Appendix E: Intensively Monitored Watersheds Plan

Monitoring of population responses by Skagit River Chinook salmon to estuary restoration

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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 urbanization 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).

Our goal is to understand changes in population characteristics (primarily abundance, productivity, and life history diversity) of wild Chinook salmon in response to reconnection and restoration of estuarine habitat. Effectively evaluating the population response to estuary restoration hinges on our ability to address several questions. First, we need to examine the influence of estuary restoration on population change at a relevant spatial scale (see below) while simultaneously taking into account the influence of larger-scale environmental patterns. In addition, we need to identify what habitats best support juvenile Chinook salmon, how these habitats influence growth and survival, and what biological and physical factors limit productivity and capacity in the estuary.

The current monitoring effort

These goals require long-term monitoring tied to restoration efforts. We are currently monitoring Skagit River Chinook salmon via a long-term interagency programs 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 townetting 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 migration season.

The benefits of this diverse effort are multifold. First, 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. Second, this plan systematically captures the sequence of habitat types used by juvenile Chinook salmon during migration through the estuary. Third, 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. Finally, this program provides important insights into the ecology of Chinook salmon. The outmigrant trapping has revealed a strong relationship between freshwater survival and incubation flood magnitude. This information, combined with fyke trapping in the delta, provide strong support for density dependence and a habitat area constraint in the tidal delta. Samples gained from systematic beach seining have revealed strong relationships between nearshore growth rates and residence in the delta. 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.

Despite the success of these current efforts, our program has several weaknesses. First, our consistent use of index sites to monitor juvenile Chinook salmon has resulted in low resolution for assessing spatial variation of the habitats sampled. 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 it possible bottlenecks to productivity, it was not explicitly designed for testing effects of restoration at a system-wide scale. Thus, the current sampling design may be ineffective at detecting population responses to restoration.

IMW plan

Funding through the Intensively Monitored Watersheds Program would help us extend our monitoring time series to test the effects of planned estuary restoration projects. To effectively evaluate the population response of Chinook salmon to estuary restoration, we need a systematic monitoring program that can detect population changes linked with restoration project planning. In order to accomplish this goal, we will

- Continue established monitoring protocols
- Link restoration planning with monitoring to test population effects of restoration
- Incorporate spatial variability using randomized sampling

[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. The Skagit Chinook Life History Study uses otolith microstructure to identify specific juvenile life history types and complete 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). This study will be concluded in 2006.

- Conduct studies of survival
- Improve automation of data collection

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 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 would need to put in a river specific context (e.g., you should know population sizes and habitat areas).

Established monitoring protocols

We propose to continue monitoring index sites at the same temporal frequency that has been conducted over the last decade (Table 1). 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 1. A more detailed sampling plan for each site is shown in Appendix 1.

Table 1. Current monitoring program related to assessing the effects of restoration in the Skagit River estuary.

Method	Habitat	Sampling regime	# of sites	# of years
Outmigrant trapping	Mainstem	Daily, Feb-Aug	1	12
Fyke trapping	Tidal Delta & Swinomish Channel	Biweekly, Feb-July Monthly, August	11	12
Beach seining	Nearshore[2] & Swinomish Channel	Biweekly, Feb-August Monthly Sept-Oct	23	10
Townetting	Offshore	Monthly, Mar-Oct	12	4

Linking restoration planning with monitoring

One approach that long-term monitoring offers for examining how Chinook salmon respond to restoration is to examine system-wide population characteristics before and after restoration to look for the "signal" of restoration. For the last 10 years, SRSC has been monitoring the abundance of four life history types of Chinook salmon: 1) yearlings, which rear in freshwater for one year before migrating out of the Skagit system without extensively using estuarine habitat, 2) parr migrants, which rear up to three months in freshwater before also rapidly migrating through the estuary, 3) delta fry, which rear for one to three months in freshwater before migrating downstream and

[2] Includes 4 pocket estuary sites: Lone Tree Lagoon, Arrowhead Lagoon, Grasser's Lagoon, and Turner's Lagoon. Pocket estuary sampling started in 2002.

rearing in the tidal delta for one to three months, and 4) fry migrants, which rear for a very short period in freshwater before migrating downstream, bypassing the tidal delta, and rearing for and extended period of time in the Skagit Bay nearshore. These life history types can be distinguished based on differences in body size as well as differences in the times that they appear in the smolt traps at Mt Vernon, fyke traps in the Skagit delta, and beach seines in Skagit Bay. Three concomitant patterns in these data are that the density and body size of delta fry, and the proportion of fry migrants in beach seine catches all increase as a function of total outmigrant population size. These patterns strongly implicate rearing habitat limitation in the tidal delta. If this is the case, we would expect to see system-wide differences in density and size of delta fry and abundance of fry migrants when we compare data pre- and post-restoration of delta habitat. Continued fyke trapping and beach seining along, adjusted for outmigration population size measured at Mt. Vernon, can provide sufficient data to address this for the Deepwater Slough restoration project and in the future for the other projects.

