Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Salmon Populations

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Abstract

This paper summarizes what researchers understand about how the Skagit estuary is important in saving Skagit Chinook salmon. It looks at how the how juvenile Chinook salmon use nearshore estuary habitats, describes how much habitat has been lost due to human interactions and how those losses have impacted Chinook salmon populations. Skagit delta and pocket estuaries are important rearing habitat (where babies grow up) for all six wild salmon stocks. However, current tidal delta and pocket estuary habitats are smaller and more fragmented (separated) than in the past, meaning fewer locations where Chinook salmon can safely grow up. Current tidal delta habitats are limited in the number and size of juvenile Chinook salmon they can support, which causes some individuals to change their life history type to fry (baby salmon less than a few months old) migrants which have a lower survival rate. This means that some end up in pocket estuaries, which are also important juvenile salmon habitat. Finally, climate changes can influence survival and should be taken into consideration for any recovery plans, especially as their effects will vary with location. This information shows that restoration of tidal delta and pocket estuary habitats, along with the areas that connect them, are critical for any future restoration projects that will help the recovery of Skagit Chinook salmon.

Introduction

The goal is to save Skagit Chinook salmon populations that are on the Endangered Species List. Past research shows that habitat loss and degradation (lowering quality) are major causes for the loss of salmon populations in the Northwest (Nehlsen et al. 1991). This has led biologists and natural resource managers to ask questions about what needs to be done to recover these salmon populations.

Our hypothesis is that the Skagit estuary is critical to the survival of wild Chinook salmon populations. However, until recently we didn't have information about estuary habitats and how fish use them. In 1992 we began research to understand what role the Skagit estuary plays, and what actions are needed, for successful recovery of wild Chinook salmon.

This document summarizes over 10 years of studies on estuary habitat use by Chinook salmon and their life cycle changes, estuary habitat loss, ocean survival of salmon and how different effects of global warming will impact fish populations. This information is then used to identify the benefits that may come from future restoration projects aimed at recovering Skagit Chinook salmon.

