Restoration of the Native Oyster in Fidalgo Bay

Year Ten Report

Skagit County Marine Resources Committee

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Kailey Gabrian-Voorhees, Paul Dinnel and Nam Siu

Skagit MRC

NORTHWEST STRAITS
marine conservation initiative

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Restoration of the Native Oyster in Fidalgo Bay, Washington --Year Ten Report

Abstract

The native or Olympia oyster, *Ostrea lurida,* is native to the Pacific Coast of North America ranging from Sitka, Alaska to Baja California. Populations declined rapidly after the arrival of European settlers and overharvest was apparent in the late 1800's. In the early 20th century, severe pollution from pulp and paper mills heavily impacted Pacific oyster (*Crassostrea gigas*) cultivation and may have had significant adverse effects on native oyster populations, especially in South Puget Sound. In Anacortes, WA, a restoration project began in Fidalgo Bay in 2002, a cooperative work between Skagit County Marine Resources Committee (Skagit MRC), Puget Sound Restoration Fund and other partners to establish several native oyster beds. Subsequent to successful planting of seed oysters in 2002 and again in 2003, 2004 and 2006, survival rate, growth and natural recruitment have been deemed high and additional natural recruitment has been seen in Fidalgo Bay at areas outside the seed planting sites. In 2012, a "wide area" survey of Fidalgo Bay was undertaken in addition to yearly monitoring of the original trestle seeding site. The trestle area around the original seeding plots was extensively surveyed beyond normal yearly efforts and an additional three sites were examined for native oysters and substrate composition: Weaverling Spit, Crandall Spit and the rip rapped west end of the trestle structure. Shell cultch bags deployed around Fidalgo Bay in 2011 were collected in 2012 and assessed for natural recruitment. Temperature data were collected from June 2011 to June 2012 at locations thought suitable for future oyster seed planting as well as at the trestle restoration site. Additionally, a salinity sensor was placed in one location and data analyzed as to site suitability.

Introduction

Native to the marine waters from Sitka, Alaska to Baja California, the native or Olympia oyster (*Ostrea lurida*) is found on the Pacific Coast of North America (Ricketts and Calvin 1968). Native tribes recognized the native oyster's significance and settled where they could harvest the oysters and other shellfish as food resources. The Skokomish Tribe knew them as Tusa'yad (Steele 1957). Native American exploitation of the native oyster began in the pre-colonial days, though starting in the 1850's, harvest and cultivation of the beds in Willapa Bay, Puget Sound and Hood Canal began and later included diking systems that were fairly elaborate (Steele 1957). During the California gold rush of the 1850's, oyster prospectors found sparse native oyster resources in California estuaries (Ingersoll 1881) and oyster laden schooners from Puget Sound and Willapa Bay soon filled the need, transporting native oysters south and garnering as much as a dollar per oyster. In the late 1800's and early 1900's, the commercial viability of the native oyster was seriously compromised due to over harvest (PSAT 2003). Additionally, the operation of pulp and paper mills between the 1930's and 1950's created severe water quality problems for Pacific oyster (*Crassostrea gigas*) culture

(Couch and Hassler 1989) and may have helped speed the demise of native oysters in some locations, especially in South Puget Sound (Cook et al. 1998, 2000; Baker 1995, Blake and Bradbury 2012). In the 1850's in Puget Sound, 10,000 bushels of native oysters were harvested and that number rose to 130,000 bushels by 1890. During the 1900's, harvests declined and by around 1980 effectively no harvest of wild native oysters was reported.

Native oysters are native to Puget Sound unlike the Pacific oyster, which was imported from Japan, and is now found naturally in many areas (Suttles 1974). Additionally imported, although unintentionally, Japanese oyster drills (*Ocenebra japonica*) and other potential oyster predators and parasites were brought to Washington from Japan with the Pacific oysters (Robinette et al. 2004; Barsh et al. 2004, Blake and Bradbury 2012). Historic native oyster beds are reported to have existed in the North Puget Sound region in Boundary Bay (just north of the Canadian border), Drayton Harbor, Bellingham Bay, Chuckanut Bay, Orcas and Shaw Island areas, Fidalgo Bay, Similk Bay, Samish Bay, Padilla Bay, Dugalla Bay, Penn Cove (Blake and Bradbury 2012), and Guemes Island (from a report of Indians living on Guemes Island providing Spanish explorers with "verdigones") (Suttles 1974). Early Guemes Island Indians were reported to have harvested oysters as reported by Ashbach and Veal (1986) and additionally from a bay on the northeastern side of Whidbey Island (*Northwest Enterprise* 1884, *Skagit News* 1888, Townsend 1893, Hatch et al. 2005). In Samish Bay (*The Coast* 1907) and perhaps Bellingham Bay (Townsend 1893) in the North Puget Sound region, commercial quantities of native oysters were historically found but are very rare today (Cook et al. 1998, 2000; Baker 1995). Brady Blake (WDFW, pers. comm.) has estimated that there is solid evidence that there was as many 2,000 acres (with the possibility of substantially more) of native oyster beds in both Samish and Padilla Bays prior to their wholesale exploitation (PSRF 2012a). In the early 1900's in Similk Bay, an attempt to raise native oysters was made but did not continue (*Anacortes American* 1906). In recent years an occasional native oyster has been identified from various North Puget Sound locations including Bellingham Bay, Cypress Island, (Stahl 1999), Drayton Harbor (Brady Blake, WDFW, pers. comm.), Samish Bay and Lopez Island (Betsy Peabody, pers. comm.). Native oysters are a small oyster, with maximum sizes being reported as 75 mm (Hertlein 1959) to 90 mm (Harbo 1997). They are much smaller than the Pacific oyster and are usually smaller the recreational size limit of 2.5" for oysters.

Native oysters and their beds are valuable to the local ecosystem. They provide habitat for many marine species and oysters are filter feeders, feeding on phytoplankton and purifying the water, which helps to maintain water quality in the estuaries in which they are found. They may also provide future tribal opportunities for harvest, offering both an ecological and economical resource (Gregory and Volety 2005; Luckenbach et al. 1999). In order to identify the current populations of native oysters in Puget Sound, to improve, manage and enhance the species and its population by natural and artificial means, and to investigate their genetic integrity, the Washington Department of Fish and Wildlife (WDFW) drafted a native oyster recovery plan in the late 1990's (Cook et al. 1998), although this plan was never implemented By WDFW. However, a consortium of government agencies, tribes, non-profit organizations, industry, academia and citizen volunteers has worked with WDFW to promote native oyster restoration efforts in Puget Sound during the last decade. In 2004 and 2005, in order to advance Puget Sound restoration projects, NOAA's Community Restoration Fund awarded restoration grants to the Puget Sound Restoration Fund. Additional funds were awarded in 2010 to Northwest Straits Foundation by the National Fish and Wildlife Foundation to increase restoration works in North Puget Sound. Approximately 12 million native oyster seed have been planted at 80 experimental and restoration sites by 2010, thanks to the involvement in restoration efforts of over 100 tribes, private tideland owners, local organizations, shellfish farmers, public agencies, and business sponsors (Blake and Bradbury 2012).

In 2002, in order to plant native oyster seed as part of North Puget Sound restoration effort at two locations in South Fidalgo Bay, the Skagit County Marine Resources Committee (Skagit MRC) worked with the Samish and Swinomish Tribes, Puget Sound Restoration Fund, Taylor United Shellfish, Shell Puget Sound Refinery, the City of Anacortes and others (Robinette and Dinnel 2003; Barsh 2003). This signified the first native oyster restoration effort in the North Sound area other than several minute plantings on Orcas Island (Betsy Peabody, pers. comm.). The next closest native oyster restoration project, located in Discovery Bay on the northern end of the Olympic Peninsula, is being managed by WDFW, with the assistance of the Jefferson County Marine Resources Committee as the local lead entity, and focuses on an already existent natural population (Lull 2010).

In 2001, both Samish Bay and Fidalgo Bay were originally considered as planting sites and Fidalgo Bay was selected when it was found to be free of Japanese oyster drills that can negatively impact restoration efforts. The first seeding took place in 2002. In 2003 and 2004, further oyster seed were planted and growth and survival were monitored (Robinette et al. 2004; Barsh et al. 2004). In 2004, evidence was found of natural spawning; cultch shells deployed to catch spat showed post-larval recruitment (Dinnel et al. 2005) and this monitoring has continued. In 2006, Fidalgo Bay received a supplement of Pacific oyster shell to increase habitat, help in oyster bed building and encourage post-larval recruitment (Dinnel et al. 2006, 2009a, 2009b). In 2010, 2011 and 2012, survival and growth of the native oysters were monitored, cultch shells were monitored for natural recruitment, and four future oyster seed planting locations were assessed for suitability (Dinnel et al. 2011). This report covers the monitoring activities carried out in 2012.

Project Goals

In May 1998, WDFW published the Department's plan for native oyster restoration in Washington State titled "Olympia oyster stock rebuilding plan for Washington State public tidelands" (Cook et al. 2000). Although never actually implemented by WDFW, the goal of this plan was "To restore and maintain native oyster populations on public tidelands in their former range." The short term goal of WDFW was to identify locations and general abundance of current populations of native oysters in Puget Sound. The long term objectives included:

- ✓ Define the current and historic range of native oysters

- ✓ Develop native oyster genetic integrity guidelines for artificial stock enhancement
- ✓ Define habitat requirements and contemporary habitat limiters
- ✓ Identify areas for protection and restoration
- ✓ Define site-specific habitat limitations and species interactions that would affect native oyster stocks, and
- ✓ Restore and protect stocks as needed to achieve the stock rebuilding goal.

In September 2010, participants in the third West Coast Native Oyster Workshop (NOAA/PSRF 2010) held at Suquamish, WA, discussed the current status of native oyster restoration on the West Coast and considered future restoration activities. One informal agreement was that, based on the apparent success of the Fidalgo Bay restoration effort, restoration activities should be extended to up to ten new sites around the North Puget Sound region over the next 10 years once the genetic status of the Fidalgo Bay stock has been determined.

In 2012, WDFW updated their 1998 native oyster plan to provide a document that summarized the history of the native oyster in Puget Sound and to provide guidance to the many groups now involved in restoration activities (Blake and Bradbury 2012). In that document WDFW identified 19 priority restoration sites in Puget Sound, with six of those sites being in the North Puget Sound sub-basin (Drayton Harbor, Bellingham Bay, [including Portage Island and Chuckanut Bay], Samish Bay, Padilla Bay, Fidalgo Bay and Similk Bay.

Much can be learned from the substantial amount of work directed at restoring decimated American oyster *(Crassostrea virginica)* populations on the East and Gulf state coastlines of the U.S. Eggleston (1995) has pointed out that a conceptual framework should be developed for guiding oyster restoration efforts and that this frame work should address two questions: 1) what are the management goals in terms of restoration efforts and 2) what spatial arrangements (e.g., bed location, size, shape) of oyster habitat best meet these management goals? The management goals of oyster restoration may include, but are not limited to, maximizing:

- ✓ Recruitment to the fishery
- ✓ Spawning output
- ✓ Species diversity of the oyster bed community, and
- ✓ Water filtration and nutrient cycling.

Given the above goals and guidelines for oyster restoration projects, the following are Skagit MRC's goals for restoration of native oysters in Skagit County waters:

1. Identify areas within Skagit County that might be good sites for restoration
2. Define site-specific habitat limitations and species interactions that would affect native oyster stocks
3. Restore and protect stocks at selected sites to achieve stock rebuilding goals, including:

- Conduct test seedings at several sites
- Monitor survival and growth of seedlings
- Monitor and assess the spread of native oysters from natural spawning
- Determine the best "bed structure" for each site
- Control predators where necessary and possible

4. Identify sources and sinks for natural larval recruitment
5. Use adaptive management to modify restoration efforts based on lessons learned from local plantings and other information gleaned from other restoration efforts in Puget Sound, and
6. Conduct a public education and outreach program.

Methods

Monitoring Trestle Restoration Plot B for Survival and Growth

Native oyster seed set on Pacific oyster shell cultch were planted at the south Fidalgo Bay trestle restoration site (Figs. 1-4) in 2002, 2003, 2004 and 2006 for an estimated total of 1,429,570 seed planted. Seed survival and growth, together with subsequent natural recruits, were monitored from fall 2002 through summer 2012 and will continue in future years. In 2006 and 2008, non-seed bearing Pacific oyster shell were added to the site because evidence indicates that oyster larvae prefer to settle on oyster shell (White et al. 2009). Since the addition of non-seed bearing shell, 1/4 m^2 quadrat sampling (Fig. 5) has been used in Plot B. As in past years, in 2012 two samples were collected at the at the 14 trestle pilings next to the Plot B on the north side of each piling, at 20 feet north and 30 feet north from the center of the trestle (0 feet). All live native oysters, clam shells, and oyster shells were counted within each quadrat sample. During Plot B monitoring, all live native oysters in each quadrat sample were measured and sizes recorded.

Settlement Bags - Sampling to Assess Natural Recruitment within Fidalgo Bay

Bags of clean Pacific oyster shell cultch were deployed in the spring of 2007, 2008, 2009 and 2011 around Fidalgo Bay and at locations in Padilla Bay and Guemes Channel close to Fidalgo Bay (Table 1, Fig. 6) to monitor for larval oyster settlement and to try to discern the extent to which larvae may be distributed from spawning at the trestle restoration site. These bags were collected in the spring of 2008, 2009, 2010 and 2012 and all shells in each bag were checked for juvenile oysters. In years previous and again in 2012, all juvenile oysters found in the bags were measured for shell length.

"Wide Area" Sampling to Assess Natural Recruitment

In the summer of 2012, a "wide area" survey was undertaken at the trestle restoration site and surrounding areas. This was the largest assessment of the Fidalgo Bay area undertaken since the project began and was accomplished with the assistance of Skagit County Beach Watchers, Western Washington University staff, graduate and undergraduate students as well as many community volunteers. These surveys assessed the numbers of oyster shells, calm shells and live native oysters in systematically collected ¼ m^2 quadrat samples in and around the main restoration plot (trestle, east end), at the west end of the trestle (rip rapped section), at Weaverling Spit north of the west end of the trestle, and in the outfall channel and delta of Crandall Spit lagoon (Fig. 3). Counts of clam and oyster shells were made in addition to numbers of native oysters to provide indices of the amount of settlement substrate available to future natural oyster recruits.

East End of Trestle. From trestle piling 30 (counting from the eastern shoreline) to piling 100 on the east side of the trestle (Fig. 3), samples were collected using 1/4 m^2 quadrats. Samples were collected from the center of the trestle (considered 0 feet) and then every 10 feet, in both the north and south directions. Samples were collected to the south at 10, 20, and 30 feet, and to the north samples were collected at 10, 20, 30 and 40 feet. Additionally, to the north, samples were collected to include a rock pile and a derelict barge structure that exist on the site; these sample areas extended up to 520 feet north from piling 30 to piling 39. Samplers recorded the number of live oysters, clam shells and dead oyster shell present. A total of 698 1/4 m^2 quadrat samples were taken in this area.

