Skagit River Estuary Intensively Monitored Watershed Annual Report for 2020

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    a. Salmon Recovery Funding Board’s IMW Program, administered by the Washington State Recreation and Conservation Office,
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    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.

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 2020 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, IMW PI’s have contributed to finalizing the ESRP report entitled “Landscape, density-dependent, and bioenergetic influences upon Chinook salmon in tidal delta habitats: Comparison of four Puget Sound estuaries” (Greene et al., 2020) IMW PI’s used a cross-system approach to evaluate generalities of tidal wetland habitat loss and its contribution to negative density-dependence. Each of the four estuary systems exceeded 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. Findings from this work suggest that tidal wetlands can constrain Chinook salmon recovery, and the magnitude and frequency of constraints depends on the river system's outmigration timing, hatchery operation, and magnitude and connectivity of available habitat. Chapter abstracts are found as Appendices A. 1 – A. 3.

Second, 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 recapture efficiency in a Mark/Recapture framework, or by imperfect detection estimates within an occupancy modeling framework. We have drafted a manuscript estimating probability of detection to assess if imperfect detection of historical IMW data across common nearshore species (Appendix A. 4.). The manuscript highlights that imperfect detection on assessments of nearshore fish community structure is an important consideration and corroborates previous recapture efficiencies estimated by SRSC for juvenile Chinook salmon. We used detection probabilities from the draft manuscript to redesign beach seine monitoring to meet SRSC Covid 19 workplace precautions (see Section 1.4 Adaptive Management for details). The fundamental change in the methodology was to use small beach seines that could be operated by two individuals who could maintain a 6 foot distance. The manuscript has gone through internal review revisions and we plan to submit the manuscript to Estuaries and Coasts in the spring.

Third, we leveraged the IMW dataset to evaluate the how the Skagit River delta themalscape has changed over the last 15 years and how contemporary climate change may influence water conditions and Chinook salmon habitat in the future (Appendix A. 5). Currently, few studies have evaluated the vulnerability of delta systems to future climate, especially for species like Chinook salmon. The Skagit River estuary is important for juvenile Chinook salmon rearing and the restoration estuary habitats are critical to the recovery of Skagit River Chinook. We in this report evaluate the influence of climate drivers (e.g. air temperatures, river discharge, pacific decadal oscillations) and local sites conditions (e.g. size and vegetation cover) on water temperatures of tidal channels. Indeed, air temperature, river discharge and vegetation are associated with water temperatures in tidal channels, however, dissolved oxygen not water temperature associates with density of juvenile Chinook salmon in the Skagit River estuary. Evaluation of future scenarios suggest that juvenile Chinooks salmon habitat will decline in the coming decades, yet restoration and flow management might lessen this effect. Overall, our evaluation is a first step, and we suggest improving the temperature monitoring network in the Skagit River estuary to improve our understanding on the Skagit River estuary thermal scape.

Fourth, IMW monitoring data has been shared to examine status and trends of forage fish in Skagit Bay. These findings were reported at a workshop on Pacific Sand Lance sponsored by the Puget Sound Environmental Monitoring Program, and have been shared with Washington Department of Fish and Wildlife to determine harvest of surf smelt.

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 2020, 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. This coming year, Skagit results will be presented at the Oregon AFS Meeting, in an ESRP project completion webinar, at ESRP's nearshore summit, and likely at the Salmon Recovery Conference.

1.4. Adaptive Management

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

Methods/analysis

The Skagit IMW methodology (see Greene et al. 2016) uses large net beach seine and fyke trap to capture fish for density estimates within the nearshore of Whidbey basin nearshore and Skagit delta. At each fish capture location, conditions that include water temperature, dissolved oxygen, salinity, water velocity, and water depth are also documented. In 2020, the Covid 19 pandemic required SRSC to adopt Covid 19 Workplace Precautions that capped field teams to two individuals who had to be either masked or maintain a social distance of 6 feet. These precautions were adopted from State and Federal guidelines and were intended to keep staff safe. These precautions did not affect fyke trapping but precluded using the large net beach seine that requires more than two staff to operate. Rather than discontinuing data collection at large net beach seine sites in 2020, we determine the small net beach seine can be implemented within the adopted Covid 19 Workplace Precautions. We were uncertain, however, if the small beach seine collection would be comparable to previous large beach seine collections and we wanted 2020 data to be consistent with previous data.

We conducted a simulation analysis to evaluate if a study design using small beach seines could provide consistent information as our large beach seine methodology. We used juvenile Chinook salmon probability of detection estimates (mean and variance) for large beach seine and small beach seine from the imperfect detection manuscript (Appendix A. 4) and densities observed (mean and variance) at beach seine locations over the last 10 years. We developed 10 simulations based on the mean and variance of the estimates of a known population abundance and density derived from measured estimates from past Skagit IMW results across 100 sites. From these known values, we then took a sample of these sites applying imperfect detection measured in the draft manuscript (Kery and Schaub 2012 provide examples how to develop simulations). From the sample, we then estimated mean density which is a common reported result for the Skagit IMW. We also estimated mean density (lambda) using a n-mixture approach (Kery and Schaub 2012).

