Final Report

Nearshore Fish Assemblages in Reference and Spartina Removal Sites Located in South Skagit Bay

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Abstract

Spartina is an invasive, non-native, salt-tolerant vascular plant in Puget Sound. It was intentionally introduced in Puget Sound near Stanwood in 1961 and because of its invasive nature, the Washington Department of Fish and Wildlife began a Spartina eradication program in southern Skagit Bay in the late 1990s. The objective of this study is to evaluate the effect of Spartina removal treatment on the fish assemblage, including juvenile salmon, in the southern Skagit Bay near the town of Stanwood, Washington.

In 2007 we made 185 beach seine or fyke trap sets catching 9,852 fish of 12 different species within a study area comprised of reference and treatment habitats types relative to Spartina removal. In 2008 we made 94 beach seine or fyke trap sets catching 4,471 fish of 15 different species. Juvenile salmon utilize habitat within treated Spartina marshes. Juvenile chum, Chinook, and pink salmon were captured in both reference (flooded mudflat, blind tidal channels within native marshes) and treated Spartina marsh (flooded and blind channel) habitats. We also demonstrate that other fish species utilize habitat within treated Spartina marshes including these dominant nearshore species: surf smelt, shiner perch, Pacific staghorn sculpin.

Fish assemblages in reference mudflat flooded intertidal habitat were similar to fish assemblages in flooded mudflat w clone intertidal habitat (e.g., treated Spartina marshes) over the two years sampled. Mudflat w clone areas used to be Spartina marsh, but were successfully treated and have now reverted to a physical habitat similar to mudflat, which is a natural reference habitat. These results suggest that Spartina marshes that are treated and revert toward a mudflat condition are likely to have fish assemblages similar to mudflats never colonized by Spartina.

Fish assemblages in native marsh blind channels were similar to the fish assemblages in blind channels found in clone areas (i.e., treated Spartina marshes) in one of the two years sampled. This result suggests that blind channel habitat within successfully treated Spartina marshes can result in fish assemblages similar to those in blind channel habitat in native marsh.

Since all fish habitat within the study area is intertidal, differences in elevation by habitat types will directly relate to the frequency, depth, and duration of tidal inundation. Lower elevation habitats will be wetted more frequently, to a deeper depth, and for a longer period of time than higher elevation habitats. Relative difference in fish access opportunity to the surface elevation of each habitat type is ordered greatest to least: reference mudflat, mudflat w clones (treated Spartina marsh), Spartina marsh, and native marsh. We also found Spartina marshes have less blind channel area than native marshes when standardized by marsh area. These results suggest that mudflats colonized by Spartina are less accessible to fish than both the original mudflat (as a result of increased elevation), but also when compared to native marshes which have approximately triple the blind channel habitat area.

Introduction

Spartina is an invasive, non-native, salt-tolerant vascular plant in Puget Sound. *Spartina anglica* (English cordgrass) is the most common of the four Spartina species in Puget Sound and found extensively in Island, Skagit, and Snohomish counties (Hacker et al. 2001). *S. anglica* was intentionally introduced in Puget Sound near Stanwood in 1961 for dike stabilization and as a food source for cattle.

S. anglica can impact the physical and ecological conditions of colonized areas by out-competing native marsh vegetation and converting mudflats to Spartina meadows, resulting in reduced plant diversity (i.e., monocultures of Spartina) and elevated intertidal area through increased sediment accumulation (Thompson 1991).

Because of the invasive nature of Spartina, the Washington Department of Fish and Wildlife (WDFW) began an eradication program in southern Skagit Bay in the late 1990s. The objective of this study is to evaluate the effect of Spartina removal treatment on the fish assemblage, including juvenile salmon, in the southern Skagit Bay near the town of Stanwood, Washington (Figure 1). This project is part of a larger study, funded by the National Fish and Wildlife Foundation's Puget Sound Marine Conservation Fund (Grant #2006-0180-006), which is evaluating the effectiveness of Spartina removal treatment success on a variety of biotic and abiotic variables, including sedimentation, vegetation, birds, and benthic invertebrates.

Figure 1. Map of Skagit Bay with study area highlighted in red.

Habitat

Methods

Defining habitat types

Using printed geo-referenced aerial photos of the study area from 2003, we drew polygons or arcs of the entire area based on the data fields shown in Table 1. The scale was 1:5,000. We then digitized each arc or polygon "heads-up" in a geographic information system (GIS) and quantified their area (for polygons) using ArcGISv9. Results are shown in Figure 2. We used these results to select sites for fish sampling by beach seine and fyke trap.

Table 1. Habitat type definitions and area of these habitats found in study area.

Habitat type	**Definition**	**Area in hectares**
Mudflat	Currently mudflat; was never infested by Spartina (based on an aerial photo record since 1964 and field knowledge of the study area since 1996) but is within the elevation range that Spartina can grow.	89.2
Mudflat w/clone	Formerly Spartina marsh; has been treated in some way to remove Spartina. May have had several treatment types (e.g., spray only, spray/disk). Currently mudflat with scattered Spartina clone patches (> 5 plants per acre but not continuous marsh or meadow).	191.8
Native marsh	Marsh area currently dominated by native marsh plants. Could have history of treatment (e.g., mowing, spraying) but was never infested with Spartina. Considered reference native marsh habitat.	127.2
Spartina marsh	Marsh area currently dominated by Spartina. Could have history of treatment (e.g., mowing, disking, spraying) but is still infested with Spartina. Considered what ultimately a mudflat area would become over time without Spartina control efforts.	62.4
Blind channel	Channel that forms naturally in marsh and mudflat areas. Dead ends in the marsh, mudflat or upland.	Not quantified in GIS
Barrow channel	Drainage channel dug outside of dikes, usually paralleling the dike. Functions like blind channel.	Not quantified in GIS
Mainstem or distributary channel	Channel open on both ends and wetted at all tidal stages. Includes Davis Slough, West Pass, and the cross-over channel between them.	Not quantified in GIS

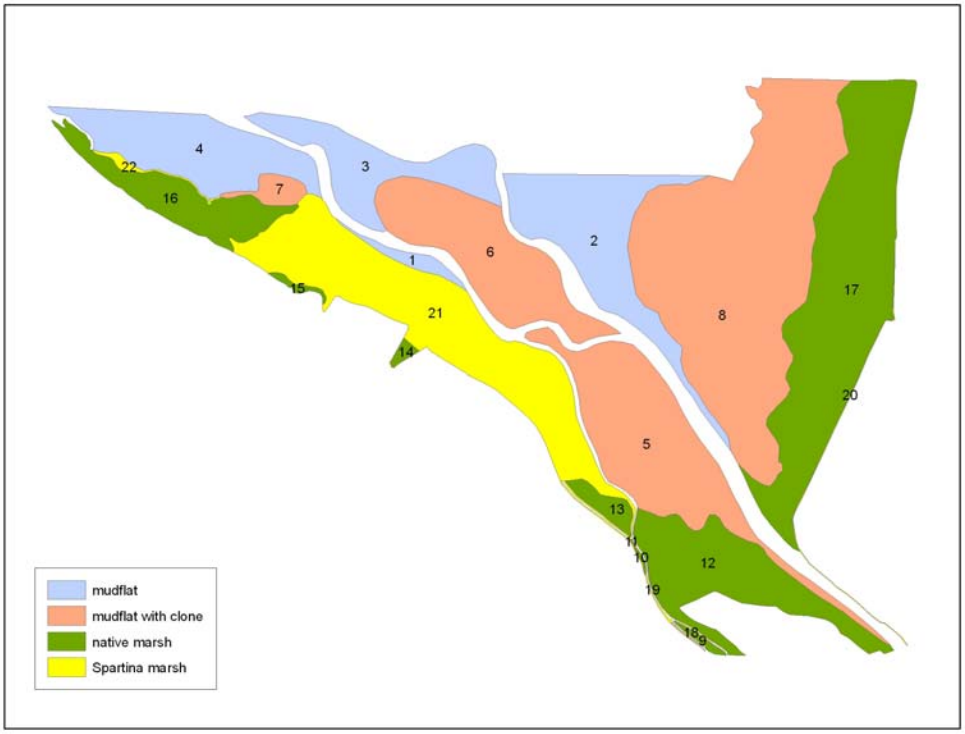

Figure 2A. Polygons by habitat type as mapped in 2006 (mudflat, mudflat with Spartina clones, native marsh, Spartina marsh). Unique identifying numbers are shown for each polygon. Some very narrow polygons do not show at this scale of a map.

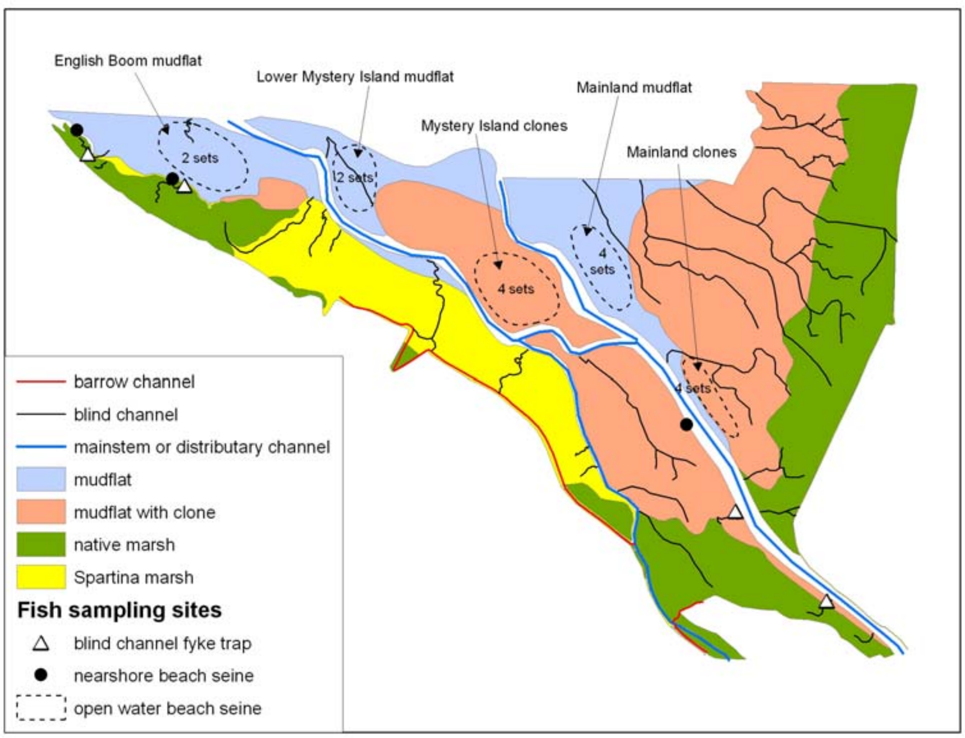

Figure 2B. Sampling sites and major channels (shown over habitat type). The locations where fish sampling was conducted are shown as black dots, white triangles, and dashed polygons.

