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

Skagit County Marine Resources Committee

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Abstract

The Olympia or native oyster, *Ostrea lurida*, is native to the Pacific Coast of North America and was common in Puget Sound prior to the arrival of European settlers. Over harvest in the late 1800s, combined with severe pollution in the first half of the 20th century from pulp and paper mills, drove many Puget Sound stocks to near extinction. Skagit County Marine Resources Committee (Skagit MRC), working in cooperation with Puget Sound Restoration Fund and other partners, initiated a project to establish several native oyster beds in Fidalgo Bay near Anacortes, Washington. One site in South Fidalgo Bay (under the railroad trestle) that has stable substrate, standing water at low tide, and an absence of oyster drills, was selected for seed planting in 2002. One-year survival (~95%) and growth (from 25 mm to 42 mm shell length) were excellent, stimulating further seed additions in 2003, 2004 and 2006. Since then, survival has remained high, growth excellent and natural recruitment of juvenile oysters has been detected during several years within about three miles of the trestle restoration site on the eastern and southwestern portions of Fidalgo Bay. These natural recruits likely resulted from successful spawning of the trestle seed oysters in 2004, 2006, 2009 and 2010. Natural recruitment apparently failed in 2005, 2007 and 2008 for reasons unknown. The bed structure at the trestle site was enhanced with clean Pacific oyster shell in 2006 (5 cubic yards) and 2009 (10 cubic yards) to improve the oyster bed structure and to provide additional substrate for larvae to settle on. Two additional small sites on Weaverling Spit (west of the trestle) have also been seeded and were previously monitored by the Samish Tribe. Monitoring will continue in future years and seeding will be expanded to an area in northern Fidalgo Bay and up to ten additional North Puget Sound sites by 2020. To aid the expanded seeding efforts, a sample of native oysters was collected from the trestle restoration bed in January 2011 and sent for DNA analysis of genetic diversity. Results of this analysis will be used to determine if the trestle population is suitable for use as broodstock for seeding additional sites in North Puget Sound.

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Introduction

The native or Olympia oyster (*Ostrea lurida*) is native to the Pacific coast of North America and occurs in marine waters from Baja California to Sitka, Alaska (Ricketts and Calvin 1968). The native oyster has a history of exploitation dating back to pre-colonial days. The native oyster (called Tusa'yad by the Skokomish Tribe) was an important food resource for native tribes, which often based settlement locations on its harvest (Steele 1957). With colonization, the native oyster supported a large commercial industry. Beginning in the 1850s, native oyster beds from Puget Sound, Hood Canal and Willapa Bay were harvested extensively, and later cultivated with an elaborate system of dikes (Steele 1957). Over harvest in the late 1800s and early 1900s severely compromised the commercial viability of the native oyster. Oyster laden schooners transported native oysters from Willapa Bay and Puget Sound to gold prospectors and entrepreneurs in Northern California who had exhausted local oyster stocks and paid as much as a dollar per oyster (PSAT 2003). In addition, severe water quality problems generated by pulp and paper mills in the 1930s to 1950s drove the native oyster to near extinction in many places (Couch and Hassler 1989), thereby terminating the Washington native oyster industry (Cook et al. 1998, 2000; Baker 1995).

Unlike the Pacific oyster (*Crassostrea gigas*) imported from Japan, Olympia oysters are native to Puget Sound. In the North Sound region, historical native oyster beds have been reported to once exist in the Orcas and Shaw Island areas, Bellingham Bay, Chuckanut Bay, Samish Bay, Padilla Bay, Fidalgo Bay, Similk Bay, Guemes Island (Suttles 1974 cites a report of Spanish explorers being provided with "verdigones" by Indians living on Guemes Island and harvest of oysters by early Guemes Indians is reported by Ashbach and Veal 1986) and from a bay on the northeastern side of Whidbey Island (*Northwest Enterprise* 1884, *Skagit News* 1888, Townsend 1893, Hatch et al. 2005). Locations where a few native oysters have been found in recent years include Cypress Island, Bellingham Bay (Stahl 1999), Samish Bay, Lopez Island (Betsy Peabody, pers. comm.) and Drayton Harbor (Brady Blake, pers. comm.).

Olympia oysters are smaller than the Pacific oyster, the maximum reported sizes being 75 mm (Hertlein 1959) to 90 mm (Harbo 1997), but are generally smaller than the 2.5" recreational harvest size limit for oysters. Oysters feed on phytoplankton by filtering the water and native oyster beds are considered valuable for water purification and as habitat for other species. In Puget Sound, many native oyster populations have remained close to extinction. Records show that 10,000 bushels of native oysters were harvested in Puget Sound in 1850 and 130,000 bushels by 1890. Harvests gradually shrunk during the 1900's, with essentially no harvests of wild native oysters after about 1980. In the North Puget Sound region, commercial quantities of native oysters were only known from Samish Bay (*The Coast* 1907), and possibly Bellingham Bay (Townsend 1893), where they are extremely scarce today (Cook et al. 1998, 2000; Baker 1995). In addition, attempts were apparently made to raise native oysters in Similk Bay during the early 1900s, but that venture apparently did not last long (*Anacortes American* 1906).

Native oysters are considered a valuable resource (they are a premium oyster in the half-shell trade), are important for maintaining water quality in estuaries, and oyster beds provide habitat for other marine species (Gregory and Volety 2005; Luckenbach et al. 1999). Thus, the Washington Department of Fish and Wildlife (WDFW) has initiated a program to identify the present distribution of native oysters in Puget Sound, investigate their genetic integrity, improve

management of the species and enhance Puget Sound populations by both natural and artificial means (Cook et al. 1998). In addition, Puget Sound Restoration Fund received restoration grants from NOAA's Community Restoration Program to expand Puget Sound restoration efforts in 2004 and 2005. Most recently, the Northwest Straits Foundation was awarded native oyster restoration funds in 2010 by the National Fish and Wildlife Foundation to further expand restoration efforts in North Puget Sound. By 2003, over 100 tribes, public agencies, local organizations, commercial shellfish farmers, business sponsors and private tideland owners were involved in restoration efforts and approximately 1.3 million native oysters have been planted at 41 experimental sites (Betsy Peabody, pers. comm.).

In 2002, the Skagit County Marine Resources Committee (Skagit MRC) teamed with Puget Sound Restoration Fund, the Samish and Swinomish Tribes, Taylor United Shellfish, Shell Puget Sound Refinery and others to assist with planting native oyster seed at two locations in South Fidalgo Bay as part of the North Puget Sound restoration effort (Robinette and Dinnel 2003; Barsh 2003). Other than several small plantings on Orcas Island, this represented the first native oyster restoration effort in the North Sound area (Betsy Peabody, pers. comm.). The next closest native oyster restoration effort is being conducted by Jefferson County Marine Resources Committee in Discovery Bay on the northeastern end of the Olympic Peninsula (Lull 2010) where a small natural population of natives oysters was already established.

Fidalgo Bay was selected as the planting site because this bay had what looked like good habitat and, unlike Samish Bay, appeared to be free of Japanese oyster drills (*Ocenebra japonica*), which were imported into Washington waters with early importation of Pacific oysters from Japan. Additional native oyster seed were planted in 2003 and the growth and survival of both plantings monitored (Robinette et al. 2004; Barsh et al. 2004). Oyster seed were again planted in 2004 and monitoring efforts continued to assess the survival and growth of all three seedings and search for the first signs of any natural spawning and post-larval recruitment on cultch shells specifically distributed to catch the spat (Dinnel et al. 2005). Seed were again planted at three locations in Fidalgo Bay in 2006 and habitats at all three sites were also enhanced by the addition of Pacific oyster shell to aid bed building activities and post-larval recruitment (Dinnel et al. 2006, 2009a, 2009b). This report covers our monitoring activities carried out in 2010 and 2011.

Project Goals

At one time, native oyster beds formed one of the "foundation" communities in Puget Sound and in coastal estuaries. Native oyster beds were important for providing 3-dimensional habitat for infaunal and encrusting invertebrates and small fishes, and provided foraging locations for larger animals including Dungeness and rock crabs, juvenile salmon, perch and a variety of bottom fishes. These oyster beds were also important for maintaining water quality by filtering large volumes of water and removing pollutants and nutrients from the water column and maintaining the water clarity so important for good growth of eelgrass and kelp. In addition, they provided a rich source of food for Native Americans and settlers until they were decimated by over harvest.

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. 1998). 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 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 agreement was that, based on the apparent success of the Fidalgo Bay restoration effort, restoration activities should be extended 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. The ten-year goal will be establishment of at least ten 1 acre native oyster beds in the North Sound region.

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:

    - Conduct test seedings at several sites
    - Monitor survival and growth of seedlings
    - 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

Seeding the Restoration Bed

Skagit MRC's first seeding of native oysters was at the Fidalgo Bay trestle (Figs. 1 and 2) in April 2002. This was part of a broad-based effort begun in 1999 at various locations in Puget Sound. Betsy Peabody of Puget Sound Restoration Fund (PSRF) led the Fidalgo Bay effort, together with Skagit MRC and Bill Taylor of Taylor Shellfish Farms. Details of the 2002 planting and subsequent seed survival and growth over the following seven months were reported in the Year 1 Report (Robinette and Dinnel 2003).

Approximately 20,000 native oyster seed (20 bags of cultch) were planted under or near the railroad trestle in April 2002. These seed were set on Pacific oyster shells (cultch) by Taylor Shellfish Farms and were about one year old at the time of planting. The brood stock was from Samish Bay. The 2002 seed were primarily planted underneath the trestle in an area that had some flowing water at extreme low tide and a solid bottom of gravel and shells (area A, Fig. 3). Some seed were also randomly spread in areas B and C (Fig. 3). Both of these areas had standing water at extreme low tides, but were somewhat siltier than area A. Initial seed density information and seed size measurements were gathered on a subsequent low tide series in late May, 2002 to provide a baseline of what was planted. Subsequent survival and growth monitoring data were then collected from fall 2002 through spring 2009.

