

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

January 16, 2006



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ACKNOWLEDGEMENTS

The following people and organizations are to be thanked for their help with this study:

- Northwest Straits Commission for partial funding in 2004
- Skagit County Marine Resources Committee for funding Lone Tree data collection in 2004
- Northwest Indian Fisheries Commission through the Pacific Salmon Treaty and Pacific Coastal Salmon Recovery for partial funding of sampling efforts in 2004 and 2005
- The Tulalip Tribes for donating funds and staff time; Robert Skoog, Tony Moses, and James Arrigoni for sampling at Tulalip Bay
- Skagit River System Cooperative fisheries technicians Bruce Brown, John Grossglass, Jason Boome, Ed Williams Jr. and Donald Damien for their part in the field work and data entry
- NOAA's Joshua Chamberlin, Sarah McIntyre, Anna Kagley, and Dan Schenk for assisting in beach seining
- Sandy Wyllie-Echeverria, Victoria Wyllie-Echeverria, Rebecca Wyllie-Echeverria, Tess Wyllie-Echeverria and Elsa Carlisle for sampling in the north Skagit County bays
- Island County Beach Watchers for help with data collection at Harrington and Race Lagoons: Jim West, Bob Buck, Joani Boose, Jim Somers, Ken Urstad, Bill Pigott, Harry Moore, Marty Crowley, and resident Ian Tully; and at Elger Bay: Barbara Brock, Alice Blandin, Bill Blandin, Shirley Caraway, Bill Griffith, Pam Cooper, Tom Perry, Vicki Perry, Duane Hoekstra, Sue Hoekstra, and Dian Jahn; and the guidance/support of Dot Irvin, Kim Bredensteiner, Jeff Hall, and Don Meehan
- Eagle Tree Estates, Culbertson Marine Construction, and private landowners at all pocket estuary sites for allowing us access to sample sites

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INTRODUCTION

Estuaries exist anywhere along the coast where geologic and hydrologic conditions create a partially enclosed, diluted marine body of water. They vary in scale, depending on the size of the enclosure and the amount of freshwater dilution. A large estuary like Puget Sound may itself contain river mouth estuaries and small-scale ‘pocket’ estuaries with more dilute marine water relative to the surrounding estuary. Pocket estuaries form behind coastal accretion landforms, at coastal embayments, or at small creek mouths (McBride et al. 2005). Compared to adjacent intertidal habitat, pocket estuaries have: (1) substrates, intertidal gradients, and vegetation consistent with low energy environments, and (2) local surface and/or groundwater freshwater inputs that depress salinity during some part of the year, usually winter and spring.

Skagit Bay research conducted in 2002 found that wild fry migrant Chinook salmon appear to prefer non-natal pocket estuaries compared to other adjacent nearshore habitat areas (Beamer et al. 2003). Evidence suggests that juvenile Chinook in pocket estuaries experience improved growth and higher survival than fish in surrounding nearshore or offshore areas during the period from February through May. Preliminary results from fish sampling in 2003 further support earlier work and find that pocket estuaries serve a nursery role for a number of other fish species including surf smelt – an important salmon prey resource. Additionally, accretion shore forms protecting pocket estuaries appear to be linked to bull trout use (Beamer et al. 2004). These results suggest that pocket estuaries are an important ecological niche for some salmon life history types and other estuarine/marine fish species.

Our understanding of Chinook salmon ecology in pocket estuaries has thus far been limited to sites within Skagit Bay. The results shown in Beamer et al. (2003) directly relate to Skagit Bay and Skagit-origin Chinook salmon, but may not infer the true importance of the pocket estuaries in a larger spatial and ecological setting. Therefore, we have expanded our research to the Whidbey Basin of Puget Sound and north Skagit County bays (Fidalgo, Padilla, and Samish) in order to better understand the potential role of pocket estuaries in larger scale nearshore habitat restoration and salmon recovery planning. This report summarizes habitat and fish use data collected in and around pocket estuaries of Whidbey Basin and north Skagit County bays. This research was conducted as part of our ongoing investigation into how salmon utilize nearshore habitats. This has been a collaborative project between the Stillaguamish, Samish, Tulalip, Sauk-Suiattle and Swinomish Indian Tribes, with technical support and field involvement from NOAA Fisheries. The project was started in 2004 with funding made available by the Northwest Straits Commission.

HABITAT MAPPING AND CHANGE ANALYSIS METHODS

Current and historic habitat conditions were mapped at eight pocket estuaries intensively monitored during 2004. The purpose of mapping was to provide data for evaluating relationships between fish use and habitat conditions and to analyze impacts of anthropogenic habitat modifications on fish use. These data will be used in evaluating restoration potential and prioritizing restoration and conservation actions.

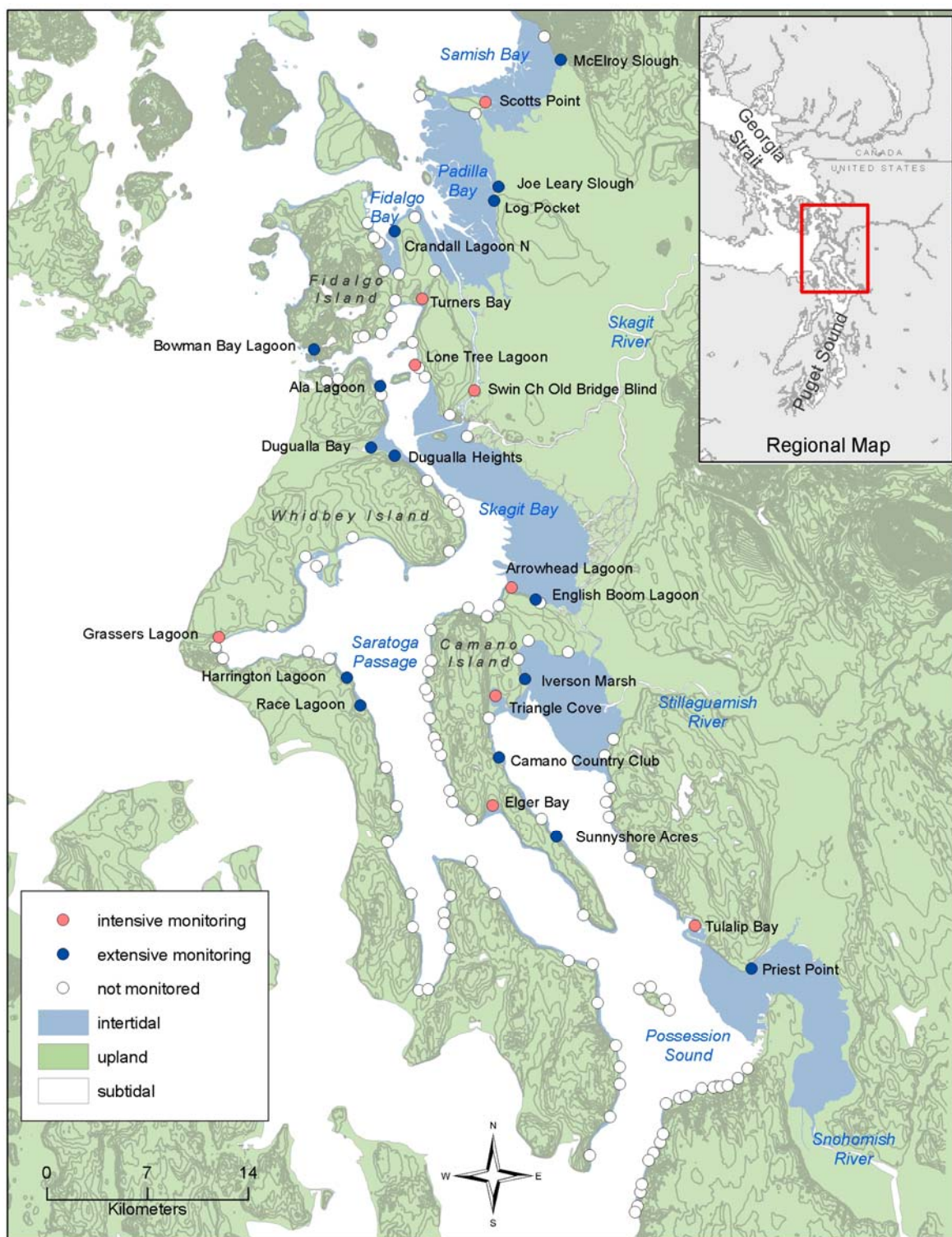


Figure 1. *Pocket estuaries within the study area.* Accessible pocket estuaries are currently open to fish access. Inaccessible pocket estuaries may or may not still have hydraulic connection to the adjacent nearshore habitat, and are not open to fish use. Pocket estuaries mapped and sampled during 2004 are labeled with site names. Some pocket estuaries shown in this figure are relic large river tidal delta habitats that function more like pocket estuaries due to their isolation from historic river processes. These are Swin Ch Old Bridge Blind, Log Pocket, and Joe Leary Slough. McElroy Slough is a true pocket at the historic delta margin.

We identified the number and location of pocket estuaries within the study area using a geomorphic habitat model (Figure 1). Within Puget Sound upland topography (a surrogate for tectonic and geologic history) and substrate material (a surrogate for resistance to erosion and geologic history), when acted upon by a given landscape process or combination of processes, will produce and maintain a predictable suite of nearshore habitat conditions (McBride et al. 2005, Beamer et al. 2005). Using this geomorphic model, we identified sites within Whidbey Basin, Fidalgo Bay, Padilla Bay, and Samish Bay that currently are, or historically have been pocket estuaries. Some of the sites identified as current pocket estuaries are, in fact, remnants of the historic Skagit/Samish River Delta (Figure 1). Had the historic delta not been diked and filled, the remnants would still be connected their rivers and would be classified as larger-scale delta habitat. However, these discontinuous ‘pockets’ of delta habitat, labeled ‘artificial pocket estuaries’ in Figure 1, currently are maintained by small scale processes, similar to true pocket estuaries, and have the habitat characteristics of pocket estuaries. Eight of the identified pocket estuaries that are still accessible to fish were selected for intensive study, to include habitat mapping and change analysis, and fish sampling.

We digitally mapped the eight sites in detail according to the zones and subzones defined in Table 1 using high-resolution aerial photography. We then re-mapped each pocket estuary using the oldest available data from historic orthophotos and maps. Digital data sources for historic reconstructions are listed in Table 2. Historic aerial photos were scanned at high resolution and georeferenced to 1998 DNR black and white orthophotos. We supported and fine tuned our photo interpretation of lower quality, black and white historic imagery with current geologic, soils and topographic maps, current LIDAR, and with US Coast and Geodetic Survey maps from the late 1800s. All data sources were georeferenced and compared visually as overlapping GIS layers during digital mapping. The final product is a single polygon layer coded for current and historic conditions by zone and subzone.

In cases where the historic photo record was incomplete, inconsistent in resolution and/or accuracy for making comparisons between data sets, or not old enough to pre-date development of a site, we pieced together historic habitats by looking for

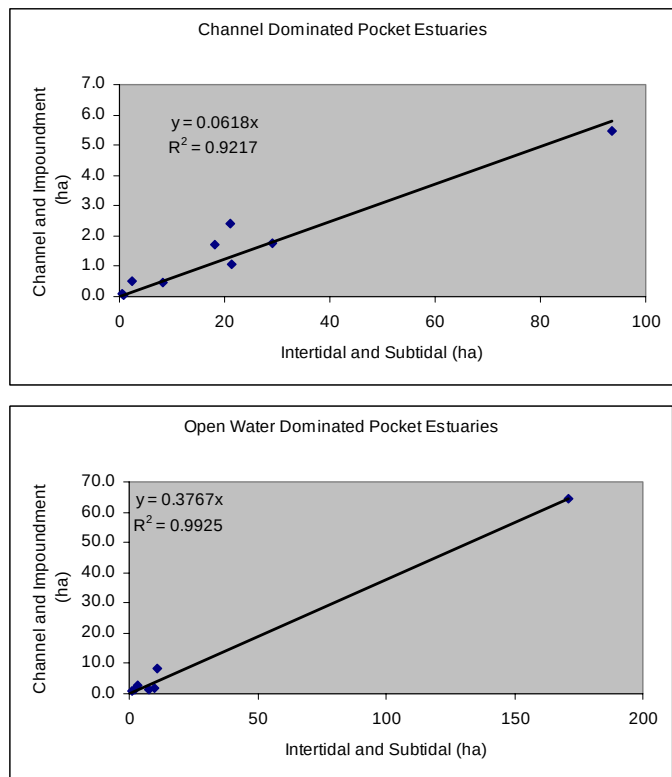


Figure 2. Regression tool. Used to estimate the amount of fish habitat (channels and impoundments) based on the mapped intertidal/subtidal footprints of pocket estuaries. Allows us to estimate habitat loss for pocket estuaries that could not be mapped in detail with data sources available. Note that the second regression appears to be driven by one large pocket estuary, however the R^2 is high both with that point included and with it omitted.

common landscape patterns in the various sources of available data. Because each site required unique methods for reconstructing historic conditions based on the data available for that site, data resolution (to zones or subzones level) varies in the historic maps produced. In cases where mapping was limited to distinguishing only intertidal and subtidal from upland due to poor image quality, we used a regression developed from all sites within Whidbey Basin for which we had channel area data to determine a relationship between pocket estuary area and fish habitat area (subset of channel, impoundment, and subtidal area) (Figure 2).

Table 1. *Nearshore Zones and Subzones.* These definitions are based on tidal elevation as inferred from landscape features that could be consistently distinguished on aerial photos and topographic maps.

Zones (based on tidal elevation)	Subzones (elevation plus form)
Subtidal—The area below extreme low water (ELW).	Impoundment Trough Flat Ramp Basin
Intertidal—The area between MHHW and ELW.	Beach Face or Plunging Rock Face Low Tide Platform Reef or Bar Driftwood Channel Impoundment Emergent Marsh Wetland Scrub-Shrub Wetland
Backshore—Coastal deposits above MHHW that are actively influenced by coastal processes.	Barrier Beach (spits, cusps and tombolos) Bar Island Berm Dunes
Watershed—Land above the upper limit of saltwater and tidal influence.	Upland Lake Wetland Fluvial
Lost—Intertidal, subtidal, and backshore habitats that have been modified such that coastal processes no longer function as they did prior to modification (~1900).	Isolated Filled Dredged

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Table 2. *Digital data used for mapping.*

Year	Project/Publication Information	Format	Scale
1880-1889	T-sheets, US Coast and Geodetic Survey	sketched field maps, georeferenced by Puget Sound River History Project, University of Washington	1:20,000
1890	H-sheets, US Coast and Geodetic Survey	sketched field maps with soundings, georeferenced by Puget Sound River History Project, University of Washington	1:20,000
1941	US Army Corps of Engineers	mosaiced black and white aerial photos, scanned and georeferenced in-house	1:20,000
1956	CWD project, US Agricultural Stabilization and Conservation Service, Salt Lake City	black and white aerial photos, scanned and georeferenced in-house	1:20,000
1964	BBi project, US Agricultural Stabilization and Conservation Service, Salt Lake City	black and white aerial photos, scanned and georeferenced in-house	1:20,000
1965	WF project, Pacific Aerial Surveys, Seattle	black and white aerial photos, scanned and georeferenced in-house	1:60,000
1966	WHIDBEY ISL project, WA Department of Transportation, Olympia (?)	black and white aerial photos, scanned and georeferenced in-house	1:24,000
1971	NASA 189 project	color infrared aerial photos, scanned and georeferenced in-house	1:58,000
1972	S72021 project, US Army Corps of Engineers	black and white aerial photos, scanned and georeferenced in-house	1:24,000
1979	SEABLOCK project, WA Department of Transportation, Olympia (?)	black and white aerial photos, scanned and georeferenced in-house	1:24,000
1980-1981	HAP 80 (high altitude photography) project, US Agricultural Stabilization and Conservation Service, Salt Lake City	color infrared aerial photos, scanned and georeferenced in-house	1:58,000
2000	Nearshore mapping project, Triathlon Ltd, Skagit River System Cooperative, LaConner	true color digital orthophotos	2ft pixel
2000	Resource management project, Triathlon Ltd, Swinomish Indian Tribal Community, LaConner	color infrared digital orthophotos	1ft pixel
2001	Resource management project, WA Department of Natural Resources, Olympia	true color aerial photos, scanned and georeferenced in-house	1ft pixel
2003	Nearshore mapping project, Walker & Associates, Stillaguamish Tribe of Indians, Arlington	true color aerial photos, mosaiced and georeferenced by Stillaguamish	1ft pixel
2003	Nearshore mapping project, Walker & Associates, Tulalip Tribes of Washington, Tulalip	true color aerial photos, mosaiced and georeferenced by Tulalip	1ft pixel
2003	Port Townsend and Seattle Quadrangle maps, WA Department of Natural Resources, Olympia	digital geology maps	1:100,000
2003	Utsalady and Conway Quadrangle maps, WA Department of Natural Resources, Olympia	digital geology maps	1:24,000
2003	LaConner and Anacortes South Quadrangle maps, WA Department of Natural Resources, Olympia	paper geology maps, digitized on tablet by SRSC	1:24,000
2003	Fidalgo Guemes Change Analysis, TerraLogic GIS, Stanwood	ArcGIS shapefiles	
2004	Resource management project, Triathlon Ltd, Swinomish Indian Tribal Community, LaConner	color infrared digital orthophotos	0.5ft pixel

HABITAT MAPPING AND CHANGE ANALYSIS RESULTS

Table 3 summarizes the changes in habitat since human settlement for mapped pocket estuaries. Figures 3 through 10 show comparisons of historic conditions in the eight pocket estuaries that were intensively sampled during 2004. In evaluating nearshore habitats and pocket estuaries, in particular, for habitat conservation and restoration, watershed conditions impacting nearshore habitats must be part of the ecological picture. Figure 11 shows pocket estuary watersheds as a reference for freshwater input potential and watershed impact evaluation.

Table 3a. Change analysis for pocket estuaries. Current conditions (subzone or **zone** areas in hectares).

Site	Back shore	Drift wood	Beach Face	Scrub Shrub	Emerg Marsh	Chan.	Impnd	Low Tide Plat.	Sub tidal	Filled	Isol.	Inter/Sub Footprint	Habitat Footprint
Arrowhead Lagoon	2.4	0.3	0.1	0.0	1.8	0.3	0.1	0.0	0.0	1.7	4.0	2.6	0.3
Elger Bay	2.2	15.7	1.6	0.9	9.3	1.8	0.0	0.0	0.0	0.0	1.9	29.2	1.8
Grassers Lagoon	0.5	0.0	0.2	0.0	1.2	0.2	1.3	4.7	0.0	1.3	0.3	7.6	1.5
Lone Tree Lagoon	0.5	0.1	0.3	0.0	0.6	0.2	1.1	0.4	0.0	1.1	0.1	2.5	1.3
Scotts Point	0.3	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	15.7	24.4	0.3	0.00
Triangle Cove	0.1	1.3	0.3	0.0	63.6	7.9	0.0	20.6	0.0	0.7	21.1	92.4	7.9
Tulalip Bay	0.5	0.0	3.6	0.0	2.7	0.6	0.0	99.0	64.9	0.5	0.1	170.8	65.6
Turners Bay	0.7	0.4	0.0	0.0	3.4	1.0	0.6	12.9	0.0	0.8	2.9	18.3	1.7

Table 3b. Historic conditions (subzone or **zone** areas in hectares).

Site	Back shore	Drift wood	Beach Face	Scrub Shrub	Emerg. Marsh	Chan.	Impnd.	Low Tide Plat.	Undiv. Inter.	Sub tidal	Inter/Sub Footprint	Mapped Habitat Footprint	Calculated Habitat Footprint
Arrowhead	4.07	1.94	0.00	0.00	4.51	0.26	0.00	0.00	0.00	0.00	6.71		0.52
Elger Bay	3.78	9.49	2.55	0.61	13.90	2.71	0.14	0.00	0.00	0.00	29.41	2.85	
Grassers	1.81	0.00	0.36	0.00	0.56	0.17	1.65	0.00	5.19	0.00	7.92	1.82	
Lone Tree	0.87	0.00	0.16	0.00	0.55	0.11	0.74	1.02	0.00	0.00	2.58	0.85	
Scotts Point	16.90	0.00	0.00	0.00	21.94	0.11	1.31	0.00	0.48	0.00	23.83		1.83
Triangle Cove	11.68	0.98	0.22	0.00	27.33	9.82	0.00	65.98	0.00	0.00	104.34	9.82	
Tulalip Bay	1.37	0.00	6.01	0.00	2.99	0.30	0.01	54.42	0.31	107.75	171.79	108.06	
Turners Bay	0.66	0.00	0.01	0.00	6.96	1.40	0.81	9.89	2.92	0.00	21.98	2.21	

Table 3c. Habitat change (subzone or **zone** areas in hectares).

Site	Back shore	Drift wood	Beach Face	Scrub Shrub	Emerg. Marsh	Chan.	Impnd.	Low Tide Plat.	Undiv. Inter.	Sub tidal	Inter/Sub Footprint	Habitat Change Mapped	Habitat Change Calculated
Arrowhead	-1.6	-1.6	0.1	0.0	-2.7	0.0	0.1	0.0	0.0	0.0	-4.1		-0.3
Elger Bay	-1.6	6.2	-1.0	0.3	-4.6	-1.0	-0.1	0.0	0.0	0.0	-0.2	-1.1	
Grassers	-1.3	0.0	-0.2	0.0	0.6	0.0	-0.3	4.7	-5.2	0.0	-0.3	-0.3	
Lone Tree	-0.4	0.1	0.1	0.0	-0.0	0.1	0.4	-0.6	0.0	0.0	-0.1	0.4	
Scotts Point	-16.6	0.0	0.1	0.0	-21.8	-0.1	-1.3	0.0	-0.5	0.0	-23.6		-1.8
Triangle Cove	0.3	0.3	0.1	0.0	36.3	-1.9	0.0	-45.4	0.0	0.0	-11.94	-1.9	
Tulalip Bay	-0.9	0.0	-2.5	0.0	-0.3	0.3	0.0	44.6	-0.3	-43.8	-1.0	-42.5	
Turners Bay	0.0	0.4	0.0	0.0	-3.6	-0.4	-0.2	3.0	-2.9	0.0	-3.7	-0.6	

Arrowhead Lagoon

Arrowhead Lagoon is a longshore lagoon, formed by a curved spit accreting out from the shoreline to partially enclose an area of intertidal habitat. The enclosed area is a low energy environment where salt marsh plants have established, sediments accumulated, and tidal channels eroded. This lagoon has been bisected by a dike. Habitat behind the dike is isolated from tides and has been partially filled and developed. The wetted area behind the dike is artificially inflated by a 0.1 ha impoundment at the dike caused by the dike and possibly by septic drainage from behind the dike. The wetted area seaward of the dike is currently filling in to establish a new equilibrium at a lower tidal volume than historically. All the channels in front of the dike are shallower and narrower than in 1956, soon after the dike was installed. Historically, the main channel of the lagoon maintained its largest width all the way back into the isolated half of the lagoon, indicating the higher flow in that channel with the higher historic tidal volume. Additionally, bridge fill currently partially blocks the main channel. Land use within the lagoon watershed is likely impacting freshwater inputs to the lagoon, though this was not investigated. Also, the spit enclosing this lagoon has been armored and paved with several boat ramps and adjacent, up-drift sediment source beaches to the south have been armored. These modifications change sediment erosion, transport and accretion dynamics that support the existence of the spit, and may threaten the long-term sustainability of the spit.

Historic reconstruction of this site is based primarily on 1956 photos. The current mapping used 2001 DNR color photos as a basis. Island County LIDAR data supports current conditions photo interpretation, as does field reconnaissance (Figure 3).

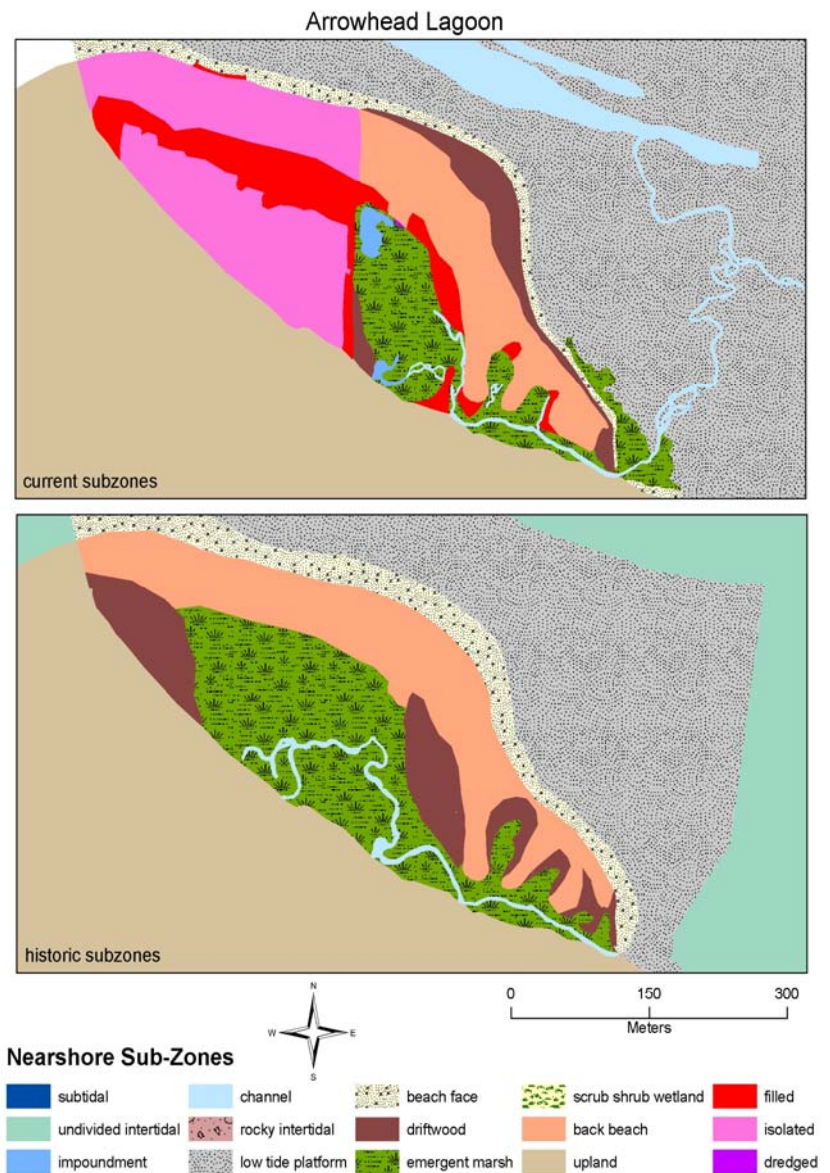


Figure 3. Current (2000) and historic (pre-settlement) habitat conditions in Arrowhead Lagoon.

Elger Bay

Elger Bay is a tidal channel lagoon formed at the mouth of an ancient glacial valley. A stream currently flows down the glacial valley into the head of Elger Bay. This pocket estuary is relatively unchanged by humans from historic conditions except for a high accumulation of large drift logs associated with logging practices around Puget Sound (MacLennan 2005). Adjacent to and outside of the pocket estuary, parts of the watershed have been developed and the spit has been developed and armored. Natural geomorphic changes at this site include a westward progradation of the spit. The USCGDS t-sheet and 1941 photos were helpful in marking the historic locations of larger channels and driftwood. The large channels are in almost exactly the same place throughout our record, though the encroaching driftwood covers and likely fills channels and salt marsh over time. One large channel that historically extended all the way to the head of the lagoon may have been connected to surface water runoff. This channel is now almost completely covered and filled with driftwood. Habitat conditions and fish use in areas dominated by driftwood wrack are unknown. Elger Bay is the lowest point of u-shaped glacial valley that receives runoff from a 640-hectare watershed with several small drainages emptying into the valley floor. Current, routing, flow, and quality of this water is an issue to investigate (Figure 4).

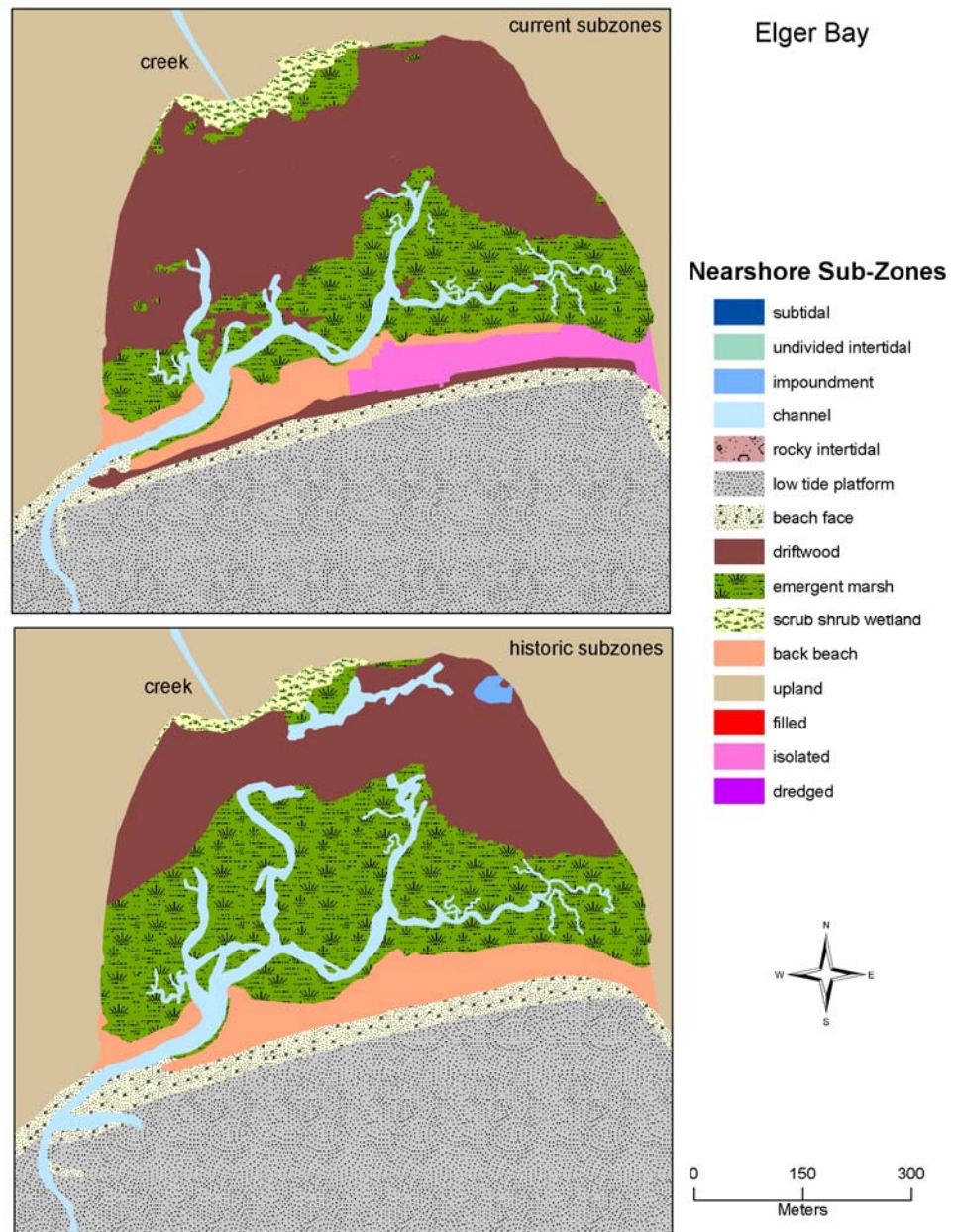


Figure 4. Current (2000) and historic habitat conditions in Elger Bay.

