JUVENILE SALMON AND NEARSHORE FISH USE IN SHORELINE AND LAGOON HABITAT ASSOCIATED WITH ALA SPIT, 2007

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2006 aerial photo of Ala Spit, courtesy WA Department of Ecology

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Purpose of report

Restoration and protection of Ala Spit and Lagoon was identified as a priority in the Skagit Chinook Recovery Plan (page 214 in SRSC & WDFW 2005) because of its importance to early rearing of wild fry migrant Chinook salmon originating from the Skagit River. Island County has sponsored a feasibility study to identify restoration and protection actions that could be taken in the Ala Spit or Lagoon area, and in its adjacent drift cell.

The Skagit River System Cooperative (SRSC) Research Program is responsible for presenting a report to Island County through its consultant, Herrera Environmental Consulting Inc., describing the nearshore fish assemblage using fish data collected during late winter through spring of 2007 by beach seining. This report also includes updated information from other SRSC studies that aids understanding of juvenile salmon and the nearshore fish assemblage at Ala Spit and Lagoon, including:

1) Juvenile salmon migration pathways from the Skagit River to shorelines in northern Skagit Bay
2) Annual variability in juvenile salmon populations found in nearshore habitats from Skagit Chinook monitoring

Study area

Ala Spit and Lagoon are part of the Puget Sound nearshore (Figure 1). The Puget Sound nearshore, as defined by the Puget Sound Nearshore Ecosystem Restoration Program, includes the Puget Sound fjord, Hood Canal, Whidbey Basin, the Strait of Juan de Fuca, the San Juan Islands, and the mainland coast to the Canadian border. Within the nearshore, coastal and upland processes interact to form a diversity of intertidal, subtidal, and terrestrial habitats. Coastal processes (wind waves, tides) create coastal habitats such as spits, dunes, tidal channels, lagoons, and salt marshes, while watershed processes (streams, groundwater seeps, rivers) contribute freshwater to the nearshore and create habitats like delta flats, marsh islands, and distributary channels.

Ala Spit and Lagoon are part of a group of nearshore habitats referred to as pocket estuaries. Pocket estuaries are partially enclosed bodies of marine water that are connected to a larger estuary (such as Puget Sound) at least part of the time, and are diluted by freshwater from the land at least part of the year (after Pritchard 1967). These small estuaries are differentiated from larger scale estuaries because the watersheds they are associated with are too small to support salmon spawning populations; thus I call them non-natal estuaries with respect to juvenile salmon use (Beamer et al. 2003). Pocket estuaries are an important habitat for wild Chinook salmon fry early in the year once they leave their natal estuary and enter nearshore areas of Whidbey Basin (Beamer et al. 2003 and 2006).

Sampling sites and methods

Beach seines were used along both sides of Ala Spit to catch fish in order to assess their abundance, species composition, and size. With the help of WSU Island County Beach Watcher volunteers a total of ten sites were beach seined twice a month from February through June of 2007(Table 1). Beach seining occurred on flood tides or neap low tide stage. Seining occurred at tidal stages lower than 4 feet or higher than 9 feet above mean lower low water (Table 1).

A small net (6 ft by 80 ft) beach seine was used to sample five sites on the inside of Ala Spit (lagoon habitat) on flooding or neap (high) low tidal stage. Adjacent nearshore habitat was beach seined at five sites along the outer part of the spit during mid to high tide levels, also by small net. Thus, two different habitat types were sampled: (1) lagoon, and (2) shallow intertidal habitat within the nearshore adjacent to the Ala Spit. The ten beach seine sites were spaced out evenly along the shoreline of the spit which is owned by Island County Parks (Figure 2). Beach seining was not done along the western side of Ala Lagoon because it is privately owned shoreline. I also did not choose to sample at the tip of the spit in 2007 because this area is a transition between lagoon and adjacent nearshore habitat. However, some existing beach seine data were available from the tip of Ala Spit. These data were collected by Skagit River System Cooperative between 1997 and 2002 using a large beach seine deployed from a boat. I make use of the results from these older data later in this report.

Figure 3 illustrates conceptually the two different habitats (lagoon, shallow intertidal within the adjacent nearshore) sampled. Pages 51-54 of Beamer et al. (2005) contains net diagrams and pictures of the seining methods. The net is set in "round haul" fashion by fixing one end of the net on the beach while the other end is deployed by wading "upstream" against the water current (if present), setting the net out of a floating tote, and then returning to the shoreline in a half circle. Both ends of the net are then retrieved, yielding a catch. One beach seine set was made at each site per sampling day. Set area was recorded for each beach seine set. The area seined, if the beach seine set was deployed perfectly, equals 92 square meters[1]. Beach seine set area for sets not deployed perfectly were adjusted based on visually observation of the set shape and completeness of the net going from shore to shore. Set area adjustments were expressed as a percentage of a perfect beach seine set (considered 100%) depending on whether the set was larger (110%, 120%, etc.) or smaller (e.g., 70%, 80%, etc.) than perfect. Beach seine set area was then calculated:

$$\text{Beach seine set area in hectares} = (92\text{m}^2 \text{ x adjustment}) / 10{,}000\text{m}^2$$

The entire fish catch (not just salmon) was identified and enumerated. Fish catch data were divided by beach seine set area to estimate fish density by each species (fish per

[1] Average set area based on measured set area from 12 beach seine sets considered "100%" using an identical net.

hectare of wetted area seined). Fish density results were averaged for each species in each of two habitat types by week or month to gain an understanding of the timing, abundance, and assemblage of the nearshore fish community using Ala Spit.

A sub-sample of up to 20 fish per species was measured for length from each beach seine set.

Salinity and temperature were collected at the time of beach seining just under the water's surface using a Model 60 YSI meter. These data were averaged for each of the two habitat types (lagoon and adjacent nearshore) by sampling date to gain an understanding of the environmental conditions experienced by fish using Ala Spit and Lagoon.

Substrate and vegetation types within the beach seined area were recorded for each set based on definitions in McBride et al. 2006. Six substrate types were observed within the beach seine set areas: fines with gravel, gravel, mixed coarse, mixed fines, mud, and sand. Beach seine sets were considered vegetated enough to record the vegetation type if more than 10% of the set area contained attached algae or plants. If more than 90% of the beach seine set area did not have the presence of attached algae or plants the set was considered unvegetated. In this project four vegetation types (eelgrass, eelgrass and algae, green algae, and salt marsh - primarily pickleweed) were observed within the beach seine set areas.

Analysis of catch data consisted of paired (lagoon v adjacent nearshore) comparisons of average fish density (by species) by sampling date using 2007 data only. I used fish data collected as part of SRSC's long-term Chinook monitoring program (described in Greene and Beamer 2006) to help inform the Ala Spit and Lagoon beach seine results from 2007. These additional data are from different sites within Skagit Bay than Ala Spit and Lagoon, and from different years than 2007. I also used data collected from Ala Spit between 1997 through 2002 using a larger (longer and deeper) beach seine to present additional results for bull trout, wild Chinook salmon, forage fish, and shiner perch.

The effort level (e.g., number of beach seine sites and number of sets possible) was determined by available funding, not any kind of statistical power analysis. Sampling effort was maximized by using volunteers (rather than paid staff) to assist with beach seining. My experience at other pocket estuaries throughout Whidbey Basin (Beamer et al. 2003 and 2006) suggests that the effort level was likely to detect a significant difference in the abundance of wild juvenile Chinook salmon between lagoon and adjacent nearshore habitat over the sampling period. However, one caveat to this thought was the expectation of a lower than average number of juvenile Chinook salmon outmigrating from the Skagit River into Skagit Bay for 2007 because of higher than average egg mortality caused by flooding during the fall of 2006. This was another reason I relied on data collected from other years by the SRSC long-term Chinook monitoring program to inform the Ala Spit and Lagoon results from 2007.

Results and Discussion

Water depth, vegetation, and substrate characteristics of areas beach seined

Lagoon habitat was slightly deeper than adjacent nearshore in the areas beach seined (Table 2). Lagoon habitat averaged 0.78 meters at maximum depth of the area beach seined while adjacent nearshore habitat averaged 0.64 meters deep.

The vegetation distribution between lagoon habitat and adjacent nearshore habitat was similar (Table 3). However, lagoon habitat had salt marsh present within the seined area whereas adjacent nearshore habitat did not. Lagoon habitat is more protected from wave energy, thus marsh habitat can develop more easily.

There was a difference in substrate composition within the lagoon compared to the adjacent nearshore areas seined (Table 4). Substrate differences indicate different wave energy regimes. Lagoon habitat was mostly comprised of small substrate sizes (mud to mixed fines) whereas adjacent nearshore was comprised of larger particles (mixed coarse and gravel).

Salinity

Salinity at Ala Spit is negatively correlated with Skagit River discharge (Figure 4, Table 5). The lagoon tends to be saltier (6 of 10 times) than the adjacent nearshore environment on the outside of Ala Spit.

I find this result a bit different than other spit/lagoon sites studied in the Whidbey Basin. However, these results make sense when you consider that only very minor amounts of local freshwater inputs are directly flowing into the lagoon area inside the spit. In contrast, the Skagit River mouth is very close by and ebbing tides bring a large plume of low salinity water right along the outside of the spit. In this case, the habitat inside the spit is sheltered somewhat from receiving the low salinity water coming from the Skagit River. This fact might influence juvenile salmon usage of the lagoon habitat if the juvenile salmon are keying into low salinities for physiological transition from freshwater to saltwater.

Temperature

Average surface water temperature ranged between 8.0 and 13.7 degrees C during the beach seine sampling period at Ala Spit. A seasonal increase in water temperature for both lagoon and adjacent nearshore habitat is evident (Figure 5, Table 6). There doesn't appear to be strong predictable differences in temperature between adjacent nearshore or lagoon areas.

The drop in temperature for June has not been observed at other nearshore areas in Skagit Bay. Four years of temperature results collected in Turners Bay found temperatures steadily increasing until July or August, then starting to decline (Beamer et al. 2007).

