JUVENILE SALMON AND NEARSHORE FISH USE IN SHORELINE AND LAGOON HABITAT ASSOCIATED WITH TURNERS BAY, 2003-2006

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Purpose of report

Restoration and protection of Turners Bay was identified as a priority in the Skagit Chinook Recovery Plan (page 202 in SRSC & WDFW 2005) because of its importance to early rearing of wild fry migrant Chinook salmon originating from the Skagit River. The Swinomish Planning Department has sponsored a habitat change analysis (McBride 2007) that identifies restoration and protection actions that could be taken within Turners Bay, and in its adjacent watershed and drift cells, for the benefit of the nearshore ecology of Turners Bay.

The Skagit River System Cooperative (SRSC) Research Program has collected fish data from sites within Turners Bay as part of their research on the factors limiting populations of wild Chinook salmon. SRSC has continued to collect fish data at sites within Turners Bay as part of its long term monitoring plan for wild Chinook salmon recovery (Greene and Beamer 2006).

We analyzed fish data from 2003 through 2006 for this report to document the nearshore fish assemblage using habitats within Turners Bay. This report also identifies the importance of protecting and restoring Turners Bay for the benefit of juvenile salmon with an emphasis on Endangered Species Act (ESA)-listed wild Chinook salmon.

Study area

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

Geomorphically-speaking, we describe Turners Bay as a tidal channel lagoon. Tidal channel lagoons, in general, are part of a group of nearshore habitats we call pocket estuaries. Pocket estuaries are partially enclosed bodies of marine water that are connected to a larger estuary (such as Puget Sound) at least part of the time, and are measurably diluted by freshwater from the land at least part of the year (after Pritchard 1967). These small estuaries are differentiated from larger scale estuaries because the watersheds they are associated with are too small to form Chinook salmon spawning habitats; thus we call them non-natal estuaries (Beamer et al. 2003). Pocket estuaries like Turners Bay are an important habitat for wild Chinook salmon fry early in the year once they leave their natal estuary and enter nearshore areas of Whidbey Basin (Beamer et al. 2003 and 2006).

Sampling sites and methods

Two types of beach seines were used within Turners Bay to catch fish in order to assess their abundance, species composition, and size. A small net (6 ft by 80 ft) beach seine was used to sample six sites within lagoon habitat at mid to high tide. Adjacent nearshore habitat was beach seined at six sites along the Turners Bay spit during mid to high tide levels. Each spit site was sampled by small net and by large net (12 ft by 120 ft) beach seine. The small net beach seine catches fish from shallow intertidal habitat while the large net beach seine catches fish from deeper intertidal-subtidal fringe habitat. Thus, we sampled three distinct habitat types: (1) lagoon habitat within the Turners Bay pocket estuary, (2) shallow intertidal habitat within the nearshore adjacent to the Turners Bay pocket estuary, and (3) deeper intertidal-subtidal fringe habitat within the nearshore adjacent to the Turners Bay pocket estuary. Figure 2 shows the location of sampling sites within Turners Bay. Figure 3 illustrates conceptually the three different habitats sampled. Pages 51-54 of Beamer et al. (2005) provide more details, net diagrams, and pictures of the seining methods.

The sampling sites were not randomly selected for this study because our task was to present a picture of juvenile salmon and nearshore fish use of Turners Bay using existing data. We used data from regularly sampled index sites established for two larger scale and longer term research/monitoring efforts (Beamer et al. 2006; Greene and Beamer 2006). These two efforts used sites within Turners Bay selected to compare fish densities by the same three habitat types listed above (i.e., lagoon, shallow intertidal, and deeper intertidal-subtidal fringe). The purpose of those efforts are consistent with the objective of this report. Graphical and multivariate analysis of relative abundance data from 15 sites over eight years in the greater Skagit estuary (including many sites in Skagit Bay) found clear among-group differences (and within-group similarities) in taxonomic composition of fish assemblages based on month and *a priori* assignment of habitat types classified by geomorphology and salinity classes (Beamer et al. 2007). Little difference among years was observed, so it was concluded that one year of monthly sampling generally provided an accurate characterization of fish assemblage composition for the habitat types and sites sampled. An important application of Beamer et al. (2007) was to develop (1) a better understanding of fish assemblages at sites not sampled and (2) predict change in fish assemblage for sites that change from one habitat type to another through restoration or other means. The report’s analyses strongly support the inference that sites of the same habitat type will contain the same fish assemblage. In addition, fish assemblage composition at index and randomly selected sites in other areas of Skagit Bay are similar (unpublished data from the monitoring effort described in Greene and Beamer 2006). Thus, we do not believe using index (rather than randomly selected) sites for this report significantly biases its findings.

Although sampling frequency varied somewhat from year to year for the period 2003-2006, we generally beach seined twice a month from February through October. In 2003, we were able to beach seine all 12 months of the year due to funding received from the Corps of Engineers.

The entire fish catch (not just salmon) was identified and enumerated. Fish catch data were divided by beach seine set area to estimate fish density by each species (fish per hectare of wetted area seined). Fish density results were averaged for each species in each of the three habitat types by month and year to gain an understanding of the timing, abundance, and assemblage of the nearshore fish community using Turners Bay.

A sub-sample of up to 20 fish per species was measured for length from each beach seine set. For this report we used only length data from the forage fish species to understand the life stages (e.g., juvenile, adult) of the forage fish species that utilize Turners Bay.

Salinity and temperature were collected at the time of beach seining just under the water's surface using a Model 30 YSI meter. These data were averaged for each of the three habitat types by month and year to gain an understanding of the environmental conditions experienced by fish using Turners Bay.

Findings

Salinity

The following specific results are observed in Figures 4 and 5:

- Surface water salinity in all nearshore habitats of Turners Bay ranged between 21 and 32 ppt.
- Variation in salinity follows a seasonal pattern each year where lower salinities in Turners Bay tend to occur early in the year, usually before June or July.
- Fluctuations in salinity are negatively correlated with Skagit River flow (regression analysis of log transformed data, $p < 0.01$). Higher river flows mean lower salinities in Turners Bay. Monthly averages of daily Skagit River flow measured at Mount Vernon explained 27-40% of the variation in salinity measured in each of the three nearshore habitat types over the four-year record.
- Monthly average salinity varied year to year responding to annual variation in Skagit River flow.
- Surface water salinities in each of the three habitat types parallel each other seasonally. However, salinity in lagoon habitat averaged about one ppt lower than salinity in adjacent subtidal and shallow intertidal habitat in months before June (paired T-test, $p < 0.001$). Salinity in lagoon habitat was not significantly different than salinity in adjacent subtidal or shallow intertidal after May.

Temperature

The following results are observed in Figure 6:

- Surface water temperature in all nearshore habitat types of Turners Bay ranged between 7 and 20 degrees Celsius over the four-year period.
- Variation in temperature follows a seasonal pattern each year with temperatures steadily increasing until July or August, then starting to decline.
- Surface water temperatures in each of the three habitat types parallel each other annually and seasonally. Temperature in lagoon habitat was not significantly different than temperature in adjacent subtidal or shallow intertidal habitat early in the year (months before June) (paired T-test, $p > 0.1$). Temperature in lagoon habitat was higher (~ ½ degree C) than temperature in adjacent subtidal or shallow intertidal habitat during summer months (June, July, August) (paired T-test, $p < 0.1$). During this time, average surface water temperature in all three nearshore habitat types exceeded 16 degrees Celsius.

Dominant fish assemblage

The following results are observed in Figure 7:

- Nearshore fish utilized all three habitat types (lagoon within pocket estuary, shallow intertidal adjacent to pocket estuary, and deeper intertidal-subtidal fringe adjacent to pocket estuary) year-round.
- Juvenile salmon are an important part of the fish assemblage early in the year (late winter and spring) for all three habitat types, but only dominated the fish assemblage in shallow intertidal and lagoon habitat during this time of year.
- Forage fish dominate the fish assemblage in deeper intertidal-subtidal fringe habitat early in the year.
- Shiner perch dominate the fish assemblage in all three habitat types during the summer months while forage fish dominate late in the year.
- Lagoon habitat within the pocket estuary had the highest overall fish density over the year compared to the other habitat types. Deeper intertidal-subtidal fringe adjacent to the pocket estuary had the seconded highest overall fish density over the entire year.

Juvenile salmon assemblage

Figures 8-11 show the juvenile salmon assemblage by year for each of the three habitat types. The following results are observed in these figures:

- Chum, pink, and Chinook salmon dominate the juvenile salmon assemblage for all three habitat types (lagoon within pocket estuary, shallow intertidal adjacent to pocket estuary, and deeper intertidal-subtidal fringe adjacent to pocket estuary). The number of hatchery Chinook (61), wild coho (7), cutthroat (3), bull trout (24), and wild steelhead (1) caught in Turners Bay over the 4 years of sampling were minor compared to the thousands of wild Chinook, pink, and chum salmon caught during the same period.

- Pink salmon fry were captured every year, but even years had many more pink salmon than odd years, reflecting the odd year dominance of returning adult pink salmon to the Skagit River. Pink salmon typically peaked in March and were gone by June or earlier.
- Chum salmon fry were captured every year, typically peaking in April (ranging from March to May). Chum salmon fry typically arrived in February and were gone by June.
- Chum salmon fry show a preference for using lagoon habitat early in the year. During the February through June period, chum salmon fry density was highest in lagoon habitat for all four years studied. Chum density in lagoon habitat averaged 5.7 times higher than chum densities found in deeper intertidal-subtidal fringe, and 7.7 times higher than shallow intertidal habitat.
- Wild Chinook salmon fry were captured every year and had the longest period of utilization of any of the juvenile salmon. Wild Chinook salmon arrived by February and were still present through August or October, depending on the year. Wild Chinook salmon fry peaked in different months in different years and habitat types, with lagoon and shallow intertidal habitat peaking earlier than deeper intertidal-subtidal habitat.
- Wild Chinook salmon fry show a strong preference for using lagoon habitat early in the year. During the February through June period, wild Chinook salmon fry density was highest in lagoon habitat for all four years studied. Chinook density in lagoon habitat averaged 16.3 times higher than Chinook densities found in deeper intertidal-subtidal fringe, and 6.9 times higher than shallow intertidal habitat. This result is consistent with findings from other pocket estuaries in Skagit Bay (Beamer et al. 2003) and throughout the Whidbey Basin (Beamer et al. 2006).
- Juvenile salmon abundance varied by year. The annual variation in Chinook salmon abundance is largely explained by fluctuations in the size of the Skagit River's outmigrating juvenile Chinook salmon population (Beamer et al. 2005 and 2006). We expect the same is true for pink and chum salmon, although we do not have outmigrating fry population estimates for these two species.