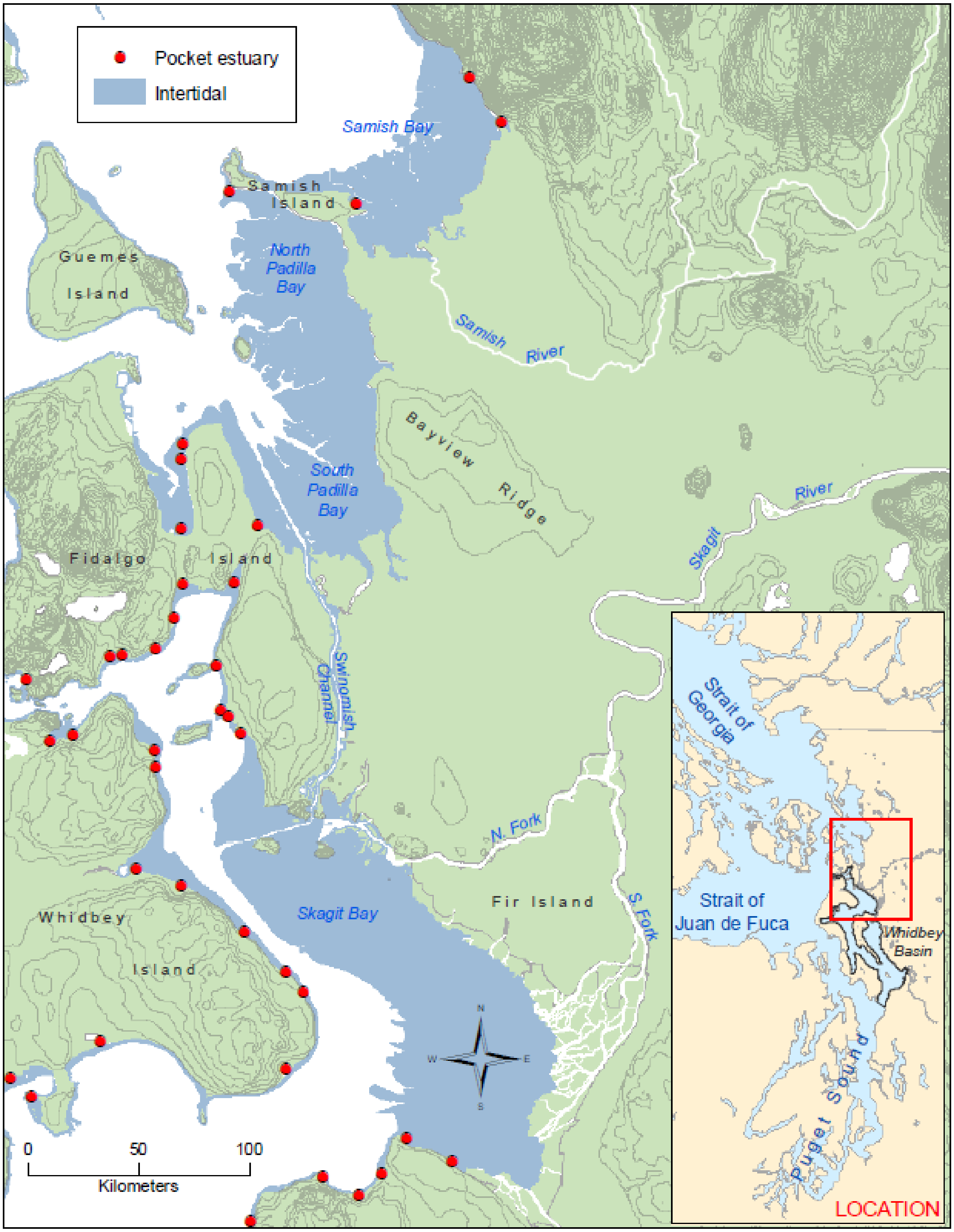

Figure 1.1. *Local and regional estuaries.* Puget Sound is a fjord estuary, containing several natal river estuaries, including the Skagit River delta, and hundreds of small, non-natal 'pocket' estuaries. The Whidbey Basin is a sub basin of Puget Sound, defined by bathymetry and water circulation patterns (Burns 1985). The Skagit River empties into Whidbey Basin.

The Need for Estuary Restoration

Salmon that hatch from the freshwater habitats of the Skagit River Basin use some part of the Salish Sea estuary during their lives.

The estuary environment is very complex and has many different habitats that salmon could use. In the past, juvenile salmon habitats near the shore have been researched at specific site locations that are often patchy (not connected). However, it has been found that using information from these studies has led to unsuccessful restoration projects.

What is known now is that how well a particular habitat functions, in this case for salmon survival, depends on the habitat in the surrounding landscape, too; everything is connected. Salmon will use specific habitats within the estuary at different points of their life history. So, the amount and quality of estuary habitat that is available to salmon, along with the characteristics of specific sites, will strongly affect the health of salmon populations.

The estuaries of the Skagit River provide four main functions for juvenile salmon: 1) places to eat and grow, 2) places to hide from predators, 3) places for their bodies to transition from freshwater to saltwater, and 4) migratory corridors (passageways) from the rivers to ocean feeding grounds. These are all connected to how well a salmon population will survive. How good these habitats are in providing these functions will determine the value of the habitat for salmon, and their recovery.

Estuaries and Juvenile Chinook Salmon

Wild juvenile Chinook salmon use a variety of different estuary habitats connected to the Skagit River at different times in their life. Understanding these patterns in habitat use is critical to developing habitat restoration plans that will be successful in recovering endangered Chinook salmon populations.