Dominant fish assemblage

This project caught 5,948 fish (17 species) in the 100 beach seine sets conducted at Ala Spit and Lagoon in 2007. However, wild juvenile Chinook salmon, juvenile chum salmon, sandlance, shiner perch, stickleback, staghorn sculpin, starry flounder, and gunnels were the most abundant or most frequently occurring fish in the beach seine sets. These species are graphed (Figure 6) as monthly average density for lagoon and adjacent nearshore habitat.

Except for the very large peak of juvenile chum in April found in adjacent nearshore habitat, lagoon habitat generally had more fish over the five month period. Juvenile salmon, comprised almost entirely of chum, dominated the fish assemblage outside of Ala Spit, whereas the fish assemblage in lagoon habitat was more evenly represented by 3-5 species each month. Staghorn sculpins were dominant in lagoon areas in May and June.

The beach seine sampling period captured nicely the juvenile salmon use period for shallow habitat around Ala Spit. However, beach seine sampling stopped before the normal onslaught of shiner perch enter shallow nearshore areas to birth their young and forage during summer months. This project captured very few surf smelt; however in February I observed sandlance (mostly juvenile sized) sometimes in large numbers. Refer to Table 7 for more details about fish densities over the season and between habitat types.

Table 8 shows the percentage of the total number of beach seine sets in which each of the dominant fish species were present, by vegetation and substrate type. Table 8 can imply species association for each substrate and vegetation type. Differences exist in the distribution of vegetation and substrate types both inside and outside the spit (Tables 3 and 4). Because habitat differences are a function of coastal processes and energy regime, the results in Table 8 can be useful for hypothesizing the responses of fish species to process-based changes in habitat (natural or restoration caused). For example, juvenile Chinook salmon were most often seined in areas associated with some salt marsh vegetation and fine grained substrates (Table 8). Salt marsh and fine grained substrates are most prevalent on the lagoon side of Ala Spit. Therefore, if coastal processes or energy regimes are changed either naturally or through restoration in such a way that these habitats decrease in area, Chinook salmon use of the lagoon could be predicted to decrease. Caution should be used, however, in applying the results shown in Table 8 when predicting outcomes in the Feasibility Study due to the small sample size (number of beach seines) for some habitats listed in Table 8.

Juvenile Chinook and chum salmon density

The density of juvenile Chinook and chum salmon varied considerably between lagoon and adjacent nearshore habitat over the sampling period (Figure 7, Tables 9 and 10). Chinook salmon density in lagoon habitat averaged 5.3 times higher over the season than in the adjacent nearshore. However, a pair-wise t-test on density was not significant at the 0.05 level ($p = 0.13$). Chum density in adjacent nearshore averaged 3.1 times higher over the season than in the lagoon. Again, a pair-wise t-test on density was not significant at the 0.05 level ($p = 0.19$).

The level of sampling done in 2007 at Ala Spit and Lagoon was not adequate to statistically detect differences in fish density between habitat types at other sites throughout the Whidbey Basin. The general curve shape for Chinook is typical of other pocket estuary sites, so I suspect that Ala Spit follows the typical pattern of fry migrant Chinook use found at other pocket estuary sites (Beamer et al. 2003 and 2006). Differences in density between lagoon and adjacent nearshore of the Ala site, compared to most Whidbey Basin sites, may be caused by Ala Lagoon's lack of (1) enclosure by a recurving spit and (2) a strong localized freshwater input.

Another important observation is the correlation of peak flow and the peak in juvenile Chinook fry abundance (Figure 7A). In the 12 years of fish data I have in Skagit Bay, flow events in late winter or early spring correlate with a peak of juvenile Chinook abundance in 8 years. The same flow effect that triggered migration of juvenile Chinook salmon was not true for chum salmon at Ala Spit in 2007 (Figure 7B). Possibly, the timing of the flow event was too early to trigger juvenile chum migration in 2007. Juvenile chum salmon consistently peak in Skagit Bay in April and there is not the same bimodal distribution I commonly see with juvenile Chinook salmon.

Taken together, these results support the idea that Ala Lagoon habitat is important for juvenile Chinook rearing or refuge because Ala Lagoon is so close the mouth of the North Fork of the Skagit River, the source of juvenile salmon. It is obvious that many chum salmon use the area, but less obvious whether there is preference for lagoon or adjacent nearshore habitat.

Juvenile Chinook and chum salmon size and their risk of predation by staghorn sculpin

Juvenile Chinook and chum salmon are slightly larger in lagoon habitat than adjacent nearshore (Figure 8, Tables 11 and 12). This may indicate juvenile salmon in the lagoon are residing in the area for some period of time, in contrast to fish on the outside of the spit, which are smaller and more recently from the river. These results may also indicate the habitat inside of the spit is a faster growing environment for juvenile salmon. Either way, these results are consistent with other pocket estuaries (Beamer et al. 2003) and support the idea that lagoon habitat is good rearing environment for juvenile salmon.

Pacific staghorn sculpins are the dominant (and only) predator species of juvenile salmon caught in the beach seine sampling conducted in 2007 (Figure 6). Staghorn sculpins are a large part of the fish assemblage, especially within the lagoon side of Ala Spit thus creating a potential predation risk to juvenile salmon. However, pocket estuaries appear to be a refuge from larger predatory fish for fry migrant Chinook salmon, compared to the adjacent nearshore environment. This working hypothesis is based on a relationship between predator size and prey size presented in Beamer et al. (2003). By applying the same predator-prey model to density and size data for Chinook salmon and staghorn sculpins caught in Ala Lagoon, I find no sculpins were large enough to prey on average sized Chinook salmon on February 13th, February 26th, March 30th and April 12th. On the peak date for Chinook abundance in lagoon habitat (March 13th), 3% of the sculpins caught in lagoon habitat were large enough to prey on average sized Chinook. After late April, when Chinook salmon were no longer caught in lagoon habitat, 1-2% of the sculpins in lagoon habitat were large enough to prey on average sized Chinook salmon. These results suggest that while staghorn sculpins are very abundant in lagoon habitat, they are not typically large enough to prey on average sized Chinook salmon when juvenile Chinook salmon are present.

Context of juvenile salmon results in 2007 with other brood years

The timing and abundance of juvenile salmon present in nearshore habitat is a function of outmigrating smolt population sizes, which fluctuate year to year. In this section of the report I use data collected 1996 through 2007 as part of the long term Chinook salmon monitoring program (Greene and Beamer 2006) in order to provide a smolt population context for the 2007 results at Ala Spit and Lagoon. The sites where these data are collected are shown in Figure 9.

<u>Juvenile Chinook salmon in Skagit Bay</u>

Figure 10 helps brings a juvenile Chinook salmon population context to the limited amount (one salmon outmigration season) of fish data collected at Ala Spit. Figure 10A shows that 2007 was a smaller than average year for juvenile Chinook in Skagit Bay. Figures 10B and 10C show the timing and abundance of the smallest and largest Chinook outmigration years in SRSC's Skagit Bay dataset. Figure 10D shows the timing and abundance curve for juvenile Chinook salmon in 2007 for comparison. Large smolt outmigration years (Figure 10C) typically have a bimodal distribution with numerous fry migrants present in the Skagit Bay nearshore environment during Feb through April. However, even small outmigration years (Figure 10B) have some fry migrants. Fry migrants, when they first arrive in Skagit Bay and while they are small (less than ~ 70 mm fork length), are strongly associated with shallow nearshore habitat, including pocket estuaries.

Figures 11A and 11B reinforce the juvenile Chinook population context for the Ala Spit and Lagoon results of 2007. Of particular note is Figure 11A, showing proportionally (not just in absolute numbers) more juvenile Chinook in Skagit Bay as early (fry) migrants when there is a larger outmigrant population).

The Chinook outmigration population size in 2007 was small compared to the majority of other years sampled in Skagit Bay. However, even in a smaller Chinook population size year, large numbers of Chinook fry were captured in Ala Spit and Lagoon areas. Since Skagit River Chinook outmigration populations are not always small, and salmon recovery efforts are planned and underway throughout the Skagit watershed and nearshore habitats to increase population size, it is reasonable to expect more juvenile Chinook will want to use Ala Spit and Lagoon habitat in future years than what was observed in 2007.

<u>Juvenile chum salmon in Skagit Bay</u>

Figure 12 helps brings a juvenile chum salmon population context to the limited amount (one salmon outmigration season) of fish data collected at Ala Spit. Figure 12A shows that 2007 was a smaller than average year for juvenile chum in Skagit Bay. Figures 12B and 12C show the timing and abundance of the smallest and largest chum abundance years in SRSC's Skagit Bay dataset. Figure 12D shows the timing and abundance curve for juvenile chum salmon in 2007 for comparison.

Like the juvenile Chinook results, 2007 wasn't a large chum population size year in Skagit Bay, yet large numbers of juvenile chum salmon were caught at Ala Spit and Lagoon habitat, especially in April. April is consistently the peak month for chum. Unlike juvenile Chinook salmon, there isn't a bimodal distribution that is related to juvenile chum population size.

Juvenile salmon migration pathways and landscape connectivity

Identifying how accessible and interconnected nearshore habitats such as Ala Spit and Lagoon are to fish populations is necessary in evaluating the ecological importance of these habitats to nearshore fish. In the case of Ala Spit, juvenile salmon using nearshore habitat must migrate to Ala Spit from salmon-producing rivers and creeks. The closest salmon-producing river to Ala Spit is the Skagit River. Therefore, how important Ala Spit is to Skagit River salmon populations not only depends on the quality, amount and type of nearshore habitat, but also on how easily juvenile salmon can get to Ala Spit.

Hydrodynamic model and landscape connectivity results demonstrate that Ala Spit and Lagoon are strategically located for use by Skagit River origin juvenile salmon.

