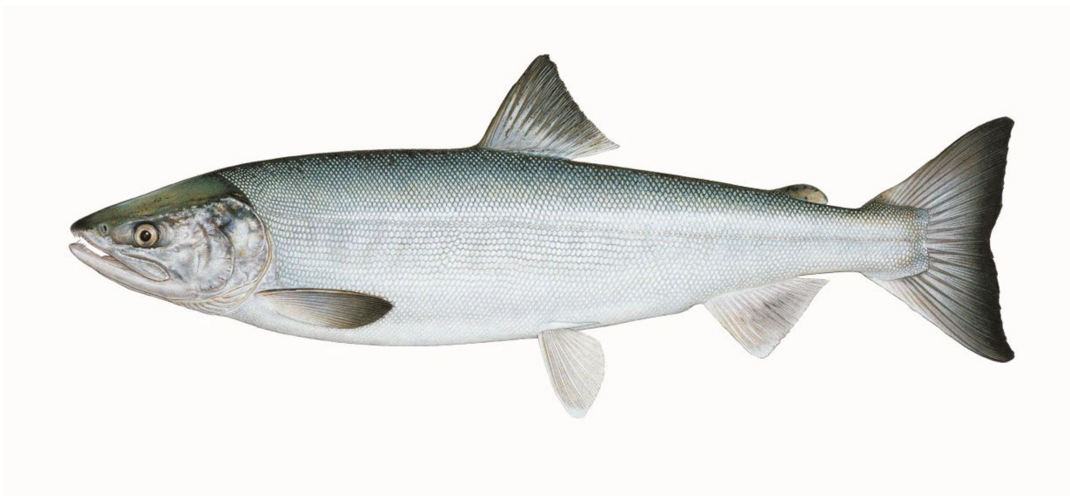
ARCTIC-YUKON-KUSKOKWIM CHUM SALMON RESEARCH AND MONITORING ACTION PLAN

EVIDENCE OF DECLINE OF CHUM SALMON POPULATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH AND MONITORING



ARCTIC-YUKON-KUSKOKWIM SUSTAINABLE SALMON INITIATIVE

AYK SSI SCIENTIFIC TECHNICAL COMMITTEE

October 4, 2024

Arctic-Yukon-Kuskokwim Chum Salmon Research and Monitoring Action Plan

Evidence of Decline of Chum Salmon Populations and Recommendations for Future Research and Monitoring

Prepared for

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CONTENTS

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List of Figures

Executive Summary

Historically, over the past 40 years, chum salmon (*Oncorhynchus keta*) populations of the Arctic-Yukon-Kuskokwim (AYK) region have varied widely in abundance from year-to-year, sometimes with sharp declines but later followed by recovery with no persistent patterns or trends. However, beginning as early as 2018 and at most locations during 2020, the pattern of collapse and later recovery has changed. Declines in abundance have been widespread and have not yet been followed by a return to former abundance in the Yukon River, Kuskokwim River, and rivers in the Norton Sound region. The goal of the Chum Salmon Research and Monitoring Action Plan is:

> *To promote a better understanding of the trends and causes of variation in chum salmon abundance by using a collaborative and inclusive process to obtain new information and synthesize and integrate existing information.*

The plan was developed to promote the undertaking of chum salmon research and monitoring projects and to guide decision-making by AYK SSI for funding of new projects.

Based on a review of population trends, the decline in chum salmon abundance has occurred concurrently across all systems over the geographically large AYK region and was consistent between summer- and fall-run ecotypes. The AYK chum salmon stocks across regions show temporal synchronization in their downward trend in abundance over the past 3+ years. These observations motivate several key questions that would help understand recent changes in chum salmon abundance.

- Which variables, acting alone or in synergy, account for these declines in abundance?
- Is the synchrony across regions due to common stressors such as climate change effects, marine bycatch mortality, overall productivity changes in the Bering Sea, or something else? Or is the synchrony simply chance concurrence of stressors affecting the stocks in different ways in the drainage systems?
- Are the major stressors responsible for the chum salmon declines acting predominately in the freshwater phase or the marine portion of the chum salmon life cycle?
- What are the potential options, and their associated trade-offs, for managing fisheries and conserving chum salmon in the AYK region to enable fisheries to occur given considerable and inevitable uncertainty in our understanding of their ecology?

The plan describes six general themes (listed below) to guide future funding and to help explain the variation in chum salmon abundance observed in the AYK region. While the variables represented within the themes are listed separately, an expectation exists that multiple variables may have additive or synergistic effects on chum salmon populations.

1. **Monitoring to Quantify Population Dynamics of Chum Salmon** – Have dynamics of AYK chum salmon fundamentally changed, reflecting some unknown combination of environmental changes in salmon ecosystems? What approaches to monitoring vulnerable populations are most effective for detecting changes?

2. **Freshwater Habitats –** Have changes in the suitability or productivity of freshwater habitats used for spawning, rearing, and migration (juveniles and adults) contributed to declines in AYK chum salmon stocks?

3. **Marine Natural Mortality and Ocean Conditions** – Has the chum salmon mortality rate increased during their marine life phase because ocean conditions (physical and biological) have changed in the Bering Sea and North Pacific and contributed to the decline of AYK chum salmon stocks?

4. **Marine Bycatch and Interception in Coastal Fisheries** – Has mortality from marine fisheries increased and contributed to the decline of AYK chum salmon stocks and hindered recovery?

5. **Changes in Escapement Quality** – Have changes in natural or fishing mortality, or other environmental drivers, during freshwater spawning migration of adults altered stocks through natural selection and thus changed the quantity and quality of egg deposition and reduced recruitment in AYK chum salmon stocks.

6. **Management for Sustainability Under Uncertainty** – What management approaches are likely to be most effective considering the high level of uncertainties in our understanding of the causal mechanisms affecting AYK chum salmon abundance and productivity?

Example study questions are provided for each theme described above. All research themes and questions qualify as important for funding and can be the subject of proposals.

Completely novel research and monitoring proposals focused on new questions or hypotheses not articulated within this plan will also be considered carefully. Projects, when possible, should use existing data, encourage the formation of collaborations, and maximize use of AYK SSI funds.

The criteria that follow will be used to guide funding decisions. Some criteria may not apply to all projects.

- **Goal** – Projects must directly help to answer one or more of the key questions described above and identify the applicable theme addressed as described above.

- **Knowledge Gaps** – Projects must fill clear gaps in knowledge that are unaddressed by other programs and projects.

- **Time Efficient** – Projects must produce results within a reasonable time frame. Retrospective analyses of existing time-series data are especially valuable.

- **Indigenous Knowledge (IK)** – Projects should appropriately incorporate IK and contribute to capacity building. For example, retrospective historical analyses of changes in salmon abundance and their causes would benefit from incorporation of this information.

- **Ecological Processes** – Projects should link ecological processes across a range of spatial and temporal scales that characterize the chum salmon life cycle.
- **Recruitment Variation** – Applicable projects focused on this topic should promote process-based understanding of the causes for changes in population dynamics, explore the use of environmental conditions as causes for variation.
- **Forecasting** – Projects should encourage the development of new methods to forecast future abundance of chum salmon spawning runs and predict the responses of the fishery to regulatory changes.
- **Relevance to Management Under Uncertainty** – Applicable projects should investigate strategies for assessment and management to determine which approaches perform best in light of the uncertainties about AYK chum salmon ecosystems and their responses to changing environmental conditions and management actions.

For more information, go to https://www.aykssi.org/

1.0 Introduction

Chum salmon *Oncorhynchus keta* of the Arctic-Yukon-Kuskokwim (AYK) region are of critical importance to the fisheries and residents of the region (Bue et al. 2009; Linderman and Bergstrom 2009; Menard et al. 2009). Over the past 40 years, chum salmon populations have varied widely in abundance from year-to-year sometimes with sharp declines but later followed by recovery with no persistent patterns or trends (e.g., Bue et al. 2009). For example, an analysis of summer chum salmon found returns to the East Fork Andreafsky and Gisasa rivers of the Yukon River together had abundances varying from 36,500 to 366,600 between 1994 and 2016; both rivers showed recovery with only a slight, but non-significant, decline over time in abundance (Brown et al. 2020). On the other hand, a persistent chum salmon decline, including subsistence harvests, has been noted at least since the late 1980s in the Norton Sound region (Raymond-Yakoubian and Raymond-Yakoubian 2015). Notably, since 2018 the pattern of collapse and recovery may have changed within the portion of the AYK region considered within this plan. Declines in abundance of chum salmon recently have been widespread and not yet has been followed by a return to former abundance. At a broad geographical scale, the Yukon River, Kuskokwim River, and rivers in the Norton Sound region have experienced concurrent sharp declines of chum salmon without indications of recovery (2019–2022; see Section 2.0 for details). These regionwide population declines have resulted in widespread commercial fishing closures and recently complete closures of subsistence fisheries. The effects on local communities have been substantial, especially when considering the concurrent failures of Chinook salmon (*O. tshawytscha*) and in some cases coho salmon (*O. kisutch*) populations. To investigate causes of the population declines is challenging, in part, due to the life history of the chum salmon, especially because of the brief time juveniles spend in freshwater making studies of this life stage difficult. Because of the short freshwater life stage, the marine life stage may be of critical importance in determining subsequent stock abundance. The management challenge is how to respond to promote recovery of these stocks when the causes of the collapse of the chum salmon stocks are not known.