We found using small net methodology would not compromise results as long as the number of sites sampled and the number of sets increased due to the smaller net size, and if our understanding of probability of detection is correct (Figure 1). Comparing direct densities while not accounting for known imperfect detection, however, resulted in a consistent bias between simulated and measured densities. We then conducted an n-mixture analysis to correct for imperfect detection across all combinations of sets and sites (Figure 2). Correcting for imperfect detection provided a clearer evaluation of the requisite number of sites and sets. We estimated that we need to increase from 32 sites to 36 sites and increase our sets at a site from two to four.

Once needed effort was better understood, we revised our field logistics and schedules. We worked in three teams of two for beach seine sampling bouts. In previous years, much of the IMW large beach seine work involved five staff so this adjustment represents some additional costs. Each team required a boat, truck, net, field equipment and data record devices. The change in crew units also increased the number of boat/truck units required. Social distancing requirements under Covid conditions also required staff to drive their own vehicles to boat launches rather than carpooling within boat/truck units. Additionally, our office building where the computer network resides for digital data synchronization with our field tablets was closed under Covid conditions. This closure precluded us from using real time data entry for the 2020 season.

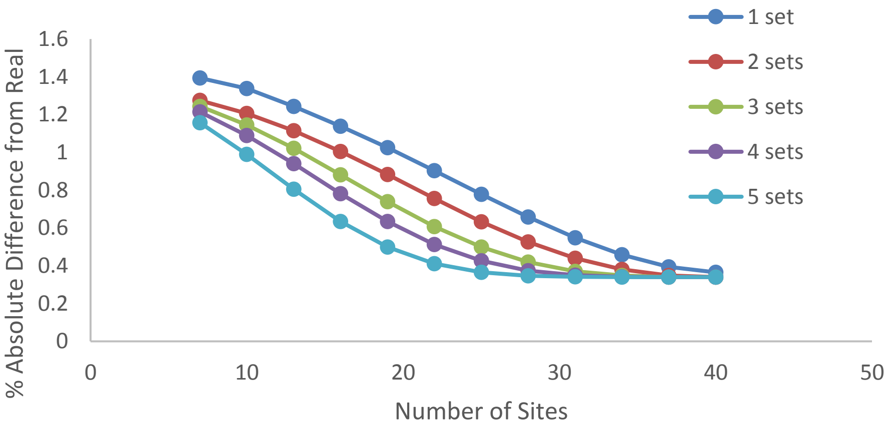

Figure 1. Comparison of mean near shore densities between simulated (i.e. real densities) and sampled small beach seine (i.e. estimated densities).

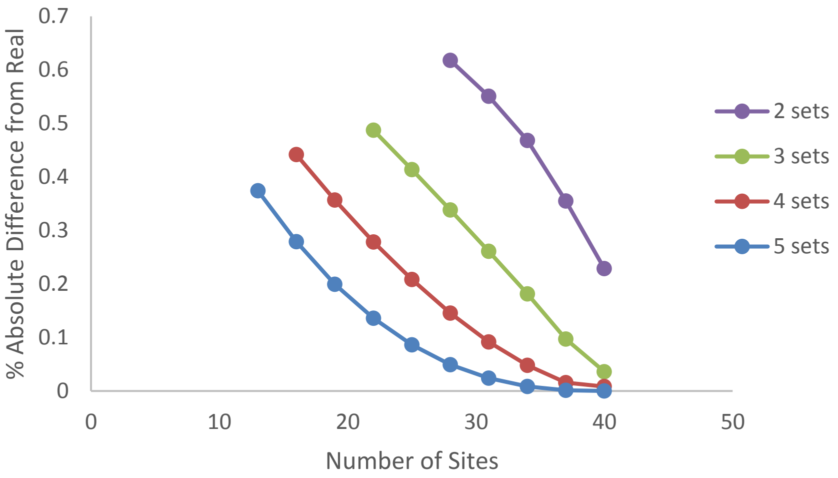

Figure 2. Mean difference between simulated densities (i.e. real densities) and sampled small beach seine (i.e. estimated densities) using n-mixture approach to correct for imperfect detection.

Data management

In 2020, we reverted to paper data recording that required us to transcribe data into the database. Three staff were assigned to data entry in the fall post sampling to transcribe paper records into the digital database. All data were entered into the database by 12/1/20. We completed 100% QA of the data transcription of the IMW data by 1/5/21.

During 2020, we identified the limitations of our electronic data entry (eforms) system during Covid 19. In the fall of 2020, we have made several adjustments to allow eforms to be used in 2021. First, we worked to extend our wireless networks and security so staff can connect remotely to our databases, which was completed in fall. Next, we worked on improving our eforms that integrates QA procedures that include warnings for missing data and limits for certain data entries (i.e. water temperature cannot be >25 °C). These database improvements will be completed by the end of January 2021. We are also seeking additional funds to secure tablets and cases for each field team. It is our hope that 2021 will return to direct data entry from the field to our database through the eforms. The eforms shorten times to when data are available for reporting and analyses, allow for efficient data entry, as well as improved data security.

Given the additional tasks associated with Covid 19, 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 focused on getting 2020 data entered, QA'd and preparing for Covid-19 in 2021. We still hold this as a priority and hope to make more database advances in 2021.