This monitoring plan will link with future restoration in order to detect possible Chinook salmon population responses to system-wide restoration in the delta. Delta restoration projects will (1) increase delta rearing capacity by increasing the area of delta habitat available to fish and/or (2) increase delta connectivity by opening delta distributary channels to provide fish an opportunity to more directly access available habitat. Both types of restoration are currently being discussed and planned by agencies and tribes with salmon recovery jurisdiction along with stakeholders with local interests (Table 2). Skagit delta restoration plans will ultimately be adopted as part of an ESA Puget Sound Chinook Recovery Plan; however, monitoring hypotheses for delta restoration must be crafted now because some restoration has already been done while others are planned for the near future. General system-level monitoring hypotheses include:

Table 2. List of delta restoration projects completed or currently under feasibility/design.

Site Name	**Sub-delta Polygon affected**	**Project type (Area restored to river/tidal hydrology)**	**Year complete**	**First year juvenile Chinook could benefit**
Deepwater Slough	#4	Capacity/Connectivity (200 ac)	2000	2001
Fornsby Cr	#1	Capacity (100 ac)	2005	2006
Milltown	#4	Capacity (170 ac)	2005	2006
Dike Dist 3 setback	#4	Capacity (40 ac)	2005	2006
Wiley Slough	#4	Capacity/Connectivity (180 ac)	2007	2008
Swinomish Channel Causeway	#1	Connectivity (na)	2008	2009
Fisher Slough	#4	Capacity (60 ac)	2008	2009

- Effects of restored delta capacity on juvenile Chinook abundance, size, and life history type distribution for the population
- Effects of restored connectivity on juvenile Chinook abundance, size, and life history type distribution for the population
- Effects of restored pocket estuary capacity on juvenile Chinook abundance, size, and life history type distribution for the population

We developed sub-delta monitoring hypotheses by thinking how current delta habitat is being utilized by juvenile Chinook salmon (Figure 2) and then hypothesizing how juvenile Chinook salmon would respond to planned delta restoration (Figure 3). In Figures 2 and 3, 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. Arrow thickness represents the number of juvenile Chinook salmon using each pathway based on the current or restored habitat amount and configuration. Figure 3 shows planned restoration areas in pink. Because of limitations in the migratory pathways that fish can take within delta habitat, we expect subsets of delta habitat to respond to delta restoration in similar ways. 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 3. Monitoring hypotheses are stated for each area in Table 3. All monitoring hypotheses will be interpreted as functions to account for varying outmigration population sizes, habitat conditions (e.g. channels with deep areas with low tide impoundments v. channels without these features), and environment (e.g., floods, temperature, salinity).

An additional way to examine population responses to restoration is by using before-after-control designs at smaller scales. The most basic analysis examines site-specific effectiveness of restoration efforts in the tidal delta. The Skagit River System Cooperative is employing this technique via study and reference reaches to examine whether restoration at Deepwater Slough has successfully increased habitat utilization to match reference levels. Project-scale effectiveness monitoring will not be done under this proposal but project level monitor results will fit within our system-level monitoring framework to provide a clear linkage between projects and system-level population responses to delta restoration.

In addition to site-specific effectiveness monitoring approaches, the Skagit Watershed offers us a unique opportunity to examine population responses to estuary restoration if we take advantage of the fact that restoration has been targeted primarily on the South Fork of the Skagit. We therefore can compare portions of the outmigrant population that experience the effects of restoration (outmigrants in the South Fork) to those that do not (outmigrants on the North Fork), before and after restoration projects. Continued monitoring of beach seine and tidal delta sites contiguous to the North and South Fork will allow us to examine how size and life history diversity has changed in response to the Deepwater Slough restoration.

Table 3. Draft monitoring hypotheses for juvenile Chinook salmon abundance in sub-delta polygons shown in Figure 3.

