Monitoring Population Responses to Estuary Restoration by Skagit River Chinook Salmon

Intensively Monitored Watershed Project
Annual Report, 2011

by

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EXECUTIVE SUMMARY

While much restoration in Pacific Northwest estuaries has been implemented in order to improve rearing conditions for juvenile Chinook salmon, no studies to date have documented population responses in the focal stock to these restoration efforts. With this intention, we examined the responses of Skagit River Chinook salmon to reconnection and restoration of estuarine by implementing long-term monitoring of juvenile Chinook salmon rearing in tidal delta channels, nearshore, and offshore estuarine habitats. These habitats are strongly associated with rearing stages of juvenile Chinook salmon, especially in fish of wild origin.

This report focuses on results of population monitoring through 2010 and addresses three general questions: 1) Are salmon limited during the early estuarine life stages by capacity and connectivity constraints? 2) Does broad-scale restoration influence local population density? and 3) Has estuary restoration resulted in population- or system-level responses? Our results showed that 1) restoration in the Skagit River tidal delta is needed to address capacity and connectivity limitations, 2) local restoration did improve rearing densities for juvenile Chinook salmon, and 3) system-wide responses can be detected using a before/after control-impact (BACI) design. In addition, it appears capacity limitations still exist in the Skagit River tidal delta, as judged from recruitment patterns into shoreline habitat, and that further tidal delta restoration is warranted. Thus far, we estimate that the amount of restoration work completed in the tidal delta is 12% of goal of the *Skagit River Chinook Recovery Plan*, and our monitoring work corroborates this estimate.

These findings also shed light on the utility of extensive monitoring in order to document effects of restoration. Responses to restoration would have been impossible to determine without extensive pre-restoration status monitoring and juvenile migrant trapping throughout both pre- and post-restoration phases. Monitoring of transitional estuarine rearing habitats at multiple life stages is helping to pinpoint the contribution of potential rearing areas within the Skagit tidal delta.

Further monitoring as part of the Intensively Monitored Watershed Project (IMW) is needed to refine our ability to detect change at a population level and to examine the sensitivity of other life-stage specific monitoring metrics (nearshore recruits, adult returns) to restoration in the tidal delta. Finally, ongoing monitoring is shedding important light on the status and trends of multiple species of importance in the Skagit River estuary, including Chinook and coho salmon, bull trout, Pacific herring, and surf smelt.

CONTENTS

INTRODUCTION

Juvenile Chinook salmon are well known for utilizing “pocket estuaries” such as nearshore lagoons, marshes, and other estuarine habitats within the tidal delta for rearing during migration (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 experimental groups given access to different habitat zones (Levings et al. 1989) or by comparing survival rates among populations with varying levels of estuary habitat degradation (Magnuson and Hilborn 2003).

These studies support the hypothesis that estuarine habitat is vital for juvenile Chinook salmon; however, these coarse-scale studies provide no information on how estuarine habitat restoration at a watershed scale contributes to population characteristics. This knowledge is critical to understanding how to restore Chinook salmon populations, many of which have lost rearing habitat with the conversion of Puget Sound estuaries to agriculture and urbanization land uses. Our goal in this multi-year study was 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.

To accomplish this goal, we intensively monitored Skagit River Chinook salmon populations. Monitoring focused on two general methodologies to examine responses of juveniles to estuary restoration: 1) long-term monitoring of the population in three estuarine habitat types: the tidal delta, shoreline, and nearshore (subtidal neritic), and 2) tagging studies during tidal delta and offshore habitat phases to examine survival. Monitoring started in 1995, while the tagging studies commenced in 2005. These programs allow us to examine changes in abundance as fish migrate out of the estuary.

In addition, the long time-series of data produced by this monitoring will allow us to examine the effects of large-scale restoration projects in the tidal delta, which commenced in 2001 and will continue in future years. In previous years, monitoring focused on index sites, which allowed us to obtain accurate data on population trends. However, these data may have produced biased estimates of total abundance because index sites were not randomly chosen. Starting in 2005, we modified sampling methodologies to include both random and index sites in order to allow both estimates of population trends and unbiased estimates of abundance.

Given the reliance of juvenile Chinook salmon on estuary habitat and the amount of historical habitat loss, we would expect Skagit River estuary restoration to have disproportionate benefits to Chinook populations. Starting in 2000, a systematic effort to restore estuary habitat has resulted in seven successful projects with over 750 acres of restored habitat (Table 1). These projects include improvements to capacity (amount of rearing habitat), connectivity (connection among rearing areas), or both. With the exception of Deepwater Slough, all efforts count toward the recovery goal objectives for estuary restoration. Subsequent projects fulfill about 12% of estuary restoration actions specified in the *Skagit River Chinook Recovery Plan* (Beamer et al. 2005). These restoration efforts were performed in the context of a portfolio of management goals that include habitat protection and restoration in tributary, floodplain, and nearshore habitats.

This report focuses on results of population monitoring through 2010, and addresses three general questions relevant to the response of Chinook salmon to estuary restoration: 1) Is estuary residence by juvenile salmon limited by tidal delta capacity and connectivity? 2) Does restoration influence local change in density? and 3) Has estuary restoration improved residency at a system-wide level?

Table 1. Near-term restoration projects planned in the Skagit River estuary, dates, benefit to salmon, and their acreage. Projects contributing to Skagit Chinook Salmon Recovery Goals start in 2005.

Site	Year	Benefit to salmon (connectivity, capacity, or both)	Acres
Deepwater Slough	2000	Both	221
Smokehouse Floodplain	2005-2008	Capacity	43
Milltown Island	2006-2007	Capacity	212
South Fork Skagit R dike setback	2007	Capacity	40
Swinomish Channel fill removal	2008	Capacity	12
Wiley Slough	2009	Both	161
Fisher Slough	2010-2011	Capacity	68
McGlinn Island Causeway	~2014	Connectivity	--
Total			**757**

STUDY AREA

The Skagit River estuary is part of the larger Puget Sound fjord estuary, and comprises several habitat types of varying salinity, with a tidal delta between the North and South Forks. These tidal delta habitats are adjacent to the more marine environment of Skagit Bay (Figure 1). Our estuarine study sites consisted of blind tidal channels within the Skagit River tidal delta and of shoreline and nearshore (subtidal neritic) areas of Skagit Bay.