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

WDFW: Due to the state government stay-at-home order during early stages of the pandemic. WDFW did not perform outmigration monitoring from March 25 to April 13. This gap occurred during the typical peak migration period for Skagit Chinook salmon. WDFW biologists are using statistical methods to infer outmigration results during the monitoring gap.

SRSC: Covid-19 pandemic provided many challenges to our monitoring program. We describe in this report the changing field logistics for beach seining and fyke trapping to meet Covid-19 constraints and additional data entry that was needed. These challenges were surmountable but required additional work that pulled resources from manuscript development.

We provided a memorandum to the IMW Program detailing additional costs associated with 2020 sampling and projected 2021 additional costs in October of 2020 (Appendix B). Additional funds were provided for the 2020 Covid-19 related costs; however, we still do not have the estimate $20,100 to cover purchasing of small beach seines and tablets. To conduct 2020 sampling, we patched old small beach seines from previous projects and by the end of 2020 these old seines could not be repaired. We currently do not have the necessary resources to conduct a continue a monitoring plan as we performed in 2020.

NOAA: During the pandemic, NOAA shut down all field operations from March to August, and allowed after this time period only activities with a very low risk of Covid transmission. Surface trawling requires a minimum of 5 crew each day of sampling, including operators of two vessels. Due to the close quarters required for operation and because of the very late start to operations, monitoring was halted for the entire year. IMW funds were repurposed for vessel maintenance as well as data analysis and manuscripts (see below).

Pace and extent of restoration treatments

There are no new challenges to the pace and extent of restoration identified in 2020. Our thoughts on how to address the existing challenges remain the same as articulated in the 2017 annual report.

Staff

For 2020 there were no changes in IMW staff, just a reallocation existing staff as described above due to Covid constraints.

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) with the exception of constraints induced on work flow for years under Covid pandemic conditions (described above). 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, SRSC, and WDFW are finalizing a manuscript to be submitted for publication in 2021 on density-dependent limitations resulting from estuary habitat limitations. This manuscript integrates annualized data from the intensive monitoring effort, and provides initial results on the benefits of restoration through changes in body size.
- 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. In conjunction with ESRP funding IMW funds to NOAA were repurposed to further develop two aspects of the proposal dealing with the Skagit IMW: statistical analysis of the effects of tidal delta restoration on juvenile Chinook salmon and development of an individual-based model for improving understanding of effects of restoration and density dependence on individual growth and movement. Both efforts require integration of GIS data on wetland change due to restoration, and both SRSC and NOAA scientists worked to produce data products relevant to the two above research elements.
- 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.

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. 2020, Appendix A.1 – A.3) 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 the following statistical designs for elucidating the benefits of restoration on juvenile Chinook salmon cohorts:

- BA (Before-After) designs to test for benefits of estuary restoration in the nearshore (the life stage following estuary rearing).
- 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).
- Because monitoring continues throughout all restoration actions, which improve connectivity and capacity for future cohorts, we are investigating the use of stairstep designs to improve our understanding of the benefits of restoration.

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 and Dunlap are 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 (Britt Slough, SF Dike Setback Phase 2, Deepwater Phase 2, Milltown Phase 2) 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 looking at the Skagit system 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 2020

3.1. Data collection in 2020

We collect data in 2020 per our study plan (Greene et al 2015), which is summarized by method and lead entity in Table 4. We report 2020 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	27
Fyke trapping*	SRSC	Tidal delta & Swinomish Channel	Biweekly, Feb-July; monthly in August	10	28
Beach seining*	SRSC	Skagit Bay shore & Swinomish Channel	Biweekly, Feb-Aug; monthly, Sept-Oct	128**	26
Kodiak trawling*	NWFSC	Skagit Bay neritic	Monthly, Apr-Oct	60	19

* Partially supported by SRFB/IMW funding.
** In 2020, we adapted our beach seining methods to meet Covid 19 Workplace precautions this resulted in 328 sites sampled by small beach seine.

Outmigrant trapping.

Juvenile Chinook salmon outmigration estimates in the Skagit IMW are from 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 collected outmigrant data in 2020 but there is currently no population estimate for the Skagit River natural origin subyearling Chinook salmon outmigration. WDFW will provide outmigrant estimates sometime in early 2021. The Skagit River trap was operated February 14 through March 24, and then from April 14 through July 6. The start of the 2020 trapping season was delayed due to high river flows and was hampered by COVID-19 constraints throughout the season starting on March 24.

Fyke trapping.

SRSC completed 130 fyke trap sets at 10 index sites and caught total of 5,002 unmarked juvenile Chinook salmon in the Skagit tidal delta from February 17 to August 21, 2020 (Figure 3). 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 2020 index sites have been updated so standardized unmarked juvenile Chinook salmon density results are available for 2020.

In 2020 unmarked juvenile Chinook salmon were present February – August, displaying a broad peak April through June of over3,000 fish per hectare of blind tidal channel (Figure 3). By August, subyearling Chinook salmon densities in tidal delta habitat were low, averaging only 33 fish per hectare. Geometric mean annual density in 2020 was 96 fish/hectare which is approximately twice as large as densities in 2019. However, average density in was well below the long term average of 251 fish/hectare (Figure 4).

Beach seining.