Juvenile salmon migration pathways

Identifying how accessible and interconnected nearshore habitats such as Turners Bay are to fish populations is necessary in evaluating the ecological importance of these habitats to nearshore fish. In the case of juvenile salmon, Turners Bay is not a natal estuary. This means juvenile salmon using Turners Bay are not coming from adult salmon spawning in creeks directly entering into Turners Bay. The vast majority of juvenile salmon using Turners Bay habitat must migrate there from other salmon-producing rivers and creeks. The closest salmon-producing river to Turners Bay is the Skagit River. Therefore, how important Turners Bay is to Skagit River salmon populations not only depends on the quality, amount and type of nearshore habitat, but also on how easily juvenile salmon can get to Turners Bay.

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

- Turners Bay has the fifth longest migration pathway of eight pocket estuaries studied in the Whidbey Basin (Beamer et al. 2006). However, Turners Bay juvenile Chinook salmon densities are consistently in the top third of all pocket estuary sites studied within the Whidbey Basin (Beamer et al. 2006). This is presumably due to Turners Bay's proximity to the North Fork Skagit River, where large numbers of wild Chinook salmon exit the Skagit River due to loss and simplification of delta habitat (Beamer et al. 2005).
- Of the three pocket estuaries in northern Skagit Bay currently able to support juvenile salmon (Lone Tree, Ala, and Turners Bay), Turners Bay has the longest and most complicated migration pathway. However, hydrodynamic modeling and juvenile salmon data indicate that juvenile salmon exiting from the North Fork Skagit River can reach Turners Bay in one day from either the Whidbey lsland or Fidalgo Island shorelines.
- Hydrodynamic modeling indicates that juvenile salmon fry are transported to the vicinity of either Ala Lagoon or Lone Tree Lagoon via surface water currents before they reach Turners Bay.
- Hydrodynamic modeling indicates that most salmon fry in the vicinity of Lone Tree Lagoon are pushed via surface water currents into upper Similk Bay on spring tides, and thus can reach Turners Bay easily.

Forage fish assemblage

Figures 12-15 show the forage fish assemblage by year for each of the three habitat types. The following results are observed in these figures:

- Four species of small schooling pelagic fish, commonly known as forage fish, were captured in Turners Bay. In order of importance based on frequency of capture they are: surf smelt, herring, sandlance, and anchovy.
- Northern Anchovy were captured in only 10 of the 108 months sampled over the 2003-2006 period. However, on two occasions, a large school of anchovies was captured (tens of thousands of fish per hectare).
- Sandlance were captured in 20 of the 108 months sampled over the 2003-2006 period. No sandlance were captured in lagoon habitat. The majority were captured in deeper intertidal-subtidal fringe habitat of the adjacent nearshore.
- Herring were captured in 35 of the 108 months sampled over the 2003-2006 period. The majority of herring captured were in deeper intertidal-subtidal fringe

habitat during summer months. However, herring were captured in all three habitat types, including lagoon.

- Surf smelt were captured in 91 of the 108 months sampled over the 2003-2006 period. Over the four years of sampling, two abundance periods for smelt are evident: late winter and late summer/early fall. Lagoon habitat typically had higher densities of smelt than adjacent nearshore habitat, suggesting the lagoon habitat is an important nursery area for smelt.
- Abundance of forage fish varied over the 4 year period. Annual abundance varied by a factor of 17, 7, and 33 for herring, smelt, and sandlance, respectively. In 2003 no anchovy were caught. This study was not long-term enough to detect population trends and causes of variation, nor to suggest whether the observed level of variation is normal for forage fish populations.

Lengths of forage fish

Length frequency data from forage fish are useful in determining what life stages of forage fish are using Turners Bay. The following results suggest Turners Bay nearshore habitats are important nursery areas for juvenile forage fish. Figures 16 and 17 illustrate the following results:

- The majority of anchovy captured were juvenile sized, with some indication of smaller fish preferring lagoon habitat over adjacent nearshore.
- The majority of sandlance measured were juvenile sized.
- The majority of herring captured were young-of-the-year sized, with some indication of smaller fish preferring lagoon habitat over adjacent nearshore.
- Juvenile smelt dominated the smelt catch in all seasons, but some larger (spawner sized) smelt were also captured in every season. The two high abundance periods of smelt (late winter and late summer/early fall) coincide with young-of-the-year smelt recruitment from the winter and summer spawning periods.

Dungeness crab

Macro invertebrate (such as crab) catches were incidental to our fish catches. Sub-legal Dungeness crab (mostly juvenile sized with a carapace width typically < 100 mm) were captured in all three habitat types within Turners Bay, indicating this area is a nursery area for Dungeness crab. Figure 18 supports the following results:

- Over the four-year period of study, juvenile Dungeness crabs were consistently captured in spring through summer months.
- Crab densities commonly approached (and in some cases exceeded) 500 crabs per hectare of area seined.

Salmon recovery benefits of restoration in Turners Bay

Pocket estuary habitats are much smaller and more fragmented throughout Skagit Bay and the rest of the Whidbey Basin than they were historically (Beamer et al. 2005). Fry sized juvenile Chinook salmon rear and take refuge in pocket estuaries throughout Skagit Bay (Beamer et al. 2003) and the Whidbey Basin (Beamer et al. 2006). We find the same fish use in Turners Bay (Figures 8-11). Therefore, any actions that protect or restore lagoon/tidal marsh area within Turners Bay will benefit wild fry migrant Chinook salmon.

Areas within the nearshore landscape like Turners Bay can also be important for juvenile salmon as they move from freshwater to marine habitat by providing habitat opportunity that minimizes physiological stress to fish as they transition from fresh to saltwater. Our salinity results show that factors outside of Turners Bay (i.e., Skagit River flow) influence salinity within Turners Bay, and lower salinities are present in Turners Bay during the period when juvenile salmon typically dominate the fish assemblage. Moreover, when juvenile salmon are most abundant in lagoon habitat, salinity within the lagoon is lower than salinity in adjacent nearshore habitat. Existing hydrodynamic processes within Turners Bay lagoon may help retain freshwater (more dilute marine water) layers entering the lagoon from Skagit Bay, and local freshwater sources entering the lagoon may help lower salinity within the lagoon. These factors demonstrate how lagoon areas like Turners Bay can be important to juvenile salmon other than as a productive foraging (rearing) or predation refuge habitat. Any actions that protect or restore natural tidal and freshwater processes within Turners Bay and its surrounding watershed would benefit juvenile salmon.

The Turners Bay Change Analysis (McBride 2007) identifies potential actions that, if implemented, would protect or restore natural processes within Turners Bay or its adjacent watershed and drift cells. Here we identify some of the salmon recovery benefits of these actions.

Increase in pocket estuary capacity and osmoregulatory opportunity for fry migrant Chinook salmon

- Restoration actions that restore lagoon/tidal marsh area will increase capacity for wild fry migrant Chinook salmon. An estimated 5.17 hectares of new channel habitat could be available for juvenile Chinook use if actions listed in the Turners Bay Change Analysis (McBride 2007) are implemented. An increase of 5.17 hectares of channel to the Turners Bay pocket estuary is predicted to increase the wild fry migrant Chinook population size by 23,826 smolts annually. This prediction is based on methods described in Beamer et al. (2005), which were developed to estimate the fish benefits of nearshore and delta restoration projects in the Skagit Chinook Recovery Plan (SRSC & WDFW 2005). This new estimate (23,826 smolts) is an update to the old estimate in the Chinook Recovery Plan of

15,200 smolts. The updated estimate is based on new channel area information included in the aforementioned change analysis report.

- Restoration of salmon fry migration pathways to the upper end of Turners Bay and its small freshwater inputs will provide wild fry migrant Chinook salmon with increased osmoregulatory (physiological transition from freshwater to saltwater) opportunity. This conclusion is based on the hypothesis that allowing Chinook salmon fry low salinity or brackish water habitat in pocket estuaries during late winter and early spring gives individual fish the opportunity to choose a wide range of salinities during the period when they are undergoing physiological transition from freshwater to saltwater. While it is clear Chinook salmon fry can tolerate salinities found in Skagit Bay early in the year for short periods of time (e.g., the many observations of Chinook fry caught in Skagit Bay), recent observations from sampling the distribution of Chinook salmon fry within the Lone Tree Lagoon pocket estuary suggest that fry may prefer lower salinities than salinities typically present in Skagit Bay during winter and early spring months. After restoration was completed in lower Lone Tree Creek, allowing juvenile salmon access to the lower creek, we found juvenile Chinook salmon fry congregated as far upstream as they physically could get (unpublished data from winter and spring of 2007), possibly seeking low-to-no salinities when first arriving to the Lone Tree pocket estuary from Skagit Bay.