West End of Trestle (Rip Rap Section). The "wide area" survey undertaken in the summer of 2012 included a survey on both the north and south sides of the west end of the trestle west of the restoration area (Fig. 3). This section of the trestle is armored by rip rap consisting of large boulders. 1/4 m^2 quadrat samples were collected along lines north and south of the rip rap approximately 20 feet seaward of the rip rap. Samples were collected every 20 feet for 1200 feet on the south side and 1560 feet on the north side of the trestle. The number of live oysters, clam shells and dead oyster shells in each sample were recorded. A total of 140 1/4 m^2 quadrat samples were collected in this area.

Crandall Spit. Crandall spit is located on the northeast end of Fidalgo Bay (Fig. 1, inset) and is refinery-owned property. About 5-10 cubic yards of Pacific oyster shell will be added to the Crandall Spit lagoon entrance channel during the summer of 2013 to enhance native oyster recruitment substrate. To create pre-shell addition baseline data for this area, 1/4 m^2 quadrat samples of live oysters, clam shells and dead oyster shells were collected at the Crandall Spit site. Utilizing the naturally occurring outflow channel exiting the lagoon on the north side of the spit as the centerline, ¼ m^2 quadrat samples were collected in the outflow channel in July, 2012. Samples were collected in the outflow channel at 10 foot intervals for 60 feet (south to north), then in a triangular area of the delta north of this with quadrat samples being collected at 10 foot intervals on east/west transect lines 10 feet apart (the width increasing in a northward direction). A temperature probe was installed in the exit channel where the water level meets the substrate and will be retrieved in 2013. A total of 70 1/4 m^2 quadrat samples were collected in this area.

Weaverling Spit. Weaverling spit is located just north of the trestle rip rap section (west end of the trestle, Fig. 3); the northern portion of the spit runs parallel to the trestle on its northern side. This area will also receive about 5-10 cubic yards of Pacific oyster shell to improve settlement substrate during the summer of 2013. In July 2012, 1/4 m^2 quadrat samples were collected in an east to west rectangle with a distance of 10 feet between each sample and each transect line. Transect lines ran west to east for 70 feet and counts of native oysters, clam shells and dead oyster shells were recorded. A total of 40 1/4 m^2 quadrat samples were collected in this area.

Subtidal Channel Diver Survey

Two SCUBA equipped divers surveyed the bottom of the main north-south running Fidalgo Bay channel near the trestle in July 2012. The divers spent about 50 minutes exploring the channel bottom just north of the trestle during which time they randomly explored the bottom for clam and oyster shell to which native oysters may be attached. GPS coordinates for this dive locations were 48° 28.765' N and 122° 34.727' W and the depths surveyed were from -5 to -11' relative to Mean Lower Low Water (MLLW). Additionally, the divers randomly picked up batches of shells, which were brought to the surface and assessed more closely for the presence/absence of native oysters.

Suitability of Additional Planting Locations

Four sites that had previously been identified as promising future seed planting sites (Dinnel et al. 2011) had Hobo® brand recording temperature sensors installed to record temperature at the water/sediment interface at one-hour intervals from June 2011 through June 2012. Additionally, a temperature sensor was placed at the Fidalgo trestle seeding location. The four new sites are: 1) North Fidalgo Bay at Sea Farers Park in the area of the major Scott paper mill clean up and shoreline restoration project, 2) the eastern shore of Padilla Bay in tide pools inshore of eelgrass (*Zostera marina*), 3) Lone Tree Point lagoon on the eastern shore of Skagit Bay on the Swinomish Tribal reservation, and 4) Kiket Island lagoon (part of the new State Parks/Swinomish Tribe Kukutali Preserve), also on the eastern shore of Skagit Bay on the Swinomish Tribal reservation. Since there is a freshwater stream flowing into the Lone Tree Point Lagoon, a recording conductivity (salinity) recording sensor was added at this location, also recording on one-hour intervals. All sensors were deployed in June 2011 and recovered September 30, 2012. Sensors were replaced at Padilla Bay, Lone Tree Point lagoon, Kiket Island lagoon and the trestle location in August 2012.

Skagit Bay Seed Additions

In September 2012, 18 bags of native oyster seed set on Pacific oyster cultch were planted (maintained in bags) in Lone Tree lagoon and another 23 bags planted in Kiket Island lagoon by Puget Sound Restoration Fund and Swinomish Tribal biologists. Both of these sites are pocket estuaries along the eastern shore of Skagit Bay. Most of the bags contained ~125 shells/bag while a few contained ~250 shells/bag. Average density of spat on the cultch shells varied from about 2 to 36 spat/shell, with an average density of 17.7 spat/shell. Size of the spat at planting ranged from <1 mm to 5 mm, with most being in the 2-4 mm shell length range. All progeny were from brood stock collected from the Fidalgo Bay restoration site. Seed planted at the Lone Tree and Kiket Island lagoons will be monitored in the future for survival and growth by Swinomish Tribal biologists.

Results

Trestle Plot B Monitoring

Native Oyster Densities, 2002 through 2012. On the basis of number of live oysters derived from the 1/4 m^2 quadrat sampling in Plot B, oyster densities averaged about $45/m^2$ in 2002 and 2003, $130/m^2$ in 2011 and $114/m^2$ in 2012 (Table 2, Fig. 7). The last addition of seed to Plot B was in 2006; thus, increases in oyster density from 2008 through 2011 and decrease in 2012 is due to natural recruitment or lack thereof. In terms of total numbers of native oysters in Plot B, the population has ranged from about 11,000 oysters in 2002 and 2003 to a high of 32,630 oysters in 2011. The estimated population slightly decreased in 2012 to 28,704 (Table 2, Fig. 8).

Oyster Sizes. Native oysters in Plot B have been measured for size when sampled yearly. After seeding in 2006, average shell length increased until addition of small seed oysters in August 2005 (Fig. 9). Samples from Plot B from 2008 to 2011 show a gradually aging population of oysters through time with signs of minor natural recruitment in 2008 (1.6% of the population) and 2009 (2.9%), with strong natural recruitment of young oysters in 2010 (23.5%), moderate recruitment in 2011 (5.3%) and minor recruitment in 2011 (3.2%). In 2012, the size of native oysters sampled in Plot B ranged from 12 to 74 mm shell length with 1.1% of the total being identified as spat derived from the 2011 spawning (size range = 12-20 mm) (Fig. 10). Fluctuation in average size of native oysters at the trestle will most likely be the rule as new oysters are recruited via spawning and older oysters die.

Settlement Bags – Sampling to Assess Natural Recruitment within Fidalgo Bay

In 2004, 2005 and 2007, clean Pacific oyster cultch shells in bags were hung along the length of the trestle next to the seed planting beds and were checked for natural recruitment of native oysters at the trestle site. A low density of natural recruitment was found in 2004 and 2006. In 2007, 2008, 2009 and 2011, bags of clean cultch shells were placed at the trestle and around Fidalgo Bay as well as at nearby locations in Padilla Bay and Guemes Channel (Fig. 6). For the years 2007 and 2008, no native oysters were found but site-frequency plots of oysters in Plot B from the same time period suggested minor natural recruitment. In 2010, the shell bags showed substantial natural recruitment, which was limited to south Fidalgo Bay.

Shell bags collected in 2012 (placed in 2011) showed signs of some natural recruitment throughout Fidalgo Bay with the heaviest recruitment near the trestle site and the lightest settlement at sites furthest from the trestle. Shell bags at the trestle site averaged 10 naturally recruited juvenile native oysters per 100 shells, while overall the average was 6 native oyster recruits per 100 shells (Table 1, Fig. 11).

"Wide Area" Sampling to Assess Natural Recruitment

The "wide area" sampling resulted in collection of 948 ¼ m2 quadrat samples in four areas: 1) the east end of the trestle surrounding the original seeding sites, 2) the north and south shores of the west end of the rip rapped trestle, 3) Weaverling Spit, north of the west end of the trestle and 4) the north side of Crandall Spit at the lagoon exit channel (Figs. 1-3). The results of these sampling efforts are discussed below and itemized by sample in Appendix 1.

Trestle Restoration Area. A total of 698 ¼ m^2 samples were collected at and around the trestle restoration seeding plots in July 2012. The numbers of native oysters, clam shells and oyster shells found in these samples are summarized in color plots (Figs. 13-17) and in a line graph (Fig. 18). These graphics show that the average native oyster densities per set of pilings (n = 8, except n = 21 between pilings 30 and 39) ranged from zero at the far east and west ends of the sampling area to a high of 37 oysters/m^2 at piling #50 (Fig. 18). The overall average number of native oysters for all 698 trestle samples was 5.1 oysters per 1/4 m^2 (Table 3), which equals a total population estimate of 158,732 native oysters for the entire area sampled. Generally, the densities of native oysters were highest in the previously seeded areas (Plots A, B and C between pilings 55-70 – Fig. 4), but the highest densities were found just east of the seeded areas (pilings 49-54) and mostly the result of natural recruitment (Fig. 18).

Clam shell substrate was plentiful in most sampled, although the densities tapered off at the eastern end of the sampling area (Figs. 15 and 18). The average overall density of clam shells in the sampling area was 21.5 shells per 1/4 m^2, about four times the density of native oysters (Table 3). Oyster shell (essentially all dead Pacific oyster shells) substrate was most plentiful between pilings 49 and 72, which is the area previously enhanced with about 10 cubic yards of Pacific oyster shell (Figs. 16 and 18). Low densities of oyster shell exist between pilings 72 and 100, some of these being large live Pacific oysters from a natural settlement in the 1990's.

West End of Trestle – North Side. The majority of the samples in this area contained no native oysters while about 14% of the 79 samples collected in this area contained 1-8 oysters per ¼ m^2 (Fig. 19). The overall density of native oysters on the north side was 0.4 oysters per ¼ m^2 for an estimated population of 2,550 native oysters (assumes that the transect samples were representative of a 10 foot wide swath). The average numbers of clam and oyster shells in this area were 8.1 and 3.6 shells per ¼ m^2 (Table 3).

West End of Trestle – South Side. Again, the majority of the samples on the south side of the trestle contained no native oysters while about 39% of the 61 samples collected in this area contained 1-6 oysters per ¼ m^2 (Fig. 19). The overall density of native oysters on the south side was 0.9 oysters per ¼ m^2 for an estimated population of 2,550 native oysters (assumes that the transect samples were representative of a 10 foot wide swath). The average numbers of clam and oyster shells in this area were 17.3 and 1.7 shells per ¼ m^2 (Table 3).

Crandall Spit. Few native oysters were found in the 70 samples collected in the area of the lagoon outfall channel and channel delta. Only four of the 70 samples (6%) contained native oysters (1 per sample), which yielded a population estimate of 156 oysters (Table 3). The average numbers of clam and oyster shells in this area were 11.3 and 0.1 shells per ¼ m^2 (Table 3). This area is also scheduled for to receive Pacific oyster shell substrate enhancement in 2013, so these data serve as baseline data for post-enhancement years.

Weaverling Spit. A sandy seepage area on Weaverling Spit (Figs. 1 and 3) yielded zero native oysters in the 40 samples collected in this area, although a few native oysters were observed in this area in previous years. The average numbers of clam and oyster shells in this area were 10.1 and 0.1 shells per ¼ m^2 (Table 3). This area is scheduled for shell enhancement in summer 2013, so these data serve as a baseline for future change.

Subtidal Channel Diver Survey

The divers encountered a mostly sand to silty-sand bottom with scattered clam (mostly) and oyster shells. They did not observe any live native oysters. The divers returned with 138 clam shells, which, upon close inspection on the boat, did not contain any native oysters. They also recovered 3 native oyster shells (single valves), which were likely deposited in the channel by currents that washed the shells from the nearby intertidal restoration bed at the trestle.

Temperature and Salinity

Temperature sensors were collected from east Padilla Bay, Lone Tree Point lagoon, Kiket Island lagoon and the trestle Plot B site; additionally, a salinity sensor was retrieved from Lone Tree Point lagoon. Temperature and salinity data were recorded every 30 minutes from June 1, 2011 through June 30, 2012 and analyzed for maximum, minimum and average temperatures and salinity (Table 4, Figs. 20-24). The highest temperatures recorded at east Padilla Bay, Lone Tree Point lagoon, Kiket Island lagoon and the trestle Plot B were 34.2; 32.5; 29.3 and 27.6 °C, respectively, and were all observed in June 2011. Lone Tree Point lagoon, east Padilla Bay and trestle Plot B all experienced the lowest temperatures in January 2012 which were: 2.3, -1.7 and 0.7 °C, respectively. Kiket Island lagoon experienced the lowest temperature in November 2011, which was 3.0 °C. East Padilla Bay had the highest temperatures followed by Kiket Island lagoon; trestle Plot B and Lone Tree Point lagoon, respectively, for the spring (March to June 2012) and summer (June to September 2011) months. East Padilla Bay had the lowest temperatures from October 2011 to February 2012, followed by trestle Plot B. Lone Tree Point lagoon and Kiket Island lagoon exhibited higher winter temperatures, with Kiket Island lagoon being colder in the winter and Lone Tree Point lagoon being colder in the early spring (Table 4, Figs. 20-23). Salinity data recorded at Lone Tree Point lagoon from June 5, 2011 through June 30, 2012 showed a high of 16.8 psu on January 17, 2012 and a low of 9.4 psu on August 24, 2011. Salinity monthly averages ranged from 11.7 to 14.7 psu (Fig. 24).

Volunteer Hours

Twenty one volunteers participated in Fidalgo Bay native oyster restoration planning, monitoring and report preparation from March 2012 through April 2013. The estimated time spent by volunteers during this time was about 410 hours. This included the following activities: planning meetings and communications with Puget Sound

Restoration Fund, tribal biologists and WDFW personnel, filling and deploying cultch shell bags to monitor natural recruitment, annual monitoring of trestle Plot B, "wide area" sampling in summer 2012, collection and redeployment of temperature and salinity recording devices, surveys of sites to be seeded or enhanced with Pacific oyster shell in 2013, assistance with the 2013 JARPA permit application, data analyses and report preparation.

Discussion

With the goal of establishing native oyster beds in Puget Sound that successfully spawn, produce larvae and act as "source populations", the Skagit MRC, Puget Sound Restoration Fund and other partners developed the trestle restoration site in Fidalgo Bay in 2002. The location was chosen due to its standing water at low tide, general absence of oyster predators and low recreational use. Additionally, the area underneath the trestle and approximately 3 meters to either side has a very firm substrate and from 3-10 meters the substrate is also firm but has increased siltation.

Oyster seed was planted in 2002, 2003, 2004 and 2006, and additional substrate (Pacific oyster shell) was added in 2006 and 2009 (five cubic yards each year). Native oyster growth resulting from the four seedings and subsequent natural recruitment are slowly creating a structured oyster bed at the trestle site with the density of native oysters in Plot B being >100 oysters per m^2 since 2010. According to the newest WDFW native oyster restoration plan (Blake and Bradbury 2012) "the minimal threshold for determining successful restoration is the observation of significant reproduction, recruitment, survival, utilization, expansion and colonization ….. during any three years within a 10-year period." The Fidalgo Bay restoration site has exceeded this threshold with successful post larval recruitment from natural spawning in 6 of nine years since 2002 and significant off-site spat recruitment around Fidalgo Bay.