Calculating elevation by habitat type

Elevations were calculated in feet for each polygon in the study area using Spatial Analyst's 'Zonal Statistics' function using available LiDAR (Light Detection And Ranging) data that included the study area. We used the Fir Island LiDAR dataset flown by Spencer B. Gross, Inc. on 4/1/2002. The Vertical datum is NGVD 29/47 and pixel resolution is 3-meter. Elevation values for each polygon calculated were: minimum, maximum, mean, and standard deviation. There are a few gaps in the dataset that are not accounted for in the elevation analysis. Gaps are primarily due to standing water in the study area; this LiDAR survey was not designed to penetrate water.

We made adjustments to the elevation values for this LiDAR dataset following methods described in Hood (2007). Hood found that correction was necessary with this LiDAR dataset to obtain bare earth elevations. Adjustments were done only on low emergent marsh polygons. The correction factor was elevation minus 0.164 feet (5cm).

Estimating blind channel area within native marsh and Spartina marsh polygons

Blind channels form within tidal marshes and are commonly used by many nearshore fish species, including juvenile salmon. We planned to sample fish in some blind channels within the study area. We also planned to compare the amount of blind channel area between native marsh and Spartina marshes. Thus, we located the mouths of blind channel networks within marsh polygons of the study area and estimated their area.

Only five native marsh and one Spartina marsh polygons in the study area are large enough to develop blind channels within them. The native marsh polygons are numbers 9, 12, 13, 16, and 17 and the Spartina marsh polygon is number 21 (Figure 2A). All remaining Spartina marsh polygons are narrow strips bordering barrow channels and would not be expected to have blind channels form within them.

We identified the mouths of blind channels and their channel width by photo and field inventory for each polygon. For each channel, we applied the regression equation (1) from Collins (1998) to convert top width at the channel’s mouth to total channel area. We then summed the channel areas, yielding a total channel area for each polygon. Results were converted to hectares.

Equation 1: $Y = 81.73X^{1.7}$ where,

Y = blind channel area (in meters squared), and
X = top width at blind channel mouth (in meters)

Results and discussion

We looked at three habitat variables—elevation, blind channel area, and the number of blind channel networks—that likely affect fish access and use of the four habitat types defined for the study area.

Elevation by habitat type

In GIS we classified the study area by four polygon types. We selected fish sampling sites within available habitat for each of the four polygon types. Since all fish habitat within the study area is intertidal, differences in elevation by habitat types will directly relate to the frequency, depth, and duration of tidal inundation. Lower elevation habitats will be wetted more frequently, to a deeper depth, and for a longer period of time than higher elevation habitats. Relative difference in fish access opportunity to the surface elevation of each habitat type is ordered greatest to least: reference mudflat, mudflat w clones (treated Spartina marsh), Spartina marsh, and native marsh.

Average elevation of all mudflat polygons in the study area is -0.73 ft and are the lowest elevation polygon type (Figure 4A). These areas were never Spartina marshes and are considered reference mudflats. Reference mudflats are also several feet lower than polygons defined as Mudflat w clones (formerly Spartina marsh).

Average elevation of mudflat with clones polygons is 1.80 ft (Figure 4B). These areas were formerly Spartina marshes but were treated successfully and have reverted to habitat similar reference mudflat. It is unknown whether the higher elevation of these areas compared to the reference mudflats are a result of a higher starting elevation before Spartina infestation, or a higher elevation due to sediment accretion during the period when these areas were Spartina marshes.

Native marsh polygons were the highest in elevation of all four polygon types. Average elevation of all native marsh polygons is 5.54 ft (Figure 4C).

The overall average elevation of all Spartina marsh polygons is 3.62 ft. However, polygon #20 has a much higher than average elevation at 7.07ft than the others (Figure 4D); it is a narrow strip of Spartina marsh bordering the northern side of West Pass and may not be representative of the elevation that Spartina pioneers in mudflat. The remaining four Spartina polygons shown in Figure 4D have elevations (average elevation of 2.76 ft) more similar to, but still nearly 1 foot higher than Mudflat w clones polygons (Figure 4B). Again, it is unknown whether the lower elevation of these areas compared to the mudflats w clones (formerly Spartina marsh) are a result of a higher starting elevation before Spartina infestation, or a higher elevation due to sediment accretion now that the area is Spartina marsh.

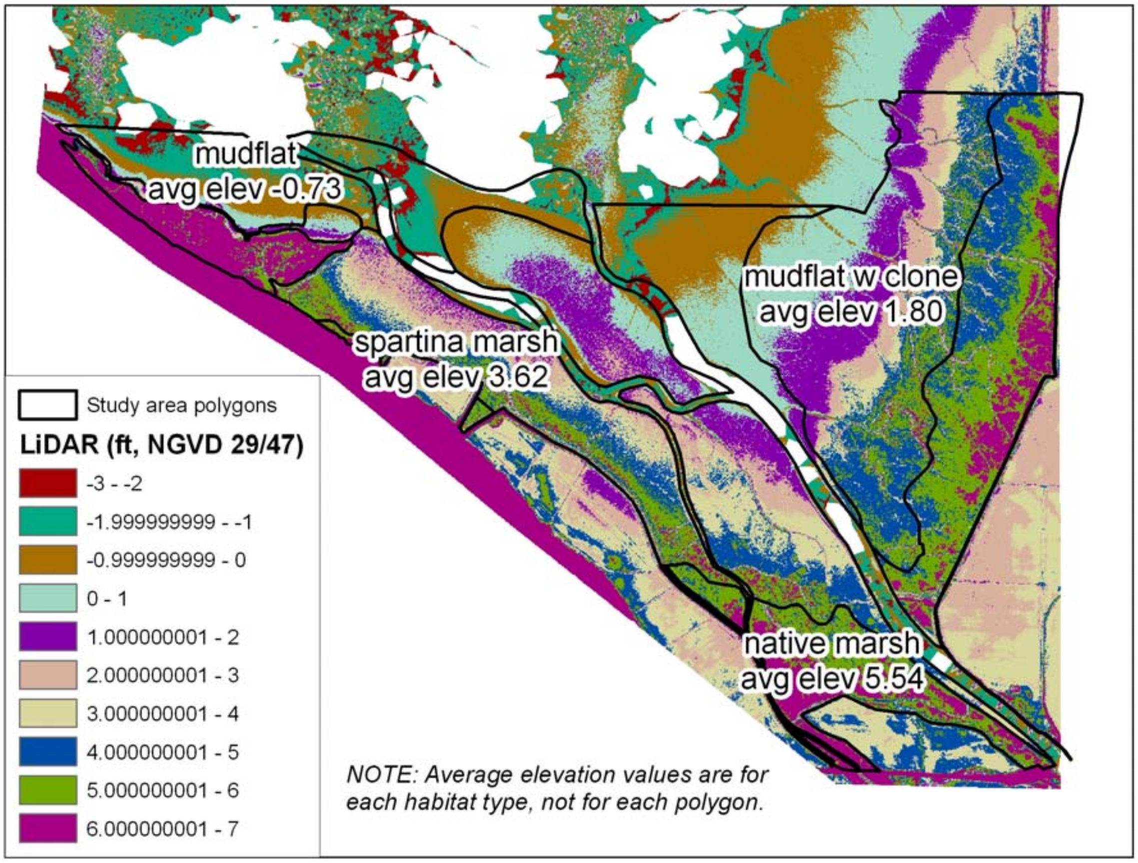

Figure 3. Study area polygons shown over the LiDAR.

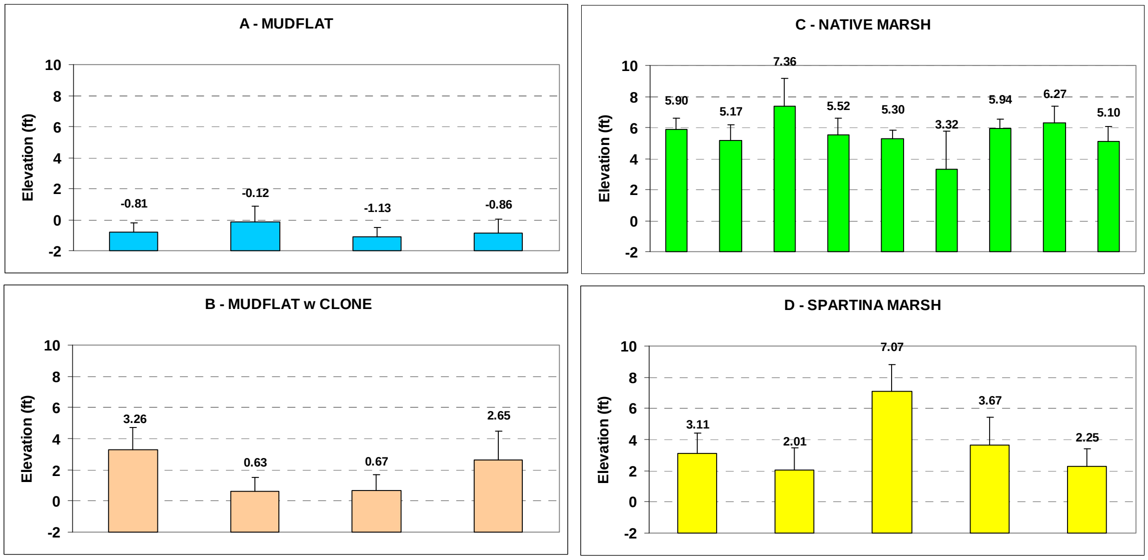

Figure 4. Average elevation of individual polygons by type. The datum is NGVD 29/47. Error bars are one standard deviation.