Salmon and bull trout food web linkages

Forage fish and shiner perch are an important part of the food web for ESA-listed Chinook salmon and bull trout in Puget Sound. Surf smelt, herring, and sandlance are commonly consumed by Chinook salmon when the salmon exceed about 120 mm in length. Surf smelt, herring, sandlance, and shiner perch are an important part of the diet of anadromous bull trout. The Skagit has the largest population of anadromous bull trout and wild Chinook salmon in Puget Sound. Thus, actions in Turners Bay that protect and restore habitat for forage fish or shiner perch will benefit Puget Sound ESA-listed salmonids. Our results indicate implementation of the following ideas would benefit the forage fish populations, shiner perch, and food web linkages for ESA-listed salmonids:

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

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Figures

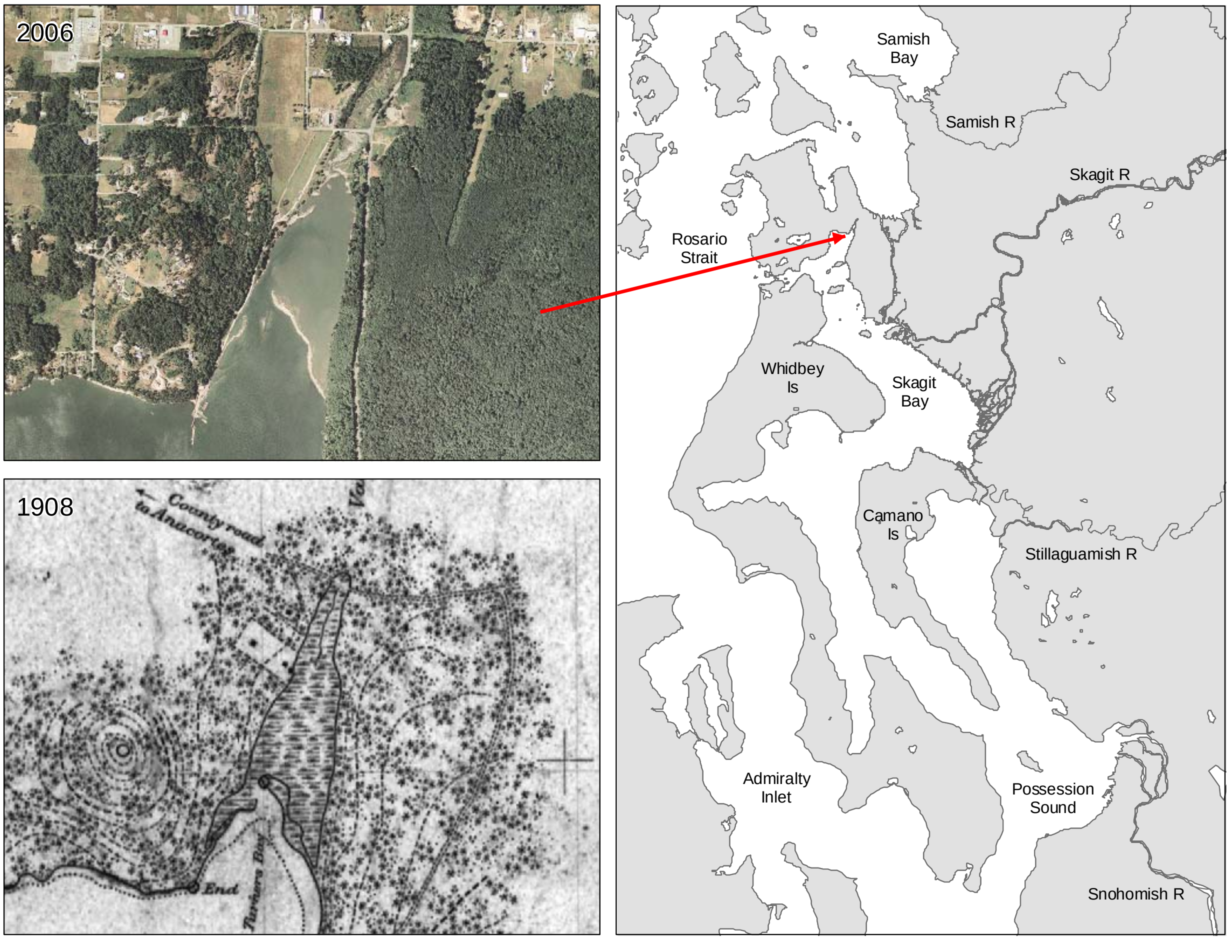

Figure 1. Location of Turners Bay on the northern end of Skagit Bay, along with contemporary (2006) and historic (1908) views of the site.

Figure 2. Location of beach seine sites at Turners Bay, 2003-2006. Yellow triangles represent sites within lagoon habitat of Turners Bay. Pink squares represent sties in the adjacent nearshore, at which we sampled both shallow intertidal and deeper intertidal-subtidal fringe habitat.

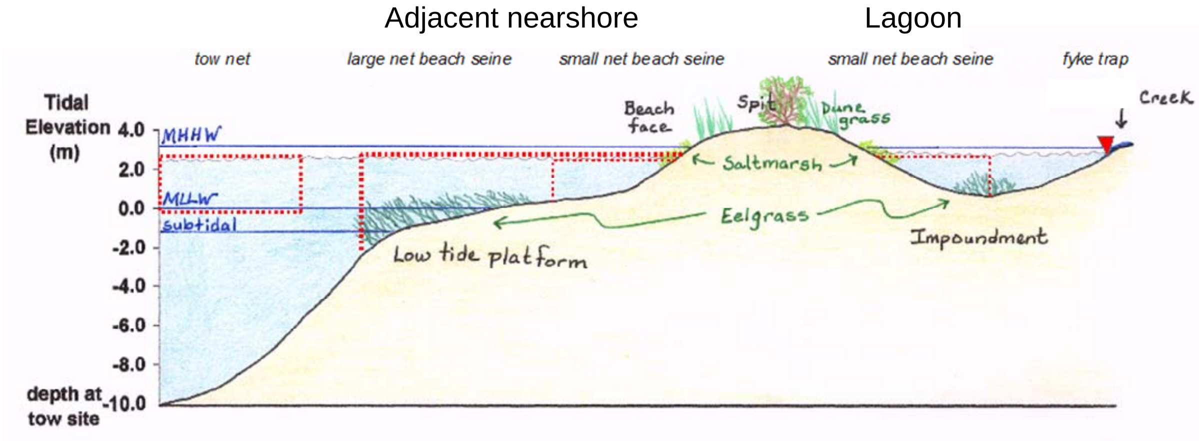

Figure 3. Cartoon of nearshore habitat in an area like Turners Bay. Note the differences in sampling extent and location by the two different beach seine methods.

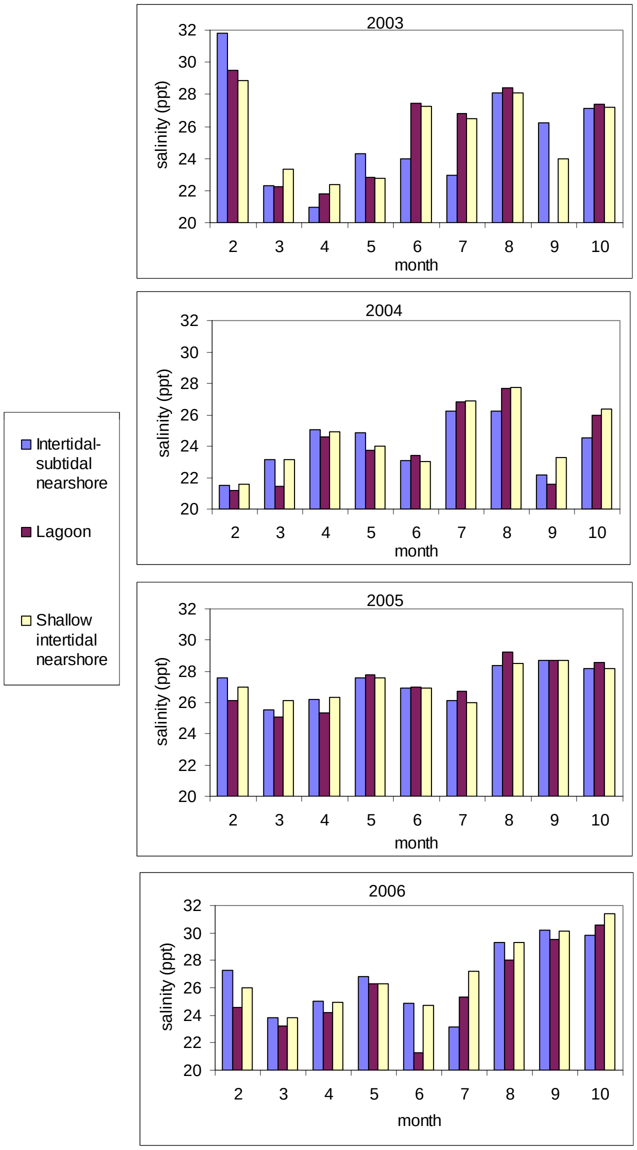

Figure 4. Salinity in nearshore and lagoon habitat of Turners Bay. Results are monthly averages of surface salinity measured during the time of beach seining and graphed for each year.

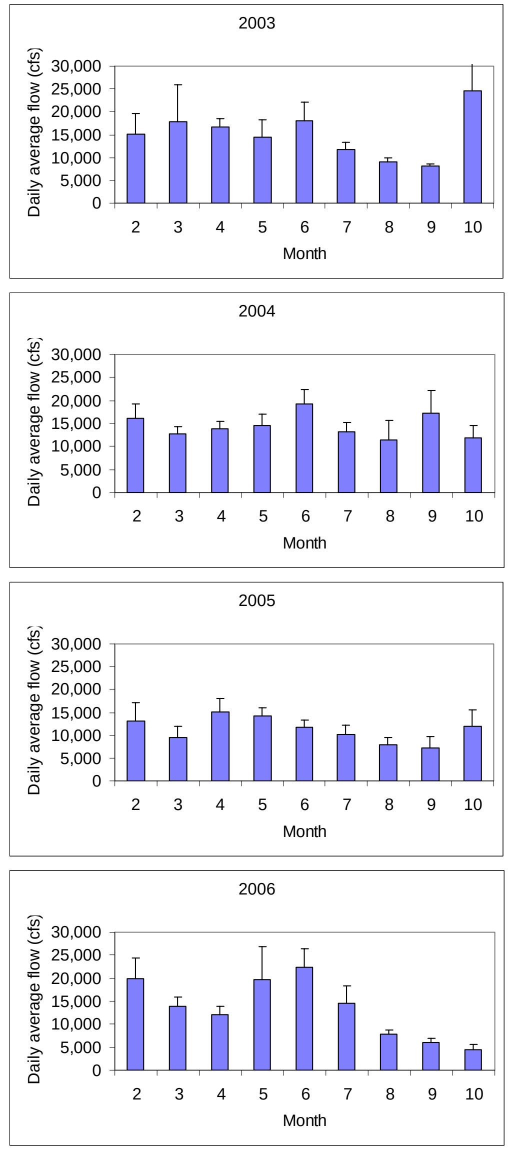

Figure 5. Monthly average daily river flow (cfs) by year from the Skagit River at Mount Vernon. Error bars are one standard deviation. Data from USGS.