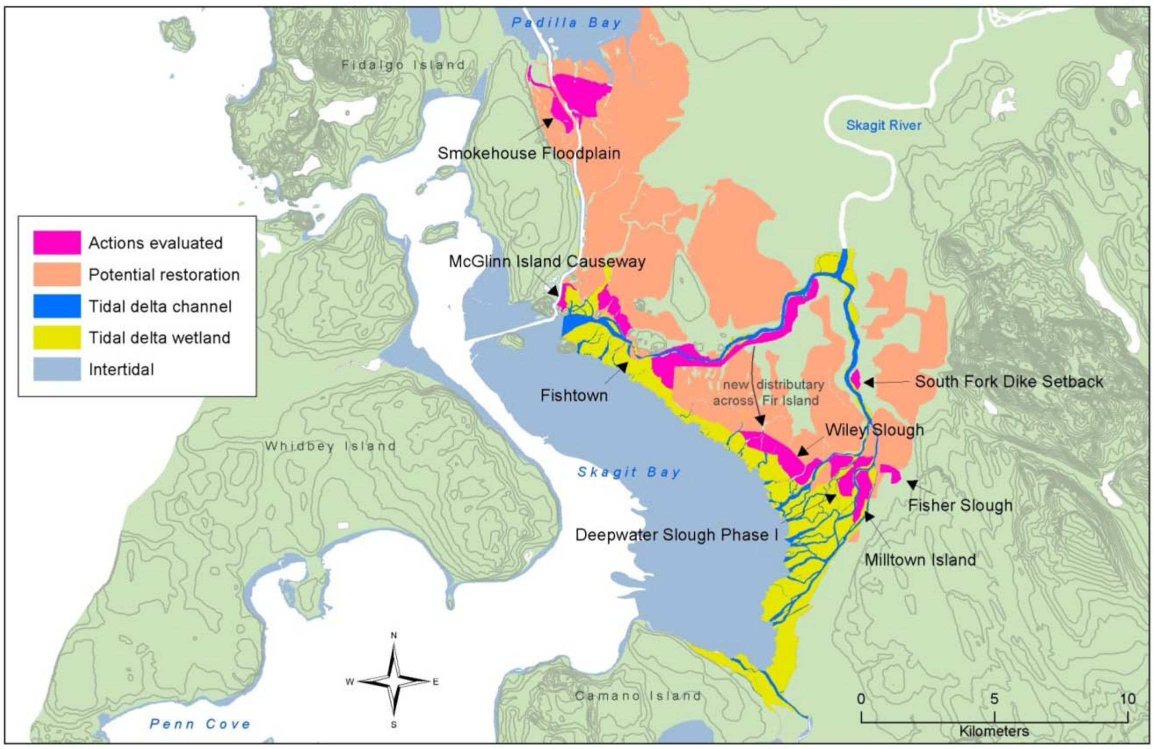

Figure 1. The Skagit River estuary, areas within the restoration plan (peach) and actual sites planned for restoration within the historical footprint of the tidal delta (pink).

The Skagit River tidal delta is a prograding-to-neutral fan delta with numerous distributary channels. When describing tidal delta habitat, we refer to *the tidal estuarine mixing zone* as the area of river channels and wetlands where freshwater is tidally mixed with marine water (Day et al. 1989), and which includes the channeled emergent and scrub-shrub marshes where freshwater mixes with salt water. In contrast, the *riverine tidal zone* is the area of river channels and wetlands where freshwater is tidally pushed but not mixed with marine water. Within these areas a diversity of estuarine habitats are formed and maintained by tidal and riverine processes, creating a mosaic of wetlands and channels. These include blind tidal channels, which served as our fish sampling units within the tidal delta.

The shoreline of Skagit Bay is 127.4 km in length, and its intertidal area is 8,838 ha. Skagit Bay shorelines include a mixture of beach types, which vary based on differences in adjacent upland geologic material (bedrock, glacial sediments, and recent coastal or river sediments) and also based on shoreline gradients, and geomorphic process within longshore-drift cells. Beaches that dominate much of Skagit Bay were the sampling units for this study.

Landscape analyses have indicated that despite considerable areas of extant shoreline and tidal delta, the Skagit River has lost much estuarine habitat to agricultural and residential development (Collins et al. 2003). Prior to diking, dredging, and filling (circa 1860s) the tidal delta footprint of the Skagit River was 11,483 ha (Collins et al. 2003), while in 1991 it was 3,118 ha (Beamer et al 2005). In addition, much remaining estuarine habitat in the Skagit tidal delta has been disconnected from floodplain and tidal processes. Contiguous estuarine habitat areas remain in the vicinity of Fir Island, with a fringe extending from southern Padilla Bay to the north end of Camano Island. These estimates account for gains in delta habitat area caused by progradation between the 1860s and 1991 (Beamer et al. 2005) and for indirect loss of habitat resulting from changes in tidal process and sediment deposition (Hood 2004). In sum, 73% of tidal delta has been disconnected from floodplain and tidal processes, and 24% of the Skagit Bay shoreline has been armored to protect land uses adjacent to accretion shoreforms or eroding sediment source bluffs (McBride et al., unpublished data).
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METHODS

Intensive monitoring efforts in the Skagit River allowed us to examine abundance at several life stages: freshwater rearing in Skagit River, estuarine rearing in the tidal delta, estuarine shoreline rearing in Skagit Bay, and nearshore neritic residency. Freshwater rearing data are essential for considering downstream abundance measures in the context of total size of the juvenile migration.