A second planting of approximately 65,520 native oyster seed (39 bags of cultch) were planted under or near the railroad trestle in Fidalgo Bay in August 2003 (Fig. 3). The brood stock was from Samish Bay and seed were set on Pacific oyster cultch by the Lummi Tribal Hatchery, Bellingham. The seed were several months old at the time of planting in August 2003. The 2003 seed were planted in a variety of locations, as follows:

- Twelve bags were spread in area A (Fig. 3) to supplement those planted in this location in 2002.
- Twenty-four bags were planted in standing water in area B. Eighteen bags were opened and the cultch shells spread on the shelly/silty bottom. Six unopened bags were also placed in area B in case the area proved to be too silty for the seed spread directly on the bottom.
- Three bags of cultch were placed directly underneath the trestle, an area with firm gravel/shell substrate but no flowing or standing water at low tide. Two of the bags were opened and spread on the bottom and the third bag was left unopened.
- One bag was used in caged substrate experiments on Weaverling Spit by Samish Tribal members (see Barsh 2003 and Barsh et al. 2004 for Weaverling Spit reports).

Initial seed density and size data were gathered on the day of planting to provide a baseline of what was planted. Seed density was estimated by counting the number of seed that had set on shell subsamples from two bags of cultch shells. Seed size data were gathered by measuring seed on a haphazardly selected subset of the planted cultch. Subsequent survival and growth monitoring data for the 2003 seeding (and future plantings) were then collected in spring 2004 through summer 2011.

For the third seeding in 2004, adult native oysters obtained by Betsy Peabody from Lopez Island in April 2004 were spawned, and the larvae set on cultch shells by the Lummi Tribal Hatchery. Approximately 37 bags of seed-containing cultch were then planted in areas A and B in August

2004. Seed planted at the trestle site in 2004, together with seed from the 2002 and 2003 plantings, were monitored for survival and growth from spring 2005 through 2011.

In summer 2006, 190 bags of native oyster seed were set on Pacific oyster shell cultch by the Lummi Tribal Hatchery. The seed source was the Fidalgo Bay trestle population, which was a mixture of seed derived from Samish Bay and Lopez Island sources. The Fidalgo Bay oysters were checked for diseases prior to shipment to the Lummi Hatchery and found to be disease free. 170 of the bags of seed were distributed along the Fidalgo Bay trestle (primarily in areas B and C in Fig. 3) in August 2006, and the balance of 20 bags was planted on the north side of Weaverling Spit at two new locations. Subsamples of the native oyster seed were assessed for spat density on the cultch shells and measured for spat size at planting.

In summary, native oyster seed set on Pacific oyster cultch were planted at the south Fidalgo Bay trestle site in 2002, 2003, 2004 and 2006. The numbers of seed planted in each year are summarized in Table 1. The total number of seed planted for all four years combined is estimated to be 1,429,570. This estimate is based on an average of 240 cultch shells/seed bag for years 2002-2004 and 270 shells/seed bag in 2006.

Monitoring for Survival and Growth

Monitoring for seed survival and growth was carried out from fall 2002 through spring 2011 and will continue in future years. From 2002 through 2006, survival was largely monitored by haphazardly sampling a number of seeded cultch shells from several trestle areas and assessing the number live/dead per cultch shell, which estimated survival based on percentages of live and dead oysters in the population. In 2008 (no samples in 2007), we added haphazard 1/4 m^2 quadrat sampling in Plot B (Fig. 3) at 14 pilings along the trestle (two samples at each piling) where all cultch shells, live oysters and, in some years, dead oysters (oyster scars) were counted from each quadrat sample. This method now provides estimates of survival based on density estimates in Plot B. The change to quadrat sampling for survival and density estimates was required following enhancement Plot B with non-seed bearing Pacific oyster shell. Previously, all oyster shell in Plot B had contained oyster seed, but additions of seedless oyster shell meant that we could no longer use the seed/cultch counts for survival/density estimates.

Addition of Pacific Oyster Shell for Substrate and Bed Enhancement

Experimental evidence indicates that native oyster larvae prefer to settle on oyster shell (either native or Pacific oyster) compared to gravel or bare ground (White et al. 2009). Thus, we added Pacific oyster shell to the trestle and Weaverling Spit sites to enhance the possible settlement of naturally spawned oyster larvae from the trestle restoration site. Five cubic yards of old Pacific oyster shells, donated by Blau Oyster Company on Samish Island and inspected and permitted by WDFW, was spread at the trestle restoration beds in summer 2006. Addition of the shell to the trestle site was greatly aided by the newly opened Tommy Thompson Trail built on top of the old railroad trestle. Volunteers were able to use carts and hand trucks to transport the shell along the trail to the planting location, where the shell was tossed over the side of the trestle. A second batch of shell (also 5 cubic yards) was spread by volunteers at the two new Weaverling Spit sites to firm up the substrate and provide settlement substrate for any naturally spawned larvae. An additional 10 cubic yards of Pacific oyster shell was again obtained from Blau Oyster Company in spring 2009 and distributed along both the north and south sides of the trestle (west of Plot B and east of Plot C, Fig. 3).

Sampling to Assess Natural Recruitment

Bags of clean cultch shell were deployed in the spring of 2003, 2004 and 2006 along the length of the trestle, the bags being spaced at about 5 piling intervals (about 50 feet) and tied to the pilings. Volunteers returned to the trestle site in August 2004 and the spring of 2005 and 2007 to sample shells from the cultch bags. In 2004 and 2005, volunteers collected about 20-30 shells from each of 19 bags starting at piling set 21 and ending at set 104 next to the mid-bay channel. In 2007, entire bags were collected from pilings 35 through 90 and all shells in each bag were assessed for settlement. These shell samples were taken to Shannon Point Marine Center where they were washed, counted and assessed for spat settlement. Any juvenile oysters encountered were counted and measured to the nearest mm.

In 2007, 2008 and 2009, bags of clean Pacific oyster cultch were distributed around Fidalgo Bay and at locations in Padilla Bay and Guemes Channel close to Fidalgo Bay (Fig. 4) to monitor for larval oyster settlement and to try to discern the extent to which larvae may be distributed from a spawning at the trestle restoration bed. These bags were collected in spring 2008, 2009 and 2010 and all shells in each bag were checked for juvenile oysters. Additional haphazard monitoring for natural native oyster recruitment was carried out from 2006 through 2008 on several occasions by checking various substrates (Pacific oyster shell, wood and pieces of metal). Once settlement sites were detected, more intensive surveys were carried out in 2008-2011 to quantify native oyster settlement densities and oyster sizes at about eight locations around Fidalgo Bay.

Exploration of Additional Planting Locations

A variety of other locations within Fidalgo Bay and in nearby Padilla Bay were investigated during the summer of 2006 and again in 2009 as possible sites for establishing future native oyster beds. Each site was checked for stability of substrate, presence of standing or flowing seawater during periods of extreme low tides, and presence or absence of native oysters. In April 2011, MRC, WDFW, Padilla Bay Reserve staff and Swinomish Tribal biologists conducted site visits to four locations that appeared to have good potential for establishing new native oyster beds. These four sites were: 1) North Fidalgo Bay in the area of the major Scott Paper Mill cleanup and shoreline restoration project (on the south edge of Cap Sante marina) just completed by the Port of Anacortes, WDOE and other partners, 2) the eastern shore of Padilla Bay in tide pools inshore of eelgrass (*Zostera marina*) beds, 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 Swinomish reservation about 1-2 miles north of Lone Tree Point lagoon.

Each of these four areas appears well suited for placing trial batches of seed in the spring/summer of 2012 following production of seed in a commercial hatchery. In anticipation of this possibility, Hobo® brand recording temperature sensors, set to record temperature at the water/sediment interface at 1 hour intervals over the next year, were deployed at each of the four sites mentioned above plus an additional unit was deployed at the trestle restoration site. In addition, since there is a freshwater stream flowing into the Lone Tree Point lagoon, a recording conductivity (salinity) sensor was added at this location, also recording at 1-hour intervals. All sensors were deployed between June 2nd and 3rd, 2011.

A summery report by Brady Blake, WDFW, that describes each of these sites, together with a photograph of each site appears in Appendix 1. Also appearing in Appendix 1 is a summary of a site visit to Chuckanut Cove in southern Whatcom County by Betsy Peabody, Puget Sound Restoration Fund, and her recommendations for this site.

Results

Seed Additions to the Trestle Restoration Plot

Seed oysters set on Pacific oyster cultch shells in hatcheries were added to the trestle plots in 2002, 2003, 2004 and 2006. Numbers of seed planted ranged from 24,960 to 1,124,550 for a total of 1,429,570 by the end of 2006 (Table 1). Oyster seed planted in 2002 were age 1+ with an average size of 24.8 mm. Seed planted in the following three years were age 0+ with average sizes ranging from 4.8 to 9.5 mm (Table 1). No new hatchery seed have been added to the trestle site since 2006.

Oyster Seed Survival and Densities, 2002 Through 2011

Survival and densities of native oysters at the trestle restoration site were monitored one or two times per year with the exception of 2007. Most monitoring took place in Plot B (Fig. 3), the northern plot containing standing water at extreme low tides. Survival of the seed oysters planted from 2002 through 2006 was roughly 90 % for the first several years (Table 2) and gradually decreased to about 39 % by May 2009. The density of native oysters on a live oyster per cultch shell basis ranged from 4 to 5 in 2002/2003 to a high of 22.5 in May 2004. Recent estimates (2008 and 2009) were about 1 oyster per cultch shell, but one reason for this low number is that about three cubic yards of seedless Pacific oyster shells were added to Plot B in 2006, effectively diluting the oysters/shell estimates.

Because of the addition of seedless oyster shells to the trestle restoration site in 2006 (and again in 2009), we could no longer use the number of oysters/cultch shell method for monitoring year by year densities in Plot B. Therefore, we switched to ¼ m^2 quadrat sampling beginning in 2008 (quadrat sampling was also conducted in 2003 and 2004 following initial seed planting). On the basis of number of live oysters per ¼ m^2 quadrat sampling, oyster densities averaged about 45/m^2 in 2002 and 2003 and have gradually increased since then to about 130/m^2 in June 2011 (Table 2). The last seed addition to Plot B was in 2006; thus, the increase in oyster densities from 2008 through 2011 is due entirely to natural recruitment. The total number of native oysters in Plot B has gradually increased from about 12,000 in 2002 to about 33,000 as of June 2011 (Fig. 5)

Oyster Sizes

Native oysters sampled in Plot B were measured each year for their sizes. Average shell length was 24.8 mm in May 2002, which reflected the average size of the age 1+ seed planted that year (Table 2, Fig. 6). Average size then increased through August 2004 to a high of 47.0 mm and decreased in April 2005 to 26.4 mm due to the addition of small seed oysters in August 2005 (Fig. 6). Average sizes in 2008 through 2011 ranged from 32.2 to 38.1 mm. Size-frequency plots of oyster sizes sampled at Plot B from 2008 through 2011 show a gradually aging population of oysters through time (black bars, Figs. 7a-d) 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% of the population) and moderate recruitment (5.3%) in 2011 (white bars, Fig. 7 a-d). The average size of native oysters at the trestle will likely continue to fluctuate as new oysters are recruited via spawning and natural post larval recruitment and older oysters die.

