Study Plan for the Intensively Monitored Watershed Program: Skagit River Estuary Complex

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Prepared by:
Intensively Monitored Watersheds
Scientific Oversight Committee*
and IMW Partners

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Introduction

The Intensively Monitored Watershed program is a basin-scale validation monitoring effort to evaluate the effectiveness of salmon habitat restoration activities in increasing the production of salmon as recommended in the Washington State Comprehensive Monitoring Strategy (Crawford, et al 2002). The base program is funded by the Salmon Recovery Funding Board (SFRB), administered through the Washington Department of Ecology, and implemented by the IMW partners.

The basic premise of the Intensively Monitored Watersheds (IMW) program is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations. The data required to evaluate the response of fish populations to management actions that affect habitat quality or quantity are difficult and expensive to collect. Focusing efforts on a relatively few locations enables enough data on physical and biological attributes of a system to be collected to develop a comprehensive understanding of the factors affecting salmon production in freshwater.

The ultimate objective of nearly all efforts intended to improve salmon habitat is to increase the abundance of the fish. Therefore, the most meaningful measurements of the effectiveness of a restoration program are those related to the performance of the fish during their period of freshwater residency; from adult spawning through smolting of their offspring. Because salmon use multiple habitat types during freshwater rearing and may move throughout the watershed to locate these habitats, the spatial scale at which an evaluation is conducted should be large enough to encompass all the habitats required for the salmon to complete this phase of their life history. The size of the area required to capture the full range of habitats needed to complete freshwater rearing will vary by species.

The IMW Program consists of three elements:
- Studies at three complexes of three or four watersheds each focusing on coho salmon and steelhead trout (Figure 1),
- Evaluation of the effects of estuary restoration on juvenile chinook salmon growth and survival on the Skagit River Estuary.
- A Pacific Northwest-wide landscape classification intended to guide the application of IMW results to other watersheds. The classification is based on similarity of physical and biological characteristics to the watersheds included in the IMW project. Watersheds which have biophysical characteristics and patterns of human activities comparable to IMW sites will be locations where IMW results can be extended with the greatest degree of certainty. This effort is led by the Northwest Fisheries Science Center.

This document describes the IMW monitoring efforts in the Skagit River estuary focusing on chinook salmon. The three coho/steelhead complexes are described elsewhere (refs for

![Map showing the locations of the four IMW study sites: Strait of Juan de Fuca, Hood Canal, Lower Columbia, and the Skagit River Estuary.](image)

**Figure 1.** Locations of the four IMW study sites: Strait Juan de Fuca, Hood Canal, Lower Columbia, and the Skagit River Estuary.

Chinook salmon require a substantially larger watershed to complete their freshwater rearing than coho, steelhead and cutthroat. The larger area required by this species makes it very difficult to use a treatment-reference comparison at the level of an entire watershed, as we are doing for the other species. We are working with the Skagit River System Cooperative and the Northwest Fisheries Science Center that focuses on the effect of estuary restoration on Chinook salmon growth and survival.

Chinook salmon are well known for utilizing natal river tidal deltas, non-natal “pocket estuaries” (nearshore lagoons and marshes), and other estuarine habitats for rearing during outmigration (Reimers 1973, Healey 1980, Beamer et al 2003). Several studies have linked population responses to availability of estuary habitat, either by examining return rates of groups of fish given access to different habitat zones (Levings et al. 1989).
or by comparing survival rates of fish from populations with varying levels of estuary habitat degradation (Magnusson and Hilborn 2003). These studies support the hypothesis that estuarine habitat is vital for juvenile Chinook salmon. However, these necessarily coarse-scale studies have ignored how large-scale estuarine habitat restoration within a watershed contributes to population characteristics. These issues may be critical to understand how to best restore Chinook salmon populations, as many estuaries within Puget Sound and elsewhere have been converted to agriculture and urban land uses. For example, the Duwamish River has lost more than 99% of its tidal delta habitat (Simenstad et al 1982), while the Skagit River, which contains the largest tidal delta in Puget Sound, has lost 80-90% of its aquatic habitat area (Collins et al. 2003).

**IMW Goals and Historic Monitoring**

Our goal is to understand changes in population characteristics (e.g., abundance, productivity, survival, and life history diversity) of wild Chinook salmon in response to reconnection and restoration of estuarine habitat. This issue requires us to examine the effects of restoration at a system-wide scale, i.e., the spatial extent that encompasses the entire population of Chinook salmon rearing in the estuary. As the Skagit “estuary” includes wetlands of the tidal delta as well as nearshore and offshore zones of Skagit Bay, this task is by no means easy.

Our goals require long-term monitoring tied to restoration efforts. Historically, we have monitored Skagit River Chinook salmon via a long-term interagency program involving sampling of outmigrants at Mt Vernon (Washington Department of Fish and Wildlife, WDFW), fyke trapping of fish rearing in the tidal delta (Skagit River System Cooperative, SRSC), beach seining of nearshore habitats in Skagit Bay (SRSC), and towenetting of offshore areas in Skagit Bay (Northwest Fisheries Science Center, NWFSC). This program provides us a system-wide analysis of patterns of abundance and life history diversity across the juvenile salmon migration season.

The benefits of this diverse effort include:

- this program provides adequate redundancy should one element of the monitoring effort fail due to temporary failure of equipment, loss of personnel, or inclement conditions.
- this program systematically captures the sequence of habitat types used by juvenile Chinook salmon during migration through the estuary.
- much of this effort has been in place for 10+ years, and therefore provides a good time series to establish a baseline for evaluating the large-scale effects of restoration.
- this program provides important insights into the ecology of Chinook salmon.

The outmigrant trapping has documented an important relationship between freshwater survival and incubation flood magnitude (Seiler et al. 2003). This combined with fyke trapping in the delta, has provided strong support for density dependence and a habitat area constraint in the tidal delta (Beamer et al. 2005). Systematic beach seining has revealed relationships between nearshore growth rates and residence in the delta (Beamer...
and Larsen 2004). In addition, analysis of the seasonal distribution of fish caught during townetting indicates that hatchery and wild fish have very different patterns of nearshore residency (Rice et al. 2001).

However, this program had several weaknesses. First, the consistent use of index sites to monitor juvenile Chinook salmon has resulted in low resolution for assessing spatial variation of the habitats sampled, and complicates assessments of abundance. Second, no studies to date have effectively measured survival of juvenile Chinook salmon in estuarine habitats; leaving open questions how restoration of estuarine habitats improved population productivity\(^1\). Third, because the current sampling scheme was developed to build an understanding of the actual juvenile life history types using the Skagit estuary and its possible bottlenecks to productivity, it was not explicitly designed for testing effects of restoration at a system-wide scale. Thus, the historic sampling design was not designed to detect population responses to restoration.

Through a partnership with the IMW, the existing monitoring was supplemented to build a systematic monitoring program that can detect population changes linked with Restoration project implementation. In order to accomplish this, we use several study designs, linked to both index monitoring to assess population trends and random sampling to obtain unbiased estimates of population density. In addition, we conduct several types of studies which should allow us to estimate survival during rearing in the tidal delta. These efforts, in combination with site-specific efforts to examine effectiveness of several large-scale estuary restoration projects, will allow us to evaluate the role of estuary restoration for the recovering Chinook salmon population in the Skagit River. Lessons learned in the Skagit estuary could benefit recovery efforts in other Puget Sound Chinook salmon bearing rivers. This should be true in places that have the same habitat and life history types as the Skagit, although out of system transferability will need to put in a river specific context.