Number of blind channel networks and their area

Blind tidal channels form in marsh areas due to erosive tidal processes acting on the marsh surface. While marsh areas are generally the highest of intertidal habitats, the channels within marshes are much lower and are known to be directly used by numerous fish species, including juvenile salmon (Congleton et al 1981; Levy and Northcote 1981; Beamer et al 2005,). We expect blind channel networks to be present within both native and Spartina marsh polygons. We also wanted to observe whether there are differences in the amount of blind channel habitat that is formed between the two polygon types: native marsh and Spartina marsh. Differences in blind channel characteristics might be due to differences in elevation (Figures 4C and D) and/or differences in above/below ground plant characteristics that influence sediment erosion and deposition.

We found Spartina marshes in our study have about one third the channel area (Figure 5A) and slightly fewer (90%) blind channel networks (Figure 5B) than native marsh areas when standardized by marsh area. These results suggest that mudflats that become Spartina marshes are not only reduced in their opportunity to provide fish access to the marsh's surface due to increased elevation but there is also not equivalent amounts of blind channel habitat for fish in Spartina marshes as native marshes.

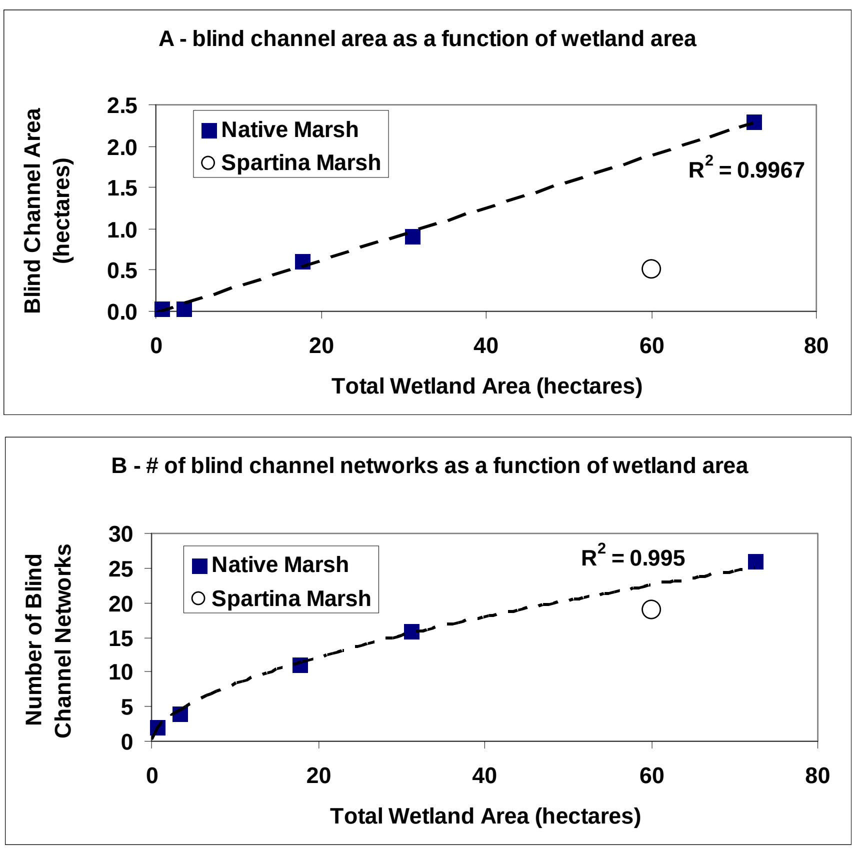

Figure 5. Relationship between wetland area and (A) total area of blind channels or (B) number of blind channel networks.

Fish

Methods

This section explains methods related to the capture and analysis of fish data.

Effort level and gear used for each habitat type

We collected fish catch data for seven months in 2007. Sampling started in January as a pilot effort to identify sites and work out the mechanics of sampling a very shallow and extremely soft substrate environment. We sampled monthly February through May to coincide with a juvenile salmon outmigration period for shallow nearshore habitat. In 2007, we also sampled in August and October to represent end of summer and fall conditions. We repeated sampling in 2008 during the juvenile salmon outmigration period (February through June) to represent two different years that varied in juvenile salmon species (1) composition (pink and non-pink years) and (2) population size (high and low chum salmon population years).

Physical limitations (access ability to sites and tides) within the study area influenced our ability to sample all habitat types for fish use. Thus, different fish capture methods were used for the different habitat types present within the study area. Because different methods required different tidal stages, we were forced to sample the different habitat types on different days to accommodate each method. Sampling sites are shown in Figure 2B. Sampling effort by habitat type is shown in Table 2.

Table 2. Fish capture methods and number of sets made for each habitat type for one (usually monthly) sampling event.

Habitat Type	Open water	Blind channel	Nearshore edge or open channel edge
Mudflat	Open water beach seine, 8 sets	none	none
Mudflat w/clone	Open water beach seine, 8 sets	Fyke trap, 2 sets	Beach seine, 2 sets
Native marsh	none	Fyke trap, 1 set Beach seine, 1-2 sets	Beach seine, 6-7 sets
Spartina marsh	none	none	none

Mudflat and Mudflat with clones - We sampled flooded reference mudflat and mudflat with clones sites using "open water" beach seining methods, using a small net (6 ft by 80 ft by 1/8 inch mesh) beach seine. The exact location of each set varied month to month due to tidal height, thus we show the general location of these open water sets as clusters within dashed lines (Figure 2B). In order to sample these areas on the same day, we seined on days with small flood tides. For days that we seined, the high tide needed to be at least 10.0 ft in order to adequately flood each of the tidal flat sites. We made a total of 16 open water beach seine sets on each day we sampled. Sampling was done monthly (February through May, August, and October). We represented both sides of the study area. Eight open water beach seine sets were sampled on the mainland side of West Pass and eight open water beach seine sets were sampled on the Camano Island side of West Pass each sampling day (Figure 2B).

Blind channels - Four blind channel sites were sampled (Figure 2B). We were able to sample one "extra" site thanks to help from the Camano Island community (mainly WSU Island County Beach Watchers). The extra site (English Boom Pocket Estuary) is located in the northwest edge of the study area. Three of the blind channels were sampled using fyke traps. Fyke traps are essentially a beach seine with an attached net bag used to collect fish. Fyke traps are set at high tide and fished through the ebb tide. Fyke trap days were set for days with early morning high tides of ~10.0 ft (or higher) followed by an ebb tide that drops to ~0.0 ft. One blind channel was sampled by beach seine at ebb tide stage near its mouth. Blind channel sites were sampled every two weeks during the expected outmigration period for juvenile salmon fry (February through May).

Nearshore edge - Eight to nine nearshore beach seine sets were sampled at three sites using a small net (6 ft by 80 ft by 1/8 inch mesh) beach seine (Figure 2B). These sites were sampled on ebbing tides during the time we waited for water to drain from the blind channel sites being sampled by fyke traps.

Fishing methods and density calculations

We standardized fish catch results into density (fish per hectare of wetted habitat area) in order to directly compare results from the different fishing gear types used. This section describes the different fishing gear methods and fish density calculations.

Beach seine - The area sampled by an open water beach seine set was estimated as $120m^2$. The area sampled by a normal (shoreline to shoreline) beach seine set was estimated as $96m^2$. Beach seine set area for sets not deployed perfectly were adjusted based on visual observation of the set shape and completeness of the net going from shore to shore (or boat to boat for open water sets). Set area adjustments were expressed as a percentage of a perfect beach seine set (100%) depending on whether the set was larger (110%, 120%, etc.) or smaller (70%, 80%, etc.) than perfect. Beach seine set area was then calculated: Beach seine set area = $96m^2$ (or $120m^2$ if open water set) multiplied by % adjustment. Fish density results from beach seine were calculated as: catch divided by adjusted set area. We did not adjust fish density results by a catch efficiency coefficient for beach seine data. Our past experience on smooth substrate has shown high capture efficiency with this net (>80%).

Fyke trap - Fyke trap sites had differing amounts of habitat and fish capture efficiency associated with them. The habitat area upstream of each fyke trap was calculated for each site (ranged between $173m^2$ and $871m^2$) and fish capture efficiency was calculated for each site based on mark and recapture experiments. Fish capture efficiency ranged between 9% and 44% for the three sites. Fish density at fyke trap sites was calculated as: catch divided by capture efficiency divided by set area.

Fish assemblage analysis

The broad objective of this study is to evaluate the effect of Spartina removal treatment on fish assemblages, including juvenile salmon, in two habitat types invaded by Spartina.

The mudflat w clone areas used to be Spartina marsh before they were treated (see classification in Table 1). Clone areas were successfully treated for Spartina eradication and have now reverted to a physical habitat that is quite similar to uninvaded mudflat. Mudflat and clone areas are intertidal and thus give fish opportunity to live directly within mudflat or clone areas when flooded. These non-channel wetted habitats are defined ‘flooded intertidal.’ Also, both native and Spartina marshes contain blind channels. Blind channels are also intertidal but are at a lower elevation than the marsh surface. Blind channel can contain wetted areas at any tidal stage through local hydraulic controls of water surface (e.g., sediment sills, beaver dams). Blind channels provide direct access for fish. Thus, we compared the difference/similarity of fish assemblages for two possible treatment/reference habitats: flooded intertidal and blind channels.

To evaluate the influence of Spartina removal treatment on fish we hypothesized that:

1. Fish assemblages in reference mudflat flooded intertidal habitat are similar to fish assemblages in flooded mudflat w clone intertidal habitat (e.g., treated Spartina marshes).
2. Fish assemblages in native marsh blind channels are similar to the fish assemblages in blind channels found in clone areas (i.e., treated Spartina marshes).

To statistically compare the taxonomic composition of fish assemblages by habitat type, we used non-metric multidimensional scaling (MDS) ordinations based on resemblance matrices of Bray-Curtis similarity of fish density data, following the approach of Clarke and Warwick using Primer statistical software version 6 (Clarke and Warwick 2001, Clarke and Gorley 2006). The MDS plots allowed us to visualize the distribution of samples from the habitat types. Input data were fish density by species, month, year, and habitat type. We averaged densities for each habitat, month, and year combination, and a square-root transformation was applied to the data matrix to down-weight the influence of highly abundant species.