During the larval stage, which lasts 10 to 16 days (Imai et al. 1954), larvae are distributed by the water currents. Data are lacking, however, as to how far oyster larvae will be dispersed, which is likely affected by heretofore poorly understood aspects of larval behavior and the current dynamics specific to each site. Data on the intensity and distribution of natural recruitment in and around Fidalgo Bay from the shell cultch bags suggest that natural recruitment can vary substantially between years (and be zero in some years), and that most larvae are likely settling within Fidalgo Bay. Current evidence strongly suggests that successful spawning of the oysters at the trestle restoration site occurred in 2004, 2006, 2009, 2011 and 2012. The reasons for lack of recruitment or spawning in other years are unknown. So far, only one native oyster natural recruit has been found outside of Fidalgo Bay, this one being an individual that set in a cultch bag near the Port of Anacortes facilities on the south shore of eastern Guemes Channel. For 2012, as in past years, the annual patterns of natural settlement strongly suggest that larvae are originating from the Fidalgo Bay trestle restoration site, as the pattern has always been that settlement is highest at and close to the trestle and decreases with distance to the north, south and west. Natural recruitment will continue to be monitored in future years of the project.

Additional sites in Fidalgo Bay were more closely surveyed in 2012 ("wide area" and subtidal channel surveys) for native oyster and settlement substrate (clam and oysters shells) densities, including the west end of the trestle, Crandall Spit, Weaverling Spit and the subtidal channel just west of the trestle restoration site. Natural recruitment was detected at both the west end of the trestle and Crandall Spit, with denser settlement at the west end of the trestle than Crandall Spit. Lack of oysters in the subtidal channel survey and at Weaverling Spit correspond to low substrate densities for larvae to settle on and possibly lack of larvae reaching the bottom of the channel (~10 to 15 feet in depth).

Temperature data collected at the trestle restoration site, east Padilla Bay, Lone Tree Point and Kiket Island lagoons indicate that for the one year that has been monitored so far, minimum temperatures all stayed above freezing except for east Padilla Bay, which showed subfreezing temperatures in three winter months, but only as low as -1.7 °C, which can be tolerated by native oysters for short periods of time (e.g., during winter low tide periods). Maximum temperatures at these same sites ranged from 27.6 °C in Fidalgo Bay to 34.2 °C at east Padilla Bay. Once again, these temperatures should be able to be tolerated by native oysters during summer low tides. Salinity data recorded at Lone Tree Point lagoon showed a high of 16.8 psu on January 17, 2012 and a low of 9.4 psu on August 24, 2011. Salinity monthly averages ranged from 11.7 to 14.7 psu (Fig. 24). These salinity values, caused by a freshwater stream flowing into the lagoon, are rather low for native oysters. Hatchery raised native oyster seed were placed in Lone Tree Point lagoon in summer 2012 and it will be interesting to see what survival and growth will be at this site.

The above discussion (and discussions in previous project reports) has assumed that all of the natural recruitment that has been observed in Fidalgo Bay has come from larvae spawned at and around the trestle restoration site. This assumption has been based on several things: 1) Prior to oyster seeding in 2002 there were no known native oysters in Fidalgo Bay or in surrounding areas, 2) there were no accumulations of dead native oyster shells and 3) natural recruitment has always been most dense at and around the trestle seed plots with decreasing recruit densities north, south and west of the trestle. However, recent genetic analyses by Oregon State University (PSRF 2012b) that compared the genetic "fingerprints" of the original seed oysters and natural recruits that had settle on clam shells at the trestle have indicated that most, if not all, of the Fidalgo Bay natural recruits have not come from larvae produced by the trestle seed oysters. Specifically, the PSRF (2012b) report says:

> "Significant genetic F_{ST} differentiation ($P \leq 0.005$) provides evidence that the Fidalgo Bay natural set (Oc58 collected off clam shells) is not coming from the original Fidalgo Bay restoration effort (Oc55). This conclusion is also supported by measures for actual genetic differentiation, D_{ST} (Jost 2008) as well as the unbiased estimate of relative differentiation, G_{ST} (Nei and Chesser 1983) and standardized measure of genetic differentiation, G'_{ST} (Hedrick 2005). The Fidalgo Bay natural set appears to be most related with the Discovery Bay site. This does not mean that the set originated from Discovery Bay. It also does not

> mean the original Fidalgo Bay plant-out is not breeding. The most likely explanation is that there is a substantial population of Olympia oysters somewhere near the Fidalgo Bay site that has periodic gene flow with Discovery Bay and that the genetics associated with this unknown site is the dominant component in the new Fidalgo Bay set. However, the possibility that the set did originate in Discovery Bay cannot be precluded. The only pairwise comparison between population groups demonstrating greater gene flow than between Discovery Bay and the new set from Fidalgo Bay occurred between Bywater Bay and Point Whitney Dabob Bay samples. There is no evidence that any Hood Canal site contributed to the new Fidalgo Bay set."

Thus, there is a mystery surrounding natural recruitment in Fidalgo Bay. The genetic "fingerprinting" evidence appears to be quite conclusive that recruits are coming from some unknown native oyster bed in or near Fidalgo Bay and not from the trestle hatchery seed. However, virtually all natural recruit sampling data collected in the past few years strongly point to the trestle population as the source of the larvae. Clearly, additional exploration and mapping of future natural recruitment, combined with additional genetic analyses will be necessary to solve this mystery. One possible tool that might prove to be useful is chemical analyses of larval shells compared to possible parental stock using laser ablation inductively coupled plasma mass spectrometry methods, which has been successfully used to trace larval sources in southern California (Carson 2010). Use of this method in Fidalgo Bay is now being proposed by researchers at the University of Washington and Northwest Indian College.

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Table 1. Numbers of live juvenile Olympia oysters found in larval settlement cultch bags deployed in and around Fidalgo Bay spring 2011 and assessed in summer 2012. See Figure 6 for station locations.

Bag #	Location	Live Oysters	Number of Cultch Shells	Oysters per Cultch Shell	Average Shell Length, mm	Standard Deviation	Number of Oysters per 100 cultch shells
1	Northeast March's Point	Missing	----	----	----	----	----
2	Crandall Spit lagoon entrance	Silted in	----	----	----	----	----
3	North derelict barge	23	79	0.29	11.4	4.3	29.1
4	South derelict barge	15	69	0.22	11.5	4.0	21.7
5	Channel on SE side of trestle	4	68	0.06	24.5	8.1	5.9
6	SE Fidalgo Bay, end of shell berm	Missing	----	----	----	----	----
7	Trestle Plot B - east end	11	81	0.14	9.1	2.0	13.6
8	Trestle Plot B - mid-plot	1	82	0.01	7.0	0.0	1.2
9	Trestle Plot B - west end	2	78	0.03	7.5	1.5	2.6
10	Rock trestle - north side	3	69	0.04	14.7	10.3	4.3
11	Rock trestle - south side	3	76	0.04	9.7	2.9	3.9
12	Samish east	1	83	0.01	18.0	18.0	1.2
13	Samish west	1	83	0.01	4.0	0.0	1.2
14	South of old plywood mill	0	74	0.00	----	----	0.0
15	30th St. Marina, base of rip rap	Missing	----	----	----	----	----
16	Anacortes Marina log boom	Missing	----	----	----	----	----
17	Sea Farer's Park	3	67	0.04	20.7	2.8	4.5
18	Cap Sante Head	0	79	0.00	----	----	0.0
19	Port Dock	1	65	0.02	14.0	0.0	1.5

Table 2. Estimated number of live native oysters in Trestle Plot B based on ¼ m^2 quadrat samples, May 2002 to July 2012.

Month/Year	Number per m^2	Total Live in Plot B
May 2002	46.0	46,184
April 2003	43.6	43,774
May 2004*	0.0	0
April 2005*	0.0	0
August 2006*	0.0	0
May 2007*	0.0	0
June 2008	84.4	84,738
May 2009	91.6	91,966
July 2010	110.8	111,243
June 2011	130.0	130,520
July 2012	112.4	112,850

Size of Plot B = 15' x 180' m = 251 m^2.

*No measurements were made on a number/m^2 basis in these years.

Table 3. Summary of average densities of clam shells, oyster shells and native oysters at five locations sampled in Fidalgo Bay in 2012.

	East Trestle	West Trestle North side	West Trestle South Side	Weaverling Spit	Crandall Spit
Number of samples	698	79	61	40	70
Sampling area in m^2	7,781	1,449	1,115	372	650
Average # of clam shells per 1/4 m^2	21.5	8.1	17.3	10.1	11.3
Average # of oyster shells per 1/4 m^2	3.1	3.6	1.7	0.1	0.1
Average # of native oysters per 1/4 m^2	5.1	0.4	0.9	0.0	0.1
Estimated total number of native oysters	158,732	2,550	3,880	0	156

See Figure 3 for sampling locations.

Table 4. Monthly temperature averages and ranges from June 2011 to June 2012 at Kiket Island lagoon, Lone Tree Point lagoon, east Padilla Bay and Fidalgo Bay trestle sites. Data are from continuous recording thermometers placed at the water-sediment interfaces.

Kiket Lagoon

Month	Maximum	Minimum	Average
June-11	29.32	11.54	16.60
July-11	27.04	12.27	16.60
August-11	24.75	11.69	16.54
September-11	22.59	10.91	14.91
October-11	14.96	8.10	11.39
November-11	11.37	3.04	8.04
December-11	8.79	3.12	6.87
January-12	8.22	3.14	6.53
February-12	10.61	5.33	7.65
March-12	14.17	5.87	8.20
April-12	19.27	7.87	11.75
May-12	23.67	10.15	14.58
June-12	24.68	10.54	15.02

Lonetree Point Lagoon

Month	Maximum	Minimum	Average
June-11	32.54	10.32	15.01
July-11	22.97	11.08	14.74
August-11	23.28	11.05	15.05
September-11	18.72	10.47	13.47
October-11	14.53	7.80	11.11
November-11	11.03	3.67	8.13
December-11	8.87	3.99	7.19
January-12	8.89	2.29	6.45
February-12	10.47	5.13	7.48
March-12	13.95	5.51	7.70
April-12	16.42	7.04	10.38
May-12	19.77	8.49	12.84
June-12	21.44	9.31	13.25

Padilla Bay

Month	Maximum	Minimum	Average
June-11	34.23	11.98	17.59
July-11	32.67	12.94	17.70
August-11	29.82	14.19	18.26
September-11	27.53	10.61	16.13
October-11	13.79	6.08	11.04
November-11	9.44	1.45	6.71
December-11	8.52	-1.04	5.28
January-12	8.94	-1.70	4.89
February-12	12.58	0.88	6.68
March-12	16.42	-0.14	7.59
April-12	26.57	7.42	12.39
May-12	30.52	10.57	16.13
June-12	31.36	10.86	15.93

Fidalgo Bay

Month	Maximum	Minimum	Average
June-11	27.65	11.13	15.40
July-11	26.55	11.27	15.11
August-11	20.44	12.58	16.06
September-11	19.25	11.30	14.81
October-11	13.59	7.67	11.22
November-11	9.29	3.25	7.10
December-11	7.92	2.26	5.73
January-12	7.92	0.74	5.33
February-12	8.25	4.77	6.68
March-12	10.27	5.57	7.31
April-12	18.01	7.54	10.69
May-12	23.55	9.44	13.79
June-12	23.35	11.20	14.05

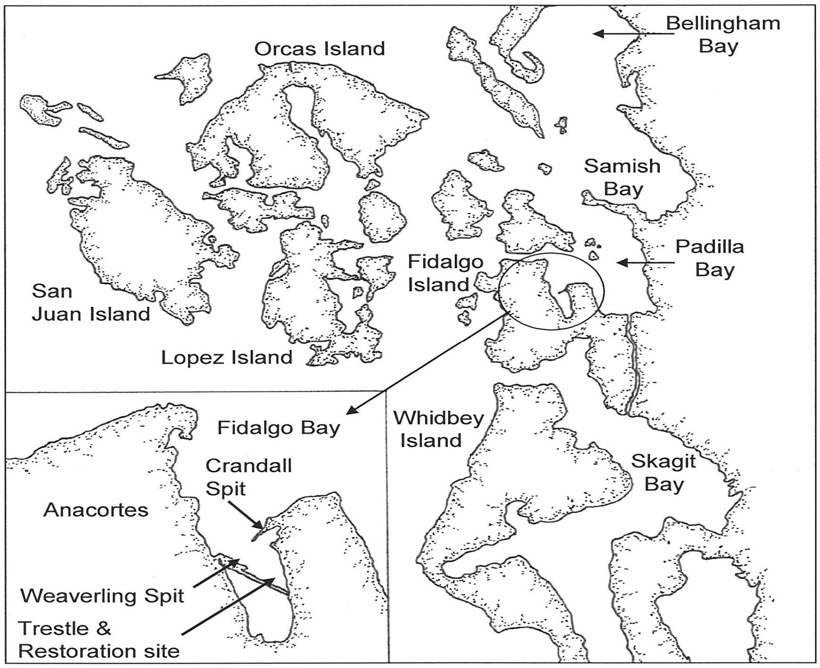

Figure 1. Map of North Puget Sound showing the location of Fidalgo Bay. Figure from Dinnel et al. 2009b.

Figure 2. Location of the trestle native oyster restoration site (circle) in South Fidalgo Bay, 2002-2012 (WDOE Shoreline photo).

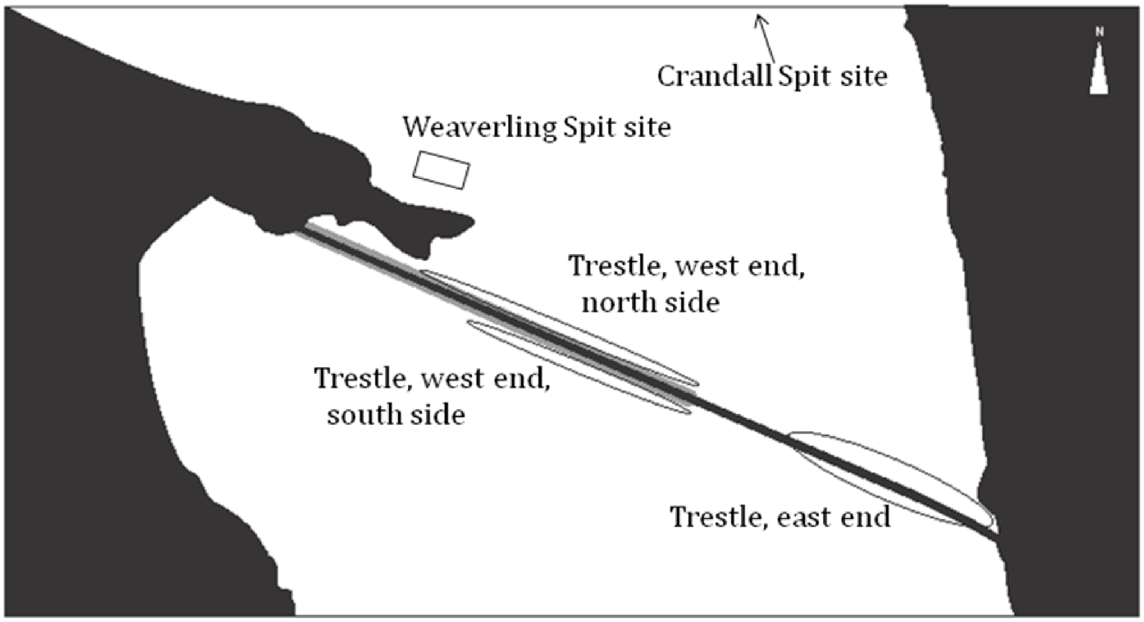

Figure 3. Locations of "wide area" ¼ m quadrat sampling in Fidalgo Bay during summer 2012. The Crandall Spit site is about a mile north of the trestle.

