) that is also highly isolated. However, genetic diversity in this population is not depressed, suggesting that genetic concerns due to inbreeding are likely minimal. The King Salmon River supports a small population with an average abundance of 201 from 2019 to 2023. This population is highly genetically isolated, and displays the greatest reduction in H_O compared to surrounding populations in our dataset. However, A_R

is only slightly lower than surrounding populations. While this suggests that the King Salmon River may contain adequate diversity for population persistence, the risk of inbreeding cannot be sufficiently quantified without genome-wide data (Kardos et al. 2015). Small populations have been shown to be viable across large time periods in many animals, including salmon (McElhany et al. 2000), and may act as metapopulations, often going through periods of low abundance and even extinction followed by recolonization (Harrison 2008). However, available genetic data suggest that this extinction/recolonization cycle either has not occurred for the King Salmon River or has not occurred for many generations.

3.4 Summary of Genetic Data Focused on GOA Populations

Populations of Chinook salmon from the South Alaska Peninsula to the border with British Columbia are distributed unevenly, with large habitat breaks corresponding to rugged, glacial landscape features. Additionally, a lineage break corresponding to colonization from different glacial refugia occurs between the Alsek River near Yakutat and the Chilkat River near Haines. Populations from the Chilkat River and south belong to the eastern lineage, and populations from the Alsek and north belong to the western lineage. Across the Gulf of Alaska, large concentrations of populations occur in Cook Inlet, the Copper River, and Southeast Alaska, while vast stretches of coastline have few or no populations. This spatial isolation has resulted in moderate to high genetic differentiation among regions. Based on genetic analyses, populations across the Gulf of Alaska cluster into four primary groups: (1) Chignik, Karluk, and Ayakulik Rivers; (2) Cook Inlet; (3) Copper and Alsek Rivers; and (4) Southeast Alaska. Overall, genetic differentiation follows an isolation-by-distance pattern, with isolated systems like the Chignik River exhibiting relatively high pairwise F_{ST} values, and geographically closer populations, such as those in the Susitna drainage in Cook Inlet, showing lower levels of differentiation. Genetic differentiation within major groups was high in some situations, such as within the Copper River and between the west and east sides of Cook Inlet.

Chinook salmon populations from the eastern versus western lineages display differences in genetic diversity, with eastern lineage populations averaging higher heterozygosity ($H_O = 0.29$) and allelic richness ($A_R = 1.88$) than western lineage populations ($H_O = 0.21$; $A_R = 1.69$), a pattern influenced by their distinct demographic histories. Four populations in the dataset (Chignik, Russian, Situk, and King Salmon Rivers) were genetically isolated, with minimum pairwise F_{ST} values of 0.04 or greater. However, despite their distinctiveness, these populations generally maintain levels of genetic diversity that are comparable (but sometimes slightly lower) than other proximate populations, suggesting that these isolated, small populations may preserve sufficient genetic diversity for long-term persistence.

4 ESU CONFIGURATION

Three ESUs were delineated for GOA Chinook salmon: (1) Southeast Gulf of Alaska (populations from the southern border of Alaska to Cape Fairweather), (2) Central Gulf of Alaska

(populations from Cape Fairweather through Prince William Sound), and (3) Northwest Gulf of Alaska (populations from the Kenai Peninsula through Chignik) (Figure 1).

Each ESU includes multiple spawning populations of Chinook salmon and extends over a considerable geographic area. These delineations are consistent with the NMFS' species definition paper, "Definition of a species under the Endangered Species Act: application to Pacific salmon", which states that, in general, "ESUs should correspond to more comprehensive units unless there is clear evidence that evolutionarily important differences exist between smaller population segments" (Waples 1991a). However, it should be noted that considerable diversity in genetic or life-history traits or habitat features exists within most ESUs, and maintaining this diversity is critical to their overall health.

There is no specific definition of what constitutes an ESU, but guidance from (Waples 1991a), NMFS' ESU Policy (56 FR 58612), and previous ESA status review reports is useful for ensuring that ESUs are defined as consistently as possible. The three ESUs were delineated primarily based on genetic differentiation, but habitat variation and discontinuity, abundance trends, and ocean distributions were also considered. The SRT determined that these three ESUs represent important components of the evolutionary legacy of the species and should not be combined. The SRT also acknowledged that each ESU contains substantial genetic variation.

First, the SRT considered whether GOA Chinook salmon should be a single ESU. The SRT decided that one ESU is not appropriate, because GOA Chinook salmon span a major lineage break at Cape Fairweather (discussed above). Populations found east and west of this split are highly genetically diverged, and there is little evidence of secondary contact/introgression. Delineation of ESUs that represent distinct divergent genetic lineages is common in multiple salmon species, including Chinook salmon (Myers et al. 1998). Additionally, populations south of Cape Fairweather have different ocean distributions than populations north of this point.

The SRT next considered whether to split populations east and west of Cape Fairweather into additional ESUs. This decision was non-trivial, as there are multiple genetically differentiated populations and/or groups of populations both east and west of Cape Fairweather. Examination of the genetic data identified seven major groups across the GOA: South Alaska Peninsula (populations from Chignik and Kodiak), Northern Cook Inlet (populations from the north shore of Cook Inlet through Turnagain Arm), Southern Cook Inlet (populations from the Kenai Peninsula, including early and late runs in the Kenai River), Upper Copper River, Middle/Lower Copper River/Alsek River/Situk River, Chilkat River, and Central/Southern Southeast Alaska (populations south of the Chilkat River). Additionally, there are two populations that are not genetically similar to any other populations in the dataset (King Salmon River in Central/Southern Southeast Alaska and Chignik River from the South Alaska Peninsula). These two populations are sufficiently genetically diverged from all other populations to be considered as potential ESUs, but the SRT concluded that these populations did not represent evolutionarily unique components of the species because the divergence is likely due to drift caused by small population size rather than adaptive differences.

The SRT determined that the seven genetic groups outlined above did not represent distinct ESUs; rather, three ESUs encapsulate the primary evolutionarily significant groups of populations across the GOA. In addition to separating populations at Cape Fairweather (discussed above), the SRT separated populations west of Cape Fairweather into two ESUs primarily based on the high level of genetic differentiation between populations from the Copper River and Cook Inlet. Copper River, and especially Upper Copper River, populations are highly genetically distinct, inhabit diverse and heterogeneous habitats, and harbor substantial adaptive diversity. Populations from the Alsek and Situk Rivers were included in the ESU containing Copper River populations because they are most geographically proximate to the Copper River, and the Alsek River is genetically similar to Copper River populations. Next, there is a major distributional break associated with a lack of habitat for Chinook salmon between the Copper River and Kenai Peninsula, providing biogeographic support for grouping populations from east and west of this break into different ESUs. Finally, populations from the Northwest GOA and Central GOA have different abundance trends, with nearly all populations from the Northwest GOA experiencing recent declines, while populations from the Central GOA have not experienced similar declines. These trends suggest that different ecological factors may influence population dynamics in these two regions and provides further support for separating them into distinct ESUs. Although genetic differences exist among populations from the Kenai Peninsula, Cook Inlet, and the South Alaska Peninsula, these differences are generally smaller than those found between Copper River populations and populations to the west of the Copper River. Additionally, distributional breaks in this region are generally smaller than the break between the Copper River and Kenai Peninsula populations, with the exception of the habitat break between Chignik and Kodiak. Together, these factors prompted us to place populations east and west of the Kenai Peninsula into different ESUs, but not to split populations west of the Kenai Peninsula into additional ESUs.

Genetic differences among these three ESUs are similar to those found among ESUs for coastal Chinook salmon in Washington, Oregon, and California (Myers et al. 1998, OC and SONCC Status Review Team 2024). Additionally, the geographic scope of these ESUs is similar to those ESUs (Figure 5). The descriptions below briefly summarize some of the notable types of diversity within each ESU, and this diversity is considered in the section evaluating risk to the ESUs as a whole.

4.1 Southeast Gulf of Alaska ESU

The Southeast Gulf of Alaska (SEGOA) ESU includes populations from the Chilkat River in northern Southeast Alaska to the Keta and Blossom Rivers entering Behm Canal in southern Southeast Alaska near the northern coastal border of British Columbia (Figure 2). Abundance trends of populations in this ESU are variable, with some populations decreasing in abundance recently and others displaying relative stable abundance trends. Populations in SEGOA are part of the eastern genetic lineage and are highly genetically diverged from the closest populations to the north (Alsek River), which are part of the western lineage. Populations from SEGOA and

the Alsek River are also separated by a large geographic distance (350 km waterway distance). Populations at the southern end of this ESU (Keta and Blossom Rivers) are separated from the nearest populations to the south in Portland Inlet across the U.S. border in British Columbia by approximately 150 km. Southern Southeast Alaska populations are somewhat genetically similar to a small number of populations in Portland Inlet but substantially diverged from the more productive populations in the Nass and Skeena Rivers to the south. Fish from the Taku and Stikine Rivers are classified as “outside rearing,” primarily rear in the GOA and Bering Sea, and are not caught frequently in inside waters as immatures. Contrastingly, other stocks in SEGOA are classified as “inside rearing” and a portion of them rear in Southeast Alaska inside waters and are caught as immatures in this region; some also use the GOA and Bering Sea as rearing habitat.

This ESU contains four primary genetic groups: Chilkat River, King Salmon River, Taku and Stikine Rivers, and the short, coastal streams in southern Southeast Alaska. The Chilkat River drains a dynamic glacial floodplain in northern Lynn Canal and is highly genetically diverged from other populations in Southeast Alaska. King Salmon River is a small population on Admiralty Island that displays high genetic divergence with relatively proximate populations in the Taku and Stikine Rivers, which are ~200 ocean km away. This population also displays some signals of reduced genetic diversity consistent with small population size. The available genetic data suggest that this population has been stable at a small size for many generations and does not receive substantial gene flow from neighboring populations. There is limited evidence that this population contains unique life history variation compared to surrounding populations, although there are some anecdotal reports of differences in spawn timing between the King Salmon River population and others in Southeast Alaska.

The largest Chinook salmon populations in this ESU are found in the Taku and Stikine Rivers. These rivers traverse the coastal mountain range and most of the spawning populations are found in upland plateaus. The upper Taku and Stikine watersheds are adjacent and populations in this region are genetically similar, likely because of historical stream capture (and potentially some ongoing gene flow). There are a few populations in the lower Stikine (e.g., Andrew Creek) that are somewhat genetically distinct from populations farther upriver. It is likely that upriver stream capture events did not significantly influence the genetic structure of these populations. Populations that inhabit shorter coastal streams in southern Southeast Alaska are genetically similar to each other but distinct from populations to the north.

4.2 Central Gulf of Alaska ESU

The Central Gulf of Alaska (CGOA) ESU includes populations from the Copper, Situk, and Alsek Rivers (Figure 3). It is hypothesized that populations from this ESU and the NWGOA ESU occupy somewhat similar areas of the ocean (i.e., the Gulf of Alaska and potentially eastern Bering Sea), although CGOA fish are encountered less frequently in fisheries, even after accounting for differences in run sizes between the ESUs. This suggests that fish from these two ESUs may rear

in slightly different areas, although data on the oceanic distributions of populations in this ESU is extremely scarce. Abundances of populations in this region increased in the late 1990s and early 2000s and have since decreased and stabilized at levels similar to the late 1980s. The Copper River is the primary producer of Chinook salmon in this ESU, with an average run size of 47,451 from 2019-2023 compared to an average run of 4,822 for the Alsek River and 1,005 for the Situk River. Populations from the Copper River are highly genetically differentiated from Cook Inlet populations to the north and populations from Southeast Alaska to the south. Levels of genetic differentiation between Copper River populations and populations in ESUs to the north and south are similar or higher than genetic differentiation between ESUs established for Chinook salmon in coastal Washington, Oregon, and California. Copper River populations are also isolated by major habitat breaks. To the north, populations from the Copper River are separated from the closest populations on the Kenai Peninsula (~500 km away) by Prince William Sound, a rugged mountainous region that does not contain any known self-sustaining Chinook salmon populations. To the south, Copper River populations are separated from the Situk and Alsek Rivers by an area of rugged coastline containing glacially influenced rivers that do not support sizeable populations of Chinook salmon.

There is substantial habitat variation in the Copper River which has likely led to the high levels of genetic heterogeneity and life history variation observed among populations in this system. Populations from the upper Copper River enter the river first, followed by populations from the middle and then lower Copper River. These fish spawn in vastly different habitats ranging from recently deglaciated rivers in rugged mountainous terrain to upland highlands draining tundra. There are three major genetic groups in the Copper River: Upper Copper River, Middle Copper River (Gulkana River), and Lower Copper River. Genetic heterogeneity also exists within the upper and lower river groups. Genetic differentiation is generally high within the Copper River compared to other populations of Chinook salmon across the Gulf of Alaska suggesting that habitat heterogeneity and potentially a patchy distribution of suitable spawning habitats has led to high levels of reproductive isolation. Additionally, data from a locus that is putatively under selection (MHC) suggests that there is substantial fine-scale adaptive variation among Copper River populations.

The Situk and Alsek are the only two rivers monitored for Chinook escapement by ADF&G in an 800 km region between the Copper River to the north and the Chilkat River in Southeast Alaska. Both of these populations appear to be recently colonized based on genetic data, which is unsurprising given the dynamic nature of this landscape characterized by shifting glaciers. The Situk River appears genetically intermediate between populations in the western genetic lineage and also displays elevated allelic richness, indicating that it is potentially a mixture of multiple founding populations. To our knowledge, the Situk is also the only population composed primarily of ocean type Chinook salmon in Alaska. The Alsek River is genetically similar to lower Copper River populations, indicating that it may have been recently colonized by strays from these populations. The Alsek River is extremely dynamic; it is likely that salmon populations in this river may have gone through multiple extinctions and recolonizations since

the last glacial maximum. The shallow structure and genetic similarity to Copper River populations that is observed in Chinook salmon is also present in sockeye salmon from the Alsek. There is a major habitat break for Chinook salmon to the south of the Alsek River near Cape Fairweather, with ~350 km separating it from the next closest Chinook salmon populations in the Chilkat and Taku Rivers. This also spans the break between the eastern and western genetic lineage for Chinook salmon. Notably, even though the Situk and Alsek Rivers are nearly as close to populations in the eastern lineage as they are to populations in the western lineage, there is no evidence of colonization of these populations by individuals from the eastern lineage.

The SRT determined that grouping the Alsek River populations in the same ESU as the Copper River populations was appropriate given their genetic similarity and the fact that no conspicuous life history differences exist between lower Copper River and Alsek River populations. Contrastingly, the Situk River is unique both in terms of life history (ocean type) and genetics (intermediate between many populations). However, the SRT did not conclude that it constitutes an evolutionarily unique population because it may have been recently recolonized from strays from many populations, may undergo periodic extinction and recolonization events, and/or may be a sink for strays that prevents it from evolving independently. The team therefore chose to group it in an ESU with the most geographically proximate populations.

4.3 Northwest Gulf of Alaska ESU

The Northwest Gulf of Alaska (NWGOA) ESU includes populations from the Chignik River on the South Alaska Peninsula, Kodiak Island (Ayakulik and Karluk Rivers), and Cook Inlet (includes the Susitna drainage and populations on the Kenai Peninsula) (Figure 4). Populations in the NWGOA ESU display the most consistent and dramatic declines in abundance across the GOA. Nearly all populations with available run size data have undergone large declines since the mid-2000s. Populations from this ESU rear in the Gulf of Alaska and the eastern Bering Sea based on intermittent tag recoveries and genetic stock identification data from fish encountered in commercial fisheries. There is considerable genetic diversity within this ESU corresponding to three major genetic groups: South Alaska Peninsula (includes Chignik River and populations from Kodiak), northern Cook Inlet (includes coastal populations from roughly Tyonek through Turnagain Arm as well as populations in the Susitna drainage), and the Kenai Peninsula (includes Kenai and Kasilof Rivers and coastal tributaries). It is also important to note that there is additional structure within the Kenai Peninsula group, especially in the Kenai and Kasilof Rivers, where late run mainstem populations are genetically diverged from populations that spawn in tributaries flowing into these rivers; these late run populations can spawn 4-6 weeks later, on average, than other populations in this system.

The NWGOA ESU boundaries also correspond to habitat breaks. Populations from the North Alaska Peninsula beyond the north boundary of the ESU inhabit relatively low gradient coastal

tributaries that drain flat tundra areas, whereas the South Alaska Peninsula is much more rugged and mountainous. Populations in Cook Inlet at the other margin of the ESU are separated from populations in the Copper River by Prince William Sound, which contains steep mountains and glaciers that do not provide suitable habitat for self-sustaining populations of Chinook salmon.

There is also habitat, genetic, and life history diversity within this ESU. Populations on the South Alaska Peninsula inhabit rugged coastal rivers that drain mountainous regions and contain large lakes. Populations in northern Cook Inlet primarily inhabit low-lying coastal streams or tributaries of the Susitna River, which drains a large valley. Genetic differentiation is low among northern Cook Inlet populations; this is likely due to relatively low habitat heterogeneity and potentially high rates of straying among populations with short migration distances that inhabit similar habitats. Habitat heterogeneity and genetic differentiation is much higher among populations from south of Turnagain Arm that inhabit the Kenai and Kasilof Rivers and other coastal tributaries. The Kenai and Kasilof drainages contain a large number of glaciers and the Kenai River extends into the Kenai Mountains. This heterogeneous habitat facilitates genetic differentiation, life history diversity, and notably early-run and late-run populations. The Kenai River late run has historically been one of the most productive populations in Cook Inlet and is managed separately from the early run, which is less productive. Populations on the western Kenai Peninsula inhabit similar habitats to coastal streams in northern Cook Inlet, but they are genetically different from those tributaries.

Although genetic differences exist among populations from the Kenai Peninsula, Cook Inlet, and the South Alaska Peninsula, these differences are generally smaller than those found between ESUs. Additionally, distributional breaks in this region are generally smaller than the break between other ESUs, with the exception of the habitat break between Chignik and Kodiak. Furthermore, there is no evidence that different genetic subgroupings within the Northwest GOA ESU contain unique life history diversity that is important to maintaining the evolutionary legacy of the species. Together, these factors prompted us to not split populations in the NWGOA ESU into further ESUs.

5 HATCHERY PROPAGATION

The effects of hatchery programs on the status of an ESU depend on which of the four key attributes: abundance, productivity, spatial structure, and diversity are currently limiting the ESU, as well as how the presence of hatchery fish within the ESU influences each of these attributes (NMFS 2005).

Artificial propagation is an important consideration in ESA evaluations of anadromous Pacific salmonids for several reasons. First, although natural fish are the primary focus of ESU determinations, the potential effects of artificial propagation on natural populations must also be assessed. For example, stock transfers could alter the genetic basis or phenotypic expression

of life-history characteristics in a natural population, making it appear either less or more distinctive than it was historically.

Second, artificial propagation poses several risks to natural populations that may influence their likelihood of extinction or endangerment. These risks are discussed below in the "Genetic and ecological interactions between hatchery and wild salmon in the Gulf of Alaska" section of this report.

Finally, if any natural populations are listed under the ESA, it will be necessary to determine the ESA status of all associated hatchery populations. This determination would be made following a proposed listing, and is not considered further in this document.

The remainder of this section provides an overview of the nature and scope of artificial propagation activities for GOA Chinook salmon.

5.1 Alaska Chinook Salmon Artificial Propagation within Proposed GOA ESUs

The hatchery programs for salmon in Alaska have a long and varied history and focus mainly on salmon species other than Chinook salmon. In fact, long before the first salmon hatchery was developed by Euro-Americans, there is evidence that Alaska Natives manipulated salmon by burying eggs and moving adult salmon to unpopulated streams to spread the resource (Roppel 1982).

Some of the first attempts at hatchery propagation of Chinook salmon in Alaska began in the 1920s, but did not gain consistent traction until the early 1970s. The initial efforts were fraught with challenges, including disease outbreaks and logistical difficulties in transporting eggs and fry over long distances. Early hatchery projects included those at Ketchikan Territorial Hatchery and the introduction of eggs from the Columbia River and other sources in Oregon and Washington. These early attempts faced numerous setbacks, including a significant outbreak of infectious hematopoietic necrosis virus (IHNV), and were abandoned as broodstock in the early 1970s (Templin 2001).

The modern era of hatchery development began in earnest with the establishment of the Fisheries Rehabilitation, Enhancement, and Development (FRED) Division by ADF&G in 1971. This initiative was a response to historically low salmon populations and aimed to supplement natural production without replacing it. The state legislature's approval of the FRED Division marked a significant commitment to enhancing fishery resources through scientific and controlled means (Clark et al. 2006, Evenson et al. 2018).

The legislative framework that supports hatchery operations in Alaska is designed to supplement commercial, sport, and subsistence fisheries with enhanced salmon while also prioritizing the protection of wild salmon stocks. This framework includes a series of policies,

regulations, and management practices established by ADF&G, the Alaska Board of Fisheries, and other relevant authorities (ENRI 2001, Evenson et al. 2018, Wilson 2023).

5.2 Key Hatchery Policies and Regulations

1. The *Genetic Policy*, initially formulated in 1975 and revised in 1985 (Davis et al. 1985), aims to maintain the genetic integrity of wild salmon stocks (Evenson et al. 2018). Key provisions include the following:
 - Restrictions on the importation of salmonids from outside the state and the transport of stocks between major geographic areas within the state.
 - Requirements for using local broodstock and maintaining genetic diversity by using large numbers of broodstock collected across the entire run.
 - Identification and protection of significant and unique wild stocks and the establishment of wild stock sanctuaries.
2. The *Fish Health and Disease Control Policy* (5 AAC 41.080) is designed to prevent the spread of infectious diseases in fish and shellfish (Evenson et al. 2018). It mandates rigorous health protocols for hatcheries, including the following:
 - Disinfection of salmon eggs transported between watersheds.
 - Regular inspections of hatchery facilities.
 - Detailed disease reporting and isolation measures to control disease spread.
3. The *Sustainable Salmon Fisheries Policy* (5 AAC 39.222), adopted in 2000, mandates the application of precautionary approaches to manage salmon stocks, fisheries, artificial propagation, and essential habitats conservatively (Evenson et al. 2018). It emphasizes
 - Protection of wild salmon stocks as a priority.
 - Establishment of scientifically based escapement goals to ensure sustainable harvests.
 - Assessment of the effects and interactions of introduced or enhanced salmon stocks on wild stocks.
4. The *Mixed Stock Salmon Fishery Policy* (5 AAC 39.220) prioritizes the conservation of wild stocks in the management of mixed-stock fisheries (Evenson et al. 2018). It requires fishery managers to consider the interactions of wild and hatchery salmon stocks when reviewing hatchery management plans and permits.

Other key legislative acts included the 1974 authorization allowing Private Non-Profit (PNP) corporations to operate hatcheries and the 1988 legislation enabling these corporations to manage state-owned hatcheries. These laws aimed to relieve the state of financial burdens while ensuring that hatchery operations did not adversely affect wild salmon populations (ENRI 2001, Evenson et al. 2018, Wilson 2023).

All PNP hatcheries operate under four documents: PNP hatchery permit, basic management plan (BMP), fish transport permits (FTP), and an annual management plan (AMP). All of these documents require an ADF&G department and public review and approval by the ADF&G

commissioner (Wilson 2023). Acquisition of hatchery permits in Alaska is an extensive process as outlined in (Figure 17) (Evenson et al. 2018).

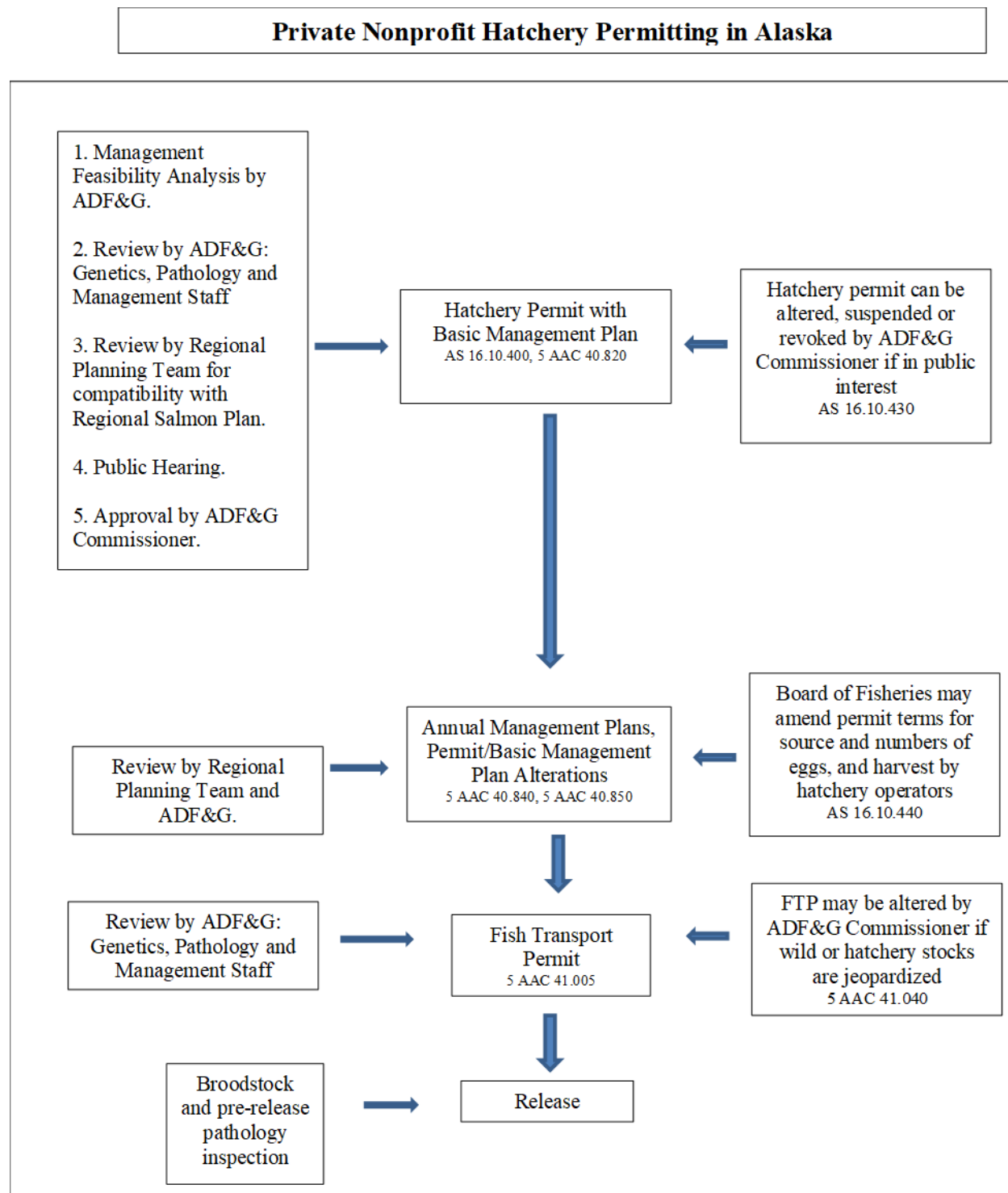


Figure 17. -- Flowchart of Alaska hatchery permitting process (from Evenson et al. 2018).

5.3 Description of Hatchery Chinook Salmon Stocks within the Gulf of Alaska

Here, we present information on current hatchery Chinook stocks that have been in use since 2010 for each ESU. While many of these hatcheries also had releases prior to 2010, we chose to only provide recent (2010-2023) averages below to represent current hatchery output. Roppel (1982) provides a more complete description of early efforts to produce Chinook salmon (as well as other salmonids) in hatcheries in Alaska from the early 1900s until 1959, when Alaska became a state. In the description below, we follow the broad definitions of the terms “segregated” and “integrated,” where a segregated stock refers to a hatchery population that incorporates few or no natural-origin fish into the broodstock on a regular basis and minimizes the number of hatchery-origin fish on natural spawning grounds. An integrated stock, in contrast, refers to a stock in which at least some natural-origin fish are regularly used in the broodstock and hatchery-origin fish are allowed on natural spawning grounds. Stocks described this way may not necessarily meet the conservation guidelines for integrated and segregated stocks defined by other organizations (e.g., Mobrand et al. 2005a).

5.3.1 Southeast Gulf of Alaska ESU

Most of the State of Alaska’s Chinook salmon hatchery production occurs in Southeast Alaska. This strong focus on Chinook salmon enhancement stems from the signing of the Pacific Salmon Treaty (PST) in 1985, which included funding to support Chinook salmon hatcheries in Southeast Alaska as a means to offset the harvest concessions made in the treaty. Both wild and hatchery-origin Chinook salmon are targeted year-round by commercial troll and sport fishing fleets and are harvested by net fleets during the summer months. Harvesting Alaska hatchery-produced Chinook salmon is encouraged by State of Alaska fisheries managers, as most of these fish do not count toward the PST all-gear harvest limit. Currently, 12 hatchery facilities have been actively producing Chinook salmon since 2010 (Evenson et al. 2018): 4 are operated by the Southern Southeast Regional Aquaculture Association (SSRAA), 3 by the Northern Southeast Regional Aquaculture Association (NSRAA), 1 by Armstrong Keta Incorporated (AKI), one by Douglas Island Pink and Chum (DIPAC), 1 by the National Oceanic and Atmospheric Administration (NOAA), 1 by the Sitka Sound Science Center (SSSC), and 1 by the Metlakatla Indian Community (MIC). Chinook salmon releases from these operations generally occur in saltwater and either take place at the hatchery or in remote inlets and bays (Figure 18). All hatchery Chinook programs in Southeast Alaska are considered segregated programs. Between 2010 and 2023, the estimated annual return of adult Chinook from hatcheries to Southeast Alaska was approximately 80,000 (data from White 2011, Vercessi 2012, Vercessi 2014, Vercessi 2015, Stopha 2016a, Stopha 2017a, Stopha 2018, Stopha 2019, Wilson 2020, Wilson 2021, Wilson 2022, Wilson 2023, Wilson 2024), although hatchery contributions to sport harvest are known to be underestimated at some locations (Wilson 2024). In comparison, the minimum estimated annual return of wild adult Chinook salmon,

based on ADF&G-provided run reconstruction data for the major Chinook systems, was approximately 53,000 during the same time period.

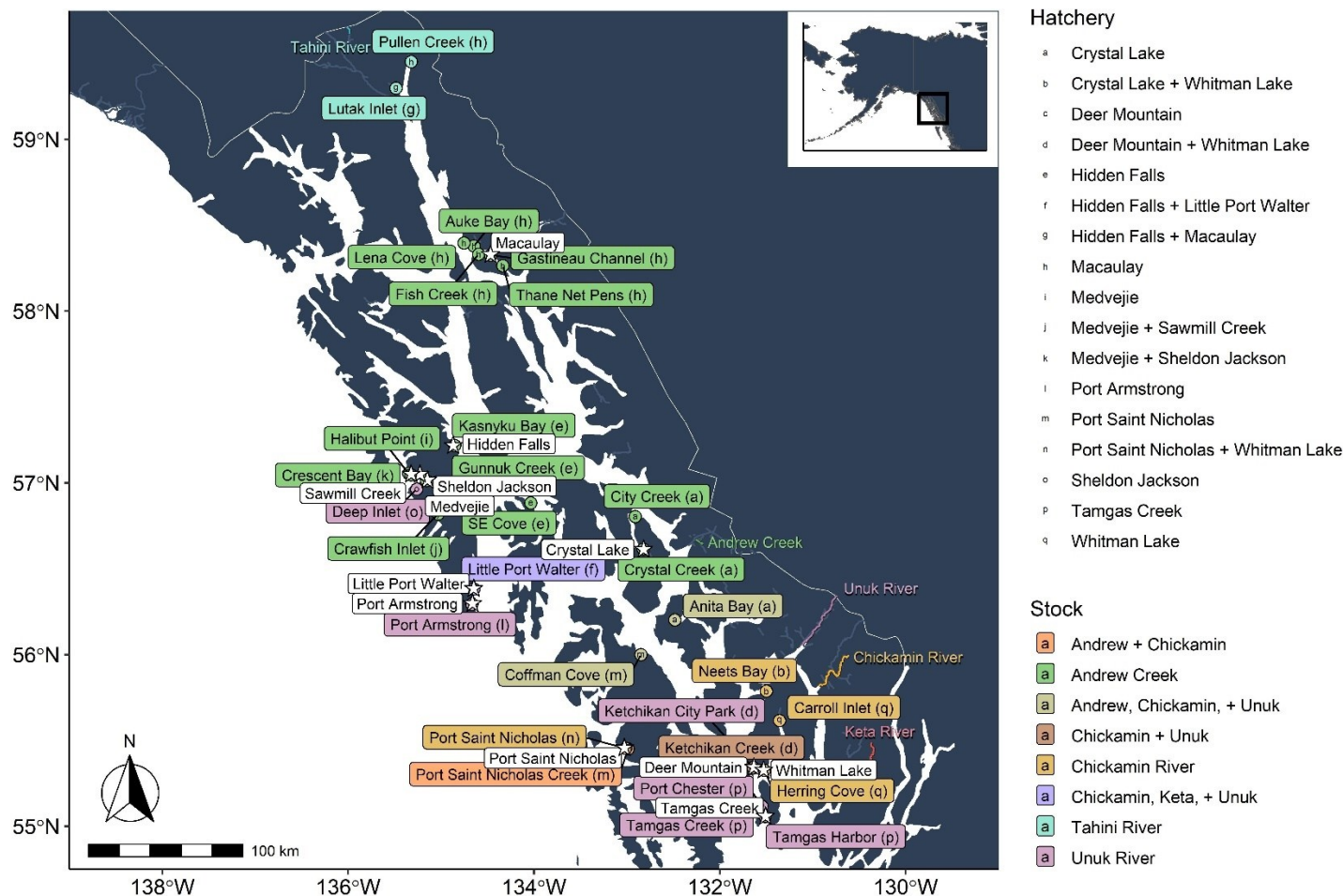


Figure 18. --Locations of release sites in Southeast Alaska, with labels colored by ancestral stock(s). Ancestral rivers are also displayed and colored accordingly. The letter in parentheses following each release site name corresponds to the releasing hatchery or hatcheries. Hatcheries are displayed on the map with white stars and labels.

Table 3. -- Hatchery releases by operator, hatchery, release site, and ancestral stock within Southeast Alaska. Operators are Armstrong-Keta, Inc. (AKI), Douglas Island Pink and Chum, Inc. (DIPAC), Metlakatla Indian Community (MIC), National Oceanic and Atmospheric Administration (NOAA), Northern Southeast Regional Aquaculture Association (NSRAA), Southern Southeast Regional Aquaculture Association (SSRAA), or Sitka Sound Science Center (SSSC). Hatcheries are Port Armstrong, Macaulay, Tamgas Creek, Little Port Walter, Hidden Falls, Medevejie, Sawmill Creek, Crystal Lake, Deer Mountain, Port Saint Nicholas, Whitman Lake, or Sheldon Jackson. The release site is the site at which juveniles were released, and the ancestral stock indicates the original ancestry of the hatchery broodstock. Annual average is the average number released in years when releases occurred. The annual average release is also set to a color scale, with the lowest number in purple and the highest number in yellow. Information on marking is also included: coded wire tagging (CWT), adipose fin clipping (Ad), and otolith thermal marking (OT).

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
AKI	Port Armstrong	Port Armstrong	Unuk River	2010-2016	268,454	20% avg. CWT + Ad.
DIPAC	Macaulay	Auke Bay	Andrew Creek	2010-2019	87,022	11% avg. CWT + Ad.
		Crystal Lake	Andrew Creek	2010	500	0% avg. CWT + Ad.
		Dredge Lake	Andrew Creek	2012-2014	1,667	0% avg. CWT + Ad.
		Fish Creek	Andrew Creek	2010-2020; 2022-2023	269,090	100% OT in 2022-2023. 100% Ad in 2023. 13% avg. CWT + Ad.
		Gastineau Channel	Andrew Creek	2010-2020; 2022-2023	343,105	100% OT in 2022-2023. 100% Ad in 2023. 16% avg. CWT + Ad.
		Glacier Lake	Andrew Creek	2010	500	0% avg. CWT + Ad.
		Lena Cove	Andrew Creek	2014-2017; 2019; 2022-2023	170,255	100% OT in 2022-2023. 100% Ad in 2023. 16% avg. CWT + Ad.
		Lutak Inlet	Tahini River	2011	92,785	11% avg. CWT + Ad.
		Moraine Lake	Andrew Creek	2010	500	0% avg. CWT + Ad.

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
		Pullen Creek	Tahini River	2010-2013; 2015	172,004	100% OT in 2012. 16% avg. CWT + Ad.
		Thane Net Pens	Andrew Creek	2016-2017; 2019	152,333	12% avg. CWT + Ad.
		Twin Lakes	Andrew Creek	2010-2018; 2020	8,479	0% avg. CWT + Ad.
MIC	Tamgas Creek	Port Chester	Unuk River	2020-2022	183,896	18% avg. CWT + Ad.
		Tamgas Creek	Unuk River	2010-2014; 2016-2020	241,444	5% avg. CWT + Ad.
		Tamgas Harbor	Unuk River	2021-2023	246,936	13% avg. CWT + Ad.
NOAA	Little Port Walter	Little Port Walter	Chickamin River	2010-2013	55,862	98% avg. CWT + Ad.
			Keta River	2015-2017; 2019-2022	43,654	94% avg. CWT + Ad in 2015-2017, 2019, & 2021-2022. Unmarked in 2020.
			Unuk River	2010-2021	126,479	88% avg. CWT + Ad in 2010-2019 & 2021. Unmarked in 2020.
NSRAA	Hidden Falls	Gunnuk Creek & Kasnyku Bay	Andrew Creek	2018	232,377	100% OT. 13% avg. CWT + Ad.
		Gunnuk Creek	Andrew Creek	2019-2023	164,793	100% OT. 21% avg. CWT + Ad.
		Kasnyku Bay	Andrew Creek	2010-2021	570,258	7% avg. CWT + Ad.
		Little Port Walter	Keta River	2023	40,313	99% avg. CWT + Ad.
		Lutak Inlet	Tahini River	2010	80,672	100% OT. 14% avg. CWT + Ad.
		SE Cove	Andrew Creek	2022-2023	329,856	100% OT. 11% avg. CWT + Ad.
	Medvejie	Bear Cove	Andrew Creek	2010-2023	1,970,465	100% OT. 7% avg. CWT + Ad.

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
		Bear Cove & Halibut Point	Andrew Creek	2012	443,296	100% OT. 10% avg. CWT + Ad.
		Crawfish Inlet	Andrew Creek	2016-2023	395,807	100% OT. 12% avg. CWT + Ad.
		Crawfish Inlet & Halibut Point	Andrew Creek	2017-2018	314,096	100% OT. 13% avg. CWT + Ad.
		Crescent Bay	Andrew Creek	2019-2023	367,199	100% OT. 12% avg. CWT + Ad.
		Halibut Point	Andrew Creek	2012-2016; 2018	329,946	100% OT. 7% avg. CWT + Ad.
	Sawmill Creek	Crawfish Inlet	Andrew Creek	2021-2022	430,565	100% OT. 2% avg. CWT + Ad.
SSRAA	Crystal Lake	Anita Bay	Andrew Creek	2010-2023	422,785	100% OT in 2010. 100% Ad in 2022-2023. 11% avg. CWT + Ad.
			Chickamin River	2021; 2023	196,195	100% Ad in 2023. 18% avg. CWT + Ad.
		Anita Bay (cont'd)	Unuk River	2014	52,300	19% avg. CWT + Ad.
		City Creek	Andrew Creek	2014; 2016-2020; 2022	114,877	100% Ad in 2022. 17% avg. CWT + Ad.
		Crystal Creek	Andrew Creek	2010-2023	639,914	100% Ad in 2022-2023. 12% avg. CWT + Ad.
		Neets Bay	Chickamin River	2010-2020	407,665	100% OT in 2010-2017 & 2019-2020. 9% avg. CWT + Ad.
	Deer Mountain	Ketchikan City Park	Unuk River	2011-2013	1,819	0% CWT + Ad.
		Ketchikan Creek	Chickamin River	2017; 2020-2023	28,711	58% avg. CWT + Ad.
			Unuk River	2010-2013	55,816	14% avg. CWT + Ad.
	Port Saint Nicholas	Coffman Cove	Andrew Creek	2011-2012	80,248	39% avg. CWT + Ad.

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
			Chickamin River	2014-2016	51,433	100% OT. 60% avg. CWT + Ad.
			Unuk River	2010-2011	110,133	41% avg. CWT + Ad.
		Port Saint Nicholas	Chickamin River	2017-2023	352,222	100% Ad in 2022-2023. 19% avg. CWT + Ad.
		Port Saint Nicholas Creek	Andrew Creek	2012	96,737	34% avg. CWT + Ad.
			Chickamin River	2010-2011; 2013-2016	163,607	100% OT in 2010 & 2014-2016. 16% avg. CWT + Ad.
	Whitman Lake	Carroll Inlet	Chickamin River	2016-2023	546,124	100% OT. 100% Ad in 2022-2023. 16% avg. CWT + Ad.
		Herring Cove	Chickamin River	2010-2023	660,921	100% OT. 100% Ad in 2022-2023. 12% avg. CWT + Ad.
		Ketchikan Creek	Chickamin River	2015-2016; 2018-2023	89,918	100% OT. 100% Ad in 2022-2023. 22% avg. CWT + Ad.
	Whitman Lake (cont'd)	Neets Bay	Chickamin River	2010-2017	264,693	100% OT in 2010-2011 & 2013-2017. 8% avg. CWT + Ad.
		Port Saint Nicholas	Chickamin River	2023	99,342	100% OT & 100% Ad. 19% avg. CWT + Ad.
SSSC	Sheldon Jackson	Crescent Bay	Andrew Creek	2010-2012	62,128	25% avg. CWT + Ad.
		Deep Inlet	Unuk River	2022	39,074	8% avg. CWT + Ad.

5.3.1.1 Southern Southeast Regional Aquaculture Association (SSRAA) operations:

5.3.1.1.1 Crystal Lake Hatchery

The Crystal Lake Hatchery (CLH) is located 17.5 miles south of Petersburg, Alaska. Operated by the SSRAA under contract with the ADF&G, CLH primarily sources its water from Crystal Lake itself. Currently, CLH is permitted for a maximum of 250,000 coho eggs and 4 million Chinook salmon eggs (ADF&G 2023a)

Chinook salmon production at CLH began in the early 1970s, with eggs sourced from several locations, including the Fort Richardson Hatchery (Chignik River Chinook), Fire Lake Hatchery (Ship Creek Chinook) from the Alaska Peninsula, Carson National Fish Hatchery in Oregon, and the Chickamin, Nakina, and King Salmon River stocks in Southeast Alaska (Templin 2001). However, disease outbreaks in 1976 and 1977 led to the discontinuation of these initial stocks.

Despite these early setbacks, success came in the late 1970s when the hatchery began using broodstock from a more local source—Andrew Creek, at the mouth of the Stikine River. By 1980, Andrew Creek Chinook salmon returning to CLH were used for broodstock, and by 1999, the Chickamin River Chinook stock from Whitman Lake Hatchery was added to the inventory. These two stocks continue to be the primary sources for the hatchery's Chinook program today (Templin 2001).¹⁵

As one of the few wild stock supplementation programs initiated in Southeast Alaska, CLH was used to supplement the wild Chinook stocks of the Harding River, Farragut River, and Tahini River from 1983 until 1993 when the projects were discontinued. During these projects, wild gametes were collected for each brood and brought into the hatchery. Each stock was reared separately before being released back into their respective river systems as tagged fry (Templin 2001).¹⁵

From 2010 to 2023, CLH has released approximately 1.5 million Chinook smolts each year across four release sites, primarily utilizing hatchery stocks from both Andrew Creek and Chickamin River (Table 3).

5.3.1.1.2 Neets Bay Hatchery

Neets Bay Hatchery is located in Neets Bay on Behm Canal, 35 air miles north of Ketchikan, Alaska on the west coast of Revillagigedo Island in southern Southeast Alaska. The hatchery was established in 1981 under the management of SSRAA.

Neets Bay Hatchery's Chinook salmon production has been a significant component of local fisheries. The program began in 1981 using Unuk River Chinook salmon as the primary broodstock source. The Unuk River stock was selected due to its availability and suitability for the hatchery environment. The broodstock at Neets Bay was developed from Unuk River stock

¹⁵ADF&G, Division of Commercial Fisheries, Mark, Tag and Age Laboratory. Coded Wire Tag database, 1976 – present, Hatchery Releases. Available from: <https://mtalab.ADF&G.alaska.gov/CWT/reports/hatcheryrelease.aspx>, accessed February 2025.

gametes obtained from Deer Mountain Hatchery, NOAA's Little Port Walter Research Station (LPW), Whitman Lake Hatchery, and eggs collected directly from the Unuk River (Cripple Creek tributary). From 1986 to 1990, Neets Bay Hatchery returns were used for broodstock. In 1991, the Neets Bay Hatchery switched Chinook salmon production to Chickamin River stock obtained from SSRAA's Whitman Lake Hatchery. The 2004 brood marked the final year that Chinook salmon were raised at Neets Bay. Starting with the 2005 brood, SSRAA began releasing Chickamin River Chinook smolts reared at both Crystal Lake Hatchery and Whitman Lake Hatchery into Neets Bay. In 2020, SSRAA discontinued the release of Chickamin Chinook salmon at Neets Bay (Templin 2001, Stopha 2017b).¹⁵

5.3.1.1.3 Whitman Lake Hatchery

Whitman Lake Hatchery is located in Herring Cove in George Inlet near Ketchikan, Alaska. SSRAA applied for a permit for the Whitman Lake Hatchery in 1977.

The Chinook program at Whitman Lake Hatchery was started in 1980 with a broodstock development project utilizing Unuk River and Chickamin River Chinook stocks. In 1980, SSRAA collected Chinook salmon eggs from the Unuk River system (Cripple Creek) for release from the hatchery as part of a Chinook salmon research project to evaluate Chinook salmon survival of releases of ocean type and stream type smolts. Unuk River stock eggs were also received from LPW in 1981 and 1982. By 1985, enough Unuk hatchery returns were available to use as broodstock. The Whitman Lake Unuk River Chinook stock was used for egg transfers to Neets Bay and Tamgas Creek hatcheries and juvenile releases into Carroll inlet and Neets Bay. The Unuk River stock was discontinued at Whitman Lake hatchery with the release of the 1987 brood (Templin 2001, Stopha 2016c).

The Chickamin River broodstock development project also started in 1980 with gametes mainly collected from wild Chickamin River Chinook, but also sourced for a few years from LPW. By 1988 enough Chickamin River hatchery returns were available to use as broodstock into the future (Templin 2001, Stopha 2016c). Through the years, the Whitman Lake Chickamin River Chinook stock has been mainly used for juvenile releases from the hatchery at Herring Cove and Carroll inlet, with transfer of gametes to Medvejie Creek Hatchery, Neets Bay Hatchery in the 1990s, and Deer Mountain Hatchery in 2014 (Templin 2001, Stopha 2016c).¹⁵

From 2010 to 2023, Chinook salmon production averaged approximately 1.2 million smolts per year. These smolts, derived from the Chickamin River stock, have been released across five different sites, with Herring Cove consistently having the highest and most frequent smolt releases over time (Table 3).

5.3.1.1.4 Port Saint Nicholas

The Prince of Wales Hatchery Association (POWHA), a private nonprofit, managed two hatcheries on Prince of Wales Island: Klawock River Hatchery near Klawock and Port St. Nicholas Hatchery near Craig. In the late 1990s to mid-2000s, POWHA and the town of Coffman Cove investigated a Chinook salmon release program to enhance local fisheries. The Klawock

River Hatchery permit was amended in 1999 to allow Chinook salmon egg incubation and smolt release from Coffman Cove (Stopha 2016b). However, warm water and disease concerns at Klawock led POWHA to consider the Port St. Nicholas site instead. When the Port St. Nicholas Hatchery permit was obtained, the Chinook salmon capacity was removed from Klawock River Hatchery. No Chinook were ever incubated at the Klawock River Hatchery. The Port St. Nicholas Hatchery was completed in 2007 with funds from the Pacific Coastal Salmon Recovery Fund. The hatchery is located at the City of Craig municipal water plant and was operated by POWHA until 2016 when SSRAA acquired the hatchery (Stopha 2016b).

Port St. Nicholas Hatchery applied for and received a permit in October 2003, requesting to incubate 325,000 Chickamin River Chinook salmon gametes sourced from SSRAA's Whitman Lake Hatchery for release in Coffman Cove. In 2006, Port St. Nicholas Hatchery requested an additional 385,000 Unuk River Chinook salmon eggs, sourced from Port Armstrong Hatchery, for their release program at Coffman Cove (Stopha 2016b). In 2010, Port St. Nicholas Hatchery shifted the primary stock for Coffman Cove releases to Chickamin River stock sourced from Whitman Lake hatchery, citing reliability and efficiency of transfer. In 2011, POWHA sought approval to use Andrew Creek Chinook salmon stock for one year due to a significant loss of their Chickamin River stock (Stopha 2016b).¹⁵

From 2010 to 2023, Chinook production averaged approximately 300,000 smolts per year, released across three sites.¹⁵ During this period, Chinook stocks from Andrew Creek, Unuk River, and Chickamin River were utilized, with the Chickamin River stock becoming the dominant one and exclusively used since 2017 (Table 3).

5.3.1.1.5 Deer Mountain Hatchery

The Deer Mountain Hatchery (DMH) is located in Ketchikan, Alaska (ADF&G 2017). Between 1955 and 1967, Deer Mountain hatchery sourced its Chinook salmon gametes from Soos Creek Chinook salmon in Washington State, and juveniles were released in Ketchikan Creek. By 1960, enough salmon returned to continue the program. However, a severe disease outbreak in 1967 prompted the closure of the program. The lack of suitable spawning and rearing habitat in Ketchikan Creek ensured the salmon run could not persist after the program was closed.

The State of Alaska reopened DMH in 1971 and began developing a new broodstock of Chinook salmon, with gametes sourced from wild Unuk River Chinook and Unuk River hatchery stock from NOAA's Little Port Walter Research Station. By 1983 DMH returns of Unuk River stock were used as broodstock. From 1994 through 2013, the Ketchikan Tribal Hatchery Corporation managed the facility under an ADF&G private nonprofit hatchery permit. During this time, DMH was permitted for 133,000 Unuk River stock Chinook salmon eggs. In 2014, the SSRAA assumed operational control of DMH and was permitted to increase Chinook salmon capacity to 600,000 eggs. SSRAA discontinued the Unuk River stock and replaced it with SSRAA's Whitman Lake Hatchery Chickamin River Chinook stock (Templin 2001, ADF&G 2017).

From 2010 to 2023, Chinook production has been intermittent, with an average of approximately 41,000 smolts released annually at two release sites. Unuk River stock was used exclusively from 2010 to 2013, while Chickamin River stock has been used since 2017 (Table 3).

5.3.1.2 Northern Southeast Regional Aquaculture Association (NSRAA) operations

5.3.1.2.1 Hidden Falls Hatchery

Hidden Falls Hatchery, located on Baranof Island along Chatham Strait in Southeast Alaska, is owned by the state of Alaska and operated by NSRAA.

The Chinook salmon program at Hidden Falls Hatchery began with the collection of wild Chinook salmon gametes from Andrew Creek, a tributary to the lower Stikine River north of Wrangell, during 1981-1983. These eggs were incubated, reared, and released from the hatchery. To help build the Chinook broodstock at Hidden Falls, Andrew Creek stock eggs were transferred from Crystal Lake Hatchery to Hidden Falls Hatchery from 1984 to 1986. By 1987, enough returning adults to the hatchery were available to support gamete collection into the future. Currently, the Andrew Creek stock is the main stock propagated for release at the hatchery (Templin 2001, Stopha 2015a).

Although the Andrew Creek stock is the main Chinook stock propagated at Hidden Falls, the hatchery has been used to propagate other Chinook stocks for release in Southeast Alaska. Eggs from Chinook salmon from the Tahini River, a tributary of the Chilkat River near Haines, were also collected annually from 1983 to 1990 for incubation and rearing at the hatchery. The fry from these broods were released both from Hidden Falls Hatchery, Lutak Inlet near Haines, and Burro Creek Hatchery near Skagway, Alaska. However, due to continued poor returns to Hidden Falls, this program was discontinued after the release of the 1993 brood year. From 2007 to 2009, Tahini River stock Chinook salmon eggs were collected from returns to the Pullen Creek release site near Skagway, incubated at Macaulay Salmon Hatchery, and then transferred to Hidden Falls Hatchery for further incubation and release in Lutak Inlet near Haines. The Tahini project was completely transferred to Macaulay Salmon Hatchery in 2010 (Templin 2001, Stopha 2015a).

From 2010 to 2023, Chinook production at Hidden Falls Hatchery averaged approximately 620,000 smolts annually, released differentially across five sites. During this period, Andrew Creek Chinook stock was primarily used, with the last release of Tahini stock in 2010. In 2023, Keta River Chinook stock from NOAA's Little Port Walter Research Station was introduced into production (Table 3).

5.3.1.2.2 Medvejie Creek Hatchery

The Medvejie Creek Hatchery is located in Bear Cove near Sitka, Alaska. The Chinook salmon program at Medvejie Creek Hatchery began in the early 1980s with the primary goal of supporting local sport and commercial fisheries. Initially, the hatchery examined various Chinook salmon stocks to find one ideally suited for propagation. Chinook stocks from the Situk River and Farragut River were considered, but by 1982, the Andrew Creek stock was the most

viable option, with initial gametes sourced from wild Andrew Creek stock and Andrew Creek hatchery stock from Crystal Lake Hatchery. By 1986, Andrew Creek Chinook returning to Medvejie were used as broodstock with supplemental Andrew Creek Chinook stock gametes sourced from Crystal Lake Hatchery. Significant expansions occurred in 1987 and 1997, increasing the Chinook salmon egg capacity from 300,000 to 3.2 million eggs. In 1989, NSRAA switched from Andrew Creek stock to Chickamin River stock sourced from Whitman Lake Hatchery in an effort to increase marine survival of releases and harvest rates of returning adults. By 1992, Chickamin River stock was the only Chinook stock released from the hatchery. However, by 1993, NSRAA switched back to Andrew Creek stock, sourcing gametes from Hidden Falls, Macaulay, and Crystal Lake Hatcheries. In 1997, NSRAA was able to resume sourcing gametes from Andrew Creek stock returning to Medvejie Creek Hatchery (Templin 2001, Stopha 2015b).

Medvejie Creek Hatchery is the largest NSRAA hatchery, and from 2010 to 2023, it produced approximately 2.5 million Chinook smolts annually. The hatchery exclusively used Andrew Creek Chinook stock and released smolts across six sites around the Sitka, Alaska, area (Table 3).

5.3.1.2.3 Sawmill Creek Hatchery

The Sawmill Creek Hatchery is located in Sitka, Alaska, and is the newest facility operated by NSRAA. The Sawmill Creek Hatchery is exclusively used as an incubation and rearing facility, utilizing eggs collected from Medvejie Creek Hatchery. No fish are released at Sawmill Creek to avoid potential impacts on resident salmonids in the Sawmill Creek watershed.

Chinook salmon production at the Sawmill Creek Hatchery is a relatively new initiative for NSRAA. In 2019, after a 15,000-square-foot expansion of the facility, the hatchery was permitted for a maximum capacity of 2 million Andrew Creek stock Chinook salmon annually, to be released in Crawfish Inlet to support commercial troll and sport fisheries. Andrew Creek stock Chinook eggs from Medvejie Creek Hatchery arrived at the new building in 2020 and 2021, were incubated and reared to smolt size, and were released into Crawfish Inlet in 2021 and 2022 (Table 3). Due to a shortage of Chinook broodstock returning to Medvejie hatchery, eggs were not obtained for Sawmill Creek in 2023 but the program is expected to continue in future (ADF&G 2024b).

5.3.1.3 Armstrong Keta, Inc. (AKI)

5.3.1.3.1 Port Armstrong Hatchery

Port Armstrong Hatchery (PAH) is located on southeastern Baranof Island in lower Chatham Strait, Alaska, and sources its water from Jetty Lake and Betty Lake. The salmon produced and released from the PAH facility is harvested in both commercial and sport fisheries (Stopha 2015c, ADF&G 2024c).

The Chinook salmon program at Port Armstrong Hatchery began with fry and egg transfers from the Unuk River stock via LPW starting in 1985. Initially, the program faced challenges, including a pipeline failure in 1991 that resulted in the loss of a brood year. In 1992, with funding from

the Pacific Salmon Commission, AKI expanded the program to release 1.5 million smolts annually. During this time, ADF&G directed AKI to switch to the King Salmon River stock being developed at LPW. While waiting for King Salmon River stock gametes to become available from LPW, ADF&G released a mix of Andrew Creek and Unuk River stock Chinook salmon smolts in 1992 and 1993 from Port Armstrong saltwater net pens. Returns from these releases were not used as broodstock in subsequent years. Due to low returns of the King Salmon River stock to LPW, development of a King Salmon River stock at AKI was abandoned.

In 2001, Port Armstrong renewed its use of Unuk River stock gametes sourced from LPW to develop its own broodstock. From 2006 to 2014, returns to the hatchery were used for broodstock and juveniles were released at the hatchery. AKI discontinued their Chinook Salmon program in 2015 with the last release of Chinook smolts in 2016 (Stopha 2015c). From 2010 until the last release of Chinook in 2016, Port Armstrong Hatchery produced approximately 268,000 Unuk River stock Chinook smolts annually and released them into Port Armstrong Bay (Table 3).

5.3.1.4 Douglas Island Pink and Chum, Inc. (DIPAC)

5.3.1.4.1 Macaulay Salmon Hatchery

The Macaulay Salmon Hatchery is located on the Juneau waterfront in Southeast Alaska, in Gastineau Channel. The Macaulay Chinook salmon program began before the hatchery was completed. From 1987 to 1993, Chinook salmon smolts from the Andrew Creek stock were released at Sheep Creek, located approximately 4 miles south of Juneau. These smolts were sourced from the Southern Southeast Regional Aquaculture Association's Crystal Lake Hatchery. By 1994, Macaulay Hatchery was rearing Chinook salmon from gametes collected from returning Andrew Creek stock. This stock is the primary stock reared at the hatchery and is released both directly from the hatchery and from saltwater net pens at the mouths of several local non-Chinook salmon streams in the Juneau area (Templin 2001, Stopha 2014).

Although the Andrew Creek stock is the main stock used, in the early years, the Alaska Department of Fish and Game requested that DIPAC use a different Chinook stock to comply with the State Genetics Policy. From 1990 to 1992, Macaulay Hatchery reared Chinook salmon from the Big Boulder Creek stock, a tributary of the Klehini River near Haines, Alaska, using gametes collected from wild adults. The juveniles were released back into Big Boulder Creek to supplement the wild Chinook population, which had been depressed due to a natural event that altered the creek's flow and habitat. This project ended with the release of the 1992 brood in 1994 (Templin 2001, Stopha 2014).

From 1993 to 1996, DIPAC tried to develop a broodstock of King Salmon River Chinook, sourced from LPW. These broods were raised and released from the hatchery and from sites around Juneau. However, due to poor ocean survival, the King Salmon River broodstock development project ended in 1996 (Templin 2001, Stopha 2014).

Shortly after the King Salmon River project, DIPAC started a new broodstock development program in 1998 using Tahini River stock (a tributary of the Chilkat River). This stock was being produced in small numbers at Burro Creek Hatchery in Skagway, Alaska. However, production setbacks and the addition of other salmon projects at Macaulay Salmon Hatchery delayed the full transition from the Andrew Creek stock to the Tahini River stock (Templin 2001, Stopha 2014).

In 2010, with little evidence of the Andrew Creek stock straying into other Chinook systems, ADF&G rescinded their directive for DIPAC to change their Chinook broodstock at Macaulay Salmon Hatchery. This allowed DIPAC to continue using the Andrew Creek stock for the Juneau area programs. The Tahini River stock continues to be used for the Pullen Creek and Lutak Inlet releases in Haines and Skagway, Alaska (Templin 2001, Stopha 2014).

From 2010 to 2023, the Macaulay Salmon Hatchery produced approximately 823,000 Chinook smolts annually, released at various times across 12 sites. Andrew Creek Chinook stock was used for releases around the Juneau, Alaska, area, while Tahini River stock was released exclusively in the Haines/Skogway, Alaska, area (Table 3).

5.3.1.5 National Oceanic and Atmospheric Administration (NOAA)

5.3.1.5.1 Little Port Walter Research Station

Little Port Walter (LPW) Research Station is a research unit of NOAA's Alaska Fisheries Science Center, specifically within the Auke Bay Laboratories. Located 110 miles south of Juneau, Alaska, near the southern tip of Baranof Island, LPW is the oldest year-round biological research station in Alaska. Since its establishment in 1934, it has hosted a wide variety of fisheries research projects. The first 40 years primarily focused on the ecology, population dynamics, and life histories of fish in Sashin Creek, including pink, chum, and coho salmon, steelhead trout, and Dolly Varden char.

In the early 1970s, when the State of Alaska initiated its fisheries enhancement program under the ADF&G FRED division, LPW began an extended period of cooperative enhancement research with ADF&G, private hatchery groups, and several universities. A small-scale salmon hatchery at LPW was built in 1971 for enhancement studies on coho salmon. By 1976, Chinook salmon enhancement research was added to LPW's research portfolio, while coho enhancement research was phased out in the early 1980s.

LPW's water source for culturing salmon is drawn from Sashin Creek, which drains Sashin and Round Lakes. Sashin Creek has endemic runs of pink and coho salmon, as well as rainbow and steelhead trout and Dolly Varden. However, Sashin Creek does not support Chinook salmon. Much of the salmon enhancement research at LPW has addressed issues related to the U.S.-Canada Pacific Salmon Treaty. From its inception, LPW's salmon enhancement activities have focused solely on research, not on commercial or sport production, making it unique in Alaska and one of a few salmon hatchery research facilities in the Pacific Northwest. Chinook salmon propagation at LPW began in 1976 to support enhancement research, to develop broodstocks

for other Southeast Alaska hatcheries, and (later) to support Chinook management under the Pacific Salmon Treaty. The isolation of Sashin Creek from wild Chinook salmon populations and the presence of the research facility were primary reasons for establishing the Chinook salmon research program at LPW.

In 1976, eggs and milt were collected from wild adults in the Chickamin and Unuk Rivers on Behm Canal in Southeast Alaska and transported to LPW for fertilization and rearing. Wild gametes from the Unuk River were also collected annually from 1977 to 1981. Starting with the 1982 brood, all Chinook salmon smolts released from LPW were progeny of adults that returned to the facility. Fish from the two stocks were incubated and reared separately, marked, and coded-wire tagged throughout the years they were utilized at the research station. Over time, smolts from LPW have mostly been released into the estuary, with a few releases occurring in saltwater within a mile of the research station during the early years of the program.

The Chickamin River stock was discontinued at LPW following brood year 2011, and the Unuk River stock was discontinued following brood year 2019, marking the end of a 45-year time series focused on understanding the mechanisms regulating growth, size, age at maturation, and survival of Chinook salmon in a changing environmental system. These two stocks have been replaced by the Keta River broodstock of Chinook salmon through a collaborative effort with local private, non-profit hatchery groups. The Keta River broodstock at LPW was established by sourcing wild Chinook gametes from the Keta River, located approximately 45 miles east of Ketchikan near Boca de Quadra Bay, in years 2013-2015 and 2017-2018.

From 2010 to 2023, the average annual release of Chinook salmon at LPW was approximately 157,000 (Table 3).

5.3.1.6 Sitka Sound Science Center (SSSC)

5.3.1.6.1 *Sheldon Jackson Hatchery*

Sheldon Jackson Hatchery is situated at the Sitka Sound Science Center (SSSC) in Sitka, Alaska. The SSSC's mission is to sustain fish culture operations at the Sheldon Jackson Hatchery, providing institutions such as the University of Alaska Fairbanks, the University of Alaska Southeast, and local secondary schools with a platform for training students in fisheries and hatchery science. Simultaneously, the hatchery contributes salmon to the common property fisheries of Sitka Sound and Southeast Alaska.

Since 1984, the Andrew Creek stock of Chinook salmon has been released from the Sheldon Jackson Hatchery. The Chinook program concluded with the closure of Sheldon Jackson College, marking the final release of Chinook in 2012. From 2010 to 2012, the average annual release of Chinook salmon at Sheldon Jackson Hatchery was approximately 62,000. In 2022, however, due to funding challenges at LPW, the Unuk stock of Chinook raised at Little Port Walter (brood year 2020) was transferred to the Sheldon Jackson Hatchery. This stock was then released in Deep Inlet under the care and permit of NSRAA, a release of approximately 39,000 fish (Table 3).

5.3.1.7 Metlakatla Indian Community (MIC)

5.3.1.7.1 Tamgas Creek Hatchery

Tamgas Creek Hatchery is one of three Federal hatcheries in Alaska and is located within the Metlakatla Indian Community (MIC) on Annette Island in Southeast Alaska, the only Native Reservation in Alaska.

In 1982 and 1989, Tamgas Creek Hatchery began developing a Chinook enhancement program sourcing Unuk River Chinook stock gametes from LPW, SSRAA's Whitman Lake and Neets Bay Hatcheries, and ADF&G's Deer Mountain Hatchery. In 1986 and for one year only, Tamgas received Chickamin River Chinook stock from LPW and released them along with the Unuk River stock. By 1990 adult Unuk River Chinook hatchery returns were numerous enough for gametes to be sourced directly from those returning adults. The Tamgas Creek Hatchery still uses Unuk River Chinook salmon returning to the hatchery as broodstock (Templin 2001).¹⁵

From 2010 to 2023, Chinook production at Tamgas Creek Hatchery has averaged approximately 285,000 smolts annually. The Unuk River Chinook stock has been used exclusively, with smolts released across three sites during this period (Table 3).

5.3.2 Central Gulf of Alaska ESU

There are no salmon hatcheries in this ESU producing Chinook salmon.

5.3.3 Northwest Gulf of Alaska ESU

Enhancement activities within this ESU date back to before Alaska Statehood, with varying degrees of success. Significant progress began in the 1970s with the establishment of ADF&G's FRED division, which expanded hatcheries in the region to support commercial, sport, and subsistence fisheries amid declining salmon populations. Most enhancement efforts have focused on sockeye, coho, and pink salmon. Many Cook Inlet streams have wild Chinook salmon populations but are too small to sustain recreational fisheries, and some systems have been impacted by urbanization, resulting in only small numbers of harvestable fish (ADF&G 2019). Likewise, there are no substantial Chinook systems in Prince William Sound and very few on Kodiak Island. Consequently, Chinook salmon enhancement has primarily aimed to increase recreational fishing opportunities in rivers, terminal saltwater areas, and lakes within this ESU to help avoid overharvesting wild Chinook stocks. Unlike the exclusively segregated Chinook salmon hatchery programs in the SEGOA ESU, those in the NWGOA ESU include both integrated programs in Cook Inlet and segregated programs in Kodiak.

Historically, there were a number of ADF&G hatcheries in this ESU producing salmon for sport fishing opportunities. However, by the early 1990s, most were either closed or transferred to private nonprofit aquaculture associations. Most state-managed salmon enhancement projects in the Cook Inlet area were consolidated into the Elmendorf and Fort Richardson Air Force base hatcheries run by ADF&G's sportfish division. When these hatcheries closed in the early 2000s, the enhancement projects were moved to the newly constructed William Jack Hernandez

hatchery in 2011, also operated by ADF&G's sportfish division. Currently, there are 11 active hatcheries in this ESU: four in Cook Inlet, two on Kodiak Island, and five in Prince William Sound. Of these, only three hatcheries (William Jack Hernandez in Cook Inlet, Pillar Creek in Kodiak, and Wally Noerenberg in Prince William Sound) have been propagating Chinook salmon for enhancement activities since 2010 (Figure 19).

Between 2010 and 2023, the estimated annual return of adult Chinook from hatcheries to this ESU was approximately 8,000 (data from White 2011, Vercessi 2012, Vercessi 2014, Vercessi 2015, Stopha 2016a, Stopha 2017a, Stopha 2018, Stopha 2019, Wilson 2020, Wilson 2021, Wilson 2022, Wilson 2023, Wilson 2024), although hatchery contributions to sport harvest are known to be underestimated at some locations (Wilson 2024). In comparison, the minimum estimated annual return of wild adult Chinook salmon, based on ADF&G-provided run reconstruction and escapement data for the major Chinook systems, was approximately 103,865 fish during the same time period.

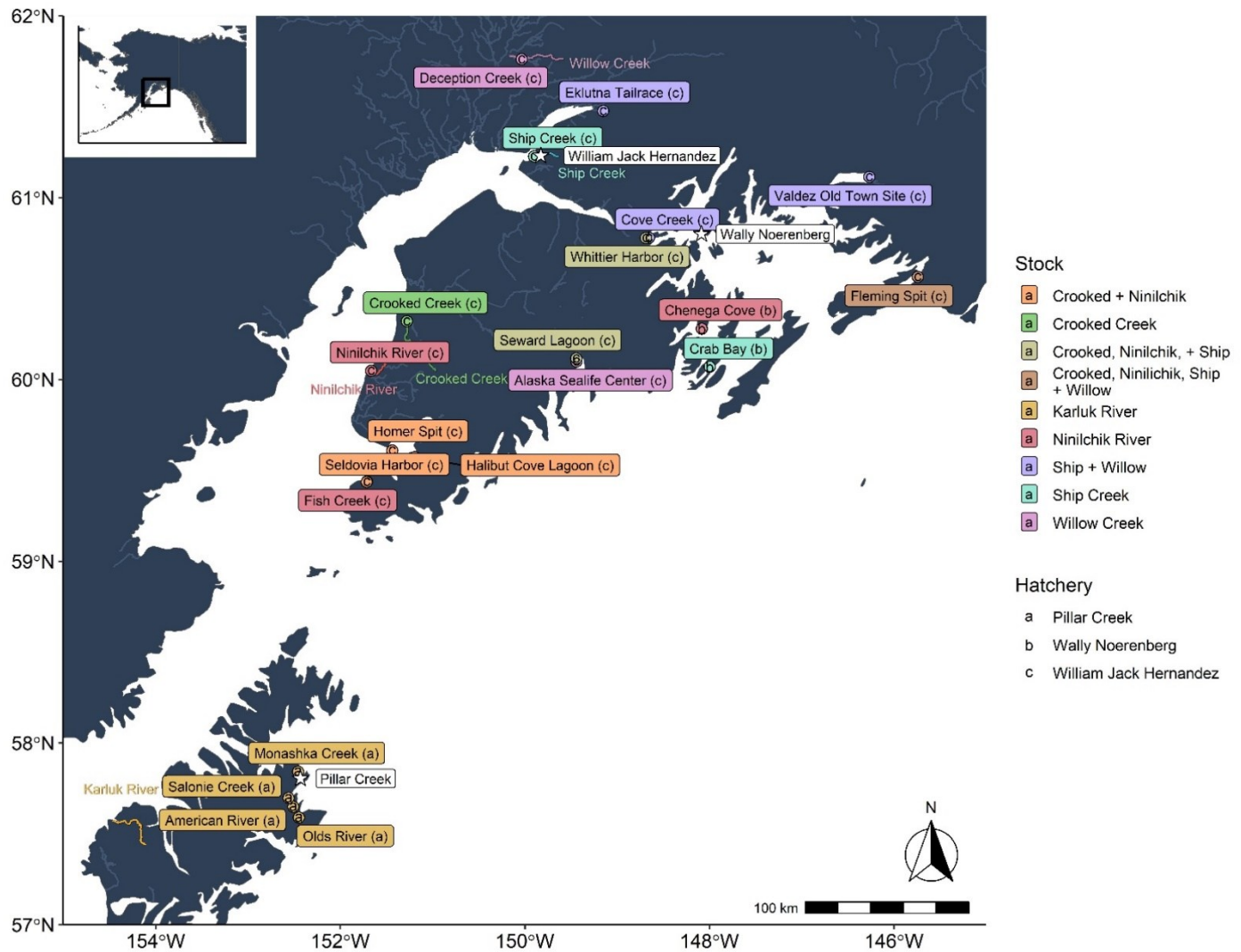


Figure 19. --Locations of release sites in the Northwest Gulf of Alaska, with labels colored by ancestral stock(s). Ancestral rivers are also displayed and colored accordingly. The letter in parentheses following each release site name corresponds to the releasing hatchery or hatcheries. Hatcheries are displayed on the map with white stars and labels.

Table 4. -- Hatchery releases by operator, hatchery, release site, and ancestral stock within the Northwest Gulf of Alaska. Operators are Alaska Department of Fish and Game (ADF&G), Prince William Sound Aquaculture Corporation (PWSAC), or Kodiak Regional Aquaculture Association (KRAA). Hatcheries are Elmendorf, Fort Richardson (FR), William Jack Hernandez (WJH), Wally Noerenberg, or Pillar Creek. Note, Elmendorf, FR, and WJH are combined because Elmendorf and FR were merged under WJH in 2012. The release site is the site at which juveniles were released, and the ancestral stock indicates the original ancestry of the hatchery broodstock. Annual average is the average number released in years when releases occurred. The annual average release is also set to a color scale, with the lowest number in purple and the highest number in yellow. Information on marking is also included: coded wire tagged and adipose fin clipped (CWT + Ad), otolith thermal marked (OT), both otolith thermal marked and adipose fin clipped (OT + Ad), or unmarked.

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
ADF&G	Elmendorf/FR/WJH	Cove Creek/Whittier Harbor	Crooked Creek	2020-2021	51,729	100% OT
			Ninilchik River	2019-2021	81,783	100% OT
			Ship Creek	2011; 2013; 2015-2018; 2020; 2022-2023	87,221	100% OT
			Willow Creek	2012; 2014	95,091	100% OT
		Crooked Creek	Crooked Creek	2010-2012; 2014-2023	116,072	100% OT + Ad in 2011-2012, 2015, & 2018-2023. 100% OT & 97% avg. CWT + Ad in 2010, 2014, & 2016-2017.
		Deception Creek	Willow Creek	2010-2018	155,976	99% CWT + Ad in 2010. 100% OT +

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
						Ad in 2011-2014 & 2018. 100% OT & 97% avg. CWT + Ad in 2015-2017.
		Eklutna Tailrace	Ship Creek	2010-2013; 2019-2023	230,692	100% OT in 2010-2012. 100% OT + Ad in 2013 & 2019-2023.
			Willow Creek	2014-2020	330,958	100% OT + Ad
		Fleming Spit	Crooked Creek	2020-2021	42,106	100% OT
			Ninilchik River	2019-2021	75,700	100% OT
			Ship Creek	2012-2013; 2015-2018; 2020; 2022-2023	91,091	100% OT
			Willow Creek	2010-2011; 2014	94,985	100% OT
		Halibut Cove	Crooked Creek	2013-2016	89,947	100% OT
			Ninilchik River	2010-2012; 2017	105,730	100% OT
		Homer Spit	Crooked Creek	2010-2011; 2013-2016; 2018;	209,986	100% OT

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
				2020-2022		
			Ninilchik River	2010-2012; 2017; 2019; 2022-2023	220,965	100% OT
		Lowell Creek	Crooked Creek	2010	109,779	100% OT
		Ninilchik River	Ninilchik River	2010-2023	115,246	100% OT & 98% avg. CWT + Ad in 2010 & 2015-2016. 100% OT + Ad in 2011-2014 & 2017-2022. 100% OT in 2023.
		Passage Canal	Willow Creek	2010	108,881	100% OT
		Seldovia Harbor	Crooked Creek	2011; 2013-2016; 2018; 2020-2021	90,847	100% OT
			Ninilchik River	2017; 2019; 2022-2023	98,532	100% OT
		Seward Lagoon	Crooked Creek	2010-2012; 2015-2023	254,881	100% OT
			Ninilchik River	2019	79,507	100% OT

Operator	Hatchery	Release Site	Ancestral Stock	Years Released	Annual Avg.	Marking
			Ship Creek	2011; 2013-2014; 2017	147,891	100% OT
		Ship Creek	Ship Creek	2010-2023	415,067	100% OT
		Valdez Old Town Site	Ship Creek	2013	70,656	100% OT
			Willow Creek	2010-2012	109,933	100% OT
		Lake Stocking	Ship Creek	2018-2023	71,597	100% Unmarked
PWSAC	Wally Noerenberg	Chenega Cove	Ninilchik River	2021-2022	46,420	100% OT
		Crab Bay	Ship Creek	2012-2019; 2023	39,343	100% OT
KRAA	Pillar Creek	American River	Karluk River	2010-2015; 2017-2018	48,029	100% Unmarked
		Monashka Creek	Karluk River	2010-2015; 2023	54,102	100% Unmarked
		Olds River	Karluk River	2010-2015; 2017-2018; 2020	46,669	100% Unmarked
		Salonie Creek	Karluk River	2014-2018; 2020-2023	35,684	100% Unmarked

5.3.3.1 Cook Inlet: William Jack Hernandez ADF&G Sport Fish Hatchery

The ADF&G, Division of Sport Fish (DSF), operates the William Jack Hernandez Sport Fish Hatchery (WJHSFH) in Anchorage, Alaska, near the original Elmendorf and Fort Richardson hatcheries. The hatchery meets sport fish stocking needs for the Cook Inlet and Prince William Sound areas, providing rainbow trout, Arctic char, lake trout, Chinook, and coho salmon for stocking into rivers, lakes, and saltwater locations. As of 2024, Chinook brood sources include Ship Creek, Crooked Creek, and Ninilchik River (ADF&G 2024e). Planned production goals are approximately 3.3 million Chinook salmon eggs (ADF&G 2024e).

5.3.3.2 In-River Chinook salmon integrated supplementation projects

5.3.3.2.1 Ship Creek

The first Chinook salmon enhancement project in the Cook Inlet area began in 1963 with gametes collected from wild Ship Creek Chinook, incubated, and reared to smolt size at the Elmendorf Fish Hatchery (Kubik 1973). These smolts were then released back into Ship Creek as part of a supplementation project aimed at boosting the low production of wild Chinook salmon to meet the growing demand for sport fishing opportunities in the Anchorage area. Both the Elmendorf and Fort Richardson hatcheries were used as incubation and rearing facilities for the project until their closures in the early 2000s. The WJHSFH has served as the incubation and rearing facility since 2011.

Since the project's inception, broodstock have been collected annually at Ship Creek, with the exception of 1964, 1965, and 1966, when Chinook from the Green River in Washington State were used, and again in 1983 and 1988, when Crooked Creek stock was used (Kubik 1973).¹⁵ Chinook smolts released back into Ship Creek have not been externally marked, except from 1994 to 1999, when a portion of the releases were adipose-clipped and coded-wire tagged.¹⁵ Since the early 2000s, the Chinook smolts for this project have been tagged with a thermally marked otolith but without a physical mark before release into Ship Creek (ADF&G 2019, ADF&G 2024g).¹⁵

From 2010 to 2023, approximately 415,000 hatchery-reared, Ship Creek stock otolith-marked smolts have been released annually into Ship Creek (Table 4). The Ship Creek Chinook salmon population is now considered an integrated natural population, not a wild population.

5.3.3.2.2 Crooked Creek

In the early 1970s, Crooked Creek, a main tributary of the Kasilof River, saw thousands of wild early-run Chinook salmon return annually, but not in numbers sufficient to sustain the significant sport fishery desired by the public. The ADF&G Sport Fish Division's Crooked Creek Hatchery, built in the mid-1970s, aimed to boost sport fishing opportunities by producing various salmon species, including the early-run Chinook salmon native to Crooked Creek. The first significant return of hatchery-raised Chinook salmon occurred in 1978 (ADF&G 2019, ADF&G 2024g). Responsibility for incubation and rearing was transferred to the Elmendorf Hatchery from 1982 to 2001, and to the Fort Richardson Hatchery from 2002 to 2009.¹⁵ This

project continues today, with the William Jack Hernandez Sport Fish Hatchery (2011-present) serving as the incubation and rearing site for the Crooked Creek Chinook stock.

Annual broodstock and gametes collections occur at Crooked Creek, with hatchery-released fish identified by fin clips during brood collection and carcass surveys (ADF&G 2019, ADF&G 2024g). Gametes are obtained from naturally produced Chinook salmon (adipose fin present) for smolts released into Crooked Creek, and from either naturally produced or hatchery-produced (adipose fin missing) Chinook salmon for smolts released into other terminal fisheries (ADF&G 2019, ADF&G 2024g). The collected gametes are transferred to the WJHSFH, where they are reared to the smolt stage, otolith marked and adipose clipped, and transported back to Crooked Creek for release (ADF&G 2019, ADF&G 2024g).

From 2010 to 2023, approximately 116,000 adipose clipped, otolith-marked Crooked Creek stock Chinook salmon smolts were released into Crooked Creek annually (Table 4). Smolts released in 2010, 2015, 2016, and 2017 were also coded-wire tagged at a tag rate greater than 95%.

5.3.3.2.3 Deception Creek

A supplementation program began at Deception Creek, a tributary to Willow Creek, in 1983 to meet the growing demand for sport fishing. Initially, gametes were collected from wild Willow Creek Chinook salmon (1983–1989), reared to smolt size at the Fort Richardson Hatchery, and released with an adipose clip into Deception Creek (Chlupach 1988). Annual broodstock and gamete collections were conducted from Chinook salmon returning to Deception Creek from 1991 to 2017.¹⁵ Hatchery-released fish were identified by the adipose fin clip during brood collection and carcass surveys (ADF&G 2019). Gametes used for smolt releases into Deception Creek were obtained from naturally produced Chinook salmon (adipose fin present), while those for other terminal fisheries may have been obtained from naturally produced or hatchery-produced Chinook salmon (adipose fin missing) (ADF&G 2019). Once collected from broodstock at Deception Creek, gametes were transferred to the Fort Richardson Hatchery (1983–2010) and later to the William Jack Hernandez Sport Fish Hatchery (2011–2017), where they were raised to smolt size, marked and released into Deception Creek and other terminal fisheries (ADF&G 2019).¹⁵ Production at Deception Creek, a tributary of Willow Creek, used naturally-spawning Chinook salmon in Willow Creek as brood (Oslund 2013). Releases in Deception Creek were suspended starting in 2019 due to a shortage of naturally-spawning Willow Creek returns starting in 2018 (Munro and Chenoweth 2025). From 2010 to 2018, approximately 156,000 Deception Creek stock Chinook salmon smolts were released into Deception Creek annually. Smolts were adipose clipped and either otolith marked, CWT-tagged, or both (Table 4).