Freshwater Abundance

Freshwater abundance of wild Chinook salmon in the Skagit River was estimated based on catches from a juvenile fish trap operated by the Washington Department of Fish and Wildlife (WDFW) at river kilometer (rkm) 39.1 in the city of Mount Vernon. Freshwater juvenile monitoring provided both abundance and life history data, including abundance by migrant type (fry, parr, yearling), juvenile body size, migration timing, and tissue for genetic analysis (Kinsel et al. 2008).

Operation of this trap began in 1990 for the purpose of estimating coho smolt production. The focus of this trapping operation has expanded over time, and the trap is now used to estimate the annual number of wild juvenile Chinook salmon migrating from the entire Skagit Basin (Seiler et al. 1998). The juvenile trap is operated each year beginning in mid-January and continuing through the end of July. This time frame was selected based on results from three extended trapping seasons conducted in the mid-1990s.

The trap is actually two traps: an inclined-plane and a screw trap. The rectangular inclined plane trap (1.8 × 4.9 m) is fished by lowering the trap approximately 1 m into the water at an oblique angle. Fish swimming within a 2-m^2 cross-sectional area near the surface are then caught, forced onto the inclined plane, and washed into a collection box. The screw trap (2.5-m diameter) is fished by lowering it completely into the water. Fish swimming downstream enter the 2.35-m^2 cross-sectional entryway of the trap, and the rotation of plates within the trap forces fish into a collection box.

Annual catches from these traps are highly correlated with each other ($R = 0.99$), and in this analysis we focus on results of the inclined plane trap. This trap catches only a portion of the total number of juvenile Chinook migrating from the Skagit River. Therefore, total abundance was estimated using a mark-recapture study design in order to expand the catch by a calibration factor (Volkhardt et al. 2007). Catches missed during trap outages were estimated, and these estimates were included in the final estimate.

To evaluate trap efficiencies during the juvenile migration period, a known number of marked fish (dye or fin-clip) were released upstream, and a portion of these were recaptured in the trap. Releases of marked fish were conducted throughout the juvenile migration period in order to account for differences in trap efficiency due to changing river conditions. The resulting trap efficiency data was applied to catch data in order to estimate total migrant abundance (Zimmerman et al. in review).

Abundance in Tidal Delta

To measure abundance in tidal delta habitats, we sampled unmarked subyearling Chinook juveniles in blind channels using fyke traps. Fyke trapping followed the methods of Levy and Northcote (1982) with nets constructed of knotless nylon (0.3-cm mesh) with a cone (diameter 0.6 to 2.7 m) sewn into the net. Fish entered the net as water was draining the channel on an ebb tide. We used a lead line to sink the net bottom to the benthos and a float line to maintain the top of the net at the water surface. Overall net dimensions (length and depth) varied depending on cross-sectional dimensions of the channel, but all nets were sized to completely block fish access at high tide.

We captured fish by setting the fyke trap across the mouth of the blind channel site at high tide and "fishing" the channel throughout one ebb tide cycle. Fish were captured as they moved out of the channel with the receding tide. We sampled index sites twice a month from February through August during spring tide series. This effort started with four index sites in 1992 and was expanded to six sites in 1995. Index sites were selected to represent the three estuarine wetland zones present within the Skagit delta (emergent, scrub-shrub, and riverine tidal), as well as the two major delta rearing areas associated with Chinook salmon (North and South Fork Skagit River).

Trap recovery efficiencies (REs) were derived by releasing a known number of marked fish upstream from the trap at high tide. Catches of juvenile Chinook salmon were adjusted by the RE, which was unique to each site and was related to hydraulic characteristics of the site during trapping (e.g., change in water surface elevation during trapping or water surface elevation at the end of trapping). We conducted 5-8 different mark and recapture tests at each site. Data from these tests were used either to calculate average RE at the site or to develop a regression model. Regression models were used to convert raw catch data from a given day to an expanded number of Chinook salmon that were present within the habitat upstream from the fyke trap on that day. Average RE for the six fyke trap sites ranged 29-57%. To calculate juvenile Chinook density for each fyke trap set, we use the adjusted catch divided by the topwidth channel area of the blind channel upstream from the trap. Topwidth channel area was measured in the field.

Abundance in Skagit Bay Shoreline

To measure density of unmarked Chinook salmon rearing along shoreline habitats, we used a beach seine (37- × 3.7-m) with knotless nylon mesh (0.3-cm). The net was deployed by fixing one end on the beach and the other on a boat, which set the net across the current and returned to the beach at a point upstream at a distance of approximately 60% of the net length (~22 m). The set was held open against the tidal current for a few minutes, and then the boat returned to the shoreline edge and both ends of the net were retrieved, yielding a catch in the bunt section.

We made three seine sets per site on each sampling day. Habitat area sampled with the large-net beach seine varied among sample sites and days because tow times, set widths, and tidal current velocities moving past the site all varied dynamically. Tow time, set width and water surface velocity were measured for each beach seine set in order to calculate a set area. Juvenile Chinook catch for each set was then adjusted by set area to calculate Chinook density. Average set area for the six large net beach seine sites in Skagit Bay was 486 m^2.

We also conducted 34 mark and recapture tests to estimate RE for beach seine methods. Two groups of marked fish were introduced to each seined area. The first was released just before setting the net and the second just prior to closing the net and retrieving it to shore. Overall RE for the six beach seine sites was consistently high, averaging 84.5% (±10.1% CI). Since RE for beach seining was consistently high, we did not adjust the “raw” juvenile Chinook catch by RE for beach seine sites.