SRSC completed 1994 beach seine sets at 328 sites (random and index) and caught total of 563 unmarked juvenile Chinook salmon in Skagit Bay nearshore habitat over the time period: February 24 to October 7, 2020. In 2020, unmarked juvenile Chinook salmon were present from February to August and absent in September and October with a peak observed over April and May (Figure 5). Geometric mean annual density of unmarked juvenile Chinook salmon density in nearshore habitat (index sites) in 2020 was about 20% of the 25-year average (1.1 compared to 5.9 fish/hectare) for index sites (Figure 6). Random site data collection was initiated in 2006. The annual geometric mean densities track each other temporally, but random sites are about 15 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: $R^2 = 0.53$, $P = 0.006$; without 2012 & 2013: $R^2 = 0.89$, $P < 0.0001$).

We expected the small beach seine method to be negatively bias because of imperfect detection. We observed a precipitous decline in catch during the months August, September and October and is the first time that no unmarked Chinook salmon were caught in both September or October since 2001. We believe there are four possible explanations for this. 1) Chinook salmon recruitment was ordinarily low so that outmigration abundance is low. Unfortunately, we do not have outmigration estimates provided by WDFW at this time. 2) An early flood event on February 2, 2020 of 73,400 cfs could have pushed many Chinook salmon fry out into the estuary early and their period of rearing in the nearshore would have been truncated. We do see that peak densities in the estuary and nearshore are earlier than usual compared to previous years. 3) During the year, juvenile Chinook salmon fry grow in the estuary and near shore. Juvenile Chinook salmon fry increasing in size could decrease small beach seines capture efficiency and thus probability of detection. 4) In the summer season, juvenile Chinook salmon use deeper habitats that could be missed by the small beach seine (McCabe et al. 1986).

The 2020 dataset gives us a unique opportunity to further evaluate imperfect detection and if funding is available further evaluate catchability while operating under Covid 19. Small beach seine data were limited in the historical dataset, especially with repeated sets with replacement that is best for estimating imperfect detection. We intend to incorporate these data into the manuscript as four set at a site would improve estimates of probability detection. In addition, we hope to conduct some mark/recapture work and adjust sampling to test whether we are missing fish in deeper water during the summer. This effort will further refine our approach, provide improved corrections to these unique Covid 19 years so to maintain the data timeseries and flexibility of using different methods to infer ecological process.

Surface trawling.

NWFSC was unable to sample Skagit Bay neritic habitat (subtidal surface of water column) in 2020 due to COVID-19 constraints on fieldwork within NOAA.

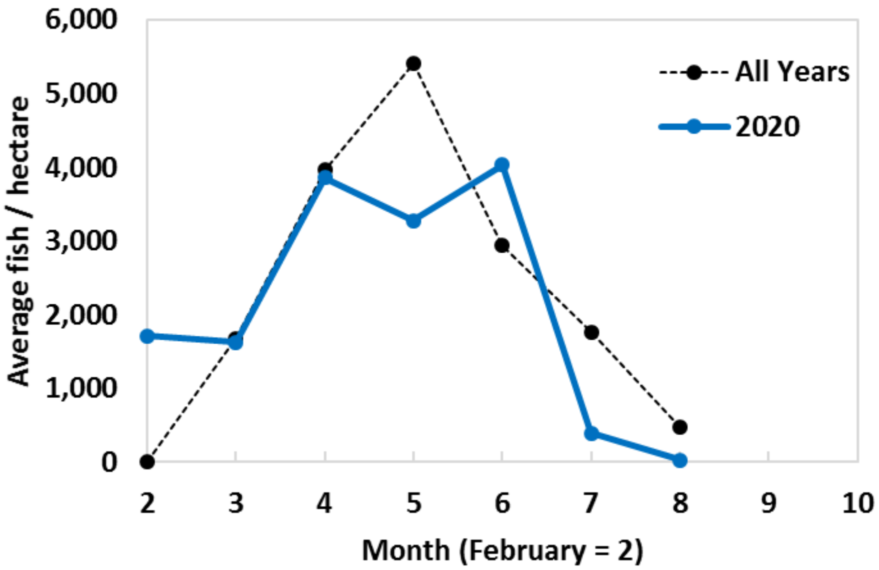

Figure 3. Seasonal density of unmarked juvenile Chinook salmon by Index fyke traps in the Skagit tidal delta, 2020 (solid line) compared to the average of all years combined (dashed line).

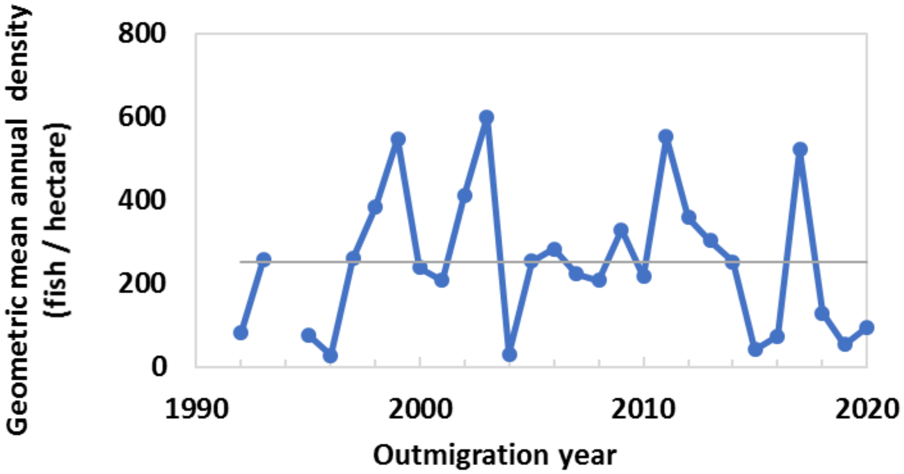

Figure 4. Unmarked juvenile Chinook salmon density trend over time from Index fyke traps in the Skagit tidal delta. Note: there are no results for Index fyke traps in 1994. The average for the entire time period is shown as the horizontal gray line.