Hydrodynamic Model

SRSC conducted drift buoy trials and incorporated their results into a hydrodynamic model being developed by Battelle's Seattle Research Center. The modeling effort is overseen by an *ad hoc* committee of nearshore salmon ecologists from SRSC and NOAA Fisheries. One of the purposes of the hydrodynamic model is to predict juvenile salmon migration pathways by predicting surface water movements (tidal currents), salinity and temperature. My analysis of the existing hydrodynamic model and SRSC's dataset of juvenile salmon timing and abundance throughout the Whidbey Basin finds:

- Pocket estuaries in northern Skagit Bay have consistently higher juvenile Chinook salmon densities compared to all pocket estuary sites studied within the Whidbey Basin (Beamer et al. 2006). This is presumably due to northern Skagit Bay's proximity to the North Fork Skagit River, where large numbers of wild Chinook salmon exit the Skagit River due to loss and simplification of delta habitat (Beamer et al. 2005).
- Of the three pocket estuaries in northern Skagit Bay currently able to support juvenile salmon (Lone Tree, Ala Spit, and Turners Bay), Ala Spit has the shortest and least complicated migration pathway. However, hydrodynamic modeling and juvenile salmon data indicate that juvenile salmon exiting from the North Fork Skagit River can reach Ala Spit in one day from either the Whidbey lsland or Fidalgo Island shoreline.
- Hydrodynamic modeling results demonstrate that the most direct route for juvenile salmon fry to be transported to the vicinity of Ala Lagoon via surface water currents is from the North Fork Skagit River.

Landscape Connectivity

Within the delta and nearshore ecosystems of the Skagit River, Beamer et al.(2005) used habitat connectivity as an attribute to help value specific habitat types for Chinook salmon recovery planning. They considered connectivity at two different scales. First, they referred to landscape or large scale connectivity as the relative distances and pathways that salmon must travel to find habitat. Landscape connectivity is defined as a function of both the length and the complexity of the pathway that salmon must follow to certain types of habitats, like blind tidal channels in deltas and pocket estuaries. Habitat connectivity decreases as the complexity of the route fish must swim increases and as the distance the fish must swim increases. Within the Skagit Delta and its immediate nearshore, the complexity of the route fish must take to find key habitat was measured by the delta distributary channel bifurcation order and distance traveled. After the fish leave the delta, connectivity is measured as distance traveled in the bay along surface current vectors mapped by drift buoy trials. Thus, a pocket estuary located within 10 km of the delta is of higher value (other factors being equal) than a pocket estuary located 20 km from the delta along the drift path. Beamer et al. (2005) 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 (see pages 20-21 of Beamer et al. 2005).

Figure 13 is a plot showing the landscape context of Ala Lagoon habitat with other similar habitats in Skagit Bay. Figure 13 is the same kind of plot used in Beamer et al. (2006) that investigates the role of landscape connectivity on Chinook salmon using pocket estuaries throughout the Whidbey Basin. Ala Lagoon connectivity is intermediate compared to other sites in the sample area. Juvenile Chinook usage at Ala (measured as seasonal fish density) is under the curve shown in Figure 7A for lagoon habitat. However, Ala Lagoon's fish usage is somewhat of an outlier (lower) compared to the other five sites in Figure 13.

It is unknown why juvenile Chinook use at Ala Lagoon is lower than the connectivity relationship for the other five sites. There are not enough data to test any theories at this time. The result might be spurious, or it might be related to the habitat conditions at Ala Spit (e.g., lack of spit enclosure of the lagoon area and lack of a strong localized freshwater input compared to other pocket estuary sites). It is possible I shouldn't expect Ala Lagoon to reflect juvenile Chinook salmon use like other pocket estuary sites because it is physically different.

Salmon recovery benefits related to restoration or protection

Protection of existing opportunity for fry migrant rearing and refuge

Pocket estuary habitats are much smaller and more fragmented throughout Skagit Bay and the rest of the Whidbey Basin than they were historically (Beamer et al. 2005). Fry sized juvenile Chinook salmon rear and take refuge in pocket estuaries throughout Skagit Bay (Beamer et al. 2003) and the Whidbey Basin (Beamer et al. 2006). The results in this report find similar juvenile Chinook use patterns for Ala Spit and Lagoon. Therefore, any actions that protect or restore lagoon/marsh area within Ala Lagoon should benefit wild fry migrant Chinook salmon:

- Protection actions that maintain existing lagoon/marsh habitat will maintain existing foraging and predator refuge capacity for wild fry migrant Chinook salmon.
- Restoration actions that increase existing lagoon/marsh habitat will increase existing foraging and predator refuge capacity for wild fry migrant Chinook salmon.

The Skagit Chinook Recovery Plan (page 214) estimates the existing lagoon area to support a carrying capacity of approximately 14,000 wild juvenile Chinook smolt annually. This prediction is based on methods described in Beamer et al. (2005), which were developed to estimate the fish benefits of nearshore and delta restoration projects in the Skagit Chinook Recovery Plan (SRSC & WDFW 2005).

Salmon and bull trout food web linkages

Forage fish and shiner perch are an important part of the food web for ESA-listed Chinook salmon and bull trout in Puget Sound. Surf smelt, herring, and sandlance are commonly consumed by Chinook salmon when the salmon exceed about 120 mm in length. Surf smelt, herring, sandlance, and shiner perch are an important part of the diet of anadromous bull trout. The Skagit has the largest population of anadromous bull trout and wild Chinook salmon in Puget Sound. Thus, actions that protect and restore habitat at Ala Spit and Lagoon for forage fish and shiner perch will benefit Puget Sound ESA-listed salmonids.

The short season of sampling (only February through June) and use of only a small beach seine to sample at Ala Spit and Lagoon in 2007 was adequate to document fish use associated with Ala Spit and Lagoon during the time when juvenile salmon, especially fry sized salmon, live directly in shallow intertidal habitat. Using only results derived from the short time period and small net beach seine may limit my ability to draw conclusions about the ecological role of Ala Spit and Lagoon on older/larger salmonids and forage fish. Therefore, I am relying on older beach seine data collected by Skagit River System Cooperative between 1997 and 2002 to present a picture of the timing and abundance of wild Chinook salmon, bull trout, three forage fish species, and shiner perch in the vicinity of the Ala Spit and Lagoon sites sampled in 2007. These older data are not as broadly collected around Ala Spit as data collected in 2007 (one site compared to ten, see Figure 2), but they are collected over a longer sampling period (February through October compared to February through June) and over more years. The larger beach seine used to collect these older data is longer (120 ft compared to 80 ft) and deeper (12 ft compared to 6 ft) than the small net beach seine used in this study. The large net beach seine samples habitat out to the subtidal fringe. Results from the older dataset demonstrate that:

- Bull trout utilize the area from April through August, peaking in July (Figure 14A).
- Wild juvenile Chinook salmon are typically present at Ala Spit from February through September (Figure 14B), peaking in both February (fry migrants) and June (potentially all juvenile life history types). As juvenile Chinook salmon grow larger later in summer they move progressively more offshore to deeper water and thus are not directly in shallow intertidal habitat by about July (see Figure 2.1 in Beamer et al. 2005)
- Three species of forage fish (Figure 14C) and shiner perch (Figure 14D) are common at Ala Spit. Highest abundance for all species is typically during summer (after the time of the beach seining for this study in 2007). The majority of forage fish captured were juvenile sized with the exception of surf smelt in late summer. Surf smelt in late summer included large numbers of adult spawners.

I am also relying on findings from three recent local references (Beamer et al. 2004, 2006 and 2007) to support my conclusion that the following ideas would benefit the forage fish populations, shiner perch, and food web linkages for ESA-listed salmonids:

- Restoration that increases lagoon/marsh area and/or its quality will also provide additional nursery habitat for juvenile forage fish (primarily surf smelt) and shiner perch. Protection of existing lagoon/tidal marsh area and/or its quality maintains existing nursery habitat in Ala Lagoon.
- Restoration of beach face will increase spawning area for surf smelt and sand lance. Protection of existing beach face habitat maintains existing spawning habitat along Ala Spit.
- Restoration of low tide platform and subtidal fringe habitat will benefit juvenile forage fish, including surf smelt, herring, and sandlance. Protection of existing low tide platform and subtidal fringe habitat maintains existing rearing habitat in the Ala Spit area for forage fish.

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Tables

Table 1. Summary of beach seine effort and tidal height during beach seining. Tidal predictions are from http://tbone.biol.sc.edu/tide/sites_uswest.html for Ala Spit. Mean lower low water (MLLW) is 0.0 feet and mean sea level is 6.0 feet.

		Number of beach seine sets	
Date	Tidal height during beach seine sampling (feet above MLLW)	Adjacent nearshore	Lagoon
13-Feb-07	8.4 – 9.1	5	5
26-Feb-07	8.1 – 9.2	5	5
13-Mar-07	8.0 – 8.4	5	5
30-Mar-07	4.3 – 7.8	5	5
12-Apr-07	6.3 – 7.6	5	5
25-Apr-07	5.8 – 7.1	5	5
11-May-07	4.8 – 7.1	5	5
25-May-07	4.2 – 6.7	5	5
08-Jun-07	4.9 – 6.9	5	5
22-Jun-07	4.3 – 6.5	5	5

Table 2.

	Adjacent nearshore	Lagoon
Average of Max Water Depth (m)	**0.64**	**0.78**
StdDev of Max Water Depth (m)	0.30	0.23
count	50	50

Table 3.

Vegetation Type	Adjacent nearshore	Lagoon
Eelgrass	0.0%	2.0%
Eelgrass and algae	4.0%	0.0%
Green algae	38.0%	22.0%
Salt marsh	0.0%	24.0%
Unvegetated	58.0%	52.0%

Table 4.

Substrate Type	Adjacent nearshore	Lagoon
Fines with gravel	56.0%	36.0%
Gravel	2.0%	2.0%
Mixed coarse	40.0%	0.0%
Mixed fines	2.0%	42.0%
Mud	0.0%	16.0%
Sand	0.0%	4.0%

Table 5. Average salinity (ppt) at Ala Spit beach seine sites.

		Monthly Avg of Daily Avg of Surface Sal	
Date	Daily Avg Skagit River Flow (cfs)	Adjacent nearshore (ppt)	Lagoon (ppt)
13-Feb-07	16,600	21.4	21.1
26-Feb-07	18,400	16.7	21.9
13-Mar-07	60,400	6.9	18.8
30-Mar-07	22,900	23.1	19.9
12-Apr-07	17,600	18.8	23.4
25-Apr-07	19,800	20.3	21.0
11-May-07	18,800	26.9	25.3
25-May-07	16,800	25.7	25.2
08-Jun-07	26,500	25.9	23.9
22-Jun-07	26,000	24.1	24.3

Table 6. Average surface water temperature (degrees C) at Ala Spit beach seine sites.