Sub-delta polygon #, name	Potential Restored Area (acres)	Juvenile Chinook response Pre-restoration	Juvenile Chinook response Post-restoration
#1 Swinomish Channel Corridor	770	Density lowest of all sub-delta polygons	Density increases and becomes more homogeneous due to increased connectivity with the North Fork Population increases due to increase capacity along the Swinomish Channel Corridor
#2 North Fork Delta	980	Density highest of all sub-delta polygons	Density decreases and becomes more homogeneous due to increased connectivity to other areas within the delta Population increases due to increase capacity within the North Fork Delta
#3 Central Fir Island Delta	470	Density 2nd lowest of all sub-delta polygons	Density increases and becomes more homogeneous due to increased connectivity via a cross island corridor restoration project Population increases due to restored capacity within Central Fir Island
#4 South Fork Delta	630	Density is intermediate of all sub-delta polygons	Density remain the same but become more homogeneous due to increased connectivity within the South Fork Delta Population increases due to increase capacity with the South Fork Delta
#5 Stanwood/English Boom Delta Fringe	None Currently Identified	Density lowest of all sub-delta polygons	Density and population increases due to increased source population increase originating from Stillaguamish and Skagit Rivers.

<u>Incorporate spatial variability</u>

This monitoring proposal 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 or habitat type. The habitat types are offshore, nearshore (including pocket estuaries), and delta blind channels.

Figure 4 show 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 3 and randomly select site to sample. We will devote one crew per sampling week to conduct this effort. A minimum of 13 sites will be sampled over the season.

Figure 5 show the population of potential nearshore sampling sites. There are 184 nearshore geomorphic units (includes pocket estuaries) within the Skagit Bay Study area. We will stratify by the same spatial basis determined for offshore habitat and randomly select sites to sample. We will include two sites per sampling week to conduct this effort. A minimum of 32 sites will be sampled over the season.

We propose a similar plan for potential offshore areas to be townet sampled. However, we have yet to divide the offshore area into potential sampling polygons. Therefore, our process starts with an effort to classify offshore habitat by relevant habitat variables (e.g., geomorphology, tidal currents, wind energy potential, water temperature and salinity). After the classification system had been developed, we will apply it to our study area and randomly select sites to sample during to regular index sampling effort. We plan to sample a minimum of one randomly selected site per monthly trip.

Survival studies

Our primary goal of the monitoring program is to document population responses to estuary restoration. Potential responses may include changes in local abundance, frequency of life history types, body size, or survival. Our existing monitoring plan has been sensitive enough to capture temporal changes in local abundance and the frequency of life history types at a system-wide scale, and we expect that our proposed changes will only improve these capabilities. Our existing plan has also enabled us to detect variation in body size, but thus far we have not been able to examine the consequences of body size variation or to perform studies of survival. These goals require studies of survival at several spatial scales. The results of these studies can inform population models to better allow us to predict the population effects of restoration, and provide field tests to validate these models.

We are proposing several types of survival studies as part of our future monitoring plan. At local spatial scales we will conduct several studies using enclosure designs. At larger spatial scales, we will conduct mark-recapture and age structure studies to estimate survival.

Enclosure designs involving isolating habitat units used by salmon, introducing a known number of individuals or marking a known proportion of residents, and examining the loss of these individuals over time. These studies provide an estimate of survival at a small spatial scale and require a relatively small investment in time and money. They are also useful for testing hypotheses concerning the mechanisms influencing mortality, since enclosure systems can be experimentally manipulated. This design can be used to model the benefits of restoration, and can be used to test the benefits of project-specific restoration. However, the results must be carefully applied to the population due to their small spatial scale and environmental manipulation. We are currently conducting a study of survival by enclosing ponds in the Skagit River delta, and will continue this study in 2005. In later years, this type of study may be applied to blind channels or pocket estuaries.

Mark-recapture studies can be used at larger spatial scales to examine survival by batch-marking a known proportion of individuals and repeatedly testing for changes in the frequency of marked fish, or individually marking fish and examining the disappearance of these individuals over time. Both designs can provide ecologically relevant estimates of survival at medium to large spatial scales, but are logistically challenging because many individuals need to be marked to insure sufficient recaptures and much effort needs to be placed in recapture efforts. If these problems can be surmounted, individual mark-recapture studies are preferable to batch-mark studies because survival can be related to aspects of individual condition like body size. We envision several possible applications of mark-recapture studies:

- Batch marking and recapturing of fish in tidal channels
- PIT tagging fish and recapturing them using pit tag detectors in tidal channels
- Acoustic tagging of smolts in Skagit Bay and relocating them using linear arrays of nearshore receivers at the exits to Skagit Bay (following Welch et al. 2003).