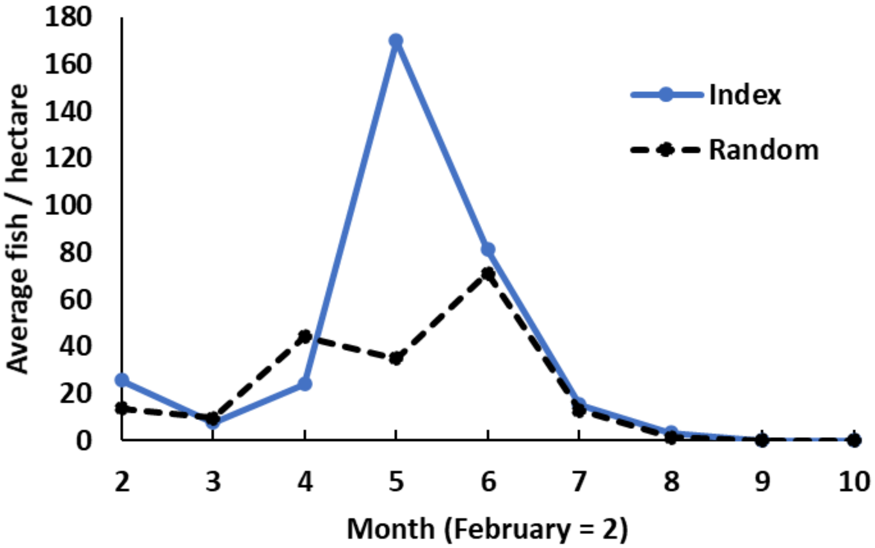

Figure 5. Seasonal density of unmarked juvenile Chinook salmon by large net beach seine in the Skagit Bay, 2020.

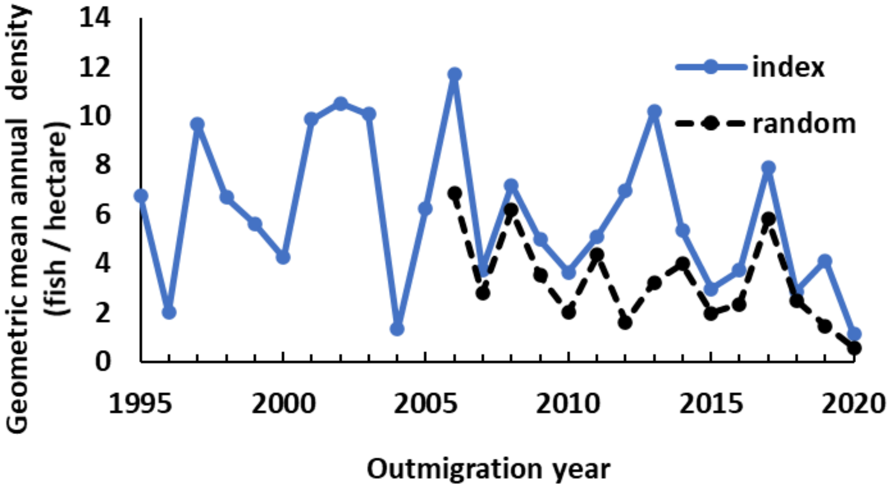

Figure 6. Unmarked juvenile Chinook salmon density trend over time in nearshore habitats of Skagit Bay.

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 and within 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), the Skagit Watershed Council, 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, six additional restoration projects are anticipated to be completed, totaling 402 acres restored to tidal inundation. The updated results in Table 5 for near-term unbuilt restoration projects are based on communications with staff from SRSC Restoration Department, WDFW, Skagit County, and Skagit Watershed Council. Some specific details about each project are following:

- **Milltown Island**: Although the 212-acre site is already subject to tidal and riverine inundation, much of the historic levee and dike system is still in place. Actions to improve natural processes and connectivity are currently under consideration. WDFW is working with a technical advisory group to assess alternatives and has funding in hand for final design and permitting, which is scheduled to be completed by June 2021. Construction could begin as early as 2022 if funding can be secured.
- **Smokehouse Dike Setback**: A large dike setback project of approximately 120 acres is planned as another phase of restoration at Smokehouse Floodplain on the Swinomish Tribe's reservation. SRSC and the Swinomish Tribal Community secured SRFB funding for design work which could be completed in 2021. Funding for final design, permitting, and implementation would be pursued starting in 2022 and with luck fulfilled in time for a 2023 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 alternatives for the 268-acre Deepwater/Island Unit site are currently being assessed, including no restoration, partial restoration and full restoration. If a partial or full restoration alternative is selected, WDFW will seek design funding in early 2021 and construction could begin as early as 2023 if funding can be secured.
- **North Leque Island**: WDFW will construct a restoration project in 2021 or 2022 that involves removing a remnant perimeter dike to better connect 26 acres of intertidal marsh in the Stanwood/English Boom Delta Fringe located in southern Skagit Bay. A single opening in the dike currently allows muted tides to inundate the site. The project intends to improve juvenile salmon accessibility and natural processes by connecting eight additional channels into the site and reintroducing sheet flow. The project is expected to receive final funding in 2021 and is currently in the permitting stage.