Grassers Lagoon

Grassers Lagoon is a delta lagoon at the head of an ancient glacial valley (Penn Cove). Delta lagoons are stream mouths across which a spit has formed, partially enclosing the stream mouth and its delta, and forming a lagoon (McBride et al. 2005). Wave deposition and fluvial deposition processes dominate geomorphic signatures in these types of pocket estuaries. Historically this lagoon was dominated by an impoundment in the northern half of the site. The impoundment may have been dredged at some point in the past. Over one half of the shoreline within the lagoon has been armored, limiting the development of salt marsh and backshore habitat. This site also includes a small marsh fragment to the east that was formed by the same spit enclosing the stream mouth. This now isolated wetland has been partially filled.

Impacts within the watershed and impacts to the spit forming the pocket estuary have also resulted in habitat changes within the site. The existing eastside spit has apparently been extended into the pocket estuary with fill (based on field reconnaissance and photos). Also, the historic beach face outside the spit was much wider and the western spit higher base on vegetation signatures observed in historic photos. This may be evidence of a sediment-starved spit. Potential sediment source beaches to the east are armored. Historically a stream entered into the lagoon north of the large impoundment. The channel connecting the historic stream mouth to the impoundment was wider than the channel present today.

The 1941 photo was the basis for most of the reconstruction and change analysis. The 1965 photo was also used to support 1941 interpretations. A road already impacted this site at the time of our earliest

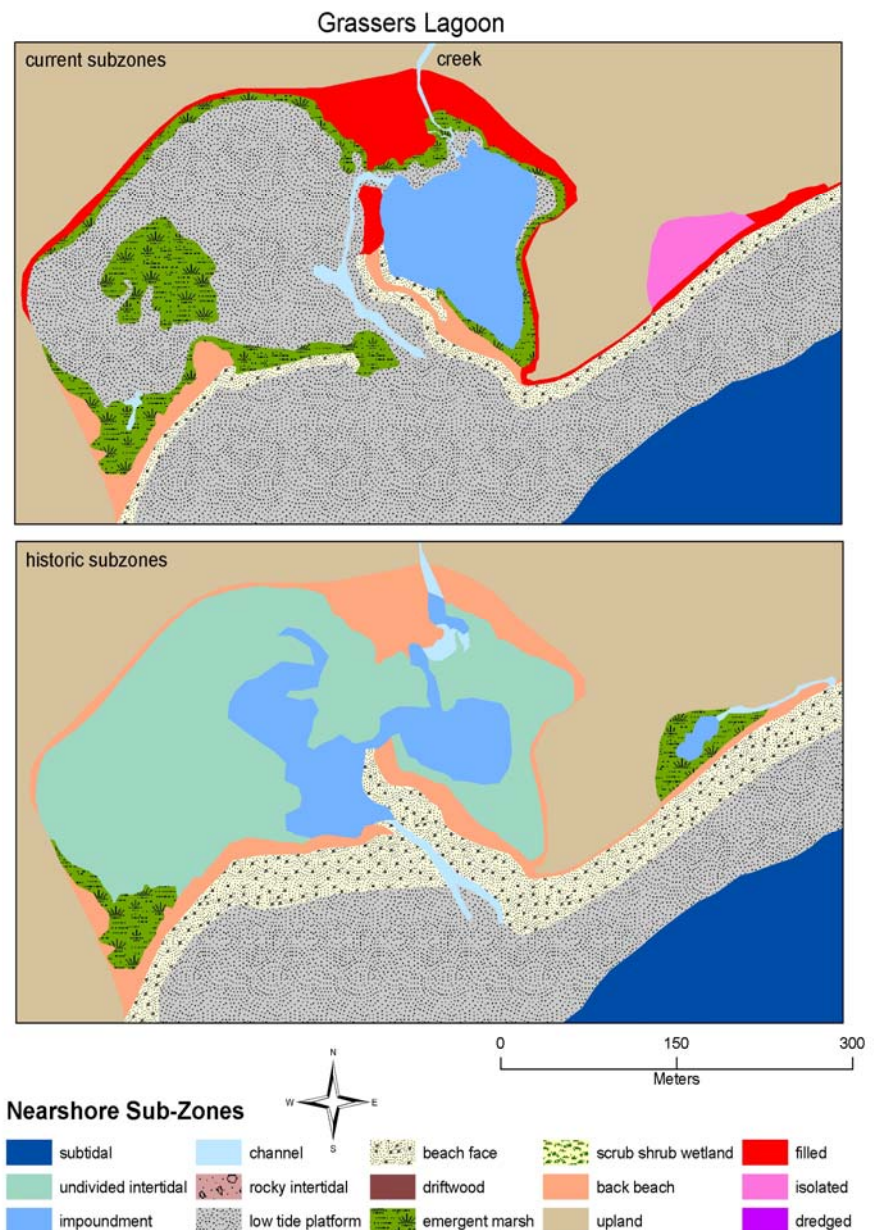


Figure 5. Current (2001) and historic habitat conditions in Grassers Lagoon.

photo record. The t-sheet was too coarse in scale to show this site, except a rough outline of the spit. We were unable to divide most of the intertidal in the lagoon due to the resolution of the 1941 photos and the fact that they are black and white. We can probably assume that conditions were similar to current, since this is true for most of the rest of the site, except where noted above. Current conditions were mapped using 2001 DNR color photos. Island County LIDAR data supports current conditions photo interpretation, as does field reconnaissance (Figure 5).

Lone Tree Lagoon

This site is a drowned channel lagoon. A drowned channel lagoon pocket estuary is characterized by a stream mouth that is tidally inundated and lacks an obvious delta fan (the drowned channel). The stream mouth is also protected by a spit or other barrier beach, creating an enclosure across the stream mouth (the lagoon). Lone Tree Lagoon varies from this model in that it includes a rocky island around which the spit has formed. The southern spit, bridging the gap between the rocky island and the Fidalgo shoreline is covered by water during very high tides. This site also includes a small tidal channel to the southeast, along a probable alternate stream channel depression. Currently culverts and fill have limited the extent of the main drowned channel within the lagoon. Restoration planning is in process. The spit to the north has changed historically, breaching and building periodically, due to natural processes. Sediment sources are actively eroding though partially armored. However, the spit to the south appears to be losing sediment, possibly due to armoring immediately to the north and to the south (The spit receives sediment from both directions.). Historic reconstruction was based on photos, soil maps, and field mapping for the restoration feasibility (Figure 6).

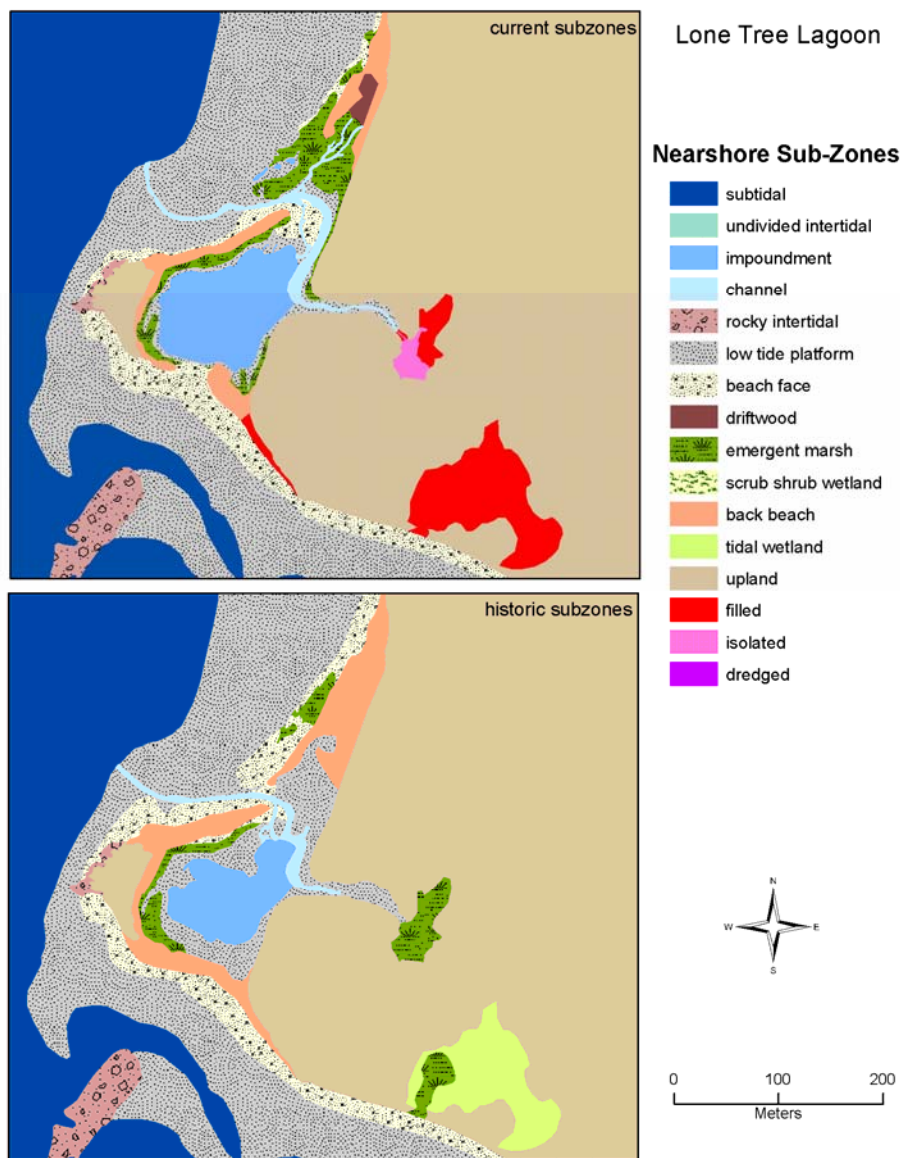


Figure 6. Current (2000) and historic habitat conditions in Lone Tree Lagoon.

Scotts Point

This site is completely isolated from coastal and riverine processes at this time. Historically it was a longshore lagoon located along, and influenced by, the Samish Delta. Pocket estuaries along the delta margin have delta characteristics as well as pocket estuary characteristics, making reconstruction more difficult. Historic data for this site are also sparse and of poor resolution. Soil maps, in combination with landform interpretation on photos, were the basis for the reconstruction. At the time of the earliest record, 1889 t-sheets, the site had already been diked at the likely location of the original longshore lagoon. The t-sheet does indicate the extent of the marsh area, though no distinction is made as to whether this was fresh or salt marsh, backshore or emergent marsh. The entire site was diked by 1937. A large impoundment known locally as Freestad Lake does not show up in either the 1889 map or the 1937 photos. This feature was dredged in about 1950 based on anecdotal evidence. A full understanding of this site will require further geologic research (Figure 7).

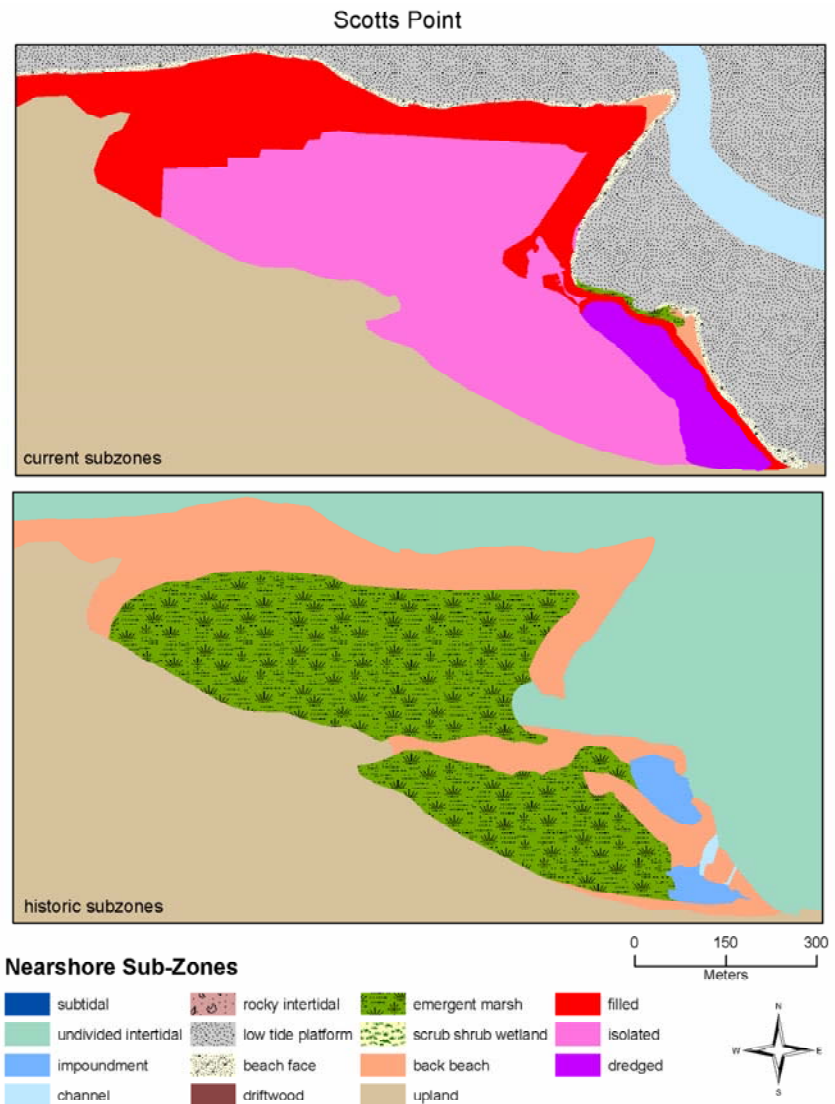


Figure 7. Current (2000) and historic habitat conditions at Scotts Point.

Triangle Cove

Triangle Cove is a tidal channel lagoon formed within a flooded ancient glacial valley. Though mostly intact, this site has been diked and armored along the spit, isolating approximately 45 hectares of marsh and channel habitat. However, an important impact to Triangle Cove is an overwhelming infestation of *Spartina*, which has converted former tide flats and openwater areas to marsh and channels. Freshwater inputs from Kristoferson Creek have also been altered in quantity and quality. Historic reconstruction was based on a good photo record (Figure 8).

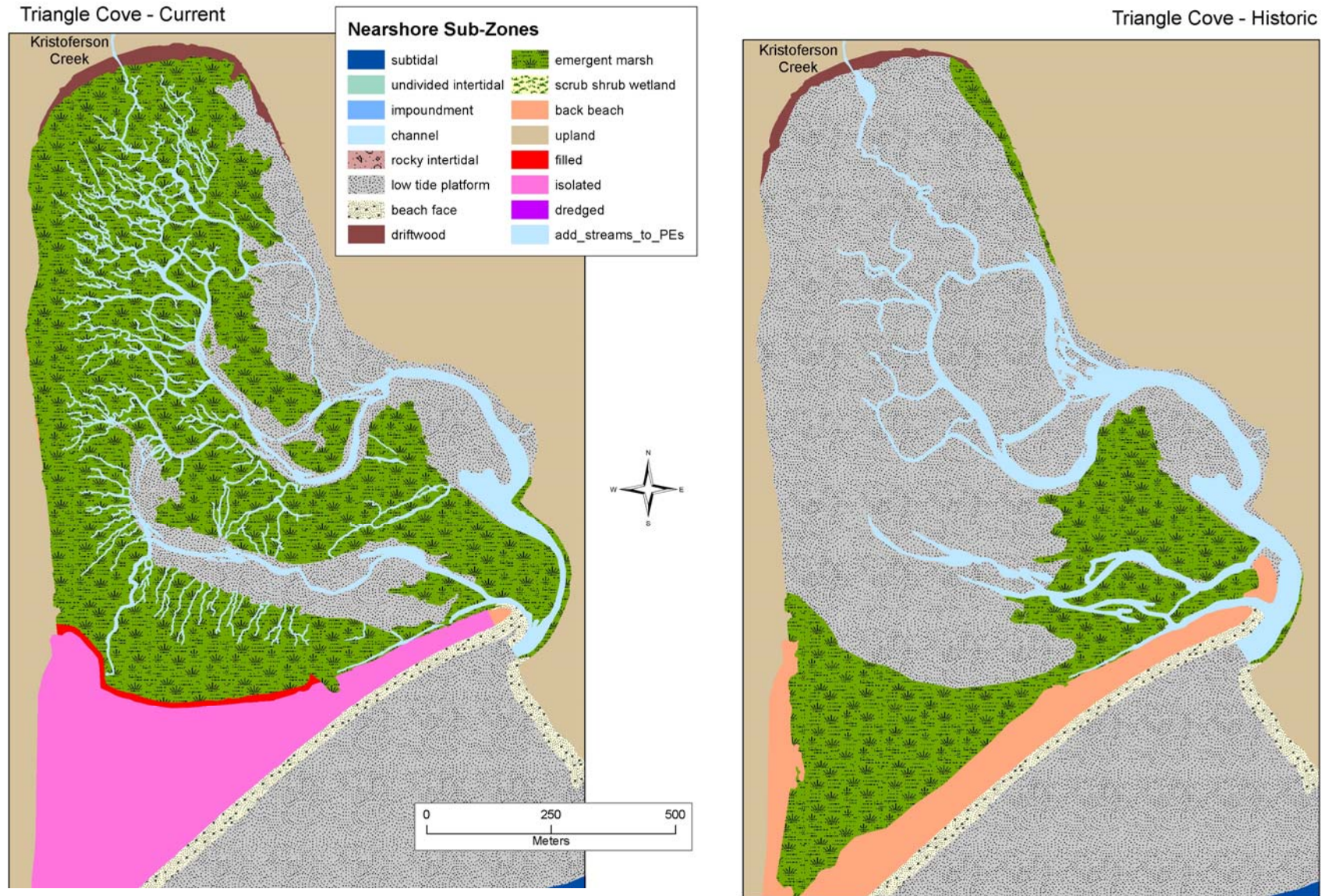


Figure 8. Triangle Cove current and historic habitat conditions.

Tulalip Bay

This estuary is a flooded glacial depression (very small kind of fjord estuary) with two streams draining into it. Both streams have drowned channels. A spit has also developed landward of the south bay margin. The size and complexity of this site make it unique from other estuaries mapped. Changes at this site include armoring and filling along most of the shore, dredging and filling at the marina, and modifications at all the stream channel mouths. Because the historic photos available were taken at unknown tidal stages and because the t-sheets have a certain amount of error associated with field mapping, we estimated the loss of subtidal area by comparing dock length in 1964 with dock lengths in 2001. Dock lengths have increased consistently by 120% since 1964, suggesting that the intertidal zone has gotten wider either at the expense of the subtidal zone or at the expense of the backshore. The backshore line appears to be unchanged, therefore we assume that infilling has decreased subtidal habitat, thus the large mapped habitat loss shown in Table 3. The cause of infilling may be sediment from wave erosion (most likely), suspended sediment from the Snohomish River or from the two creeks within the estuary (less likely).

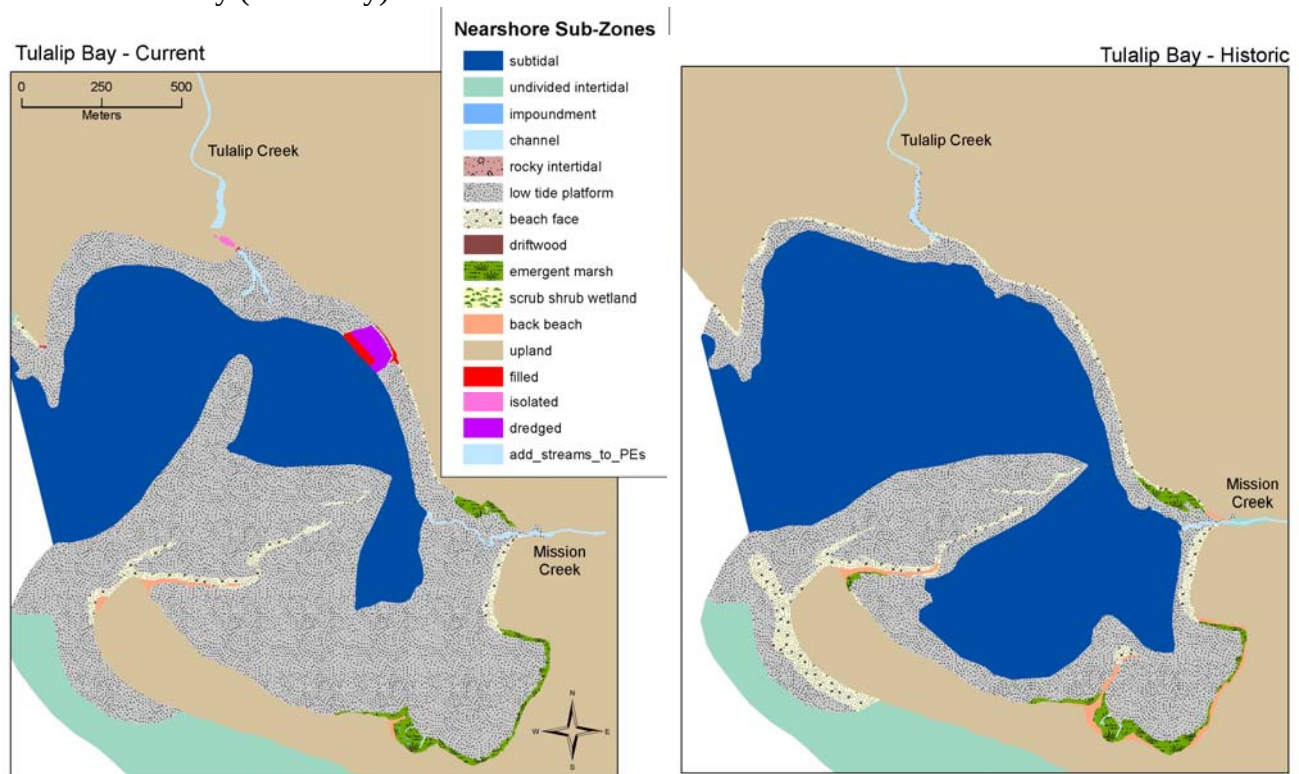


Figure 9. *Tulalip Bay current and historic habitat conditions*

The creek mouth at Tulalip Creek has been severely impacted by hydraulic controls located near the mouth of the creek. The exact extent of historic upstream tidal influence in Tulalip Creek is unknown. However, 1964 photos suggest the presence of a low tide platform adjacent to the creek channel for an extent similar to the mapped tidal channel on the t-sheet. This likely indicates a drowned channel estuary at the mouth of the creek. At the point on the low tide platform where the mapped channel stops, the drainage fanned out to many poorly defined

distributaries (1964 photo and noted on t-sheet). The beach face sub-zone historically existed continuously along the northern bay shoreline, but is currently absent or replaced by a narrow fringe of emergent marsh, likely due to shoreline armoring. Reconstruction was based primarily on photos (Figure 9).

Turners Bay

Turners Bay is a tidal channel lagoon with freshwater inputs from seeps along adjacent sediment bluffs and from a small creek draining valley bottom wetlands. Nearshore deposits fill the bottom of the valley (Dragovich et al. 2000). The valley is mostly enclosed by two spits and a bar island and artificially blocked by fill at the Padilla Bay side. The valley wetlands and tidal channels have been isolated at least partially from the historic tidal prism due to road fill and a tide gate (recently converted to a small culvert). Additionally, small areas of fringing marsh have been isolated and filled by shoreline land use. *Spartina* infestation impacts the southeast corner of the lagoon. Freshwater quality and routing has also been impacted by watershed development. Marine water quality is impacted by failed septic systems in the backshore zone. Reconstruction was based primarily on photos (Figure 10).

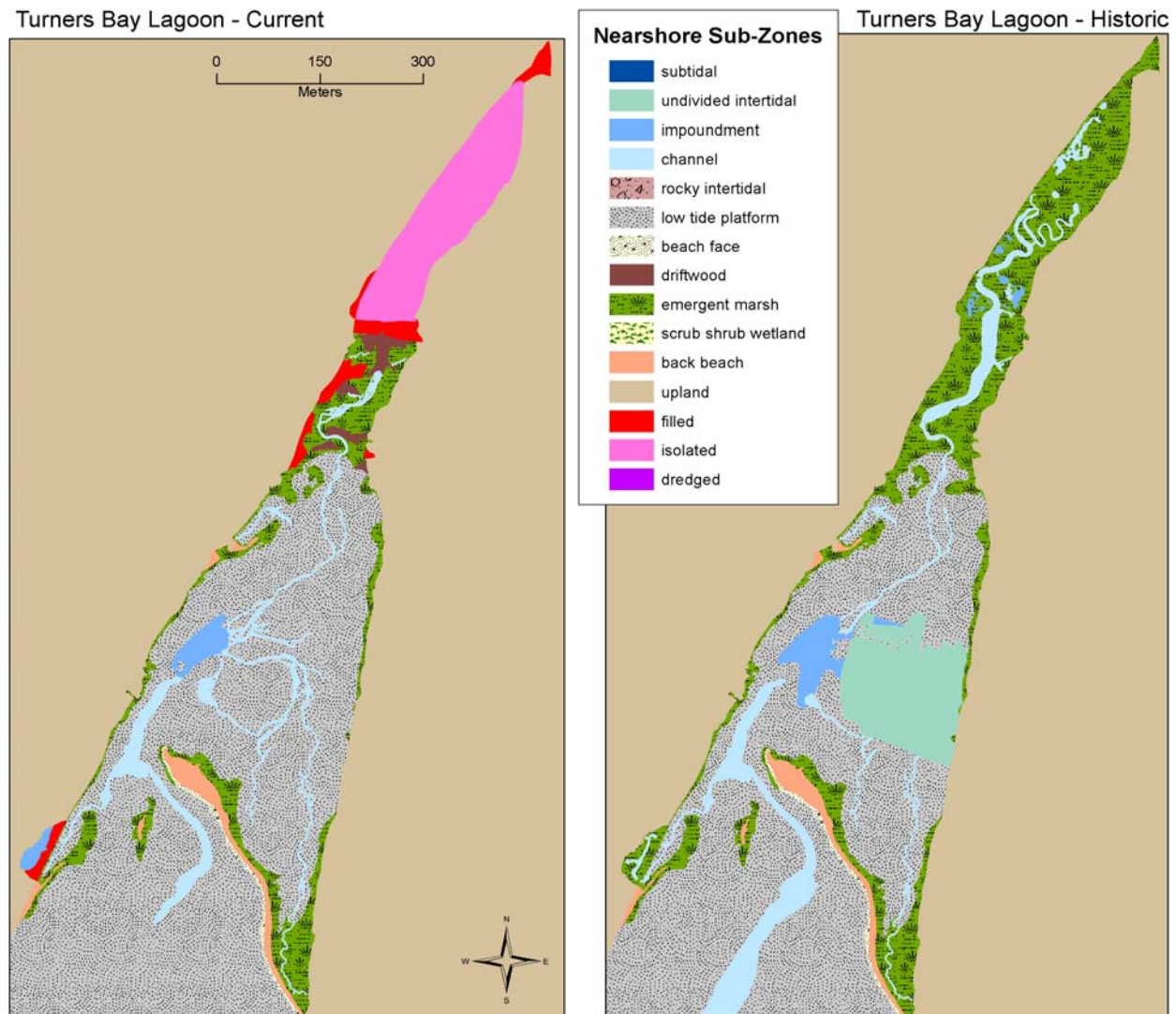


Figure 10. Current (2004) and historic habitat conditions at Turners Bay.



Figure 11. Watershed areas for each of the intensively monitored pocket estuaries.

COMPLETING INVENTORIES FOR SAMISH, PADILLA, AND FIDALGO BAYS

Although we have identified pocket estuary points and relic delta polygons in the north Skagit County bays, we have yet to complete a full habitat inventory there (Figure 12). We have compiled existing data for Samish, Fidalgo, and Padilla Bays in order to identify data gaps for completing a habitat classification in those areas. We have completed a preliminary assessment of Fidalgo Bay based on existing data and brief field reconnaissance. Notably, we are lacking geologic mapping at the 1:24,000 scale (most desirable) to use in applying the geomorphic model in the north Skagit County bays. Geology at a scale of 1:100,000 is available. We have the drift and topographic data needed. Tasks for completing a habitat inventory for Samish, Padilla, and Fidalgo Bays (study area) are:

- 1) Improve upon and classify geologic data according to SRSC geomorphic model.
- 2) Digitize and classify longshore drift data according to SRSC geomorphic model.
- 3) Classify topographic data according to SRSC geomorphic model.
- 4) Analyze these data to map geomorphic units in the study area.

Additionally, we can utilize existing data sets to supplement and expand our analysis of nearshore habitats in the study area, including vegetation, substrate, and shoreline modification data from:

1. Berry, HD, and RA Ritter. 1997. Puget Sound intertidal habitat inventory 1996: vegetation and shoreline characteristics classification methods. Washington Department of Natural Resources, Aquatic Lands Division, Nearshore Habitat Program, Olympia. 34 pages.
2. Padilla Bay NERR vegetation data (in production).
3. Anchor Environmental and People for Puget Sound. 2002. Final Report: Northwest Straits Nearshore Habitat Evaluation. Prepared for the Northwest Straits Commission, Mount Vernon, WA.
4. People for Puget Sound. 2001. March Point Rapid Shoreline Inventory. Prepared for the Skagit County Marine Resources Committee.
5. Fung, J, K O'Connell, M Calvi, P Block, and J White: People for Puget Sound. 2004. Northern Skagit County Bays and Shoreline Habitat Conservation and Restoration Blueprint. Prepared for the Skagit County Marine Resources Committee.
6. Antrim, LD, RM Thom, AB Borde, and JA Southard. 2000. Plan for Habitat Protection, Restoration, and Enhancement in the Fidalgo/Guemes Area. Prepared for the City of Anacortes by Batelle Marine Sciences Laboratory, Sequim, WA.
7. Dinnel, P, M Schwertner, R Knowles, E Pickett, P Sund, R Barsh, and R Haley. 2005. Skagit County Creosote Inventory and Removal Project: Phase I. Skagit County Marine Resources Committee.
8. Williams, BW, S Wyllie-Echeverria, and A Bailey. 2003. Historic Nearshore Habitat Change Analysis: Fidalgo Bay and Guemes Channel. Prepared for Texaco Trustees Restoration Committee.