5.3.3.2.4 Ninilchik River

In 1988, the Alaska Department of Fish and Game (ADF&G) initiated the Ninilchik River program. This program aimed to enhance sustainable Chinook salmon fishing opportunities on the Ninilchik River by supplementing its wild run with hatchery-reared fish. Similar to other

supplementation projects, Chinook salmon gametes from the Ninilchik River were collected and transferred to the Elmendorf Sportfish Hatchery, where they were raised to the smolt stage before being released back into the river. Hatchery released fish are identified by the clipped adipose fin during brood collection (ADF&G 2019, ADF&G 2024g). Gametes used to produce smolt released into the Ninilchik river are obtained from naturally produced (adipose fin present) Chinook salmon (ADF&G 2019, ADF&G 2024g). Gametes used to produce smolt released into other terminal fisheries may be obtained from either naturally produced Chinook salmon or hatchery produced (adipose fin missing) Chinook salmon (ADF&G 2019, ADF&G 2024g).

During the initial stage of the project, 200,000 smolts were stocked, with only 20% of them being adipose fin-clipped and tagged with coded wire tags. In 1995, concerns over high straying rates into nearby wild Chinook systems (King and Breakfield 2002) led to a reduction in the stocking level to 50,000 smolts, all of which were adipose clipped and coded wire tagged. This reduction provided additional protection to nearby wild stocks (Begich and Evans 2005, Kerkvliet 2008). The 100% marking also allowed for a more accurate assessment of hatchery-reared versus wild-stock production in the Ninilchik, and reduced genetic concerns by enabling the use of only natural Chinook salmon for broodstock.

However, from 2011 to 2014, as a cost-saving measure, smolts stocked in the Ninilchik River were not coded wire tagged, although their adipose fins were clipped and otoliths marked (ADF&G 2019). Chinook smolts stocked in 2015 and 2016 were again coded wire tagged but this practice ceased starting in 2017; adipose clipped and thermally marked otoliths have been the standard marking technique ever since (ADF&G 2019).¹⁵ Since 2011, the project has been supported by utilizing the WJHSFH as the incubation and rearing facility for the Ninilchik stock (ADF&G 2019, ADF&G 2024g).¹⁵

From 2010 to 2023, approximately 115,000 adipose clipped, otolith-marked Ninilchik stock Chinook salmon smolts were released into Ninilchik River annually (Table 4). Smolts released in 2010, 2015, and 2016 were also adipose-clipped and coded-wire tagged at a tag rate greater than 95%.

5.3.3.2.5 Eklutna Tailrace

In 2002, ADF&G established a Chinook salmon fishery at the Eklutna Hydroelectric Project Tailrace, an artificial channel approximately half a mile long that flows into the Knik River. Initially, the site supported a recreational fishery stocked with hatchery coho, sockeye, and chum salmon returning to the Cook Inlet Aquaculture Association's (CIAA) hatchery, located at the head of the tailrace. This private nonprofit hatchery was operational from 1981 through 1998. From 1998 to 2009, the fishery was supported by hatchery-reared coho and Chinook

salmon from the Fort Richardson Hatchery, which were released into the tailrace. Since 2011, the WJHSFH has supported this fishery.¹⁶

Since the project's inception, both Ship Creek and Deception Creek hatchery stocks have been used to stock the Eklutna Tailrace.¹⁵ Smolts released into the Eklutna Tailrace have thermally marked otoliths but do not have any external marks identifying them as hatchery-origin fish.¹⁵ From 2010 to 2023, approximately 314,000 Ship Creek or Deception Creek stock Chinook were released annually into the Eklutna Tailrace (Table 4).

5.3.3.3 Terminal Chinook Fisheries Projects

5.3.3.3.1 Kachemak Bay

The Kachemak Bay Chinook fisheries enhancement projects were initiated in the early 1970s to increase sport fishing opportunities in the area. While Chinook salmon return to some tributaries, their numbers are insufficient to support a fishery. Since 1974, hatchery-reared early-run Chinook salmon have been stocked in Halibut Cove Lagoon on the Homer Spit since 1984, and in Seldovia Bay since 1987 (Dudiak et al. 1987, ADF&G 2019). These are all terminal fisheries, where Chinook salmon smolts are held in saltwater net pens until they imprint on local freshwater streams or groundwater before being released.

Chinook salmon returning to these release sites are harvested by both commercial and sport fisheries. Ninilchik River and Crooked Creek hatchery-reared Chinook salmon smolts were supplied for this project by Elmendorf or Fort Richardson Hatcheries until 2011. Since 2011, the WJHSFH has supplied a mixture of Crooked Creek, Ninilchik, and Ship Creek smolts (ADF&G 2019, ADF&G 2024g).¹⁵ Hatchery Chinook salmon smolts released at Kachemak Bay sites are not tagged, but since the early 2000s, they have been thermally marked on their otoliths.¹⁵

From 2010 to 2023, approximately 400,000 otolith-marked smolts have been released annually across the three sites in Kachemak Bay. Releases at Halibut Cove ended in 2017, with releases at Homer Spit increasing in 2018 (Table 4).

5.3.3.3.2 Resurrection Bay

The Resurrection Bay Chinook enhancement project began in 1983 to support a terminal Chinook salmon sport fishery for residents of the City of Seward. Although the Resurrection Bay drainages support various species of salmon, they do not sustain wild Chinook salmon runs (ADF&G 2019). Historically, two distinct Chinook salmon runs were developed in Resurrection Bay through hatchery enhancement, primarily using Crooked Creek hatchery stocks. The late-run Chinook salmon program was canceled in 1998 due to a lack of available broodstock (ADF&G 2019). Crooked Creek hatchery Chinook salmon smolts have been the primary stock

¹⁶ ADF&G, Recreational Angler Access Projects, available at <https://www.ADF&G.alaska.gov/index.cfm?ADF&G=fishingSportAnglerAccessSouthcentral eklutna>, accessed March 5, 2205.

used for both the Lowell Creek and Seward Lagoon sites, though Willow Creek, Deception Creek, Ship Creek, and Ninilchik hatchery stocks have also been used at times.¹⁵

Hatchery Chinook salmon smolts released at Resurrection Bay sites are not physically marked, but since the early 2000s their otoliths have been thermally marked.¹⁵ From 2010 to 2023, approximately 266,000 otolith-marked smolts have been released annually at Seward Lagoon. Crooked Creek, Ninilchik River, and Ship Creek hatchery stocks have been released at Seward Lagoon during this time frame. The last release of approximately 110,000 Crooked Creek hatchery stock Chinook smolts at the Lowell Creek site was in 2010 (Table 4).

5.3.3.3.3 Cove Creek/Passage Canal/Whittier Harbor (Prince William Sound)

The Whittier Chinook salmon stocking program was terminated in 2005 due to a lack of rearing space at Fort Richardson hatchery (ADF&G 2019). However, this project was resumed in 2011 utilizing Crooked Creek, Ninilchik River, and Ship Creek Stocks of hatchery Chinook from the WJHSFH.¹⁵ Otolith-marked Chinook salmon smolts are delivered to a net pen in Whittier, and local residents feed and monitor these fish for two weeks while they imprint to the stocking location in the harbor, passage canal, and off the mouth of Cove Creek. From 2011 to 2023, approximately 102,000 otolith-marked smolts have been released annually in Cove Creek/Whittier Harbor (Table 4).

5.3.3.3.4 Fleming Spit (Prince William Sound)

The Fleming Spit site at Cordova is a brackish water lagoon that has supported a sportfish Chinook fishery since the 1980s. Elmendorf and Fort Richardson hatcheries supported this fishery with mainly Deception and Willow Creek hatchery stocks of Chinook until 2012 when Chinook smolts were supplied by WJHSFH. The purpose of this project is to release ~100,000 otolith marked Chinook smolts annually to provide sportfishing opportunities for the residents of Cordova (ADF&G 2019). Between 2010 and 2023, Crooked Creek, Ninilchik River, Ship Creek and Willow Creek Stocks of hatchery Chinook have been used to stock this site (Table 4).

5.3.3.3.5 Old Town Valdez Project

Between 1999 and 2003, ADF&G and the Valdez Fisheries Development Association attempted to develop a "put-and-take" Chinook sport fishery at Valdez Glacier and Valdez Harbor. Deception Creek hatchery stock from Fort Richardson was selected, and approximately 100,000 otolith marked Chinook smolts were released each year.¹⁵ Adult returns from these releases were very poor. In 2004, a new release site in Old Town Valdez was selected, and stocking of otolith marked Deception Creek hatchery Chinook salmon commenced in the spring of that year. Between 2010 and 2013, otolith marked Deception Creek and Ship Creek stocks from Fort Richardson and subsequently the William Jack Hernandez Hatchery were used to stock the site (Table 4).

Although this new release site was an improvement over the previous ones, this particular stocking venture was not productive, and there was no evidence that it produced any returns.

Consequently, the Valdez Fisheries Development Association and ADF&G staff terminated the project in 2013 (ADF&G 2019).

5.3.3.4 Lake Stocking Projects

Lake stocking of Chinook salmon, along with other species of salmon, trout, and char, has occurred for many years in the Cook Inlet area. These are non-anadromous stocking programs in landlocked lakes, designed to support a "put-and-take" sport fishery for the general public. The Ship Creek stock of hatchery Chinook salmon, initially sourced from the Elmendorf-Richardson base hatcheries and more recently from the WJHSFH, has primarily been used for these programs. The Chinook used for lake stocking are triploid and considered sterile. Between 2010 and 2023, 17 lakes in the Cook Inlet area have been stocked with unmarked Ship Creek stock Chinook salmon, with an annual production of approximately 72,000 smolts spread across all 17 lakes (Table 4) (ADF&G 2019, ADF&G 2024g).¹⁵

5.3.3.5 Prince William Sound: Wally Noerenberg Hatchery

The Wally Noerenberg Hatchery (WNH) is located on Esther Island in Prince William Sound (PWS), about 20 miles east of Whittier, Alaska. Chinook production at WNH began in 1986. Copper River Chinook salmon stocks were initially considered as donor stocks but were rejected due to their small population size, disease history, and logistical issues. The Deshka River Chinook salmon stock from Cook Inlet was then chosen because its return timing fit the hatchery's management needs, the returning fish were expected to be in good condition, and the stock showed signs of advanced early development, potentially allowing for release from the hatchery in their first year (Stopha 2013). Initial releases used Deshka River stock transferred from the Fort Richardson State Hatchery in Anchorage, with gametes collected from broodstock returning to the WNH from 1988 to 1996. This initial program ended with the last release of smolts in 1997 (Stopha 2013, ADF&G 2024d).¹⁵

The program restarted in 2010 with Ship Creek stock (Cook Inlet) eggs transferred from the Fort Richardson State Fish Hatchery, and continued in 2011 with both Ship Creek and Ninilchik River Chinook stock eggs transferred from the WJHSFH (Stopha 2013). The current Chinook program at WNH is much smaller compared to the initial program, releasing fewer than 50,000 otolith-marked Chinook salmon smolts at Crab Bay and Chenega Cove annually to support local sport fisheries (Table 4).

5.3.3.6 Kodiak Island: Pillar Creek Hatchery

Pillar Creek Hatchery (PCH) was established in 1990 as a cooperative project between ADF&G and the Kodiak Regional Aquaculture Association (KRAA) (Musselwhite 2011). The Chinook salmon program at Pillar Creek Hatchery began in 2000, with wild Chinook salmon gamete collections from the Karluk River occurring from 2000 to 2004 (Schwarz et al. 2009). The Karluk River, located on the opposite side of Kodiak Island, is the closest wild Chinook salmon population to the hatchery (Figure 19). The rearing process involved the initial stages of incubation and freshwater rearing at the Pillar Creek Hatchery facility, with final rearing and

release at Monashka Creek. By 2005, adult returns to Monashka Creek were sufficient to use as broodstock (Schwarz et al. 2009). In 2007, a portion of Chinook smolts from Pillar Creek were used to stock the American and Olds Rivers. Additionally, Salomie Creek has been stocked with Pillar Creek Hatchery Chinook since 2014.

Since 2010, broodstock have also been collected from the Olds, American, and Salomie drainages (ADF&G 2019, ADF&G 2024g). Currently, annual Chinook production from Pillar Creek Hatchery is released in the American and Olds Rivers and Salomie Creek. Stocking of Monashka Creek was discontinued in 2015 due to chronically low returns but resumed in 2023 (ADF&G 2024g).

Since the program's inception, Pillar Creek Hatchery Chinook smolts have not been marked before release¹⁵ and should be considered a segregated hatchery stock since wild gametes have not been infused into the project since 2004. From 2010 to 2023, approximately 116,000 unmarked Karluk River stock hatchery smolts have been released annually, spread across four release sites near the city of Kodiak (Table 4).

6 DEMOGRAPHIC RISK ANALYSIS

6.1 Statistical Methods for Time-series Analysis

To investigate trends in the abundance of GOA Chinook salmon, we focused on two primary questions: have there been any short-term and/or long-term declines in abundance across the available data? To address these questions, we analyzed 31 populations spanning three ESU designations. Similar reviews conducted by Status Review Teams (SRTs) across the Pacific Northwest have identified escapement data as the most reliable metric of the available data for such assessments (Ford 2022, OC and SONCC Status Review Team 2024). For all 31 populations, escapement estimates were available, provided by ADF&G. Additionally, for 22 of these populations, ADF&G supplied run-size estimates, which integrate harvest and escapement data (A. Munro, ADF&G, personal communication). Run size estimates provide a more accurate estimate of abundance, which is a better metric to assess population trends.

The short-term analytical methods employed here were selected to closely follow those used in previous ESA status reviews. In addition to our short-term analysis, we also developed and applied a novel long-term modeling approach to provide an independent assessment of demographic patterns over the full time series. This complementary framework allows us to retain methodological consistency for comparability while also incorporating a new perspective that characterize long-term trends in GOA Chinook salmon populations.

These data provided by ADF&G represent the most current available data as of 28 May 2025. These data are subject to change with the addition of new information and error checking. Some of these data are estimated and, therefore, may not match previously published estimates and will change with additional data, model improvements, and future model runs.

While this analysis uses the best available escapement, harvest, and run-size information from ADF&G, the underlying data are not uniform in quality across regions. The Southeast Alaska monitoring program provides the most comprehensive and reliable estimates, with long-term standardized observation methods, frequent validation of survey expansion factors, high tag-marking rates for juvenile outmigrants, and consistent measures of uncertainty for run reconstruction statistics. In contrast, other regions rely on a mix of enumeration methods, such as single aerial or foot surveys, observer counts, or incomplete harvest coverage, which can introduce greater uncertainty and reduce comparability. Differences in monitoring intensity, methodological rigor, and validation frequency mean that, while all datasets contribute valuable information to this review, their precision and reliability vary, with Southeast Alaska data representing the highest standard currently available along the coast.

6.1.1 Short-term trends

Across the Gulf of Alaska, fluctuations in Pacific salmon abundance have been documented over the past 100 years (Beamish 2022). For our short-term analysis (15-year periods), we focused on identifying distinct regimes to highlight trends in abundance within the time series. The 15-year time frame was selected to align with previous studies and reports, and it represents approximately three generations of Chinook salmon (Groot and Margolis 1991). Our analytical approach closely follows (Ford 2022) and the OC and SONCC Status Review Team (2024) in employing multivariate dynamic linear models (DLMs) to estimate population-specific trends for the Gulf of Alaska Chinook stocks with sufficient data. A DLM approach provided an estimate of the smoothed abundance after accounting for observations and the process errors (see Ford (2022) and citations therein for a broader review of DLMs and their use in salmon time-series analysis). We used the multivariate autoregressive state-space modeling (MARSS) package in R to fit a multivariate DLM to the log-spawner abundances (Holmes et al. 2012, Holmes et al. 2021, Holmes et al. 2024, R Core Team 2024). Within our model, the structure of our variance-covariance matrix, Q and R, respectively, were set with Q being diagonal with equal variances (Q = “equalvarcov” in the MARSS package) and R being diagonal with equal variances (R = “diagonal and equal” in the MARSS package). This matrix configuration enables the generation of smoothed abundance estimates for populations with missing data by incorporating information from other populations, thereby improving accuracy. While other configurations were explored, this configuration was selected to maintain consistency with previous ESA status reviews and to facilitate direct comparisons of trends across stocks within the Gulf of Alaska. Additionally, it effectively controlled for populations with high levels of noise in the data.

A linear regression was conducted on 15-year trends using the log-transformed smoothed estimates derived from the DLM. For each population, the slope (trend), 95% confidence intervals, and significance were calculated and reported. To ensure robust analyses, trends were only assessed for populations with at least four smoothed estimates and at least two observations within both the first and last 5 years of the 15-year period.

Using the DLM estimates, 5-year geometric means $((y_1 \cdot y_2 \cdot y_3 \cdot y_4 \cdot y_5)^{1/5})$ were calculated. The geometric mean was computed only when at least two values were available within the 5-year period. For periods with missing values, the geometric mean was derived exclusively from the available (non-missing) values $((y_1 \cdot y_2 \cdot \dots \cdot y_n)^{1/n})$. Geometric means are useful for small sample sizes to prevent extreme realizations to dominate the mean which can occur in lognormally distributed data like run-seize estimates. Both the DLM-derived estimates and observed values were reported, where available, to provide a comprehensive comparison.

6.1.2 Long-term trends

Our analysis of long-term (all available data) demographic patterns among Chinook salmon stocks was based on a Bayesian multivariate state-space modeling approach. Models were fitted separately to each ESU, with the exception of the NWGOA. Due to the large number of populations and inability to estimate the process error covariance matrix for the NWGOA ESU, we split this ESU into three geographic subgroups for the purpose of model fitting: Northern Cook Inlet, Kenai Peninsula, and Southern Peninsula (Kodiak Island/Chignik). Models were fitted for each ESU/subgroup's available (1) escapement data, and (2) run size data. While escapement data is more widely available across populations and years, run size (which includes both harvest and escapement) is better suited to detect declines in abundance, as under a fixed escapement policy, lower abundance will typically lead to reduced harvest before a reduction in escapement is realized.

For a given abundance metric (i.e., run size or escapement), abundance over time was specified to follow a multivariate random walk:

$$A_{y,p} = \begin{cases} A_{init_p} \sim Normal(0,10), & y = 1 \\ A_{y-1,p} + u_p + \varepsilon_{y,p}, & y > 1 \end{cases} \quad (1)$$

where $A_{y,p}$ is the model-predicted log abundance (escapement or total run) of population p in year y , which is specified as the sum of the previous year's value ($A_{y-1,p}$), an additive linear trend term (u_p), and an annual process error ($\varepsilon_{y,p}$). A_{init_p} are the initial values of the time-series for each population, which were drawn from vague normal priors. Linear trend terms for each population were also assigned a vague normal prior:

$$u_p \sim Normal(0,1). \quad (2)$$

Annual process errors were assumed to be multivariate-normally distributed with a freely estimated covariance matrix (Σ):

$$\varepsilon_y \sim MVN(0, \Sigma) \quad (3)$$

that was specified in terms of a correlation matrix (Ω) and independent error terms specific to each population (σ_p), which were assigned vague half-normal priors:

$$\Sigma = \text{diag}(\sigma)\Omega \text{diag}(\sigma) \quad (4)$$

$$\sigma_p \sim \text{Half-Normal}(0,5).$$

The correlation matrix was freely estimated through its Cholesky factor (L_Ω) decomposition via an LKJ (Lewandowski–Kurowicka–Joe) prior distribution (Lewandowski et al. 2009):

$$L_\Omega \sim \text{LKJCorr}(\eta), \quad (5)$$

where:

$$\Omega = L_\Omega L_\Omega^\top. \quad (6)$$

In the LKJ distribution, the shape parameter (η), controls the expected degree of correlation among elements, which was fixed at 2, representing a weakly informative prior expectation of little correlation among time-series (Stan Development Team 2019). Model-predicted estimates of abundance were assumed to follow a lognormal likelihood:

$$I_{y,p} \sim \text{Lognormal}(A_{y,p}, \sigma_{obs}), \quad (7)$$

where $I_{y,p}$ is the observed abundance index (either escapement or run size depending on model) for population p in year y , and σ_{obs} is an observation error term, which was freely estimated where possible, or fixed at 0.1 in the case of escapement data, and 0.2 in the case of run size data.

Posterior sampling was achieved using No-U-Turn (NUTS) Hamiltonian Monte Carlo (HMC) via the *Stan* model building software (Stan Development Team 2023) implemented in R with the *Rstan* package (2.32.6). Convergence was assessed using the Gelman–Rubin diagnostic ($\hat{R} \leq 1.01$) (Gelman and Rubin 1992) and effective number of samples ($N_{eff} \geq 400$). Posterior sampling was monitored for divergent transitions and low Bayesian fraction of missing information (BFMI), neither of which were indicated in model fits. Posterior sampling occurred over 5 chains of 5000 iterations each, with the first 2000 constituting the warmup period and were discarded.

A key output from model fits to the escapement and run size time-series was the estimated posterior distribution of the linear trend term (u_p) for each population. A negative trend estimate is consistent with evidence of a sustained, long-term decline in a given population. In determining the strength of support for a negative trend estimate, a 95% credible interval (CI) that is negative and non-overlapping with zero is considered strong evidence of long-term, consistent decline, while a 50% CI that is negative and does not overlap with zero is considered moderate evidence. Additionally, we compared estimated abundance levels over time to the abundance level in the first year of the time-series (to assess the degree to which recent values deviate from historical ones), and the long-term median to examine the extent to which recent

variation in abundance represents short term fluctuations versus sustained departures from long-term expectations.

6.2 Southeast Gulf of Alaska ESU

6.2.1 Current populations and data descriptions

This section provides an overview of the demographic data and trends for the Southeast Gulf of Alaska (SEGOA) ESU of Chinook salmon. The analysis focuses on nine systems spanning broad geographical areas and a range of abundance levels (Table 5; Figure 2). The data, representing the most current information available as of May 28, 2025, were provided by the State of Alaska (A. Munro, ADF&G, personal communication, May 28, 2025). For all systems that we modeled within the SEGOA ESU, escapement and run size estimates are available. Furthermore, ADF&G has established BEGs for these stocks using spawner-recruit analyses (SRAs), with the Chilkat River relying on a theoretical SRA framework. A full review of escapement goals for stocks within this ESU are also available from the State of Alaska (Munro 2023b).

Table 5. -- Current Southeast Gulf of Alaska Chinook salmon systems including escapement enumeration methods, run-size availability, escapement goal methods, escapement goal type, year that current goal was established or updated, and escapement goal range. For the Initial Year column, many stocks had escapement goals prior to the date listed. Adapted from Munro (2023b).

System	Enumeration Method	Run Size Estimate	2023 Escapement Goals				
			Goal Method	Goal Type	Initial Year	Lower	Upper
Andrew Creek (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	1998	650	1,500
Blossom River (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	2018	500	1,400
Chickamin River (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	2018	2,150	4,300
Chilkat River (age 5+)	Mark-Recapture	Yes	Theoretical SRA	BEG	2003	1,750	3,500
Keta River (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	2018	550	1,300
King Salmon River (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	1997	120	240
Stikine River (lg. fish)	Mark-Recapture	Yes	SRA	BEG	2000	14,000	28,000
Taku River (lg. fish)	Mark-Recapture	Yes	SRA	BEG	2009	19,000	36,000
Unuk River (lg. fish)	PAS (Expanded)	Yes	SRA	BEG	2009	1,800	3,800

Across the SEGOA ESU, data availability varies by system (Figure 20). For most systems, escapement and run-size values are reported exclusively for large fish (≥ 660 mm from mid-eye to tail fork [METF]), with Chilkat River data limited to age 5+ individuals. These subsets, provided by ADF&G, represent the most comprehensive and representative data available for these systems. In general, escapement time-series are longer and more complete than the data available for run-size estimates.

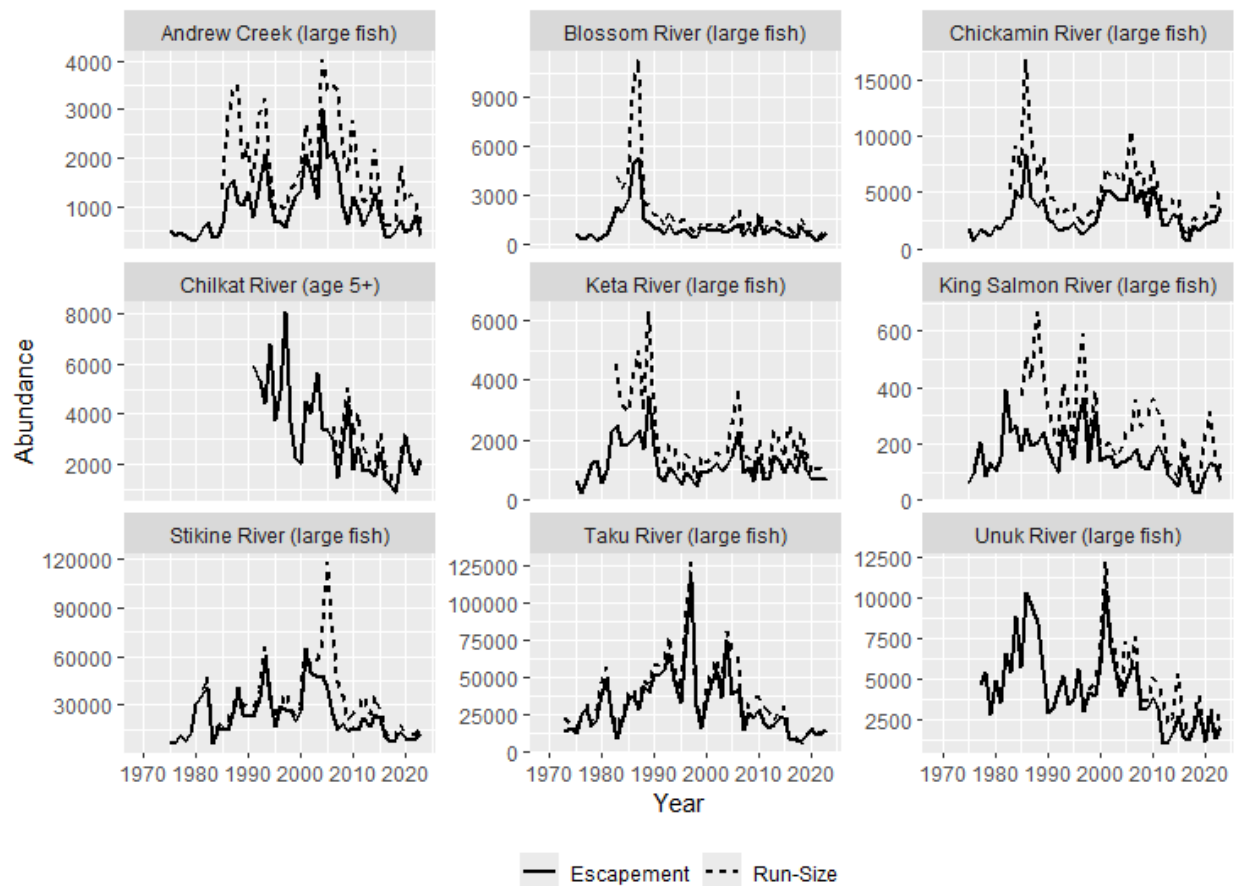


Figure 20. -- Southeast Gulf of Alaska Chinook salmon escapement and run-size.

6.2.2 Trend analyses

6.2.2.1 Short-term: Escapement

Trends across the nine river systems in the SEGOA ESU varied considerably between 1979 and 2023, with general patterns of decline seen in recent decades (Figure 21). Systems such as the Stikine, Taku, and Chilkat Rivers (no observed data available before 1991) exhibited marked decreases in escapement after the mid-1990s, following periods of higher escapement in the 1980s and early 1990s. The observed declines were most pronounced in the past two decades, with the variability in escapement levels generally decreasing over time. The analysis of the log-transformed smoothed estimates derived from the DLM across the 15-year periods (1979–1993, 1994–2008, and 2009–2023) further supports the observed patterns (Figure 22, Table 6). Early periods (1979–1993) show predominantly positive trends in escapement for systems such as Andrew Creek and Taku River, with significant increases in some cases ($p < 0.05$). However, recent decades (2009–2023) are characterized by predominantly negative trends, including

significant declines for Andrew Creek, Blossom River, Keta River, King Salmon River, Stikine River, Taku River, and Unuk River. Five-year geometric means also show declining averages across most systems since the 1990s, with some systems showing increases in the most recent years (Table 7). These results highlight a consistent pattern of declining escapement across multiple systems, particularly since 2009.

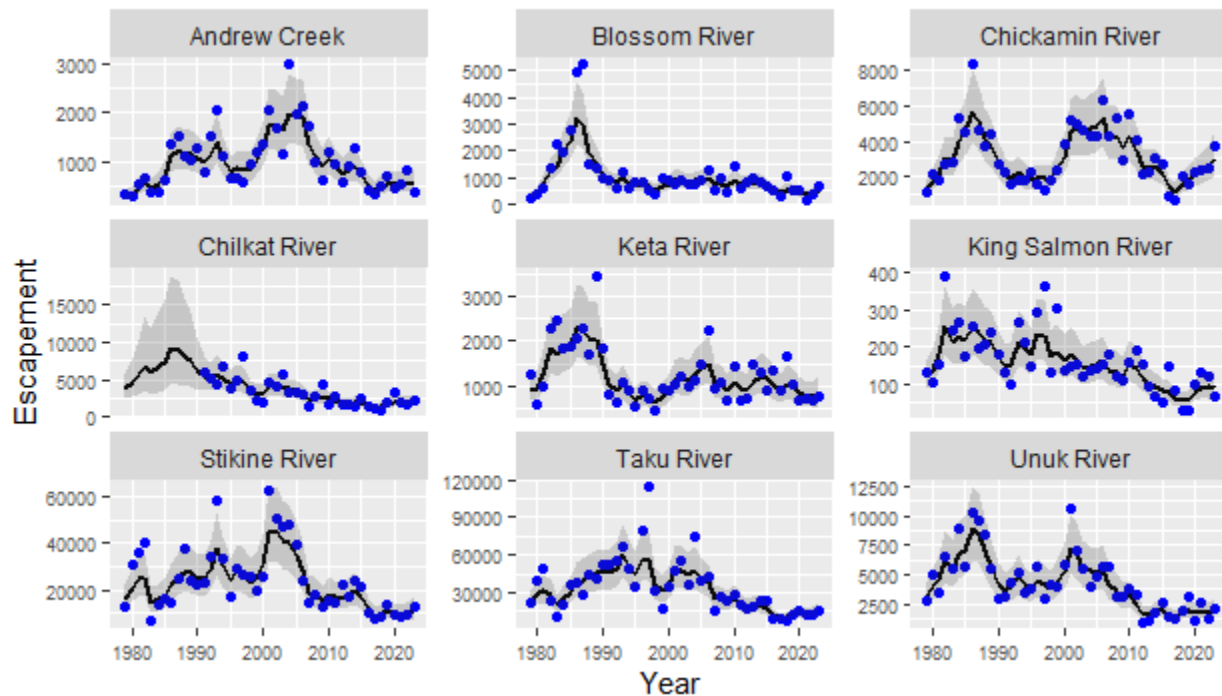


Figure 21. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Southeast Gulf of Alaska Chinook escapement. Points in blue show the annual observed escapement.

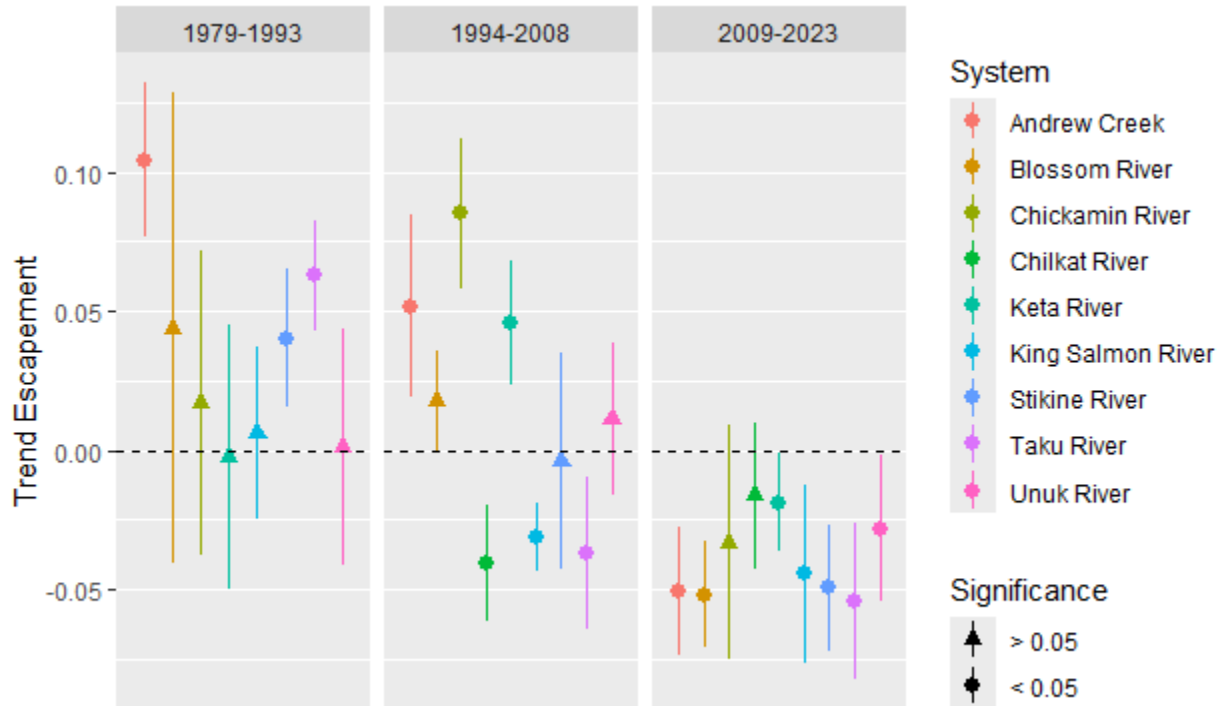


Figure 22. -- 15-year trends estimated for Southeast Gulf of Alaska Chinook escapement. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 6. -- 15-year trends (slope) in log escapement for the Southeast Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log escapement estimate versus year. Included are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first 5 years and last 5 years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Andrew Creek	0.10	0.08,0.13	0.00	0.05	0.02, 0.08	0.00	-0.05	-0.07, -0.03	0.00
Blossom River	0.04	-0.04,0.13	0.28	0.02	-0.00, 0.04	0.06	-0.05	-0.07, -0.03	0.00
Chickamin River	0.02	-0.04,0.07	0.51	0.08	0.06, 0.11	0.00	-0.03	-0.08, 0.01	0.11
Chilkat River				-0.04	-0.06, -0.02	0.00	-0.02	-0.04, 0.01	0.20
Keta River	0.00	-0.05,0.04	0.92	0.05	0.02, 0.07	0.00	-0.02	-0.04, -0.00	0.04
King Salmon River	0.01	-0.02,0.04	0.67	-0.03	-0.04, -0.02	0.00	-0.04	-0.08, -0.01	0.01
Stikine River	0.04	0.02,0.06	0.00	0.00	-0.04, 0.04	0.84	-0.05	-0.07, -0.03	0.00
Taku River	0.06	0.04,0.08	0.00	-0.04	-0.06, -0.01	0.01	-0.05	-0.08, -0.03	0.00
Unuk River	0.00	-0.04,0.04	0.95	0.01	-0.02, 0.04	0.39	-0.03	-0.05, -0.00	0.04

Table 7. -- 5-year geometric mean of escapement for Southeast Gulf of Alaska Chinook salmon stocks. Smoothed escapement estimates are shown. In parentheses, the 5-year geometric mean of observed escapement is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Andrew Creek	414 (414)	909 (893)	1148 (1268)	876 (766)	1468 (1453)	1611 (1845)	886 (825)	588 (584)	553 (560)
Blossom River	715 (670)	2436 (2905)	1034 (964)	676 (608)	808 (862)	846 (852)	772 (785)	598 (636)	456 (419)
Chickamin River	2156 (2022)	4596 (5087)	2516 (2423)	1882 (1746)	3726 (4024)	4640 (4808)	3193 (3135)	1726 (1649)	2356 (2419)
Chilkat River	5266	7982	5954 (5174)	4507 (5175)	3631 (3423)	2989 (2695)	2170 (2288)	1537 (1396)	1950 (2155)
Keta River	1285 (1327)	2080 (1956)	1232 (1299)	738 (678)	1002 (1018)	1235 (1312)	976 (926)	1066 (1195)	824 (762)
King Salmon River	176 (184)	231 (217)	177 (172)	201 (213)	167 (163)	147 (145)	125 (137)	71 (67)	79 (79)
Stikine River	19836 (20494)	21183 (19862)	28380 (30326)	26429 (25626)	36765 (37801)	26656 (26305)	16818 (16061)	12677 (12852)	10414 (10559)
Taku River	25821 (25027)	34152 (32569)	48636 (52566)	48270 (54044)	40759 (35318)	33705 (34378)	20860 (20781)	12848 (12490)	12530 (13086)
Unuk River	4568 (4432)	7559 (8402)	4375 (4051)	4010 (3886)	5750 (6231)	4615 (4510)	2288 (2112)	1686 (1727)	1851 (1911)

6.2.2.2 Short-term: Run size

Trends across nine river systems in the SEGOA ESU were analyzed for the period 1979–2023, showing substantial temporal variation and general declines in large fish in more recent decades (Figure 23). Notable systems such as the Taku River experienced peak run sizes in the late 1980s to early 1990s, and the Stikine River in the early 2000s, followed by significant reductions after the early 2000s. Other systems, including the Blossom and Keta Rivers, exhibited more gradual declines over time, while some systems, such as the Chickamin River, displayed periods of recovery within the mid-1990s to early 2000s. The smoothed trends highlight variability across systems but consistently indicate declining run sizes during the 2009–2023 period, with some systems showing slight increases in the last five years. Run size trends revealed shifts from positive or neutral trends in earlier periods to significant negative trends in more recent decades (Figure 24, Table 8). For the 1979–1993 period, systems such as the Stikine and Taku Rivers exhibited positive trends, though not all were significant. These two systems were the only systems for which run size information was available for the earliest period. From 1994 to 2008, systems like Andrew Creek, Stikine River, and Chickamin River showed moderate positive trends, while others began to decline. In the 2009–2023 period, all systems, with the exception of King Salmon River, showed significant negative trends. Average

run sizes across 5-year blocks further supported the observed declines (Table 9). Early periods (1979–1993) recorded the highest run sizes for several systems; however, more recent blocks (2009–2023) indicated marked reductions. Andrew Creek, and the Chickamin, Chilkat, and King Salmon Rivers are showing increases in the most recent 5-year period. Collectively, these results indicate significant and widespread reductions in run sizes across river systems in the last 15 years.

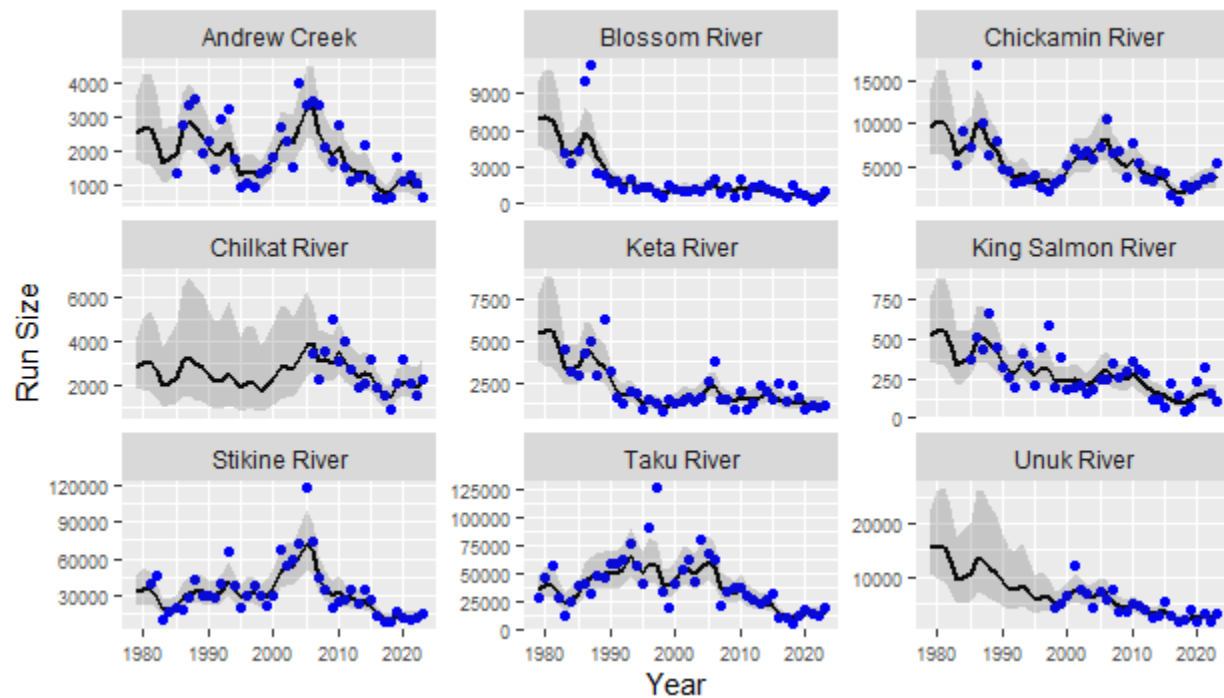


Figure 23. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Southeast Alaska Chinook run size. Points in blue show the annual observed run size.

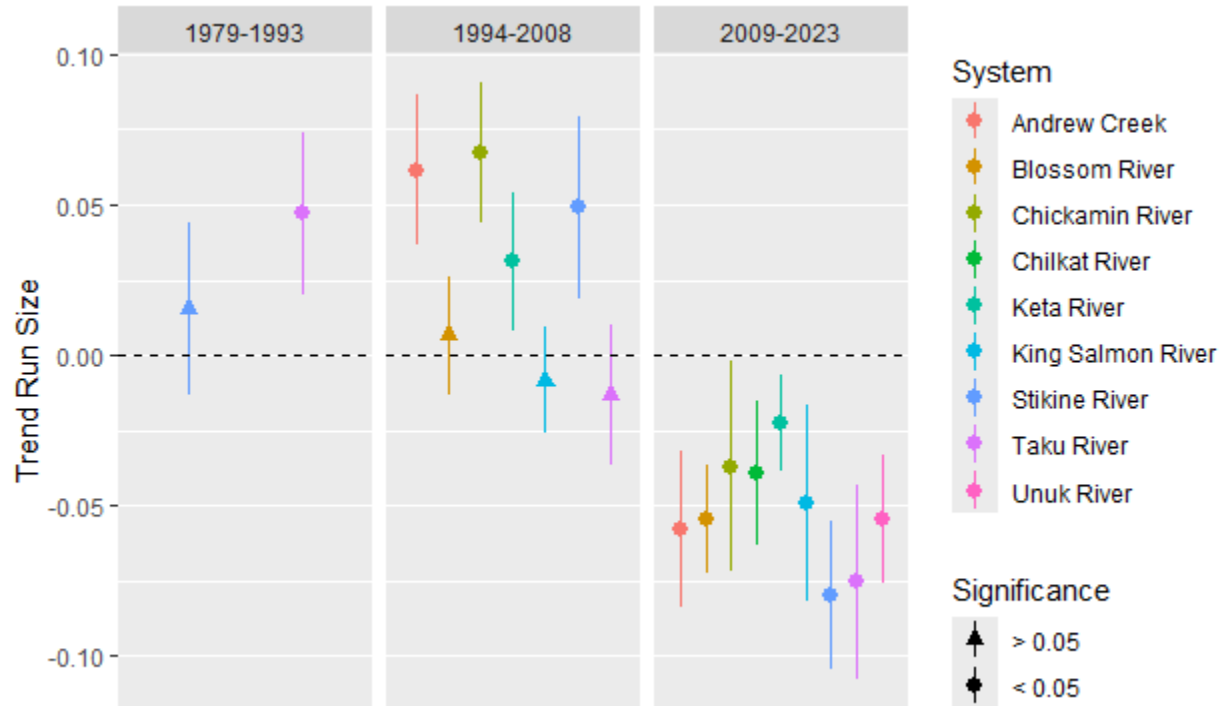


Figure 24. -- 15-year trends estimated for Southeast Alaska Chinook run size. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 8. -- 15-year trends (slope) in log run size for the Southeast Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log run size versus year. Included are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first 5 years and last 5 years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Andrew Creek				0.06	0.04, 0.09	0.00	-0.06	-0.08, -0.03	0.00
Blossom River				0.01	-0.01, 0.03	0.48	-0.05	-0.07, -0.04	0.00
Chickamin River				0.07	0.04, 0.09	0.00	-0.04	-0.07, -0.00	0.04
Chilkat River							-0.04	-0.06, -0.02	0.00
Keta River				0.03	0.01, 0.05	0.01	-0.02	-0.04, -0.01	0.01
King Salmon River				-0.01	-0.03, 0.01	0.33	-0.05	-0.08, -0.02	0.01
Stikine River	0.02	-0.01, 0.04	0.27	0.05	0.02, 0.08	0.00	-0.08	-0.10, -0.06	0.00
Taku River	0.05	0.02, 0.07	0.00	-0.01	-0.04, 0.01	0.23	-0.08	-0.11, -0.04	0.00
Unuk River							-0.05	-0.08, -0.03	0.00

Table 9. -- 5-year geometric mean of run size for Southeast Gulf of Alaska Chinook salmon stocks. Smoothed run size estimates are shown. In parentheses, the 5-year geometric mean of observed run size is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Andrew Creek	2306	2333 (2580)	2106 (2280)	1379 (1158)	1950 (1902)	2762 (3213)	1682 (1572)	977 (901)	998 (1098)
Blossom River	5912	4607 (5306)	2012 (1777)	1161 (1062)	1143 (1200)	1311 (1281)	1132 (1133)	863 (980)	662 (605)
Chickamin River	8879	8324 (9291)	4807 (4464)	3313 (3050)	5102 (5604)	6921 (7232)	4688 (4525)	2698 (2539)	3333 (3495)
Chilkat River	2695	2769	2457	2040	2554	3436 (3044)	2965 (3198)	1940 (1814)	2086 (2207)
Keta River	4815	3825 (3573)	2286 (2393)	1282 (1185)	1423 (1418)	1869 (1974)	1491 (1337)	1501 (1839)	1221 (1102)
King Salmon River	478	441 (485)	336 (310)	286 (323)	230 (213)	267 (252)	226 (261)	121 (103)	143 (155)
Stikine River	28989 (27075)	26469 (24036)	33471 (36738)	30964 (30396)	43671 (42610)	54408 (63012)	29023 (26139)	16442 (16367)	13345 (13230)
Taku River	33128 (30284)	37875 (36039)	53663 (59951)	52209 (62259)	47226 (41029)	47429 (46908)	29034 (30205)	14828 (13751)	14045 (14619)
Unuk River	13524	11572	8552	5914	6418 (7227)	5937 (5401)	3860 (3691)	2497 (2515)	2321 (2409)

6.2.2.3 Long-term: Escapement

Of the populations comprising the SEGOA ESU, estimated posterior distributions for the linear trend term (u_p) overlapped zero for both the 50% and 95% credibility intervals across all stocks in model fits to the escapement data (Figure 25). While there was little support for evidence of sustained, long-term declines in escapement as indicated by the trend estimate, some stocks showed signs of more recent declines. In particular, several stocks experienced a downward trend in escapement abundance beginning in the early-mid 2000s. For instance, the Chilkat River's escapement has consistently declined since the early 2000s, and has remained below the stock's long-term median escapement level for much of the past two decades. Similarly, the Unuk River showed a pronounced decline in escapement abundance in 2012, and has remained well below historical escapement levels since then (Figure 25). Several other stocks, such as the King Salmon River, Stikine River, and Taku River, have also shown recent declines in escapement levels below the long-term median since the early to mid 2010s (Figure 25). While the escapement abundance of other stocks, such as Andrew Creek, Blossom River, Chickamin River, and Keta River, has been low in some recent years, these variations appear within the scope of the populations' historical variability in escapements (Figure 25). The estimated correlation matrix (Ω) from model fits to the SEGOA ESU indicated moderate-to-strong synchrony (positive correlations) for interannual variation in escapement abundance between

the Blossom River, Keta River, Andrew Creek, Chickamin River, and Unuk River stocks (Figure 26). Similarly, the Chilkat River, Stikine River, and Taku River stocks showed evidence of synchrony in escapement abundance trends over time (Figure 26).

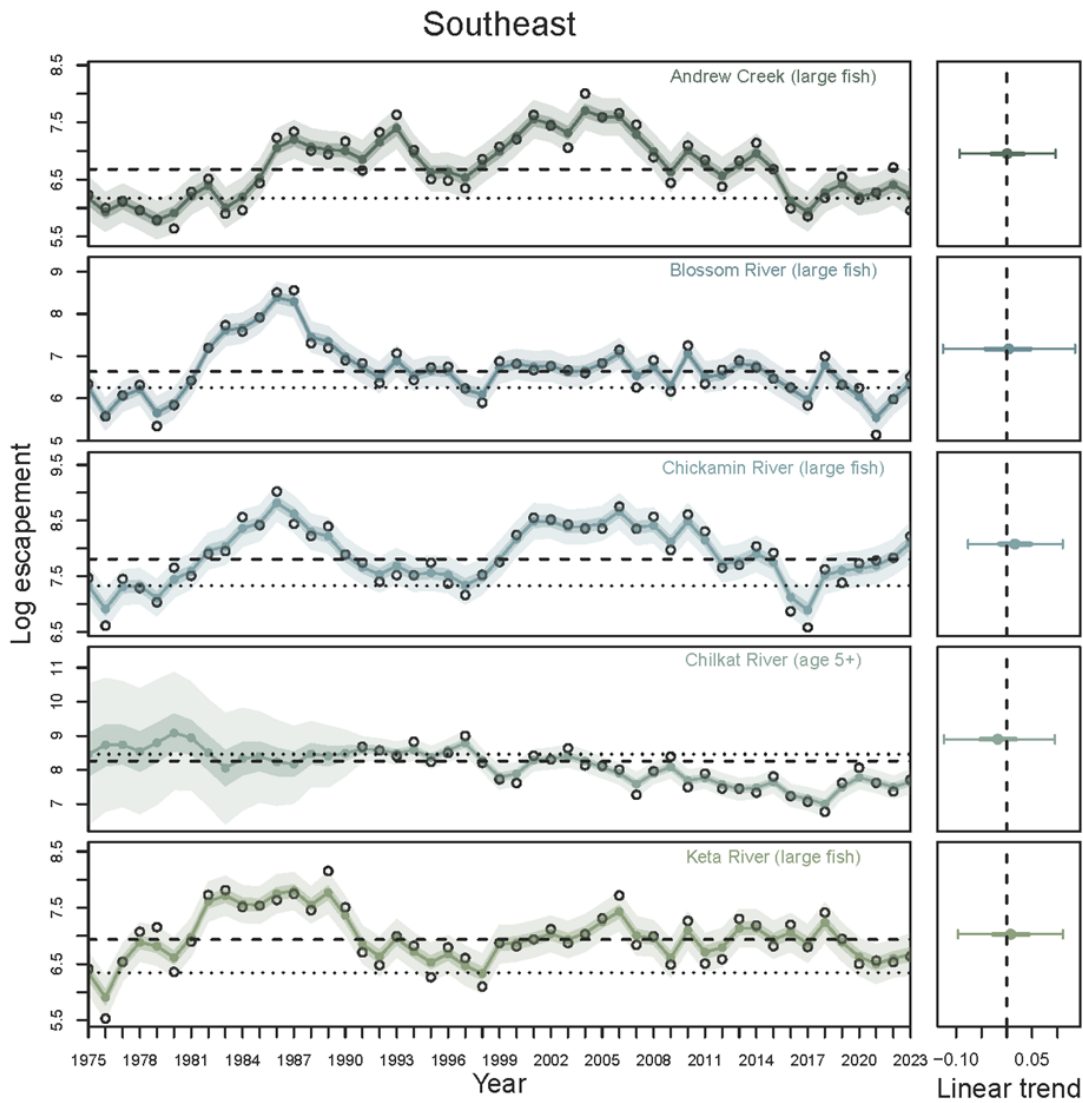


Figure 25. -- Southeast Gulf of Alaska ESU model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Southeast Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

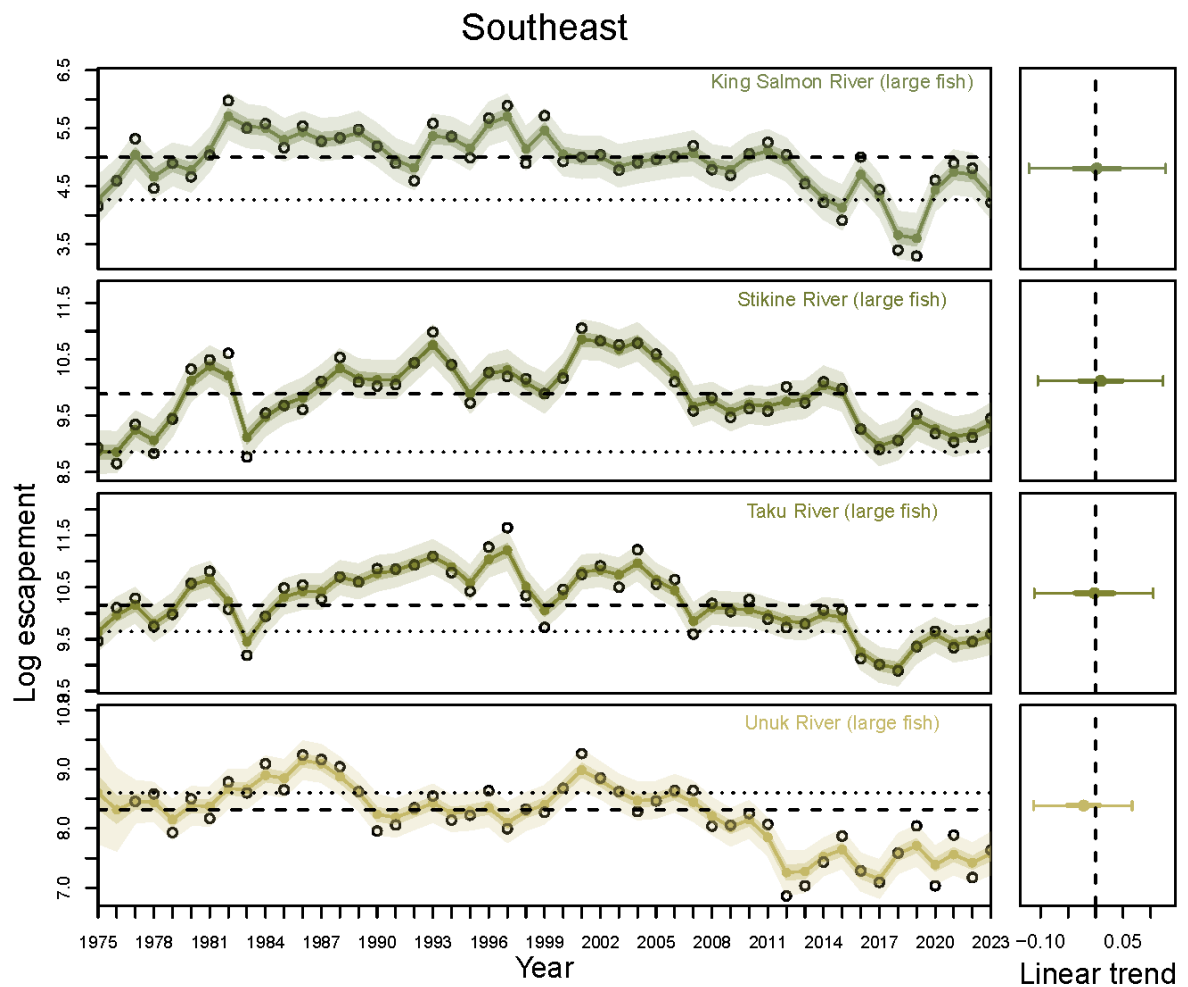


Figure 25. -- Continued. Southeast Gulf of Alaska ESU model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Southeast Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

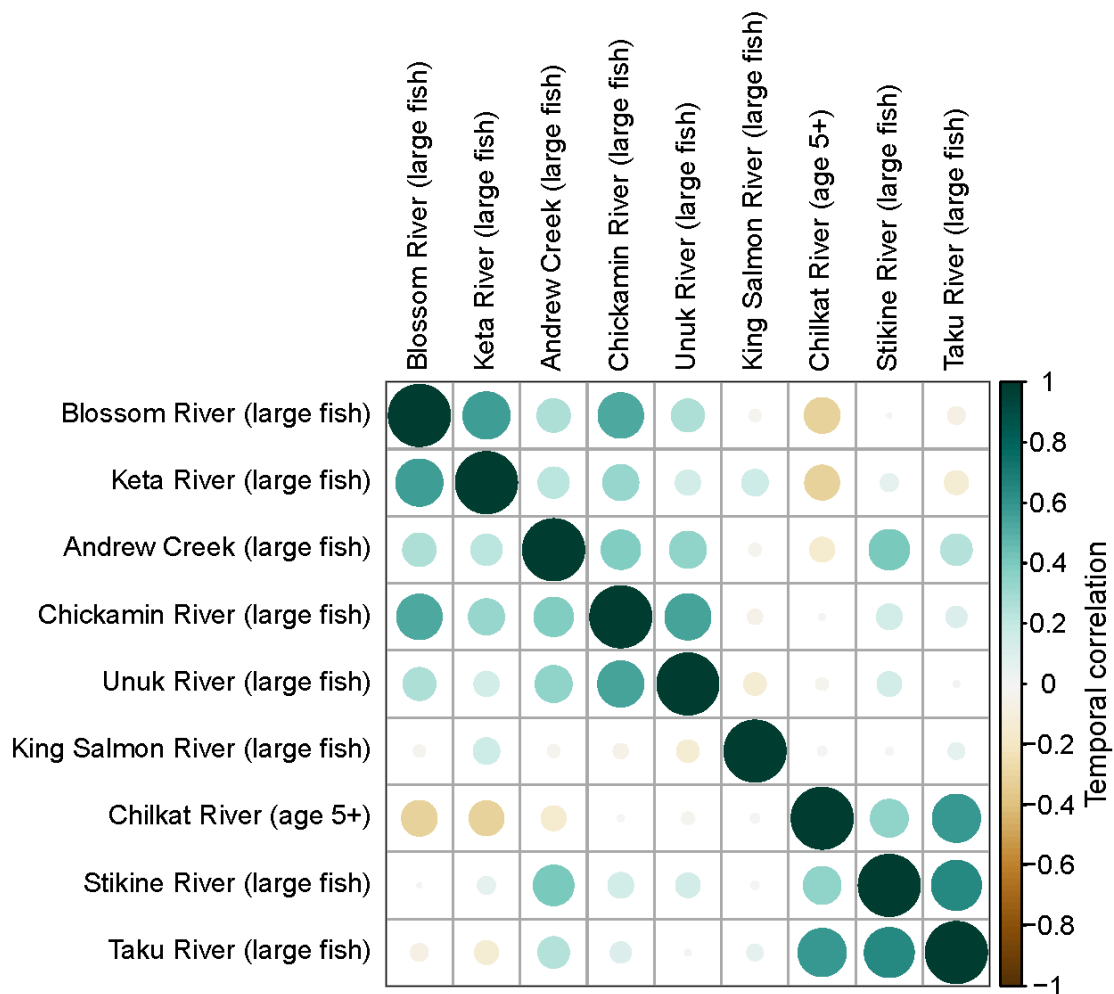


Figure 26. -- Estimated correlation matrix ($\hat{\Omega}$) from model fits to the Southeast Gulf of Alaska ESU's escapement data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.2.2.4 Long-term: Run size

Estimated posterior distributions for the linear trend term (u_p) from model fits to total run size overlapped zero for both the 50% and 95% credibility intervals across all stocks with available run size data within the SEGOA ESU (Figure 27). While there was little support for evidence of

sustained, long-term declines as indicated by the trend estimates, some stocks exhibited signs of more recent declines in run size. For instance, the Unuk River has shown a steady decline in run size since the early 2000s, and has consistently remained below the long-term median run size for this population (Figure 27). While some other stocks have recently shown transient reductions in run size, such as the Taku River, King Salmon River and Chickamin River, these fluctuations appear within the scope of historical variability and recent abundance levels have been near the long-term median/early run sizes for these stocks in several years (Figure 27). The estimated correlation matrix (Ω) from model fits to the SEGOA ESU's run size data indicated moderate-to-strong synchrony (positive correlations) for interannual variation in run size between the Chilkat and Taku Rivers, between the Blossom and Keta Rivers, and between the Blossom and Chickamin Rivers (Figure 28).

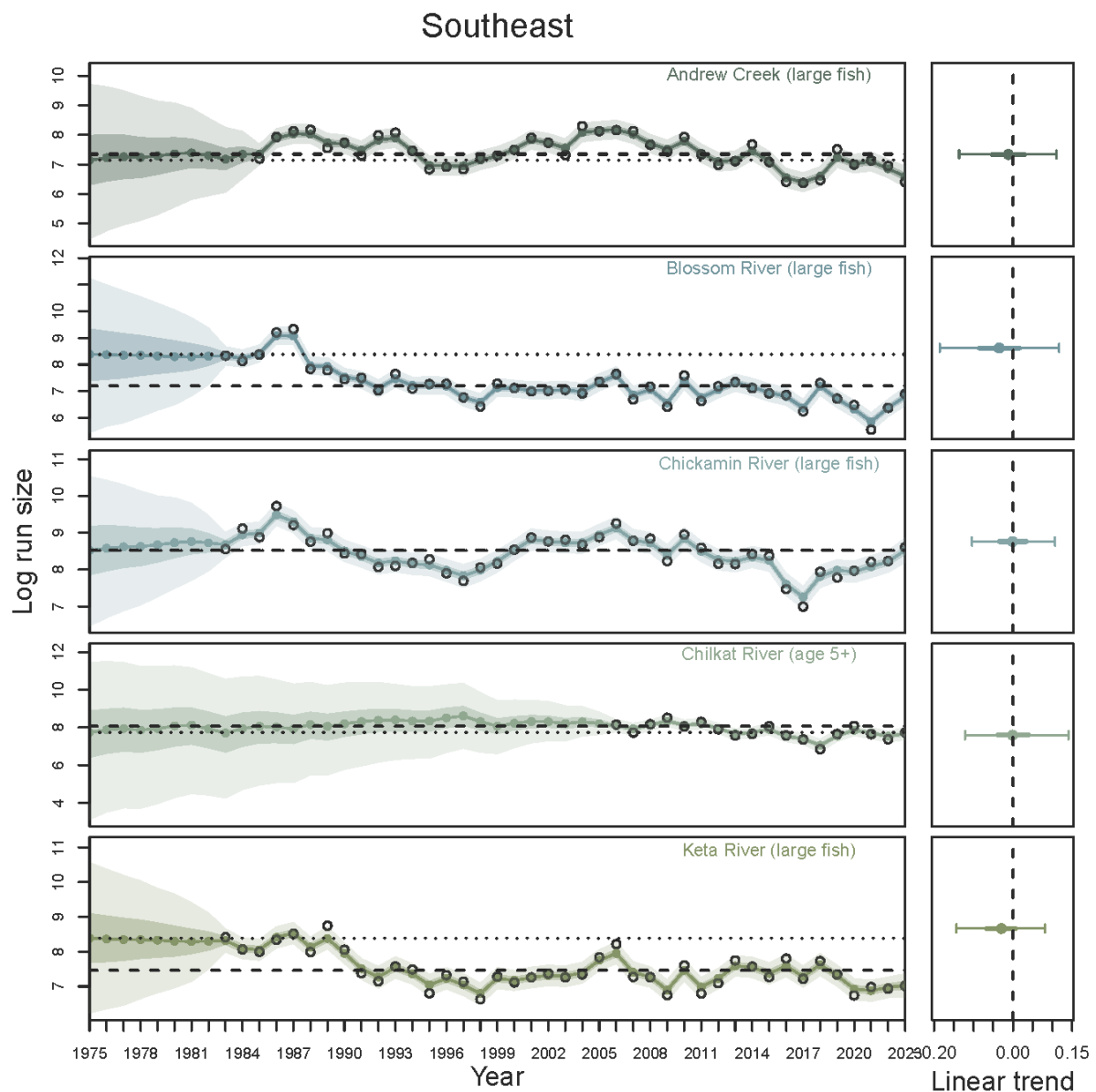


Figure 27. -- Southeast Gulf of Alaska ESU model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Southeast Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

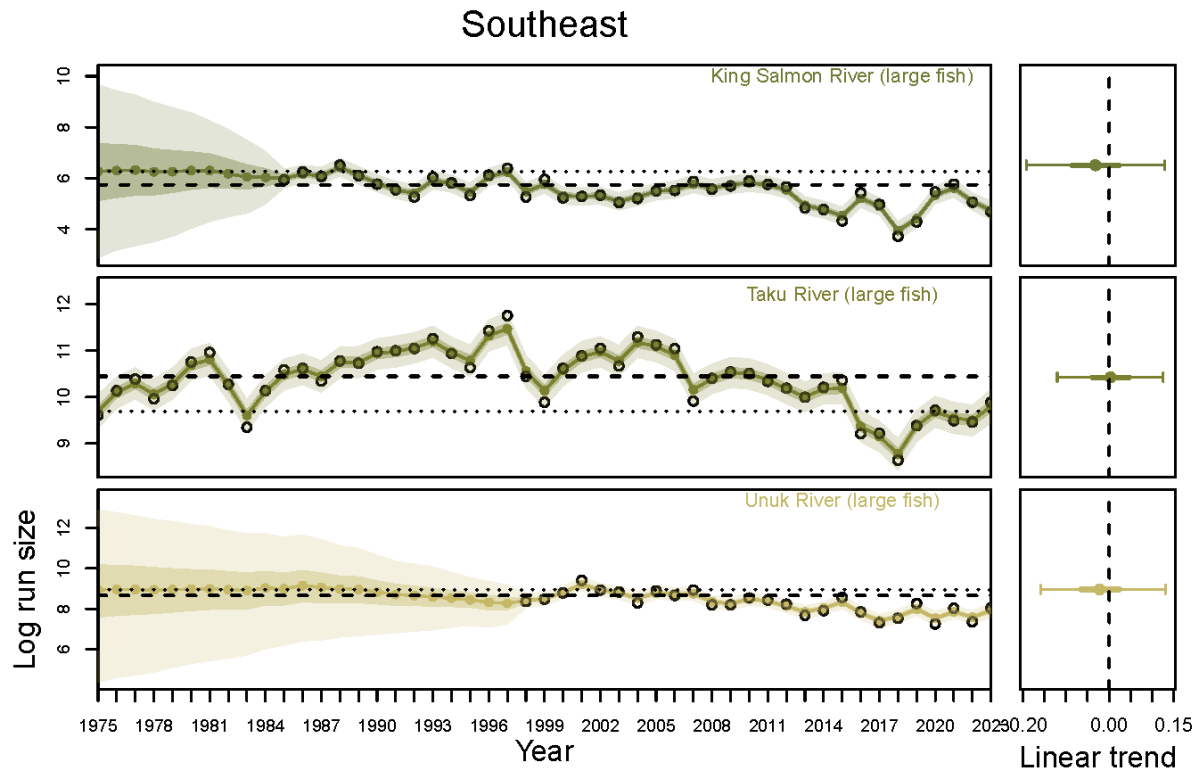


Figure 27. -- Continued. Southeast Gulf of Alaska ESU model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Southeast Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

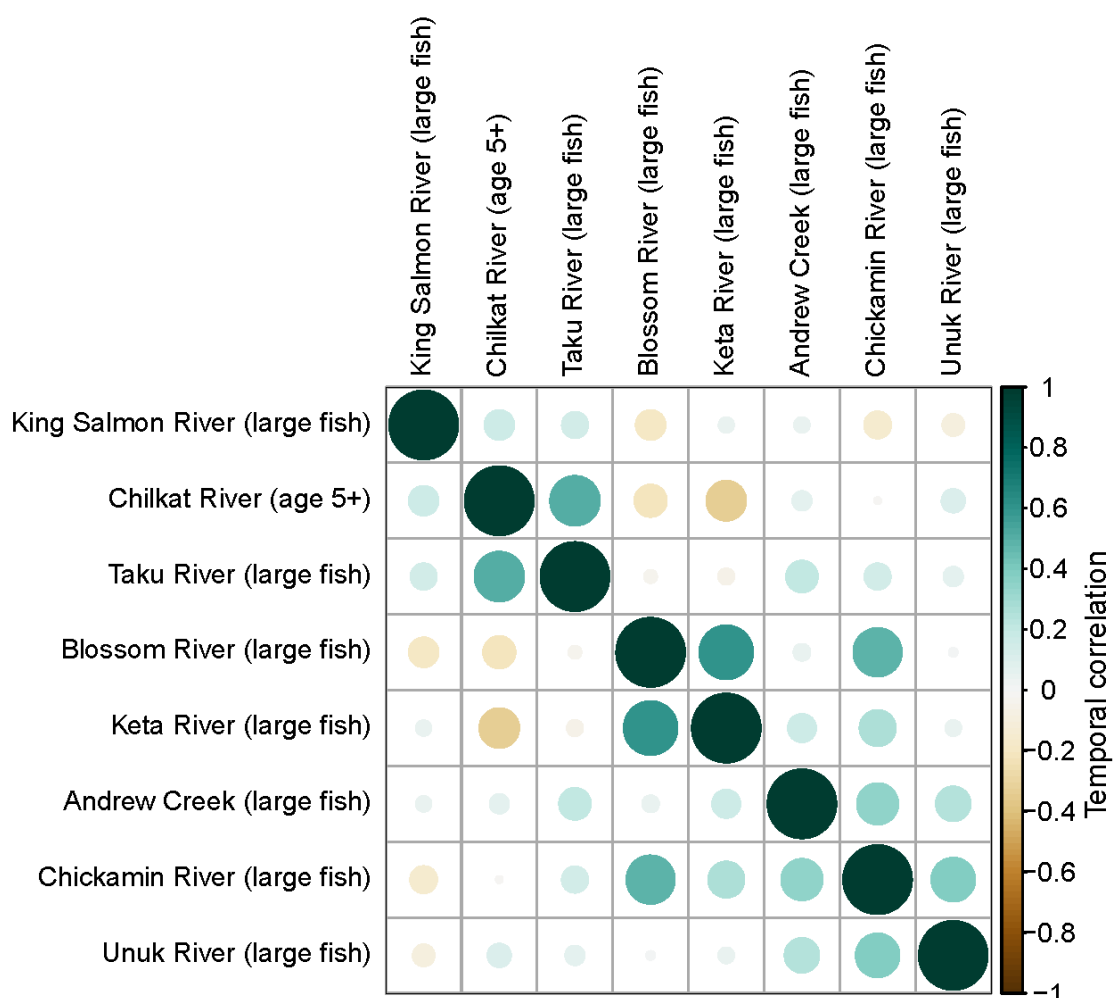


Figure 28. -- Estimated correlation matrix ($\hat{\Omega}$) from model fits to the Southeast Gulf of Alaska ESU's run size data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.2.3 Summary of Southeast Gulf of Alaska ESU demographic analyses

Short-term and long-term analyses of escapement and run size trends for the Southeast Gulf of Alaska ESU of Chinook salmon present a complex picture of population dynamics. While long-term trends do not provide strong evidence of sustained declines across the ESU, short-term analyses highlight more recent declines in several stocks, particularly since the early 2000s and 2010s. Escapement has decreased in systems such as the Chilkat, Unuk, King Salmon, Stikine, and Taku Rivers, but these declines generally remain within the scope of historical variability.

Some stocks, including King Salmon, Taku, and Chilkat Rivers, have shown early signs of recovery in recent years, a pattern that contrasts with the declines noted in earlier short-term assessments. Run size trends follow a similar trajectory, with notable reductions in the past 15 years but some signs of stabilization or increase in specific stocks, particularly in the most recent 5-year period. These recent increases suggest that while short-term trends have raised concerns, they may not necessarily indicate sustained long-term declines, and in some cases, they may represent transient fluctuations rather than directional shifts in population viability.

Escapement trends exhibit clear clustering in the degree of synchrony among stocks, with stocks such as Andrew Creek and Blossom, Keta, Chickamin, and Unuk Rivers demonstrating correlated trends, while Chilkat, Stikine, and Taku Rivers form a second, distinct group. In contrast, run size trends display weaker coherence among stocks. This contrast between patterns of synchrony by escapement versus run size could reflect the role of fisheries management on mixed stock harvest in response to fluctuating abundance levels.

Despite evidence of declines in the short term, long-term trend estimates indicate that observed changes largely fall within the range of historical variability. Some stocks, such as the Unuk River, have exhibited more persistent declines in escapement and run size, yet the overall trend across the ESU does not strongly support a conclusion of long-term decline. Stocks that experienced short-term reductions, such as the Taku and King Salmon Rivers, have shown recent increases. However, the persistence of such increases remains uncertain, as short-term improvements may be temporary fluctuations rather than indicators of sustained recovery. The contrast between short-term declines and long-term stability underscores the importance of continued monitoring, as recent stabilizations may either signal a reversal of previous declines or reflect natural fluctuations within a broader historical context. Understanding whether short-term declines translate into persistent long-term changes remains a key challenge, particularly given the influence of large-scale oceanographic and climatic drivers that may shape future population trajectories.

6.3 Central Gulf of Alaska ESU

6.3.1 Current populations and data descriptions

This section provides an overview of the demographic data and trends for the Central Gulf of Alaska ESU of Chinook salmon. The analysis focuses on three systems with a range of abundance levels (Table 10; Figure 3). These time-series represent the most current information available as of October 4, 2024, and were provided by the State of Alaska (A. Munro, ADF&G, personal communication, October 4, 2024). For all systems we analyzed within the Central Gulf of Alaska ESU, escapement and total run-size estimates are available. Furthermore, ADF&G has established BEGs for the Alsek and Situk Rivers and an SEG for the Copper River. All goals were established using SRAs for all stocks. A full review of escapement goals for stocks within this ESU is also available from the State of Alaska (Munro 2023b).

Table 10. -- Current Central Gulf of Alaska Chinook salmon systems including escapement enumeration methods, run-size availability, escapement goal methods, escapement goal type, year that current goal was established or updated, and escapement goal range. For the Initial Year column, many stocks had escapement goals prior to the date listed. Adapted from Munro (2023b).

System	Enumeration Method	Run Size Estimate	2023 Escapement Goals				
			Goal Method	Goal Type	Initial Year	Lower	Upper
Alsek River (age 4+)	Weir Count (Expanded)	Yes	SRA	BEG	2013	3,500	5,300
Copper River	Mark-Recapture	Yes	SRA	SEG	2022	21,000	31,000
Situk River (lg. fish)	Weir Count	Yes	SRA	BEG	2003	450	1,050

Across the CGOA ESU, data availability is near complete for the three systems (Figure 29). For the Alsek River, abundance is presented for age 4+ individuals and large fish only for the Situk River. These subsets, provided by ADF&G, represent the most comprehensive and representative data available for these systems.

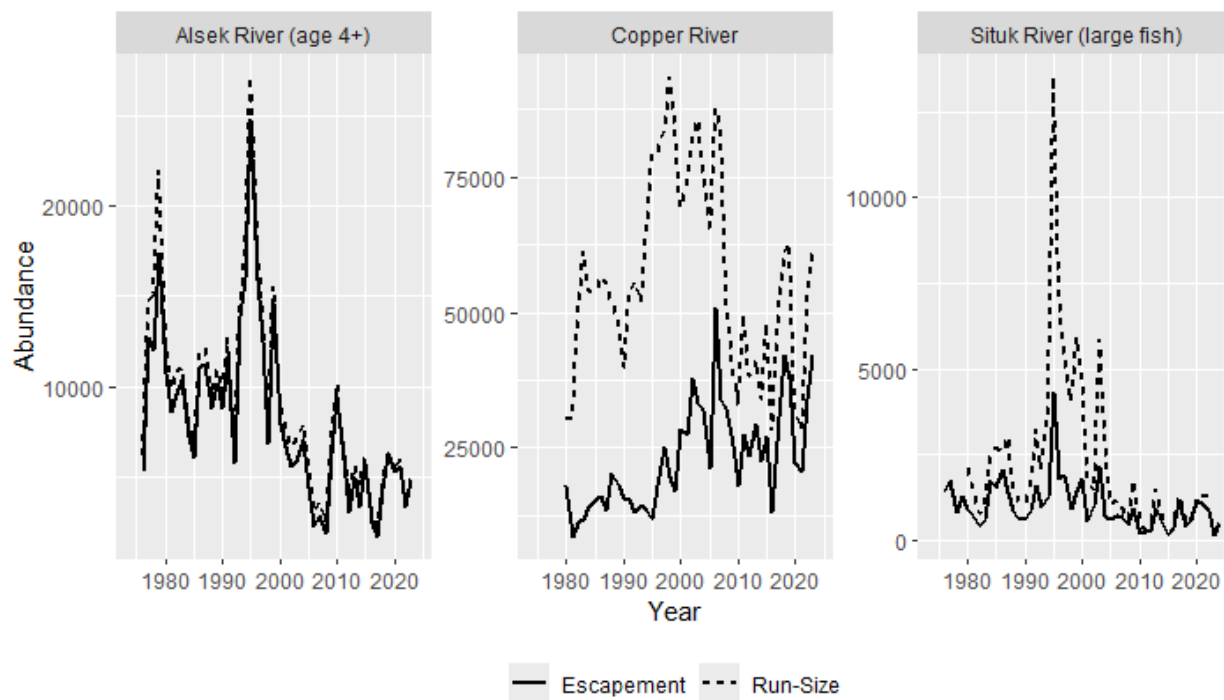


Figure 29. -- Central Gulf of Alaska Chinook salmon escapement and run-size.

6.3.2 Trend analyses

6.3.2.1 Short-term: Escapement

Trends for the Alsek, Copper, and Situk Rivers were evaluated from 1979 to 2023, with distinct patterns of variability across systems (Figure 30). The Copper River exhibited a strong and consistent increase in escapement over the time series, particularly after the mid-1990s, reaching peak levels around 2020. In contrast, the Alsek River showed a marked decline in escapement from the mid-1990s, stabilizing at lower levels after 2000. The Situk River demonstrated high interannual variability, with an overall declining trend, particularly between 1994 and 2013, followed by a modest recovery in the most recent decade. Trends analysis across three time periods (1979–1993, 1994–2008, 2009–2023) highlights differences in escapement dynamics among the systems (Figure 31, Table 11). The Copper River exhibited significant positive trends in all periods, indicative of consistent growth over time. The Situk River displayed a positive trend in the earliest period, a significant decline from 1994 to 2008, and a modest recovery from 2009 to 2023. In contrast, the Alsek River showed a significant negative trend in 1994–2008, while trends in other periods were nonsignificant. Five-year block geometric averages further illustrate these trends (Table 12). The Copper River showed continuous increases in escapement, while the Alsek River experienced a marked decrease in average escapement after 1994, before stabilizing in the last decade. The Situk River displayed fluctuating escapement levels, with higher averages observed in 1994–1998, followed by reductions during 2009–2018, before a slight increase in 2019–2023. Collectively, these results emphasize variable escapement dynamics, with pronounced declines in the Alsek and Situk Rivers, and sustained growth in the Copper River.

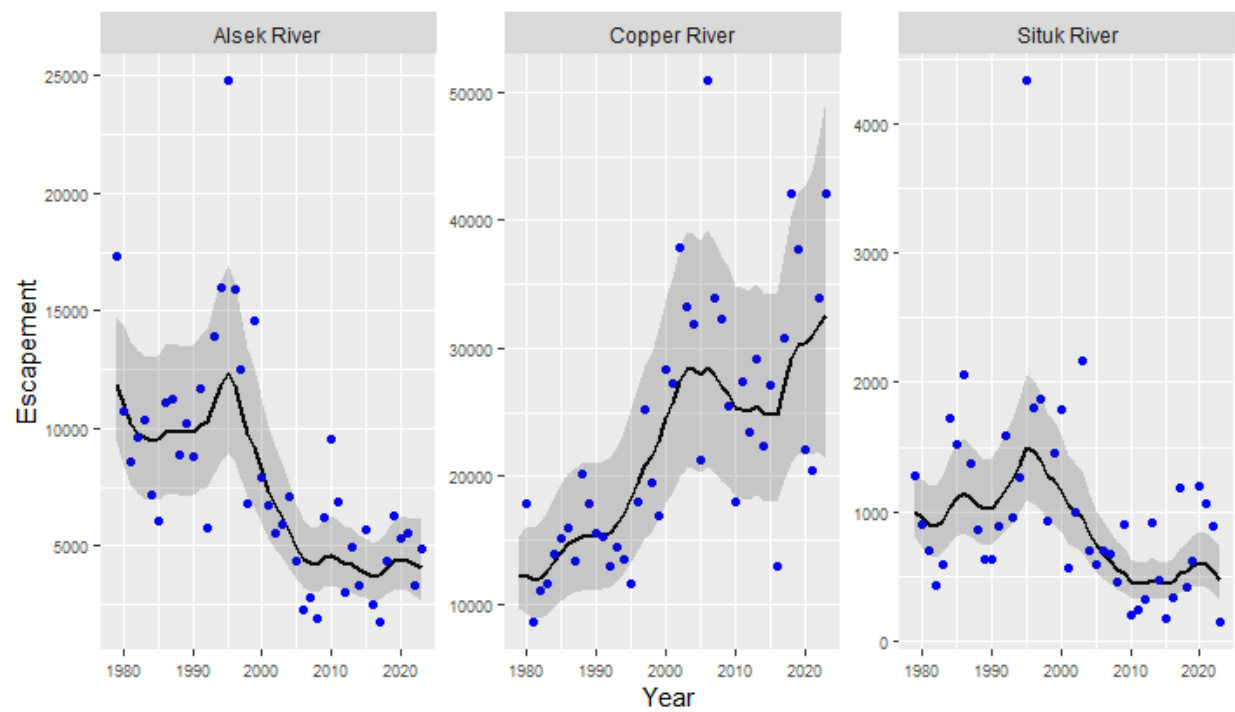


Figure 30. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Central Gulf of Alaska Chinook escapement. Points in blue show the annual observed escapement.