Natural Recruitment

A series of bags of clean cultch shells hung along the length of the trestle next to the seed planting beds were checked in August 2004 and spring of 2005 and 2007 for any signs of natural recruitment of native oysters from spawning at the trestle site. No signs of post-larval recruitment were found in 2004, but a low density of natural spat was observed on the cultch shells in April 2005. Volunteers returned to the trestle in late June 2005 to collect samples of shells from the shell bags. Assessment of 442 shells resulted in a total of 104 juvenile oysters that had to have set from natural spawning, for an average density of 0.24 spat/cultch shell. Shell in bags set out in 2005 and sampled in spring 2006 did not contain any native oyster recruits, indicating a lack of successful spawning in 2005.

Shell bags were again deployed along the trestle in spring 2006 and recovered in spring 2007. These bags contained moderate numbers of juvenile native oysters (0.18 oysters/cultch shell), indicating a successful spawn at the trestle in summer 2006. These oysters ranged in size from 14 to 26 mm shell length and averaged 19.4 mm.

In spring 2007, 2008 and 2009, bags of clean Pacific oyster cultch were distributed at the trestle and around Fidalgo Bay and nearby locations in Padilla Bay and Guemes Channel (Fig. 4). These bags were retrieved and checked for settlement of juvenile native oysters in spring 2008, 2009 and 2010. No native oysters were found in any of these bags in 2008 and 2009, indicating that the oysters at the trestle failed to spawn successfully in 2007 and 2008. However, despite not finding recruits in the cultch bags collected in 2008 and 2009, size-frequency plots of oyster sizes sampled at Plot B in 2008 and 2009 (Fig. 7 a and b) suggest that there may have been some minor natural recruitment during 2007 and 2008 (note those oysters in Fig. 7 a and b that are indicated by the clear bars).

Shell bags recovered in 2010 showed that there was a substantial natural recruitment in 2009. Three bags of shell recovered from Plot B at the trestle contained an average of 2.7 juvenile oysters per cultch shell (Fig. 8). These oysters averaged about 22 mm in shell length and ranged in size from 6 to 38 mm shell length (Fig. 9). This same pattern of natural recruitment was observed in the Plot B samples collected at the trestle in July 2010. Indeed, samples collected from Plot B indicated that 23.5% of the oysters in Plot B in July 2010 were juveniles recruited from a natural spawn in 2009 (Fig. 7d).

Other bags collected from around Fidalgo Bay in 2010 also showed varying densities of settlement of 2009 recruits (Table 3, Fig. 10). However, the recruitment was limited to south Fidalgo Bay, with no recruits being found in the Cap Sante Head, Guemes Channel or east March's Point locations.

Fidalgo Bay Surveys for Native Oyster Settlement

Several checks of old Pacific oyster shell, clam shells, wood and metal debris were made during the summer of 2006. Low densities of native oysters, some fairly large in size, were found attached to these substrates. These juvenile native oysters had set in the last several years and had to have come from naturally spawned native oyster larvae since some juveniles were found on old seed cultch and on top of seed oysters planted in the last few years. These juveniles were likely recruits from a 2004 spawning at the trestle restoration site.

Surveys of possible native oyster habitats around Fidalgo Bay were conducted in summer 2008 and springs of 2009, 2010 and 2011 for an assessment of native oyster recruitment originating from spawn from the trestle restoration bed. The number of native oysters found at these locations

ranged from 0 to 620, with the highest numbers being found closest to the trestle (Fig. 11). These oysters ranged in size from 18 to 74 mm. Both the density and size data suggest that these oysters originated from several successful spawnings at the trestle from 2004 to 2010.

In 2011, we found 53 native oysters at the South Fidalgo Bay berm site (Fig. 11, lower right corner). The sizes of these oysters were quite bimodal (Fig. 12), indicating that oysters >30 mm shell length settled in this location in years previous to 2010 and oysters <30 mm settled in summer 2010.

Native Oysters in Clam Shell Habitat

In 2010 we noticed that there were an increasing number of native oysters occurring in the substantial amount of clam shells that are present around the trestle restoration site (Figs. 13 and 14). Two haphazardly collected ¼ m^2 samples in 2010 showed an average of 0.23 native oysters/clam shell and an average of 9 oysters per ¼ m^2 sample. Ten additional ¼ m^2 haphazard samples collected in 2011 resulted in an average of 0.19 oysters/clam shell and an average of 13.7 oysters per ¼ m^2 sample (= 54.8 oysters/m^2). The size frequency distribution of these oysters (Fig. 15) was similar to that observed in trestle Plot B – Fig. 7d), with a size range of 13 to 54 mm shell length. There can be little doubt that substantial natural recruitment has taken place in the local natural clam shell habitat and the oyster densities in the clam shells are now approaching half the density found in the Plot B seeded restoration bed.

DNA Analyses

To aid the expanded seeding efforts, a sample of native oysters (the original seed oysters produced in hatcheries) was collected from the trestle restoration bed in January 2011 and sent to Oregon State University (OSU) for DNA analysis of genetic diversity. Results of this analysis will be used to determine if the trestle population is suitable for use as broodstock for seeding additional sites in North Puget Sound. The analysis is currently underway and the results will be reported at a later date. A second set of native oysters was collected on June 14, 2011 for DNA analysis by OSU. This was a collection of oysters that had settled on old clam shells; hence, these oysters are known to be naturally spawned and set progeny of the original seed oysters.

Education and Outreach

Education and outreach on native oyster restoration was an ongoing task during 2009-2011 and included the following:

- Platform presentation at the third West Coast Native Oyster Workshop held in Suquamish, Washington, 16-17 September 2010. Abstract published in NOAA/PSRF 2010.
- Training presentation to Skagit Beach Watchers class, Padilla Bay Reserve, 9 April 2010.
- Platform presentation, Samish Tribe Fidalgo Bay Science Conference, 23 February 2011.
- Presentation at the National Estuarine Research Reserve System GIS Workshop at Padilla Bay Reserve, 27 February 2011.
- Native oyster training workshop at the trestle, June 14, 2011.
- Tour of the trestle restoration site by Skagit land Trust members, June 15, 2011.

Volunteer Hours

Approximately 17 volunteers participated in native oyster restoration efforts from July 2009 through June 2011. The estimated time spent by volunteers doing field work (filling, deploying and retrieving shell bags, assessing oysters in shell bags, obtaining trestle density and survival data, habitat surveys, monitoring for natural post-larval recruitment, DNA analyses, project coordination, data analyses, report writing and oral/poster presentations) was 250 hours. Additional hours were also provided by staff of Puget Sound Restoration Fund, Northwest Straits Foundation, Padilla Bay National Estuarine Research Reserve, WDFW and the Samish and Swinomish Tribes. Oyster shell was donated by Blau Oyster Company, Samish Island. David Stick, Oregon State University, also donated approximately $500 worth of supplies for conducting DNA analyses of the Fidalgo Bay trestle restoration bed oysters.

Discussion

The trestle site in South Fidalgo Bay was originally chosen by Betsy Peabody (PSRF) and Bill Taylor (Taylor Shellfish Farms) because of the site's firm substrate, standing water at low tide, absence of oyster drills and minimal recreational use. The initial success of the 2002, 2003 and 2004 seedings, both in terms of survival and growth, validated this location as a viable restoration site in North Puget Sound (see Robinette and Dinnel, 2003 for results of our first year's work at the trestle site, Robinette et al., 2004 for the second year and Dinnel et al., 2005 for the third year). Discovery of significant numbers of naturally recruited native oysters at the trestle site and surrounding areas in Fidalgo Bay further validates this site. Since there are no other documented concentrations of native oysters in the North Puget Sound region (a few remnant native oysters have been found in Bellingham and Samish bays and on Lopez Island), then the natural recruits found in Fidalgo Bay are almost certainly from spawnings at the trestle restoration site.

The area underneath the trestle, and within about 3 meters on either side, has a very firm substrate composed of gravel and accumulations of clam and oyster shells. Areas further from the trestle (about 3 to 10 meters) still have fairly firm substrate and good standing water at extreme low tides, but also have increased siltation that has caused a minor amount of mortality of very small seed oysters. Predation by crabs, drills, diving ducks and other predators continues to be very low so far, although the potential for eventual predation by some crabs is certainly possible (Henoch 2004). Most seed appear to be staying on site and are not being carried very far by currents or waves.

Growth of all four batches of oyster seed, together with new natural recruits, is gradually providing the beginnings of a structured oyster bed at the trestle site. The main seeding sites at the trestle (areas A, B and C – Fig. 3), as well as some of the outer fringes of the trestle site, were enhanced in 2006 by adding Pacific oyster shells to the somewhat silty substrate to provide more solid support for small native oyster seed and to provide additional settlement substrate for any naturally-spawned larvae that might settle. A second oyster shell enhancement effort (10 cubic yards) was undertaken in 2009 to increase the amounts of oyster shell substrate in the area west of Plot B and inside Plot C. Juvenile native oysters are now recruiting in abundance to this enhanced shell habitat.

An experimental bed structure using both rocks and oyster shell was constructed by the Samish Tribe on Weaverling Spit and seeded with native oyster seed in 2003 and 2004 (Barsh 2003; Barsh et al. 2004). However, assessment of this site in 2006 showed that there were few, if any, surviving native oysters. This site was higher than the trestle site and did not have any standing water present

during periods of very low tides. Therefore, this site was abandoned in 2006 in favor of two other sites that do have standing water at extreme low tides. Each of these two sites were "firmed up" by the addition of approximately five cubic yards of Pacific oyster shell obtained from Samish Island. Subsequently, each site was seeded with 10 bags (~65,000 seed) of native oyster seed in August 2006. As with the first Weaverling Spit site, native oysters seeded at these two new locations have not fared well for reasons presently unknown.