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN
AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

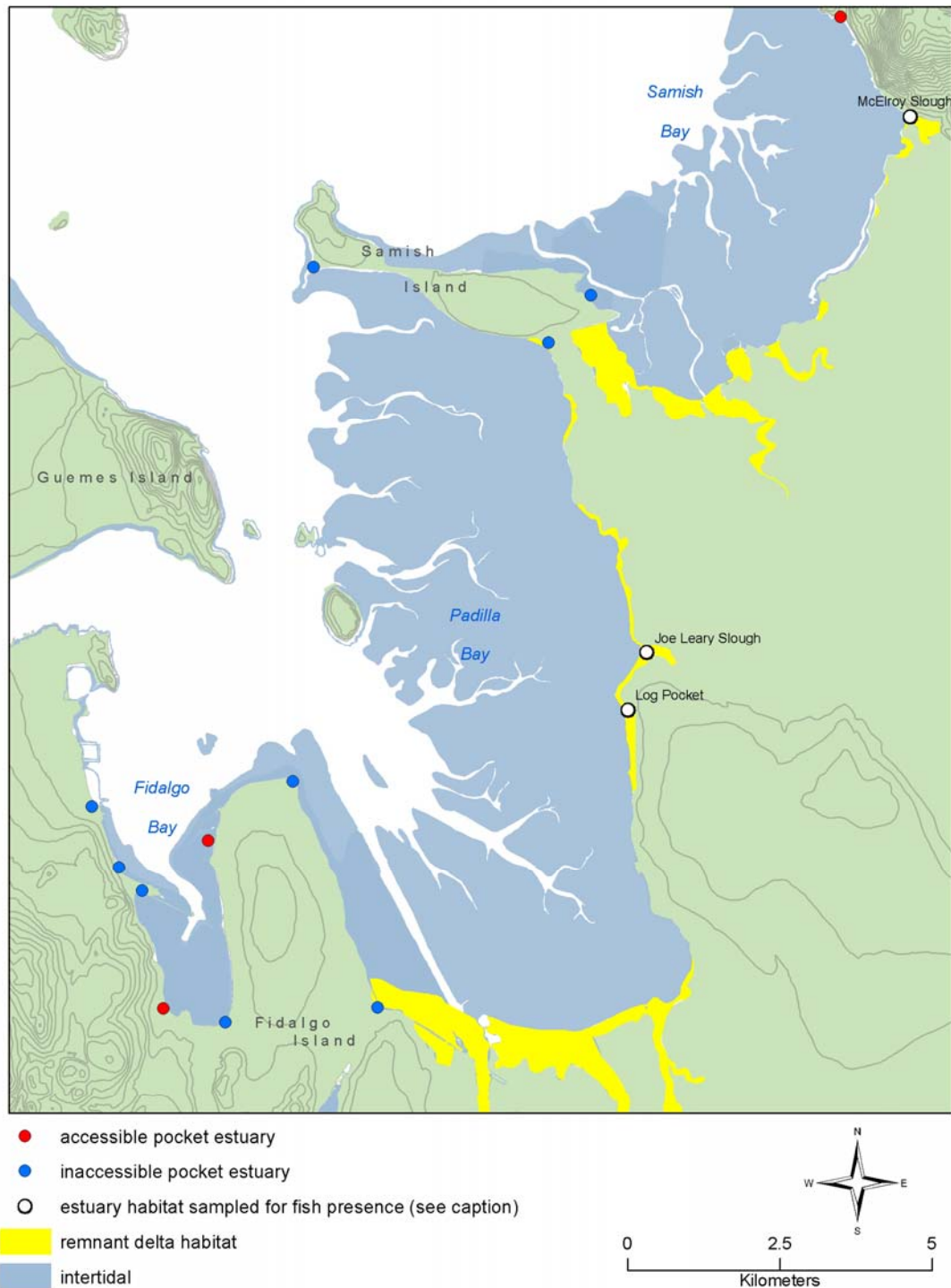


Figure 12. Inventory of pocket estuaries in Samish, Padilla, and Fidalgo Bays. Accessible pocket estuaries are currently open to fish access. Inaccessible pocket estuaries may or may not still have hydraulic connection to the adjacent nearshore habitat, and are not open to fish use.

FISH SAMPLING METHODS

Twenty-four different areas within the Whidbey Basin and north Skagit County bays (Fidalgo, Padilla, and Samish) (Figure 1) were sampled using beach seines and fyke traps to understand fish use within pocket estuary habitat and the adjacent nearshore. This section explains the sampling methods used and site selection process.

Site Selection

Pocket Estuary Sites within the Whidbey Basin and North Skagit County Bays

Much of our understanding of Chinook salmon ecology in pocket estuaries has thus far been limited to sites within Skagit Bay (e.g., Beamer et al. 2003). This work directly relates to Skagit Bay habitat and Skagit river origin Chinook salmon, but may not represent the true importance of the pocket estuaries in a larger spatial or ecological setting. Therefore, we selected sixteen true pocket estuaries throughout the Whidbey Basin and north Skagit County bays (Figure 1, Table 4) to collect fish use data to gain a broader spatial coverage of sites as well as diversity in pocket estuary size, geomorphic type, habitat condition, and proximity to Chinook salmon bearing rivers. At all these sites we sampled habitat within the pocket estuary itself and the adjacent nearshore. Many of these sites also have restoration potential, so the data collected could serve as background information should any of these sites be considered for restoration.

Five additional sites were selected for sampling even though they did not have much pocket estuary habitat remaining that is accessible to juvenile salmon. These sites are Camano Country Club², Dugualla Bay, Dugualla Heights, Priest Point, and Scotts Point³ (Figure 1, Table 4). These sites are very close to the mouths of Chinook salmon-bearing rivers and were selected for sampling based on their restoration potential. Each site was: (1) historically large compared to the average pocket estuary size, (2) close to the source of fish that could occupy the habitat, and (3) not fully developed with houses or other more permanent infrastructure. This does not mean the historic estuaries are not without political or logistical constraints to restoration. It does mean, in our view, that each site still has the physical potential to be restored to part or all of the historic estuary area and to be accessible to juvenile salmon. Data from this study could provide background fish use information important to the restoration planning process for each site.

The remaining three sites that were sampled are not true pocket estuaries. The mouth of Joe Leary Slough, Log Pocket, and Swinomish Channel Old Bridge Blind are all relic Skagit delta habitats (Figure 1, Table 4). These sites are no longer well-connected with Skagit River sediments or hydrology so they function more like pocket estuaries than large river delta habitat⁴. We added these sites to gain further spatial coverage. Each site also has restoration potential so

² The outlet of the Camano Country Club pocket estuary runs through a culvert that does not have a tidegate. Estuarine fish including salmon may move through the culvert. However, we were unable to conduct any beach seining upstream of the culvert at this site.

³ An artificial impoundment (i.e., small lake) is all that remains of the lagoon/tidal marsh habitat for pocket estuary at Scotts Point. This impoundment is not accessible to juvenile salmon, but it was sampled by beach seine to provide background fish use information before restoration of the site.

⁴ These sites function more like pocket estuaries because they have been isolated from the large river delta processes of hydrology and sediment. They are maintained by more local processes. For juvenile salmon, they function more like pocket estuaries because juvenile salmon must leave river delta habitat and travel, at least some distance, in more marine habitat before accessing these areas.

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN
AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

data from this study could provide background fish use information important to the restoration planning process for each site.

Table 4. Summary of pocket estuary sites sampled in 2004.

Pocket estuary sampling area	Pocket estuary type	Number of sites sampled within each pocket estuary		Restoration potential	Closest Chinook salmon bearing river	Historic intertidal/subtidal area (hectare)
		Pocket estuary	Adjacent nearshore			
Ala Lagoon	true pocket estuary (longshore lagoon)	8 beach seine	3 beach seine	yes	Skagit	10.3
Arrowhead Lagoon	true pocket estuary (longshore lagoon)	1 fyke, 7 beach seine	3 beach seine	yes	Skagit/Stillaguamish	6.7
Bowman Bay Lagoon	true pocket estuary (pocket beach estuary)	3 beach seine	6 beach seine	yes	Skagit (distant)	0.6
Camano Country Club	true pocket estuary (longshore lagoon)	habitat is accessible to estuarine fish, but was not sampled	3 beach seine	yes	Stillaguamish	unknown
Crandall Lagoon N	true pocket estuary (longshore lagoon)	3 beach seine	6 beach seine	yes	Skagit/Samish	unknown
Dugualla Bay	true pocket estuary (tidal channel lagoon)	0, habitat not accessible to estuarine fish	6 beach seine	yes	Skagit	163.6
Dugualla Heights	true pocket estuary (longshore lagoon)	0, habitat not accessible to estuarine fish	3 beach seine	yes	Skagit	4.1
Elger Bay	true pocket estuary (tidal channel lagoon)	6 beach seine	6 beach seine	protect existing	Skagit/Still./Snohomish	29.4
English Boom Lagoon	true pocket estuary (longshore lagoon on delta margin)	1 fyke	3 beach seine	yes	Skagit/Stillaguamish	0.6
Grassers Lagoon	true pocket estuary (delta lagoon)	11 beach seine	6 beach seine	yes	Skagit/Still./Snohomish	7.9
Harrington Lagoon	true pocket estuary (longshore lagoon)	5 beach seine	3 beach seine	protect existing	Skagit/Still./Snohomish	10.2
Iverson Marsh	true pocket estuary (longshore lagoon)	3 beach seine	3 beach seine	yes	Stillaguamish	64.4
Joe Leary Slough	artificial pocket estuary (relic delta habitat)	4 beach seine	3 beach seine	yes	Samish	unknown
Log Pocket	artificial pocket estuary (relic delta habitat)	4 beach seine	5 beach seine	yes	Skagit/Samish	unknown
Lone Tree Lagoon	true pocket estuary (drowned channel lagoon)	6 beach seine	6 beach seine	yes	Skagit	2.6
McElroy Slough	true pocket estuary (drowned channel on delta margin)	3 beach seine	7 beach seine	yes	Samish	unknown
Priest Point	true pocket estuary (longshore lagoon)	0, habitat not accessible to estuarine fish	9 beach seine	yes	Snohomish	14.3
Race Lagoon	true pocket estuary (drowned channel lagoon)	4 beach seine	2 beach seine	yes	Skagit/Still./Snohomish	12.1
Scotts Point	true pocket estuary (longshore lagoon)	3 beach seine	14 beach seine	yes	Samish	23.8
Sunnyshore Acres	true pocket estuary (longshore lagoon)	3 beach seine	3 beach seine	yes	Stillaguamish/Snohomish	8.1
Swin Ch Old Bridge Blind	artificial pocket estuary (relic delta habitat)	1 fyke	3 beach seine	yes	Skagit	unknown
Triangle Cove	true pocket estuary (delta lagoon)	9 beach seine	6 beach seine	yes	Stillaguamish	104.3
Tulip Bay	true pocket estuary (delta lagoon)	5 beach seine	6 beach seine	yes	Snohomish	171.8
Turners Bay	true pocket estuary (drowned channel lagoon)	6 beach seine	6 beach seine	yes	Skagit	22.0

Sites Within Pocket Estuaries and Their Adjacent Nearshore

The exact beach seine sampling locations for each pocket estuary site was determined on a site by site basis. Site selection was intended to represent habitat conditions at each pocket estuary site or the adjacent nearshore. However, each site was also selected based on logistics that allow a field crew to conduct the sampling. Logistical controls include physical conditions that might prevent sampling like substrate that is too soft for walking or tidal conditions that prevent access to the area. Landowner consent was also a logistic concern and we did not sample in areas without landowner permission. These constraints prevented us from randomly selecting the exact sites within a selected pocket estuary or its adjacent nearshore habitat. However, sites selected for sampling were selected to represent habitats in the area in terms of geomorphology, depth, salinity, vegetation, and substrate.

Sampling Methods

Small Net Beach Seine

Small net beach seine methods were used for sampling nearshore areas adjacent to pocket estuaries and lagoon impoundments or larger channel habitats within pocket estuaries. The areas seined are typically less than four feet deep (1.2 m), and have relatively homogeneous habitat features (water depth, velocity, substrate, and vegetation). Small net beach seine methodology uses an 80-foot (24.4 m) by 6-foot (1.8 m) by 1/8-inch (0.3 cm) mesh knotless nylon net. 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, hauling the net in a floating tote, and then returning to the shoreline in a half circle. Both ends of the net are then retrieved, yielding a catch. We typically conduct three sets per site. Average beach seine set area is 96 square meters. The catch was divided by set area for wild juvenile Chinook salmon, all juvenile salmon combined, and surf smelt, yielding density (fish/hectare) estimates for these species.

The specific number of beach seine sets conducted at each pocket estuary varies and is shown in Table 4. The location of each beach seine set is shown in map figures later in this document under the section entitled: “Results for Individual Pocket Estuaries”.

Fyke Trap

Fyke trap methods are used for sampling smaller blind tidal channel habitat within pocket estuary sites dominated by tidal channels. Fyke trap methodology uses nets constructed of 1/8-inch (0.3 cm) mesh knotless nylon with a 2-foot (0.6 m) by 9-foot (2.7 m) diameter cone sewn into the net to collect fish draining out of the blind channel site. Overall net dimensions (length and depth) are variable depending on the site’s cross-sectional channel dimensions. All nets are sized to completely block fish access at high tide. The net is set across the blind channel site at high tide and “fished” through the ebb tide, yielding a catch. The juvenile Chinook catch is adjusted by a trap recovery efficiency (RE) estimate derived from mark-recapture experiments using a known number of marked fish released upstream of the trap at high tide. The RE is usually related to hydraulic characteristics unique to the site (e.g., change in water surface elevation during trapping, or water surface elevation at the end of trapping). Multiple RE tests (several times per season) at each site are used to develop a regression model to convert the “raw” juvenile Chinook catch to an estimated population within the habitat upstream of the fyke

trap on any sampling day. The top width channel area upstream of the fyke trap site was used as the habitat area sampled by the trap. The RE adjusted catch for wild juvenile Chinook salmon was divided by set area to estimate density (fish/hectare). For all juvenile salmon combined and surf smelt we used the same procedure to estimate fish density.

FISH SAMPLING RESULTS

This section presents findings and results from beach seine and fyke trap sampling done in 2004. We also present results for some sites where we have additional data (collected prior to or after the 2004 season). We included the additional results if it added to our understanding of fish use at any of the Northwest Straits Commission sponsored sites shown in Figure 1 or Table 4.

We first summarize the 2004 fish catch results (total effort, total catches, number of species caught) for both intensively and extensively monitored sites shown. Next, we present 2004 results for juvenile Chinook salmon, all juvenile salmon combined, and surf smelt for the twenty-four individual pocket estuaries sampled. We present results for individual sites because there are unique local interests at many sites. These data may be helpful as background information for understanding restoration potential or neighborhood stewardship needs. Finally, we present more global analysis results for juvenile Chinook salmon, all juvenile salmon combined, and surf smelt. These results help further our understanding of the importance of pocket estuaries for salmon and forage fish ecology at the landscape scale (e.g., Whidbey Basin).

Intensively Monitored Pocket Estuaries in 2004

We sampled eight true pocket estuaries using beach seines or fyke traps to understand fish use over the juvenile Chinook salmon outmigration period. We sampled at least monthly from March 2004 through June 2004 at all eight sites. A broader sampling period extended from February through October for most sites. The sites are: Arrowhead Lagoon, Elger Bay, Grassers Lagoon, Lone Tree Lagoon, Scotts Point, Triangle Cove, Tulalip Bay, and Turners Bay (Figure 1). We also sampled Swinomish Channel Old Bridge Blind, a relic delta habitat near LaConner. We consider this site an artificial pocket estuary because it is disconnected from the Skagit River and is adjacent to the currently dredged marine navigation channel (Swinomish Channel). This site has a small creek draining directly into the small marsh and channel complex and therefore functions more like a pocket estuary than the Skagit delta estuary.

The Northwest Straits Commission funded sampling at Elger Bay, Grassers Lagoon, Scotts Point, Triangle Cove, and Tulalip Bay. The remaining sites were sampled using funding from separate sources.

We made 1,034 beach seine or fyke trap sets capturing 122,663 fish representing 34 different species. Six fish species dominated the catch: young of the year pink salmon (4.7%), young of the year chum salmon (4.1%), stickleback (27.1%), staghorn sculpin (14.9%), shiner perch (39.2%), and surf smelt (6.9%).

Wild young of the year Chinook salmon were also present in the catch. Juvenile Chinook salmon were captured in adjacent nearshore habitat of all nine intensively sampled pocket estuaries, as well as inside all these pocket estuaries except the Scotts Point site. It is not

surprising that pocket estuary habitat at Scotts Point did not yield any juvenile Chinook salmon because the lagoon is disconnected from adjacent nearshore habitat by dikes and tidegates.

The Skagit River sub-yearling wild juvenile Chinook salmon outmigration population in 2004 was small due to several high river flow events that caused high mortality during the egg incubation phase of naturally spawned fish. We suspect this phenomenon occurred in all four Chinook salmon-bearing rivers associated with this study (Samish, Skagit, Stillaguamish, and Snohomish Rivers). Therefore results from our pocket estuary sampling effort in 2004 represent fish use in years with few juvenile Chinook to populate nearshore habitat.

Extensively Monitored Pocket Estuaries in 2004

In addition to the intensively sampled pocket estuary sites, we sampled at 15 additional pocket estuaries dispersed throughout Whidbey Basin and north Skagit County bays (Figure 1). This extensive sampling effort was done to determine presence of juvenile salmon, especially Chinook salmon. We sampled during times when juvenile salmon were present within the intensively monitored sites. The entire extensive sampling effort was funded by the Northwest Straits Commission.

We made 214 beach seine or fyke trap sets, capturing 25,348 fish representing 19 different species. As with the intensively monitored sites, six fish species dominated the catch: young of the year pink salmon (12.9%), young of the year chum salmon (12.2%), stickleback (22.9%), staghorn sculpin (17.7%), shiner perch (16.6%), and surf smelt (6.1%).

Very few wild young of the year Chinook salmon were present in the extensive sampling catch. However, juvenile Chinook salmon were captured within nearshore habitat adjacent to four of the 15 sites: Dugualla Bay, Iverson Marsh, Priest Point and Sunnyshore Acres. Wild juvenile Chinook salmon were also captured within the Iverson Marsh and Sunnyshore Acres pocket estuaries. We did not sample behind pump stations or tidegates at Dugualla Bay and Priest Point.

In contrast to juvenile Chinook salmon, juvenile pink or chum salmon were found at all sampled pocket estuaries except the Log Pocket site located in Padilla Bay. As discussed above, the results from our pocket estuary sampling effort in 2004 represents fish use in years with few juvenile Chinook to populate nearshore habitat.

Results for Individual Pocket Estuaries

In this section we present 2004 results for juvenile Chinook salmon, all juvenile salmon combined, and surf smelt for 24 individual pocket estuaries. Sites are shown in Figure 1 and methods are summarized in Table 4. We also present results for some sites where we have additional data (collected prior to or after the 2004 season). We included the additional results when they added to our understanding of fish use at any site. We present results for individual sites because there are unique local interests at many sites. These data may be helpful as background information for understanding restoration potential or neighborhood stewardship needs.

All fish catch results in this section are reported as fish caught per hectare of wetted habitat, where pocket estuary and adjacent nearshore habitats are shallow intertidal or subtidal areas along the shorelines that are beach seined per methods described above. The average maximum depth of habitat in both nearshore and pocket estuaries is approximately 0.75 meters. There are three sites where we have exceptions to beach seining shallow shoreline habitat. They are: Arrowhead Lagoon, English Boom Lagoon, and Swinomish Channel Old Bridge Blind. We used fyke trapping methods to sample marsh channels that form the pocket estuary habitat at these sites. Fyke trap fish catch results are standardized into fish density estimates per methods described above. While the wetted areas are different than those sampled by beach seine, we believe the standardized results (fish density) are comparable between the two methods.

The wild juvenile Chinook salmon smolt populations migrating out of the Skagit and Stillaguamish Rivers in 2004 were small compared to other recent years. The cause was due to several high river flow events causing high Chinook salmon mortality during the egg incubation phase of naturally spawned fish. We suspect this phenomenon occurred in all four Chinook salmon-bearing rivers (Samish, Skagit, Stillaguamish, and Snohomish Rivers) associated with study results in 2004. Therefore results from our pocket estuary sampling effort in 2004 represent fish use in years with few juvenile Chinook salmon to populate nearshore habitat. We discuss this result later in the document under the wild juvenile Chinook salmon section entitled “Influence of Freshwater Smolt Outmigration Population Size on Pocket Estuary Use”.

Ala Lagoon (Skagit Bay)

Ala Lagoon was sampled as part of our extensive sampling effort. We were able to sample within Ala Lagoon and its adjacent nearshore on April 15, 2004 and again on June 11, 2004. We also sampled one lagoon location on May 21, 2004. The sites where beach seining occurred within the lagoon and its adjacent nearshore habitat are shown in Figure 16. Adjacent nearshore habitat was sampled using a beach seine. We made three consecutively placed sets along the shoreline at the northern tip of Ala Spit (shown as a single point in Figure 16). To sample habitat within the lagoon, we made single beach seine sets along the publicly owned perimeter of Ala Lagoon. Each set location is shown in Figure 16 as a single point.

No juvenile Chinook salmon were captured at either the spit or lagoon in 2004 due to very few juvenile Chinook present in the nearshore and pocket estuary habitat during this year compared to other years, and limited sampling effort.

While no juvenile Chinook were captured at the Ala Lagoon and Ala Spit sites in 2004, many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured. The sampling in April 2004 found an average of 17,475 juvenile salmon per hectare. This is over 25 times a higher density of juvenile salmon than along the spit's shoreline habitat. This may indicate that young chum and pink fry are accumulating within the shallow protected areas of Ala Lagoon on their way to the ocean. However,

sampling later in the year (June 2004), we found the reverse pattern (i.e., higher density of juvenile salmon along the spit than along the lagoon's shoreline), but overall juvenile salmon density was much lower than the

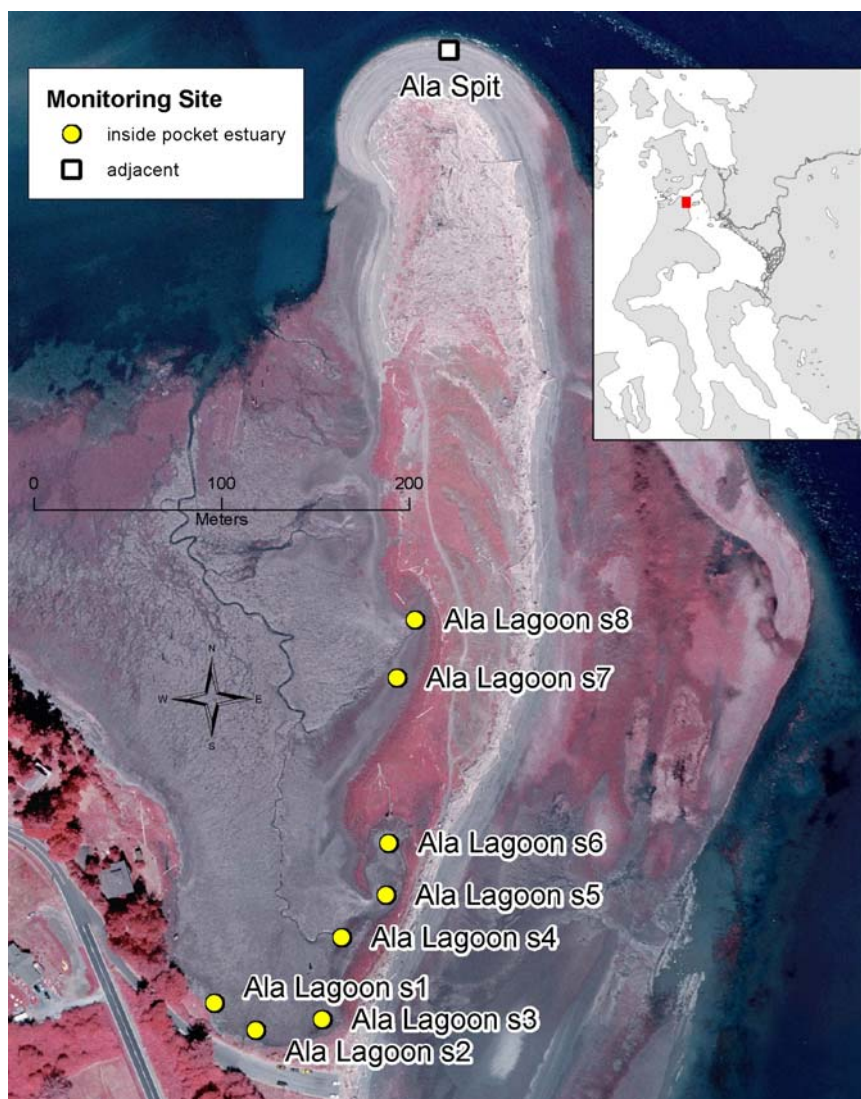


Figure 16. Ala Lagoon sampling sites.

April sampling event (35 fish per hectare) indicating that juvenile chum and pink salmon had largely moved out of Skagit Bay or to more offshore habitats within Skagit Bay.

We did not catch any surf smelt at Ala Lagoon or Ala Spit sites in 2004.

The fish use data are limited from Ala Lagoon and Ala Spit in 2004 because we sampled only in April and June. However, we do have a long sampling record from the same site on Ala Spit to help us understand fish use in this area of Skagit Bay. The Ala Spit site was beach seined monthly (February through October) by Skagit River System Cooperative for the six year period 1997 through 2002. Juvenile Chinook salmon were commonly captured at Ala Spit during this time (Figure 17A), exhibiting an early peak (February) and another peak typically in June. These results show that in most years juvenile Chinook salmon are within the vicinity of Ala Lagoon early in the year, suggesting it is likely that juvenile Chinook salmon do use Ala Lagoon based on our understanding of juvenile Chinook preference for lagoon habitats located nearby in Skagit Bay (Beamer et al. 2003).

We also found many surf smelt at Ala Spit over the six year period, although monthly and yearly differences were highly variable (Figure 17B). We caught almost no surf smelt at Ala Spit in April over six years and the first four years (1997-2000) yielded few surf smelt in June, but years 2001 and 2002 yielded thousands. These results demonstrate that surf smelt do use Ala Spit at least during some part of the year. The highest use period usually coincides with summer months when adult fish are staged for spawning along the spit. We believe it is likely that Ala Lagoon is also used by juvenile surf smelt in the same way we observed at the intensively monitored pocket estuaries (see surf smelt section later in this document). However, we did not sample enough times and over long enough of a period to detect surf smelt in 2004.

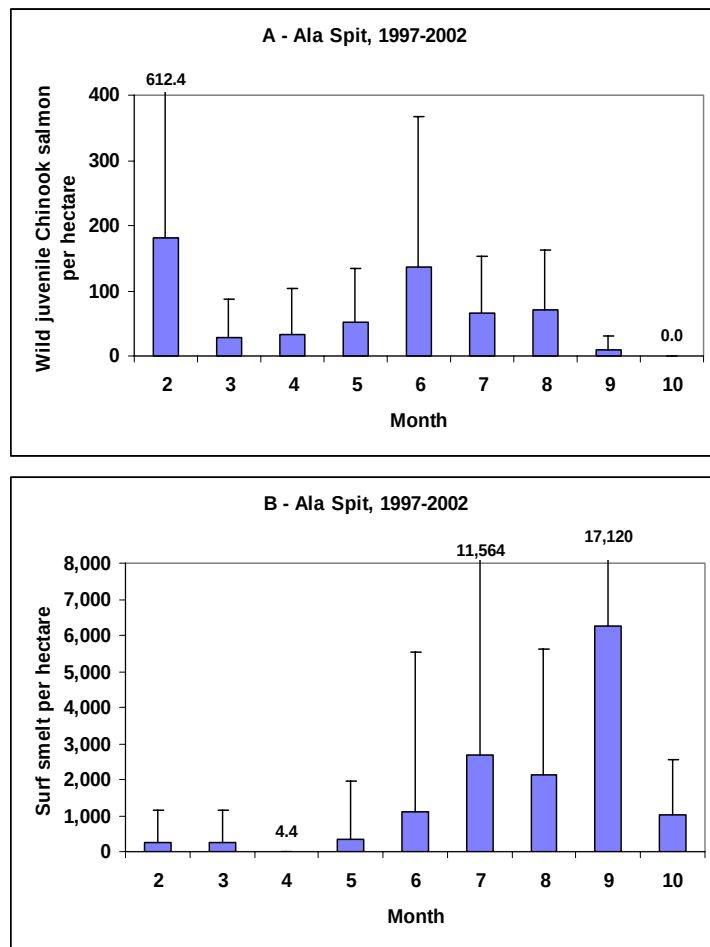


Figure 17. Monthly average density of (A) wild juvenile Chinook salmon and (B) surf smelt caught at Ala Spit during the period February through October over the years 1997 through 2002. Error bars are 1 standard deviation (data from Skagit River System Cooperative).

Arrowhead Lagoon (Skagit Bay)

We sampled within Arrowhead Lagoon and its adjacent nearshore beginning January 12, 2004 and ending October 18, 2004. The Arrowhead Lagoon pocket estuary was sampled as part of our intensive sampling effort so monthly sampling was done throughout this period. The sites where beach seining or fyke trap sampling occurred within the pocket estuary or its adjacent nearshore habitat are shown in Figure 18. Adjacent nearshore habitat was sampled using a beach seine, making three consecutively placed sets along the shoreline at Brown Point (shown as a single point in Figure 18). To sample habitat within the lagoon, we made single beach seine sets within channels throughout the length of the lagoon. Each set location is shown in Figure 18 as a single point. A fyke trap was set at entrance of the lagoon (Arrowhead Lagoon point in Figure 18).