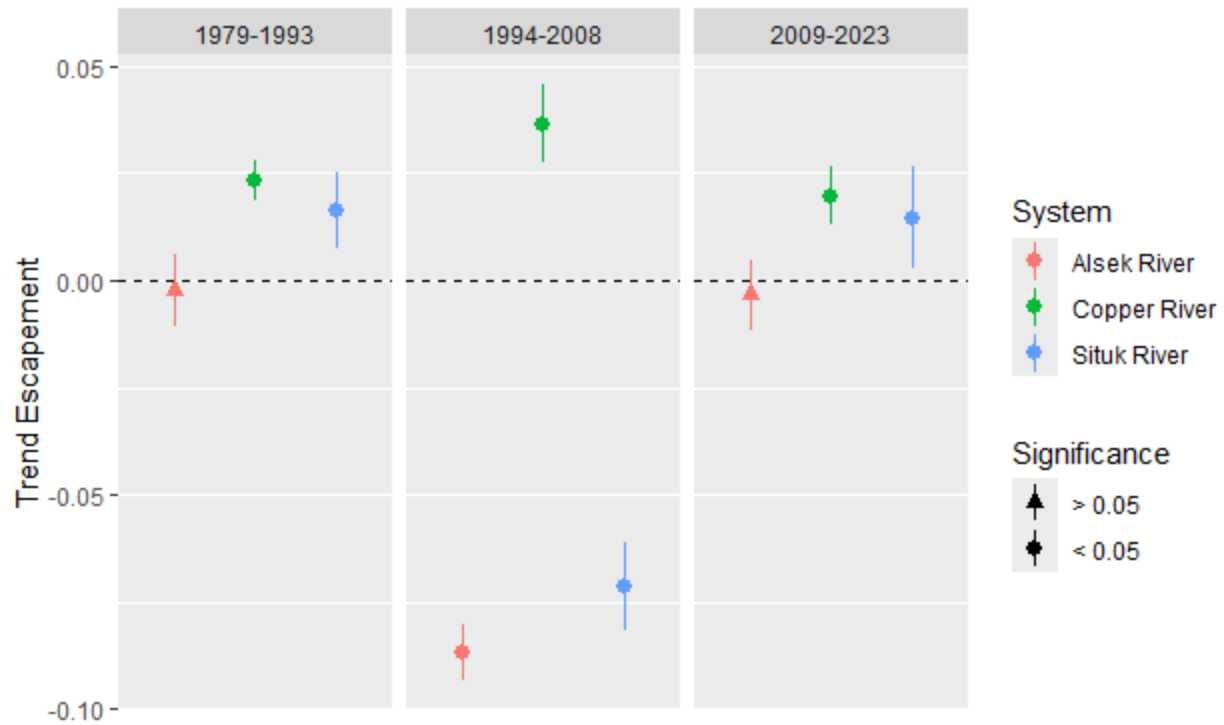


Figure 31. --15-year trends estimated for Central Gulf of Alaska Chinook escapement. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 11. -- 15-year trends (slope) in log escapement for the Central Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log escapement estimate versus year. Included are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first five years and last five years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Alsek River	0.00	-0.01, 0.01	0.54	-0.09	-0.09, -0.08	0.00	0.00	-0.01, 0.00	0.39
Copper River	0.02	0.02, 0.03	0.00	0.04	0.03, 0.05	0.00	0.02	0.01, 0.03	0.00
Situk River	0.02	0.01, 0.03	0.00	-0.07	-0.08, -0.06	0.00	0.01	0.00, 0.03	0.02

Table 12. -- 5-year geometric mean of escapement for Central Gulf of Alaska Chinook salmon stocks. Smoothed escapement estimates are shown. In parentheses, the 5-year geometric mean of observed escapement is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Alsek River	10468 (10963)	9727 (8653)	10237 (9651)	11261 (14000)	7461 (7607)	4663 (3289)	4377 (5725)	3885 (3252)	4278 (4974)
Copper River	12209 (11865)	14467 (15560)	15537 (15145)	19373 (16891)	25728 (27738)	27949 (32788)	25505 (24349)	26125 (25199)	31208 (29980)
Situk River	934 (732)	1090 (1454)	1106 (884)	1401 (1766)	1075 (1260)	677 (617)	468 (416)	483 (427)	557 (632)

6.3.2.2 Short-term: Run size

Trends for the Alsek, Copper, and Situk Rivers from 1979 to 2023 exhibited significant temporal variation and system-specific patterns (Figure 32). The Copper River displayed consistently high run sizes, peaking during the late 1990s, followed by a decline post-2000 and partial recovery in recent years. The Alsek River demonstrated a pronounced decline in run size starting in the mid-1990s, stabilizing at lower levels from 2000 onward. In contrast, the Situk River showed highly variable trends, with significant peaks during the mid-1990s, followed by sharp declines and modest recovery in the last 5 years. Analysis of trends across three periods (1979–1993, 1994–2008, 2009–2023) reveals distinct dynamics among the systems (Figure 33, Table 13). The Copper River exhibited a significant positive trend during 1979–1993, a significant negative trend from 1994 to 2008, and a nonsignificant positive trend from 2009 to 2023. The Alsek River showed a significant negative trend in 1994–2008, with nonsignificant trends during the other periods. The Situk River experienced significant positive trends in both 1979–1993 and 2009–2023, but a marked and significant negative trend during 1994–2008. Five-year block averages further illustrate these patterns (Table 14). The Copper River consistently recorded the highest run sizes, peaking during 1994–1998 and subsequently declining to 2009–2013 levels, with a partial rebound in 2019–2023. The Alsek River exhibited a decline in earlier years, with a modest recovery in 2019–2023. The Situk River displayed substantial variability, with its highest average in 1994–1998, followed by declines during 2004–2018, and a recent increase in 2019–2023. These results emphasize significant declines in run sizes across systems during the mid-period (1994–2008), with variable recovery patterns in the most recent years.

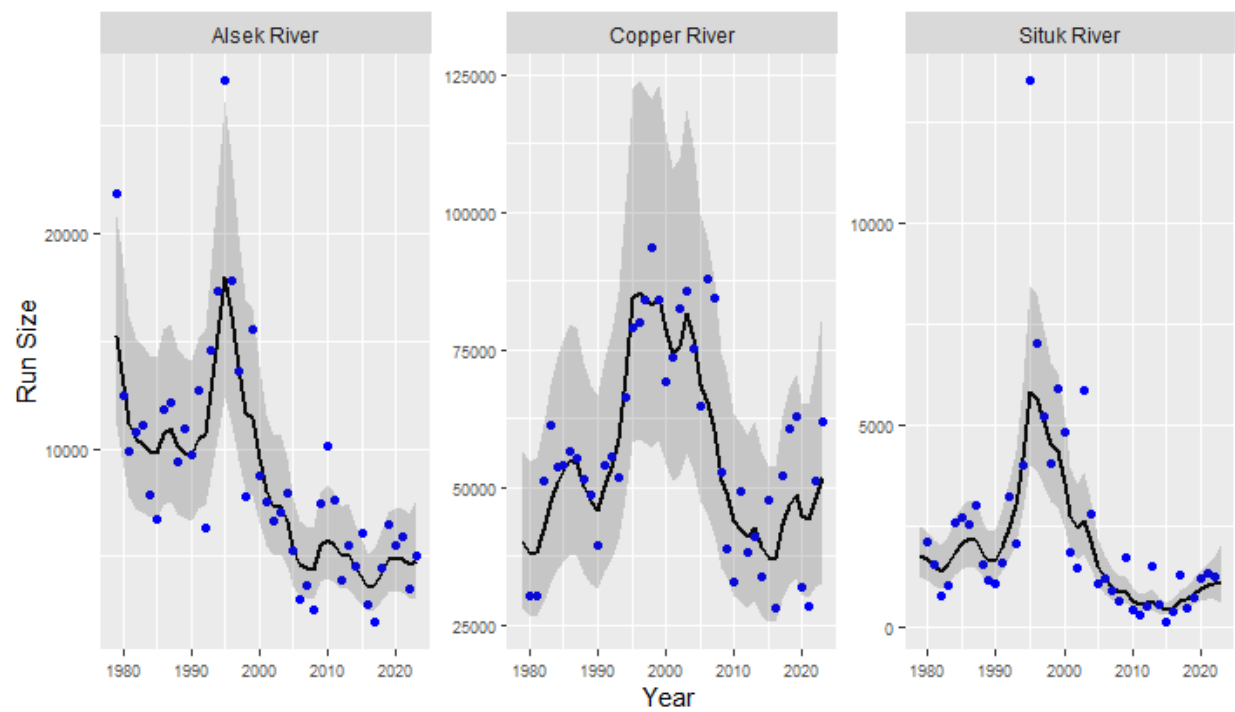


Figure 32. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Central Gulf of Alaska Chinook run size. Points in blue show the annual observed run size.

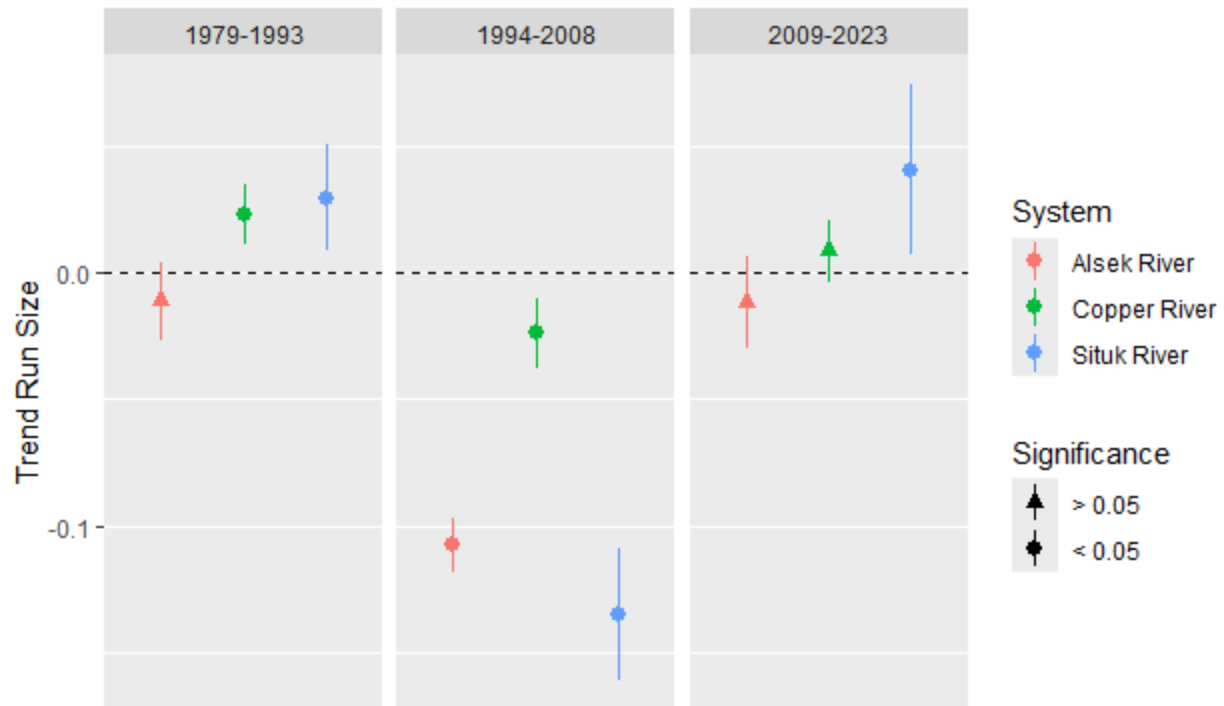


Figure 33. -- 15-year trends estimated for Central Gulf of Alaska Chinook run size. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 13. -- 15-year trends (slope) in log run size for the Central Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log run size versus year. Included are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first five years and last five years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Alsek River	-0.01	-0.03, 0.00	0.15	-0.11	-0.12, -0.10	0.00	-0.01	-0.03, 0.01	0.18
Copper River	0.02	0.01, 0.04	0.00	-0.02	-0.04, -0.01	0.00	0.01	-0.00, 0.02	0.16
Situk River	0.03	0.01, 0.05	0.01	-0.13	-0.16, -0.11	0.00	0.04	0.01, 0.07	0.02

Table 14. --5-year geometric mean of run size for Central Gulf of Alaska Chinook salmon stocks.

Smoothed run size estimates are shown. In parentheses, the 5-year geometric mean of observed run size is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Alsek River	11886 (12652)	10292 (9347)	10619 (10447)	14828 (15486)	8597 (8658)	5015 (4120)	5376 (6614)	3975 (3652)	4822 (5188)
Copper River	41057 (41157)	52614 (54285)	51066 (49590)	81262 (80154)	78997 (78857)	64003 (71833)	43733 (39686)	40522 (42844)	47451 (44836)
Situk River	1570 (1280)	2009 (2430)	2095 (1684)	5007 (6053)	3078 (3391)	1278 (1167)	663 (717)	540 (439)	1005 (1105)

6.3.2.3 Long-term: Escapement

For all three stocks comprising the Central Gulf of Alaska ESU, the estimated 50% and 95% credible intervals for the linear trend term (u_p) overlapped with zero, suggesting little evidence of consistent long-term declines in escapement (Figure 34). Trends in escapement abundance were weakly positive for the Copper River, while both the Alsek and Situk Rivers exhibited a weakly negative trend in escapement abundance in the early 2000s (Figure 34). Nonetheless, escapement levels for the Alsek and Situk have fluctuated considerably in the past two decades, and have been near or at the long-term median escapement abundance in several years within this period (Figure 34). The estimated correlation matrix (Ω) indicated little evidence of coherence among any of the Central Gulf of Alaska ESU stocks, indicating that temporal variability in escapement abundance is largely independent among the stocks that comprise this ESU (Figure 35).

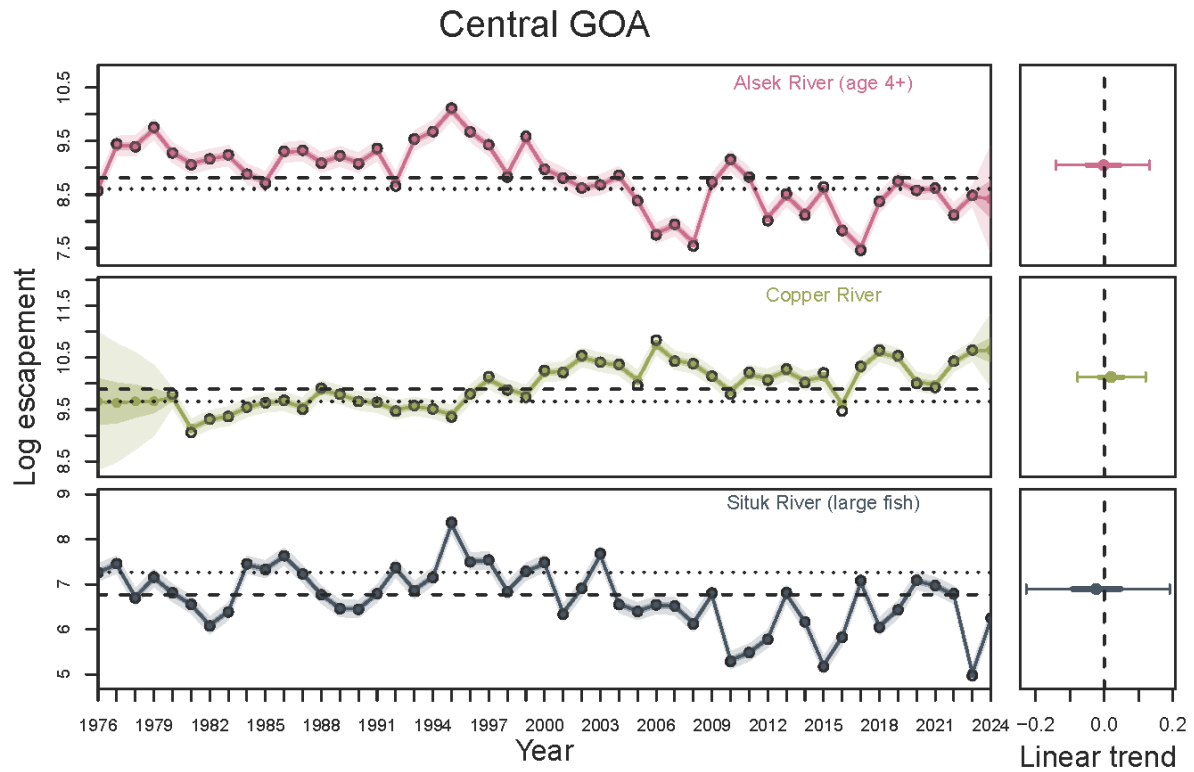


Figure 34. -- Central Gulf of Alaska ESU model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Central Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right-hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

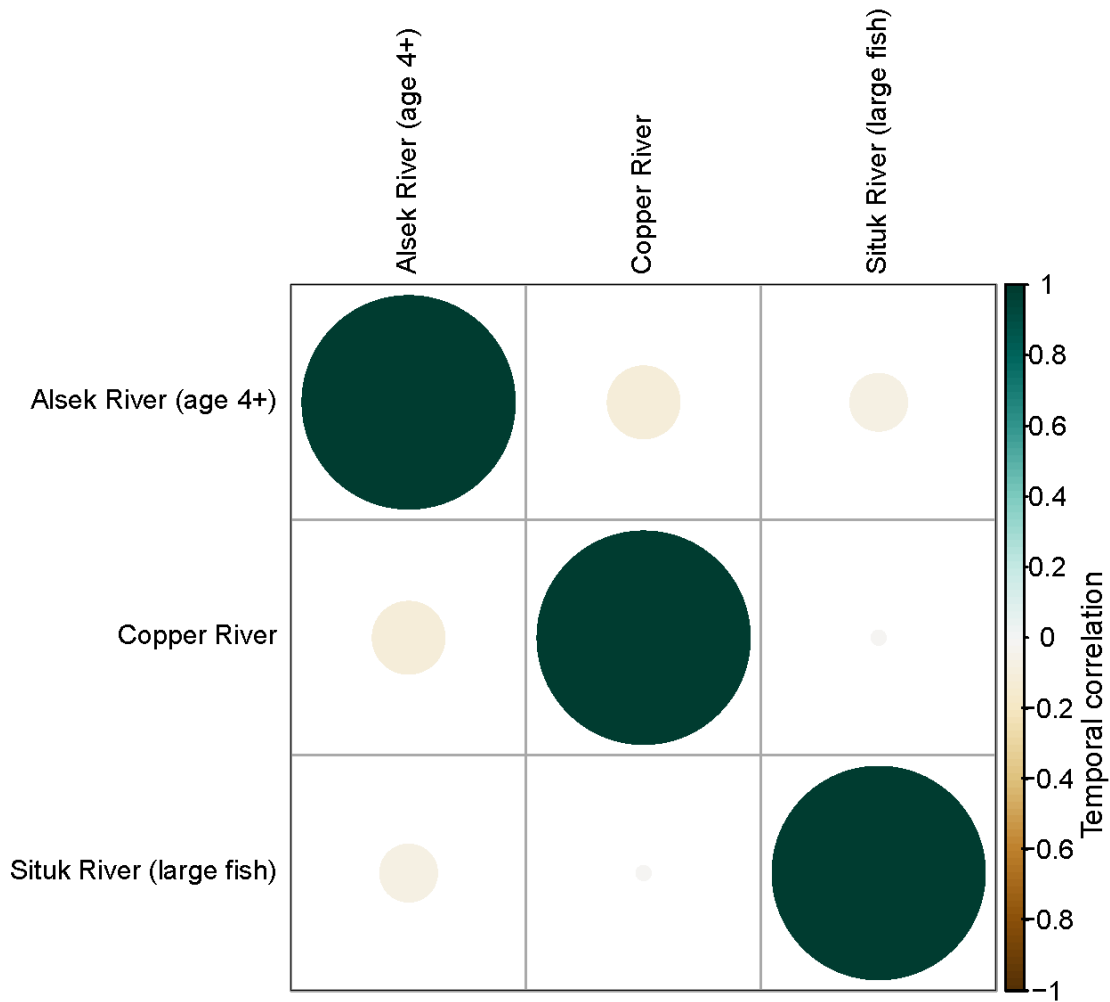


Figure 35. --Estimated correlation matrix (Ω) from model fits to the Central Gulf of Alaska ESU's escapement data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.3.2.4 Long-term: Run size

For all three stocks comprising the Central Gulf of Alaska ESU, the estimated 50% and 95% credible intervals for the linear trend term (u_p) overlapped with zero, suggesting little evidence of consistent long-term declines in run size for these stocks (Figure 36). However, all three stocks have shown reduced run size since the early 2000s (Figure 36). Nonetheless, even during this period, run sizes have been at or near long-term median/historically observed values in several years, particularly for the Situk and Copper Rivers (Figure 36). The estimated correlation matrix (Ω) indicated little evidence of coherence among any of the Central Gulf of Alaska ESU

stocks, indicating that temporal variability in run size is largely independent among the stocks that comprise this ESU (Figure 37).

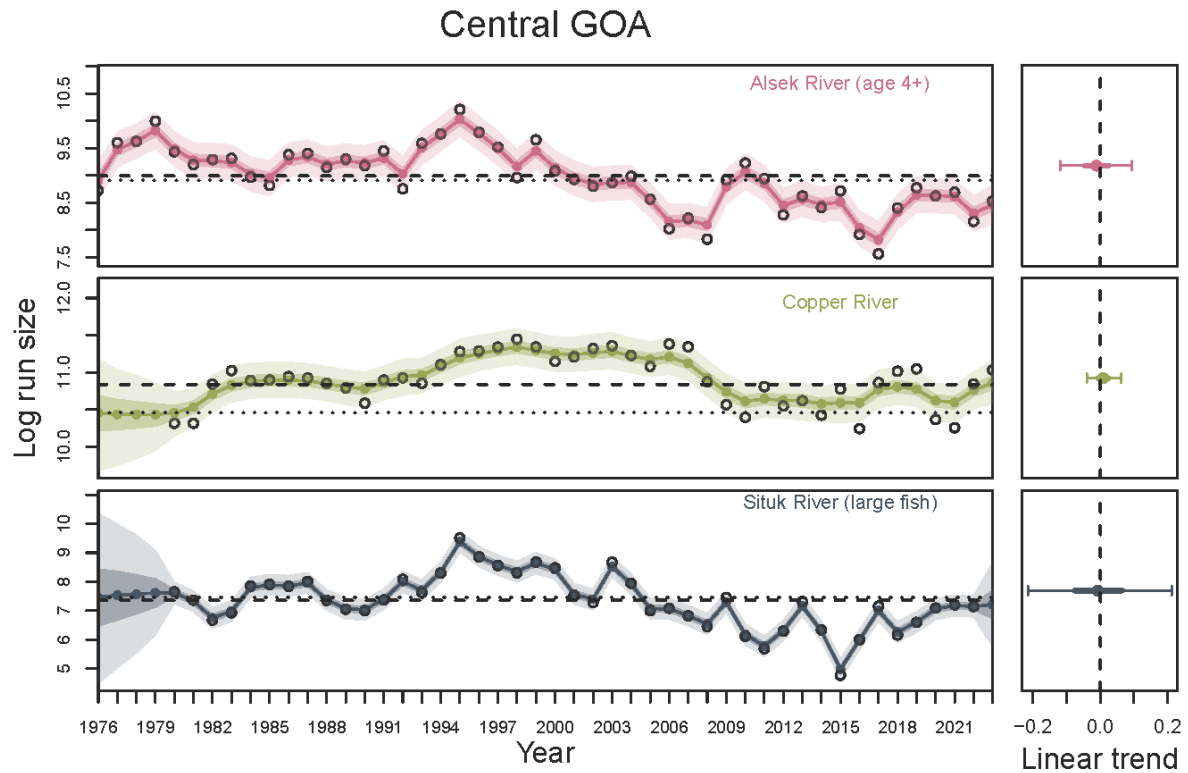


Figure 36. -- Central Gulf of Alaska ESU model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Central Gulf of Alaska ESU. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

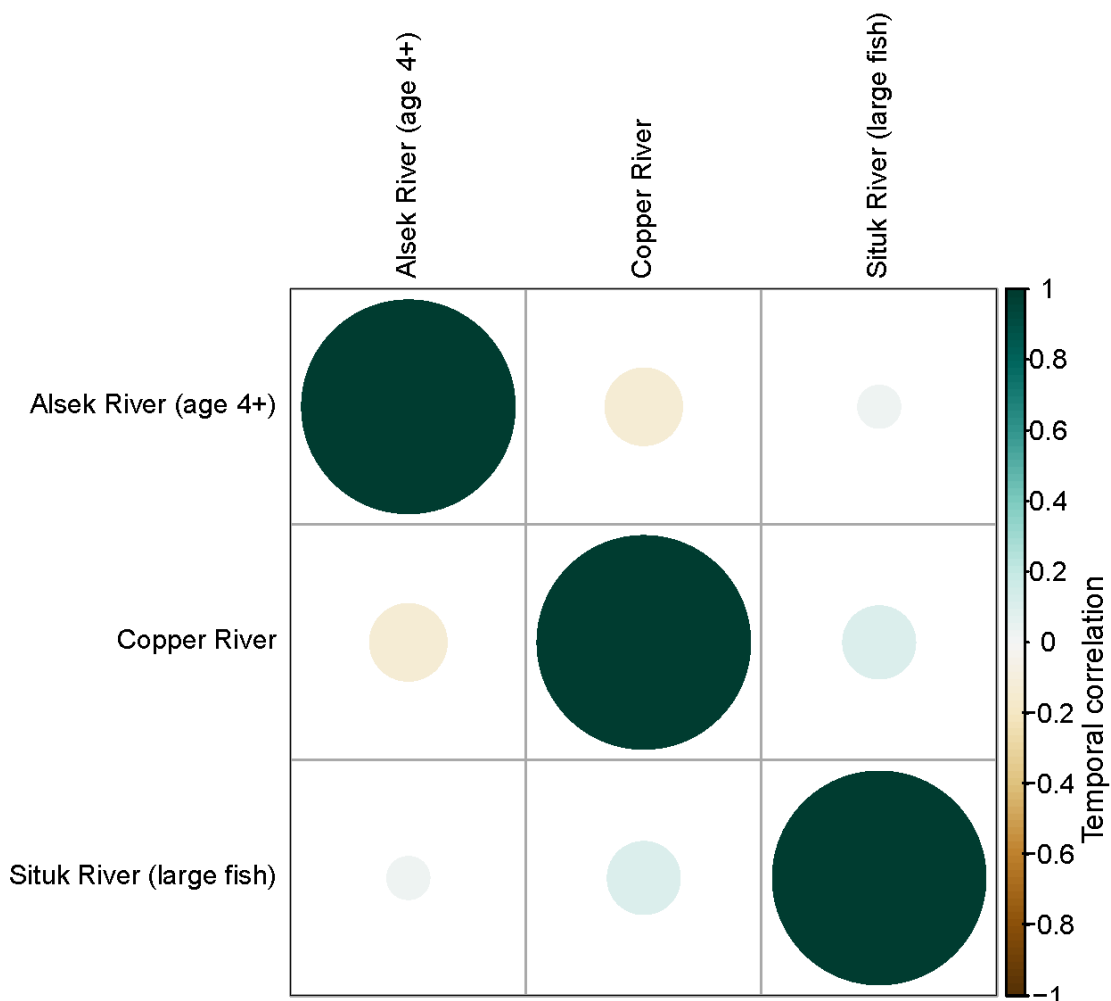


Figure 37. -- Estimated correlation matrix ($\hat{\Omega}$) from model fits to the Central Gulf of Alaska ESU's run size data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.3.3 Summary of Central Gulf of Alaska ESU demographic analyses

Short-term and long-term analyses of escapement and run size trends for the Central Gulf of Alaska ESU of Chinook salmon indicate an overall stable population trajectory, with no strong evidence of sustained declines across the ESU. However, short-term analyses highlight more recent declines in specific stocks, particularly the Alsek and Situk Rivers, where both escapement and run size have decreased since the early 2000s. While these declines were initially pronounced, recent abundance levels in both rivers have been near long-term median values. In contrast, the Copper River has exhibited a long-term pattern of increasing escapement over multiple decades. This divergence in trends underscores the variability among

stocks within the ESU, where some systems have shown short-term reductions while others have remained stable or increased.

A notable characteristic of the Central Gulf of Alaska ESU is the lack of strong interannual synchrony among stocks for both escapement and run size. The absence of synchronous population trends suggests that stock dynamics may be influenced more by localized environmental or biological factors rather than broad-scale drivers affecting multiple systems simultaneously. This is particularly evident when comparing the distinct trajectories of the Alsek and Situk Rivers, which experienced mid-period declines, to the Copper River, which has exhibited consistent positive trends over time. Run size trends similarly lack strong coherence, suggesting that fluctuations in one system are not necessarily reflective of broader trends across the ESU.

Short-term analyses reveal significant declines in run size for the Alsek and Situk Rivers between 1994 and 2008, followed by stabilization or modest recovery in the past decade. In contrast, the Copper River experienced a peak in run size in the late 1990s, followed by a decline post-2000 and partial recovery in recent years. These patterns suggest that while stocks within this ESU have undergone fluctuations, their population dynamics remain largely independent of one another. The variability observed in short-term trends highlights the importance of assessing each stock individually rather than inferring broader ESU-wide trends based on changes in any single system.

Long-term analyses further support the conclusion that there is little evidence of sustained declines in either escapement or run size across the Central Gulf of Alaska ESU. While the Alsek and Situk Rivers experienced periods of lower abundance, recent abundance levels have also been near long-term median levels, suggesting that declines may have represented transient fluctuations rather than a persistent downward trend. The Copper River's long-term increase in escapement provides further contrast, reinforcing the overall stability of the ESU when viewed across a broader temporal scale. The lack of strong correlations among stocks suggests that the factors influencing population dynamics may be system-specific rather than regionally uniform. Given these findings, continued monitoring remains essential to determine whether recent stabilizations persist and to further understand the underlying mechanisms driving variability in individual stocks.

6.4 Northwest Gulf of Alaska ESU

6.4.1 Current populations and data descriptions

This section provides an overview of the demographic data and trends for the Northwest Gulf of Alaska ESU of Chinook salmon. The analysis focuses on 19 stocks with a broad range of abundance levels (Table 15; Figure 4). These time-series represent the most current information available as of October 4, 2024, and were provided by the State of Alaska (A. Munro, ADF&G, personal communication, October 4, 2024). Within the Northwest Gulf of

Alaska ESU, escapement is available for all of the stocks and total run-size estimates are available for only ten of the stocks. For these stocks, ADF&G has established escapement goals using BEGs for 5 of the stocks, SEGs for 12 of the stocks, and a lower bound SEG for 2 of the stocks. These goals were established using a mix of SRAs, percentile approaches, and risk analysis for Campbell Creek. A full review of escapement goals for stocks within this ESU is also available from the State of Alaska (Munro 2023b).

Table 15. -- Current Northwest Gulf of Alaska Chinook salmon systems including escapement enumeration methods, run-size availability, escapement goal methods, escapement goal type, year that current goal was established or updated, and escapement goal range. For the Initial Year column, many stocks had escapement goals prior to the date listed. Adapted from Munro (2023b).

System	Enumeration Method	Run Size Estimate	2023 Escapement Goals				
			Goal Method	Goal Type	Initial Year	Lower	Upper
Alexander Creek	Single Aerial Survey	No	Percentile	SEG	2020	1,900	3,700
Anchor River	Sonar, Weir Count	Yes	SRA	SEG	2017	3,800	7,600
Ayakulik River	Weir Count	Yes	SRA	BEG	2017	4,800	8,400
Campbell Creek	Single Foot Survey	No	Risk Analysis	LB SEG	2011	380	-
Chignik River	Weir Count	Yes	SRA	BEG	2002	1,300	2,700
Chuitna River	Single Aerial Survey	No	Percentile	SEG	2020	1,000	1,500
Chulitna River	Single Aerial Survey	No	Percentile	SEG	2020	1,200	2,900
Crooked Creek	Weir Count	No	Percentile	SEG	2020	700	1,400
Deep Creek	Single Aerial Survey	No	Percentile	LB SEG	2017	350	-
Deshka River	Run Reconstruction	Yes	SRA	BEG	2020	9,000	18,000
Eastside Susitna River	Run Reconstruction	Yes	SRA	BEG	2020	13,000	25,000
Karluk River	Weir Count	Yes	SRA	BEG	2011	3,000	6,000
Kenai R. - Early Run (lg. fish)	Sonar	Yes	SRA	SEG	2017	2,800	5,600
Kenai R. - Late Run (lg. fish)	Sonar	Yes	SRA	SEG	2017	13,500	27,000
Little Susitna River	Weir Count	No	Percentile	SEG	2017	2,100	4,300
	Single Aerial Survey	No	Percentile	SEG	2020	700	1,500
Ninilchik River	Weir Count	No	Percentile	SEG	2017	750	1,300
Talkeetna River	Run Reconstruction	Yes	SRA	SEG	2020	9,000	17,500
Theodore River	Single Aerial Survey	No	Percentile	SEG	2020	500	1,000
Yentna River	Run Reconstruction	Yes	SRA	SEG	2020	13,000	22,000

Across the Northwest Gulf of Alaska ESU, data availability varies greatly by system (Figure 38). These time series, provided by ADF&G, represent the most comprehensive and representative data available for these systems. For systems with both escapement and run-size, the time series of escapement is generally longer. ADF&G does not produce estimates of run-size for the

following stocks: Alexander Creek, Campbell Creek, Chuitna River, Chulitna River, Crooked Creek, Deep Creek, Little Susitna River, Ninilchik River, and Theodore River. All of the stocks without run-size data are in the Upper and Lower Cook Inlet management areas. ADF&G only uses the Little Susitna River Chinook salmon aerial survey goal to assess escapement if weir counts are not available.

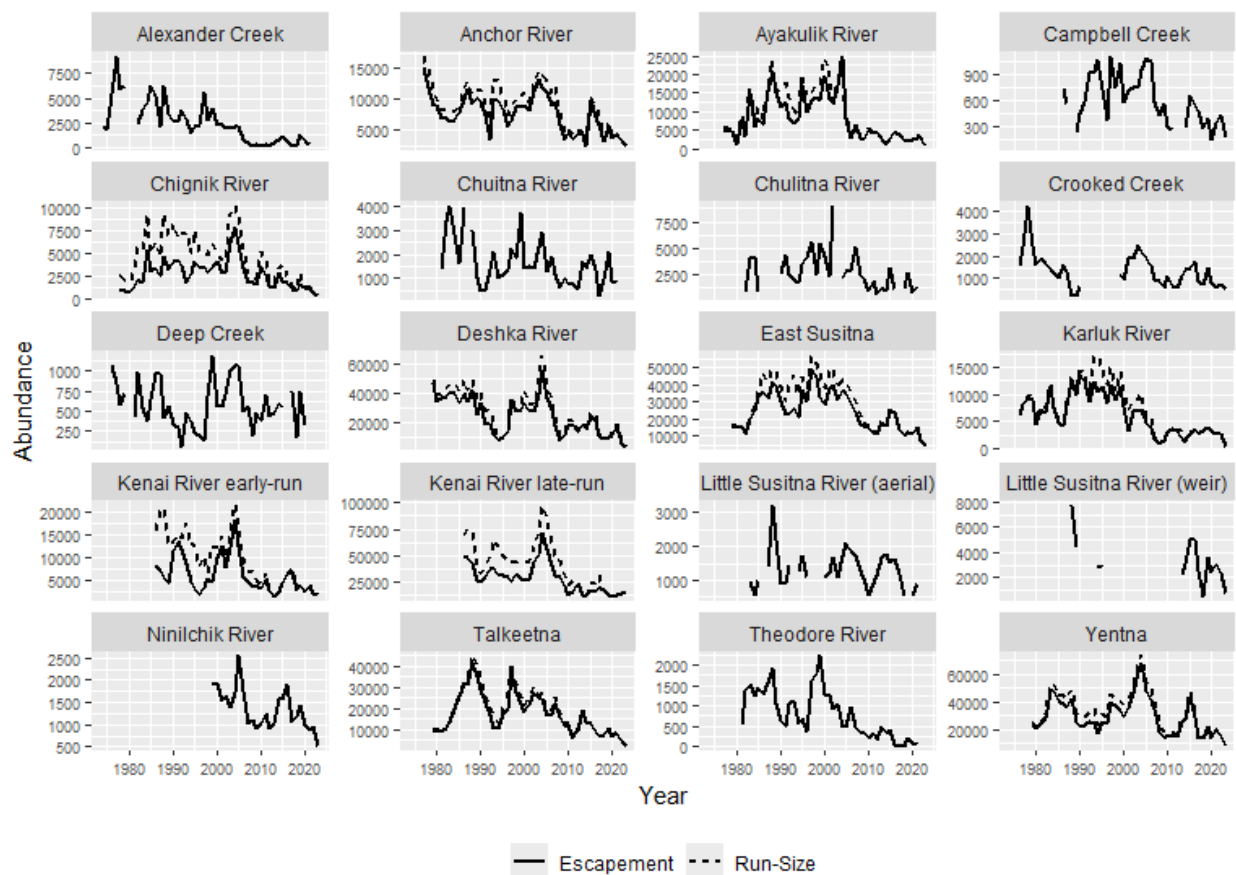


Figure 38. -- Northwest Gulf of Alaska Chinook salmon escapement and run-size.

6.4.2 Trend analyses

6.4.2.1 Short-term: Escapement

Trends for 19 stocks (18 river systems) were analyzed from 1979 to 2023, with substantial variability across systems and time periods (Figure 39). Rivers such as the Ayakulik and Kenai (late-run) exhibited relatively high escapement during earlier periods, followed by significant declines after 2000. Systems like Alexander Creek and Theodore River showed consistent long-term declines, while others, including the Anchor River, displayed less pronounced temporal changes. Variability in escapement was evident across most systems, with the magnitude and

direction of trends differing significantly by river and time period. Analysis of trends across three periods (1979–1993, 1994–2008, and 2009–2023) reveals system-specific patterns (Figure 40 and Table 16). The Ayakulik and Chignik Rivers showed significant positive trends during 1979–1993 but transitioned to negative or nonsignificant trends in subsequent periods. Systems such as the Theodore and East Susitna Rivers demonstrated significant negative trends in 2009–2023, consistent with declining escapement levels in recent decades. Alexander Creek showed consistent declines across all periods, including a significant negative trend in 1994–2008 (-0.12 , $p < 0.05$). However, some stocks, such as the Anchor River and Campbell Creek, exhibited nonsignificant or minor changes across all periods, suggesting relative stability in escapement levels. Five-year block averages provide further detail on escapement dynamics (Table 17). High average escapement levels were observed for the Yentna River during 1999–2003, but levels declined by 2019–2023. Similar declining patterns were evident for rivers like the Theodore River, which experienced a sharp reduction from 1999–2003 to 2019–2023. Conversely, the Anchor River exhibited more consistent escapement averages, reflecting more moderate changes over time. Collectively, these results highlight declines in escapement for many systems, particularly in recent decades, while some systems have demonstrated stability or slower rates of decline.

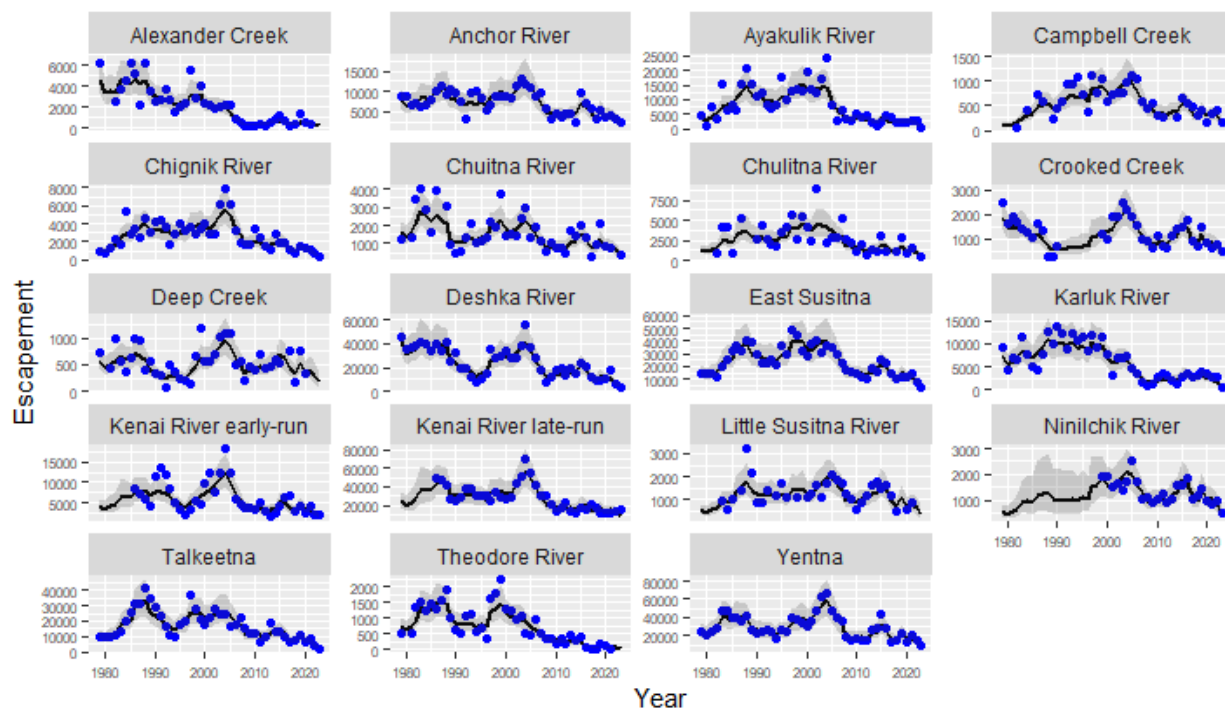


Figure 39. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Northwest Gulf of Alaska Chinook escapement. Points in blue show the annual observed escapement.

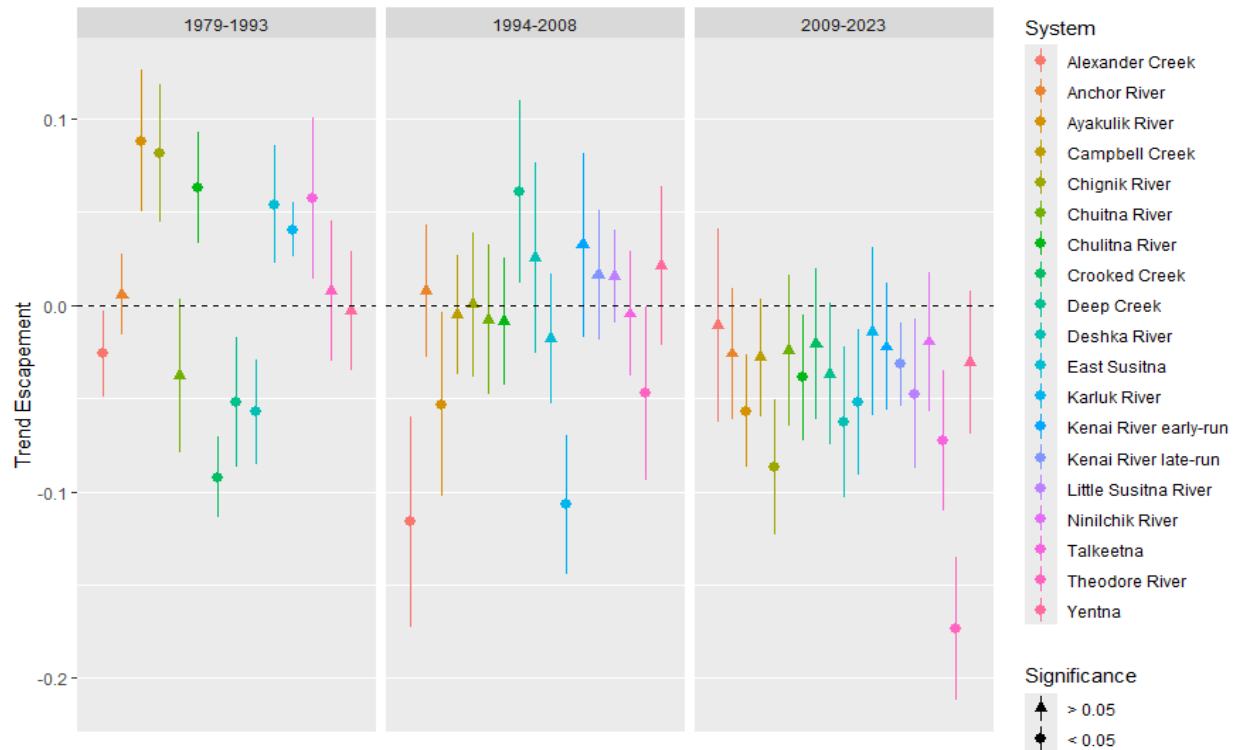


Figure 40. -- 15-year trends estimated for Northwest Gulf of Alaska Chinook escapement. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 16. -- 15-year trends (slope) in log escapement for the Northwest Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log escapement estimate versus year. Included are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first 5 years and last 5 years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Alexander Creek	-0.03	-0.05, -0.00	0.03	-0.12	-0.17, -0.06	0.00	-0.01	-0.06, 0.04	0.66
Anchor River	0.01	-0.02, 0.03	0.58	0.01	-0.03, 0.04	0.66	-0.03	-0.06, 0.01	0.13
Ayakulik River	0.09	0.05, 0.13	0.00	-0.05	-0.10, -0.00	0.04	-0.06	-0.09, -0.03	0.00
Campbell Creek				0.00	-0.04, 0.03	0.74	-0.03	-0.06, 0.00	0.08
Chignik River	0.08	0.04, 0.12	0.00	0.00	-0.04, 0.04	0.98	-0.09	-0.12, -0.05	0.00
Chuitna River	-0.04	-0.08, 0.00	0.07	-0.01	-0.05, 0.03	0.68	-0.02	-0.07, 0.02	0.21
Chulitna River	0.06	0.03, 0.09	0.00	-0.01	-0.04, 0.03	0.59	-0.04	-0.07, -0.01	0.03
Crooked Creek	-0.09	-0.11, -0.07	0.00				-0.02	-0.06, 0.02	0.28
Deep Creek	-0.05	-0.09, -0.02	0.01	0.06	0.01, 0.11	0.02	-0.04	-0.07, 0.00	0.06
Deshka River	-0.06	-0.09, -0.03	0.00	0.03	-0.03, 0.08	0.30	-0.06	-0.10, -0.02	0.01
East Susitna	0.05	0.02, 0.09	0.00	-0.02	-0.05, 0.02	0.28	-0.05	-0.09, -0.01	0.01
Karluk River	0.04	0.03, 0.06	0.00	-0.11	-0.14, -0.07	0.00	-0.01	-0.06, 0.03	0.50
Kenai River early-run				0.03	-0.02, 0.08	0.18	-0.02	-0.06, 0.01	0.18
Kenai River late-run				0.02	-0.02, 0.05	0.33	-0.03	-0.05, -0.01	0.01
Little Susitna River				0.02	-0.01, 0.04	0.20	-0.05	-0.09, -0.01	0.02
Ninilchik River							-0.02	-0.06, 0.02	0.27
Talkeetna	0.06	0.01, 0.10	0.01	0.00	-0.04, 0.03	0.76	-0.07	-0.11, -0.04	0.00
Theodore River	0.01	-0.03, 0.05	0.68	-0.05	-0.09, -0.00	0.05	-0.17	-0.21, -0.13	0.00
Yentna	0.00	-0.04, 0.03	0.83	0.02	-0.02, 0.06	0.31	-0.03	-0.07, 0.01	0.11

Table 17. -- 5-year geometric mean of escapement for Northwest Gulf of Alaska Chinook salmon stocks. Smoothed escapement estimates are shown. In parentheses, the 5-year geometric mean of observed escapement is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Alexander Creek	3818 (3902)	4467 (4588)	2918 (3026)	2590 (2584)	2333 (2416)	847 (787)	334 (282)	510 (522)	341 (606)
Anchor River	7272 (7495)	9509 (8955)	7576 (7534)	7503 (7705)	10016 (9995)	8561 (9230)	4289 (4036)	5065 (5033)	3629 (3639)
Ayakulik River	4423 (4405)	10386 (9986)	10451 (10321)	11335 (12088)	13875 (14794)	6917 (6457)	3169 (3647)	2679 (2402)	1944 (1876)
Campbell Creek	145	428 (562)	557 (552)	715 (757)	818 (754)	719 (779)	355 (347)	403 (421)	292 (272)
Chignik River	1423 (1247)	3318 (3592)	3174 (3234)	3153 (3297)	3959 (3707)	3371 (3433)	1831 (1887)	1541 (1568)	851 (842)
Chuitna River	1840 (2204)	2346 (2715)	1146 (934)	1481 (1458)	1917 (1926)	1426 (1384)	851 (858)	1016 (964)	746 (862)
Chulitna River	1530 (1871)	2902 (2583)	2814 (2804)	3248 (3278)	4131 (4699)	3015 (2962)	1398 (1283)	1431 (1424)	1068 (1154)
Crooked Creek	1521 (1780)	1022 (903)	571 (425)	803	1526 (1597)	1392 (1401)	844 (789)	1115 (1185)	754 (765)
Deep Creek	543 (639)	633 (624)	310 (281)	313 (272)	675 (761)	623 (581)	441 (488)	501 (458)	332 (496)
Deshka River	36877 (39187)	38627 (38124)	20383 (20476)	17975 (16078)	31290 (31307)	24372 (23675)	14519 (15820)	14794 (15073)	8471 (8331)
East Susitna	16158 (14961)	31662 (33238)	27502 (27440)	31472 (34896)	36254 (33829)	26941 (27312)	14461 (14010)	15899 (16874)	9497 (9081)
Karluk River	6767 (7357)	8523 (6882)	9962 (11277)	9257 (10156)	6909 (6709)	3304 (2755)	2061 (2378)	2617 (2473)	1974 (2051)
Kenai River early-run	4407	7151 (6990)	7114 (9151)	4596 (3492)	8375 (8819)	6981 (7328)	3261 (3087)	3883 (4205)	2869 (2764)
Kenai River late-run	25273	40263 (46321)	31180 (30799)	29856 (30047)	37879 (34240)	37486 (43241)	17151 (16896)	16289 (16139)	13461 (12793)
Little Susitna River	613	1284 (1256)	1268 (1268)	1254 (1253)	1453 (1258)	1540 (1714)	1036 (1005)	1174 (1221)	694 (704)
Ninilchik River	619	1117	1017	1211	1713 (1671)	1518 (1540)	1046 (1025)	1324 (1423)	940 (901)
Talkeetna	11600 (10383)	26303 (28915)	20754 (21186)	19421 (20575)	23759 (22635)	18774 (19066)	10695 (10874)	9931 (9657)	5690 (5591)
Theodore River	838 (869)	1366 (1471)	859 (829)	895 (844)	1108 (1281)	569 (519)	255 (288)	111 (81)	50 (95)
Yentna	27382 (27841)	39405 (41118)	25495 (24310)	27593 (27492)	41576 (40338)	35799 (38418)	18601 (16959)	22281 (23295)	15026 (15021)

6.4.2.2 Short-term: Run size

Trends across nine stocks from 1979 to 2023 reveal variable patterns of growth, decline, and stabilization across time periods (Figure 41). The Ayakulik and East Susitna Rivers exhibited pronounced peaks during the late 1980s and early 1990s, followed by sharp declines in subsequent years. Similarly, the Kenai River (late-run) showed high run sizes during earlier periods, with significant declines post-2000. In contrast, systems such as the Anchor and Yentna Rivers demonstrated more gradual declines, while the Talkeetna River experienced sharp reductions in the most recent decades. These results underscore varying system-specific responses. Trend analysis over three periods (1979–1993, 1994–2008, 2009–2023) highlights shifts across systems (Figure 42, Table 18). Several systems, including the Ayakulik and Chignik Rivers, exhibited significant positive trends during 1979–1993, transitioning to negative trends in later periods. The Ayakulik River showed significant negative slopes during both 1994–2008 and 2009–2023. The Kenai River (late-run) shows a significant negative trend in 2009–2023. Other systems, such as the Anchor River, displayed nonsignificant trends across all periods, indicating relative stability in run sizes. Systems such as the Talkeetna and Deshka Rivers demonstrated significant negative slopes in the most recent period. Five-year block averages further illustrate the observed trends (Table 19). High run size averages were observed in earlier periods for the East Susitna River, peaking during 1999–2003, before declining by 2019–2023. Similarly, the Ayakulik River exhibited a peak average run size during 1999–2003 before declining sharply in 2019–2023. The Kenai River (late-run) also demonstrated declines, with abundance declines in 2019–2023. In contrast, the Anchor River exhibited more consistent run size averages over time. Numerous systems pre-1990 had low run sizes that increased in later periods, before decreasing again. These findings indicate significant declines in run sizes across most systems, particularly since the early 2000s.

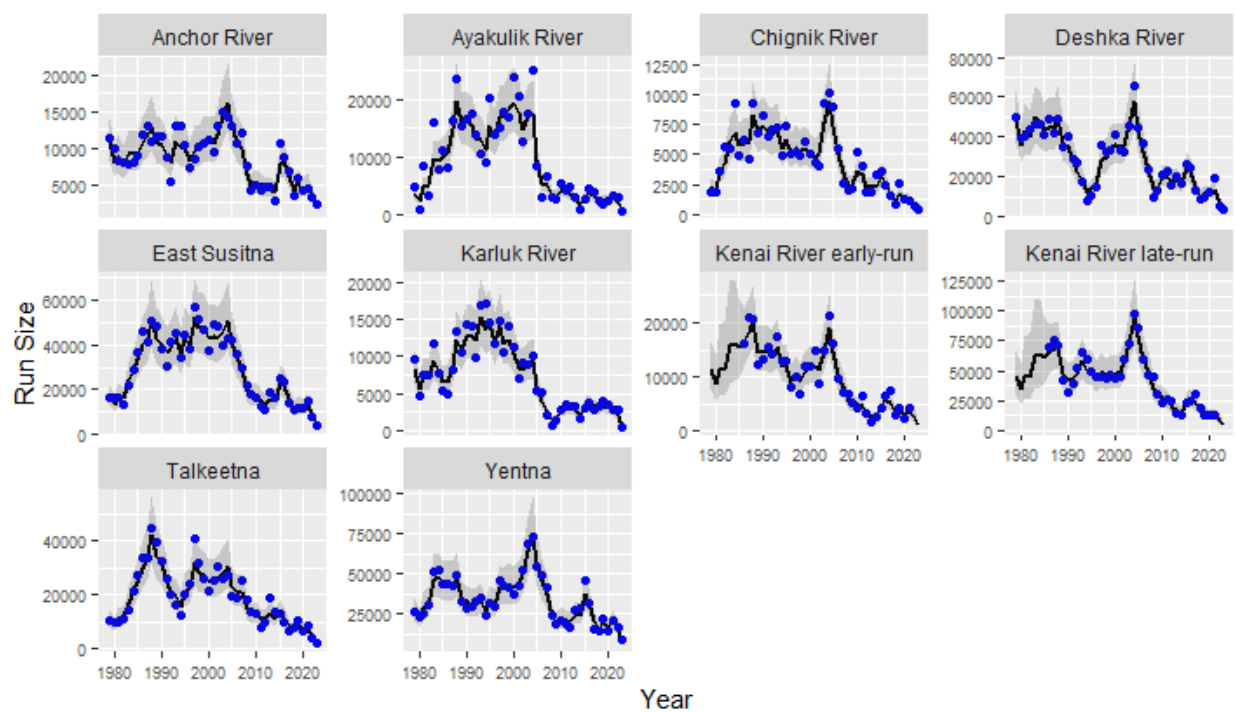


Figure 41. -- Smoothed trend in estimated (black line, with 95% confidence interval in gray) Northwest Gulf of Alaska Chinook run size. Points in blue show the annual observed run size.



Figure 42. -- 15-year trends estimated for Northwest Gulf of Alaska Chinook run size. Points are alphabetical and show estimated trend (regression slope) through time and 95% confidence interval for individual stocks.

Table 18. -- 15-year trends (slope) in log run size for the Northwest Gulf of Alaska ESU, computed from a linear regression applied to the smoothed log run size versus year. Include are the upper and lower 95% CIs and significance. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first 5 years and last 5 years of the 15-year ranges are shown.

System	1979-1993			1994-2008			2009-2023		
	Slope	95% CI	Sig	Slope	95% CI	Sig	Slope	95% CI	Sig
Anchor River	0.01	-0.01, 0.03	0.29	0.01	-0.02, 0.04	0.66	-0.03	-0.07, 0.01	0.12
Ayakulik River	0.12	0.07, 0.16	0.00	-0.08	-0.14, -0.02	0.01	-0.06	-0.10, -0.01	0.01
Chignik River	0.08	0.04, 0.11	0.00	-0.02	-0.06, 0.02	0.28	-0.11	-0.15, -0.07	0.00
Deshka River	-0.04	-0.07, -0.02	0.00	0.04	-0.02, 0.10	0.15	-0.08	-0.12, -0.03	0.00
East Susitna	0.08	0.05, 0.11	0.00	-0.03	-0.06, -0.00	0.05	-0.06	-0.10, -0.02	0.01
Karluk River	0.06	0.03, 0.08	0.00	-0.13	-0.18, -0.09	0.00	-0.02	-0.08, 0.03	0.41
Kenai River early-run				-0.01	-0.05, 0.03	0.54	-0.05	-0.09, -0.00	0.04
Kenai River late-run				0.02	-0.02, 0.05	0.33	-0.09	-0.13, -0.05	0.00
Talkeetna	0.08	0.03, 0.12	0.00	-0.01	-0.04, 0.02	0.60	-0.08	-0.12, -0.05	0.00
Yentna	0.01	-0.02, 0.04	0.43	0.02	-0.02, 0.06	0.26	-0.04	-0.08, -0.00	0.05

Table 19. -- 5-year geometric mean of run size for Northwest Gulf of Alaska Chinook salmon stocks. Smoothed run size estimates are shown. In parentheses, the 5-year geometric mean of observed run size is shown. A minimum of 2 values were used to compute the geometric mean. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5).

System	1979-83	1984-88	1989-93	1994-98	1999-03	2004-08	2009-13	2014-18	2019-23
Anchor River	8935 (9056)	10672 (10401)	9815 (9669)	9518 (9697)	11567 (11718)	10842 (11318)	4836 (4611)	5854 (5770)	3797 (3852)
Ayakulik River	4582 (4649)	12467 (12280)	14770 (14623)	14672 (14757)	17386 (17991)	6919 (6666)	3540 (3897)	2765 (2584)	2067 (2024)
Chignik River	3378 (3302)	6502 (6542)	6955 (7177)	5523 (5428)	5578 (5468)	4901 (4804)	2750 (2757)	2104 (2078)	984 (1037)
Deshka River	42883 (43625)	45713 (45557)	27540 (28986)	18651 (17025)	37097 (36993)	30391 (30121)	17519 (18082)	16658 (16700)	8683 (8716)
East Susitna	17282 (16572)	38545 (39896)	39934 (40159)	43167 (44272)	44505 (43965)	33304 (33665)	15667 (15078)	16819 (17209)	9370 (9309)
Karluk River	7484 (7892)	8168 (7436)	12743 (12896)	13124 (13545)	9588 (9795)	3783 (3459)	2457 (2717)	2998 (2826)	2065 (2115)
Kenai River early-run	11489	17199 (19027)	14663 (14529)	10503 (9930)	12127 (12246)	10552 (11086)	3935 (3708)	4140 (4347)	2659 (3512)
Kenai River late-run	45783	64983 (71853)	47439 (44889)	47256 (47776)	53662 (51991)	59873 (63869)	23493 (22971)	20257 (21093)	10036 (12785)
Talkeetna	11554 (10986)	29681 (31185)	25512 (25631)	23375 (24109)	26129 (25664)	21415 (21488)	12122 (12094)	10174 (9849)	5650 (5734)
Yentna	29772 (29887)	45059 (46280)	32318 (31692)	33615 (33455)	47544 (47235)	44122 (45399)	21001 (19803)	24368 (24742)	15164 (15397)

6.4.2.3 Long-term: Escapement

Within the Northwest Gulf of Alaska ESU, estimated posterior distributions for the linear trend term (u_p) showed moderate evidence (50% CI negative, non-overlapping of zero) of long-term declines in escapement for Alexander Creek, Deshka River, Theodore River, Ninilchik River, and Karluk River (Figs. 43, 45, 47). Similar to other ESUs, several stocks within the Northwest Gulf of Alaska ESU showed declines in escapement beginning in the early 2000s (e.g., Ayakulik River, Karluk River, Anchor River, Kenai River Late-Run, Ninilchik River, Alexander Creek, Deshka River, East Susitna, Theodore River) (Figs. 43, 45, 47). While several other stocks in the Northwest Gulf of Alaska showed low escapement abundance levels in recent years, these short-term fluctuations appear to be within the scope of previously observed levels of variation around the long-term median (e.g., Campbell Creek, Chuitna River, Chulitna River, Yentna River, Little Susitna River, Kenai River Early Run, Crooked Creek) (Figs. 43, 45, 47). Estimated correlation matrices for the Southern Peninsula (Kodiak Island/Chignik) stock group were strong between the Karluk River and Ayakulik Rivers, and weaker between either stock and the Chignik River, suggesting synchrony in interannual escapement patterns among populations returning to Kodiak Island (Ayakulik, Karluk) versus those returning to the Alaska Peninsula (Chignik) (Figure 44). Among the Kenai stock group, there was evidence of moderate-to-strong

coherence between the Crooked Creek and Ninilchik River stocks, but little evidence of synchrony among any other populations' escapement patterns (Figure 46). Within the Northern Cook Inlet stock group, estimated correlations in temporal variability were generally moderately positively across all stocks, with particularly strong coherence among the East Susitna and Talkeetna stocks, and among the Alexander Creek and Yentna, Deshka, East Susitna, and Chuitna Rivers stocks) (Figure 48).

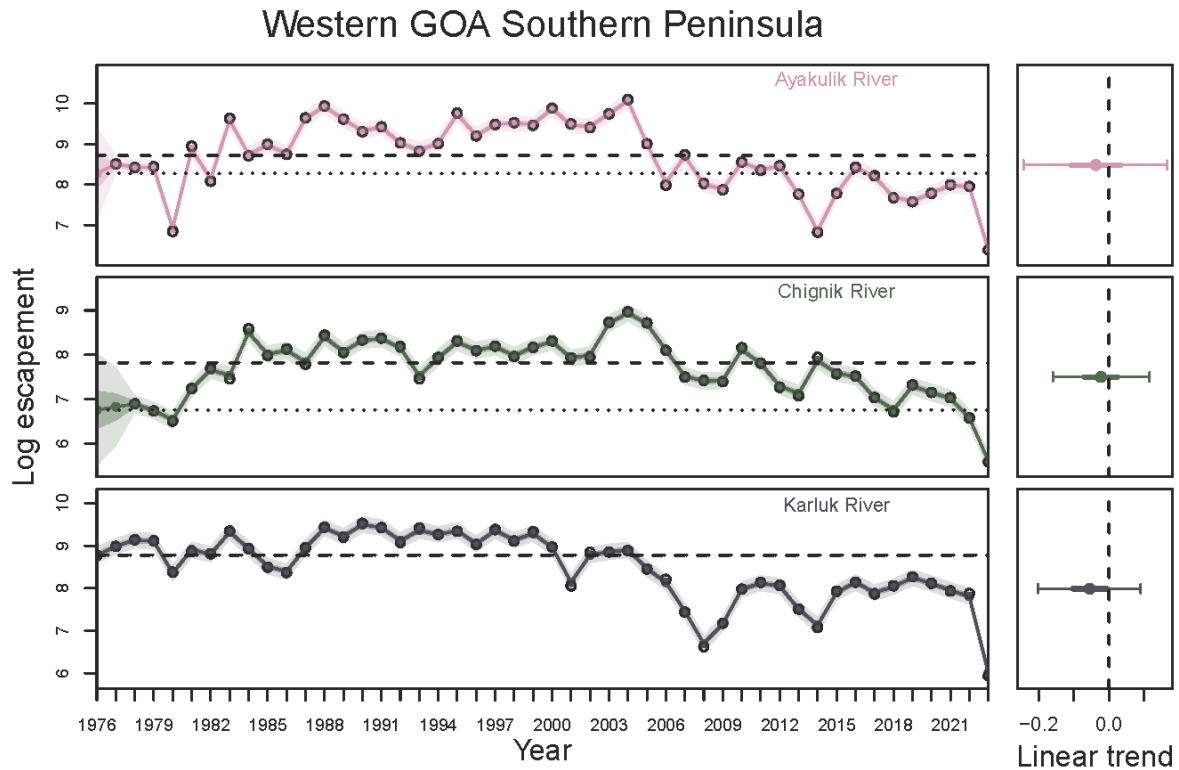


Figure 43. -- Western GOA Southern Peninsula stock group model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Northwest Gulf of Alaska ESU Southern Peninsula stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

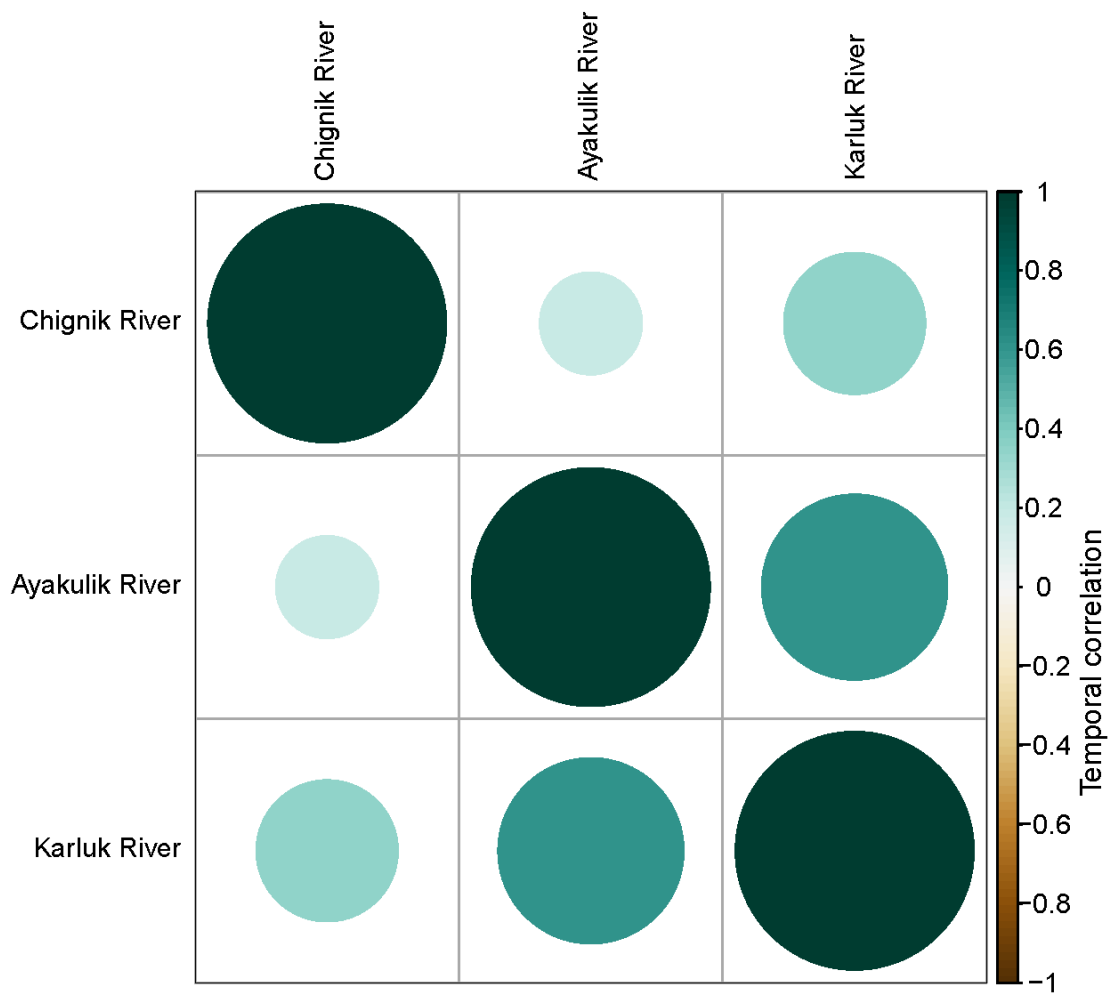


Figure 44. -- Estimated correlation matrix (Ω) from model fits to the Western GOA Southern Peninsula stock group's escapement data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

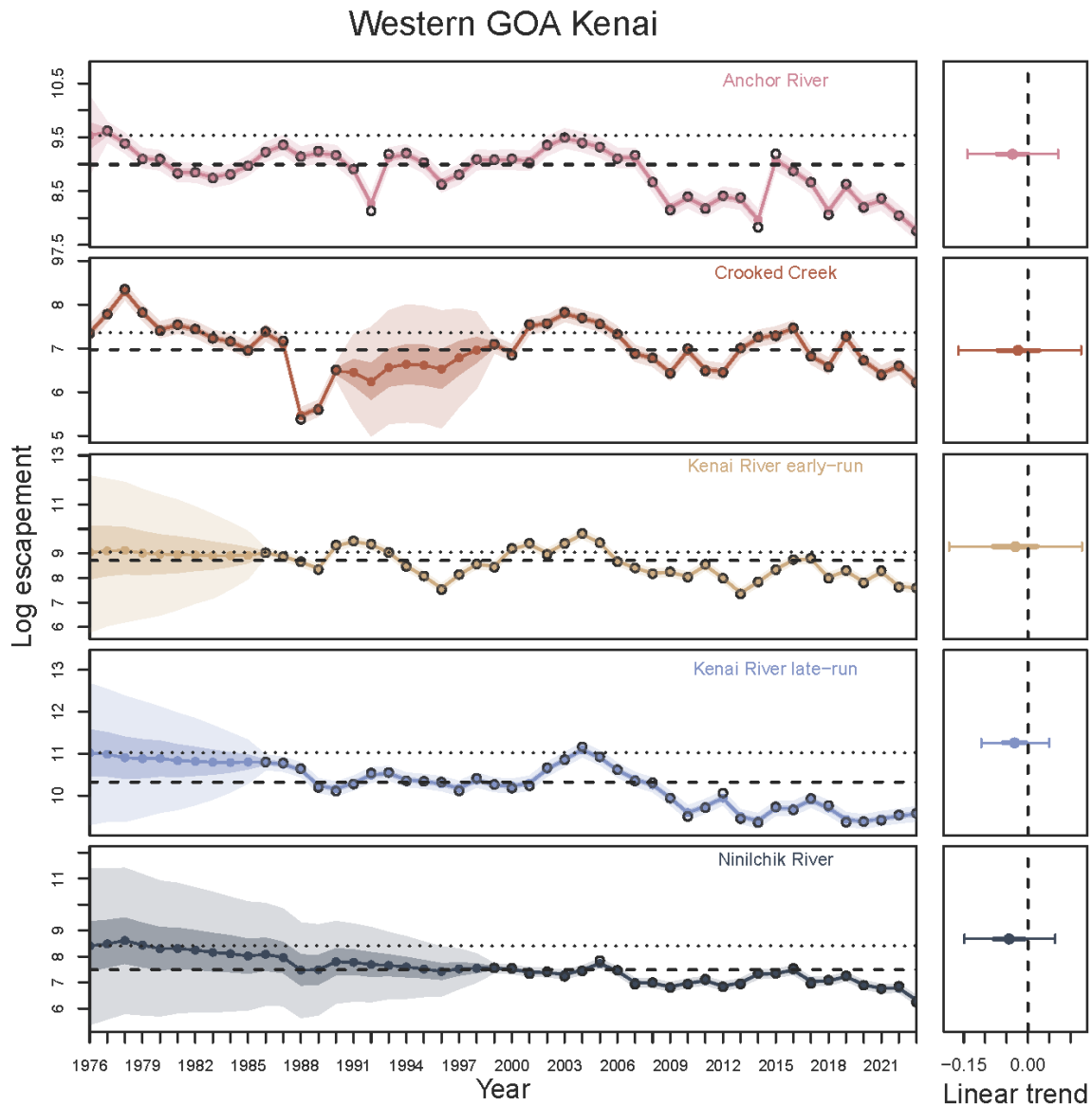


Figure 45. -- Western GOA Kenai stock group model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Northwest Gulf of Alaska ESU Kenai stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

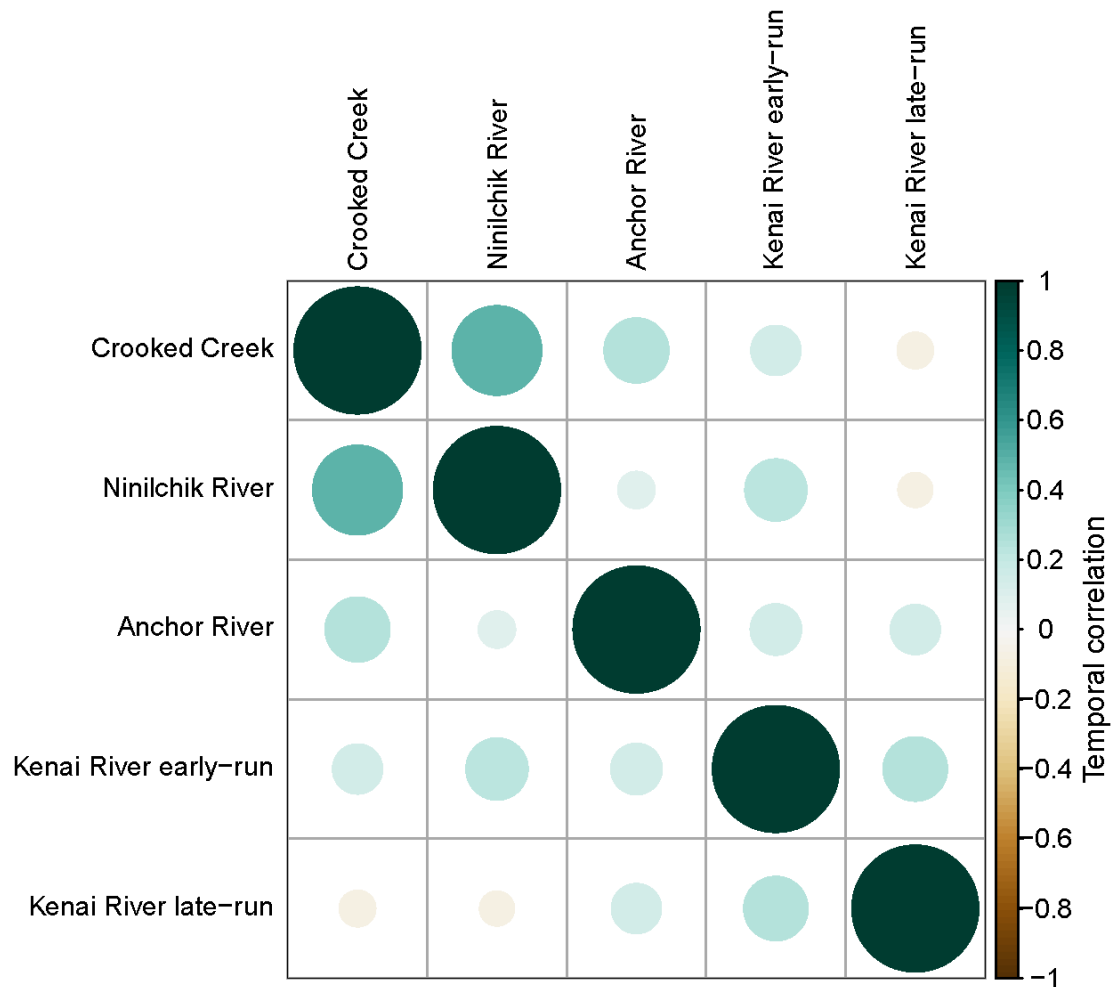


Figure 46. -- Estimated correlation matrix (Ω) from model fits to the Western GOA Kenai stock group's escapement data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

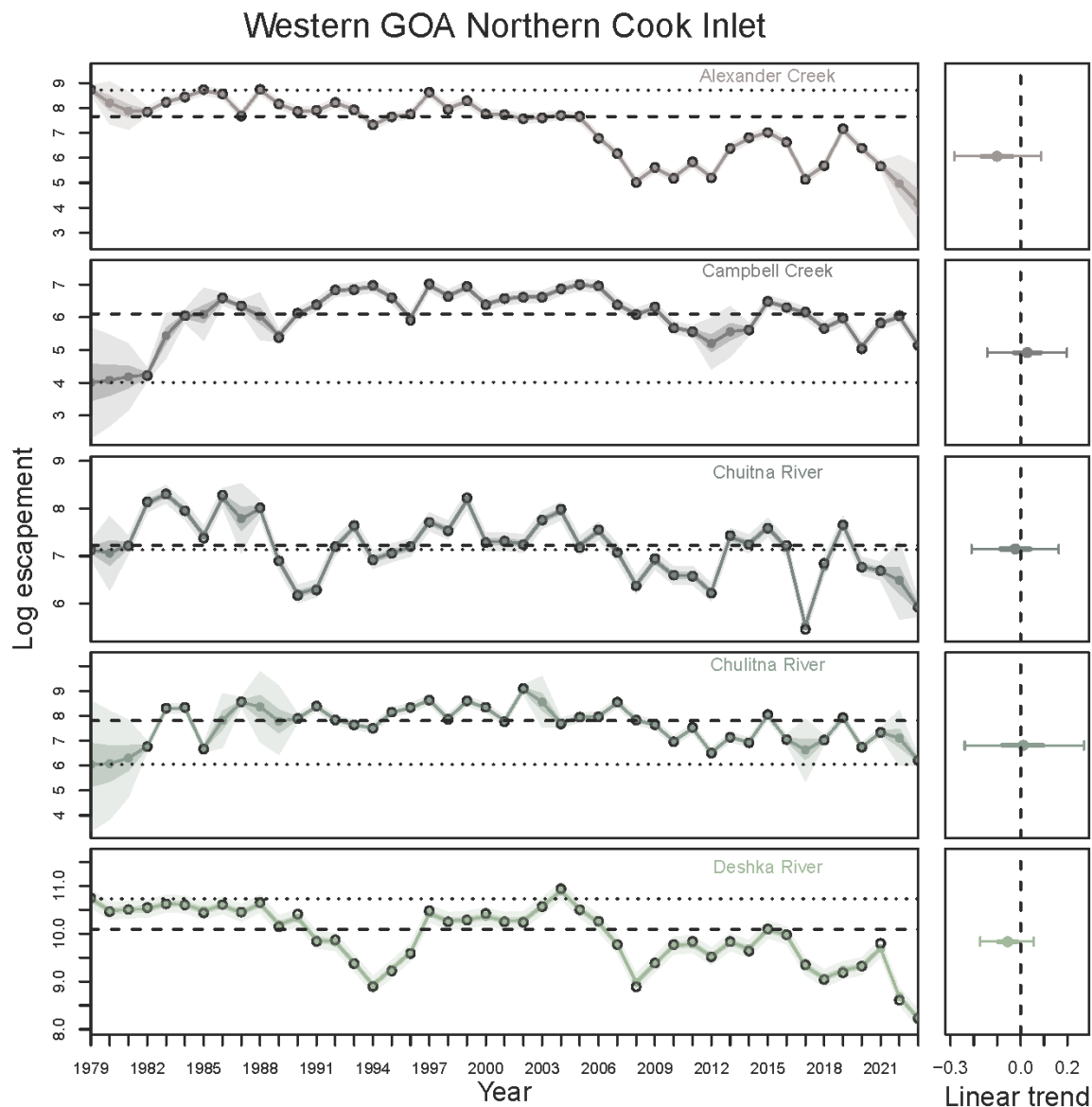


Figure 47. -- Western GOA Northern Cook Inlet stock group model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Northwest Gulf of Alaska ESU Northern Cook Inlet stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

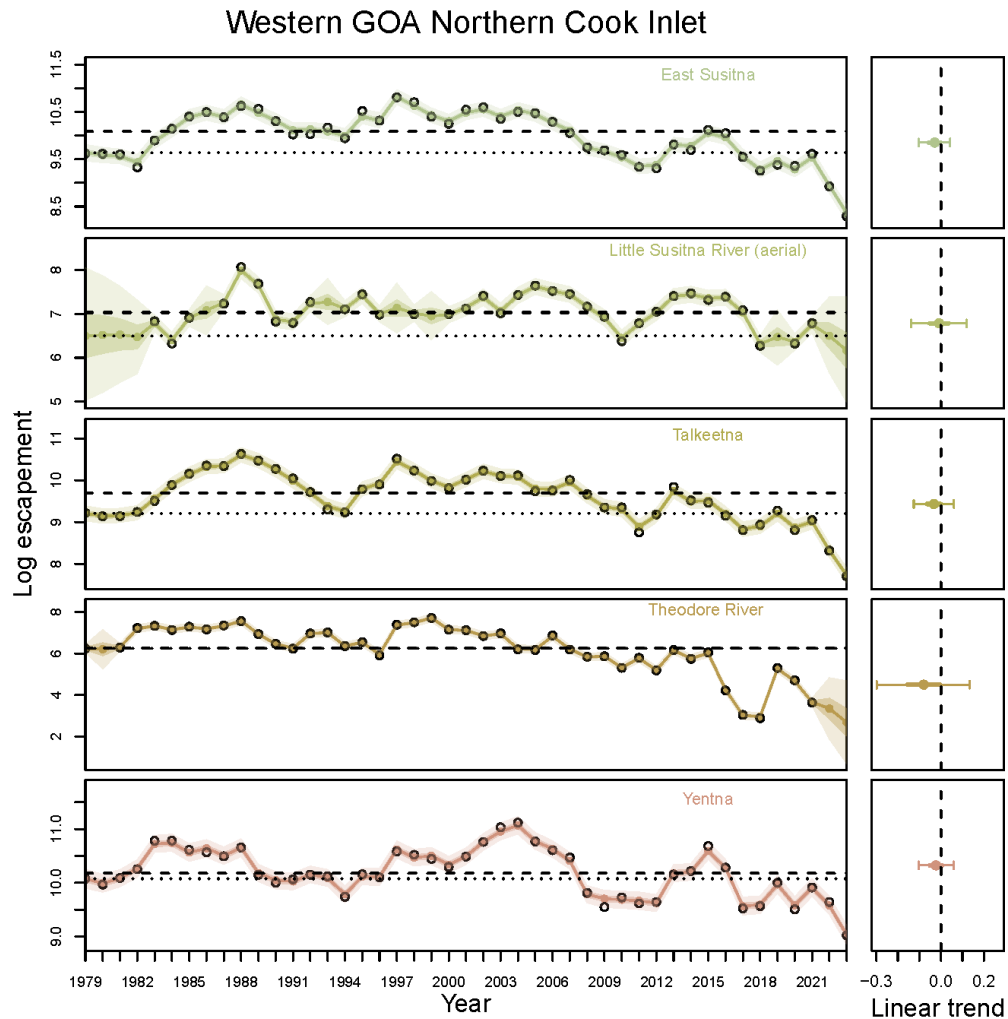


Figure 47. -- Continued. Western GOA Northern Cook Inlet stock group model fits and escapement abundance trends. Each left-hand panel shows the posterior distribution of the estimated log escapement abundance trajectory for a given population comprising the Northwest Gulf of Alaska ESU Northern Cook Inlet stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed escapement data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

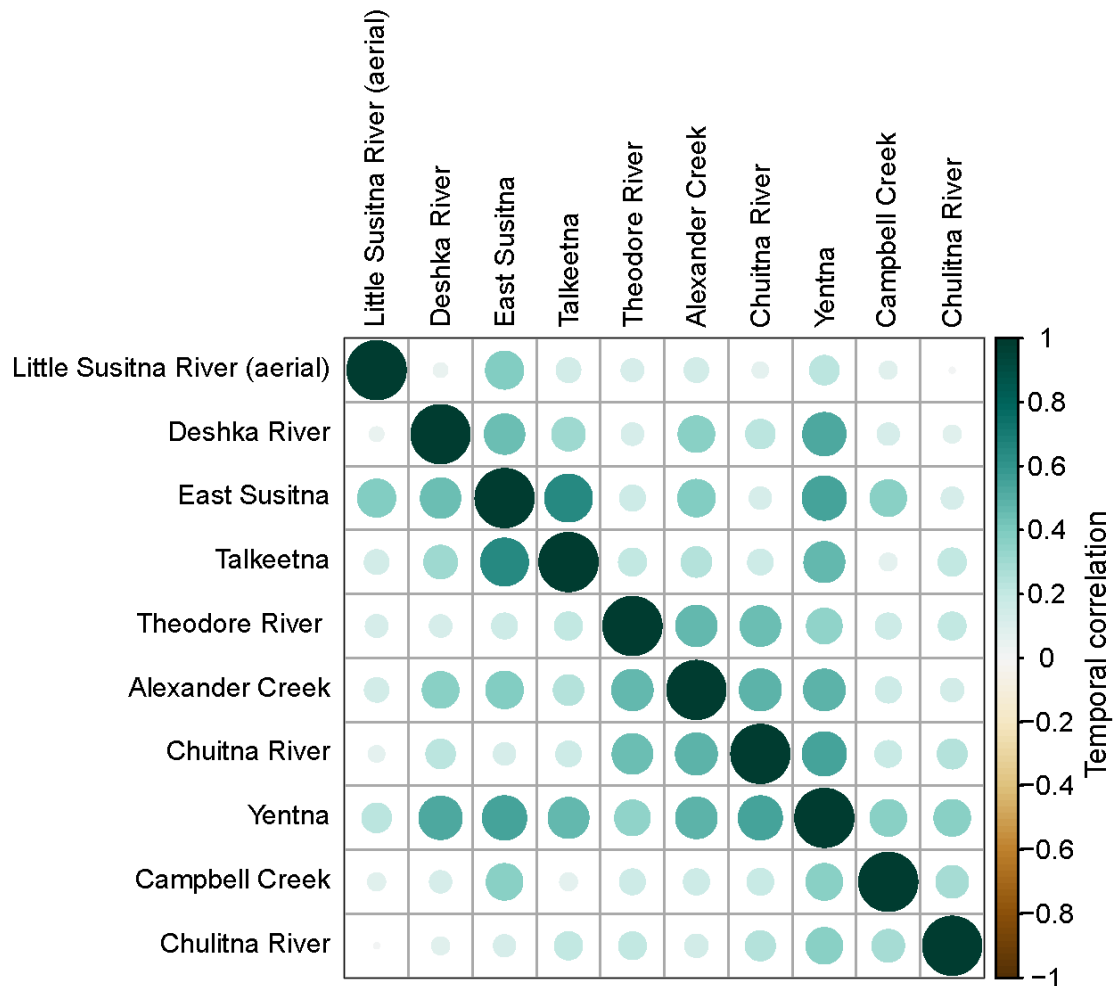


Figure 48. -- Estimated correlation matrix ($\hat{\Omega}$) from model fits to Western GOA Northern Cook Inlet stock group's escapement data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.4.2.4 Long-term: Run size

Of the populations with available run size data within the Northwest Gulf of Alaska ESU, estimated posterior distributions for the linear trend term (u_p) showed moderate evidence (50% CI negative, non-overlapping of zero) of long-term declines in run size for the Karluk River, Anchor River, Kenai River (early and late runs), Deshka River, East Susitna, Talkeetna River, and the Yentna River (Figs. 49, 51, 53). Similar to patterns in the escapement data, declines in run size for these stocks typically began in the early 2000s. While the 50% credible intervals of the trend term overlapped zero for both the Ayakulik and Chignik River model fits, both stocks have exhibited reduced run sizes since the early 2000s as well (Figure 49). Estimated correlation

matrices for the Southern Peninsula stock group indicated strong coherence between the Karluk River and Ayakulik Rivers, but also between the Karluk and Chignik Rivers, and to a lesser extent, between Chignik and Ayakulik as well (Figure 50). Within the Kenai stock group, temporal variability in run size was largely coherent among all populations (Figure 52). Similarly, within the Northern Cook Inlet stock group, estimated correlations in temporal variability were generally moderately to strongly positive across all stocks (Figure 54).