Estuaries happen where conditions cause an enclosed, diluted (lower salt concentration) body of water to form. The Salish Sea (Puget Sound, Strait of Juan de Fuca, and Strait of Georgia) is a large estuary that also has river mouth estuaries and small-scale ‘pocket’ estuaries that have even more dilute waters compared to whole Salish Sea. Think of it as small estuaries that are all different from one another within a bigger estuary! Juvenile Skagit Chinook salmon use the estuary of the river where they were born (their native river) and nearshore habitats next to and far away from their native estuary, including pocket estuaries in the Whidbey Basin of Puget Sound to feed and grow big and strong for their upcoming migration to the Alaska Gyre and back.

Wild juvenile Chinook salmon are known to use estuary habitats consistently from February to October. The fish generally travel downstream (river to estuary) and offshore over time. Depending on their life history type (what stage in their life cycle they migrate to the estuary, Table 2.1), juvenile Chinook salmon born in the same year use different habitats, at different times. Different life history types will be exposed to different conditions that can affect their growth and survival, based on the habitat they choose. It is important to identify what juvenile life history types are present in which habitats for planning salmon population recovery.

Table 2.1. *Description of known juvenile life history strategies for wild Skagit Chinook salmon.*

Life history type	Life History Strategy Description
Ocean type	*Fry Migrants* – These fry emerge from egg pockets and migrate quickly downstream to Skagit Bay usually in February and March, at an average fork length of 39 mm. Some fry migrants take up residence in pocket estuary habitat that are thought to provide them with a survival or growth advantage over other habitats.
Ocean type	*Tidal Delta Rearing Migrants* – Tidal delta rearing fry emerge from egg pockets and migrate downstream at the same time as fry migrants. However, they reside in tidal delta habitat from several weeks up to several months, reaching an average size of 74 mm before entering Skagit Bay usually starting in late May or June.
Ocean type	*Parr Migrants* – These fry emerge from egg pockets and rear for a couple of months in freshwater to achieve a similar size as the tidal delta rearing fry over the same time period. They then move through the tidal delta and into Skagit Bay, usually starting in late May or June at the average size of 75 mm. Parr migrants do not reside in tidal delta habitats. Some of these fish may reside in side-channel habitat within the floodplain areas of the Skagit River.
Stream type	*Yearlings* – These fry emerge from egg pockets and rear in freshwater for over one year. Movement patterns and what habitats they use in freshwater are largely unknown. Yearlings migrate to the estuary generally from late March through May at the average size of 120 mm. Yearlings seem to pass through tidal delta habitats, possibly lingering briefly, on to nearshore areas. Yearlings are most commonly detected in deeper subtidal or offshore habitats. Residence in nearshore areas of Skagit Bay by yearlings appears to be shorter than ocean type life histories.

Life History Strategies and Skagit Chinook Salmon Stocks

We looked at the otoliths (ear bones) of juvenile salmon caught in the Skagit Delta and Bay and fish that were returning to spawn in the Skagit River between 1995 to 2004. Otolith content is built up while in their eggs before they hatch and can identify where in the river they hatched (their population stock). By analyzing otoliths, the researchers can connect the habitats where the juvenile fish are found and tell which of the six population stocks they are from. Each life history type (fry migrants, delta users, parr migrants, yearlings) is important for each population stock's recovery, so understanding what habitats each stock is using is critical. All six Skagit Chinook salmon stocks have multiple juvenile life history types that depend on estuary habitats. With this knowledge we can start to figure out how the fish stocks will respond to estuary habitat loss in tidal delta and pocket estuary habitats.

Estuarine Habitat Conditions

All six Skagit Chinook stocks use estuary habitat as delta rearing or fry migrant life history stages. It is important to understand how humans have changed the Skagit tidal delta and nearshore pocket estuaries in Whidbey Basin that can affect the habitat quality for the salmon.

Loss of habitat in the Skagit River Tidal Delta

The delta has been diked (walls added), dredged (removing material on the seafloor) and filled (adding sand/gravel to replace water) which led to a loss of 74.6% of the tidal delta estuary habitat area. This also fragmented the habitat, meaning the habitats were smaller, and no longer connected (Figure 3.1).