The goal of any native oyster project is to establish a bed that successfully spawns, produces larvae, and acts as a "source population" that exports larvae to other areas. The larval stage lasts about 11 to 16 days (Imai et al. 1954), during which time they will be distributed by water currents. However, virtually no data exist about how far native oyster larvae will be dispersed, and dispersion is most certainly a function of the specific locale and larval behavior. Since the trestle population is so far the only significant concentration of native oysters in this region, we are able to trace settlement patterns within and outside Fidalgo Bay and determine the extent of larval transport taking place in this area. Indeed, data collected around Fidalgo Bay following successful spawning of the trestle population during several previous years have shown that larvae do stay fairly close to home, with the highest post larval recruitment being close to the trestle site and becoming more diluted with distance from the trestle. So far, we have found signs of post larval recruitment about 1/2 mile south of the trestle (very limited habitat in this area), about 3 miles north of the trestle at the Crandall Spit Lagoon entrance and about 3 miles northwest near the old plywood mill site. So far, we have not seen any signs of recruitment outside of Fidalgo Bay or in the northwest corner of the bay.

Evidence to date strongly suggests that native oysters at the trestle restoration bed successfully spawned in 2004, 2006, 2009 and 2010. Why spawning and/or recruitment were apparently poor or unsuccessful in 2005, 2007 and 2008 is presently unknown. Monitoring for natural recruitment will continue in future years of this project.

Data collected in 2010 and 2011 show that native oysters are now successfully settling on the abundance of clam shells that occur along the length of the eastern portion of the trestle. Indeed, the density of native oysters newly recruited to these clam shell accumulations is now approaching about 40% the density of the original seeded restoration plot. Thus, the potential exists for this whole trestle area to become a functional native oyster bed that is many times the size of the original seeded areas.

Currently, native oysters have only been planted at the South Fidalgo Bay sites (trestle and Weaverling Spit) and represent the only restoration location in the North Puget Sound region (except for a few small plantings on private property on Orcas Island). Restoration of native oysters in the North Sound region will require more restoration sites so that naturally-spawned larvae are produced at a "network" of sites. In 2012, with funding from the National Fish and Wildlife Foundation and assistance from various partners, we plan on expanding our seeding operations to additional sites in north Fidalgo Bay, Padilla Bay and to two sites in Skagit Bay (See Appendix 1).

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Table 1. Number of bags of native oyster seed, average seed density on cultch shells, total number of seed planted and size and age at planting at the South Fidalgo Bay trestle site, 2002-2006.

Year	# of Bags Seeded	Average # Seed/shell	# of Seed Planted*	Ave. Length, mm	Age
2002	20	5.2	24,960	24.8	1+
2003	39	7.0	91,360	5.1	0+
2004	37	17.0	188,700	9.5	0+
2006	170	24.5	1,124,550	4.8	0+
Total	266	-----	1,429,570	------	-----

* Based on an average of 240 cultch shells/bag for 2002-2004 and 270 shells/bag for 2006.

Table 2. Summary of native oyster densities, live and dead per cultch shell and sizes in Trestle Plot B, 2002-2011.

Month/Year	Ave. # Live Per m^2	Ave. # Live Per Cultch Shell	Ave. # Dead Per Cultch Shell	Percentage Live Oysters	Ave. Length, mm	Comments
May 2002	46.0	4.8	0.7	87.3	24.8	Size of seed at plant
Nov. 2002	27.6	3.4	0.1	97.1	34.2	
April 2003	43.6	4.6	0.8	85.2	34.4	
Aug. 2003	44.8	4.7	1.2	79.7	40.4	Prior to 2003 seed addition
May 2004	NM*	22.5	2.4	90.4	41.6	
Aug. 2004	NM	NM	NM	NM	47.0	Prior to 2004 seed addition
April 2005	NM	8.7	2.6	77.0	26.4	
Aug. 2006	NM	10.5	3.7	73.9	36.5	Prior to 2006 seed addition
June 2008	84.4	1.0**	NM	NM	32.2	Slight natural recruitment
May 2009	91.6	0.7	1.0	39.2	36.8	Slight natural recruitment
July 2010	110.8	NM	NM	NM	38.1	Heavy natural recruitment
June 2011	130.0	NM	NM	NM	37.2	Moderate natural recruitment

* NM = Not Measured.

** Large reduction in number of oysters/shell due to enhancement of Plot B in August 2006 with several cubic yards of non-seed bearing Pacific oyster shell.

Table 3. Numbers of live juvenile native oysters found in cultch bags deployed around Fidalgo Bay in spring 2009 and assessed in July 2010.

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	East March's Point	0	71	0.00			0
2	East Crandall Spit Pond	26	82	0.32	27.6	6.4	32
3	West Crandall Spit Pond	2	68	0.03	32.0	2.8	3
4	North Barge	Lost					
5	South Barge	249	88	2.83	20.4	5.8	283
6	Channel SE side of Trestle	355	103	3.45	24.5	8.1	345
7	Plot B - East end	329	96	3.43	19.8	6.2	343
8	Plot B - Mid-Plot	279	96	2.91	19.6	5.6	291
9	Plot B - West end	171	103	1.66	22.1	5.3	166
10	Rock trestle - north side	25	70	0.36	12.2	4.6	36
11	Rock trestle - south side	Lost					
12	Samish East	0	79	0.00			0
13	Samish Middle	2	88	0.02	21.0	14.1	2
14	Samish West	29	84	0.35	23.6	8.0	35
15	North side of Grimm's	Lost					
16	South side of Plywood Mill	5	88	0.06	20.4	5.0	6
17	Sea Farer's Park	Lost					
18	Cap Sante Head	0	33	0.00			0
19	Port Dock	0	69	0.00			0
20	Trident Dock	Lost					

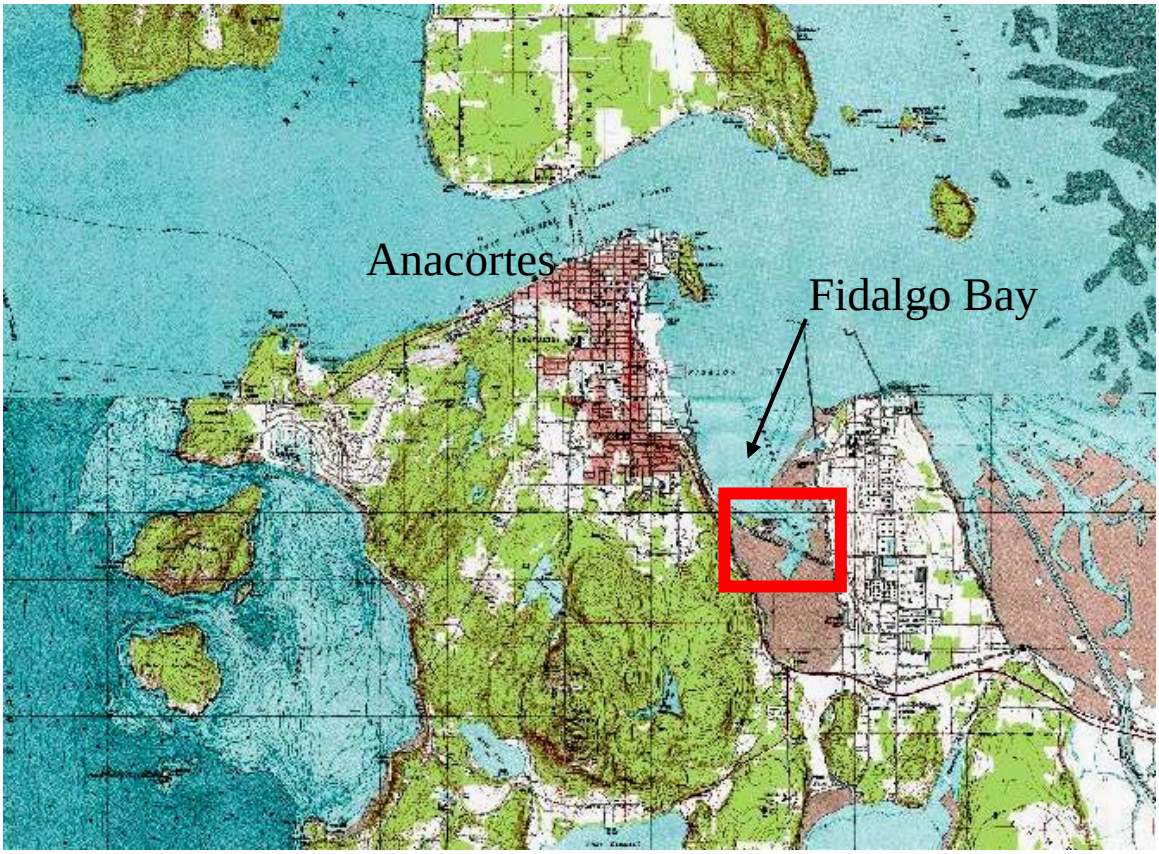

Figure 1. Location of Fidalgo Bay on Fidalgo Island, North Puget Sound.

Figure 2. Location of the trestle native oyster restoration site in South Fidalgo Bay, 2002-2011 (WDOE Shoreline photo).