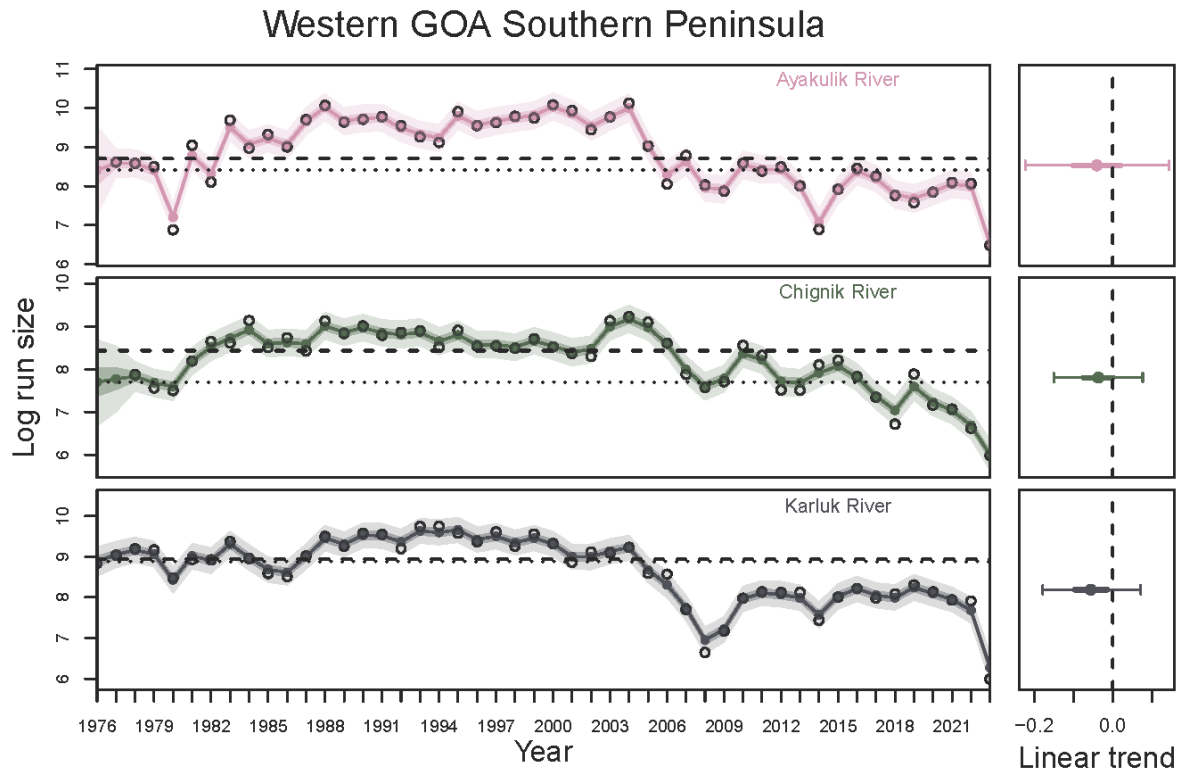


Figure 49. -- Western GOA Southern Peninsula stock group model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Northwest Gulf of Alaska ESU's Southern Peninsula stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

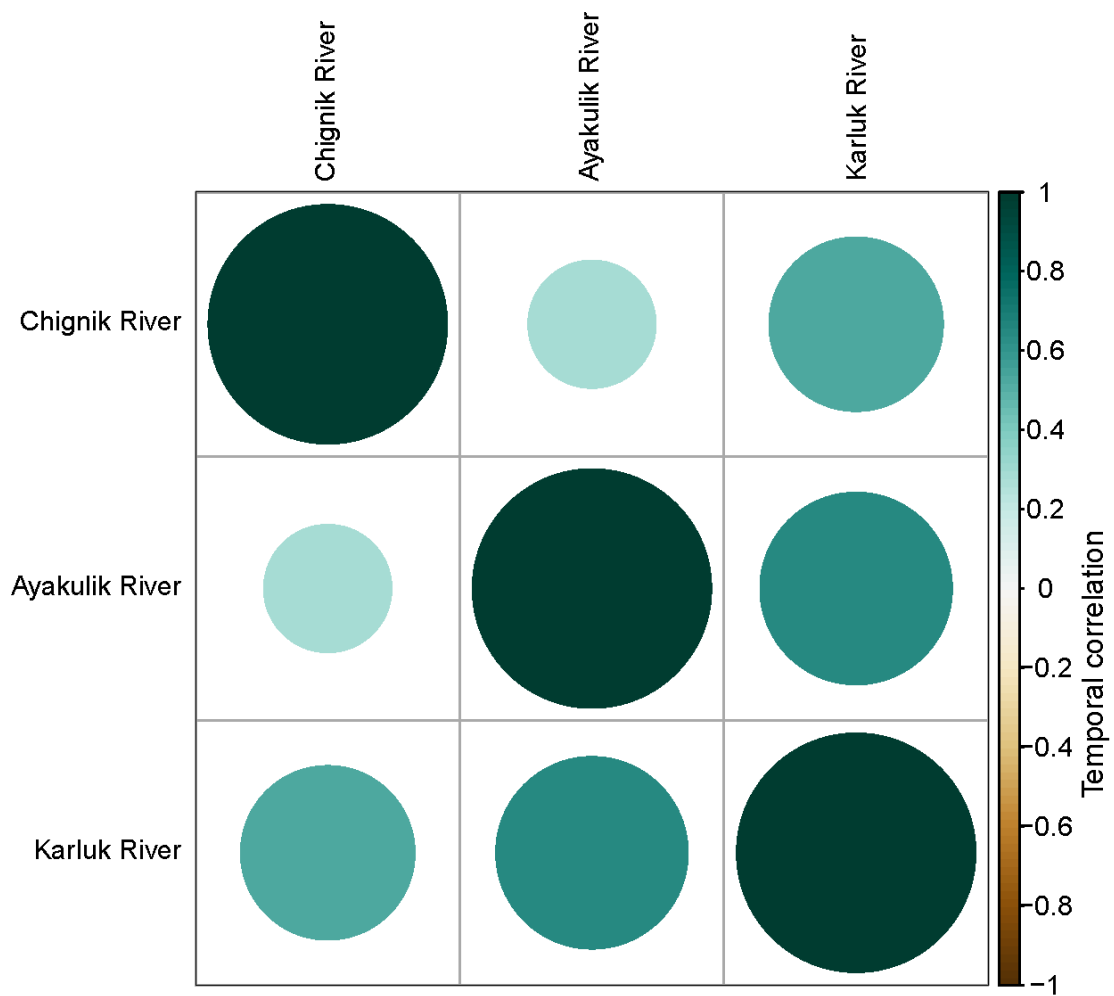


Figure 50. -- Estimated correlation matrix (Ω) from model fits to the Western GOA Southern Peninsula stock group run size data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

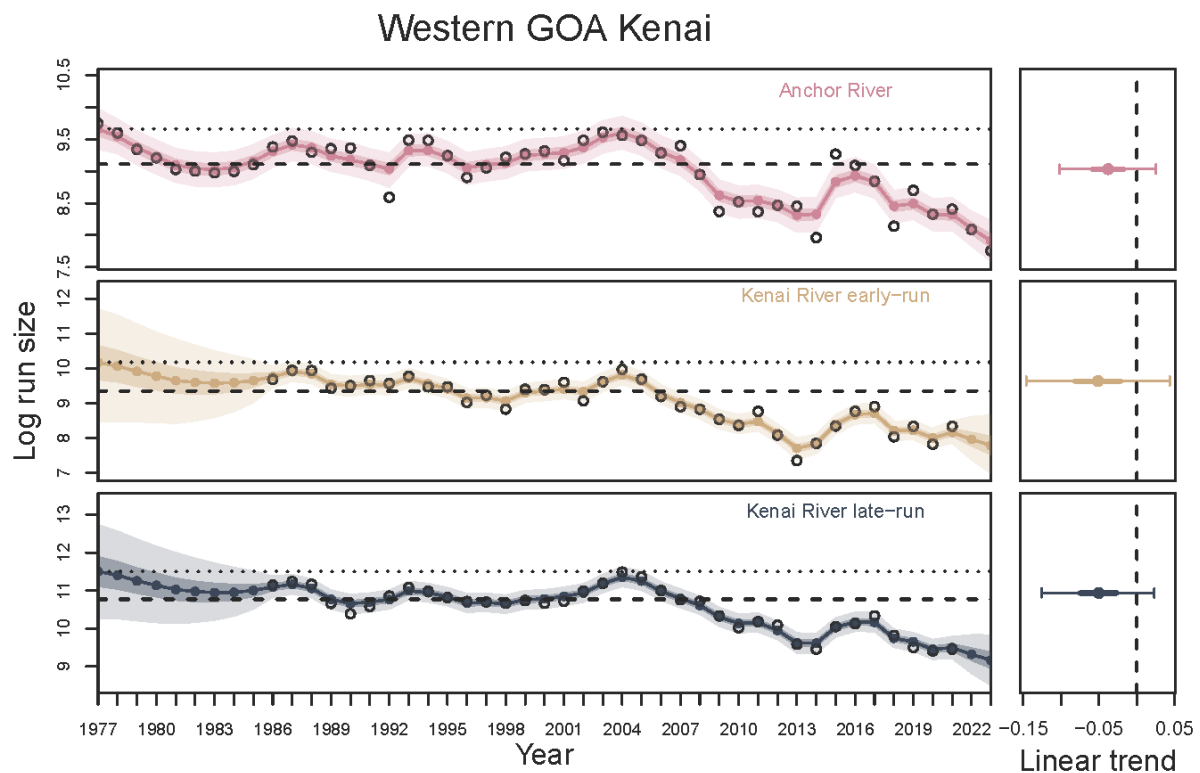


Figure 51. -- Western GOA Kenai stock group model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Northwest Gulf of Alaska ESU's Kenai stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time series, and black dashed lines represent the long-term median value over the course of the time series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

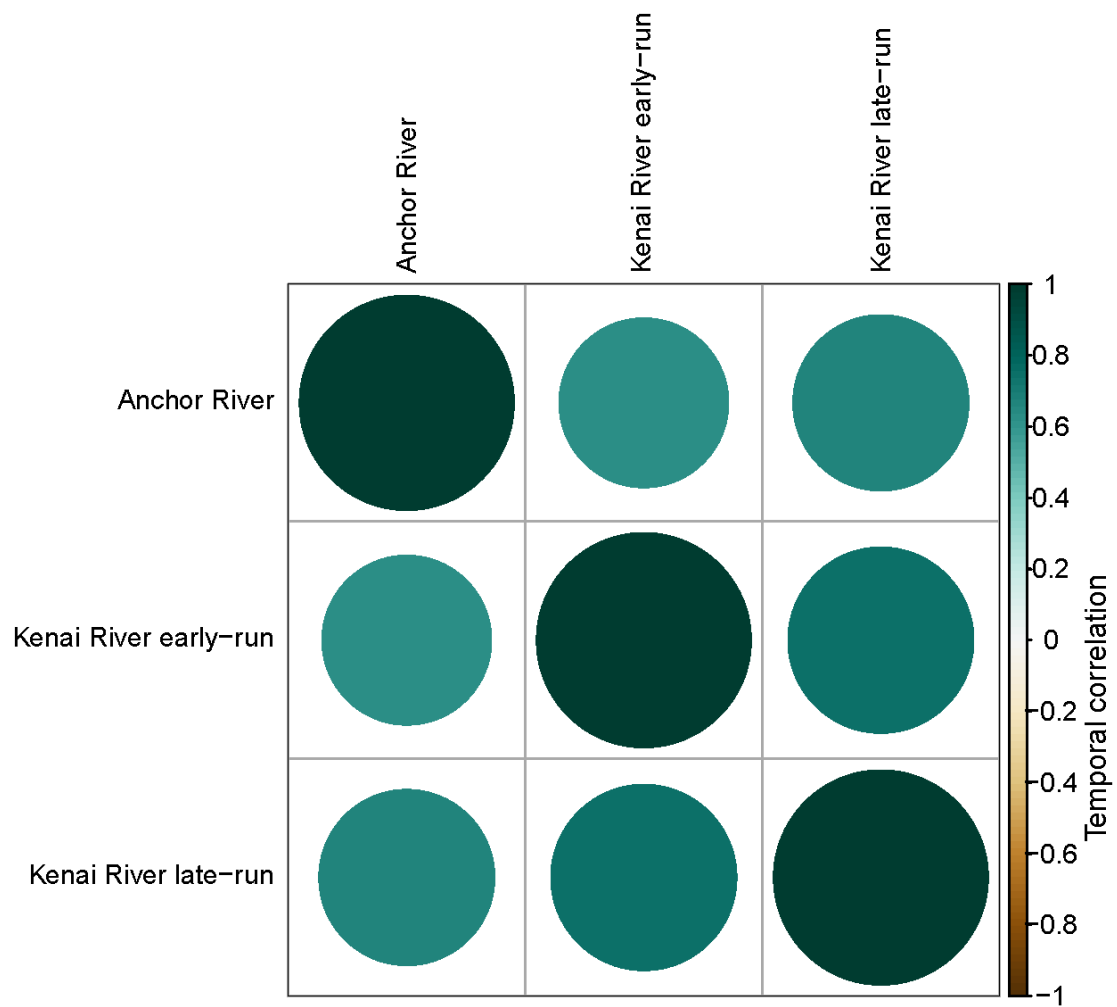


Figure 52. -- Estimated correlation matrix (Ω) from model fits to the Western GOA Kenai stock group run size data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

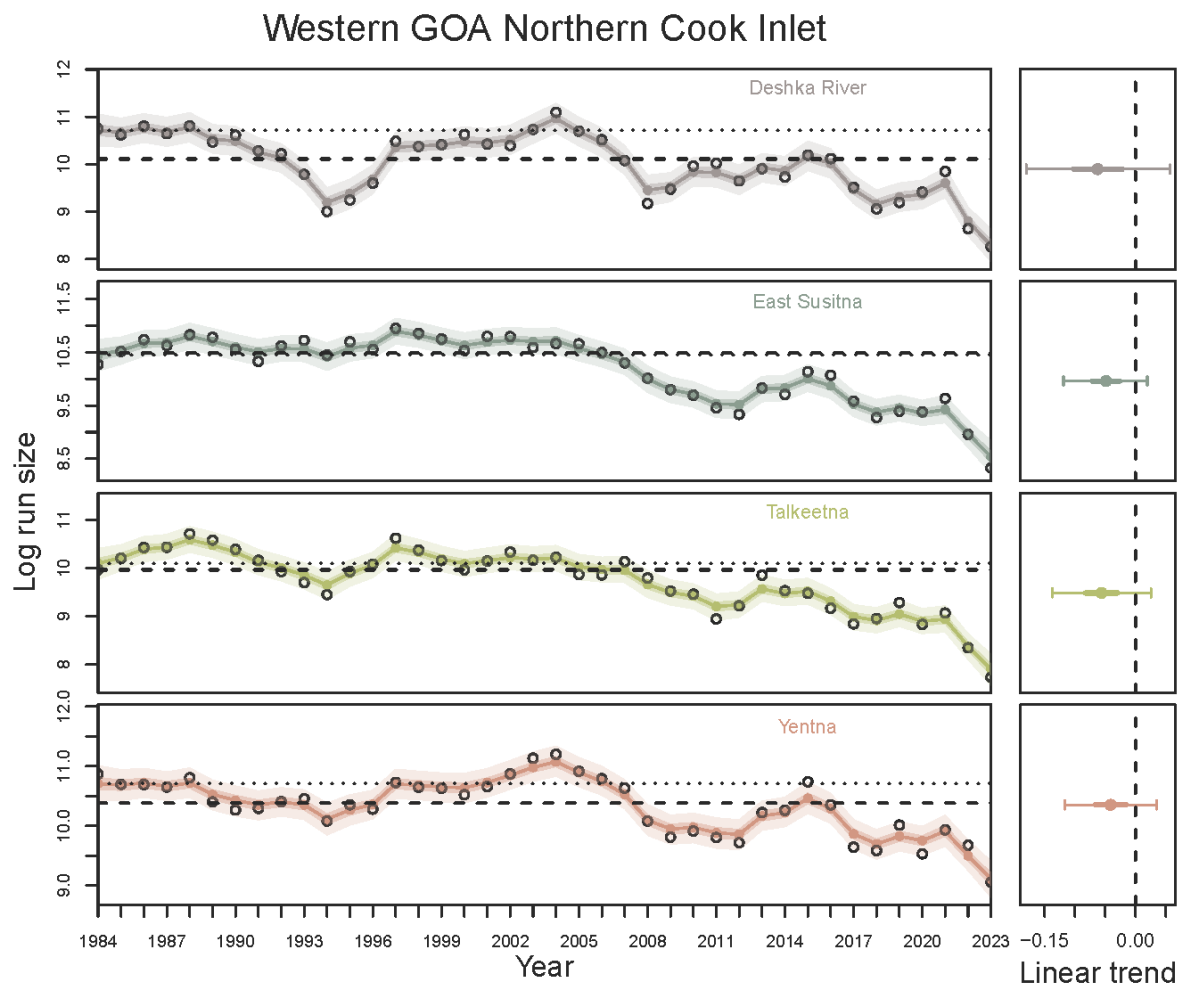


Figure 53. -- Western GOA Northern Cook Inlet stock group model fits and run size abundance trends. Each left-hand panel shows the posterior distribution of the estimated log run size trajectory for a given population comprising the Northwest Gulf of Alaska ESU's Northern Cook Inlet stock group. Solid colored lines and filled circles show the posterior median, dark shaded boundaries show the 50% credible interval, and light shaded boundaries represent the 95% credible interval. Open black circles represent the observed run size data for a given year and population. Dotted black lines represent the estimated abundance level in the first year of the time-series, and black dashed lines represent the long-term median value over the course of the time-series. Right hand panels show the estimated posterior distribution of the linear drift term for a given population (u_p), with filled circles representing the posterior median, thick lines representing the 50% credible interval, and thin lines representing the 95% credible interval.

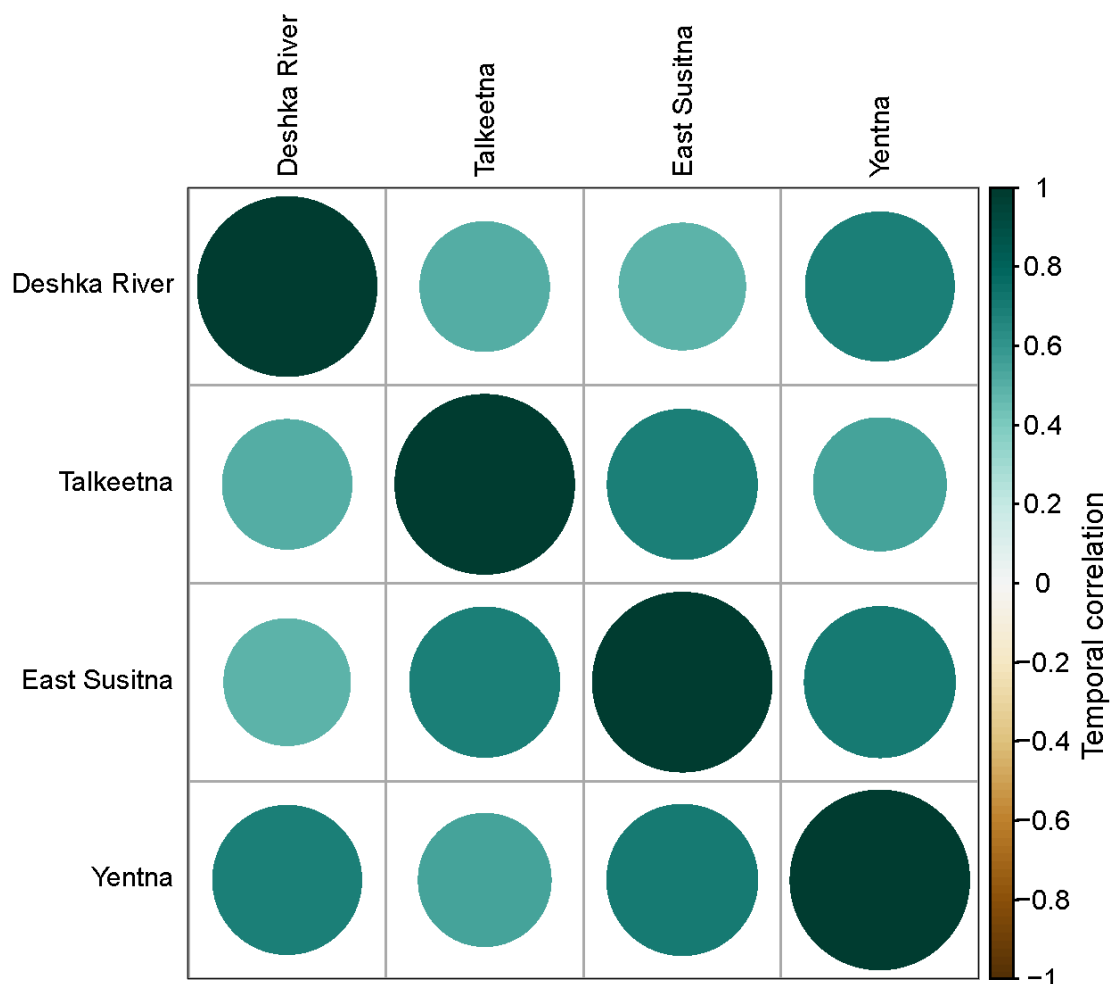


Figure 54. -- Estimated correlation matrix (Ω) from model fits to the Western GOA Northern Cook Inlet stock group run size data. Populations are grouped using hierarchical clustering. The strength of a given correlation estimate is indicated by the size of the circle, with positive correlations shown in teal, and negative correlations shown in brown.

6.4.3 Summary of Northwest Gulf of Alaska ESU demographic analyses

Short-term and long-term analyses of escapement and run size trends for the Northwest Gulf of Alaska ESU of Chinook salmon reveal moderate evidence of long-term declines across multiple stocks, with patterns of decline generally beginning in the early 2000s. Short-term analyses indicate that many stocks, including Alexander Creek, Deshka River, Theodore River, Ninilchik River, and Karluk River, have experienced significant reductions in escapement in recent decades. Similarly, declines in run size have been observed in several stocks, including the Anchor River, Kenai River (early and late runs), East Susitna, Talkeetna, and Yentna Rivers. While these declines have persisted over multiple periods, some stocks show signs of

stabilization, though at lower abundance levels than historical averages. The degree of decline varies by system, with some stocks exhibiting gradual reductions while others have shown more abrupt decreases, particularly in the early 2000s.

A distinguishing characteristic of this ESU is the broad-scale coherence in interannual abundance trends across multiple stocks. Unlike some other ESUs, where stock dynamics appear more independent, the Northwest Gulf of Alaska ESU demonstrates moderate-to-strong synchrony among stocks, particularly within certain regional groupings. For example, stocks within the Southern Peninsula (Karluk and Ayakulik Rivers) show strong correlations in both escapement and run size trends, suggesting shared environmental drivers or population dynamics. Similarly, the Kenai and Northern Cook Inlet stock groups exhibit moderate-to-strong coherence in both escapement and run size, indicating that population fluctuations may be influenced by large-scale environmental factors rather than localized conditions alone. This synchronization suggests that broad-scale environmental shifts, such as changes in ocean productivity or climate-driven habitat alterations, may be playing a role in the observed declines.

Short-term trends in escapement highlight system-specific variability, with some rivers, such as the Ayakulik and Chignik Rivers, exhibiting relatively high escapement in earlier periods, followed by declines post-2000. Other stocks, including the Theodore and East Susitna Rivers, have experienced more consistent declines over the past 15 years. The Kenai River (late-run) also exhibited a significant negative trend in the most recent period, while some stocks, such as the Anchor River, displayed less pronounced temporal changes. Five-year geometric mean estimates further illustrate these trends, with many stocks showing peak escapement levels in the late 1990s or early 2000s, followed by substantial reductions in the most recent decades. The persistence of declining escapement across multiple systems supports the broader pattern of long-term reduction observed in this ESU.

Run size analyses similarly indicate widespread declines, with many stocks experiencing peak run sizes in the late 1980s or 1990s before entering a period of decline. Notably, the East Susitna and Kenai (late-run) Rivers stocks showed some of the most pronounced reductions in run size, particularly in the 2009–2023 period. In contrast, stocks such as the Anchor River exhibited a more gradual decrease over time. The synchrony observed among multiple stocks in run size trends further supports the idea that large-scale environmental drivers may be influencing population trajectories rather than localized stock-specific factors alone.

Long-term analyses reinforce the findings from short-term assessments, with moderate evidence of sustained declines in escapement and run size across multiple stocks. The estimated posterior distributions for escapement trends indicate moderate evidence of long-term declines in stocks such as Alexander Creek, Deshka River, Theodore River, Ninilchik River, and Karluk River. Similarly, long-term run size trends indicate persistent reductions for stocks including the Karluk River, Anchor River, Kenai River (early and late runs), Deshka River, East Susitna, Talkeetna, and Yentna Rivers. Given the strong interannual coherence observed among

multiple stocks, ongoing monitoring will be critical to determine whether recent declines persist or whether stabilization at lower abundance levels represents a new equilibrium for these populations.

6.5 Statistical Analysis of Depensation in Spawner-Recruit Dynamics

Conventional population dynamics models typically assume that per-capita productivity increases at low abundance levels. Such increased production at low population sizes, also known as compensation, may arise due to reduced competition among individuals during density-dependent life history stages. For instance, in Pacific salmon, recruitment compensation may be the result of reduced competition among spawners for nesting sites, and/or among juveniles for limiting resources. The strength of a population's compensatory response is a critical determinant of its resilience to harvest and its capacity to recover from diminished abundance levels. However, there may also be population sizes below which per-capita productivity declines rather than increases. A decline in productivity at low abundance, known as depensation, or Allee effects, may be the result of disruptions in reproduction, environmental conditioning, or predator saturation (i.e., 'predator pits') (Liermann and Hilborn 2001). In Pacific salmon, plausible mechanisms for depensation include impaired reproduction (i.e., difficulty finding mates on the spawning grounds at low abundance levels) and predator saturation (i.e., because juvenile salmon are only available to predators during a portion of the year, predator population size may not decline with reductions in salmon abundance, such that total consumption levels remain constant and per-capita predation rates increase at low salmon abundance) (Peterman 1987). Crucially, depensation can restrict a population's capacity to recover from low abundance, even under limited fishing, and is thus an important consideration in conservation planning and ESA listing criteria.

6.5.1 Methods

To assess evidence of depensation in 16 Gulf of Alaska Chinook salmon stocks for which requisite data were available, we employed a Bayesian hierarchical modeling approach that allows for depensation in the stock-recruit function following the methods of Liermann and Hilborn (1997). We fit this model to all stocks with available spawner-recruit data simultaneously using a modified form of the Beverton-Holt model. While the Ricker model is commonly used for stock-recruit analyses of Alaskan salmon, we chose the Beverton-Holt here to be consistent with the methodology of Liermann and Hilborn (1997). The depensatory Beverton-Holt model follows the form:

$$R_{p,y} = \frac{\alpha_p S_{p,y}^{d_p}}{b_p^{d_p} + S_{p,y}^{d_p}} e^{\varepsilon_{p,y}}, \quad (1)$$

where $R_{p,y}$ are the predicted recruits for stock p originating from brood year y , $S_{p,y}$ represents the spawner abundance (i.e., escapement) for stock p in brood year y , α_p represents the asymptotic recruitment, b_p is the levels of spawners that produces $\alpha_p/2$ recruits, d_p is the

depensatory parameter, and $\varepsilon_{p,y}$ are lognormally distributed recruitment errors. The parameters α_p and b_p were hierarchically distributed among stocks using a non-centered parameterization:

$$\text{Log}(\alpha_p) = \mu_\alpha + \sigma_\alpha z_\alpha \quad (2)$$

$$\text{Log}(b_p) = \mu_b + \sigma_b z_b , \quad (3)$$

where μ_α and μ_b are the among-stock means of $\text{Log}(\alpha_p)$ and $\text{Log}(b_p)$ respectively, σ_α and σ_b are the among-stock standard deviation of $\text{Log}(\alpha_p)$ and $\text{Log}(b_p)$ respectively, and z_α and z_b are standard scaling factors that are normally distributed with means of 0 and standard deviations of 1. Mean and standard deviation terms for these among-stock hierarchical distributions were drawn from vague normal priors:

$$\mu_\alpha \sim \text{Normal}(0,12) \quad (4)$$

$$\mu_b \sim \text{Normal}(0,12) \quad (5)$$

$$\sigma_\alpha \sim \text{Half-Normal}(0,5)[0,] \quad (6)$$

$$\sigma_b \sim \text{Half-Normal}(0,5)[0,] . \quad (7)$$

Note that the brackets on the prior distributions for the σ parameters represent the lower-bound of zero that exists for these terms.

Recruitment deviations ($\varepsilon_{p,y}$) were drawn from stock-specific distributions:

$$\varepsilon_{p,y} \sim \text{Normal}\left(-\frac{\sigma_{Rp}^2}{2}, \sigma_{Rp}\right) , \quad (8)$$

where σ_{Rp} is the recruitment error standard deviation for stock p , and $-\frac{\sigma_{Rp}^2}{2}$ represents a lognormal bias-correction factor. Recruitment error standard deviations were also hierarchically distributed among stocks:

$$\text{Log}(\sigma_{Rp}) = \mu_{\sigma_R} + \sigma_{\sigma_R} z_{\sigma_R} \quad (9)$$

$$\mu_{\sigma_R} \sim \text{Normal}(0,5) \quad (10)$$

$$\sigma_{\sigma_R} \sim \text{Half-Normal}(0,5)[0,] , \quad (11)$$

where μ_{σ_R} and σ_{σ_R} are the mean and standard deviation respectively of the among-stock distribution of $\text{Log}(\sigma_{Rp})$, and z_{σ_R} is a standard $\text{Normal}(0,1)$ scaling factor. Stock-specific depensation terms (d_p) were estimated independently for each stock:

$$d_p \sim \text{Normal}(1,1)[0,] . \quad (12)$$

Spawner abundance (S) was assumed to be observed without error for these analyses, and recruit abundance (R) followed a lognormal likelihood, with a fixed observation error term ($\sigma_{obs} = 0.2$):

$$A_{p,y} \sim \text{Lognormal}(R_{p,y}, \sigma_{obs}) , \quad (13)$$

where $A_{p,y}$ is the ‘observed’ recruitment to stock p in brood year y based on run reconstruction estimates.

Model estimation was conducted in a Bayesian framework, with posterior sampling achieved via Hamiltonian Monte Carlo (HMC) No-U-turn sampling (NUTS) through the *Stan* model building software, implemented in R (4.3.2) (R Core Team 2023) using the *Rstan* (2.32.6) package (Stan Development Team 2024). Sampling occurred across five HMC chains with lengths of 5,000 iterations each. The first 2,500 of samples of each chain were discarded as a “warmup” and each subsequent sample was saved to construct the posterior distribution. Convergence was assessed using the Gelman-Rubin diagnostic (Gelman and Rubin 1992) ($\hat{R} \leq 1.01$) and effective number of samples (≥ 400). Posterior sampling was monitored for divergent transitions and low Bayesian Fraction of Missing Information (BFMI), neither of which were present.

The degree of depensation displayed by Equation 1 is influenced by the exponent term (d_p), where a value of $d_p=1$ indicates normal Beverton-Holt model behavior, a value of $d_p > 1$ indicates depensatory behavior, and $d_p < 1$ indicates hypercompensation. However, as noted by Liermann and Hilborn (1997), the value of d_p has no biologically meaningful interpretation with regard to the intensity of depensation, which is influenced by the values of other parameters in the model (b_p , and particularly α_p). For instance, a given value of $d_p > 1$ may indicate very slight or intense depensation depending on the values of other Beverton-Holt parameters. As such, Liermann and Hilborn (1997) introduced a re-parameterization of the depensatory stock-recruit model based on S^* , R^* , z , and q , where q provides a biologically meaningful measure of the strength of depensation. In this reparameterization, S^* is defined as the maximum observed spawning level for a given stock, and R^* as the corresponding predicted recruitment at this spawner level:

$$R_p^* = \frac{\alpha_p S_p^{*d_p}}{b_p^{d_p} + S_p^{*d_p}}. \quad (14)$$

After defining R_p^* , z is then calculated as the proportion of R_p^* occurring at $0.5 S_p^*$, adapted from the commonly used steepness parameterization of the Beverton-Holt model put forth in Mace and Doonan (1988):

$$z_p = \frac{\alpha_p (0.5 S_p^*)^{d_p}}{b_p^{d_p} + (0.5 S_p^*)^{d_p}}. \quad (15)$$

Using these values of R_p^* and z_p , we then derive the parameters α_p' and b_p' for the standard Beverton-Holt curve (without depensation) which has the same z and R_p^* as the depensatory

model (*i.e.* predicted recruitment at S_p^* and $0.5S_p^*$ are the same between the depensatory and non-depensatory curves) by setting $d = 1$ and solving for Equations 14 and 15 simultaneously:

$$\alpha_p' = \frac{0.5R_p^*z_p}{z_p - 0.5} \quad (16)$$

$$b_p' = \frac{0.5S_p^*(1-z_p)}{z_p - 0.5}. \quad (17)$$

Finally, q is then calculated as the ratio between the depensatory and standard Beverton-Holt models at $0.1S_p^*$ (*i.e.* at low stock size):

$$q_p = \frac{\frac{\alpha_p(0.1S_p^*)^{d_p}}{b_p^{d_p} + (0.1S_p^*)^{d_p}}}{\frac{\alpha_p'(0.1S_p^*)}{b_p' + (0.1S_p^*)}}. \quad (18)$$

As a measure of depensation, q_p has a relatively straightforward biological interpretation; values of $q_p < 1$ represent depensation, while values of $q_p > 1$ represent hypercompensation (q_p is analytically bounded between 0 and approximately 1.55 (Liermann and Hilborn 1997, Supplementary materials). Importantly in our analysis, q_p is calculated for each draw from the joint posterior of the fitted model, thereby propagating parameter uncertainty and correlations from the joint posterior into the estimated posterior distribution of q .

6.5.2 Results

Evidence for depensation among Gulf of Alaska Chinook salmon stocks with available stock-recruit data was highly variable. Stocks for which the 95% credible interval of q was less than 1 are considered to exhibit strong evidence of depensation, while those for which the 50% credible interval were less than 1 are considered to exhibit moderate evidence of depensation, and those for which the 50% credible interval overlaps 1 are considered to exhibit little to no evidence of depensation. Similarly, stocks for which the 95% or 50% credible intervals were greater than 1 are considered to exhibit strong and moderate evidence of hypercompensation respectively. Across all stocks considered here, none exhibited 95% credible intervals for q that were consistently below 1 (Figure 55). However, the East Susitna, Kenai late-run, Stikine, and Talkeetna Rivers stocks exhibited 50% credible intervals for q that were consistently below 1, indicating moderate evidence of depensation for these stocks (Figure 55). It is worth noting that these stocks also exhibited some of the widest credible intervals for q in general (Figure 55). Conversely, the 95% credible interval of q was greater than 1 for the Chignik River stock, indicating strong evidence of hypercompensation, and the 50% credible intervals of q were greater than 1 for the Anchor, Ayakulik, Chilkat, and Kenai (early-run) Rivers, indicating moderate evidence of hypercompensation for these stocks (Figure 55).

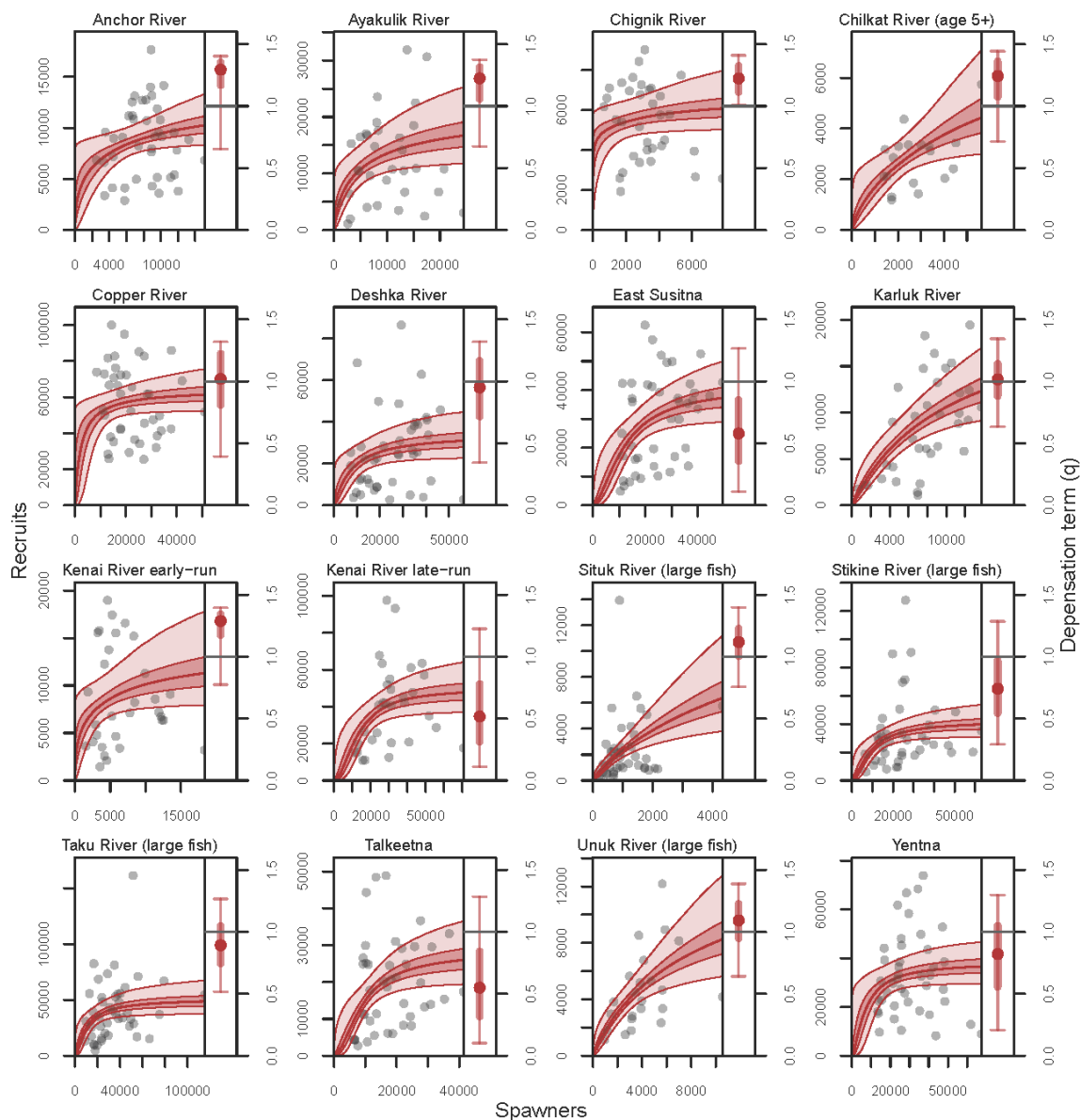


Figure 55. -- Stock recruit patterns and estimates of depensation for Gulf of Alaska Chinook salmon stocks. In each panel, the predicted recruitment across the range of observed spawner abundances (escapement) is shown on the left-hand side. Median posterior estimates are indicated by solid lines, and 50 and 95% credible intervals are indicated by dark and light shaded polygons respectively. Realized spawner and recruit abundance data are shown as gray circles. In the right-hand portion of each panel, the posterior distribution of the estimated depensation term (q) for each stock is shown, with the median indicated by a solid red circle, and 50% and 95% credible intervals indicated by thick and thin lines respectively. Horizontal lines at $q = 1$ (no depensation, no hypercompensation) indicate the distinction between depensatory ($q < 1$) and hypercompensatory ($q > 1$) parameter values of q .

6.5.3 Discussion

Overall, stock-recruit analyses of 16 Gulf of Alaska Chinook salmon stocks showed limited evidence for depensation. No stock exhibited strong evidence of depensation, as indicated by the posterior distributions of q . Four out of the 16 stocks exhibited moderate evidence of depensation. Thus, we conclude that our analysis does not indicate convincing evidence for widespread depensation among the Gulf of Alaska Chinook salmon stocks analyzed here, but that depensatory dynamics are possible (i.e., at least some portion of the posterior distribution of q is < 1) for all stocks. It is important to note that limited support for depensation should not necessarily be interpreted as evidence that depensation is not a risk, but may simply indicate that spawner abundances have not been sufficiently reduced to trigger strong depensatory responses. Moreover, it should be noted that there was at least some evidence of depensation for nearly all stocks, suggesting that the risk of depensation cannot be ruled out. Similarly, there was at least some evidence of hypercompensation (some portion of the posterior distribution of q is > 1) for all stocks as well. The uncertainty in estimating depensation/hypercompensation likely arises from the substantial ‘noise’ (i.e., process and observation error) that is characteristic of stock-recruit data, and may be further complicated by factors such as time-varying productivity.

Despite the uncertainty surrounding our estimates of depensation among Gulf of Alaska Chinook salmon stocks, incorporating depensation into management reference points and procedures may be useful as a precautionary measure (Liermann and Hilborn 1997). Management reference points that account for depensation can be derived analytically/numerically, and simulation studies that explore the outcomes of alternative harvest control rules across the posterior distribution of depensatory stock-recruit parameters may be useful for determining robust management procedures. Among the four stocks for which we detected moderate evidence of depensation (East Susitna, Kenai late-run, Stikine, and Talkeetna Rivers), particular caution may be warranted in management to avoid low spawner abundances and possible depensatory responses. It should be noted that our stock-recruit analyses did not account for observation error in spawner abundance estimates, and assumed a fixed, arbitrary observation error term for recruit abundance, which may have impacted results (Hilborn and Walters 1992). Likewise, we did not account for time-varying productivity, which is difficult to estimate alongside depensatory dynamics but could influence the results.

7 ANALYSIS OF ESA SECTION 4(A)(1) FACTORS

7.1 Introduction

Section 4(a)(1) of the ESA requires NMFS to determine whether any species is a threatened or endangered species based on any one or combination of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or

predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or man-made factors affecting its continued existence. In the sections below, we discuss each of these factors as they relate to Gulf of Alaska Chinook salmon.

7.2 The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

This section focuses on human activities that can have adverse impacts on nearshore, estuarine, and freshwater habitats for the different life history stages of Chinook salmon. The intensity of the various activities differs between ESUs, though the impacts are largely the same. We describe the effects of non-fishing activities and concerns for habitat in the Southeast Gulf of Alaska subsection (Southeast Gulf of Alaska ESU) and then use those descriptions as a reference for the following subsections while highlighting what makes each ESU unique. We also incorporate by reference the report *Impacts to Essential Fish Habitat from Non-Fishing Activities in Alaska: EFH 5-year review from 2018-2023* ("Non-Fishing Effects Report", Limpinsel et al. 2023). The Non-Fishing Effects Report outlines the potential adverse effects of non-fishing activities on essential fish habitat (EFH) and provides conservation recommendations to avoid and minimize those effects.

For the purposes of this review, we will focus on EFH defined for Chinook salmon in the GOA. EFH is habitat necessary to fish for spawning, breeding, feeding, and growth to maturity (16 USC 1802(10)). For salmon, EFH includes freshwater habitat for egg, alevin, fry, juvenile, and returning adult life history stages. Salmon EFH during freshwater life history stages includes all streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to salmon in the state (NPFMC 2024 - Appendix A). Over 14,000 water bodies containing anadromous salmonids identified in the state represent only part of the salmon EFH in Alaska, because many likely habitats have not been surveyed. ADF&G identifies various streams that are used either for migration, spawning, or rearing in the *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes* (often referred to as the Anadromous Waters Catalog or AWC). The AWC is divided regionally, and the streams feeding into the GOA can be found in the Southeast, Southcentral, and Southwest Region special publications (e.g., Giefer and Graziano 2024). Additionally, there is information on which species are present in each water body in the catalog. So, for most threats we were able to assess threats for Chinook habitat specifically.

7.2.1 Southeast Gulf of Alaska ESU

A summary of habitat impacts for this ESU can be found in Table 20.

7.2.1.1 Land use

Approximately 88% of the land in Alaska is publicly owned, with much of this public land having some level of protection (ADF&G Habitat¹⁷). At the state level, land and water protection includes State Game Refuges, Critical Habitat Areas, Wildlife Sanctuaries, State Range Areas, Anadromous Waters Catalog protections, Controlled Use Areas, State Parks, Preserves, and Recreation Areas, State Forests, and Special Use Areas (ADF&G Habitat). Federally protected lands include National Wildlife Refuges, National Parks, Preserves, and Monuments, National Forests, National Landscape Conservation Units, Wilderness Areas, Marine Protected Areas, and Endangered Species Critical Habitat (ADF&G Habitat). There are also areas in Alaska with important wildlife designations (e.g., Important Bird Areas) that lack additional protections, but have some level of national or international recognition (ADF&G Habitat). Due to these protections and other factors, many habitats in Alaska are in good condition, especially compared to the contiguous United States. A report that modeled habitat intactness in Alaska found that over 95% of the state is considered to have “very high” intactness, 3% is “high” or “moderate,” and less than 0.5% is “very low” (Trammell and Aisu 2015, Reynolds et al. 2018). Specifically, the authors collated data on pipelines, powerlines, telephone lines, the Alaska Endangered Plants Information Clearinghouse (AKEPIC) invasive species database, BLM trails, ice and rolligon roads (seasonal winter roads), major rivers, transportation, mining, logging, and the national landcover database to assess total human impacts to include in their model, and assigned an impact score and decay distance to each factor (Trammell and Aisu 2015). Despite the high level of overall intactness, they found that no ecoregions in Alaska can be considered pristine, with some level of human disturbance in all (Reynolds et al. 2018). In total, they determined there are approximately 3,156 km of highways, 17,180 km of secondary roads, 37,255 km of trails, 6,120 km of 4WD/OHV roads, 42 km² of high-density urban development, 119 km² of medium-density urban development, 1,224 km² of low-density urban development, 288 km² of agriculture, and 2,446 km² of active logging across the entire state (Trammell and Aisu 2015).

Timber harvest is a land use that may have significant impacts on Chinook salmon and their habitat, with categories of associated impacts including roads, culverts, vegetation removal, log transfer facilities, and in-water log storage (Limpinsel et al. 2023). The primary risk from logging roads is erosion, with erosion leading to increased sedimentation and decreased water quality; on a larger scale, erosion leading to landslides may also smother salmon eggs or block fish passage (Limpinsel et al. 2023). Culverts associated with these logging roads threaten upstream and downstream fish passage, as they may alter flow in a way that impedes fish passage, and blocked culverts may prevent fish passage entirely (Limpinsel et al. 2023). Timber harvest also often results in the removal of streamside vegetation, which both alters stream temperature (higher in the summer and lower in the winter) and reduces in-stream habitat complexity by

¹⁷ Alaska Department of Fish and Game, Habitat Section. Conservation Areas. Available at <https://www.ADF&G.alaska.gov/index.cfm?ADF&G=conservationareas.main>. Accessed April 25, 2025.

reducing the amount of vegetation and large woody debris entering the stream (Limpinsel et al. 2023). Finally, the in-stream transport and storage of logs can also damage Chinook habitat through physical destruction of habitat and degradation of water quality (Limpinsel et al. 2023). Guidance in place to minimize the impacts of timber harvest on fish habitat includes the Alaska Forest Resources and Practices Act and U.S. Forest Service plans for the Tongass and Chugach National Forests. These laws and guidelines include designing roads and culverts in ways that minimize impacts to streams, preserving vegetated buffers along streams, and reforestation (USDA 2016, USDA 2020)(ADNR 2017¹⁸).

Two more land uses with potential impacts on Chinook and their habitat are agriculture and oil and gas extraction; however, these land uses are only found in the Northwest GOA ESU and are not present in the Central GOA or Southeast Gulf of Alaska ESUs. There are two primary ways in which agriculture may impact Chinook habitat: physical habitat alteration and impacts on water quality. Potential physical habitat alterations include erosion and loss of wetlands, while water quality impacts include altered temperature, increased nutrients (eutrophication), reduced dissolved oxygen, release of pesticides, and increased turbidity (Limpinsel et al. 2023). Potential impacts from oil and natural gas exploration, development, and production include increased noise, physical habitat alteration, and pollution from either accidental oil spills or routine waste discharge (Limpinsel et al. 2023).

To assess land use in each ESU specifically, we overlaid polygons for watersheds (HUC 8 subbasins in the United States; sub-subbasins in Canada) containing GOA Chinook habitat from the Anadromous Waters Catalog (hereafter, “ESU boundaries”) with polygons for different types of land use and land protection. The land use categories included were active and terminated timber sale areas in the United States, satellite-detected areas of historical (1984-2015) timber harvest in Canada, and sawmills in both countries; areas of agriculture via 30 m-resolution Landsat satellite imagery of global croplands in 2019; oil and gas lease sale tracts in the United States, and oil and gas wells in both the United States and Canada (Guindon et al. 2017, ADCCED 2019, ADNR 2022, Potapov et al. 2022, ADNR 2023, ADNR 2024, Esri Canada 2025). The protected land categories included were National Parks, National Wildlife Refuges, National Forests, and Alaska State Parks in the United States; and National Parks and Protected and Conserved Areas in Canada (Natural Resources Canada 2022, Environment and Climate Change Canada 2024, ADNR 2025, NPS 2025, USFS 2025, USFWS 2025).

We calculated percentages of land area within ESU boundaries occupied by each of these land use classifications within the “field calculator” function for the ESU boundary’s layer in QGIS using the following function:

¹⁸ ADNR (Alaska Department of Natural Resources). 2017. Alaska Forest Resources and Practices Act. Available at <https://forestry.alaska.gov/forestpractices>. Accessed April 25, 2025.

$$\text{area}(\text{intersection}(\$geometry, \text{collect\_geometries}(\text{overlay\_intersects}('name of land use/land protection layer', \$geometry))))/\text{area}(\$geometry)*100 .$$

We also quantified point features for land use (e.g., saw mills, oil and gas wells) in each ESU, and visually examined their proximity to Chinook-bearing streams.

In the SEGOA ESU, 48.5% of the land is protected: 35.44% is National Forest, 12.75% is Canadian Protected and Conserved, 0.3% is Alaska State Park, and 0.01% is National Park (Figure 56). In terms of land use, 0.06% is historical Canadian timber harvest, 0.05% is terminated U.S. timber harvest, and < 0.01% is active U.S. timber harvest (Figure 56). There are 11 sawmills within ESU boundaries, five of which are near Chinook-bearing streams (within 10 km). There are no agricultural areas in the SEGOA ESU in either the United States or Canada, nor are there any oil and gas lease areas or wells within the ESU in either country. Land use for mining and gravel extraction in particular is detailed in the following section, 7.2.1.2 Mining and gravel extraction.

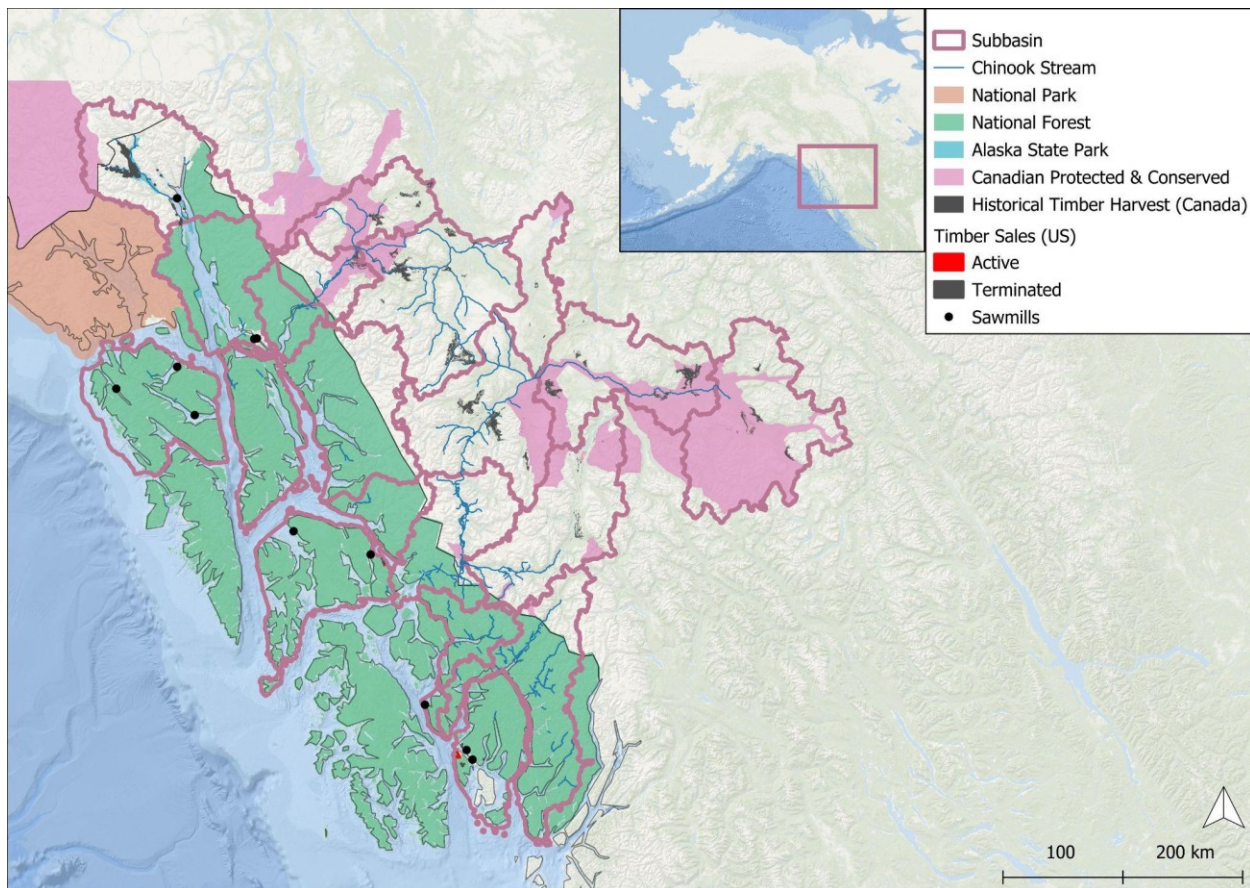


Figure 56. --Land use in the Southeast Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as purple polygons, with Chinook-bearing streams shown in blue. Protected lands in this ESU are also shown: National Parks in orange, National Forests in green, Alaska State Parks in blue, and Canadian Protected and Conserved Areas in pink. Timber harvest is also shown; areas with active timber sale are displayed as red polygons and terminated timber sale as gray polygons, with sawmills displayed as black points. In Canadian watersheds, areas of historical timber harvest (between 1984 and 2015) are shown in gray.

7.2.1.2 Mining and gravel extraction

Large-scale mining operations in anadromous watersheds have the potential to impact EFH in several ways. The scale depends on the type of mineral extraction, the storage of tailings, the methods for processing minerals, the scope of the project, and the dynamics of the surrounding ecosystem processes (Sergeant et al. 2022). The greatest risk to salmon habitat is tailings dam failures, which can release large quantities of toxic mine waste and contaminated water into the nearby watershed. Smaller impacts are also considered for cumulative effects to an area, especially if multiple mine operations are active or proposed within the same watershed. When action agencies evaluate proposed mining projects and produce EFH assessments, their focus is often on five major activities with adverse impacts to EFH: tailings storage and tailings dam

failures, water storage and treatment, water removal from adjacent streams, heavy metal dispersal (e.g. fugitive dust), and acid mine drainage (Limpinsel et al. 2023).

Adverse impacts from mining actions include, largely, negative impacts to water quality. The risk of certain types of tailings and water storage is that, if untreated water leaches, it can carry harmful heavy metal contaminants into surface or groundwater. Exposure to metal contaminants influences migratory behavior and predator avoidance mechanisms in fish (Brix et al. 2001, Hecht et al. 2007). Numerous studies have shown how exposure to toxic contaminants in surface waters can affect fish olfaction, which is critical for behaviors such as mating, locating prey, and avoiding predators (McIntyre et al. 2012, Morris et al. 2019). Contaminated freshwater invertebrate prey species are also a pathway for toxins to affect salmonids (Hansen et al. 2004). The depletion of water quality therefore directly impacts fish survival in these impacted areas and downstream habitats. Elevated concentrations of metals have led to the extirpation of local salmon populations (Mebane et al. 2015).

We incorporate by reference *Section 2.3 Habitat for more regionally specific information on domestic mining operations* from ADF&G (2024f). We note that NMFS's findings for the level of impact of mining operations and other non-fishing activities may differ from ADF&G for the purposes of impacts to EFH of Fishery Management Plan (FMP) species.

Salmon habitat in the SEGOA is impacted by both domestic and transboundary mining projects. There are about 27 active, 56 inactive, and 33 undetermined mine sites in SEAK Chinook watersheds (USGS 2024)(Figure 57). There are also about 109 active and inactive proposed mines being pursued in the same area.

The SEGOA also has gravel extraction operations, with gravel bars and streambeds being common sources for gravel used in construction projects. While sand and gravel extraction is preferred from upland sources, a fish habitat permit may be issued from ADF&G for in-water actions (ADF&G 2023¹⁹). Impacts to salmon EFH associated with these activities include: the creation of turbidity plumes and re-suspension of sediment and nutrients, the removal of spawning habitat, and the alteration of channel morphology. These can cause secondary impacts like disrupting migration patterns, changing stream dynamics, decreasing nutrients with the loss of riparian vegetation, and decreasing prey availability (Limpinsel et al. 2023). The Alaska Department of Environmental Conservation (DEC) has a manual on best management practices for gravel and rock aggregate extraction to protect surface water and groundwater quality (ADEC 2021). Juneau, Alaska, has two sand, gravel, and hardrock operation locations in the Lemon Creek area; however, we note that while Lemon Creek fits the definition of EFH for Chinook salmon, it is only identified as an anadromous stream used by chum, coho, and pink salmon, and Dolly Varden char (Giefer and Graziano 2024).

¹⁹ ADF&G. Southeastern Alaska Streams Application. Available at https://www.ADF&G.alaska.gov/static/license/uselicense/pdfs/southeast_mining_application.pdf. Accessed April 25, 2025.

There are several past, current, and proposed mining operations in British Columbia (BC) that link to Alaska through transboundary watersheds. The Taku, Stikine, Unuk, and Nass Watersheds all connect BC and Alaska. There are more than 450 Canadian companies working towards claims staking and mine exploration near rivers, streams, and glaciers in Northwest British Columbia (EIA 2024). While many companies do not pursue mineral extraction, the impacts from site selection and exploratory drilling can affect habitat, and consideration should be taken for cumulative effects. NOAA is a technical advisor with the management agency B.C. Environmental Assessment Office and currently reviews two proposed mine projects: Eskay Creek Revitalization²⁰ project in the Unuk Watershed and the New Polaris Gold Mine²¹ in the Taku Watershed. Project components that could have the greatest impacts on fish habitat include constructing tailings dams for subaqueous tailings storage and barging cyanide and other materials to the mine site, respectively. Both transboundary rivers are identified as Chinook salmon EFH (Gieffer and Graziano 2024, NPFMC 2024).

²⁰ British Columbia EPIC. Eskay Creek Revitalization. Available at <https://projects.eao.gov.bc.ca/p/60f078d3332ebd0022a39224/project-details>.

²¹ British Columbia EPIC. New Polaris Gold Mine. Available at <https://www.projects.eao.gov.bc.ca/p/63fe919f30ceae0022e0ca28/project-details>.

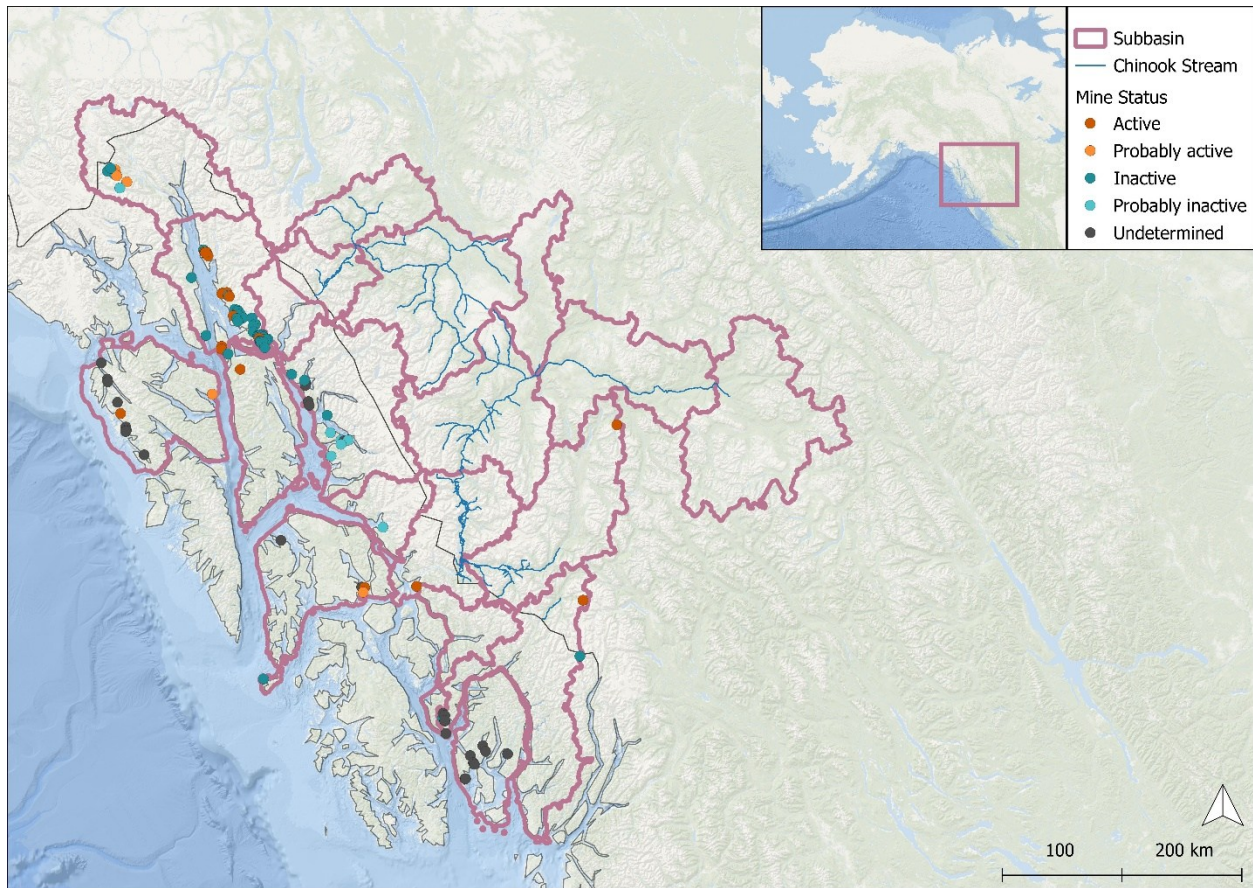


Figure 57. -- Mines in the Southeast Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as purple polygons, with Chinook-bearing streams shown in blue. Mines are displayed as points colored by site status: “Active” in dark orange, “Probably active” in light orange, “Inactive” in dark turquoise, “Probably inactive” in light turquoise, or “Undetermined” in gray. Only active mines are displayed in Canada.

7.2.1.3 Urbanization

Urban and suburban development significantly negatively impacts fish and fish habitat. While development is minimal in Alaska compared to many other places, it still may have significant impacts on some Chinook systems, especially in areas with higher population densities. One impact of urbanization is simply the physical loss of shoreline and riparian habitat, with negative impacts from the removal of vegetation in these habitats including increased stream temperatures, reduced habitat complexity, reduced sources of prey, and altered nutrient concentrations (Limpinsel et al. 2023). Urbanization also leads to increased impervious cover, with impervious surfaces being those that prevent rainwater from entering the ground or groundwater from leaving the ground (e.g., roads, parking lots, buildings). One major impact of impervious surfaces is increased runoff volumes, with runoff being the most widespread source of pollutants entering watersheds in the nation (McCarthy et al. 2008, Limpinsel et al. 2023). These pollutants from commercial, residential, industrial, and agricultural sources may include

pesticides, fertilizers, chemicals, heavy metals, sediment, oil, bacteria, waste, and many other contaminants (McCarthy et al. 2008). Beyond the pollution from runoff, stormwater management systems in developed areas may also lead to high-volume, high velocity flows entering watersheds and accelerating erosion and sedimentation (Limpinsel et al. 2023). A review of the impacts associated with impervious cover and urbanization found a negative relationship between urban and suburban development in watersheds and 26 different indicators of stream quality, finding impacts on stream quality when a watershed exceeded only 10% impervious cover (CWP 2003). A study on coho salmon in Washington found that coho were rarely found in watersheds with impervious cover greater than 10-15% (Luchetti and Feurstenburg 1993).

The processes of urban and suburban development may also have additional impacts on Chinook habitat. The process of freshwater or marine dredging for fill generation or flood risk mitigation may physically remove or bury aquatic animals and vegetation, cause injury or mortality, increase turbidity, and release nutrients, chemicals, bacteria, and other contaminants (Limpinsel et al. 2023). Additionally, the disposal of dredged material or discharge of fill material results in a permanent loss of habitat, as well as alterations to habitat and habitat functions in nearby areas (Limpinsel et al. 2023). Discharge of these materials may also alter water quality parameters, including turbidity, temperature, oxygen concentration, and nutrient concentrations (Limpinsel et al. 2023).

Road development is a significant habitat impact associated with urbanization, with roads and their impacts often reaching far beyond areas of high population density. Impacts from roads include habitat fragmentation, barriers to fish passage, and alteration of water flow (Limpinsel et al. 2023). Road construction and maintenance may also remove large woody debris and other vegetation from riparian habitats, potentially leading to decreased habitat complexity, cover, and prey sources, as well as alterations of channel structure and flow (Limpinsel et al. 2023). As discussed in earlier paragraphs, roads are also a type of impervious cover, leading to increased runoff; runoff from roads may contain particularly harmful pollutants such as motor oil and de-icing chemicals (Limpinsel et al. 2023). A variety of chemicals used in transportation may cause lethal or sublethal effects to salmonids when they run-off into aquatic environments. Examples include 6PPD-quinone, a chemical found in tires (e.g., Brinkmann et al. 2022, Lo et al. 2023); copper in brake pads (e.g., Baldwin et al. 2011); road deicing salts (e.g., Mahrosh et al. 2014, Hintz and Relyea 2017); aircraft deicers (e.g., Freeman et al. 2015), and fire retardants (e.g., PFAS, Fraley et al. 2020). Other development associated with roads, such as culverts, can pose threats to fish passage. Improperly sized or blocked culverts may physically block all fish passage, especially for larger fish; even when fish could pass through the culvert itself, undersized culverts may increase flow to the point where the flow rate is prohibitive to passage.

Culverts in Alaska are collated in the Alaska Department of Fish and Game Fish Passage Inventory Database, which assigns each culvert a rating of “likely to provide adequate juvenile

fish passage” in green, “may be inadequate for juvenile fish passage” in gray, “assumed to be inadequate for juvenile fish passage” in red, and “unable to assign fish passage rating” in black (O'Doherty and Eisenman 2021). Culverts that are inadequate for fish passage have been targeted in many recent culvert replacement efforts, with some recent culvert replacement projects from the U.S. Fish and Wildlife Service including Copper River and Tyonek Creek (USFWS 2019, Limpinsel et al. 2023). Culverts in Alaska are collated in the Alaska Department of Fish and Game Fish Passage Inventory Database, which assigns each culvert a rating of “likely to provide adequate juvenile fish passage” in green, “may be inadequate for juvenile fish passage” in gray, “assumed to be inadequate for juvenile fish passage” in red, and “unable to assign fish passage rating” in black (O'Doherty and Eisenman 2021). Culverts that are inadequate for fish passage have been targeted in many recent culvert replacement efforts, with some recent culvert replacement projects from the U.S. Fish and Wildlife Service including Copper River and Tyonek Creek (USFWS 2019). Additional fish passage improvement projects can be found in the NOAA Habitat Restoration Atlas²².

To assess urbanization in each ESU specifically, we overlaid the ESU boundary polygons with a raster of modeled 2020 population density at a 30 arc-second (approximately 1 kilometer at the equator, with this distance decreasing at higher latitudes) resolution from the fourth version of the Gridded Population of the World model (Center for International Earth Science Information Network 2018). Only 30 arc-second grids with a density of greater than one person per grid are included in our maps. Cities in Alaska with a population greater than 1,000 are also labeled on the maps; no cities in Canada within ESU boundaries have a population greater than 1,000. We also overlaid roads in Alaska and Canada, and quantified total km of roads in each ESU in QGIS using the “field calculator” to calculate length per section of roads clipped to the ESU polygon ($\text{length} / 1000$), and then summing these sections with the “sum” function under the “basic statistics for fields” tool (ADOTPF 2024, Statistics Canada 2024). To assess potential fish passage barriers associated with roads, we also included data on culverts in Alaska and Canada, both quantifying them and examining potential impacts on passage in Chinook-bearing streams (M. Mazzacavallo, ADF&G, personal communication, April 9, 2025)(Columbia 2023, Government of Yukon 2025a, Government of Yukon 2025b). Specific culvert data varied based on the source; culvert data in British Columbia, Canada only include “drainage” culverts (< 3 m opening), culverts in the Yukon Territory, Canada were classified as either “drainage” culverts (< 2 m opening) or “structural” culverts (> 2 m opening), while culverts in Alaska were classified by fish passage status by ADF&G and color-coded accordingly. The ADF&G system classifies them as “likely to provide adequate juvenile fish passage” in green, “may be inadequate for juvenile fish passage” in gray, “assumed to be inadequate for juvenile fish passage” in red, and “unable to assign fish passage rating” in black (O'Doherty and Eisenman 2021).

²² NOAA Fisheries Office of Habitat Conservation, NOAA Restoration Center. Restoration Atlas. Available at <https://www.habitat.noaa.gov/apps/restoration-atlas/>. Accessed April 25, 2025.

In the SEGOA ESU, there are four cities in Alaska within ESU boundaries with populations greater than 1,000: Juneau (population ~32,000), Ketchikan (population ~8,000), Petersburg (population ~3,000), and Haines (population ~2,000) (Figure 58A). Note, there may be additional locations within this ESU with populations greater than 1,000, such as boroughs (e.g., Skagway; population ~1,000) and other census-designated places. There are no Canadian cities with populations greater than 1,000 within ESU boundaries. There are “hotspots” of higher population densities near those four larger Alaska cities, but the population in the SEGOA ESU is still fairly low overall. Areas with higher population densities within the ESU are small and geographically constrained. There are 1,343 km of roads in the Alaska portion and 404 km of roads in Canada portion of the SEGOA ESU (Figure 58B). Along Canadian roads, there are 1,192 drainage culverts (< 3 m opening) along Highway 37 (Stewart-Cassiar Highway) and Telegraph Creek Road, potentially impacting the Stikine River and its tributaries. There are 451 culverts on Chinook-bearing streams within the Alaska portion of the ESU: 45 with unassigned fish passage status, 134 with likely adequate fish passage, 97 that may be inadequate for fish passage, and 175 assumed inadequate for fish passage. The culverts in Alaska are all located near five cities: Skagway, Haines, Juneau, Petersburg, and Ketchikan. Some culverts near Haines may potentially impact the Chilkat River and its tributaries. Dams as an urbanization impact are discussed in the following section, 7.2.1.4 Dams.

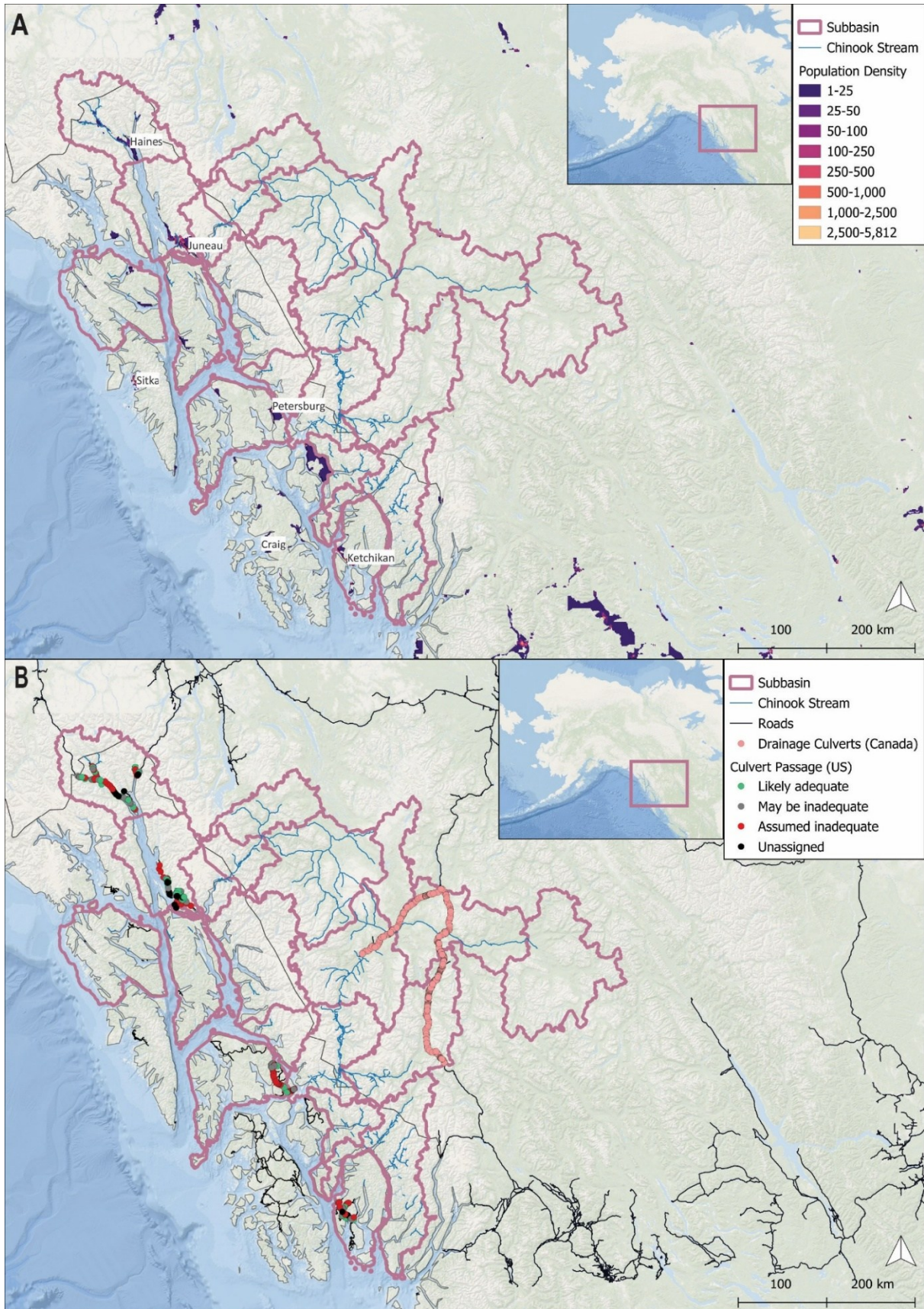


Figure 58. -- Population and urbanization in the Southeast Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as purple polygons, with Chinook-bearing streams shown in blue. Population density (modeled count of people per 30 arc-second grid divided by area of 30 arc-second grid) is shown on a color scale ranging from low density in dark purple to high density in light orange in panel A. Only grids with a population density of greater than 1 person are displayed on the map. Cities in Alaska with a population greater than 1,000 are also labeled; no cities in Canada within ESU boundaries have a population greater than 1,000. Roads are shown in black in panel B. Drainage culverts (< 3 m) in Canada are shown as light pink points, while culverts in Alaska are colored by fish passage status: likely to provide adequate juvenile fish passage in green, may be inadequate for juvenile fish passage in gray, assumed to be inadequate for juvenile fish passage in red, and unable to assign fish passage rating in black.

7.2.1.4 Dams

There are state and federal regulatory mechanisms in place to minimize the impact of dams on fish habitat and fish passage, such as the Federal Energy Regulatory Commission (FERC) licensing process for hydropower facilities under the Federal Power Act (FPA; 16 USC 791a et seq.), which includes sections for recommending protection of fish habitat (section 10(j)), and the ability to prescribe mandatory fishways (i.e. upstream and downstream fish passage) (section 18) (Limpinsel et al. 2023). However, there are still existing hydropower facilities in Alaska that prevent the migration of Pacific salmon (Limpinsel et al. 2023). Dams for other purposes, including water storage and flood control, may also have significant impacts (Limpinsel et al. 2017, Limpinsel et al. 2023). When considering the impacts of dams on GOA Chinook habitat, there are two broad categories: one, impacts from dams as a physical barrier to fish passage, and two, impacts from dams altering fish habitat characteristics.

As physical barriers, dams occurring in anadromous waters may physically prevent adult Chinook salmon from continuing their migration upstream. When upstream passage is inhibited, spawning and rearing habitat is reduced, leading to lower reproductive success, and ultimately, fewer returning adult Chinook. Even when mechanisms are in place for adult passage upstream, dams slow Chinook migration and may negatively impact physiology and fitness through both increased energy expenditure and temperature changes (Caudill 2007, Caudill 2013). There may also be increased mortality for smolts during their downstream passage through the dam upon outmigration. Multiple potential mechanisms for increased injury or mortality have been found to affect the survival of smolts passing through hydropower facilities, including barotrauma from pressure differentials upstream and downstream of the dam, shear stress from hydraulic forces, both direct blade strikes and disorientation from turbines, and increased presence of predators at dam locations (Hogan et al. 2014, Trumbo et al. 2014, Mueller et al. 2020, Limpinsel et al. 2023).

