Skagit River Estuary Intensively Monitored Watershed Annual Report for 2019

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Report to:

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1. Funding for the Skagit Intensively Monitored Watershed (IMW) effort is from:
    a. Salmon Recovery Funding Board's IMW Program, administered by the Washington State Recreation and Conservation Office,
    b. Pacific Salmon Treaty Implementation funding administered through the Northwest Indian Fisheries Commission to Skagit River System Cooperative, and
    c. NOAA Fisheries, Northwest Fisheries Science Center
2. Juvenile Chinook outmigration estimates used in the Skagit IMW are from the Washington Department of Fish and Wildlife.

1.0. Skagit Intensively Monitored Watershed (IMW) Summary

1.1. Species of concern

a. What are your focal species and their associated listing status?

Chinook salmon originating from within the Skagit River basin are the focal species of the Skagit IMW (Table 1). Skagit Chinook salmon make up six of the twenty-two independent populations of Chinook salmon within the Puget Sound ESU. Each population is listed as 'threatened' under Endangered Species Act (Federal Register on June 28, 2005; updated and reaffirmed Federal Register on April 14, 2014).

Skagit chum salmon and coho salmon are also expected to benefit from Skagit estuary restoration. Skagit chum salmon and coho salmon area not listed under ESA, however Skagit chum salmon like many other Puget Sound chum stocks are declining and at low abundance. In 2019, we leveraged the long term IMW monitoring to evaluate the causes of Skagit chum salmon declines (see Section 1.3).

Table 1. Independent populations of Chinook salmon within the Skagit River basin (from Ruckelshaus et al. 2006), their adult run timing, and listing status.

Population	Run Timing	ESA Status
Lower Skagit River	Fall	Threatened
Upper Skagit River	Summer	
Upper Cascade River	Spring	
Lower Sauk River	Summer	
Upper Sauk River	Spring	
Suiattle River	Spring	

1.2. Effectiveness

a. What are the limiting factors believed to be in your watershed?

Limiting factors to Skagit Chinook salmon populations were identified assessing juvenile Chinook salmon population dynamics and habitat conditions. Separate studies examined three discrete life stages (egg to fry; freshwater rearing; estuary rearing). The influence of estuary habitat conditions on Skagit Chinook salmon populations were reported in Beamer et al. (2005) and are summarized in the current Skagit IMW Study Plan (Greene et al. 2015). In simplistic terms, Skagit Chinook salmon commonly exhibit extensive estuary rearing. Millions of fish typically out-migrate each year and rear in the tidal channels and marshes of the estuary as fry in late winter or early spring and leave approximately a month later after nearly doubling their length and increasing in weight by 10-fold. Successful estuary rearing likely increases survival to adulthood, because fish can grow quickly and attain a size at the right time of year to move to marine waters of the Salish Sea and capitalize on abundant marine prey. However, the current amount and connectivity of Skagit estuary habitat is limiting the number of Chinook salmon fry that can rear in the estuary. Observations suggests that both estuary residence and individual growth are reduced as available habitats fill up with individuals through the year. In addition, some individuals maybe be displaced into Skagit Bay before they are ready. Collectively, field observations support the conclusion that wild Skagit Chinook salmon populations would benefit from more estuarine habitat and improved connectivity between estuary habitats.

b. How were specific restoration actions tied to limiting factors?

The research findings described above were developed into predictive tools to estimate benefits of potential estuary restoration, thus linking restoration to the quantitative recovery goals for Skagit Chinook salmon. The Skagit Chinook Recovery Plan goal for estuary habitat restoration is to increase juvenile Chinook salmon carrying capacity of the Skagit estuary by 60%, from 2.25 to 3.6 million estuary rearing smolts annually (SRSC and WDFW 2005). As salmon recovery actions are implemented, candidate Skagit estuary restoration action must be vetted through a local (Skagit watershed) and regional (Puget Sound ESU) salmon recovery plan process. Each project must be consistent with the goals of the Skagit Chinook Recovery Plan.

c. Are the findings of this IMW applicable to other watersheds?

The Skagit IMW has broad applicability to other large river estuaries with estuarine-dependent salmon. It focuses on two key recovery questions that are not being addressed by other watershed-scale monitoring projects. Is capacity and connectivity in estuaries limiting Chinook salmon production? Will the habitats and Chinook salmon populations respond to restoration within the estuary?

Specifically, the Skagit IMW effort highlights the importance of life history diversity and estuarine density dependence in regulating juvenile Chinook salmon population dynamics. The findings are most specifically applicable to Salish Sea natal Chinook salmon populations dominated by subyearling migrants and a watershed with an existing (or historical) tidal delta estuary.

1.3. Collaboration and Communication

a. Cite examples of how your program has collaborated with monitoring partners

We use existing Skagit IMW data to plan for Skagit Chinook salmon future restoration actions or as baseline information to assess effectiveness of completed restoration projects. We also use Skagit IMW data, collection methods, and/or analysis approach to assist other Puget Sound watersheds to measure juvenile Chinook salmon population dynamics and communicate the importance of estuarine habitats to Chinook salmon. Specifically, in 2019 we were involved with three different projects related to the Skagit IMW or its data. A synopsis of each project, and its connection to the Skagit IMW, is provided below.

First, SRSC, in collaboration with Skagit co-managers and funded through a Seattle City Light mitigation program, conducted a retrospective analysis of Skagit River chum salmon population dynamics to assess drivers to observed population trends. Since 2004, the returning abundances of adult Skagit River chum salmon have declined to concerning levels. We utilized IMW beach seine data, along with smolt trap abundances and spawn ground survey data to develop the first multi-stage model for natural origin chum salmon within the Puget Sound. Our findings suggest that Skagit River chum salmon population trends are driven by marine survival rather than freshwater productivity. Given the data, it is difficult to partition if estuary survival or ocean survival is more significant and we are working on strategies to elucidate this further in the future. These results and development of a modeling framework for Skagit River chum salmon will allow for more detailed investigations in the future. This work has been presented at the Seattle City Light Nonflow Coordination Committee and Swinomish Tribe and Sauk-Suaittle Tribe. Final Report (Ruff et al. *in prep*), will be available early in 2020.

Second, IMW PI's have finalized a report entitled "Density-dependent habitat limitations for juvenile Chinook salmon in four large river deltas of Puget Sound, WA" (Appenidx 1). IMW PI's used a cross-system approach to evaluate generalities of tidal wetland habitat loss and its contribution to negative density-dependence. All systems approached predicted carrying-capacity some of the time each year, yet timing and frequency of these exceedances varied between systems and were associated with hatchery releases. Results suggest that tidal wetlands are constraining Chinook salmon recovery and these constraints depend on the system's outmigration time, hatchery operation and available habitat.