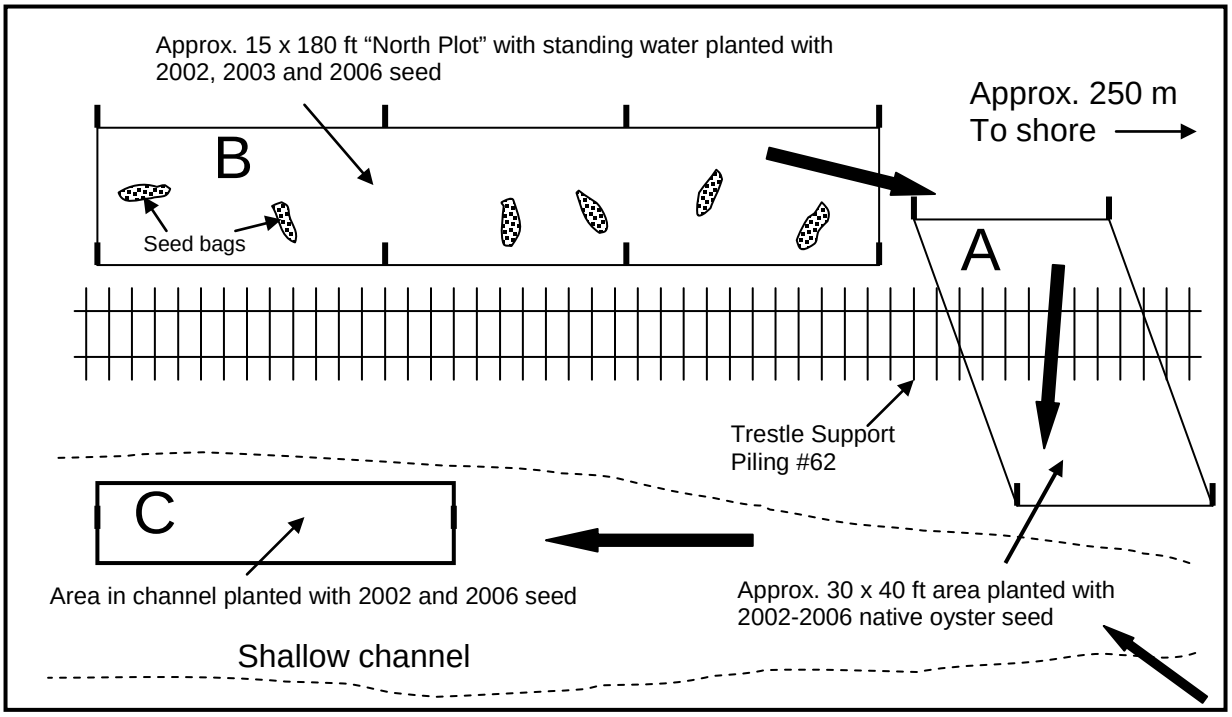

Figure 3. Trestle site plan showing the seeding locations, 2002-2006. Large arrows show the directions of water drainage at low tide. Map derived from site drawings by Robert Knowles.

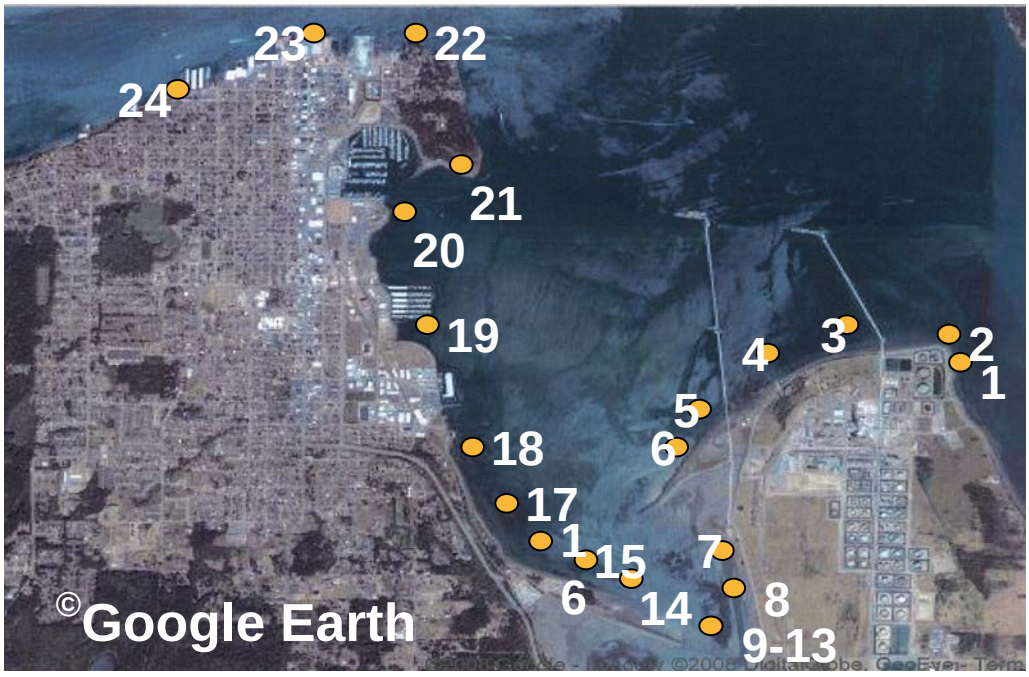

Figure 4. Locations in and around Fidalgo Bay where oyster shell cultch bags were deployed in 2007, 2008 and 2009 to monitor dispersal of native oyster larvae spawned at the trestle restoration bed in south Fidalgo Bay. Note: bags were not recovered from all locations in every year.

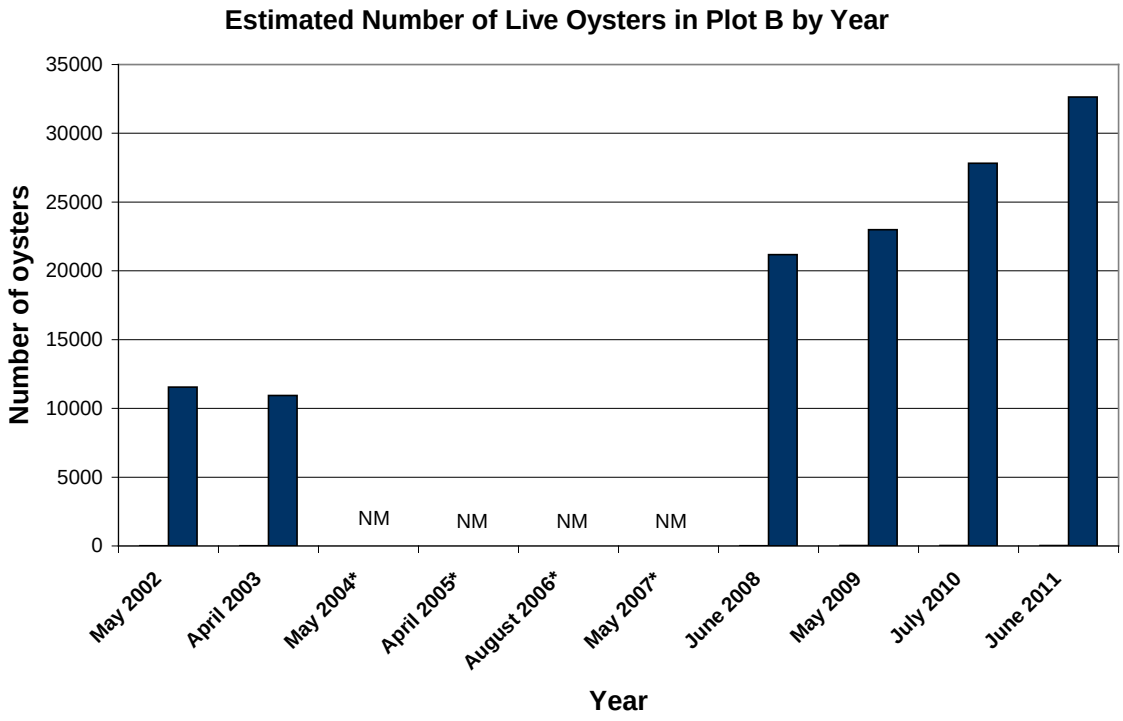

Figure 5. Estimated number of native oysters in trestle restoration plot B, 2002 to 2011.

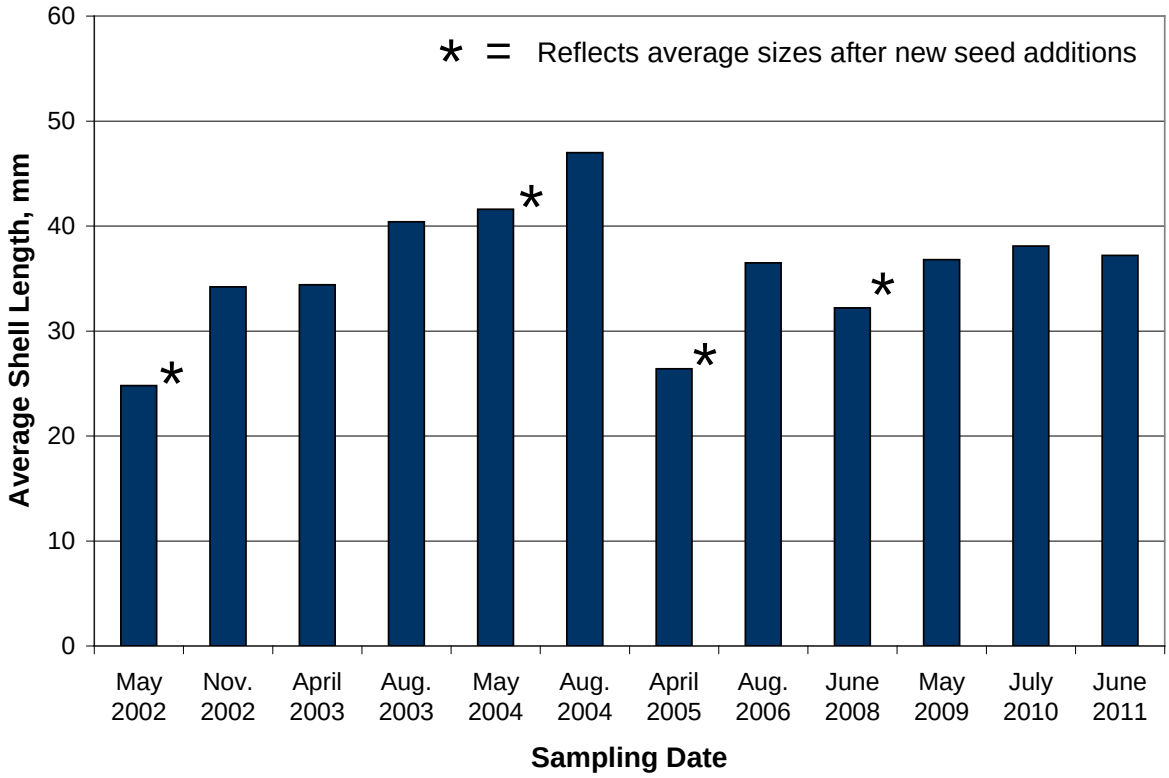

Figure 6. Average native oyster shell length by sample date for oysters sampled at the trestle restoration site in Fidalgo Bay, 2002-2011.