### Skagit River Estuary-Description

Monitoring Chinook salmon in the Skagit estuary started from several premises: 1) Chinook salmon are federally threatened in the Pacific Northwest, 2) Chinook salmon require estuary habitat for successful rearing and transition to the marine environment, and 3) estuary habitat loss and degradation in the Skagit system has resulted in reduced capacity for salmon. While the first of these premises was supported by other researchers (Myers et al. 1997) at the time monitoring began, the other premises had weak (if any) support. Therefore, for the last 10 years, our monitoring goals have been to examine population characteristics and habitat use of the Skagit estuary by different life history types of Chinook salmon, with the goal of identifying their limiting factors.

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\(^1\) One study currently underway (Skagit Chinook Life History Study) does estimate marine survival (beginning of nearshore residency to returning adult) of juvenile life history types. This study uses otolith microstructure to identify specific juvenile life history types and relative survival estimates will be made for two brood years with very different outmigration sizes: 1994 (2.2 million outmigrants) and 1998 (7.1 million outmigrants). While this study does give us a tool to quantify the benefits of different restoration actions that benefit specific life history types, it doesn’t directly measure survival at specific juvenile stages. This study is primarily funded by Seattle City Light and Northwest Indian Fisheries Commission. Principle investigators are Eric Beamer (SRSC) and Kim Larsen (USGS WFRC).
Our efforts provided strong support for the second two premises. We have documented that the majority of fish use the tidal delta during rearing for up to eight weeks, and may reside in Skagit Bay for several months (Beamer et al. 2000; Beamer and Larsen 2004). Furthermore, we have found that density of fish in the tidal delta peaks at high outmigrations, that body size declines as a function of tidal delta density, and that the frequency of one life history subtype – fry migrants – increases as a function of the abundance of the population entering the tidal delta (Figure 2). Furthermore, we have found that the return rate of adult salmon is limited by the abundance of juveniles (Greene et al. 2005). All these findings support the third premise, and provide a strong argument for restoration of habitat in the Skagit estuary. The Skagit River System Cooperative and WDFW produced a recovery plan that emphasizes estuary restoration as the centerpiece for recovery of Chinook salmon in the Skagit River (Skagit River System Cooperative and Washington Department of Fish and Wildlife 2005). This plan features several restoration projects already completed or in preparation, as well as some that are currently at conceptual stages. The result will be the first large-scale experiment on the effects of estuary restoration on Chinook salmon populations.

Hypotheses

If we interpreted the results in Figure 2 strictly and applied it equally to the entire Skagit estuary, we should expect restoration in the Skagit tidal delta to reduce local tidal delta Chinook salmon densities, thereby causing increases in body size and overall population abundance and a decrease in the frequency of fry migrants.

However, because of variation in the accessibility and the current availability of habitat across the estuary, hypotheses should differ in different areas of the estuary. We used a system-scale approach to generate hypotheses about how restoration of tidal delta capacity and connectivity and pocket estuary capacity effect juvenile Chinook abundance, size, and the frequency of life history types (Table 1).

Table 1. List of delta restoration projects completed or currently under feasibility/design. See Restoration section for more details.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Sub-delta Polygon affected (Fig. 3)</th>
<th>Project type (Area restored to river/tidal hydrology)</th>
<th>Year complete</th>
<th>First year juvenile Chinook could benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deepwater Slough</td>
<td>#4</td>
<td>Capacity/Connectivity (221 ac)</td>
<td>2000</td>
<td>2001</td>
</tr>
<tr>
<td>Smokehouse Floodplain</td>
<td>#1</td>
<td>Capacity (62 ac)</td>
<td>2005-7</td>
<td>2006-8</td>
</tr>
<tr>
<td>Milltown</td>
<td>#4</td>
<td>Capacity (212 ac)</td>
<td>2006/7</td>
<td>2007/8</td>
</tr>
<tr>
<td>South Fork Dike Setback</td>
<td>#4</td>
<td>Capacity (40 ac)</td>
<td>2004</td>
<td>2005</td>
</tr>
<tr>
<td>Wiley Slough</td>
<td>#4</td>
<td>Capacity/Connectivity (161 ac)</td>
<td>2007</td>
<td>2008</td>
</tr>
<tr>
<td>Swinomish Channel Causeway</td>
<td>#1</td>
<td>Connectivity (na)</td>
<td>2008</td>
<td>2009</td>
</tr>
<tr>
<td>Fisher Slough</td>
<td>#4</td>
<td>Capacity (68 ac)</td>
<td>2008</td>
<td>2009</td>
</tr>
</tbody>
</table>
Figure 2. Functional relationships for wild juvenile Chinook salmon from the Skagit River, delta and nearshore (from Beamer et al 2005). Points and solid lines represent the results of a decade of field study while dashed lines illustrate conceptually how these relationships should respond to habitat restoration planned for the Skagit tidal delta. (A) The relationship between freshwater smolt outmigration population size and the density of juvenile Chinook in tidal delta habitat. (B) The relationship between freshwater smolt outmigration population size and the percentage of juvenile Chinook in nearshore habitat that exhibit the fry migrant life history type. (C) The relationship between Chinook salmon density in tidal delta habitat and the size of juvenile Chinook in tidal delta habitat. (D) The relationship between Chinook salmon density in tidal delta habitat and the size of juvenile Chinook in nearshore habitat.

We developed sub-delta monitoring hypotheses by thinking how current delta habitat is being utilized by juvenile Chinook salmon (Figure 3) and then by hypothesizing how juvenile Chinook salmon would respond to planned delta restoration (Figure 4). In Figures 3 and 4, the arrow directions depict how juvenile Chinook salmon move through delta habitat and into Skagit Bay. The pathways within the delta are based where delta distributary channels are located or planned to be restored. The pathways for fish moving from delta habitat to Skagit Bay were derived from drift buoy data (see Beamer et al. 2005). Arrow thickness represents the number of juvenile Chinook salmon using each pathway based on the current or restored habitat amount and configuration. Figure 4 shows planned restoration areas in pink. Because of limitations in the migratory pathways that fish can take within delta habitat, we do not expect the entire delta will respond to
specific restoration projects in a homogeneous fashion. The sub-delta areas that we do expect to respond similarly are numbered and circled in Figure 4. Monitoring hypotheses are stated for each area in Table 2. All monitoring hypotheses are interpreted as functions to account for varying outmigration population sizes, habitat conditions (e.g. channels with deep areas with low tide impoundments vs. channels without these features), and environment (e.g., floods, temperature, salinity).

Table 2. Draft monitoring hypotheses for juvenile Chinook salmon abundance in sub-delta polygons shown in Figure 4.