Third, IMW beach seine densities have consistently differed between index and random sites where random sites have lower estimated densities than index sites (see Section 3.0). In 2019, we began assessing if catchability might influence beach seine catches. Catchability can be described by detection efficiency through multiple sets in a depletion framework, or by individual recapture efficiency in a Mark/Recapture framework, or by imperfect detection estimates within an occupancy modeling framework. We began to assess if imperfect detection exists using historical IMW data and developed a manuscript detailing differences in imperfect detection across common species (Appendix 1). This manuscript highlights that when assessing nearshore fish community structure imperfect detection is important. Through the initial imperfect detection assessments early in 2019, we also included one additional beach seine set to both index sites (3 sets) and random sites (2 sets) in 2019 to improve estimates of imperfect detection specifically for juvenile Chinook salmon. Our goal is to better understand the differences in juvenile Chinook salmon densities between index sites and random sites. Our initial findings suggest that index sites had higher probability of detection than random sites. In 2019, we found that beach seine snags occurred more often at random sites than index sites.

b. List reports and other technical products

Annual reports and study plan updates can be found on SRSC's website (http://skagitcoop.org/documents/). Skagit IMW annual reports typically highlight products completed each year related to the Skagit IMW. For 2019, these products are described in the section immediately above (3. Collaboration and Communication).

Skagit IMW results are presented on a regular basis to local and regional audiences. Locally, presentations are provided to salmon recovery stakeholders and co-managers, usually through a Skagit Watershed Council venue. Regionally, presentation are made at the Salish Sea Conference (e.g., https://wp.wwu.edu/salishseaconference/), Washington's Salmon Recovery Conference (e.g., https://rco.wa.gov/salmon-recovery/salmon-recovery-conference/), and AFS Chapter meetings.

1.4. Adaptive Management

a. Please identify any specific changes made over the reporting period.

Methods/analysis

No changes were made to our field sampling methodology in 2018.

In 2018, we implemented a change in the statistical approach to obtain annual summaries of seasonal juvenile Chinook salmon abundance from surface trawl data. The methodology employed a space-time model (Lindgren and Rue 2015) to account for spatial and temporal autocorrelation. The method was applied to all survey years and continued in 2019. See report section 3.1 (Surface trawling) for details.

Data management

We've continued the real time data entry system discussed in the 2017 annual report. These data management improvements shorten times to when data are available for reporting and analyses, allow for efficient data entry, as well as improved data security.

We have not yet implemented a query system to rapidly calculate summary annual IMW metrics from accumulated data from the three PI organizations (SRSC's fyke trap and beach seine monitoring, WDFW's outmigrant monitoring, and NWFSC surface trawling efforts). We delayed this action because of necessary software updates to keep our current real time data entry system operational. These software updates were associated web-based systems so we were keeping congruent with web standards (i.e. https and service workers updates). Through this process we discovered a few issues within SRSC's database and resolved those issues. Because of this we plan to move toward data integration in 2020.

b. What challenges have you encountered in implementing your monitoring program?

Pace and extent of restoration treatments

There are no new challenges to the pace and extent of restoration identified in 2019. Our thoughts on how to address the existing challenges remain the same as articulated in the 2017 annual report.

Monitoring distributary channel depth

There are no new challenges to monitoring the new North Fork distributary channel identified in 2019. Our thoughts on how to address the existing challenges remain the same as articulated in the 2017 annual report. Monitoring changes in distributary channel planform and extent is part of SRSC's Habitat Status and Trends Program and a contribution to the Skagit IMW.

Staff

SRSC: 2019 was the first full year of the three new staff supporting the Skagit IMW workplan. Mike LeMoine supervised staff, proposed funding proposals (PMEP, Community Change Assessment), and evaluated current IMW methods. Brian Henrichs and Neal Robertson were trained on broader field methods and logistics associated with the project. In addition, Mike started a program to allow college interns from Bellingham Technical College, Skagit Valley College, University of Washington and Western Washington University. Intern program not only provided a more flexible field staff pool for IMW workplan, but an opportunity for community outreach and education.

NOAA: Surface trawling requires 5-8 crew each day of sampling, including operators of two vessels. Due to competing field projects, it was challenging to find staff to operate the skiff, resulting in 3 months in which the number of days of sampling were reduced to just 2 days. Without dedicated funding or a skiff operator, we foresee that it will be difficult to maintain three days of sampling each month.

Funding

Fully funding all aspects of the Skagit IMW continues to be challenging. Here we describe the status of funding for data collection/management and analyses/manuscripts.

Data collection & management: Data collection and data management are the only components of the Skagit IMW that are funded by IMW. For data collections, additional resources to support the Skagit IMW are provided SRSC and NOAA. With the new data management system of 2016 - 2019, annual data collection and storage is financially solvent at existing funding levels (i.e., IMW, SRSC, and NOAA funding combined). Also, the Skagit IMW would not be possible without WDFW's Skagit River juvenile salmon outmigration trapping effort which is supported by non-IMW funding.

Analyses & manuscripts: Currently, conducting analyses and preparing manuscript are not directly supported by IMW funding and were underfunded by SRSC and NOAA in 2019. To help secure additional funding for these tasks, the Skagit IMW PIs submitted proposals to various funding opportunities in 2018. Two proposals were awarded in 2019 and have recently been contracted making funds available for 2020 and 2021. Specifically:

- NOAA and SRSC were awarded an ESRP learning objective grant (ESRP Project #D18-06) to evaluate the effects of estuary restoration on Chinook salmon population dynamics across Puget Sound including specific tasks to analyze Skagit IMW data. This project is of direct relevance to the question of whether estuary restoration is having universal effects on Chinook populations across Puget Sound. The Skagit IMW results will be one important component of ESRP LO award, and funding was budgeted to produce a publication on the Skagit IMW.

- SRSC secured funds from the Puget Sound National Estuary Program for Near-term Action (NTA) titled: Status and trends of Skagit Chinook salmon abundance, life history diversity, and productivity in response to recovery plan actions and environmental variability (NTA 2018-0697). This NTA will compile: 1) existing life stage specific Skagit Chinook data with habitat status and trends data and 2) develop an analytical framework to isolate the effects of human actions and environmental variability on the status of Skagit Chinook. The NTA funding supports analyses for the Skagit IMW but also expands the effort to include the influence of freshwater restoration on Chinook recovery within the Skagit River.