To statistically compare the treatments, we used ANOSIM (analysis of similarity). ANOSIM results indicate whether there were significant differences among the treatment areas. We used SIMPER (similarity percentages) to determine which species contributed most to taxonomic similarity of the areas.

Results and Discussion

Total fish catch

In 2007 we made 185 beach seine or fyke trap sets between January 25th and October 15th, catching 9,852 fish of 12 different species (Table 3). In 2008 we made 94 beach seine or fyke trap sets between February 15th and June 20th, focusing effort only during the juvenile salmon period. We caught 4,471 fish of 15 different species in 2008 (Table 3).

Table 3. Total fish catch (and average fish catch per set, in parentheses) per set by year.

Fish species groups	2007	2008
Juvenile salmon species and mark:		
Chum salmon, subyearling *Oncorhynchus keta*	1,601 (8.65)	178 (1.89)
Pink salmon, subyearling *Oncorhynchus gorbuscha*	0 (0.00)	245 (2.61)
Chinook salmon, unmarked subyearling *Oncorhynchus tshawytscha*	61 (0.33)	56 (0.60)
Chinook salmon, unmarked yearling *Oncorhynchus tshawytscha*	1 (0.01)	0 (0.00)
Chinook salmon, marked subyearling *Oncorhynchus tshawytscha*	1 (0.01)	5 (0.05)
Chinook salmon, marked yearling *Oncorhynchus tshawytscha*	1 (0.01)	0 (0.00)
Coho salmon, unmarked fry *Oncorhynchus kisutch*	3 (0.02)	4 (0.04)
Coho salmon, unmarked yearling *Oncorhynchus kisutch*	24 (0.13)	0 (0.00)
Total juvenile salmon	**1,692 (9.15)**	**488 (5.19)**
Sculpin species:		
Pacific staghorn sculpin *Leptocottus armatus*	775 (4.19)	1,231 (13.10)
Prickly sculpin *Cottus asper*	0 (0.00)	2 (0.02)
Sharpnose sculpin *Clinocottus acuticeps*	22 (0.12)	2 (0.02)
Total sculpins	**797 (4.31)**	**1,235 (13.14)**
Flatfish species:		
Starry flounder *Platichthys stellatus*	51 (0.28)	13 (0.14)
Total flatfish	**51 (0.28)**	**13 (0.14)**
Forage fish species:		
Surf smelt, post larval juvenile *Hypomesus pretiosus*	5,902 (31.90)	1,890 (20.11)
Surf smelt, adult-like in body form *Hypomesus pretiosus*	513 (2.77)	85 (0.90)
Pacific herring, post larval juvenile *Clupea harengus*	0 (0.00)	4 (0.04)
Pacific herring, adult-like in body form *Clupea harengus*	0 (0.00)	15 (0.16)
Total forage fish	**6,415 (34.68)**	**1,994 (21.21)**
Other nearshore or estuarine fish species:		
Shiner perch *Cymatogaster aggregate*	827 (4.47)	651 (6.93)
Striped perch *Embiotoca lateralis*	3 (0.02)	0 (0.00)
Snake Prickleback *Lumpenus sagitta*	0 (0.00)	5 (0.05)
Threespine stickleback *Gasterosteus aculeatus*	40 (0.22)	40 (0.43)
Arrow goby *Clevelandia ios*	26 (0.14)	8 (0.09)
Peamouth chub *Mylocheilus caurinus*	1 (0.01)	37 (0.42)
Grand Total	**9,852 (53.25)**	**4,471 (47.59)**

We sampled during two different years representing juvenile salmon migrations that varied in species composition (pink and non-pink years) and population size (high and low chum salmon population years). Juvenile pink salmon were not present in 2007 when juvenile chum salmon dominated the salmon catch. Pink salmon were the most abundant juvenile salmon in 2008. Chum salmon were nearly an order of magnitude less abundant in the pink year (2008) than the non-pink year (2007). Total juvenile Chinook salmon catch was similar in both years, but average catch per set was nearly two times greater in 2008 than 2007.

Four fish species (juvenile chum salmon, surf smelt, shiner perch, and staghorn sculpin) made up approximately 98% and 90% of the total catch in 2007 and 2008, respectively. Juvenile salmon used habitat within treated Spartina marshes, and juvenile chum, Chinook, and pink salmon were captured in both reference (flooded mudflat, blind tidal channels within native marshes) and treated Spartina marsh (flooded and blind channel) habitats (Figures 6-12). Other fish species also used habitat within treated Spartina marshes including these dominant nearshore species: surf smelt, shiner perch, Pacific staghorn sculpin.

Fish assemblages by habitat type

Graphical analysis of raw fish density data (Figures 6-12) and MDS ordination plots (Figures 13 and 14), and multivariate statistical analysis of taxonomic composition (Tables 4-6), generally agreed with respect to the effect of the experimental treatments, but also pointed out the major influence of natural environmental gradients.

Graphical illustrations of fish assemblage seasonality and abundance are best observed in Figures 6-12 while differences/similarities in fish assemblage by habitat type are observed in Figures 13 and 14. However, the focus of this study was to compare fish assemblages for two habitat pairings hypothesized to be similar as a result of Spartina removal.

Comparing flooded intertidal in mudflat and clone areas

Mudflat / flooded intertidal and clones / flooded intertidal habitat had very similar fish assemblage structure over the two years sampled (Figures 13 and 14). In both MDS plots, fish assemblage points for flooded intertidal habitat in mudflat and clone areas grouped together. ANOSIM results support the graphic representation in the MDS plots of fish assemblage similarity (Table 4). Both habitat types were dominated by surf smelt and shiner perch in 2007 and surf smelt and Pacific staghorn sculpin in 2008 (Figures 11 and 12, Table 5). Juvenile salmon, including Chinook, chum, and pink salmon, were found in both habitat types (Figures 11 and 12).

Clone areas used to be Spartina marsh, but were successfully treated and have now reverted to a physical habitat similar to mudflat, which is a natural reference habitat. These results suggest that Spartina marshes that are treated and revert toward a mudflat condition are likely to have fish assemblages similar to mudflats never colonized by Spartina.

Comparing blind channel in native and Spartina marsh areas:
Comparing fish assemblages in blind channel habitat occurring within native and treated Spartina marshes is a two step process in order to avoid a possible bias imposed by differences in habitat connectivity between sites.

Within the delta and nearshore ecosystems of the Skagit estuary, Beamer et al (2005) found differences in habitat connectivity influenced juvenile salmon abundance within the estuary. They consider connectivity at two different scales. The first scale was landscape connectivity. It is a function of both the distance and complexity of the pathway that salmon must follow to certain types of habitats (e.g., blind tidal channels). Habitat connectivity decreases as complexity of the route the fish must swim increases and the distance the fish must swim increases. In addition to landscape scale connectivity, local scale connectivity also influenced juvenile salmon abundance at specific sites within the Skagit estuary. Local connectivity refers to the accessibility of habitat to juvenile salmon and is defined by channel depth at high tide of the entrance to an area such as blind tidal channel network. A deeper channel will have higher connectivity than a shallower channel. We have three independent results suggesting that differences in landscape and local connectivity will influence our comparison of fish assemblage results for blind channels.

1. Tissue samples were collected from 54 of the 56 juvenile Chinook salmon caught within the study area during 2008. These samples were used to determine fish origin based on genetic analysis of DNA. Seventy-four (74%) of the samples were Skagit River origin while the next highest group (15%) were from the Stillaguamish River (David. Teel, NOAA Fisheries,Unpublished data). These results suggest that landscape connectivity for juvenile salmon is more related to the Skagit River than the Stillaguamish River thus we looked at differences in landscape connectivity between our study sites calculated as the migration pathways from the Skagit River. By applying the landscape connectivity equation described in Beamer et al. (2005) to our site data, we find only a significant difference in connectivity for the blind channel pairings, not the flooded intertidal pairing. The native marsh high elevation blind channel sites are located in the northwest corner of our study area (Figures 1 and 2). They have a better connection to the Skagit River via a large distributary (Tom Moore Slough) flowing on the east side of the Skagit delta than the native marsh and clone areas with low elevation blind channel sites, which are located in West Pass in the southeast corner of our study area (Figures 1 and 2). This difference in landscape connectivity may explain why juvenile salmon density was much higher in native marsh high elevation blind channel sites (Figures 10A and B) in both years when compared to native marsh or clone area low elevation blind channel sites (Figures 9A and B, Figures 8A and B).

2. Differences in local connectivity were calculated for all fish sampling sites, including blind channels. The high elevation blind channel sites were over 4 ft higher in elevation than low elevation blind channel sites.

3. Points in the MDS plots of fish assemblage structure for high and low elevation blind channels in native marsh did not group together for either sampling year (Figures 13 and 14). ANOSIM results support the graphic representation in the MDS plots of fish assemblage similarity (Table 4).

The differences in landscape connectivity and local connectivity (i.e., high v. low elevation sites) between our four blind channel sites, and the ANOSIM result demonstrate the only appropriate pairing for comparing possible effect of our experimental treatments on fish assemblages in blind channels is native marsh low elevation blind channel versus clones (formerly Spartina marsh) low elevation blind channel. However, we only have two sites to make this comparison so data are limited. These two sites are similar in both landscape and local connectivity values.

Clones / blind channel habitat at low elevation and native marsh / blind channel habitat at low elevation had weak similarity in fish assemblage structure in one of the two years sampled. Points in the MDS plot for 2007 shows fish assemblage results for low elevation blind channels (clone and native marsh) did not group together, but were more similar than the native marsh high elevation group which is in the lower right side of the plot (Figure 13). The MDS plot for 2008 shows fish assemblage results for low elevation blind channels (clone and native marsh) do group together, although not tightly (Figure 14). ANOSIM results of fish assemblage support dissimilarity between the two groups in 2007 and similarity in 2008(Table 4). Juvenile salmon, including Chinook, chum, and pink salmon, were consistently found in both habitat types (Figures 8 and 9, Table 6).

This result suggests that blind channel habitat within successfully treated Spartina marshes can result in fish assemblages similar to those in blind channel habitat in native marsh.