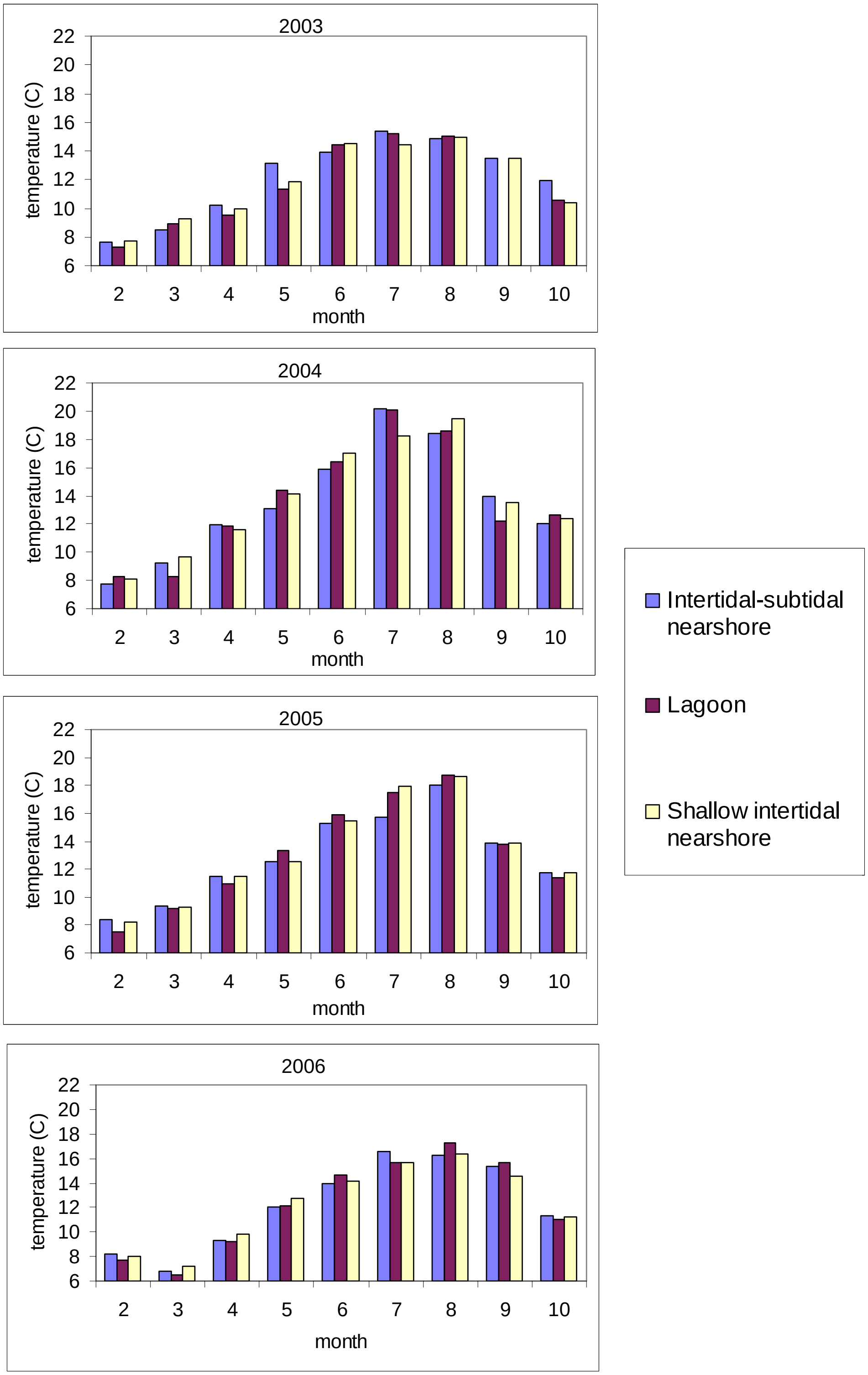

Figure 6. Temperature in nearshore and lagoon habitat of Turners Bay. Results are monthly averages of water surface temperature measured during the time of beach seining and graphed for each year.

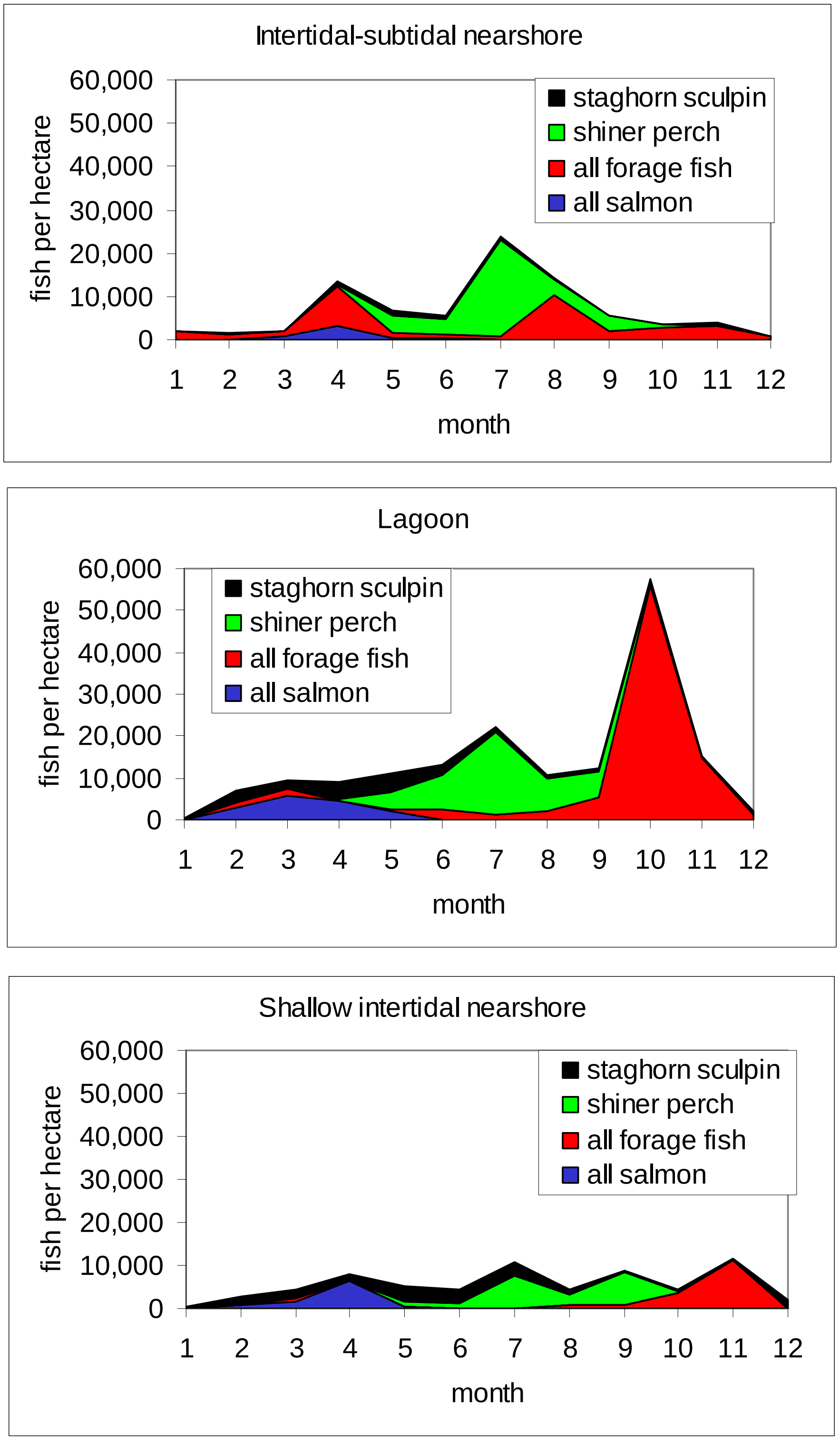

Figure 7. Assemblage of dominant fish in nearshore and lagoon habitat of Turners Bay. Results are monthly averages using data collected 2003-2006. Note differing y-axis scales.