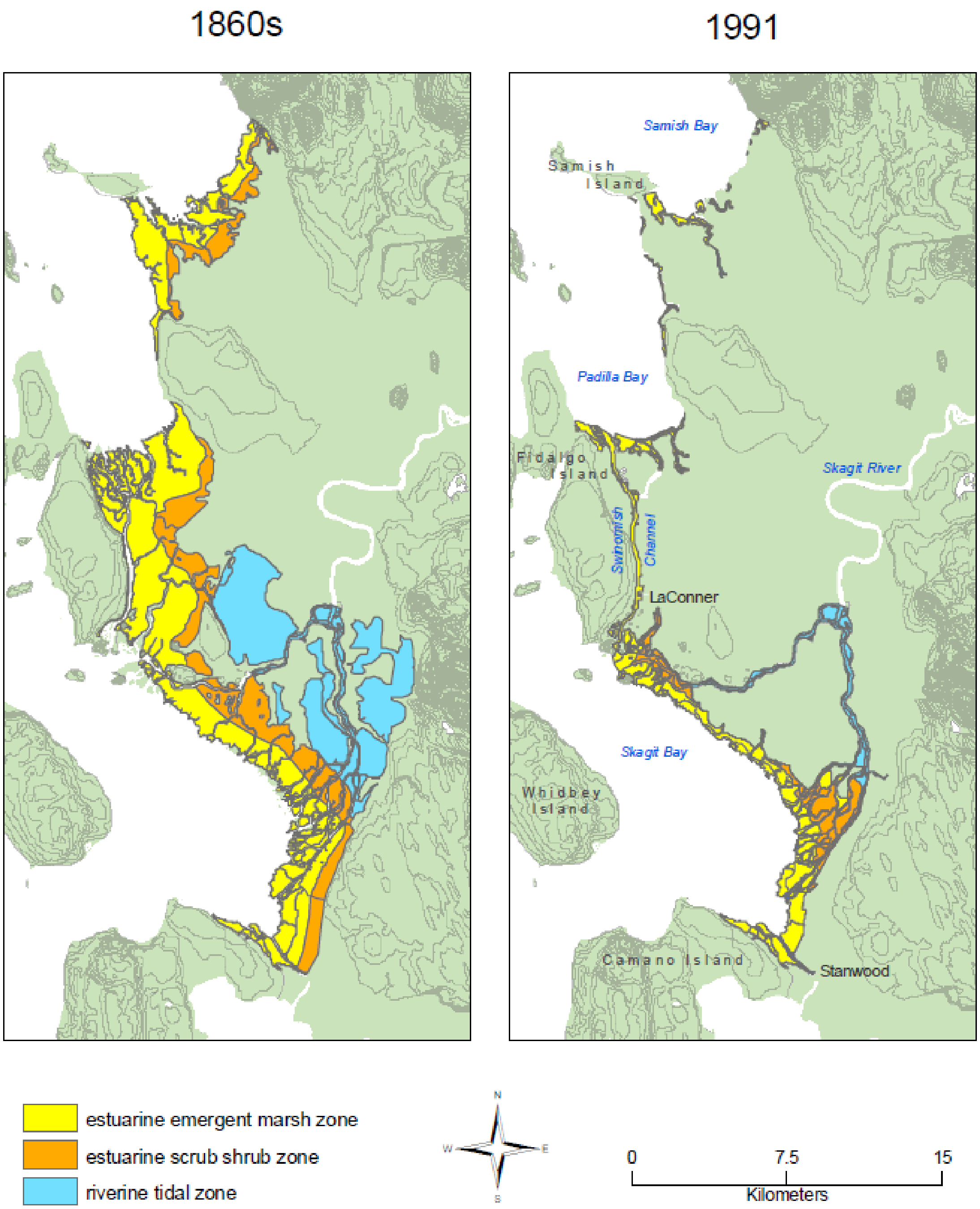

Figure 3.1. Changes to estuary habitats in Skagit delta. Notice in 1991 the large reduction in all habitat types and the loss of connection. The gray color between areas of color that symbolizes lost habitat in that area.