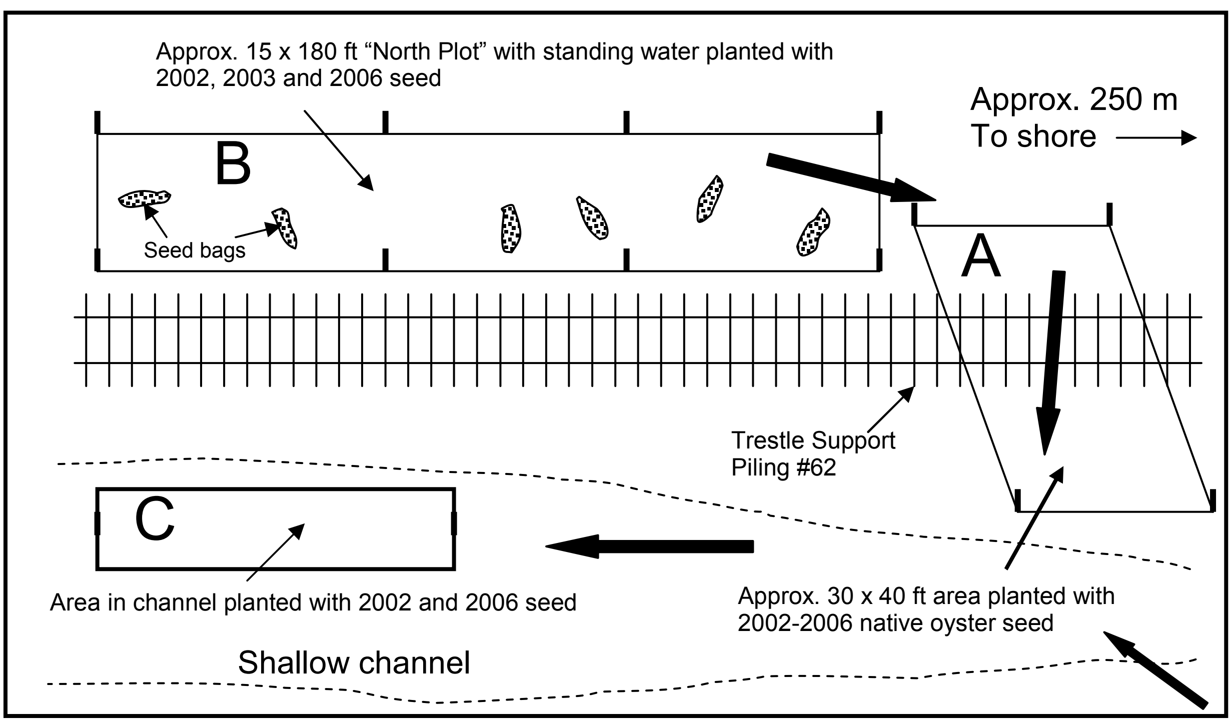

Figure 4. Trestle site plan showing the seeding locations at Plots A, B and C, 2002-2006. Large arrows show the directions of water drainage at low tide. Map derived from site drawings by Robert Knowles.

Figure 5. Example of the ¼ m^2 quadrat used to sample native oysters, clam shells and oyster shells and the shell rubble habitat surrounding the trestle restoration site Plot B in which native oysters are settling and growing.

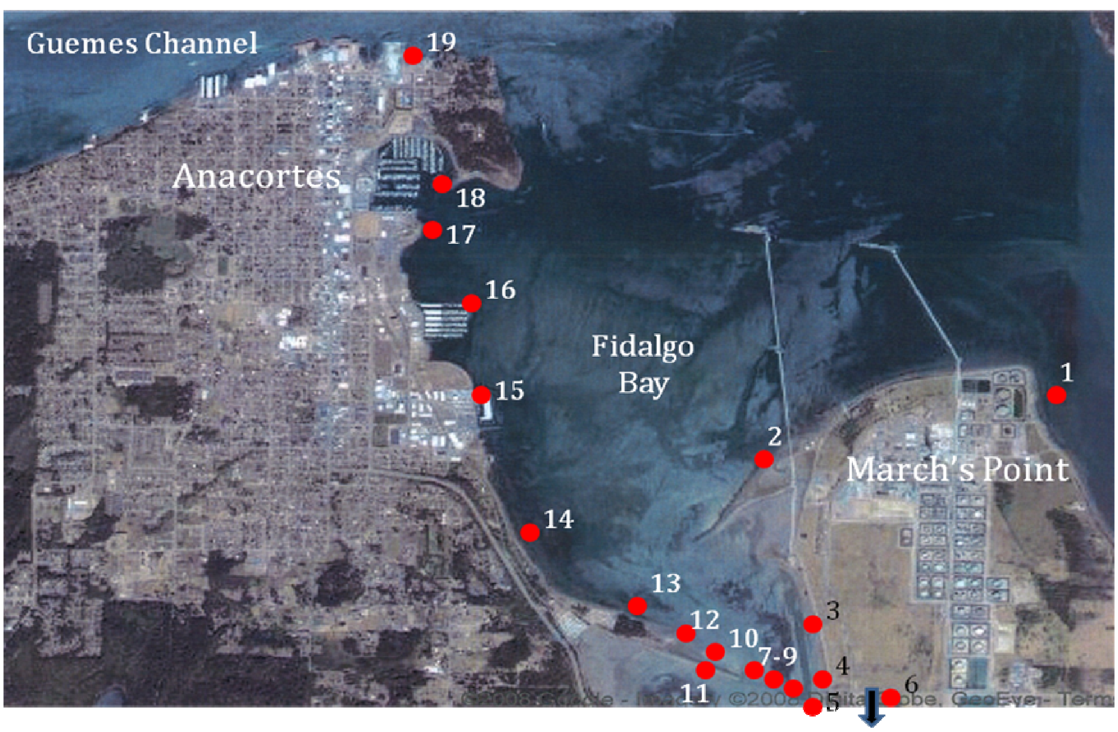

Figure 6. Photograph showing the locations where larval settlement cultch bags were set out in summer 2011 and retrieved in summer 2012. Station 6 was at the west end of the south Fidalgo Bay shell berm several hundered meters south of the trestle.

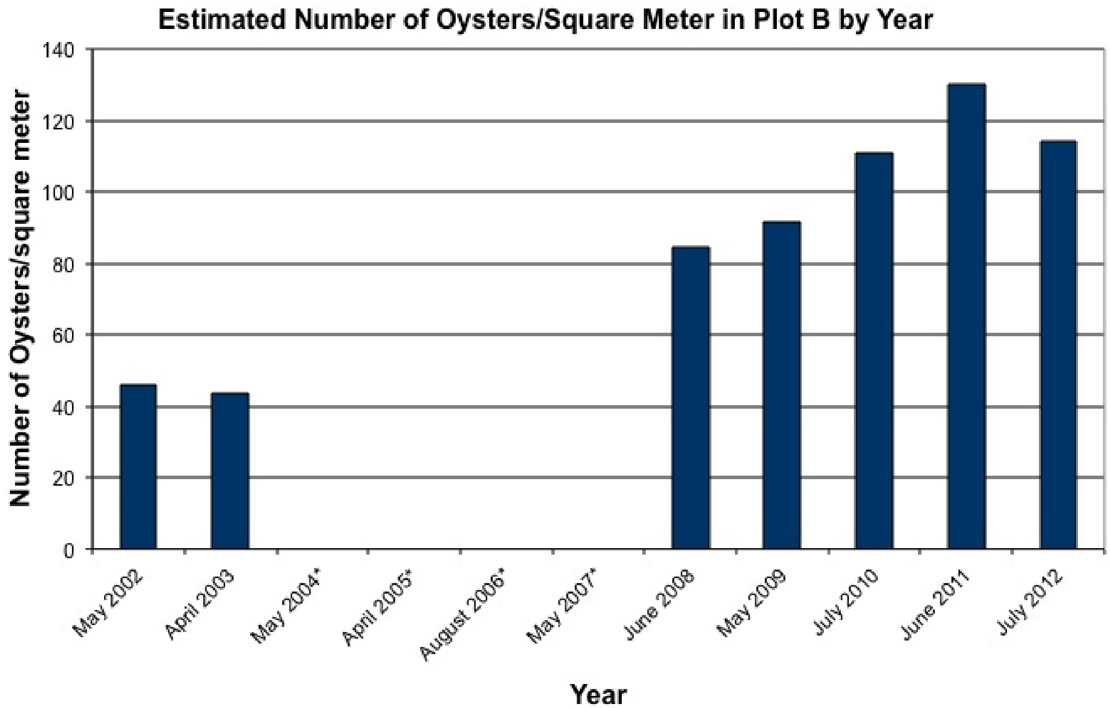

Figure 7. Estimated number of native oysters/m^2 in trestle restoration Plot B, 2002-2012. Sampling designed to estimate the number of oysters/m^2 was not conducted in 2004-2007.

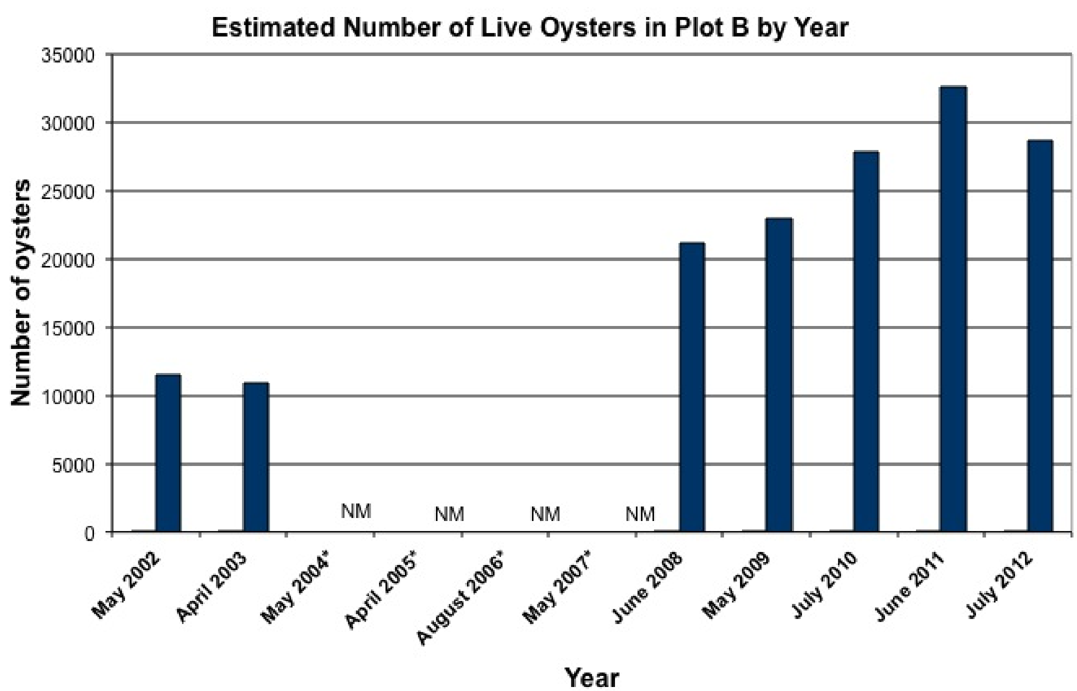

Figure 8. Estimated total number of native oysters in trestle restoration plot B, 2002-2012. Sampling designed to estimate the number of oysters in Plot B was not conducted in 2004-2007.

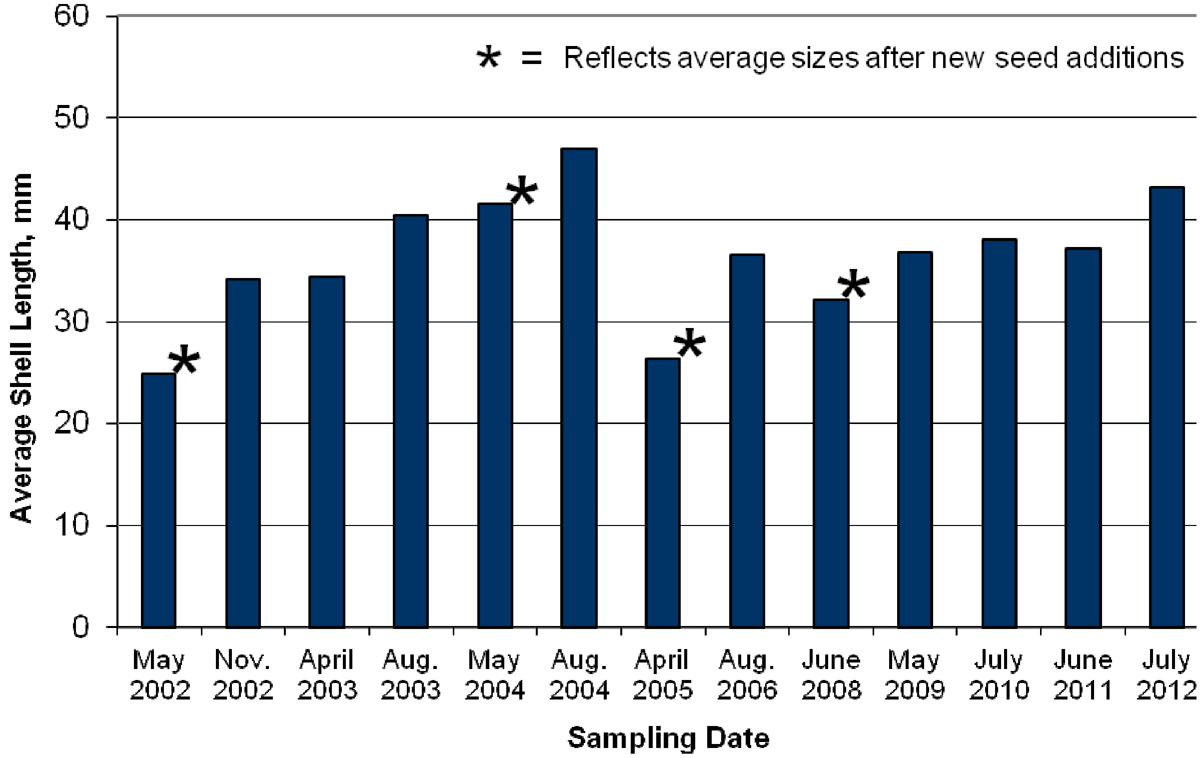

Figure 9. Average native oyster shell length by sample date for oysters sampled at the trestle restoration Plot B from May 2002 to July 2012.