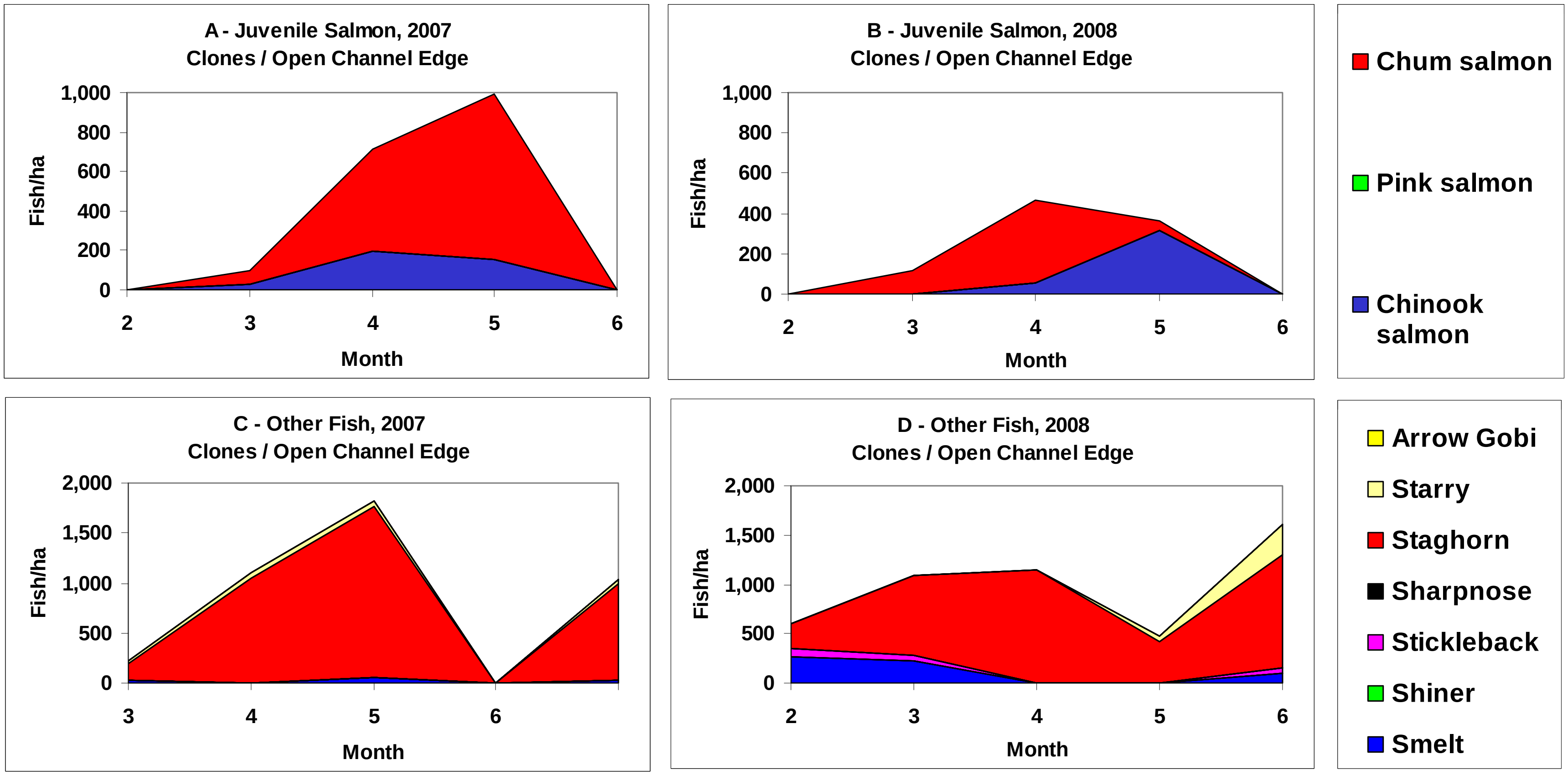

Figure 6. Fish density by month in clones/open channel edge habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

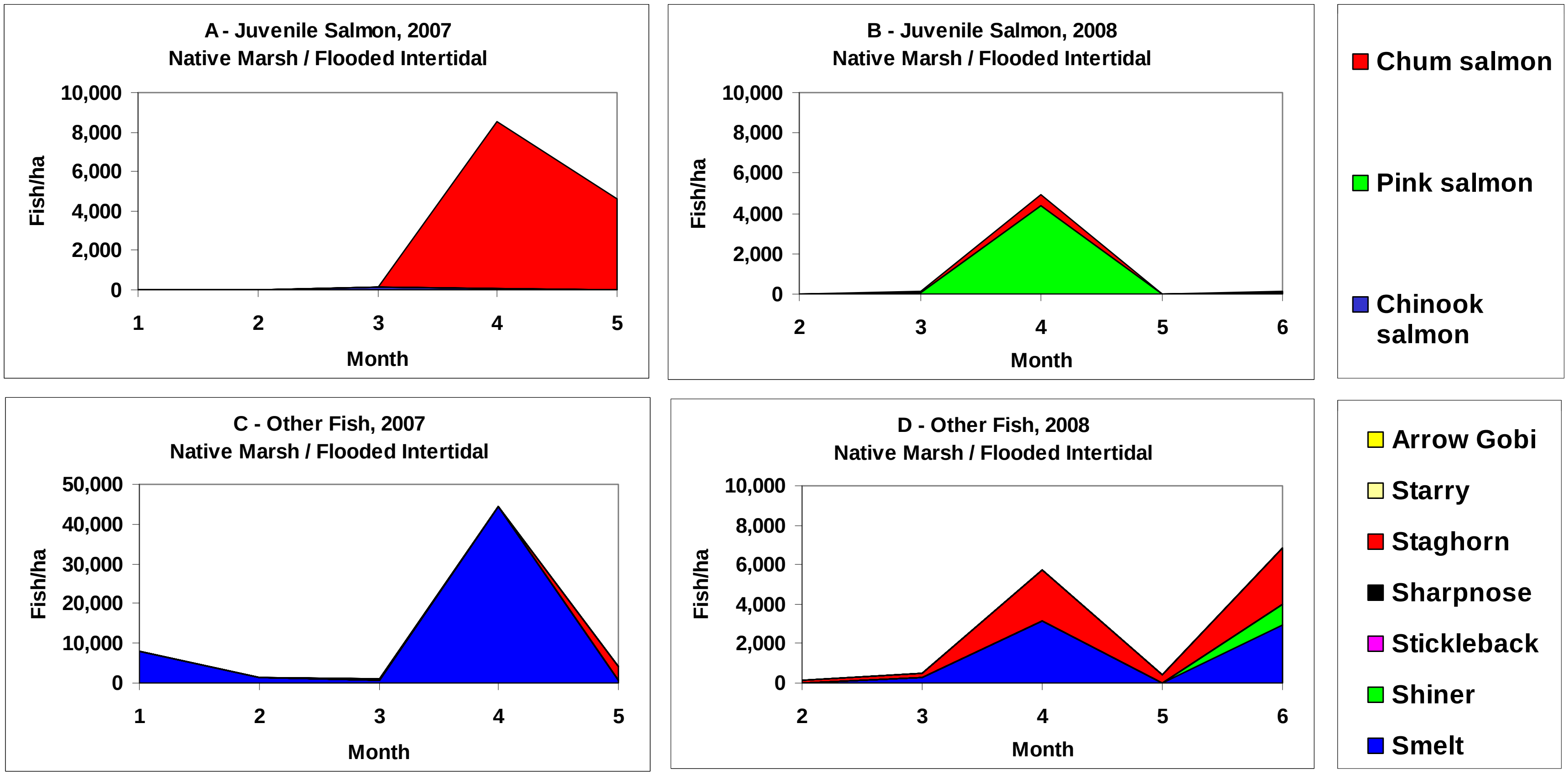

Figure 7. Fish density by month in native marsh/flooded intertidal habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

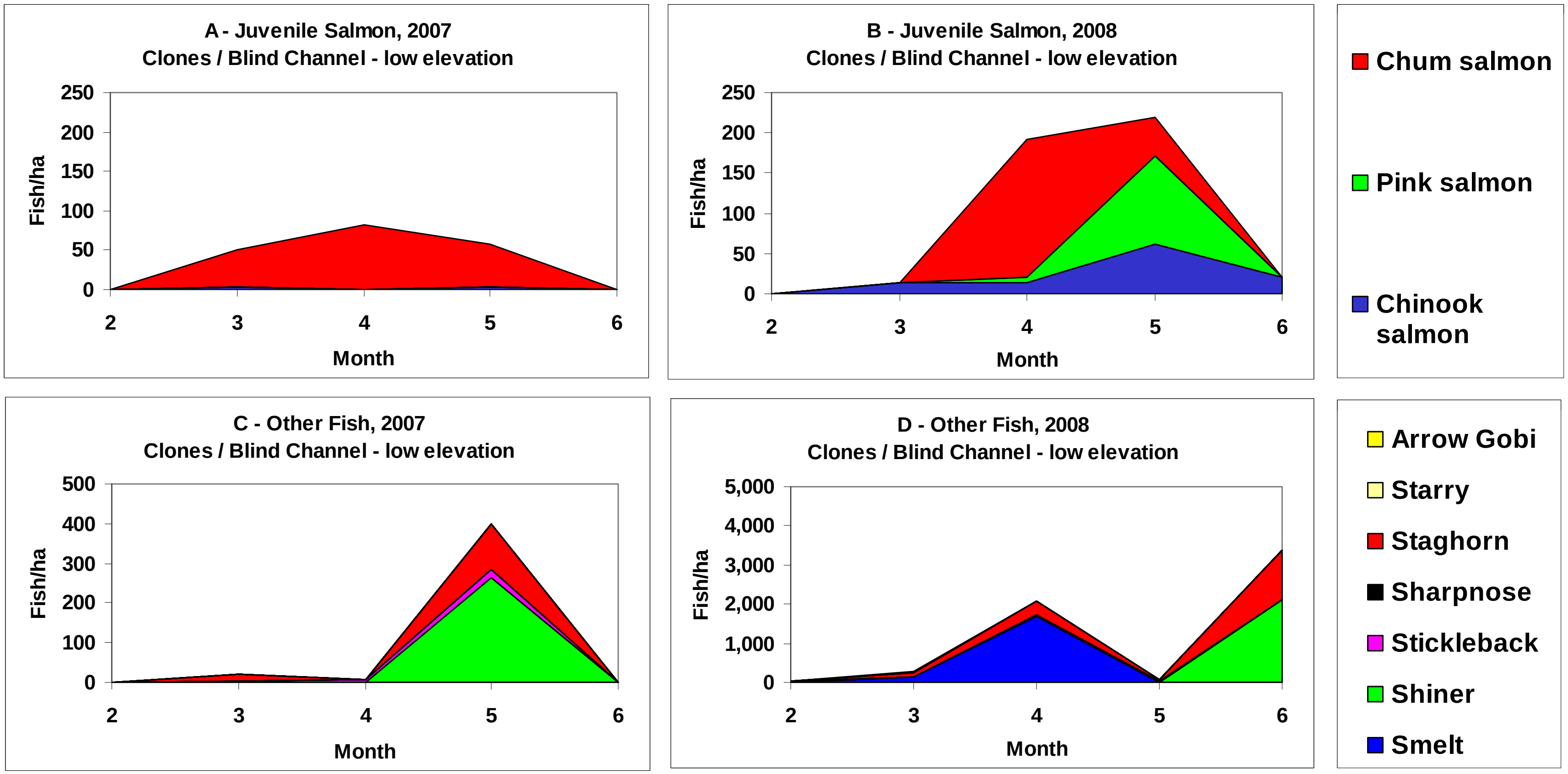

Figure 8. Fish density by month in clones/blind channel (low elevation) habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