In addition, SRSC has submitted funding proposals to further evaluate fish community changes from 25 years of estuary and delta monitoring which we intend to use to further refine beach seine methodology issues of catchability and imperfect detection within an occupancy modeling framework (see previous section 1.3 on collaboration).

Future Direction

We recommend the Skagit IMW continue according to its fundamental study design with continued:

1. Annual monitoring at local scale (restoration project) and population scale (Skagit estuary) of juvenile fish, including metrics for abundance, timing, and body size. Fish monitoring should include specifically designed elements for sub-system level treatment effects (see Tables 2 and 3).
2. Update estuary habitat conditions and connectivity as necessary. Restoration is ongoing in the Skagit estuary. Changes to habitat conditions should be measured post restoration projects. Natural changes to the estuary should be updated approximately every five years.

c. How will the findings of this IMW inform future salmon recovery

The Skagit IMW has broad applicability to other large river estuaries with estuarine-dependent salmon. Its findings are most specifically applicable to Salish Sea natal Chinook salmon populations dominated by subyearling migrants and a watershed with an existing (or historical) tidal delta estuary.

Specifically, Skagit IMW results inform the local (Skagit watershed) and regional (Puget Sound) Chinook salmon monitoring and adaptive management process overseen by co-managers, lead entities, and the Puget Sound Partnership. More generally, Skagit IMW results inform Puget Sound Chinook recovery efforts. A good example is the recent ESRP report (i.e., Greene et al. in review) where guidance on when large scale restoration of system carrying capacity is merited based on juvenile Chinook salmon population dynamics standardized for any Puget Sound watershed with a natal Chinook salmon rearing in the estuary.

2.0. Skagit IMW hypotheses and results

2.1. Objectives and hypotheses of the monitoring effort

Given the reliance of juvenile subyearling Chinook salmon on estuary habitat and the amount of historical habitat loss, we would expect estuary restoration to benefit Skagit River Chinook populations following the schematic shown in Table 2.

Table 2: Skagit IMW project goals, actions, and indicators measured.

Goal	Objective/Action	Indictor
Increase juvenile Chinook salmon carrying capacity of the Skagit estuary by 60%, from 2.25 to 3.6 million estuary rearing smolts annually	1) Restore approximately 2,700 acres of historic Skagit estuary to tidal inundation 2) Provide fish access to restored and existing estuary habitats	1a) Estuary habitat extent by habitat types (channels, wetlands, etc) 2a) Juvenile Chinook salmon abundance, timing, and body size 2b) Factors or covariates matched with fish observations for landscape attributes (connectivity, habitat type) and local environment (temperature, salinity, DO)

Our study plan (Greene et al. 2015) details the hypotheses, restoration projects, methodologies, and results of the Skagit system-wide monitoring. In doing so, we address how our methodologies are answering two general questions relevant to monitoring the population response of Chinook salmon to estuary restoration:

1) do Chinook salmon exhibit limitations during estuarine life stages related to capacity and connectivity, and
2) has estuary restoration resulted in population- or system-level responses?

Specifically, we use:

- BACI (Before-After-Control-Impact) design to test for significant effects of estuary restoration actions upon the Chinook salmon population within the Skagit estuary. North Fork data are used as the control while restoration occurs in other areas of the estuary (Table 3).
- BA (Before-After) designs to test for benefits of estuary restoration in the nearshore (the life stage following estuary rearing).

An additional question – do restoration projects increase utilization of estuary habitat by juvenile salmon – is encompassed in project effectiveness monitoring at smaller spatial scales. Effectiveness monitoring is not funded through the Skagit IMW and depends upon funding within restoration project budgets. Monitoring is ongoing since 1994; restoration treatments began in 2001 and continue through present.

Table 3. Proposed schedule for each testable hypothesis.

Sub-delta polygon #, name	Juvenile Chinook response post-restoration	Analysis and report
#1 Swinomish Channel Corridor	Overall increase in average densities and between-site densities become less variable due to increased connectivity with the North Fork Population increases due to increased capacity along the Swinomish Channel Corridor	BACI design underway with index sites being sampled since 2004. The post treatment period is expected to start within 5 years (McGlinn Island Causeway, see Table 5). Ongoing analyses. Existing restoration within this area is part of the system level response. New restoration at Smokehouse Floodplain is likely within 5 years (Table 5)
#2 North Fork Delta	Overall decrease in average densities and between-site densities become less variable due to increased connectivity to other areas within the delta Population increases due to increased capacity within the North Fork Delta	Ongoing BACI with the South Fork. Analyses shown in Figure 5 can be updated periodically. New BACI with the Swinomish Channel Corridor within 5 years (McGlinn Island Causeway, see Table 5). Ongoing analyses. No restoration is expected within the North Fork within 5 years.
#3 Central Fir Island Delta	Overall increase in average densities and between-site densities become less variable due to increased connectivity via a cross island corridor restoration project Population increases due to restored capacity within Central Fir Island	No cross island connectivity restoration expected within 5 years. Ongoing analyses. The Fir Island Farm project adds to the system level response starting in 2017
#4 South Fork Delta	Density remains the same but between-site densities become less variable due to increased connectivity within the South Fork Delta Population increases due to increased capacity within the South Fork Delta	Ongoing BACI with the South Fork until new BACI with the Swinomish Channel Corridor expected to begin within 5 years Ongoing analyses. Existing and near future restoration (Deepwater Phase 2, Milltown) within this area is part of the system level response (Table 5).
#5 Stanwood/English Boom Delta Fringe	Density and population increases due to increased source population increase originating from Stillaguamish and Skagit Rivers	No analysis planned, but restoration in the the nearby Stillaguamish delta (Zis a ba and Leque) is expected to benefit the numerous outmigrating Skagit fish in addition to Stillaguamish origin fish

2.2. Key findings to date

The key findings to date remain the same as articulated in the 2017 annual report and are repeated below.

Restoration accomplishments and habitat response

Overall, the Skagit estuary is gaining more habitat than it is losing with habitat restoration being the most important reason for these gains. Direct human causes of lost estuary extent have been minor. Natural gains and losses of estuary habitat have also been documented, with a net loss observed. The largest area of loss is along the bay front of Fir Island where the estuary is sheltered from river sediment deposition and more exposed to wave caused erosion. Starting in 2000, there has been a systematic effort to restore estuary habitat, resulting in eight completed projects and 653 acres of habitat restored to tidal inundation. Within the next five years, four additional restoration projects are anticipated to be completed, totaling 398 acres. Details of completed and planned restoration are found in section 3.2 of this report.