Juvenile Chinook salmon that grow up in delta estuaries prefer specific habitats: blind channels and the edges of channels. The total area of these types of habitats has been greatly reduced (table 3.2).

Table 3.2. Current and historic tidal delta channel habitat areas from Camano Island to southern Padilla Bay, ha = hectares. Notice large reductions, especially in blind tidal channels and areas preferred by delta rearing Chinook salmon.

Habitat types	Historic (~1860s)	Current (2000)	Change
Area of all open channels	1,223.8 ha	851.7 ha	-30.4%
Edge area of all open channels	114.7 ha	90.9 ha	-20.7%
Blind tidal channel area	1,158.0 ha	62.7 ha	-94.6%
Area preferred by delta rearing Chinook salmon	1,272.7 ha	153.6 ha	-87.9%

Loss of Whidbey Basin Pocket Estuaries

Pocket estuaries are small estuaries within the larger Puget Sound. The water is generally calmer (a less energy environment) and have freshwater that decreases the salt concentration (salinity) of the water during some part of the year. They are usually not connected, so the migration pathways between them (how they get from one to the other) are very important to salmon, and if lost can greatly impact salmon survival.

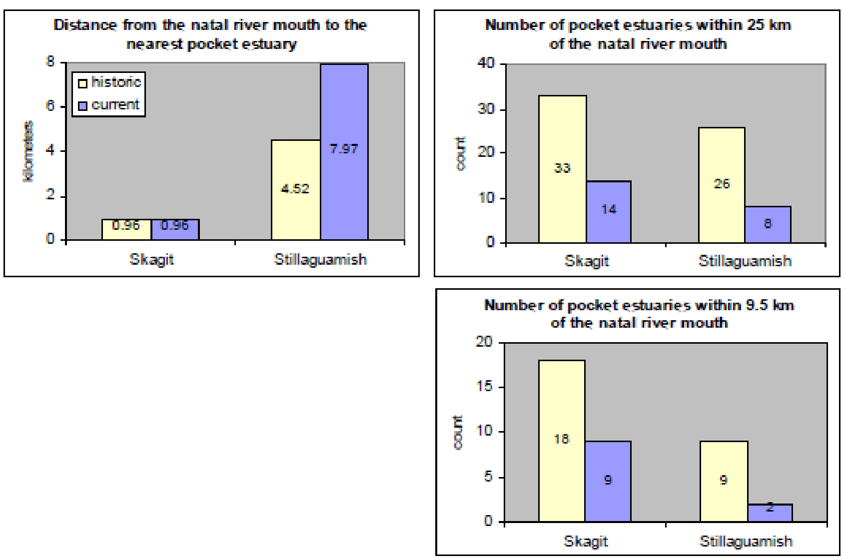

Figure 3.4. Distance from native rivers to nearest pocket estuary in the Whidbey Basin historically and current. Current times (purple) shows increased distance of pocket estuaries from natal rivers (panel 1) and fewer pocket estuaries within 25km (panel 2). We calculated that 9.5 km is a distance that most juvenile Chinook salmon can travel from a delta, and pocket estuaries in that range may be more important. Current numbers of pocket estuaries in this distance from native rivers has been greatly reduced (panel 3).

Much of the pocket estuary habitat and connections between them have been lost due to human land use. Salmon can no longer get to 68% (58 out of 85) of the pocket estuaries. The other 27 that are available have all been modified (dredging, filling, shoreline hardening, and diking) and reduced in size by 50%. This means there is about an 80% loss of pocket estuary habitat in Whidbey Basin. This reduces the area available to the salmon, and increases the distance they need to travel to get from one pocket estuary to the next, or from their natal river to a pocket estuary (Figure 3.4 and 3.5). This can decrease their ability to survive.