Abundance in Skagit Bay Nearshore

We sampled subtidal neritic (surface and subsurface) areas of Skagit Bay using a Kodiak surface trawl (3.1-m high × 6.1-m wide), towed between two boats, each with a 15.2-m towline connected to a bridle on the net. Mesh sizes in the net were 7.6 cm stretch in the forward section, 3.8 and 1.9 cm in the middle sections, and 0.6 cm in the cod end. The primary vessel (13.7 m long, 174 hp inboard diesel) towed the left wing of the trawl and the second vessel (5.5 m long, 225 hp gasoline outboard) towed the right wing, with both vessels moving in an upcurrent direction.

The net was towed at the surface for 10 minutes per tow, at 900-1000 rotations per minute (RPM) on the engine of the primary vessel and a typical towing speed of 2-3 knots. Distance was recorded with a mechanical flow meter (General Oceanics model 2030) deployed by the smaller vessel. Area swept was calculated as distance traveled multiplied by width of the net opening.

Measures of Abundance

Measures of abundance varied for each life stage. During the freshwater migration season, abundance was measured using the total number of juvenile migrants calculated by WDFW from trap operations. In addition, we also used the total abundance of fish migrating as fry, because it is this life history component that is most likely to rear in the tidal delta and therefore benefit from restoration. For measures of abundance in the tidal delta and shoreline, we used two indices: density and cumulative density. Density was measured as average density across blind channel index sites and months.

Cumulative density was a measure of abundance per unit area over the entire rearing period. Cumulative Chinook salmon density was estimated for blind channel habitat during February-August (over 200 d) and for shoreline habitat during February-October (over 270 d). Both measures encompassed the entire utilization curve of juvenile Chinook salmon in each habitat. Cumulative density (fish × d × ha^{-1}) was calculated as

$$C = \sum_{m=F}^{L} D_m n_m \qquad \text{Eq. 1}$$

where D_m is average monthly density, n_m is number of days in the month, and F and L is the first and last month (m) sampled, respectively.

Both density and cumulative density have interesting properties when viewed in the context of restoration. In a given stream segment, restoration that improved local abundance or survival should result in increases in the density metric; this change would reflect the direction we normally predict after restoration. However, the prediction is different for restoration at larger spatial and temporal scales because an overall increase in habitat capacity should reduce density. Hence, the predicted outcome following system-wide restoration would be a reduction in either or both density metrics. Outside the tidal delta, we expect restoration to increase recruitment, thereby resulting in an increase in density metrics.

Sampling Effort

We use differing levels of survey effort for the three main types of sampling in the Skagit River estuary. Table 1 summarizes the number of sites, frequency, and duration of sampling. One major change that has occurred since the beginning of funding through the Intensively Monitored Watersheds project (IMW) has been a shift from an index-only sampling design to a sampling design that employs both random and index sites. As shown in Table 2, this change has added a substantial number of sites.

Table 2. Sampling effort in different habitats monitored through the Skagit River Intensively Monitored Watersheds project and number of index and random sampling sites for each habitat type pre- and post-IMW funding.

Habitat	Years*	Duration	Frequency	Index sites per sampling	Random sites per sampling
Mainstem	1990-2011	Feb-Jul	Daily	1	
Tidal delta	1992-2006	Feb-Jul	Biweekly	8	
	2007-2011			16	2
Shoreline	1995-2006	Feb-Oct	Biweekly	6	
	2007-2011			11	12
Nearshore	2001-2004	Apr-Oct	Monthly	12	
	2005-2011			4	15

* IMW funding commenced in 2005.

RESULTS

Is Tidal Delta Habitat Limiting Estuary Residence?

Central to the idea that restoration will improve the productivity of Skagit River Chinook salmon is the assumption that estuarine habitat is limited such that rearing juveniles compete with each other. We used our pre-and post-restoration monitoring data to test this assumption for Chinook salmon life stages associated with transition through tidal delta and shoreline habitats. We hypothesized that in the Skagit River tidal delta, reductions in habitat capacity have led to strong density dependence, and that population density can be reduced via restored connectivity and increased capacity of tidal delta habitats. To test this hypothesis, we examined three density-dependent relationships:

1) Average density of juvenile Chinook salmon in the tidal delta × total juvenile Chinook salmon outmigrants (expanded from freshwater migrant trap data)
2) Size of Chinook fry (fish < 50 cm) in the tidal delta × total juvenile migrants
3) Cumulative density of Chinook salmon fry in shoreline habitats × density juvenile Chinook salmon in the tidal delta.

We regressed two variables (average density in the tidal delta and size of Chinook fry) against total size of the general population of freshwater juvenile migrants (measured at the juvenile migrant trap in Mt. Vernon). Average density in the tidal delta was used on the assumption that high densities discourage longer residency; therefore we would expect a higher incidence of fry-sized migrants in these habitats after restoration. All variables exhibited a strong density-dependent response: average density increased as a function of total juvenile migrants to an asymptote of approximately 2500 fish/ha at a juvenile migration population size of approximately 4.5 million (Figure 2A). Average size of fry exhibited a concomitant decline as a function of total freshwater migrant population size, leveling off at approximately the same number of freshwater outmigrants (Figure 2B). Cumulative density of fry measured in beach seines increased sharply at densities matching the asymptote of average density vs. total juvenile migrants (Figure 2C).

Although capacity is a strong system-wide limiting factor, additional limitations exist at local levels due to differences in habitat connectivity. We calculated connectivity relative to the general population of freshwater migrants using a function that included both distance from the mainstem source and channel width nearest the sampling location (Beamer et al. 2005, Appendix D). As shown in Figure 3, local density varied over several orders of magnitude at lower levels of connectivity, but appeared to level off above these levels.