Chum salmon return to spawn in the rivers of the AYK region during the summer and fall. In the Yukon River, and possibly elsewhere, they return as two distinct groups or races (ecotypes) referred to as summer and fall chum salmon (Salo 1991; Flannery et al. 2007). Summer chum salmon return early-to-midsummer and spawn in mainstem reaches of streams in the lower Yukon River. In contrast, fall chum salmon return in late summer and spawn in late fall or early winter in upper Yukon River tributaries or main-stem regions with perennial springs or upwelling areas (Bue et al. 2009; Wirth et al. 2012). Fertilized eggs incubate over the winter. Juvenile chum salmon, after hatching and emergence, migrate directly downstream to the sea and most arrive in estuaries between mid-June and mid-July (Hillgruber and Zimmerman 2009; Vega et al. 2017). As a result, juvenile chum salmon spend little time in freshwater in comparison to juvenile Chinook, coho, and sockeye salmon (*O. nerka*).

Chum salmon migrate through the Bering Sea and into the North Pacific Ocean by their first winter at sea (Salo 1991; Myers et al. 2009; Urawa et al. 2009). They feed in the North Pacific Ocean for 2–4 years until spring when they mature and migrate back to AYK rivers. Historically, summer chum salmon returns in the Yukon River are dominated by brood-year ages-4 and -5 in nearly equal proportions, with a few fish returning at age-3 and age-6 (Estensen et al. 2012). Fall chum salmon returns have been strongly dominated by age-4 fish, with smaller components of age-3, -5, and -6 fish (Bue et al. 2009; Fleischmann and Borba 2009; Estensen et al. 2012). Recently, some of the dominant age classes have not been returning as expected indicating that shifts in age-at-maturity may be occurring.

The Scientific Technical Committee (STC) of the AYK Sustainable Salmon Initiative (AYK SSI) has identified the following questions to motivate research and monitoring efforts to help recover chum salmon in the AYK region.

1) Which variables, acting alone or in synergy, account for these declines in abundance?
2) Is the synchrony among regions due to common stressors such as climate change, marine bycatch mortality, overall productivity changes in the Bering Sea, or something else? Or is the synchrony simply chance concurrence of different stressors affecting the stocks in similar ways in the drainage systems?
3) Are the major stressors responsible for the chum salmon declines acting predominately in the freshwater phase or the marine portion of the chum salmon life cycle (e.g., Wilson et al. 2021)?
4) What are the potential options, and their associated trade-offs, for managing fisheries and conserving chum salmon in the AYK region to enable fisheries to occur given considerable and inevitable uncertainty in our understanding of their ecology?

This research and monitoring action plan aims to help establish priorities for the AYK SSI program and to guide decision-making for funding future projects. Notably, AYK SSI seeks to provide funding for monitoring projects on specific systems to assess changes in chum salmon abundance to provide data to enable run re-constructions and assessment of stock productivity.

The STC considered development of a theme within this plan addressing the "human dimensions of the salmon ecosystem" that would focus on understanding subsistence needs and uses and causes for changes in salmon abundance, emphasizing the use of Indigenous Knowledge.

Indigenous Knowledge (also referred to as Traditional Ecological Knowledge, Traditional Knowledge, Local Knowledge) is a body of observations, oral and written knowledge, innovations, practices, and beliefs developed by Tribes and Indigenous Peoples through interaction and experience with the environment. It is applied to phenomena across biological, physical, social, cultural, and spiritual systems. Indigenous Knowledge is developed over millennia, continues to develop, and includes understanding based on evidence acquired through direct contact with the environment and long-term experiences, as well as extensive observations, lessons, and skills passed from generation to generation (for further discussion see Prabhakar and Mallory 2022 and Raymond-Yakoubian and Raymond-Yakoubian 2015).

The STC believes that such a "human dimensions" theme would need to be much broader than focused on just one species such as chum salmon. For example, in times of resource scarcity (e.g., a chum salmon decline), subsistence uses will shift to other species of fish or mammals and understanding these shifts to other species must be included to best understand changes in subsistence uses. Forthcoming will be a stand-alone human dimensions research theme that will span across species important to the users of the AYK region. Prior to the new theme's availability, the STC encourages investigators within their project proposals to address the human dimensions of the salmon ecosystem.

More information about why chum salmon vary in abundance may lead to differing and better approaches to management; however, likely the most valuable consequence of improved understanding will be to help create realistic future expectations among users. Helpful input to this plan was provided by the Alaska Salmon Research Task Force report and within its embedded

Arctic Yukon Kuskokwim Working Group Report (2024; https://www.fisheries.noaa.gov/resource/outreach-materials/alaska-salmon-research-task-force-report). The general approach of considering the entire life cycle of the salmon was used here in AYK SSI plan as well as consideration of the AYK working group freshwater and marine hypotheses (Appendix 10, pages 143-144).

1.1 Goal and Objectives

The goal of the Chum Salmon Research and Monitoring Action Plan is:

> *To promote a better understanding of the trends and causes of variation in chum salmon abundance by using a collaborative and inclusive process to obtain new information and synthesize and integrate existing information.*

In the context of this goal, the specific objectives of the action plan are to promote:

1) **Synthesis of Existing Knowledge of Chum Salmon**
   Survey the current state of knowledge regarding the observed patterns in abundance of AYK chum salmon stocks, identify the potential variables that could be driving those patterns, and determine critical data gaps in assessing run abundance.
2) **Identification of Key Variables and Processes that Affect Chum Salmon Abundance**
   Identify and describe causes for the recent declines in chum salmon abundance, including likely ecological mechanisms responsible for these declines.
3) **Recommendations for Future Research and Monitoring**
   Identify and describe specific research themes to improve understanding of, and to the extent possible, address the drivers of decline in the abundance of AYK chum salmon and develop monitoring projects necessary to quantify future changes in abundance and demographic patterns.

1.2 Linkages to the Arctic-Yukon-Kuskokwim Salmon Research and Restoration Plan

Formed in 2001, the AYK SSI is an innovative partnership between public and private institutions that provides a forum for non-governmental organizations and state and federal agencies to cooperatively identify and address salmon research and restoration needs. The portion of the AYK region addressed by this plan includes the watersheds of the Norton Sound region up to and including the village of Shishmaref, the Yukon River watershed within Alaska, the Kuskokwim River watershed (including the coastal watersheds north of Cape Newenham), plus the Bering Sea marine ecosystem. The first step taken by the AYK SSI was to develop a comprehensive research plan to understand causes for the decline of AYK salmon (AYK SSI 2006).

The overall goal of the AYK SSI Research and Restoration Program is:

> *To understand the trends and causes of variation in salmon abundance and fisheries through the synthesis of existing information, gaining new information, and improving management and restoration approaches through a collaborative and inclusive process.*

The Research and Restoration Plan in Sections 9.5 and 9.6 (page 59) specifies that the plan is to be reviewed periodically to establish new research priorities. This Chum Salmon Research and Monitoring Action Plan accomplishes this purpose for chum salmon.

1.3 Structure of Action Plan

The content and structure of this plan is as follows.

Section 2 describes the recent declines and variability of chum salmon stocks within the AYK region. This section also presents information on selected chum salmon populations outside of the AYK region such as Bristol Bay, British Columbia, and the North Pacific and compares them with patterns observed within AYK chum salmon stocks.

Section 3 describes six general themes to stimulate future research and monitoring projects to help explain variation in chum salmon abundance in the AYK region. Example study questions are provided for each theme to encourage development of project proposals.

Section 4 provides priorities and criteria for evaluating project proposals.

1.4 Constraints, limitations, and realistic expectations

Substantial constraints and limitations exist on the plan's ability to promote and guide research and monitoring. **First**, the underlying ecosystems within which chum salmon live contain complex interacting elements operating over large spatial and temporal scales. This complexity makes the isolation of individual, well-defined relationships difficult. **Second**, the information base is incomplete and dynamic – substantial gaps exist in the data available to evaluate the hypothesized drivers of decline. **Third**, this research and monitoring plan must be placed within the context of the broader AYK SSI Research and Restoration Plan (AYK SSI 2006). Constraints exist on the program's funding capability to address all proposed research themes fully.

Ecosystem Complexity

The ecosystems of which chum salmon are members are highly dynamic, containing complex sets of interacting physical and biological components. Most likely, the observed patterns of decline will not be attributed to single causes – the causes are more likely the result of interactions among multiple variables and possibly within both freshwater and marine phases of their life cycle (Wilson et al. 2021).

Data and Information

Available data on AYK chum salmon are incomplete among stocks, across years, and across life stages. Data available on environmental variables are also limited in space, time, and quality. In some cases, specific systems may be critically important to understanding dynamics of chum salmon abundance but no annual assessment monitoring is occurring. These systems then could become the focus for new monitoring projects.

Monitoring and Assessment

Under this plan, the AYK SSI will consider funding projects that propose monitoring of populations and environmental variables when combined with a formalized assessment or analysis plan for new data. The intent of the AYK SSI is not to replace funds for well-established monitoring projects that have been consistently funded in the past. The AYK SSI will consider that the best monitoring projects to fund are those that integrate monitoring and assessment with research for improving our understanding of chum salmon ecosystems. Such connections between monitoring and research should be pursued across a range of spatial scales.

2.0 Decline and Variability of AYK Region Chum Salmon Abundance

The recent declines and variability of chum salmon stocks in the Yukon, Kuskokwim, and Norton Sound area rivers are examined below in separate subsections. The material in this section is drawn predominantly from reports prepared by the Alaska Department of Fish and Game and Kuskokwim River Inter-Tribal Fish Commission. Data on chum salmon returns to this region are incomplete and likely have considerable uncertainty that derive from the logistical difficulties of accessing these remote areas, thus yielding limited sampling and enumeration in these watersheds. Subsistence and commercial harvest trends, and abundance measures are presented when available. In addition, brief synopses of chum salmon abundance are provided for Kotzebue Sound, Bristol Bay, Alaska south of Bristol Bay, British Columbia, and North Pacific Ocean including Asian populations.