Due to the large costs of mark-recapture studies, IMW funds will be supplemented with funds from other sources. Currently, we have applied for funding from the Pacific Salmon Commission for acoustic tagging in 2005, and this study will be contingent on receiving these funds.

A final 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.

<u>Improve automation</u>

Improving the automation of data collection has several benefits. It will reduce collection and processing errors and therefore improve data accuracy, allow us to more rapidly use data for publication and planning, and allow other researchers more rapid access. We are currently interested in implementing several types of automation:

- temperature/salinity/tide level loggers in delta sites, enabling us to continuously collect data at index sites

- automated measuring boards and data entry for beach seining and townetting. This would reduce variability among field-workers and transcription errors from fieldnotes to computer.
- Standardization of databases for NWFSC and SRSC. This would greatly facilitate comparisons across methodologies and life stages.

As more technologies become available, we plan to tailor appropriate technologies to our monitoring needs.

Budget

We are requesting $220,000 per year for intensively monitoring the response of Skagit River Chinook salmon to estuary restoration. The current break-down for this budget is:

72% ($158,182 requested): Fyke trapping in the tidal delta (SRSC). 11 sites will be monitored from February through August. This monitoring includes sites on the North and South Forks of the Skagit River, two sites along the bay front of Fir Island, and two sites along Swinomish Channel. A minimum of 13 additional sites will be trapped as part of the stratified random sampling design.

(SRSC Matching): Beach seining of nearshore sites in Skagit Bay and along the Swinomish Channel Corridor. 16 nearshore geomorphic units will be monitored from February through October. This monitoring includes 10 sites contiguous to the North and South Forks of the Skagit as well as 4 pocket estuaries and 9 sites within Swinomish Channel. A minimum of 32 additional sites will be seined as part of the stratified random sampling design. The estimated cost of monitoring the Skagit Bay nearshore is $162,504. SRSC provides this sampling as a match to the Skagit IMW program.

14% ($31,818): Townetting of offshore sites in Skagit Bay (NWFSC). 12 sites will be monitored monthly from March through October, and a minimum of 8 randomly selected sites will be measured once during this time. This monitoring includes sites contiguous to the North and South Forks of the Skagit and pocket estuaries, as well as sites demarking exit points of Skagit Bay (Saratoga Passage, Deception Pass).

14% ($30,000): Survival and life history studies (NWFSC).

This breakdown may change from year to year based on funding needs for specific programs, but will not exceed $220,000 in any year.

Time line

Table 4 provides an overview of the major changes to the monitoring program resulting from IMW funding over the next five years. Restoration-related activities will include creating a design that can link proposed restoration projects with system-wide monitoring (following Fig. 3), and initiating several restoration projects. Changes to monitoring studies will include initiating in 2005 the spatial randomization of juvenile sampling and comparing this approach with index sampling strategies after three years, when a sufficient number of randomized sites have been sampled. In addition, we will compare North Fork and South Fork monitoring data pre-and post- restoration in Deepwater Slough for changes in abundance, timing, and body size of juveniles. Survival studies include enclosure studies within the delta habitats and pocket estuaries, acoustic tagging studies in Skagit Bay, and design and implementation of a mark-recapture study to examine population responses to Wylie Slough restoration. Other planned projects relate to data automation.

Table 4. Five-year timeline for IMW-funded projects related to monitoring population responses to estuary restoration.

Year	Restoration activities	Monitoring studies	Survival Studies	Other
2005	Refine design for linking currently planned restoration projects with biological responses	Initiate spatially randomized fyke trapping, beach seining, and townetting Continue index site monitoring	Delta (enclosure) Bay pilot (acoustic mark-recapture) Age structure pilot	Purchase data loggers, automated measuring devices
2006	Fornsby, Milltown, and DD3 Setback Restoration habitat benefits start	Compare NF and SF data for restoration signals of Deepwater restoration	Delta (enclosure) Bay (acoustic mark-recapture) Delta mark-recapture feasibility study Skagit Chinook Life History Study Completed	Standardize databases
2007		Compare randomized and index sampling techniques	Delta (mark-recapture) Pocket estuary (enclosure)	
2008	Wiley Slough Restoration habitat benefit starts		Delta (mark-recapture)	
2009	Swinomish Channel Causeway and Fisher Slough Restoration habitat benefits start		Delta (mark-recapture)	