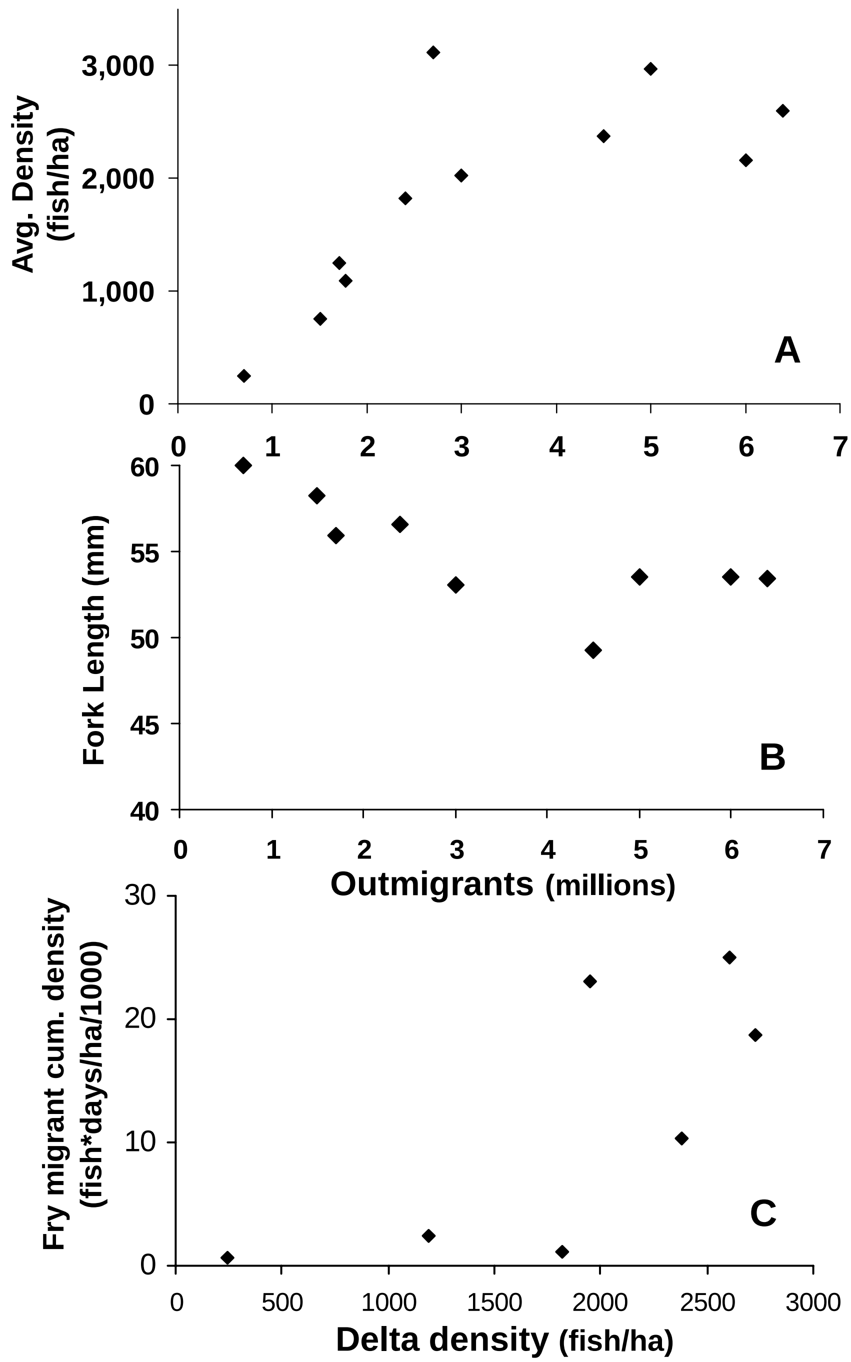

Figure 2. Panels A and B show average density (A) and length (B) of juvenile Chinook salmon rearing in the tidal delta as a function of total freshwater juvenile migrants. Panel C shows cumulative density of fry migrants (length < 50 mm) captured along shorelines as a function of density in the tidal delta.

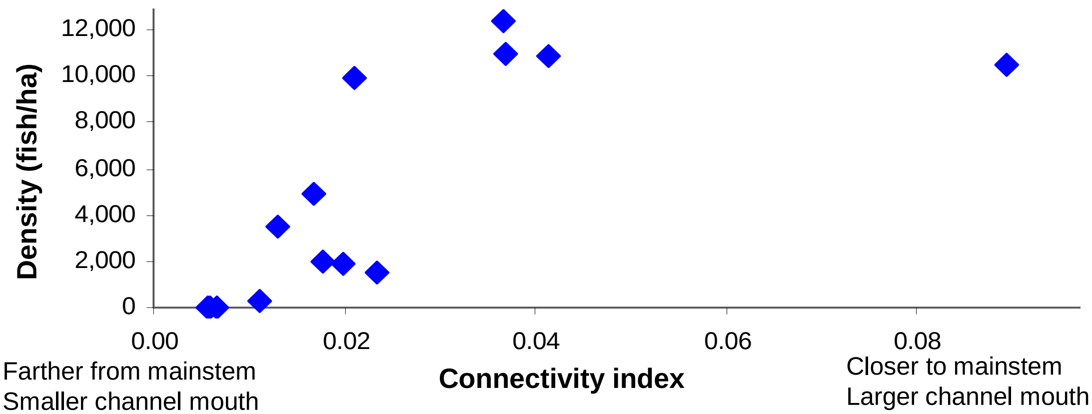

Figure 3. Density of subyearling Chinook salmon measured in 2002 at sites of varying levels of connectivity, with lower connectivity at further distances from the mainstem (bifurcation of the North and South Fork Skagit River) and for smaller channel entrances (Beamer et al. 2005).

Do We See Positive Local Effects of Restoration from Completed Projects?

Given the existence of habitat limitations in the Skagit River tidal delta, we would expect to see increases in local juvenile Chinook salmon density in response to habitat restoration, after which densities at treatment (restored) sites should match those at reference (natural) sites. We tested this hypothesis by examining data collected as part of effectiveness monitoring of the Deepwater Slough restoration project (completed in 2000), as well as the Smokehouse Floodplain and Swinomish Channel setbacks (both completed in 2008).