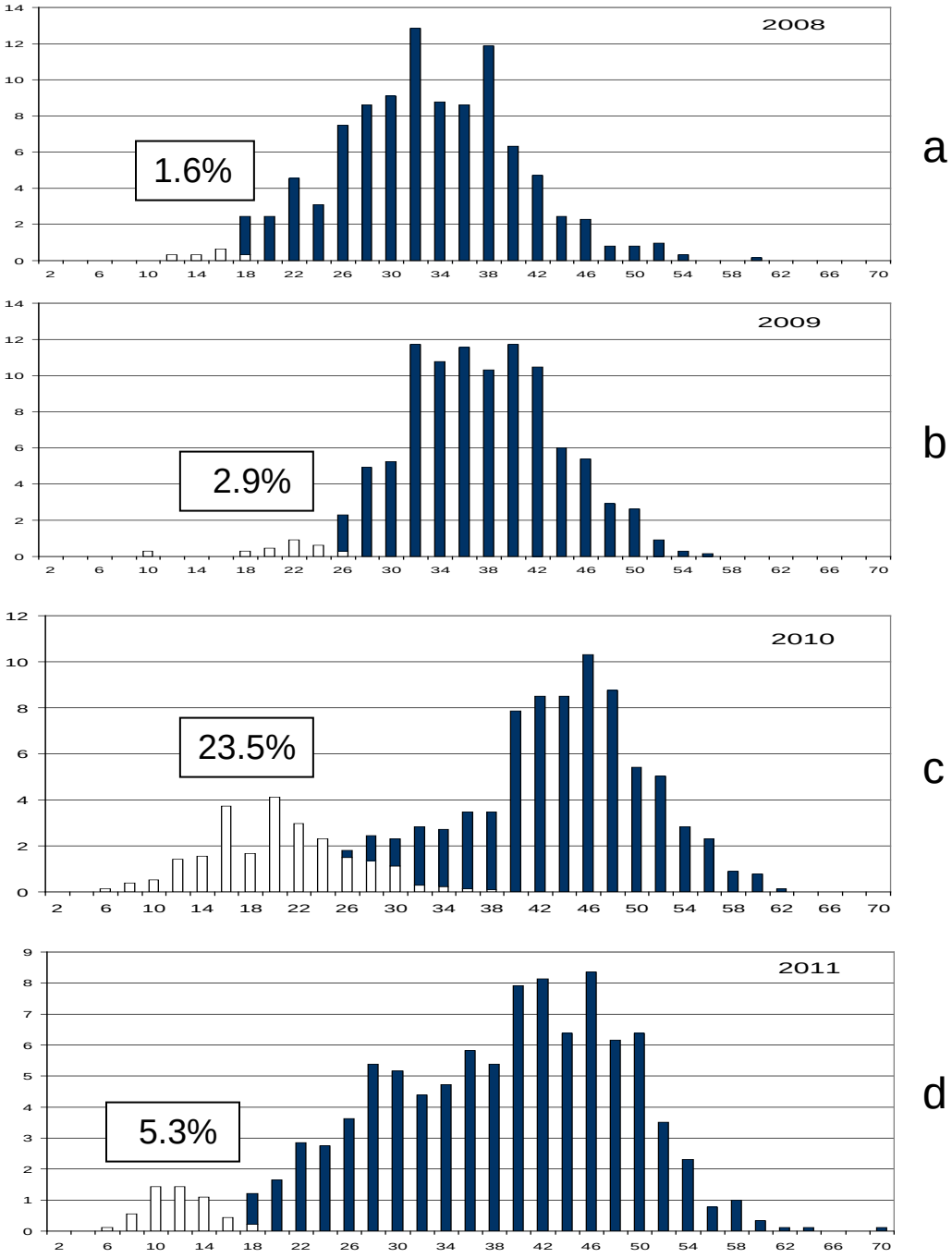

Figure 7. Trestle restoration Plot B native oyster size frequency plots for years 2008-2011. The clear bars indicate oysters that resulted from natural post larval recruitment in the previous year while the dark bars indicate older oysters. The percentages above the clear bars are estimates of the percentage of oysters that are new recruits for each given year. The y-axis is Percent Frequency.

Figure 8. Photograph of juvenile native oysters that settled on Pacific oyster shells in the cultch bags deployed at the trestle restoration site in 2009 and retrieved in 2010. These oysters originated from natural spawning at the trestle in 2009.

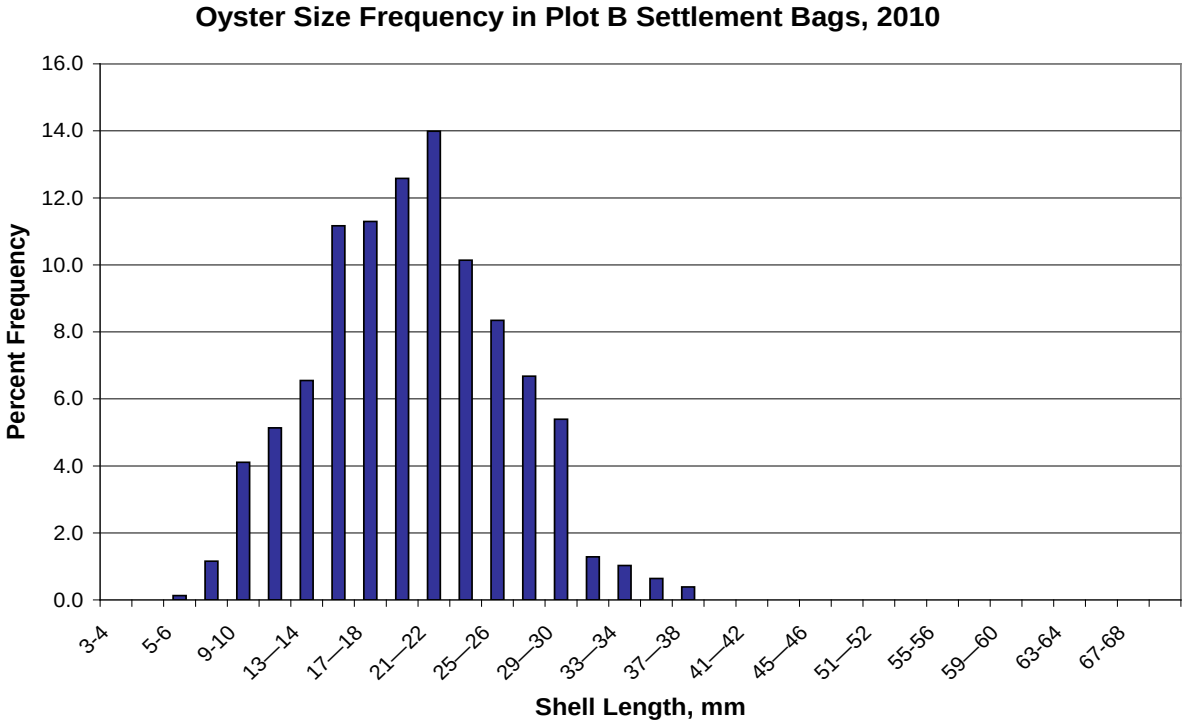

Figure 9. Sizes of native oysters recovered in the cultch bags deployed at the trestle restoration site in 2009 and retrieved in 2010.

Figure 10. Number of juvenile native oysters/100 cultch shells recovered from the shell cultch bags deployed in 2009 and retrieved in 2010.

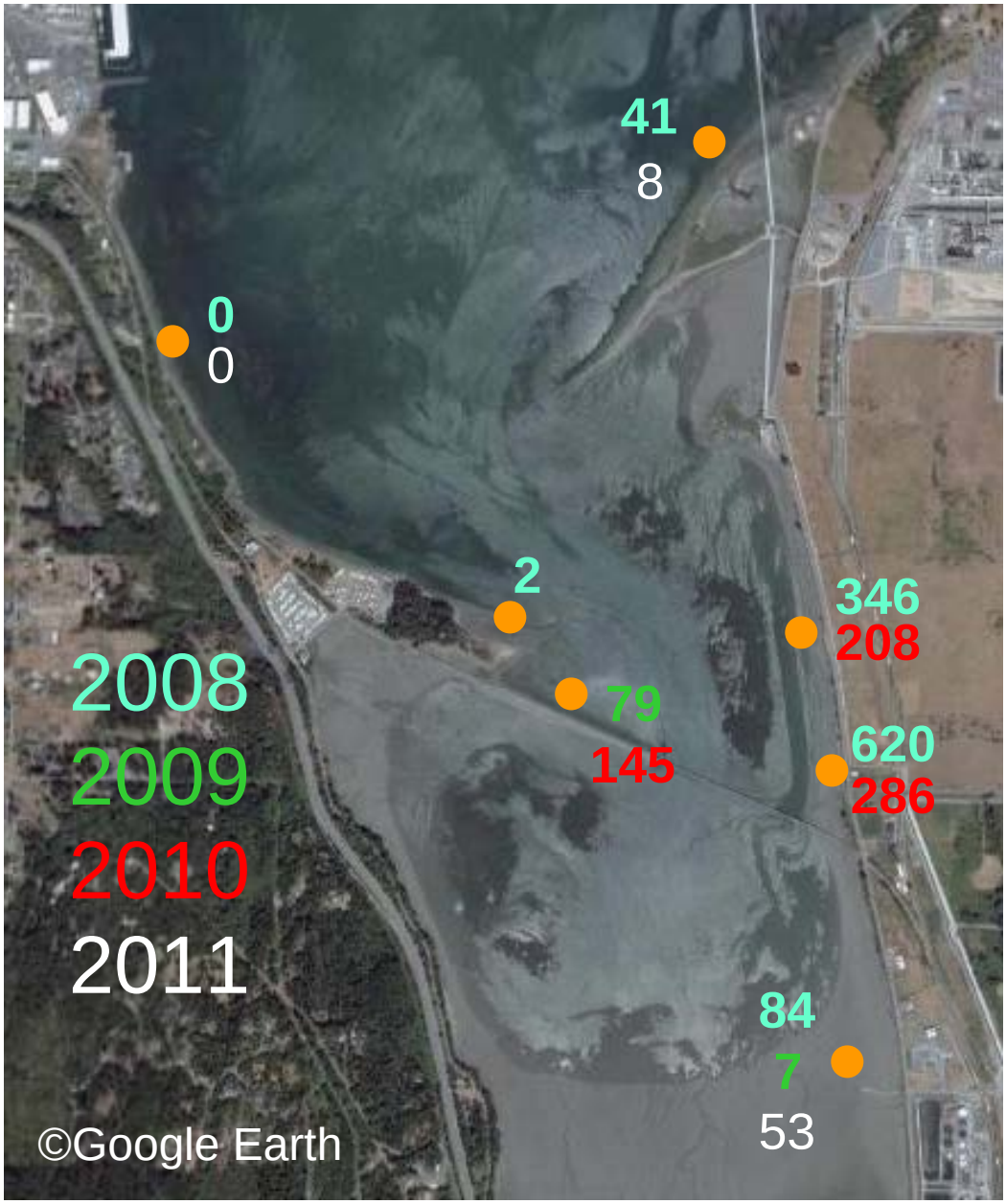

Figure 11. Numbers of native oysters found in natural habitats around south Fidalgo Bay in 2008 through 2011. These native oysters likely recruited to these areas following spawning of oysters at the trestle restoration bed in various years.