Measures of Abundance

Measures of abundance (mainly from sonar and weir enumeration, harvest data, and test-fishery catch-per-unit-effort (CPUE) provide different metrics reflecting the strength and timing of spawning runs. In some cases, enumeration has been provided by aerial surveys and visual counts from towers all of which have been used in developing escapement goals and assessing annual escapement. While subsistence and commercial harvest levels provide important information, they as well as escapement counts, can be affected by variables, such as changes in harvest regulations (e.g., fishing openers, gear restrictions) and river conditions (e.g., discharge, turbidity).

2.1 Trends in Kuskokwim River Chum Salmon Populations

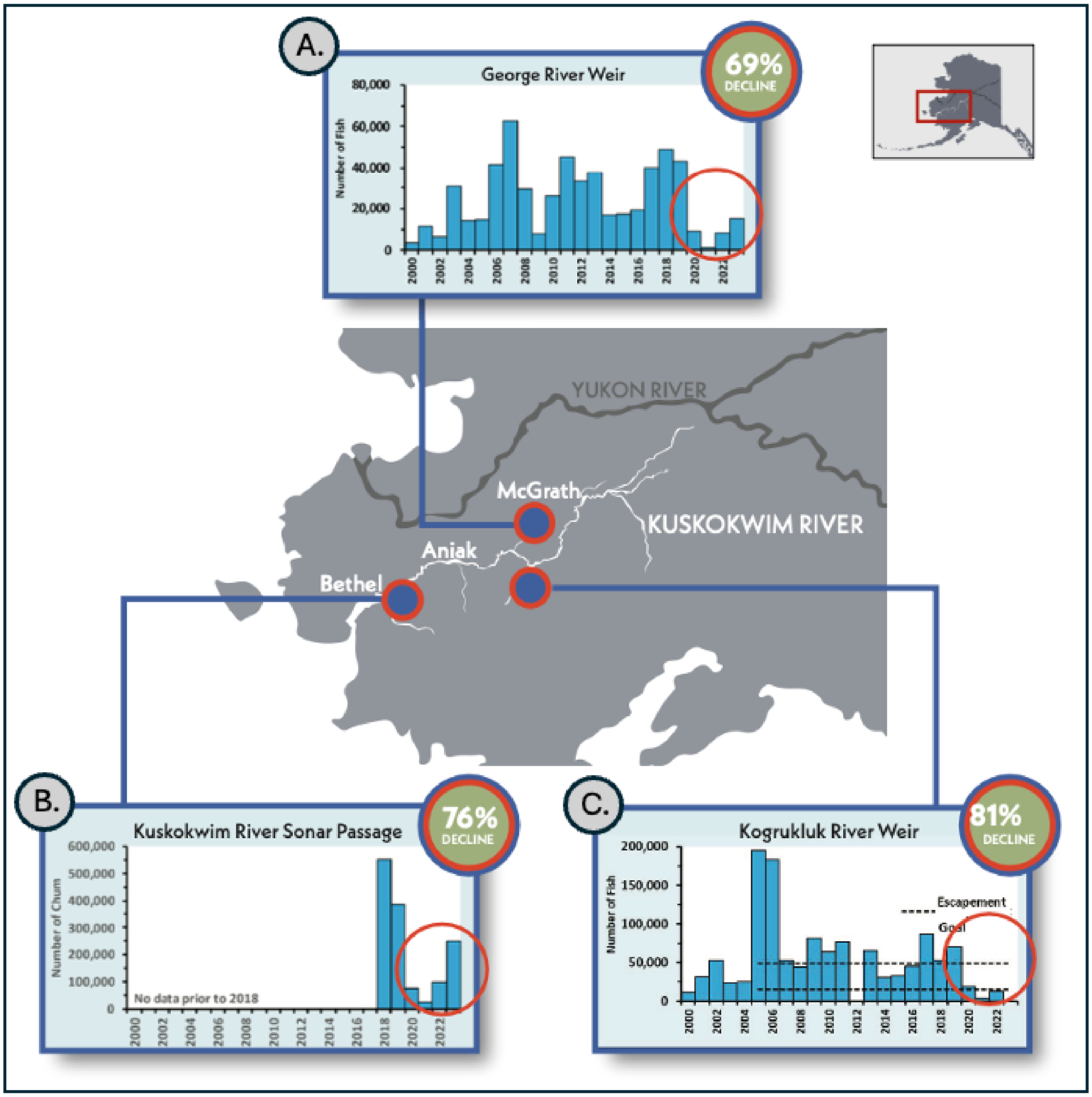

Figure 1: Evidence of low 2020–2022 Kuskokwim River chum salmon abundance compared to 2000–2019: A. George River weir, 2000–2023; B. Cumulative annual counts of chum salmon from the Kuskokwim River sonar project, 2018–2023; C. Kogrukluk River weir, 2000–2022. (Source: Arctic Yukon Kuskokwim Data Base Management System (AYKDBMS) https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx).

A precipitous decline in chum salmon abundance occurred in the Kuskokwim River and its tributaries beginning in 2020 (Figure 1). The 2020–2023 average Kuskowim River Sonar Project passage showed a 76% decline compared to the 2018–2019 average. Weir counts at the upstream tributaries Kongrukluk River and George River showed similar steep declines beginning in 2020. (Figure 1). The 2020–2022 average Kongrukluk weir passage showed an 81% decline compared to the 2000–2019 average, while the George River weir showed a 69% decline from the 2000-2019 average compared to the average for 2020-2023 (Figure 1).

2.2 Trends in Yukon River Chum Salmon Populations

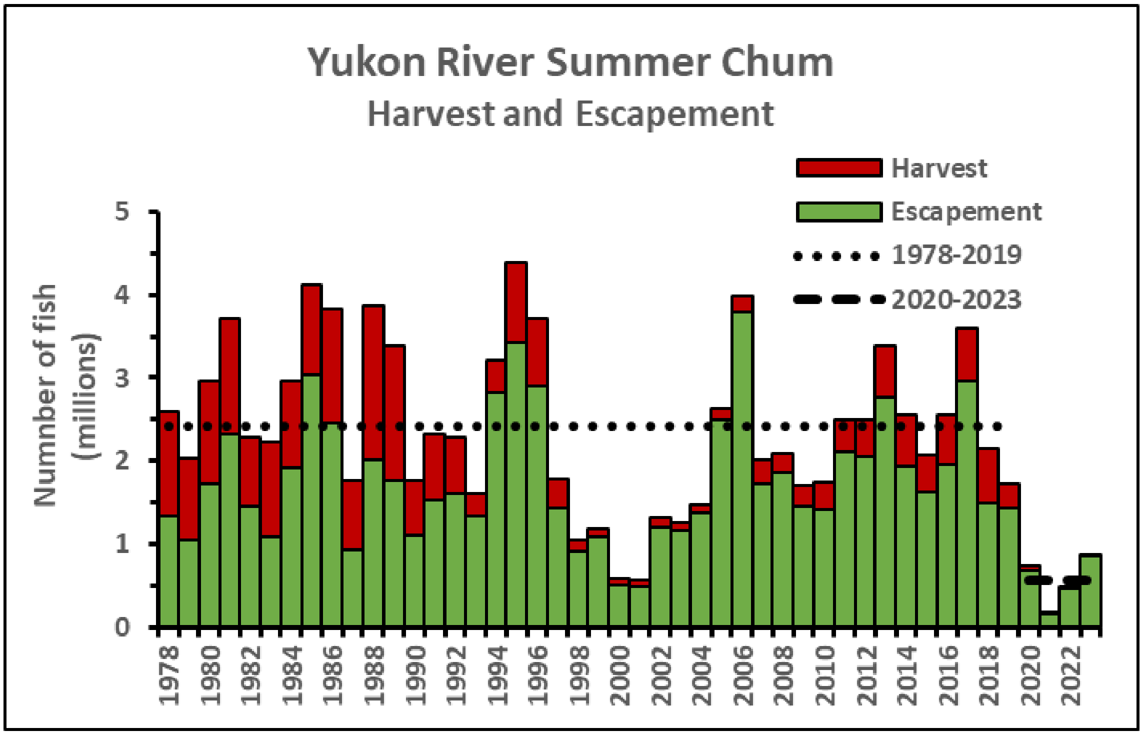

Figure 2: Estimated Yukon River summer chum salmon run size based on the combination of harvest and escapement estimates (Hamazaki and Conitz 2015; Jallen et al. 2022; Joint Technical Committee 2023; AYKDBMS; ADF&G 2023). The average total return during 2020–2023 shows a 77% decline from the 1978–2019 average.

In 2021, only 153,497 summer chum salmon were counted at the Pilot Station sonar just upstream from the Yukon River mouth. This count was the lowest in sonar operation history (1995–2021) and well below (90.5% less) the historical median of 1.6 million fish (Figure 2). Forecasting models did not accurately predict the poor return for 2021; the preseason forecast was for approximately 1.2 million summer chum salmon. No commercial fishing periods occurred on the Yukon River for summer chum salmon during 2021–2023. In addition, no directed subsistence fishing opportunities to target summer chum salmon occurred on the Yukon River during 2021–2022 and summer chum salmon subsistence opportunity was restricted to live release gear only in 2023 to conserve the concurrent poor Chinook salmon run. No escapement goals were met in 2021 or 2022. While the drainage-wide escapement goal for summer chum salmon was met in 2023, observed escapement counts at other assessment projects, such as the East Fork Andreafsky, Anvik, Chena, Gisasa, and Salcha rivers, were poor and remained well below average. The East Fork Andreafsky and Anvik rivers were impacted by high water events during peak summer chum passage times and their respective escapement goals could not be fully assessed in 2023. Based on the summer chum passage observed at these tributaries in 2023, it is unlikely their escapement goals were met. No directed gillnet opportunities were allowed. Because abundance of salmon was low, amounts reasonably necessary for subsistence (ANS) were not met for rural residents.