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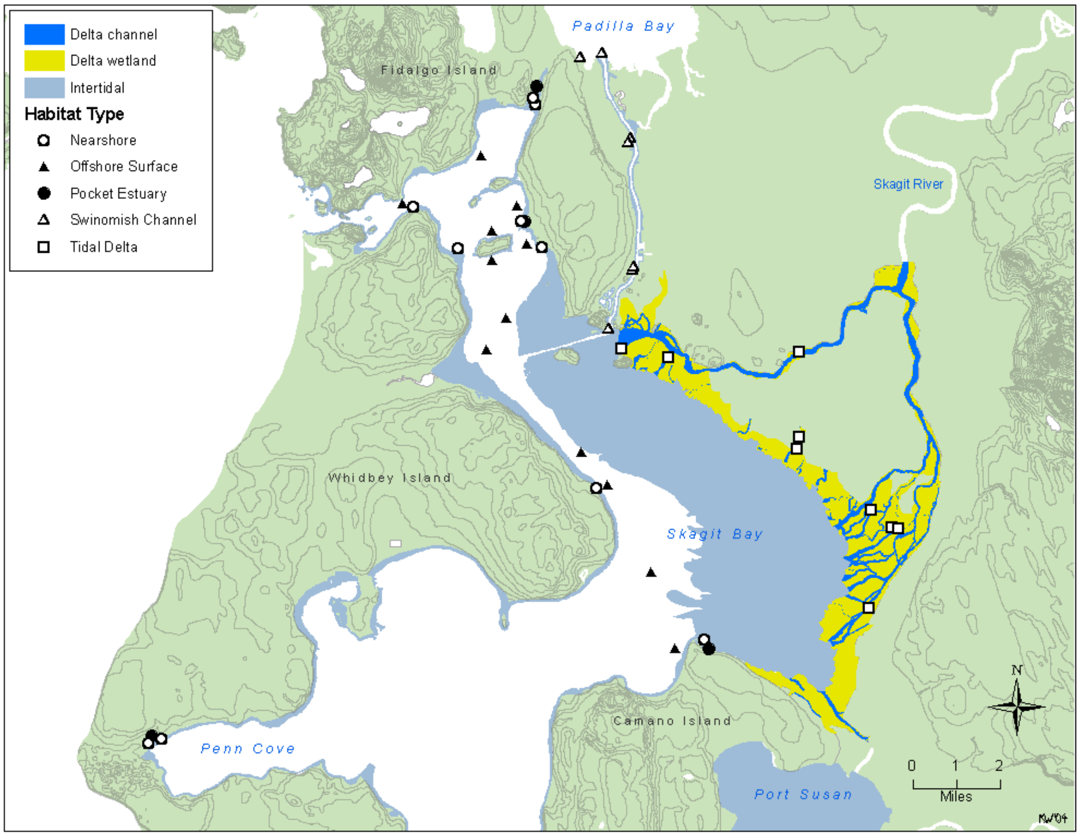

Figure 1. Year 2005 sampling sites in the Skagit delta, Swinomish Channel, nearshore (including pocket estuaries), and offshore.