Date	Adjacent nearshore	Lagoon
13-Feb-07	8.2	8.0
26-Feb-07	6.4	6.8
13-Mar-07	6.1	8.1
30-Mar-07	9.1	9.6
12-Apr-07	9.8	9.2
25-Apr-07	10.0	9.6
11-May-07	11.0	11.6
25-May-07	13.7	12.9
08-Jun-07	11.6	10.6
22-Jun-07	11.5	11.5

Table 7. Density of dominant nearshore fish assemblage at Ala Spit, 2007.

A - A**djacent nearshore** habitat (fish per ha)

Date	wild Chinook	Chum	Sandlance	Shiner Perch	Stickleback	P. Staghorn	Starry Flounder	Gunnel sp.
13-Feb-07	0.0	0.0	2,087.0	0.0	324.4	87.0	43.5	0.0
26-Feb-07	21.7	0.0	109.8	0.0	65.2	0.0	43.5	0.0
13-Mar-07	122.5	772.7	65.2	0.0	39.5	0.0	83.0	0.0
30-Mar-07	14.5	1,550.7	45.9	0.0	21.7	65.2	0.0	0.0
12-Apr-07	194.6	31,935.8	21.7	42.4	42.4	0.0	0.0	0.0
25-Apr-07	0.0	6,209.1	21.7	0.0	0.0	126.1	0.0	0.0
11-May-07	0.0	550.2	0.0	21.7	18.9	370.1	190.6	43.5
25-May-07	0.0	161.6	0.0	629.4	0.0	461.8	62.1	108.7
08-Jun-07	0.0	21.3	0.0	0.0	0.0	641.7	0.0	42.6
22-Jun-07	0.0	0.0	0.0	21.7	0.0	1,667.5	108.7	87.0
Season Avg	35.3	4,120.1	235.1	71.5	51.2	341.9	53.1	28.2

B - **Lagoon** habitat (fish per ha)

Date	wild Chinook	Chum	Sandlance	Shiner Perch	Stickleback	P. Staghorn	Starry Flounder	Gunnel sp.
13-Feb-07	0.0	0.0	0.0	65.2	395.3	140.3	41.5	0.0
26-Feb-07	326.1	630.4	11,000.0	21.7	1,858.7	168.5	92.4	0.0
13-Mar-07	1,347.8	2,369.6	21.7	21.7	1,065.2	652.2	87.0	0.0
30-Mar-07	81.4	1,774.4	56.0	0.0	79.7	1,271.4	0.0	0.0
12-Apr-07	0.0	1,319.8	63.2	18.1	130.4	1,823.8	79.4	0.0
25-Apr-07	67.6	5,698.1	0.0	0.0	0.0	5,328.5	0.0	0.0
11-May-07	45.9	1,565.2	0.0	108.7	21.7	7,807.0	85.0	181.8
25-May-07	0.0	0.0	0.0	587.0	0.0	6,074.9	357.5	369.6
08-Jun-07	0.0	0.0	0.0	21.7	0.0	7,417.9	87.0	66.6
22-Jun-07	0.0	0.0	0.0	3,553.8	0.0	7,347.8	521.7	922.4
Season Avg	186.9	1,335.7	1,114.1	439.8	355.1	3,803.2	135.1	154.0

Table 8. Percentage of seine attempts in which each of the dominant fish species were present by (A) vegetation and (B) substrate type for Ala Spit and Lagoon, 2007. The number of beach seine sets for each vegetation and substrate type is shown in parentheses.

A

Vegetation Type	Chinook	Chum	Sandlance	Shiner perch	3 spine stickleback	Pacific staghorn sculpin	Starry flounder	Gunnel sp.	Mean
Eelgrass (3)	0.0%	66.7%	0.0%	33.3%	0.0%	100.0%	33.3%	33.3%	33.3%
Green algae (30)	13.3%	50.0%	6.7%	26.7%	16.7%	83.3%	20.0%	20.0%	29.6%
Salt marsh (12)	33.3%	50.0%	33.3%	33.3%	83.3%	75.0%	50.0%	0.0%	44.8%
Unvegetated (55)	21.8%	38.2%	21.8%	7.3%	23.6%	54.5%	27.3%	12.7%	25.9%

B

Substrate Type	Chinook	Chum	Sandlance	Shiner perch	3 spine stickleback	Pacific staghorn sculpin	Starry flounder	Gunnel sp.	Mean
Fines with gravel (46)	15.2%	39.1%	15.2%	13.0%	26.1%	71.7%	26.1%	15.2%	27.7%
Gravel (2)	0.0%	50.0%	50.0%	0.0%	50.0%	50.0%	50.0%	0.0%	31.3%
Mixed coarse (20)	30.0%	65.0%	25.0%	15.0%	20.0%	25.0%	20.0%	10.0%	26.3%
Mixed fines (22)	22.7%	27.3%	9.1%	31.8%	36.4%	86.4%	36.4%	18.2%	33.5%
Mud (8)	25.0%	62.5%	12.5%	12.5%	25.0%	100.0%	25.0%	12.5%	34.4%
Sand (2)	0.0%	50.0%	100.0%	0.0%	50.0%	50.0%	50.0%	0.0%	37.5%

Table 9. Average density of wild juvenile Chinook by sampling date at Ala Spit, 2007. Gray shading shows the dates when juvenile Chinook were present.

Date	Fish per ha		Transformed fish per ha = log(x+1)	
	Adjacent nearshore	Lagoon	Adjacent nearshore	Lagoon
13-Feb-07	0.0	0.0	0.0000	0.0000
26-Feb-07	21.7	326.1	0.4080	0.6425
13-Mar-07	122.5	1,347.8	1.3357	2.5051
30-Mar-07	14.5	81.4	0.3732	1.2600
12-Apr-07	194.6	0.0	1.4595	0.0000
25-Apr-07	0.0	67.6	0.0000	0.8850
11-May-07	0.0	45.9	0.0000	0.8251
25-May-07	0.0	0.0	0.0000	0.0000
08-Jun-07	0.0	0.0	0.0000	0.0000
22-Jun-07	0.0	0.0	0.0000	0.0000
Season Avg.	35.3	186.9	0.3576	0.6118

Table 10. Average density of juvenile chum by sampling date at Ala Spit, 2007. Yellow shading shows the dates when juvenile chum were present.

Date	Fish per ha		log(x+1) transformed fish per ha	
	Adjacent nearshore	Lagoon	Adjacent nearshore	Lagoon
13-Feb-07	0.0	0.0	0.0000	0.0000
26-Feb-07	0.0	630.4	0.0000	2.8003
13-Mar-07	772.7	2,369.6	2.8886	3.3749
30-Mar-07	1,550.7	1,774.4	3.1908	3.2493
12-Apr-07	31,935.8	1,319.8	4.5043	3.1208
25-Apr-07	6,209.1	5,698.1	3.7931	3.7558
11-May-07	550.2	1,565.2	2.7413	3.1949
25-May-07	161.6	0.0	2.2113	0.0000
08-Jun-07	21.3	0.0	1.3486	0.0000
22-Jun-07	0.0	0.0	0.0000	0.0000
Grand Total	4,120.1	1,335.7	3.6150	3.1260

Table 11. Summary of wild juvenile Chinook salmon length at Ala Spit, 2007.

A. Count of wild Chinook salmon fork lengths

Date	Adjacent nearshore	Lagoon
26-Feb-07	1	15
13-Mar-07	6	51
30-Mar-07	1	4
12-Apr-07	9	
25-Apr-07		4
11-May-07		2
Grand Total	17	76

B. Average of wild Chinook salmon fork length (mm)

Date	Adjacent nearshore	Lagoon
26-Feb-07	39.0	41.5
13-Mar-07	39.5	42.7
30-Mar-07	40.0	43.0
12-Apr-07	42.8	
25-Apr-07		61.5
11-May-07		48.5
Grand Total	41.2	43.6

C. 1 standard deviation of fork lengths (mm)

Date	Adjacent nearshore	Lagoon
26-Feb-07		3.5
13-Mar-07	2.7	3.6
30-Mar-07		1.4
12-Apr-07	1.9	
25-Apr-07		30.9
11-May-07		9.2
Grand Total	2.6	8.3

Table 12. Summary of juvenile chum salmon length at Ala Spit, 2007.

A. Count of chum salmon fork lengths

Date	Adjacent nearshore	Lagoon
26-Feb-07		22
13-Mar-07	31	69
30-Mar-07	48	59
12-Apr-07	93	47
25-Apr-07	100	43
11-May-07	29	29
25-May-07	8	
Grand Total	309	269

B. Average of chum salmon fork length (mm)

Date	Adjacent nearshore	Lagoon
26-Feb-07		38.6
13-Mar-07	34.4	39.7
30-Mar-07	38.1	38.3
12-Apr-07	37.5	38.4
25-Apr-07	38.0	39.1
11-May-07	38.7	40.1
25-May-07	40.1	
Grand Total	37.6	39.0

C. 1 standard deviation of fork lengths (mm)

Date	Adjacent nearshore	Lagoon
26-Feb-07		3.7
13-Mar-07	2.3	3.4
30-Mar-07	1.9	2.0
12-Apr-07	3.0	2.3
25-Apr-07	3.6	3.2
11-May-07	3.7	3.8
25-May-07	2.7	
Grand Total	3.3	3.1

Table 13. Summary of Pacific Staghorn sculpin length at Ala Spit, 2007.

A. Number of P. Staghorn length samples

Date	Adjacent nearshore	Lagoon
13-Feb-07	4	7
26-Feb-07		7
13-Mar-07		30
30-Mar-07	3	49
12-Apr-07		40
25-Apr-07	6	85
11-May-07	18	94
25-May-07	22	98
Grand Total	53	410

B. Average P. Staghorn length (mm)

Date	Adjacent nearshore	Lagoon
13-Feb-07	113.5	34.7
26-Feb-07		44.3
13-Mar-07		44.4
30-Mar-07	11.7	46.2
12-Apr-07		41.4
25-Apr-07	18.3	32.4
11-May-07	32.2	53.8
25-May-07	40.6	76.2
Grand Total	39.1	51.4

C. 1 standard deviation (mm)

Date	Adjacent nearshore	Lagoon
13-Feb-07	70.6	8.8
26-Feb-07		21.0
13-Mar-07		24.7
30-Mar-07	2.1	12.7
12-Apr-07		19.4
25-Apr-07	2.5	22.4
11-May-07	15.7	29.8
25-May-07	33.7	27.0
Grand Total	36.9	28.8

Figures

Figure 1. Location of Ala Spit along the northeastern shoreline of Whidbey Island within Skagit Bay.