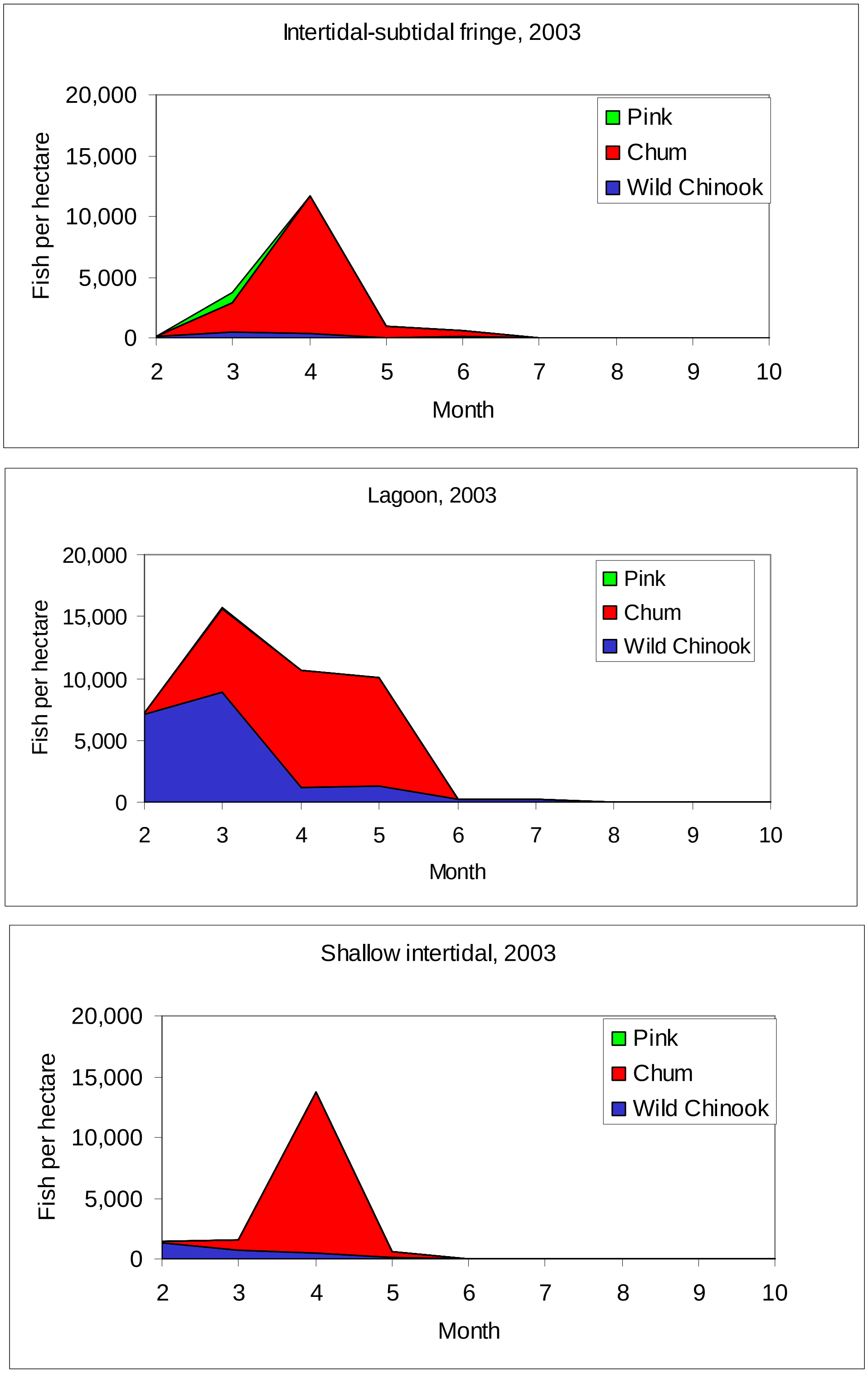

Figure 8. Assemblage of juvenile salmon in nearshore and lagoon habitat in Turners Bay, 2003. Note differing y-axis scales.

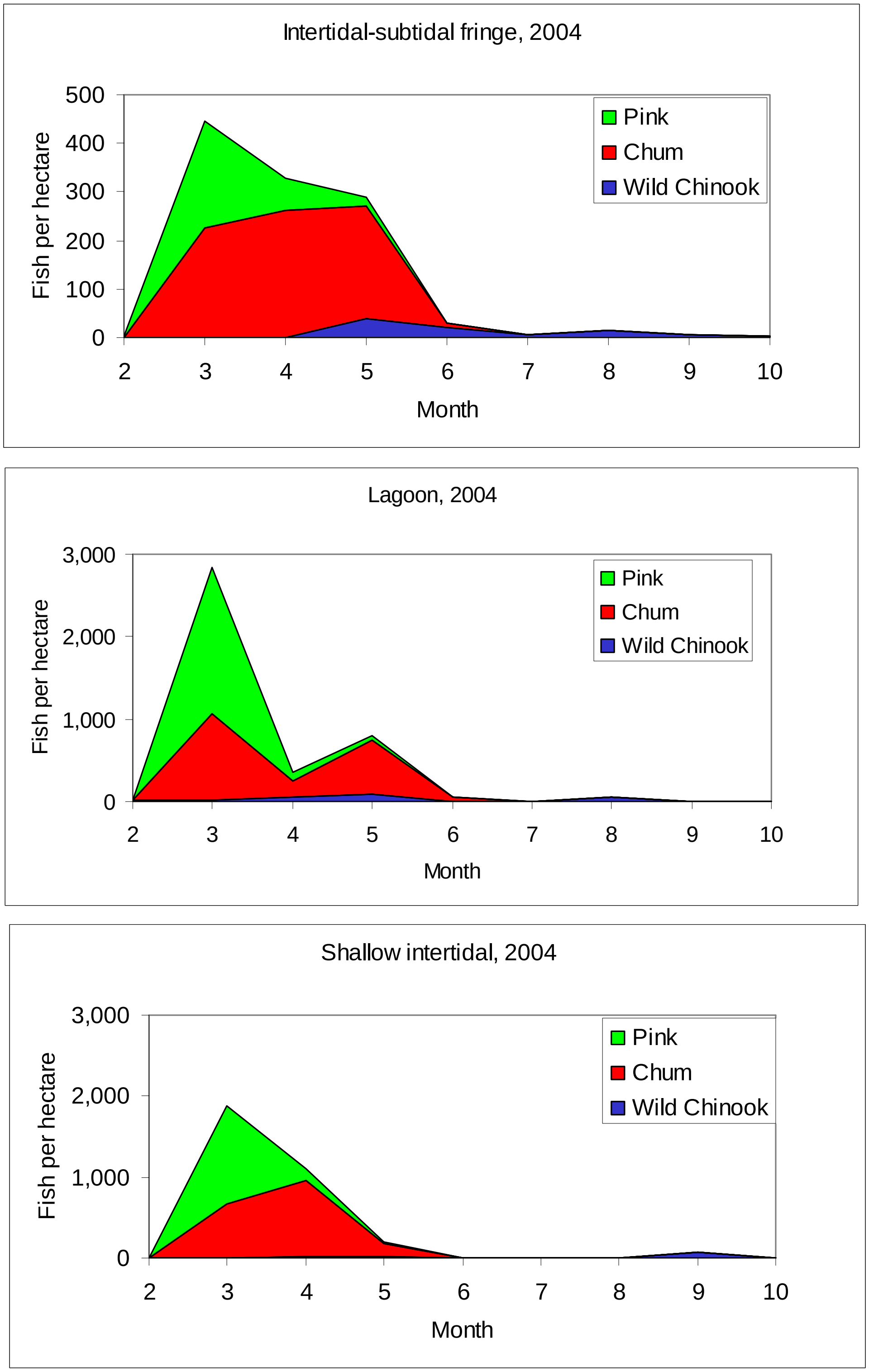

Figure 9. Assemblage of juvenile salmon in nearshore and lagoon habitat in Turners Bay, 2004. Note differing y-axis scales.

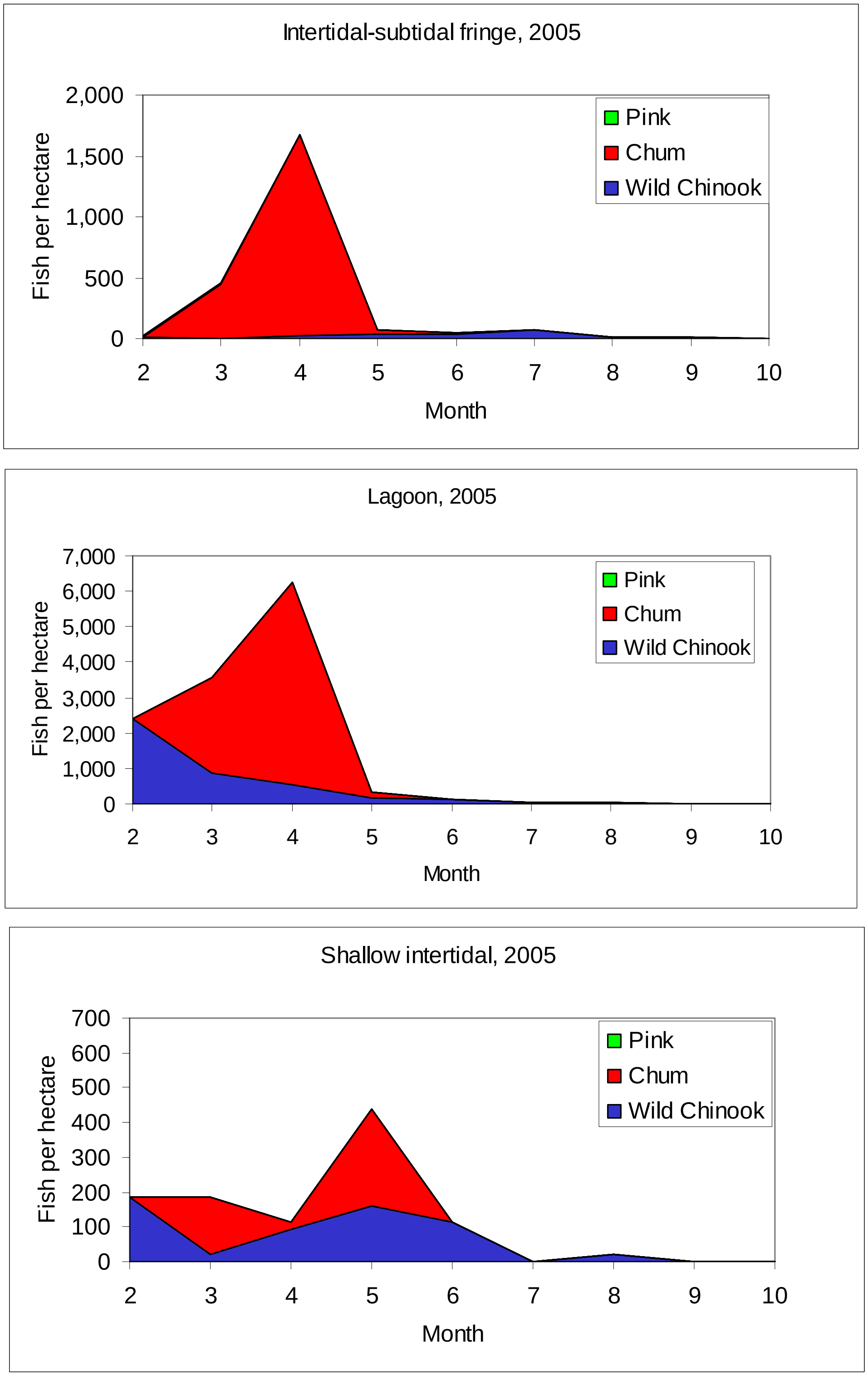

Figure 10. Assemblage of juvenile salmon in nearshore and lagoon habitat in Turners Bay, 2005. Note differing y-axis scales.