Additionally, there are multiple ways in which dams may impact characteristics of Chinook habitat, and subsequently the success and survival of Chinook at numerous life stages. All types of dams, including water storage, flood control, and hydropower, rely on the alteration of water

flow, leading to downstream effects on water level, velocity, temperature, and turbidity, among other factors. Water storage and flood control dams suppress peak flows, leading to a reduction in the variation in flow a given river experiences (Waples et al. 2009). This reduction in flow variation, and suppression of large flows, can reduce the formation of side-channel habitat and the recruitment of woody debris from surrounding areas to the river, both of which reduce the diversity of salmon habitat in the river (Waples et al. 2009). Conversely, other dam operations, such as hydropower facilities, rely on pulse-type flows. The shorter bursts of high flow can scour salmon habitat and redds and lead to developing fish becoming trapped or stranded when the water levels quickly recede (Reiser et al. 2018²³). However, spawning and rearing habitats do require seasonally high flows to maintain their function; these higher flows can both remove larger rocks that may obstruct access to appropriately-sized gravel and remove finer particles that may prevent adequate circulation of water within the gravel (Kondolf et al. 2000).

All Chinook life stages require specific in-stream conditions, including particular ranges in flow rate, water depth, and water temperature. Near spawning areas, flow rates must be high enough to maintain an adequate depth for adult Chinook to both migrate upstream and be submerged while spawning (Limpinsel et al. 2023). Once eggs have been laid, sufficient flow rates must continue to prevent eggs from freezing and to provide adequate oxygenation for eggs and early life stages, with Chinook alevin requiring 6 milligrams per liter of dissolved oxygen (Groves and Chandler 2005, Limpinsel et al. 2023). Freezing is a risk because the water temperature downstream of dams is often reduced if the dam's water intake comes from lower levels in the reservoir above; however, some dam operations may raise water temperatures, with temperatures above 13°C being lethal to eggs, and temperatures above 18°C negatively impacting spawning and rearing salmon (Mauger et al. 2017, Limpinsel et al. 2023). Beyond temperature considerations, developing Chinook have additional habitat needs, including areas with lower flow and adequate food sources. Ideal rearing habitats are often found in side channels or in areas of the main channel with higher habitat complexity, both habitat features which may be lost under certain dam operations, such as pulse releases (Limpinsel et al. 2023).

We assessed potential impacts from dams in each ESU specifically by overlaying Chinook habitat from the ADF&G Anadromous Waters Catalog (AWC) with dams in Alaska from the U.S. Army Corps of Engineers (USACE) National Inventory of Dams to determine which dams are located in GOA Chinook habitat (USACE 2020, ADF&G 2024a). We also incorporated information from the NOAA Alaska Regional Office Hydropower Projects Review (hereafter cited as "Hydropower Projects Review") and Alaska Dam Inventory (hereafter cited as "Alaska Dam Inventory") that includes comments on impacts to anadromous fishes (pers. comm., Julianne Rossett, NOAA Alaska Regional Office Habitat Conservation Division). For ESUs

²³ Reiser, D.W., T.L. Nightengale, A.N. Hendrix, & S.M. Beck. 2008. Effects of Pulse-Type Flows on Aquatic Biota. Available at <https://www.renewableenergyworld.com/hydro-power/dams-civil-structures/effects-of-pulse-type-flows-on-aquatic-biota/>.

including transboundary systems (SEGOA and CGOA), we also included data on dams in Canada from the Canadian Wildlife Federation Canadian Aquatic Barriers Database, and assessed areas of overlap with Chinook rivers from the Yukon Fisheries Information Summary System and Fish Sampling Atlas from the Community Mapping Network and Fisheries and Oceans Canada (Community Mapping Network 2017, Canadian Wildlife Federation 2024). For both the United States and Canada, we classified dams as “impact likely” if the dam appears to directly overlap with Chinook habitat, “impact possible” if the dam does not appear to directly overlap with Chinook habitat but is on a Chinook system (i.e., upstream or on a tributary), or “impact unlikely” if the dam does not appear to be on a Chinook system, but it is within any of the GOA Chinook subbasins.

Within watersheds in the U.S. portion of the SEGOA ESU, there are no “impact likely,” two “impact possible,” and 24 “impact unlikely” dams (Figure 59). The two “impact possible” dams are the Crystal Lake Dam and the Ketchikan Lakes Dam. The Crystal Lake Dam is on Mitkof Island southeast of Petersburg, Alaska, and northwest of Wrangell, Alaska. The dam is on Crystal Lake, at the head of Crystal Creek, upstream of any anadromous fish runs. Crystal Creek does not contain native Chinook salmon, but does contain hatchery Chinook released by the Crystal Lake Hatchery. The Ketchikan Lakes Dam is located in Ketchikan, Alaska, on Lower Ketchikan Lake at the head of Ketchikan Creek. While Chinook salmon return to Ketchikan Creek, the dam is slightly upstream of the Chinook habitat extent mapped in the AWC. Therefore, it is unlikely that the dam is a physical barrier to Chinook passage, particularly because of two, 35-foot barrier falls downstream of the dam (Hydropower Projects Review). However, Chinook habitat in Ketchikan Creek may still be impacted by the dam in other ways (e.g., flow or temperature).

Within watersheds in the Canadian portion of the SEGOA ESU, there are three “impact likely,” one “impact possible,” and two “impact unlikely” dams (Figure 59). One of the “impact likely” dams is Tahltan Lake Creek Dam, northwest of Telegraph Creek, British Columbia. It is located on Tahltan Lake, at the head of the Tahltan Lake Creek, a Chinook-bearing tributary of the Tahltan River. It is classified as a “barrier” in the Canadian Aquatic Barriers Database. The one remaining “impact likely” dam, the Forrest Kerr Generating Station Dam, and two “impact possible” dams, McLymont Creek Dam and Volcano Creek Dam, are all located on, or on tributaries of, the Iskut River. All three are classified as a “barrier” in the Canadian Aquatic Barriers Database, although the McLymont Creek Dam and Volcano Creek Dam are located on non-Chinook bearing tributaries. The Forest Kerr Generating Station Dam is located on the mainstem Iskut River, which is classified as Chinook habitat. This dam does include a return channel, allowing fish caught in the sluiceway to return to the river (Hatch 2015²⁴).

²⁴ Hatch, Forrest Kerr 195-HW Hydroelectric Power Project, available at https://www.canadianconsultingengineer.com/awards/pdfs/2015/E3_HatchForrestKerrHydro.pdf, Accessed April 25, 2025.

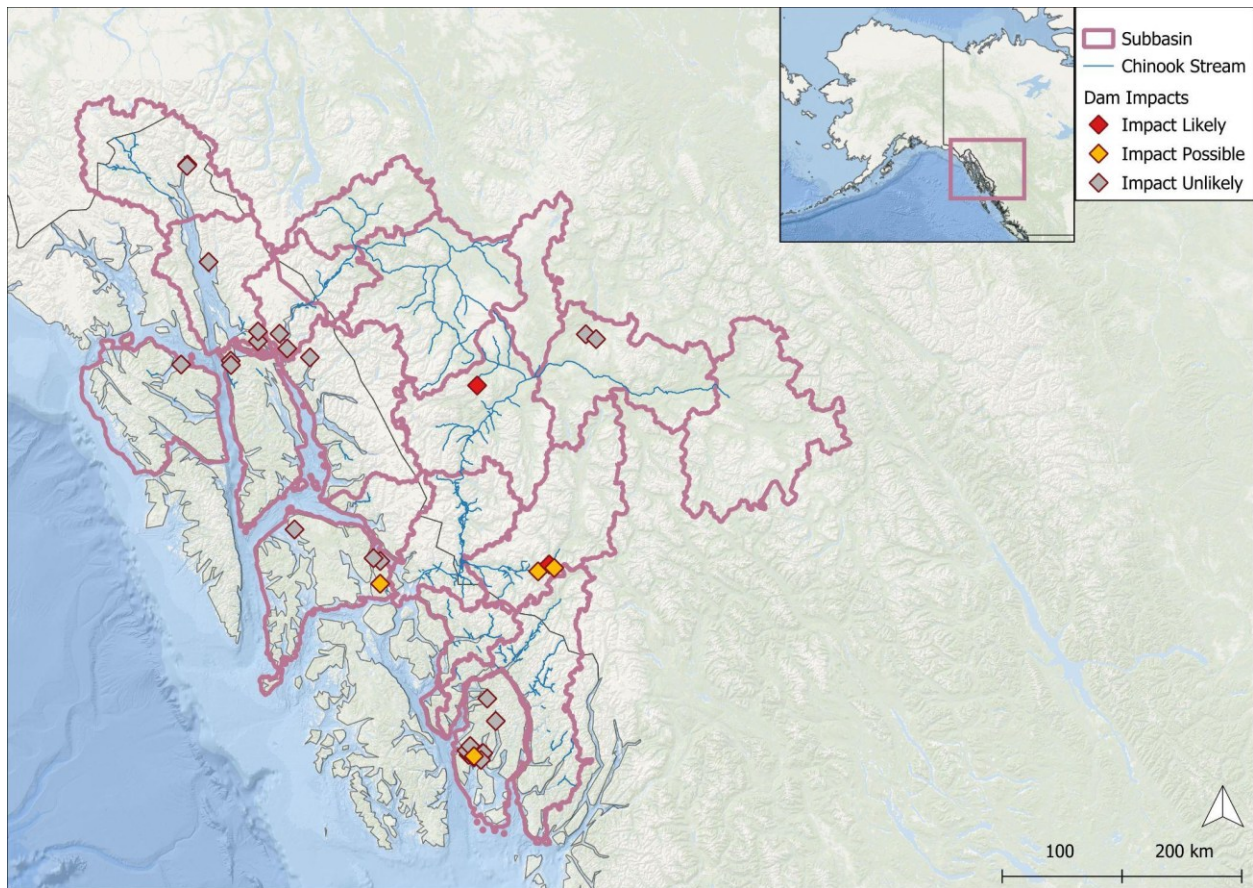


Figure 59. --Dams in the Southeast Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as purple polygons, with Chinook-bearing streams shown in blue. All dams in this ESU are displayed as diamonds, classified as “Impact Likely” if the dam appears to directly overlap with Chinook habitat (displayed in red), “Impact Possible” if the dam does not appear to directly overlap with Chinook habitat, but is on a Chinook system (i.e., upstream or on a tributary; displayed in yellow), or “Impact Unlikely” if the dam does not appear to be on a Chinook system, but it is within any of the GOA Chinook subbasins (displayed in gray).

Table 20. --Land use and urbanization impacts for each index stream in the Southeast Gulf of Alaska ESU. Populations are rounded to the nearest thousand when greater than 1,000; otherwise, to nearest 100. Distances are as the crow flies from the mouth of the stream to the center of the nearest city with a population of greater than 100 people, and rounded to the nearest 10 km. See text for more details about other classifications (e.g., mine status, culvert passage status).

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Andrew Creek	Entirely in Natl. Forest	1 active nearby	-	-	-	Wrangell, AK (~2,000)	~20 km	-	-	-
Blossom River	Entirely in Natl. Forest	-	-	-	-	Ketchikan, AK (~8,000)	~70 km	-	-	-
Chickamin River	Entirely in Natl. Forest	-	-	-	-	Ketchikan, AK (~8,000)	~70 km	-	-	-
Chilkat River	Mostly in State Park	Some active & inactive nearby	Significant terminated harvest; 1 sawmill	-	-	Haines, AK (~2,000)	<1 km	A few roads; 1 crossing	Many of all passage statuses	-
Keta River	Entirely in Natl. Forest	-	-	-	-	Ketchikan, AK (~8,000)	~70 km	-	-	-
King Salmon River	Entirely in Natl. Forest	1 active nearby	-	-	-	Juneau, AK (~32,000)	~30 km	-	-	-

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Stikine River	Some in Natl. Forest & some in Canadian Protected & Conserved	1 active nearby	Historical harvest nearby in Canada	-	-	Wrangell, AK (~2,000)	~20 km	2 roads in Canada; 1 crossing	Multiple drainage culverts in Canada	A few on tributaries
Taku River	Entirely in Natl. Forest & Canadian Protected & Conserved	-	Historical harvest nearby in Canada	-	-	Juneau, AK (~32,000)	~30 km	-	-	-
Unuk River	Mostly in Natl. Forest & Canadian Protected & Conserved	1 active nearby in Canada	Minimal historical harvest nearby in Canada	-	-	Ketchikan, AK (~8,000)	~90 km	-	-	-

7.2.2 Central Gulf of Alaska ESU

A summary of habitat impacts for this ESU can be found in Table 21.

7.2.2.1 Land use

In the CGOA ESU, 79.17% of the land is protected: 37% is National Park, 18.82% is Canadian Protected and Conserved, 13.05% is Canadian National Park, 10.27% is National Forest, 0.03% is Alaska State Park, and < 0.01% is National Wildlife Refuge (Figure 60). This ESU has the highest percentage of protected land, roughly 30% higher than the SEGOA ESU and roughly 40% higher than the NWGOA ESU. There is no historical Canadian timber harvest, nor is there any active U.S. timber harvest, but < 0.01% of the land is terminated U.S. timber harvest (Figure 60). There are three sawmills within ESU boundaries, all of which are within 10 km of Chinook-bearing streams. There are no agricultural areas in the CGOA ESU in either the United States or Canada, nor are there any oil and gas lease areas or wells within the ESU in either country. Land use for mining and gravel extraction in particular is detailed in the following section, 7.2.2.2 Mining and gravel extraction.

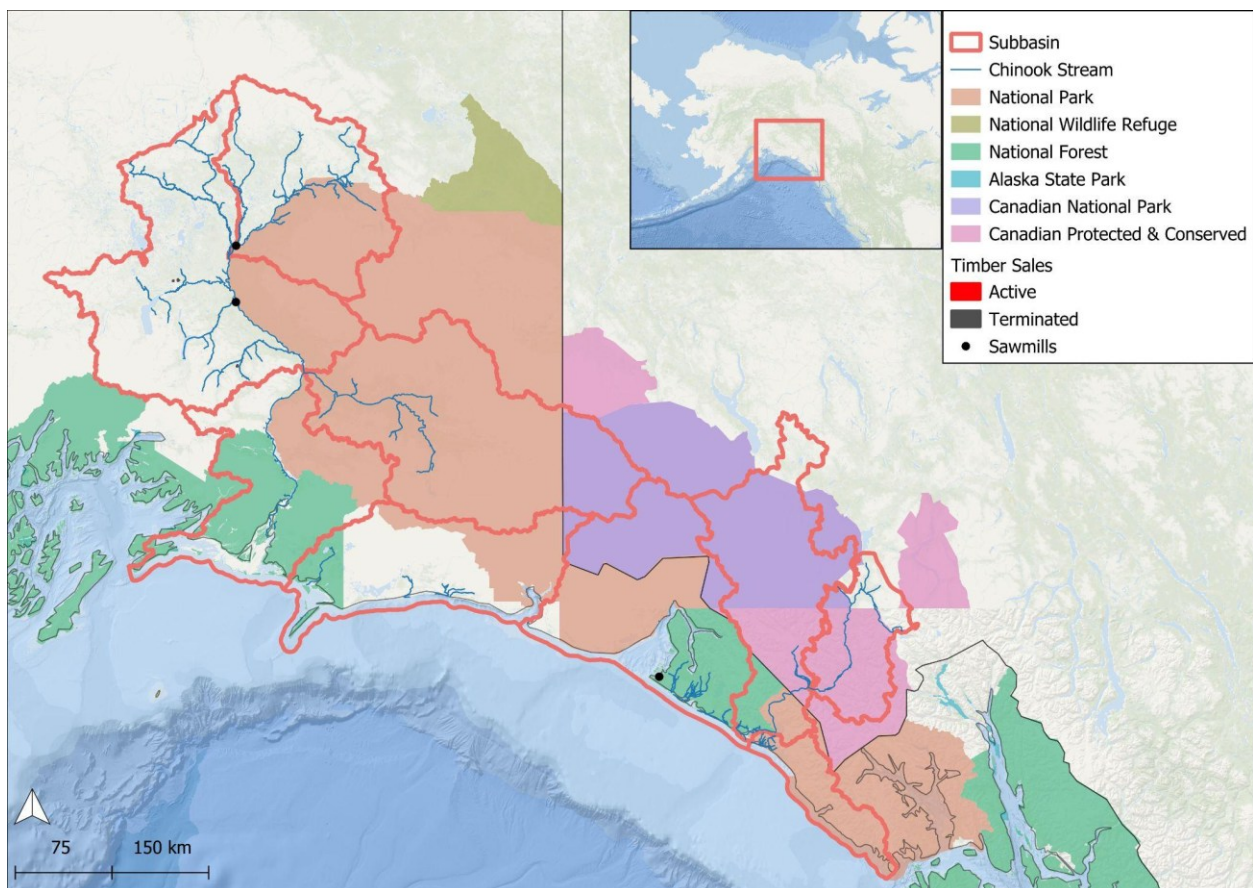


Figure 60. -- Land use in the Central Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as red polygons, with Chinook-bearing streams shown in blue. Protected lands in this ESU are also shown: National Parks in orange, National Forests in green, National Wildlife Refuges in olive, and Alaska State Parks in blue. Timber harvest is also shown; areas with active timber sale are displayed as red polygons and terminated timber sale as gray polygons, with sawmills displayed as black points.

7.2.2.2 Mining and gravel extraction

Mining can impact CGOA ESU Chinook salmon habitat in largely similar ways to the domestic mining operations and actions described above for the SEGOA. The CGOA ESU is not impacted by transboundary mining operations. There are about 3 active, 57 inactive, and 2 undetermined mine sites in subbasins associated with the CGOA ESU (USGS 2024)(Figure 61). There are also about 157 active and inactive proposed mines being pursued in the same area. Proposed mines and mining exploration activities adversely affect habitat through road building and stream crossing for site access, moss removal, footpath brushing, and exploratory drilling. Water withdrawal for the drill sites can also affect stream dynamics including flow rate, temperature, and sedimentation. Depending on the time of work, water withdrawal can displace salmon eggs or larvae, or in-water work can disturb spawning adults (Limpinsel et al. 2023).

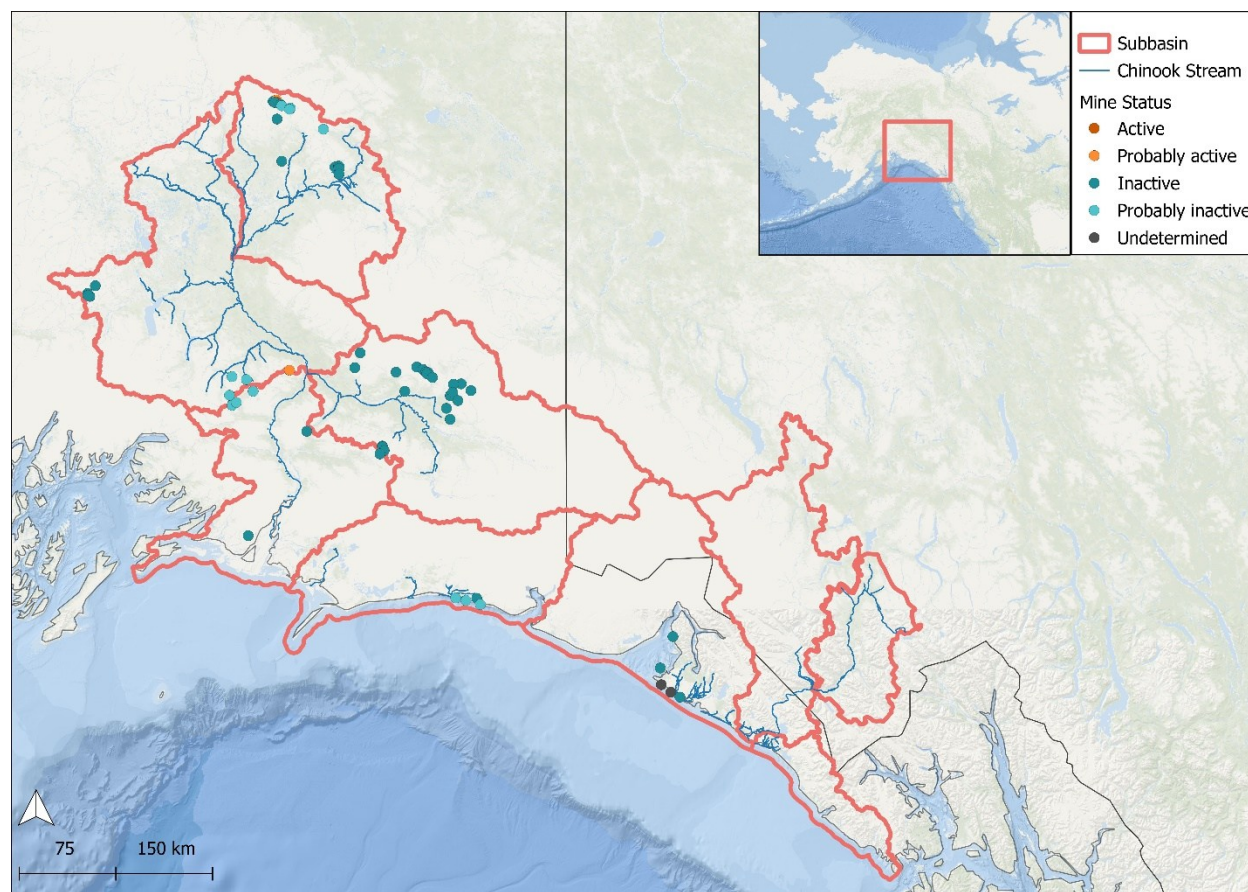


Figure 61. --Mines in the Central Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as red polygons, with Chinook-bearing streams shown in blue. Mines are displayed as points colored by site status: “Active” in dark orange, “Probably active” in light orange, “Inactive” in dark turquoise, “Probably inactive” in light turquoise, or “Undetermined” in gray.

7.2.2.3 Urbanization

In the CGOA ESU, there are no cities with populations greater than 1,000 fully within ESU boundaries, but Cordova, Alaska (population ~2,000), is located on the western border of the ESU (Figure 62A). Only two areas within ESU boundaries have a population density of greater than one person per 30 arc-second grid, Yakutat, Alaska, and the outskirts of Cordova, Alaska. There are 1,177 km of roads in Alaska, plus 132 km of roads in Canada, in the CGOA ESU (Figure 62B). In the Canadian portion of the ESU along Yukon Highway 3, there are 171 drainage culverts (< 2 m opening) and 8 structural culverts (> 2 m opening), potentially impacting the Tatshenshini River, a tributary of the Alsek River, and its tributaries. There are 231 culverts within ESU boundaries in CGOA: 16 with unassigned fish passage status, 42 with likely adequate fish passage, 63 that may be inadequate for fish passage, and 110 assumed inadequate for fish passage. Areas with culverts in this ESU are Cordova, Alaska and the Copper River Highway leaving town, with potential impacts to the Copper River, as well as Alaska Route 1 (Glenn Highway; Tok Highway), Alaska Route 4 (Richardson Highway), and their intersection, with potential impacts to the Copper River and its tributaries. However, there are numerous culvert replacement projects occurring along the Copper River^{25,26}. Dams as an urbanization impact are discussed in the following section, 7.2.2.4 Dams.

²⁵ Copper River Watershed Project. Fish Passage. Available at <https://copperriver.org/programs/fish-habitat-restoration/culverts-are-the-culprits/>. Accessed April 25, 2025.

²⁶ U.S. Fish and Wildlife Service. Making Progress Towards a Barrier-Free Copper River. Available at <https://www.fws.gov/project/making-progress-towards-barrier-free-copper-river>. Accessed April 25, 2025.

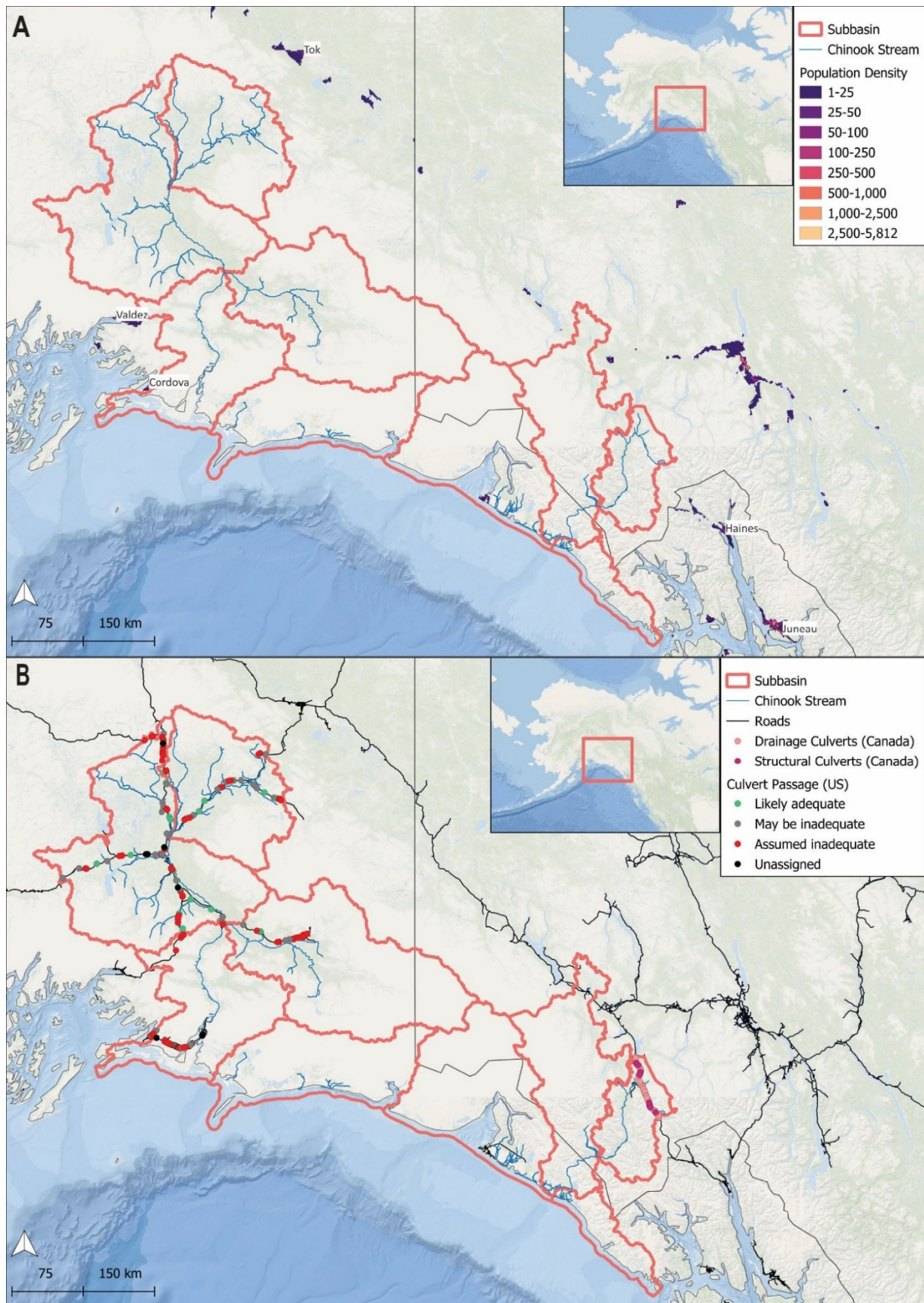


Figure 62. -- Population and urbanization in the Central Gulf of Alaska ESU. Subbasins (HUC 8 subbasins in the United States; sub-sub drainage areas in Canada) included in this ESU are shown as red polygons, with Chinook-bearing streams shown in blue. Population density (modeled count of people per 30 arc-second grid divided by area of 30 arc-second grid) is shown on a color scale ranging from low density in dark purple to high density in light orange in panel A. Only grids with a population density of greater than 1 person are displayed on the map. Cities in Alaska with a population greater than 1,000 are also labeled with white stars; no cities in Canada within ESU boundaries have a population greater than 1,000. Roads are shown in black in panel B. Culverts in Canada are shown as points: drainage (< 2 m) in light pink and structural (> 2 m) in dark pink, while culverts in Alaska are colored by fish passage status: likely to provide adequate juvenile fish passage in green, may be inadequate for juvenile fish passage in gray, assumed to be inadequate for juvenile fish passage in red, and unable to assign fish passage rating in black.

7.2.2.4 Dams

Within watersheds in the U.S. portion of the CGOA ESU, there are no “impact likely” or “impact possible” dams, and only one “impact unlikely” dam near Cordova, Alaska. There are no dams within watersheds in the Canadian portion of the CGOA ESU.

Table 21. -- Land use and urbanization impacts for each index stream in the Central Gulf of Alaska ESU. Populations are rounded to the nearest thousand when greater than 1,000; otherwise, to nearest 100. Distances are as the crow flies from the mouth of the stream to the center of the nearest city with a population of greater than 100 people, and rounded to the nearest 10 km. See text for more details about other classifications (e.g., mine status, culvert passage status).

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Alsek River	Entirely in Natl. Park, Natl. Forest, & Canadian Protected & Conserved	-	-	-	-	Yakutat, AK (~500)	~80 km	-	-	-
Copper River	Partially in Natl. Park & Natl. Forest	Multiple active & inactive nearby	Some terminated harvest nearby	-	-	Cordova, AK (~2,000)	~50 km	Multiple roads; multiple crossings	Many of all passage statuses	-
Situk River	Entirely in Natl. Forest	Few inactive & undetermined nearby	-	-	-	Yakutat, AK (~500)	~10 km	2 roads; 1 crossing	-	-

7.2.3 Northwest Gulf of Alaska ESU

A summary of habitat impacts for this ESU can be found in Table 22.

7.2.3.1 Land use

In the NWGOA ESU, 37.19% of the land is protected: 14.36% is National Wildlife Refuge, 13.77% is National Park, 9.06% is National Forest, and 3.84% is Alaska State Park (Figure 63). This ESU has the lowest percentage of protected land of the three ESUs. For timber harvest, < 0.01% of the land has active timber sales and 0.1% is a terminated timber sale area (Figure 63). There are 19 sawmills within ESU boundaries, 18 of which are near Chinook-bearing streams (within 10 km of Chinook-bearing streams). The NWGOA ESU is the only ESU with agricultural areas, with 0.01% of the land classified as cropland (Figure 63). These small areas of cropland are concentrated near the Matanuska-Susitna Valley, Palmer, Alaska, and Soldotna, Alaska. Chinook-bearing streams near cropland include the Little Susitna River, the Matanuska River, the Knik River, Wasilla Creek, Ship Creek, the Kenai River and its tributaries, the Ninilchik River, and Deep Creek. Additionally, NWGOA is the only ESU with oil and gas operations. Six percent of the land is within oil and gas lease tracts, with three oil and gas well sites within ESU boundaries, all in the Cook Inlet area (Figure 63). Seven Chinook-bearing streams are near these well sites (within 10 km): the Susitna, Ivan, Lewis, Theodore, Beluga, and Chuitna Rivers, and Threemile Creek, as well as a few additional river tributaries. Land use for mining and gravel extraction in particular is detailed in the following section, 7.2.3.2 Mining and gravel extraction.

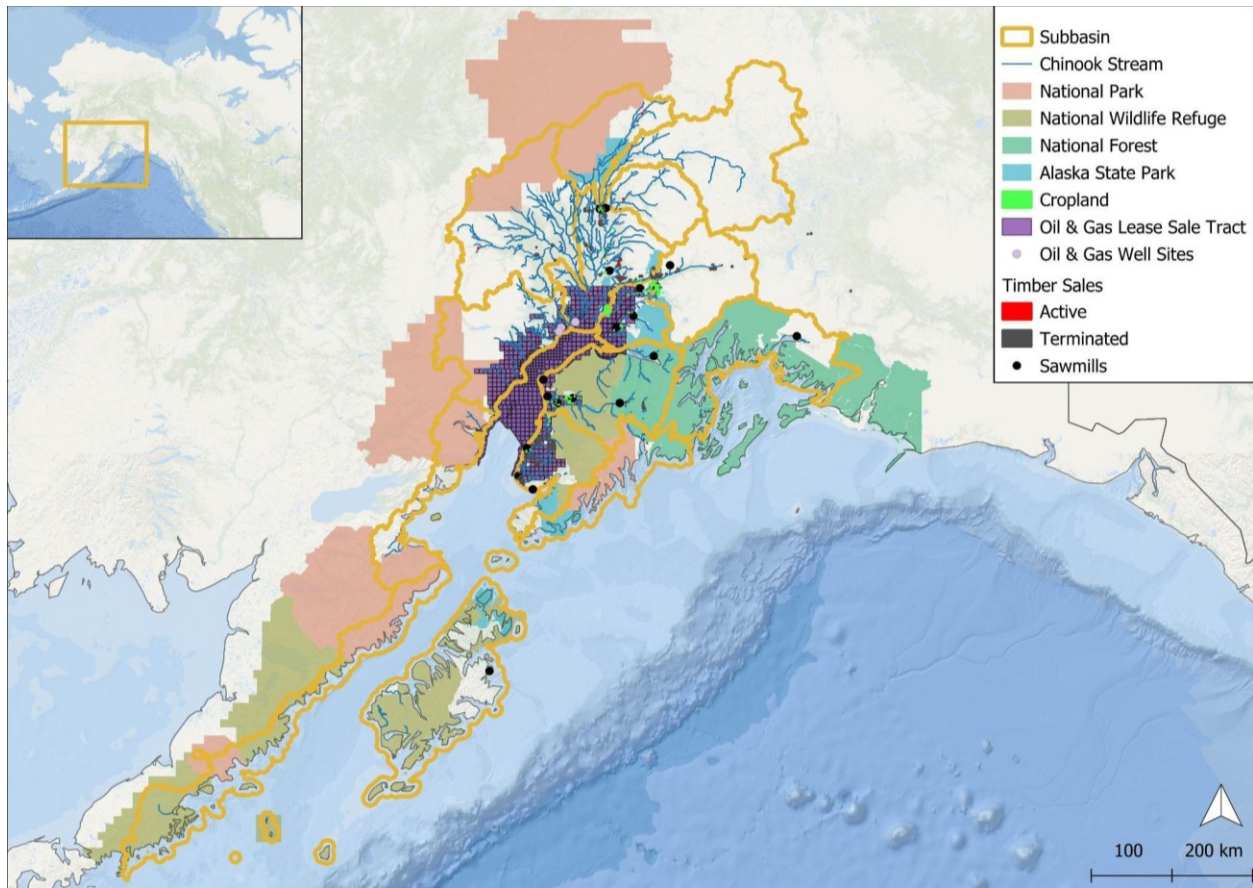


Figure 63. -- Land use in the Northwest Gulf of Alaska ESU. Subbasins (HUC 8) included in this ESU are shown as yellow polygons, with Chinook-bearing streams shown in blue. Protected lands in this ESU are also shown: National Parks in orange, National Forests in green, National Wildlife Refuges in olive, and Alaska State Parks in blue. Croplands are shown in lime green. Timber harvest is also shown; areas with active timber sale are displayed as red polygons and terminated timber sale as gray polygons, with sawmills displayed as black points. The purple polygon shows oil and gas lease sale tracts, with light purple points indicating oil and gas wells.

7.2.3.2 Mining and gravel extraction

Similar to the CGOA ESU, the NWGOA ESU habitat is impacted by domestic mining operations. There are more mine sites in this ESU area's subbasins than other ESUs, with about 27 active and 178 inactive, in addition to 20 undetermined, mine sites (USGS 2024)(Figure 64). This area also has a higher count for proposed mining operations on a scale similar to what we have observed for claims staking in British Columbia with about 275 proposed mines being pursued in the subbasins of the NWGOA ESU. See the previous ESU descriptions for impacts to salmon habitat by mining operations. Overall, mining operations can have small or large impacts to water quality, sediment quality for redds, habitat suitability, fish passage and spawning stream access, and cumulative effects from multiple projects in one area (Limpinsel et al. 2023).

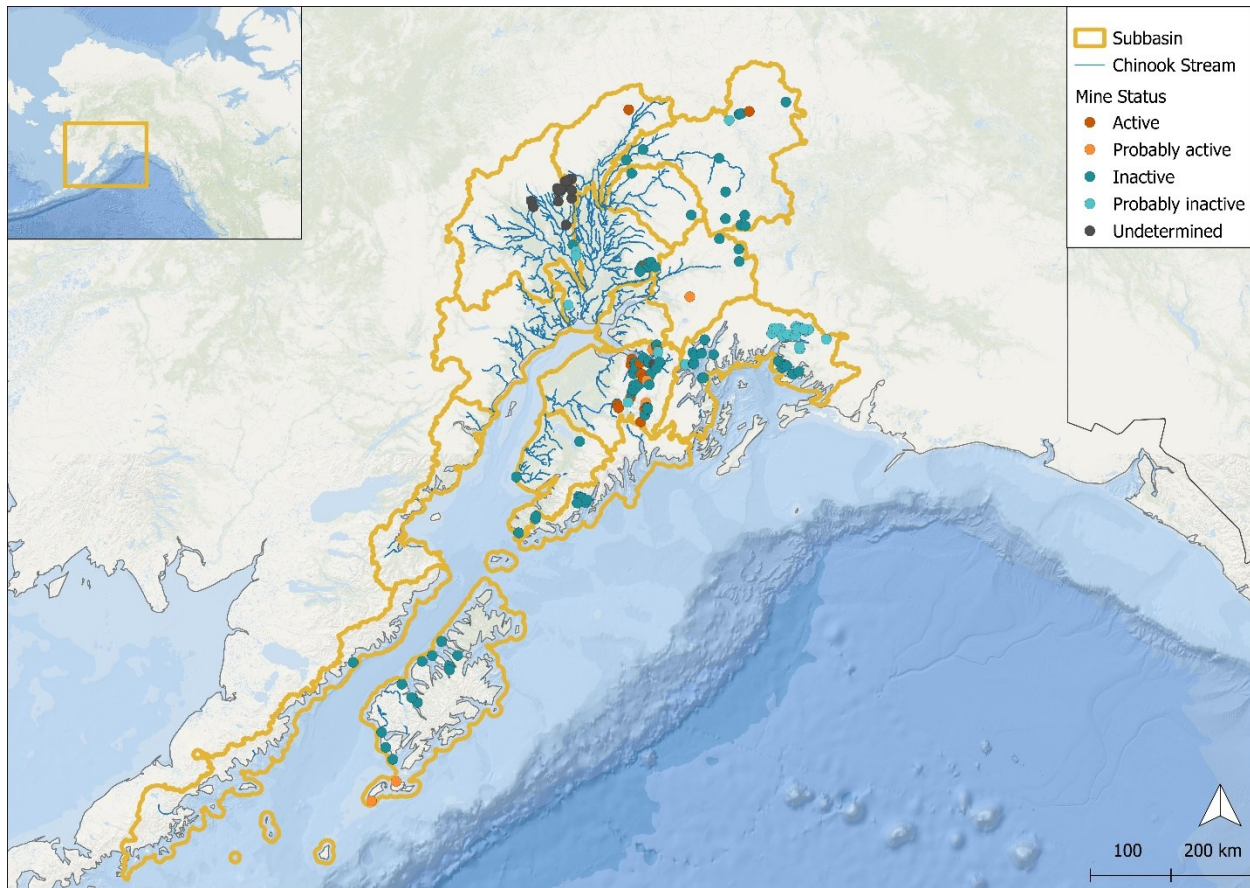


Figure 64. -- Mines in the Northwest Gulf of Alaska ESU. Subbasins (HUC 8) included in this ESU are shown as yellow polygons, with Chinook-bearing streams from the ADF&G Anadromous Waters Catalog (AWC) shown in blue. Mines are displayed as points colored by site status: “Active” in dark orange, “Probably active” in light orange, “Inactive” in dark turquoise, “Probably inactive” in light turquoise, or “Undetermined” in gray.

7.2.3.3 Urbanization

In the NWGOA ESU, there are ten cities with populations greater than 1,000: Anchorage (population ~286,000), Wasilla (population ~10,000), Kenai (population ~8,000), Palmer (population ~6,000), Homer (population ~6,000), Soldotna (population ~5,000), Kodiak (population ~5,000), Valdez (population ~4,000), Seward (population ~3,000), and Cordova (population ~2,000) (Figure 65A). Note, there may be additional locations within this ESU with populations greater than 1,000, such as boroughs and other census-designated places. The NWGOA ESU has the highest population densities of the three ESUs, and larger areas of high population density, particularly Cook Inlet and the Kenai Peninsula. However, it is still more sparsely populated than many areas in the rest of the United States; for example, the population of Seattle, Washington, is larger than the entire population of Alaska. There are 10,088 km of roads in this ESU and 1,501 culverts (Figure 65B). Of these culverts, 187 have unassigned fish passage status, 444 have likely adequate fish passage, 264 may be inadequate for fish passage, and 606 have assumed inadequate fish passage. Areas with culverts include

Kodiak, the Kenai Peninsula, Cook Inlet, and Prince William Sound. Impacted Chinook streams include the Anchor River and its tributaries, Campbell Creek and its tributaries, Deep Creek and its tributaries, Ninilchik River and its tributaries, Kenai River and its tributaries, Matanuska River and its tributaries, Susitna River and its tributaries, and Little Susitna River and its tributaries. There is currently a review process underway for plans for the development of an additional road, the West Susitna Access Road, in a currently roadless area west of the Susitna River²⁷. If these plans move forward, the construction and use of this road will likely have additional impacts on the Susitna River and its tributaries²⁸. Dams as an urbanization impact are discussed in the following section, 7.2.3.4 Dams.

²⁷ Alaska Department of Transportation and Public Facilities. West Susitna Access Road Project. Available at <https://westsuaccess.com/>. Accessed April 25, 2025.

²⁸ Susitna River Coalition. The West Susitna Industrial Corridor. Available at <https://www.susitnarivercoalition.org/west-susitna-mining-rd>. Accessed April 25, 2025.

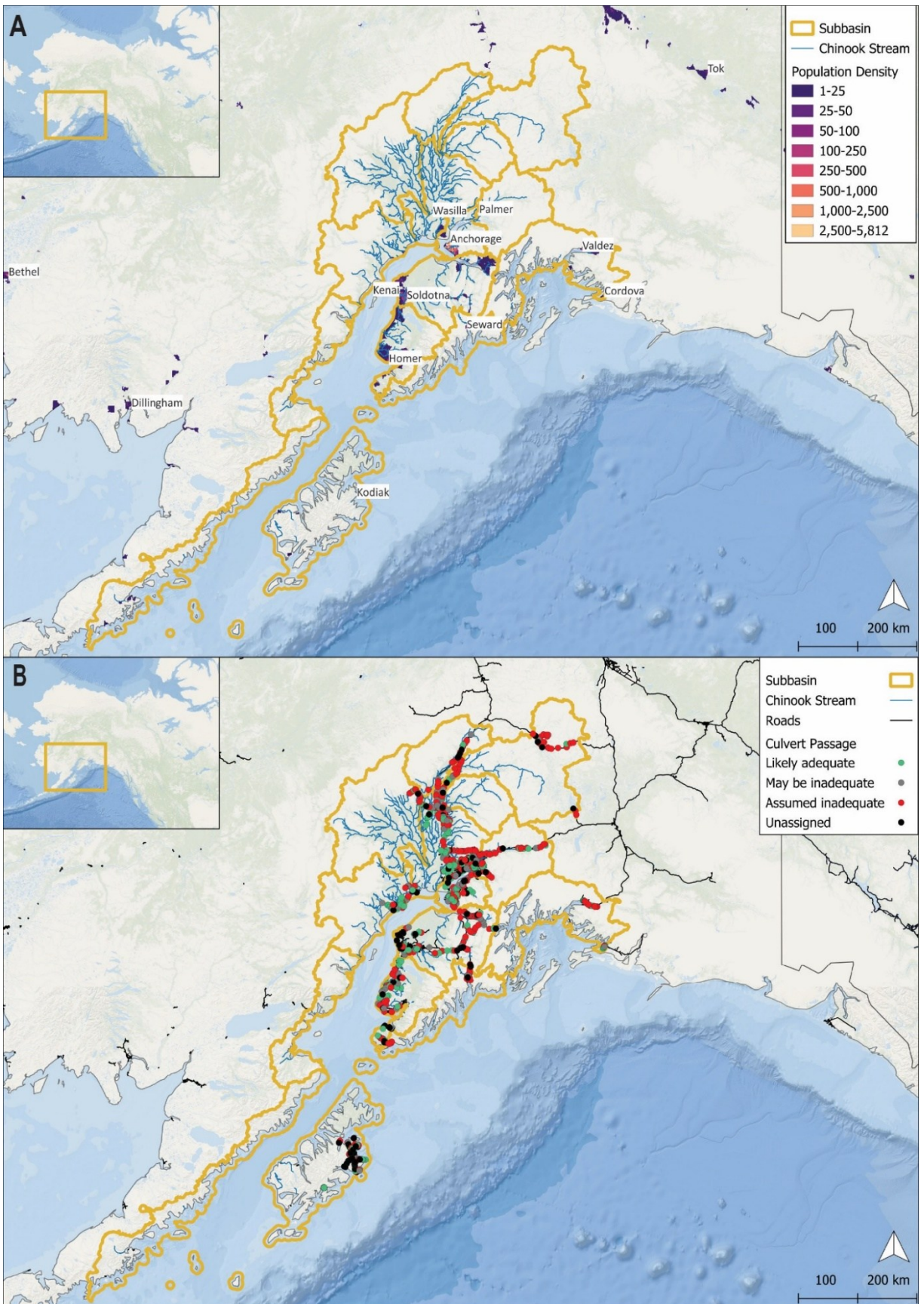


Figure 65. -- Population and urbanization in the Northwest Gulf of Alaska ESU. Subbasins (HUC 8) included in this ESU are shown as yellow polygons, with Chinook-bearing streams shown in blue. Population density (modeled count of people per 30 arc-second grid divided by area of 30 arc-second grid) is shown on a color scale ranging from low density in dark purple to high density in light orange in panel A. Only grids with a population density of greater than 1 person are displayed on the map. Cities in Alaska with a population greater than 1,000 are also labeled with white stars. Roads are shown in black in panel B. Culverts are displayed as points colored by fish passage status: likely to provide adequate juvenile fish passage in green, may be inadequate for juvenile fish passage in gray, assumed to be inadequate for juvenile fish passage in red, and unable to assign fish passage rating in black.

7.2.3.4 Dams

Within watersheds in the NWGOA ESU, there are four “impact likely,” ten “impact possible” dams, and 29 “impact unlikely” dams (Figure 66). The four “impact likely” dams, all in the Cook Inlet area, are Campbell Lake Dam, Ship Creek Dam, Gregory Lake Dam, and Caswell Lakes Road Dam. Campbell Lake Dam is located in Anchorage, Alaska, near the mouth of Campbell Creek, a Chinook-bearing creek with multiple Chinook-bearing tributaries. Therefore, there is a significant amount of Chinook habitat upstream of the dam. It is not a hydropower project; it is a rockfill and earthen dam with the purpose of damming Campbell Lake for recreation and debris control (Alaska Dam Inventory). Ship Creek Dam is a water supply dam, creating Ship Creek Reservoir on Ship Creek in Anchorage, Alaska. Ship Creek Dam is believed to be a partial barrier, due to observations of coho salmon spawning upstream of the reservoir in 2021 (Alaska Dam Inventory). However, mapped Chinook habitat ends immediately downstream of the dam, so it may be a barrier for Chinook. Gregory Lake Dam is an earthen dam on Sixmile Creek, a Chinook-bearing creek in Anchorage, Alaska. The dam is owned by the U.S. Air Force, with the purpose of creating Sixmile Reservoir as a float plane base (Alaska Dam Inventory). Mapped Chinook habitat in the AWC extends upstream of the dam, and the dam is not believed to block passage, as coho, pink, and sockeye salmon, as well as Dolly Varden, were observed spawning in a pond upstream of the dam in 2017 (Alaska Dam Inventory). Caswell Lakes Road Dam is located on Caswell Creek, in an area with multiple small lakes, southeast of Susitna North, Alaska and northeast of Willow, Alaska. Chinook habitat in Caswell Creek in the AWC extends upstream of the dam. It is an earthen dam for recreational purposes, and unlikely to block passage, as a 2019 survey found fishes in all but one of the Caswell Lakes (Alaska Dam Inventory).

The ten “impact possible” dams are Monashka Creek Dam and Monashka Creek Dike on Kodiak; Bradley Lake Dam, Bradley Lake Spillway, Cooper Lake Dam, and Roycroft Lake Dam on the Kenai Peninsula; and Lower Fire Lake Dam, Lower Eklutna Dam, Eklutna Dam, and Lake Lucille Dam in the Cook Inlet area. On Kodiak Island, Monashka Creek Dam and Dike are located northwest of Kodiak, Alaska. Monashka Creek Dam is a rockfill dam, creating Monashka Reservoir along Monashka Creek for water supply (Alaska Dam Inventory). The extent of Chinook habitat in Monashka Creek in the AWC appears to end downstream of the dam, and

coho and pink salmon were observed in creeks exiting Monashka Reservoir in 2018 (Alaska Dam Inventory).

On the Kenai Peninsula, Bradley Lake Dam and Bradley Lake Spillway Dam are a hydroelectric project located on Bradley Lake at the head of Bradley River, near the head of Kachemak Bay southeast of Fox River, Alaska. Mapped Chinook habitat in Bradley River in the AWC ends far downstream of the dams. A survey in 1997 noted coho, chum, and pink salmon about halfway up Bradley River, with natural barrier falls too large for salmon to reach the dam (Alaska Dam Inventory). Cooper Lake Dam is a hydropower dam located on Cooper Lake at the head of Cooper Creek, south of Cooper Landing, Alaska. The extent of Chinook habitat in Cooper Creek in the AWC ends far downstream of the dam. Roycroft Lake Dam is a private hydroelectric dam located on a small lake at the head of a creek that feeds into Trail Creek in Moose Pass, Alaska (Alaska Dam Inventory). While Trail Creek is Chinook habitat, the creek feeding into it from Roycroft Lake is not mapped as Chinook habitat in the AWC.

In Cook Inlet, Lower Fire Lake Dam is located on Lower Fire Lake at the head of Fire Creek in Eagle River, Alaska. Chinook habitat in Fire Creek in the AWC ends downstream of the dam, in an area where the creek passes under two roads. The dam is for recreational purposes on Lower Fire Lake, and the Alaska Dam Inventory notes that fish stop at the spillway, with observations of spawning coho and sockeye salmon in 2021 (Alaska Dam Inventory). Two dams, Lower Eklutna Dam and Eklutna Dam, are found along the Eklutna River in Chugiak, Alaska. Chinook habitat in Eklutna River in the AWC ends downstream of Lower Eklutna Dam. Eklutna Dam is a hydroelectric dam, and a 2021 survey found coho and Chinook salmon approximately 6.5 miles downstream of the dam, which would place them around the area of the Lower Eklutna Dam (Alaska Dam Inventory). Lake Lucille Dam is located on Lucille Lake at the head of Lucille Creek in Wasilla, Alaska. Chinook habitat in Lucille Creek in the AWC ends downstream of the dam, where a culvert blocks fish passage (Alaska Dam Inventory).

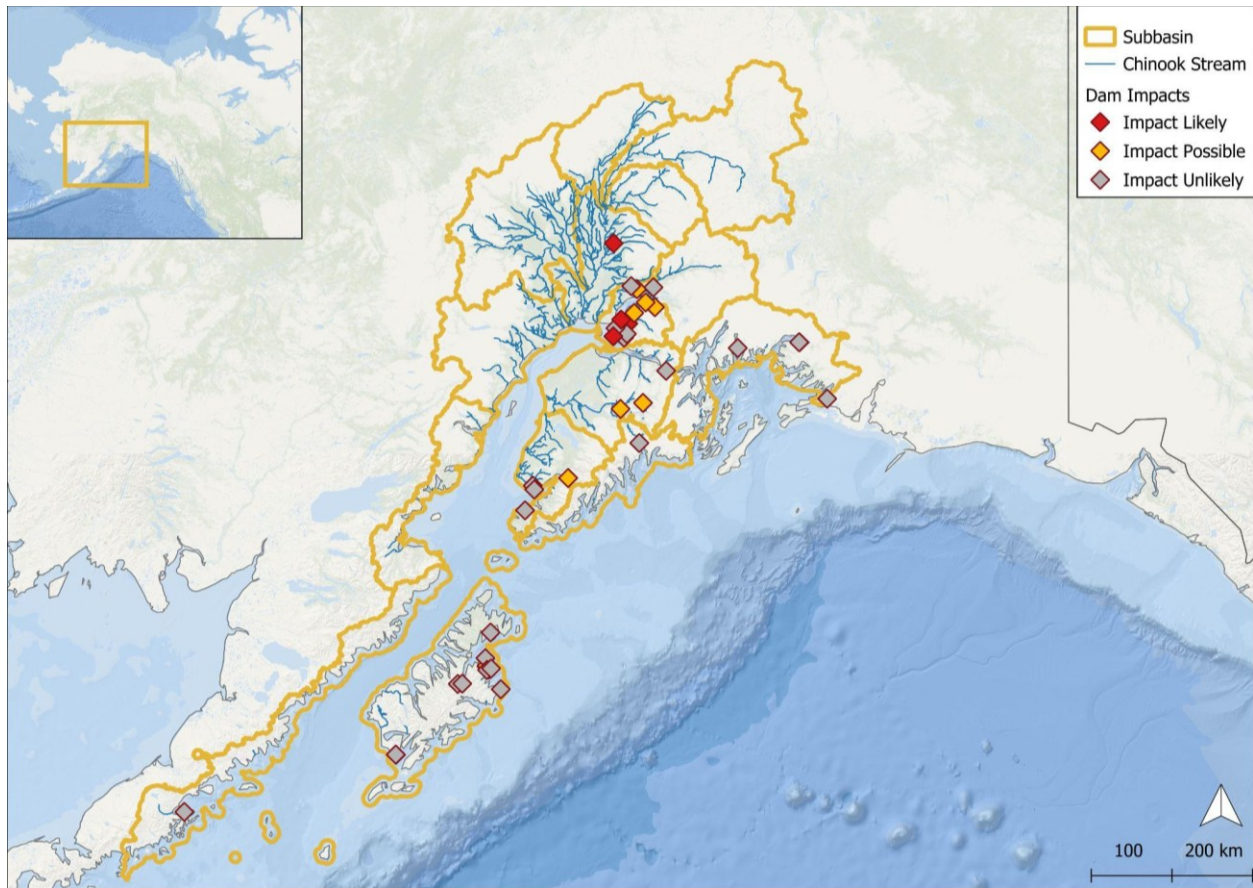


Figure 66. -- Dams in the Northwest Gulf of Alaska ESU. Subbasins (HUC 8) included in this ESU are shown as yellow polygons, with Chinook-bearing streams from the ADF&G Anadromous Waters Catalog (AWC) shown in blue. All dams in this ESU are displayed as diamonds, classified as “Impact Likely” if the dam appears to directly overlap with Chinook habitat (displayed in red), “Impact Possible” if the dam does not appear to directly overlap with Chinook habitat, but is on a Chinook system (i.e., upstream or on a tributary; displayed in yellow), or “Impact Unlikely” if the dam does not appear to be on a Chinook system, but is within any of the GOA Chinook subbasins (displayed in gray).

Table 22. -- Land use and urbanization impacts for each index stream in the Northwest Gulf of Alaska ESU. Populations are rounded to the nearest thousand when greater than 1,000; otherwise, to nearest 100. Distances are as the crow flies from the mouth of the stream to the center of the nearest city with a population of greater than 100 people, and rounded to the nearest 10 km. See text for more details about other classifications (e.g., mine status, culvert passage status).

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Alexander Creek	-	-	-	Near cropland in Matanuska-Susitna Valley	Within lease sale tract	Anchorage, AK (~286,000)	~40 km	-	-	-
Anchor River	Small amount in State Park	1 inactive nearby	Terminated harvest nearby	-	Mostly within lease sale tract	Anchor Point, AK (~2,000)	<1 km	Multiple roads; 4 crossings	A few of multiple passage statuses	-
Ayakulik River	Almost entirely in Natl. Wildlife Refuge	1 inactive nearby	-	-	-	Kodiak, AK (~5,000)	~140 km	-	-	-
Campbell Creek	-	-	-	-	Within lease sale tract	Anchorage, AK (~286,000)	~10 km	Many; 10 crossings of main & more on tributaries	1 on main; many on some tributaries	Dam near mouth
Chignik River	Entirely within Natl.	-	-	-	-	Sand Point, AK (~600)	~160 km	A couple roads; no crossings	-	-

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
	Wildlife Refuge									
Chuitna River	-	-	-	-	Within lease sale tract	Tyonek, AK (~300)	<10 km	A few roads; 1 crossing	A couple nearby of multiple passage statuses	-
Chulitna River	Some in State Park	1 active nearby	Some terminated harvest nearby; 2 sawmills	Minimal cropland nearby	-	Talkeetna, AK (~1,000)	<10 km	2 roads; 3 crossings	Many of multiple passage statuses	-
Crooked Creek	Some in National Wildlife Refuge	1 inactive nearby	Small active harvest nearby; terminated harvest nearby	Minimal cropland nearby	Partly within lease sale tract	Kasilof, AK (~400)	<1 km	Multiple roads; 2 crossings	2 with adequate passage	-
Deep Creek	Small amount in State Park	-	Terminated harvest nearby	Some cropland nearby	Within lease sale tract	Ninilchik, AK (~1,000)	<10 km	Multiple roads; 1 crossing	A few nearby of multiple passage statuses	-
Deshka River	-	-	Terminated harvest nearby	-	-	Willow, AK (~2,000)	~20 km	2 roads; 2 crossings	A few nearby of multiple passage statuses	-

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Eastside Susitna River	Some in State Park	Few inactive nearby	Small active harvest nearby; terminated harvest nearby; some sawmills nearby	Near cropland in Matanuska-Susitna Valley	Partly within lease sale tract	Anchorage, AK (~286,000)	~40 km	Multiple roads; 1 crossing	Many of multiple passage statuses	-
Karluk River	Partly within Natl. Wildlife Refuge	Few inactive nearby	-	-	-	Kodiak, AK (~5,000)	~120 km	1 road; no crossings	-	-
Kenai River – Early Run	Partly within Natl. Wildlife Refuge & Natl. Forest	Few active & inactive nearby	Multiple sawmills nearby	Significant cropland	Partly within lease sale tract	Kenai, AK (~8,000)	<1 km	Multiple roads; 3 crossings	Many of multiple passage statuses	2 dams on tributaries
Kenai River – Late Run	Partly within Natl. Wildlife Refuge & Natl. Forest	Few active & inactive nearby	Multiple sawmills nearby	Significant cropland	Partly within lease sale tract	Kenai, AK (~8,000)	<1 km	Multiple roads; 3 crossings	Many of multiple passage statuses	2 dams on tributaries

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
Little Susitna River	Small amount in State Park	Many active and inactive near head	Small active harvest nearby; terminated harvest nearby	Significant cropland	Partly within lease sale tract	Anchorage, AK (~286,000)	~20 km	Multiple roads; 5 crossings	Many of multiple passage statuses	-
Ninilchik River	Small amount in State Park	-	Terminated harvest nearby	Minimal cropland nearby	Within lease sale tract	Ninilchik, AK (~1,000)	<1 km	Multiple roads; 4 crossings	A few of multiple passage statuses	-
Talkeetna River	-	-	Small amounts of active & terminated harvest nearby; 1 sawmill nearby	-	-	Talkeetna, AK (~1,000)	<1 km	A few roads; 1 crossing	-	-
Theodore River	-	-	-	-	Mostly within lease sale tract; 3 well sites nearby	Anchorage, AK (~286,000)	~50 km	2 roads; 1 crossing	A few of multiple passage statuses nearby	-
Yentna River	-	Few inactive nearby	Some terminated	-	-	Willow, AK (~2,000)	~30 km	-	-	-

Index Stream	Land Use					Urbanization				
	<i>Protected Land</i>	<i>Mining</i>	<i>Timber Harvest</i>	<i>Agriculture</i>	<i>Oil and Gas</i>	<i>Nearest city (pop.)</i>	<i>Distance from nearest city</i>	<i>Roads</i>	<i>Culverts</i>	<i>Dams</i>
			harvest nearby							

7.3 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes (Harvest)

This section describes Chinook salmon harvest estimates across the Gulf of Alaska, with an emphasis on describing stock-specific harvests for indicator stocks within each ESU. Often, marine harvests consist of a mixture of stocks of various origins. For these harvests, stock-specific harvest has been derived by subtracting estimated spawning escapement abundance from total run size, both provided by ADF&G. Regulations and management actions — including measures taken to conserve stocks, such as limiting the amount of time and area that are open to fishing — are substantial factors that determine historical harvest levels. As such, it cannot be assumed that the level of harvest during a given year is indicative of overall abundance or the relative health of a stock or stocks.

Harvest records for Chinook salmon across the Gulf of Alaska began in the late 1800s (Edfelt 1973), when commercial fisheries authorized and managed by the U.S. government displaced indigenous fisheries, facilitated in part by federal legislation that outlawed indigenous fishing methods, such as fish traps and weirs, in 1889 (Ramos and Mason 2004). The records for early commercial harvests are summarized in Alaska Department of Fish and Game (ADF&G) reports (Edfelt 1973, Pirtle 1976, Byerly et al. 1999, etc.), which in turn cite a variety of older federal publications and other sources. Available records have documented Chinook salmon harvests throughout the marine environment of the Gulf of Alaska and the freshwater systems that drain into it. Harvests have occurred in many different fisheries, including: commercial, recreational/sport, personal use, educational, and subsistence fisheries; as well as for scientific research, and as bycatch for non-salmon fisheries. Harvest methods have included purse seine, set gillnet, drift gillnet, hand troll, power troll, hook-and-line, dipnet, and trawl (Edfelt 1973).

More contemporary harvest data for all harvest types include those available in reports published by ADF&G or in their harvest databases, reports of salmon bycatch in federally managed groundfish fisheries (NMFS 2025), and harvests associated with the Cook Inlet Exclusive Economic Zone Area fishery that began in 2024 (Brenner et al. 2024, Brenner et al. 2025). Salmon harvest data are largely collected by ADF&G and attributed to ADF&G management areas, but these management areas do not align with designated ESUs; therefore, only stock-specific harvests that could be attributed to stocks within ESUs are provided.

The stock-specific data provided from ADF&G represent the most current available data as of May 28, 2025. These data are subject to change with addition of new data and information and error checking. Some of these data are estimated and, therefore, may not match previously published estimates and will change with additional data, model improvements and future model runs.

7.3.1 Harvest trend summary for Gulf of Alaska Chinook salmon

The time series for Gulf of Alaska Chinook salmon harvest estimates includes 133 years of data from 1890 to 2022 (Figure 67). Mean annual harvest during this period was 423,484 fish, median harvest was 410,237 fish, and the average harvest over the last 10 years was 434,081 fish. The maximum harvest was 992,000 fish in 1937, and the minimum was 0 fish harvested in 1892.

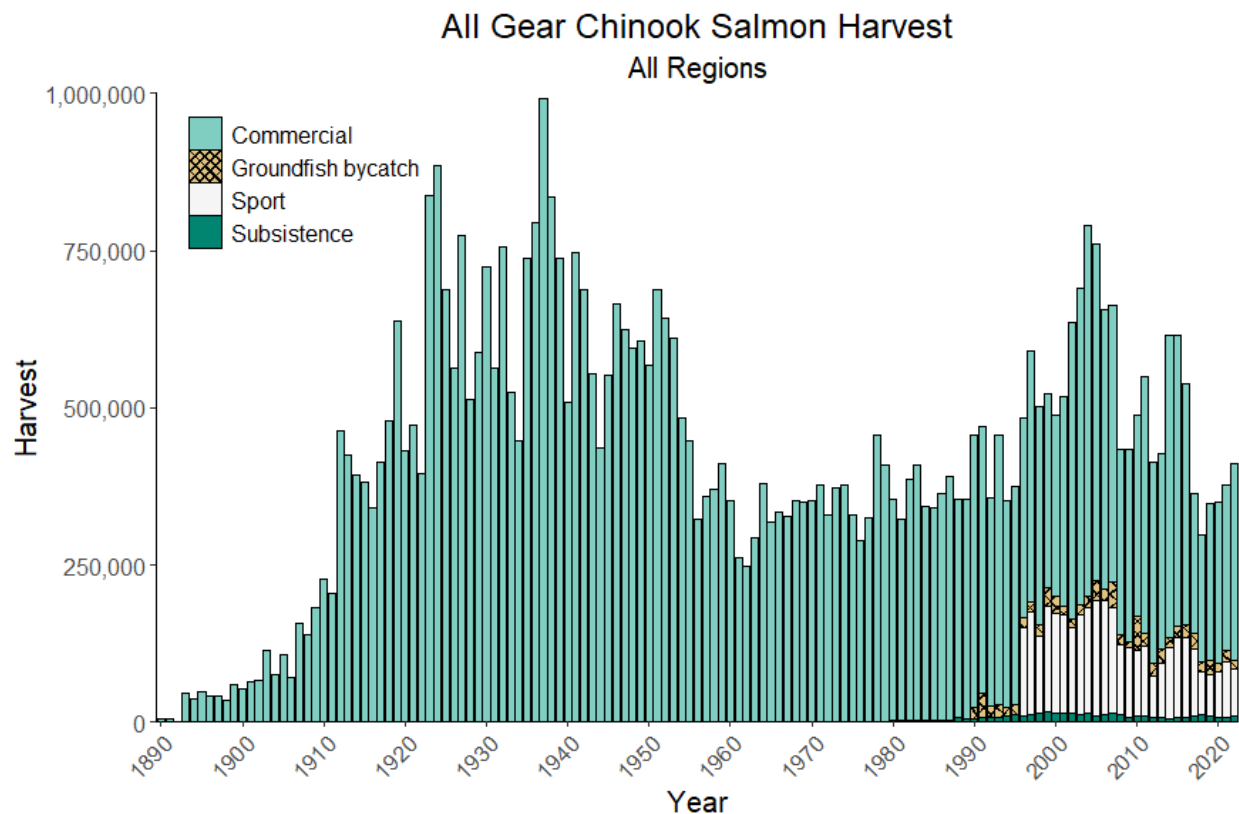


Figure 67. -- Historical Chinook salmon harvests across all Gulf of Alaska Regions and fisheries (1890-2022).

For Figure 67, sport harvest data begins in 1996, as this is when such data are consistently available for areas across the Gulf of Alaska. For many regions and areas, sport and subsistence estimates are known to date back many years prior to 1996 section.

7.3.2 Southeast Gulf of Alaska ESU Harvest

This section provides historical Chinook salmon harvest estimates and associated harvest trends for stocks associated with the Southeast Gulf of Alaska ESU. Harvests that occur in the SEGOA ESU include a complex mixture of stocks, gear types, and fisheries.

Available harvest data are generally reported according to ADF&G spatial management units. ADF&G's Southeast Alaska Region (marine and freshwater drainages between Cape Suckling

and Dixon Entrance) includes all of the stocks attributed to SEGOA ESU; however, Area 1 of this ADF&G Southeast Alaska Region includes stocks from the CGOA ESU (Figure 68).

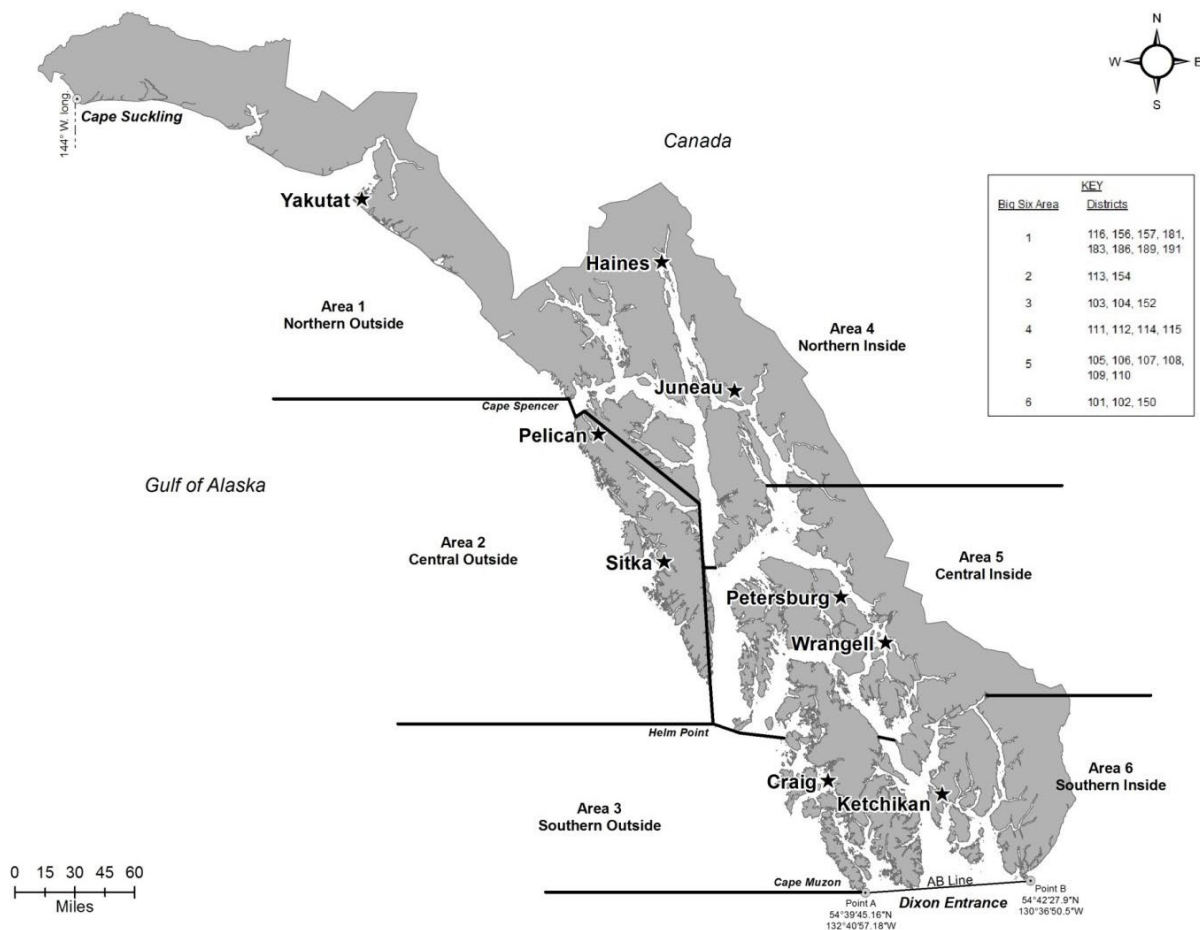


Figure 68. --Map of Southeast Alaska Region commercial troll fishery and the Big Six management areas, Cape Suckling to Dixon Entrance. Image copied from Hagerman et al. (2022).

Harvests of Chinook salmon in Southeast Alaska fisheries often include mixtures of stocks that originate from Alaska, British Columbia, Washington, and Oregon (CTC 2025); and harvests presented within this section contain varying degrees of separation by stock and fishery. A given report may provide total estimated Chinook salmon harvests within a fishery by year, while other reports provide estimated harvests by stock. To illustrate this, Hagerman et al. (2022) provides estimated Chinook salmon harvests by fishery. In contrast, Peterson et al. (2024) provides breakouts of Chinook salmon for SEGOA and non-SEGOA stocks, including stock-specific harvest estimates. Therefore, this section discusses stock-specific harvest estimates for the nine Chinook salmon indicator stocks within the SEGOA ESU that are representative of the 25 known Chinook salmon stocks for the SEGOA ESU (Kissner 1978 as cited in Priest et al. 2024).

There are nine ADF&G Chinook salmon indicator stocks within the SEGOA ESU (Figure 2):

1. Andrew Creek (large fish).
2. Chickamin River (large fish).
3. Chilkat River (age 5+).
4. Keta River (large fish).
5. Blossom River (large fish).
6. Taku River (large fish).
7. Stikine River (large fish).
8. King Salmon River (large fish).
9. Unuk River (large fish).

Note that for all stocks within the SEGOA ESU, escapement goals are currently managed using some variation of “large fish” goals, whereby only fish of a certain size or age class count towards the spawning escapement goals. As such, stock-specific harvest estimates presented in this section are also confined to the estimated number of fish of a certain size that have been harvested each year.

Some Southeast Alaska stocks are not tagged with coded-wire tags (e.g., Andrew Creek, and Blossom, Chickamin, Keta, and King Salmon Rivers), and marine harvest of these stocks cannot be directly estimated. For these stocks, harvest rates at nearby hatcheries are used as surrogates for run reconstruction purposes. The indicator for Andrew Creek and King Salmon River is ACI, consisting of Andrew Creek broodstock released by Southern Southeast Regional Aquaculture Association (SSRAA) at the Crystal Lake facility. For Blossom, Chickamin, and Keta Rivers, the indicator is AKB, which comprises Chickamin River broodstock released by SSRAA at Neets Bay, Whitman Lake, and Ketchikan Creek. Cohort reconstructions for both ACI and AKB are produced annually by the PSC CTC as part of the exploitation rate (CTC 2025). The methodology for translating these reconstructions into production estimates is detailed in CTC (2024), Chapter 3.1, and CTC (2025), Chapter 2.1.4. Total run is calculated as escapement divided by the mature run equivalent exploitation rate, with adjustments made to account for known differences between the hatchery indicators and their corresponding wild stocks (e.g., terminal fishery impacts).

7.3.2.1 Andrew Creek (large fish) stock specific harvest and harvest rate estimates

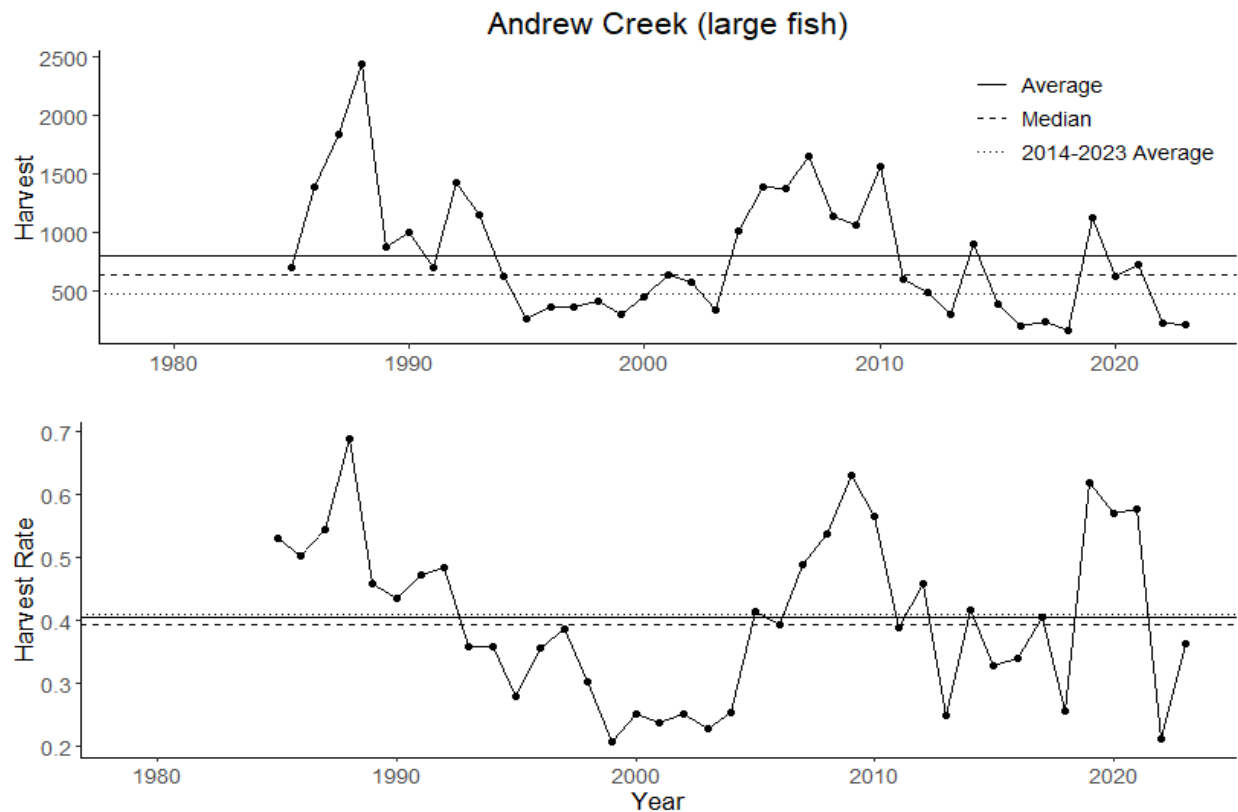


Figure 69. -- Andrew Creek large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1985-2023.

The time series for Andrew Creek (large fish) includes 39 years of data from 1985-2023 (Figure 69). Mean harvest was 804, median harvest was 643, and the average harvest over the last 10 years was 483. The maximum harvest was 2443 in 1988, and the minimum was 166 in 2018. For harvest rate, the mean was 0.406, the median was 0.394, and the most recent 10-year average was 0.409. The maximum harvest rate was 0.69 in 1988, and the minimum was 0.207 in 1999.

7.3.2.2 Chickamin River (large fish) stock specific harvest and harvest rate estimates

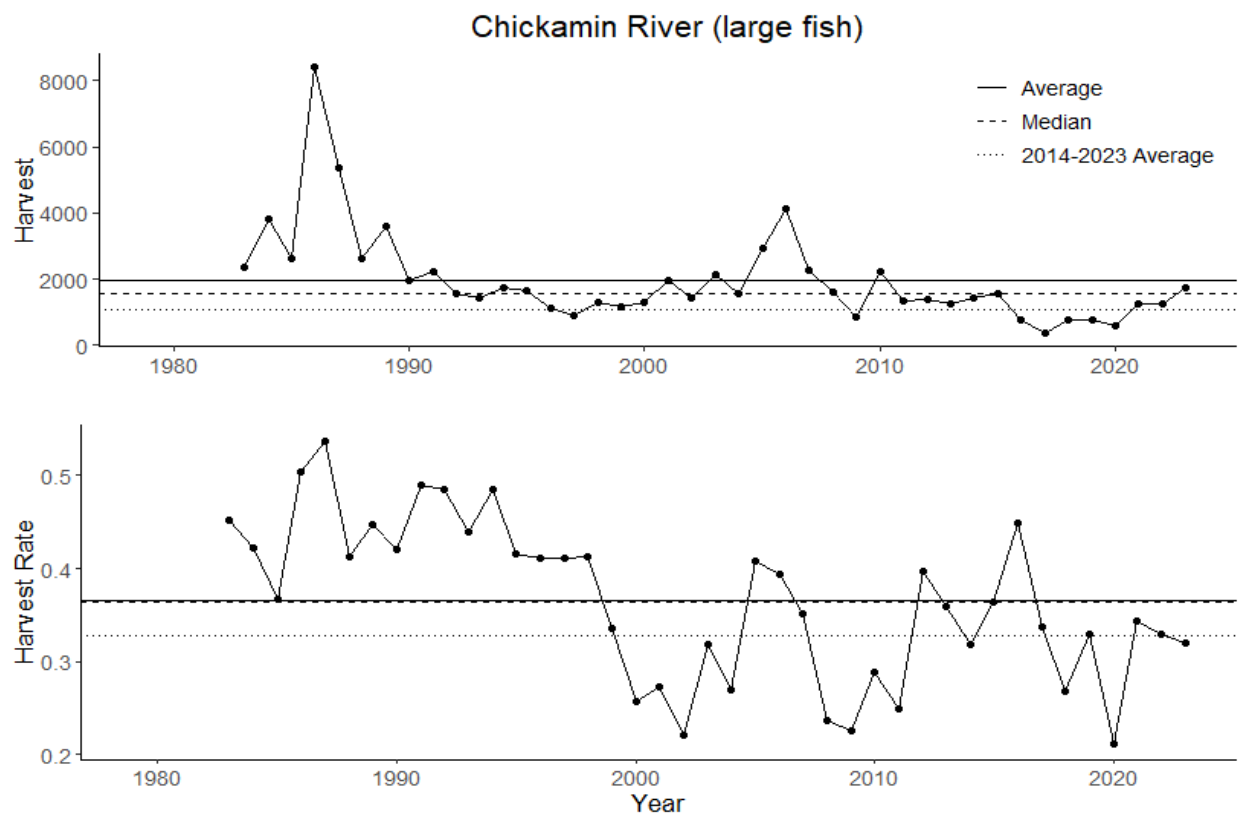


Figure 70. -- Chickamin River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1983-2023.

The time series for Chickamin River (large fish) includes 41 years of data from 1983 to 2023 (Figure 70). Mean harvest was 1,972, median harvest was 1,579, and the average harvest over the last 10 years was 1057. The maximum harvest was 8,419 in 1986, and the minimum was 368 in 2017. For harvest rate, the mean was 0.365, the median was 0.364, and the most recent 10-year average was 0.327. The maximum harvest rate was 0.537 in 1987, and the minimum was 0.211 in 2020.

7.3.2.3 Chilkat River (age 5+) stock specific harvest and harvest rate estimates

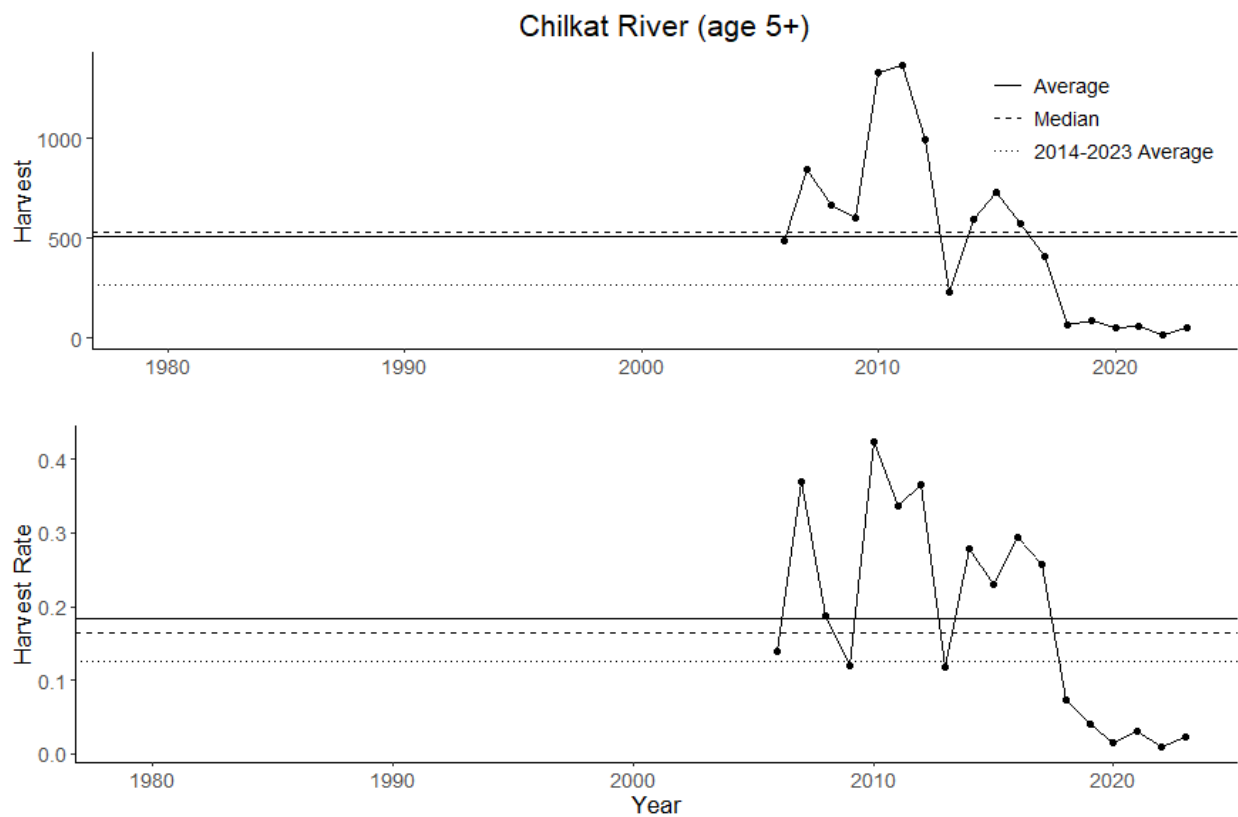


Figure 71. -- Chilkat River large (age 5+) Chinook salmon estimated harvests (top) and harvest rates (bottom) 2006-2023.