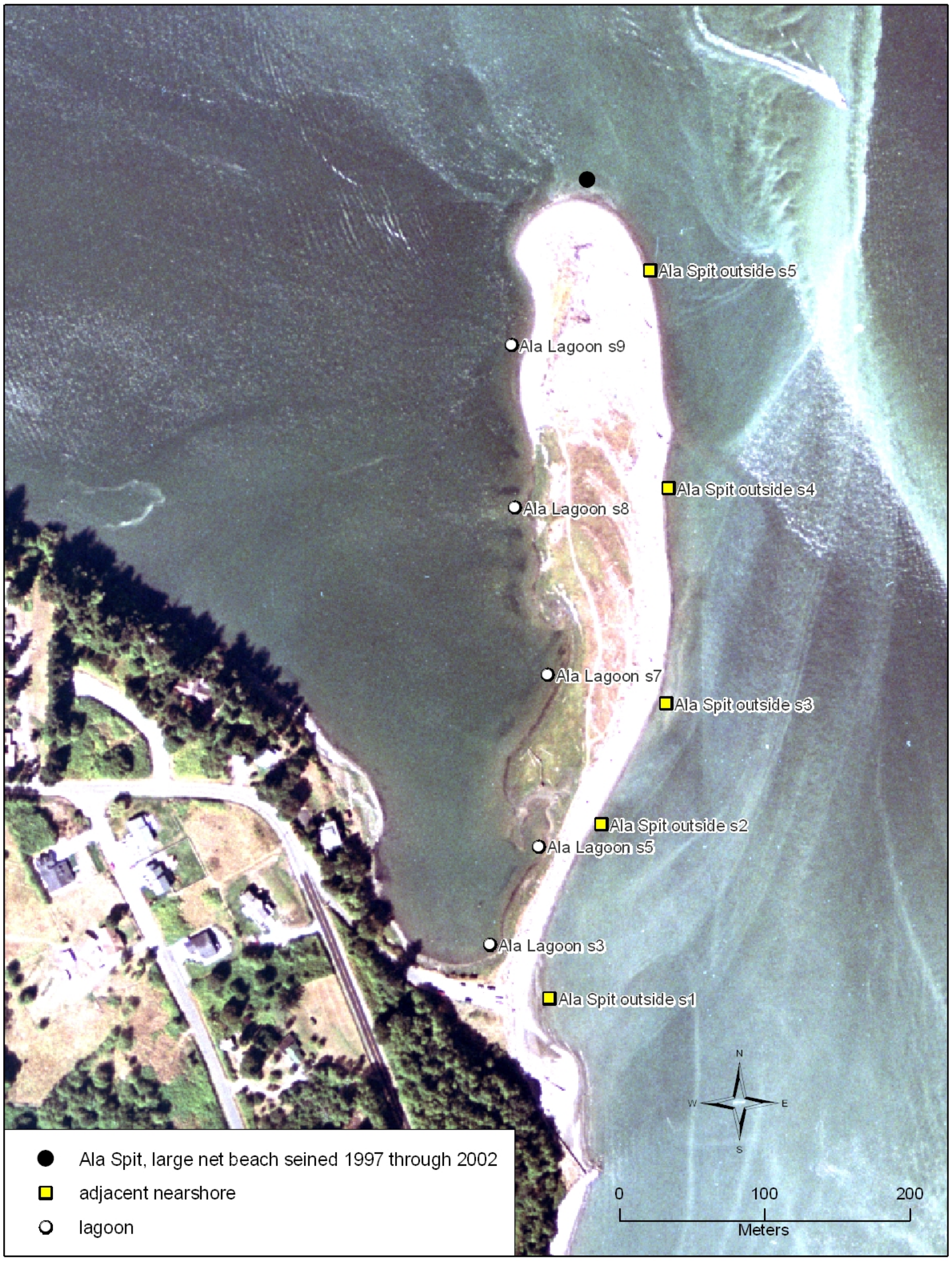


Figure 2. Location of beach seine sites sampled at Ala Spit. Yellow squares and white circles were sampled in 2007. The black circle was sampled by Skagit River System Cooperative as part of a juvenile salmon research effort from 1997-2002.

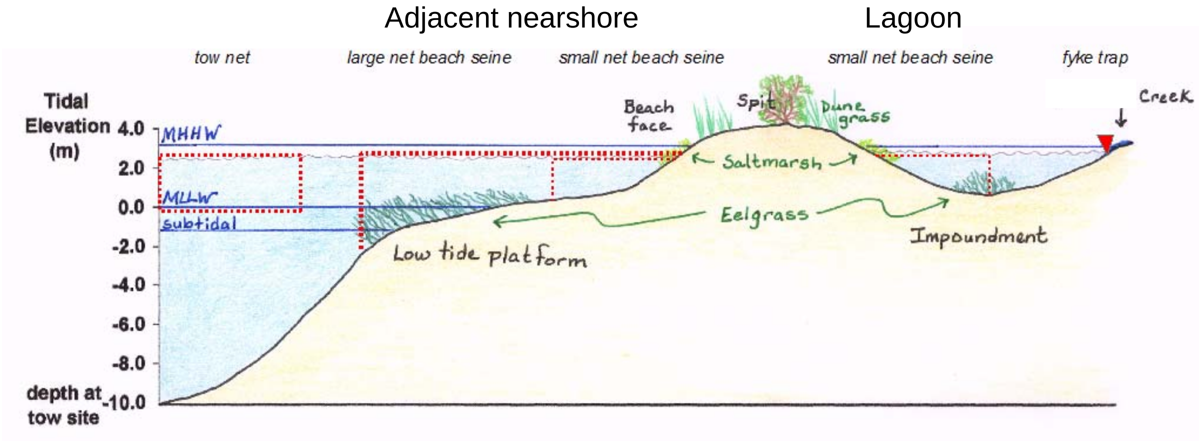


Figure 3. Cartoon of nearshore habitat in an area like Ala Spit.

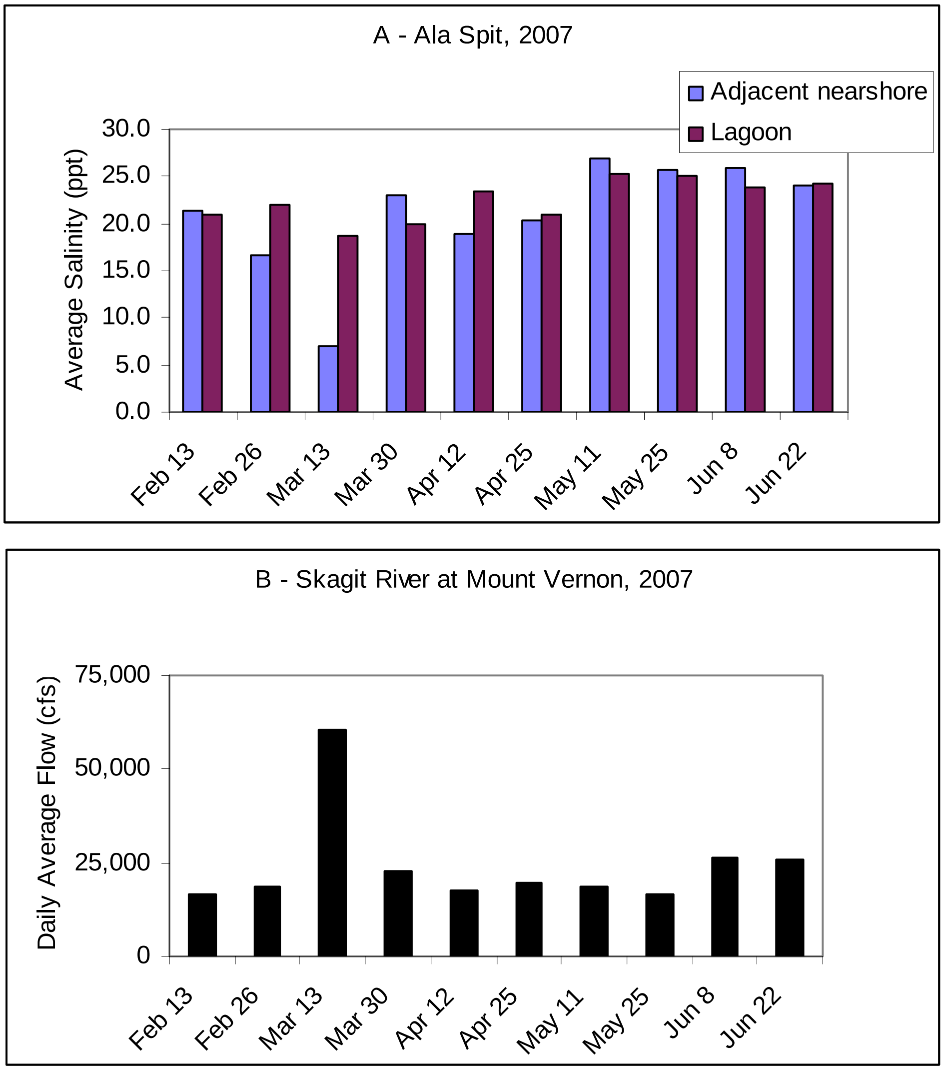


Figure 4. (A) Surface salinity at Ala Spit and (B) Daily average Skagit River flow (in cfs) at Mount Vernon on the dates when beach seining occurred at Ala Spit. Salinity values are averages of surface salinity measured during the time of beach seining. Five sites were measured on the inside (lagoon) of Ala Spit and five sites were measured on the outside (adjacent nearshore) of Ala Spit. Flow data are from USGS.