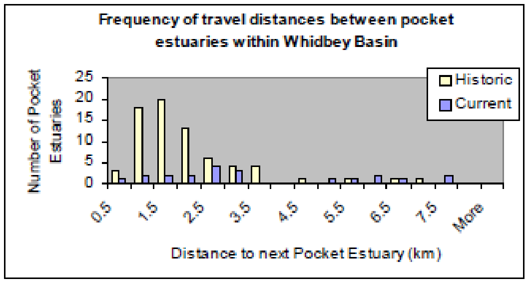

Figure 3.5. The number of lagoon type pocket estuaries in the Whidbey Basin by distance to next pocket estuary historically and current. The amount of pocket estuaries within few kilometers of another pocket estuary (allowing salmon to easily travel between) are greatly reduced in the current time, especially for those estuaries within 2.5 km.

Juvenile Chinook Salmon in Pocket Estuaries

Pocket estuaries are critical for fry migrant life history types and fish that have to move from tidal delta habitats (where sometimes it gets overcrowded). The pocket estuary habitat may be providing the best feeding area, which allows the fish to grow quickly. There appears to be fewer predators in these habitats as well, which means the small fry don't get eaten! Both of these increase their chances of survival. In addition, pocket estuaries are home to many different life history types that are important for each salmon stock's recovery. Thus restoration of pocket estuary habitat is very important for Skagit Chinook salmon population recovery.

Biological response to Connectivity

Salmon habitat is not just the places they live in, but also the pathways that connect those places. These migration routes are just as important to salmon survival because they are how the fish travel between habitats throughout their life history stages and it influences how many juvenile salmon are in estuary habitats. How connected the habitats are depends on how far the salmon have to travel, and how difficult the pathway is. Connection between habitats is lost as the distance and complexity of the path increases. Think of a short, clear, straight road, versus a long, curved road with many obstacles – which one is easier to get to the final destination? The greater the connection between habitats, the more juvenile Chinook salmon will be found in pocket estuary habitats. Restoring connectivity between these habitats in the delta should be a priority in Chinook salmon population recovery plans.

Implications for Restoration

The data shows that Skagit tidal delta and pocket estuary habitats are critical for a variety of life history types for all six wild Chinook salmon stocks. However, these habitats are much smaller and more fragmented than in the past, reducing the area available for Chinook salmon to grow up in. The reduced size of tidal delta habitats is limiting the number and size of juvenile Chinook salmon rearing in that habitat, which is important for their survival later in their life cycle. These difficulties make some salmon switch to a fry migrant life history type that has a lower survival rate. Pocket estuaries are particularly important for fry migrant life history type and can provide space when the delta habitats get overcrowded. It is clear that wild Skagit Chinook salmon populations will greatly benefit from restoration of both tidal delta and pocket estuary habitats, and improved connections between these important habitats (Table 6.3). In addition, climate changes can affect salmon survival (Table 6.3). Recovery plans need to take this into consideration to be sure that recovery of the fish populations happens under a variety of possible conditions.

Difference between current and restored	Juveniles per season	Adults per year (low survival-low regime)	Adults per year (average survival-low regime)	Adults per year (average survival-high regime)
Tidal delta restoration	1,352,790	1,476	7,003	20,522
Pocket estuary restoration	147,871	161	766	2,247

Table 6.3. The numbers here are the differences in the number of individuals between current and restored habitats and include how climate may affect these number of surviving adults. For example, there will be an increase of 1,352,790 juveniles per season at restored tidal delta habitats. Low regime means a climate scenario with low salmon survival, and high regime means a climate scenario with high salmon survival. Low survival-low regime shows the ‘worst case scenario’ for salmon survival. Restoration will have a positive influence on survival of adults, even in climate scenarios with low survival.