Juvenile Chinook salmon were present in Arrowhead Lagoon and the adjacent nearshore habitat at Brown Point during the 2004 season (Figure 19A). However, very few juvenile Chinook salmon were captured in either the pocket estuary or its adjacent nearshore habitat and there was no clear pattern of preference by juvenile Chinook for the pocket estuary during 2004. The 2004 results at Arrowhead are probably due to the small number of wild juvenile Skagit Chinook salmon migrating to sea in 2004. Thus, very few juvenile Chinook were available to occupy nearshore and pocket estuary habitat during this year compared to other years.



Figure 18. Arrowhead Lagoon sampling sites.

In contrast to the few juvenile Chinook salmon at the Arrowhead sites in 2004, we caught many other juvenile salmon (mostly age 0+ chum and pink salmon) in 2004 (Figure 19B). Juvenile salmon within Arrowhead lagoon were found from February through May, peaking in April with an average of 3,392 juvenile salmon per hectare. Juvenile salmon in adjacent nearshore habitat were found from March through June, peaking in May with an average of 2,674 juvenile salmon per hectare.

Surf smelt were also caught at the Arrowhead and Brown Point sites in 2004 (Figure 19C). Surf smelt were abundant in either the pocket estuary or its adjacent nearshore during January and again during the August through October period. Both adult and juvenile surf smelt were caught in adjacent nearshore habitat during July through September while only juvenile surf smelt were caught within the pocket estuary during these same months. Juvenile surf smelt were abundant in both the pocket estuary and its adjacent nearshore habitat during October. Juvenile surf smelt were also abundant within the pocket estuary during January.

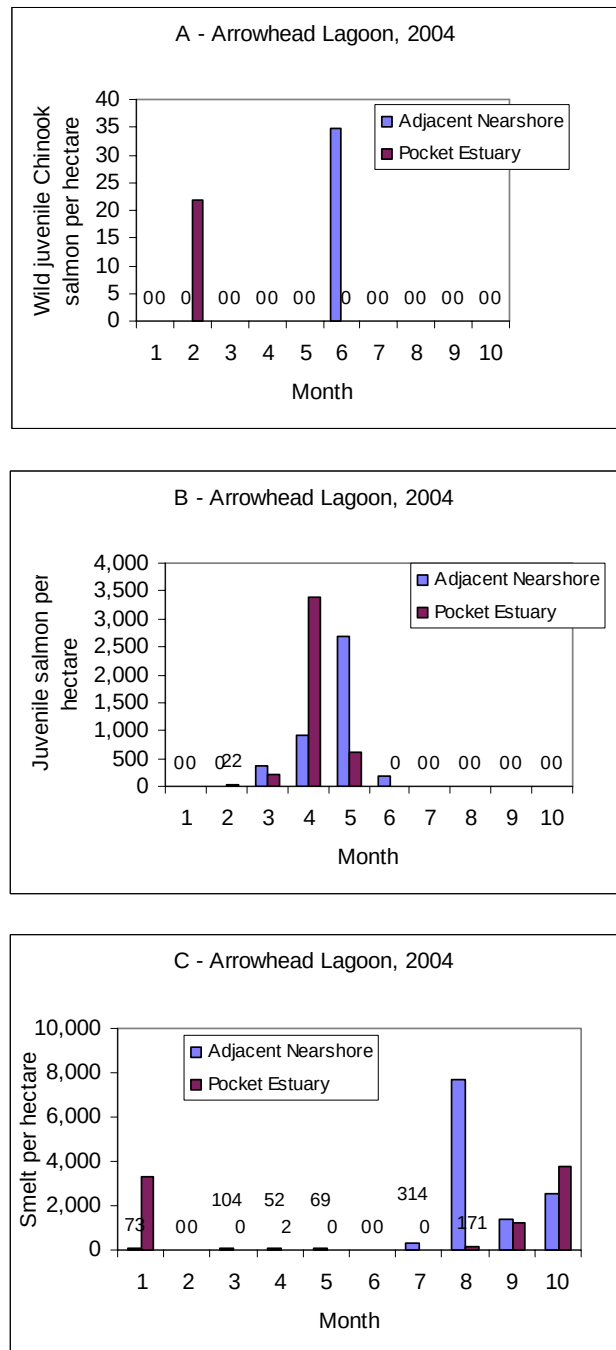


Figure 19. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Arrowhead Lagoon and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Bowman Bay Lagoon (Rosario Straits)

We sampled within Bowman Bay at the beach (adjacent nearshore) and within a backshore wetland (pocket estuary) marginally connected to the bay on April 7, 2004. This site was sampled as part of the extensive sampling and therefore was only sampled once in 2004. The sites where beach seining occurred within the pocket estuary and its adjacent nearshore habitat are shown in Figure 20. We made three consecutively placed sets at two locations along the beach face of Bowman Bay (shown as a single point in Figure 20). To sample habitat within the lagoon, we made single beach seine sets at three different locations. Each set location is shown in Figure 20 as a single point.

No juvenile Chinook salmon were captured at either the shoreline or lagoon in 2004.

While no juvenile Chinook were captured, there were other juvenile salmon (all were age 0+ pink salmon) captured on the adjacent shoreline. The sampling in April 2004 found an average of 17.4 juvenile salmon per hectare. No other juvenile salmon were found inside the lagoon.

There were no surf smelt captured either in the lagoon or on the adjacent shoreline.

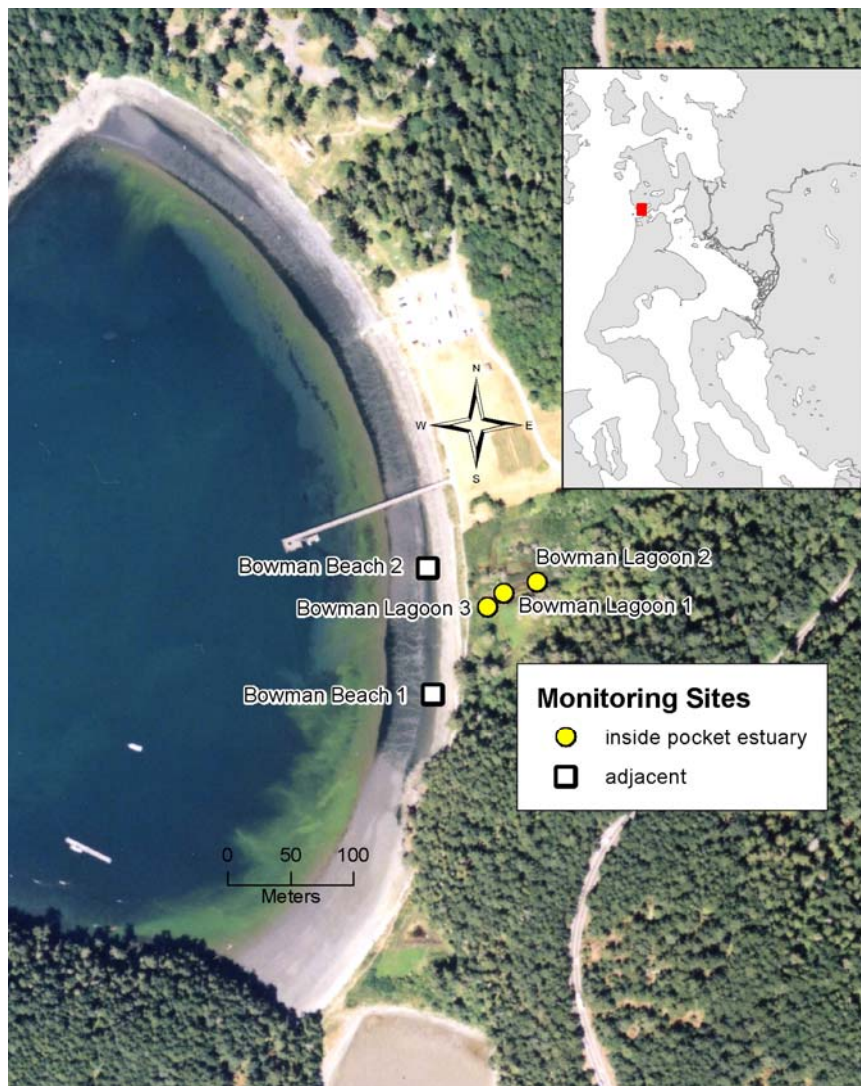


Figure 20. Bowman Bay Lagoon sampling sites.

Camano Country Club (Port Susan)

We sampled outside the lagoon on July 9, 2004 as part of the extensive sampling effort (Figure 21). We made three consecutively placed sets at one location along the shoreline at the northern end of Camano Country Club Lagoon (shown as a single point in Figure 21). The outlet of the Camano Country Club pocket estuary runs through a culvert pipe that does not have a tidegate. We assume estuarine fish, including salmon, can move through the culvert. We did not conduct any sampling within the lagoon at this site

There were no juvenile wild Chinook salmon found at this site.

While no juvenile wild Chinook were captured at this site, we found one hatchery origin Chinook that had been released from the Wallace River Hatchery (a tributary to the Skykomish River) earlier in 2004, resulting in an average of 35 fish per hectare.

There were no surf smelt captured at this site.



Figure 21. Camano Country Club sampling sites.

Crandall Lagoon North (Fidalgo Bay)

We sampled within the large, northern lagoon behind Crandall Spit and adjacent nearshore on April 7, 2004 as part of the extensive sampling (Figure 22). Adjacent nearshore habitat was sampled using a beach seine. We made single beach seine sets along the shoreline of Crandall Spit. To sample habitat within the lagoon, we also made single beach seine sets throughout the length of the lagoon's outlet channel. Two sets were made at Crandall Lagoon s2. Each set location is shown in Figure 22 as a single point.

No juvenile Chinook salmon were captured at either Crandall Spit or in Crandall Lagoon in 2004.

While no juvenile Chinook were captured there were other juvenile salmon (mostly age 0+ chum and pink salmon) captured on the adjacent shoreline. The sampling in April 2004 indicated an average of 1,250 juvenile salmon per hectare. No other juvenile salmon were found inside the lagoon.

We did not catch any surf smelt at Crandall Lagoon or Crandall Spit sites in 2004.

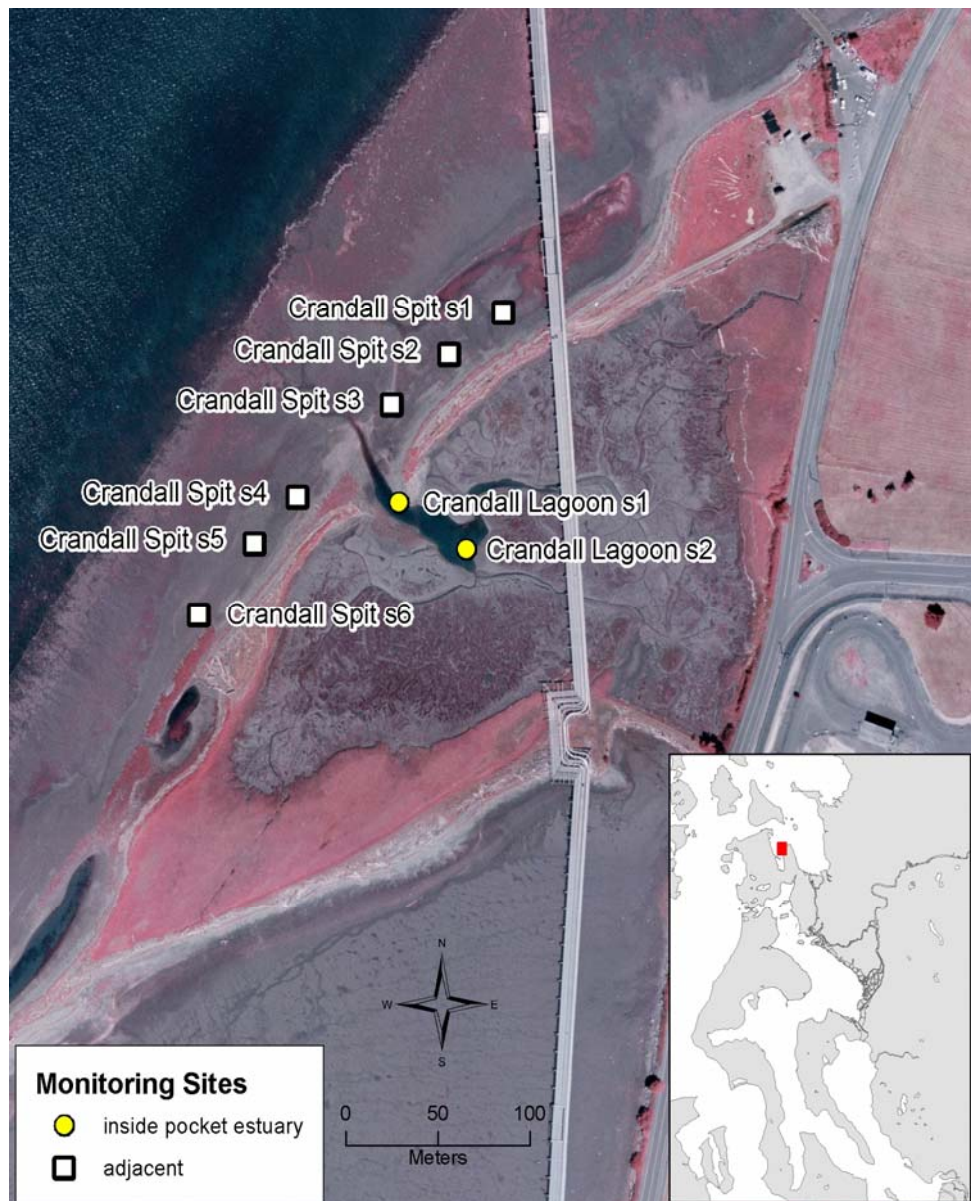


Figure 22. Crandall Lagoon North sampling sites.

Dugualla Bay (Skagit Bay)

This pocket estuary is currently blocked to fish use. We sampled Dugualla Bay nearshore habitat outside the tide gate, adjacent to the isolated lagoon, from March through October, 2004. Three single beach seine sets were made along the western shoreline edge of Dugualla Bay (Figure 23).

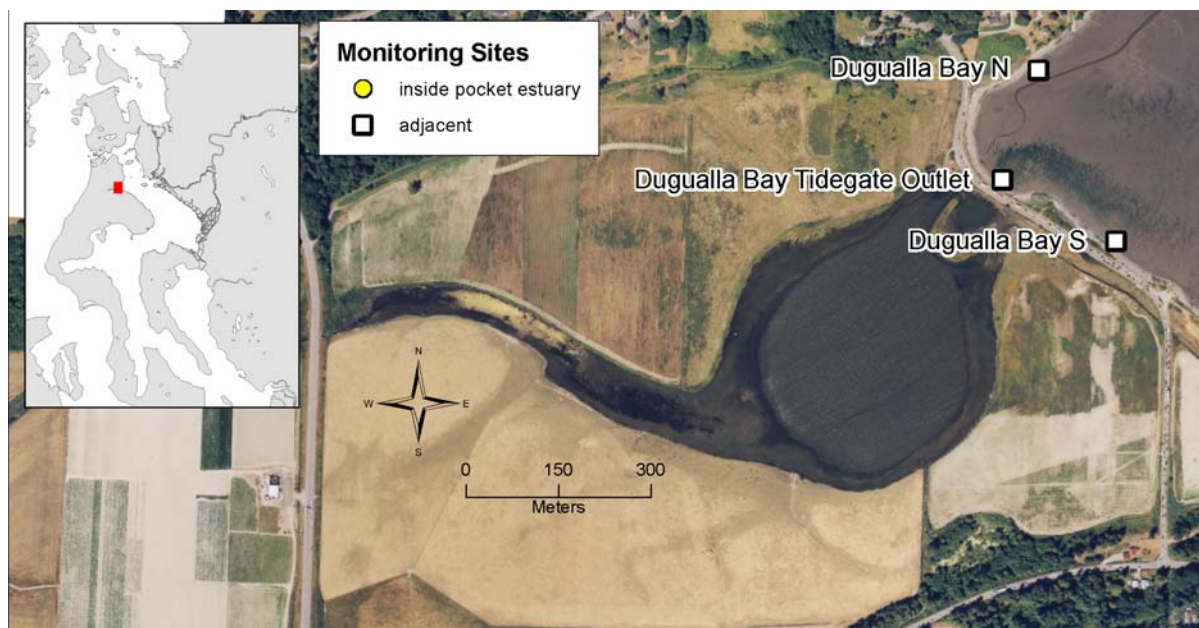


Figure 23. Dugualla Bay sampling sites.

Juvenile Chinook salmon were present at Dugualla Bay, but only during the first portion of the sampling season. March yielded an average of 23 Chinook per hectare while the sampling during April found an average of 17 juvenile Chinook salmon per hectare. No juvenile Chinook were found at this site during the remainder of the season (Figure 24A).

During the same time that the Chinook salmon were found in 2004 there was also an abundance of other juvenile salmon species captured. Sampling during March found an average of 2,995 juvenile salmon per hectare, 8,156 juvenile salmon per hectare in April, and 729 juvenile salmon per hectare in May (Figure 24B). The juvenile salmon were mostly age 0+ chum and pink salmon.

Surf smelt were found through out the sampling period in 2004 except for the month of May (Figure 24C). The population of surf smelt captured included both adult and juvenile smelt. The results showed the smelt ranged from 17 fish per hectare in July to a high of 1,737 smelt per hectare in March during 2004.

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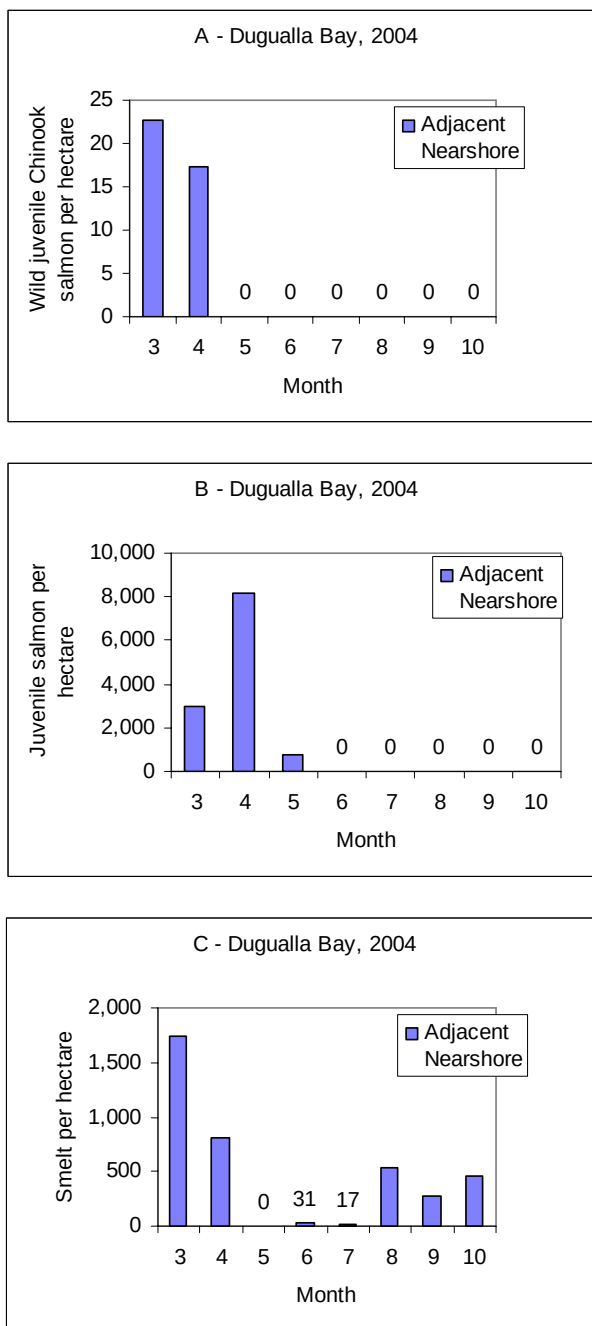


Figure 24. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Dugualla Bay adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Dugualla Heights (Skagit Bay)

We sampled nearshore habitat adjacent to Dugualla Heights Lagoon from March through October 2004 as part of the intensive sampling effort. This pocket estuary is currently blocked to fish use. We made three consecutively placed sets along the shoreline at the northern edge of Dugualla Heights (shown as a single point in Figure 25). Since the pocket estuary is currently blocked we did not make any beach seine sets inside the lagoon.

We found no juvenile Chinook at this site in 2004.

While no juvenile Chinook were captured at the Dugualla Heights adjacent shoreline in 2004, many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured. April sampling found an average of 3,611 juvenile salmon per hectare (Figure 26A). There were no juvenile salmon found at this site after the June sampling.

Surf smelt were found throughout the sampling period in 2004, except for the month of May. The population of surf smelt captured included both adult and juvenile smelt. The results showed the smelt ranged from 35 smelt per hectare in July, 2004 to a high of 3,611 smelt per hectare in March, 2004 (Figure 26B). This is also the same time period that the smelt were found at the Dugualla Bay site located nearby.



Figure 25. *Dugualla Heights.* Note that the sampling site is located east of the tide gate even though the site name is “Dugualla Ht. Tidegate Outlet”.

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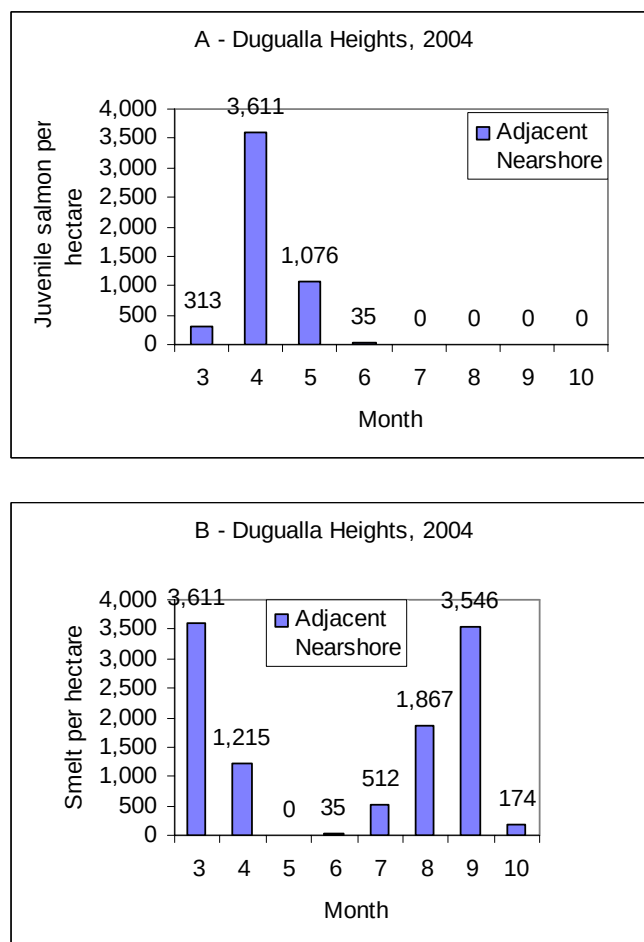


Figure 26. Average monthly density of all juvenile salmon (A), and surf smelt (B) at Dugualla Heights nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Elger Bay (Saratoga Passage)

We sampled in Elger Bay Lagoon and the adjacent nearshore from February 13 through June 15, 2004 as part of the intensive sampling effort (Figure 27). Adjacent nearshore habitat was sampled using a beach seine, making three consecutively placed sets along the shoreline at Elger Spit and along Elger Bay Beach. Within the lagoon, we made two consecutively placed beach seine sets at each sample along the main channel of the lagoon. Each sampling site is shown as a single point in Figure 27.

Juvenile Chinook were found within Elger Bay only during February and March, 2004. The sampling found an average of 35 juvenile Chinook per hectare in February and 130 juvenile Chinook per hectare in March. We found no juvenile Chinook along the adjacent shoreline until May, 2004, when average fish concentrations were 26 juvenile Chinook per hectare (Figure 28A).

Juvenile salmon (mostly age 0+ chum and pink salmon) were present both within Elger Lagoon and along the adjacent shoreline during the 2004 season. In Elger Lagoon, the peak capture was in February, averaging 1,563 juvenile salmon per hectare. At the same time we found 21,007 juvenile salmon per hectare along the adjacent shoreline at Elger Spit and Elger Beach (Figure 28B). Juvenile salmon were not found within the pocket estuary after April 2004 and were not found along the adjacent shorelines after May, 2004.

There were no surf smelt found inside Elger Bay in 2004. However, there was one juvenile surf smelt caught along the adjacent shoreline at Elger Spit in May of 2004 (Figure 28C). We also found an absence of smelt within Harrington Lagoon and its adjacent shoreline during 2004.

Both Elger and Harrington lagoons were beach seined monthly, February through June in 2005 and again few surf smelt were captured. The reason for the lack of surf smelt at this site is unclear at this time.

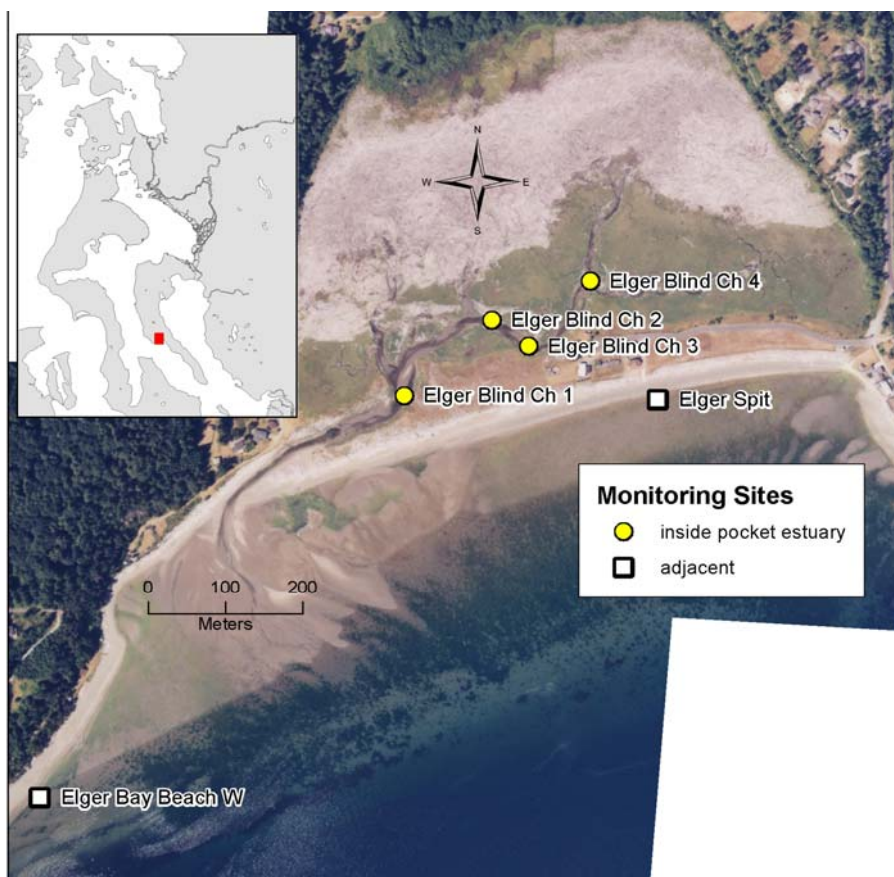


Figure 27. Elger Bay sample sites.

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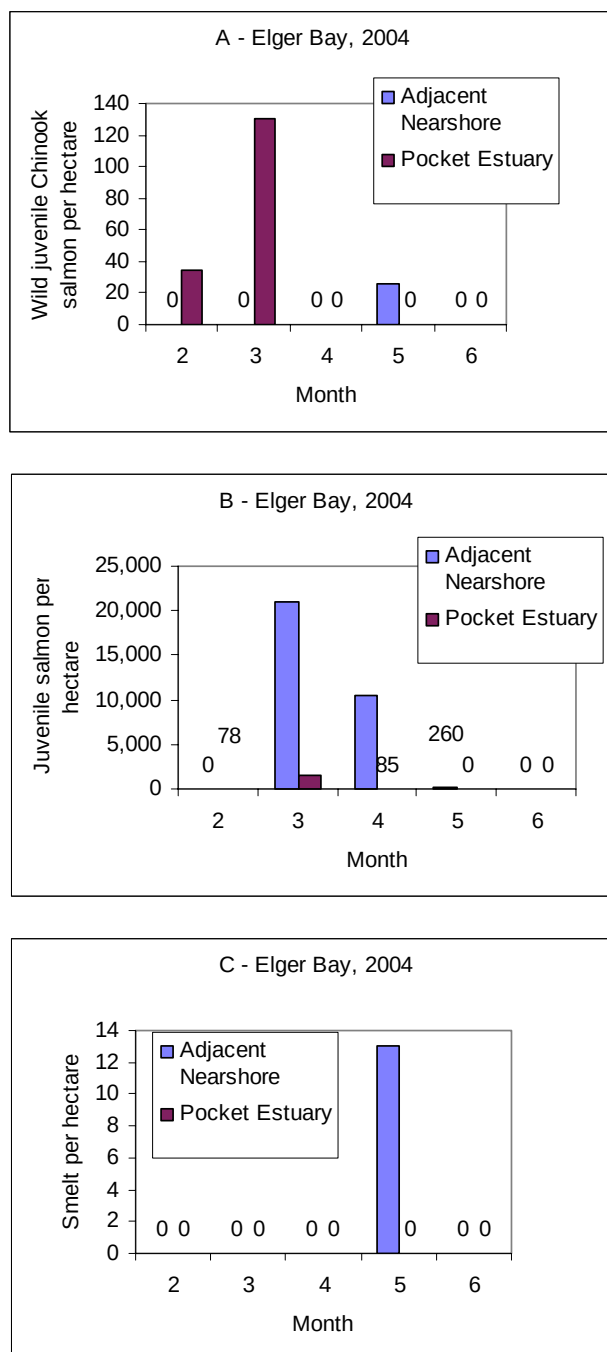


Figure 28. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Elger Bay and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

English Boom Lagoon (Skagit Bay)

We sampled English Boom Lagoon and the adjacent nearshore on April 9, 2004 as part of the extensive sampling effort. Sampling along the adjacent shoreline was done with a beach seine at three locations (Figure 29). The sampling inside English Boom Lagoon was done by placing a fyke trap at the mouth of the blind channel at high tide and fishing throughout the tidal drop (Figure 29).

No juvenile Chinook salmon were captured at either the spit or lagoon in 2004.

While no juvenile Chinook salmon were captured at English Boom Lagoon, many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured. The sampling inside English Boom Lagoon found an average of 6,705 juvenile salmon per hectare. Along the adjacent spit we found 31,478 juvenile salmon per hectare.