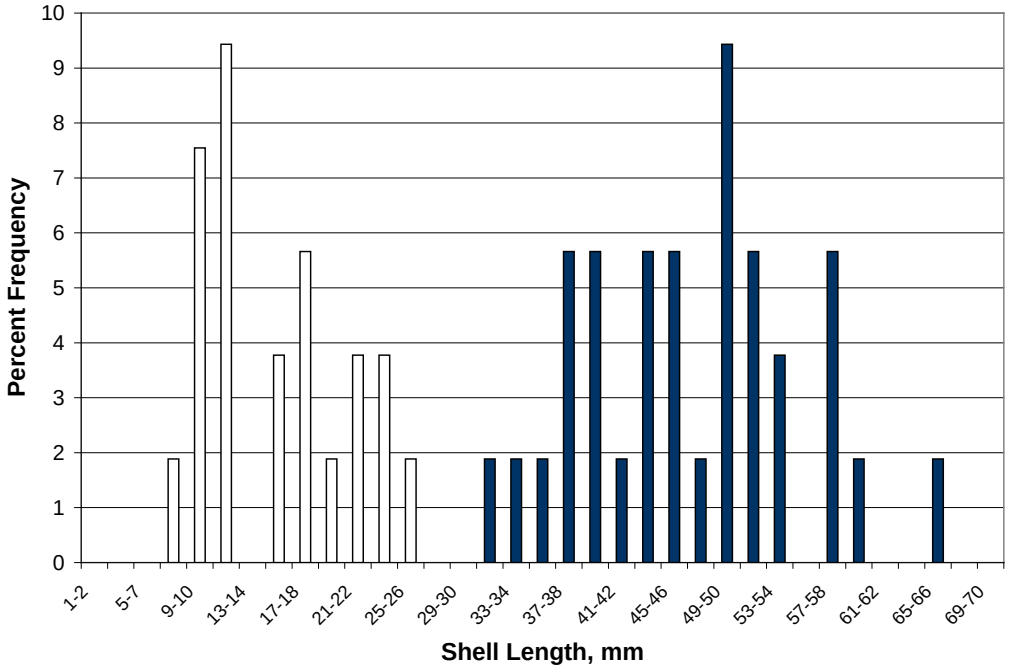

Figure 12. Size frequency histogram of native oysters found at the shell berm in South Fidalgo Bay (lower right corner, Figure 11), spring 2011. The clear bars indicate oysters that settled in 2010 and the dark bars are oysters that settled in previous years.

Figure 13. Example of clam shell rubble habitat surrounding the trestle restoration site in which increasing numbers of native oysters are settling and growing.

Figure 14. Examples of native oysters settling and growing on an assortment of clam shells (including littleneck, cockle, horse, butter and eastern soft shell) a mussel shell and a native oyster drill shell (inset).

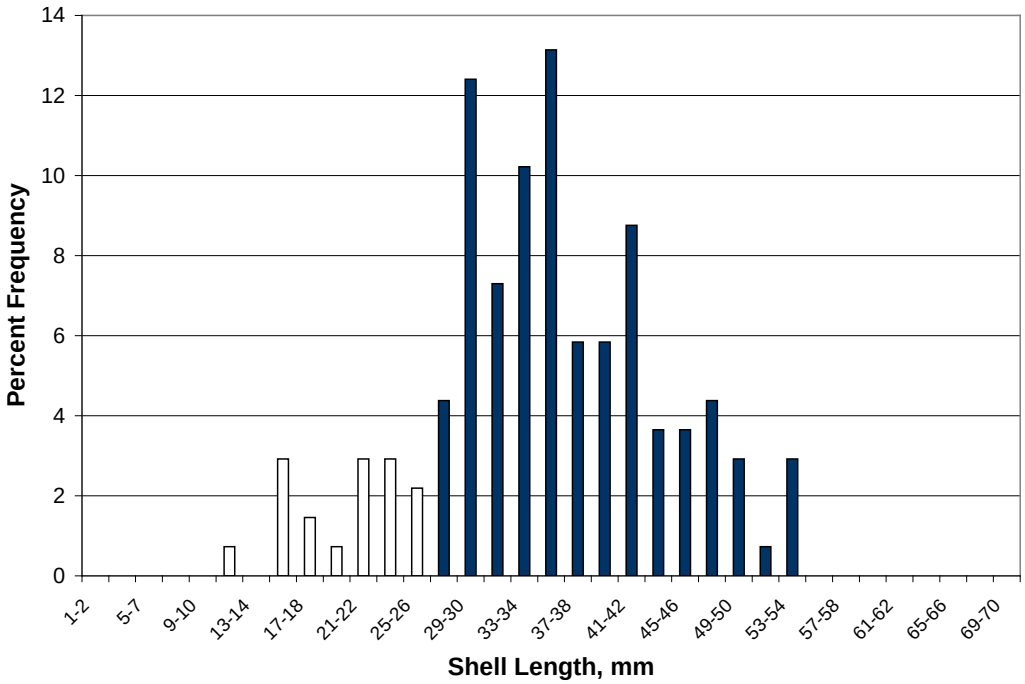

Figure 15. Size frequency histogram of native oysters found in clam shell rubble next to the trestle restoration site in Fidalgo Bay, spring 2011. The clear bars indicate oysters that settled in 2010 and the dark bars are oysters that settled in previous years.

Appendix 1

Site Survey Reports for Possible New Native Oyster Restoration Efforts in North Puget Sound, 19 - 21 April 2011

By

Brady Blake, WDFW
and Betsy Peabody, Puget Sound Restoration Fund

Site Survey Report for Possible New Native Oyster Restoration Efforts in North Puget Sound, 20 and 21 April 2011

By: Brady Blake, Washington Department of Fish and Wildlife, Brinnon Shellfish Laboratory
Date: 27 April 2011

Survey participants: Brady Blake, WDFW; Paul Dinnel, Skagit MRC; Sharon Riggs, Padilla Bay National Estuarine Research Reserve; Jim Gibson and Julie Barber, Swinomish Tribe; Vicki McNeil, Volunteer.

All:

That was a very productive field trip! My observations and recommendations are as follows:

Drayton Harbor: Found 4 relict shells all of which were very large and deeply cupped for native oysters plus one "nickel" sized live oyster on the rocky/gravel tidelands immediately south of the Semiahmoo marina on the east side of the spit. Tide height was estimated to be from a +1 to +2 MLLW. Habitat is coarse rock and gravel that exhibited a considerable amount of moisture plus several tidepools. Beach is very exposed to the east and north to wind and freezing events. PSRF found a single adult and some relict shell in 2010 inside the California Creek estuary on the northeast side of the bay. Recommendations are that we place 10 bags of large single seed oysters in several experimental plots on the Semiahmoo beach in 2011 and also conduct a more extensive presence sweep of that beach this summer using volunteers on a lower tide than the +1 that I visited on. I can probable fit that in to my schedule. Restoration here may require some discussions with WDOH due to recent discussions regarding the Whatcom MRC proposal to plant Pacific oysters on these tidelands which was discouraged by WDOH and WDFW. Native oysters won't create the same health and harvest issues on these tidelands. Potentially several acres here but would be unlikely to form what I would call a dense bed but may provide for a home for several hundred thousand scattered oysters. This would provide a larval source for increasing presence within the bay and possibly a potential source of broodstock for relays and hatchery production.

East Padilla Bay: No evidence of oysters found. The potential for restoration is high given the quality of the habitat I observed. The habitat is located within a patchwork of shallow tidepools (Fig. A1) and channels with two types of substrate. The first is gravel/shell which would provide the hard substrate for larval sets and would support seeding with large single seed or seed on Pacific oyster shell. The second is silt/sand/mud with some occurrences of Zoster japonica but not in all cases and would require use of seed set on shell. There are some hurdles to work through for this site such as objections to use of Pacific oyster shell because it comes from a non-native species albeit the calcium carbonate certainly is native. I leave it to Paul to decide what he wants to do here and I only suggest after discussing it with Betsy that we experimentally plant 20 bags of seed on half shells and five bags of large single seed. The available habitat could eventually easily support an outplanting of 200 bags of seed and given the available habitat already present should result in patches of bed structure. Additional shell substrate could be added to increase the amount of structure and the eventual bed footprint. It would be nice to map out as much of the potential restoration habitat as we can. Again I'll leave it to Paul to decide what should be done here. If need be I can assist with working through any objections raised at this site.

Cap Santé Marina: No evidence of oysters found. The site has undergone an immense amount of remediation and has several small potential opportunities for establishing larval sources as an extension of that being developed inside Fidalgo Bay (Fig. A2). Again I'll leave it up to Paul to decide the details but I would suggest providing 25 bags of seed on whole shell for several

experimental plots. Also Paul may want to provide some shell based habitat structure in the case where the substrate is too muddy for clutched seed to work by itself. Potentially the oysters at this site would recruit to the considerable amount of artificial habitat associated with the marina and provide additional larvae to what the Fidalgo trestle population provides for expansion of native oyster presence in the vicinity and fits well with the strategic goal of creating source populations of oysters in North Sound. Nice opportunity to tie native oysters to the wonderful work being done at the former mill site!

Kiket Island Lagoon: No evidence of oysters found. This is a potential native oyster supporting habitat (Fig. A3) typical of what we have observed elsewhere such as the Bywater Bay lagoon. Historical references indicate a historical native oyster presence at the extreme head of Skagit Bay in both Similk and Turner bays. This site should provide a larval source for recruitment to those locations and also to the considerable amount of currently available habitat in the vicinity. I would suggest that we provide 40 bags of seed on shell and 25 bags of large single seed for this site as there are opportunities to use both here. I'll leave it to Jim, Julie and Paul to decide how they want to proceed here. I have to say that I was really pleased by the potential that I observed at this site. The eventual result should be a small partial acre bed structure of oysters in the lagoon and within the outlet channel plus recruitment to the vicinity.