Fall chum salmon returns to the Yukon River in 2020–2023 were similarly low, with the 2021 passage of 146,197 fall chum salmon at Pilot Station being the lowest documented since records began in 1974, and the 2020–2023 passages being some of the lowest in 25 years (Figures 3 and 4). No commercial fishing periods occurred on the Yukon River for fall chum salmon during 2020–2023, and no directed subsistence gillnet fishing opportunities targeting fall chum salmon occurred in 2021 and 2022 or on the mainstem Yukon River in 2023. The lower bounds of the three established escapement goals (drainage-wide, Teedriinjik (Chandalar), and Delta rivers) for fall chum salmon in the Alaska portion of Yukon River drainage were all met in 2023, but with severe harvest restrictions. Fall chum salmon passage at the Canadian border has failed to meet the passage goal agreed to by international treaty since 2020.

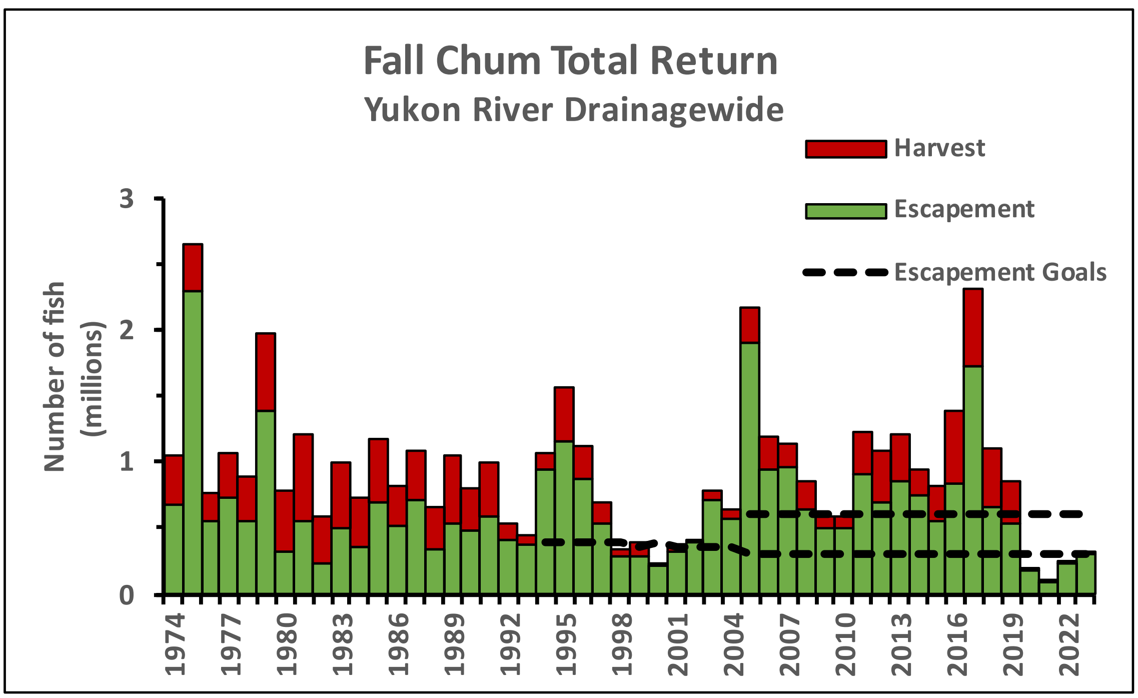

Figure 3. Yukon River fall chum salmon harvest, spawning escapement, and minimum escapement goals or ranges, 1974–2022 (JTC 2023).

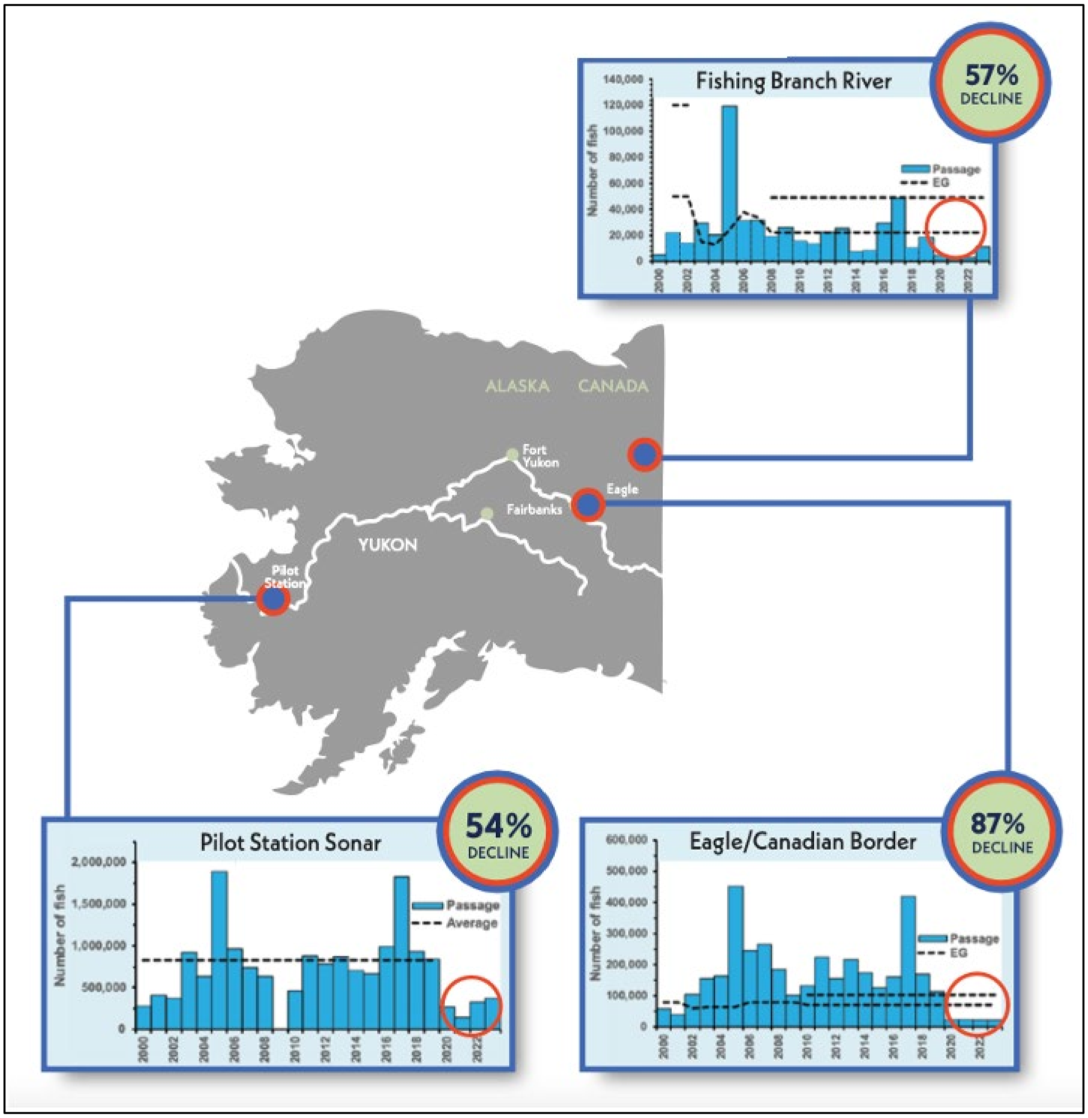

Figure 4. Yukon River fall chum salmon spawning escapement at the Fishing Branch River, Pilot Station sonar, and Eagle/Canadian Border sonar project, 2000–2023 (JTC 2023).

2.3 Trends in Norton Sound Chum Salmon Populations

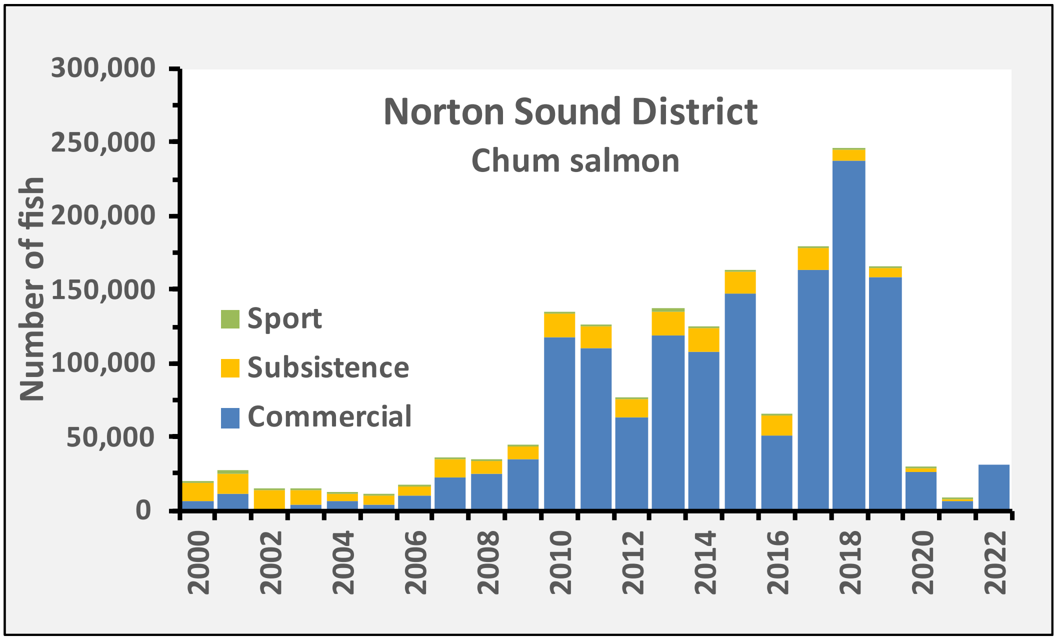

Figure 5. Chum salmon catch in Norton Sound District during 2000–2022. Source: Clark and Henslee 2023.