<table>
<thead>
<tr>
<th>Sub-delta polygon # and name</th>
<th>Potential Restored Area (ac)</th>
<th>Pre-restoration</th>
<th>Post-restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Swinomish Channel Corridor</td>
<td>770</td>
<td>Juvenile Chinook density is lowest (along with polygon #5) compared to other sub-delta polygons</td>
<td>Juvenile Chinook density will increase following restoration that improves connectivity with the North Fork Delta. Juvenile Chinook salmon population &amp; body size will increase following restoration that increases rearing capacity along the Swinomish Channel Corridor.</td>
</tr>
<tr>
<td>#2 North Fork Delta</td>
<td>980</td>
<td>Juvenile Chinook density is highest compared to other sub-delta polygons</td>
<td>Juvenile Chinook density will decrease following restoration projects that increase connectivity to other areas within the delta. Juvenile Chinook salmon population &amp; body size will increase following restoration that increases rearing capacity within the North Fork Delta.</td>
</tr>
<tr>
<td>#3 Central Fir Island Delta</td>
<td>470</td>
<td>Juvenile Chinook density is 2nd lowest compared to other sub-delta polygons</td>
<td>Juvenile Chinook density will increase following restoration that increases connectivity to central Fir Island. Juvenile Chinook salmon population &amp; body size will increase following restoration that increases rearing capacity within Central Fir Island.</td>
</tr>
<tr>
<td>#4 South Fork Delta</td>
<td>630</td>
<td>Juvenile Chinook density is intermediate compared to other sub-delta polygons</td>
<td>Juvenile Chinook density will remain intermediate compared to other sub-delta polygons. Juvenile Chinook salmon population &amp; body size will increase following restoration that increases rearing capacity within the South Fork Delta.</td>
</tr>
<tr>
<td>#5 Stanwood/English Boom Delta Fringe</td>
<td>None Currently Identified</td>
<td>Juvenile Chinook density is lowest (along with polygon #1) compared to other sub-delta polygons</td>
<td>Juvenile Chinook salmon population &amp; body size will increase following restoration that increases source population size originating from Skagit and Stillaguamish Rivers.</td>
</tr>
</tbody>
</table>
The nature of the system presents a set of challenges. First, there is but one natal tidal delta for the Skagit River population, making replication across watersheds impossible. Nor can other river systems in Puget Sound act as comparisons, due to the sheer cost of such a monitoring effort and the highly variable degree to which populations are monitored and supplemented (see IMWSOC, 2004). Second, conditions of fish and habitat in the tidal delta may reflect to some degree conditions upstream. Third, the vast changes in body size and habitat use that Chinook salmon undergo during estuary rearing require us to use several techniques to monitor outmigrants. Despite these challenges, we believe we can
provide a system-wide assessment of the effects of estuary restoration on Chinook salmon populations.

**Experimental Design**

We will use different monitoring designs at different spatial scales to evaluate the effects of restoration. At a project scale, we use before-after-control-impact (BACI) designs to examine effectiveness of each restoration project. The Skagit River System Cooperative is employing this technique via treatment and reference reaches to examine whether restoration at Deepwater Slough has successfully increased habitat utilization to match or exceed reference levels. With the exception of proposed mark-recapture studies (see below), all project-specific monitoring is funded from other sources.

BACI designs may also be possible at larger spatial extents due to the independence of two delta subsystems, the North and South Fork of the Skagit. Because much of the initial restoration has been and will be targeted primarily on the South Fork of the Skagit, we have the opportunity to use a BACI design, where data obtained in the South Fork area can be used as a before-after comparison of a restoration treatment and data obtained from the North Fork acts as a reference during this entire period of time. Data from both beach seine and tidal delta sites contiguous to the North and South Fork will allow us to examine how body size and life history diversity change in response to this restoration. BACI designs will also be possible for two other larger scale analyses related to major restoration projects that improve migration pathways (connectivity) to habitat within Swinomish Channel (polygon #1 in Figure 4, Table 2) and the bayfront along Fir Island (polygon #3 in Figure 4, Table 2). Each of these polygons has multiple sites with ten years of data.

BACI designs are appropriate as long as restoration does not occur in the North Fork. When restoration begins (in 2009), the effects of restoration will need to be examined at a system-wide scale. To tackle estuary restoration at the system-wide scale, other monitoring designs are required because there is no control possible for the Skagit River tidal delta. For some variables, a before-after (BA) intensive design (Roni et al. 2005) with comparisons among multiple subregions of the Skagit estuary is possible because of 10 years of existing sampling at index sites. Our plan will also provide us with two or three years of randomized data collection before the second major estuary restoration projects are implemented, and should therefore provide the basis for a BA design. However, this design will require some modification because multiple restoration projects will be completed over a span of years, not at one single time which the BA design usually assumes. Consequently, we may use regression designs to examine changes in key variables over time as projects are completed. The dashed lines in Figure 2 illustrate conceptually how different biotic variables might respond to delta habitat restoration.

**Sampling methodology**

In most systems, a complete census of the entire monitoring area is impossible, and therefore requires some sort of sampling. Status and trends monitoring often follows one of two general sampling approaches: 1) use of “index” sites that are repeatedly sampled
over time, or 2) random selection of sites during each sampling event (Larsen et al. 2001). Because site-level environmental variation is largely controlled for by sampling at index sites, they are ideal for detecting trends over time. However, they suffer from the fact that they are not random samples and therefore may produce biased estimates for variables of interest (Larsen et al. 2001). Our monitoring plan shifts some effort from index-site to randomized sampling schemes, while at the same time maintaining some index sites for monitoring trends. This will allow us to obtain unbiased estimates of population density while we continue to monitor trends over time.

Index sites. We propose to continue monitoring index sites at the same temporal frequency that has been conducted over the last decade (Table 3). Current sampling sites include the Skagit River, tidal delta, nearshore and offshore areas of Skagit Bay. The nearshore/offshore study area extends from Deception Pass (north) to Saratoga Passage (south) to be roughly equal in distance from the mouths of North Fork and South Fork Skagit River sloughs. Sites are shown in Figure 5.

Table 3. Current monitoring program related to assessing the effects of restoration in the Skagit River estuary.

<table>
<thead>
<tr>
<th>Method</th>
<th>Habitat</th>
<th>Sampling regime</th>
<th># index sites</th>
<th># years at index sites</th>
<th>Random sites (# per sample trip/# per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outmigrant trapping</td>
<td>Mainstem</td>
<td>Daily: Feb-Aug</td>
<td>1</td>
<td>12</td>
<td>----</td>
</tr>
<tr>
<td>Fyke trapping</td>
<td>Tidal delta &amp; Swinomish Channel</td>
<td>Biweekly: Feb-July, Monthly: August</td>
<td>11</td>
<td>12</td>
<td>4/40</td>
</tr>
<tr>
<td>Townnetting</td>
<td>Offshore</td>
<td>Monthly: Mar-Oct</td>
<td>4</td>
<td>4</td>
<td>16/112</td>
</tr>
</tbody>
</table>

1Includes 4 pocket estuary sites: Lone Tree Lagoon, Arrowhead Lagoon, Grasser’s Lagoon, and Turner’s Lagoon. Pocket estuary sampling started in 2002.

Randomized sites. We will augment the current site-specific monitoring with spatial randomization to test whether our understanding of Chinook salmon populations in index sites is the same throughout the study. We use a stratified random design to account for large differences in space/connectivity. We will stratify sampling for three habitat types: delta blind channels, nearshore (including pocket estuaries), and offshore (Table 3).

Figure 6 shows the population of potential delta blind channel sampling sites. There are 498 blind channel complexes within the existing tidal delta habitat when you include the
delta fringe running from Camano Island to Padilla Bay. We will stratify by the same sub-delta polygons shown in Figure 4 and randomly select sites to sample. We will devote one crew per sampling week to conduct this effort. Approximately 40 sites will be sampled over the season.