Deepwater Slough restoration resulted in large improvements in both connectivity and capacity. Deepwater Slough was historically a distributary, but had been impounded at its upstream end, causing it to function as a blind channel (Figure 4). Removal of the impoundment as well as a number of dikes in the Deepwater Slough area consequently increased the amount of channel and tidally influenced wetlands by 89 ha. Effectiveness monitoring of this site employed a post-treatment/reference design, and results exhibited treatment effects that were strong in the first 2 years but leveled off by 2003 (Figure 5).

Additional effectiveness monitoring studies employing before/after control-impact (BACI) designs have also documented increases in local density of juvenile Chinook salmon following estuary restoration of the Swinomish Channel. Restoration here has led to more moderate increases in local density, due to the disconnectedness of the Swinomish Channel from the Skagit River mainstem and to idiosyncrasies of restoration at specific sites (e.g., limited connectivity resulting from installation of self-regulating tide gates, Greene et al. 2012).

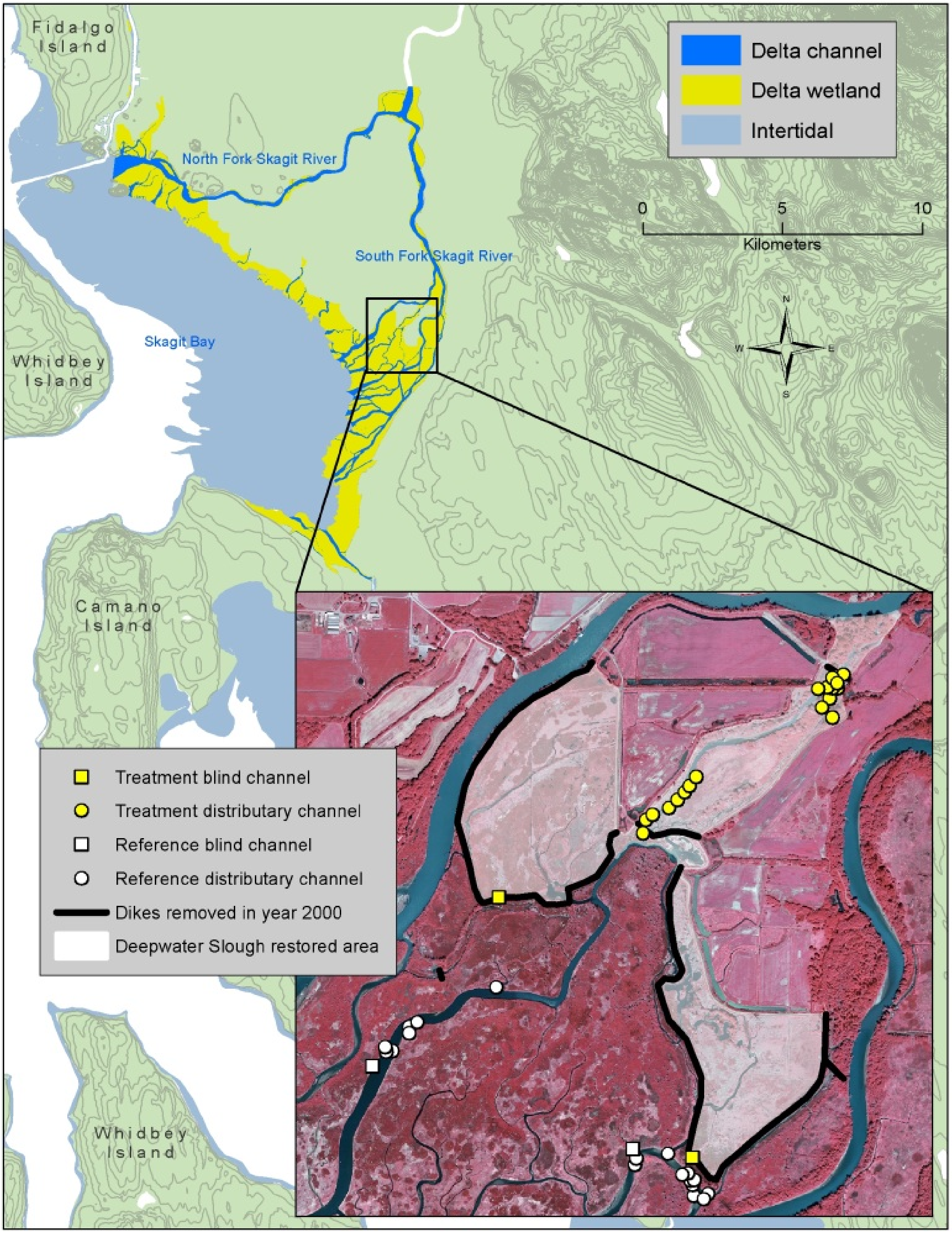

Figure 4. The Deepwater Slough restoration and monitoring design, showing location in the Skagit estuary, the area restored, and effectiveness monitoring sites.