The time series for Chilkat River (age 5+) includes 18 years of data from 2006 to 2023 (Figure 71). Mean harvest was 509, median harvest was 530, and the average harvest over the last 10 years was 264. The maximum harvest was 1,363 in 2011, and the minimum was 15 in 2022. For harvest rate, the mean was 0.184, the median was 0.163, and the most recent 10-year average was 0.125. The maximum harvest rate was 0.425 in 2010, and the minimum was 0.009 in 2022.

7.3.2.4 Keta River (large fish) stock specific harvest and harvest rate estimates

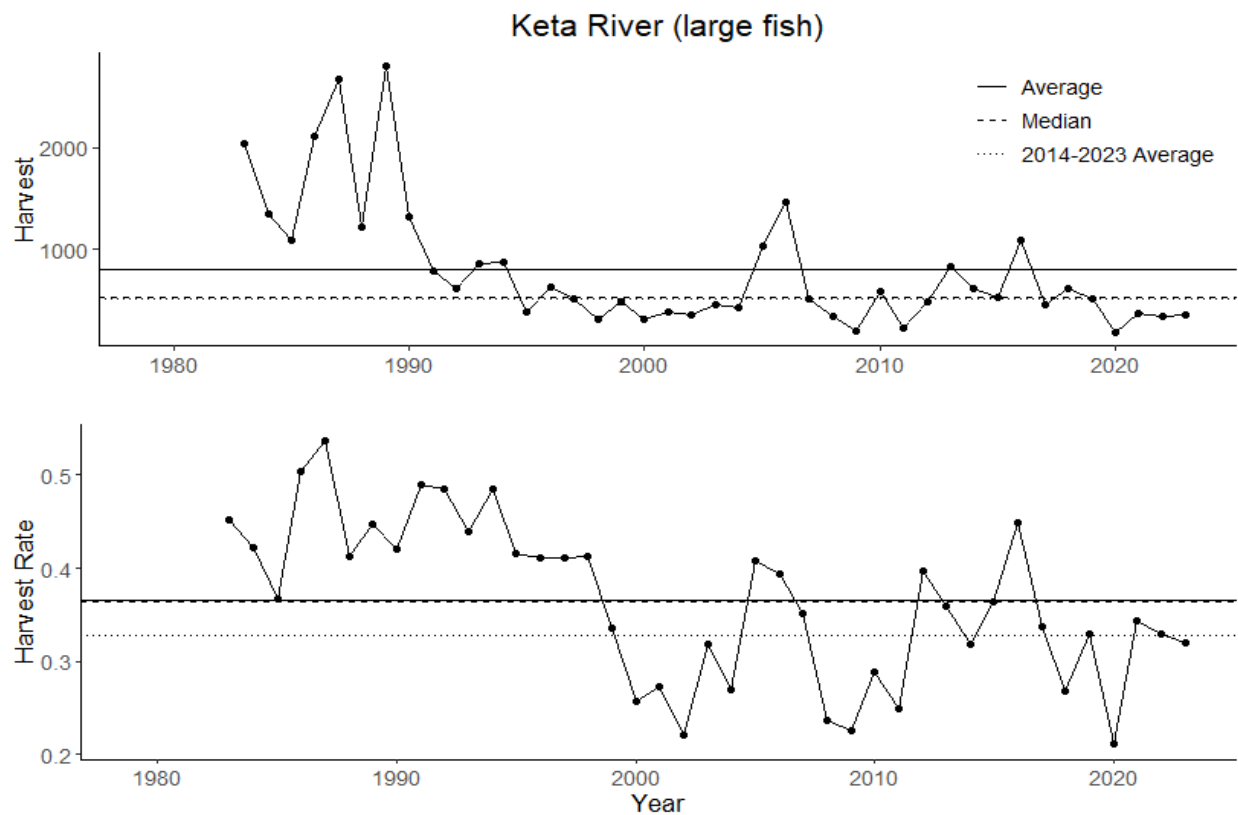


Figure 72. -- Keta River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1983-2023.

The time series for Keta River (large fish) includes 41 years of data from 1983 to 2023 (Figure 72). Mean harvest was 797, median harvest was 524, and the average harvest over the last 10 years was 506. The maximum harvest was 2810 in 1989, and the minimum was 179 in 2020. For harvest rate, the mean was 0.365, the median was 0.364, and the most recent 10-year average was 0.327. The maximum harvest rate was 0.537 in 1987, and the minimum was 0.211 in 2020.

7.3.2.5 Blossom River (large fish) stock specific harvest and harvest rate estimates

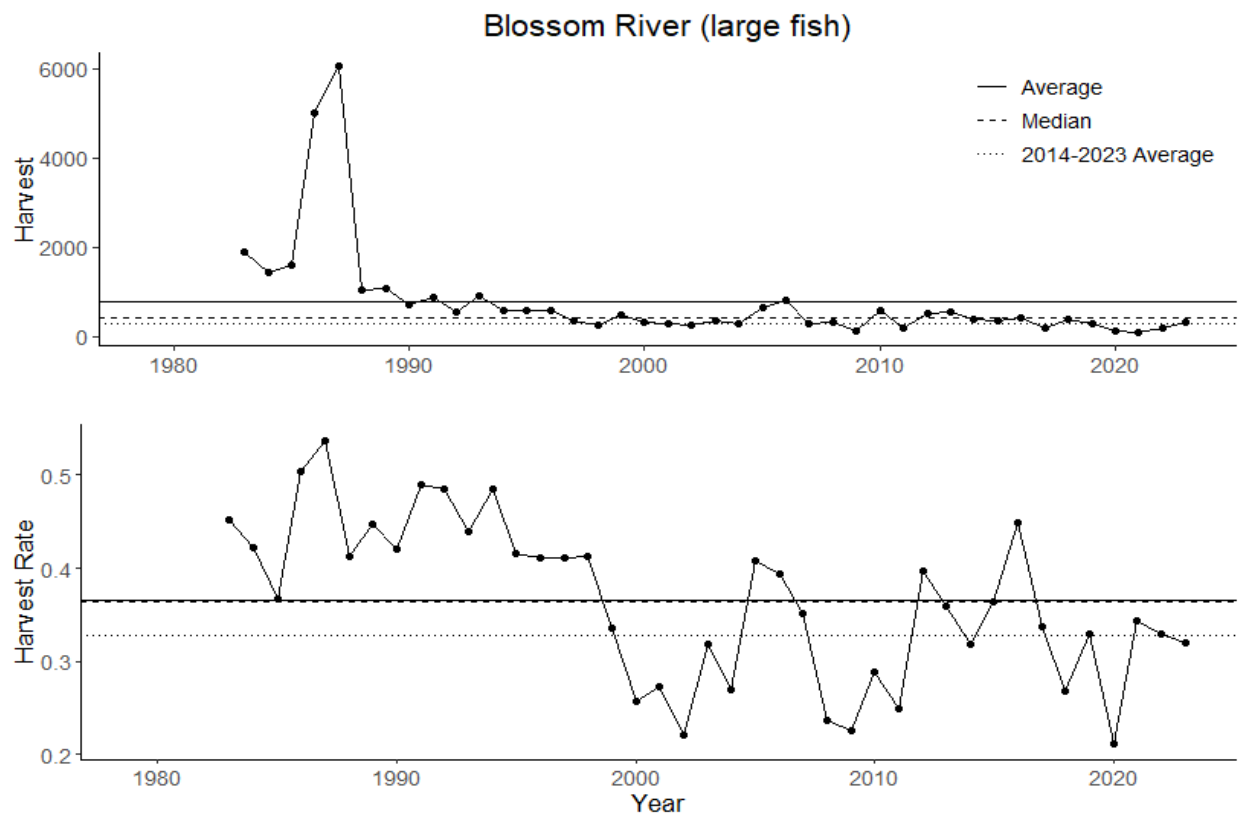


Figure 73. -- Blossom River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1983-2023.

The time series for Blossom River (large fish) includes 41 years of data from 1983 to 2023 (Figure 73). Mean harvest was 790, median harvest was 426, and the average harvest over the last 10 years was 277. The maximum harvest was 6062 in 1987, and the minimum was 89 in 2021. For harvest rate, the mean was 0.365, the median was 0.364, and the most recent 10-year average was 0.327. The maximum harvest rate was 0.537 in 1987, and the minimum was 0.211 in 2020.

7.3.2.6 Taku River (large fish) stock specific harvest and harvest rate estimates

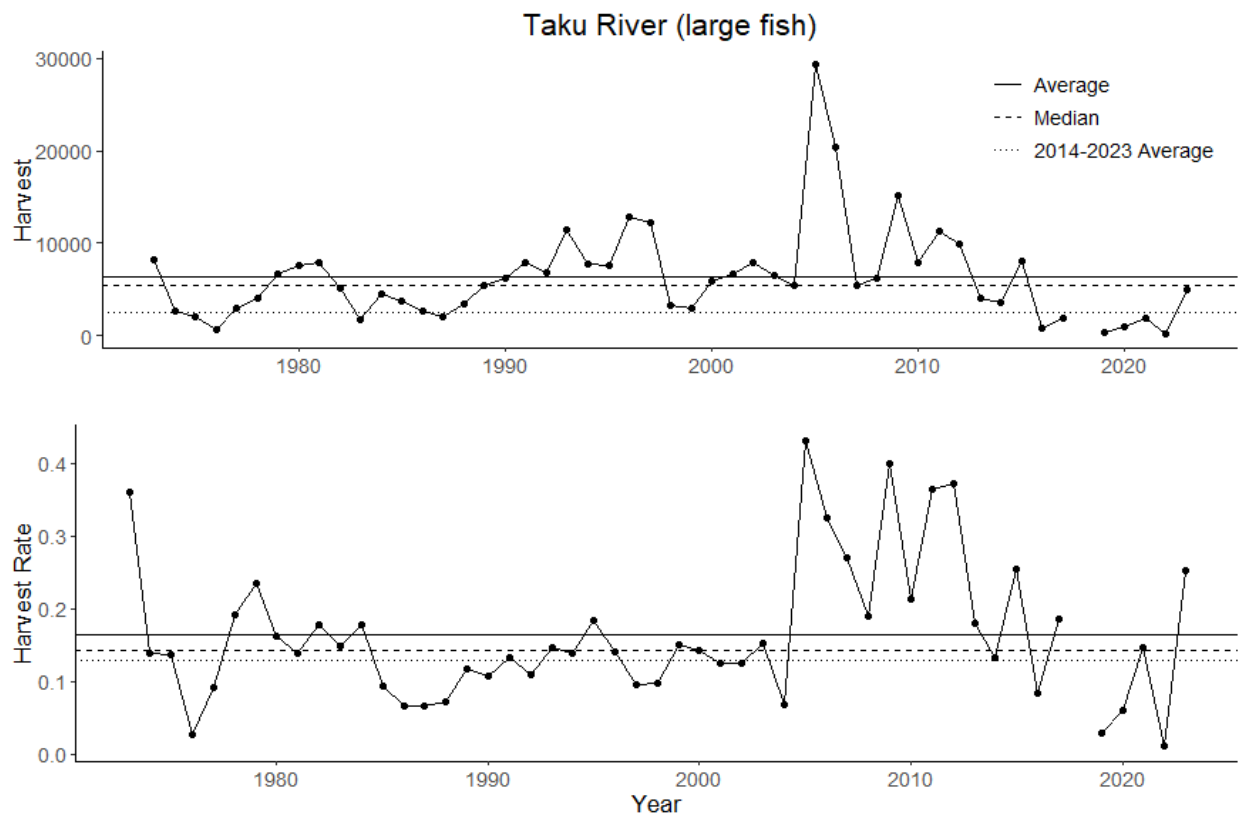


Figure 74. -- Taku River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1973-2023. Missing 2018 point omitted due to uncertainty indicating a negative harvest.

The time series for Taku River (large fish) includes 51 years of data from 1973 to 2023 (Figure 74). Mean harvest was 6,310, median harvest was 5,446, and the average harvest over the last 10 years was 2,535. The maximum harvest was 29,318 in 2005, and the minimum was 151 in 2022. For harvest rate, the mean was 0.165, the median was 0.142, and the most recent 10-year average was 0.129. The maximum harvest rate was 0.432 in 2005, and the minimum was 0.012 in 2022.

7.3.2.7 Stikine River (large fish) stock specific harvest and harvest rate estimates

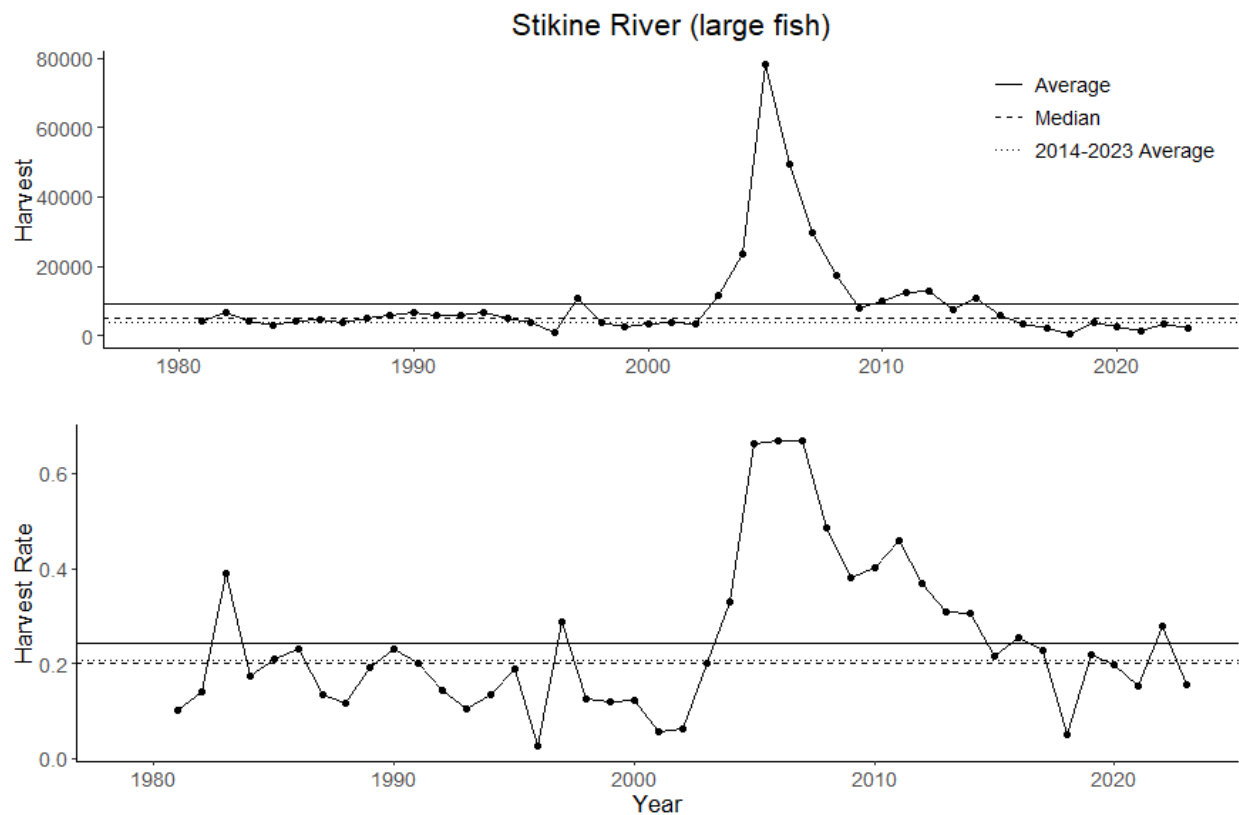


Figure 75. -- Stikine River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1981-2023.

The time series for Stikine River (large fish) includes 43 years of data from 1981 to 2023 (Figure 75). Mean harvest was 9,325, median harvest was 4,937, and the average harvest over the last 10 years was 3,648. The maximum harvest was 78,115 in 2005, and the minimum was 452 in 2018. For harvest rate, the mean was 0.243, the median was 0.2, and the most recent 10-year average was 0.205. The maximum harvest rate was 0.67 in 2007, and the minimum was 0.026 in 1996.

7.3.2.8 King Salmon River (large fish) stock specific harvest and harvest rate estimates

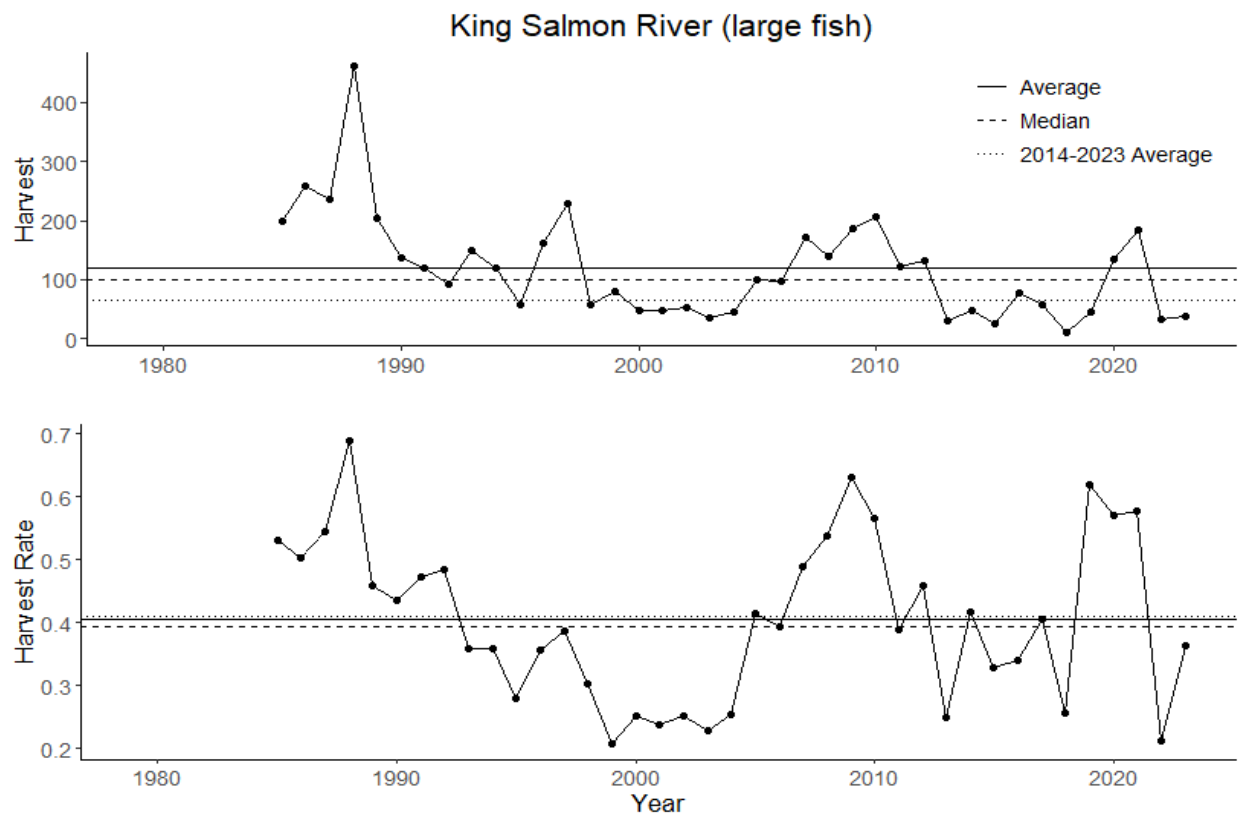


Figure 76. -- King Salmon River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1985-2023.

The time series for King Salmon River (large fish) includes 39 years of data from 1985 to 2023 (Figure 76). Mean harvest was 119, median harvest was 101, and the average harvest over the last 10 years was 65. The maximum harvest was 462 in 1988, and the minimum was 10 in 2018. For harvest rate, the mean was 0.406, the median was 0.394, and the most recent 10-year average was 0.409. The maximum harvest rate was 0.69 in 1988, and the minimum was 0.207 in 1999.

7.3.2.9 Unuk River (large fish) stock specific harvest and harvest rate estimates

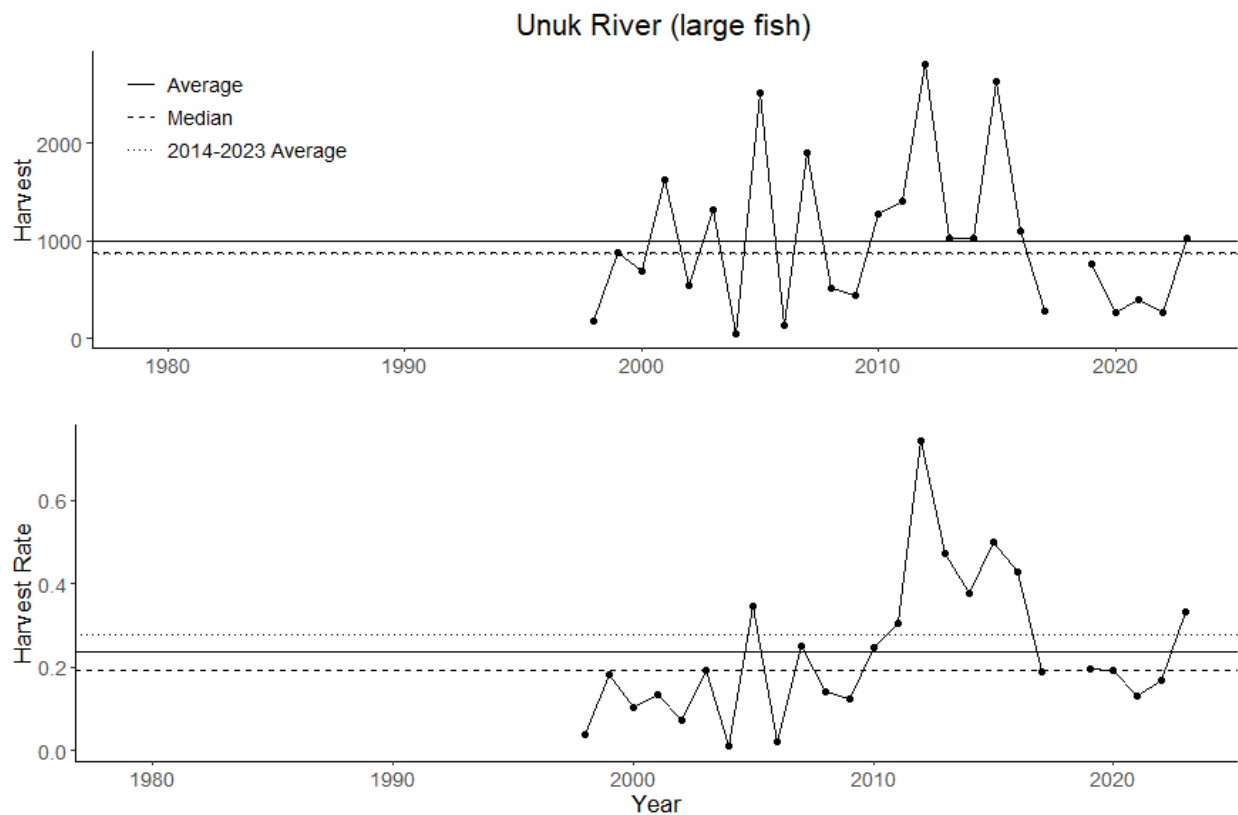


Figure 77. -- Unuk River large Chinook salmon estimated harvests (top) and harvest rates (bottom) 1998-2023. Missing 2018 point omitted due to uncertainty indicating a negative harvest.

The time series for Unuk River (large fish) includes 26 years of data from 1998 to 2023 (Figure 77). Mean harvest was 1,000, median harvest was 881, and the average harvest over the last 10 years was 862. The maximum harvest was 2,798 in 2012, and the minimum was 46 in 2004. For harvest rate, the mean was 0.236, the median was 0.191, and the most recent 10-year average was 0.28. The maximum harvest rate was 0.745 in 2012, and the minimum was 0.011 in 2004.

7.3.3 Central Gulf of Alaska ESU Harvest

This section provides historical harvest information for Chinook salmon associated with the Central Gulf of Alaska ESU. As mentioned previously, the three Chinook salmon indicator stocks associated with the CGOA ESU (Figure 3) reside within different ADF&G management regions and areas:

- The Alsek and Situk rivers drain into the marine waters of ADF&G's Yakutat Management Area (area between Cape Suckling and Cape Fairweather), which is part of ADF&G's Southeast Alaska Region.

- The Copper River drains into the marine waters of ADF&G's Copper River District, within the Prince William Sound Management Area (Cape Fairfield to Cape Suckling), which is part of ADF&G's Central Region.

ADF&G's Southeast Alaska Region was described previously. ADF&G's Central region includes marine waters of ADF&G's Prince William Sound, Cook Inlet (Lower and Upper Cook Inlet), and Bristol Bay management areas. However, Bristol Bay Chinook salmon stocks are not included in this overall assessment and every effort has been made to be transparent with respect to the inclusion or exclusion of Bristol Bay harvests in the estimates provided.

7.3.3.1 Alsek River Stock Specific Harvest and Harvest Rate Estimates

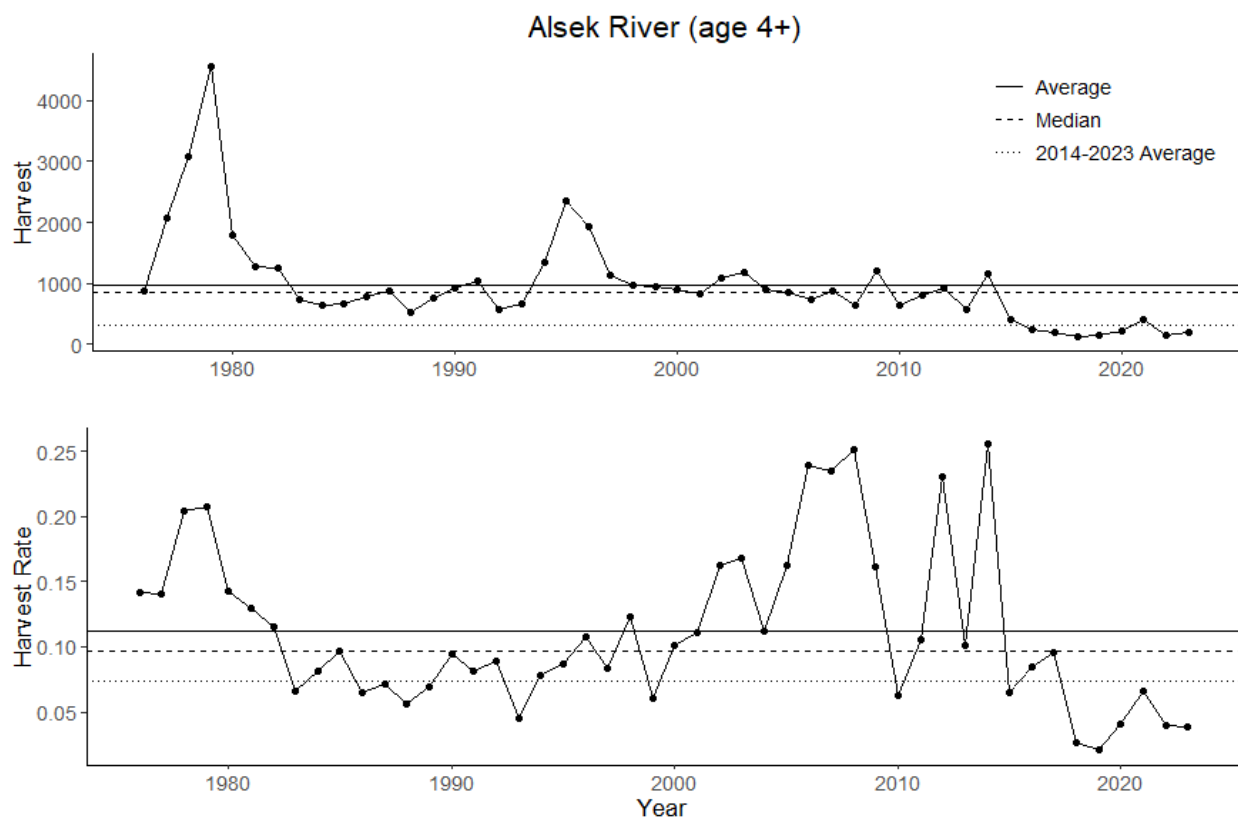


Figure 78. -- Alsek River (age 4+) Chinook salmon estimated harvests (top) and harvest rates (bottom) 1976–2023.

The time series for Alsek River (age 4+) includes 48 years of data from 1976 to 2023 (Figure 78). Mean harvest was 978, median harvest was 860, and the average harvest over the last 10 years was 318. The maximum harvest was 4,555 in 1979, and the minimum was 116 in 2018. For harvest rate, the mean was 0.112, the median was 0.097, and the most recent 10-year average was 0.073. The maximum harvest rate was 0.256 in 2014, and the minimum was 0.021 in 2019.

7.3.3.2 Situk River Stock Specific Harvest and Harvest Rate Estimates

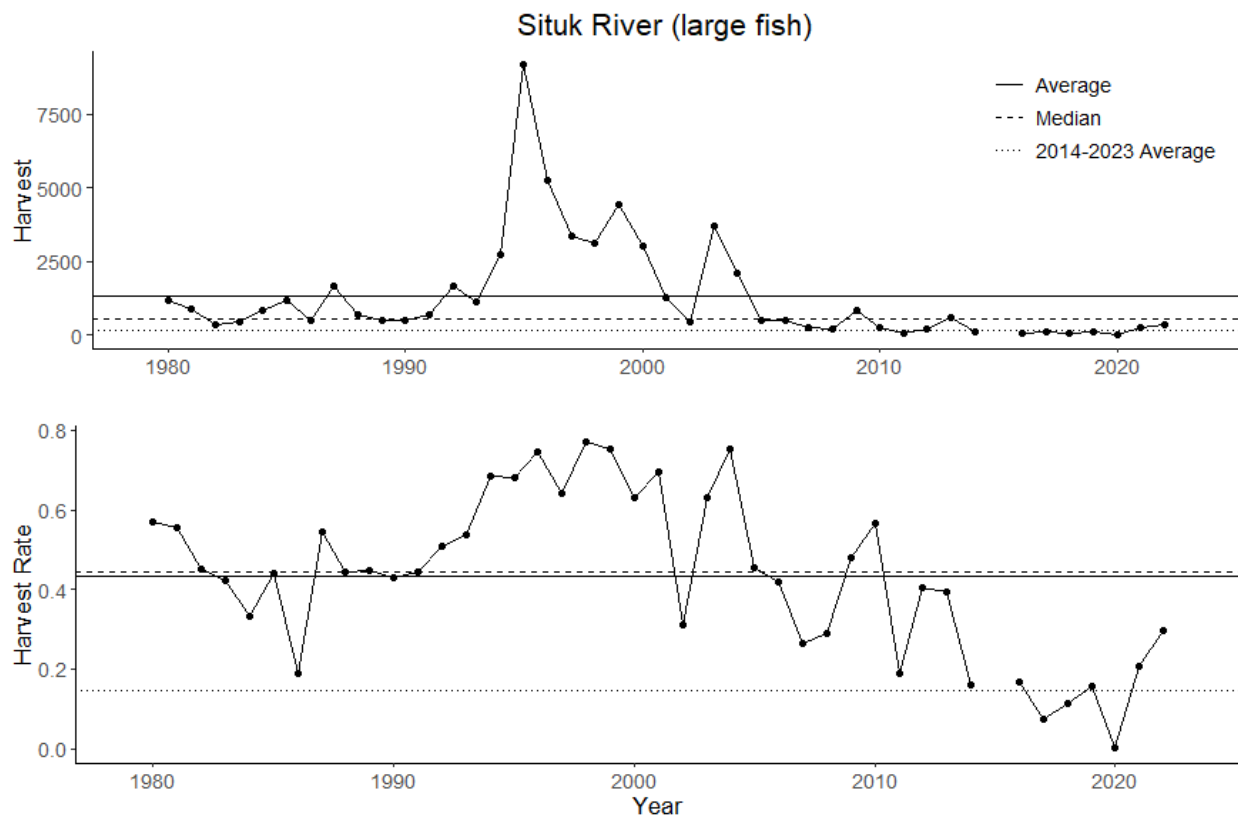


Figure 79. -- Situk River (large fish) Chinook salmon estimated harvests (top) and harvest rates (bottom) 1980-2022. Missing 2015 point omitted due to uncertainty indicating a negative harvest.

The time series for Situk River (large fish) includes 43 years of data from 1980 to 2022 (Figure 79). Mean harvest was 1,318, median harvest was 552, and the average harvest over the last 10 years was 140. The maximum harvest was 9,186 in 1995, and the minimum was 3 in 2020. For harvest rate, the mean was 0.434, the median was 0.444, and the most recent 10-year average was 0.145. The maximum harvest rate was 0.772 in 1998, and the minimum was 0.002 in 2020.

7.3.3.3 Copper River Stock Specific Harvest and Harvest Rate Estimates

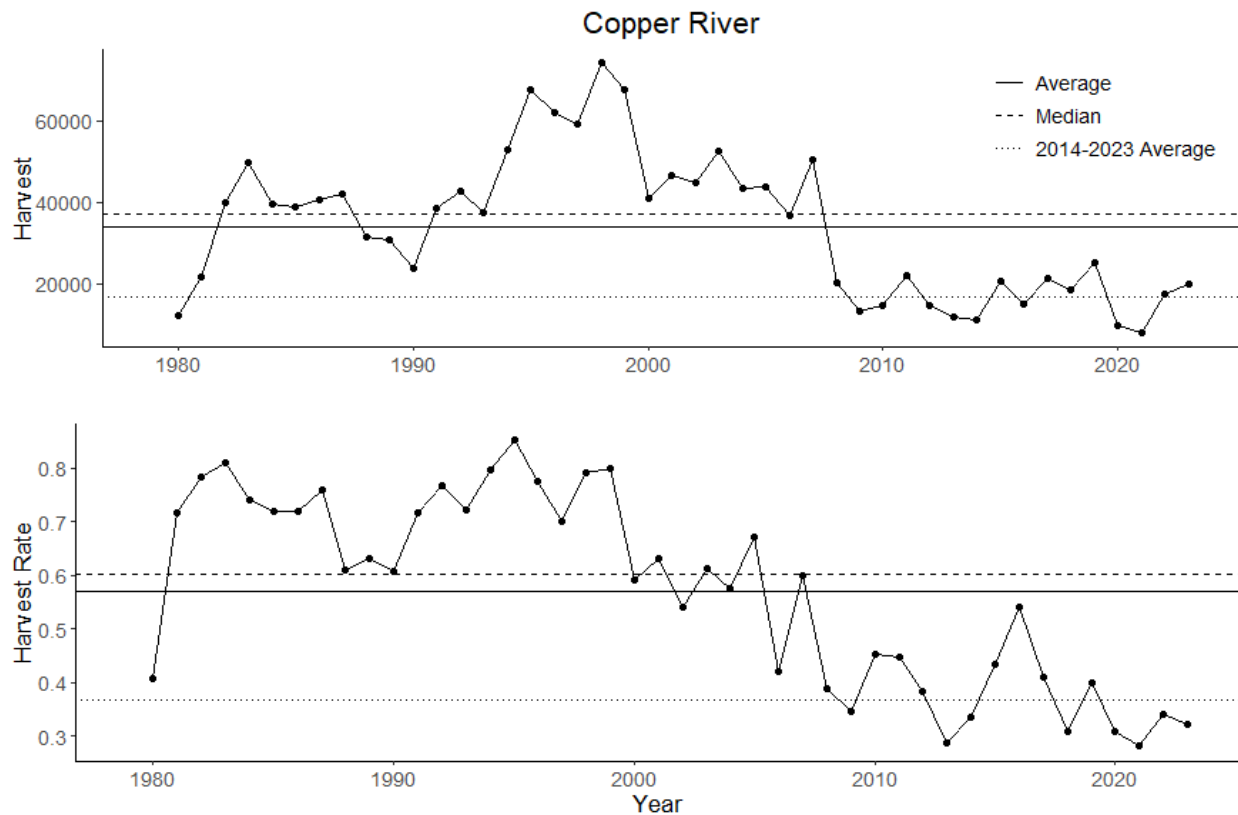


Figure 80. -- Copper River Chinook salmon estimated harvests (top) and harvest rates (bottom) 1980-2023.

The time series for Copper River includes 44 years of data from 1980 to 2023 (Figure 80). Mean harvest was 34,031, median harvest was 37,126, and the average harvest over the last 10 years was 16,784. The maximum harvest was 74,116 in 1998, and the minimum was 8,040 in 2021. For harvest rate, the mean was 0.569, the median was 0.603, and the most recent 10-year average was 0.368. The maximum harvest rate was 0.854 in 1995, and the minimum harvest rate was 0.282 in 2021.

7.3.4 Northwest Gulf of Alaska ESU Harvest

This section includes Chinook salmon harvest estimates for the Northwest Gulf of Alaska ESU. This ESU includes indicator stocks and associated harvests that occur in ADF&G's Cook Inlet, Kodiak, Chignik, and South Alaska Peninsula management areas of the Central and Westward Regions.

The NWGOA ESU spans the following ADF&G management regions and areas and includes 10 Chinook salmon indicator stocks (Figure 4):

- Cook Inlet Management Area (including Lower and Upper Cook Inlet sub-areas) of the Central Region: Kenai early run, Kenai River late run, Kasilof, Anchor, and Susitna Rivers

(including the Deshka, East Susitna, Talkeetna, and Yentna Rivers, tributaries of the Susitna River).

- Kodiak Management Area of the Westward Region: Ayakulik and Karluk Rivers.
- Chignik Management Area of the Westward Region: Chignik River on the Alaska Peninsula
- South Alaska Peninsula Management Area of the Westward Region: harvest data, but no indicator stocks.

ADF&G Divisions of Sport and Commercial Fisheries do not share management boundaries for the NWGOA ESU. For example, the Cook Inlet Management Area for ADF&G's Commercial Fisheries Division resides within that division's Central Region. In contrast, ADF&G's Sport Fish Division's Southcentral Region extends from Cape Suckling through Bristol Bay (including Cook Inlet) and includes Kodiak Island, which is not part of the Central Region for commercial fisheries management. As such, across all fisheries and gear types, harvest reporting for the NWGOA ESU does not always fit cleanly into a given management report. Nevertheless, this assessment attempts to include complete harvests across management boundaries.

7.3.4.1 Anchor River

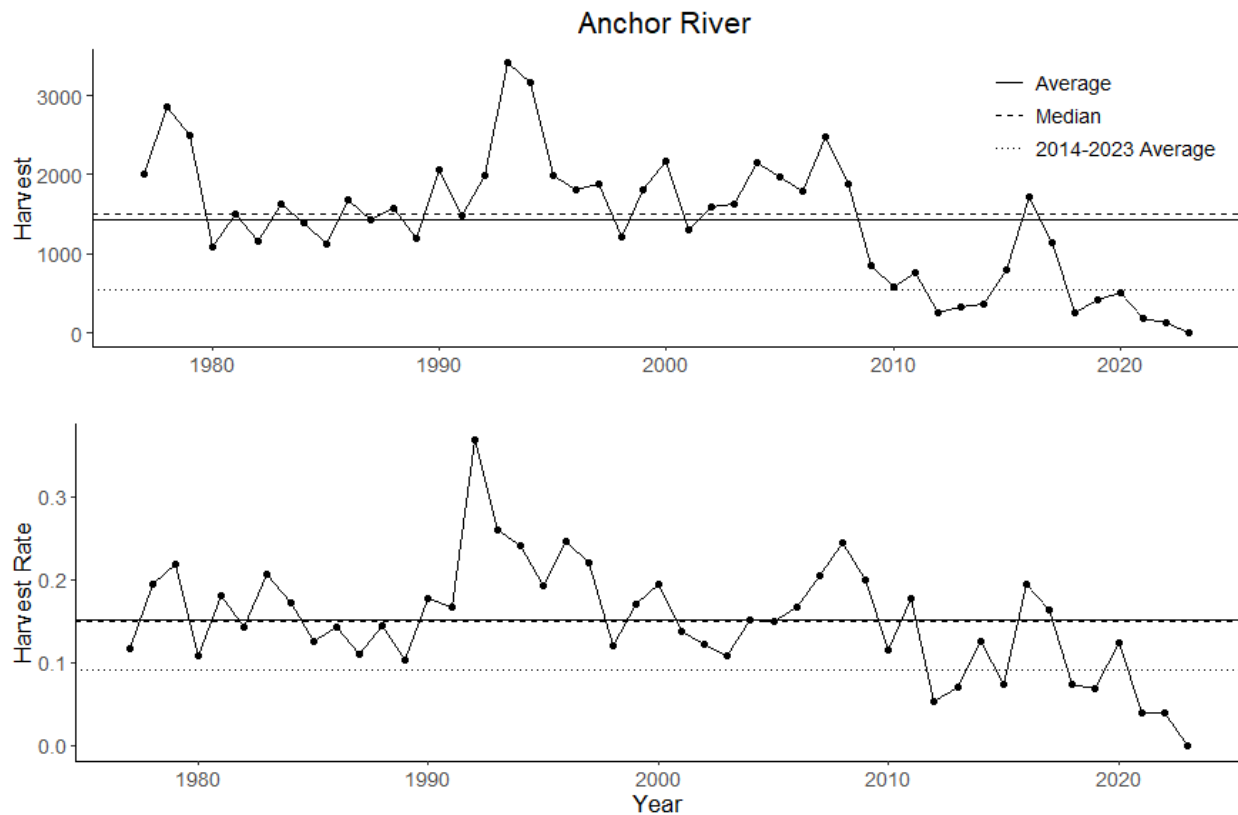


Figure 81. -- Historical Chinook salmon harvest and harvest rate estimates for the Anchor River stock (1977 to 2023). Data from ADF&G.

The time series for Anchor River includes 47 years of data from 1977-2023 (Figure 81). Mean harvest was 1,430, median harvest was 1,500, and the average harvest over the last 10 years was 550. The maximum harvest was 3,412 in 1993, and the minimum was 0 in 2023. For harvest rate, the mean was 0.152, the median was 0.15, and the most recent 10-year average was 0.09. The maximum harvest rate was 0.369 in 1992, and the minimum was 0 in 2023.

7.3.4.2 Kenai River early-run

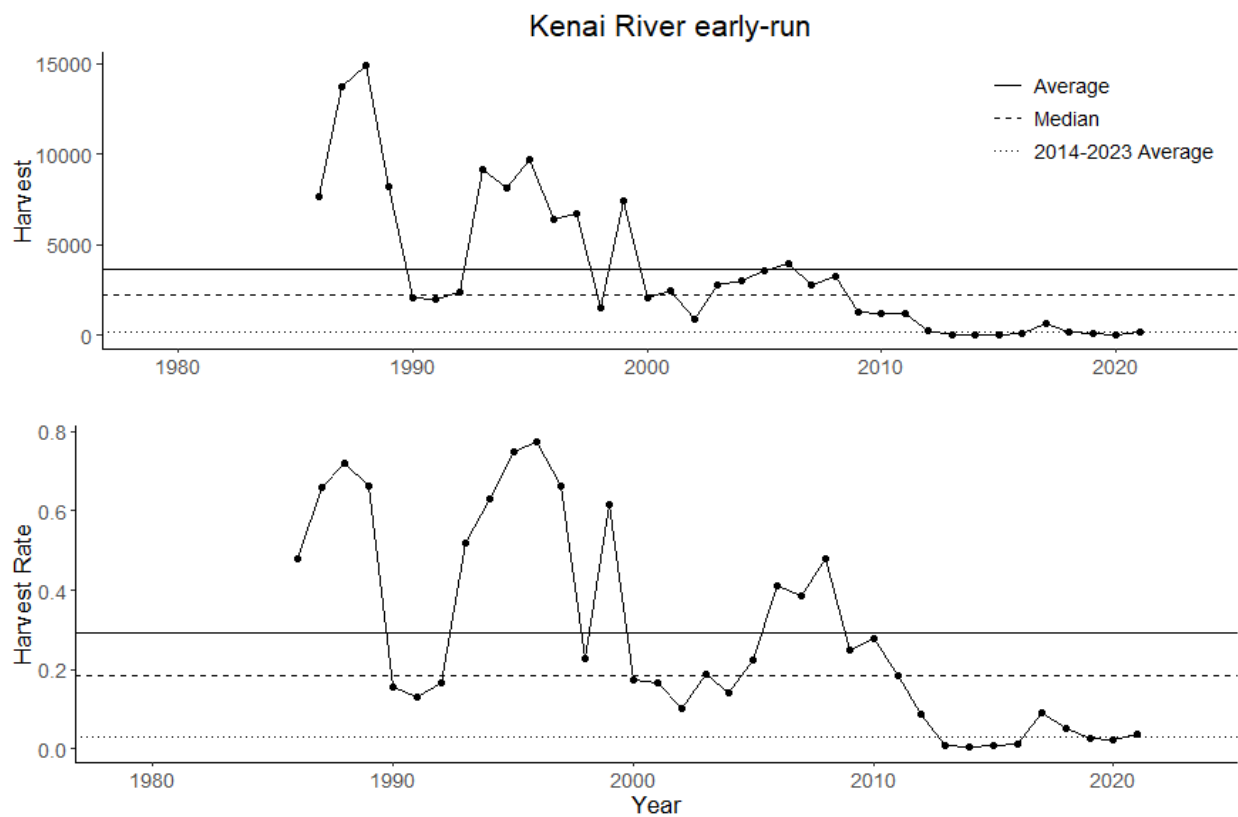


Figure 82. -- Historical Chinook salmon harvest and harvest rate estimates for the Kenai River early-run stock (1986 to 2021). Data from ADF&G.

The time series for Kenai River early-run includes 36 years of data from 1986 to 2021 (Figure 82). Mean harvest was 3,617, median harvest was 2,222, and the average harvest over the last 10 years was 153. The maximum harvest was 14,900 in 1988, and the minimum was 11 in 2014. For harvest rate, the mean was 0.291, the median was 0.186, and the most recent 10-year average was 0.03. The maximum harvest rate was 0.776 in 1996, and the minimum was 0.004 in 2014.

7.3.4.3 Kenai River late-run

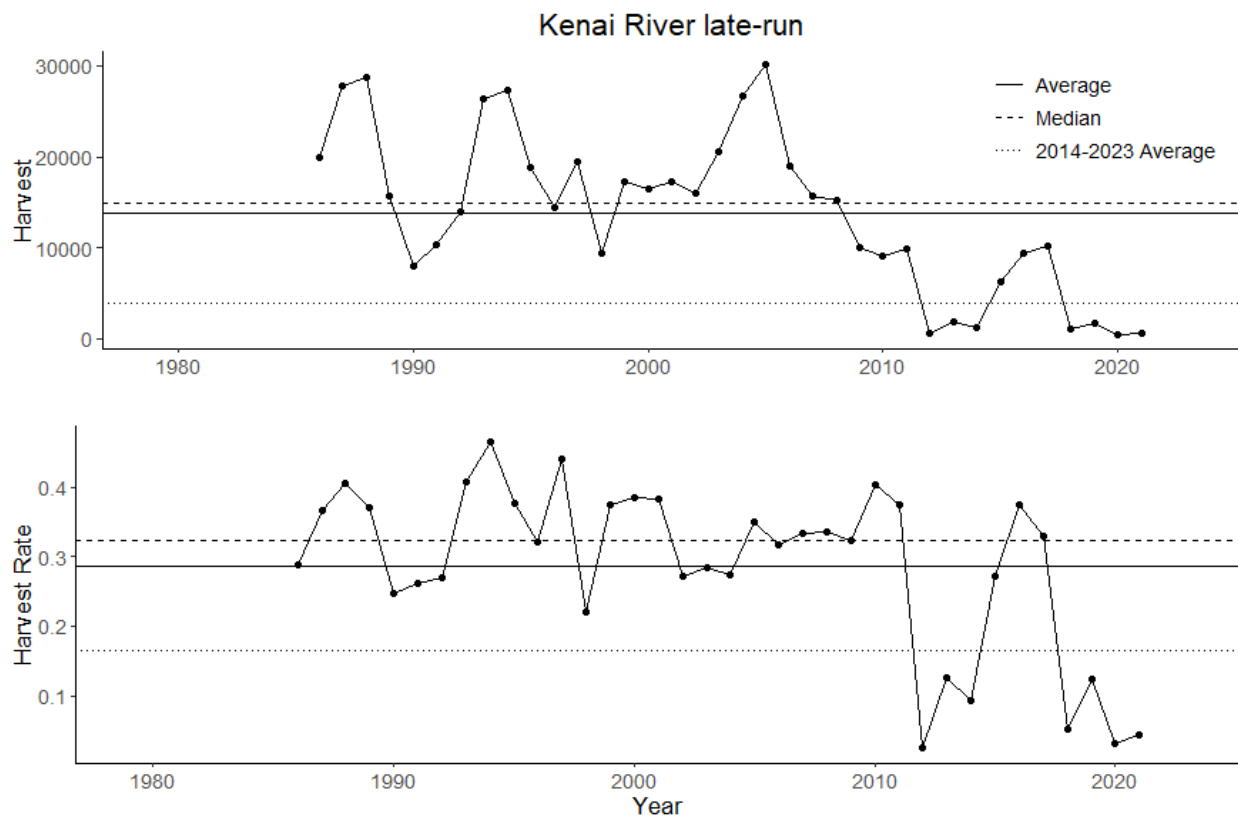


Figure 83. -- Historical Chinook salmon harvest and harvest rate estimates for the Kenai River late-run stock (1986 to 2021). Data from ADF&G.

The time series for Kenai River late-run includes 36 years of data from 1986 to 2021 (Figure 83). Mean harvest was 13,790, median harvest was 14,811, and the average harvest over the last 10 years was 3,817. The maximum harvest was 30,115 in 2005, and the minimum was 372 in 2020. For harvest rate, the mean was 0.287, the median was 0.323, and the most recent 10-year average was 0.165. The maximum harvest rate was 0.466 in 1994, and the minimum was 0.025 in 2012.

7.3.4.4 Deshka River

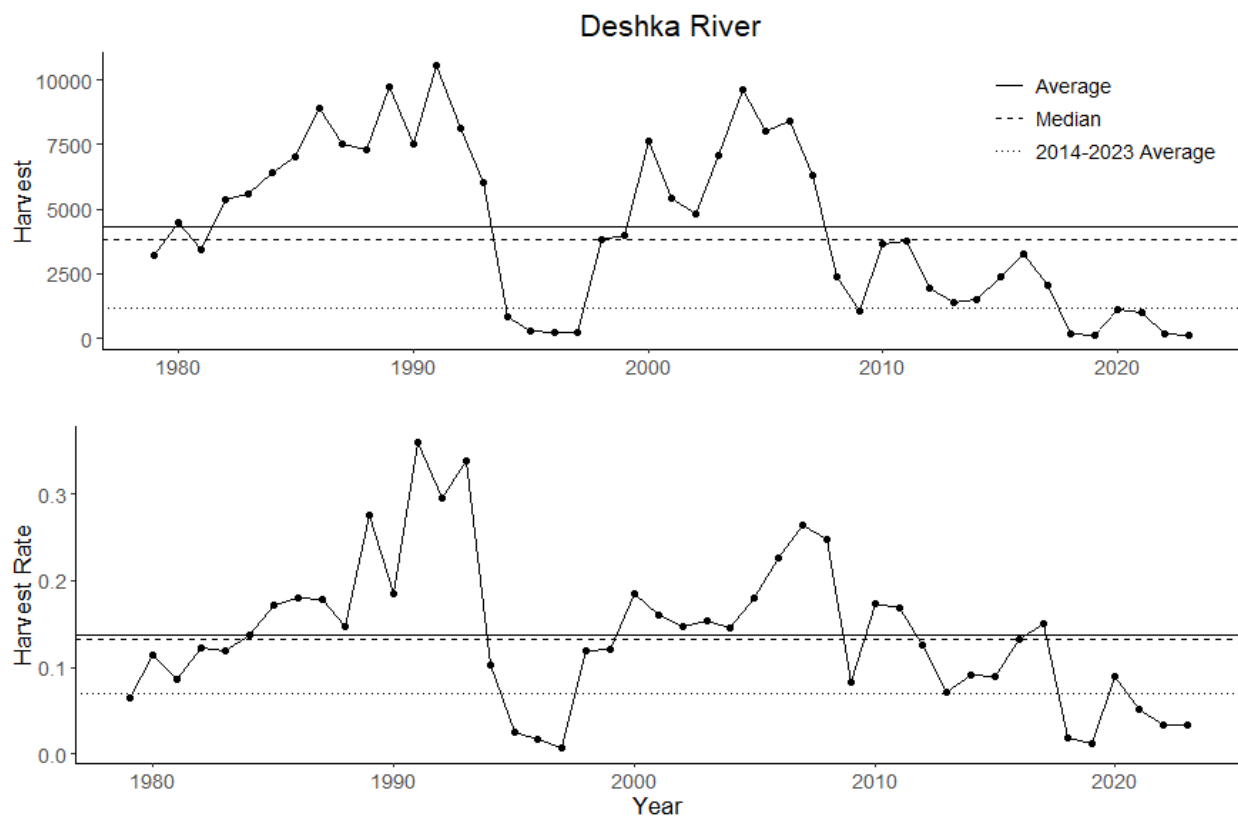


Figure 84. -- Historical Chinook salmon harvest and harvest rate estimates for the Deshka River stock (1979 to 2023). Data from ADF&G.

The time series for Deshka River includes 45 years of data from 1979 to 2023 (Figure 84). Mean harvest was 4,310, median harvest was 3,815, and the average harvest over the last 10 years was 1,192. The maximum harvest was 10,539 in 1991, and the minimum was 116 in 2019. For harvest rate, the mean was 0.138, the median was 0.132, and the most recent 10-year average was 0.07. The maximum harvest rate was 0.36 in 1991, and the minimum was 0.007 in 1997.

7.3.4.5 East Susitna River

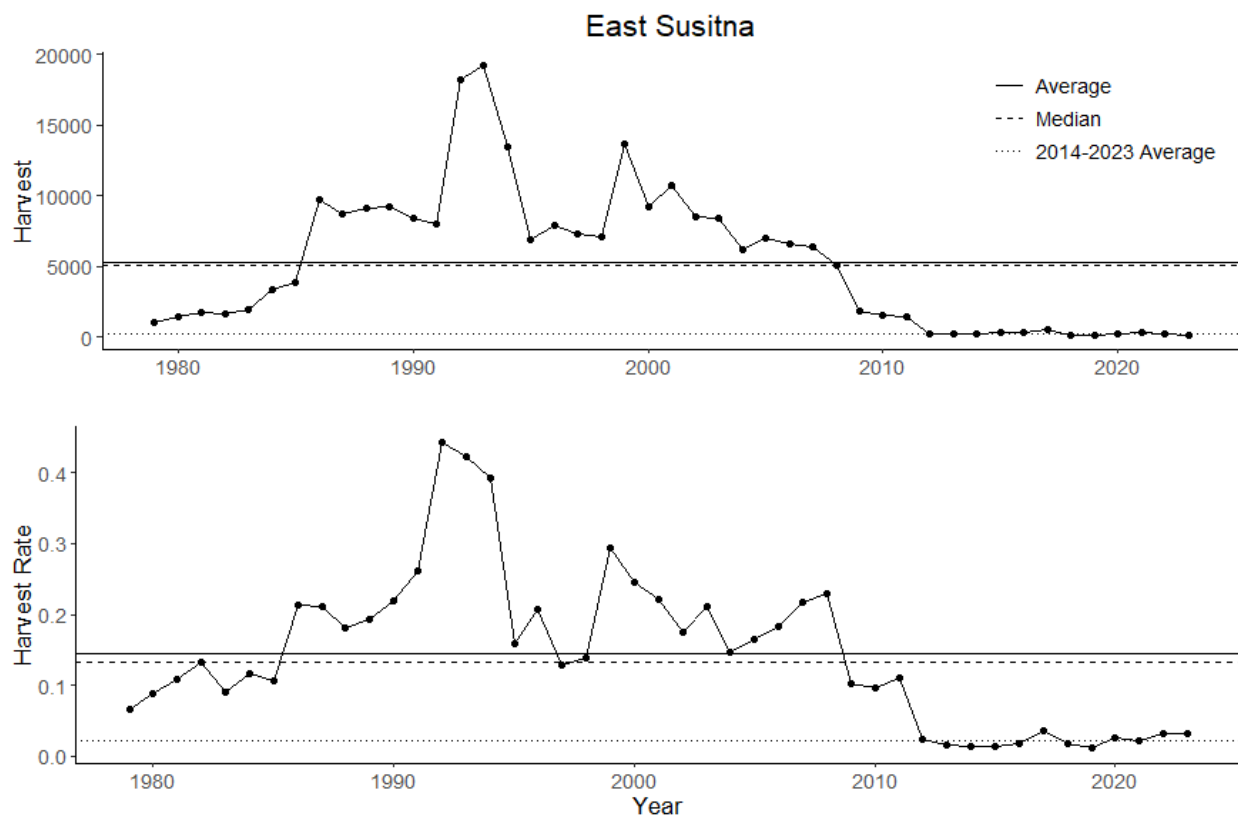


Figure 85. -- Historical Chinook salmon harvest and harvest rate estimates for the East Susitna River stock (1979 to 2023). Data from ADF&G.

The time series for East Susitna includes 45 years of data from 1979 to 2023 (Figure 85). Mean harvest was 5,311, median harvest was 5,096, and the average harvest over the last 10 years was 281. The maximum harvest was 19,204 in 1993, and the minimum was 130 in 2023. For harvest rate, the mean was 0.145, the median was 0.132, and the most recent 10-year average was 0.022. The maximum harvest rate was 0.444 in 1992, and the minimum was 0.012 in 2019.

7.3.4.6 Talkeetna River

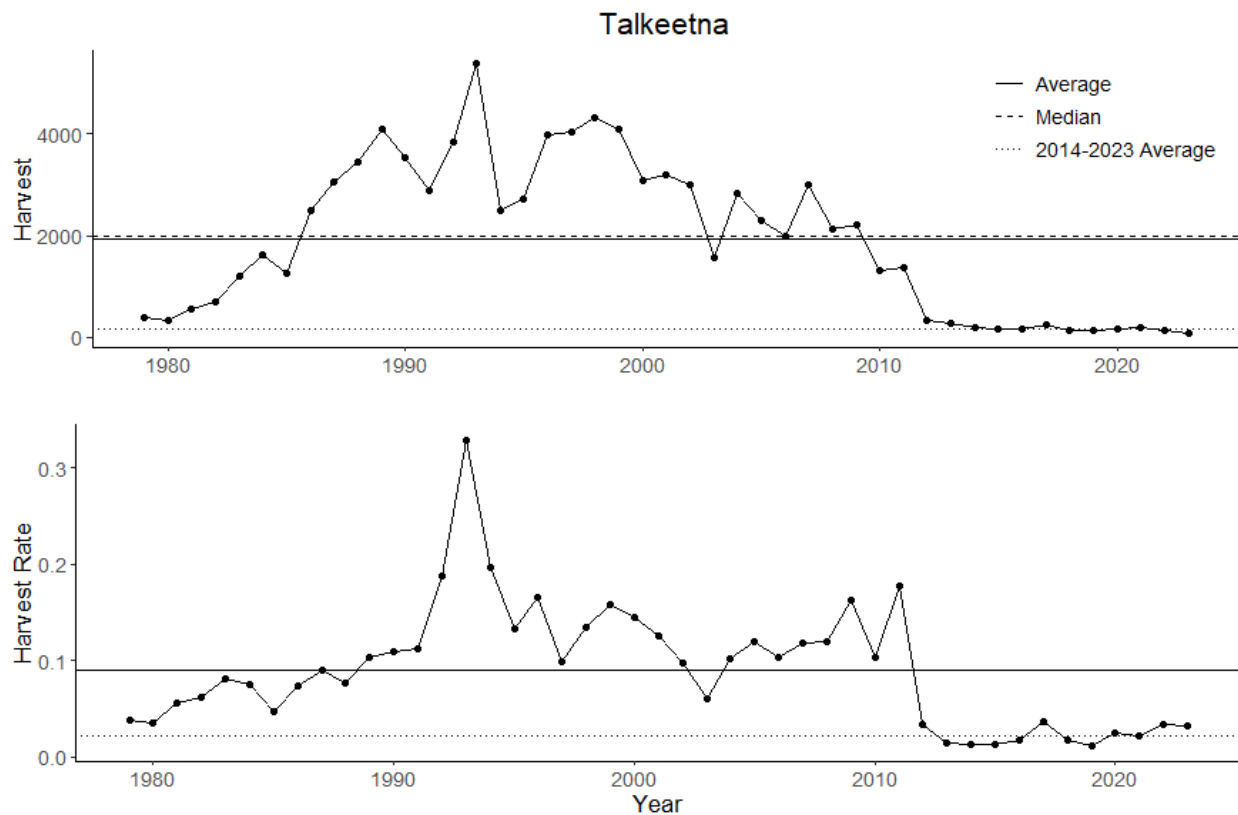


Figure 86. -- Historical Chinook salmon harvest and harvest rate estimates for the Talkeetna River stock (1979 to 2023). Data from ADF&G.

The time series for Talkeetna includes 45 years of data from 1979 to 2023 (Figure 86). Mean harvest was 1,927, median harvest was 1,981, and the average harvest over the last 10 years was 162. The maximum harvest was 5,377 in 1993, and the minimum was 74 in 2023. For harvest rate, the mean was 0.091, the median was 0.09, and the most recent 10-year average was 0.022. The maximum harvest rate was 0.329 in 1993, and the minimum was 0.012 in 2019.

7.3.4.7 Yentna River

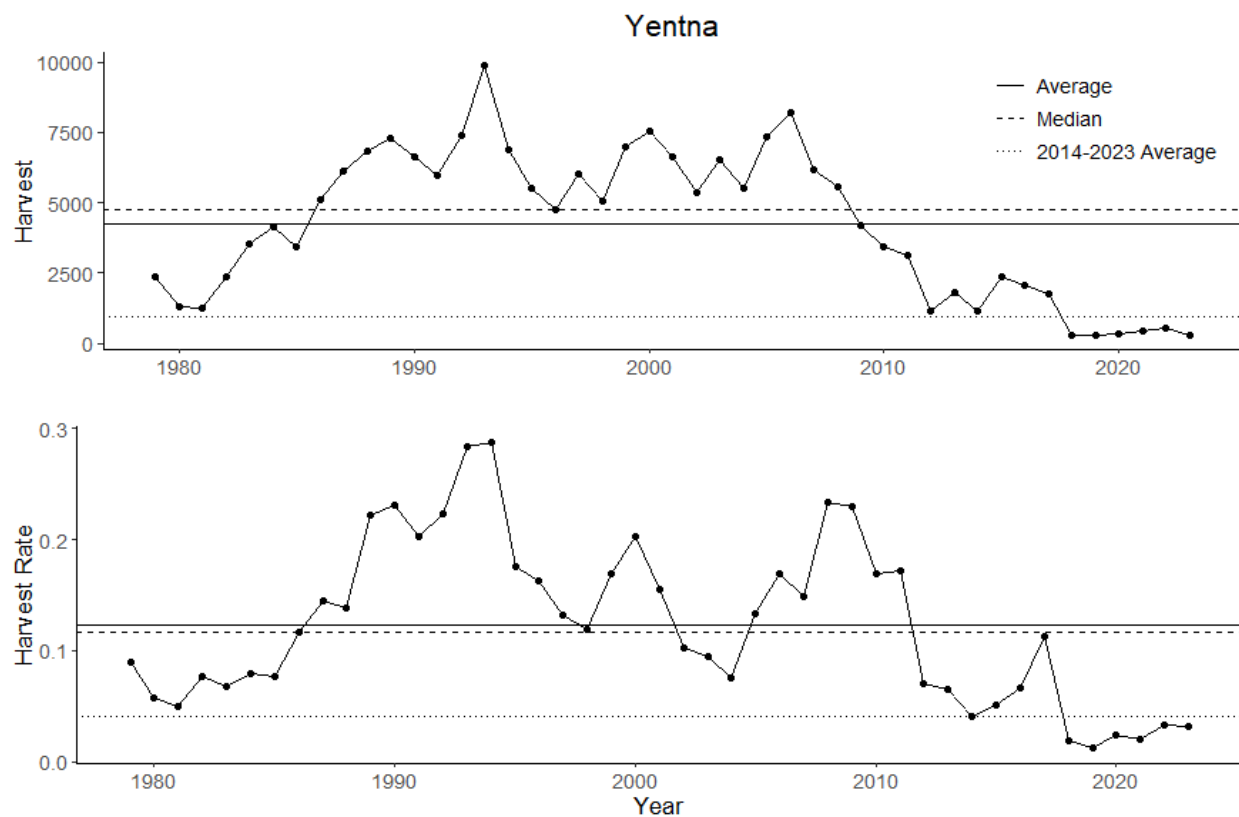


Figure 87. -- Historical Chinook salmon harvest and harvest rate estimates for the Yentna River stock (1979 to 2023). Data from ADF&G.

The time series for Yentna River Chinook salmon includes 45 years of data from 1979 to 2023 (Figure 87). Mean harvest was 4,239, median harvest was 4,751, and the average harvest over the last 10 years was 943. The maximum harvest was 9,862 in 1993, and the minimum was 276 in 2018. For harvest rate, the mean was 0.123, the median was 0.116, and the most recent 10-year average was 0.041. The maximum harvest rate was 0.288 in 1994, and the minimum was 0.013 in 2019.

7.3.4.8 Ayakulik River Chinook salmon stock

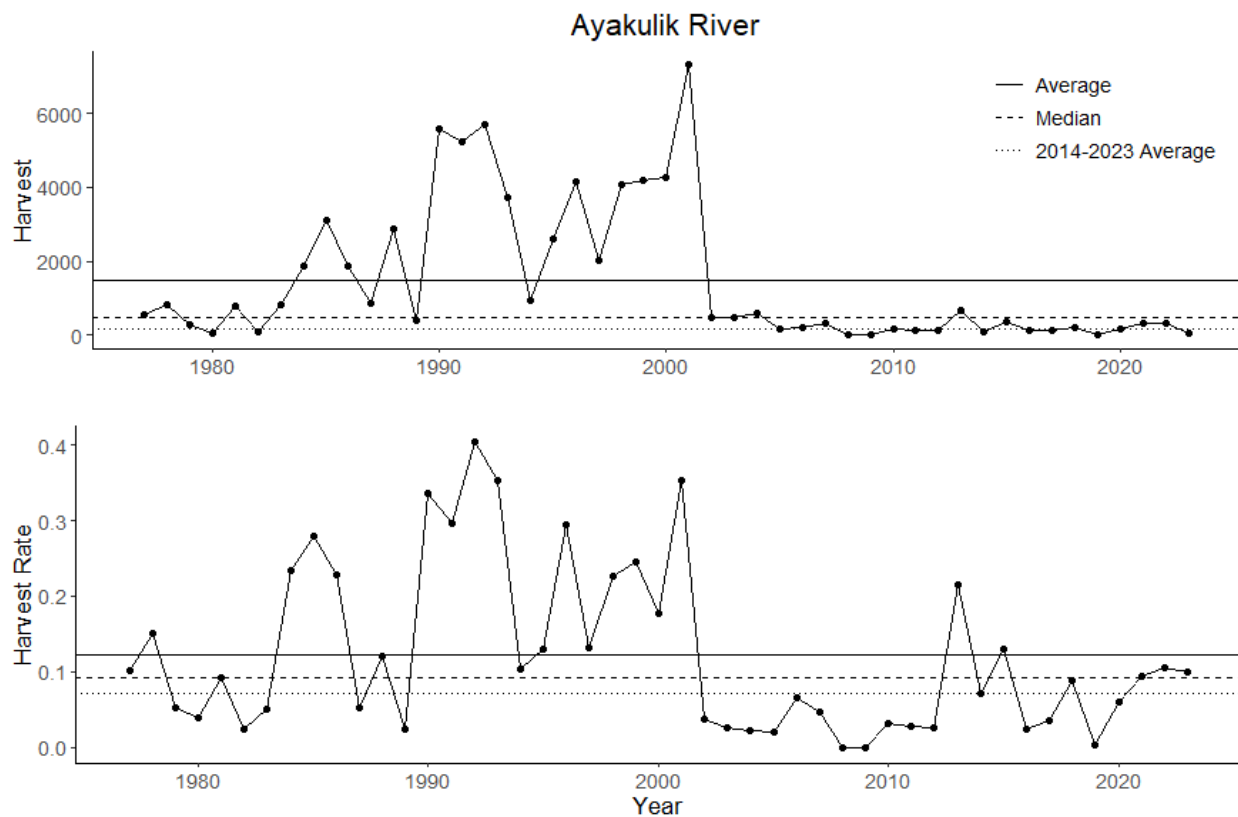


Figure 88. -- Ayakulik River Chinook salmon estimated harvests (top) and harvest rates (bottom) 1977–2023.

The time series for Ayakulik River includes 47 years of data from 1977 to 2023 (Figure 88). Mean harvest was 1,469, median harvest was 470, and the average harvest over the last 10 years was 175. The maximum harvest was 7,311 in 2001, and the minimum was 0 in 2008. For harvest rate, the mean was 0.122, the median was 0.093, and the most recent 10-year average was 0.071. The maximum harvest rate was 0.405 in 1992, and the minimum was 0 in 2008.

7.3.4.9 Karluk River

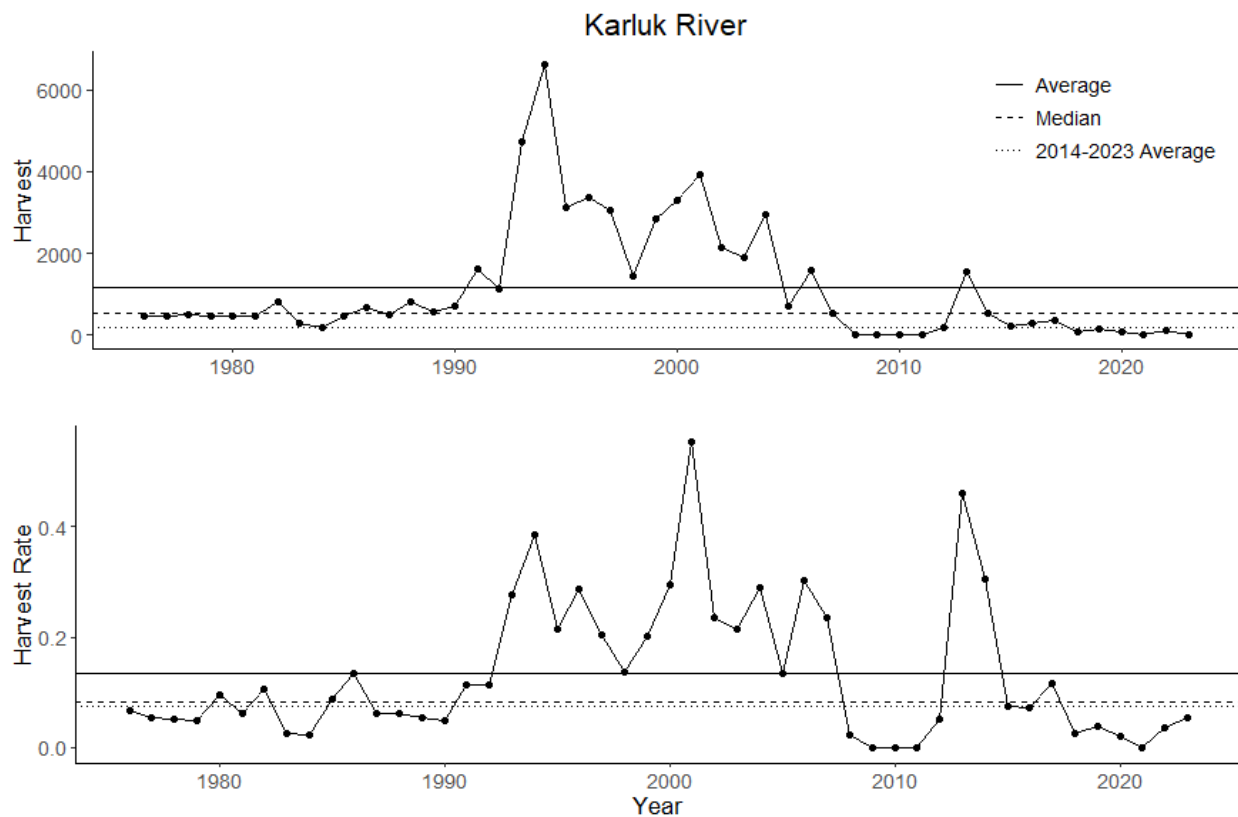


Figure 89. -- Karluk River Chinook salmon estimated harvests (top) and harvest rates (bottom), 1976–2023.

The time series for Karluk River includes 48 years of data from 1976 to 2023 (Figure 89). Mean harvest was 1,171, median harvest was 515, and the average harvest over the last 10 years was 179. The maximum harvest was 6,610 in 1994, and the minimum was 0 in 2009. For harvest rate, the mean was 0.134, the median was 0.082, and the most recent 10-year average was 0.075. The maximum harvest rate was 0.554 in 2001, and the minimum was 0 in 2009.

7.3.4.10 Chignik River Chinook salmon stock

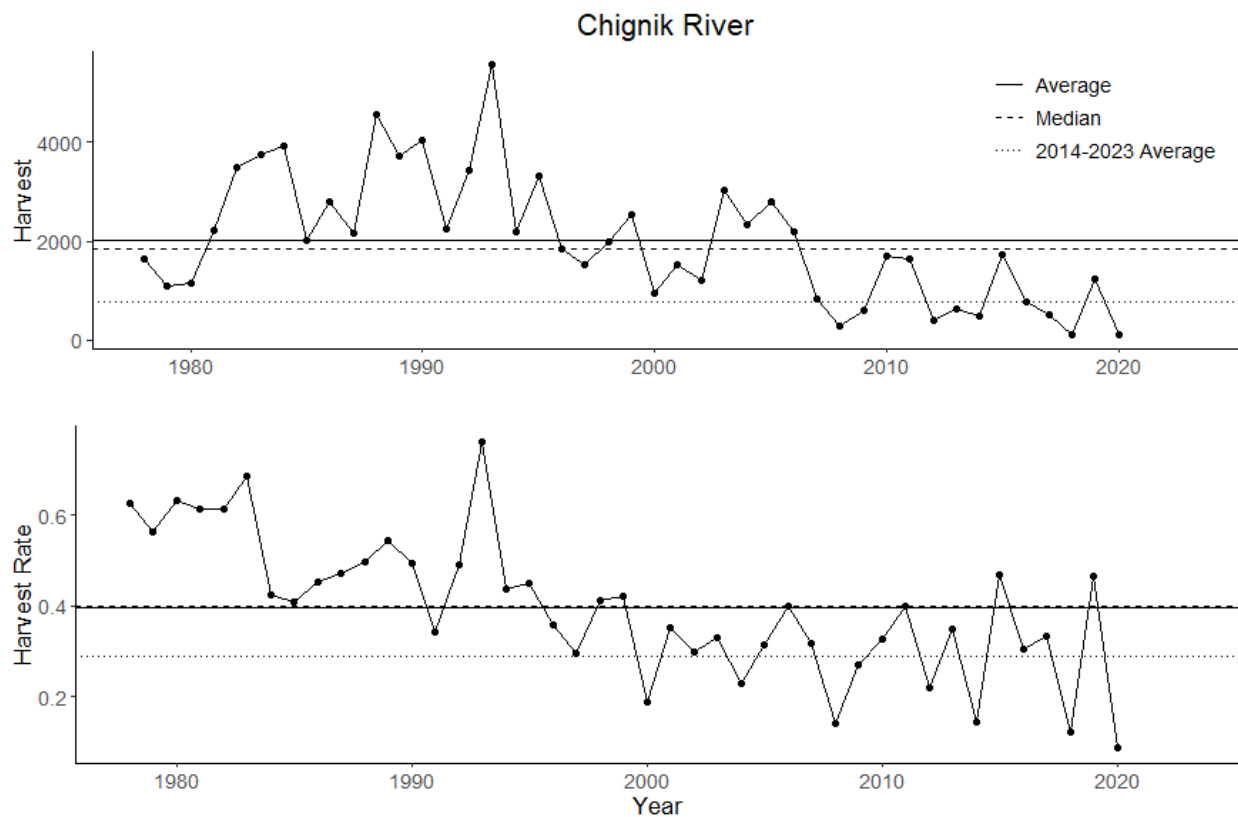


Figure 90. -- Chignik River Chinook salmon estimated harvests (top) and harvest rates (bottom), 1978–2020.

The time series for Chignik River includes 43 years of data from 1978 to 2020 (Figure 90). Mean harvest was 2,006, median harvest was 1,834, and the average harvest over the last 10 years was 761. The maximum harvest was 5,569 in 1993, and the minimum was 101 in 2018. For harvest rate, the mean was 0.396, the median was 0.4, and the most recent 10-year average was 0.289. The maximum harvest rate was 0.762 in 1993, and the minimum was 0.088 in 2020.

7.3.5 Summary of Chinook salmon harvest and harvest rate estimates across Gulf of Alaska regions for ESU indicator stocks

While Gulf of Alaska harvest estimates include mixtures of wild and hatchery-origin fish from populations that spawn in Alaska and elsewhere, harvest and harvest rate estimates for ESU indicator stocks provide estimates that are specific to those stocks. As such, stock-specific harvest and harvest rate estimates should be considered informative for assessing potential impacts of harvests (potential overutilization) to the indicator stocks, and the overall ESUs.

As discussed previously, there are major caveats associated with estimates of stock-specific harvests and harvest rates. For example, as there is uncertainty for estimates of total run size and spawning escapements, there is also uncertainty with respect to attributing harvests to

specific stocks. Harvest estimates in this assessment are often assumed to represent the difference between annual estimates of total run size and estimates of spawning escapements. In turn, harvest rates are defined as annual stock-specific harvest estimates divided by the total run sizes for those stocks. Therefore, uncertainty in total run size, escapement, and harvests all contribute to uncertainty in harvest rates.

Across ESUs, estimates of stock-specific Chinook salmon harvests and harvest rates (harvest relative to total run size) have generally declined in recent years, likely as management actions have restricted fisheries in response to low levels of Chinook salmon abundance. However, harvest rates have been relatively high for some stocks during the most recent 10 years, with the highest estimated harvest rates occurring for stocks in the Southeast Gulf of Alaska ESU. For this ESU, mean harvest rates during the most recent 10 years ranged from 0.128 to 0.409. For the Central Gulf of Alaska ESU, mean harvest rates during the most recent 10 years ranged from 0.073 to 0.368. In contrast, estimated mean harvest rates for the most recent 10 years were lowest for the Northwest Gulf of Alaska ESU stocks, with a range of 0.022 to 0.289.

7.3.6 Bycatch in federal and state groundfish fisheries

7.3.6.1 Prohibited species catch limits

Chinook salmon from the Gulf of Alaska are caught as bycatch in state and federal groundfish fisheries. Salmon are caught incidentally in the GOA and Bering Sea and Aleutian Islands (BSAI) federal offshore trawl fisheries, especially in the pollock pelagic trawl fishery. Salmon are considered a prohibited species catch (PSC) in groundfish fisheries, and cannot be retained for sale or personal use (50 CFR 679.7; 50 CFR 679.21). Nearly all salmon taken as bycatch are Chinook salmon and chum salmon. To limit the amount of bycatch of Chinook salmon, the NPFMC and NMFS have implemented mandatory PSC limits, apportioned by fishery sector. In the Gulf of Alaska, total catch of Chinook salmon PSC in the Central and Western GOA trawl fisheries cannot exceed 32,500 Chinook per year. In the BSAI, the annual PSC limit depends on the abundance of salmon in a three-river index system (Upper Yukon, Kuskokwim, and Unalakleet Rivers). In years when the index is greater than 250,000 fish, the PSC limit is 60,000 fish. In years of lower abundance, the PSC limit is 45,000 fish. The attainment of a PSC limit results in the closure of the responsible fishery.

The federal fisheries that catch the most Chinook PSC have high rates of observer coverage, and are required to retain all bycaught salmon for sampling^{29,30}. While GOA fishing vessels do not

²⁹ NOAA Fisheries. Bycatch Data Reporting from Observer Programs Database. Available at <https://www.fisheries.noaa.gov/national/fisheries-observers/bycatch-data-reporting-observer-programs-database>. Accessed August 12, 2025.

³⁰ North Pacific Fishery Management Council. Salmon Bycatch Frequently Asked Questions. Available at <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.npfmc.org/wp-content/PDFdocuments/bycatch/SalmonBycatchFAQ.pdf>. Accessed August 12, 2025.

have 100% observer coverage, logged pollock fishing trips are randomly sampled for Chinook³¹. Salmon bycaught in GOA groundfish fisheries are examined for coded wire tags and clipped adipose fins, and tissue samples are retained for genetic analyses; all of these metrics can provide information on the origin of the salmon (e.g., river system(s), lake(s), or ESU).

The AFSC's Auke Bay Laboratories analyzes the salmon PSC samples and data, and prepares an annual report that summarizes salmon bycatch in the fishery by region of origin³², as well as another report that summarizes coded wire tag (CWT) recoveries.³³ NMFS uses genetic stock identification to determine the regional stock composition of Chinook caught in these fisheries and CWTs are used to identify bycaught fish to their specific stock of origin.