Lone Tree Point Lagoon: No evidence of oysters found. This is a potential native oyster supporting habitat (Fig. A4) typical of what we have observed elsewhere such as the Bywater Bay lagoon and the Disco Bay site and potentially offers several acres of eventual native oyster presence. Historical references indicate a historical native oyster presence at the extreme head of Skagit Bay in both Similk and Turner bays. This site should provide a larval source for recruitment to those locations and also to the considerable amount of currently available habitat in the vicinity. I would suggest that we provide 50 bags of seed on shell and 25 bags of large single seed for this site as there are opportunities to use both here. I'll leave it to Jim, Julie and Paul to decide how they want to proceed here. I have to say also that I was really pleased by the potential that I observed at this site. It has a good diversity of habitats for native oysters. The eventual result should be a near an acre bed structure of oysters in the lagoon and within the outlet channel plus recruitment to the vicinity.

Thank you all for helping out on this!

Brady Blake

Supplemental survey report by Betsy Peabody, Puget Sound Restoration Fund.

I can add to the North Sound field report as well. I went up to Chuckanut Cove on April 19th with a Taylor employee. Turns out the report we had received about "native oysters" in the cove referred to jingle oysters, not Olympia oysters. Bit of a disappointment. So, we did not find Olympia oysters and were not able to collect a genetic sample. Though the cove looks like it might have good habitat and seepage conditions. I would not recommend Chuckanut Cove for oyster enhancement activities for the following reasons:

1. There is a lot of recreational harvest that occurs in the cove, in spite of closures, in the channel that meanders through the cove and on all sides of the trestle entrance.

2. There are TONS of sea stars at the entrance to the cove under and around the trestle. Lots of predators in the areas where there is running water would pose a problem.

3. Brady mentioned something about plans down the road to widen the cove entrance by making changes to the trestle. Changes in the tidal regime would probably make the area unsuitable. It would open up the cove to a pretty high energy environment with lots of weather coming up from the south.

Those are my thoughts. I'm excited about potential enhancement opportunities at Semiahmoo as a possible alternative.

Betsy

Site Photos

Figure A1. Potential native oyster habitat in a shallow pool with gravel and shell located along the shore of east Padilla Bay.

Figure A2. Potential native oyster restoration site at the newly cleaned and restored Port of Anacortes shoreline on the south side of Cap Sante Marina in Anacortes.

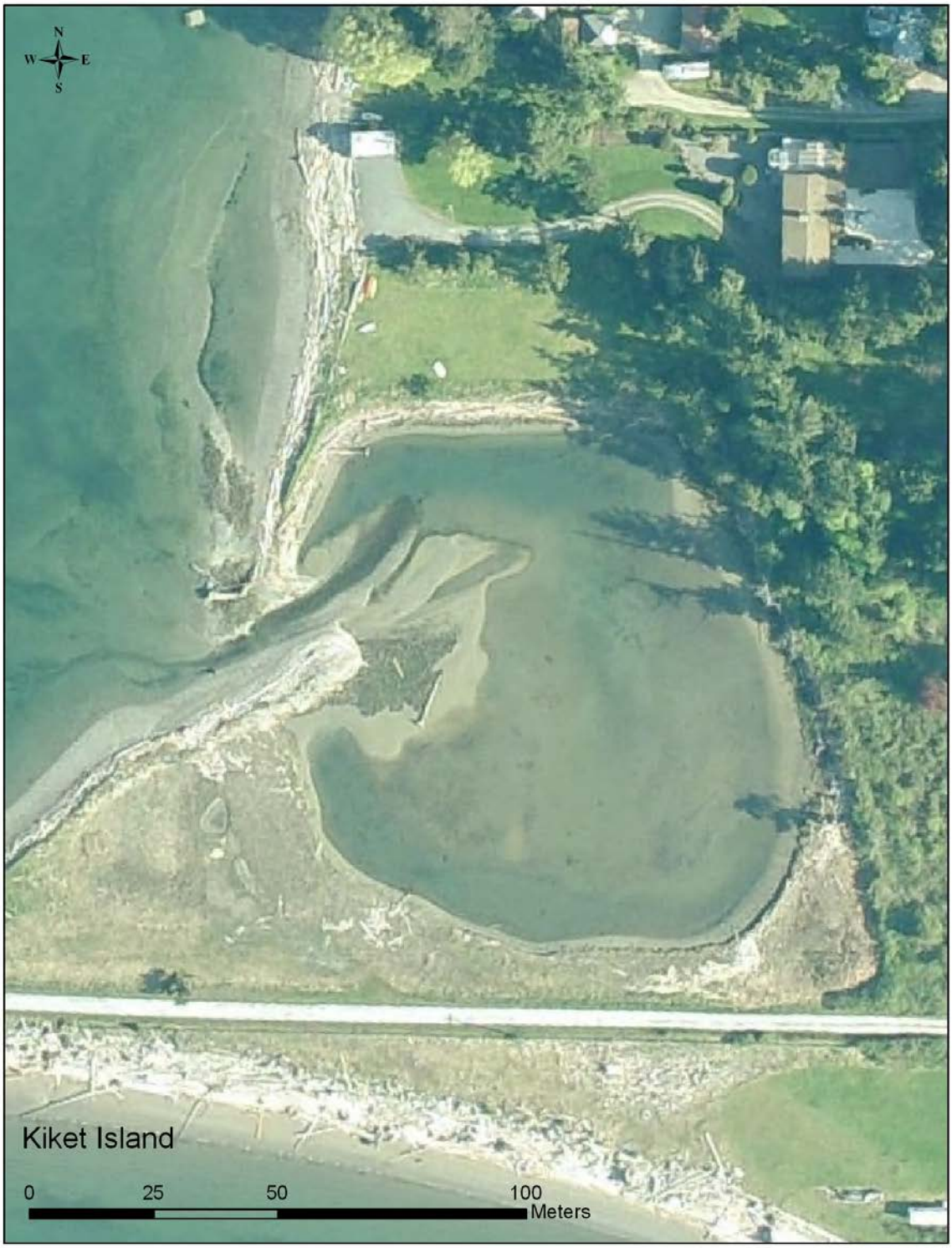

Figure A3. Possible native oyster restoration site at Kiket Island (Kukatali Preserve) lagoon located on north Skagit Bay on the Swinomish Tribal Reservation.

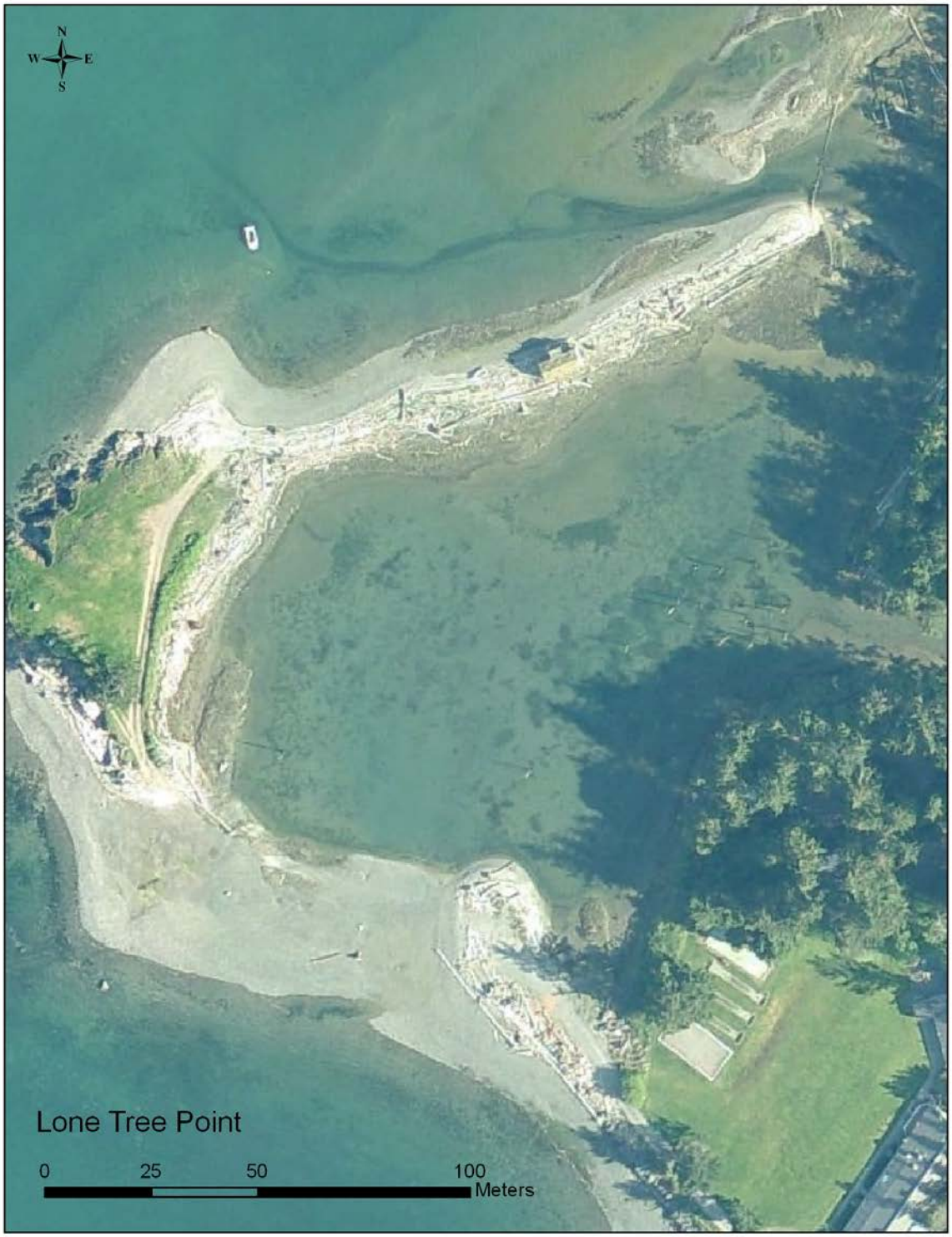

Figure A4. Possible native oyster restoration site at Lone Tree Point lagoon located on Skagit Bay on the Swinomish Tribal Reservation.