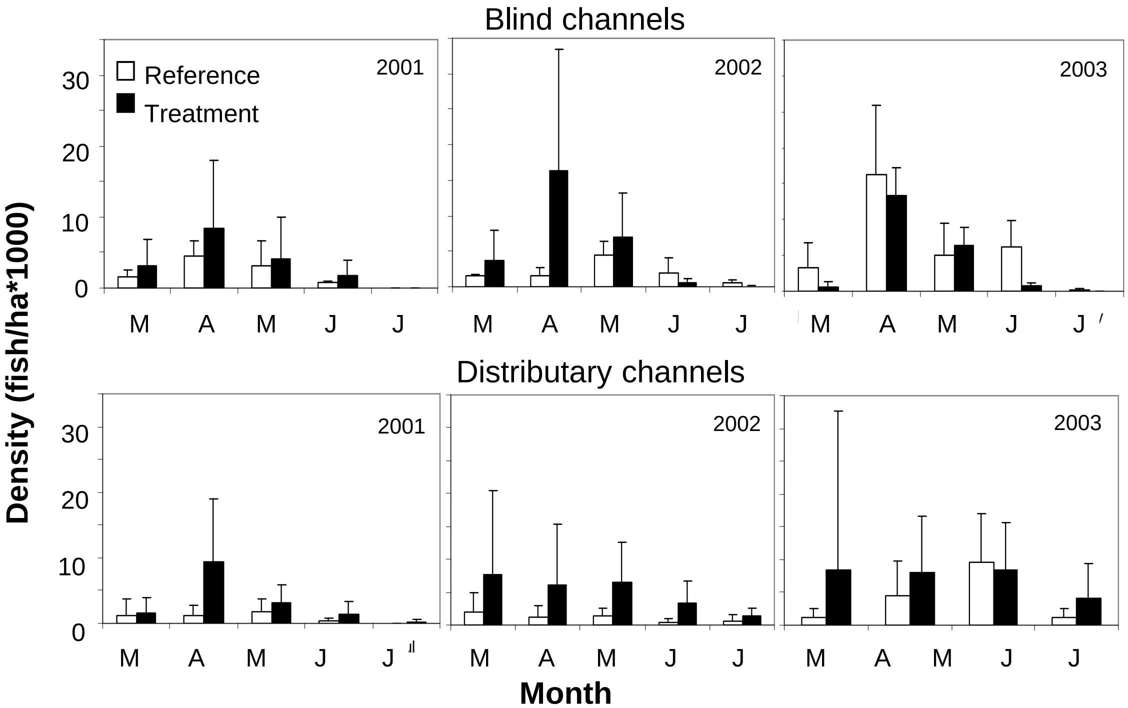

Figure 5. Post-restoration densities of juvenile Chinook salmon captured in controla dn treatment blind and distributary channels during Deepwater Slough restoration monitoring, 2001-2003.

Does Tidal Delta Restoration Improve Residency at a System-Wide Level?

If these improvements had measurable improvements to the Skagit River population, we would expect to see at least two population responses: juvenile Chinook salmon cumulative density should *decrease* in habitat areas of the South Fork Skagit River relative to the North Fork. This would be expected because fish are rearing over an increased amount of slough habitat in the South Fork, but the same amount in the North Fork (where no restoration occurred). This hypothesis was tested using a BACI design, with sites on the North Fork Skagit River used as the control. Second, if restoration strongly improves survival or capacity, recruits to Skagit Bay shoreline should increase following restoration, and the percentage of recruits that are fry migrants should decrease.

We tested the first prediction by regressing cumulative density in the South Fork Skagit River (treatment) against cumulative density in the North Fork (control) for years before and after restoration in the South Fork. Results supported a measurable response, with the slope of the regression shifting lower following restoration. This indicated that restoration along the South Fork coincided with reductions in cumulative density there, compared with densities in the North fork across the entire time period (Figure 6). Note that as more restoration was completed, cumulative density in the South Fork tended to shift farther away from the pre-restoration line.

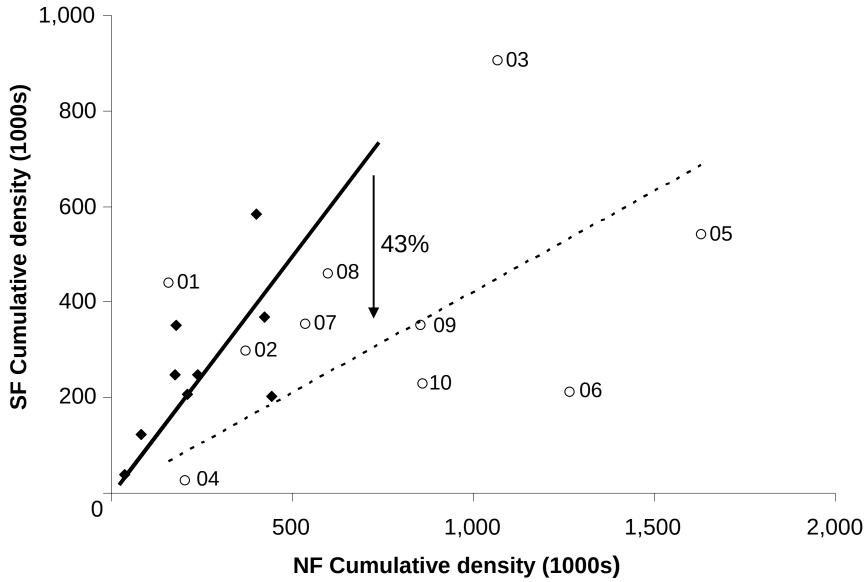

Figure 6. Changes in the relationship between cumulative density in the South Fork Skagit River (where restoration occurred) and that in the North Fork (no restoration). Black line and closed diamonds represent pre-restoration data (outmigrant years 1993-2000), and dashed line and open circles (labeled by year) represent post-restoration data.

The second prediction was tested by calculating the proportion of the shoreline cumulative density composed of fry migrants and measuring this against the number of fry outmigrants measured at the Skagit River trap. In these cases, we used a before-after design, since fish rearing in North Fork and South Fork have at least partially mixed by the time they are sampled in Skagit Bay, and there is no reference population that can be directly compared with the Skagit. As shown in Figure 7, both recruitment metrics did not exhibit an obvious difference before and after restoration in the South Fork commenced, and continued to exhibit strong density dependence over the entire time series. The upper limit to the fry migrant proportion was quite similar before (0.342, one year) and after (0.336, average of five years) initial restoration at Deepwater Slough (Fig. 7B). These findings suggest that restoration in the tidal delta needs much greater effort or more years of study in order to observe noticeable changes in recruitment.