Chinook salmon originating from the GOA are bycaught in federal Bering Sea groundfish fisheries (primarily in summer), with an average of 1,081 GOA-origin Chinook salmon caught each year from 2010 to 2023 (range = 198–2,336). Chinook salmon originating from the GOA are also caught in GOA federal groundfish fisheries, with an average of 3,325 GOA Chinook salmon caught each year from 2010 to 2023 (range = 1,633–5,857). The primary stocks harvested in federal groundfish fisheries from the Bering Sea and GOA are from the SEGOA and NWGOA ESUs, with an average of 2,755 fish harvested from the SEGOA ESU from 2011 to 2023 (range = 1,810–4,091) and 1,416 fish harvested from the NWGOA ESU from 2011 to 2023 (range = 500–4,333). Stocks from the CGOA ESU are rarely encountered in federally managed groundfish fisheries (2011–2023 yearly average = 234, range= 35–646). Historical and current Chinook bycatch data are available on the NMFS website.³⁴

A small number of Chinook salmon originating from the GOA are also caught as bycatch in state non-salmon fisheries (e.g., state-managed trawl fisheries; fewer than 1,000 fish annually, with an annual average of 275 over the most recent 15 years), and many of those salmon are likely from stocks outside the GOA (ADF&G 2024f). Chinook salmon bycatch in state salmon fisheries is described in Section 1.5-Overview of Chinook Salmon Management.

³¹ North Pacific Fishery Management Council. Salmon Bycatch Frequently Asked Questions. Available at <https://www.npfmc.org/fisheries-issues/bycatch/salmon-bycatch/>. Accessed August 12, 2025.

³² NOAA Fisheries. Annual Report for the Alaska Groundfish Fisheries Chinook Salmon Incidental Catch and ESA Consultation. Available at <https://www.fisheries.noaa.gov/resource/document/annual-report-alaska-groundfish-fisheries-chinook-salmon-incident-catch-and-esa>. Accessed November 1, 2024.

³³ NOAA Fisheries. Annual Report for the Alaska Groundfish Fisheries Chinook Salmon Coded Wire Tag and Recovery Data for ESA Consultations. Available at <https://www.fisheries.noaa.gov/resource/document/annual-report-alaska-groundfish-fisheries-chinook-salmon-coded-wire-tag-and>. Accessed August 30, 2024.

³⁴ NOAA Fisheries. Fisheries Catch and Landings Reports in Alaska. Available at <https://www.fisheries.noaa.gov/alaska/commercial-fishing/fisheries-catch-and-landings-reports-alaska#bsai/goa-groundfish-combined>. Accessed April 10, 2025.

7.3.6.2 Additional bycatch reduction and utilization measures

7.3.6.2.1 *Salmon excluder devices*

One method for avoiding bycatch is through gear modifications. NMFS has authorized the use of gear modifications to reduce Chinook salmon bycatch. Salmon excluder devices are trawl gear modifications that allow salmonid species to escape the trawl while retaining targeted pollock catch. Salmon excluder devices are essentially large escape panels worked into existing trawl gear that utilize the stronger swimming ability of salmon compared to pollock, thereby allowing salmon to swim out through the escape panel. Salmon excluder devices are a requirement of the current incentive plan agreement for the Bering Sea pollock trawl fleet, but exceptions are permitted for gear repairs and other contingencies³⁵. About half of the GOA pollock trawl fleet currently use salmon excluder devices. There are ongoing efforts between NMFS and the pollock trawl fleets to design and test improved salmon excluder devices (90 FR 13856, March 27, 2025).

7.3.6.2.2 *Incentive plan agreements*

Another method to reduce salmon bycatch is by incentivizing vessels to avoid areas of high bycatch. Since the early 2000s, the Bering Sea pollock fleet has cooperatively worked to communicate and share data to identify areas on the pollock fishing grounds with high salmon bycatch encounters and move the fleet to new areas to target pollock. These dynamic time and area closures are referred to as “rolling hotspots” and are identified based on near real-time catch and bycatch data. In 2011, these rolling hotspots were incorporated into Bering Sea Incentive Plan Agreements (IPAs), which are designed to minimize bycatch by motivating fishery participants to avoid Chinook salmon bycatch through vessel-level incentives created through contracts among the participants. Beginning in 2017, IPAs also began including provisions to reduce chum salmon bycatch. Annual reports on all measures implemented by IPAs and the performance of IPAs are provided to the Council. Pollock fisheries in the GOA do not have the same IPA for Chinook bycatch as fisheries in the BSAI. This is because there isn't a regulatory catch share program for the GOA pollock fishery, and therefore Chinook salmon PSC limits are not further apportioned to cooperatives like they are in the Bering Sea. However, for the Central GOA, most trawl catcher vessels are members of Alaska Groundfish Data Bank and have industry representatives who help them manage their Chinook PSC. This can include hotspot reporting and industry closures of areas with high Chinook catch rates. In years past, the Central GOA pollock fleet has voluntarily stopped fishing temporarily to avoid high Chinook PSC catch rates.

7.3.6.2.3 *Seafood donation program*

NMFS and the NPFMC have also created a program to better utilize bycaught Chinook salmon. In 1993, the NPFMC and NMFS established a Prohibited Species Donation Program, whereby

³⁵ NOAA Fisheries. Fisheries of the Exclusive Economic Zone Off Alaska; Bycatch Management in the Bering Sea Pollock Fishery. Available at <https://www.federalregister.gov/documents/2016/06/10/2016-13697/fisheries-of-the-exclusive-economic-zone-off-alaska-bycatch-management-in-the-bering-sea-pollock>. Accessed August 8, 2025.

vessels can retain bycaught salmon (and other species) from BSAI and GOA fisheries for distribution for hunger-relief by an organization called SeaShare.³⁶ As of 2023, SeaShare had distributed more than 6.5 million pounds of incidentally caught chum salmon, Chinook salmon, and halibut to food banks and Alaska communities. Alaska locations that have received seafood from SeaShare include: Anchorage, Kodiak, Kenai, Juneau, Nome, Cordova, Kotzebue, Fairbanks, St. Paul, Bethel, Dillingham, and other more remote locations.

7.4 Disease

Infectious disease is one of many factors that influence adult and juvenile salmon survival. Chinook are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Following is a list of endemic infectious agents detected in wild and cultured Alaska fish stocks, most from the Gulf of Alaska watersheds where over 90% of the fish hatcheries and aquaculture projects in Alaska are located, including large active commercial and sport fisheries. A complete listing of disease agents, discussion and details on species affected, clinical signs, transmission, diagnosis and host prognosis is provided in Meyers et al. (2019).

7.4.1 Endemic diseases of Chinook salmon in the Gulf of Alaska

7.4.1.1 Bacteria and fungi

- *Aeromonas salmonicida*–Furunculosis–Occasional in most wild and hatchery salmonids.
- *Aeromonas/Pseudomonas*–Motile Bacterial Septicemia–Common opportunistic infections in most salmonids and other fish species worldwide.
- *Flavobacterium psychrophilum*–Coldwater Disease–Occurs in all cultured salmonids but occasionally in coho and Chinook salmon–Other Flavobacteria (Bacterial Gill Disease)–occasionally occurs in most salmonids as well as other fish species.
- *Tenacibaculum maritimum*–Marine external skin erosion (mouth-rot)–Occurs in many different marine species including salmonids (occasional in net pen-reared salmonids).
- *Renibacterium salmoninarum* (Rs)–Bacterial Kidney Disease (BKD)–Common in wild and cultured Chinook and coho salmon 6-months old or older.
- *Vibrio anguillarum*–Vibriosis–Common in marine reared salmonids and many other fish species.
- *Yersinia ruckeri* Types 1 and 2–Enteric Redmouth (ERM)–occasional to uncommon in cultured salmonids and other fish species
- *Phoma* sp.–Fungal saprophyte of plants–Systemic occasionally in cultured salmonids in the Pacific Northwest

³⁶ SeaShare. Available at <http://www.seashare.org>. Accessed March 18, 2025.

7.4.1.2 Protozoa

- *Saprolegnia*–*Filamentous protozoan*–Water Mold–Commonly infects all wild and cultured fish species and their eggs.
- *Ichthyophonus* sp.–*Mesomycetozoea protozoan* –Rare in most watersheds but common in Yukon River Chinook salmon and several marine forage species.
- *Ichthyobodo* (*Costia*) sp.–*Flagellated protozoan*–Common in many freshwater fishes, occasionally found in hatchery juvenile salmonids.
- *Trichodina* sp.–*Ciliated protozoan*–Common in both wild and captive marine and freshwater species of fish.
- *Tricophrya* (*Capriniana*) sp.–*Suctorian protozoan*–Common on the gills of many freshwater fishes in North America.
- *Cryptocaryon irritans* (marine) and *Ichthyophthirius multifiliis* (freshwater)–*Ciliated protozoa*–Infrequently reported in Alaska. Causes white spot disease in many species of wild and cultured fish.

7.4.1.3 Cnidaria: Myxosporea

- *Ceratonova* (*Certomyxa*) *shasta*–Infrequently detected in a few watersheds in Alaska but not in hatchery salmonids
- *Henneguya* sp.–*Tapioca Muscle Disease*–Frequent in many adult species of marine, anadromous and freshwater fishes, but not in juvenile hatchery fish.
- *Kudoa thyrsites*–*Soft Flesh Disease*–Infrequent in adult Alaska coho, Chinook, and pink salmon, Pacific halibut, but can be common elsewhere in other fish species.
- *Myxobolus neurotropus*–new record in Alaska in wild rainbow trout–Frequency unknown; *M. squamalis*–common in adult returning coho salmon.
- *Tetracapsuloides bryosalmonae*–*Proliferative Kidney Disease (PKD)*–Rarely causing disease in Alaska salmonids but occasionally detected in adult returning salmon by qPCR.

7.4.1.4 Copepods and parasitic worms

Various life stages of copepods, nematodes, tapeworms, digenean trematodes and monogenean flukes (common in various fish life stages and species; see Meyers et al. 2019)

7.4.1.5 Viruses

- *Infectious Hematopoietic Necrosis Virus* (Clade Up)–*IHN* Disease–*Rhabdovirus* naturally infecting wild and cultured sockeye salmon only, with occasional spillover into resistant adult coho and pink salmon; other susceptible species include chum and Chinook salmon and rainbow trout.
- *Viral Hemorrhagic Septicemia Virus* (VHSV Type IVa)–*Common rhabdovirus* in Pacific herring and other marine forage fish and infrequently detected in asymptomatic adult pink salmon.

- *Aquareovirus*—Infrequently occurs in Chinook salmon adults (species B) and geoduck clams (species A).
- *Aquaparamyxovirus*—Pacific salmon paramyxovirus (PsaPV)—Infrequent in adult wild or returning Chinook salmon.
- Piscine orthoreovirus (PRV1a)—Infrequently detected in a few healthy Alaska adult Pacific salmon stocks by molecular methods.
- Erythrocytic Inclusion Body Syndrome Virus (EIBS)—Only one case in Alaska net pen-reared juvenile Chinook salmon and likely related to PRV1a in the marine environment.
- Viral Erythrocytic Necrosis (VEN)—Iridovirus common infecting Pacific herring erythrocytes.

7.4.2 Diseases of hatchery origin

Importation of fish for aquaculture is prohibited by Alaska law (5 AAC 41.070), which has greatly reduced the potential for introduction of exotic infectious agents via this route. Consequently, Alaska hatchery stocks originate from native salmonid stocks that are already exposed to or infected with various indigenous pathogens (see list above) that were present before the Alaska hatchery program began in the 1970s (for example, prevalence of Rs and IHNV can approach 90–100% in certain wild fish stocks that have not been exposed to hatchery fish or hatchery practices).

Use of native fish stocks is an important concept that reduces the risk of hatchery fish transmitting new pathogens to wild stocks, but the risk is further reduced by other management strategies, such as requiring the use of broodstocks obtained near the sited hatcheries so that hatchery fish would have similar disease histories. Secondly, hatcheries are generally built away from watersheds having significant wild salmon stocks, which reduces the possibility of disease transmission from adult fish returning to spawn. Spawning coincides with the weakening of the immune system when pathogen shedding/exposure is more likely than from healthy immature fish dispersed in the open ocean. Fish health policies also prevent the release of diseased fish that may require destruction (Meyers 2014) and restrict the transplant or release of fish known to be infected with a pathogen only to areas or watersheds with a similar disease history and occurrence of that pathogen(s).

Alaska hatchery practices release juvenile smolt to forage in the open ocean for one to six years before returning to spawn at their release sites. Also of note, cultured pink and chum salmon are less likely to spread diseases to wild Chinook salmon because these species smolt quickly after emergence and therefore have only limited exposure to stress and potential infectious diseases while at the culture facilities. Avian and mammalian predators as vectors of hatchery diseases while fish are under culture is not a significant threat in Alaska, because nearly all hatcheries have predator exclusion devices to prevent direct access to cultured fish or immediate water supplies. Finally, management criteria and regulations prioritize wild stocks with the marking of hatchery fish for recognition and the continuation of studies examining

hatchery and wild stock interactions to determine whether disease (or genetic) issues have changed or have been introduced.

Despite practices to mitigate disease risk, pathogens still persist in hatchery and wild populations. Below are brief descriptions of pathogens and diseases that are of particular concern in the Gulf of Alaska.

7.4.2.1 Indicator pathogens for hatchery-wild disease interaction

7.4.2.1.1 *Infectious Hematopoietic Necrosis Virus (IHNV)*

IHNV primarily affects wild and cultured sockeye salmon. The Sockeye Salmon Culture Policy (McDaniel et al. 1994) has successfully managed IHNV in Alaska since 1981, allowing the state to become a leader in successful sockeye salmon culture. During these many years, the virus, which infects all sockeye salmon stocks, has not been provided the selective pressure from hatchery culture that would be necessary for it to evolve beyond the single original Up genotype (Black et al. 2016, Páez et al. 2022). Hence, the virus is confined to sockeye salmon as the only carrier fish species in Alaska.

7.4.2.1.2 *Renibacterium salmoninarum (Rs)*

Rs, the agent of BKD, is successfully managed in coho and Chinook salmon stocks (Meyers et al. 2003) by statewide monitoring of broodstock using the enzyme-linked immunosorbent assay or ELISA (8,800 kidney tissues examined during 2023 and 9,162 in 2022) and subsequent culling of infected eggs.

Research study results on these two indicator pathogens - IHNV and Rs - include Meyers (2005) and Emmenegger et al. (2000). Overall, the cyclical peaks and declines of these two pathogens do not show significant changes in prevalence (or homogeneity of IHNV) in wild fish stocks that can be attributed to hatchery practices and/or wild fish interactions with hatchery fish stocks.

7.4.3 Other diseases of concern

7.4.3.1 Furunculosis

Furunculosis is caused by a bacterial obligate pathogen (*A. salmonicida*) present in carrier fish but is not transmitted vertically in the egg. This is one of the most encountered bacterial diseases in cultured salmonids and many other non-salmonid species of fish in both marine and freshwater reported in North America, Europe, Asia and Africa. Therefore, this bacterial organism is ubiquitous in other host species in both fresh and saltwater environments encountered by GOA Chinook salmon, so healthy hatchery-released salmonids are unlikely to be a significant source of potential exposure. The bacterial organism is controlled in Alaska hatcheries by disinfecting eggs, reducing or eliminating native fish species in the hatchery water supplies, and recognizing the disease early for culling of dead and moribund fish followed by veterinary-prescribed antibiotic therapy before major epizootic outbreaks occur. Over the last 24 years, there have been approximately reported 45 cases of furunculosis in juvenile hatchery

fish in Alaska. These fish were only released into watersheds having the same pathogen history and only after the disease was effectively treated.

7.4.3.2 Bacterial gill disease

Bacterial gill disease is a nonspecific description for bacterial infection of the gills by various opportunistic bacteria but primarily includes various flavobacteria that commonly occur in the environment and infect fish when water quality is poor and/or fish are stressed. Occasionally the infection can become systemic as in Coldwater Disease caused by *F. psychrophilum*, which requires antibiotic therapy. When detected early, external treatments with various approved drugs such as formalin, chloramine-T, or hydrogen peroxide will generally resolve the infection. All salmonids are susceptible, but juveniles more so than adults, and the disease is found worldwide. Again, healthy juvenile salmonids released from Alaska hatcheries are not a significant source of exposure to this disease for stocks of GOA Chinook salmon.

7.4.3.3 Piscine orthoreovirus (PRV)

PRV, the causative agent of heart and skeletal muscle inflammation (HSMI), has various strains that differ significantly in infectivity and pathogenicity for salmonids. The strain endemic in several wild and hatchery stocks of Pacific salmon, PRV1a, is hypothesized to be a less virulent sub-genotype that is not associated with clinical HSMI (Kibenge et al. 2013, Purcell et al. 2018).

The scientific information continues to support the conclusion that endemic PRV-1a in the PNW should be considered low risk (not zero) to Pacific salmon, thus requiring no significant changes to agency fish health policies (Meyers and Hickey 2022). However, evaluation of the risk for PRV1a is ongoing by fish health professionals. Studies in British Columbia have shown that freshwater hatcheries provide a minimal contribution to the prevalence and persistence of PRV1a in wild Pacific salmon and are not sources for non-endemic forms of the virus (Polinski et al. 2023). These data confirm that seawater reservoirs are the primary source for PRV1a persistence in that region, and likely in Alaska as well. Consequently, released hatchery juvenile salmonids should be of negligible risk as a source of infection by PRV1a to GOA Chinook salmon stocks.

7.4.3.4 *Ichthyophonus hoferi*

Ichthyophonus hoferi (also called “ich” or “white spot disease”) is a protozoan parasite of marine and anadromous fishes, including salmon, that primarily infects cardiac muscles but also spreads throughout the body of a host, reducing swimming performance and stamina of the host, and sometimes leading to pre-spawning mortality (Hamazaki et al. 2013).

Ichthyophonus does not seem to be a threat to GOA Chinook stocks because it has rarely been detected in the Gulf of Alaska. This is likely because its prevalence in forage species is low. Should it become more present in the future, its effect will likely be mitigated by the short in river migrations of most GOA stocks.

7.4.4 Surveillance for emerging and exotic infectious agents

Active surveillance for emerging and exotic pathogens in cooperation with the USDA and USGS indicate that exotic pathogens such as infectious salmon anemia virus (ISAV), salmonid alphavirus (SAV) and piscine myocarditis virus (PMCV) do not occur in the Pacific Northwest or Alaska (Gustafson et al. 2018). As previously indicated, piscine orthoreovirus (PRV1a) was discovered as endemic in Alaska and the PNW and has been shown to be relatively benign to Pacific salmon (Purcell et al. 2020). The PRV public controversy effectively illustrates an important caveat regarding fish health evaluation; the detection of an infectious agent, especially by molecular methods, does not indicate that it is causing disease (Meyers and Hickey 2022). We should not be surprised that some infectious agents like PRV1a may have very little negative impact while still infecting certain host species.

7.4.5 ADF&G Fish/Shellfish Health Program

The statewide ADF&G Fish/Shellfish Health Program (SFSHP) has been in place for more than 40 years and was legislated to manage and protect wild stocks from infectious disease agents that might also occur in cultured stocks of fish and shellfish. The mission and objectives of the SFSHP are to provide pathology expertise and diagnostic services to fisheries managers, state and private non-profit salmon hatcheries, aquatic farmers, and sport fishers to protect the health of wild and cultured fish and shellfish resources. This includes regulatory oversight of finfish/shellfish pathogens, development of disease policies, and application of technical expertise to prevent, detect, and manage diseases in cultured/wild fish and shellfish in Alaska. The SFSHP is administered by fish health specialists certified by the Fish Health Section of the American Fisheries Society as required by state regulations (AS 16.05.733). The SFSHP provides the following products and services:

- Diagnostic Services- wild and cultured fish/shellfish
- Hatchery Support and Oversight
- Regulatory Authority
- Statewide Fish and Shellfish Disease Policy
- Applied Research - Publications
- Public Education
- Continuing surveillance for existing, emerging and exotic disease agents

7.4.6 Disease summary

In summary, the State of Alaska has a robust fish health monitoring program and strict protocols to minimize transmission of diseases between hatchery and wild fish, including Chinook salmon. No indigenous or emerging exotic diseases have been identified as major threats to Chinook salmon in the Gulf of Alaska.

7.5 Predation

Salmon are an integral part of the food web, and predation on salmon naturally occurs at all salmon life stages in both freshwater and marine environments. Predation occurs from a variety of native piscine, avian, and mammalian species, as well as some introduced species such as northern pike (*Esox lucius*).

7.5.1 Freshwater predation

Predation in freshwater and estuarine environments affects Chinook salmon at the early life history stages (egg, alevin, fry, juvenile, and smolt) and as adults returning to freshwater to spawn.

7.5.1.1 Eggs and juveniles

Predation on Chinook salmon from egg deposition through early juvenile stages is a significant factor shaping their early life history, and they face numerous predators in both freshwater and estuarine environments. Predatory fish such as rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarkii*), and Dolly Varden (*Salvelinus malma*) will feed on both eggs and juvenile Chinook (Healey 1991, Schoen et al. 2022), while coast range sculpin (*Cottus aleuticus*), slimy sculpin (*C. cognatus*), and prickly sculpin (*C. asper*) are predominantly egg predators, but will consume juvenile salmonids once they reach a critical size (Hunter 1959, Tabor et al. 2007, Swain et al. 2014). Beamish et al. (1992) documented predation of hatchery-reared Chinook and coho salmon in an estuary by spiny dogfish, *Squalus suckleyi*. Beamish and Neville (1995) estimated that river lamprey (*Lampetra ayresii*) consume millions of juvenile Chinook salmon in the Fraser River plume annually. Northern pike (*Esox lucius*) are invasive to Southcentral Alaska and feed on juvenile Chinook in northern Cook Inlet (Sepulveda et al. 2013); Northern pike are discussed in more detail below. Birds, including gulls (e.g., *Larus* spp.), cormorants (e.g., *Nannopterum auritum* and *Urile pelagicus*), mergansers (*Mergus* spp.), belted kingfisher (*Megaceryle alcyon*), American dipper (*Cinclus mexicanus*), and others are also significant predators of Chinook eggs and/or juveniles in both freshwater and estuarine habitats (Wood 1986, Collis et al. 2002, Tonra et al. 2016, Sherker et al. 2021). These avian predators often target juvenile salmon during their downstream migration or in shallow estuarine areas where the fish are more exposed. Piscivorous mammals such as American mink (*Neogale vison*) and North American river otter (*Lontra canadensis*) also consume juvenile Chinook. Predation risk in the freshwater environment can be influenced by environmental factors such as water clarity and flow conditions. Similarly, complex estuarine habitats with abundant vegetation and submerged structures can provide refuge from bird predation.

7.5.1.2 Invasive northern pike

Northern pike (*Esox lucius*) are an apex predator and a native species in Interior and Western Alaska. However, they have become a highly invasive species in Southcentral Alaska, particularly in the Upper Cook Inlet region. Originally introduced in the 1950s, and again later in

the 1970s, northern pike have since spread across much of the region and altered aquatic ecosystems by preying on juvenile Chinook salmon and other native fish species (Rutz 1996). Northern pike are now widespread in the Cook Inlet area and have been detected in numerous anadromous water bodies. Pike have also been documented migrating through estuarine environments with moderate salinity, increasing the risk of range expansion beyond current known habitats (Wooller et al. 2024). Pike are now present in more than 120 lake and river systems in Southcentral Alaska; including Anchorage area systems, Susitna River drainage, Knik Arm, northern Kenai Peninsula, and West Cook Inlet drainages (Rutz 1996, Dunker et al. 2020, Wooller et al. 2024).

The presence of northern pike in salmon habitats has impacted salmon populations in Southcentral Alaska. In their native range, salmonids and pike often do not significantly overlap in habitat use or seasonality, allowing for coexistence. However, in the invaded regions, pike have both spatial and temporal overlap with juvenile salmon, leading to intense predation pressure. Studies have demonstrated that northern pike preferentially target salmonids, and when salmon numbers decrease, they shift their diet toward other native fish species (Haught and von Hippel 2011). Studies in the Deshka River found Pacific salmon as the dominant prey in pike stomachs, with juvenile Chinook comprising the majority of the diet in May and June (Sepulveda et al. 2013).

With respect to Chinook salmon in the northern Cook Inlet, the most severely affected area includes Alexander Lake and Alexander Creek, a tributary of the Susitna River that was once highly productive for Chinook salmon (Rutz et al. 2020, Bradley et al. 2022). Today, northern pike are widespread throughout the system, which is shallow and densely vegetated with numerous sloughs and oxbows, making it ideal northern pike habitat. Northern pike have been present in Alexander Lake since the 1960s, but they did not establish in the lower reach of Alexander Creek until the late 1990s (Rutz 1996). The lower reach of Alexander Creek, below the confluence with Sucker Creek, is historically where the majority of Chinook salmon production occurred. Soon after northern pike became prevalent in the lower reach, Chinook salmon abundance decreased to less than 185 returning adults, which is well below the sustainable escapement goal of 2,100–6,000 fish. To date, Chinook salmon abundance has remained far below the escapement goal (Rutz 1996, Rutz et al. 2020, Bradley et al. 2022, Oslund and Querin 2024)

Although declining Chinook salmon abundance has been prevalent throughout Cook Inlet, the driving factor in Alexander Creek is predation by northern pike on juvenile Chinook salmon. From the 1970s until the late 1990s when northern pike became established in Alexander Creek, Chinook salmon abundance for this system tracked closely with the Talachulitna River, a proximate drainage where northern pike do not occur. Within a few years of northern pike establishment in lower Alexander Creek, abundance patterns between the two systems shifted, with Alexander Creek Chinook abundances becoming substantially lower than in the Talachulitna River. ADF&G attributes a reduction in Chinook salmon production in Alexander

Creek due to northern pike predation on juvenile salmon (Oslund and Querin 2024). Currently, Chinook salmon fisheries in Alexander Creek are closed to harvest, and Alexander Creek Chinook salmon are an Alaska Board of Fisheries designated Stock of Management Concern (Oslund and Querin 2024).

Declines of Chinook in the Deshka River, another Cook Inlet system, are being attributed in part to the presence of northern pike (Oslund and Querin 2024). Unlike Alexander Creek, the Deshka River is a much larger drainage with a greater mix of freshwater habitat and many small tributaries supporting salmon. It is thought that waters like this offer potential refugia from northern pike predation and experience ecosystem-level impacts from invasive northern pike more slowly (Dunker et al. 2018). Although some northern pike habitat exists in the Deshka drainage, it is not as extensive as that found throughout Alexander Creek. Over time, however, northern pike have now come to occupy almost all of the Deshka drainage, including most of the lakes within the drainage that historically supported salmon rearing. It is unknown when northern pike first appeared in the Deshka drainage, but they likely arrived in the late 1970s or 1980s. Because of the diversity of habitat with more refugia, impacts to Chinook salmon in the Deshka have been slower to occur than in Alexander Creek. However, because northern pike have now spread throughout the system, declines in Chinook salmon abundance are being observed (Oslund and Querin 2024).

Given the impact of northern pike on native fish populations, partners of the Alaska Invasive Species Partnership have implemented multiple strategies for pike eradication and suppression, particularly in high-impact areas such as the Kenai Peninsula, Anchorage, and Mat-Su Valley (Dunker et al. 2022). The use of rotenone treatments has increased, and in conjunction with fish salvage programs, native salmonids are being reintroduced into lakes where pike populations have been eradicated. Improved gillnetting strategies, with year-round monitoring efforts, have led to significant reductions in pike densities in targeted lakes. Experimental exclusion barriers are being installed in critical migration corridors to prevent pike from entering high-priority salmon habitats. Long-term monitoring and mitigation efforts are planned to ensure that restored salmon populations remain stable and viable in previously impacted watersheds.

7.5.1.3 Spawning adults

While juvenile Chinook salmon face predation primarily from fishes and birds, adult Chinook encounter a different set of predators as they return to freshwater systems to spawn. Once Chinook salmon enter rivers and streams for their spawning migrations, they become targets for larger predators such as bears, canids (wolves, coyotes, and foxes), weasels, large cats, and marine mammals. In Alaska, brown bears (*Ursus arctos*) and black bears (*U. americanus*) are among the most prominent predators of adult Chinook salmon. Bears actively hunt salmon during the spawning season, taking advantage of the dense aggregations of fish in rivers and streams (Jacoby et al. 1999). While bears primarily consume the most energy-rich parts of the

salmon, such as the skin, eggs, and brain, they often leave the rest of the carcass behind. This feeding behavior has significant ecological implications, as the leftover carcasses contribute marine-derived nutrients to the surrounding ecosystem, providing food for scavengers (e.g., eagles, gulls, smaller mammals) and supporting nutrient cycling (Reimchen 2000, Lincoln and Quinn 2018). Predation on adult Chinook salmon by aquatic mammals such as river otters, harbor seals (*Phoca vitulina*), and Steller sea lions (*Eumetopias jubatus*) also occur, particularly in estuarine and nearshore environments (Chasco et al. 2017a). These mammals may target adult salmon as they return to freshwater to spawn or during their staging period in estuaries before migration upriver. While the overall impact of mammalian predation on adult Chinook salmon is less well-studied than avian and fish predation on juveniles, it remains an important part of the complex predator-prey dynamics that shape salmon populations. Marine mammal predation is described further below.

7.5.2 Marine predation

While at sea, Chinook salmon have three distinct life stages—juvenile, immature, and maturing—that each have the potential to interact with different predators. Below we describe vulnerability to marine predation by life stage, then we discuss groups of marine predators of Chinook salmon.

The juvenile life stage (the first year at sea) is generally identified as a critical bottleneck for salmon survival (Beamish and Mahnken 2001). During their first summer at sea, juveniles of most salmon species tend to be concentrated nearshore before their offshore dispersal. Predation-based mortality immediately following ocean entry is hypothesized to be size-dependent, with smaller-sized salmon being more susceptible to predation events (critical size–critical period hypothesis; Beamish and Mahnken 2001). Because Alaska Chinook salmon have predominantly a stream-type life history (fry rear for one or more years in freshwater before ocean entry), they are generally larger than most juveniles of other species of salmon at marine entry, which is believed to provide some protection from predation, particularly for gape-limited predators like fishes. Likewise, the densities of juvenile Chinook salmon are much lower than for other species of salmon with different life history strategies, such as pink and chum salmon. It is speculated that outmigration of Chinook salmon at the same time as these high-density salmon species may allow for a predator-swamping effect, which could buffer juvenile Chinook salmon from predatory impacts (Riddell et al. 2018).

During the immature stage, most GOA Chinook salmon spend the next few years of their life distributed across the GOA and even into the Bering Sea, though a small proportion of Southeast Alaska Chinook remain coastal in inside waters (Larson et al. 2013, Heintz et al. 2017). During this time, Chinook salmon are exposed to numerous predators, though data are limited on predation rates and risk during this time. At this life stage, the most likely predators are teleost fishes (longnose lancetfish, daggertooth, and Pacific lamprey); sharks (salmon shark, spiny dogfish); and marine mammals including pinnipeds and cetaceans (Weitkamp and Garcia 2022).

As Chinook salmon mature and re-enter coastal waters prior to river entry, their density becomes more concentrated compared to the immature life stage in the open ocean. At this life stage, hypothesized impacts of predators are largely focused on the potential for size-selective predation to contribute to reduced size at maturity rather than direct impacts to population abundance (e.g., Ohlberger et al. 2018).

A recent analysis suggests that predation during the immature and maturing life stages could contribute to a decline in Yukon River Chinook salmon age at maturity (Manishin et al. 2021). While this modeling approach demonstrates that it is theoretically possible that predators like salmon sharks and killer whales could reduce the age at maturity for a Chinook salmon population, there is no direct evidence to validate the assertion. In addition, the analysis did not include any populations from the Gulf of Alaska. Further, the authors also state that, "it is implausible that all observed changes in Chinook salmon demographics are attributable to one agent of selection such as predation."

Regardless of the life stage affected, hypotheses implicating size-selective predation as contributing to reduced size/age at maturity of Chinook salmon fail to acknowledge documented concurrent declines in size-at-age for other, smaller salmon species and a variety of marine teleost species in northern oceans (Morita and Fukuwaka 2007, Beamish 2008, Baudron et al. 2014). Rather than concluding these broadly observed demographic changes are due to size-selective predation, a more parsimonious explanation for this widespread phenomenon is changing environmental conditions that broadly impact diverse taxa of ectotherms.

Predation is a known natural cause of mortality for any salmon in marine waters; however, there is no direct evidence that predatory impacts are outside of normal ecosystem dynamics and imperiling the long-term existence of GOA Chinook salmon populations. Unfortunately, direct measurements of predator-prey interactions at sea are practically impossible, and quantifying predator-prey interactions through modeling will always have some uncertainty and depend on the validity of assumptions.

There is currently no quantified measure of marine predation on Chinook salmon, so it is not possible to compare the relative effect of predation (in all its forms) to the known effect of harvest. It may be possible to develop models using available data (e.g., satellite tagging of Chinook; Courtney et al. 2021) and well-considered assumptions to better understand the interactions between Chinook and their marine predators (e.g., Sobocinski et al. 2021). Ohlberger et al. (2019) attempted this kind of modeling effort to explore the potential for size-selective predation by resident killer whales on Chinook salmon age and size at maturity. However, caution is warranted when interpreting such models, given the large uncertainties (e.g., lack of data and untested assumptions) on marine predator abundance and marine predation of GOA Chinook salmon.

7.5.2.1 Marine fish

A variety of marine fishes are known to consume Chinook salmon including: sculpins (*Cottoidea*), cod (*Gadidae*), Pacific hake (*Merluccius productus*), mackerel (*Scombridae*), and lamprey (*Petromyzontidae*). Likely predators of Chinook salmon on the high seas include fishes such as longnose lancetfish (*Alepisaurus ferox*), daggertooth (*Anotopterus nikparini*), and Pacific lamprey (*Entosphenus tridentatus*); and sharks such as salmon shark (*Lamna ditropis*), and spiny dogfish (*Squalus suckleyi*).

Historically, Chinook salmon were rarely identified in salmon shark stomachs (Sano 1960b, Sano 1962). Recently, however, immature Chinook salmon carrying satellite transmitters were depredated by salmon sharks along the Aleutian Islands and southern Bering Sea shelf (Seitz et al. 2019). Seitz et al. (2019) noted that salmon shark predation may be a substantial source of oceanic mortality of immature and maturing Chinook salmon in the Gulf of Alaska. They also speculated that management of sharks under the Magnuson-Stevens Act has likely contributed to increases in abundance of salmon sharks in the North Pacific Ocean. Based on the results of their study, Seitz et al. (2019) speculated that Pacific halibut (*Hippoglossus stenolepis*) and Pacific sleeper sharks (*Somniosus pacificus*) may also be predators of Chinook salmon. Subsequent studies support their hypothesis that salmon sharks, sleeper sharks, and halibut are predators of adult Chinook salmon. In an unpublished study of 190 tagged adult Chinook salmon, of the 106 tags for which survival data were recovered, 42 were eaten by salmon sharks and 10 by other fish, indicating that in some areas, predation by sharks and other large fish species may be an important source of mortality (Seitz et al. 2025). Information on salmon shark abundance would help determine if predation of Pacific salmon by salmon sharks has increased; such abundance estimates are currently not available for the North Pacific Ocean³⁷ (Sano 1960a, Sano 1962, Seitz et al. 2019). It should be noted that there is the potential for tag effects to make a tagged salmon more detectable by predators and/or impair escape behaviors in tagged salmon; therefore, these estimates may not be indicative of non-tagged Chinook salmon mortalities.

7.5.2.2 Marine mammals

Congress passed the Marine Mammal Protection Act (MMPA) in 1972 in response to increasing concerns among scientists and the public that significant declines in some species of marine mammals were caused by human activities. The Act's protections have stopped the decline of many marine mammal populations and have led to the recovery of several in the Northeast Pacific Ocean, such as populations of harbor seals, Steller sea lions, resident killer whales, and humpback whales.

Common marine mammal predators of salmonids in the Northeast Pacific Ocean are harbor seals (*Phoca vitulina richardii*), fish-eating killer whales (*Orcinus orca*), Steller sea lions

³⁷ IUCN Red List. Salmon shark, *Lamna ditropis*. Available at <https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39342A124402990.en>. Accessed April 10, 2025.

(*Eumetopias jubatus*), and northern fur seals (*Callorhinus ursinus*). Recent research suggests that predation pressure on salmon and steelhead from seals, sea lions, and killer whales has been increasing in the Northeast Pacific Ocean over the past few decades (Chasco et al. 2017b) as these populations recover from historical declines.

7.5.2.2.1 Killer whales

Killer whales are classified as top predators in the food chain and are the world's most widely distributed marine mammal. There are approximately 921 killer whales of the resident sub-species (*Orcinus orca ater*) in the Gulf of Alaska (Young et al. 2023). These killer whales consume many species of fish and at least one species of squid (Ford et al. 1998, Ford et al. 2000, Ford and Ellis 2006, Ford et al. 2016, Hanson et al. 2021), but salmon are their primary prey. Three populations of resident killer whales occur in Alaska waters: Southern Residents; Northern Residents; and Alaska Residents. Chinook salmon may therefore be prey to multiple geographically distant killer whale populations.

The diet of killer whales is the subject of ongoing research, including direct observation of feeding, scale and tissue sampling of prey remains, and fecal sampling. The diet data suggest that they are consuming mostly larger (i.e., generally age-3 and up) Chinook salmon (Ford and Ellis 2006). Scale and tissue sampling from May to September in inland waters of Washington and British Columbia, Canada, indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90%; Hanson et al. 2010, Ford et al. 2016). Ford et al. (2016) confirmed the importance of Chinook salmon to resident killer whales in the summer months using DNA sequencing from whale feces.

While there is a lack of published research regarding killer whale depredation on Chinook troll fisheries, some anecdotal evidence exists, as well as accounts from recreational and charter fishermen.

7.5.2.2.2 Beluga whales

Beluga whales (*Delphinapterus leucas*) are opportunistic predators with a diet that varies regionally and seasonally across Alaska. In Bristol Bay, historical analyses of beluga stomach contents revealed regular predation on both juvenile and adult salmon, including Chinook, particularly during periods of low salmon returns (Brooks 1954, Brooks 1955). In Cook Inlet, subsistence harvest data indicate that salmon, including Chinook, are common prey (Quakenbush 2015). Evidence from satellite telemetry and dive data suggests that belugas in Cook Inlet frequently occupy nearshore river mouths during salmon runs, with movement patterns consistent with foraging on salmon (Citta 2016). Traditional knowledge from Indigenous communities also supports the idea that belugas consume Chinook salmon in the Cook Inlet region (Huntington 2000). Although direct observations of Chinook predation are rare, anecdotal reports and traditional knowledge accounts suggest such interactions occur.

In Yakutat Bay, acoustic monitoring confirms year-round presence of a small, isolated beluga population with increased foraging activity during salmon runs (Castellote 2015). While Chinook

were not directly studied in that analysis, the overlap in seasonal presence and the similarity in migratory behavior suggest that Chinook may also be vulnerable to beluga predation in this region. Given the beluga whales' documented preference for salmonids when available, and their restricted home range within proximity to salmon spawning habitats, it is reasonable to infer potential consumption of Chinook in Yakutat Bay.

7.5.2.2.3 Pinnipeds

Pinnipeds are marine mammals in Order Pinnipedia, that includes seals, fur seals, and sea lions. These marine mammals are known to consume salmon and overlap in habitat-use and range with Chinook salmon (Courtney et al. 2021, Langan et al. 2024) (Pitcher 1980, Pitcher 1981, Sinclair et al. 2013, Tollit et al. 2015, Trzcinski et al. 2024). Northern fur seals (*Callorhinus ursinus*) breed in the Bering Sea among the Pribilof and Bogoslof Islands, where salmon are part of adult female diets during the summer pup-rearing season in the Bering Sea (Zeppelin and Ream 2006, Sinclair et al. 2008, Kuhn et al. 2022). The fur seal population largely winters in the North Pacific Ocean, potentially overlapping with Gulf of Alaska Chinook salmon (Ream et al. 2005, Deeg et al. 2023).

Populations of Steller sea lions, harbor seals, and northern fur seals in Alaska underwent major declines throughout the 1970s–2000s, though with regional and temporal differences in trends among populations and species, with some populations continuing to decline. This history largely contrasts with pinniped populations of the Pacific Northwest (Washington, Oregon, and California) that have sustained recent increasing trends. Marine mammals are managed under the MMPA, and the ESA if they are listed as threatened or endangered. Steller sea lions are separated at 144°W longitude into the western (includes the Aleutian Islands and Gulf of Alaska) and eastern (Southeast Alaska, British Columbia, Washington, Oregon, and California) distinct population segments (Young et al. 2024). Steller sea lion populations in Alaska underwent major declines throughout the 1970s–2000s, resulting in listing under the ESA in 1990.³⁸ More recently, the western DPS increased overall between 2008 and 2023 (at ~1% per year for non-pups), though declines continue in the western-central Aleutian Islands (Sweeney et al. 2023). In contrast, the eastern DPS population in Southeast Alaska increased at just over 4% per year during 1987–2017. There are 12 recognized stocks of harbor seals in Alaska, and population trends are strongly regional and localized (Young et al. 2024). While some harbor seal stocks have been stable, many areas that have had long-term declines have not recovered. Northern fur seals of the Eastern Pacific Stock (designated as depleted under the MMPA, but not ESA-listed) in Alaska have sustained continuing population declines since the 1970s (Young et al. 2024).

³⁸ Steller sea lions were originally listed under the ESA as threatened in 1990 (55 FR49204). In 1997, they were divided into two DPSs – eastern and western – with the eastern DPS remaining threatened and the western DPS being elevated to endangered (62 FR 24345). In 2013, the eastern DPS was delisted (78 FR 66140). The western DPS remains listed as endangered.

Pinniped diets are traditionally estimated based on the identification of prey remains found in scats dropped on haulouts, or historically in digestive tracts of directly-collected animals at-sea or on land. Depending upon their uniqueness and wear, prey hard parts from scats (otoliths, bones) can be identified to family, genus, or species, a size estimated, and a minimum number present in the scat sample counted. A simple and commonly-reported index is the percent frequency of occurrence (FO), which is simply an indication of the presence of a prey species in a scat relative to all the scats collected in the study; it is not a measure of the quantity of prey consumed (Laake et al. 2002). A variety of indices are employed to provide quantitative estimates of biomass reconstruction in diets (Bowen and Iverson 2013), including analysis of prey signatures in blubber fatty acids (Iverson et al. 1997), stable isotope ratios in whiskers (Doll et al. 2018), and DNA analyses of scat soft parts (Tollit et al. 2015). Because there are broad ranges of individual behaviors, foraging areas, and prey species biology, pinniped diets can vary greatly by individual, gender, age, season, region, and among years (Iverson et al. 1997, Trites and Calkins 2008, Sigler et al. 2009, Sinclair et al. 2013, Schwarz et al. 2018, Smith et al. 2019, Voelker et al. 2020, Bishop et al. 2024), leading to challenges for estimating diet and prey consumption (Bowen and Iverson 2013). Pinnipeds are considered to be opportunistic predators, taking advantage of spatially and temporally abundant prey (Womble et al. 2005, Sigler et al. 2009, Sinclair et al. 2013, Trzcinski et al. 2024). The occurrence and relative importance of salmon species detected in diets varies with the season and timing of collection, largely reflective of salmon life history patterns.

In Gulf of Alaska waters, Steller sea lions and harbor seals forage in a variety of pelagic, benthic, and nearshore habitats (including fjords, bays, and river entrances), and also target oceanographic features and boundary zones (Fadely et al. 2005, Lander et al. 2009, Womble and Gende 2013, Lander et al. 2020), where locally abundant prey resources can be targeted (Womble et al. 2005, Sigler et al. 2009, Womble et al. 2009). Salmonids are a part of both species' diets in the Gulf of Alaska; however, only two studies have identified Chinook salmon specifically as a prey item.

Salmonids occur year-round in the diets of western stock Steller sea lions at 28% FO overall but are slightly more frequent (35%) in summer than winter (16% FO) diets (Sinclair et al. 2013). The occurrence of salmonids in the diet of sea lions in the eastern-central Gulf did not increase significantly between the periods of 1990–1998 and 1999–2009 (Sinclair et al. 2013). There is considerable regional and temporal variation in salmon consumption. In the eastern Gulf of Alaska, salmon appeared to be an important part of maternal diets in the late winter and early spring based on whisker samples collected during 1998–2011 (Scherer et al. 2015), but they were a minor component of diets during winter months in the Resurrection Bay during and after the 2014–2016 marine heatwave event (Maniscalco 2023). Salmonids were among most the important prey species detected in scat at northern Kodiak Island area sites with increased importance during summer and fall seasons (McKenzie and Wynne 2008). However, further west in the Aleutian Islands salmon were not a dominant prey item during March–April (9th ranked prey type consumed at about 3% of the diet). Based on DNA analysis of those scat

samples, Chinook salmon comprised 11% of the salmon species identified that also included sockeye or pink (60%), and chum (24%) salmon (Tollit et al. 2017). In Southeast Alaska salmonids have been identified as a seasonally-dependent key prey species at 12% FO overall (Sigler et al. 2009), with occurrence in scats differing between female sea lions (28% FO) and males (3% FO; Trites and Calkins 2008).

Similarly, salmonids are important components of harbor seal diets around the Gulf of Alaska (Pitcher 1980, Herreman et al. 2009, Geiger et al. 2013, Smith et al. 2019). In British Columbia waters, harbor seal consumption of salmon varies by season and region, with the overall mean presence of salmon in their diet of about 4.5% chum salmon and 1.2% Chinook salmon (Trzcinski et al. 2024). Harbor seals living year-round in Lake Iliamna, Alaska, largely depend upon sockeye salmon and some non-salmonid species during summer months, but Chinook salmon were not detected in their diet, despite being available in that system (Hauser et al. 2008).

Northern fur seals depart Bering Sea breeding rookeries in the fall and undertake large migrations to pelagic habitats while remaining at-sea for at least 7 months; males occupy the Bering Sea and northern North Pacific Ocean while females tend to occupy the Gulf of Alaska and California Current region off the B.C. and western U.S. coasts (Ream et al. 2005, Sterling et al. 2014). Because migrating fur seals occupy pelagic habitats without hauling-out, estimation of diet through scat analysis is not possible and is based on historic at-sea collections and inference from dive behavior. Ream et al. (2005) summarized diet habits data from pelagic seal collections made during 1958–1974 in the North Pacific Ocean, and salmon (of unspecified species) were found in female seals collected near British Columbia, but not the Gulf of Alaska or the Pacific Northwest. However, diving behavior of adult female seals in the California Current was consistent with foraging on prey assemblages that included salmonids (Sterling et al. 2014).

Predator impacts on salmonids have been explored on broader ecosystem scales by studies using meta-analytical methods combining findings from previously-published diet studies. In a meta-analysis combining diet studies of killer whales and pinnipeds spanning the Pacific Northwest through the Aleutian Islands covering 1915–2015, Adams et al. (2016) found that while killer whales consumed the most Chinook salmon, there was a trend for increased reporting over time of Chinook salmon in Steller sea lion and harbor seal diets (though overall at less than 2% FO), suggesting an increase in frequency of occurrence in their diet, better detection and reporting of Chinook salmon as a prey item, or both (Adams et al. 2016). Another study that incorporated bioenergetic models found Chinook salmon consumption by pinnipeds increased between 1975 and 2015, with consumption in the Pacific Northwest being higher than consumption in the Gulf of Alaska (including the Southeast Gulf of Alaska) (Chasco et al. 2017b). Importantly, the study also concluded that estimated consumption of Chinook by pinnipeds was less than the number of Chinook removed by fisheries harvests (Chasco et al. 2017b). The ability of pinnipeds to switch diets seasonally, annually, and regionally in response

to changes in prey abundance due to life-history characteristics or changes in the ecosystem (Tollit et al. 2015, Feddern et al. 2022, McHuron et al. 2024) create a challenge for estimating potential impacts of pinniped foraging on any prey species, including Chinook salmon (Trzcinski et al. 2024).

7.5.2.2.4 Humpback whales

Humpback whales feed primarily on euphausiids (krill) and small schooling fish (Clapham and Mead 1999), and exhibit localized differences in diet, with some individuals being more piscivorous than others (Kosma 2019). Wild Chinook salmon are known for agonistic (aggressive) behavior and diffuse distributions (not forming schools). As a result, they are not typically conducive as prey to the foraging style of humpback whales. However, staff at several hatcheries in Southeast Alaska observed a few humpback whales targeting large releases of juvenile Chinook, coho, and chum salmon between 1999 and 2018 (Chenoweth et al. 2017). Chenoweth et al. (2017) determined that hatchery release practices such as daytime mass releases were creating foraging opportunities for these whales that do not exist with wild Chinook. A later study concluded that, despite these observed foraging events of large numbers of juvenile salmon, there was no significant effect of humpback whale predation on Chinook salmon survival rates, which tended to have low survival rates even in years with no depredation, possibly due to compensatory depredation from other sources (Chenoweth and Criddle 2019). Modified release practices may reduce humpback whale depredation, but increase predation by other species (Chenoweth and Criddle 2019). There is no evidence that humpback whales are increasing their consumption of wild Chinook salmon.

7.6 Inadequacy of existing regulatory mechanisms to address identified threats

A variety of Federal, State, Tribal, and local laws, regulations, treaties, and measures affect the abundance and survival of GOA Chinook salmon and the quality of their habitat. Below, we summarize the current management plans/strategies for federal, state, borough, and municipal agencies, tribes, and international regulations. This represents the current threats posed from inadequate regulation as of January 2025.

7.6.1 Federal land and water management

7.6.1.1 U.S. Forest Service (USFS)

The scope of the status review encompasses two National Forests in Alaska: Tongass National Forest (Southeast Alaska) and Chugach National Forest (Southcentral Alaska). Together, these two National Forests encompass 22.4 million acres. Management plans of both National Forests describe the fish and fish habitat management objectives, as well as the regulatory mechanisms to protect them.

The Chugach National Forest operates under the 2020 Land Management Plan (USDA 2020). The Watershed and Aquatic Ecosystems section (FW-GL3-WAE-DC) of the management plan

outlines the desired conditions for watersheds and aquatic ecosystems within the Chugach National Forest. These desired conditions include, but are not limited to, retention of undisturbed riparian habitat, unimpeded hydrologic connectivity, maintenance of natural stream morphology, and watershed services maintaining healthy populations of native fish and other aquatic organisms. The objectives section (FW-GL3-WAE-OBJ) describes USFS goals to restore and remediate impacted watersheds, improve fish passage, and establish water reservations. These desired conditions and objectives would benefit native salmonids, including Chinook salmon (USDA 2020).

The Tongass National Forest Land and Resource Management Plan (USDA 2016) is the current forest management plan being utilized for the Tongass National Forest. Chapter 4, Pages 4-9 through 4-13, describes the standards and guidelines by which fish species and their habitats will be maintained within the forest. Priorities include fish habitat inventory and mapping, fish habitat restoration, and maintenance or restoration of conditions necessary for healthy fish populations and watersheds. Some of the priorities for Management Affecting Fish Habitat (page 4-13) include establishing baseline conditions for future restoration efforts, and maintaining stream banks and channel processes, large woody debris (LWD), fish passage at road-stream crossings, and monitoring.

7.6.1.2 U.S. Fish and Wildlife Service (USFWS)

The USFWS maintains five refuges which may contain Chinook habitat within the scope of this status review. They are the Kenai, Alaska Peninsula, Izembek, Kodiak, and Becharof National Wildlife Refuges. Together, they comprise approximately 9 million acres. All of these refuges were established under the National Wildlife Refuge System Administration Act (16 U.S.C. 668dd et seq).

The National Wildlife Refuge System Administration Act “...provides authority, guidelines and directives for the Service to improve the National Wildlife Refuge System; administers a national network of lands and waters for the conservation, management, and restoration of fish, wildlife and plant resources and habitat; ensures the biological integrity, diversity, and environmental health of refuges is maintained; defines compatible wildlife-dependent recreation as appropriate general public use of refuges; establishes hunting, fishing, wildlife observation and photography, and environmental education as priority uses; establish a formal process for determining compatible uses of refuges; and provide for public involvement in developing comprehensive conservation plans for refuges”³⁹.

7.6.1.3 U.S. Army Corps of Engineers (USACE)/ Environmental Protection Agency (EPA)

The Federal Clean Water Act (CWA) of 1973 (33 U.S.C. 1251 et seq.) addresses the development and implementation of water quality standards, the development of Total Maximum Daily

³⁹ USFWS. National Wildlife Refuge System Administration Act. Available at <https://www.fws.gov/law/national-wildlife-refuge-system-administration-act>. Accessed February 2025.

Loads (TMDLs), filling of wetlands, point source permitting, the regulation of storm water, and other provisions related to protection of U.S. waters. Some authority for clean water regulation is enforced by the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE), while some authority is also delegated to individual states.

The USACE regulates the discharge of dredged and fill material into “waters of the United States” (WOTUS), including wetlands, through permitting under the CWA Section 404 Program. The CWA 404 standard is that permitted activities should not “cause or contribute to significant degradation of the WOTUS.” Activities that are regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways, harbors, and airports) and mining projects as well as smaller individual projects such as docks and shoreline stabilization. Section 404 requires a permit before dredged or fill material may be discharged into WOTUS, including anadromous waters (OC and SONCC Status Review Team 2024).

Section 10 of the River and Harbors Act of 1899 requires that a permit be issued by the USACE for the construction of any structure in or over a navigable water, including activities which may affect the course, location or condition of the water body. Activities regulated under Section 10 include dredging, filling of waters, channelization, and bank armoring. The intent of Section 10 is to prevent any activity which may reduce the navigability of a waterway. Large anadromous rivers such as the Susitna and Kenai River, among others, fall under the jurisdiction of Section 10.

Section 103 of the Marine Protection, Research and Sanctuaries Act (33 U.S.C. 1413) requires that the dumping of dredging spoils into the marine environment be permitted by USACE prior to disposal. Subsections (b), (c) and (d) of Section 103 authorize USACE to permit the dumping of dredged material if the dumping will not “...*unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological system, or economic potentialities.*”

7.6.1.4 Bureau of Land Management

The Bureau of Land Management (BLM) manages over 70 million surface acres in Alaska. Only a small portion of these lands falls within the scope of this status review. BLM lands in Alaska are managed according to published Resource Management Plans (RMPs).

The approved Eastern Alaska RMP, which covers lands containing anadromous habitat relevant to this status review, contains fish habitat management goals in Section F. Some goals outlined in Section F are: maintain and protect fish habitat on public lands, provide for the habitat needs of fish resources necessary to maintain or enhance such populations and to ensure the continued public use, economic and subsistence benefits of such resources, and to maintain wild stocks of salmon and steelhead (BLM 2006).

The BLM is participating in the Gravel-to-Gravel Initiative, an interagency effort to invest in the resiliency of Pacific salmon, strengthening co-stewardship of shared resources, and respond to ecosystem threats to food security. To accomplish this, the BLM is focusing their efforts on

expanded habitat assessments and fish inventories, restoration of degraded streams, riverscape restoration, and invasive species management.

7.6.1.5 National Marine Fisheries Service

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) was established in 1976 and serves as the primary law governing federal marine fisheries in the United States. It has undergone a number of amendments since its establishment, most recently in 2006. The MSA establishes regional Fishery Management Councils, which are charged with developing Fishery Management Plans (FMPs) for their respective regions. The council members are selected by the U.S. Secretary of Commerce, and are charged with creating FMPs to restore, preserve, and protect Federally-managed fish stocks.

One of the objectives of the FMPs is to designate Essential Fish Habitat (EFH) and descriptions for federally managed species included in an FMP (16 U.S.C. 1853(a)(7)). The MSA defines EFH as “...*those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.*” 16 U.S.C. 1802(10). For GOA Chinook salmon, EFH is described in Chapter 6 of the *Fishery Management Plan for the Salmon Fisheries in the EEZ off Alaska*, and textual descriptions and maps of EFH for each salmon life stage are contained in Appendix A (NPFMC 2024).

The MSA requires each federal agency, for any action funded, authorized, or undertaken by the agency, to consult with the NMFS if the proposed action may result in adverse effect on EFH (16 U.S.C. 1855(b)). The NMFS has 30 days to provide the federal agency with conservation recommendations to preserve or protect EFH that may be impacted by the project. If a federal agency does not follow the conservation recommendations, they must explain its reasons and include scientific justification. The MSA does not require state agencies to consult regarding EFH. NMFS uses existing coordination procedures or may establish new procedures to identify state actions that may adversely affect EFH, and to determine the most appropriate method for providing EFH conservation recommendations to state agencies.

7.6.1.6 National Park Service

Six national parks encompass approximately 29 million acres within the scope of this status review. They are Kenai Fjords, Denali, Glacier, Wrangell Saint Elias, Lake Clark, and Katmai National Parks. The National Park Service Organic Act of 1916 established the National Park Service, with the stated goal to conserve the “...*scenery and the natural and historic objects and the wildlife therein and to provide for their enjoyment in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*” (54 U.S.C. 100101). Under this guidance, the NPS restricts development on lands under their jurisdiction, effectively maintaining fish habitat on their lands in pristine condition.

7.6.1.7 Federal Energy Regulatory Commission

Hydropower projects that are not owned by a federal entity are regulated by the Federal Energy Regulatory Commission (FERC) via the Federal Power Act (FPA). The FPA establishes a comprehensive regulatory framework, whereby FERC is required to balance energy generation with the allocation of river flow (the alternation or interruption of which can impact fish habitat), upstream and downstream fish passage, water quality, and other potential environmental impacts. While FERC's responsibility under the FPA is to strike an appropriate balance among competing interests, several other statutes affect hydropower regulation and impacts to fish habitat. These include, but are not limited to, NEPA, the Clean Water Act, the ESA, and the Fish and Wildlife Coordination Act. While the FPA requires hydropower project owners to obtain a license from FERC, and FERC to balance power and environmental protection(s), the FPA also authorizes the National Marine Fisheries Service to issue mandatory prescriptions for fish passage (pursuant to FPA section 18) and to recommend other measures (pursuant to FPA sections 10(a) and 10(j)) to protect anadromous salmon and to improve their habitats. For example, NMFS staff set standards for upstream and downstream fish passage and recommend improvements to water quality, spawning gravel, and other important aspects of salmonid habitat.

7.6.2 State land and water management

7.6.2.1 Alaska Department of Fish and Game

7.6.2.1.1 Fish habitat regulations

The Alaska Department of Fish and Game (ADF&G) regulates impacts to anadromous and resident fish habitat through two regulatory mechanisms: the Anadromous Fish Act and the Fishway Act. Together, the two regulatory mandates require that an individual or agency notify and obtain authorization from ADF&G for any activity which could impact or degrade fish habitat. These regulations cover the geographic scope of this status review.

The Anadromous Fish Act (AS 16.05.871-.901) requires prior notification and permit approval from ADF&G before changing or affecting an anadromous waterbody. All activities within or across an anadromous waterbody require approval from the ADF&G Habitat Section, including *"...road crossings, gravel removal, mining, water withdrawals, the use of vehicles or equipment in the waterway, stream realignment or diversion, bank stabilization, and the placement, excavation, deposition, or removal of any material. Permitting requirements apply to individuals, commercial entities, government agencies, and other organizations"*.⁴⁰

The Fishway Act (AS 16.05.841), requires that an individual, government agency, or business notify ADF&G, Habitat Section for activities within or across a waterbody used by fish

⁴⁰ ADF&G. Fish Passage Improvement Program Resources: Laws and Regulations. Available at <https://www.ADF&G.alaska.gov/index.cfm?ADF&G=fishpassage.regulations#:~:text=The%20Anadromous%20Fish%20Act%20requires,or%20bed%22%20of%20a%20specified>. Accessed February 2025.

(anadromous and resident species) and to obtain authorization if the habitat section determines the activity could impede fish passage.

7.6.2.1.2 *Anadromous Waters Catalog*

Alaska Statute 16.05.871(a) requires the ADF&G to identify the waterbodies which support anadromous fish across the state of Alaska. ADF&G has created databases to store this information in two separate formats, the Anadromous Waters Catalog (AWC) and the Anadromous Waters Atlas. The catalog stores numerically all of the streams that have been surveyed and found to contain anadromous fish, while the atlas displays these streams in an online map. Streams must be nominated to anadromous waters catalog, via field survey, before being afforded protections under AS 16.05.871 and AS 16.05.841. The AWC is used by ADF&G and other regulatory agencies as the primary resource for determining whether a freshwater body should be protected under the applicable fish habitat regulations.

7.6.2.1.3 *Aquatic resource regulations*

ADF&G requires an Aquatic Resource Permit (ARP) for any person or entity looking to collect fish, amphibian, shellfish or marine aquatic plants not covered under sport, personal use, aquatic farm, and commercial regulations (5 AAC 41). Permits are only issued to individuals or agencies collecting specimens for uses such as, but not limited to, scientific purposes, invasive species monitoring, or for temporary removal of fish during construction. The permit requires the applicant to record the disposition of captured fish (released unharmed, euthanized for further study, etc.). The ARP also regulates the method and means of capture (fyke net, minnow trap, electrofishing, etc.).⁴¹

7.6.2.1.4 *Special Area regulations*

ADF&G maintains multiple Special Areas with anadromous fish habitat within the geographic scope of the status review. These special areas are split into three categories; Refuges, Critical Habitat Areas, and Sanctuaries. The Special Areas are managed jointly between ADF&G's Habitat Division and the Division of Wildlife Conservation.

Nine state game refuges exist within the scope of this status review: Anchorage Coastal (AS 16.20.031), McNeil River (AS 16.20.041), Goose Bay (AS 16.20.030(c)-(e)), Izembek (AS 16.20.030(a)(14)), Mendenhall wetlands (AS 16.20.034), Palmer Hay Flats (AS 16.20.032), Susitna Flats (AS 16.20.036), Trading Bay (AS 16.20.038), and Yakataga (AS 16.20.033) state game refuges. The game refuge system was established under AS 16.20.010, with the purpose of protecting and preserving the natural habitat and game populations in certain designated areas of the state.

Nine critical habitat areas (CHA) exist within the scope of this status review: Anchor River/Fritz Creek (AS 16.20.605), Chilkat River (AS 16.20.585), Clam Gulch (AS 16.20.595), Copper River

⁴¹ ADF&G. Aquatic Resource Permits. Available at https://www.adfg.alaska.gov/index.cfm?adfg=otherlicense.aquatic_resource. Accessed February 2025.

Delta (AS 16.20.600), Dude Creek (AS 16.20.610), Fox River Flats (AS 16.20.580), Homer Airport (AS 16.20.030), Kachemak Bay (AS 16.20.590), Kalgin Island (AS 16.20.575), Redoubt Bay (AS 16.20.625), Tugidak Island (AS 16.05.615), and Willow Mountain (AS 16.20.620) critical habitat areas. The purpose of CHAs is to *“protect and preserve habitat areas especially crucial to the perpetuation of fish and wildlife, and to restrict all other uses not compatible with that primary purpose.”* (AS 16.20.500).

Two state game sanctuaries exist within the scope of this status review: McNeil River (AS 16.20.160-162), and Stan Price (AS 16.20.150) sanctuaries. Of the Special Use areas identified in statute, the sanctuaries have the most restrictive land use practices and degradation of fish habitat is likely minimal.

7.6.2.2 Alaska Department of Natural Resources (ADNR)

7.6.2.2.1 State Parks

Multiple state parks and state recreation areas contain anadromous habitat within the scope of this status review, including the Kenai River State Park, Chugach State Park, and Willow Creek State Recreation area. Each state park is governed by a management plan which details how resources within the recreation area or state park will be preserved or restored.

The Kenai River State Park is one of the state parks which contains waters important for Chinook salmon within the scope of the status review. The Kenai River Comprehensive Plan guides the management of state land and water in the Kenai River Special Management Area (ADNR 1997). The Comprehensive Plan dictates that all development within the flowing waters of the Kenai River be permitted by a representative of Alaska State Parks. The permitting guidelines include restrictions on in-water structures, financial incentives for habitat restoration, and guidelines for the maintenance of fish passage (ADNR, 1998). Other state park management plans stipulate similar restrictions on development in anadromous waters within the state park or recreation area.

7.6.2.2.2 Forestry

The Alaska Forest Resources and Protection Act (FRPA, AS 41.17) regulates activities such as timber harvest, reforestation, and timber access on state, private, and municipal lands. The Act sets standards for forest management and timber harvest activities, including buffers, to protect fish habitat and water quality.

7.6.2.2.3 ADNR lands

The management of ADNR retained lands is governed by published area plans. Within the scope of this status review, 18 separate land management area plans dictate the protective measures in place to preserve anadromous fish habitat on ADNR lands. The measures in place to protect anadromous streams and other freshwater bodies on ADNR lands vary by area plan, but generally a 50- to 200-foot vegetated buffer must be retained along streams and other waterbodies. The width of the buffer is determined by the perceived value of the waterbody and the type of development being proposed (ADNR, 2025).

7.6.2.2.4 Mining

Alaska Statute 27.19.010 covers mining regulations for mines which fall under the ADNR jurisdiction. Sections 27.198.010-.070 dictate the policies and procedures for post-mining operations reclamation and restoration of disturbed lands and waters. The intent of these regulations is to preserve the pre-mining conditions at each mining site to the greatest extent possible, and reclaiming the mined area to a stable condition post-mining operations.

7.6.2.3 Alaska Department of Environmental Conservation

The Alaska Department of Environmental Conservation (ADEC) administers the Alaska Clean Water Act (ACWA), which was created through Administrative Order 200 in 1972. This Act established a process by which Alaska's resource agencies (ADEC, ADF&G, and ADNR) can work together to view Alaska's watersheds in a holistic manner by sharing data, expertise, and other information. The ACWA creates a cooperative method to collect information and direct resources to prevent, correct, and restore water quality issues. It also provides an opportunity to identify areas where pollution prevention and watershed planning efforts would be beneficial to protect or restore water quality.⁴²

7.6.3 Boroughs & municipalities

There are 14 boroughs and one municipality that own lands and regulate land uses within the scope of this status review. The land use regulations vary by geography, but 10 of the 14 boroughs and the Municipality of Anchorage have development set-backs enforced along anadromous streams or all surface water bodies. The regulations vary by Borough; the Kenai Peninsula Borough (KPB 21.18) and the Municipality of Anchorage (AMC 21.07.020) restrict all development within a specified distance from the ordinary high water (OHW) line of anadromous streams, whereas other Boroughs, such as the Matanuska-Susitna Borough, restrict the construction of buildings within a specified distance from any water body.

7.6.4 Tribal lands and water management

There are 229 federally recognized tribes in Alaska, and approximately 10% of Alaska's lands are tribally-owned. The Alaska Native Claims Settlement Act of 1971 (ANCSA; 43 U.S.C. 1601 et seq.) established 12 regional corporations for the benefit of tribal shareholders; these corporations are major landowners across Alaska and within the scope of this status review. Seven regional corporations own lands within the scope of this status review: Sealaska Corporation, Chugach Alaska Corporation, Ahtna Incorporated, Cook Inlet Region Incorporated (CIRI), Bristol Bay Native Corporation, Koniag Incorporated, and the Aleut Corporation.

⁴² ADEC. Alaska Clean Water Action (AWCA). Available at: <https://dec.alaska.gov/water/water-quality/nonpoint-source-control/alaska-clean-water-actions/>. Accessed February 2025.

7.6.4.1 Tribal lands

Of the 229 federally recognized tribes in Alaska, approximately 68 have lands that likely contain anadromous waters relevant to this status review. Each tribe manages their lands differently, but many have conservation efforts in place and restrictions on the way in which their lands can be developed. One recurring theme that arises when reviewing land management policies for individual tribes is an emphasis on preserving and restoring salmon habitat for their value as a source of traditional subsistence foods.

Within the Cook Inlet Region, three tribes have established tribal conservation districts: the Knik Tribal Conservation District, the Tyonek Tribal Conservation District (TTCD), and the Eklutna Tribal Conservation District (ETCD). The purpose of tribal conservation districts is to conserve and restore tribal lands in accordance with the goals of the tribe. Both TTCD and ETCD have prioritized the preservation and restoration of fish and wildlife habitat as top priorities for their conservation districts.

The TTCD's Habitat Monitoring & Restoration Program was established to accomplish their first strategic goal to monitor and restore fish and wildlife habitat. "The Tebughna ("Beach People") have fished, hunted, and gathered in the Tyonek area for hundreds of years, and preserving subsistence resource goes hand in hand with preserving the cultural identity of this people. For this reason, protecting fish and wildlife habitat has been a major priority for TTCD since our formation."⁴³ Working cooperatively with the Native Village of Tyonek, the Tyonek Native Corporation, the U.S. Natural Resources Conservation Service, the U.S. Fish & Wildlife Service, the ADF&G, and many others, TTCD monitors natural resources and addresses natural resource concerns. In conjunction with the Native Village of Eklutna (NVE), the ETCD operates the following programs to achieve the above goals: Community Garden and Aquaponics, Public Safety and Works, NVE Contaminated Sites Program, and Eklutna River Monitoring. For example, the NVE and Environment Department conducts river flow monitoring, adult salmon counts and salmon habitat assessments, removed an illegal dump from the river canyon, and developed restoration recommendations for the Eklutna River Watershed.⁴⁴

7.6.4.2 Village corporation lands

While ANCSA extinguished aboriginal land title, it mandated the creation of private, for-profit corporations owned by Alaska Native shareholders.⁴⁵ Alaska Native village corporations are owned by Alaska Native shareholders and hold title to nearly 17 million acres of land across Alaska. Alaska Native village corporations manage the land for the benefit of their shareholders. There are currently 174 village corporations operating in Alaska.⁴⁵

⁴³ Tyonek Tribal Conservation District. Available at <https://ttcd.org/>. Accessed March 17, 2025.

⁴⁴ Native Village of Eklutna. Eklutna Tribal Conservation District. Available at <https://eklutna-nsn.gov/departments/land-and-environment/etcd>. Accessed March 17, 2025.

⁴⁵ ANCSA Regional Association. Overview of Entities Operating in the Twelve Regions. Available at <https://ancsaregional.com/overview-of-entities/>. Accessed March 17, 2025.

Some are operated as for-profit entities with a focus on resource development resulting in profit to shareholders, whereas others operate as non-profit entities with a focus on preservation of corporation lands for shareholder use and subsistence. Each Alaska Native village originally had their own village corporation under ANCSA, but many have subsequently merged with other village corporations or merged with their respective regional corporations. Some village corporation lands contain anadromous waters within the scope of this status review.

7.6.4.3 Regional corporation lands

Statewide, Alaska Native Regional Corporations control 44 million subsurface acres and 22 million surface acres.⁴⁵ Regional corporations are set up for revenue sharing amongst corporation shareholders. Some corporations are heavily focused on resource development on their lands, whereas others are focused on conservation. There are 12 regional corporations in Alaska, 7 of which own lands within the scope of this status review.

Each regional corporation has differing priorities and goals when managing the lands under their purview. For example, Sealaska Corporation, which represents tribes in Southeast Alaska, owns and manages 362,000 acres, 162,000 acres of which are maintained in an undeveloped condition for carbon sequestration.⁴⁶ In 2021, the corporation transitioned away from logging on their corporation lands. Preserving and revitalizing fish habitat on their lands is a core value of their land management policy.

Cook Inlet Region Incorporated (CIRI) is one of the largest landowners in Southcentral Alaska, centered around Cook Inlet. They control 529,500 surface acres and 1.6 million acres of subsurface. The land selections through ANCSA primarily offered mountainous and remote acreage. CIRI's early leadership fought for and negotiated the historic Cook Inlet Land Exchange, passed by Congress in 1976. The land exchange allowed CIRI to trade its ANCSA selections for undeveloped resource-rich lands with great potential.⁴⁷ The CIRI strives to prioritize striking a balance between sustainably developing resources to improve opportunities for CIRI Shareholders and their descendants, while protecting the land for future generations.⁴⁷ CIRI has a permitting process for development and other uses of their lands, and their lands can be leased for development as well.

7.6.5 International regulatory mechanisms

International regulations that would have direct influence on the Gulf of Alaska and salmon habitat would largely come from British Columbia (B.C.), Canada. There are both provincial and federal environmental assessment processes, land and resource use management policies, and supporting regulations. While U.S. agencies do not have jurisdiction on Canada-based projects,

⁴⁶ Sealaska Corporation. Sustainability. Available at <https://sealaska.com/sustainability/>. Accessed March 17, 2025.

⁴⁷ Cook Inlet Region Incorporated. CIRI Lands. Available at <https://www.ciri.com/our-corporation/ciri-lands/>. Accessed March 17, 2025.

U.S. state and federal agencies and U.S. Tribes are often invited to act as technical advisors on projects with potential transboundary impacts.

Two main acts that guide environmental assessments are the Environmental Assessment Act (EAA) and the Impact Assessment Act (IAA). The provincial EAA (SBC 2018, c 51) requires that certain large projects must undergo an environmental assessment and obtain an Environmental Assessment Certificate if the project actions meet or exceed thresholds defined in the Reviewable Projects Regulation before they can proceed. The EAA and its accompanying regulations and policies establish the framework for an assessment, including the scope and procedures, though the framework is specific to each proposed project. The federal IAA (SC 2019, c 28, s 1) also requires that an assessment be conducted for designated projects but sets out its own framework for assessments. However, under the 2019 “Impact Assessment Cooperation Agreement” between Canada and B.C., the provincial EAA process can be substituted for the federal IAA process.

The EAA process is supported by several additional regulations, including the Reviewable Project Regulation. The Reviewable Project Regulation (BC Reg 243/2019) establishes thresholds for determining whether a proposed project and its activities are considered a reviewable project and required to undergo a provincial environmental assessment. Similarly, the IAA process is supported by two main regulations: the Physical Activities Regulations and Information and Management of Time Limits Regulation. The Physical Activities Regulations (SOR/2019-285) determine whether a project’s actions constitute it as a designated IAA project based on a list of physical activities. The Schedule of Physical Activities within the Physical Activities Regulations describes thresholds for different types of projects. The Information and Management of Time Limits Regulation (SOR/2019-283) details information requirements for the project to proceed to the next phase of the regulatory assessment process.

In addition to regulatory mechanisms by the province and country, Canada and the United States hold treaty agreements that influence salmon management and habitat decisions. The Pacific Salmon Treaty was signed in March 1985 with the countries agreeing to cooperate in Pacific salmon management, research, and stock enhancement. The goals of the Pacific Salmon Treaty are to prevent overfishing, provide for optimum production, and ensure both countries receive equal benefits from salmon relative to where salmon production occurs. The Boundary Waters Treaty of 1909 was signed between Canada and the United States to prevent and resolve disputes over the use of shared waters and to settle other transboundary issues. The treaty established the International Joint Commission (IJC) to help the two countries carry out its provisions, and the IJC continues this work. An example of the IJC’s work is implementing a shared reference for the same water quality standard on both sides of the border in the Elk/Kootenai transboundary watershed in response to mining activity in British Columbia. Article IV of the Boundary Waters Treaty has direct importance to salmon habitat with the agreement: “that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.”

7.7 Other Natural or Human Factors

7.7.1 Increasing environmental variability

Increasing environmental variability observed throughout the range of GOA Chinook salmon is a challenge for maintaining stock productivity and predictability. Trends of increased environmental variability include observations of pronounced changes to hydrologic structures and processes in GOA Chinook salmon freshwater systems, and increased prevalence and severity of marine heatwaves.

Recent climate vulnerability assessments for salmon indicate that some populations exhibit moderate-to-high vulnerability to increased environmental variability, depending on their life history, geographic location, and habitat use (Crozier et al. 2019). Changes in freshwater temperature, flow variability, and marine prey availability all contribute to their vulnerability. Chinook salmon, which exhibit extended freshwater rearing and extensive marine migrations, are considered to be among the more sensitive salmon species (Crozier et al. 2019).

7.7.1.1 Freshwater warming and hydrologic impacts on GOA Chinook salmon

For salmon in the Gulf of Alaska, projected changes to freshwater habitats include increased stream temperatures (Figure 91), altered precipitation patterns (Figure 92), and changes in flow regimes. Warmer winters are leading to reduced snowpack, earlier snowmelt, and an increase in winter rain at the expense of snow in intermediate-elevation watersheds. These changes alter both streamflow patterns and summer water temperatures.

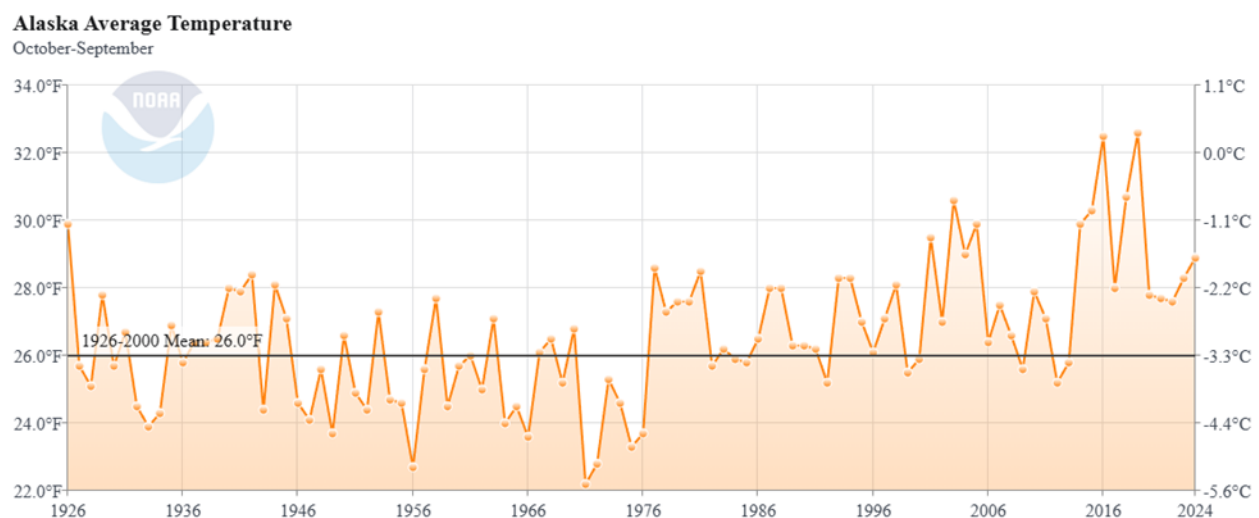


Figure 91. --Annual average temperatures in Alaska from 1926 to 2024 (October-September water year), with temperatures represented in both Fahrenheit and Celsius, and the historical mean for the period 1926–2000 marked as 26.0°F (-3.3°C).

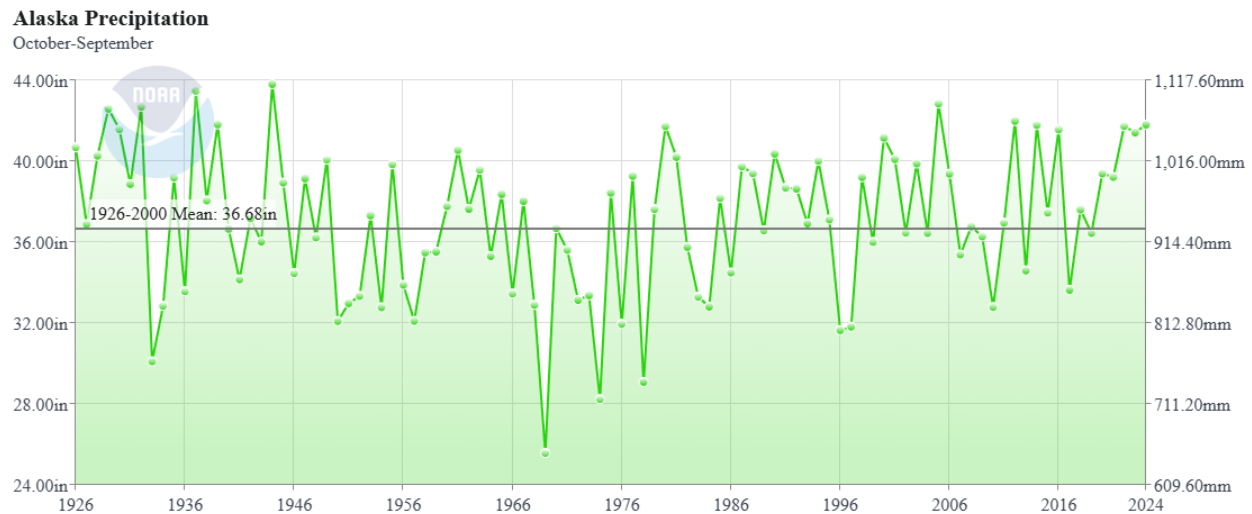


Figure 92. -- Annual precipitation in Alaska from 1926 to 2024 (October-September water year) in both inches and millimeters, along with a historical mean line for the period 1926–2000.

Effects of elevated river temperatures during inriver migration, spawning, egg incubation and rearing have been better studied in lower latitude salmon systems compared to GOA systems. In lower latitude salmon systems, increased temperatures have been associated with reduced growth rates (Crozier 2010), impaired reproductive success due to prespawn mortality (Bowerman 2018), and increased susceptibility to disease and predation (Teffer 2019, McInturf 2022). Within GOA river systems, there have been documented widespread premature mortality of salmon in some years due to high water temperatures and drought conditions (von Biela et al. 2022), though GOA Chinook salmon were not among these premature mortality observations. Potential thermal refuges, such as shaded tributaries, groundwater inputs, or glacial-fed rivers, may buffer some of these impacts at smaller spatial scales (Lisi et al. 2013).

7.7.1.2 Regional hydrologic changes for GOA Chinook salmon

Increasing environmental variability is expected to drive regionally distinct transformations in the hydrology of Alaska’s freshwater systems. These transformations may be especially consequential for Chinook salmon, whose freshwater life stages are tightly linked to seasonal streamflow timing, snowmelt patterns, and summer baseflow conditions. Across the GOA, river systems are projected to shift away from snow- and glacier-dominated flow regimes toward increasingly rain-dominated, flashier hydrologic profiles (Wolken et al. 2011). Such hydrologic changes are frequently associated with negative effects in more southerly Chinook salmon populations in Washington, Oregon and California (Honea et al. 2016, Crozier et al. 2021). However, it has also been posited that deglaciation may increase available spawning habitat for Alaskan salmon (Pitman et al. 2020, Pitman et al. 2021). Climatic variability is estimated to be more impactful to Alaska stream fishes compared to other anthropogenic stressors (e.g., land use or fire) (Murdoch et al. 2020). It should be noted that actual hydrologic changes in GOA

freshwater landscapes will be impacted by local factors, such as vegetation, fine-scale topography and wind (Littell et al. 2018); therefore, the timing, magnitude, and ecological consequences of these transitions will vary depending on microclimate, watershed physiography, and elevation.

This section provides region-by-region summaries of projected hydrologic changes in Southeast Alaska, Central Gulf of Alaska, and Northwest Gulf of Alaska. Given a paucity of region-specific information, there are few observational and modeling studies to assess possible ecological consequences of these changes and the adaptive capacity of GOA Chinook salmon populations. However, it is clear the hydrologic systems that support Chinook salmon across the Gulf of Alaska are undergoing rapid and regionally distinct transformations. The cumulative effects of glacier loss, diminished snowpack, earlier snowmelt, increased rainfall, and rising stream temperatures are converging to reduce the predictability and stability of freshwater habitats. These shifts present challenges and reduce predictability for Chinook salmon survival and productivity, especially during spawning, incubation, rearing, and migration periods.