Norton Sound chum salmon have also experienced recent sharp declines. Commercial and subsistence catch of chum salmon (Figure 5) mirrored the escapement estimates in four Norton Sound tributaries (Figure 6) with sharp declines beginning in 2020 and continuing through 2023.

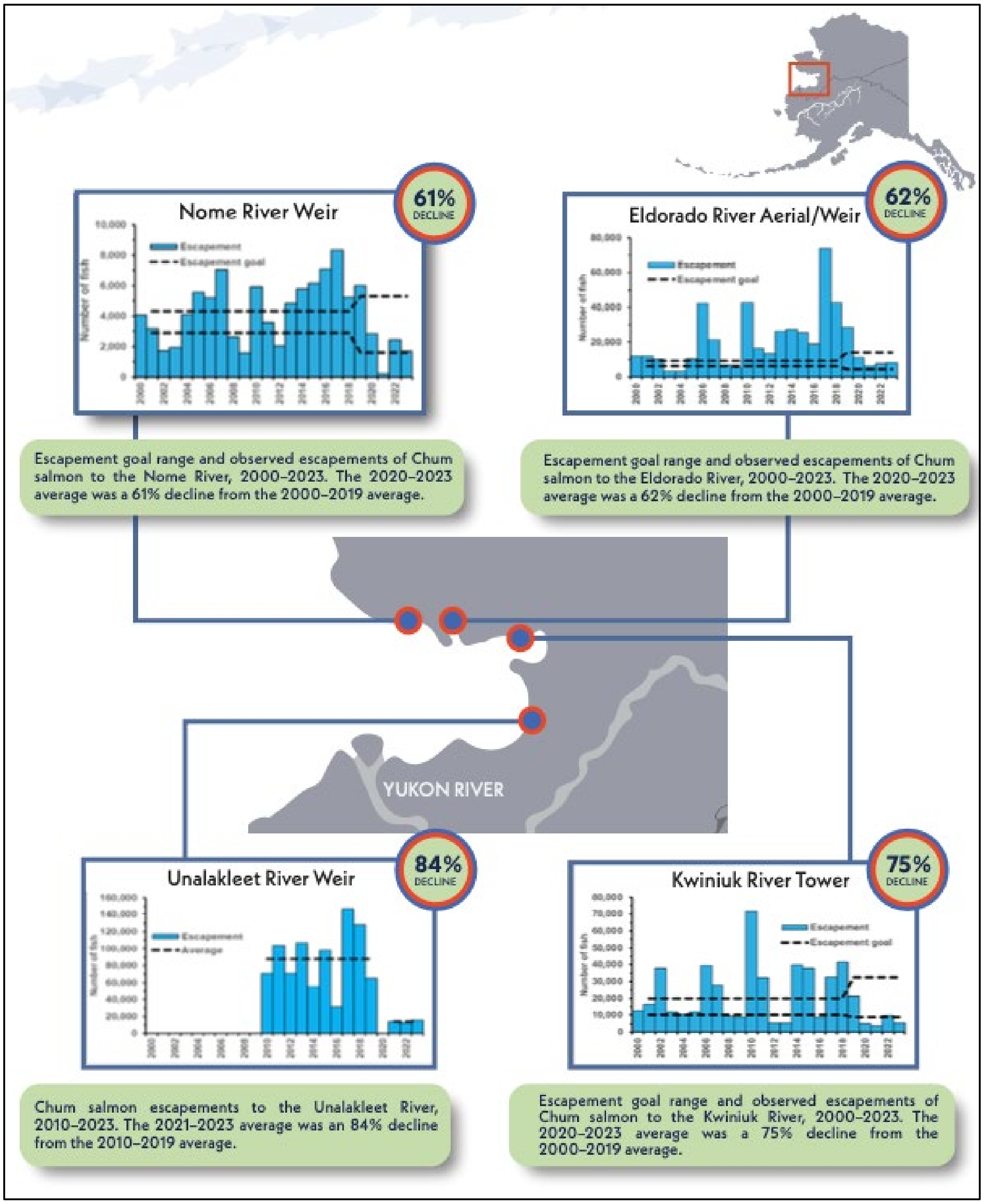

Figure 6. Chum salmon escapements in Norton Sound District during 2000–2023 Source: Clark and Henslee 2023.

2.4 Summary of Decline of AYK Chum Salmon Stocks

The decline in chum salmon abundance is remarkable because it has occurred concurrently across nearly all systems over the geographically large AYK region (exception Kotzebue area north of Norton Sound) and was consistent between summer and fall-run ecotypes. The AYK chum salmon stocks across multiple systems and management areas show similar trends in their declining abundances over the past three years.

2.5 Non-AYK Region Chum Salmon Populations

Are abundance patterns for non-AYK stocks similar to AYK stocks as addressed in this plan? Understanding whether chum salmon abundance outside the AYK region has varied similarly over time could be helpful in in identifying environmental drivers of abundance especially if the variation has occurred during the same time periods as AYK changes in abundance. Similar trends in abundance variation that is synchronous over the same time periods would lend support for the existence of spatially broad, influential environmental mechanisms affecting salmon abundance across a large region.

Kotzebue Sound

Relatively low commercial harvests in Kotzebue Sound of chum salmon occurred in 2020, and 2023, with the 2021 harvest being the lowest since the mid-2000s. The rebound in 2022 was comparable to past high harvests and was the seventh largest harvest since estimates began in 1962 (Menard and Clark 2022; Clark and Henslee 2023). Run size and escapement data are unavailable. Kotzebue Sound stocks, while technically in the broader AYK region, are north of the region addressed in this plan.

Bristol Bay

Escapement of chum salmon in the Nushagak River failed to meet escapement goal in 2020–2023 (Figure 7). Interestingly, escapement in 2018 and 2019 well exceeded the escapement goal. Bristol Bay commercial fisheries caught about 317,000 chum salmon in 2021, 300,000 in 2022, and 343,000 in 2023, all much less than the long-term average catch of 1.1 million fish. Most of these salmon are produced in the Nushagak River and harvested in the Nushagak Fishing District.

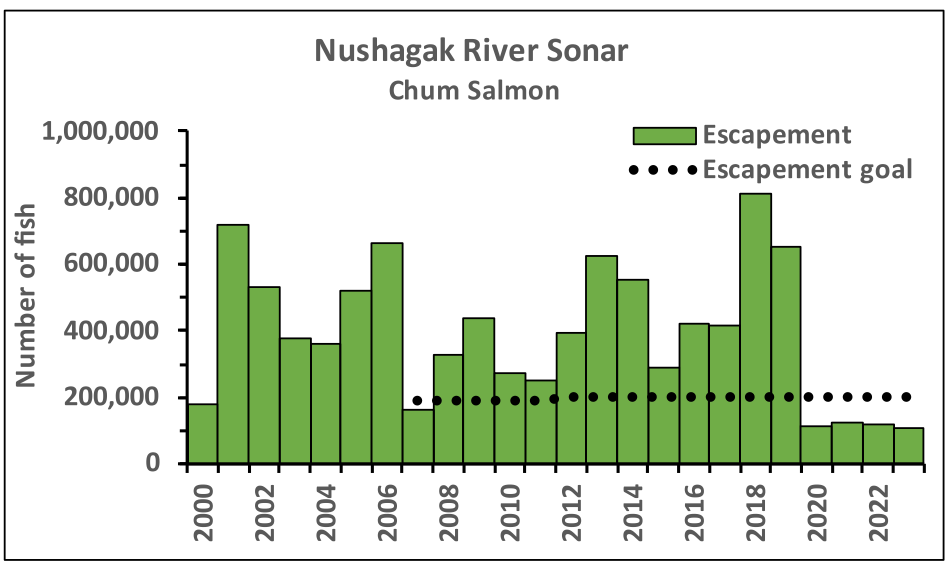

Figure 7. Lower-bound escapement goal and annual passage of chum salmon at the Nushagak River sonar site, 2001–2023 (Buck 2019; Vega et al. 2022; ADF&G Fish Counts: https://www.adfg.alaska.gov/sf/FishCounts/index.cfm?ADFG=main.home).

Alaska South of Bristol Bay

Abundance indices for southeast Alaska, Prince William Sound, Cook Inlet, Kodiak, Chignik, and south Alaska Peninsula were generally lower than average for the years 2018 through 2020, with exceptions of Prince William Sound and south Alaska Peninsula stocks in 2019 (Riddell et al. 2022).

British Columbia

Chum salmon using rivers along the central and north coasts of British Columbia have, in recent decades, experienced both increasing variability and declining abundance. In an analysis of 25 watersheds along the central coast organized into six population groupings, chum salmon declined by ~90% since 1960, with notably sharp declines occurring in all six groupings after 2018 (Atlas et al. 2022). The recent sharp decline is temporally synchronous with the chum salmon collapse in western Alaska described above.

Similarly, below average returns of chum salmon have occurred since 2017 in the Fraser River. More than 50% deviation occurred from average in 2019 and 2020 (Riddell et al. 2022). A notable exception is the Nass River where returns that were below average since 2016 rebounded in 2020 (Riddell et al. 2022).