Chinook salmon response

Chinook salmon responses to Skagit estuary restoration were last described in detail in the 2016 annual report (Greene et al. 2016). General results have not changed and are reiterated below.

Local level (restoration project): Overall, Skagit estuary restoration is working to the benefit of juvenile Chinook salmon but there are some caveats. Below is a synopsis of our findings:

- *If you build it, they will come*! We found all monitored projects in all years after restoration to have juvenile Chinook salmon using the restored habitat. What is the reason for this result? The Skagit River produces ample numbers of out-migrating Chinook salmon fry (millions), but has limited estuarine habitat to support them. Thus, it stands to reason that fish would immediately take advantage of newly restored habitat.
- *Some restoration designs work better than others.* Generally, restoration projects that have muted hydrology or have limited connectivity to adjacent river channels (and the source of fish that colonize restored habitat) perform poorer than projects with higher connectivity. This is an important message to convey to restoration project designers and funders because Chinook recovery actions need to maximize full efficiency from every restoration opportunity if society is to achieve salmon recovery goals.

Population level:

The two well supported findings from BACI and full system analyses are: a) juvenile Chinook salmon become less crowded in the estuary as restoration increased habitat opportunity, and b) the length of fish residence in the estuary increased as restoration increased. Less supported but encouraging results from full system analyses suggests: c) reduced frequency of fry migrants in marine habitats and d) higher smolt-adult return (SAR) rates as restored area increased. Detecting future changes to the fry migrant and SAR metrics might be expected to require years of high abundance when the benefits of restoration are most fully realized and/or a larger restoration treatment effect. Alternately, scenario testing using various life cycle modeling techniques may be able to test the consequences of cumulative restoration when large out-migrations have occurred. These efforts are currently under development.

3.0. Skagit IMW Updates for 2019

3.1. Data collection in 2019

We collect data in 2019 per our study plan (Greene et al 2015), which is summarized by method and lead entity in Table 4. We report 2019 results below by sampling method.

Table 4. Current monitoring programs for assessing effects of restoration in the Skagit River estuary.

Method	Lead entity	Habitat	Sampling regime	Sites (N)	Years (N)
Outmigrant trapping	WDFW	Mainstem	Daily, Feb-Jul	1	26
Fyke trapping*	SRSC	Tidal delta & Swinomish Channel	Biweekly, Feb-July; monthly in August	10	27
Beach seining*	SRSC	Skagit Bay shore & Swinomish Channel	Biweekly, Feb-Aug; monthly, Sept-Oct	128	25
Kodiak trawling*	NWFSC	Skagit Bay neritic	Monthly, Apr-Oct	60	19

* Partially supported by SRFB/IMW funding.

Outmigrant trapping.

Juvenile Chinook salmon outmigration estimates in the Skagit IMW are from the Joseph Anderson and Clayton Kinsel of Washington Department of Fish and Wildlife. Skagit River outmigrant trapping is funded separately from the Skagit IMW, but its results are critical to Skagit IMW analyses.

WDFW analysis of 2019 outmigrant data and estimate the natural origin subyearling Chinook salmon outmigration population size of 1,801,632 (CV = 13.88%) fish. The life history type fractions of the subyearling outmigration are 72.4% fry and 27.6% parr. The total subyearling Chinook salmon outmigration in 2019 is approximately 1.65 million fewer fish than the overall average outmigration of 3,455,290 fish for the 26-year period of record.

Fyke trapping.

SRSC completed 129 fyke trap sets at 10 index sites and caught total of 3,223 unmarked juvenile Chinook salmon in the Skagit tidal delta over the time period: February 25 to August 17, 2019 (Figure 1). SRSC completed mark and recapture trials at fyke trap sites. The purpose of the mark and recapture trials is to estimate trap efficiency which is used in calculations of fish density. Trap efficiency regression models for 2019 index sites have been updated so standardized unmarked juvenile Chinook salmon density results are available for 2019.

In 2019 unmarked juvenile Chinook salmon were present February – July, but not in August, displaying a sharp peak April of over 8,000 fish per hectare of blind tidal channel (Figure 1). By July, subyearling Chinook salmon densities in tidal delta habitat were low, averaging only 193 fish per hectare. Geometric mean annual density in 2019 was fifth lowest of the 27-year record with 53.4 fish/hectare compared to an overall average of 249 fish/hectare (Figure 2).

Beach seining.

SRSC completed 607 beach seine sets at 108 sites (random and index) and caught total of 1,409 unmarked juvenile Chinook salmon in Skagit Bay nearshore habitat over the time period: February 19 to October 8, 2019. In 2019, unmarked juvenile Chinook salmon were present throughout the sampling period (February – October) with a peak from May through June (Figure 3). Geometric mean annual density of unmarked juvenile Chinook salmon density in nearshore habitat (index sites) in 2019 was about two-thirds of the 25-year average (4.1 compared to 5.5 fish/hectare) for index sites (Figure 4). Random site data collection was initiated in 2006. On average, geometric mean annual densities track each other temporally, but random sites are about 0.5 fish/hectare lower than index sites. Even with the two outlier years (2012 and 2013), a positive correlation was observed between the random site density and the index site density (all years: $R^2 = 0.46$, $P = 0.007$; without 2012 & 2013: $R^2 = 0.86$, $P < 0.0001$).

Random and index beach seine estimates of unmarked juvenile Chinook salmon densities have been consistently different since 2006 with some years having more divergent density estimates. In 2019, we began to evaluate potential explanations for the difference between index and random beach seine unmarked juvenile Chinook salmon densities. These efforts have resulted in a draft manuscript on imperfect detection of common nearshore species (Appendix 1) and continued evaluation of unmarked juvenile Chinook salmon densities estimates based on current IMW methods (described earlier - (see section 1.3. Collaboration and Communication)

Surface trawling.

NWFSC completed 123 sets at 60 sites (random and index), and caught total of 383 unmarked juvenile Chinook salmon in Skagit Bay neritic habitat (subtidal surface of water column) over the time period of April 15 to September 5, 2019. Unmarked juvenile Chinook exhibited fairly typical densities compared to the annual average pattern of abundance for most of the season (Figure 5). However, they displayed a less protracted timing: much higher in abundance in July, and lower in abundance in August. Geometric mean annual density of unmarked juvenile Chinook density in neritic habitat in 2019 nearly matched the 19-year average (gray lines in Fig. 6) and continued a pattern of near-normal levels after a five-year decline from the highest observed annual density in 2012 (which was also the most poorly sampled year).