Figure 7 shows the population of potential nearshore sampling sites. There are 184 nearshore geomorphic units (includes pocket estuaries) within the Skagit Bay Study area. From these 184 units, we will eliminate those that cannot be sampled via beach seining, and then stratify based on three general divisions of Skagit Bay: south of Strawberry Point (south), Hope Island to Strawberry Point (middle), and Hope Island and points north (north). These areas differ in habitat use patterns, and correspond roughly to areas that would be colonized primarily by fish from the South Fork (south), areas colonized by fish from both North and South Fork (middle), and areas subsequently used by both North and South Fork fish (north). We will include two sites per sampling week to conduct this effort. Approximately 192 sites will be sampled over the season.

We will randomly select offshore sites using the same three strata determined for beach seining (north, middle, and south Skagit Bay), selecting points deeper than 30 feet within these areas based on a uniform grid. Based on the variance determined from previous index sites, this type of design should provide an unbiased estimate of offshore Chinook salmon population density with 27% relative error at $\alpha = 0.90$ if we sample 12-16 sites randomly per month (relative error for our data asymptotes at 25%). The remainder of our effort will be devoted to sampling four index sites each month.
Figure 5. Index sites in the tidal delta, nearshore, and offshore.
Figure 6. Map of potential blind channel. Each point represents an individual blind channel complex that could be fyke trapped or beach seined.
Figure 7. Map of potential nearshore sampling sites. Each number represents a geomorphic unit that could be beach seined.
Variables of interest

Estuary restoration should have a number of system-scale consequences for Chinook salmon. These can be summed up as changes in abundance, changes in spatial distribution, changes in survival, and changes in life history variation (body size, life history types). Our monitoring plan incorporates a number of measures of the juvenile outmigration that can be used to test for effects of restoration. Most of these measures are made at a number of sites (index or randomly sampled), from which we expand to assess population-level changes.

Changes in abundance/density. The most direct measure of the population is an estimate of abundance. The Skagit River watershed benefits from four juvenile abundance estimates, made through the cooperation of three different agencies. The first direct estimate of juvenile population size is made prior to estuary residency, based on the number of outmigrants captured by WDFW in a screw trap at Mount Vernon. This estimate of abundance is critical to our proposed restoration monitoring effort because it provides information about the Chinook salmon population entering the tidal delta and nearshore. The three abundance estimates made in the estuary are via fyke trapping in the tidal delta, beach seining in the Skagit Bay nearshore, and townetting in the offshore. Because all these abundance estimates will depend on the amount of habitat sampled, we convert all abundance measures to densities. In the tidal delta, 36% of the variation in density is explained by environmental variation (temperature, salinity, discharge, and tidal exchange) related to connectivity of sites within the distributary channel network, and 31% is explained by a density-dependent relationship with the number of outmigrants estimated at Mount Vernon (Appendix D.VII in Beamer et al. 2005). Because of these relationships, we can predict the added capacity of any estuary restoration project. This provides our first way to test for system-wide changes due to estuary restoration. The Skagit River Chinook salmon recovery plan did this very exercise to conclude that the proposed number of restoration projects should be sufficient to support recovery of the population (Skagit River System Cooperative and Washington Department of Fish and Wildlife 2005).

Changes in spatial distribution. According to our predictions, tidal delta restoration should restructure the migration pathways of salmon through the tidal delta and into the Skagit Bay nearshore. Testing this hypothesis requires comparisons of Chinook salmon abundance in different regions over time. Therefore, sampling at the site level needs to be stratified across different regions. Changes in spatial distribution over time (years) will be tested using regression designs.

Changes in body size. Our monitoring data support the hypothesis that body size of smolts is most directly related to density in the tidal delta. Therefore, we should be able to test the prediction that restoration should result in an increase in mean body size of fish captured in the nearshore, especially those fish captured near the restoration projects. Our standard monitoring procedure involves taking length and weight of up to 20 fish captured at each site, and as long as the spatial distribution of sampling sites is well distributed, this design should be sufficient for estimating changes in body size due to restoration using regression designs.
Changes in the frequency of history types. Our monitoring supports the hypothesis that fry migrant subtypes (but not others) are the product of density-dependent migration through the tidal delta (Figure 2B). If so, estuary restoration should decrease the frequency of fry migrants captured in the nearshore. Testing this prediction boils down to our ability to equally detect fry migrants and other life history types in the nearshore. While it is sometimes not possible to distinguish other life history subtypes, the timing and size of fry migrants in the nearshore make this a very distinct population segment. A randomized sampling scheme should allow us to detect decreases in fry migrants using a regression design.

Changes in survival. We are proposing three types of survival studies as part of our future monitoring plan. These consist of mark-recapture studies at project or system-level scales and age structure and population abundance studies at a system scale. Mark-recapture studies can be used to examine survival by individually marking fish and examining the disappearance of these individuals over time. These studies can be logistically challenging because many individuals need to be marked to insure sufficient recaptures and much effort needs to be placed in recapture efforts. However, such problems can be at least partially overcome by using automated tag reading systems. Given the size constraints of juvenile chinook in the estuary, automated systems are limited, but can be used in two circumstances. First, at a project scale, we can PIT tag fish and recapture them using automated pit tag detectors in tidal channels. At a system-wide scale, we can tag large smolts in Skagit Bay or at the Mount Vernon trap and relocate them using linear arrays of nearshore receivers at the exits to Skagit Bay (following Welch et al. 2003).

We are proposing to compare residency and survival of PIT-tagged fish at the Wiley Slough restoration site. This project would involve a BACI design and require the installation of two sets of PIT tag readers, one in a slough undergoing restoration as part of the Wiley Slough project, and one nearby control slough that will not be affected by restoration. This restoration project is slated to be completed in 2008, thereby allowing us two years of pre-project data collection.

In 2005, we received funding from the Pacific Salmon Commission for acoustic tagging. During the summer of 2005, we conducted some preliminary field trials, and plan a much more extensive release in the future. This study would be repeated over the course of the next decade to evaluate the effect of restoration on survival using a regression design.

Another technique for measuring survival is using changes in age structure. These so-called life table approaches have generally been used on populations to estimate annual survival rates in age-structured populations. By extension, these studies can also be applied to study weekly or monthly survival as long as age-structure data exists at this temporal resolution. This type of study should have the benefit of being relatively straightforward to collect, and will be relevant at medium to large spatial scales as long as sufficient data are collected. The disadvantage of this type of study is the investment in otolith preparation and analysis. We now have several years of otolith data from both delta and nearshore life stages with which we can apply this approach and test its utility for estimating survival. Depending upon the results of this preliminary study, we may
use this approach based on annual collections of fish in the nearshore to evaluate survival each year, and then examine the effect of restoration using a regression design.

A final approach is to estimate survival through the tidal delta using population estimates of outmigrants made at the Mount Vernon trap and in the Skagit Bay. The second population estimate will incorporate site-specific density information for both nearshore and offshore, expanded to account for availability of these habitats, amount of sampling, and length of residency. We anticipate that these estimates will be unbiased (since they will be based on a randomized design), but may have low precision due to the expansion factors. Even so, they will be useful to compare with the life table approach. These analyses would rely on a regression design to examine changes in survival as additional restoration projects are completed.

**Analysis**

As described in the Experimental Design section, analyses will utilize the BACI design, when possible and the Before-After design otherwise. The specific statistical tests and confidence levels to be used are shown below (Table 4).