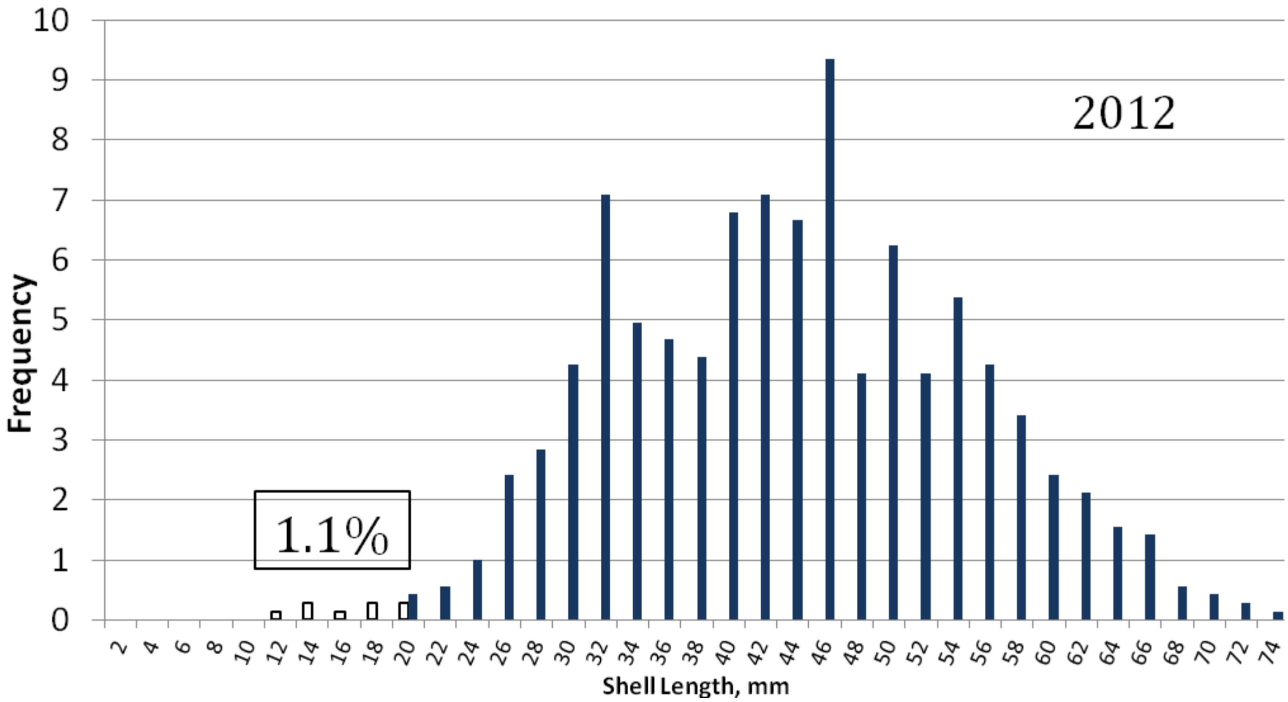

Figure 10. Trestle restoration Plot B native oyster size frequency for summer 2012. 1.1% of the oysters were from the 2011 spawning (white bars).

Figure 11. Number of juvenile native oysters per 100 oyster cultch shells found in the settlement bags deployed around Fidalgo Bay summer 2011 and collected summer 2012. The cultch bag at station 6 several hundred meters south of the trestle was missing. L = lost bag.

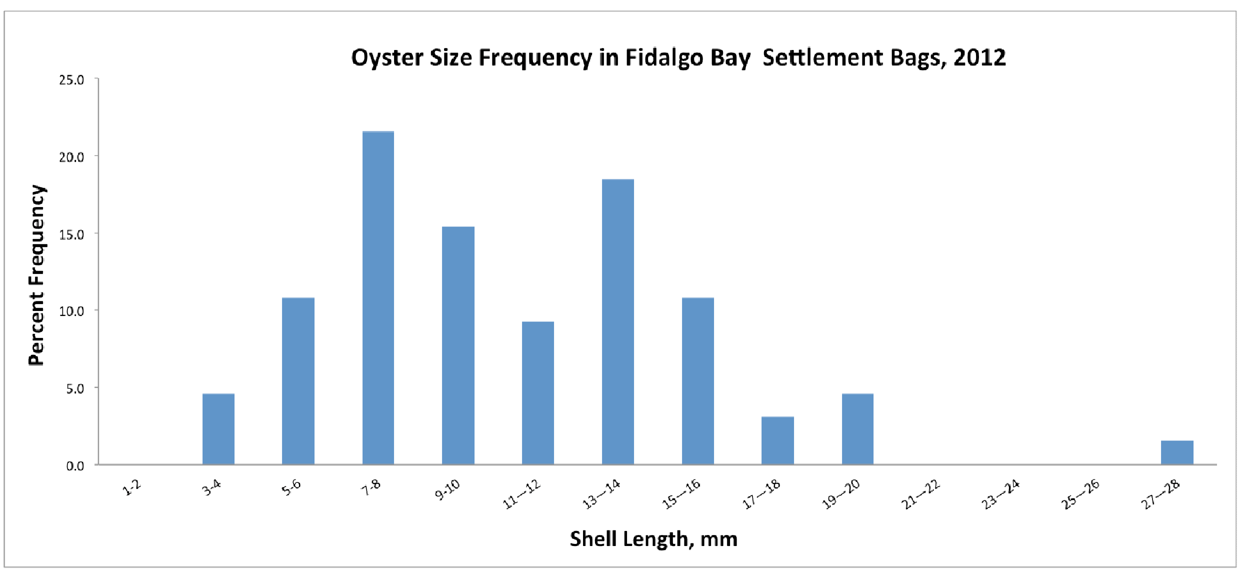

Figure 12. Shell length histogram of naturally recruited native oysters found in cultch bags deployed in Fidalgo Bay in summer 2011 and collected in summer 2012.

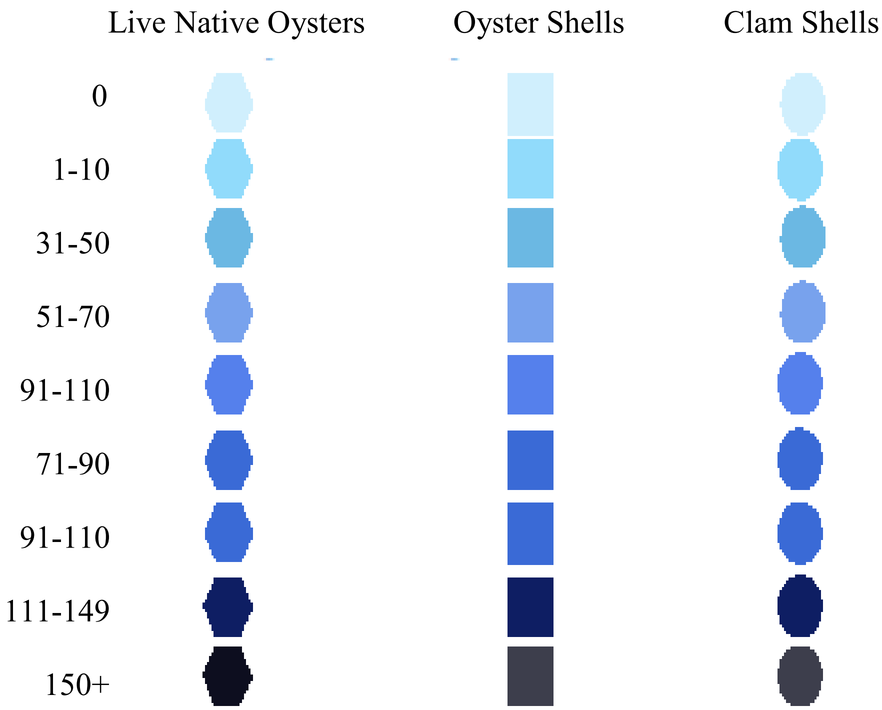

Figure 13. Color key to numbers of native oysters, oyster shell and clam shells found in ¼ m^2 quadrat samples collected at the east and west ends of the Fidalgo Bay trestle in 2012 (see Figs. 14-17 and 19).

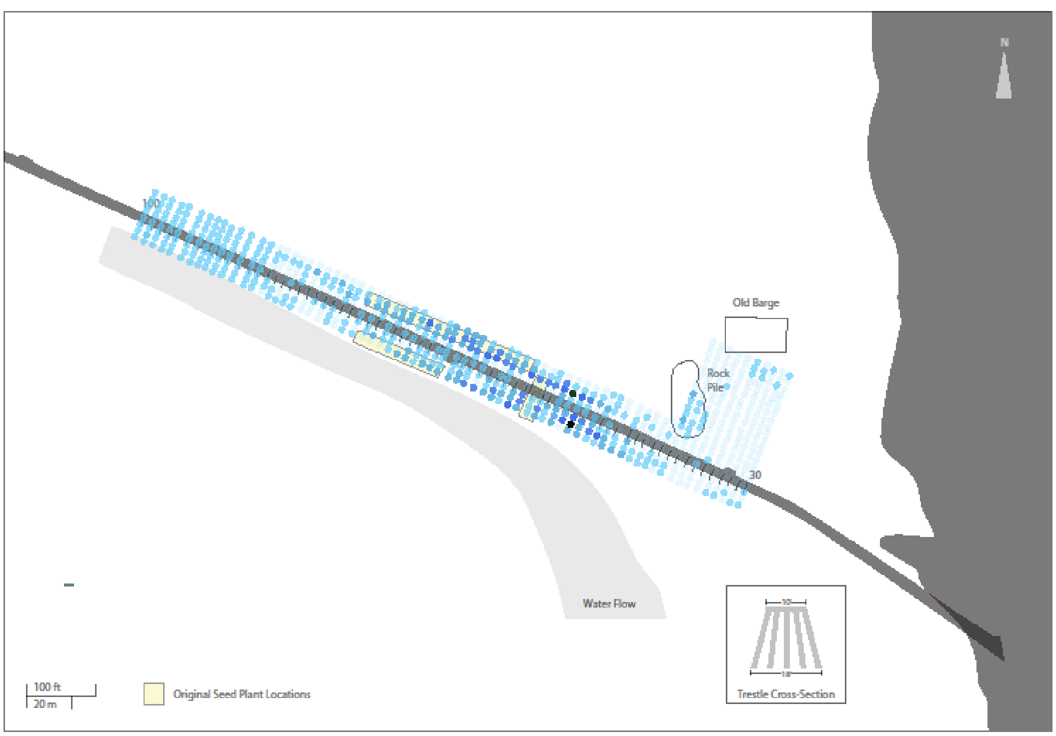

Figure 14. Number of native oysters in 698 ¼ m^2 samples collected in summer 2012 at the east end of the trestle surrounding the original seeding sites. See Fig. 13 for the color key.

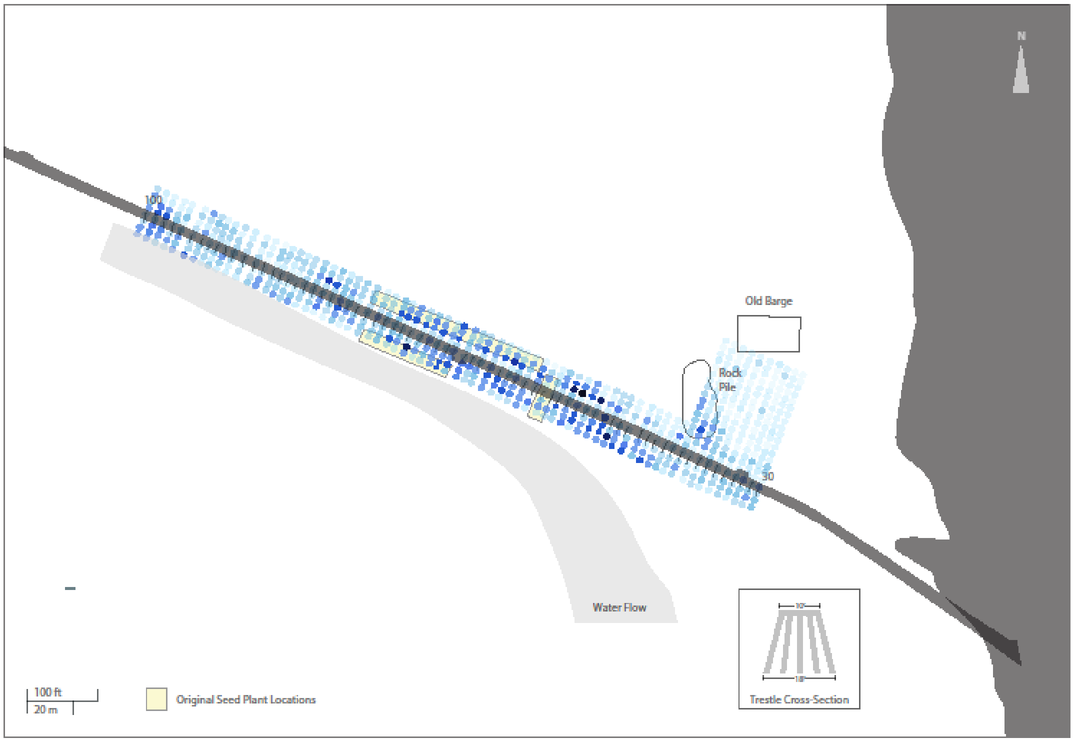

Figure 15. Number of clam shells in 698 ¼ m^2 samples collected in summer 2012 at the east end of the trestle surrounding the original seeding sites. See Fig. 13 for the color key.

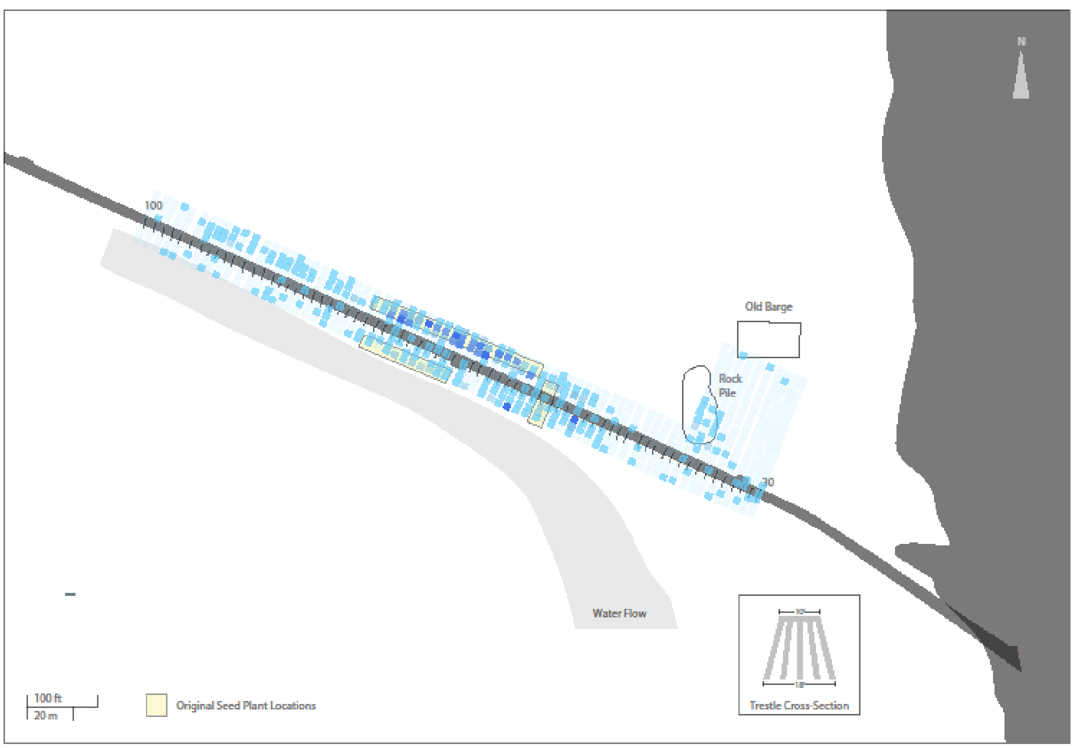

Figure 16. Number of oyster shells in 698 ¼ m^2 samples collected in summer 2012 at the east end of the trestle surrounding the original seeding sites. See Fig. 13 for the color key.