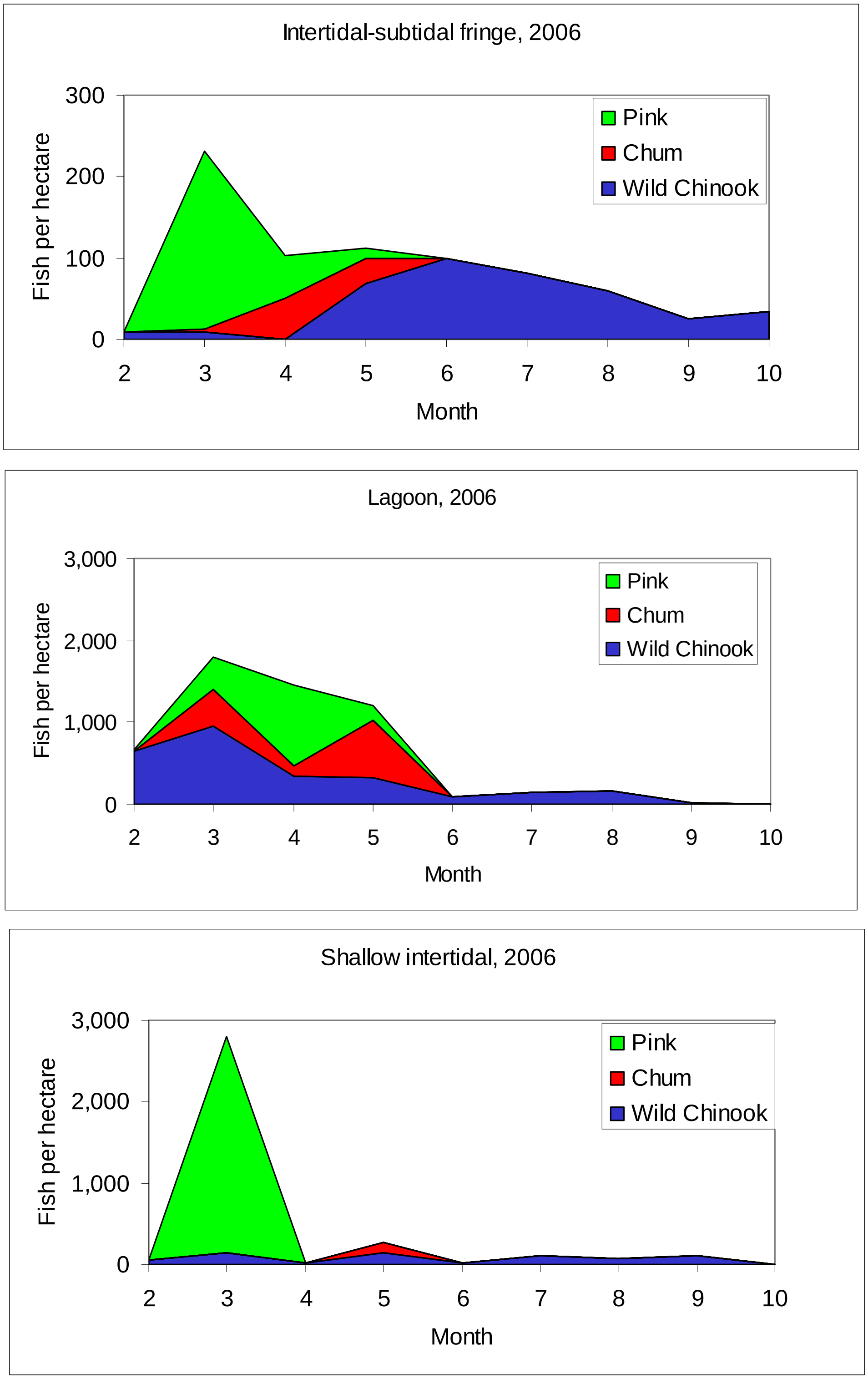

Figure 11. Assemblage of juvenile salmon in nearshore and lagoon habitat in Turners Bay, 2006. Note differing y-axis scales.

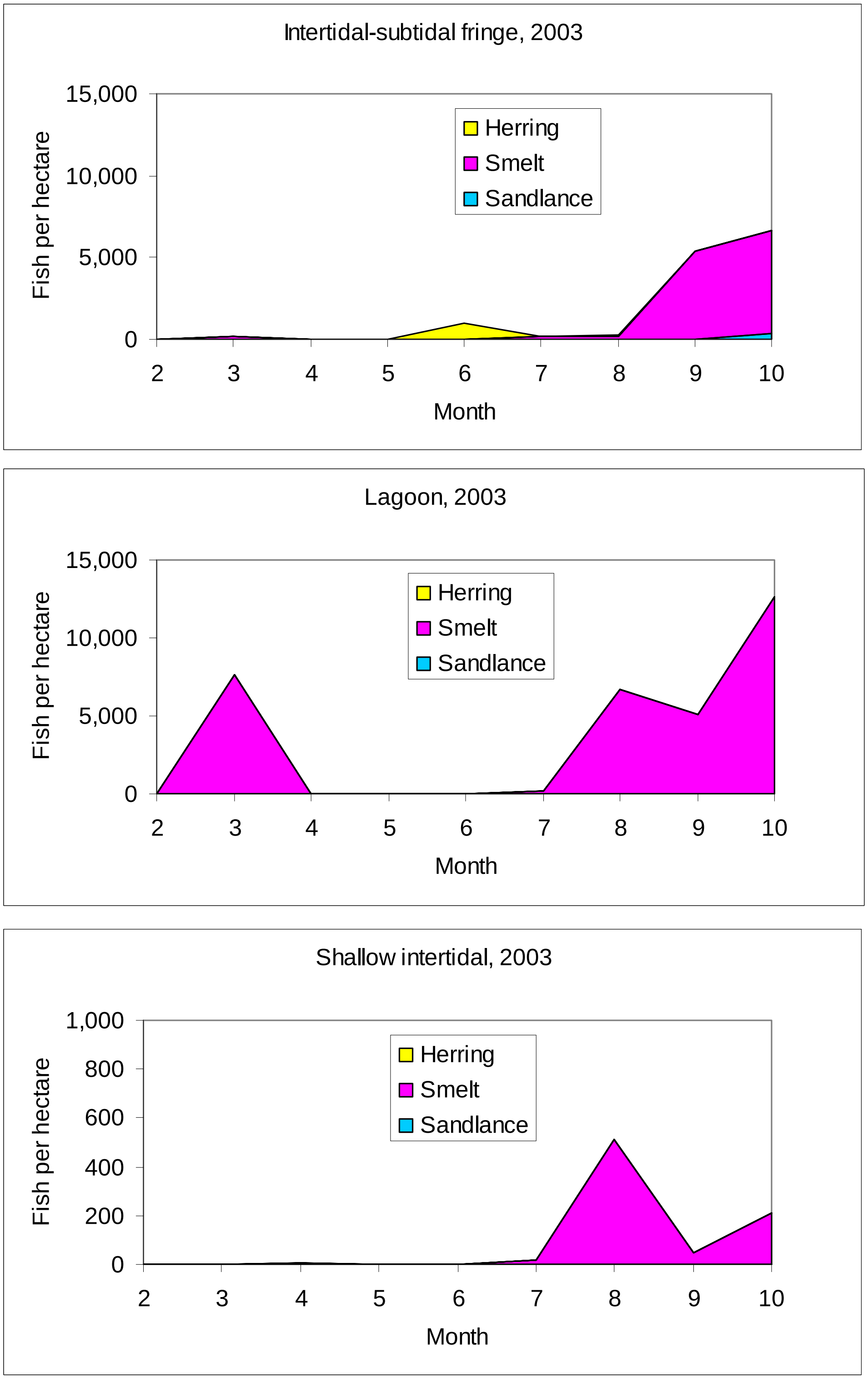

Figure 12. Assemblage of forage fish in nearshore and lagoon habitat in Turners Bay, 2003. Note differing y-axis scales.

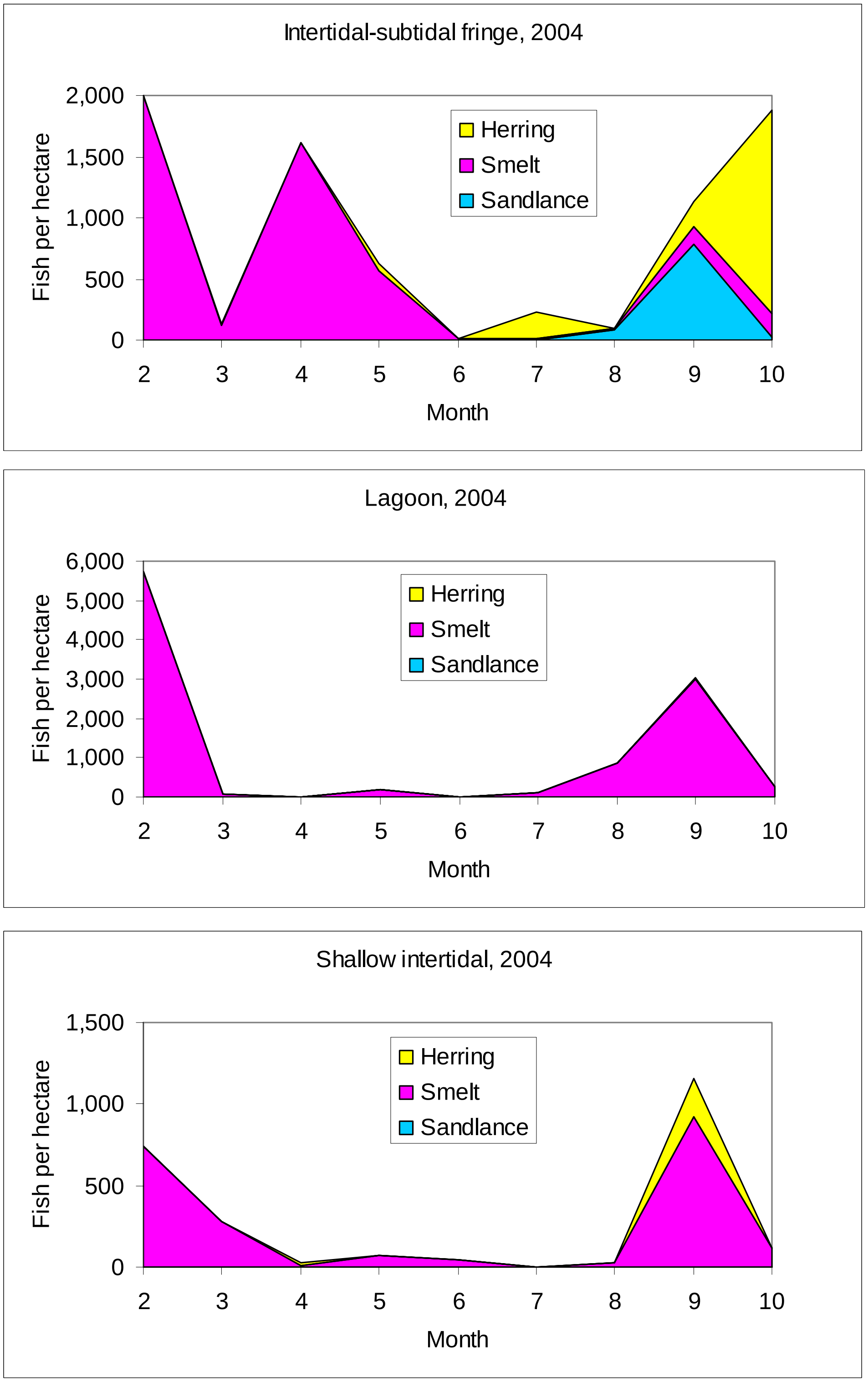

Figure 13. Assemblage of forage fish in nearshore and lagoon habitat in Turners Bay, 2004. Note differing y-axis scales.