**Table 4. Statistical analyses and criteria proposed for the indicators described above.**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Metric</th>
<th>Statistical test</th>
<th>Statistical criteria</th>
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</thead>
<tbody>
<tr>
<td>Abundance/density</td>
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<td>Regression</td>
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<td>Proportion fry migrants</td>
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</tr>
<tr>
<td>Survival</td>
<td>%</td>
<td>Regression</td>
<td>α =0.10</td>
</tr>
</tbody>
</table>

**Power Analysis**

We examined our ability to detect a response in cumulative abundance to restoration in the tidal delta by performing a power analysis using the available monitoring data in a BACI design. In the case of the Skagit delta, monitoring data from the South Fork acted as a treatment because of the Deepwater Slough restoration, while data from the North Fork acted as a reference because no restoration projects have been implemented yet. We used cumulative abundance over the sampling season from the three index sites on each river fork sampled for eight years pre-restoration and three years post-restoration. Cumulative abundance is based on the density of fish sampled in tidal channels every two weeks between February and June. If restoration works as we hypothesize, density of fish – and by extension cumulative abundance – would decline in the South Fork index due to the increase in rearing habitat capacity in the Deepwater Slough restoration project.
The minimum detectable change (assuming a one-tailed, two-sample t-test) is a function of the confidence level ($\alpha$), power ($\beta$), the variance of the data, and the sample size (Equation 1). We have set $\alpha=\beta=0.10$ for all analyses.

$$\Delta P = \sqrt{\frac{2s^2(t_{1-\alpha} + t_{1-\beta})^2}{n}}$$

where $\Delta P =$ the detectable change in smolt production,

$s^2 =$ variance of the pre-restoration data (for the Before-After case) or the residuals of the treatment vs. reference stream regression (for the BACI design),

$t_{1-\alpha} = t_{(0.90, n)} (\alpha = 0.10, \text{one-tailed test})$

$t_{1-\beta} = t_{(0.90, n)} (\beta = 0.10)$

$n =$ number of years of pre and post-restoration monitoring (sample size).

We performed our power analysis by regressing pre-treatment data from the South Fork against that from the North Fork and inserting the variance of the residuals from this regression into Equation 1. We also plotted the post-treatment data as a comparison. As shown by Figure 8, there was a strong correlation ($r^2=0.50$) in cumulative abundance between North Fork and South Fork pre-restoration data (filled diamonds). This correlation substantially improves our ability to detect a response to restoration. We plotted the minimum detectable percentage change in cumulative abundance based on the number of years of monitoring data post-restoration. As shown in Figure 9, the minimum detectable change improves from approximately 17% change in cumulative abundance detectable with five years of post-restoration data, to an 11% change detectable with 10 years of monitoring data, with diminishing returns thereafter.

Because we already had three years of post-restoration monitoring data, we were able to estimate the actual change in cumulative abundance resulting from the Deepwater Slough restoration project. In Figure 8 the open circles and dashed line represent post-restoration data. Restoration of Deepwater Slough apparently resulted in a reduction in the cumulative abundance by $\approx 164969$ fish-days (the difference between the regression lines, assuming equal slopes), which is 54% of the average pre-restoration cumulative abundance. This change to date is actually much higher than the minimum detectable change (Figure 9); hence, additional large restoration projects have a very good chance of providing a detectable signal at the spatial scale of the entire tidal delta. As the data become available, we will perform similar power analyses on the other variables of interest described earlier.
Figure 8. Regression of Cumulative Abundance at index sites in the South Fork (SF) vs. the North Fork (NF) Skagit River. Limited post-Deepwater Slough restoration data indicate a 54% reduction in cumulative fish abundance at the South Fork index sites.

Figure 9. Minimum detectable change in cumulative abundance, shown as a percentage of the mean, vs. number of years of post-treatment data collected based on a BACI analysis using the North Fork as a reference for the South Fork Deepwater Slough restoration actions (α= 0.10, β= 0.90).
**Restoration Actions**

The tidal delta is the lower portion of the Skagit geomorphic delta that is influenced by tidal hydraulics and saltwater mixing. Biological evidence indicates a significant need for improvements in both estuarine habitat capacity and connectivity in order to achieve recovery of wild Skagit Chinook salmon populations. Beamer et al. (2005) contains detailed information regarding studies that have been conducted within the Skagit Basin that led us to this conclusion. All six Skagit Chinook stocks benefit from restoration of tidally influenced delta habitat.

Under present day conditions, the contiguous habitat area of the Skagit delta that is exposed to tidal and river hydrology totals about 3,118 hectares (Figure 10). This is mostly the delta area in the vicinity of Fir Island, but it also includes a fringe of estuarine habitat extending from La Conner to the north end of Camano Island. Historically, the contiguous habitat area of the Skagit delta included the same area, but also included the Swinomish Channel corridor and extended to the southern end of Padilla Bay (Collins 2000). The historic area equaled 11,483 hectares. This results in a seventy-three percent (73%) loss of tidal delta footprint.

Based on the arrangement of existing delta habitat and the need for more of it, it is unlikely that the Skagit Chinook salmon populations could achieve recovery without at least two delta restoration projects that improve the pathways juvenile Chinook salmon need to find and occupy delta habitat. Therefore, the Skagit Chinook Recovery Plan has included two connectivity projects, one for central Fir Island and another for Swinomish Channel. The Swinomish Channel project would take advantage of the large restoration potential along Swinomish Channel and southern Padilla Bay as well as improve pathways to existing under utilized nearshore habitat within Padilla Bay. The suite of potential delta restoration sites listed in the Skagit Chinook Recovery Plan is shown in Figure 11.

The Plan described implementation of delta restoration over two timeframes (near-term and long-term) in order to recognize logistic complexities, scientific and engineering challenges, funding constraints and social barriers to implementing restoration actions. We report the progress of six projects that were listed under the near-term implementation section of the Plan. These specific projects discussed are shown on Figure 11. Each of these projects is listed because they are either in the construction/design phase of restoration, or a feasibility phase that is highly likely to end in a restoration project. We believe that restoration will occur at these sites within the first few years of the IMW monitoring period, thus our effectiveness monitoring design has planned for a biotic response within the Skagit delta from these projects. The following sections describe the restoration projects in more detail.

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Figure 10. Changes to the estuarine habitat zones within the geomorphic Skagit Delta. Figure from Beamer et al. 2005.
Figure 11. Existing delta habitats and potential restoration areas. Location of existing delta habitats that are easily accessible to delta rearing Chinook salmon (yellow and blue polygons) and the location of potential delta restoration (pink polygons) presented in the Skagit Chinook Recovery Plan. Six projects (labeled) are currently under construction, design, or feasibility in 2005.
Wiley Slough

Project Summary

This project will set back dikes to the pre-1956 footprint of the levee system along Wiley Slough. The property is currently in public ownership (WDFW). Details are available in a recently published design report (SRSC 2005) and are shown in map form in Figure 12. The project will improve delta habitat connectivity and capacity for all six stocks of Skagit Chinook salmon. The project design was funded by the Salmon Recovery Funding Board and matched with funds from Seattle City Light and in-kind contributions from WDFW and several other organizations. Design funding cost approximately $150,000. Preliminary cost estimates from the design phase place implementation costs near $2.5 Million.

This project has a high likelihood of being constructed assuming agency concurrence project funding and permitting can begin almost immediately. Successful funding can potentially lead to project implementation as early as 2006. However, 2007 implementation will likely be more realistic given the size of the funding need and the potential for delays from challenges by user groups. Hunting groups are adamantly opposed to this project and will make every effort to prevent its implementation. Legal challenges are a possibility and could delay implementation for several years if the challenges are considered meritorious by the judicial system.