Figure 17. Side-by-side comparison of the number of native oysters, clam shells and oyster shells in 698 ¼ m^2 samples collected on the eastern end of the trestle in summer, 2012. See Fig. 13 for the color key.

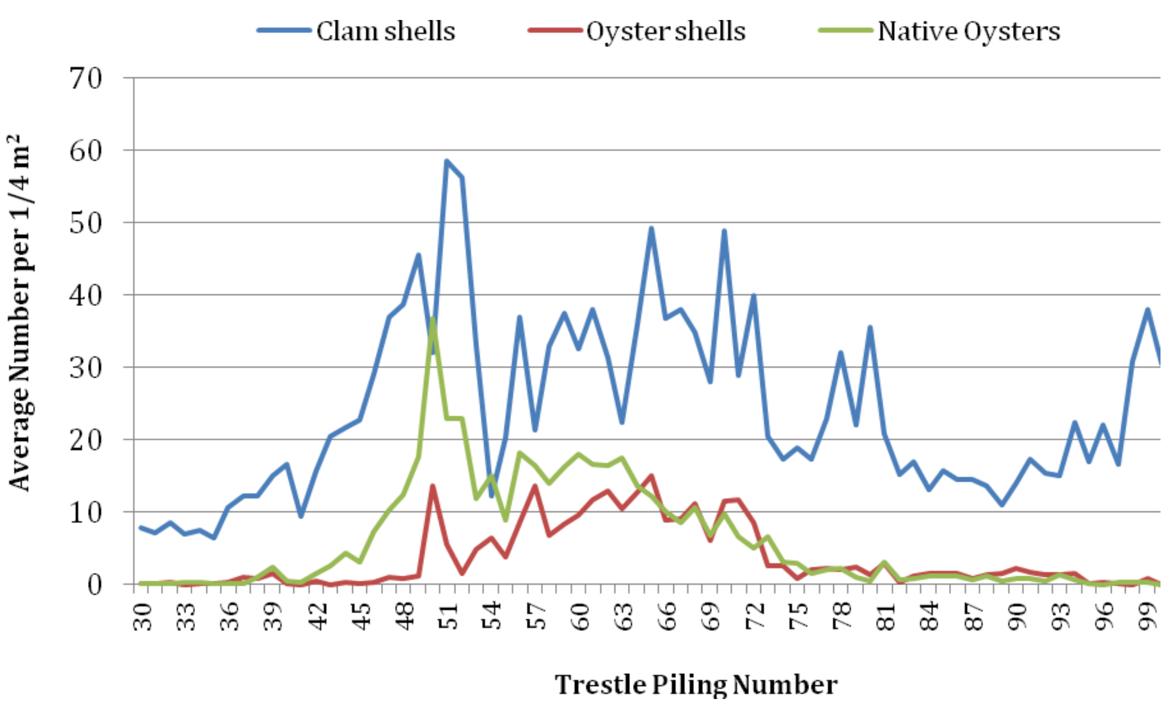

Figure 18. Average number of clam shells, oyster shells and native oysters per piling along the east end of the trestle.

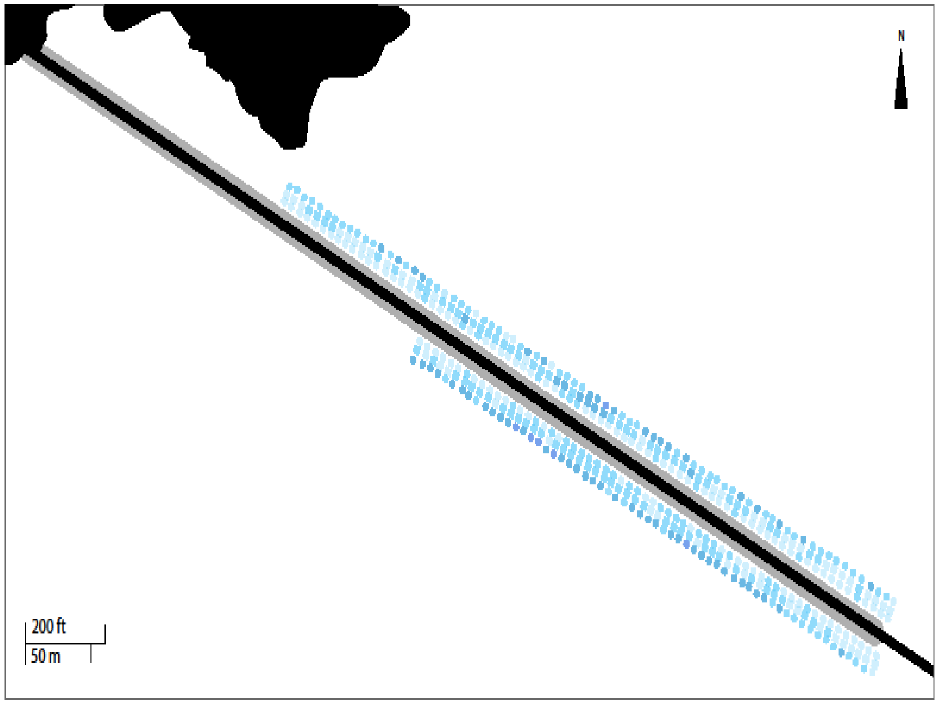

Figure 19. Numbers of native oysters in 140 ¼ m^2 samples collected on the north and south sides of the west end of the trestle in summer, 2012. See Fig. 13 for the color key.

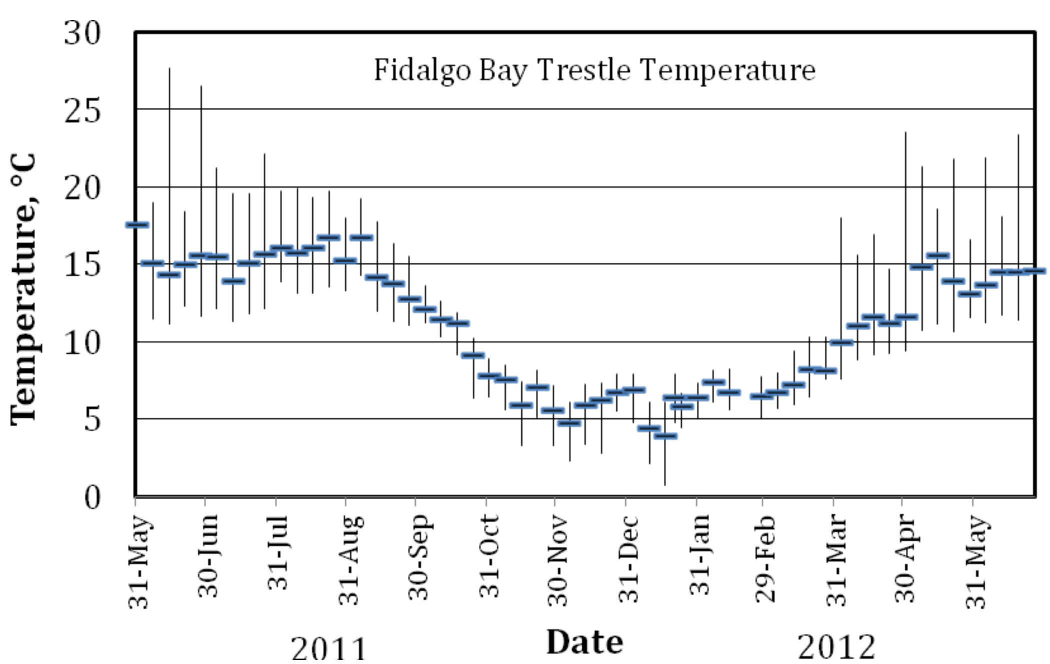

Figure 20. Average weekly temperatures, June 2011 through June 2012, at the Fidalgo Bay trestle restoration plot.

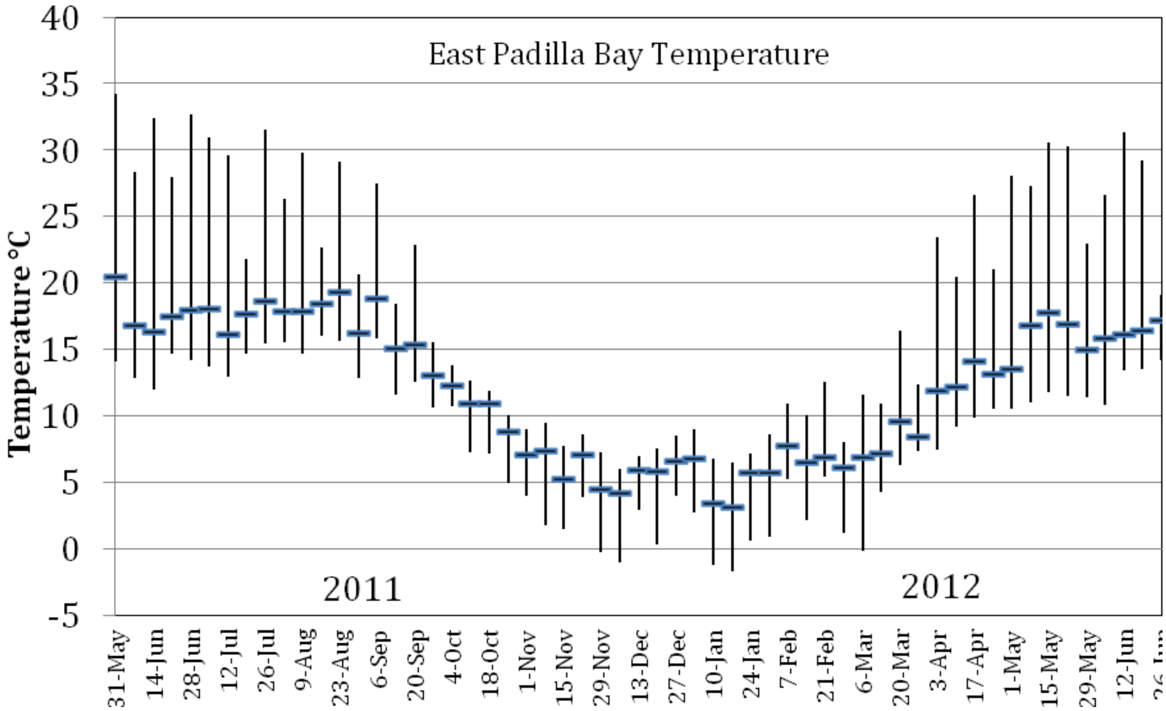

Figure 21. Average weekly temperatures, June 2011 through June 2012, at east Padilla Bay.

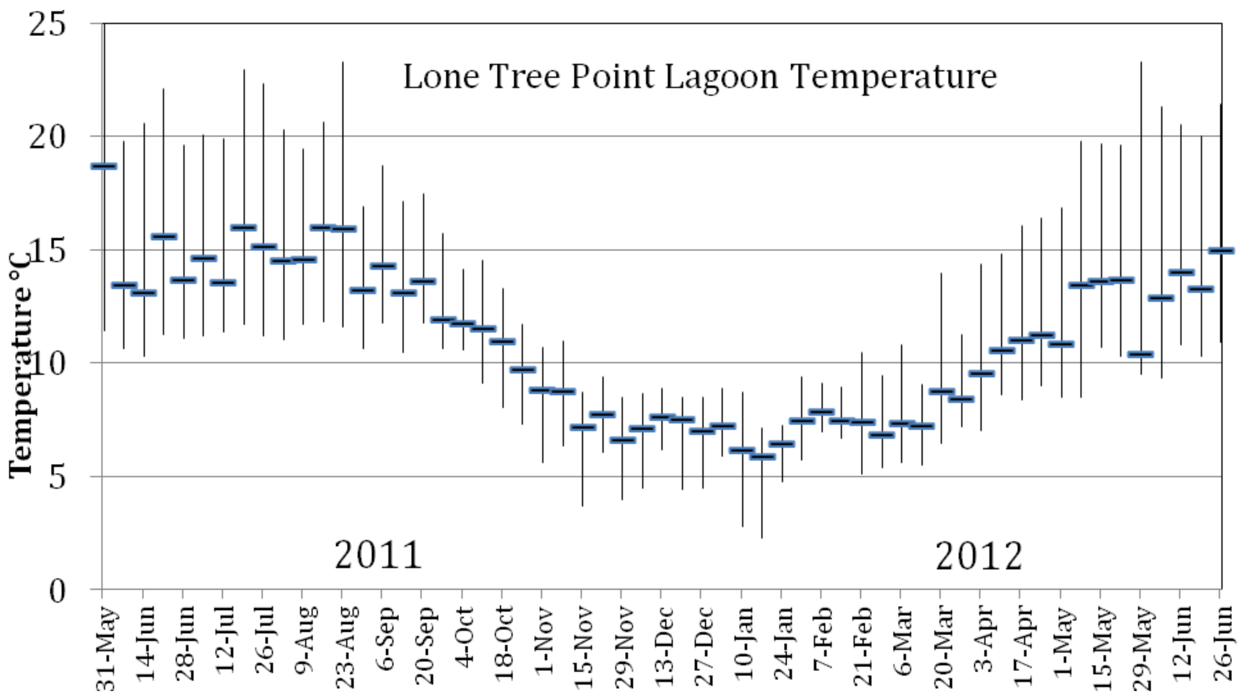

Figure 22. Average weekly temperatures, June 2011 through June 2012, at Lone Tree Point lagoon, Skagit Bay.