There were no surf smelt found in the lagoon but sampling along the adjacent shoreline showed an average abundance of 12,211 smelt per hectare.

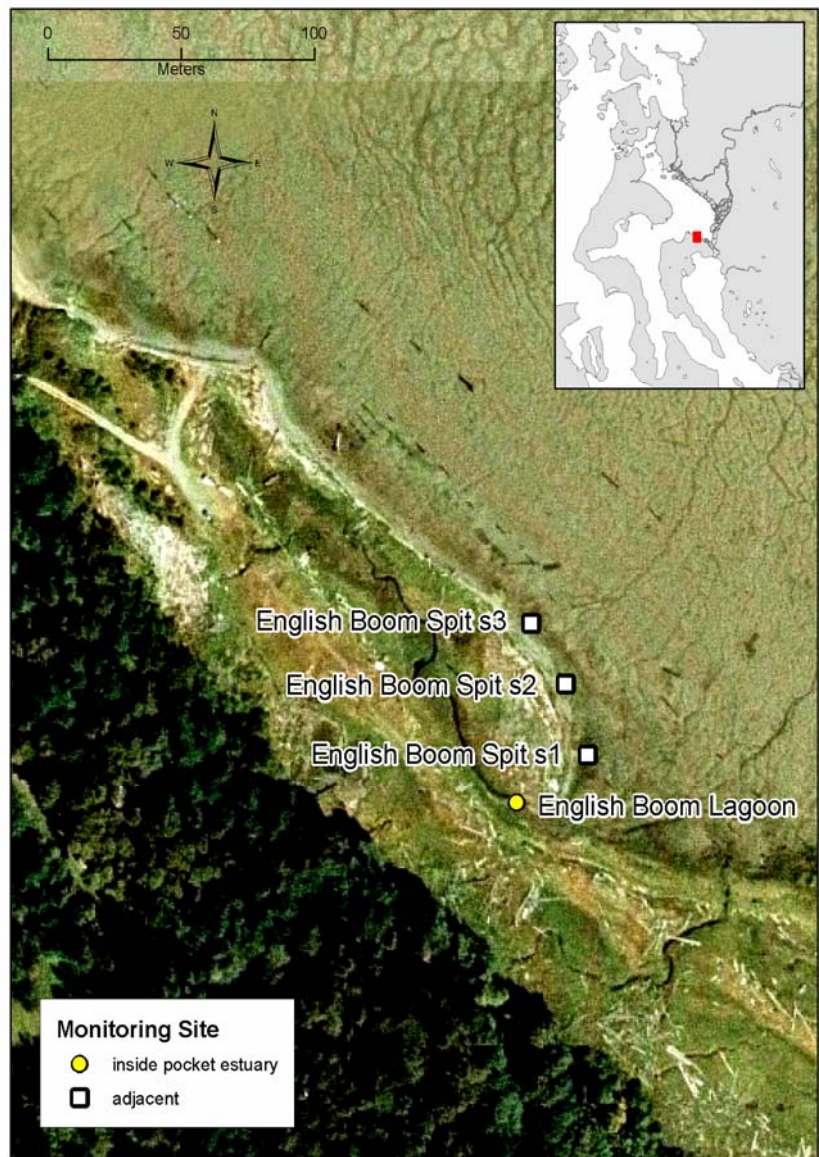


Figure 29. English Boom Lagoon sampling sites.

Grassers Lagoon (Penn Cove)

We sampled in Grassers Lagoon and the adjacent nearshore from February 19 through October 21, 2004 as part of the intensive sampling effort. We sampled bi-weekly during February through April and monthly for the remainder of the season. We made three consecutively placed beach seine sets along the shoreline of Grassers Spit and along Grassers Beach East located to the northeast of the lagoon (each is shown as a single point in Figure 30). To sample habitat within the lagoon, we made 5 single beach seine sets along the perimeter of each lobe of the lagoon (Figure 30).

Juvenile wild Chinook salmon were sporadically present within Grassers Lagoon throughout the sampling period. The peak catch was in August, when we captured an average of 46 juvenile Chinook per hectare and 17 juvenile Chinook pre hectare outside the lagoon (Figure 31A). August was the only month we found Chinook along the adjacent spit beaches. The low abundance of outmigrating Skagit Chinook in 2004 and the distance from any

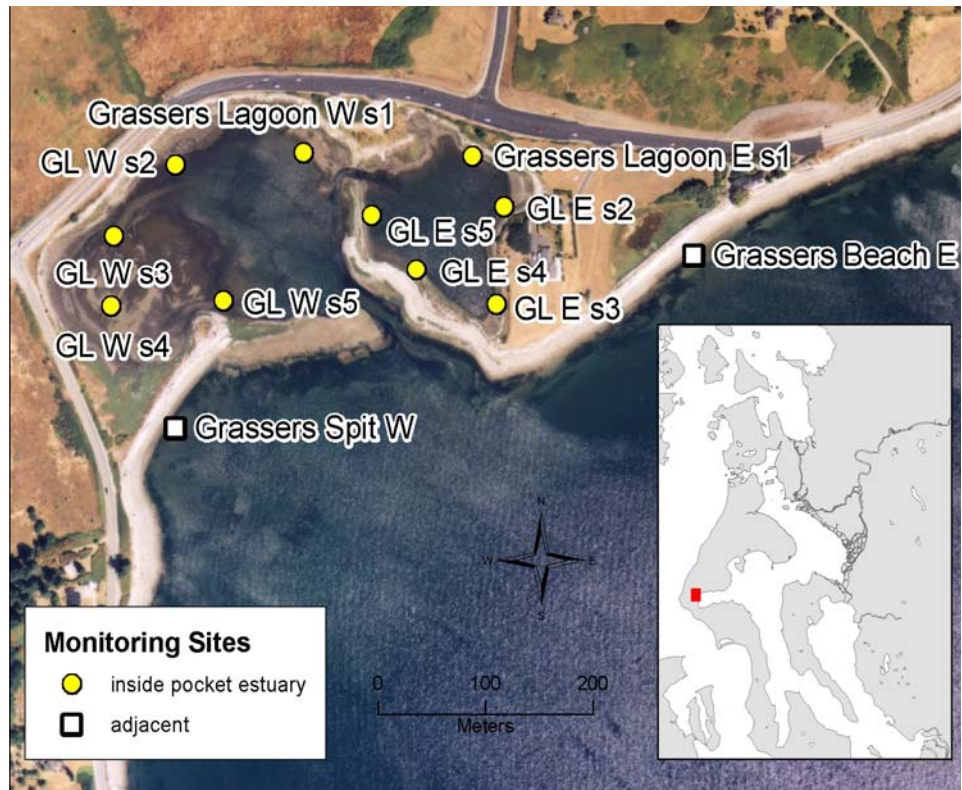


Figure 30. Grassers Lagoon sampling sites.

of the major natal rivers in the Whidbey Basin are believed to be factors influencing the low abundance of Chinook at Grassers Lagoon.

Juvenile salmon (mainly age 0+ chum and pink salmon) were found at Grassers Lagoon during most of the sampling period. Inside Grassers Lagoon, the juvenile salmon were most abundant during February, March and April, when we captured an average of 1,250, 1,666 and 1,184 salmon per hectare, respectively. During these same months, adjacent nearshore sites averaged of 35, 244 and 1,299 per month of salmon per hectare. There were not any juvenile salmon found in this area after August of 2004 (Figure 31B)

Surf smelt were found within Grassers Lagoon only during the first three months of sampling. The peak was in April when the results showed an average of 314 smelt per hectare. Smelt were

found on the adjacent shoreline sites but in much less abundance. The peak catch during February resulted in an average of 35 smelt per hectare (Figure 31C).

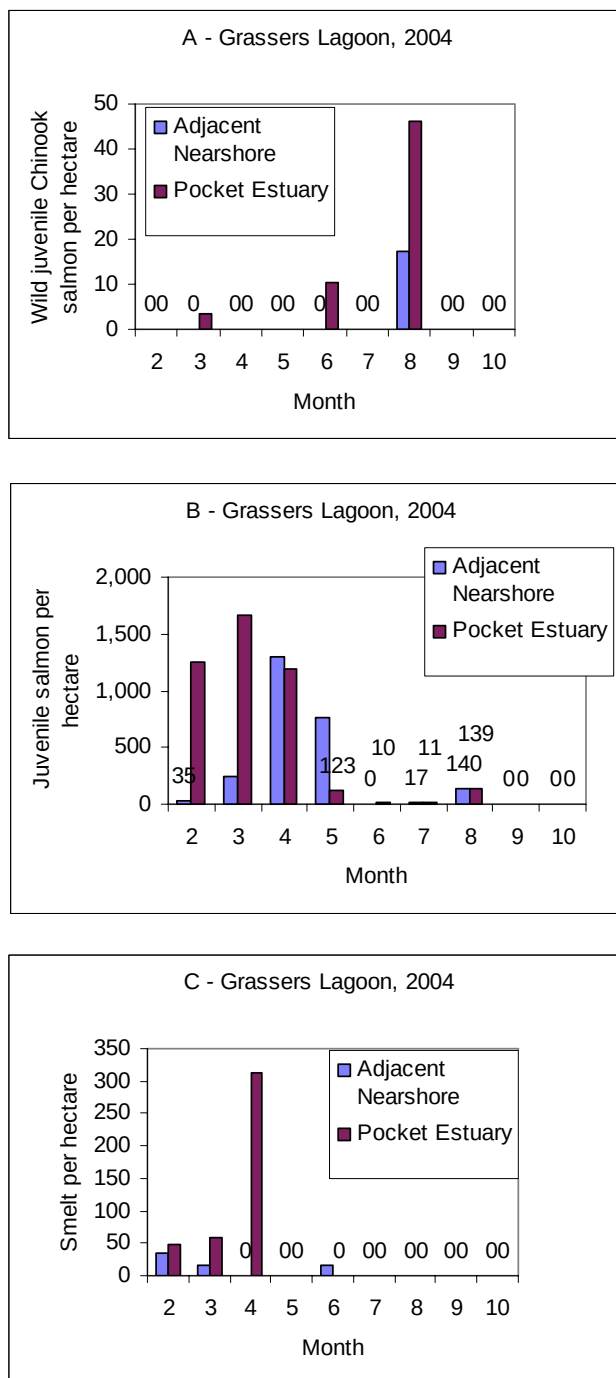


Figure 31. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Grassers Lagoon and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Harrington Lagoon (Saratoga Passage)

We sampled inside Harrington Lagoon and along the adjacent nearshore on April 14, 2004 as part of the extensive sampling effort. Harrington Spit was sampled using a beach seine for three consecutively placed sets along the shoreline. Each set is represented as a single point in Figure 32. To sample habitat within the lagoon, we made 5 single beach seine sets along the northern perimeter of the lagoon (Figure 32).

No juvenile Chinook salmon were captured either along the spit or within the lagoon in 2004. These results are probably due the small number of wild juvenile Skagit Chinook salmon migrating to sea in 2004 and the one-time sampling of this area. Monthly sampling of this site in 2005 yielded Chinook salmon February through May.

While no juvenile Chinook were captured at the Harrington Lagoon or Harrington Spit sites in 2004, many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured. The sampling inside Harrington Lagoon found an average of 250 juvenile salmon per hectare. The sampling along the adjoining spit showed an average density of 17,089 juvenile salmon per hectare

There were no surf smelt found during the sampling at Harrington Lagoon or Harrington Spit. Elger Bay, located to the southeast across Saratoga Passage from Harrington Lagoon, also had no surf smelt. Both sites were sampled again in 2005, yielding the same results. The reason for the lack of surf smelt at this site is unclear at this time.

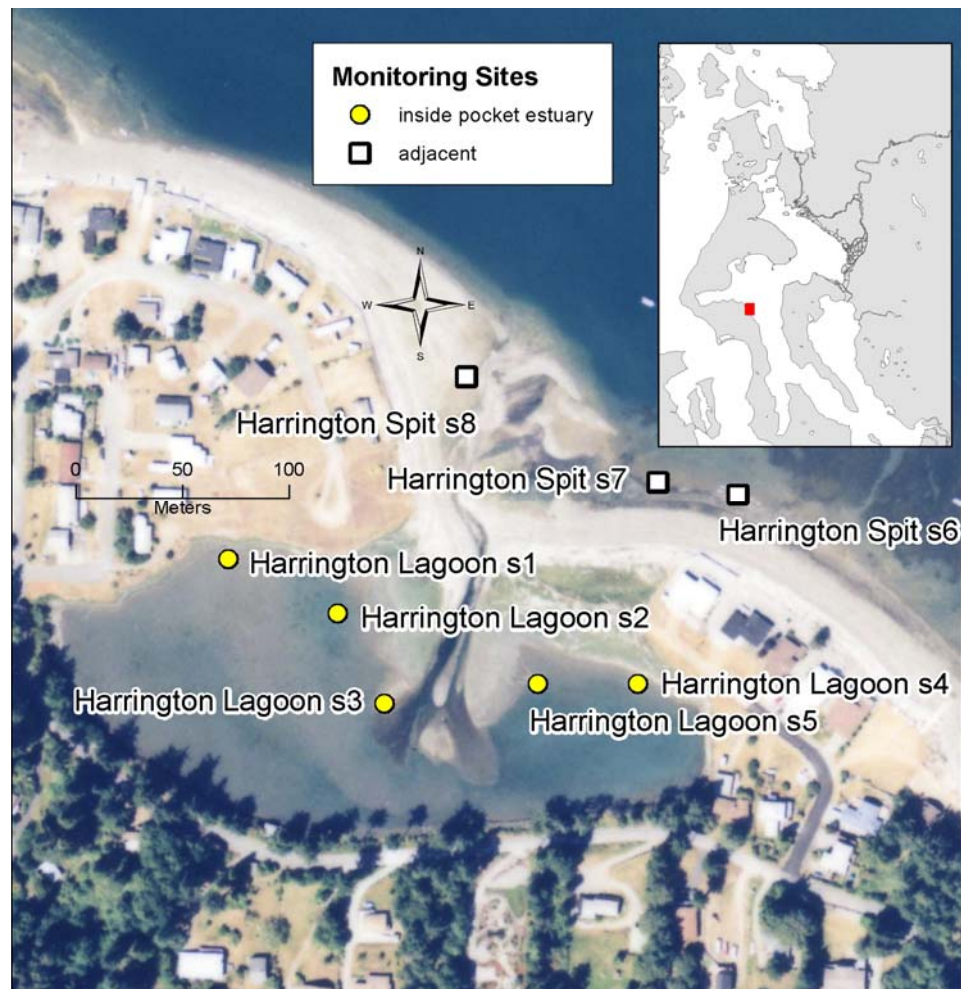


Figure 32. *Harrington Lagoon sampling sites.*

Iverson Marsh (Port Susan)

We sampled in Iverson Marsh and the adjacent nearshore monthly in March, April and May of 2004 as part of the extensive sampling effort. While this sampling effort was more than the one time sampling conducted at most of the extensive sites, it did not cover the full outmigration period for the juvenile Chinook salmon. We made three consecutively placed sets along the shoreline of Iverson Spit (shown as a single point in Figure 33). To sample habitat within the pocket estuary, we made single beach seine sets at three locations along the main channel within the lagoon (Figure 33).

Juvenile Chinook were found inside Iverson Marsh during March at an average of 35 juvenile Chinook salmon per hectare. Juvenile Chinook were only found on the adjacent Iverson Spit during the May sampling, when the catch resulted in an average of 35 juvenile Chinook salmon per hectare.

Juvenile salmon (mainly age 0+ chum and pink salmon) were found on the adjacent spit during all three months of sampling. The peak catch was during April, at 8,090 juvenile salmon per hectare. Juvenile salmon other than Chinook were also found within Iverson Marsh during March and April 2004, with the peak catch in March of 429 salmon per hectare.

Surf smelt were found at both locations, but in very few numbers. They were found inside Iverson Marsh only during the March sampling resulting in an average of 35 smelt per hectare. The smelt were found on the spit during all three months, peaking during May at 69 smelt per hectare.

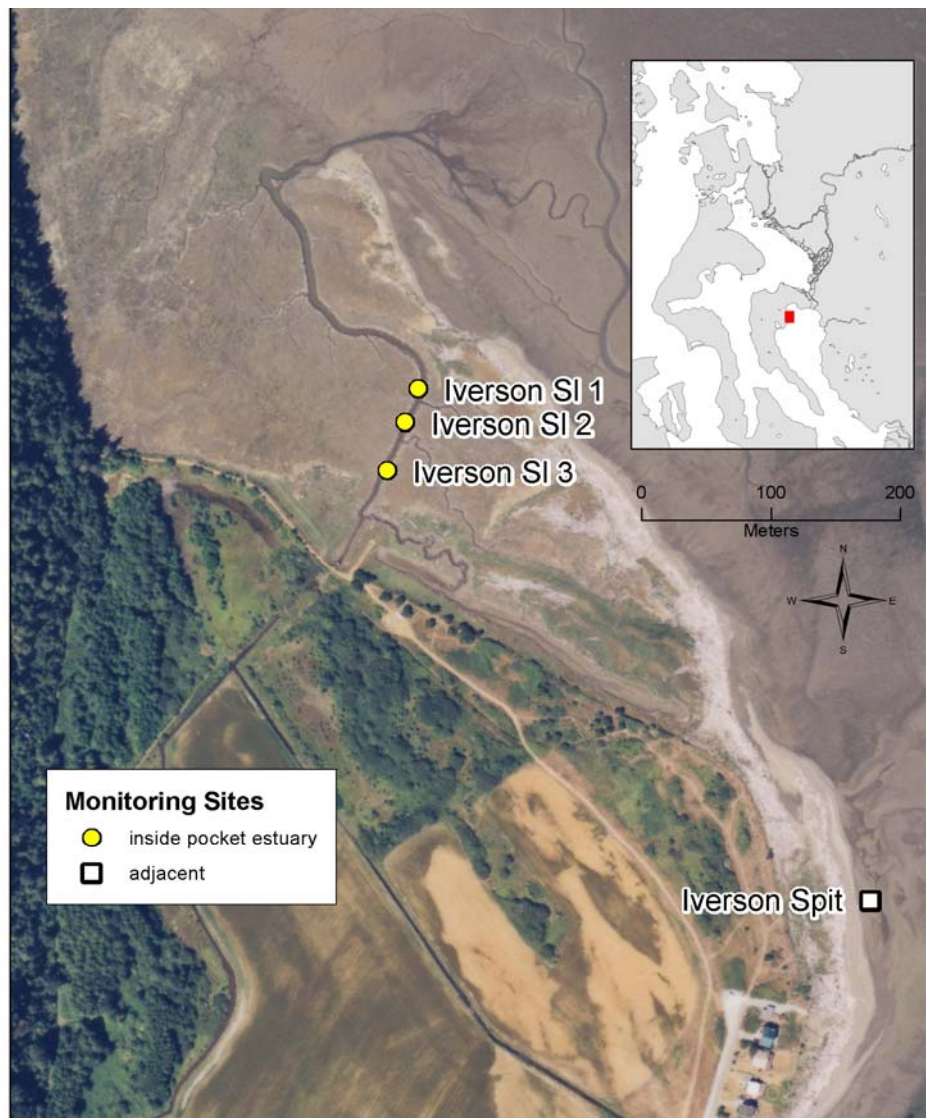


Figure 33. Iverson Marsh sampling sites.

Joe Leary Slough (Padilla Bay)

We sampled within Joe Leary Slough and along adjacent nearshore habitat on April 23, 2004 as part of the extensive sampling effort. The sites were sampled by beach seining at individual sites both within this artificial pocket estuary and along its adjacent nearshore habitat. The sites are shown in Figure 34.

No juvenile Chinook salmon were captured inside or outside at Joe Leary Slough during 2004.

There were, however, a few juvenile salmon captured both inside the pocket estuary and along the adjacent shoreline. We found an average salmon density of 71 fish per hectare inside the pocket estuary and 35 fish per hectare outside the pocket estuary.

There were no surf smelt found outside the pocket estuary and only a few smelt found within Joe Leary Slough at a density of 33 smelt per hectare.

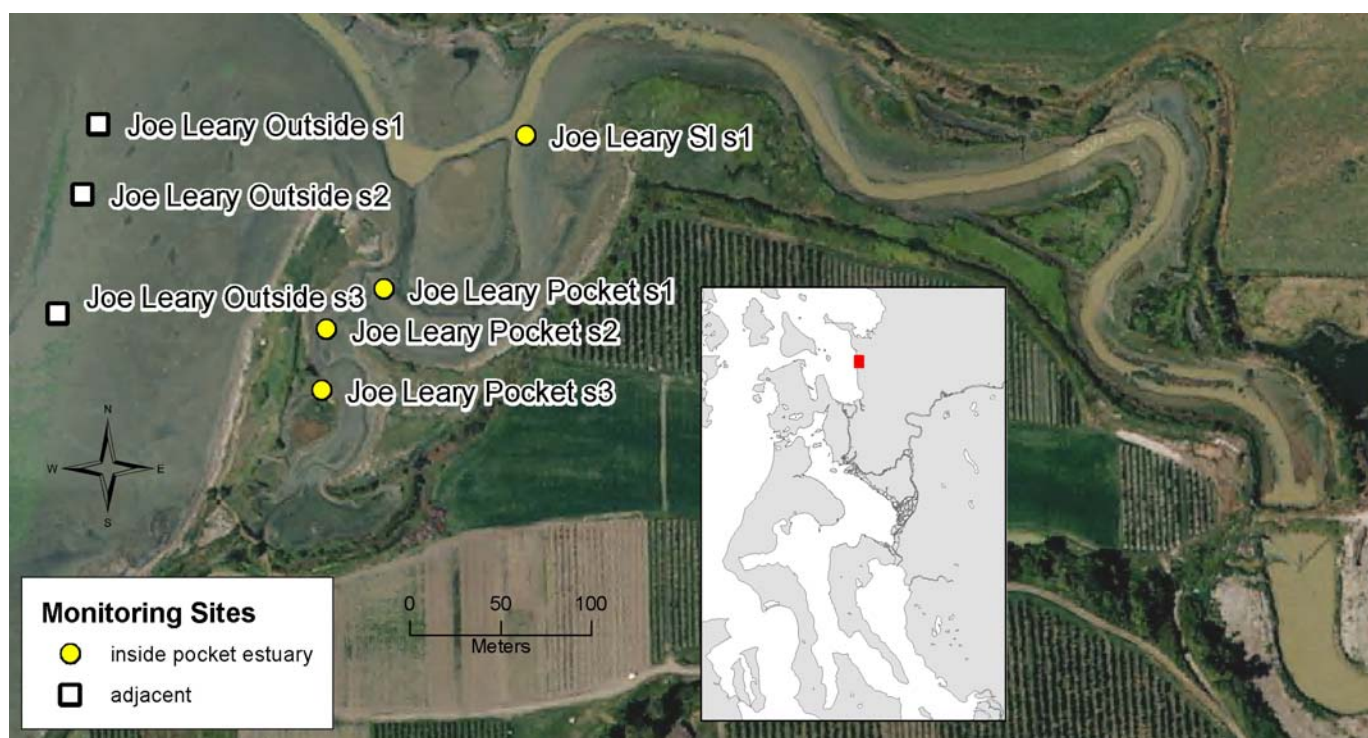


Figure 34. Joe Leary Slough sample sites.

Log Pocket (Padilla Bay)

We sampled inside this artificial pocket estuary and along adjacent nearshore beaches on April 16, 2004 as part of the extensive sampling effort, using a beach seine. We made two consecutively placed sets along the shoreline at the northern tip of Log Pocket Spit and three consecutively placed sets along the beach to the north of the spit. To sample habitat within the pocket estuary, we made four beach seine sets within the lagoon. Beach seine locations are shown in Figure 35.

There were no juvenile Chinook salmon found at any of the Log Pocket sites

There were no other species of juvenile salmon found at any of the sites either, nor any surf smelt.



Figure 35. Log Pocket sampling sites.

Lone Tree Lagoon (Skagit Bay)

We sampled within Lone Tree Lagoon and adjacent nearshore from February 13 through December 14, 2004 as part of the intensive sampling. We conducted bi-weekly sampling through the end of May and monthly sampling for the remainder of the time period.

Adjacent nearshore habitat was sampled using a beach seine for three consecutively placed sets along the western edge Lone Tree Point and at SneeOosh N located to the south of the headland (Figure 36). These two sites are shown as single points in Figure 36. To sample habitat within the lagoon, we made six single beach seine sets along the perimeter of Lone Tree Lagoon. Each set location within the lagoon is shown in Figure 36 as single points.

Juvenile Chinook salmon were found within Lone Tree lagoon from the start of the sampling in February through the end of May, 2004. Juvenile Chinook were also captured along the adjacent shoreline during this same time period. February through April, the density of wild Chinook within Lone Tree Lagoon was twice as high as the density of Chinook found at the two adjacent sites (Figure 37A). The peak catch was in March when fish density was 1,013 juvenile Chinook per hectare compared to 52 Chinook per hectare on the two adjacent shoreline sample sites. During May there were still Chinook found inside the lagoon but the density was higher along the adjacent shoreline (Figure 37A). We did not find any Chinook at these locations during the summer months after May except for during December. At that time there were equal fish densities both inside Lone Tree lagoon and along adjacent beaches.



Figure 36. Lone Tree Lagoon sampling sites.

Many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured both inside the lagoon and along the adjacent beaches from February through May. Peak density was during April, with 7,283 juvenile salmon per hectare within the lagoon and 6,373 juvenile salmon per hectare at the adjacent sites. Density distributions varied between the lagoon and the adjacent shoreline sites. In March there was higher density of juvenile salmon found inside the lagoon, while in May there was a higher density of juvenile salmon found along the adjacent shoreline sampling sites (Figure 37B). We did not find any juvenile salmon at these locations during the summer months after May until our sampling in December.

Surf smelt were sporadically found within Lone Tree Lagoon and along adjacent shorelines throughout the sampling period. At the times when smelt were detected, the density of smelt within the lagoon was always higher than the density of smelt along the adjacent shoreline, except in November (Figure 37C).

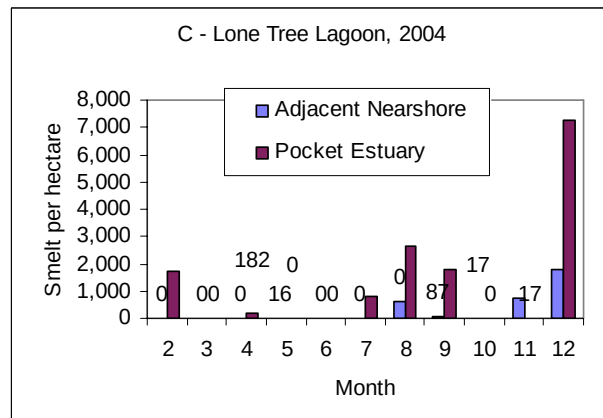
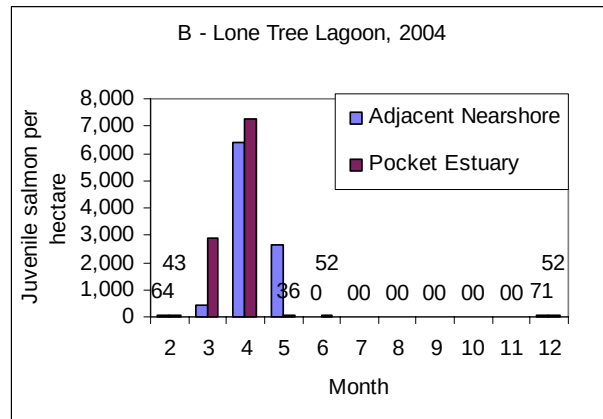
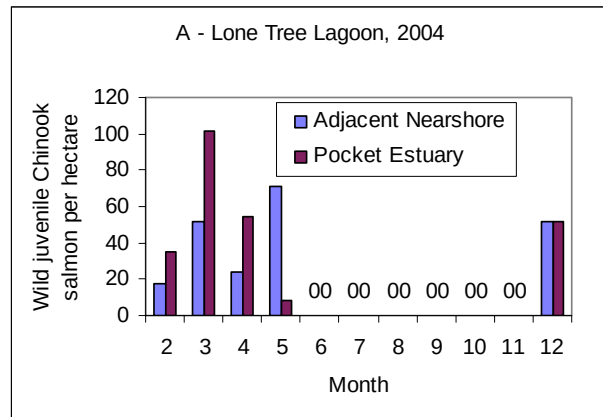


Figure 37. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Lone Tree Lagoon and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

McElroy Slough (Samish Bay)

We sampled in McElroy Slough and along the adjacent nearshore on April 21, 2004 as part of the extensive sampling effort. Adjacent nearshore habitat was sampled at two sites using a beach seine for three consecutively placed sets for each site along the northwestern edge of McElroy Spit (Figure 38). To sample habitat within the lagoon, we made three single beach seine sets along the eastern edge of McElroy Lagoon near the tidegate outlets. Each set location is shown in Figure 38.

There were no juvenile Chinook salmon caught at any of the McElroy sampling sites.

There were, however, juvenile salmon (all age 0+ chum salmon) caught inside McElroy Lagoon at an average density of 521 juvenile salmon per hectare. No other juvenile salmon were caught along the adjacent shoreline sites.

Surf smelt were caught inside McElroy Lagoon (494 smelt per hectare), but not at the adjacent shoreline sites.