- **South Fork Dike Setback Phase 2**: Approximately 5.3 acres of wetted habitat, which includes 2,200 linear feet of channel and two large ponds, will be constructed within the 37-acre Dike District 3 property on the South Fork of the Skagit River, just below the forks. Pending receipt of all required permits and final funding, the County plans to begin construction during the summer of 2021. Skagit County has partnered with Skagit Fisheries Enhancement Group to complete site re-vegetation and invasive management. The County will be working with SRSC to develop a monitoring plan which will track effectiveness and sustainability of the project for the next 15-20 years.
- **Swinomish Channel Phase 3 Tidal Marsh Restoration (Dunlap)**: This project will restore 4.4 acres of tidal marsh along the Swinomish Channel on property owned by the Swinomish Tribe and previously leased to Dunlap Towing. This will include removing dredge spoils from 3.3 acres of former marsh, reconnecting 1.1 acres of adjacent remnant marsh and a freshwater stream, and excavating 350 meters of tidal channels. This project is currently funded by SRFB and hopefully ESRP. Design work should move forward in 2021 with anticipated construction in 2022 or 2023.
- **McGlinn Island Causeway**: Progress on the McGlinn Island Causeway project had languished over complex political issues. However, based upon conversations with the Army Corps of Engineers (ACOE) the past six months it is possible the project could still 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. Recent avulsion of the North Fork Skagit Distributary is likely to facilitate project progress because the avulsion directs most of the discharge and riverine sediment sediment away from the Swinomish Channel, thereby reducing the need for the causeway or jetty to intercept riverine sediment. To quantitatively estimate the reduction in sediment delivery, the ACOE has agreed to update previous hydrodynamic modeling to include the new bathymetry of the avulsion. 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.
- **Britt Slough:** On the upland fringe of the tidal delta, a project to improve hydrologic connection of 7.8 acres of tidal floodplain forested wetland for Chinook salmon rearing habitat is in construction phase, to be constructed in 2021, with revegetation following. This project restores the flow path that existed prior to Britt Slough being diverted into the mainstem Skagit and connects the existing forested wetland to a tributary flow source and the south fork of the Skagit River. This project improves habitat connectivity especially during dry months.

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	2022	Both	South Fork	0*	Not designed
Smokehouse Floodplain dike setback	2023	Capacity	Swinomish Channel	120	Planned BACI, 2005-present
Deepwater Phase II	2023	Capacity	South Fork	268	Not designed
North Leque Island	2021/22	Connectivity	Stanwood/English Boom Delta Fringe	0**	Not designed
South Fork Dike Setback Phase 2	2021	Both	South Fork	0***	Not designed
Britt Slough	2021	Connectivity	South Fork	0****	Not designed
Swinomish Channel Phase 3 Tidal Marsh Restoration (Dunlap)	2022/23	Capacity	Swinomish Channel	4.4	Not designed
McGlinn Island Causeway	<5 years	Connectivity	North Fork-Swinomish Channel	10	Planned BACI, 2005-present
TOTAL				**1055.4**	

* Milltown Island restoration does not significantly change the Skagit estuary’s tidal footprint. Restoration at Milltown improves connectivity to existing channels and adds channel area over the site’s 212-acre tidal footprint.

** North Leque Island restoration does not significantly change the Skagit estuary’s tidal footprint. Restoration at North Leque will improve connectivity to existing channels over the site’s 26-acre tidal footprint.

*** South Fork Dike Setback Phase 2 does not significantly change the Skagit estuary’s tidal footprint. Phase 2 restoration at South Fork Dike Setback will improve connectivity to existing channels over the site’s 37-acre tidal footprint.

**** Britt Slough restoration does not significantly change the Skagit estuary’s tidal footprint. Restoration at Britt Slough will improve connectivity to existing channels and ponds with the river.

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

Population level analyses were updated in 2020 but the manuscript is currently in draft form. We expect completed population response analyses in 2021 and 2022 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.

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Appendix A. Skagit IMW related reports or manuscripts completed in 2020.

A.1. Landscape determinants of estuarine river delta habitat use by juvenile wild and hatchery origin Chinook salmon (*Oncorhynchus tschawytscha*)

Eric Beamer, Correigh Greene, Joshua Chamberlin, W. Gregory Hood, Chris Ellings, Sayre Hodgson, and Todd Zackey

Abstract: To improve habitat restoration planning and design for threatened species, science from monitoring efforts can help inform what habitat features are important to populations. We examined how landscape structure influences habitat use by juvenile natural origin (NOr) and hatchery origin (HOr) Chinook salmon in four river deltas. Using long-term records from beach seine and fyke trapping, we modelled how landscape characteristics (distributary vs. blind channel types, three wetland vegetation communities, and a channel network connectivity index) influenced juvenile salmon densities. We used two-stage general additive models for zero-inflated data; the first stage estimated probability of a non-zero response, while the second stage used positive (fish present) density values to model biweekly local density. All candidate models included the terms, “Week”, “System” and “Year” to account for seasonal trends, differences between deltas, and inter-annual variation.