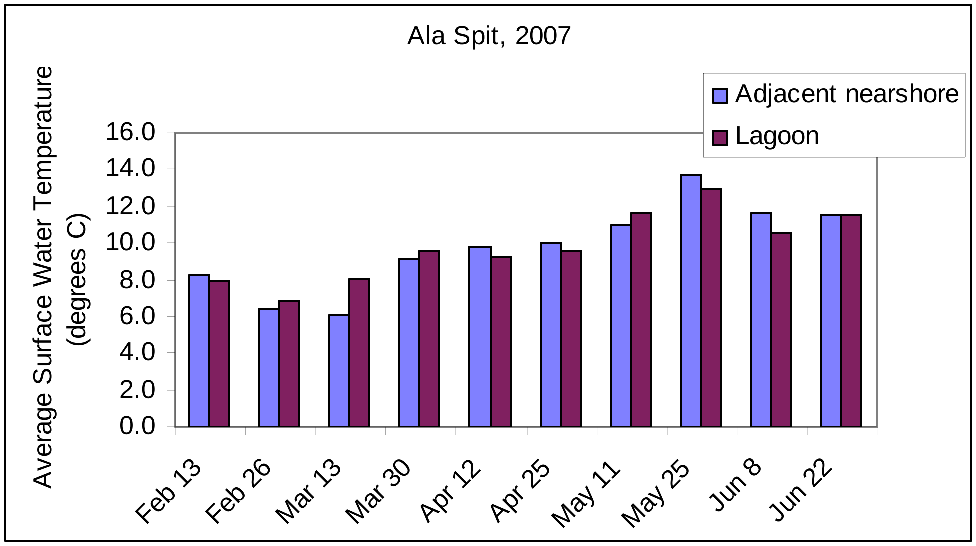


Figure 5. Surface water temperature on the dates when beach seining occurred at Ala Spit. Values are averages of surface water temperature measured during the time of beach seining. Five sites were measure on the inside (lagoon) of Ala Spit and five sites were measured on the outside (adjacent nearshore) of Ala Spit.

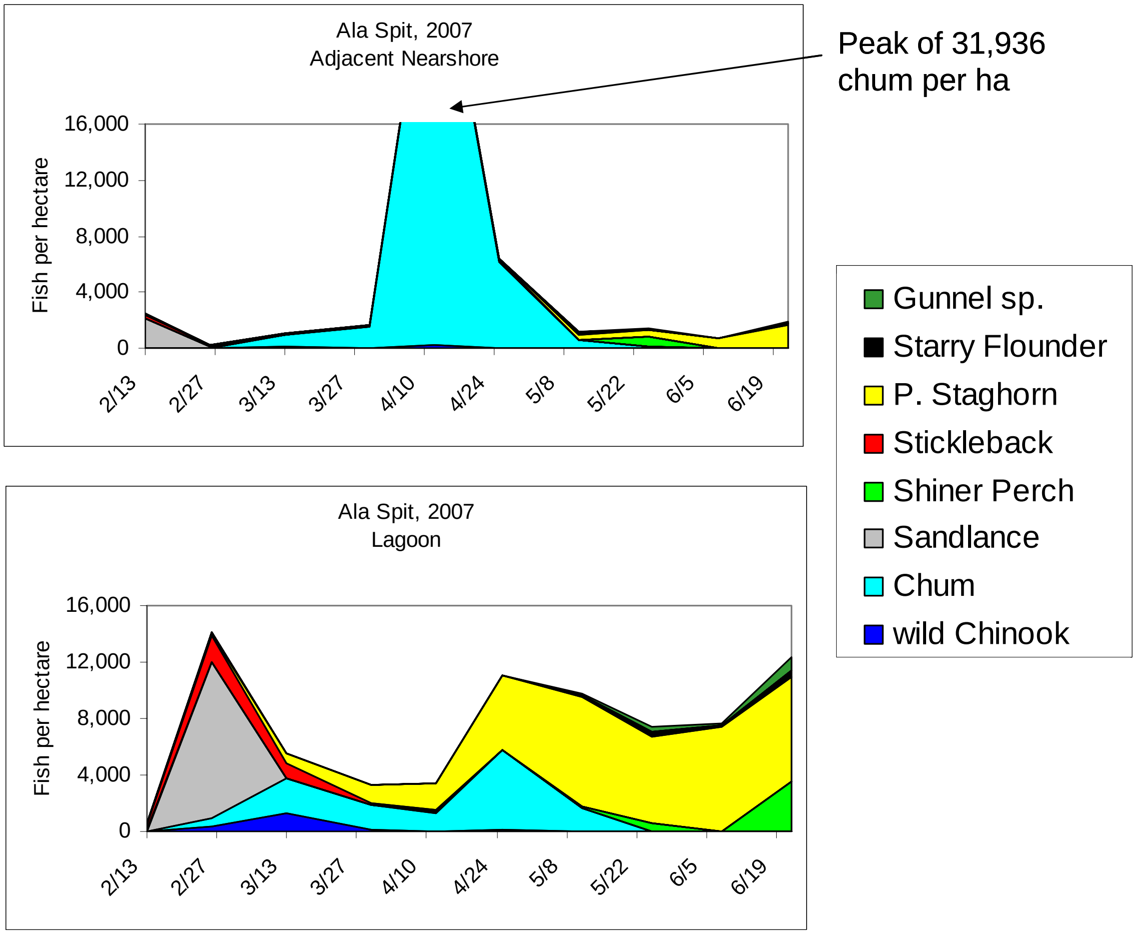


Figure 6. Assemblage of dominant fish in nearshore and lagoon habitat of Ala Spit. Results are shown as averages by sampling date.

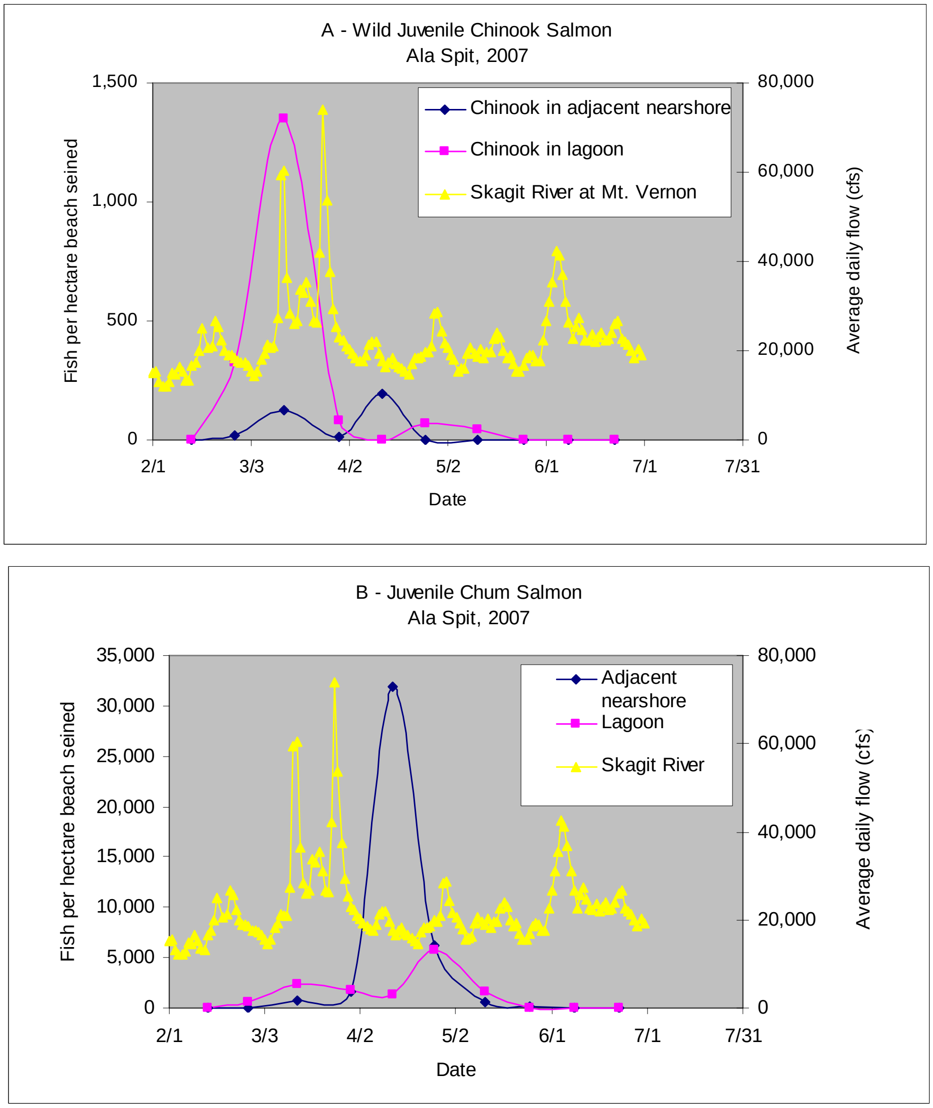


Figure 7. Density of (A) wild juvenile Chinook and (B) juvenile chum salmon in lagoon and adjacent nearshore habitat associated with Ala Spit, 2007.