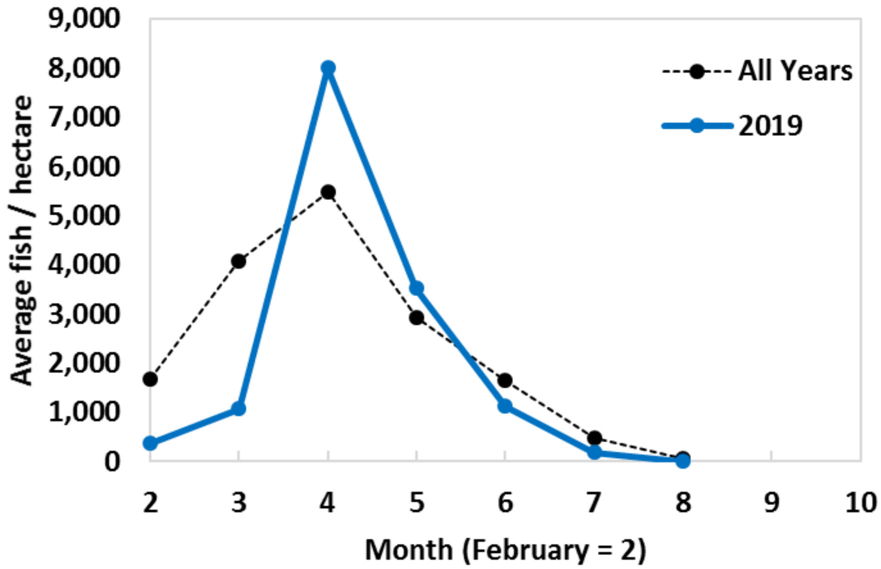

Figure 1. Seasonal density of unmarked juvenile Chinook salmon by Index fyke traps in the Skagit tidal delta, 2019 (solid line) compared to the average of all years combined (dashed line).

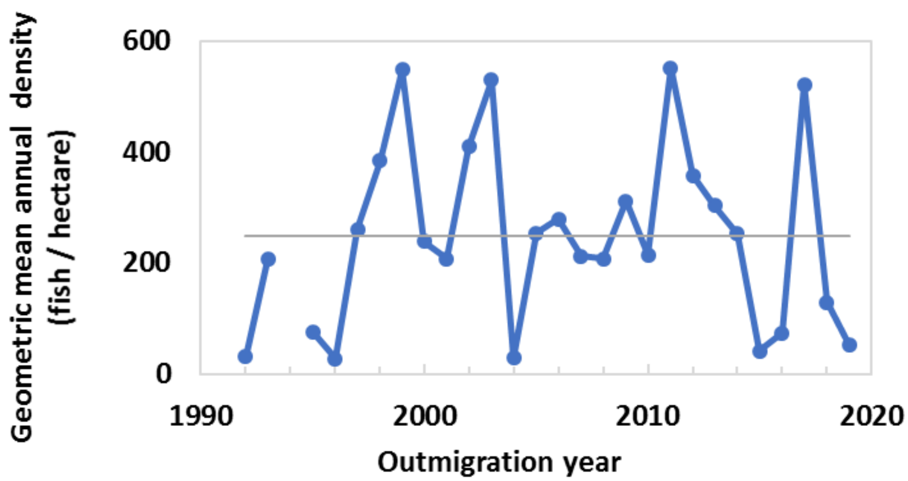

Figure 2. Unmarked juvenile Chinook salmon density trend over time from Index fyke traps in the Skagit tidal delta. Note: there are no results for Index fyke traps in 1994. The average for the entire time period is shown as the horizontal gray line.

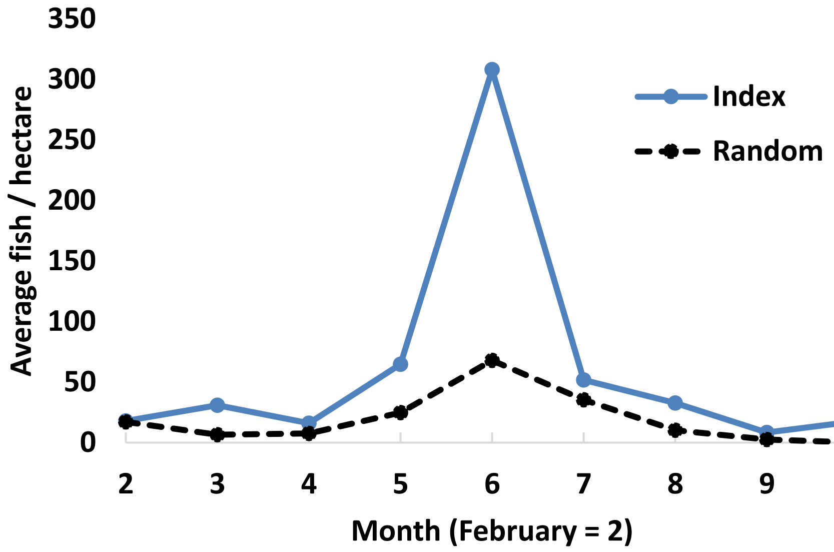

Figure 3. Seasonal density of unmarked juvenile Chinook salmon by large net beach seine in the Skagit Bay, 2019.

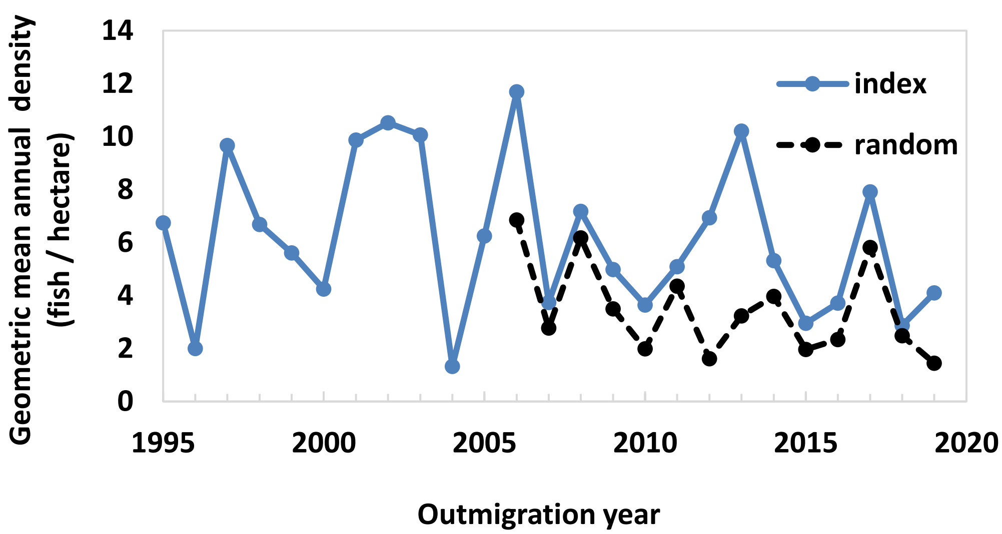

Figure 4. Unmarked juvenile Chinook salmon density trend over time from large net beach seine in the Skagit Bay.