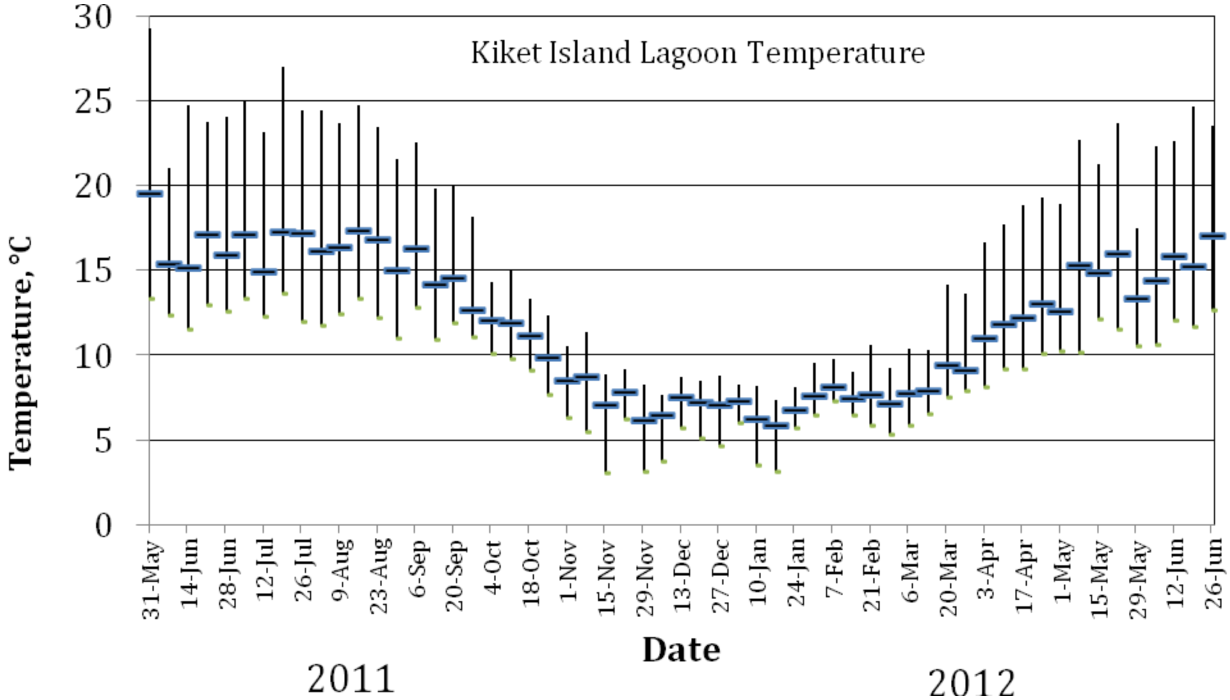

Figure 23. Average weekly temperatures, June 2011 through June 2012, at Kiket Island lagoon, Skagit Bay.

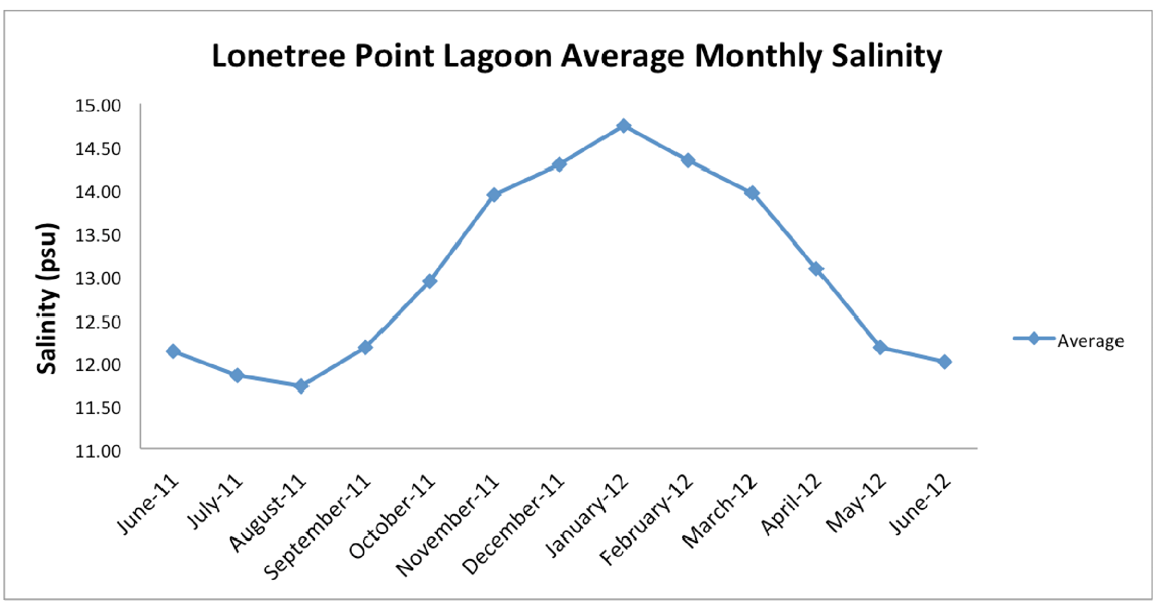

Figure 24. Lone Tree Point Lagoon average monthly salinity (psu), June 2011 through June 2012.

APPENDIX

Appendix Table 1. Numbers of native oysters, clam shells and oysters shells collected in 1/4 m^2 quadrat samples at the east end of the trestle, north and south sides of the west end of the trestle, Weaverling Spit and Crandall Spit, July 2012.

First number of the sample number (e.g., 30-50N) is the piling number and the second number is distance in feet north or south of the trestle midline (0 foot sample).

Sample #	Number of Clam Shells	Number of Oyster Shells	Number of Native Oysters
Trestle*			
30-0	36	1	0
30-10N	4	1	0
30-20N	16	0	0
30-30N	21	0	0
30-40N	1	0	0
30-50N	6	0	0
30-60N	1	0	0
30-70N	2	0	0
30-80N	2	0	0
30-90N	3	0	0
30-100N	1	0	0
30-110N	2	0	0
30-120N	1	0	0
30-130N	0	0	0
30-140N	1	0	0
30-150NB	1	0	0
30-160NB	0	0	0
30-170NB	0	0	1
30-10S	14	1	1
30-20S	26	0	0
30-30S	27	0	2
31-0	18	0	0
31-10N	4	0	0
31-20N	11	0	0
31-30N	10	0	0
31-40N	7	0	0
31-50N	8	0	0
31-60N	0	0	0
31-70N	3	0	0
31-80N	6	0	0
31-90N	1	0	0
31-100N	1	0	0
31-110N	1	0	0
31-120N	1	0	0
31-130N	1	0	0
31-140N	2	0	0
31-150NB	0	0	2
31-160NB	2	1	0
31-170NB	0	0	0
31-10S	22	1	0

31-20S	41	0	0
31-30S	12	0	2
32-0	45	2	0
32-10N	13	1	0
32-20N	10	0	0
32-30N	26	0	0
32-40N	0	0	0
32-50N	4	0	0
32-60N	0	0	0
32-70N	0	0	0
32-80N	1	0	0
32-90N	0	0	0
32-100N	0	0	0
32-110N	1	0	0
32-120N	0	0	0
32-130N	0	0	0
32-140N	0	0	0
32-150NB	0	0	0
32-160NB	12	1	0
32-170NB	5	0	2
32-10S	23	0	0
32-20S	26	1	1
32-30S	13	0	0
33-0	26	1	0
33-10N	10	0	0
33-20N	7	0	0
33-30N	6	0	0
33-40N	2	0	0
33-50N	0	0	0
33-60N	5	0	0
33-70N	0	0	0
33-80N	1	0	0
33-90N	2	0	0
33-100N	19	0	0
33-110N	1	0	0
33-120N	3	0	0
33-130N	5	0	0
33-140N	0	0	0
33-150NB	0	0	5
33-160NB	0	0	1
33-170NB	7	0	0
33-10S	15	0	0
33-20S	26	0	0
33-30S	10	0	2
34-0	25	0	0
34-10N	2	0	0
34-20N	25	1	0
34-30N	8	0	0
34-40N	0	0	0
34-50N	2	0	0
34-60N	5	0	0

34-70N	2	0	0
34-80N	5	0	0
34-90N	1	0	0
34-100N	0	0	0
34-110N	0	0	0
34-120N	1	0	0
34-130N	5	0	0
34-140N	0	0	0
34-150NB	4	0	1
34-160NB	3	0	2
34-170NB	1	1	1
34-10S	26	0	0
34-20S	22	1	0
34-30S	20	0	2
35-0	19	0	0
35-10N	6	0	2
35-20N	26	0	0
35-30N	15	1	0
35-40N	3	0	0
35-50N	1	0	0
35-60N	1	0	0
35-70N	1	0	0
35-80N	0	0	0
35-90N	5	0	0
35-100N	2	0	0
35-110N	3	0	0
35-120N	0	0	0
35-130N	1	0	0
35-140N	0	0	0
35-150NB	11	0	0
35-160NB	2	0	0
35-170NB	1	0	0
35-10S	14	0	0
35-20S	17	0	0
35-30S	9	1	0
36-0	22	1	1
36-10N	25	0	0
36-20N	24	0	0
36-30NR	25	1	0
36-40NR	16	0	0
36-50NR	30	3	0
36-60N	2	0	0
36-70N	1	0	0
36-80N	0	0	0
36-90N	0	0	0
36-100N	2	0	0
36-110N	0	0	0
36-120N	2	0	2
36-130N	1	0	0
36-140N	10	0	0
36-150N	3	0	0

36-160N	4	0	0
36-170N	2	0	0
36-10S	21	0	0
36-20S	27	0	0
36-30S	8	0	0
37-0	13	0	0
37-10N	1	0	0
37-20N	35	0	0
37-30NR	34	12	0
37-40NR	20	0	0
37-50NR	37	1	1
37-60NR	30	4	1
37-70NR	11	1	1
37-80NR	7	1	0
37-90NR	1	0	0
37-100N	2	0	0
37-110N	1	0	0
37-120N	4	0	0
37-130N	1	0	0
37-140N	21	0	0
37-150N	0	0	0
37-160N	0	0	0
37-170N	1	1	0
37-10S	10	0	0
37-20S	16	0	0
37-30S	11	0	0
38-0	7	0	0
38-10N	2	0	0
38-20N	22	1	0
38-30NR	32	2	3
38-40NR	56	5	8
38-50NR	34	0	1
38-60NR	15	7	0
38-70NR	10	0	9
38-80NR	7	1	1
38-90NR	19	0	0
38-100NR	7	0	0
38-110N	4	0	0
38-120N	0	0	0
38-130N	6	0	0
38-140N	2	0	0
38-150N	1	0	0
38-160N	2	0	0
38-170N	0	0	0
38-10S	10	1	0
38-20S	20	0	0
38-30S	3	0	0
39-0	17	1	0
39-10N	22	0	0
39-20N	8	0	0
39-30N	18	1	0

39-40N	17	0	1
39-50NR	23	13	22
39-60NR	30	4	3
39-70NR	33	2	3
39-80NR	31	2	2
39-90NR	19	10	18
39-100NR	12	0	0
39-110N	3	0	0
39-120N	4	0	0
39-130N	0	0	0
39-140N	7	0	0
39-150N	3	0	0
39-160N	0	0	0
39-170N	1	0	0
39-10S	17	0	0
39-20S	35	0	1
39-30S	17	1	1
40-0	24	0	0
40-10N	7	0	0
40-20N	52	0	1
40-30N	3	0	0
40-40N	2	0	0
40-10S	19	0	0
40-20S	18	0	3
40-30S	8	1	0
41-0	6	0	0
41-10N	2	0	0
41-20N	7	0	0
41-30N	1	0	0
41-40N	2	0	0
41-10S	13	0	0
41-20S	17	0	1
41-30S	27	0	2
42-0	8	0	1
42-10N	10	0	0
42-20N	5	1	1
42-30N	5	0	0
42-40N	5	0	0
42-10S	11	0	0
42-20S	42	1	3
42-30S	40	2	7
43-0	3	0	0
43-10N	4	0	0
43-20N	17	0	0
43-30N	6	0	2
43-40N	1	0	0
43-10S	8	0	0
43-20S	34	0	10
43-30S	91	0	9
44-0	4	0	0
44-10N	9	0	1

44-20N	33	0	3
44-30N	3	0	0
44-40N	9	0	0
44-10S	39	1	15
44-20S	48	0	3
44-30S	29	1	13
45-0	11	0	0
45-10N	4	1	0
45-20N	19	0	1
45-30N	4	0	0
45-40N	2	0	0
45-10S	25	0	3
45-20S	51	0	3
45-30S	66	0	18
46-0	26	0	1
46-10N	5	1	0
46-20N	13	0	1
46-30N	17	0	1
46-40N	12	0	2
46-10S	39	0	6
46-20S	45	0	25
46-30S	75	1	23
47-0	9	0	0
47-10N	12	0	3
47-20N	51	1	15
47-30N	14	0	0
47-40N	15	0	2
47-10S	25	1	1
47-20S	124	5	59
47-30S	45	1	3
48-0	67	2	15
48-10N	7	0	0
48-20N	38	0	15
48-30N	5	0	1
48-40N	13	0	0
48-10S	60	4	24
48-20S	76	1	35
48-30S	44	0	10
49-0	25	0	8
49-10N	15	0	3
49-20N	131	1	44
49-30N	5	1	3
49-40N	3	0	0
49-10S	65	4	42
49-20S	81	3	24
49-30S	40	0	17
50-0	28	5	13
50-10N	5	1	1
50-20N	75	18	61
50-30N	31	1	4
50-40N	34	0	0

50-10S	18	53	69
50-20S	33	26	119
50-30S	33	5	27
51-0	45	0	2
51-10N	9	0	2
51-20N	235	28	109
51-30N	62	5	5
51-40N	7	0	0
51-10S	45	1	11
51-20S	58	10	54
51-30S	8	0	0
52-0	19	1	12
52-10N	27	1	15
52-20N	141	3	60
52-30N	81	2	45
52-40N	13	0	0
52-10S	43	2	14
52-20S	72	3	22
52-30S	54	1	16
53-0	13	0	0
53-10N	13	0	0
53-20N	62	19	42
53-30N	31	10	10
53-40N	22	5	5
53-10S	78	5	23
53-20S	28	0	8
53-30S	18	0	7
54-0	11	0	0
54-10N	2	2	0
54-20N	25	12	37
54-30N	10	1	9
54-40N	3	0	0
54-10S	0	16	3
54-20S	34	18	57
54-30S	13	3	14
55-0	5	0	0
55-10N	7	0	0
55-20N	46	6	43
55-30N	18	9	10
55-40N	0	0	0
55-10S	30	2	5
55-20S	48	6	10
55-30S	8	8	3
56-0	5	1	0
56-10N	41	0	0
56-20N	81	39	53
56-30N	62	7	15
56-40N	4	0	2
56-10S	43	6	31
56-20S	51	10	31
56-30S	9	5	13

57-0	12	0	0
57-10N	7	0	0
57-20N	22	23	16
57-30N	6	19	26
57-40N	4	0	2
57-10S	37	2	16
57-20S	34	6	15
57-30S	48	59	56
58-0	41	0	3
58-10N	21	3	9
58-20N	67	11	41
58-30N	19	32	19
58-40N	3	0	1
58-10S	39	1	9
58-20S	63	1	23
58-30S	11	6	7
59-0	27	0	4
59-10N	7	0	0
59-20N	111	10	45
59-30N	31	36	15
59-40N	6	2	5
59-10S	40	2	9
59-20S	68	5	38
59-30S	10	12	14
60-0	8	0	0
60-10N	2	0	0
60-20N	90	22	61
60-30N	19	45	40
60-40N	8	2	0
60-10S	68	2	12
60-20S	54	5	10
60-30S	12	1	21
61-0	36	0	3
61-10N	14	1	5
61-20N	36	59	55
61-30N	44	26	26
61-40N	15	0	1
61-10S	88	0	5
61-20S	31	4	0
61-30S	41	4	38
62-0	29	0	2
62-10N	11	0	1
62-20N	66	35	49
62-30N	39	44	18
62-40N	14	12	15
62-10S	44	0	2
62-20S	30	0	4
62-30S	18	12	40
63-0	20	1	9
63-10N	0	0	0
63-20N	41	33	34