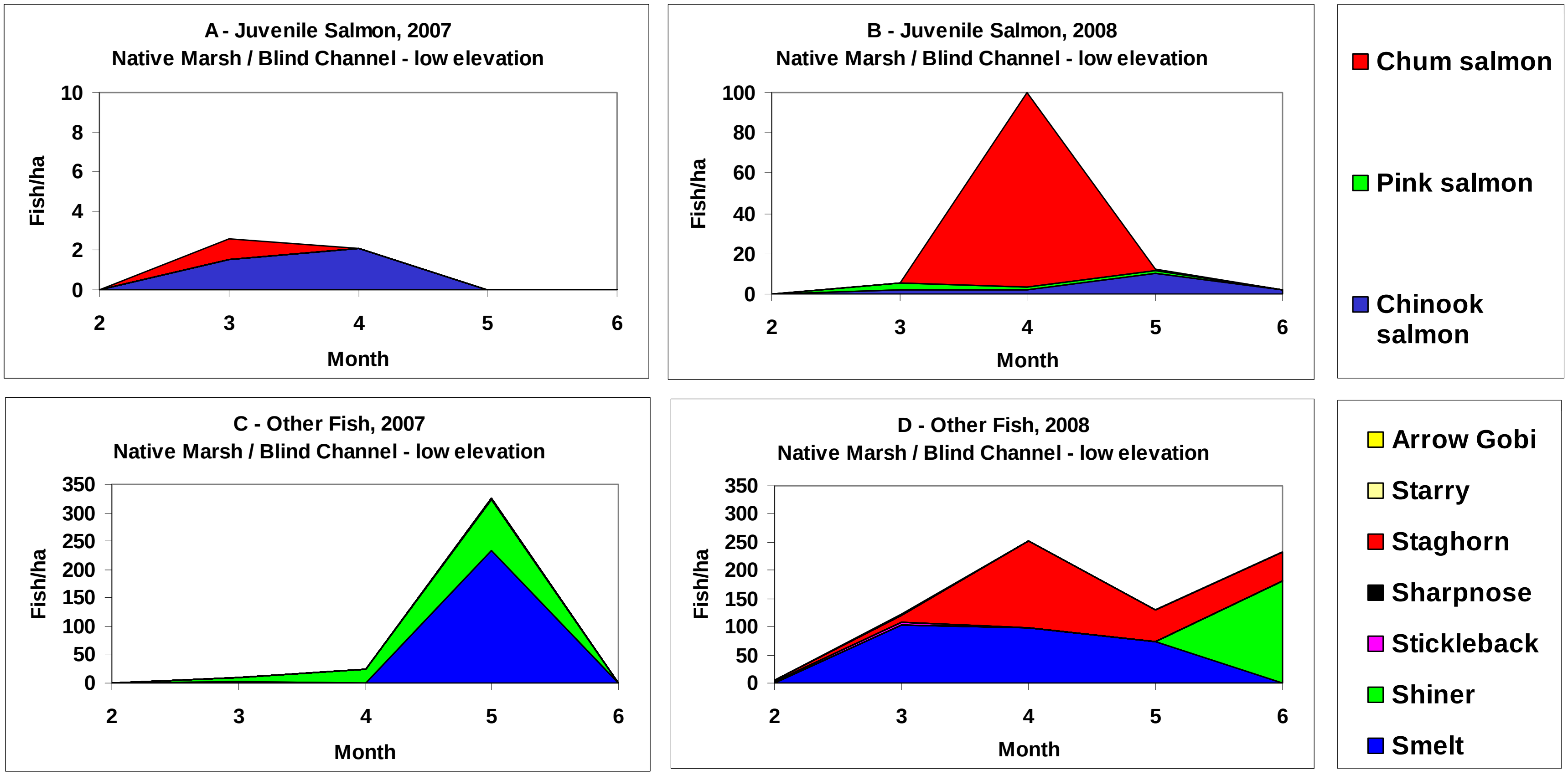

Figure 9. Fish density by month in native marsh/blind channel (low elevation) habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

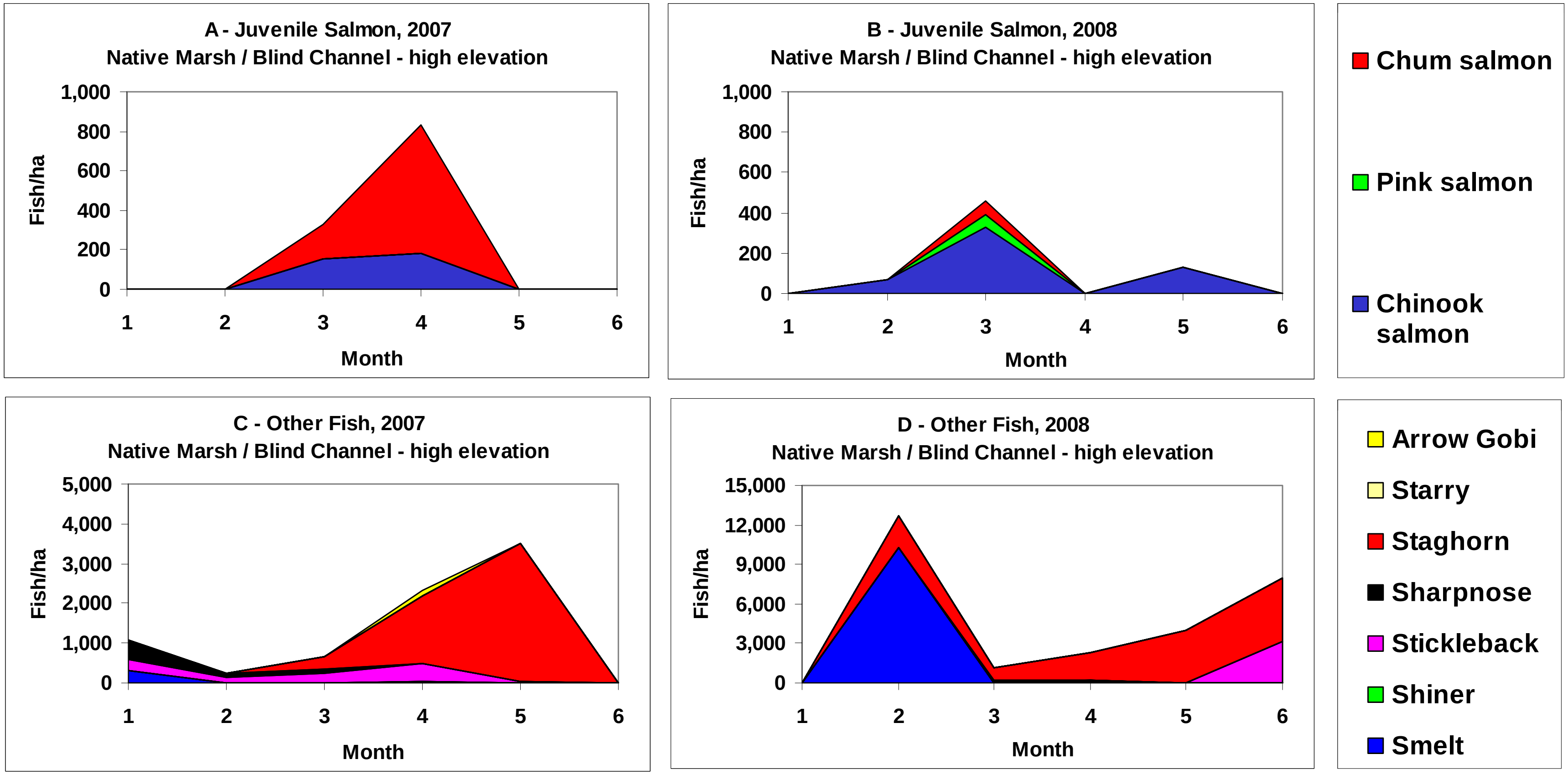

Figure 10. Fish density by month in native marsh/blind channel (high elevation) habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