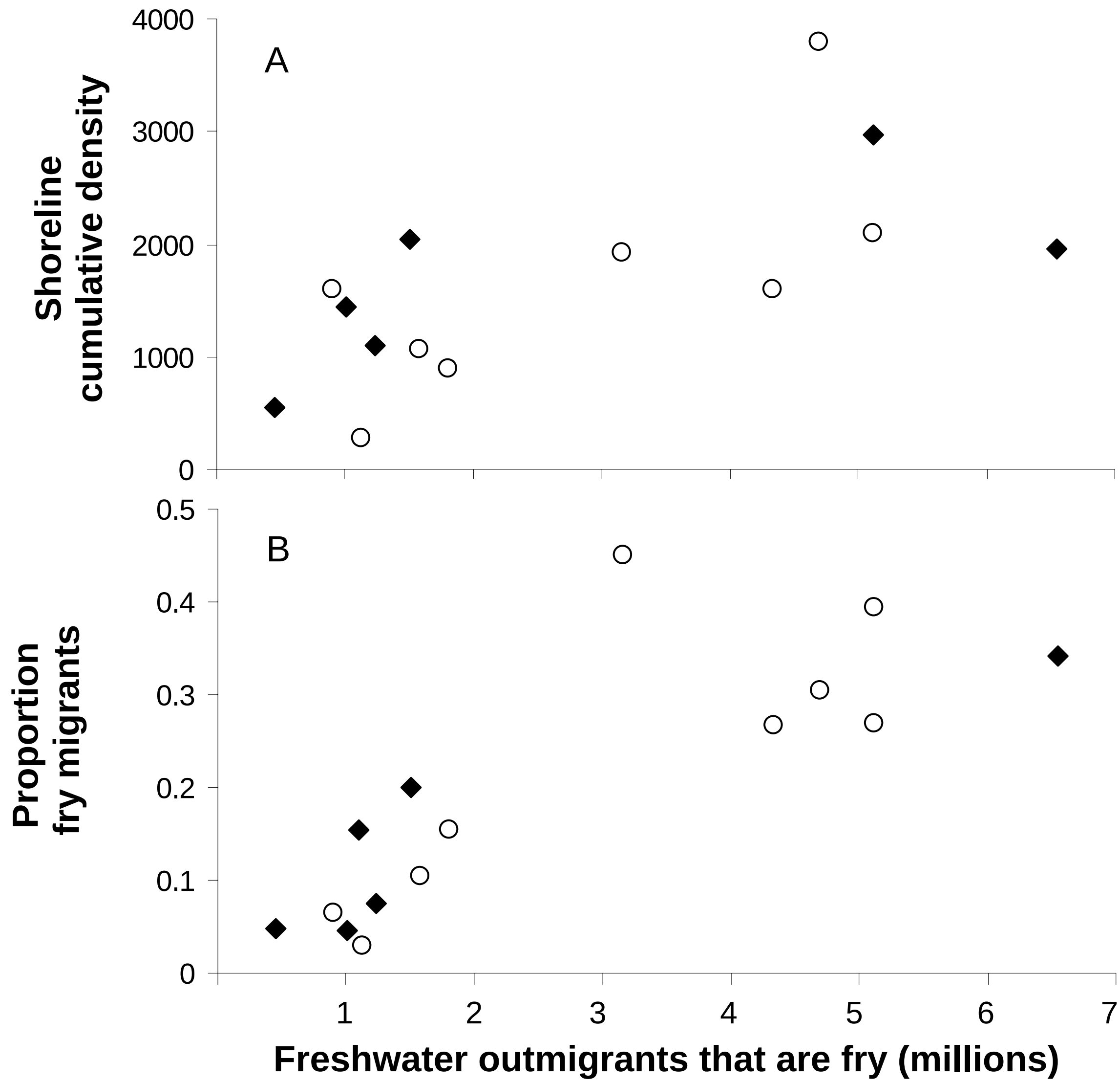

Figure 7. A) Shoreline cumulative density of juvenile Chinook salmon in Skagit Bay and B) the proportion of shoreline cumulative density composed of fry migrants as functions off the number of freshwater outmigrants that are fry (which would likely utilize the tidal delta for rearing. Closed diamonds represent pre-restoration data, and open circles represent post-restoration data.

CONCLUSIONS AND FUTURE WORK

This report documents that 1) restoration in the Skagit River tidal delta is needed to address capacity and connectivity limitations, 2) local restoration improves densities of rearing of juvenile Chinook salmon, and 3) system-wide responses can be detected using a BACI design. In addition, it appears capacity limitations still exist in the Skagit River tidal delta as judged from recruitment patterns (Fig. 7), and that further tidal delta restoration is warranted. Thus far, the amount of restoration completed in the tidal delta is roughly 12% of the Chinook Recovery Plan's objective for estuary habitat restoration (Beamer et al. 2005), and our work completed thus far corroborates this estimate.

These findings also shed light on the utility of extensive monitoring in order to document effects of restoration. Our findings would have been impossible to document without extensive pre-restoration status monitoring and outmigrant trapping throughout both pre- and post-restoration phases. Monitoring at multiple life stages during estuarine transitions helps pinpoint the contribution of rearing potential in the Skagit tidal delta.

Further monitoring as part of the IMW will help refine our ability to detect change at a Chinook salmon population level by providing additional data points across the broad span of possible outmigration sizes. In addition, it will enable us to examine the sensitivity of other life stage-specific monitoring (e.g., nearshore recruits) to restoration in the tidal delta. Finally, the monitoring effort is shedding important light on the status and trend of multiple species of importance in the Skagit estuary and nearshore that are caught incidentally with juvenile Chinook salmon during monitoring efforts, including coho salmon, bull trout, and Pacific herring and surf smelt (e.g., Reum et al. 2011). These results should be useful to examine restoration in the tidal delta in the context of the estuary foodweb.

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