North Pacific Ocean including Asia and North America Populations

Examination of trends in time of chum salmon in the North Pacific can be difficult to interpret because a substantial portion of this group of fish comes from supplementation (hatchery) programs and thus are disconnected from the spawner-recruitment dynamics of wild populations. Nevertheless, both Asia and North American chum salmon have declined severely in the North Pacific Ocean since 2018 (Ruggerone et al. 2021). Asian-origin chum salmon have declined from 2018 by an estimated 31% in 2020 in the North Pacific Ocean. North American-origin chum salmon notably have declined an estimated 53% from 2017 to 2020 with a precipitous decline between 2019 and 2020. This reduction in abundance in the North Pacific Ocean mirrors the decline observed for chum salmon in the AYK region. Thus, the recent declines observed in the AYK region of Alaska appear to be part of a general decline in chum salmon production over the last five years, with a few exceptions. Japanese fishery biologists have noted a slight increase in chum salmon in 2022 (unpublished data). In summary, in the past 2–5 years, chum salmon have shown poorer returns across the North Pacific (North Pacific Anadromous Fish Commission. 2023).

3.0 Research and Monitoring Themes

Six research themes were developed to organize research and monitoring efforts around conceptually coherent sets of questions that could have contributed to the observed declines in chum salmon stocks in the AYK region. These themes are intended to span the breadth of the most likely contributors to observed declines and should serve to stimulate researchers to craft research and monitoring project proposals.

3.1 Theme 1 – Monitoring to Quantify Population Dynamics of Chum Salmon

> *Have dynamics of AYK chum salmon fundamentally changed, reflecting some unknown combination of environmental changes in salmon ecosystems? What approaches to monitoring vulnerable populations are most effective for detecting changes?*

3.1.1 Description

By interpreting changes in aggregate biological metrics (e.g., such as those that define stock-recruit relationships) both at regional and basin-wide scales, new insights about the causes of observed changes in chum salmon population dynamics may be inferred. Work under this theme may also identify critical unmonitored stocks to motivate new monitoring projects with the hope of providing more systematic information to characterize changes in abundance and productivity of chum salmon throughout the region. Analyses of population dynamics may also lead to new methods to improve forecasting efforts for chum salmon. Examples of possible new projects to undertake within this theme are listed in Appendix 1.

Of special importance is monitoring and assessing risks to vulnerable chum salmon stocks. Chum salmon stocks in the AYK region are composed of spawning populations, with varying phenotypes and life histories. This diversity produces a stabilizing effect where unproductive populations are compensated by the most productive populations at any point in time, thereby stabilizing annual returns to river drainages or watersheds. However, in large complex watersheds, mixed stock fisheries harvest highly productive populations together with low productivity or low abundance stocks, such that the latter may suffer unsustainable exploitation. Recovering and managing at-risk stocks requires an understanding of the genetic and demographic thresholds for population viability as well as the best approaches for managing and rebuilding at-risk stocks.

3.1.2 Example Questions.

1. Which chum salmon populations should be prioritized and monitored to have the information needed to develop spawner-recruitment relationships and to better understand and compare spawner-recruitment dynamics among systems?
2. What new methods could be used to annually count returning chum salmon?

3. When chum salmon stocks are analyzed hierarchically, do they show regionally coherent relationships with broad-scale freshwater or ocean indicators?
4. Which freshwater or marine indicators hold promise for integrating into run forecasting tools?
5. How do abundance and productivity of AYK chum salmon respond to the independent and interactive effects of multiple stressors in the marine or freshwater environments?

3.2 Theme 2 – Freshwater Habitats

Have changes in the suitability or productivity of freshwater habitats used for spawning, rearing, and migration (juveniles and adults) contributed to declines in AYK chum salmon stocks?

3.2.1 Description

This theme explores ways that dynamics of chum salmon populations are linked to environmental conditions that control spawning, growth, and survival during the freshwater component of their life cycle. Adult, embryonic, and juvenile stages are all vulnerable to changes in freshwater environmental conditions. Incubating embryos could be affected by several variables including winter temperatures, discharge, oxygen regimes, flow-related gravel scouring, and entombment by deposition of fine sediments. In juvenile stages, food resources that affect growth rates and associated survival during smoltification, and mortality losses to freshwater predators, are processes that could affect salmon abundance. Growth conditions experienced in freshwater habitats can spill over to marine habitats and affect marine growth and survival. Mortality during the seaward migration in rivers could also be an important potential driver for population trends, especially for populations that have long riverine migratory routes such as Yukon River fall chum salmon (Quinn 2005). In addition, a mass *en route* mortality event was documented for adult summer chum salmon returning to the Koyukuk River in the Yukon River basin in association with a heatwave and elevated water temperatures during summer 2019 (Westley 2020). Water warmer than in the past could also increase incidence of disease and cause mortality. Thus, it is reasonable to expect that changes in freshwater habitats, either through direct anthropogenic impacts in watersheds and habitat alterations due to beavers (*Castor canadensis*) or through more indirect mechanisms associated with climate change, have contributed to the recent declines in chum salmon stocks. The central question motivating this theme is whether any specific variable in the freshwater environment, or some combination, could have contributed to the observed recent trends in AYK chum salmon (Howard and von Biela 2022).

3.2.2 Example Questions

1. Do environmental forcing variables such as flow extremes or temperature explain trends in chum salmon productivity in the AYK region? Life stages that should be included are migrating and spawning adults, incubating embryos, juveniles in overwintering habitat, and juvenile downstream migration. This analysis could guide further work on effects of climate change on freshwater habitats.

2. What are the past and current patterns of stream temperatures and discharge in AYK rivers? Which river and tributary systems would be best to begin long-term temperature and discharge monitoring?
3. Are freshwater habitat conditions linked by large-scale climate variation? Does co-variation exist across habitats due to climate variation that could confound the analyses?
4. Does variation in smolt abundance and timing of migration from freshwater to the ocean explain the variation in subsequent adult returns to rivers? Are changes in smolt growth or predation possible causative factors?
5. Are summer temperatures in AYK rivers increasing because of changes in snowmelt, glacier melt, precipitation, land and water use, and air temperature comparable to large rivers elsewhere in western North America? Increased water temperatures can contribute to an increase in the incidence of migration mortality of adults, either because of stress, energy depletion, or increased susceptibility to disease. Stress resulting from interactions with fishing gear can also increase at high temperatures.

3.3 Theme 3 – Marine Natural Mortality and Ocean Conditions

Has chum salmon natural mortality rate increased during their marine life phase because ocean conditions (physical and biological) have changed in the Bering Sea and North Pacific and contributed to the decline of AYK chum salmon stocks?

3.3.1 Description

Chum salmon spend most of their life and gain more than 99% of their weight while at sea. Changes in the physical environment (e.g., temperature) can affect salmon directly via physiological processes, with ultimate consequences for growth and survival. The physical environment can also affect salmon indirectly through changes in the food web. For example, increased upwelling can lead to increases in primary and secondary production, leading to more food availability for juvenile salmon. Changes in the biological environment, such as food-web structure (i.e., prey, competitors, predators), can affect feeding rates, growth, and ultimately survival. Importantly, both natural and human drivers play important roles in structuring the marine environment. Considerable sharing of ocean habitats occurs among stocks and among other salmon species such as pink salmon (*O. gorbuscha*), and therefore trends in survival during the ocean phase of chum salmon could produce regionally synchronous changes in salmon abundance such has been observed in the AYK region and elsewhere.

Two periods are especially important for salmon survival during their time at sea: the spring and summer months immediately after smolt out-migration, and the first winter at sea (Beamish and Mahnken 2001). An expanding body of literature links shifting conditions in the marine environment to changes in salmon survival and abundance. Potential processes at work to cause these changes include food resource availability, predation, and competition. Density-dependent effects potentially mask or interact with environmental processes. Thus, analyses to quantify effects of changing climatic conditions or ecosystem productivity on salmon populations must simultaneously account for changes in population abundance due to density-dependent processes that may also be operating.

Regime shifts in marine ecosystems such as the Gulf of Alaska are often associated with basin-scale climate variables such as the Pacific Decadal Oscillation, El Nino Southern Oscillation, and North Pacific Gyre Oscillation (Anderson and Piatt 1999; Hallowed et al. 1987; Overland et al. 2008; Suryan et al. 2022). A recent focus has been on what is termed a marine heat wave in the Gulf of Alaska 2014–2016 (peaked in 2015) that declined, then re-intensified in late 2018 and persisted into fall 2019 (Cornwall 2019; Suryan et al. 2022). Initially, the marine heat wave has been called "the Blob" (Bond et al. 2015; Frölicher and Laufkötter 2018). When the marine heat wave resurged in late 2018 and then peaked in summer 2019, it was termed Blob 2.0 (Amaya et al. 2020).

The northern Bering Sea has also experienced un precedented warming events. Farley et al. 2024 examined the impacts of these events on the early marine ecology of juvenile chum salmon over a 17-year period using surface trawl survey data. Findings indicated that warmer sea surface temperatures were associated with increased juvenile salmon biomass but decreased energy density, largely due to a diet shift towards lower-quality prey. The study highlights how warming has altered the nutritional condition of juvenile chum salmon, potentially affecting their survival during winter when energy reserves are crucial. Interestingly, the average sea surface temperature during 2021 declined (became colder) from the recent past and was just slightly above the long-term average and the subsequent energetic condition of juvenile chum salmon was the highest since 2009 (Murphy et al. 2023). The broad geographical scale of the marine heat wave in the eastern North Pacific and including warming events in the northern Bering Sea, could be the cause for synchronous decline in chum salmon abundance in the AYK region and elsewhere, including British Columbia and Asia.