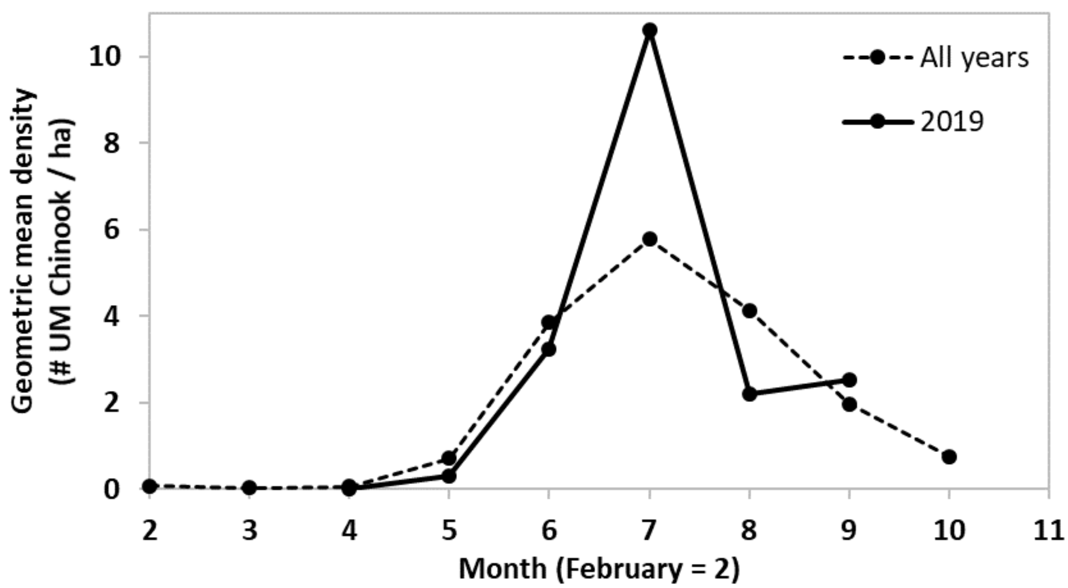

Figure 5. Geometric mean density of unmarked (presumed wild) juvenile Chinook salmon captured in neritic waters of Skagit Bay in 2019 (solid line) compared to the average of all years combined (dashed line). Sampling in 2019 occurred monthly from April to September.

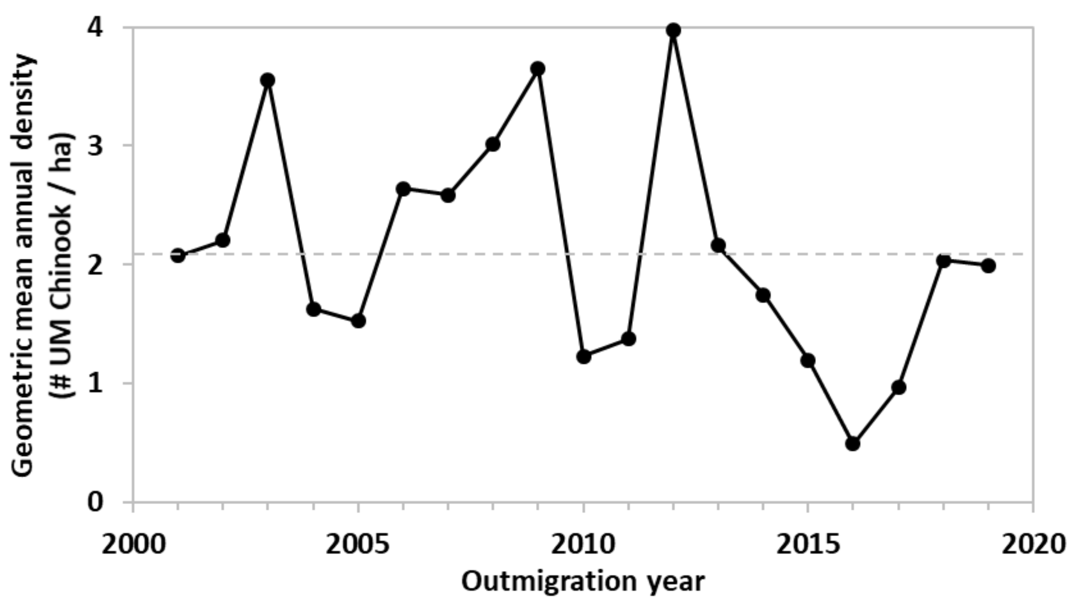

Figure 6. Geometric mean annual density of unmarked (presumed wild) juvenile Chinook salmon captured in neritic waters of Skagit Bay from 2001-2019 across all sites. Averages for the entire time period are shown as a horizontal gray dashed line.

3.2. Skagit estuary habitat change

Estuary habitat change presented in this section are not measured as part of the IMW study, but are provided by SRSC's Habitat Status and Trends program or from individual effectiveness monitoring projects.

Skagit estuary habitat change results remain the same as articulated in the 2017 annual report and are repeated below.

Overall estuary habitat changes 2004-2013

Beamer and Wolf (2017) quantified the net change in the Skagit estuary's tidally inundated footprint between 2004 and 2013. They found human and natural causes of habitat change with restoration outpacing both natural and human causes of lost estuary habitat. The fundamental estuary restoration hypothesis of the Skagit Chinook Recovery Plan was positive actions can protect and restore the tidal delta. Overall, the Skagit estuary has gained habitat and completed restoration projects have been the primary reason for the net increase. Direct human causes of lost estuary habitat were found to be minor.

However, natural changes (progradation and erosion) in Skagit estuary habitat were also observed and resulted in a net loss in tidal delta extent, primarily along the Skagit bay front, further supporting SRSC observations that sea level rise is offsetting the delta's natural habitat formation processes (Hood et al. 2016). In addition, human-caused changes to sediment routing within the delta may inhibit habitat formation by creating areas that are sheltered from sediment supply but not from sea level rise or wind wave intensity (Hood et al. 2016).