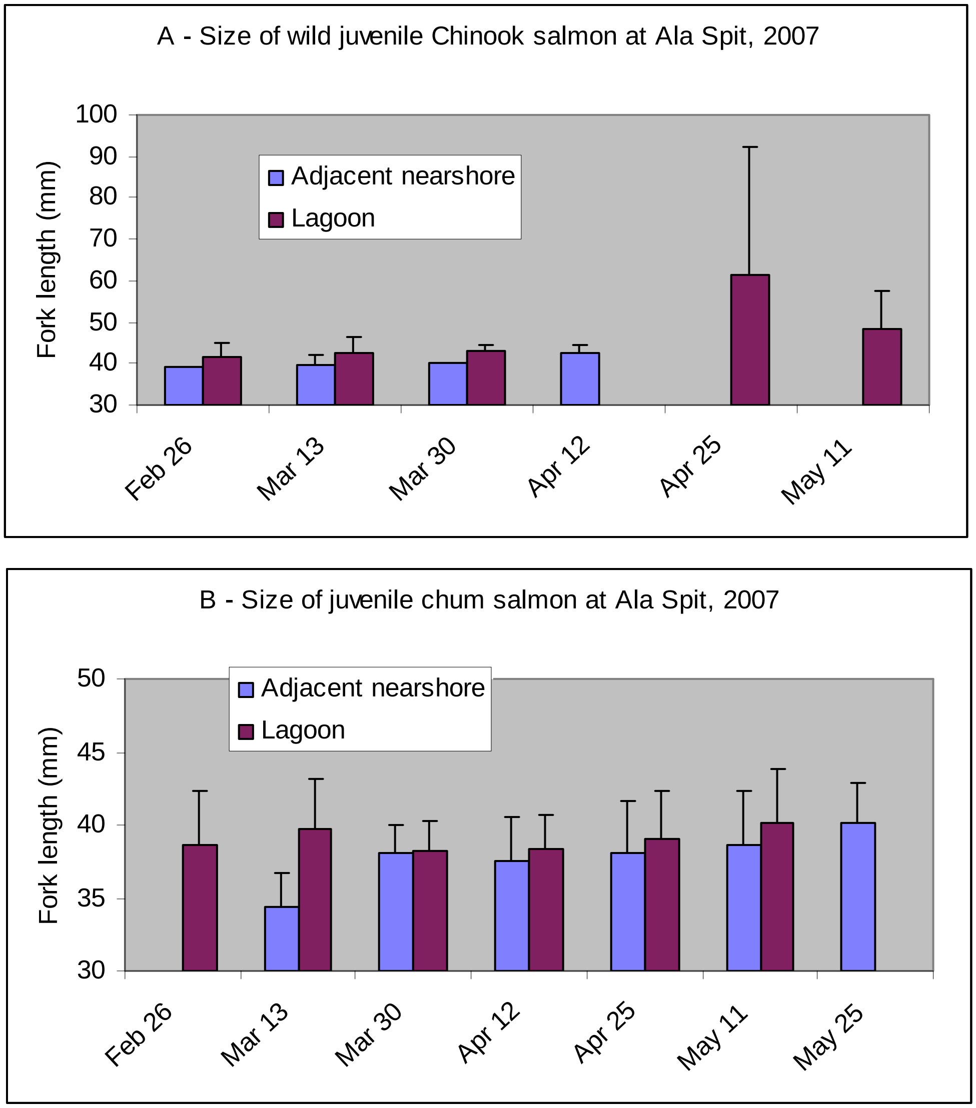


Figure 8. Monthly average size of (A) wild Chinook salmon and (B) chum salmon caught at Ala Spit and Lagoon, 2007. Error bars are one standard deviation.

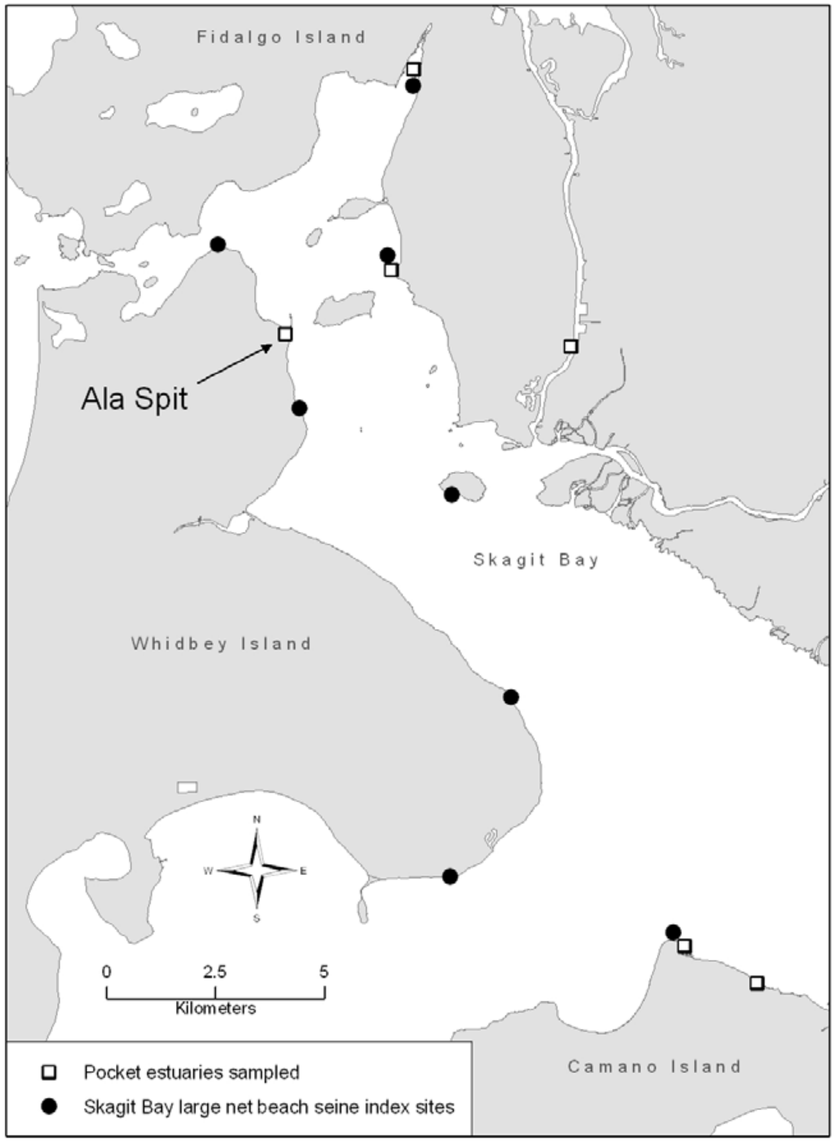


Figure 9. Location of Skagit Bay index beach seine and pocket estuary sites sampled by Skagit River System Cooperative. The black circles represent sites sampled twice per month by a large beach seine deployed from a boat. These sites are a part of the long term Chinook salmon monitoring program (Greene and Beamer 20006). The white squares represent pocket estuary sites where fish use sampling occurred in 2007.

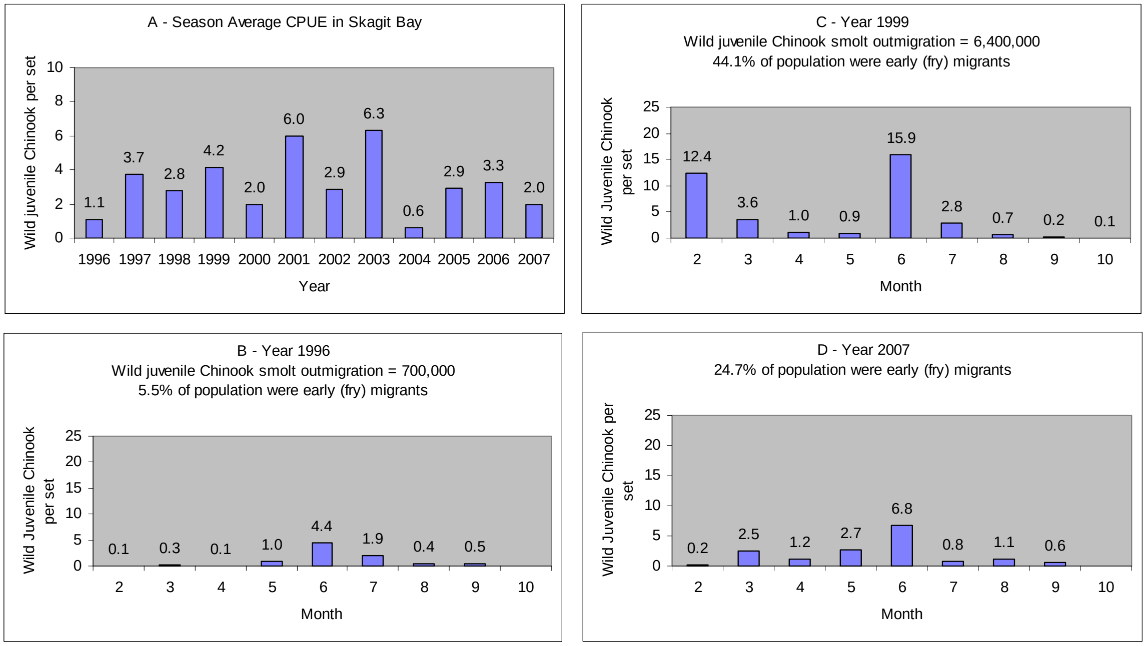
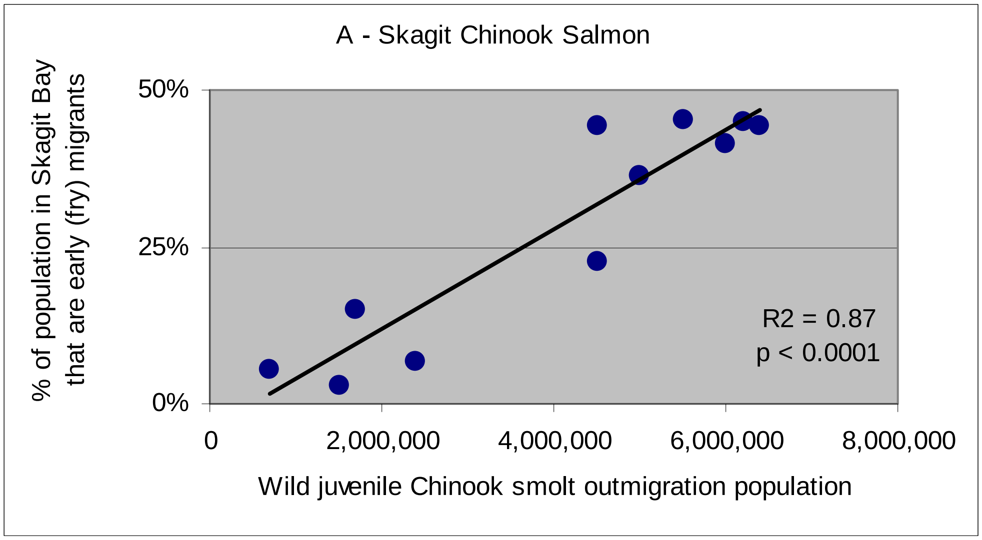


Figure 10. Wild juvenile Chinook salmon: context of 2007 Ala Spit results with population data from other brood years. All results are from twice a month (Feb-Oct) sampling by SRSC using large net beach seine at index sites within Skagit Bay (Figure 9). (A) Season average catch per unit effort (CPUE) for 12 years. (B) Monthly average CPUE for the lowest year sampled – 1996; (C) Monthly average CPUE for the highest year sampled – 1999; and (D) Monthly average CPUE for 2007.