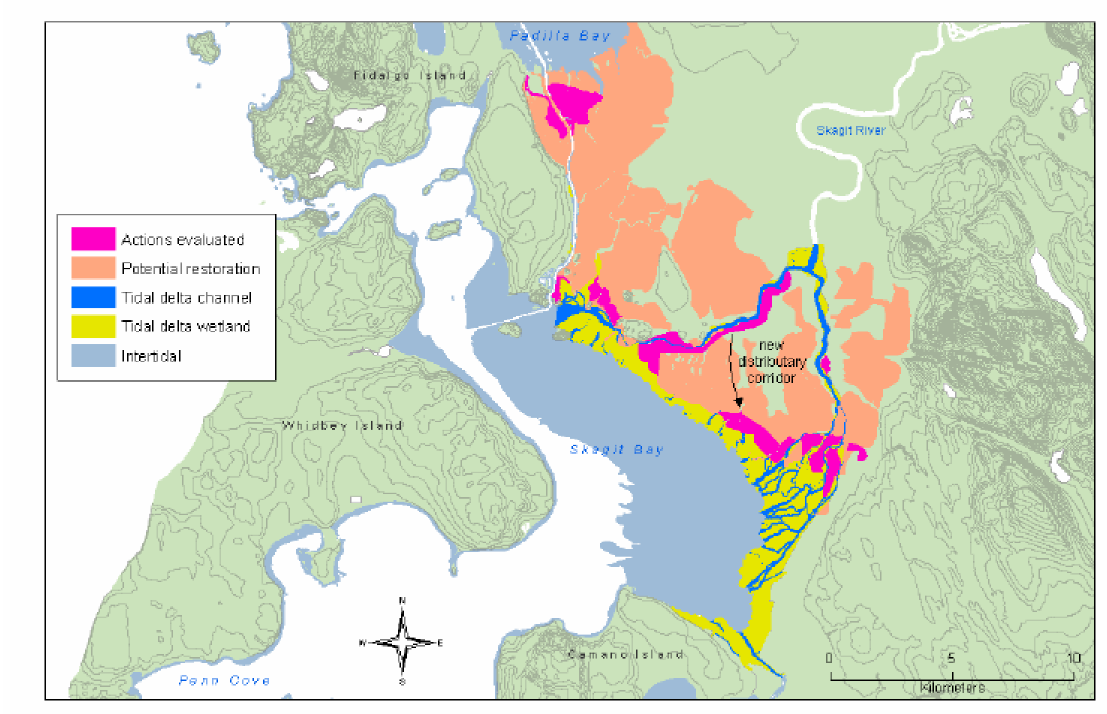

Figure 7.1. This shows the locations for possible tidal delta habitat restoration. The yellow and blue colors are areas that delta rearing Chinook salmon can get to currently. The pink color is areas that were identified in this paper as locations to restore that will most benefit salmon recovery. The orange color is areas that have the potential to be restored. Blue/gray areas are intertidal areas.

Nearshore Restoration

Juvenile Chinook salmon use inland coastal waters like Puget Sound, and survival during their time here is linked to the success of their populations as a whole (Greene et al. 2005, Beamish et al. 2004). Habitat quality (due to both natural and human influences) varies greatly between locations and affects the chances of survival for fish using that particular area. We need to be able to link specific salmon populations with specific areas and habitats within Puget Sound to better protect and restore areas that will most benefit their survival. We need to better understand the processes that influence these habitats, including erosion, tidal changes, freshwater inflow and mixing and water and sediment quality that affect habitat quality for salmon survival.

Landscape process restoration

We need to protect existing habitats and recreate lost historic habitats, including both tidal delta and pocket estuary areas. We need to protect unarmored areas and restore armored ones to their natural state. We need to protect existing and restore lost freshwater inputs to pocket estuaries, and protect existing landforms (and restore others) that help to protect and maintain pocket estuary habitat. Structures that limit sediment (sand) transport processes need to be removed. We need to protect and restore forage fish habitats as they are important prey for salmon and protect juvenile salmon in boat harbors (which they may be attracted too, but will face other challenges such as oil spills or different predators). Finally, we need to plan for predicted sea level rise in all restoration projects. We need to also focus on protecting certain areas where large amounts of salmon travel through, like Deception Pass, Swinomish Channel and Saratoga Passage because one catastrophic event (oil or other toxic spill) there could destroy a high percentage of the salmon population.