Expected Results

Physical: 65.0 ha (161 acres) of estuarine marsh area reconnected to tidal processes. Allometry predictions suggest this area can sustain 2.0 hectares of channel habitat with a connectivity rating of .040.

Biological: The resulting Chinook production is estimated to increase by approximately 38,492 delta rearing smolts.
Wiley Slough

Figure 12. Wiley Slough. Current on-site channels (red), including borrow ditches. Historical channels (black; observed from 1937 photos) often coincide with current channel remnants. The northeastern portion of the site was diked by 1889. The remainder was not diked until the early 1960s, so detailed reconstruction of historical channels on much of the site is possible through reference to historical (1937 and 1956) photos.
**Milltown Island**

*Project Summary*

Milltown Island (212 diked acres) was sold to WDFW after farming was deemed impractical in this area. The site has lain fallow and restoration efforts have been minimal, consisting of several *ad hoc* dike breaches in 2000. On-site tidal channel density and area is much less than in nearby reference areas. The project will remove old dikes to restore tidal and riverine processes that will scour and maintain on-site tidal channels and restore native vegetation (Figure 13). All Skagit Chinook salmon stocks will benefit from this project.

Design and permitting for this project is now underway. These were finished in 2005, allowing implementation work to proceed in 2006 and 2007. Funding for this project is secure: $100,000 through Seattle City Light’s ESA program. This money has been used as matching funds to secure a $350,000 commitment from the SRFB in 2004.

*Expected Direct Results*

**Physical:** Tidal channel density relationships in undiked reference tidal marshes in the South Fork Skagit delta indicate that marsh area of 212 acres (the amount of area directly influenced by Milltown Island dikes) should support approximately 19 tidal channels amounting to a total of 14.8 acres and approximately 12.2 miles length. Instead, only five tidal channels amounting to 5.3 acres and 2.9 miles length are observed in the portion of Milltown Island behind dikes (Figure 13), far less than predicted by the model. In comparison, the southern portion of Milltown Island, which was never farmed or diked and consists of 96 acres of tidal shrub wetlands, is predicted to support 11 tidal channels amounting 4.8 acres total. In fact, ten tidal channels totaling 3.9 acres are observed, which is in good agreement with model predictions. The contrast between predicted and observed tidal channel geometry for the diked versus undiked portions of Milltown Island suggests that there is potential for significant restoration of tidal channels in the diked portion of Milltown Island. The limited amount of existing dike breaches probably constrains tidal channel development. More extensive dike removal may allow greater tidal channel development.

**Biological:** Juvenile salmon (40-110mm fork length) currently have access to the site. Restoration actions on this site could result in additional tidal channel habitat (following a period of channel network development) and higher quality tidal marsh vegetation. Restoration actions include removal of at least 6,000 feet of dike. Under this scenario we expect the site to produce opportunity for an additional 57,179 smolts.
McGlinn Island Causeway

Project Summary

This action is expected to improve access by juveniles to estuarine rearing habitat in Padilla Bay. The current access, through a small opening in the rock jetty (known as the “Fish Hole”), is limited because river flow is directed away from Swinomish Channel, and the opening is inaccessible at low tides (Figure 14).

Purpose

To improve hydraulic and fish passage connectivity between the Swinomish Channel and the North Fork of the Skagit River, thereby alleviating an identified barrier to Chinook migration.

Populations Targeted

All

Figure 13. Milltown Island. Milltown Island site potential. Topography from LIDAR imagery (left). Potential vegetation, assuming elevation control (right).
Estimated Cost

Feasibility level investigations have been funded by the Salmon Recovery Funding Board for approximately $150,000 including match monies and services being supplied by the U. S. Geological Survey (USGS) who will take lead on hydraulic modeling tasks. Actual project implementation will depend on feasibility outcomes, but are expected to run in the $500,000-$700,000 range.

Timeframe

Feasibility work and preferred alternatives should be completed by the end of 2006. Implementation can be as early as 2007 if funding is made readily available. However, a 2008 start date would be more likely given the complexities of the project.

Contingencies

Key questions regarding impacts on population distribution and effect on fisheries allocations remain. If this action causes an increase in Canadian interceptions or other negative management ramifications it will be reconsidered or dropped. The question of how this project could impact harvest management or be impacted by harvest not currently being realized by the stocks (i.e., Canadian fisheries) needs to be answered during the feasibility planning.

Expected Direct Results

**Physical:** Water will flow from the Skagit River into Swinomish Channel at a depth and velocity that allows fish migration. This will increase connectivity to existing habitat throughout the Swinomish channel and Padilla Bay. This will also increase the benefits of projects being considered at the North end of the Swinomish channel.

**Biological:** Significant restoration potential exists along the northern end of Swinomish Channel. Two projects are included in our five-year implementation schedule—smokehouse floodplain and Telegraph Slough. The smolt benefit for these projects is highly dependent on the Swinomish Channel Causeway project that improves connectivity between the North Fork and Swinomish Channel. Without the causeway project, the combined benefit for these two projects is 72,622 smolts annually. With the causeway project, the combined benefit for these two projects almost doubles to 133,616 smolts annually. The Swinomish Channel causeway project also improves the value of existing habitat along Swinomish Channel and in southern Padilla Bay. The increase in productivity to existing habitat is estimated to be 40,898 smolts annually. Another important part the causeway project is that it could improve migratory pathways to eelgrass habitat within Padilla Bay that is under-utilized. Because data on habitat values for eelgrass in Padilla were not readily available this habitat contribution was not modeled.

Effectiveness Monitoring

Monitoring will focus on evaluating the relationship between modeled flows and actual flows once the project is implemented. Fish migration will need to be monitored as well to evaluate the effectiveness of predicted outcomes. A fyke net will be installed at the passage gate for limited periods of time, and will sample throughout the outmigration at different tidal stages and times of day, to estimate total fish use through the season. This
number will be estimated for different smolt outmigration levels, and compared to rearing densities observed in different estuary habitat types.

*Backup Actions (if Direct Results not achieved)*

It’s expected that feasibility investigations will address this issue in detail. It’s likely that contingency alternatives will be included in final recommendations that will allow for some adaptive management once the project has been implemented.

**South Fork Dike Setback**

*Project Summary*

2500’ of existing levee will be removed and re-graded down to the existing “bank top level” at the top end and the lower end will be graded for off-channel connectivity. The main river levee will be relocated and constructed approximately 700’ maximum from the riverbank at the mid-point of the project. 1800’ of new levee will be built adjacent to the County road with the keyway located along the riverward toe slope of the levee.

*Purpose*

To restore riverine tidal habitats for Chinook rearing.

*Populations Targeted*

All

*Estimated Cost*

Approximately $1,000,000. This includes property acquisition. $850,000 has been funded by the SRFB. $160,000 was provided as matching funds from Dike District 3 tax revenues.

*Timeframe*

Project was implemented in 2004 under the direction of Skagit County.