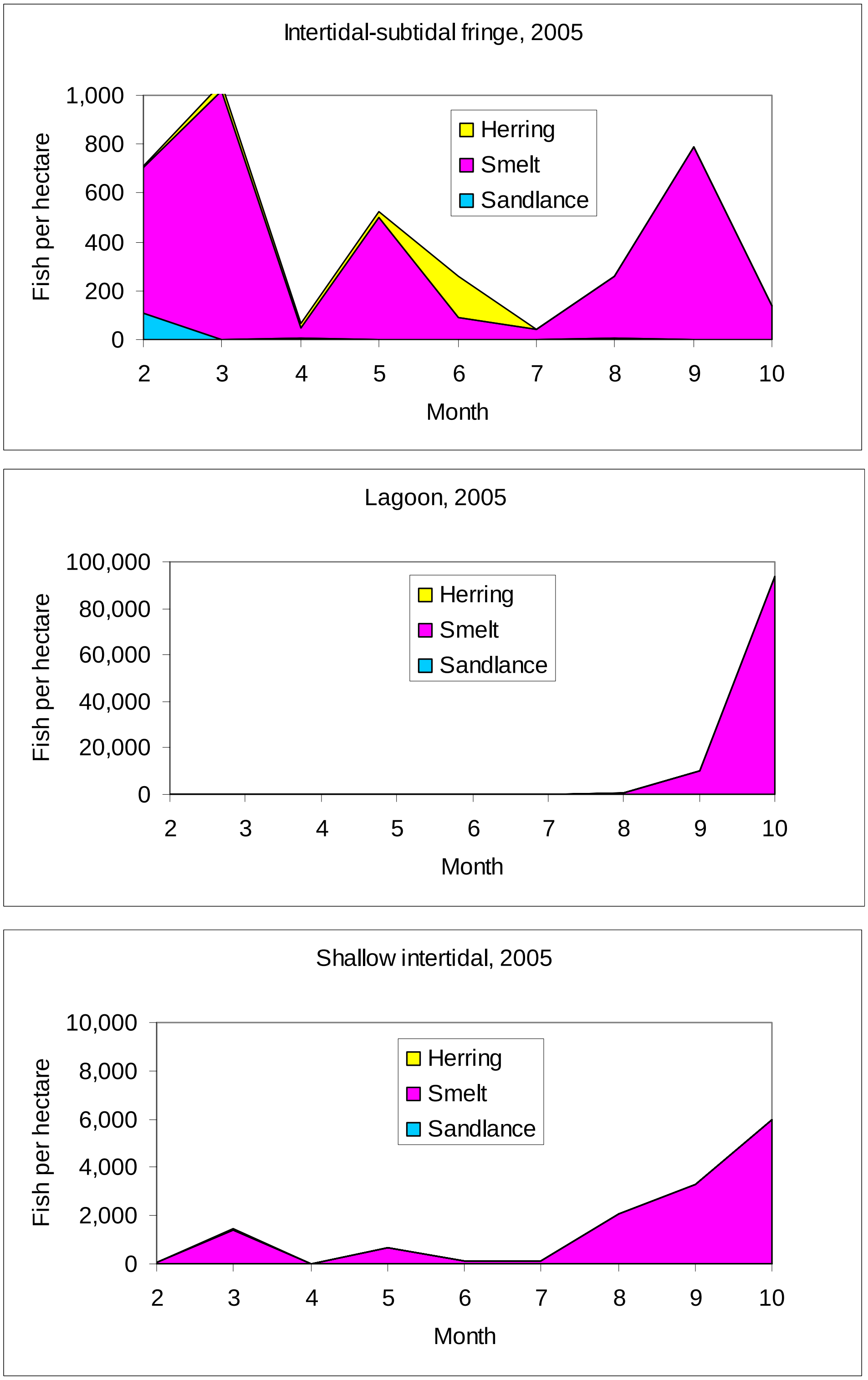

Figure 14. Assemblage of forage fish in nearshore and lagoon habitat in Turners Bay, 2005. Note differing y-axis scales.

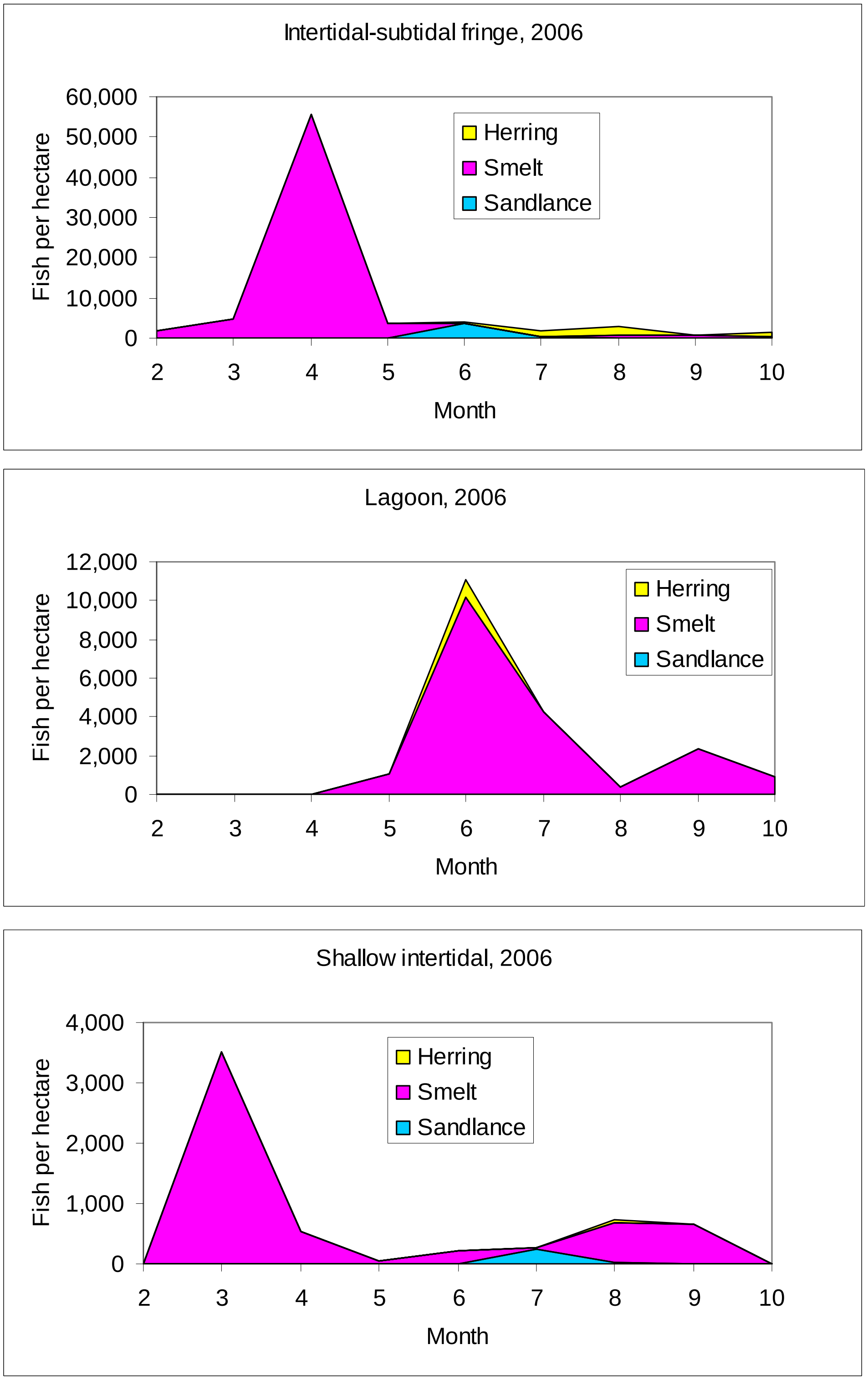

Figure 15. Assemblage of forage fish in nearshore and lagoon habitat in Turners Bay, 2006. Note differing y-axis scales.