Competition from record high pink salmon abundance in 2018 combined with the effects of the North Pacific heat wave have been implicated in record declines of Pacific salmon abundance and harvest in 2020 (Ruggerone et al. 2021). Pacific salmon harvests (as an index of abundance) declined more in 2020 than in any other period on record since 1930. Pink salmon numerically dominate the abundance of salmon (66%) in the North Pacific with 15% being from salmon released by hatcheries; however, biomass has been dominated by chum salmon (60%) compared to 22% by pink salmon (Ruggerone and Irvine 2018). The potential role of pink salmon interacting with other species likely is through trophic linkages and has been identified before (e.g., Johnson and Schindler 2009; Daly et al. 2019). For example, Batten et al. (2018) reported that pink salmon induce a trophic cascade in plankton populations around the Aleutian Islands, altering dynamics of a wide variety of species including seabirds and salmon (Springer and van Vliet 2014). Connors et al. (2020) presented evidence that abundant salmon competitors (pink salmon) combined with ocean climate changes have strongly reduced sockeye salmon productivity in some regions of the North Pacific. A similar case has been made for pink salmon affecting everything from diatoms to killer whales (*Orcinus orca;* Ruggerone et al. 2023). What might be the role of competitors other than pink salmon on affecting AYK chum salmon such as hatchery origin chum salmon which represent the largest biomass contribution of salmon in the North Pacific Ocean (Ruggerone et al. 2012; Agler et al. 2013; Ruggerone and Irvine 2018) or juvenile walleye pollock (*Gadus chalcogrammus*).

The potential exists that changes in the North Pacific Ocean could promote or enhance the abundance of predators of chum salmon. Sablefish (*Anoplopoma fimbria*) age 1 and older have been observed to eat juvenile salmon (Sturdevant et al. 2009). Of sablefish examined from trawl catches made in June and July, 63% had each consumed one to four juvenile salmon (pink, chum, or sockeye salmon). Suryan et al. (2022) detected an increase in growth rates of sablefish in response to the recent changes in the north Pacific Ocean. Killer whales can have foraging specializations and one form found in coastal waters of the temperate northeast Pacific Ocean, known as the resident ecotype, feeds predominately on salmonid prey (Ford and Ellis 2006). Chinook salmon are selectively fed upon when available, but the whales also feed on chum salmon. Salmon sharks (*Lamna ditropis*) are opportunistic feeders but occupy the highest trophic level in the food web of subarctic waters, with Pacific salmon being a major prey item (Nagasawa 1998). Species of salmon eaten varies by region, but in general sockeye salmon was most frequently fed upon followed by chum salmon. Nagasawa (1998) estimated that 12.6–25.2% of the total annual run of Pacific salmon in 1989 was consumed by salmon sharks and argues that sharks could be a major cause of mortality for Pacific salmon, although actual numbers of sharks are unknown.

3.3.2 Example Questions

1. Are changes in the northeastern Pacific Ocean associated with, and potentially the cause for, synchronous declines in chum salmon abundance in the AYK region? Which ecological processes such as competition or predation could be operative to cause large spatial scale changes in salmon abundance?
2. How will community structure and dynamics of AYK chum salmon, predators, and prey in the Bering Sea and north Pacific ecosystems be affected by the changes in species that are likely to result from ocean heat waves?
3. What processes affect the survival of AYK chum salmon during their first year at sea? How do food availability, temperature, and other variables appear to affect marine survival?
4. How does competition with pink salmon and hatchery origin chum salmon affect returns of chum salmon to the AYK region?
5. Will competitive interactions increase between AYK chum salmon and northward-migrating southern populations of salmon (Asia, Alaska, British Columbia, and US west coast) stocks in the eastern Bering Sea and north Pacific Ocean?
6. Have salmon sharks or other predator abundances increased in recent years in the north Pacific Ocean and consumed a significant proportion of AYK chum salmon?

3.4 Theme 4 – Marine Bycatch and Interception in Coastal Fisheries

Has mortality from marine fisheries increased and contributed to the decline of AYK chum salmon stocks and hindered recovery?

3.4.1 Description

This theme explores whether mortality of salmon resulting from bycatch in federally managed non-salmon fisheries and harvest in state mixed-stock salmon fisheries account for the recent declines or are preventing recovery of AYK stocks. Bycatch (fish that cannot be retained by regulation, known as "prohibited species") and illegal fishing in foreign and domestic ocean fisheries, and harvest in distant state-managed salmon fisheries, cause mortality of chum salmon prior to their return to rivers to spawn.

Evaluation of this theme requires estimates of AYK chum salmon caught in domestic and foreign ocean fisheries apportioned by stock and estimated year-of-return that then would be compared to adult returns to rivers over time. Catch estimates such as these would help determine whether an increasingly large proportion of salmon were caught in non-local fisheries prior to their return to rivers over the last decade.

The 2021 bycatch of chum salmon in the domestic Bering Sea walleye pollock trawl fishery was summarized by Barry et al. (2022). The total chum salmon bycatch in 2021 was 546,043 fish, the second highest bycatch number since 1991 and considerably higher than the 10-year average of 257,023 fish (Barry et al. 2022). Chum salmon bycatch has consistently increased since 2012. The estimated combined proportion of Western Alaska and Upper/Middle Yukon chum salmon within the total 2021 bycatch was 9.4%, similar to the proportion in 2020, but substantially less than the recent (10-year) long-term average of ~20%. The total number of Western Alaska and Upper/Middle Yukon chum salmon caught during the summer (June-October; Bering Sea Pollock B-season) in 2021 was estimated to be 51,510 fish. Despite the large total chum salmon bycatch in 2021, the number of western Alaska fish caught was similar to the long-term average of 49,290 from 2011 to 2020. Fish from Asia were by far the most numerous stocks in bycatch samples (68%), with northeast Asia contributing 55.7% and southeast Asia contributing 11.9%. Not all fish in the bycatch were necessarily returning to spawn in 2021; for example, some age-3 fish would not be returning to spawn until age-4 or age-5 and not contribute to runs during the year they were caught.

Whereas these bycatch estimates do not explain a substantial portion of the recent decline, chum salmon mortality also occurs in marine fisheries other than the domestic pollock fishery, such as in foreign fisheries. Estimates of catch of AYK chum salmon such as by the Russian groundfish fisheries in their territorial waters is unknown as well as as mortality from IUU (Illegal, unreported, unregulated) fishing activity on the high seas. Mortality estimates from these sources would be valuable to obtain to determine the effects of the total bycatch of chum salmon from all marine fisheries, domestic and foreign. To fully evaluate this question, total bycatch estimates, apportioned to the coastal western Alaska stocks, would be needed and then compared to adult returns to rivers. Whether the combined sources of mortality from the total bycatch in all marine fisheries could have contributed significantly and produced the observed declines is unknown.

AYK chum salmon are also harvested in distant mixed-stock salmon fisheries in state waters. For example, the June seine and gillnet fisheries in the South Alaska Peninsula target abundant sockeye salmon mostly bound for Bristol Bay but inadvertently also capture chum salmon co-migrating from the Gulf of Alaska on their return to AYK rivers. While chum salmon are not specifically targeted in these South Alaska Peninsula fisheries, they are vulnerable to being captured. Annual mortality rates of AYK chum salmon within these fisheries are not well estimated because of low genetic differentiation among stocks, limited monitoring of interception rates in state waters, and incomplete monitoring of chum salmon escapements throughout the AYK region. Past studies that have estimated stock composition (e.g., Dann et. al. 2023; Seeb and Crane 1999; Templin et. al. 2012), escapements (e.g., Eggers et al. 2012), and harvest and harvest rate of chum salmon in western Alaska fisheries (e.g., ADF&G 2023; Munro et al. 2012), illustrate some of the challenges. Efforts to improve all three of these dimensions of chum salmon monitoring are needed to both understand the consequences of mixed-stock fisheries for AYK chum salmon stocks, and to develop responsible management strategies.

New methods to identify stock origins of chum salmon harvested in targeted and non-targeted fisheries would provide critical tools to use to provide new information for sustainably managing the harvest on these depleted stocks. Genetic analysis is the most powerful tool for stock discrimination, but unfortunately most populations of chum salmon in western Alaska are impossible to differentiate using current genetic methods. Whole genome sequencing would increase the number of genetic markers used to differentiate stocks by orders of magnitude compared to current approaches, but these methods have not been applied to Alaska salmon. Successful development and implementation of these new tools could have immediate impact on fisheries management, but also provide the means to conserve salmon biodiversity over the long-term.

3.4.2 Example Questions

1. What is the amount of bycatch and incidental catch of AYK chum salmon in all fisheries, domestic and foreign, and has this changed through time? Are variations due to fishery methods, time of year, and area fished?
2. Do catches of chum salmon in domestic and foreign fisheries relate to subsequent inshore run abundance?
3. Has the proportion of AYK chum salmon catch in marine fisheries increased over the past decade and produced detectable changes in stock productivity estimated from inshore returns?
4. What best methods are available to identify stock origins of chum salmon in the AYK region? Would some combination of genetics, isotopes, parasites, or other variables improve resolution of stock identification?
5. What new genetics and genomics tools can be developed to improve genetic resolution of Alaska chum salmon stocks? Would whole genome sequencing of chum salmon from western Alaska lead to discovery of greater resolution in stock assignments?

6. What is the potential vulnerability of weak stocks to ocean fisheries by time of year and fishery location?
7. What are best approaches for quantifying the biological impacts of incidental harvest and bycatch in marine fisheries on stocks of AYK chum salmon that account for uncertainty in data and assessment methods?