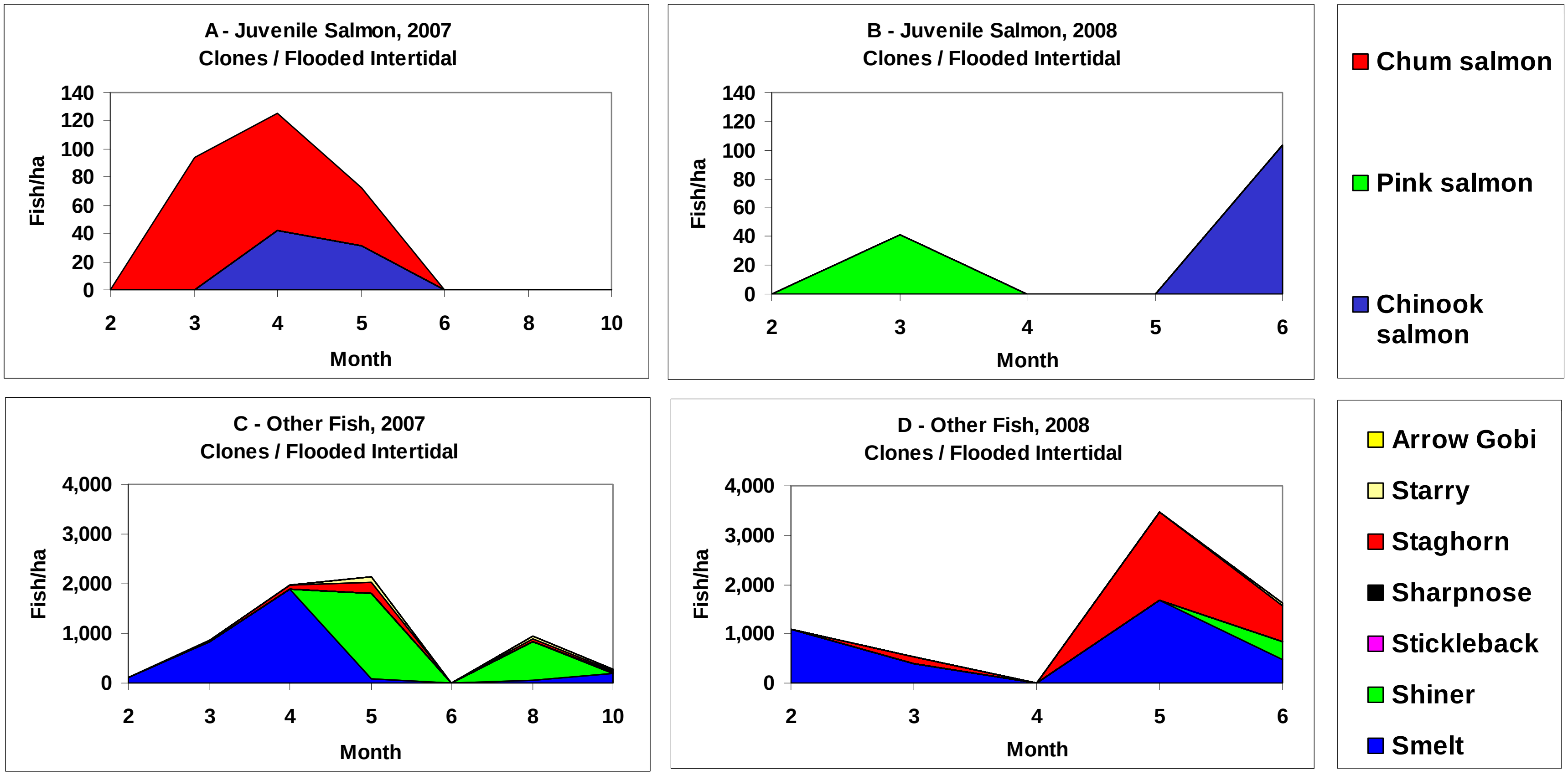

Figure 11. Fish density by month in clones/flooded intertidal habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

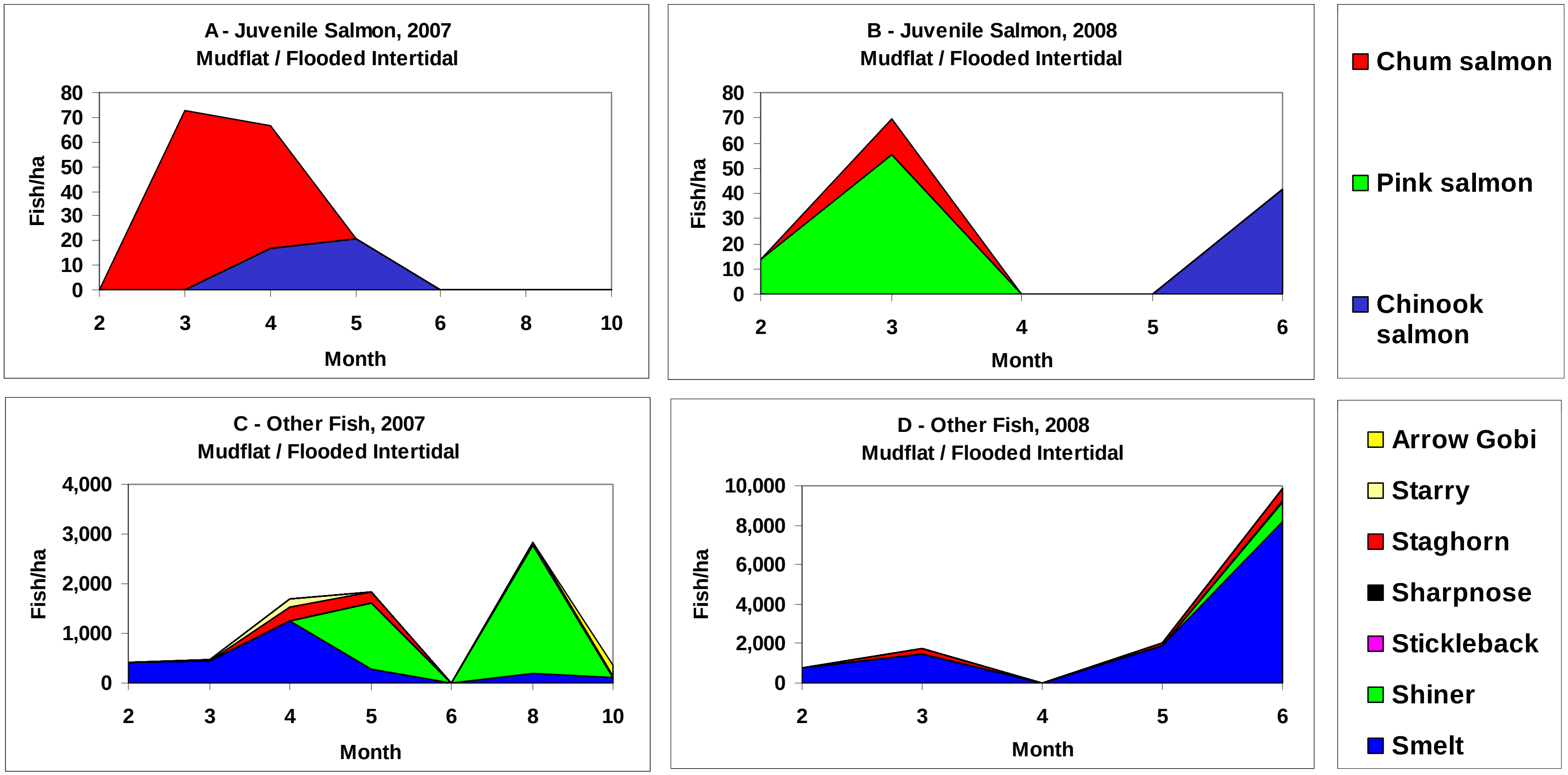

Figure 12. Fish density by month in mudflat/flooded intertidal habitat: (A) juvenile salmon in 2007; (B) juvenile salmon in 2008; (C) other fish in 2007; (D) other fish in 2008.

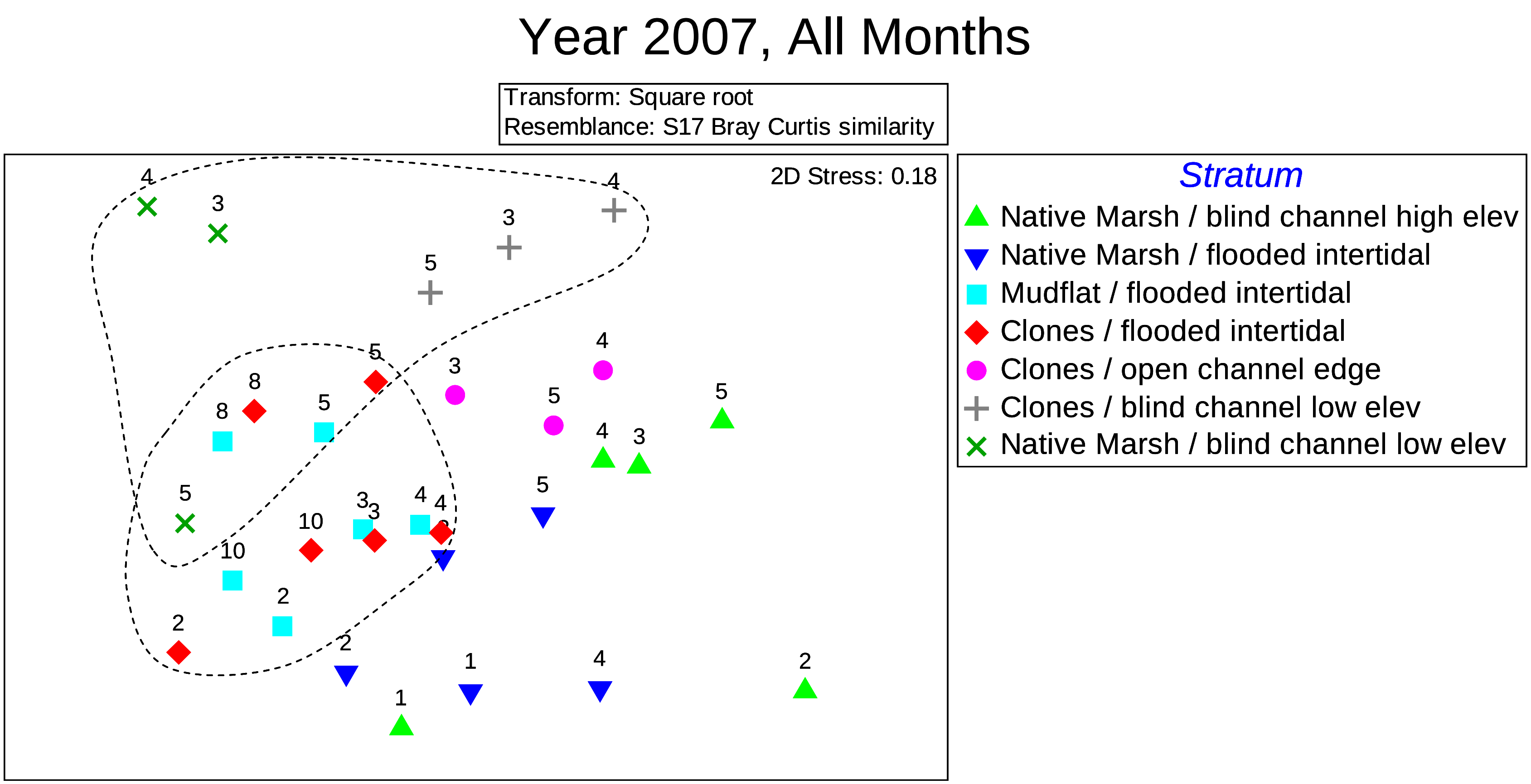

Figure 13. MDS plot for all months in 2007. Numbers next to symbols indicate month of sample. Overall ANOSIM results for data shown in this figure: Global R: 0.55 (p = 0.001).