While restoration efforts have been responsible for the net increase in Skagit tidal delta extent, the current pace of restoration will not achieve the Skagit Chinook Recovery Plan's desired future condition (DFC) for estuary habitat extent until 80-90 years from now. Moreover, assuming natural losses of estuary habitat continues, additional restoration will be needed to offset the chronic natural loss of marsh. Thus, we recommend increasing the current pace and magnitude of tidal delta restoration to: (a) realistically achieve DFC near the midpoint of a 50-year recovery plan implementation period; and (b) maintain DFC over time.

Status of individual restoration projects

Restoration implementation in the estuary has been within the context of the described Chinook salmon recovery actions that include habitat protection and restoration in tributary, floodplain, and nearshore habitats. The Skagit IMW Project does not monitor the response of Chinook salmon to restoration projects occurring within freshwater habitats located upstream of the estuary, but it does account for their influence and natural environmental variation (e.g., floods) that influence juvenile Chinook salmon migrants. This is done by maintaining the downstream migrant trap, which measures migrant population abundance, timing, and body size by life history type.

Estuary restoration includes improvements to capacity (amount of rearing habitat), connectivity (connection among rearing areas), or both. Starting in 2000, there has been a systematic effort to restore estuary habitat (Table 5). The restoration efforts resulted in eight completed projects and 653 acres of habitat restored to tidal inundation. These projects have been the collective work of Swinomish Indian Tribal Community (SITC), Skagit River System Cooperative (SRSC), Washington Department of Fish and Wildlife (WDFW), Skagit County, The Nature Conservancy (TNC), and the Army Corps of Engineers (ACOE). Four projects have been built on WDFW property, two on the Swinomish Reservation, and one each on Skagit County and private lands.

Within the next five years, four additional restoration projects are anticipated to be completed, totaling 398 acres. The updated results in Table 5 for near-term unbuilt restoration projects are based on communications with staff from SRSC Restoration Department, WDFW, Skagit Watershed Council. Some specific details about each project are following:

- **Cottonwood Island**: The Cottonwood Island project is no longer considered a project that would be built within 5 years and we removed it from Table 5.
- **Milltown Island**: Additional restoration is likely at Milltown Island, possibly as early as 2021. WDFW has completed a feasibility analysis of alternatives and now has funding in hand to complete design and permitting, which is scheduled to be completed by June 2021.
- **Smokehouse Dike Setback**: A large dike setback project of approximately 120 acres is planned as another phase of restoration at Smokehouse Floodplain, possibly as early as 2022. SRSC and the Swinomish Tribal Community secured SRFB design funding for design work which could be completed in 2020. Implementation funding and permitting would be pursued starting late 2019 and with luck fulfilled in time for a 2022 construction season. Restoration effectiveness monitoring funding has been secured for the pre-restoration phase of a BACI monitoring design through BIA.
- **Deepwater Slough Phase 2**: Several restoration alternatives are currently being assessed, including no restoration, partial restoration and full restoration of the 268-acre Deepwater/Island Unit site. If a partial or full restoration alternative is selected, the project could be constructed as early as 2023.
- **McGlinn Island Causeway**: Progress on the McGlinn Island Causeway project is languishing over complex political issues, but it still could happen within five years. The McGlinn project has a 30% design and publications speaking to its likely impacts to the Swinomish Channel. For this project to move ahead to construction requires a high-level dialog with ACOE decision-makers and political support for Congressional authorization for maintenance-dredging Swinomish Channel in concert with funding the design (or some modified version) that is already available for discussion. Conceivably, the restoration design could be offered as mitigation for the on-going maintenance-dredging for the channel. This project has widespread local support and it is included in the

PSNERP authorization package. The decision whether it moves ahead are vested with the ACOE and Congressional delegation.

Table 5. Restoration projects completed or planned in the Skagit River estuary, dates, benefit to salmon, and their acreage (area exposed to tidal inundation after restoration). Monitoring designs are: PT = post treatment design; BACI = before/after control impact design. Note: some acreage results have changed from previous versions of the table. Where updated, the new acreage results are from Beamer and Wolf (2017).

Site	Year of completion	Benefit to salmon (connectivity, capacity, or both)	Area of estuary	Acres	Effectiveness monitoring design and years monitored
Deepwater Slough	2000	Both	South Fork	221	PT, 2001-2003
Smokehouse Floodplain	2005-8	Capacity	Swinomish Channel	67	BACI, 2004-2011
Milltown Island	2006-7	Capacity	South Fork	0*	PT, 2012-2013
South Fork Dike Setback	2007	Capacity	South Fork	21	PT, 2012, 2014
Swinomish Ch Fill Removal	2008	Capacity	Swinomish Channel	8	PT, 2009-2013
Wiley Slough	2009	Capacity	South Fork	160	Partial BACI, 2003, 2012-2013
Fisher Slough	2010-11	Capacity	South Fork	46	BACI, 2009-2013 & 2015
Fir Island Farms	2016	Capacity	Central Fir Island	130	BACI, 2015-2018
Milltown Island Phase 2	<5 years	Capacity	South Fork	0*	Not designed
Smokehouse Floodplain dike setback	<5 years	Capacity	Swinomish Channel	120	Planned BACI, 2005-present
Deepwater Phase II	<5 years	Capacity	South Fork	268	Not designed
McGlinn Island Causeway	<5 years	Connectivity	North Fork-Swinomish Channel	10	Planned BACI, 2005-present
TOTAL				**1051**	

* Milltown Island restoration did not significantly change the Skagit estuary's tidal footprint. Restoration at Milltown improves connectivity to existing channels over its 212 acre area.

3.3. Juvenile Chinook salmon response to estuary restoration

Project effectiveness monitoring

SRSC has monitored juvenile Chinook response at all eight built estuary restoration projects (Table 5). The most recently built restoration project is Fir Island Farms (FIF) on WDFW property. FIF restoration was completed in the summer of 2016 restoring 131 acres of habitat to tidal inundation along the bay front of Fir Island within the Skagit tidal delta. FIF was monitored under a BACI design for four years with the technical report completed in 2018 (Beamer et al 2018, abstract provided in Appendix 1). Habitat and fish use monitoring of FIF restored area and reference sites were completed for two years pre- (2015 and 2016) and post-restoration (2017 and 2018). After restoration, in 2017 and 2018, juvenile salmon and estuarine fish species catches increased upstream of the removed tide gate, while three-spine stickleback catches declined. Prior to restoration in years 2015 and 2016, wild juvenile Chinook abundance for 'inside' habitat of Fir Island Farms was estimated at 118 and 566 fish per year. Following restoration, total annual Chinook abundance for the 'inside' habitat areas was estimated at 50,522 and 11,124 fish in 2017 and 2018, respectively.