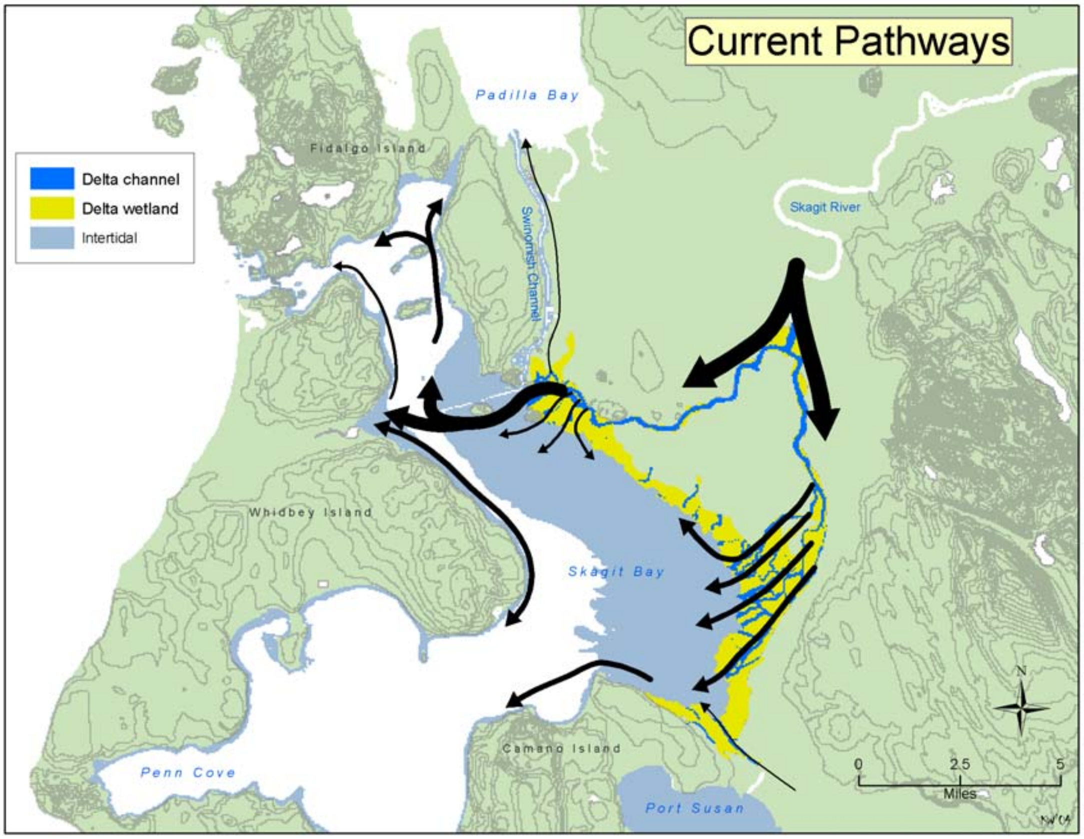

Figure 2. Current juvenile Chinook salmon migration pathways in the Skagit delta. The arrow directions depict how juvenile Chinook salmon move through delta habitat and into Skagit Bay. Arrow thickness represents the number of juvenile Chinook salmon using each pathway based on current habitat amount and configuration. Wider arrows represent more fish than narrow arrows.