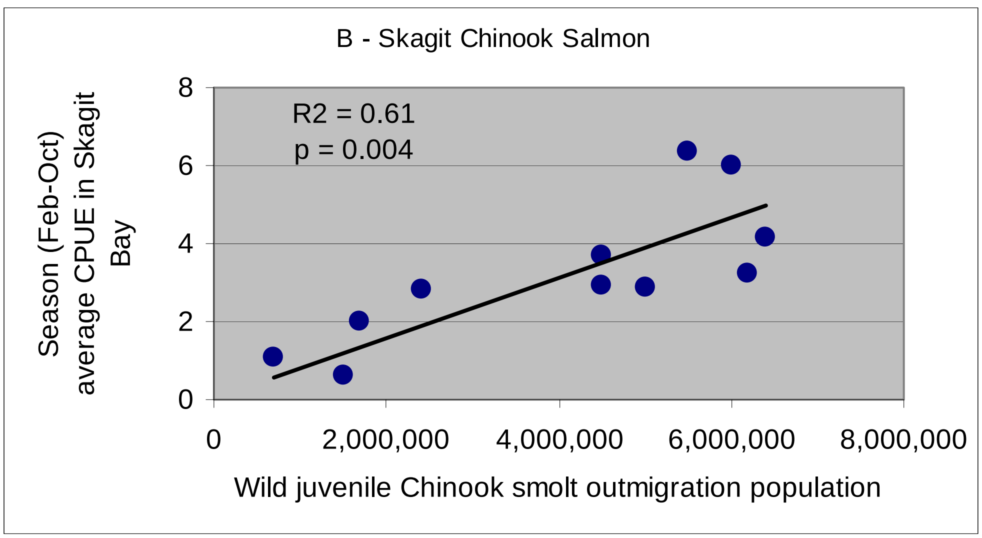


Figure 11. Juvenile Chinook salmon: context of 2007 Ala Spit results with population data from other brood years. (A) The percentage of juvenile Chinook in nearshore habitat of Skagit Bay over the entire season (Feb-Oct) as a function of the smolt outmigration population size. This regression suggests the 2007 outmigration was around 3.5 million. (B) The season average CPUE of juvenile Chinook caught in Skagit Bay as a function of the smolt outmigration population size. This regression suggests the 2007 outmigration was around 2.5 million.

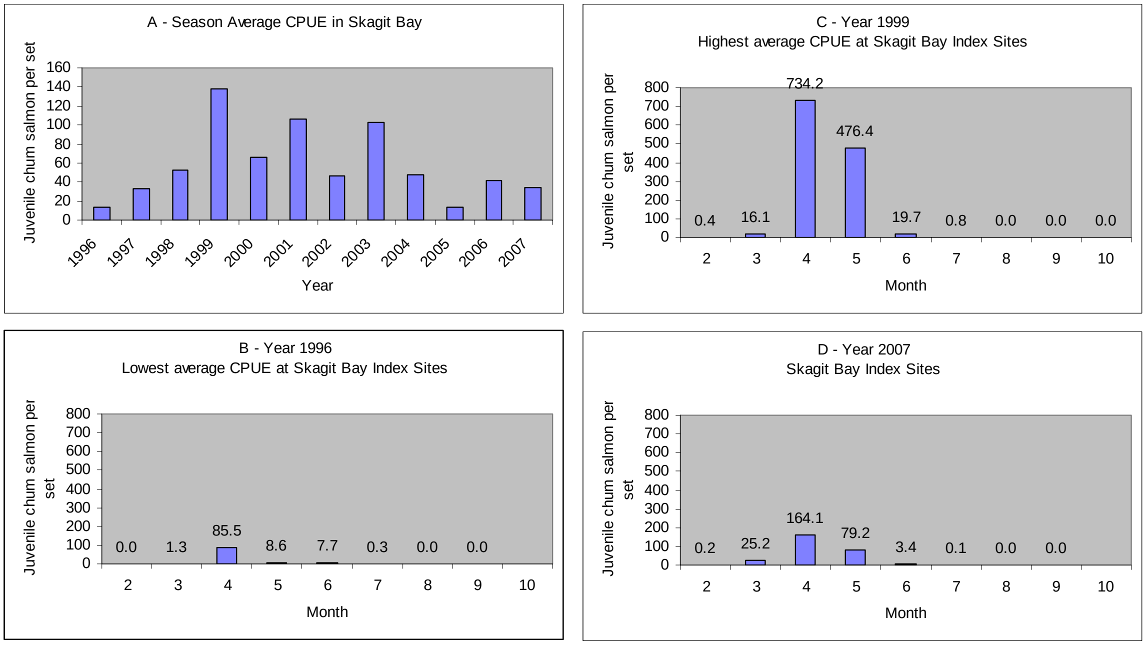


Figure 12. Juvenile Chum salmon: context of 2007 Ala Spit results with population data from other brood years. All results are from twice a month (Feb-Oct) sampling by SRSC using large net beach seine at index sites within Skagit Bay (Figure 9). (A) Season average catch per unit effort (CPUE) for 12 years. (B) Monthly average CPUE for the lowest year sampled – 1996; (C) Monthly average CPUE for the highest year sampled – 1999; and (D) Monthly average CPUE for 2007.

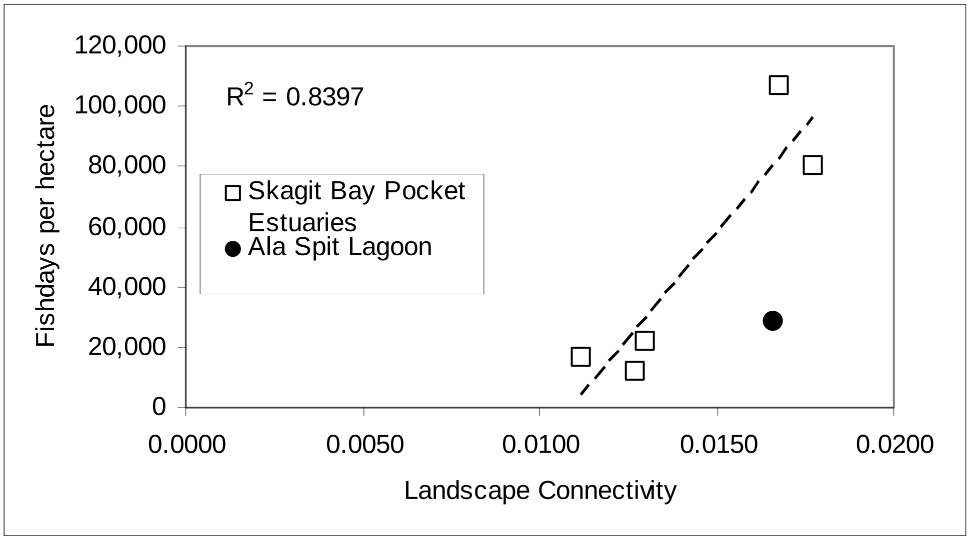


Figure 13. Relationship between the seasonal density of wild Chinook salmon and landscape connectivity for six different pocket estuaries within Skagit Bay in 2007. The white squares are results for English Boom Lagoon, Arrowhead Lagoon, Turners Bay, Lone Tree Lagoon, and Swinomish Channel Old Bridge. The black dot is for Ala Lagoon habitat. The location of each pocket estuary site is shown in Figure 9.

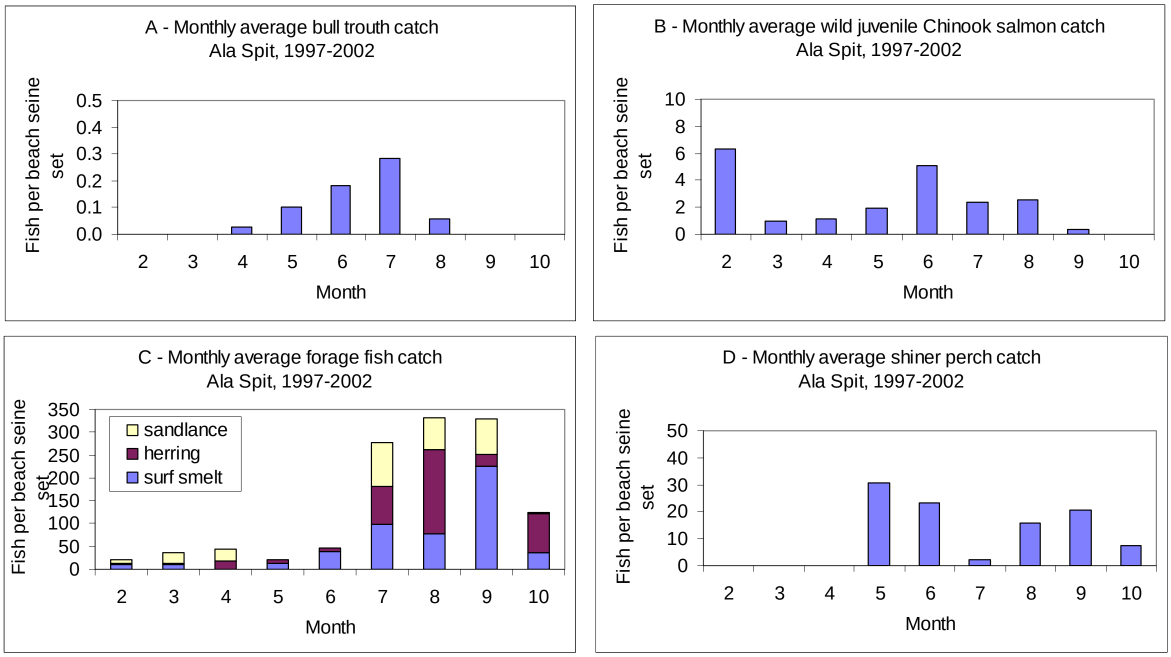


Figure 14. Monthly average catch of (A) bull trout, (B) wild juvenile Chinook salmon, (C) three forage fish species, and (D) shiner perch at Ala Spit. Results are from twice a month sampling for a nine month period (Feb-Oct) repeated for six years (1997-2002). Sampling was done by SRSC using a large net beach seine at the tip of Ala Spit. The site is shown in Figure 2.