Population level response

No population level analyses were updated in 2019. Population response analyses will be updated in 2020 and 2021 through recent ESRP and NTA funding. (see report sections 1.3a and 1.4b regarding funding challenges and opportunities). Existing population level findings are summarized above in section 2.2 of this report.

References

Beamer, E. M., A. McBride, C. M. Greene, R. Henderson, G. M. Hood, K. Wolf, K. Larsen, C. Rice, and K. L. Fresh. 2005. Skagit River Chinook recovery plan, appendix D: delta and nearshore restoration for the recovery of wild Skagit River Chinook Salmon: linking estuary restoration to wild Chinook Salmon populations. Available: http://skagitcoop.org/wp-content/uploads/Appendix-D-Estuary1.pdf

Beamer, E. and K. Wolf. 2016. The influence of a naturally formed distributary channel on the distribution of juvenile Chinook salmon within the Skagit tidal delta. Report to the NOAA/WRCO SRFB Skagit HDM Project under agreement P104051-A102542-n/a. Skagit River System Cooperative, La Conner, WA 98257. Available: http://skagitcoop.org/wp-content/uploads/Beamer-and-Wolf_Dec2016_Final.pdf

Beamer, E. and K. Wolf. 2017. Skagit Chinook Habitat Monitoring Fact Sheet: Change in Tidal Delta Habitat Extent, 2004 – 2013. Skagit River System Cooperative, La Conner, WA. Available: http://skagitcoop.org/wp-content/uploads/EB3001_Beamer-Wolf_2017.pdf

Greene, C., E. Beamer, and J. Anderson. 2015. Study plan and summary of results for the Skagit River Estuary Intensively Monitored Watershed project. National Marine Fisheries Service, Northwest Fisheries Science Center, Report to Washington State Salmon Recovery Funding Board Monitoring Review Panel, Seattle.

Greene, C., E. Beamer, and J. Anderson. 2016. Skagit River Estuary Intensively Monitored Watershed Annual Report. NOAA Northwest Fisheries Science Center, Seattle.

Greene C., E. Beamer, Chamberlin, R. Henderson, J. Hall, K. Larsen, J. Anderson, M. Pouley, T. Zackey, E. Brown, M. Davis, S. Hodgson, C. Ellings, and I. Woo. In review. Landscape, density-dependent, and bioenergetic influences upon Chinook salmon in tidal delta habitats: Comparison of four Puget Sound estuaries. Report to ESRP under agreement 13-1508P.

Hood, W. G., E.E. Grossman, and C. Veldhuisen. 2016. Assessing tidal marsh vulnerability to sea-level rise in the Skagit Delta. Northwest Science, 90: 79-93.

Lindgren, F., and H. Rue. 2015. Bayesian spatial modelling with R-INLA. Journal of Statistical Software, 63.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78, 125 p.

Salmon Recovery Funding Board Monitoring Panel. 2017. Monitoring Program Annual Review: 2017 Recommendations. Report to Washington State Salmon Recovery Funding Board.

Skagit River System Cooperative and Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. Skagit River System Cooperative, La Conner, WA. Available: http://skagitcoop.org/wp-content/uploads/Skagit-Chinook-Plan-13.pdf

Appendix 1. Skagit IMW related reports or manuscripts completed in 2019.

A.1.1. Density-dependent habitat limitations for juvenile Chinook salmon in four large river deltas of Puget Sound, WA

Correigh Greene, Eric Beamer, Joshua Chamberlin, W. Gregory Hood, Joseph Anderson, Chris Ellings, Sayre Hodgson, Matthew Pouley, and Todd Zackey. 2019. Density-dependent habitat limitations for juvenile Chinook salmon in four large river deltas of Puget Sound, WA.

Abstract: Efforts by people to restrain tidal inundation to promote agriculture and development has led to large amounts of tidal wetland habitat loss in large river deltas across the Pacific coast. These losses are one of multiple threats facing estuary-dependent species such as Chinook salmon, yet concomitant declines in these populations have raised questions about the extent to which juvenile Chinook salmon compete for limited estuary habitat and how estuary restoration will help recover populations. To examine the potential for habitat limitation, we used a cross-system approach to combine outmigrant and population density data in four large river deltas of Puget Sound. By adjusting outmigration abundance to outmigrants/ha of delta channel, we were able to develop a statistical stock-recruit model that standardized outmigrations across all four estuaries. Our analysis revealed evidence for negative density dependence throughout the range of observed outmigration sizes. All systems approached predicted capacity levels some of the time each year, although the frequency with which this occurred varied greatly by large river delta. Furthermore, conditions in time and space were systematically associated with exceedance of capacity predicted by model. These conditions depended in part on hatchery releases, which have the potential to contribute to density-dependent relationships. Habitat specific variation also existed in the highest observed population densities (90th and 95th quantiles) within deltas, and these levels were not greatly influenced by densities of hatchery-origin migrants in tidal deltas. These findings have important implications for monitoring programs, estuary restoration, and hatchery management.

A.1.2. Draft Manuscript Title: Detectability of Five Estuarine Fishes in a Beach Seine Survey of Tidal Delta and Bays of North Puget Sound.

Michael LeMoine, Eric Beamer and Casey Ruff. *In prep*. Detectability of Five Estuarine Fishes in a Beach Seine Survey of Tidal Delta and Bays of North Puget Sound.

Abstract: Detectability, the probability of encountering a species at a sampling site, is often overlooked in investigation of estuarine fishes despite its potential to obscure inferences on habitat use and bias estimates of abundance. We used occupancy models to explore differences

in probability of detection and site occupancy (ψ), the probability that a species inhabits a site, for five fish species frequently captured in Puget Sound beach seine surveys: juvenile Chinook salmon, juvenile chum salmon, surf smelt, staghorn sculpin and starry flounder. We assessed two beach seine sizes that were deployed in a similar manner. Repeated-sampling events occurred from March to August from 2014 to 2018. Large beach seine had higher probability of detection than small beach seine, but species detectability was markedly different in both methods. Mid column swimmers such as Chinook salmon had higher detection probabilities than benthic species such as starry flounder or staghorn sculpin. Highly schooling species such as surf smelt had the most varied detections over time associated with immature and mature life stages. Although the environmental factors that influenced detection probabilities varied with species, the detectability of all species was positively related to the number of that species caught. Depth of water was positively associate to juvenile Chinook salmon and juvenile chum salmon probability of detection, however negatively associated to starry flounder. Accounting for imperfect detection likely improved understanding of community structure and tracking trends in abundance for rare taxa.