We found substantial evidence that landscape features structured habitat use by juvenile Chinook salmon. Models detected strong effects of estuary system, landscape connectivity, and channel type on either presence/absence or density or both responses, although the directionality and relative importance of these features differed among NOr and HOr fish. For NOr fish, system and landscape connectivity were the strongest and second strongest predictors of density, respectively, and channel type was a strong predictor of presence/absence. Wetland type exhibited the least predicted power. The rank order of landscape predictors was similar for HOr fish, but some strong differences existed. Notably, while NOr fish presence was positively associated with blind channels, HOr fish presence was positively associated with distributaries. In addition, while interannual differences were stronger for NOr juveniles, seasonal pattern was much stronger for HOr fish and was in fact the strongest predictor of density. For both types of fish, interactions of habitat factors existed with seasonal pattern, indicating habitat utilization changed dynamically from the beginning to the end of the rearing period. FRT and EFT habitats had higher NOr densities earlier in the year whereas EEM habitats had higher densities late in the season. The pattern was less discernible for HOr juvenile and suggested EEM habitat had higher densities from the beginning of the outmigration through the peak prior to decreasing in all wetland types.

These findings have important implications for habitat restoration. Landscape connectivity was the most significant landscape influence. Recognizing that low connectivity sites have fewer fish

than high connectivity sites, we should prioritize high connectivity sites for habitat restoration and use connectivity as a covariate to compare restoration sites to reference sites. Connectivity restoration itself (e.g., reconnecting historical distributaries) can improve fish productivity by allowing access to previously isolated productive marsh, including blind channels, which emerged as important sites for residence by NOr juveniles.

A.2. Density-dependent habitat limitations for juvenile Chinook salmon in four large river deltas of Puget Sound, WA

Correigh Greene, Eric Beamer, Joshua Chamberlin, Joseph Anderson, Chris Ellings, Sayre Hodgson, Matthew Pouley, and Todd Zackey

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 natural-origin 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. This was despite substantial variation in densities in deltas, even when outmigrations from rivers were high. Within each large river delta system, fish densities approached predicted capacity levels at some site or time in most years, although the frequency with which this occurred varied greatly by system. Furthermore, exceedance frequencies systematically varied across the season and in different habitat types. Capacity exceedance depended in part on hatchery releases, which have the potential to contribute to density dependence due to co-occurrence with natural-origin fish. 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.3. Evaluating habitat-specific growth potential and consumption demand for Chinook salmon across multiple tidal deltas

Joshua Chamberlin, Correigh Greene, Eric Beamer, Melanie Davis, Joseph Anderson, Todd Zackey, Chris Ellings, Sayre Hodgson, and Isa Woo

Abstract: Habitat influences the conditions and resources that are available to individual consumers which may ultimately affect growth. As conditions and/or resources vary, individuals may use multiple habitat types to maximize growth benefits. However, if competition for resources increases in a particular habitat, growth may become limited, especially where abundance varies greatly and prey is limited. Juvenile Chinook salmon use estuaries to varying degrees during the outmigration period. Individuals that enter at different periods may experience variable conditions (environmental and demographic) that can affect growth. We used fish abundance, fish diet, prey availability, and temperature data from four tidal deltas in Puget Sound to evaluate wetland-specific growth potential and consumption demand. To evaluate variability in individual growth among cohorts and wetland types we used bioenergetics models to estimate individual growth for multiple cohorts of juvenile Chinook salmon entering the estuary at different times and sizes. Estimated individual weekly energy consumption was scaled to population abundance for each life history type in four tidal deltas to assess whether consumption demand was limited, indicative of potential density dependent growth processes within each delta. Lastly, we used estimates of overlap between diet and prey assemblages to evaluate whether similarity increased or decreased with changes in local density or individual size. Growth potential among cohorts and across wetland types was highly variable. No single wetland type offered consistently higher growth throughout the rearing period. Consumption demand never surpassed estimated prey availability, but demand approached availability in some systems during periods of peak Chinook abundance. Consumption demand was not evenly distributed among life history types through time or among systems. Diets became more similar (less selective) to prey assemblages as density increased, and results suggested extensive variability, creating a direct relationship on the upper limit of prey/diet overlap. Prey/diet overlap was not strongly associated with changes in individual size, although the relationship suggested a negative relationship between overlap and size. Our analysis highlights the importance of habitat diversity in tidal deltas to maximize growth potential for juvenile Chinook salmon that rely on estuaries for growth. Restoration planning that focuses on maintaining diversity while increasing capacity will be important for supporting population recovery and resilience.

A.4. 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.

A.5. Salmon Habitat Vulnerability Assessment for the Skagit River Estuary Thermal scape.

Michael LeMoine and Eric Beamer. 2020. Salmon Habitat Vulnerability Assessment for the Skagit River Estuary Thermal scape.