Pocket Estuary Restoration

The research in this paper shows that restoration of pocket estuaries along Skagit's nearshore environment will improve the number and survivability of Skagit Chinook salmon populations. We need to increase the ability for juvenile salmon to use pocket estuaries close to their native rivers and in Whidbey Basin in particular, and make sure healthy and functioning beaches connect pocket estuaries for the benefit of forage fish (salmon prey) and Chinook life history types.

The first priority should be to restore pocket estuaries that have a high level of connection with the Skagit Delta. This includes areas that are below (downstream of) the tidal currents that start at the river mouths. Their time in the pocket estuary, right after leaving delta or river habitats, will lower the risk of dying because they will be larger in size by the time they leave.

Potential pocket estuary restoration sites are shown in figure 7.2, each site is either an existing habitat, restoration potential or both. Juvenile salmon should have easy access to these sites, reaching any of these pocket estuary sites within 1 day of leaving the river, so they should be a restoration priority.

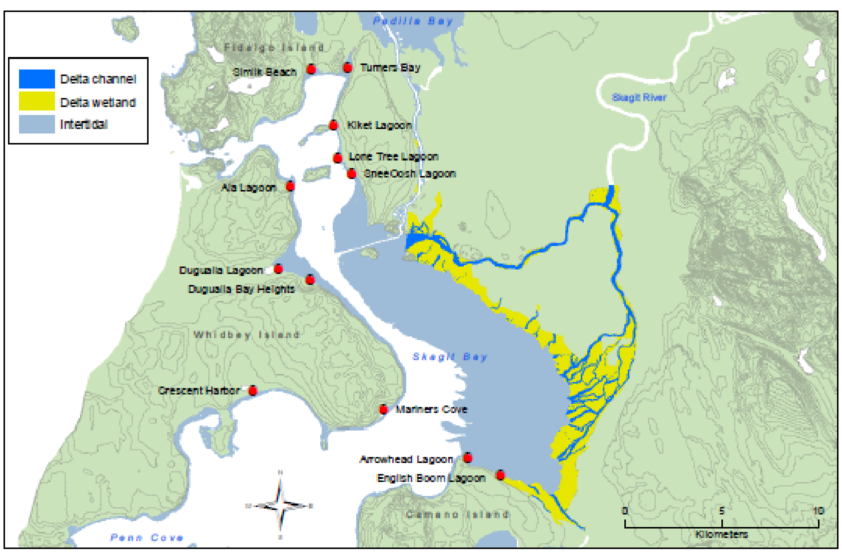

Figure 7.2 Red dots show potential pocket estuary restoration sites. All are within one day's migration for Chinook salmon from the Skagit River Delta.

Impact of Sea Level Rise on Estuary Restoration

Climate change impacts include increasing the rate of sea level rise over the next 100 years. This can greatly change the existing estuary habitats and could complicate the restoration recommendations included in this paper. Sea level rise estimates range from 34-50cm, and possibly 100cm. This affects the amount and type of vegetation in tidal delta or pocket estuaries, and could greatly change the ecosystem characteristics. Climate change will have additional impacts, with decreased freshwater flows from rivers that will increase the amount of salt (salinity) in the estuaries. Some smaller streams my dry up completely and reduce the ability for fry migrants to find pocket estuary habitats. These impacts can have large influences on the amount and quality of salmon habitat, and ultimately the survivability of juvenile salmon, but will vary for different locations. Thus site specific data needs to be considered in all recovery plans for Skagit Chinook salmon.

References

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