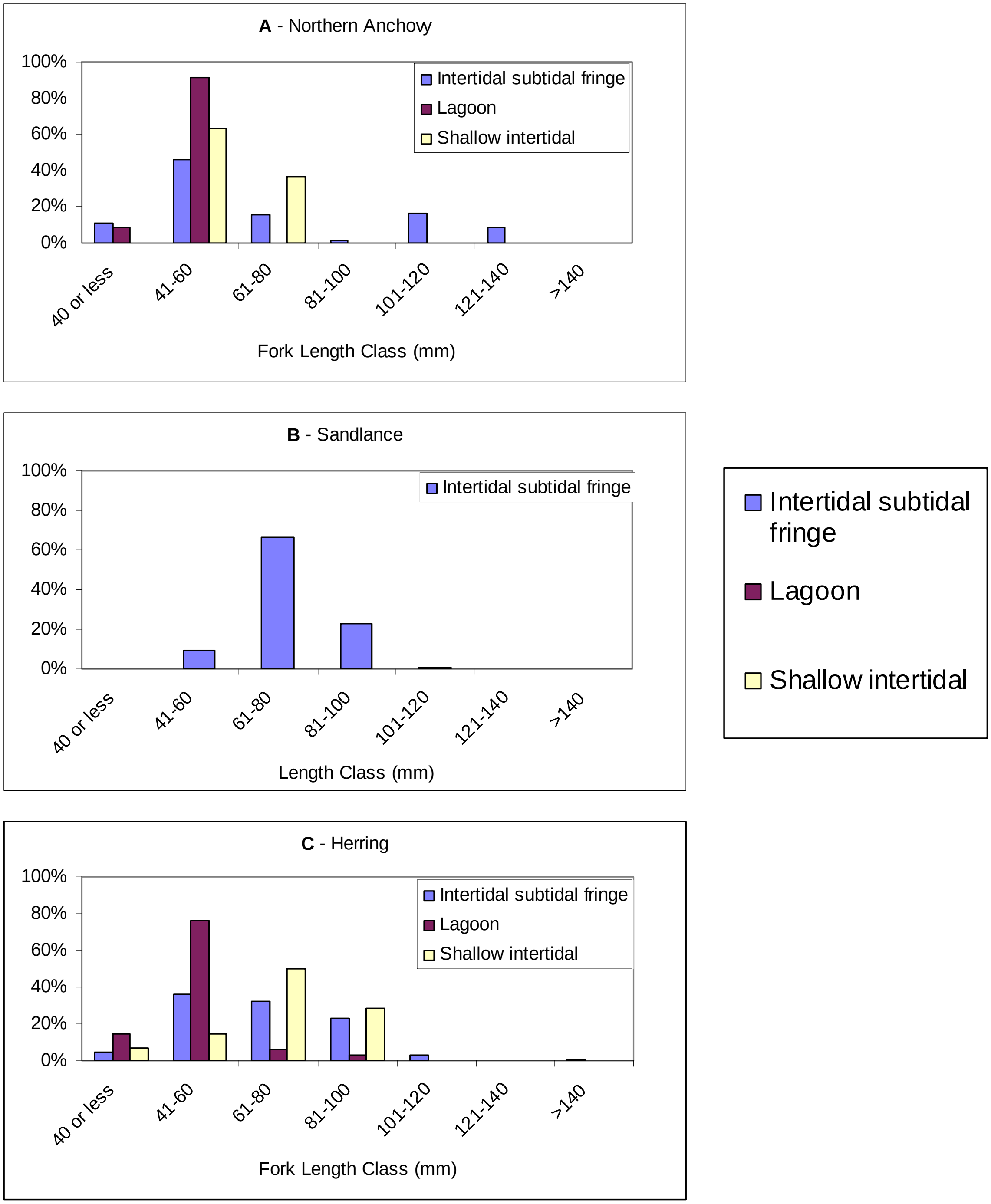

Figure 16. Length frequency of Northern Anchovy (A), Sandlance (B), and Herring (C) by habitat type.

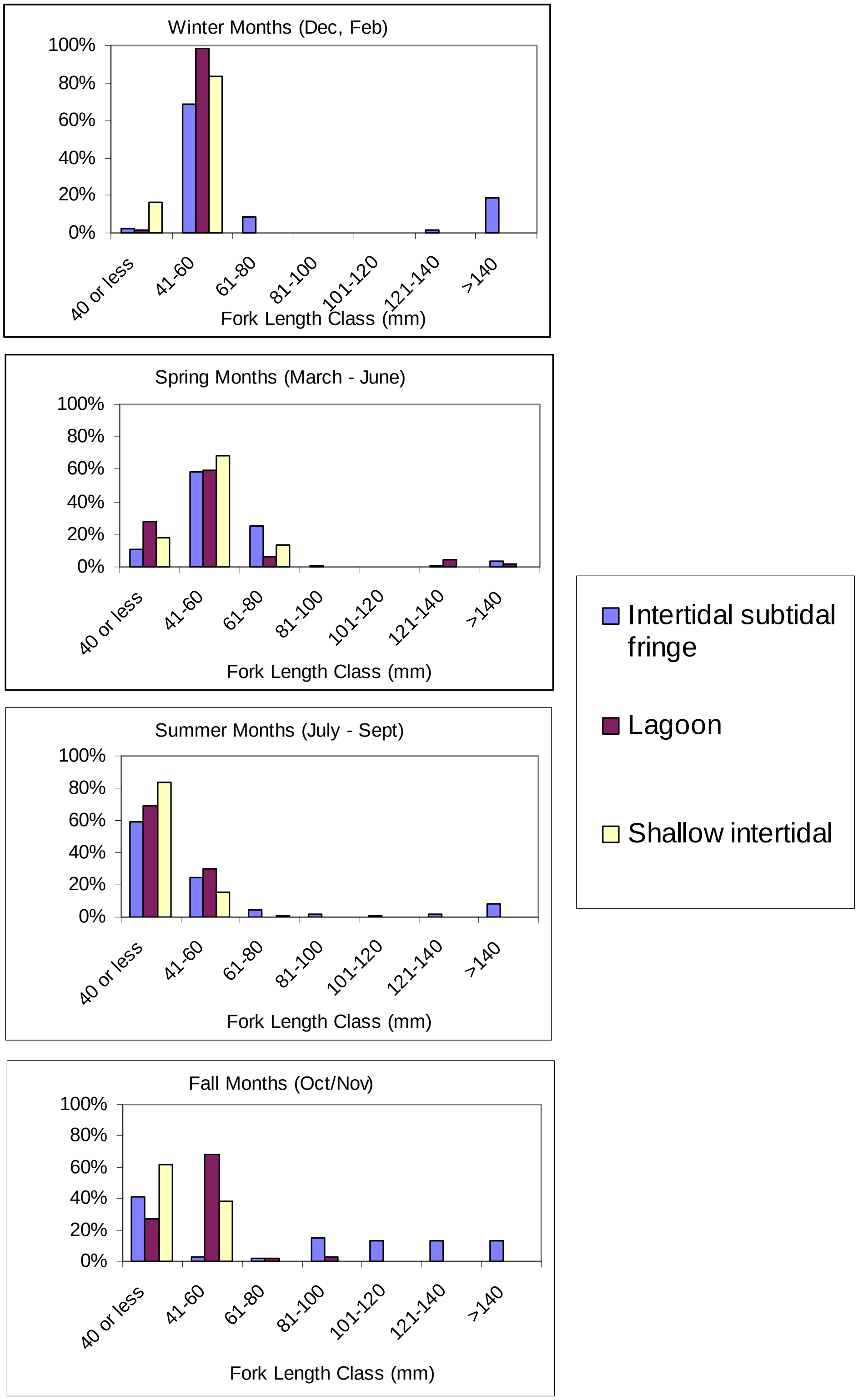

Figure 17. Length frequency of surf smelt by season and habitat type.

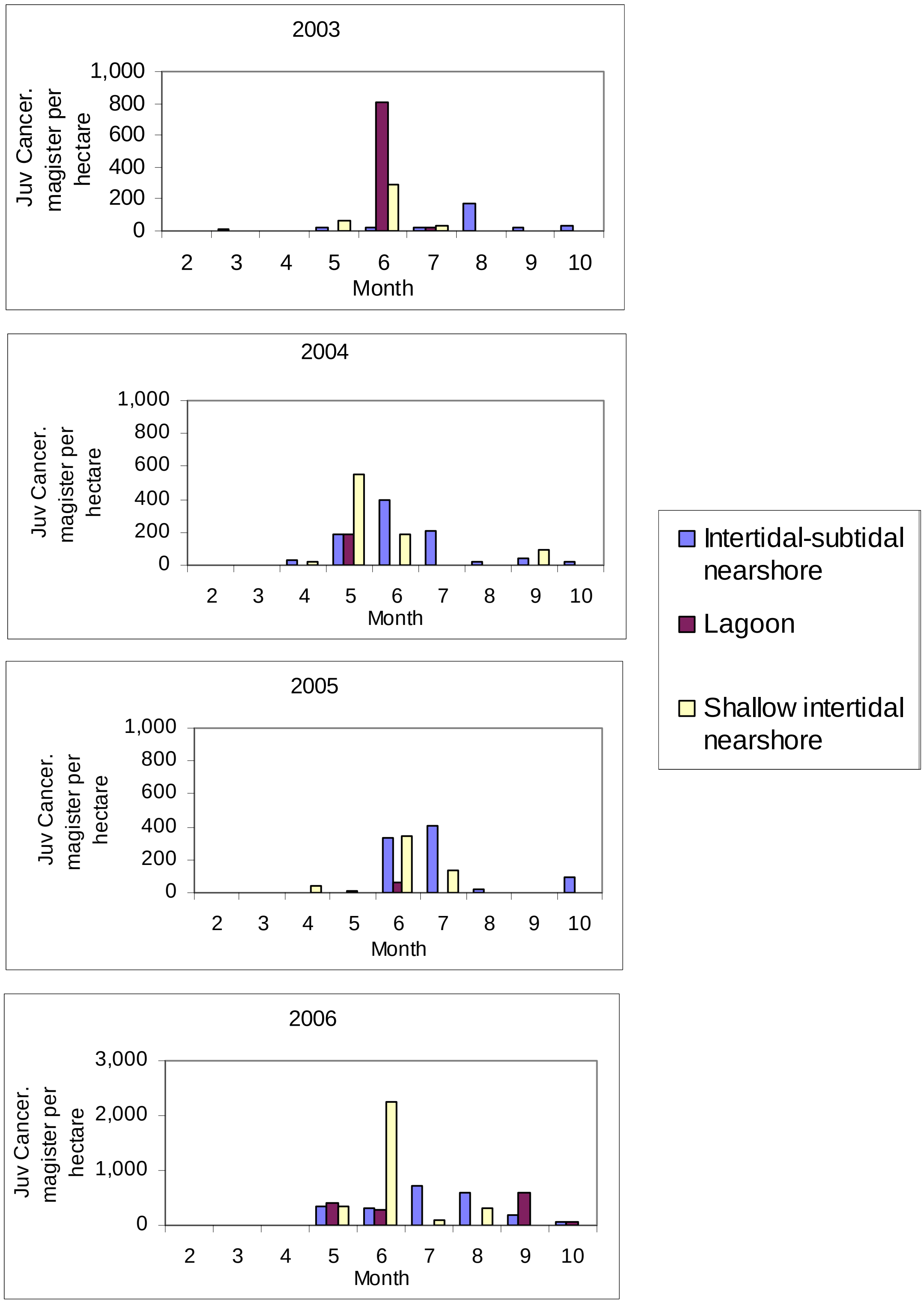

Figure 18. Density of sub-legal Dungeness crab in Turners Bay, 2003-2006. Note differing y-axis scales.