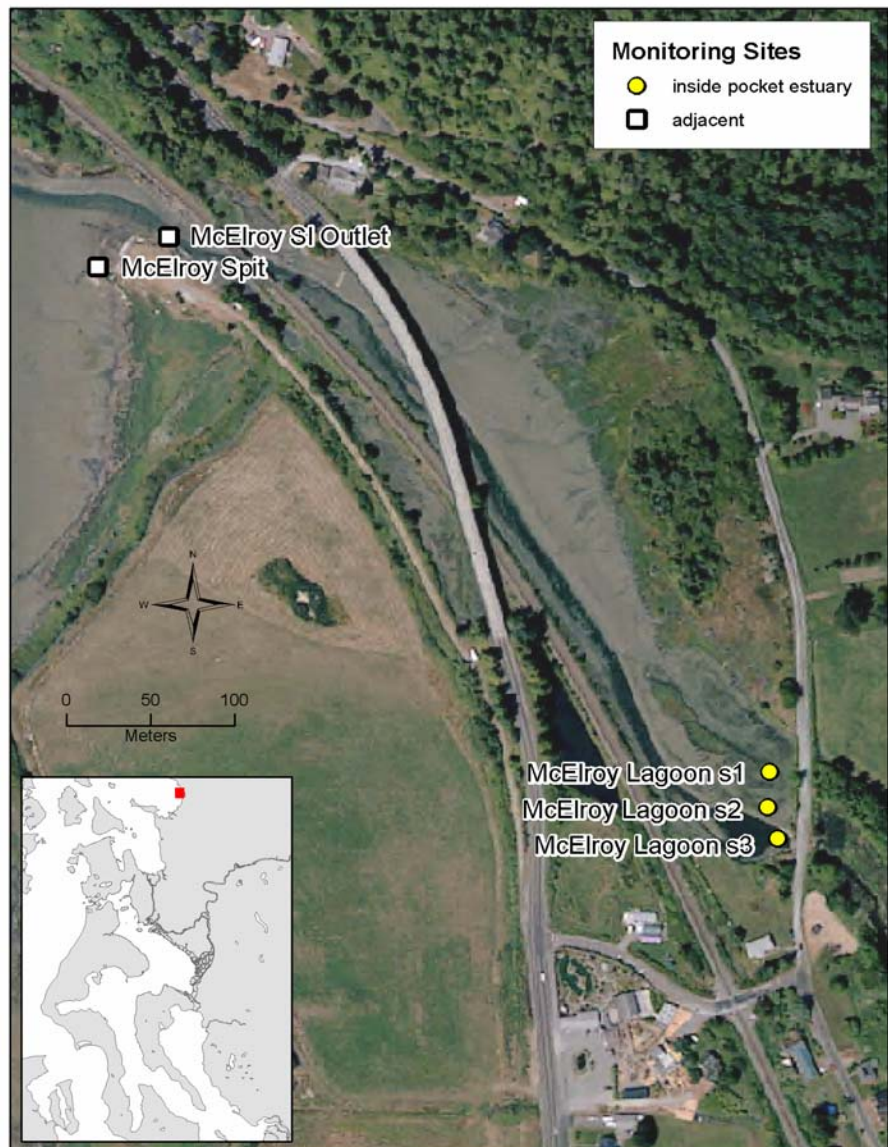


Figure 38. *McElroy Slough sampling sites.*

Priest Point (Port Gardner)

We sampled at the mouth of Priest Point Lagoon and along the adjacent nearshore on February 27, 2004 as part of the extensive sampling effort. Most of the lagoon is isolated from fish access. Adjacent nearshore habitat was sampled using a beach seine along the adjacent shoreline, shown as single points in Figure 39. To sample habitat within the lagoon, we made three beach seine sets inside Priest Pt. Lagoon. This set location is also shown in Figure 39 as a single point. Sampling was discontinued here due to concerns over the potential of contaminated water due to the presence of unidentified industrial barrels left inside the lagoon.

No juvenile Chinook salmon were found inside the mouth of the lagoon. We found a density of 52 Chinook per hectare at the adjacent sites.

No other juvenile salmon were found inside the lagoon. They were present on the adjacent shoreline sites. The catch consisted of all age 0+ pink salmon. Results showed a density of 156 juvenile salmon per hectare at the adjacent sites.

No surf smelt were found inside the lagoon. They were present on the adjacent shoreline sites. Results showed a density of 2,431 smelt per hectare at the adjacent sites.



Figure 39. Priest Point sampling sites.

Race Lagoon (Saratoga Passage)

We sampled within Race Lagoon and along adjacent nearshore on April 14 2004 as part of the extensive sampling effort. The adjacent nearshore habitat was sampled using a beach seine. We made two consecutively placed sets along the eastern edge of Race Spit. The site is shown as a single point in Figure 40. To sample habitat within the lagoon, we made four beach seine sets inside Race Lagoon (Figure 40).

There were no juvenile Chinook salmon caught inside Race Lagoon or at Race Spit during the sampling in April 2004.

While no juvenile Chinook were captured at the Race Lagoon and Race Spit sites in 2004, many other juvenile salmon (mostly age 0+ chum and pink salmon) were captured. The sampling found an average of 859 juvenile salmon per hectare inside Race Lagoon and an average of 25,000 juvenile salmon per hectare at Race Spit.

There were not any surf smelt found at either Race Lagoon or Race Spit.



Figure 40. Race Lagoon sampling sites.

Scotts Point (Samish Bay)

We sampled at Scotts Point nearshore habitat and in Freestad Lagoon from February 22 through June 21, 2004. Sampling was done monthly as part of the intensive sampling effort. Three sets were made in Freestad Lagoon and at numerous locations along the adjacent shoreline. Each set is identified as a separate location in Figure 41. Freestad Lake, an artificial impoundment, forms the remaining pocket estuary habitat at Scotts Point. However, this habitat is not accessible to juvenile salmon, but it was beach seined to provide pre-restoration fish use data.

There were not any juvenile Chinook salmon found inside Freestad Lagoon. A few Chinook few found along the adjacent shoreline sites during March and April with a peak density in April of an average of 37 Chinook per hectare (Figure 42A).

There were not any other juvenile salmon found inside Freestad Lagoon. However, there were many juvenile salmon (mostly age 0+ chum and pink salmon) found along the adjacent shoreline sites during March through May. The results showed a peak density in April with an average of 2,292 juvenile salmon per hectare (Figure 42B).

There were not any surf smelt found inside Freestad Lagoon. However, there were a few surf smelt found along the adjacent shoreline sites during February and March (Figure 42C).

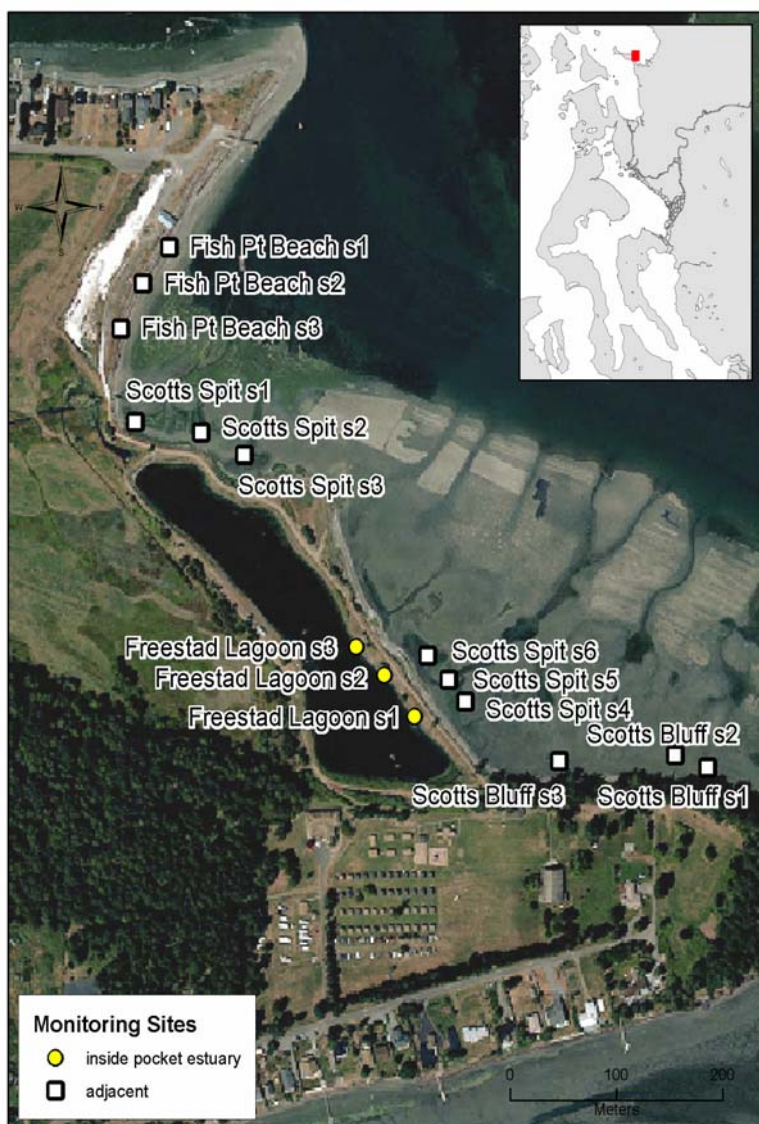


Figure 41. Scotts Point sampling sites.

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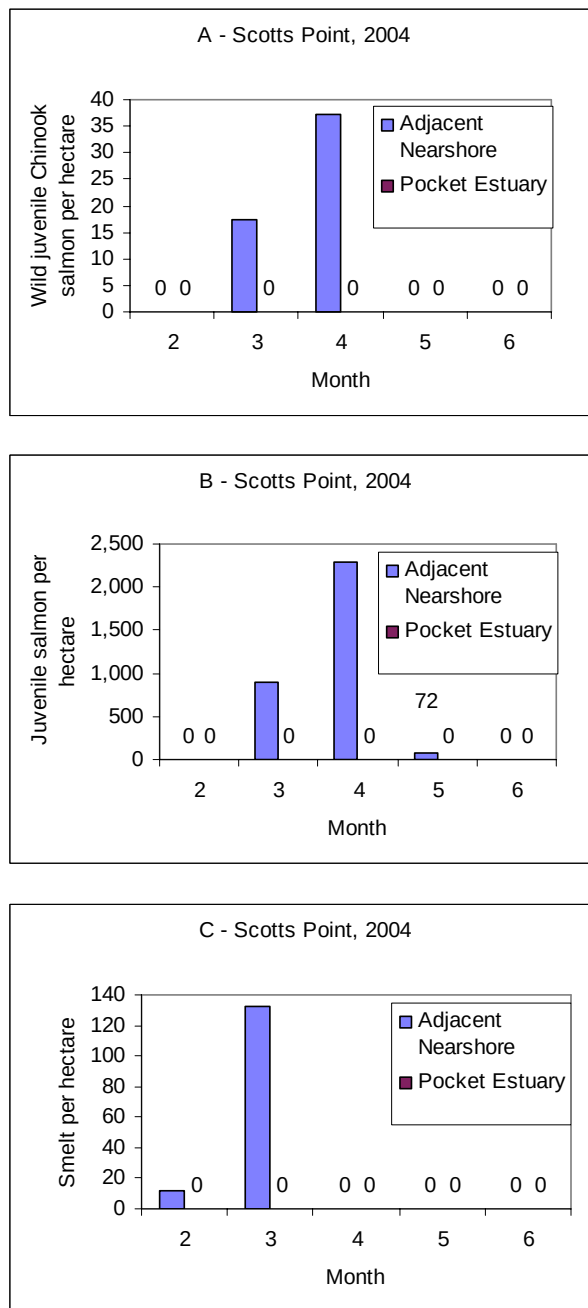


Figure 42. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Scotts Point nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Sunnyshore Acres (Port Susan)

We sampled the Sunnyshore Acres pocket estuary and its adjacent nearshore on April 19, and May 19, 2004 as part of the extensive sampling effort. We made three consecutively placed sets both within Sunnyshore Marsh and along the adjacent shoreline on the eastern edge of Sunnyshore Spit (Figure 43).

Juvenile Chinook salmon were found only during the sampling in May. There were twice as many Chinook found within Sunnyshore Marsh as there were along the Sunnyshore Spit. The results showed an average of 416 juvenile Chinook per hectare in Sunnyshore Marsh.

Juvenile salmon (mostly age0+ chum and pink salmon) were captured during both sampling events. During the sampling in April the results showed an average of 29,340 juvenile salmon per hectare on the spit compared to an average of 5,486 juvenile salmon per hectare within Sunnyshore Marsh. During the sampling in May the density of juvenile salmon was higher inside the lagoon (903 salmon per hectare) than along adjacent shoreline (234 salmon per hectare).



Figure 43. Sunnyshore Acres sampling sites.

Surf smelt were only found during the sampling in May when the results showed an average of 7,293 smelt per hectare in the marsh, compared to 69 smelt per hectare at the spit.

Swinomish Channel Old Bridge Blind

We sampled the artificial pocket estuary habitat of Swinomish Channel Old Bridge Blind and its adjacent nearshore habitat from January 15 through August 15, 2004 as part of the intensive sampling effort. We conducted bi-weekly sampling during this time period. The habitat within the blind channel was sampled with a fyke trap placed across the mouth at high tide and fished through the ebb tide. The adjacent nearshore habitat was sampled by making three consecutively placed beach seine sets on the beach to the north. The sites where beach seining or fyke trap sampling occurred within the pocket estuary or its adjacent nearshore habitat are shown in Figure 44.

Juvenile Chinook salmon were caught from February through May from inside the blind channel with a peak catch occurring in April and May when we found an average density of 130 Chinook salmon per hectare. At the same time there was an average of 93 Chinook per hectare in April and 17 Chinook per hectare in May at the adjacent shoreline sample site (Figure 45A). Juvenile Chinook were found along the adjacent shoreline during August but they were not found within the blind channel at that time.

Other juvenile salmon were caught from February through June from inside the blind channel with a peak catch occurring in April. Juvenile salmon were found along the adjacent shoreline site from March through May. The peak catch of other juvenile salmon (mostly age 0+



Figure 44. Swinomish Channel Old Bridge Blind Channel sampling sites.

chum and pink salmon) was found to be in April. The results indicate 3,704 salmon per hectare within the blind channel and 3,900 salmon per hectare along the adjacent shoreline (Figure 45B).

Surf smelt were found in the Old Bridge Blind Channel from January through May. Smelt were found at the adjacent shoreline site from February through August. During the time that the smelt were found both inside the blind channel and along the adjacent shoreline (January to May), we found that the density was consistently higher inside the blind channel compare to the adjacent shoreline site (Figure 45C).

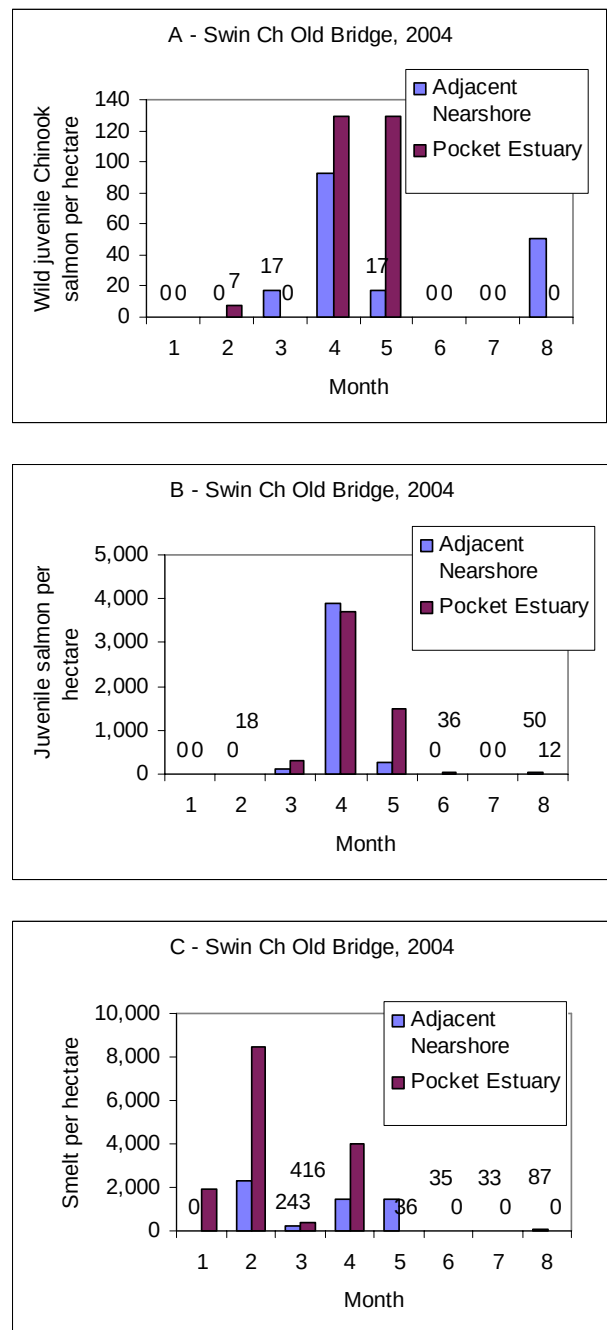


Figure 45. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) at Swinomish Channel Old Bridge and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Triangle Cove (Port Susan)

We sampled Triangle Cove and adjacent nearshore habitat from February 18 through July 19, 2004. The sampling was done once a month as part of the intensive sampling. Adjacent nearshore habitat was sampled using a beach seine. We made three consecutively placed sets along the shoreline of Triangle Spit and at a beach to the northeast at Barnum Point. Sampling was done once in February at the southern end of the spit at Triangle Spit South. Each site is shown as a single point in Figure 46. To sample habitat within the lagoon, we made single beach seine sets in the flats (Spartina Flats 1-3) and three consecutive sets at Barnum Beach and Triangle Point (each shown as a single point) on the eastern shoreline within Triangle Cove (Figure 46).

Juvenile Chinook salmon were found inside Triangle Cove from March through May and along the adjacent sites from April through June in 2004. The peak catch was in May when we found an average of 173 Chinook per hectare inside Triangle Cove and 309 Chinook per hectare at the adjacent sites. (Figure 47A) During April and May when we found Chinook both inside and outside of the pocket estuary, there were more Chinook found at the adjacent beaches than inside Triangle Cove (Figure 47A).

Other juvenile salmon (mostly age 0+ chum and pink salmon) were found inside Triangle Cove from March through May and along the adjacent sites from February through

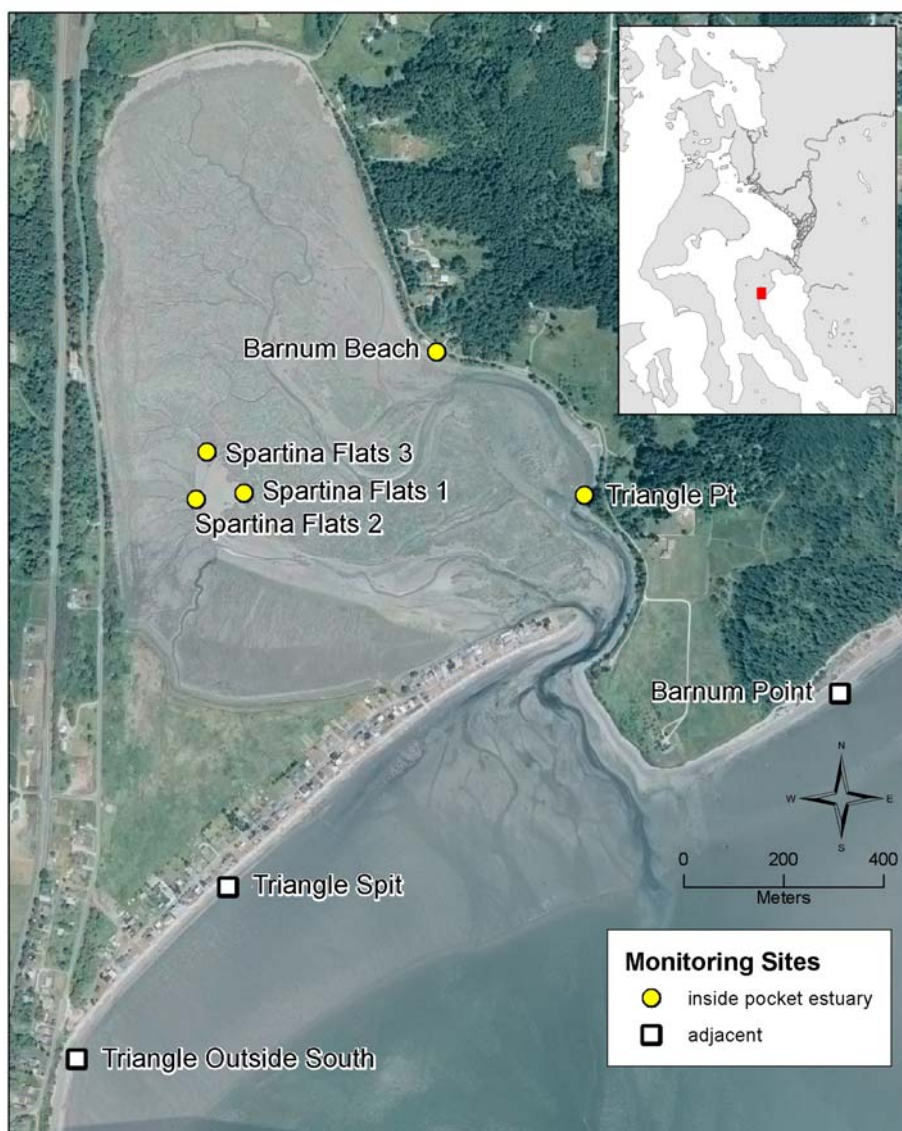


Figure 46. Triangle Cove sampling sites.

August in 2004 (Figure 47B). The peak catch of juvenile salmon was in April when we found an average of 4,411 juvenile salmon per hectare at the adjacent shoreline sites and 877 juvenile salmon per hectare inside Triangle Cove.

Surf smelt were found both inside Triangle Cove and its adjacent nearshore throughout the sampling period. During February through April we saw more smelt inside Triangle Cove than the adjacent sites, but during May through July we found more smelt at the adjacent sites than inside the pocket estuary (Figure 47C). The results showed that the peak density inside Triangle Cove was in March with an average of 1,968 smelt per hectare while at the same time there was an average of 69 smelt per hectare at the adjacent shorelines sites. Peak densities were found at the adjacent site during July when there was an average of 5,698 smelt per hectare while there were only an average of 104 smelt inside Triangle Cove (Figure 47C).

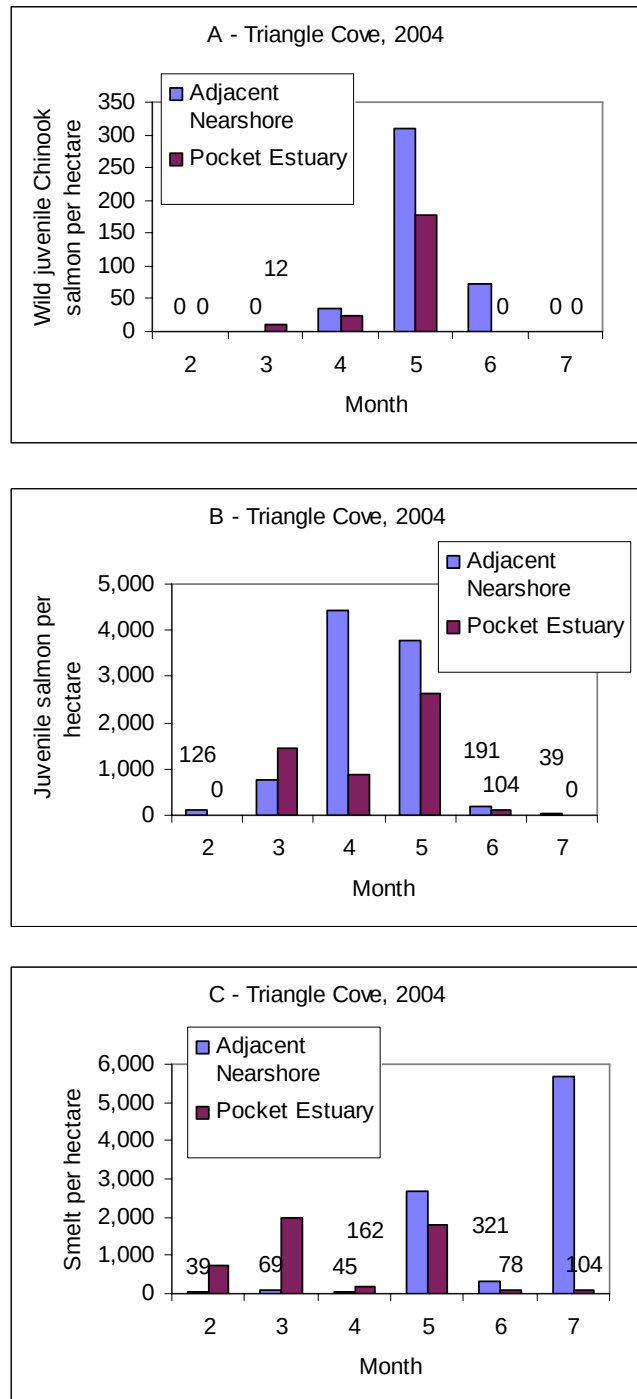


Figure 47. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Triangle Cove and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Tulalip Bay

We sampled Tulalip Bay and the adjacent nearshore habitat from March 26 through September 20, 2004. We made three consecutively placed beach seine sets along the shoreline at sites located both along the southern and northern beaches at the bay's entrance. Each site is shown as a single point in Figure 48. The adjacent nearshore habitat sites were not sampled in March. To sample habitat within Tulalip Bay, we made single beach seine sets along the perimeter of Tulalip Bay (Figure 48).

Tulalip Bay had an abundance of wild juvenile Chinook salmon during the sampling in March when there was an average of 1,752 Chinook per hectare (Figure 49A). The catch within Tulalip Bay during March was the highest catch of all the pocket estuaries sampled in 2004. Juvenile Chinook were found in Tulalip Bay through the remaining time period although in much fewer numbers. In July and August there were still Chinook salmon present within Tulalip Bay (Figure 49A). This is when other pocket estuaries consistently were not being used by Chinook salmon.

Juvenile salmon (mostly age 0+ chum and pink salmon) were also found in Tulalip Bay but in diminishing numbers from March until August (Figure 49B). The peak catch was in March at an average of 3,091 juvenile salmon per hectare.

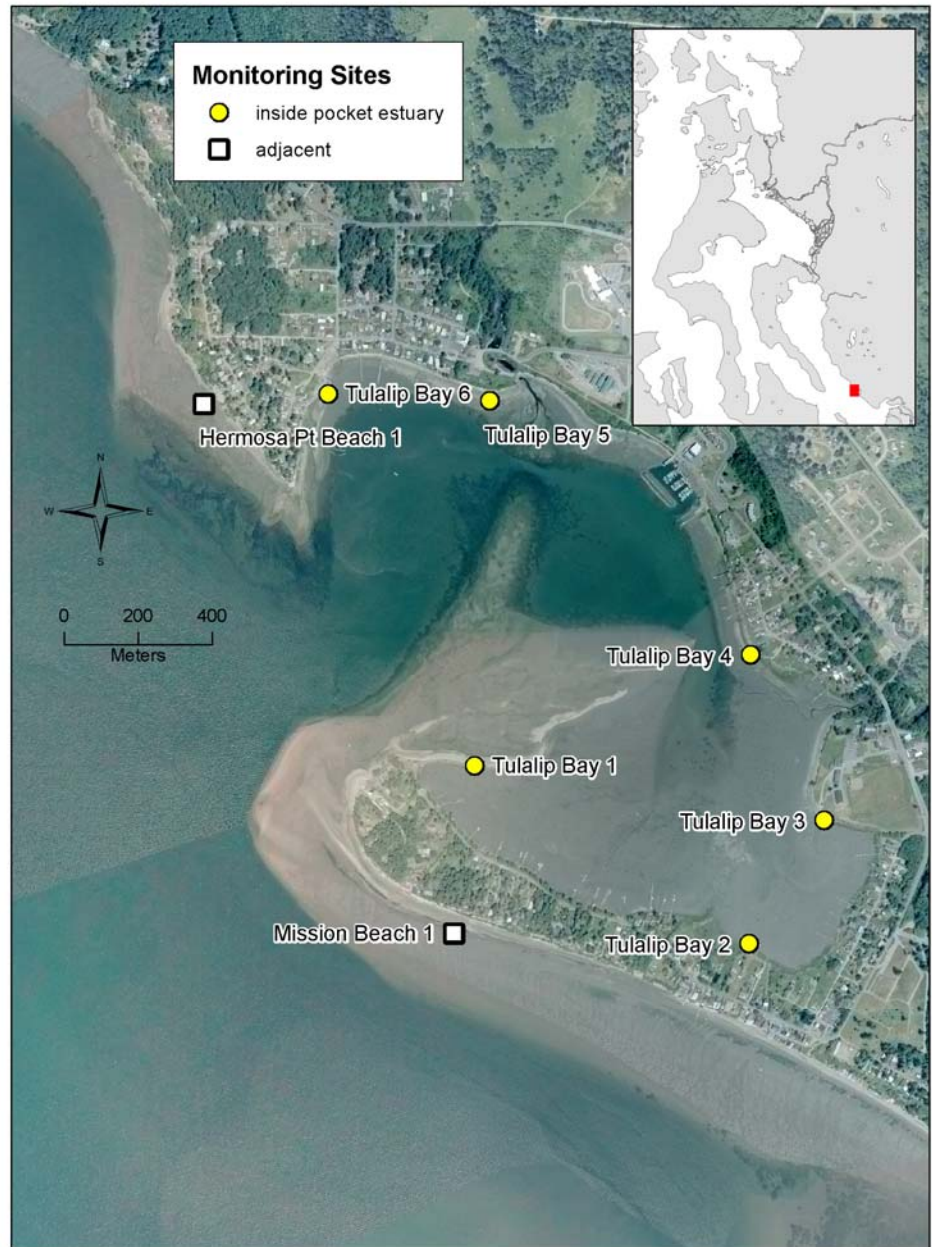


Figure 48. Tulalip Bay sampling sites.

Tulalip Bay has a salmon hatchery operated by the Tulalip Tribes. This hatchery releases a large number of Chinook salmon into Tulalip Bay each year. In 2004 the Chinook salmon release was 191,352 (coded wire tagged and adipose fin clipped) fish and 1,696,345 (adipose fin clipped only) fish. The fish were released on May 6, 2004. Sampling that occurred after the release of hatchery Chinook salmon did not find many hatchery fish. There were only four hatchery Chinook caught inside the pocket estuary and five caught at the adjacent shoreline sites. The hatchery fish were approximately 82 mm fork length when released, and fish this large might not occupy shallow nearshore waters. They might quickly swim to the offshore waters of Saratoga Passage, vacating Tulalip Bay; hence we would not detect them in our sampling effort. The sampling schedule might also have missed them as sampling was only once a month rather than more frequently.

Surf smelt were also found at this site from June through the end of sampling in September. During the sampling in September we found 6,948 smelt per hectare inside the bay and 1,354 per hectare at the adjacent shoreline sites (Figure 49C).