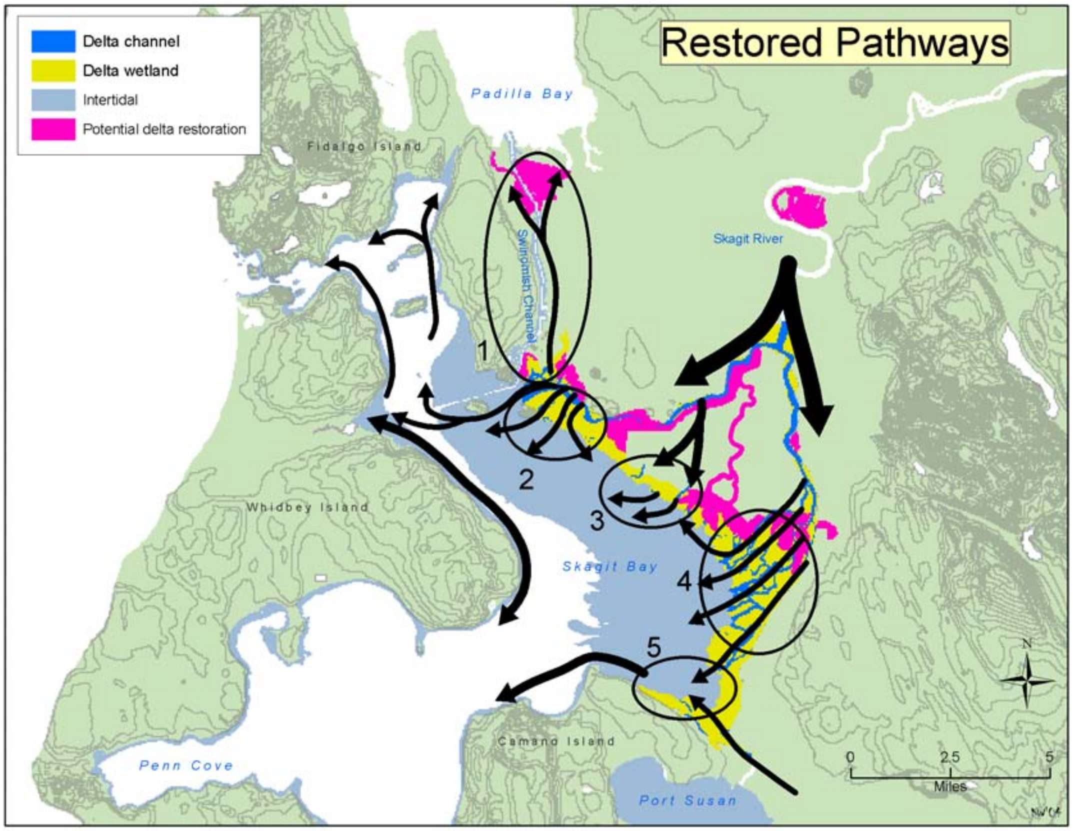

Figure 3. Future juvenile Chinook salmon migration pathways in the Skagit delta after delta restoration. The arrow directions depict how juvenile Chinook salmon move through delta habitat and into Skagit Bay. Arrow thickness represents the number of juvenile Chinook salmon using each pathway based on the newly restored habitat area and connectivity. Wider arrows represent more fish than narrow arrows. Conceptual restoration projects are shown in pink. Subsets of delta habitat are expected to respond to delta restoration in similar ways. These sub-delta areas are numbered and circled. Monitoring hypotheses are stated for each area in Table 3.

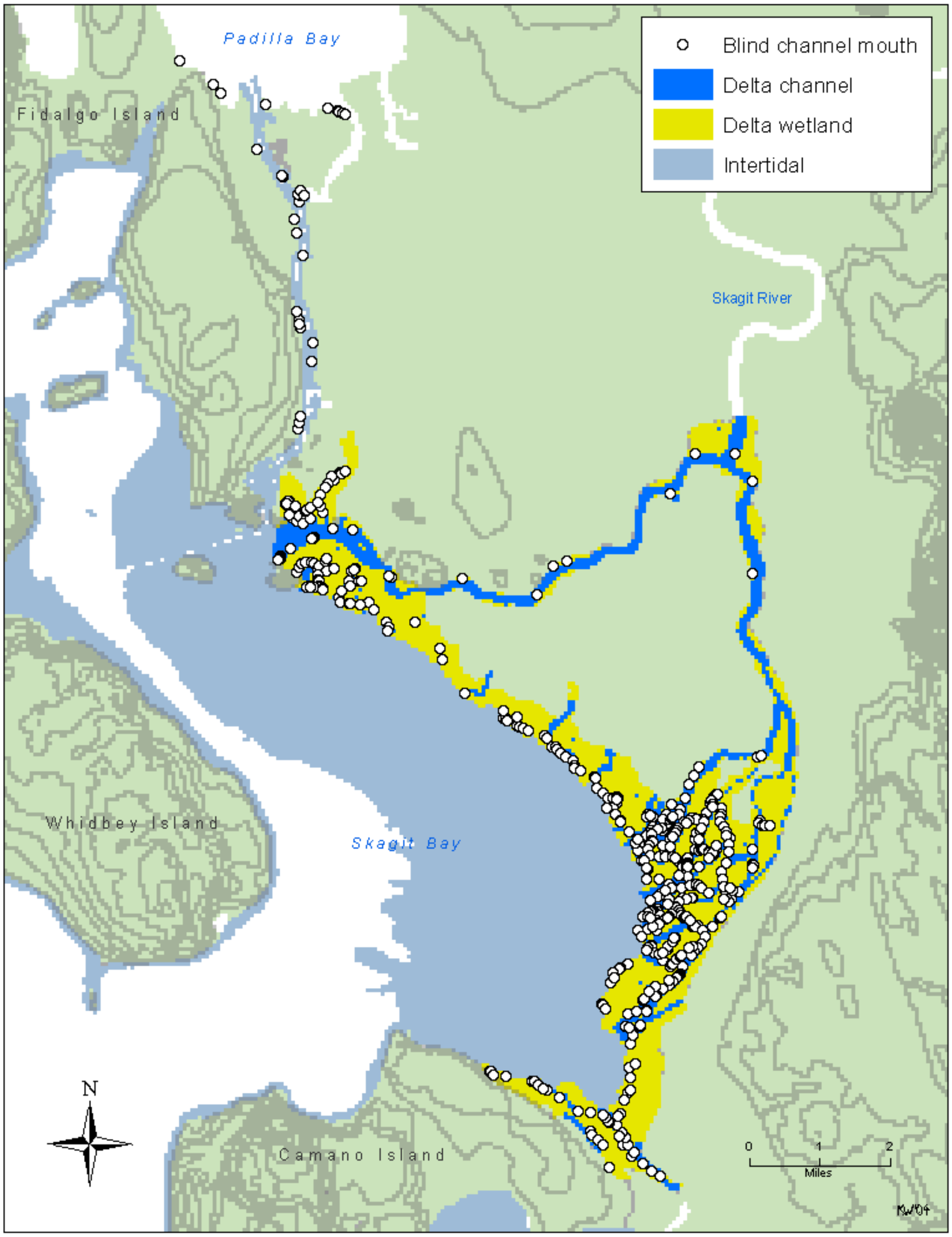

Figure 4. Map of potential delta blind channel sampling sites. Each point represent an individual blind channel complex that could potentially be Fyke trapped or beach seined.