3.5 Theme 5 – Changes in Escapement Quality

Have changes in natural or fishing mortality, or other environmental drivers, during freshwater spawning migration of adults altered stocks through natural selection and thus changed the quantity and quality of egg deposition and reduced recruitment in AYK chum salmon stocks?

3.5.1 Description

This theme focuses on the role of genetic selection caused by differential mortality over multiple generations to change the components of age, size, growth, and time to maturity (phenotypic characters). Phenotypic characters are determined both by genetics and the environment. For example, genetics control the potential for growth and the environment provides food that controls the expression of that genetic potential. As the environment changes, vulnerability to mortality can change on different phenotypes and alter natural selection pressures as experienced in the past and hence affect the genetic character of stocks. An example of environmental change, heat stress, is described below.

A mass *en route* mortality event was documented for adult summer chum salmon returning to the Koyukuk River in the Yukon River basin in association with a heatwave and elevated water temperatures during summer 2019 (Westley 2020). The mortality appeared to be size selective affecting more small fish in comparison to individuals that survived. A substantial fraction showed patterns of fungal growth consistent with secondary infections of skin lesions caused by the ubiquitous natural bacterial pathogen *Flavobacterium columnare*.

Disproportionate mortality of small fish could cause genetic selection and produce changes in population fecundity and egg quality. These effects in the short term could affect immediate escapement quality and in the long term could cause changes in the genetic components that affect age, size, migration timing, and time of maturity in salmon. If size- and age-at-maturity are highly heritable, then effects of selection would result in a propensity of stocks to propagate fewer young fish (age-3 and age-4) and more old mature fish (age-5 and age-6) in subsequent generations. Migration timing could also be affected, moving earlier or later than in the past to avoid months where hot weather and warm water may be experienced.

Differential mortality can also be caused by use of fishing gear that selectively causes mortality of certain life stages or sizes of fish. For example, gear that targets age-6 chum salmon could cause a shift in returns of younger adult fish (age-4 and age-5). Concern over the issue of genetic selection has been expressed notably for Chinook salmon (e.g., Hard et al. 2009; Lewis et al. 2015).

3.5.2 Example Questions

1. How frequent or often do *en route* mass mortality events occur in the AYK region? What is their geographic distribution in the different river systems? What fraction of the escapement dies or is physiologically compromised from such events?
2. How do the characteristics of heat stressed dead chum salmon compare to survivors in terms size, age, sex, and stage-of-maturity?
3. What are the past and current patterns of stream temperatures and discharge during spawning migration? Which river and tributary systems would be best to begin long-term temperature and discharge monitoring?
4. Are fishing gears used to catch chum salmon selective in terms of size- and age-at maturity or do they harvest fish proportionally to the total annual return across all size and age classes?
5. How has size- and age-at-maturity and fecundity of returning adults changed among stocks, and drainage areas?

3.6 THEME 6 – Management for Sustainability Under Uncertainty

What management approaches are likely to be most effective considering the high level of uncertainties in our understanding of the causal mechanisms affecting AYK chum salmon abundance and productivity?

3.6.1 Description

Considering that scientific understanding of AYK ecosystems will always be incomplete and a mechanistic understanding of the causes of variation in chum salmon populations is limited, what approaches to management should be taken to maintain sustainable levels of harvest? This theme encourages retrospective and simulation studies that assess the performance of different management and assessment approaches for maintaining productive chum salmon populations under varying levels and different sources of uncertainty.

This research could include development and application of modeling approaches that evaluate risk under different management strategies, address critical data uncertainties, develop alternative schemes for applying adaptive management to AYK chum salmon, and improve forecasting performance for AYK chum salmon returns.

3.6.2 Example Questions

1. What combination of freshwater and marine environmental variables combined with spawning stock size, and juvenile freshwater and marine life phases best predict the next generation of chum salmon returns?
2. Based on retrospective analyses of escapement data, what evidence exists that solely managing to achieve escapement numbers (escapement goal-based management) is an effective strategy to maintain sustainable harvest levels?

3. Would development of watershed habitat models for chum salmon yield new information to provide alternative metrics of habitat capacity and productivity as has been developed for Chinook salmon (Liermann et al. 2010)?
4. Are alternative management strategies possible that could be used to reduce or minimize the potential impacts of industrial-scale marine fisheries on by-catch and ecological processes that support marine growth and survival of AYK chum salmon?
5. Using simulation, what combinations of management approaches (e.g., escapement goals, bycatch control, regulation of hatchery chum salmon releases, predator control) best achieve sustainable chum salmon abundance over the long term?
6. What management strategies appear to be more robust to uncertainty about system dynamics than conventional MSY-related escapement goals, as identified through simulation studies?

4.0 Priorities and Criteria for Evaluating Proposals

The priorities and criteria listed below will be used to develop the AYK SSI's annual "invitation to submit research proposals" and subsequently used to evaluate project proposals. Over time, the integration and synthesis of new information will help to revise existing questions, develop new questions, possibly discard old ideas, and reevaluate and revise research themes. All of the research themes and questions described in Section 3 qualify as important for funding and can be the subject of proposals.

Consideration of completely novel research and monitoring proposals focused on new questions or hypotheses not articulated within Section 3 of this plan can also occur within every funding cycle. Those interested in obtaining funding should review past chum salmon projects funded by AYK SSI (Appendix 2).

4.1 Challenges in Setting Priorities

Program priorities are important to establish so that funds can be directed to those projects that have the highest probability for explaining the "*trends and causes of variation in chum salmon abundance*." Several challenges exist in setting priorities and are as follows (see also Section 1.4).

- **Diverse and large number of themes and questions**. Every question cannot be fully addressed within every funding cycle.
- **Modest funding.** Funding is not available to adequately address all questions.
- **Changing information base.** Over time as the information base about chum salmon grows, some questions will have been answered, others may be discarded as unimportant based on new knowledge.
- **Unknown future information needs.** New hypotheses that affect chum salmon population dynamics may arise, and as a result, priorities must be adaptive over time.

4.2 Criteria Used to Rank Research and Monitoring Projects

The purpose of establishing criteria is to help focus the program's efforts on the most important themes and questions concerning the variability of chum salmon returns to the AYK region. In addition, project proposals should use existing data, when possible, encourage the formation of collaborative opportunities, and maximize the use of AYK SSI funds. The criteria listed below are not mutually exclusive but must be used in combination with each other. Some criteria will not apply to all projects.

- **Goal** – Projects must directly help to address the goal, one or more of the objectives in section 1.1. and identify the applicable theme being addressed.

- **Knowledge Gaps** – Projects must fill clear gaps in knowledge that are unaddressed by other programs and projects.
- **Time Efficient** – Projects must produce results within a reasonable time frame. Retrospective analyses of existing time-series data are especially valuable.
- **Indigenous Knowledge (IK)** – Whenever possible, projects should appropriately incorporate IK via appropriate community engagement and contribute to capacity building. For example, retrospective historical analyses of changes in salmon abundance and their causes would benefit from incorporation of this information.
- **Ecological Processes** – Projects should link ecological processes across a range of spatial and temporal scales that characterize the chum salmon life cycle.
- **Recruitment Variation** – Projects focused on this topic should promote process-based understanding of the causes for changes in population dynamics, explore the use of environmental conditions as causes for variation.
- **Forecasting** – Applicable projects should encourage the development of new methods to forecast future abundance of chum salmon spawning runs and predict the responses of the fishery to regulatory changes.
- **Relevance to Management Under Uncertainty** –Projects focused on this topic should investigate strategies for assessment and management to determine which approaches perform best in light of the uncertainties about AYK chum salmon ecosystems and their responses to changing environmental conditions and management actions.

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Appendix 1: Example projects addressing monitoring aspects of Theme 1 – Population Dynamics of Chum Salmon

- Restart discontinued weir-based stock assessment projects in the Yukon and Kuskokwim rivers such as Tatlawiksuk River and Tuluksak River.
- Establish new sonar-based stock assessment projects. Potential projects include a proposed US Yukon River middle-river sonar project.
- Three-year telemetry-based mark/recapture project to estimate total Kuskokwim River chum run abundance and develop a run reconstruction model.
- Develop new stock assessment method using eDNA to estimate spawner abundance (see AYK SSI currently funded eDNA pilot project; https://www.aykssi.org/project/assessing-kuskokwim-salmon-with-environmental-dna).
- Develop new stock assessment method using drones to provide aerial-based estimates of spawner abundance (e.g., Auerbach and Fremier 2022; Groves et al 2016).
- Develop new escapement/spawner abundance estimation methods.

Appendix 2: Past projects addressing monitoring aspects of Theme 1 – Population Dynamics of Chum Salmon

PROJECT TITLE	LEAD INVESTIGATOR	YEAR	WATERSHED
Abundance, Migration and Survival of Juvenile Chum Salmon, Kwethluk River	Jim Finn	FY06	Kuskokwim River Watershed
Clear Creek chum salmon ecology studies	Christian Zimmerman	FY04	Yukon River Watershed
Distribution of summer chum salmon in the Yukon River drainage	Ted Spencer	FY04	Yukon River Watershed
Estimation of abundance and distribution of chum salmon in the Unalakleet River drainage	Jeffrey Estensen	FY04	Norton Sound Area
Factors Affecting Chum Salmon Growth and Condition	Ed Farley	FY06	Bering Sea-Marine
Fall Chum Salmon Distribution in the Upper Tanana River	Bonnie Borba	FY07	Yukon River Watershed
Retrospective Analysis of Arctic-Yukon-Kuskokwim Chum and Coho Salmon	Greg Ruggerone	FY06	Norton Sound Area
Uncertainty Analysis for Selected Western Alaska Chum Salmon Stocks	Daniel Goodman	FY03	AYK Region-wide