*Contingencies*

The project has been funded and implemented. Some site alterations might still be needed depending on the results of site monitoring. For example: re-grading the “upper” end of the project reach to restore “flow through” hydrology will be included if the need is demonstrated. Additional conifer plantings could be included as time and maturity of the site warrants.
Figure 14. McGlinn Island. Causeway conceptual design showing potential breech location. This action would likely be accompanied by work at the existing jetty fish way.
**Expected Direct Results**

**Physical:** If implemented so that hydrology can naturally influence the project site (i.e., upstream floodplain connectivity is not altered by armoring or fill) the site has over 16 hectares of site potential area. This could yield 0.374 hectares of channel habitat with a .081 connectivity rating.

**Biological:** Modeling suggests the site has potential to increase Chinook production by ~14,588 smolts.

**Effectiveness Monitoring**

The project has been implemented by Skagit County, through the use of SRFB funds, in late 2004. It is not clear if a monitoring plan has been developed for the site. We are assuming the IMW monitoring plan will be applicable in the absence of anything more detailed.

**Backup Actions**

Channel development could be impeded by toe rock remaining in place after construction. Channel development could also be impeded by topography of upstream end of the site (floodplain fill was retained to protect newly constructed levee). If channel development is limited these features should be evaluated for removal.

**Fisher Slough**

**Project Summary**

This project acquires ~50-80 acres of farmland within the riverine tidal zone and restores agricultural land to channel, scrub-shrub, forested wetland, and tributary junction habitats. In addition, this project assesses ecosystem functions supplied by the Fisher Slough subbasin, including hydrology and geomorphology, and provides conceptual alternatives for addressing high priority problems (Figure 15).

**Purpose**

To restore riverine tidal wetland habitats for juvenile rearing

**Populations Targeted**

All

**Estimated Cost**

Initial project elements have been funded by SRFB. Feasibility costs are approximately $150,000. Acquisition costs are approximately $250,000. Project costs will vary, but estimates are between $1,000,000 and $1,500,000

**Timeframe**

The feasibility and acquisition phase of this project are now underway. Probability of project implementation is very high. Expect implementation in 2007.
Contingencies

The most significant constraint on the project is the Big Ditch siphon culvert underneath Fisher Slough. The degree of Chinook benefit achieved on these parcels will depend on the degree to which hydrological connectivity can be maximized. Alternatives for passing Big Ditch flows without impeding drainage on farmland will be a principle part of the assessment. Selection of an alternative will depend on the financial cost relative to the ecological benefit provided.

Expected Direct Results

Physical: Our estimate of restoration potential indicates and area of 27.5 hectares (68 acres) of habitat could be realized at this location. This subsequently would result in about .81 hectares of channel area with a connectivity rating of .042.

Biological: If implemented such that tidal wetland is allowed to redevelop over the area of what is now locally known as the Poor Farm, this project should improve Chinook production by an estimated 16,431 smolts within 2-3 years after implementation.

Effectiveness Monitoring

A monitoring plan is being developed as a part of the feasibility project.

Backup Actions

Evaluate additional actions related to the Carpenter Creek system. If invasive species become a problem active management techniques will need to be employed to open channel corridors and control invasive spread.

Smokehouse Floodplain

Project Summary

The Fornsby Creek SRT project is a fish passage and habitat restoration project located along the Swinomish Channel of the Skagit River delta. The site was once an expansive estuarine emergent marsh over 900 acres in size (Collins and Sheik, 2002). Hydraulic modifications including installation of flap-style tide gates converted this emergent marsh to arable uplands. The modern site still contains a significant network of remnant slough channels, albeit simplified by decades of agriculture. These remnant channels are presently influenced by small freshwater tributary streams and seeps but isolated from tidal influence.

The project will replace existing impassible tide gates with self-regulating tidegates (SRTs). Tide gate replacement will restore tidal influence to the channels, enable fish passage, and increase the amount of available blind channel, distributary, and tributary habitat for all salmonid species. Allowing a wide range of tidal influence to interact with the remnant channels’ freshwater flows on the floodplain will create estuary-type freshwater and salt water mixing zones. These mixing zones are critical rearing habitat for juvenile salmonids. The project will also implement habitat restoration actions on 1.3 miles of the re-opened channel habitat. In total, the project will re-open more than five miles of channel to fish and improve over 50 acres of aquatic habitat (Figure 16).
Figure 15. Fisher Slough. Fisher Slough conceptual restoration footprint.
Figure 16. Fornsby Creek and Smokehouse Floodplain – Phase 1. Fornsby Creek and Smokehouse floodplain SRT replacement project - phase 1.
Purpose
To increase estuarine marsh habitats available to juvenile Chinook through improved passage at tide gates and riparian corridor development.

Populations Targeted
All

Estimated Cost
A total of $700,000 has been secured for this project.

Timeframe
Implementation will began in 2005. Final project elements for the first phase will be in place in 2007.

Contingencies
This site will not be able to realize its full site potential until the McGlinn Island Causeway project is constructed. The salinity barrier present in the Swinomish Channel will continue to limit the utility of the area to migrating Chinook.

Also, the complexity of individual land allotments (or Individual Indian Trust Lands) currently constrains the project scope. These allotments are often owned jointly by dozens, and in some cases hundreds, of related individuals. Securing permission to conduct project work on these lands is extremely difficult and time consuming. Therefore this project does not propose work on these lands. Work on individual allotment lands will be pursued in later phases and as agreements can be secured.

Expected Direct Results

Physical: In total, the project will re-open more than five miles of channel to fish and improve over 25 hectares (62 acres) of aquatic habitat. We believe this will result in approximately 2.59 hectares of newly available channel.

Biological: Prior to the completion of the McGlinn Causeway project the connectivity rating will be significantly lower than afterwards. Pre McGlinn connectivity is estimated at .0091 and post connectivity .016. This will result in and 20,471 smolts respectively.

Effectiveness Monitoring
The goal of the Smokehouse monitoring plan is to determine: (1) the effectiveness of the new tide gates in controlling the quantity of the water passing into and out of the reopened channels; (2) the change, if any, in water quality within the reopened channels; (3) the effect, if any, of saltwater on nearby agricultural lands; and (4) the amount of fish use within the reopened channels. The monitoring goals will be accomplished by comparing the data gathered before, during, and after the new tide gate installation (Table 5). The effects of the tide gate installations will be evaluated against pre-installation baseline data and results from a control site. The south fork of Fornsby Creek will retain the old style flap tide gate and function as this control site. This site is situated on Individual Indian Trust land, with restoration constraints as noted above. Future restoration may include this area as permissions are gained.
Table 5. Monitoring objectives and size allocation.

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<th>Control area</th>
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<td>Re-opened Channel Sites</td>
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</tr>
<tr>
<td>Soil Salinity Transects</td>
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</table>

**Backup Actions**

Increase tidal connections or expand project to include levee setback.

**Remaining phase I projects in Skagit Chinook Recovery Plan**

Two project areas (Davis/Dry Slough and Telegraph Slough-Phase 1) currently do not have active feasibility studies. During the short-term planning horizon we plan to initiate feasibility studies for both projects.

**Longer-Range Delta Restoration Projects**

Projects in the longer-range implementation horizon are those that have a significant degree of uncertainty that involve resolution by a new or established institutional mechanism. For example, the complexities involving the creation of a Fir Island cross-island connector potentially involves many different individuals and organizations. The incentive mechanisms for each of these parties differ. With these types of projects we are faced with identifying the incentive mechanisms that exist, or the mechanisms that could exist.