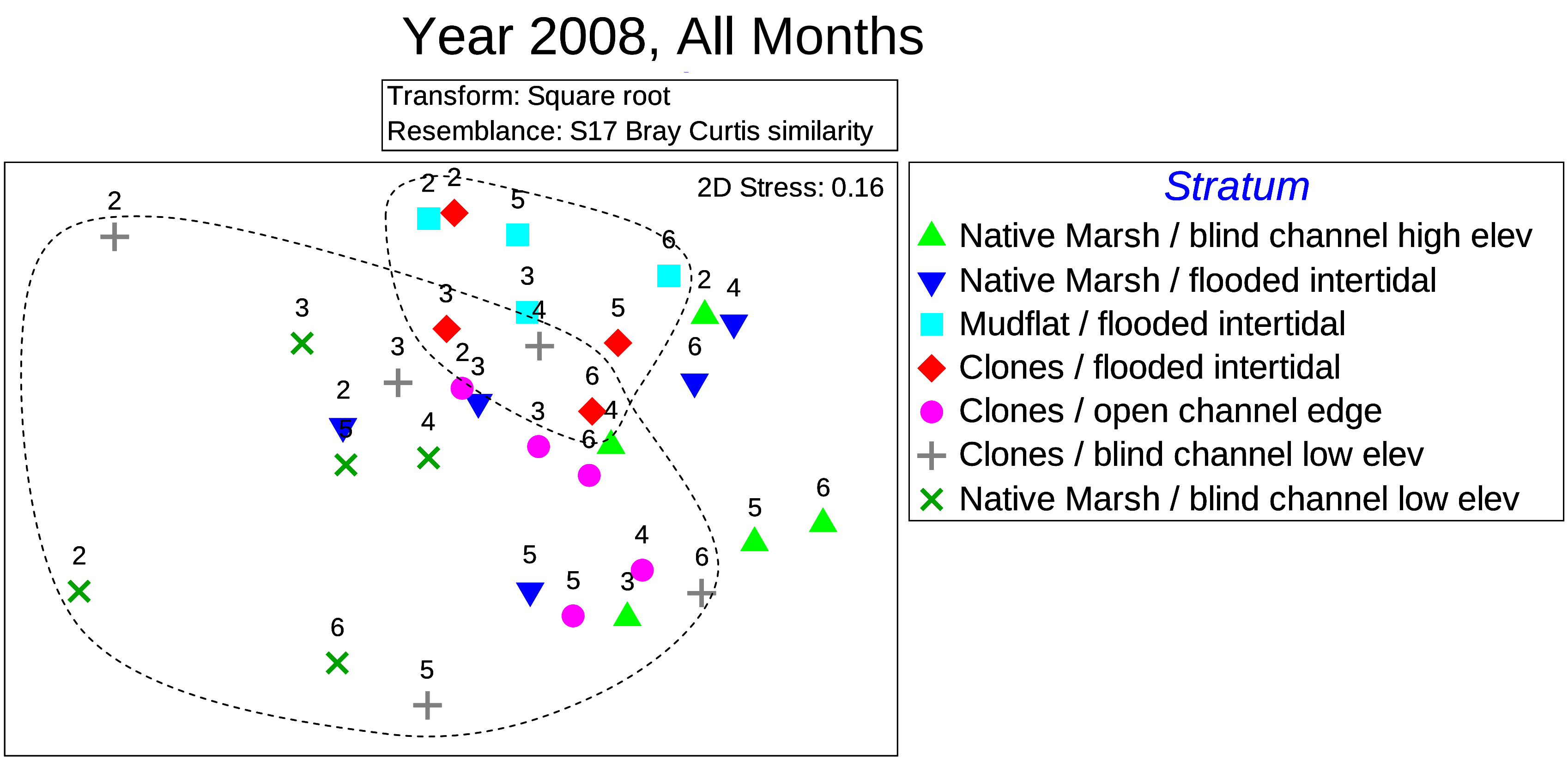

Figure 14. MDS plot for all months in 2008. Numbers next to symbols indicate month of sample. Overall ANOSIM results for data shown in this figure: Global R: 0.28 (p = 0.001)

Table 4. ANOSIM results of fish assemblage differences for habitat group pairings, 2007 and 2008. R values range from near zero (no difference) to 1 (most different). R values are more informative of similarity/dissimilarity than p values which are strongly influenced by sample size.

Habitat Group Pairings	**Year 2007**	**Year 2008**
	R Statistic	**R Statistic**
Mudflat flooded intertidal, Clones flooded intertidal	-0.13 (p = 0.85)	-0.19 (p = 0.94)
Native marsh blind channel high elevation, Native marsh blind channel low elevation	0.95 (p = 0.018)	0.80 (p = 0.008)
Clones blind channel low elevation, Native marsh blind channel low elevation	0.93 (p = 0.10)	0.07 (p = 0.31)

Table 5. Percentage of taxonomic similarity contributed by each species by habitat and year (SIMPER test; top 90% of contributions) for flooded intertidal habitat pairing, all months, 2007 and 2008.

Habitat Group, 2007

Mudflat flooded intertidal

Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Surf Smelt	15.91	21.42	0.80	47.37	47.37
Shiner perch	12.01	10.14	0.47	22.43	69.80
Staghorn	6.36	6.81	0.47	15.06	84.86
Chum	2.15	3.51	0.37	7.76	92.61

Clones flooded intertidal

Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Surf Smelt	15.93	29.89	0.93	57.47	57.47
Shiner perch	10.79	13.80	0.65	26.54	84.01
Chum	2.96	3.34	0.40	6.43	90.44

Habitat Group, 2008

Mudflat flooded intertidal

Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Surf Smelt	50.08	44.84	3.11	80.79	80.79
Staghorn	14.02	9.44	2.12	17.01	97.79

Clones flooded intertidal

Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Surf Smelt	28.87	38.30	3.14	70.49	70.49
Staghorn	21.45	16.03	1.77	29.51	100.00

Table 6. Percentage of taxonomic similarity contributed by each species by habitat and year (SIMPER test; top 90% of contributions) for blind channel habitat pairing, all months, 2007 and 2008.

Habitat Group, 2007

Native marsh blind channel high elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Staghorn	22.80	19.45	0.82	49.19	49.19
Chum	7.06	6.61	0.65	16.72	65.91
Sharpnose	6.36	5.97	0.39	15.11	81.02
Chinook	5.52	3.97	0.50	10.05	91.07

Native marsh blind channel low elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Surf Smelt	6.74	27.75	1.78	46.26	46.26
Shiner perch	5.69	24.49	4.35	40.83	87.09
Chinook	0.78	5.92	0.71	9.87	96.96

Clones blind channel low elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chum	6.93	17.77	1.16	40.73	40.73
Staghorn	5.35	16.10	2.74	36.90	77.63
Shiner perch	5.28	4.88	0.71	11.18	88.82
Stickleback	2.84	4.88	0.71	11.18	100.00

Habitat Group, 2008

Native marsh blind channel high elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Staghorn	51.50	40.86	3.50	89.31	89.31
Chinook	7.50	2.71	0.57	5.93	95.23

Native marsh blind channel low elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Staghorn	6.40	14.67	2.43	37.63	37.63
Surf Smelt	5.72	9.30	0.62	23.86	61.48
Herring	1.70	5.76	7.18	14.77	76.26
Chinook	1.51	2.98	1.15	7.64	83.89
Peamouth	1.72	2.49	0.62	6.40	90.29

Clones blind channel low elevation

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Staghorn	13.81	7.57	0.93	31.54	31.54
Surf Smelt	11.40	4.62	0.57	19.25	50.78
Chinook	3.96	3.77	1.07	15.68	66.47
Stickleback	2.84	3.22	0.98	13.40	79.86
Shiner perch	10.83	1.57	0.62	6.55	86.41
Prickly	1.05	1.29	0.32	5.36	91.77

References

Beamer, E, A McBride, C Greene, R Henderson, G Hood, K Wolf, K Larsen, C Rice and K Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: linking estuary restoration to wild Chinook salmon populations. Appendix to the Skagit Chinook Recovery Plan. Available at www.skagitcoop.org.

Clarke, KR and RN Gorley. 2006. Primer v6: user manual/ tutorial. PRIMER-E, Plymouth, UK.

Clarke, KR and RM Warwick. 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd edition: PRIMER-E. Plymouth, UK. 172p.

Collins, B. 1998. Preliminary Assessment of Historic Conditions of the Skagit River in the Fir Island Area: Implications for Salmonid Habitat Restoration. Report to Skagit System Cooperative. Available at www.skagitcoop.org.

Congleton, J.L., S.K. Davis, and S.R. Foley. 1981. Distribution, abundance and outmigration timing of chum and Chinook salmon fry in the Skagit salt marsh. Pages 153-163 *in* E. L. Brannon and E.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle.

Hacker, SD, D Heimer, CE Hellquist, B Reeves, T Riordan, and MN Dethier. 2001. A marine plant (*Spartina anglica*) invades widely varying habitats: potential mechanisms of invasion and control. *Biological Invasions* 3:211-217.

Hood, WG. 2007. Scaling tidal channel geometry with marsh island area: A tool for habitat restoration, linked to channel formation process. Water Resour. Res. 43, W03409, doi:10.1029/2006WR005083.

Levy, D.A., and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270–276.

Thompson, JD. 1991. The biology of an invasive plant: What makes *Spartina anglica* so successful? BioScience 41:393–401.