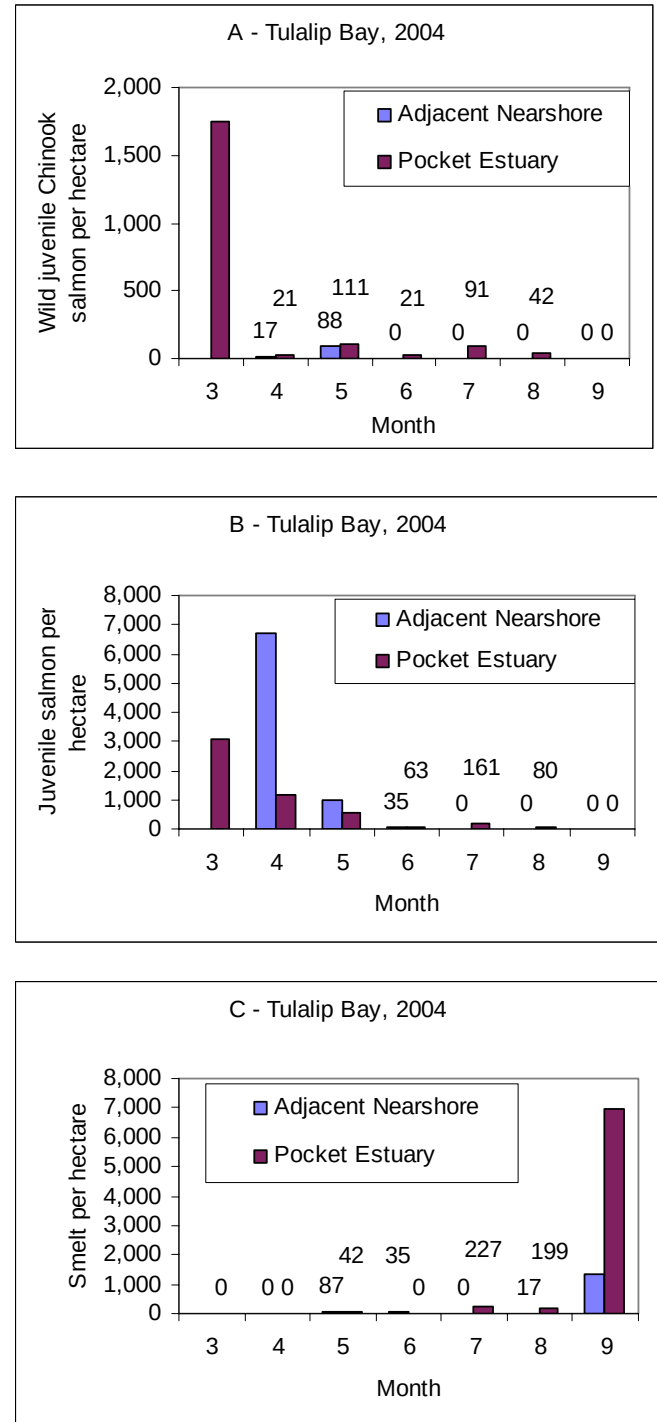


Figure 49. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Tulalip Bay and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible. We sampled only within Tulalip Bay during March.

Turners Bay (Skagit Bay)

We sampled Turners Bay and its adjacent nearshore habitat from January 16 through October 15, 2004 as part of the intensive sampling. We conducted bi-weekly sampling from February through May and then monthly from June until October. The adjacent nearshore habitat and the lagoon habitat were sampled by making three consecutively placed beach seine sets at each site shown in Figure 50. We sampled at two locations on the spit and at two locations within Turners Bay.

Juvenile Chinook salmon were found inside Turners Bay from February through May and then again in August. They were only found at the adjacent shoreline sites in April, May, and September. Peak Chinook densities inside Turners Bay were in May when there was an average of 61 juvenile Chinook per hectare while at the same time only an average of 9 juvenile Chinook per hectare at the adjacent shoreline sites (Figure 51A).

Juvenile salmon (mostly age 0+ chum and pink salmon) were found from February through June and then again in August inside Turners Bay. They were found from March through June and then again in September at the adjacent shoreline sites. The results showed the peak in March when there was an average of 2,105 juvenile salmon per hectare inside Turners Bay and an average of 1,407 juvenile salmon at the adjacent sites (Figure 51B).

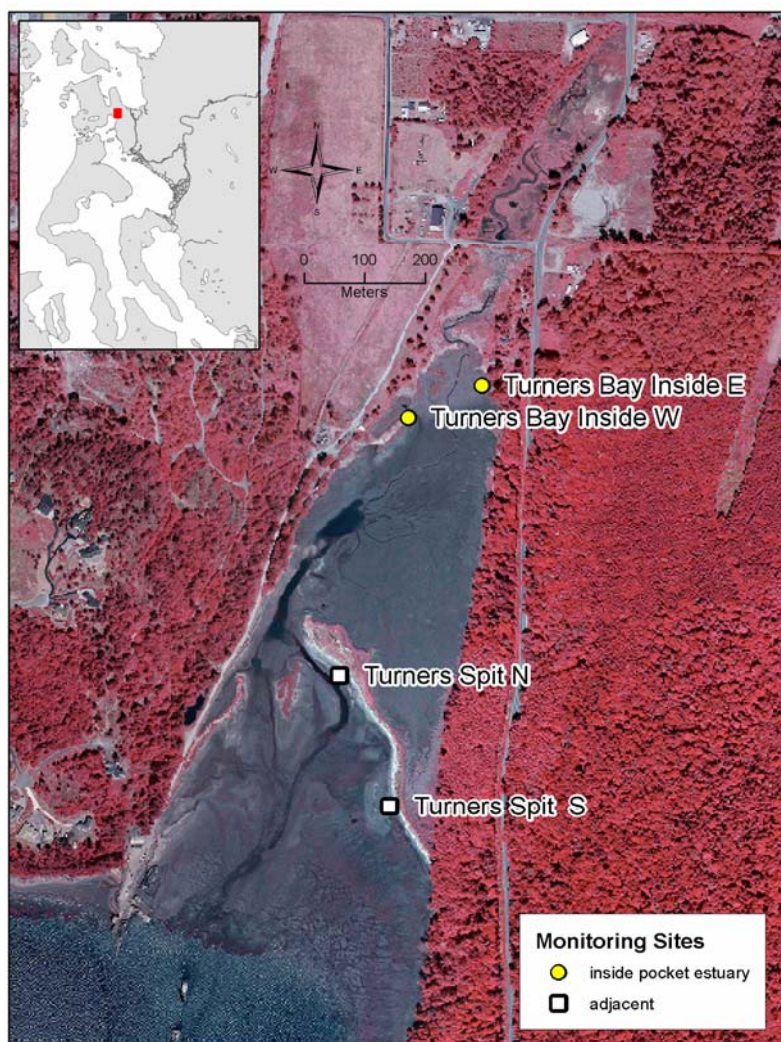


Figure 50. Turners Bay sampling sites.

Surf smelt were found both inside Turners Bay and at Turners Spit during most of the sampling period. There were two peak catch period during 2004. One occurred in February where we saw an average of 4,572 smelt per hectare inside Turners Bay and 506 smelt per hectare at Turners Spit. The other was in September when we saw an average of 2,139 smelt per hectare in Turners Bay and an average of 694 smelt per hectare at Turners Spit (Figure 51C).

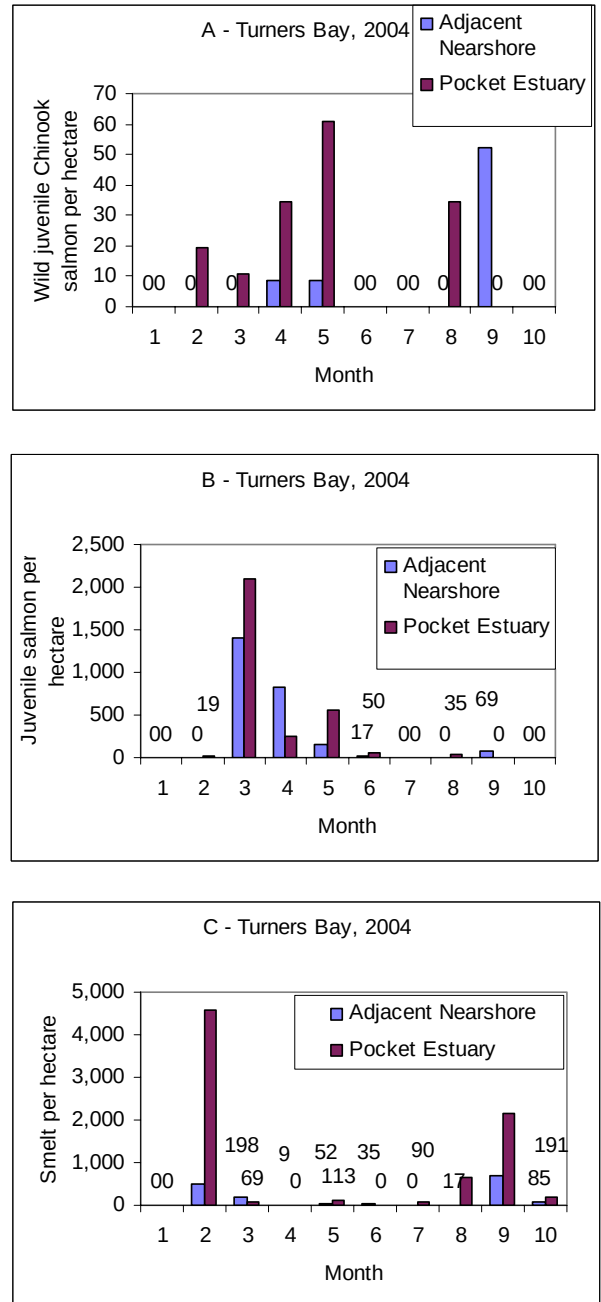


Figure 51. Average monthly density of wild juvenile Chinook salmon (A), all juvenile salmon (B), and surf smelt (C) in Turners Bay and adjacent nearshore habitat. Average densities (fish/ha) are shown above bars when not easily visible as graphed. No sampling occurred in months where no bar or value is visible.

Wild Juvenile Chinook Salmon

Density of Chinook Salmon in Pocket Estuary and Adjacent Nearshore Habitats

The idea that Chinook salmon fry prefer pocket estuary habitat is based on observations of significantly higher wild juvenile Chinook salmon densities found in pocket estuary habitat compared to adjacent nearshore habitat (Beamer et al. 2003). This pattern of Chinook salmon use for pocket estuary habitat was true for late winter and early spring months in Skagit Bay in 2002. The number of sites and years investigated were limited and therefore the results of the Beamer et al. (2003) study might not be true for other pocket estuaries, especially if they are distant from the mouth of the Skagit River, which was thought to be the source of Chinook salmon fry using pocket estuary habitat in Skagit Bay.

A main purpose of this NWSC study was to test the idea that juvenile Chinook salmon prefer pocket estuary habitat using a data set from many pocket estuaries over a larger geographic area than Skagit Bay (i.e., the Whidbey Basin, Fidalgo Bay, Padilla Bay, and Samish Bay). In order to test this hypothesis, we examined whether there are significantly higher wild juvenile Chinook salmon densities in pocket estuary habitat compared to adjacent nearshore habitat during the months from February through May. We used a paired T test approach, where Chinook salmon densities were paired by habitat type: “pocket estuary” or “adjacent nearshore”. We summarized catch data from individual pocket estuary sites by month where sampling occurred both within pocket estuary habitat and adjacent nearshore during that month. We analyzed data from only four months (February through May) because this is the time period we hypothesize juvenile Chinook density is higher in pocket estuary habitat than adjacent nearshore. We ignored “site” as a second variable because we lacked sufficient sampling effort at each site to reasonably use analysis of variance methods. Because the 2004 Chinook salmon outmigration was uncharacteristically small, the co-authors decided to sample most of the intensively monitored sites from 2004 again in 2005. Paired T-tests were done for both years, 2004 and 2005, using untransformed and log transformed data.

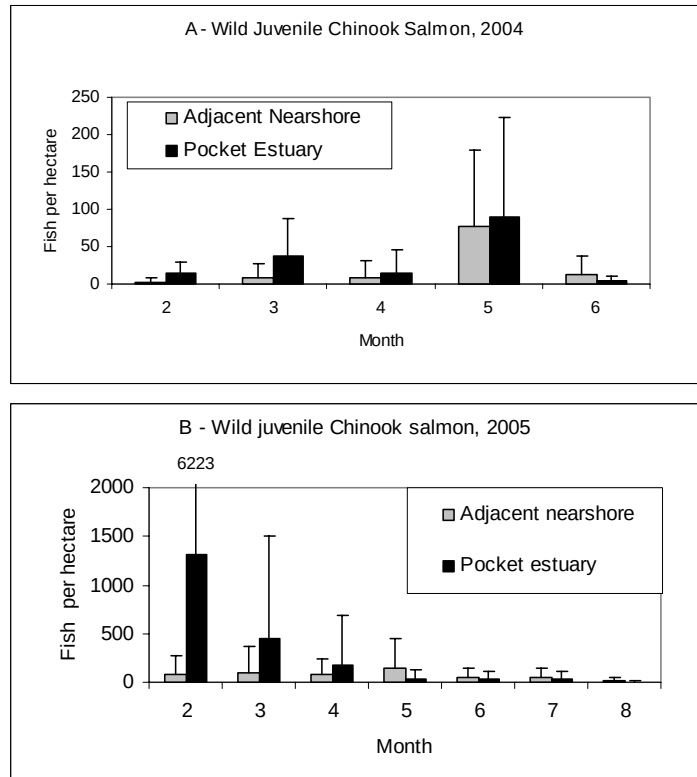


Figure 52. Average wild subyearling Chinook density in pocket estuary and adjacent nearshore habitat for (A) 2004 and (B) 2005. All pocket estuaries were combined for each year. We combined data from 19 sites sampled in 2004 that had both salmon-accessible pocket estuary habitat and adjacent nearshore. In 2005 we combined data from 9 sites that had both salmon-accessible pocket estuary habitat and adjacent nearshore. Error bars are 1 standard deviation.

Results from sampling done in 2004 were drawn from 19 different pocket estuary sites found throughout the Whidbey Basin and north Skagit County bays. At these sites wild juvenile Chinook salmon density was, on average, 52% higher in pocket estuary habitat than adjacent nearshore habitat for the February through May time period (Figure 52A). Average Chinook salmon density in pocket estuary and nearshore was 35.3 and 23.3 fish/ha respectively for the 2004 season. However, statistical results were not significant at the commonly used alpha level of 0.05 ($p = 0.11$ for untransformed data; $p = 0.07$ for log transformed data; $n = 44$).

Results from sampling done in 2005 were drawn from nine different pocket estuary sites found throughout the Whidbey Basin. We did not sample sites in Fidalgo Bay, Padilla Bay, and Samish Bay this year. At sampled sites wild juvenile Chinook salmon density was, on average, over five times higher in pocket estuary habitat than in adjacent nearshore habitat for the February through May time period (Figure 52B). Average Chinook salmon density in pocket estuary and nearshore was 519.0 and 101.5 fish/ha respectively for the 2005 season. Statistical results were significant at the commonly used alpha level of 0.05 ($p = 0.045$ for untransformed data; $p = 0.029$ for log transformed data; $n = 36$).

We also found the pattern of higher juvenile Chinook salmon densities in pocket estuary habitat early in the year to be consistent at the site level. In 2004, five of eight intensively monitored sites showed fish use patterns consistent with our hypothesis (Figure 53). In 2005, eight of nine intensively monitored sites showed the consistent pattern (Figure 54). Although juvenile Chinook were documented in the catch at Grassers Lagoon both in 2004 and 2005, the site does not show the typical pattern of higher Chinook salmon densities in either year. It might be that Grassers Lagoon is not well connected to the migration pathways that Chinook fry use early in the year to travel through nearshore habitats.

The results from both years of this study are consistent with the pattern of Chinook salmon use described in Beamer et al. (2003). While the results shown in Beamer et al. (2003) directly relate to Skagit Bay and Skagit-origin Chinook salmon, they may not infer the true importance of the pocket estuaries in a larger spatial and ecological setting. These results provide strong evidence that juvenile Chinook salmon accumulate in pocket estuary habitat in areas beyond the Skagit River. We provide two years of evidence for multiple sites throughout the Whidbey Basin.

We also observed juvenile Chinook salmon density in both nearshore and pocket estuary habitat was much higher in 2005 than 2004 (Figure 52). This year-to-year pattern was also consistent at the site level (Figures 53 and 54). Moreover, some consistent site level differences in Chinook density appear to exist. For example, Chinook densities over the season were highest in Lone Tree Lagoon for both years (Figure 53C and 54D). The yearly and site variability in Chinook salmon density we observed in this study might be explained, at least partially, by differences in Chinook salmon smolt population size for each natal river contributing fish to pocket estuaries and the pocket estuary's spatial context with these river mouths. We suggest this because juvenile Chinook salmon use of pocket estuaries is described as "non-natal" use--juvenile Chinook salmon do not originate from the watersheds draining into the pocket estuaries, they must find them via migration pathways from their natal rivers, through an estuarine/marine environment, and then into the habitat of a pocket estuary. Different 'source' population sizes

within the marine basin could impact the distribution of individuals in discontinuous pocket estuary habitat.

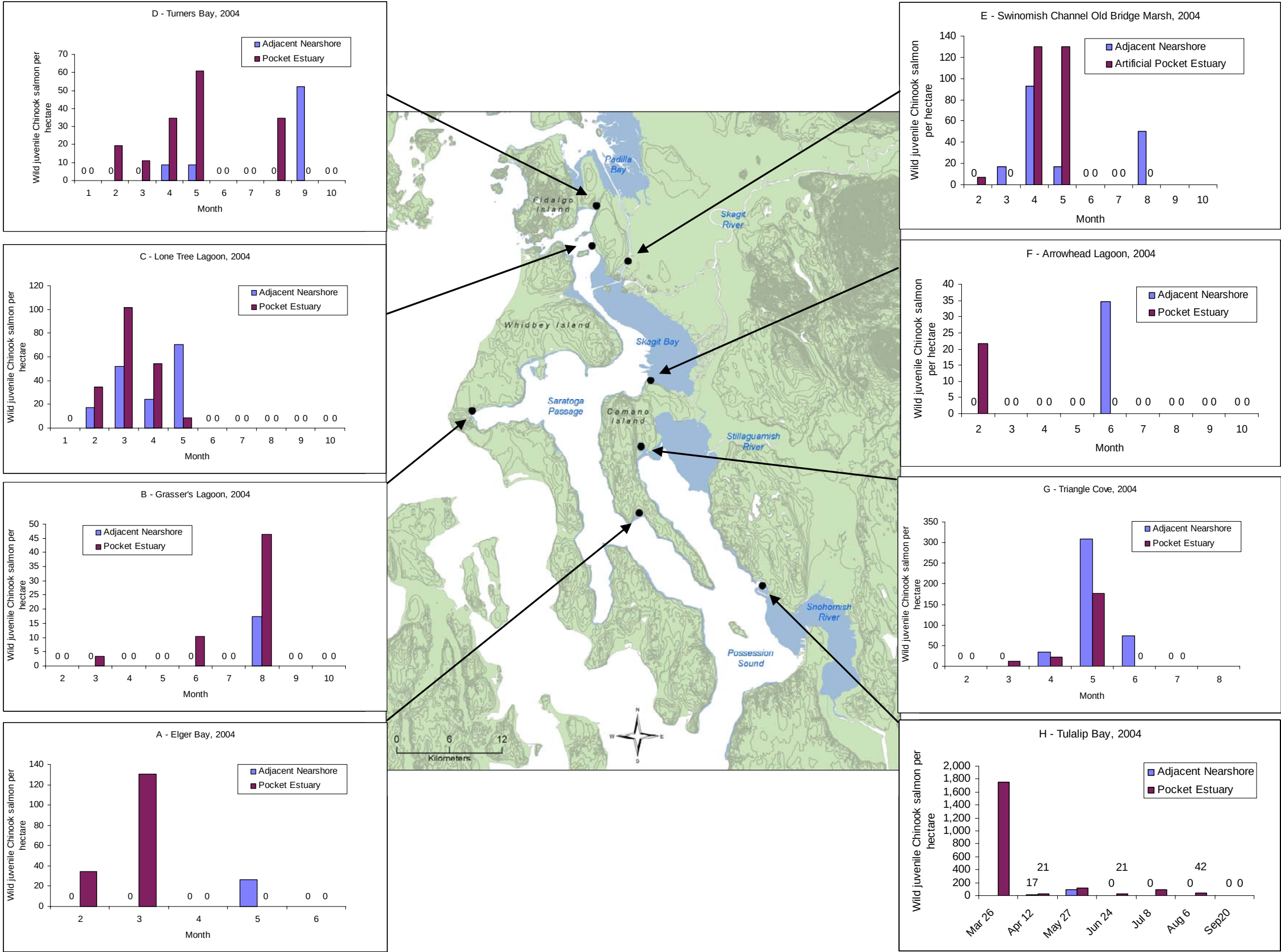


Figure 53 Monthly Chinook salmon density for nine intensively monitored pocket estuary sites located within the Whidbey Basin, 2004.

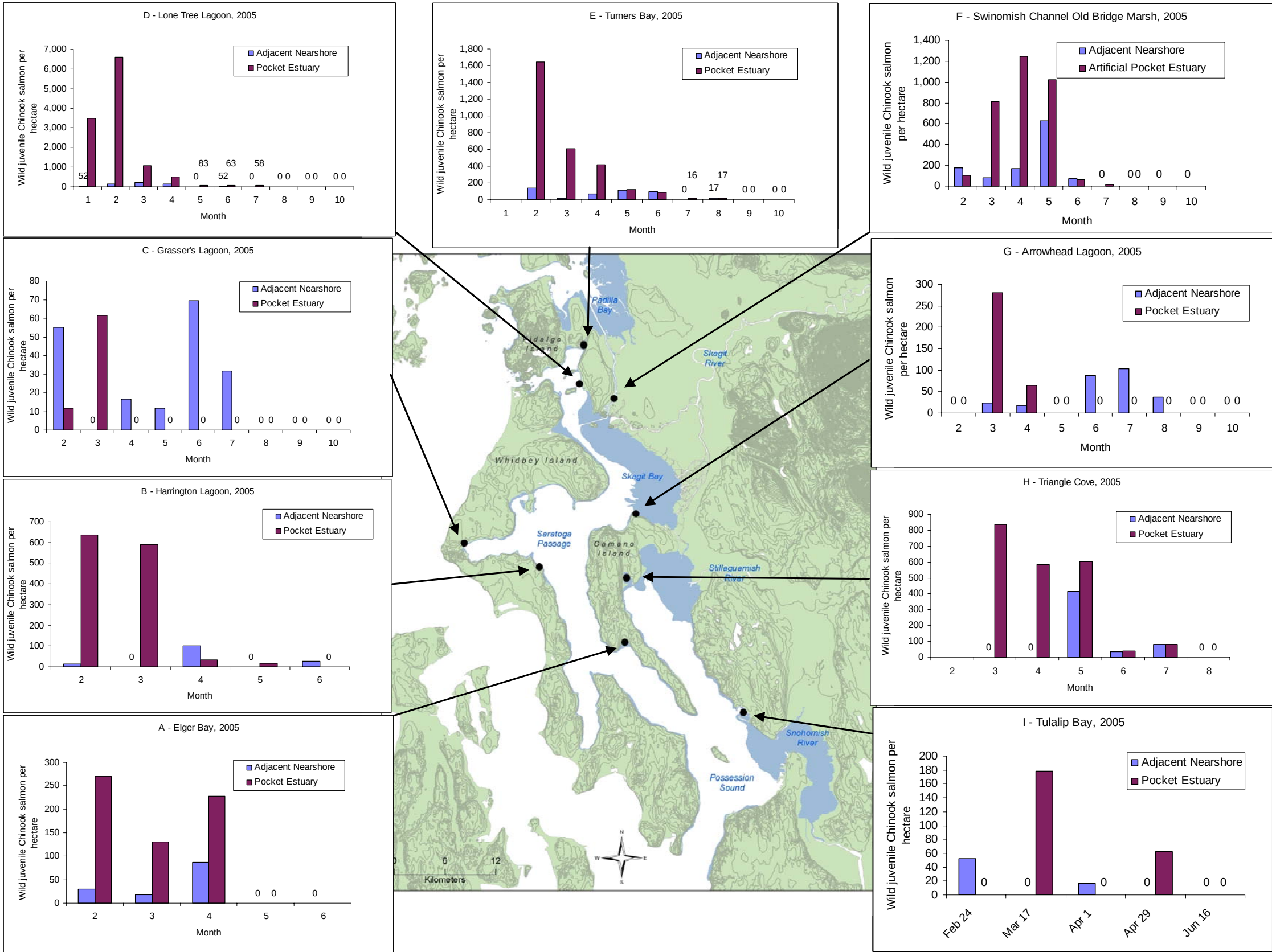


Figure 54 Monthly Chinook salmon density for nine intensively monitored pocket estuary sites located within the Whidbey Basin, 2005.

Influence of Freshwater Smolt Outmigration Population Size on Pocket Estuary Use

In the previous section, we found that juvenile Chinook salmon density in both nearshore and pocket estuary habitat was much higher in 2005 than in 2004 (Figure 52). The 2004/2005 difference in juvenile Chinook salmon density was also consistent at the site level for eight sites (Figures 53 and 54). In this section we examine the likelihood that the difference between years was caused by the fact that many more juvenile Chinook were present in 2005 than in 2004.

Juvenile Chinook salmon smolt populations have been estimated for both the Skagit and Stillaguamish River systems. The wild Skagit Chinook freshwater smolt outmigration estimate for 2004 was 1.5 million fish. In 2005 the wild Skagit Chinook freshwater smolt outmigration was estimated to be 3.0 to 5.25 million (personal communication with G. Volkhardt, WDFW, 2005). The wild Stillaguamish Chinook freshwater smolt outmigration estimate was 88,000 in 2004 and 300,000 in 2005 (personal communication with J. Griffith, Stillaguamish Tribe, 2005).

To further test the influence of Chinook smolt population size on pocket estuary fish use, we examined pocket estuary fish density results at sites that are logically linked in space to specific Chinook salmon source populations (e.g., Skagit or Stillaguamish) where we have multiple years of data. For this analysis we plotted the seasonal density (as fishday per hectare) of wild juvenile Chinook salmon found in five different pocket estuaries by the wild Chinook salmon freshwater smolt outmigration estimate. Seasonal density is estimated by multiplying the average wild juvenile Chinook density from catch sampling for each month by the number of days in each month. The period used to calculate seasonal density of juvenile Chinook salmon is February through May, based on results shown in Figures 53 and 54 as well as in Beamer et al. (2003). We used four pocket estuary sites in Skagit Bay where we have data for up to four years (2002 – 2005) and one site in Port Susan at which we have data for 2004 and 2005 (Figure 55). The Skagit Bay sites are assumed to be primarily occupied by Skagit River origin Chinook salmon, due to their close proximity to the Skagit River. The Port Susan site is assumed to be primarily occupied by Stillaguamish River origin Chinook salmon. Chinook smolt population estimates were from G. Volkhardt, WDFW, for the Skagit River; and J. Griffith, Stillaguamish Tribe, for the Stillaguamish River.

We observe a positive correlation at all five sites between wild Chinook salmon freshwater smolt population size and the seasonal density of wild juvenile Chinook salmon in pocket estuaries (Figure 55). Clearly, the number of juvenile Chinook salmon migrating out of their natal river system will influence the number of fish found in pocket estuary habitat. This analysis also shows us how poor the Chinook outmigration was in 2004 compared to several other years for which we have both outmigration and pocket estuary data. However, even with the low population size in 2004, we still observed evidence of higher densities of Chinook salmon in pocket estuaries during the late winter to early spring period than in adjacent nearshore habitat, suggesting there is a true preference for this habitat by juvenile Chinook salmon early in the year.

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

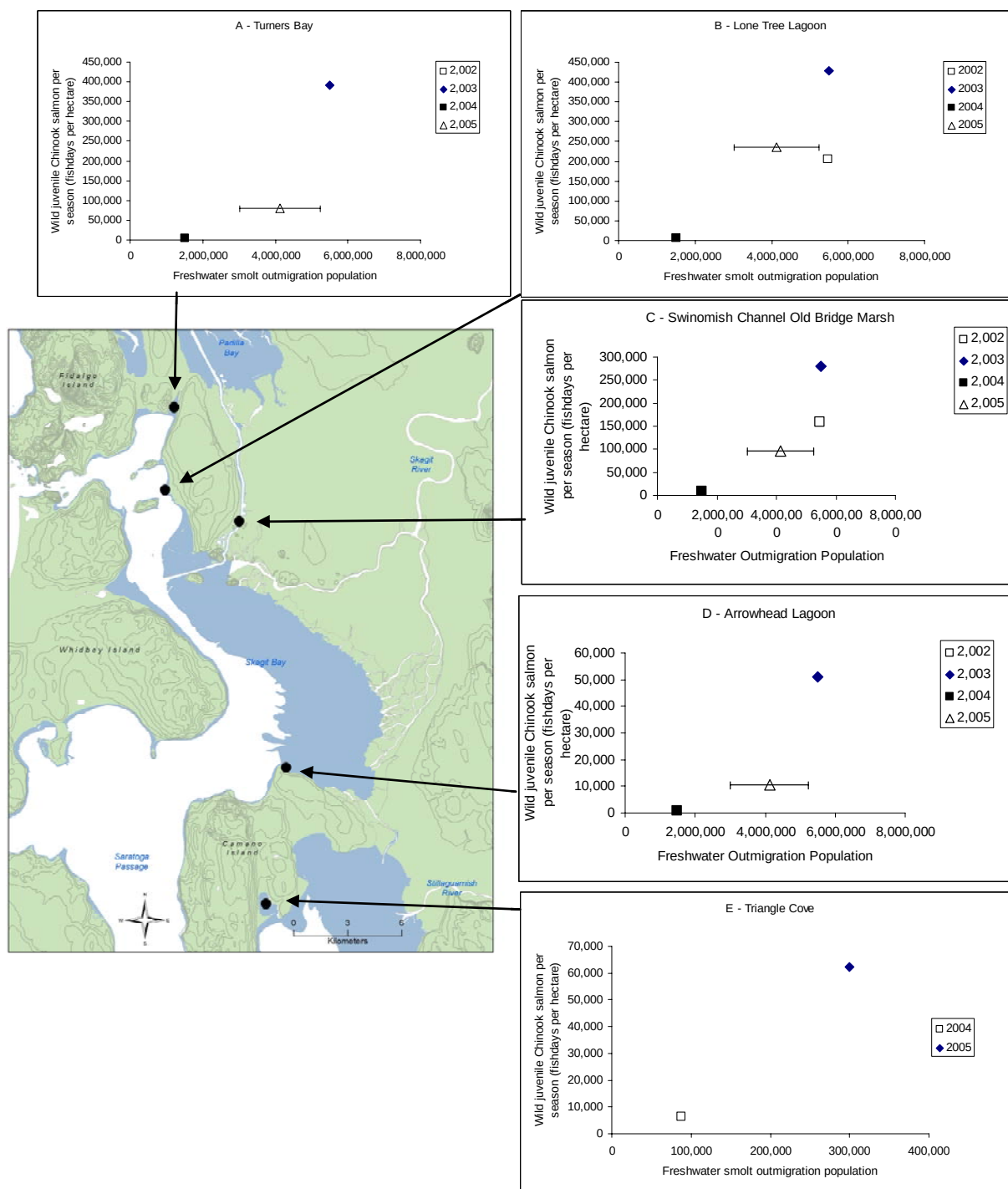


Figure 55. Relationship between juvenile Chinook salmon density in pocket estuary habitat and freshwater smolt outmigration population size. We show results for five pocket estuaries: (A) Turners Bay, (B) Lone Tree Lagoon, (C) Swinomish Channel Old Bridge Blind, (D) Arrowhead Lagoon, and (E) Triangle Cove. These sites are in close proximity to either the Skagit or Stillaguamish River mouths. Each site also has data from more than one year. Turners Bay and Arrowhead Lagoon were not sampled in 2002. Triangle Cove was not sampled before 2004.