63-30N	17	33	33
63-40N	16	10	17
63-10S	54	3	10
63-20S	20	1	13
63-30S	11	3	24
64-0	19	0	1
64-10N	18	0	0
64-20N	28	41	19
64-30N	17	36	46
64-40N	36	22	16
64-10S	51	0	9
64-20S	54	1	7
64-30S	64	2	11
65-0	37	1	1
65-10N	16	0	1
65-20N	78	35	36
65-30N	49	66	21
65-40N	68	10	14
65-10S	50	3	7
65-20S	68	2	6
65-30S	28	3	12
66-0	29	3	4
66-10N	10	1	0
66-20N	43	20	12
66-30N	12	31	26
66-40N	8	1	3
66-10S	43	0	5
66-20S	78	4	5
66-30S	71	11	26
67-0	30	1	0
67-10N	13	0	1
67-20N	93	20	21
67-30N	34	33	29
67-40N	14	1	0
67-10S	39	3	2
67-20S	46	0	2
67-30S	36	15	14
68-0	38	0	0
68-10N	13	0	2
68-20N	65	6	13
68-30N	52	58	56
68-40N	24	0	0
68-10S	43	2	2
68-20S	30	6	8
68-30S	14	18	4
69-0	22	1	1
69-10N	10	0	0
69-20N	71	8	9
69-30N	25	28	15
69-40N	14	1	4
69-10S	24	0	0

69-20S	50	5	6
69-30S	9	6	19
70-0	15	0	1
70-10N	3	0	0
70-20N	90	38	22
70-30N	48	29	28
70-40N	34	1	6
70-10S	15	4	0
70-20S	144	0	0
70-30S	42	20	21
71-0	16	1	0
71-10N	4	1	1
71-20N	67	51	26
71-30N	50	34	21
71-40N	10	0	0
71-10S	30	1	1
71-20S	47	1	1
71-30S	7	5	3
72-0	28	0	1
72-10N	29	1	0
72-20N	78	35	23
72-30N	27	28	8
72-40N	29	2	0
72-10S	28	0	1
72-20S	88	2	7
72-30S	13	0	0
73-0	22	0	0
73-10N	26	0	1
73-20N	12	10	29
73-30N	16	2	11
73-40N	6	0	0
73-10S	25	0	0
73-20S	29	8	12
73-30S	27	1	0
74-0	32	0	1
74-10N	14	0	0
74-20N	28	17	17
74-30N	11	2	3
74-40N	4	0	0
74-10S	13	0	1
74-20S	22	1	3
74-30S	15	1	0
75-0	25	0	1
75-10N	13	0	0
75-20N	22	6	11
75-30N	16	0	5
75-40N	18	0	0
75-10S	16	0	3
75-20S	24	0	0
75-30S	17	1	3
76-0	10	0	0

76-10N	9	0	0
76-20N	16	17	8
76-30N	16	0	1
76-40N	22	0	0
76-10S	24	0	0
76-20S	32	0	2
76-30S	9	0	1
77-0	30	6	0
77-10N	24	0	1
77-20N	43	10	13
77-30N	16	1	2
77-40N	12	1	0
77-10S	43	0	0
77-20S	11	0	0
77-30S	4	0	0
78-0	39	0	0
78-10N	28	0	0
78-20N	30	8	1
78-30N	22	4	11
78-40N	10	0	0
78-10S	57	1	1
78-20S	48	2	2
78-30S	23	2	3
79-0	18	0	0
79-10N	19	0	0
79-20N	59	10	5
79-30N	12	7	2
79-40N	27	1	0
79-10S	24	0	1
79-20S	14	2	0
79-30S	3	0	0
80-0	27	0	0
80-10N	14	0	0
80-20N	112	5	1
80-30N	24	3	2
80-40N	6	0	0
80-10S	44	1	1
80-20S	53	1	0
80-30S	5	1	0
81-0	21	10	0
81-10N	22	0	0
81-20N	36	4	0
81-30N	27	9	25
81-40N	19	0	0
81-10S	12	0	0
81-20S	21	1	0
81-30S	8	0	0
82-0	16	0	0
82-10N	16	0	1
82-20N	22	1	1
82-30N	11	1	1

82-40N	15	0	0
82-10S	17	0	0
82-20S	17	0	1
82-30S	8	0	1
83-0	10	0	1
83-10N	5	0	0
83-20N	15	2	0
83-30N	19	5	3
83-40N	9	1	0
83-10S	8	0	0
83-20S	27	1	2
83-30S	42	0	1
84-0	12	2	0
84-10N	5	0	0
84-20N	9	1	0
84-30N	20	7	7
84-40N	12	0	0
84-10S	9	0	0
84-20S	22	0	0
84-30S	16	3	3
85-0	13	0	0
85-10N	9	0	0
85-20N	11	3	0
85-30N	19	6	6
85-40N	7	0	0
85-10S	12	0	0
85-20S	22	2	2
85-30S	33	2	1
86-0	8	0	0
86-10N	4	0	0
86-20N	25	2	1
86-30N	25	9	7
86-40N	0	0	0
86-10S	16	0	1
86-20S	19	0	1
86-30S	20	1	0
87-0	8	0	0
87-10N	0	0	0
87-20N	10	0	0
87-30N	4	7	5
87-40N	3	0	0
87-10S	14	0	0
87-20S	39	0	0
87-30S	39	0	1
88-0	17	0	0
88-10N	20	0	0
88-20N	5	4	1
88-30N	20	6	5
88-40N	5	1	2
88-10S	4	0	0
88-20S	14	0	1

88-30S	24	0	0
89-0	14	0	0
89-10N	14	0	1
89-20N	11	9	2
89-30N	9	0	0
89-40N	8	4	1
89-10S	7	0	0
89-20S	16	0	0
89-30S	9	0	0
90-0	26	0	0
90-10N	20	0	0
90-20N	16	12	4
90-30N	2	3	1
90-40N	13	2	2
90-10S	20	0	0
90-20S	9	0	0
90-30S	6	1	0
91-0	10	0	0
91-10N	10	0	0
91-20N	18	7	3
91-30N	25	6	3
91-40N	7	0	1
91-10S	37	1	0
91-20S	22	0	0
91-30S	9	0	0
92-0	14	0	0
92-10N	13	0	1
92-20N	16	6	2
92-30N	24	4	0
92-40N	3	0	0
92-10S	23	0	0
92-20S	7	0	1
92-30S	23	1	0
93-0	19	0	0
93-10N	8	0	0
93-20N	12	6	10
93-30N	27	5	1
93-40N	14	0	0
93-10S	11	0	0
93-20S	20	0	0
93-30S	9	0	0
94-0	5	0	0
94-10N	32	0	1
94-20N	7	9	3
94-30N	13	2	0
94-40N	34	0	0
94-10S	21	0	0
94-20S	20	1	0
94-30S	47	0	1
95-0	13	0	0
95-10N	12	0	0

95-20N	5	0	0
95-30N	18	0	0
95-40N	1	0	0
95-10S	13	0	0
95-20S	17	0	0
95-30S	57	1	1
96-0	29	1	0
96-10N	4	0	0
96-20N	29	0	0
96-30N	9	0	0
96-40N	3	0	0
96-10S	37	0	0
96-20S	30	0	0
96-30S	35	2	0
97-0	14	0	0
97-10N	30	0	0
97-20N	19	0	0
97-30N	3	0	0
97-40N	2	0	0
97-10S	14	0	0
97-20S	37	1	1
97-30S	14	0	2
98-0	11	0	0
98-10N	57	0	0
98-20N	37	0	0
98-30N	8	0	0
98-40N	3	0	0
98-10S	64	0	1
98-20S	44	0	1
98-30S	23	0	0
99-0	30	0	0
99-10N	56	3	1
99-20N	51	0	1
99-30N	4	0	0
99-40N	9	0	0
99-10S	51	0	0
99-20S	64	0	1
99-30S	40	0	0
100-0	12	0	0
100-10N	48	0	0
100-20N	28	0	0
100-30N	49	0	0
100-40N	15	0	0
100-10S	14	0	0
100-20S	36	0	0
100-30S	41	0	0
Total =	**14989**	**2139**	**3556**
Average/1/4 m^2 =	**21.5**	**3.1**	**5.1**

* Collected 1/4 m sq. samples at each of these transect locations. 30 to 100 in the sample numbers refer to sets of pilings from east to west.
N = North of Trestle, S = South of Trestle, R = in Rock Pile, B = on old Barge structure. 0 samples are under the middle of the Trestle.

Sample #	Number of Clam Shells	Number of Oyster Shells	Number of Native Oysters
West trestle -- North side starting at the east end and working west*			
0 feet	0	0	0
20	2	0	0
40	6	0	0
60	14	0	0
80	8	1	1
100	10	0	0
120	3	0	0
140	2	0	0
160	8	0	0
180	8	2	0
200	8	1	0
220	12	0	1
240	21	0	0
260	8	0	0
280	4	1	0
300	18	1	0
320	8	0	0
340	12	0	0
360	8	8	0
380	5	7	3
400	7	5	0
420	10	0	0
440	4	0	0
460	10	1	0
480	28	8	1
500	6	11	0
520	11	2	0
540	14	6	0
560	29	2	0
580	4	4	0
600	5	3	0
620	3	0	0
640	15	5	0
660	43	8	0
680	14	8	1
700	13	11	1
720	4	11	2
740	8	19	0
760	8	11	0
780	8	11	8
800	0	1	0
820	11	14	0
840	8	12	0
860	12	4	0
880	3	6	0

900	0	10	0
920	1	0	0
940	1	9	6
960	8	2	0
980	0	8	7
1000	2	7	0
1020	9	6	0
1040	4	10	0
1060	0	8	0
1080	3	15	3
1100	5	8	0
1120	11	1	0
1140	12	1	0
1160	9	0	0
1180	16	3	0
1200	9	2	0
1220	18	0	0
1240	8	1	0
1260	5	0	0
1280	3	1	0
1300	8	0	0
1320	5	1	0
1340	6	0	0
1360	1	0	0
1380	7	0	0
1400	2	0	0
1420	3	0	0
1440	6	2	0
1460	5	1	0
1480	2	2	0
1500	5	1	0
1520	5	0	0
1540	7	0	0
1560	2	0	0

* Started sample collection at the east end of the rock causeway working westward collecting 1/4 m sq. samples at 20 foot intervals 10 feet above bottom of the slope.

Sample #	Number of Clam Shells	Number of Oyster Shells	Number of Native Oysters
West trestle -- South side starting at the east end and working west			
0 feet	0	0	0
20	1	0	0
40	3	0	0
60	3	0	0
80	15	0	0
100	4	0	0
120	7	1	0
140	3	0	0
160	7	1	2
180	9	1	0
200	6	0	0
220	5	0	0

240	14	1	1
260	10	2	1
280	12	1	0
300	26	0	0
320	19	2	0
340	23	0	0
360	17	1	1
380	11	0	0
400	17	1	1
420	15	2	1
440	18	3	2
460	13	0	0
480	20	1	6
500	35	1	1
520	15	4	4
540	25	6	4
560	8	0	0
580	24	0	0
600	22	5	6
620	15	4	2
640	22	1	0
660	7	5	3
680	22	3	1
700	19	3	1
720	13	7	1
740	24	5	3
760	23	5	5
780	32	2	0
800	19	2	0
820	23	2	2
840	36	0	0
860	20	4	1
880	38	5	0
900	41	2	2
920	21	2	0
940	28	2	0
960	34	3	1
980	18	0	0
1000	29	2	0
1020	26	2	0
1040	15	2	0
1060	7	2	0
1080	22	1	1
1100	22	2	0
1120	16	0	0
1140	9	0	0
1160	14	1	0
1180	15	0	0
1200	17	1	0

* Started sample collection at the east end of the rock causeway working westward collecting 1/4 m sq. samples at 20 foot intervals at bottom of slope.

Sample #	Number of Clam Shells	Number of Oyster Shells	Number of Native Oysters
Crandall Spit in the outflow channel on the north side and delta			
0	156	0	1
10	208	3	1
20	15	1	0
30	2	0	0
40	8	0	0
50	1	0	0
60	10	0	0
70	1	0	0
70-10E	4	0	0
70-10W	40	0	0
80	0	0	0
80-10E	22	0	1
80-20E	5	0	0
80-10W	3	0	0
80-20W	6	0	0
90	13	0	0
90-10E	10	0	0
90-20E	17	0	0
90-30E	4	0	0
90-10W	3	0	0
90-20W	3	0	0
90-30W	2	0	0
100	0	0	0
100-10E	23	2	1
100-20E	1	0	0
100-30E	4	0	0
100-40E	9	0	0
100-10W	4	0	0
100-20W	5	0	0
100-30W	1	0	0
100-40W	2	0	0
110	2	0	0
110-10E	29	1	0
110-20E	3	0	0
110-30E	5	0	0
110-40E	8	0	0
110-50E	4	0	0
110-10W	6	0	0
110-20W	8	0	0
110-30W	2	0	0
110-40W	5	0	0
110-50W	11	0	0
120	11	0	0
120-10E	20	0	0
120-20E	1	0	0

120-30E	11	0	0
120-40E	1	0	0
120-50E	4	0	0
120-60E	2	0	0
120-10W	1	0	0
120-20W	6	0	0
120-30W	2	0	0
120-40W	1	0	0
120-50W	14	0	0
120-60W	2	0	0
130	8	0	0
130-10E	8	0	0
130-20E	3	0	0
130-30E	1	0	0
130-40E	4	0	0
130-50E	5	0	0
130-60E	0	0	0
130-70E	1	0	0
130-10W	2	0	0
130-20W	4	0	0
130-30W	4	0	0
130-40W	7	0	0
130-50W	0	0	0
130-60W	1	0	0
130-70W	1	0	0

*Sampling was in the outlet channel of Crandall Spit lagoon and in a triangular area in the delta area below the outlet channel. Sample date = 30 July 2012

Sample #	Number of Clam Shells	Number of Oyster Shells	Number of Native Oysters
Weaverling Spit -- in the high sump area of the eastern sandbar			
0A	31	0	0
0B	6	1	0
0C	4	0	0
0D	10	0	0
0E	5	0	0
10A	15	0	0
10B	5	0	0
10C	4	0	0
10D	7	0	0
10E	9	0	0
20A	20	1	0
20B	5	0	0
20C	9	0	0
20D	10	0	0
20E	9	0	0
30A	35	0	0
30B	2	2	0
30C	7	0	0
30D	4	0	0
30E	5	0	0

40A	25	0	0
40B	9	0	0
40C	5	0	0
40D	3	0	0
40E	4	0	0
50A	24	0	0
50B	9	0	0
50C	6	0	0
50D	9	1	0
50E	2	0	0
60A	30	0	0
60B	3	0	0
60C	8	0	0
60D	5	0	0
60E	8	0	0
70A	17	0	0
70B	11	0	0
70C	12	0	0
70D	5	0	0
70E	5	0	0

*Sampling was in an east to west rectangle. Area was covered with standing water and a fairly solid cover of *Ulva*. Sample date = 31 July 2012