Abstract: Ecological responses to climate change have been observe across many aquatic ecosystems, yet in estuaries much of the focus has been on physical responses such as sea level rise, sediment movement and circulation. Currently, few studies have evaluated the vulnerability of the ecology of these systems to a future climate. The Skagit River estuary is important for juvenile Chinook salmon rearing and the restoration estuary habitats are critical to the recovery of Skagit River Chinook. We evaluated the influence of climate drivers (e.g. air temperatures, river discharge, pacific decadal oscillations) and local sites conditions (e.g. size and vegetation

cover) on water temperatures of tidal channels. Indeed, air temperature, river discharge and vegetation are associated with tidal channel water temperatures, however, water temperatures are not associated with density of juvenile Chinook salmon in the Skagit River estuary at this time. It seems currently juvenile Chinook salmon densities are more associated with dissolved oxygen levels. Further evaluation of future scenarios suggests that temperatures in tidal channels will increase in the coming decades and will likely negatively impact juvenile Chinook salmon rearing potential, especially in the summer months. Restoration that increases tidal exchange and careful consideration of river flow management might lessen this effect. Overall, our evaluation is a first step, and we suggest improving the temperature monitoring network in the Skagit River estuary to improve our understanding on the Skagit River estuary thermal scape.

Appendix B. SRSC Skagit IMW workplan: Summary of budgetary changes due to the influence of COVID-19 Pandemic on data collection and processing

October 23, 2020

The Skagit IMW methodology (see Greene et al. 2016) uses large net beach seine and fyke trap to capture fish for density estimates and document site conditions that include temperature, dissolved oxygen, salinity, water velocity, and water depth. In 2020, the Covid 19 pandemic required SRSC to adopt Covid Safety Protocols (attached) that capped field staff to two individuals who had to be either masked or maintain a social distance of 6 feet and mandated staff to drive separately to work sites. This protocol is intended to keep staff safe but precluded regular IMW sampling using the large net beach seine that requires more than two field staff to operate. Rather than discontinuing data collection at large net beach seine sites in 2020, we determine the small net beach seine can be implemented within the adopted Covid Safety Protocols. We conducted a power analysis to determine the effect of changing the methodology to small net beach seines on the long-term dataset. We found using small net methodology would not compromise results as long as the number of sites sampled and the number of sets increased due to the smaller net size. The completed power analysis informed us that we could continue data collection in 2020 and not miss a year of data collection due to the pandemic.

However, the change to small net methodology required additional equipment, an increase in the number of crew units required, and additional travel to fully implement the sampling plan (Table 1). The change in crew units also increased the number of boat/truck units required. Social distancing requirements under Covid conditions also required staff to drive their own vehicles to boat launches rather than carpooling within boat/truck units. Additionally, our office building where the computer network resides for digital data synchronization with our field tablets was closed under Covid conditions. This closure precluded us from using real time data entry for the 2020 season. These changes to field methodology resulted in increased data collection cost of $8,630 and resulted in data entry with QA/QC to occur after field season. Data entry and QA/QC is occurring now, from October through December 2020. Our inability to utilize real time data entry in 2020 delays our ability to complete the annual report by one month. Thus, we can complete the annual report by January 29, 2021.

Moving forward in 2021 we expect Covid conditions to continue. Thus, we plan to continue with the small net methodology adaptation. The same changes in net use, crew configuration, boat and vehicle use encountered in 2020 are planned to be repeated in 2021 (Table 2). However, the old small net beach seines used in 2020 were taken from SRSC surplus which were funded by past projects and all need to be replaced. Additionally, we have resolved the real time data entry issue by extending WiFi connectivity but we will need 3 additional field tablets to accommodate the increased number of crews to enable real time data entry in 2021. These changes planned for 2021 result in increased data collection cost of $20,100 and, if implemented, we can complete the 2021 annual report in December 2021.

Table 1. Summary of changes to SRSC Skagit IMW data collection and their associated costs due to Covid constraints in 2020.

Category	**Required Under Traditional Sampling Methods (Greene et al. 2016)**	**Required under Covid 19 Workplace Precautions**	**Net change**	**Cost of net change**	**Description**
Large net beach seine	2	0	0	$0	Large net methodology cannot be implemented under Covid Safety Protocols, but small net methodology can. We had 3 used small nets on hand and used them to complete the 2020 season. However, they are worn out now and should only be used as backup nets on an intermittent basis
Small net beach seine	0	3	3	$0	
Fyke trap nets	4	4	0	$0	Covid Safety Protocols does not change the number of Fyke trap nets needed
Personnel	2 crews (3 people/crew)	3 crews (2 people/crew)	0	$0	No change to the number of crew members needed to complete work under Covid Safety Protocols. Only the crew size was changed.
Boat & trailer with towing vehicle	2	3	1	$4,900	Equip rental & O/M for 7[1] months at $700/mon
Personal vehicle	0	3	3	$2,530	210 miles/month across 3 personal vehicles for 7[1] months at Federal mileage rate of $0.575
YSI (water temperature, dissolved oxygen, salinity)	2	3	1	$0	Instruments were reassigned from other projects in 2020, however the sharing of YSI cannot occur in 2021.
Velocity Meter	1	3	2	$1,200	Additional velocity meters for bay sampling were required and purchased in 2020.
			Total	**$8,630**	

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[1] The standard sampling period is 9 months, starting in February each year. Covid 19 contraints began April 2020 influencing data collection for a 7 month period.