Influence of Landscape Connectivity on Pocket Estuary Use

Differences in juvenile Chinook salmon use between pocket estuaries throughout the Whidbey Basin might also be related the spatial arrangement of habitat, including:

- its size and shape
- the location of the habitat within the nearshore basin
- the composition of surrounding habitat
- connectivity with other habitats

Within the delta and nearshore ecosystems of the Skagit River, Beamer et al (2005) explicitly 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 was defined as a function of both the length and 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).

We hypothesize that differences in habitat connectivity should influence Chinook salmon density in pocket estuaries at the scale of Whidbey Basin. We tested this hypothesis using two different variables: (1) distance to the nearest river mouth and (2) a landscape connectivity index variable defined in Beamer et al. (2005)--based on distance along tidal current vectors as approximated by drift buoys. The measure of landscape connectivity using distance to the nearest river mouth does not reflect the true migratory pathways of juvenile Chinook salmon in the Whidbey Basin. Though distance from river mouths is a good first cut at estimating landscape connectivity, it does not account for the strength and trajectory of tidal currents that likely determine where and when small salmon fry move in Whidbey Basin. For example, Grassers Lagoon is closer to the Skagit River Delta than corridor sites like Harrington Lagoon and Elger Bay, yet Grassers Lagoon had lower fish densities than these corridor sites during both 2004 and 2005 (Harrington Lagoon was intensively monitored only during 2005) (Figures 53 and 54). It is likely that tidal current vectors from the Skagit or Stillaguamish Rivers do not reach Grassers Lagoon--located at the far western end of Penn Cove--as strongly as they do sites in Saratoga Passage. Though the connectivity index for the Skagit River nearshore includes data from drift trials and is more realistic, it does not account for varying tidal changes or river discharges that would affect the strength and direction of tidal currents and thus fish pathways.

For our intensively monitored pocket estuary sites within the Whidbey Basin, in both 2004 and 2005 we found that distance from nearest Chinook salmon bearing river mouth was negatively correlated with the seasonal density of juvenile Chinook salmon within pocket estuaries throughout the Whidbey Basin (Figures 55A and 55B). These results represent sites over a 530 km² spatial scale, associated with multiple rivers (not just the Skagit), and include two to three “migratory corridor” sites. Migratory corridor sites are pocket estuaries not closely associated with any specific river—being roughly equidistance from two or more natal rivers. Grassers Lagoon, Harrington Lagoon, and Elger Bay are considered corridor sites. Though the R² value for these regressions is low, the general trend is apparent, suggesting that connectivity to natal rivers is important for pocket estuary salmon ecology.

For Skagit Bay pocket estuaries we used the Beamer et al. (2005) Connectivity Index based on delta distributary bifurcation order and distance fish must travel to find habitat. We determined distances from one set of drift trials for each of the major distributaries of the Skagit Delta. Because of the equation’s form, in this case the connectivity index should be positively correlated with seasonal Chinook density if landscape connectivity is, in fact, important to juvenile Chinook salmon. All Skagit graphs (C-E) do show positive correlations with landscape connectivity. Figure 55D shows a very strong positive correlation between landscape connectivity and the seasonal density of juvenile Chinook using four pocket estuaries in Skagit Bay. This makes sense because 2004 was the lowest smolt outmigration year (much less than the Skagit delta’s Chinook salmon rearing capacity); therefore the physical impediments related to how easily fish find available habitat would control population distribution patterns more than overcrowding pressures because delta habitats were not filled to capacity, forcing outmigrants to take refuge in pocket estuaries. If delta habitats were not limiting Chinook salmon in 2004, then differences in migration pathways (reflected in our measurement of connectivity) should explain more variation in how many fish use a pocket estuary site.

Together, our analyses present evidence that landscape connectivity does matter in the Whidbey Basin. More study is needed to quantify how fish move within the Whidbey Basin, especially after they have exited natal river estuaries. More drift buoy trials and hydrodynamic models for the Whidbey Basin can help us quantify landscape connectivity for ‘corridor’ sites not immediately adjacent to natal river mouths.

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

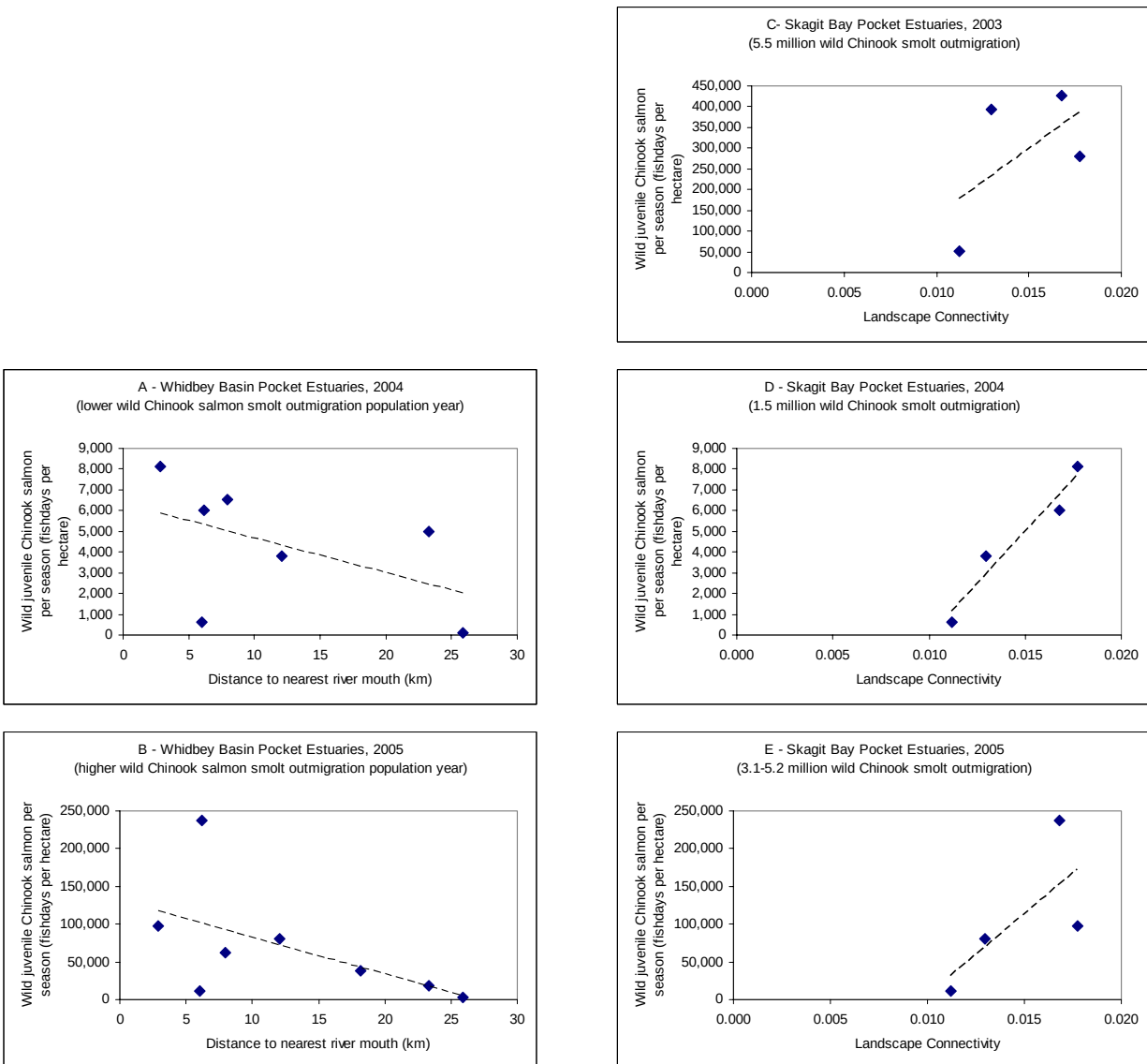


Figure 56. *Landscape connectivity and Chinook salmon use of pocket estuaries.* As distance to the nearest river mouth increases, fish use (as fishdays per hectare) decreases (A and B). Though the general trend holds, more data are needed to tighten up this correlation. Landscape connectivity for the Skagit River, measured as a connectivity index from Beamer et al. (2005), correlates positively with fish use (C, D, and E).

Fork Length

Beamer et al. (2003) reported that juvenile Chinook salmon start out similar sized in February, but for the rearing period before May, juvenile Chinook salmon in the shallow pocket estuary habitat averaged 4-6 mm longer than juvenile Chinook salmon from nearshore sites immediately adjacent to the pocket estuary. The increased size of juvenile Chinook salmon in pocket estuaries compared to fish found outside pocket estuaries suggests that productivity of pocket estuary systems may be greater than adjacent nearshore areas in winter and early spring. These systems are also somewhat warmer at this time of year than surrounding nearshore waters. If this productivity hypothesis is true, pocket estuary habitats may provide the “best” feeding area available within the nearshore landscape to the fish at this time of the year and allow fish to outgrow their potential predator population as rapidly as possible.

For this NWSC study we intended to investigate whether juvenile Chinook salmon in pocket estuaries were larger than fish found outside pocket estuaries at a larger scale: for sites throughout the Whidbey Basin. However, Chinook salmon catches were limited in 2004, so we lack the data to even make meaningful monthly comparisons for length data from all monitored sites combined –except for the month of May, where there is no significant difference between the two habitats (Figure 57). It is possible that sufficient data were collected at the 9 sites shown in Figure 54 during 2005, but it is outside the scope of work for this report to analyze these data.

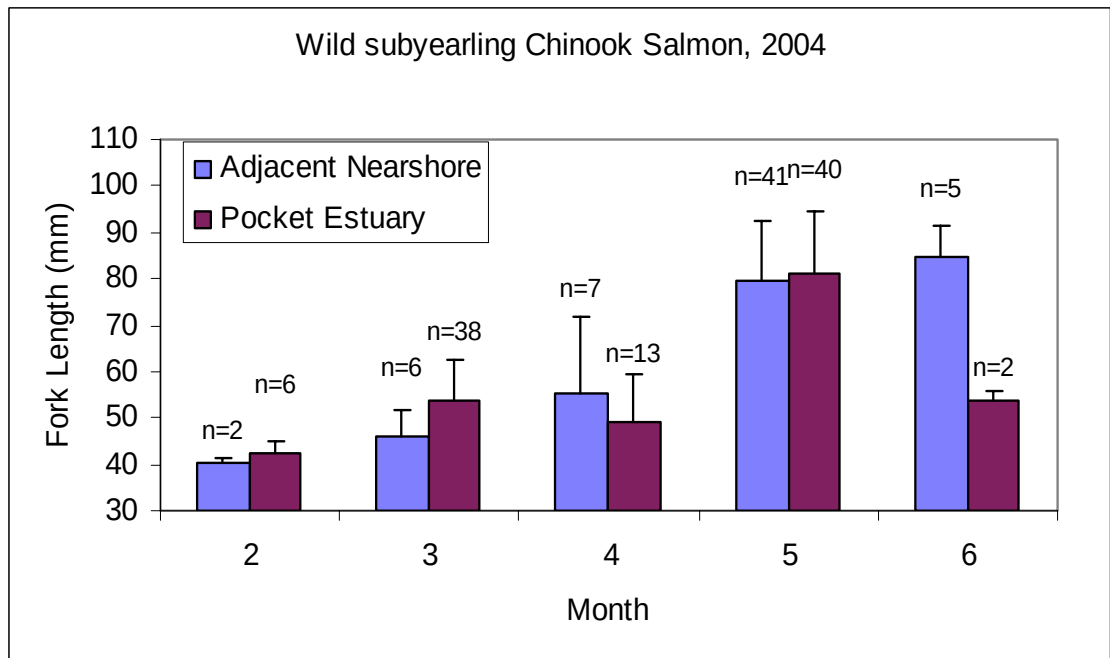


Figure 57. Monthly average fork length of wild sub-yearling Chinook salmon caught in pocket estuary and adjacent nearshore sites in 2004. The number of fish lengths averaged are shown over the bars. Error bars are 1 standard deviation.

All Juvenile Salmon Combined

Beach seining and fyke trapping caught 17,710 juvenile salmon in 2004. Chinook, chum, and pink salmon accounted for over 99% of the catch. The same percentage (>99%) was true for the 11,453 juvenile salmon caught in 2005. Figure 58 shows the monthly composition of juvenile Chinook, chum and pink salmon in both years (2004 and 2005) for pocket estuary and adjacent nearshore habitat. We have already shown the differential use of Chinook salmon by habitat type in earlier sections of this report, but this figure shows that both juvenile chum and pink salmon utilize pocket estuary habitat. While both chum and pink salmon are caught in pocket estuary habitat, they were not found in higher densities than in adjacent nearshore habitat. Also pink salmon were present in both years of sampling even though Puget Sound rivers are dominated by odd year spawning populations.

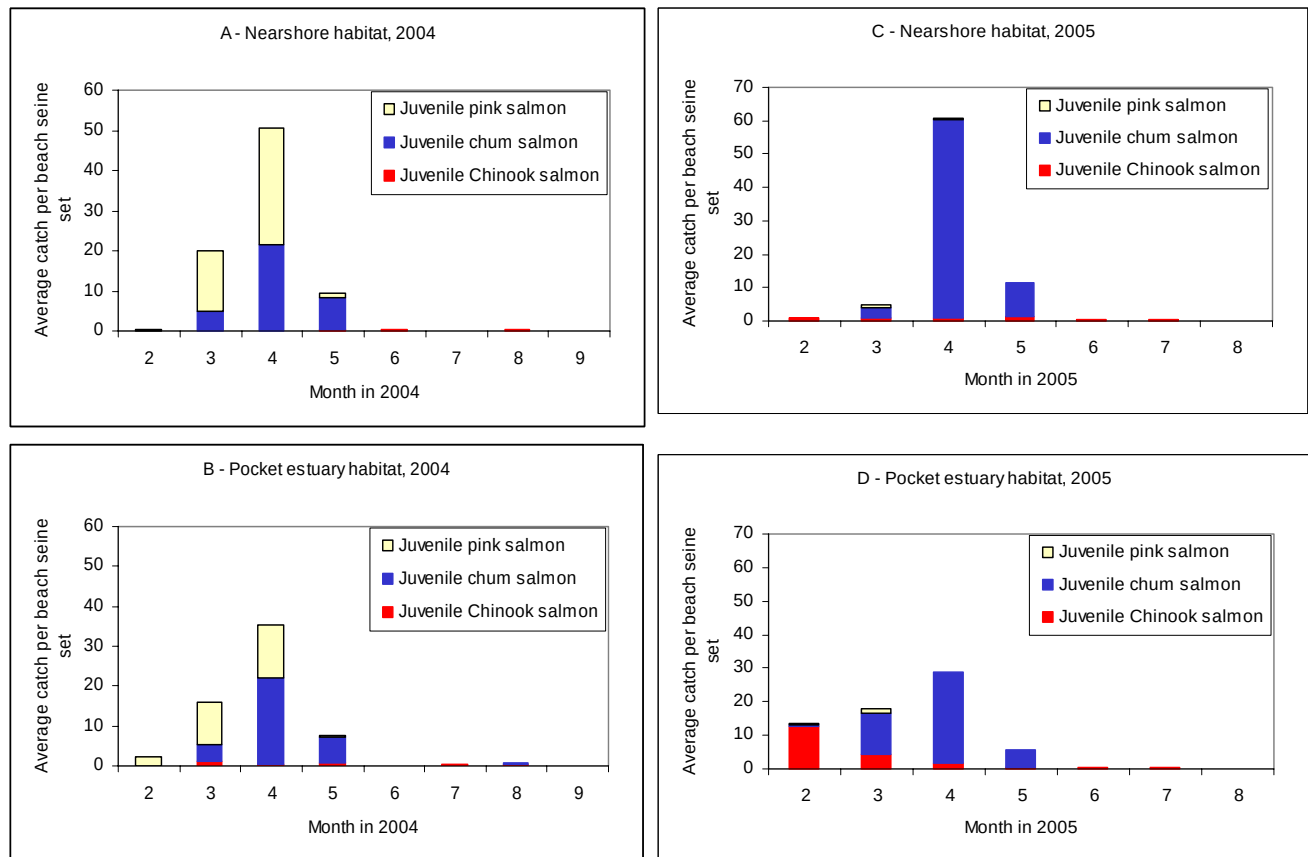


Figure 58. Stacked bar chart of monthly average catches of juvenile salmon in (A) pocket estuary in 2004 (B) adjacent nearshore habitat in 2004, (C) pocket estuary in 2005, and (D) adjacent nearshore habitat in 2005. In this analysis we used only months where we had over 30 beach seine sets to average for each strata: adjacent nearshore and pocket estuary.

Surf Smelt

Large numbers of surf smelt were caught at many pocket estuaries and in their adjacent nearshore habitat in 2004. The monthly pattern of surf smelt density by habitat type is shown in Figure 59. The monthly length frequency of surf smelt is shown in Figure 60. Only juvenile surf smelt were found in pocket estuary habitat, suggesting that pocket estuaries may serve a “nursery” function for surf smelt. Adult surf smelt were only caught in adjacent nearshore habitat and only during the summer spawning period. This fact is revealed in the length frequency data where larger surf smelt (>120 mm fork length) were only present in adjacent nearshore habitat during July through September (Figure 60). There is little to no spawning by surf smelt within the pocket estuaries we sampled, so the juveniles must either swim or drift with the tidal currents into the pocket estuary areas. Some pocket estuaries likely had significant spawning by surf smelt on adjacent spit beaches.

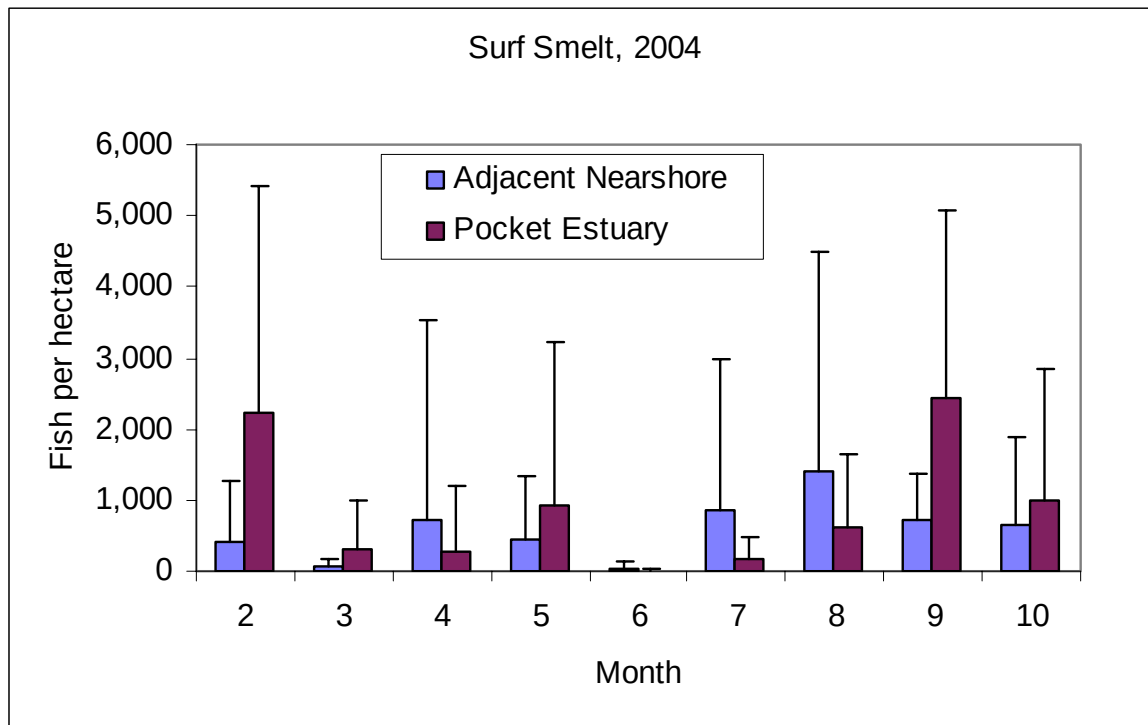


Figure 59. Monthly average density of surf smelt in pocket estuary and adjacent nearshore areas in 2004. Error bars are 1 standard deviation.

HABITAT AND FISH USE OF POCKET ESTUARIES IN THE WHIDBEY BASIN AND NORTH SKAGIT COUNTY BAYS, 2004 AND 2005

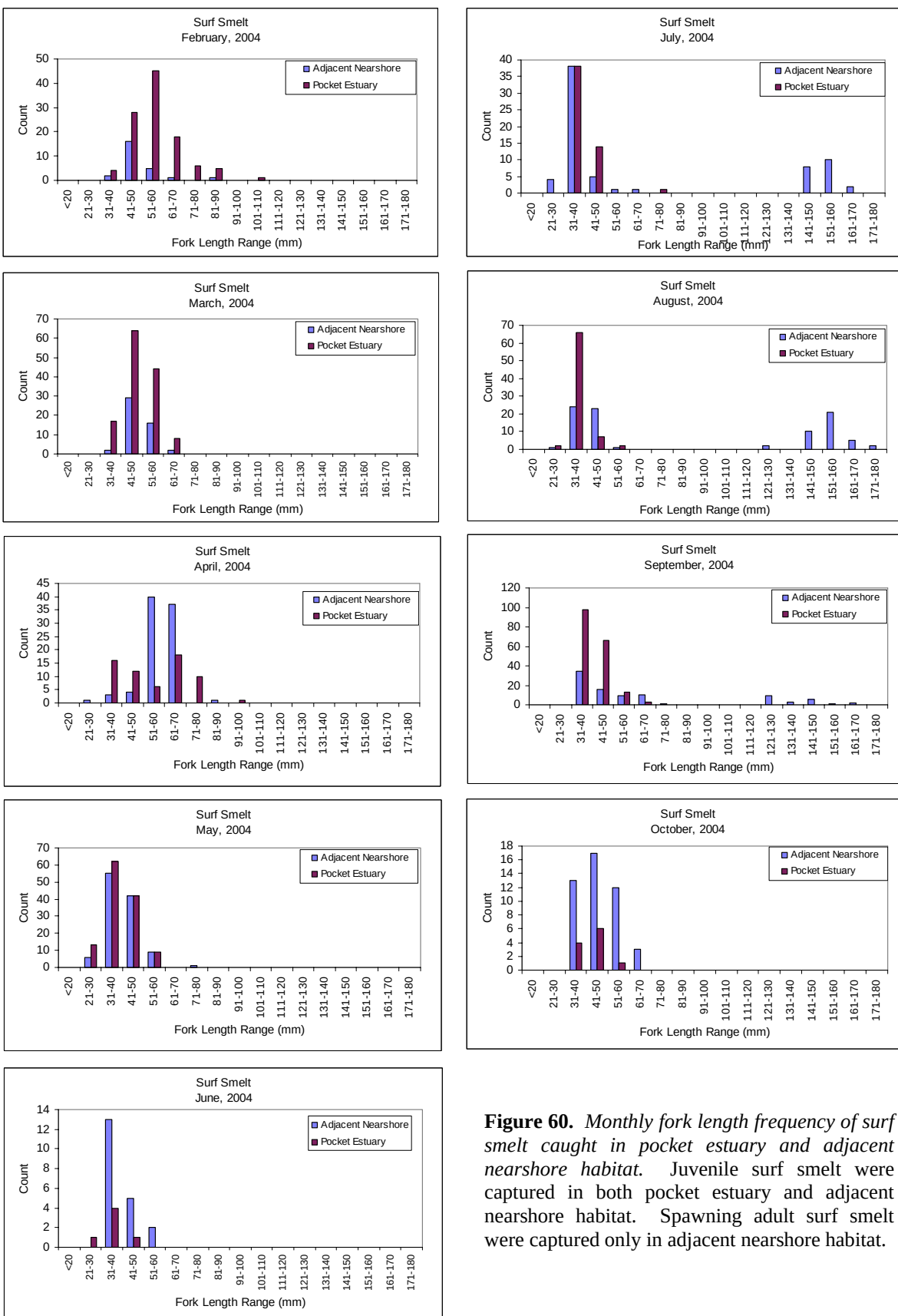


Figure 60. Monthly fork length frequency of surf smelt caught in pocket estuary and adjacent nearshore habitat. Juvenile surf smelt were captured in both pocket estuary and adjacent nearshore habitat. Spawning adult surf smelt were captured only in adjacent nearshore habitat.

CONCLUSIONS

Chinook Salmon

Our research has learned that differences in: (1) habitat type (pocket estuary compared to adjacent nearshore); (2) annual smolt population size; and (3) landscape connectivity all influence juvenile Chinook salmon use of nearshore habitats.

We found that juvenile Chinook salmon use pocket estuary habitat primarily in late winter through spring months. Juvenile Chinook salmon density in pocket estuary was about 50% higher than adjacent nearshore in 2004, a year with low numbers of juvenile Chinook salmon available to occupy habitat. In 2005, where much higher numbers of juvenile Chinook salmon were available to occupy nearshore habitats, juvenile Chinook salmon density in pocket estuary was over five times higher than adjacent nearshore areas. The results from both years of this study are consistent with the pattern of Chinook salmon use described in Beamer et al. (2003). While the results shown in Beamer et al. (2003) directly relate to Skagit Bay and Skagit-origin Chinook salmon, they may not infer the true importance of the pocket estuaries in a larger spatial and ecological setting. Our results provide strong evidence that juvenile Chinook salmon accumulate in pocket estuary habitat in areas beyond the Skagit River by providing two years of evidence for multiple sites throughout the Whidbey Basin.

We also found the number of juvenile Chinook salmon migrating out of their natal river system will influence the number of fish found in pocket estuary habitat. We showed how poor the Chinook salmon outmigration was in 2004 compared to other recent years. Even with the low smolt population size in 2004, we observed evidence of higher densities of Chinook salmon in pocket estuaries during the late winter to early spring period than in adjacent nearshore habitat, suggesting there is a true preference for this habitat by Chinook salmon.

We hypothesized that differences in habitat connectivity should influence Chinook salmon populations in pocket estuaries at the scale of Whidbey Basin. We generally observed higher densities of juvenile Chinook salmon at pocket estuary sites nearest natal Chinook river mouths, supporting the idea that restoration and protection of pocket estuaries near natal population sources is important. We found evidence of this for three different rivers: Samish, Skagit, and Stillaguamish. We did not have any good study sites to evaluate this idea for the Snohomish River. We also found two of three corridor pocket estuary sites (those distant from any river) had consistent juvenile Chinook salmon use, suggesting that corridor sites are also important in the nearshore landscape as juvenile Chinook salmon travel from their natal rivers to ocean environments. We also tested the habitat connectivity hypothesis using two different measures of landscape connectivity. Together, our analyses present evidence that landscape connectivity does influence juvenile Chinook salmon use of pocket estuaries in the Whidbey Basin. More study is needed to quantify how fish move within the nearshore environment, especially after they have exited natal river estuaries. Hydrodynamic models for discrete marine basins, such as the Whidbey Basin, can help us quantify landscape connectivity for 'corridor' sites not immediately adjacent to natal river mouths.

Surf Smelt

Pocket estuaries appear to provide nursery habitat for surf smelt – restoration and protection of pocket estuaries may be important for healthy surf smelt populations and the species that prey on them. Three sites studied in Saratoga Passage (Race Lagoon, Harrington Lagoon, and Elger Bay) did not have significant use by surf smelt in either the pocket estuary or its adjacent nearshore. It is unknown whether this is normal or abnormal.

Fish Sampling Design

We suggest that additional sampling sites are necessary to characterize fish use patterns in larger pocket estuaries, such as Triangle Cove and Tulalip Bay. In these larger sites, a random sampling selection process should be used to identify sites to beach seine and existing data could be used to determine the number of sites needed to detect different levels of fish density between habitat types, such as pocket estuary and adjacent nearshore.

We need to consider the likelihood of detecting fish with limited sampling effort for any future work. We suggest sampling multiple years over the full seasonal fish use period at a relatively high sampling frequency to reduce the risk of not detecting important fish use patterns. It turns out that few juvenile Chinook salmon were captured in 2004 due to the small populations of Chinook salmon entering our study area from their natal rivers compared to other years, and subsequently, the number of Chinook salmon fry utilizing nearshore habitat was also small in 2004. The one or two time sampling effort (in 2004) of many pocket estuary sites throughout the Whidbey Basin, Fidalgo Bay, Padilla Bay, and Samish Bay did a very poor job of detecting juvenile Chinook salmon. Moreover, the fish catch results at Tulalip Bay suggest that sampling monthly may not be frequent enough since we did not detect many of the large numbers of hatchery Chinook salmon that we know were at least briefly in the system. We suggest the minimum standard sampling period for Chinook salmon related to pocket estuary habitat is February through June at a bi-weekly frequency. To understand surf smelt use of pocket estuary habitat, the period might need to be year round in areas where summer spawning populations exist.

Habitat Restoration or Conservation

All twenty-four pocket estuaries investigated have some kind of restoration or conservation potential (Table 4). The habitat and fish catch data collected could serve as background information, should any of these sites move into the feasibility phase of restoration planning. Three sites in particular stand out: Dugualla Bay, Priest Point, and Scotts Point. Each site: (1) was historically large compared to the average pocket estuary size; (2) is close to Chinook salmon-bearing rivers – the source of fish that could occupy available habitat; and (3) is not yet fully developed with houses or other more permanent infrastructure. This does not mean the historic estuaries are not without real political, landuse, or logistical constraints to restoration. It does mean, in our view, that each site still has the physical potential to be restored and is strategically located for improving salmon productivity in the nearshore landscape.

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