Therefore, this plan recognizes the need for an incentive framework that balances the needs of the individual with those of society. The mechanism by which such a balance is struck must rest with an institution that adequately represents the social and political will of local Skagit communities, relative to their responsibilities to the welfare of the region and State. Successful implementation of complex projects will require that first the appropriate institution is identified, and then the required ways and means are made available to such an institution. These requirements, by nature will require mandates by legislative bodies charged with meeting the will and the intent of public interest.

The following projects are likely candidates for the longer-term implementation horizon.

- Blake’s Bottleneck
- Smokehouse-Phase 2
- Cross Island Connector
- Sullivan’s Hacienda
- Deepwater Slough-Phase 2
- North Fork Levee Setback
Preliminary results

The Deepwater Slough Restoration Project is located in the South Fork Skagit River delta. The project was constructed in August and September of 2000 by removing 2.77 miles of dike and restoring tidal and river hydrology to 221 acres of historic estuary (Figure 17). These natural hydrologic processes are expected to restore the area to naturally functioning estuarine marsh and channel habitats over time.

The monitoring plan called for use of “reference” and “treatment” sites after project construction to answer questions regarding juvenile salmon presence/absence and abundance within the project area. Monitoring funded within the restoration project budget was done from 2001-2003. Blind tidal channels (also called dendritic channels) and distributary channels were selected near the project area for use as reference sites. Results from the reference sites were compared to results from treatment sites located within the area where dikes were removed (Figure 17). Treatment sites also consisted of blind tidal channels and distributary channels. The treatment sites were located in channels that juvenile salmon were not able to access until dikes were physically removed in the summer of 2000. We sampled both reference and treatment sites from March through July on a bi-weekly basis. Fyke trap methods were used to sample in blind tidal channels and beach seine methods were used to sample in distributary channels. Methods are described in Appendix D.1 of Beamer et al. (2005).
Figure 17. Location of the Deepwater Slough Restoration Project area, dikes removed in 2000, and reference and treatment fish monitoring sites.
Our monitoring tested two hypotheses regarding juvenile Chinook salmon use of the Deepwater Slough Restoration Project area. The first hypothesis is related to fish presence or absence: we expected juvenile Chinook salmon to be present within treatment channels after dike removal during the normal seasonal outmigration curve period (late winter through early summer months). Results from each year (2001-2003) showed juvenile Chinook salmon were present in distributary and blind channel habitat at both treatment and reference sites (Figure 18). The results demonstrate that juvenile Chinook salmon colonized the restored habitat within the Deepwater Slough Restoration Project area in the first year after construction. In fact, higher densities of juvenile Chinook salmon were often found in the treatment areas than in the reference areas. However, significant annual, monthly, and site level variability exists for juvenile Chinook salmon abundance.

Figure 18. Monthly average juvenile Chinook salmon densities at reference and treatment sites for the Deepwater Slough Restoration Project. Yearly results for blind channel sites are shown as figures A-C. Yearly results for distributary channel sites are shown as figures D-F. Error bars are 1 standard deviation.
The second hypothesis is related to juvenile Chinook salmon abundance. If the restoration project is successful at increasing the tidal delta rearing capacity for juvenile Chinook salmon in the Skagit, then we would expect the seasonal density of juvenile Chinook salmon within the Project area to be similar to juvenile Chinook salmon densities in other tidal channels in the Skagit delta. We can directly compare Chinook salmon densities in reference sites to those within treatment sites (as shown in Figure 18), but Beamer et al. (2005) showed that differences in landscape connectivity and annual Chinook smolt outmigration population size strongly influence the densities of juvenile Chinook salmon at any site within the Skagit delta or its adjacent nearshore. The IMW monitoring sites are critical for doing this analysis. Because these sites are located throughout the Skagit tidal delta, we can analyze results from the Deepwater Restoration Project over a wide range of landscape connectivity. Each year’s monitoring results are compared separately, because each year represents a unique Chinook salmon outmigration population and migration timing.

For this report we show results from 2003, which had an outmigration population size of 5,500,000 juvenile Chinook salmon. In this year, landscape connectivity explained 68% of the variation in seasonal density of Chinook salmon at monitored sites within the Skagit estuary (Beamer et al. 2005). Landscape connectivity is a measure of the migration pathway that juvenile Chinook salmon must take to find available habitat. It is a function of both the distance Chinook salmon must travel to find habitat and the channel branching order within the delta (see pages 20-21 of Beamer et al. 2005). Figure 19 shows that average seasonal Chinook salmon density from the Deepwater Slough restoration sites is within the scatter of juvenile Chinook salmon density results from other Skagit estuary sites. This supports the conclusion that habitat created by the Deepwater Slough Restoration Project is being used by juvenile Chinook salmon at similar levels to other habitat found within the Skagit estuary when you account for landscape connectivity. This result also shows that landscape connectivity values for the Deepwater Slough reference and treatment sites are similar to each other, when compared to the range of connectivity values from the other Skagit estuary monitoring sites. Therefore a direct comparison of reference to treatment sites is appropriate. In doing these comparisons year by year, we find that juvenile Chinook salmon densities were higher in treatment sites in 2001 and 2002 but similar in 2003 (Figure 18).

Figure 19. Relationship between average juvenile Chinook salmon density in blind channel habitat as a function of landscape connectivity in 2003.
Schedule and Budget

Table 6 provides an overview of the major changes to the monitoring program resulting from IMW funding since 2005. Restoration in the Skagit Estuary is underway and substantial areas and the first phase will be completed by 2010. Positive effects of restoration (changes in fish density, and survival) should be evident by 2014.

Table 7 shows the budget for FY08, including in kind support from the IMW partners and the value of existing monitoring critical to the overall study. In kind and existing monitors provides the majority of the funding needed for the Skagit Estuary complex monitoring.

**Table 6.** Five-year timeline for IMW-funded projects related to monitoring population responses to estuary restoration.

<table>
<thead>
<tr>
<th>Year</th>
<th>Restoration activities</th>
<th>Monitoring Studies</th>
<th>Survival Studies</th>
<th>Other</th>
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<td>2005</td>
<td>Refine design for linking currently planned restoration projects with biological responses</td>
<td>Initiate spatially randomized fyke trapping, beach seineing, and townetting</td>
<td>Delta (enclosure)</td>
<td>Purchase data loggers, automated measuring devices</td>
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<td>Bay pilot (acoustic mark-recapture)</td>
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<td></td>
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<td>Age structure pilot</td>
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<td></td>
<td></td>
<td>Continue index site monitoring</td>
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<td>2006</td>
<td></td>
<td>Compare NF and SF data for restoration signals of Deepwater restoration</td>
<td>Delta (enclosure)</td>
<td>Standardize databases</td>
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<td>Delta mark-recapture feasibility study</td>
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<td>Skagit Chinook life history study completed</td>
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<td>2007</td>
<td>Smokehouse Floodplain (Fornsby), Milltown, and South Fork Dike Setback Restoration habitat benefits start</td>
<td>Compare randomized and index sampling techniques</td>
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<td>Pocket estuary (enclosure)</td>
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<td>2008</td>
<td>Wiley Slough Restoration habitat benefit starts</td>
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<td>Swinomish Channel Causeway and Fisher Slough Restoration habitat benefits start</td>
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<td>Delta (mark-recapture)</td>
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Table 7. FY08 budget for the Skagit Estuary complex. In-kind support is that provided by the IMW partners and includes monitoring and scientific oversight. Existing monitoring includes monitoring not funded by the IMW that is an integral part of and critical to the study.

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References