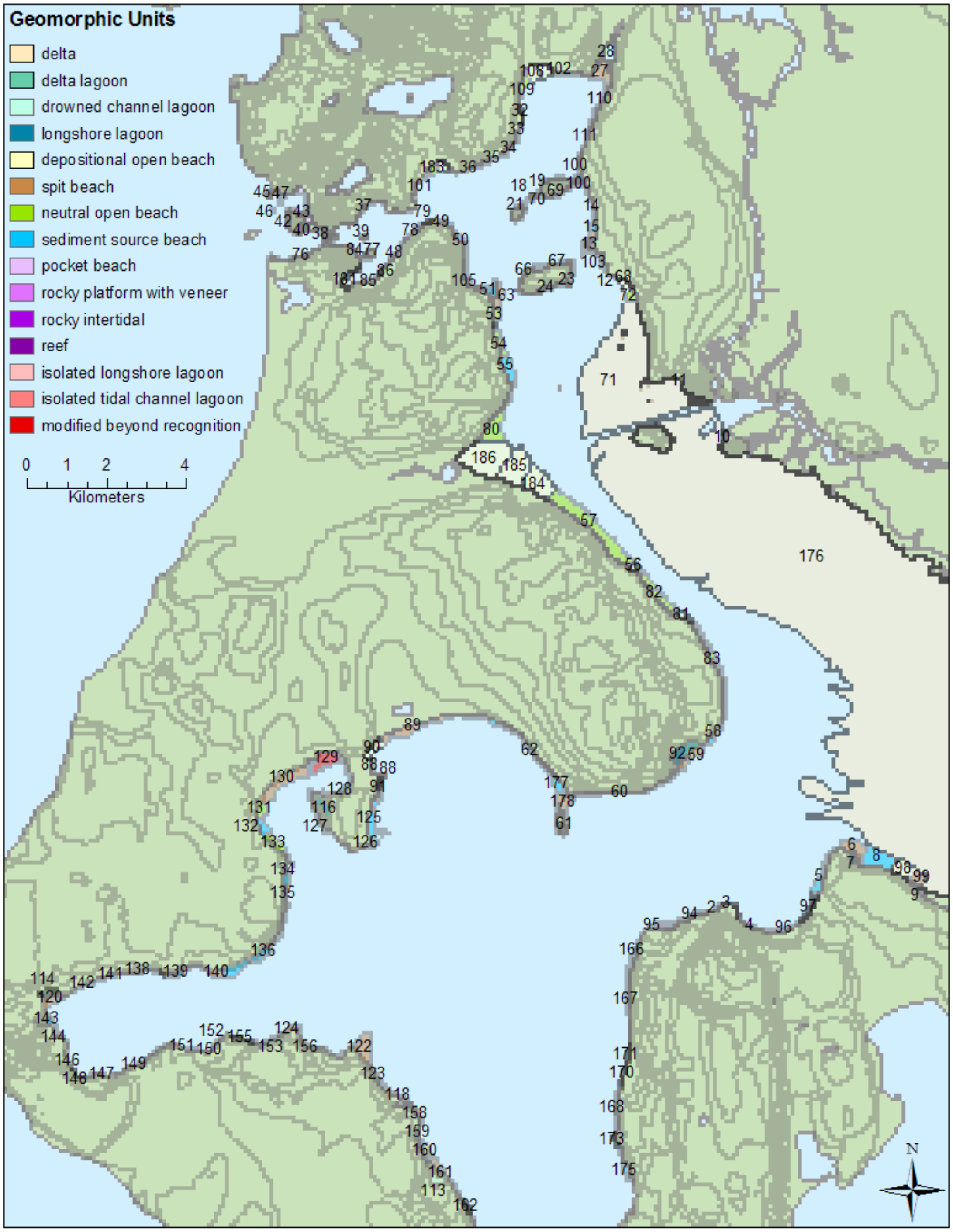

Figure 5. Map of potential nearshore and pocket estuary sampling sites. Each geomorphic unit represents a nearshore habitat area that could potentially be Fyke trapped or beach seined.