7.7.1.2.1 Southeast Gulf of Alaska ESU

Southeast Gulf of Alaska's Chinook-producing rivers, such as the Stikine, Taku, and Chilkat are heavily influenced by a combination of snowmelt and glacial runoff. These systems are already exhibiting signs of transition due to warming winters, declining snowpack, and rapid glacier loss. Littell et al. (2018) project that the South Panhandle region will lose nearly all of its snow-dominated watersheds by the 2080s, with snow water equivalent (SWE) decreasing by as much as 58%. Beamer et al. (2017) estimated that glacier runoff will decline by 14–34%, while winter runoff nearly doubles or triples, driven by increased rainfall and rain-on-snow (ROS) events. Mizukami et al. (2022) also predicted that glacier-fed rivers in Southeast will see substantial summer flow reductions as glacial mass diminishes. Southeast Alaska is expected to trend toward earlier snow melt and shifting winter precipitation from snow to rain (Wolken et al. 2011), which contributes to hydrologic instability.

While some research suggests deglaciation in Southeast Alaska could increase available spawning habitats (Pitman et al. 2020, Pitman et al. 2021), others suggest a warmer and wetter regional climate in Southeast Alaska may result in small to moderate reductions in viable Pacific salmon spawning habitat due to increased redd scour potential (Sloat et al. 2017). Predicted streamflow during the spawning and incubation period is expected to increase across Southeast Alaska 1-fold to 3-fold (Shanley and Albert 2014), highlighting the potential magnitude for redd scour increases. The ADF&G Chinook Salmon Research Initiative Subsistence Report (ADF&G 2021) also highlights concerns by Local and Traditional Knowledge holders about winter flooding and incubation success in Southeast Chinook salmon streams.

Warming river temperatures are a concern for Chinook salmon in Southeast Alaska. A loss of cool glacial input is expected to allow for higher summer stream temperatures. In 2019, warm air temperatures persisted throughout Alaska, leading to high river temperatures and widespread premature mortality of salmonids (von Biela et al. 2022). However, Southeast

Alaska was an exception to this trend, with only one mortality observation for chum salmon; higher summer rainfall totals likely moderated stream temperatures in this region in 2019 (von Biela et al. 2022).

Low gradient stream reaches are expected to be vulnerable to hypoxic conditions in Southeast Alaska, regardless of water temperatures (Sergeant et al. 2023). Such conditions may be particularly problematic in areas of high salmon density, such as near hatcheries, where higher stray abundance may be impactful.

7.7.1.2.2 Central Gulf of Alaska ESU

Central Gulf of Alaska encompasses the large Copper River watershed as well as smaller systems including the Situk and Alsek Rivers. These systems exhibit varied hydrologic regimes and are projected to undergo substantial shifts in both seasonal streamflow timing and volume under future climate scenarios. Projections anticipate a sharp rise in glacier melt in the Copper River through mid-century, followed by a long-term decline in summer flows (Valentin et al. 2018, Mizukami et al. 2022).

For Copper River, Bidlack et al. (2014) identified mean annual flow, gradient and glacial influence as important predictors for suitable juvenile Chinook salmon habitat. Presumably, hydrologic changes to flow or glacial influence associated with a changing climate would impact the amount of suitable juvenile Chinook salmon rearing habitat in this system.

Hydrologic changes in the Alsek River are expected to be significant and will likely require adaptive responses by salmon populations (Loso et al. 2021). Currently, the Grand Plateau Glacier separates Grand Plateau Lake from Alsek Lake and the present Alsek River outlet. In response to glacial thinning and retreat, both lakes have doubled in size since the late 1950s, and ongoing glacial retreat is expected to alter flow of the Alsek River outlet such that the flow would instead shift to Grand Plateau Lake outlet. While this would necessitate an adaptive response for Alsek salmon populations to alter their freshwater migratory routes, it would also necessitate changes in human salmon utilization: the future outlet would be located in designated wilderness of Glacier Bay National Park and would not be available to exploitative fishing activities under present management guidelines.

7.7.1.2.3 Northwest Gulf of Alaska ESU

The Kodiak Archipelago and Alaska Peninsula host numerous smaller Chinook salmon-producing watersheds, such as the Karluk, Ayakulik, and Chignik River systems, which are typically lower elevation and snow-rain transitional. These are highly vulnerable to rapid loss of snowpack and increased rain-dominance. In contrast, Cook Inlet is a large snow- and glacier-influenced watershed. In the Cook Inlet Basin, Deb et al. (2014) projected annual streamflow would increase 26–51% by mid-century but continue to be snowmelt-dominated. Cook Inlet watersheds are predicted to drop from 100% snow-dominated to 79-28% by the 2080s under different emissions scenarios (Littell et al. 2018).

In an examination of 15 Chinook salmon populations in Cook Inlet, Jones et al. (2020) observed that recent declines in adult returns were partly attributable to density dependence, but also influenced by increased precipitation during fall spawning and early incubation, and hot and dry summers. Across nonglacial salmon streams in Cook Inlet, recent (2008-2012) river temperatures and projected temperatures (2030-2039) have and are expected to continue to exceed established thermal criterion for spawning and incubation (13°C) in most systems (Mauger et al. 2017), but increased temperatures during spawning and rearing had variable effects on productivity across Cook Inlet systems (Jones et al. 2020). Based on growth models, juvenile Kenai River (Cook Inlet) Chinook salmon are expected to experience reduced growth rates if they feed at lower rates and live in low-elevation tributaries (Meyer et al. 2023).

7.7.1.3 Marine warming and heatwave impacts on GOA Chinook salmon

Expected changes in ocean habitat for Chinook salmon in the GOA include ocean warming, altered currents, declining nutrient availability, ocean acidification, and increased frequencies of marine heatwaves such as the anomalous warm blob event from 2014 to 2016 (Bond et al. 2015). While many of the processes described above impact production within ocean habitats for Chinook salmon, these processes tend to vary over annual and decadal scales. Marine heat waves occur with unknown frequency and can have dramatic effects on the ecosystems and marine habitats where Chinook salmon reside (Suryan et al. 2021). The Gulf of Alaska has experienced an increase in the frequency and intensity of marine heatwaves (Figure 93).

The 2013-2016 “Blob” heatwave was driven by a strong atmospheric ridge that weakened surface winds and reduced ocean mixing, leading to significant sea surface temperature anomalies (Bond et al. 2015, Di Lorenzo and Mantua 2016, Hobday et al. 2018). Another heatwave from 2018 to 2020 was caused by a weak North Pacific High, resulting in weak surface winds and less evaporative cooling, starting during a highly stratified summer period (Amaya et al. 2020, Barkhordarian et al. 2022). These marine heatwaves increased sea temperatures by more than 2.5°C over the long-term average, and they have had devastating effects on various trophic levels, affecting primary producers, commercially important fish species, and subsistence fisheries (von Biela et al. 2019, Barbeaux et al. 2020, Piatt et al. 2020, Bellquist et al. 2021, Rogers et al. 2021, Suryan et al. 2021, Weitzman et al. 2021, Ferriss and Zador 2022).

During the “Blob,” the GOA shelf experienced reduced phytoplankton production, a shift in zooplankton production from lipid-rich copepods to small lipid-poor copepods, reduced forage fish abundance or condition, and reduced Chinook salmon commercial harvest (Suryan et al. 2021). During these years phytoplankton community composition shifted due to increased sea surface temperature and thermal stratification of the water column (Suryan et al. 2021), resulting in reduced nutrient upwelling and altered phytoplankton blooms. These changes cascade throughout the ecosystem, affecting zooplankton biomass and composition, which in turn influences the distribution and abundance of forage fish species like Pacific herring, Pacific sand lance, and capelin (Arimitsu et al. 2021, Strom and Northern Gulf of Alaska Long-Term

Ecosystem Research Team 2023). Cold-water forage species, such as euphausiids, capelin, and sand lance, which are critical prey for juvenile and adult salmon, experienced declines, while warm-water species, including pyrosomes, jellyfish, and Pacific sardines, increased in abundance (Morgan et al. 2019). These changes altered salmon diets and reduced growth rates, particularly during their early marine life stages, a critical period for survival (Weitkamp and Sturdevant 2008).

Increased mortality and reduced reproductive success were observed in seabirds and marine mammals during marine heatwave years (Piatt et al. 2020, Hastings et al. 2023); because these taxa also largely consume forage fish prey, observations of mass mortalities attributable to marine heatwave conditions can provide insight for GOA Chinook salmon prey availability during these years. During marine heatwave years, Capelin declined sharply in seabird diets, especially for surface feeders, while herring increased (Womble et al. 2005). Capelin abundance on the GOA shelf dropped by 98% between 2013 and 2015 (Arimitsu et al. 2021).

Extreme events involving multiple stressors, such as heat and acidity, can cause more severe biological responses than individual stressors (Kroeker et al. 2013, Thomsen et al. 2013, Breitburg et al. 2015). The combined impact of these events can make it more challenging for organisms to adapt, potentially decreasing genetic diversity and adaptive capacity (Bell et al. 2021). The Gulf of Alaska has encountered both marine heatwaves and areas of ocean acidification. However, there is no documented evidence of these extreme events occurring simultaneously. Future projections indicate an increase in the frequency of potential extreme climate and ecosystem disturbances (Litzow et al. 2023).

Another emerging issue associated with warming marine waters is thiamine deficiency complex (TDC), a condition observed in salmon populations linked to climate driven dietary shifts. In the GOA, juvenile and adult salmon that switch prey species along with temperature driven shifts in abundance may experience thiamine degradation if the new prey species is high in thiaminase (Harder et al. 2018). This has the potential to reduce reproductive success and increasing mortality in early life stages (Harder et al. 2018). Hatcheries in Southeast Alaska have begun monitoring for signs of TDC, as recent dietary shifts in marine systems make this an area of concern. NMFS staff have started quantifying thiamine levels in adult female Chinook salmon used as broodstock in some Southeast Alaska hatcheries to better understanding the prevalence of TDC in GOA Chinook.



Figure 93. -- Total number of heatwave days over time (Year) for two regions, the Eastern Gulf of Alaska (red) and the Western Gulf of Alaska (teal). The size of the points represents the mean intensity of the heatwaves ($^{\circ}\text{C}$ above the 90th percentile).

7.7.1.4 Conclusion

The hydrologic systems that support Chinook salmon across the Gulf of Alaska are undergoing rapid and regionally distinct transformations. The cumulative effects of glacier loss, diminished snowpack, earlier snowmelt, increased rainfall, and rising stream temperatures are converging to reduce the predictability and stability of critical freshwater habitats. These shifts present substantial challenges for Chinook salmon survival and productivity, especially during spawning, incubation, rearing, and migration periods.

7.7.2 Genetic and ecological interactions between hatchery and wild salmon in the Gulf of Alaska

Concerns regarding hatchery and wild salmon interactions generally fall into three categories: 1) genetic and epigenetic interactions, 2) spatial competition for freshwater habitat, and 3) competition for food resources (Naish et al. 2008). Typically, the first category references intraspecific interactions, while the latter two categories may refer to either intraspecific or interspecific interactions, particularly with large-scale hatchery releases of pink or chum salmon. Unlike pink and chum salmon, Chinook hatchery production is more limited in Alaska, but concerns over genetic risks such as domestication selection persist (Grant 2012, Howe et al. 2024). Limited hatchery production of Chinook salmon in the GOA has led to greater focus on

interspecific interactions for both spatial competition and food resource competition in the literature.

7.7.2.1 Genetic interactions between hatchery and wild salmon

7.7.2.1.1 *Overview of potential genetic risks*

In Alaska, hatcheries are primarily used to enhance commercial, sport, personal use, and subsistence fisheries rather than to directly supplement wild populations (Evenson et al. 2018). In 2023, for example, 1.9 billion juvenile Pacific salmon were released from Alaska hatcheries for enhancement, and approximately 80 million adult hatchery salmon were caught by the commercial fleet with an exvessel value of \$131 million (Wilson 2024). Additionally, an estimated 215,000 hatchery fish were caught in sport, personal use, and subsistence fisheries. The following subsections provide a more detailed evaluation of genetic, epigenetic, and regulatory factors shaping these risks in Alaska's Chinook hatchery programs.

Despite being exposed to the hatchery environment for only part of their life cycle, hatchery-reared salmon populations are still at risk of genetic and phenotypic change (Grant 2012). Changes in hatchery-reared salmon can occur through domestication selection, inbreeding, genetic drift, epigenetic modifications, or a combination of these mechanisms. Domestication selection is the most widely recognized process by which phenotypic and genetic change can occur in hatcheries, because the fish experience a relaxation of natural selection as well as artificial conditions that may deliberately or inadvertently impose other selective pressures (e.g., no predation, no sexual selection, high rearing densities, unnatural flow regimes, and an unlimited supply of food). Domestication selection can cause genetic divergence between hatchery and wild populations, including in Chinook salmon (Waters et al. 2015, Waters et al. 2017, Ford et al. 2023, Howe et al. 2024). Adverse changes in fitness and fitness-related traits in juvenile and adult hatchery salmonids have also been attributed to domestication selection, including decreased reproductive success when spawning in the wild (Williamson et al. 2010, Christie et al. 2012, Milot et al. 2013, Christie et al. 2014, Koch et al. 2025), altered maturation timing (Waters et al. 2018) and fecundity (Joyce et al. 2004), increased vulnerability to predation (Álvarez and Nicieza 2003, Fritts et al. 2007), differences in morphology (Wessel et al. 2006b, Busack et al. 2007), and altered behavioral and competitive abilities (Metcalf et al. 2003, Wessel et al. 2006a). In the long-term, domestication selection may change adaptive genetic variation, distributions of key phenotypic traits, and overall productivity of wild populations if hatchery fish stray into spawning locations and interbreed with wild fish (Hoffnagle et al. 2008, Williamson et al. 2010, Waters et al. 2015, Waters et al. 2018, O'Sullivan et al. 2020).

Genetic drift and inbreeding are two other genetic risks that can affect genetic diversity, individual fitness, population productivity, and probability of extinction (Keller and Waller 2002, Frankham 2005, O'Grady et al. 2006, Kardos et al. 2016). Genetic drift and inbreeding can be amplified in hatchery populations due to limited rearing capacity and numbers of breeders, variance in reproductive success, and unequal sex ratios (Wang et al. 2002, Naish et al. 2008,

Waters et al. 2015, Waters et al. 2020). Numerous studies of experimental and captive populations observed adverse effects that were due to inbreeding (Calaprice 1969, Ryman 1970, Kincaid 1976, Hard et al. 2000, Wang et al. 2002, Thrower and Hard 2009, Naish et al. 2013). Notably, marine survival of rainbow and steelhead trout released into the wild was 78% lower in inbred families than in non-inbred controls (Thrower and Hard 2009), providing evidence that inbreeding can have serious demographic consequences for salmonid populations.

The hatchery environment may also cause epigenetic changes. Epigenetic changes are modifications to DNA molecules, such as DNA methylation and histone protein remodeling, that impact gene expression and function but do not change the actual DNA sequence (Bird 2002, Bossdorf et al. 2008). Importantly, epigenetic changes can be transmitted to subsequent generations (Bossdorf et al. 2008, Wellband et al. 2021). Several recent studies have documented epigenetic differences between hatchery and wild fish, including in Atlantic salmon, *Salmo salar* (Wellband et al. 2021); coho salmon (Le Luyer et al. 2017); delta smelt, *Hypomesus transpacificus* (Habibi et al. 2024); and steelhead trout (Gavery et al. 2018). To our knowledge, no epigenetic comparisons between hatchery and wild Chinook salmon have been conducted; however, one study observed epigenetic differences between juvenile Chinook reared in uniform hatchery tanks and seminatural stream channels (Venney et al. 2021). These epigenetic differences may pose risks to wild salmon populations, although the magnitude of potential risks and the degree to which they may affect fitness remains unresolved.

The ADF&G Genetic Policy, formulated in 1975 and revised in 1985, established standards and practices intended to mitigate potential genetic risks caused by hatchery rearing for the purposes of maintaining healthy wild stocks and implementing successful fisheries enhancement programs in the State of Alaska (Davis et al. 1985). Key provisions include restrictions on the transport of fish and gametes between major geographic areas within the state, as well as requirements for maintaining genetic variation within and between hatcheries (e.g., broodstock requirements to maintain effective population size), although the policy acknowledges that small population sizes may be unavoidable with Chinook salmon hatchery programs. Additionally, genetic risks cannot be eliminated completely, even when hatchery programs are specifically managed to minimize change (e.g., conservation-focused hatcheries, Waters et al. 2015, Waters et al. 2018, Koch et al. 2022, Ford et al. 2023). The potential genetic risks of hatchery-reared Chinook salmon to wild populations in the Gulf of Alaska are described below.

7.7.2.1.2 Genetic risks of hatchery Chinook salmon in the Gulf of Alaska

Of the five species of Pacific salmon propagated in Alaska hatcheries, Chinook salmon may be the most vulnerable to genetic, epigenetic, and phenotypic change due to the extended rearing time (~two years) typically required prior to their release into the marine environment. However, the extended rearing time and resources required (e.g., food, water, personnel) also make Chinook the least abundant species of anadromous salmonid propagated in Alaska

hatcheries (Wilson 2024). For example, in 2023, approximately 9.6 million Chinook salmon smolts were released from Alaska hatcheries compared to over one billion pink salmon, which require minimal hatchery rearing and resources (Wilson 2024). The comparatively low release numbers, coupled with the ADF&G Genetic Policy, likely reduce the potential for hatchery Chinook to adversely impact wild stocks. However, the degree of risk may vary between ESUs.

7.7.2.1.3 Southeast Gulf of Alaska

Building on this management context, recent empirical work has begun to assess how effectively these policies mitigate genetic divergence in practice. Approximately 75% of Alaska hatchery-origin Chinook smolts are released in the Southeast Gulf of Alaska ESU (Wilson 2024). All Chinook salmon hatcheries in this ESU are considered segregated programs (Mobrand et al. 2005b) since the primary goal is to enhance fisheries, although there is the potential for these programs to inadvertently spawn stray wild fish or those from other hatchery programs due to incomplete tagging and marking (CWT + adipose fin clip) and broodstock screening at some facilities. These hatchery programs are effective at achieving their goal; they produced an estimated average annual return of 80,000 adult hatchery Chinook between 2010 and 2023 compared to approximately 53,000 wild adult Chinook (data obtained from White 2011, Vercessi 2012, Vercessi 2014, Vercessi 2015, Stopha 2016a, Stopha 2017a, Stopha 2018, Stopha 2019, Wilson 2020, Wilson 2021, Wilson 2022, Wilson 2023, Wilson 2024), although hatchery contributions to sport harvest are known to be underestimated at some locations (Wilson 2024). However, theoretical and empirical studies indicate that segregated hatchery management, when compared to an integrated approach, increases the potential for genetic and phenotypic divergence between hatchery and wild fish (Ford 2002, Waters et al. 2015). In SEGOA, genetic comparisons between hatchery and wild Chinook salmon populations are limited. One recent study compared three hatchery stocks to their corresponding wild populations using two complementary sequencing techniques: low-coverage whole genome sequencing (~7.2 million SNPs) and a GT-seq panel of 254 SNPs (Howe et al. 2024). Putative genomic evidence of domestication selection was detected in all three hatchery populations, yet overall divergence from the wild populations was limited in the two production-focused hatchery stocks. Divergence of the third hatchery stock was largely attributed to its small census and effective population sizes; this was a stock at a federal research-focused facility and was not subject to Alaska's genetic policy. Another study at the same research-focused facility documented differences between fourth-generation hatchery and wild adults for key fitness-related traits, including fecundity (one stock), maturation timing (two stocks), and egg size (one stock; Joyce et al. 2004). These results, when combined with the low recipient stray rates observed in many wild systems (rates of 0.01% to 2.66% in most systems, Hard and Heard 1999, Heard 2012), suggest that genetic risks of production-focused Chinook hatcheries in SEGOA may be largely mitigated by current management practices. However, genetic, epigenetic, and phenotypic differences may still arise, so continued monitoring for hatchery-wild interactions is important. Increased marking of hatchery fish would facilitate monitoring efforts across space and time, as some hatchery programs currently externally mark (adipose fin clip) only 10-20%

of their Chinook releases. Importantly, stray rates of these segregated hatchery programs into a wild population (i.e. recipient stray rate) should not exceed 2-3%, as higher rates may cause the proportionate natural influence (PNI, a key metric to assess relative genetic risks of hatchery fish on wild populations) to decrease below the threshold of 0.5 and allow adaptive processes occurring in the hatchery to outweigh the adaptive influence of the natural environment (Withler et al. 2018, HSRG 2020).

7.7.2.1.4 Central Gulf of Alaska

Currently, there are no Chinook salmon hatchery releases in the Central Gulf of Alaska ESU (Wilson 2024).

7.7.2.1.5 Northwest Gulf of Alaska

There are three hatcheries in the Northwest Gulf of Alaska ESU that currently produce approximately 24% of all Alaska hatchery Chinook smolts: William Jack Hernandez (WJH) in Cook Inlet, Wally Noerenberg in Prince William Sound (receives Chinook eggs from WJH), and Pillar Creek in Kodiak (Wilson 2024). In contrast to SEGOA, Chinook salmon hatchery production in this ESU is relatively small compared to the productivity of wild stocks. For example, between 2010 and 2023, the estimated average annual return of adult hatchery Chinook to the NWGOA was 8,000 fish compared to approximately 103,865 wild Chinook (data obtained from White 2011, Vercessi 2012, Vercessi 2014, Vercessi 2015, Stopha 2016a, Stopha 2017a, Stopha 2018, Stopha 2019, Wilson 2020, Wilson 2021, Wilson 2022, Wilson 2023, Wilson 2024), although hatchery contributions to sport harvest are known to be underestimated at some locations (Wilson 2024). Using the reported estimates of hatchery Chinook releases and returns, the average survival rate of hatchery Chinook in this ESU is ~0.35% compared to ~1.03% in SEGOA.

William Jack Hernandez Hatchery produces Chinook salmon for all Cook Inlet and Prince William Sound enhancement efforts using four stocks: Crooked Creek, Ninilchik River, Ship Creek, and Willow Creek stocks. The primary goal of these enhancement efforts is to increase sport fishing harvest opportunities, and many are considered integrated hatchery programs since broodstock comprises at least a proportion of natural-origin fish (ADF&G 2019, ADF&G 2024g). However, some releases have external (i.e., adipose fin clip) marks to denote their hatchery origin, while many other releases only have thermally-marked otoliths which cannot be used to distinguish hatchery fish in real time. For example, in recent years 100% of hatchery releases into Crooked Creek, Deception Creek, and Ninilchik River have had adipose fin clips and thermally-marked otoliths (ADF&G 2019). The enhancement efforts that utilize adipose fin clips are potentially able to identify and spawn 100% natural origin broodstock, which may reduce risks of hatchery rearing. In contrast, hatchery smolts released into Ship Creek near Anchorage, and all Prince William Sound releases only have thermally-marked otoliths. Regardless of the type of marks utilized, it appears that efforts to monitor the impact of these hatchery programs on wild populations, such as the relative proportions of hatchery-origin fish on the spawning grounds (P_{HOS}) and, natural-origin fish used as broodstock (P_{NOB}), are extremely limited. P_{HOS} and P_{NOB} are used to calculate PNI, a key metric to assess relative genetic risks of hatchery fish

on wild populations (HSRG 2009, Withler et al. 2018). There are no significant wild Chinook stocks in Prince William Sound, so potential genetic risks of hatchery releases in that region are likely minimal. Nevertheless, without quantifying PNI for these integrated programs, as well as conducting genetic and epigenetic comparisons between hatchery and wild fish, it is difficult to fully assess the potential risks of hatchery enhancement efforts on wild populations. The lack of monitoring efforts is a management deficiency that should be addressed if such hatchery programs are allowed to continue.

Pillar Creek Hatchery produces all Chinook salmon hatchery releases on Kodiak Island using broodstock derived from the Karluk River, with the goal of increasing sport harvest opportunities. Contemporary releases across multiple sites average ~184,000 Chinook smolts annually (Table 4). Hatchery releases occur on the east side of Kodiak Island while the two wild Chinook populations (Karluk and Ayakulik Rivers) are located on the west side of the island. While the geographic separation is likely helpful, genetic risks of these enhancement programs cannot be evaluated, as all Chinook salmon hatchery releases from Pillar Creek are unmarked. Therefore, stray rates of hatchery fish into the wild systems, as well as broodstock composition, cannot be quantified. This is a management deficiency that should be addressed if such hatchery programs are allowed to continue.

Overall, potential genetic risks of Chinook salmon hatcheries in the Northwest Gulf of Alaska cannot be fully evaluated given the lack of adipose fin clips and CWTs for most hatchery-origin fish released, the limited monitoring efforts to estimate key metrics such as P_{HOS} , P_{NOB} , and stray rates of hatchery fish into non-target systems, and the lack of genetic and epigenetic comparisons between hatchery fish and their founding wild stocks. The low numbers of returning hatchery-origin adults to this region when compared to the productivity of wild stocks, along with the incorporation of natural-origin fish in broodstock, likely mitigates potential adverse effects. Low stray rates would also limit risks but this topic is understudied within this ESU. One project on the Kenai Peninsula revealed that 2.95% of adult Chinook returning to Deep Creek were hatchery fish from the nearby Ninilchik River (King and Breakfield 2002), which is an acceptable stray rate for both integrated and segregated hatchery management (Withler et al. 2018, HSRG 2020). However, the extent to which this stray rate can be applied to other years and regions remains unclear.

7.7.2.2 Spatial competition for freshwater habitat

Spatial competition or habitat displacement of wild Chinook salmon by hatchery-origin fish during their juvenile, freshwater life-history stages is unlikely in the Gulf of Alaska, as hatchery-origin Chinook are released as smolts to begin their marine migration. However, spatial competition or habitat displacement of adult wild Chinook by adult hatchery-origin fish on the spawning grounds may be more likely. Such intraspecific spatial competition has been documented outside of Alaska, particularly in areas where hatchery release (i.e., imprinting) sites are near wild stocks. For example, an estimated 71% of ESA-listed tule fall Chinook redds in the White Salmon River, Washington, were superimposed by stray hatchery-origin Upriver

Bright Chinook (Baker and Hand 2023). In Southeast Gulf of Alaska, many Chinook salmon hatchery programs are intentionally located away from wild stocks, which would limit this type of competition. Additionally, stray rates of stream-type Chinook salmon, which is the predominant life history strategy of Chinook in Alaska, are lower than in other species (Westley et al. 2013, Keefer and Caudill 2014), further reducing the potential for hatchery-origin Chinook salmon to displace wild Chinook salmon on spawning grounds. Stray rates of adult hatchery stream-type Chinook into many wild systems of SEGOA ranged from 0.01% to 2.66%, with relatively high stray rates of 8.5% in the Farragut River (Hard and Heard 1999, Heard 2012).

Potential for spatial competition between hatchery and wild Chinook on spawning grounds in the NWGOA ESU may be higher than in the SEGOA ESU, as hatchery programs in this ESU are integrated rather than segregated. While mixing of hatchery and wild fish on the spawning grounds is a goal for integrated hatcheries designed to supplement wild stocks, the integrated programs in the NWGOA ESU are primarily intended to support local sport fisheries. Therefore, spatial competition on the spawning grounds may be an unintended consequence of these programs. Yet, empirical studies are limited. One project on the Kenai Peninsula estimated that 2.95% of adult Chinook returning to Deep Creek were stray hatchery fish (King and Breakfield 2002). However, the impact of these stray rates to the fitness of wild Chinook (e.g., redd superimposition), and their applicability to other hatchery release sites within this ESU, is unknown.

Interspecific spatial interactions between wild Chinook and more abundant hatchery species, like chum and pink salmon which have higher stray rates, are also possible. Generally, species-specific redd site requirements, habitat partitioning, and temporal differences in spawn timing reduce the likelihood of this type of interspecific competition (Fukushima and Smoker 1998, Geist et al. 2002, Quinn 2005, Beechie et al. 2008). Hatchery-origin chum in the Skagit River basin, Washington, for example, presented a low risk of spawning site competition and redd superimposition to Chinook salmon, largely due to the species-specific differences described above (National Marine Fisheries NMFS 2022e). Potential impacts of spatial competition for spawning habitat by hatchery pink and chum salmon on wild Gulf of Alaska Chinook salmon have not been well studied. An estimated 0.8-4.5 million hatchery pink salmon and 30,000-90,000 hatchery chum salmon stray into wild streams each year within Prince William Sound (Brenner et al. 2012, Knudsen et al. 2021). While there are no significant wild Chinook populations within this region, it is unclear if hatchery pink and chum stray into Cook Inlet or the Copper River and adversely affect those wild Chinook populations. In SEGOA, the estimated proportion of stray hatchery chum salmon on wild chum spawning grounds averaged 3-6% between 2013 and 2015 but was highly variable between sites (Americus et al. 2022). The extent to which stray chum in Southeast Alaska may affect the fitness of wild spawning Chinook is also unknown. Given these data gaps regarding potential intraspecific and interspecific spatial competition, increased monitoring of localized impacts of stray hatchery fish on wild populations is warranted.

7.7.2.3 Competition for food resources

A growing body of literature has implicated increased total marine salmon abundance and biomass in the North Pacific Ocean as potential drivers of reductions in wild salmon abundance, size at maturity, growth, and other aspects of their demography (Kaeriyama 1998, Ruggerone and Connors 2015, Ohlberger et al. 2021, Ruggerone et al. 2023). Hatchery production of pink salmon is frequently implied as contributing to these declines due to their high abundance (~1.35 billion hatchery juvenile pink salmon are released into the North Pacific each year; NPAFC 2024)) and dietary overlap with other species (Davis 2003, Sturdevant et al. 2012, Cook and Sturdevant 2013). Pink salmon comprise distinct even- and odd-year lineages that differ in overall abundance (Irvine et al. 2014), which permit natural comparisons between years of higher overall pink salmon abundance in the North Pacific and years of lower overall abundance. Additionally, approximately 3.5 billion hatchery juvenile chum salmon are released each year (NPAFC 2024). Most commonly, the presumed mechanism for negative associations between total marine salmon abundance (including hatchery fish) and wild salmon abundance is density-dependent competition for marine food resources, which in turn may affect growth, size at maturity, and abundance of wild salmon (Kaeriyama et al. 2004, Ruggerone and Connors 2015).

7.7.2.3.1 *Potential for diet overlap and food resource limitation*

Evidence of diet overlap among salmon species and stocks is central to the hypothesis that species compete for food resources and the carrying capacity for salmon in the North Pacific Ocean has been reached or exceeded. Significant literature exists that documents dietary overlap among co-occurring salmon stocks and species by examining stomach contents and through stable isotope analyses (Davis 2003, Kaeriyama et al. 2004, Johnson and Schindler 2008, Daly et al. 2019, Graham et al. 2021). These studies often illustrate significant spatial, temporal, and ontogenetic variability in salmon diets, but with strongest overlap in dietary preference among more planktivorous salmon species (sockeye and chum salmon) or among more piscivorous and squid-eating species (Chinook and coho salmon). Frequently, pink salmon overlap more with the planktivorous species as juveniles (Sturdevant et al. 2012, Cook and Sturdevant 2013) and with the more piscivorous species as maturing adults (Davis 2003).

Unlike dietary overlap, studies examining potential food resource limitations and assessing ocean carrying capacity in the eastern North Pacific Ocean are limited. Generally, all Pacific salmon have been estimated to consume a small (< 5%) component of the available prey base (Sanger 1972, Cooney 1993), but concerns persist given the dynamic nature of ocean ecosystems. For example, winter surveys in the North Pacific Ocean suggest that zooplankton biomass is about 10% of that found during summer (Nagasawa 2000). Simplistic forage-demand models by Cooney and Brodeur (1998) indicated that density-dependent growth limitations would be likely when salmon production in the North Pacific Ocean is high. However, analyses of salmon biomass, consumption rates, and prey biomass in the western North Pacific Ocean

and western Bering Sea have indicated food is not limited by higher levels of salmon abundance (Shuntov and Temnykh 2005, Shuntov et al. 2018).

In response to developing salmon aquaculture (i.e., hatcheries) in the Pacific, NOAA initiated studies in the 1980s to estimate salmon ocean carrying capacity and to determine if salmon abundance was, at that time, limited by the available food supply in the ocean. This research did not find evidence of salmon abundance being limited by food supply (Honkalehto 1984). In the 1990s, NOAA Fisheries' Alaska Fisheries Science Center formed the Ocean Carrying Capacity Program (OCC) to conduct marine research on salmon in the U.S. EEZ and to understand the carrying capacity for Pacific salmon in the ocean (NMFS 1995). This program utilized large marine surveys in the Gulf of Alaska, and later the Bering Sea, to collect data on Alaska salmon populations and their ecosystems in the 1990s and into the early 2000s. This research occurred before the era of large-marine heatwaves in the GOA, and due to these changing conditions, it should be an important area of continued monitoring and study in the near future.

7.7.2.3.2 Southeast coastal monitoring surveys

Data from the Southeast Alaska Coastal Monitoring (SECM) marine surveys did not indicate food limitations for juvenile salmon, despite a high presence of juvenile hatchery chum salmon (Orsi et al. 2009, Sturdevant et al. 2012), although juvenile hatchery and wild Chinook salmon were not caught in large numbers. In recent years, SECM added sampling stations in Stephens Passage near Juneau (close proximity to the Taku River) and in the Stikine River delta near Wrangell during the peak outmigration months of June and July to more effectively sample juvenile Chinook and to better understand potential intraspecific interactions between hatchery and wild fish.

Juvenile Chinook salmon in the Taku and Stikine River regions exhibited similar patterns of spatial (Figs. 94 and 95) and dietary overlap between hatchery and wild-origin fish during early marine residence, but the extent and timing of potential competition varied between systems.

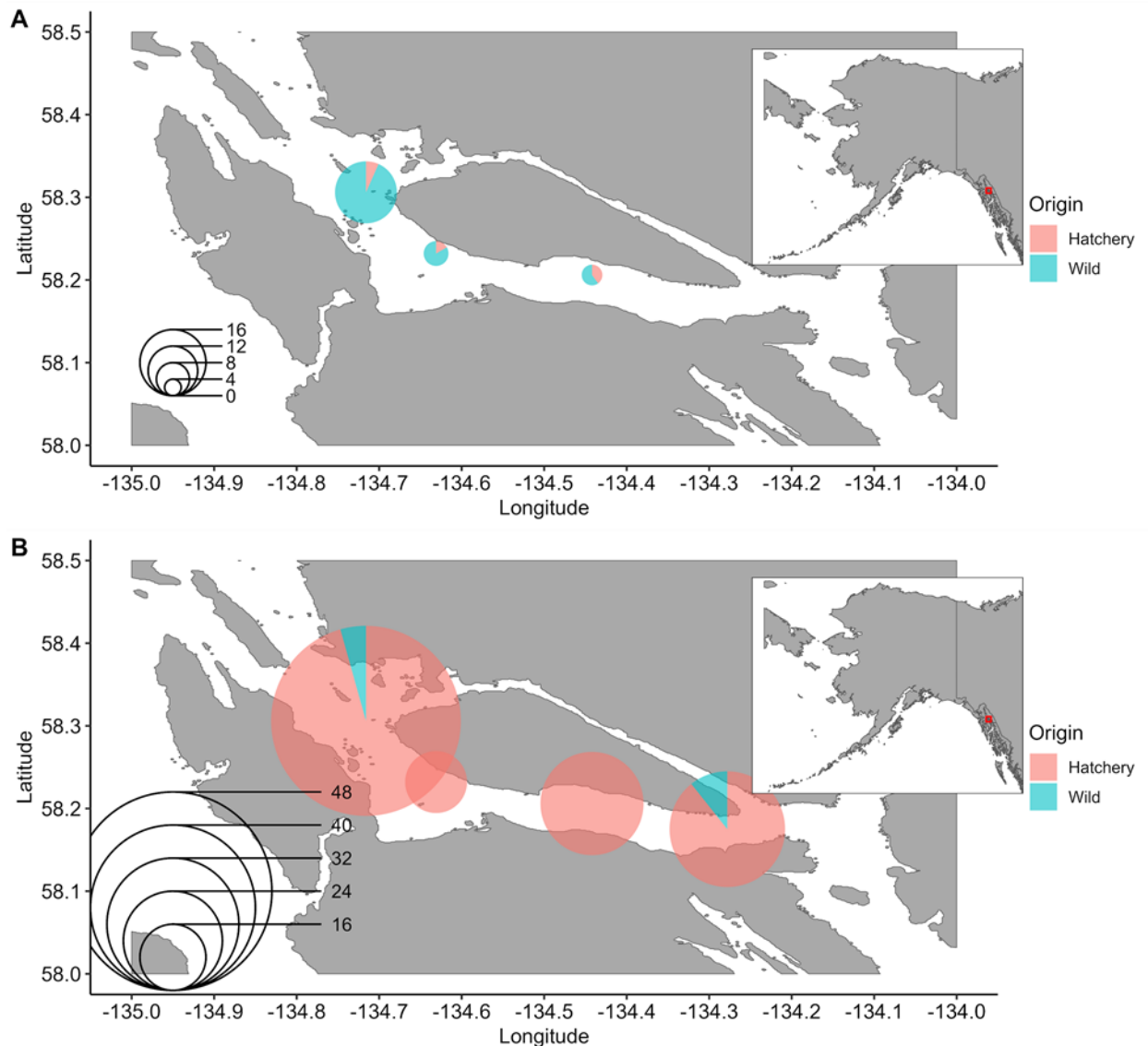


Figure 94. -- Spatial distribution and origin composition of juvenile Chinook salmon captured near the Taku River delta during early summer surveys in 2023. (A) Proportional origin composition (hatchery vs. wild) of juvenile Chinook salmon sampled in June 2023. (B) Proportional origin composition of fish sampled in July 2023. Pie charts represent the proportion of hatchery (red) and wild (blue) fish at each sampling station, with circle size scaled to the total number of fish captured. The inset map shows the location of the Taku River region in Southeast Alaska. Note the increase in sample sizes and hatchery-origin representation from June to July.

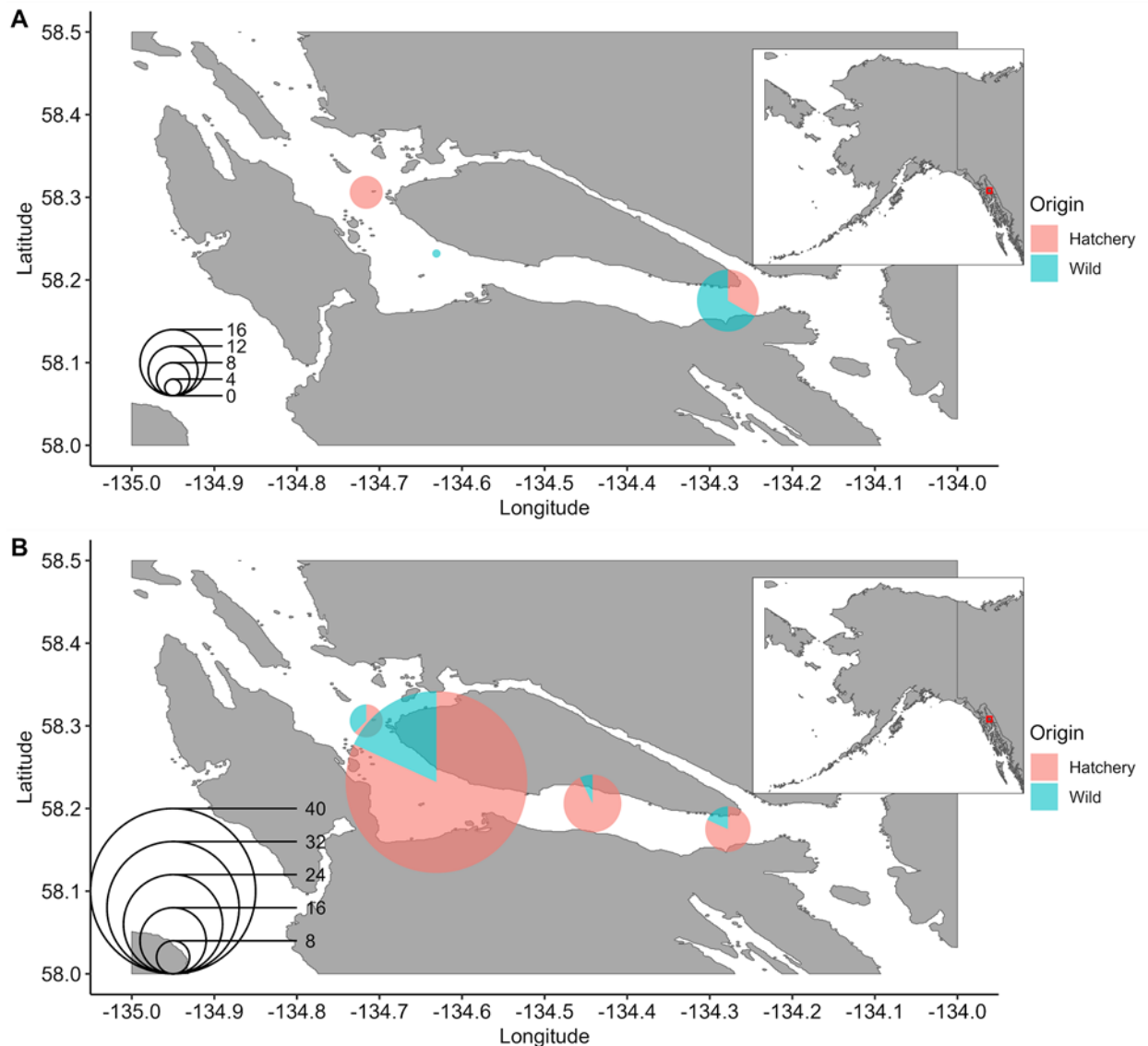


Figure 95. -- Spatial distribution and origin composition of juvenile Chinook salmon captured near the Taku River delta during early summer surveys in 2024. (A) Proportional origin composition (hatchery vs. wild) of juvenile Chinook salmon sampled in June 2024. (B) Proportional origin composition of fish sampled in July 2024. Circle size indicates the total number of fish captured at each station, while color denotes the proportion of hatchery-origin (red) and wild-origin (blue) individuals. The inset map shows the location of the Taku River region in Southeast Alaska.

In Stephens Passage near the Taku River, hatchery-origin juvenile Chinook dominated the catch by July, with broad spatial overlap with wild juvenile Chinook and clear advantages in size (Figure 96), energy density (Figure 97), and lipid reserves. Dietary overlap between hatchery and wild Chinook was moderate in June, with only marginal statistical separation (ANOSIM: $R = 0.101$, $p = 0.046$), suggesting both groups were accessing similar prey resources early in the season. By July, there were no significant differences in the diet between hatchery and wild

Chinook juveniles (ANOSIM: $R = 0.009$, $p = 0.45$). This overlap in time, space, and diet, combined with strong physiological contrasts, indicates a higher potential for intraspecific ecological competition in the Taku region, particularly during early summer when hatchery fish are widely distributed and wild juveniles are still adjusting to marine conditions. Overall, early overlap and physiological disparity in the Taku region suggest higher intraspecific competition potential, whereas geographic and hydrologic separation in the Stikine may buffer wild juveniles from intensive interactions.

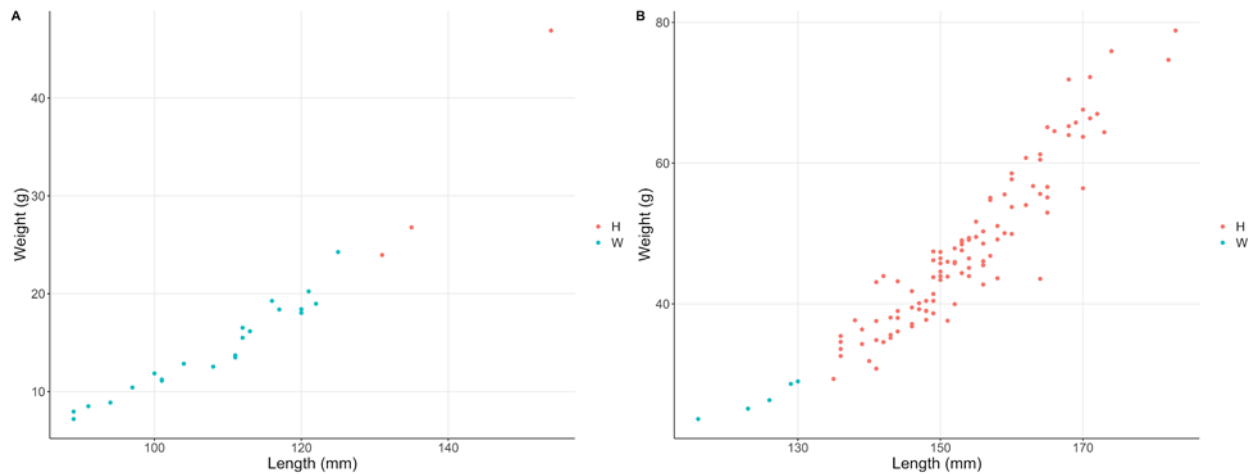


Figure 96. -- Length–weight relationships of hatchery (H) and wild (W) juvenile Chinook salmon sampled near the Taku River in June and July 2023. (A) Length and weight measurements for fish collected in June 2023. (B) Length and weight measurements for fish collected in July 2023. Points represent individual fish, colored by origin. In June, wild-origin fish were generally smaller and lighter than hatchery-origin fish, with limited overlap in body size. By July, hatchery-origin fish dominated the larger size classes, and few wild-origin fish were captured, suggesting a seasonal shift in presence or growth dynamics between the two groups.

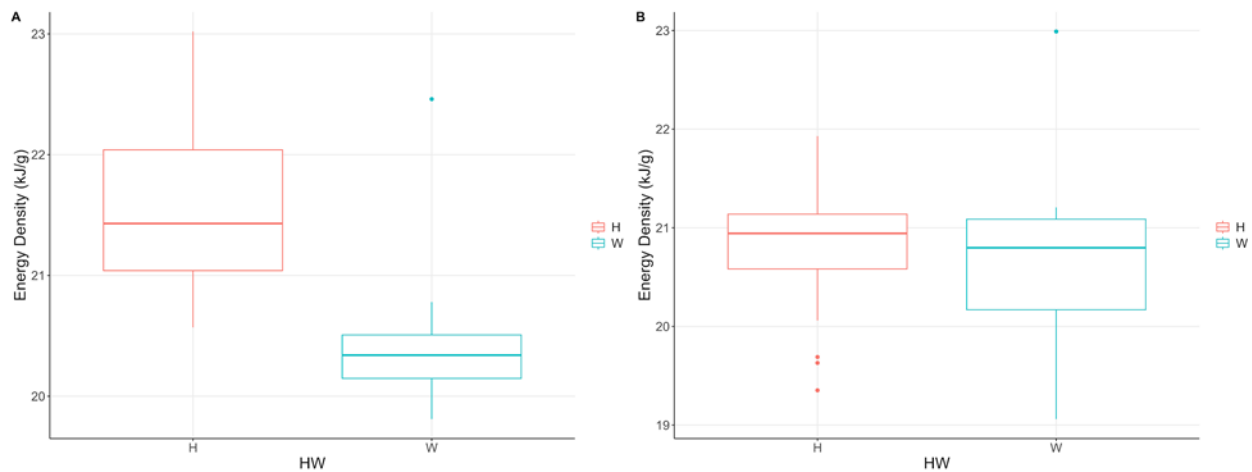


Figure 97. -- Energy density (ED) of hatchery (H) and wild (W) juvenile Chinook salmon collected near the Taku River in June and July 2024. (A) Energy density values for fish sampled in June 2024. (B) Energy density values for fish sampled in July 2024. Boxplots show the distribution of individual energy density values (kJ/g) within each origin group. In June, hatchery-origin fish exhibited higher median energy density than wild fish. By July, the distributions converged, with similar medians but greater variability among wild-origin individuals. Outliers are shown as individual points.

In contrast, the Stikine River region showed more spatial heterogeneity and evidence of natural separation (Figure 98). Hatchery and wild Chinook juveniles were frequently co-located in central areas in June 2023, but the consistent presence of exclusively wild-origin fish at the easternmost station across both sampling periods highlights the influence of the Stikine River plume in mediating habitat partitioning. Diets of hatchery and wild juvenile Chinook were significantly different in June but converged by July, implying initial separation in foraging behavior that diminished over time. Despite this early difference and similar size disparity as observed in the Taku system (Figure 99), physiological indicators such as energy density and lipid content showed less disparity between hatchery and wild Chinook (Figure 100) than in the Taku River system.

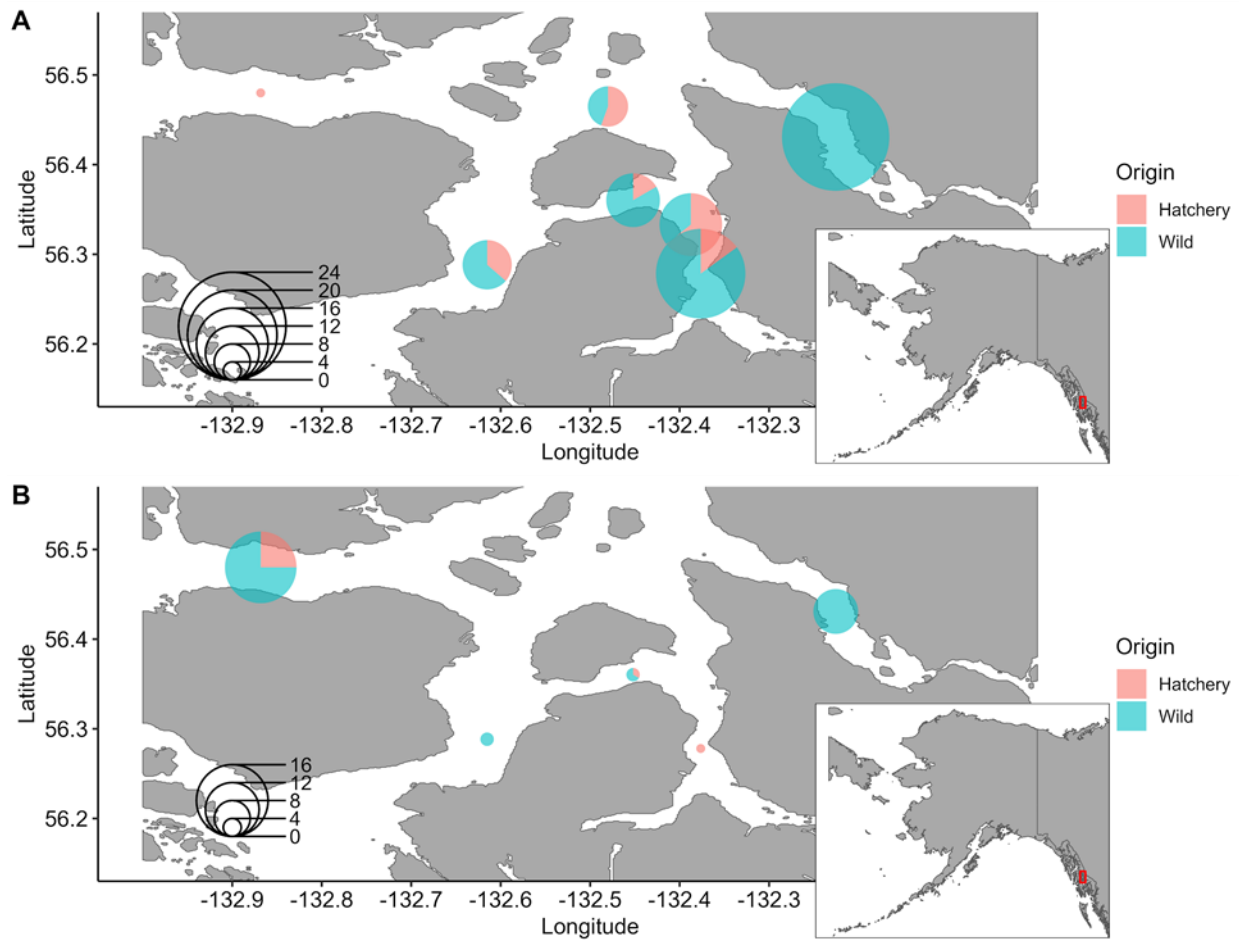


Figure 98. -- Spatial distribution and origin composition of juvenile Chinook salmon captured near the Stikine River delta during early summer surveys. (A) Proportional origin composition (hatchery vs. wild) of juvenile Chinook salmon sampled in June 2023. (B) Proportional origin composition of fish sampled in July 2022. Pie charts show the proportion of hatchery-origin (red) and wild-origin (blue) fish at each station, with circle size scaled to the total number of fish sampled. Notably, the easternmost sampling station consistently contained 100% wild-origin fish in both months, likely reflecting limited hatchery dispersal around Wrangell Island and the presence of a strong freshwater plume from the Stikine River. The inset map shows the location of the study area in Southeast Alaska.

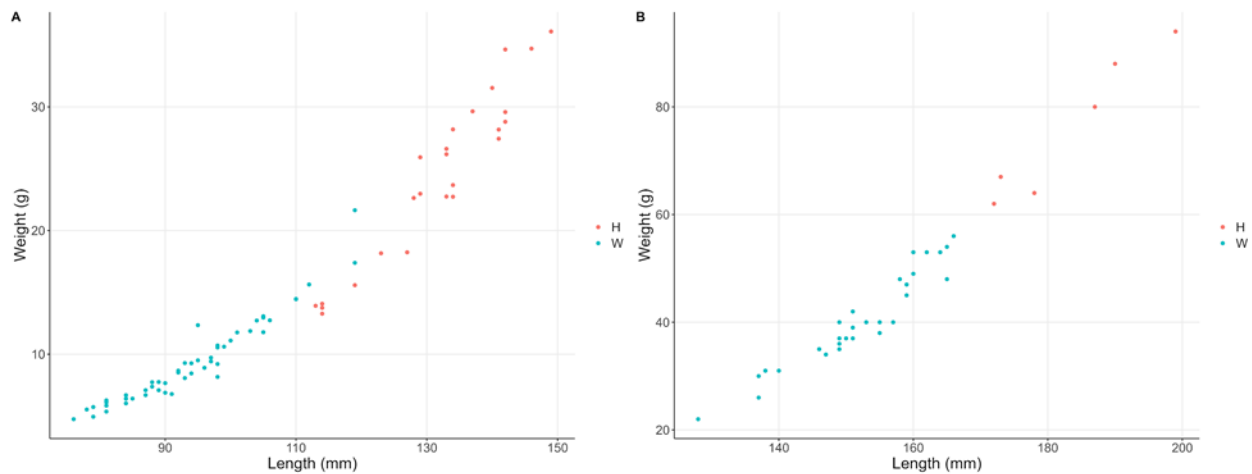


Figure 99. -- Length–weight relationships of hatchery (H) and wild (W) juvenile Chinook salmon sampled near the Stikine River Delta in June 2023 and July 2022. (A) Length and weight measurements for fish collected in June 2023. (B) Length and weight measurements for fish collected in July 2022. Points represent individual fish, colored by origin. In June 2023, wild fish spanned a broad range of sizes, with hatchery fish occurring mostly in mid-to-upper size classes. In July 2022, wild-origin fish dominated the size distribution, with only a few large hatchery-origin individuals observed. These patterns reflect seasonal and interannual variation in growth and composition between origin groups.

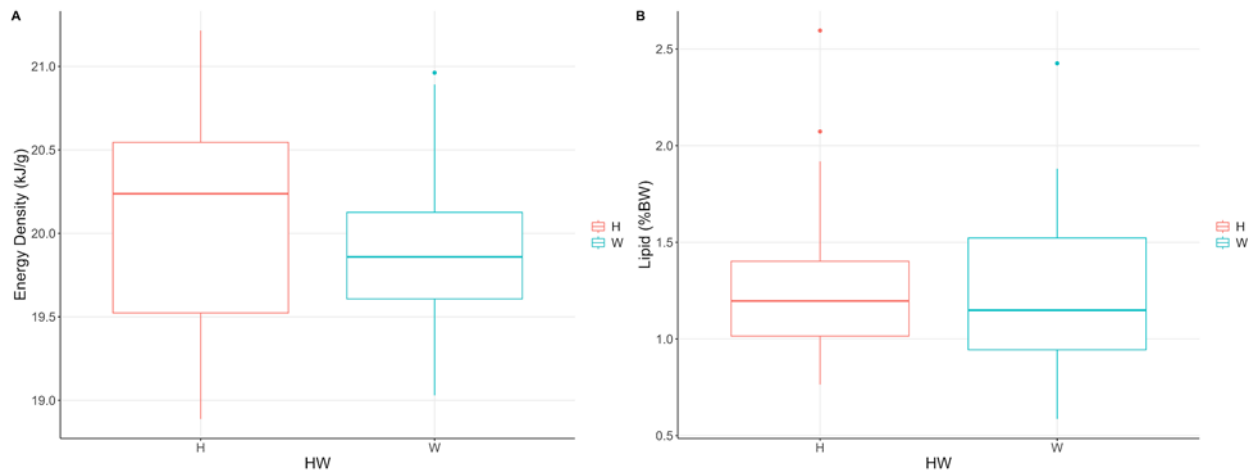


Figure 100. -- Energy density and whole-body lipid content of hatchery (H) and wild (W) juvenile Chinook salmon sampled near the Stikine River Delta in June 2023. (A) Energy density (kJ/g) comparison between origin groups. (B) Whole-body lipid content (%) comparison between origin groups. Boxplots show the distribution of individual values, with outliers plotted as points. Median energy density was slightly higher in hatchery-origin fish, while wild-origin fish exhibited a broader range in lipid content. These measures reflect early-season differences in energetic condition between hatchery and wild juveniles during their early marine residency.

One key difference between the two systems may stem from hatchery release strategies. Current practices in Southeast Alaska do not adhere to fixed release dates but instead release hatchery juveniles when they reach a target size. This practice can result in staggered entry into the marine environment across systems and years, leading to variable overlap with wild juveniles. In the Taku region, the presence of large, energetically-rich hatchery fish early in the season may intensify intraspecific competition in nearshore habitats. Conversely, the Stikine River's more complex geography and the physical barrier posed by the freshwater plume may buffer wild fish from immediate overlap, reducing the intensity and duration of competitive interactions. This finding highlights the importance of incorporating environmental features into hatchery planning. Additionally, implementing more standardized or strategically staggered release schedules, potentially guided by both fish size and environmental conditions, could further reduce overlap and promote coexistence, particularly in regions like Stephens Passage where spatial segregation is less pronounced.

7.7.2.3.3 *Potential impacts on growth and size at maturity*

Size decreases observed for adult Pacific salmon have been speculated to be caused by food competition precipitated by the expansion of hatchery programs since the 1980s (Bigler et al. 1996). Density-dependent effects have been posited to lead to reduced growth rates, delayed maturation, and lower reproductive success for wild populations (Rand et al. 2012). Recent analyses have demonstrated pronounced size declines in GOA Chinook salmon, but identified reduced age at maturity as a primary component of these declines (Oke et al. 2020); this observation is inconsistent with the expectation of delayed maturation due to reduced growth rates that would be precipitated by density-dependent food limitations. Ruggerone et al. (2023) provided supplemental analyses that included data from three to four GOA Chinook salmon stocks where inconsistent correlations (moderately negative to weak and not significant) were found between total North Pacific pink salmon numerical abundance (hatchery and wild combined) and length at age and average age at maturity for Chinook salmon. However, the degree to which these associations may be attributed specifically to interactions with hatchery salmon is unclear.

7.7.2.3.4 *Potential impacts on abundance*

Most of the existing literature implicating marine competition in Chinook salmon productivity dynamics have focused on populations of Chinook salmon that do not include Gulf of Alaska populations, focusing instead on Western Alaska, the Western U.S. coast, or British Columbia (Ruggerone and Nielsen 2005, Cunningham et al. 2018, Kendall et al. 2020, Sobocinski et al. 2021, Feddern et al. 2024). Ward *et al.* (2017) explored evidence for potential marine competition for Copper River Chinook salmon (Central Gulf of Alaska) with hatchery-origin chum and pink salmon abundance, yet found a positive relationship between hatchery salmon abundance and wild Chinook salmon productivity. This finding undermines the likelihood that strong interspecific competition for food resources is responsible for Copper River Chinook salmon productivity dynamics, although the extent to which these results can be applied to other systems is unclear.

7.7.2.4 Conclusion

Wild and hatchery salmon in the Gulf of Alaska experience intricate genetic and ecological interactions that may influence their survival, productivity, and long-term sustainability. The State of Alaska has implemented multiple precautionary measures to mitigate potential negative impacts of hatchery production and other ecological threats to wild salmon populations. However, continued research and adaptive management are essential to ensure the resilience of wild salmon populations in the face of ongoing environmental changes.

8 RISK ASSESSMENT APPROACH

8.1 Risk Matrix Assessment

For over 25 years, NMFS status reviews have employed a risk matrix framework to organize and summarize the professional judgment of panels of subject-matter experts (Myers et al. 1998, Good et al. 2005, Hard et al. 2007, OC and SONCC Status Review Team 2024). This approach has been a foundational tool in Pacific salmonid assessments, providing a consistent method for evaluating extinction risk across ESUs. In this framework, the condition of individual populations within each ESU is assessed using four core demographic viability criteria: abundance, productivity, spatial structure, and diversity. These criteria, rooted in conservation biology, represent the key attributes of a viable salmonid population and collectively serve as strong indicators of extinction risk (McElhany et al. 2000).

The SRT utilized the following sections to assess each of these four factors:

1. Abundance: Section 6 - Demographic Risk Analysis
2. Productivity: Section 6 - Demographic Risk Analysis
3. Spatial Structure: Section 3 - Genetic Information, Section 2.2 - Chinook Salmon Life History and Ecology
4. Diversity: Section 3 - Genetic Information, Section 2.2 - Chinook Salmon Life History and Ecology

In addition to the demographic criteria, team members considered the impact of threats corresponding to the five listing factors specified in section 4(a)(1) of the Endangered Species Act (ESA): (1) present or threatened destruction, modification, or curtailment of habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or anthropogenic factors. Under the fifth factor, the team specifically evaluated potential impacts from hatchery practices and environmental variability. Each of these factors can be found under the relevant subheading in Section 7 - Analysis of ESA Section 4(a)(1) Factors.

Each team member independently evaluated the demographic and threat-based risk criteria for each population using a standardized rubric, as outlined in the NMFS listing guidance:

- **Very Low Risk (1):** It is unlikely that this descriptor contributes significantly to the risk of extinction, either by itself or in combination with other factors.
- **Low Risk (2):** It is unlikely that this descriptor contributes significantly to long-term or near future risk of extinction by itself, but there is some concern that it may, in combination with other factors.
- **Moderate Risk (3):** This descriptor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.
- **High Risk (4):** This descriptor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the near future.
- **Very High Risk (5):** This descriptor by itself indicates danger of extinction in the near future.

The numerical scores used in the risk matrix function as ordered thresholds, where each category reflects a progressively greater level of concern. If a population's condition exceeds the bounds of a lower category, it is assigned to the next highest risk level. This threshold structure ensures that scores consistently reflect the level of concern warranted by the best available scientific evidence.

In cases where detailed population-level information was unavailable, assessments were conducted at the ESU level. All scores were subsequently reviewed and discussed by the team, with consideration given to the range of scientific perspectives, prior to reaching a consensus on overall extinction risk.

8.2 Rangewide Assessment

The team's determination of overall risk to the Gulf of Alaska Chinook salmon ESUs used the categories of "high risk" of extinction, "moderate risk" of extinction, or "low risk" of extinction. The NMFS has defined these levels of risk in: "Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act"⁴⁸. These risk levels have been used in prior Pacific Northwest salmonid species reviews with minor wording changes (Stout et al. 2012, Ford 2022, OC and SONCC Status Review Team 2024). They are defined as follows:

- **High Risk:** A species or ESU with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species or ESU at such a high level of risk may be highly uncertain and strongly influenced by stochastic or compensatory processes. Similarly, a species or ESU may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction,

⁴⁸ NOAA Fisheries. Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act. Available at https://media.fisheries.noaa.gov/2021-02/Final%20Listing%20Guidance_%202017%20over_revisions_02012021_external.pdf?null. Accessed June 20, 2025.

modification, or curtailment of its habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.

- **Moderate Risk:** A species or ESU is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of “High risk” above). A species or ESU may be at moderate risk of extinction due to current and/or projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or ESU is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and should also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or ESU (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. The biologist (or Team) should, to the extent possible, clearly specify the time horizon over which it has confidence in evaluating moderate risk.
- **Low Risk:** A species or ESU is at low risk of extinction if it is not at moderate or high level of extinction risk (see “Moderate risk” and “High risk” above). A species or ESU may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species or ESU at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

The extinction risk determination reflects the informed professional judgment of each SRT member, based on a synthesis of available information. The rangewide risk assessment was informed by the risk matrix, but further assessed the interactions and cumulative effects of the individual factors on overall ESU risk. For the purpose of this review, the foreseeable future was defined as a period of 25 to 40 years, corresponding to approximately 5 to 8 generations of GOA Chinook salmon. The team could not reasonably project further into the future than the length of the available time series. Additionally, the projected impacts of environmental variability, ocean conditions, and freshwater habitat trends on GOA Chinook salmon viability become uncertain beyond this time frame. Thus, the SRT felt that the 25 to 40 year timeframe was as far into the future as we can reasonably predict both the future threats and the species' responses to those threats.

Following the assessment of population-level demographic factors and other threats using the risk matrix, each team member independently evaluated the overall extinction risk for each ESU, assigning it to one of three categories: low, moderate, or high. To accommodate individual uncertainty and support a nuanced expression of expert judgment, the team applied the “likelihood point” method, commonly referred to as the FEMAT approach, based on its use in the Forest Ecosystem Management Assessment Team process (FEMAT 1993). Under this

method, each reviewer allocated ten likelihood points across the three risk categories to represent their confidence in the ESU's true status. For example, a reviewer confident in a low-risk classification might assign all ten points to that category, while a reviewer with greater uncertainty could distribute points across two or all three categories. This approach has been used in most anadromous Pacific salmonid status reviews since 1999, with the exception of five-year reviews for already listed ESUs.

8.3 Assessing Risk in a Significant Portion of each ESU's Range

As part of the ESA status review process, the SRT must perform a Significant Portion of the Range (SPR) analysis that serves as a distinct, but conceptually linked, evaluation of extinction risk within geographically or biologically discrete subsets of a species' range. If a species is not currently endangered or threatened throughout its range, that species could still potentially be listed as a threatened or endangered species based on the status of that species within a "significant portion of its range" (SPR). Such a listing requires that the portion is "significant" to the species (in a biological sense) and that within that particular portion the species is in danger of extinction either currently or in the foreseeable future. Evaluation of whether a portion of a range qualifies as "significant" is done relative to the species' current range (not relative to its historical range).

For salmonids and other species with strong population structure, the status review includes detailed population- or subpopulation-level assessments to inform the range-wide extinction risk determination. In these cases, the SPR analysis draws directly from that foundational work, using population-level data to assess whether any portion of the range may independently meet the criteria for listing as threatened or endangered. Our team took guidance for this process from other recent NMFS salmon status reviews, and the listing guidance (OC and SONCC Status Review Team 2024).

While the SPR analysis may incorporate elements of the prior risk matrix and demographic evaluation, it is guided by a different core question. Rather than asking whether the species is at risk of extinction across its entire range, the SPR framework evaluates whether the species is at risk within any particular portion, and whether that portion is significant to the species' overall viability. An affirmative answer to both these questions provides the basis for further SPR analysis. This includes assessing whether the species is in danger of extinction, or likely to become so in the foreseeable future, within the portion of interest, and whether that portion contributes meaningfully to the long-term persistence of the species. This shift in analytical lens distinguishes the SPR analysis from the range-wide assessment, even when the underlying biological data are shared.

In conducting the SPR evaluation, the SRT considers the biological importance of individual portions of the range using a relative score: low, medium, or high. Portions determined to have "low" biological importance are not considered significant to the viability of the species, while those deemed "high" would likely already influence or determine the outcome of the range-

wide status assessment. Therefore, the SPR analysis focuses on identifying portions of “medium” biological importance. Those that are not primary drivers of the current species-wide status, but that still contribute meaningfully to long-term viability. Determining whether such portions are significant is inherently case-specific and must be supported by a clear biological rationale. It is the responsibility of the SRT to articulate why a portion qualifies as significant, drawing on life-history characteristics, spatial structure, ecological function, or other relevant biological considerations.

Although the SPR analysis is conducted separately, its effectiveness depends on a coherent linkage to the preceding population-level assessments. This integrative structure allows the team to leverage the full breadth of demographic and threat information while applying a distinct set of interpretive criteria. In doing so, the SPR process helps ensure that species protections are responsive not only to broad-scale trends but also to localized vulnerabilities that could jeopardize long-term viability if left unaddressed.

The SRT analyzed individual stocks comprising the ESUs as “significant portions” to evaluate through SPR analysis, evaluating the ESU’s stock level demographic risks.

9 RISK ASSESSMENT RESULTS AND DISCUSSION

A summary of the risk matrix results is provided in Table 23, and discussed in detail below.

Table 23. -- Summary of risk matrix results. Avg = average, SD = standard deviation of risk scores within the SRT, for each attribute of demography or threat. Scores = 1–5, where 1 is very low risk (green) and 5 is very high risk (red; see text for definitions).

	Demography								Threats											
	Abundance		Productivity		Spatial Str.		Diversity		Habitat		Over-Utiliz.		Inadaq. Reg.		Dis./Pred.		Hatchery		Env. Var.	
	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD	avg	SD
Population																				
Andrew Creek	1.7	0.7	1.4	0.7	1.1	0.3	1.1	0.3	1.2	0.4	1.7	0.5	1.3	0.5	1.1	0.3	1.4	0.5	2.4	0.5
Blossom River	1.7	0.7	1.4	0.7	1.2	0.4	1.2	0.4	1.1	0.3	1.7	0.5	1.3	0.5	1.1	0.3	1.2	0.4	2.4	0.5
Chickamin River	1.6	0.5	1.4	0.7	1.2	0.4	1.2	0.4	1.1	0.3	1.6	0.5	1.3	0.5	1.1	0.3	1.3	0.5	2.3	0.5
Chilkat River	1.7	0.5	1.3	0.7	1.7	0.5	1.4	0.5	1.7	0.7	1.3	0.5	1.3	0.5	1.1	0.3	1.2	0.4	2.3	0.5
Keta River	1.7	0.7	1.4	0.7	1.2	0.4	1.2	0.4	1.2	0.4	1.8	0.7	1.3	0.5	1.1	0.3	1.4	0.7	2.4	0.5
King Salmon River	2.3	0.9	1.7	1.0	2.1	0.9	1.9	0.9	1.4	1.0	2.3	0.9	1.7	1.0	1.3	0.7	1.6	0.9	2.8	0.8
Stikine River	1.7	0.5	2.0	0.0	1.1	0.3	1.1	0.3	1.7	0.7	1.3	0.5	1.4	0.5	1.1	0.3	1.3	0.5	2.4	0.5
Taku River	1.6	0.5	1.3	0.5	1.1	0.3	1.1	0.3	1.4	0.7	1.3	0.5	1.4	0.5	1.1	0.3	1.4	0.7	2.6	0.5
Unuk River	1.8	0.7	1.3	0.5	1.1	0.3	1.1	0.3	1.2	0.4	1.7	0.7	1.3	0.5	1.1	0.3	1.3	0.5	2.3	0.5
SEAK ESU	1.7	0.7	1.5	0.7	1.3	0.6	1.3	0.5	1.3	0.6	1.6	0.6	1.4	0.6	1.1	0.4	1.4	0.6	2.5	0.5
Alsek River	1.7	0.7	1.3	0.5	1.8	0.4	1.4	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.2	0.4	1.1	0.3	2.8	0.4
Copper River	1.2	0.4	1.3	0.5	1.2	0.4	1.3	0.7	1.7	0.7	1.3	0.5	1.4	0.5	1.2	0.4	1.1	0.3	2.6	0.5
Situk River	1.6	0.7	1.4	0.7	1.8	0.8	2.0	1.1	1.3	0.5	1.6	0.7	1.4	0.7	1.2	0.4	1.1	0.3	2.6	0.5
Central ESU	1.5	0.6	1.4	0.6	1.6	0.6	1.6	0.8	1.4	0.6	1.4	0.6	1.4	0.6	1.2	0.4	1.1	0.3	2.6	0.5
Alexander Creek	2.6	0.9	1.6	0.9	1.3	0.7	1.3	0.7	1.6	0.5	1.4	0.7	1.6	0.7	2.9	0.8	1.2	0.4	2.6	0.5
Anchor River	1.8	0.7	1.3	0.7	1.3	0.7	1.2	0.4	1.7	0.7	1.3	0.5	1.4	0.5	1.4	0.7	1.4	0.5	2.4	0.5
Ayakulik River	1.8	0.4	1.2	0.4	1.6	0.7	1.3	0.5	1.2	0.4	1.3	0.5	1.3	0.5	1.3	0.5	1.4	0.5	2.4	0.5
Campbell Creek	1.9	1.1	1.6	1.0	1.6	0.7	1.4	0.9	2.9	0.9	1.4	0.7	1.8	1.0	1.6	0.7	1.4	0.7	2.7	0.7
Chignik River	1.9	0.8	1.3	0.7	2.0	0.5	1.6	0.7	1.1	0.3	1.8	0.7	1.3	0.5	1.3	0.5	1.2	0.4	2.6	0.5
Chuitna River	1.8	0.7	1.3	0.7	1.3	0.7	1.2	0.4	1.8	0.8	1.3	0.5	1.4	0.5	1.6	0.7	1.1	0.3	2.4	0.5
Chulitna River	1.8	0.7	1.4	0.7	1.2	0.4	1.2	0.4	1.8	0.8	1.3	0.5	1.4	0.5	1.8	0.7	1.2	0.4	2.4	0.5
Crooked Creek	1.7	0.7	1.3	0.7	1.3	0.7	1.3	0.7	1.7	0.7	1.4	0.5	1.4	0.5	1.6	0.7	1.6	0.5	2.6	0.5
Deep Creek	1.9	1.1	1.6	1.0	1.3	0.7	1.3	0.7	1.7	0.7	1.6	0.7	1.6	0.7	1.6	0.7	1.4	0.5	2.6	0.5
Deshka River	2.0	0.7	1.3	0.7	1.1	0.3	1.1	0.3	1.7	0.5	1.3	0.5	1.4	0.5	2.3	0.7	1.3	0.7	2.4	0.5
East Susitna	1.8	0.7	2.2	0.4	1.2	0.4	1.1	0.3	1.8	0.8	1.3	0.5	1.4	0.5	2.0	0.7	1.2	0.4	2.6	0.5
Karluk River	2.1	0.6	1.2	0.4	1.6	0.7	1.3	0.5	1.1	0.3	1.4	0.7	1.3	0.5	1.3	0.5	1.6	0.5	2.4	0.5
Kenai River early-run	1.9	0.6	1.3	0.7	1.4	0.7	1.4	0.7	1.9	0.9	1.3	0.5	1.4	0.5	1.6	0.7	1.3	0.5	2.6	0.5
Kenai River late-run	1.8	0.7	2.2	0.4	1.6	0.7	1.4	0.7	1.9	0.9	1.4	0.5	1.4	0.5	1.6	0.7	1.2	0.4	2.6	0.5
Little Susitna River	1.7	0.7	1.4	0.7	1.3	0.7	1.3	0.7	2.4	1.0	1.6	0.9	1.4	0.5	1.8	0.7	1.4	0.7	2.6	0.5
Ninilchik River	1.9	0.8	1.4	0.7	1.3	0.7	1.3	0.7	1.8	0.8	1.6	0.7	1.4	0.5	1.6	0.7	1.7	0.7	2.6	0.5
Talkeetna River	1.9	0.8	2.2	0.4	1.2	0.4	1.2	0.4	1.4	0.7	1.3	0.5	1.4	0.5	1.6	0.7	1.2	0.4	2.4	0.5
Theodore River	3.0	1.0	1.7	1.1	1.3	0.7	1.3	0.7	2.0	1.0	1.7	1.0	1.6	0.7	1.6	0.7	1.3	0.5	2.8	0.8
Yentna River	1.9	0.8	1.4	0.7	1.2	0.4	1.2	0.4	1.4	0.5	1.3	0.5	1.4	0.5	2.0	0.7	1.2	0.4	2.4	0.5
NWGOA ESU	1.9	0.8	1.5	0.8	1.4	0.6	1.3	0.6	1.7	0.8	1.4	0.6	1.5	0.6	1.7	0.8	1.4	0.5	2.5	0.5
Color Key	1	2	3	4	5															

9.1 Southeast Gulf of Alaska ESU: Rangewide Assessment

The SRT concluded that the Southeast Gulf of Alaska Chinook salmon ESU is most likely to be at low risk of extinction in the foreseeable future. Of the 90 points (10 likelihood points per 9 voting members), 87 were placed into the low risk category and 3 into moderate risk. Across all members, the average assessment was 9.7 for low risk, 0.3 for moderate risk, and 0 for high risk.

SRT members consistently cited the absence of significant long-term declines in abundance or productivity, the relatively pristine condition of freshwater and estuarine habitats, and the diversity and connectivity among populations as key factors supporting a low-risk determination. Many emphasized that although short-term declines have been observed in certain stocks, these patterns are highly variable, but are within the historical variability, and have either stabilized or begun to rebound in recent years. The risk matrix evaluations across the four viability attributes (abundance, productivity, spatial structure, and diversity) were uniformly low, with no indication of critical population-level failures.

While the overall risk was low, several SRT members acknowledged environmental variability as the most pressing emerging threat to this ESU. Concerns included shifts in streamflow patterns, reduced snowpack, increased peak flows, and marine heatwaves, all of which could negatively impact key life stages. However, these climate-related risks were generally viewed as insufficient, in isolation, to drive the ESU toward extinction within the next 25–40 years. Some SRT members assigned a small portion of likelihood points to the moderate risk category to reflect uncertainty about future environmental impacts, particularly in glacially influenced systems such as the Taku and Stikine. Nonetheless, SRT members agreed that current management actions, low levels of other threats (e.g., hatchery influence, predation, overutilization), and ecological resilience reduce the likelihood that this ESU is in danger of extinction in the foreseeable future.

9.2 Southeast Gulf of Alaska ESU: SPR Assessment

Following the determination of the overall ESU level risk for Southeast Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU's stock level threats, the SRT determined that each stock's risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

9.3 Central Gulf of Alaska ESU: Rangewide Assessment

The SRT concluded that the Central Gulf Alaska Chinook salmon ESU was most likely to be at low risk of extinction within the foreseeable future. Of the 90 points, 87 were placed into the low risk category and 3 into moderate risk. Across all members, the average assessment was 9.7 for low risk, 0.3 for moderate risk, and 0 for high risk. Most SRT members agreed that there is little evidence of long-term declines in abundance or productivity and that habitat conditions

remain largely intact, particularly in the Situk and Alsek Rivers. While some systems have experienced periods of reduced productivity, recent escapement trends have been stable or increasing, especially in the Copper River. SRT members also highlighted the presence of genetic structure within the Copper watershed and some evidence of connectivity between populations, suggesting that demographic and spatial diversity is sufficient to support viability. Across the four viability criteria (abundance, productivity, spatial structure, and diversity), there was consensus that risk remains low, and many SRT members assigned all 10 likelihood points to the low-risk category.

A few SRT members expressed caution regarding emerging threats, particularly related to environmental variability and potential ecological isolation among populations. Environmental-related concerns included altered hydrology, warming stream temperatures, and changing marine conditions, which may impact key life stages and reduce productivity over time. Some SRT members assigned some points to the moderate-risk category, citing environmental variability and past declines as justification for acknowledging uncertainty about the ESU's long-term trajectory. Additionally, concerns were noted about limited buffering capacity due to the isolation of populations and potential ecological risks from hatchery programs. However, these factors were generally not considered sufficient to elevate the extinction risk above the low category due to low levels of all threats. Within this ESU, high levels of diversity and habitat intactness, combined with recently stable or increasing trends in abundance and productivity, reduce the likelihood of extinction in the foreseeable future.

9.4 Central Gulf of Alaska ESU: SPR Assessment

Following the determination of the overall ESU level risk for Central Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU's stock level threats, the SRT determined that each stock's risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

9.5 Northwest Gulf of Alaska ESU: Rangewide Assessment

The SRT concluded that the Northwest Gulf of Alaska (NWGOA) Chinook salmon ESU was most likely to be at low risk of extinction, although several members placed some likelihood points in the moderate-risk category. Of the 90 total likelihood points, 75 were assigned to the low-risk category and 15 to moderate risk, with none assigned to high risk. Across all members, the average assessment was 8.3 points for low risk, 1.7 for moderate risk, and 0 for high risk.

The conclusion of low extinction risk was supported by the ESU's broad geographic distribution, evidence of population connectivity, and generally robust spatial structure and diversity. The SRT noted significant long-term and short-term declines in abundance and productivity in multiple populations, with some stocks exhibiting signs of demographic stress. Additionally, environmental variability was identified as the most prominent overarching threat to the ESU,

with additional cumulative stressors including predation by invasive northern pike, habitat impacts associated with urban development, and ecological risks from hatchery interactions, particularly in Cook Inlet and other road-accessible watersheds.

While these risks warrant continued attention within the NWGOA ESU, there are numerous measures in place to mitigate these concerns. Within Cook Inlet, the state has management strategies for controlling the expansion of the northern pike, an escapement-based management approach for addressing demographic stress, and habitat protections for urbanization impacts. These risks, mitigated by current actions, do not rise to a level that would place the ESU beyond the low-risk category. The SRT's inclusion of moderate-risk points was intended to acknowledge demographic stress and the potential for cumulative threats to influence long-term outcomes; however, given the time horizon chosen by the SRT, no members felt that assigning high-risk points was warranted for any of these threats. Overall, the SRT's assessment reflects a low extinction risk profile for the NWGOA Chinook salmon ESU, as it is not facing threats in abundance, productivity, spatial structure, or diversity that will lead to a risk of extinction in the foreseeable future. The SRT was also in broad agreement that continued monitoring, threat mitigation, and proactive management will help maintain population viability.

9.6 Northwest Gulf of Alaska ESU: SPR Assessment

Following the determination of the overall ESU level risk for Northwest Gulf of Alaska Chinook salmon, the SRT analyzed individual stocks comprising the ESU as significant portions to evaluate through SPR analysis. After assessing the ESU's stock level threats, the SRT determined that each stock's risk of extinction was no higher than that of the entire ESU. Given the absence of elevated risk in any discrete portion of the ESU, further SPR analysis was not warranted.

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